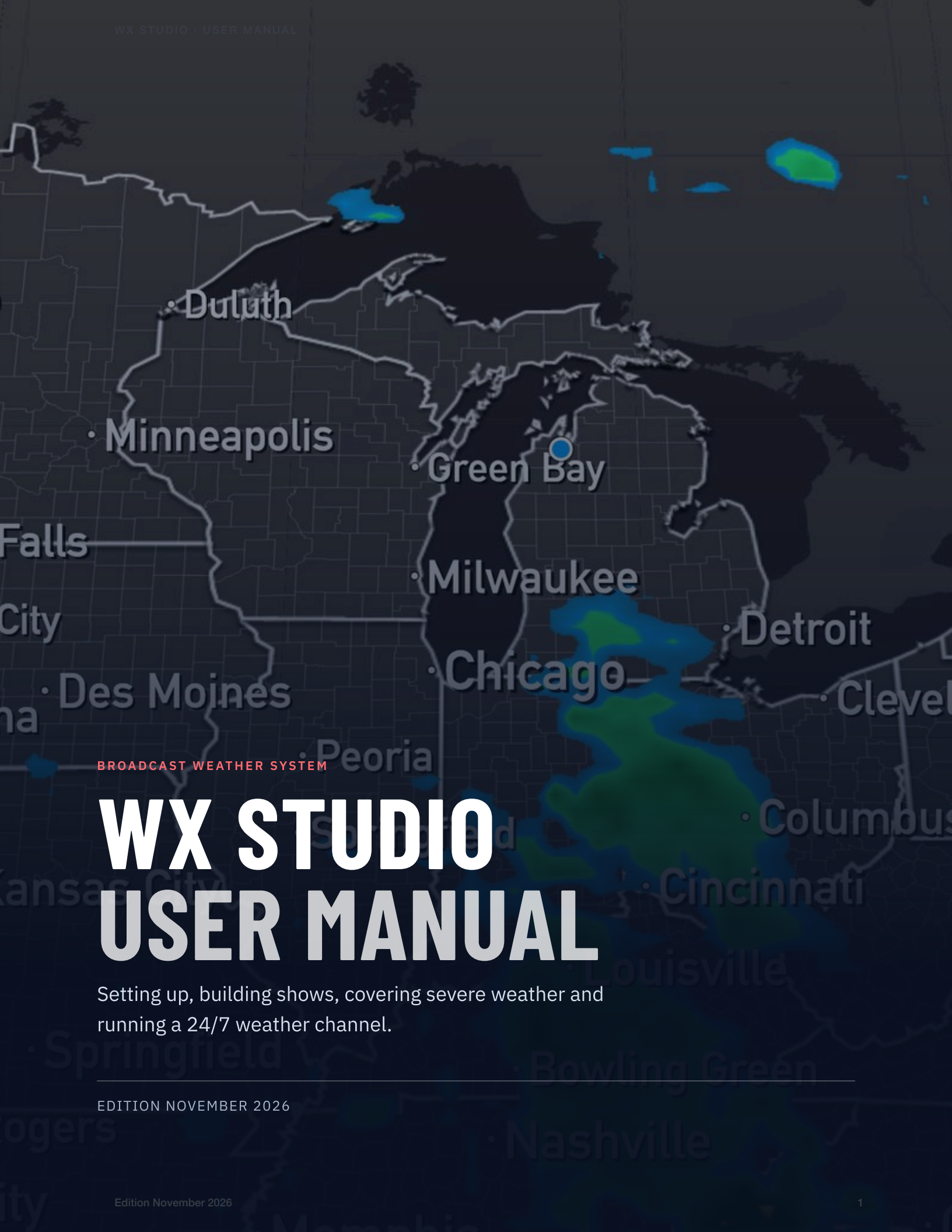

BROADCAST WEATHER SYSTEM

WX STUDIO USER MANUAL

Setting up, building shows, covering severe weather and running a 24/7 weather channel.

EDITION NOVEMBER 2026

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Bold marks a button, menu or setting as labeled in the app; **A** → **B** is a menu path. Every screen in this manual was captured from WX Studio running on live NOAA data.

PART I

GETTING STARTED

01 INSTALL AND FIRST RUN

What you need, how to activate your license, and the five things to set before your first show.

REQUIREMENTS

ITEM	REQUIREMENT
Operating system	macOS (tested on Apple silicon). Windows and Linux builds use the same code.
Graphics	A GPU with a current Metal, Vulkan or DirectX 12 driver for the 3D map. Without one, WX Studio falls back to OpenGL and the 2.5D map.
Network	An internet connection. Radar, satellite and model data are downloaded as you work.
Disk	About 2 GB free for the model and map-tile caches.
Optional	**ffmpeg** for live camera video, animated logos, MP4 renders and streaming (`brew install ffmpeg` on macOS).

BUILD AND LAUNCH

Build from the project folder with Rust 1.85 or later:

```
cargo run --release -p wx-studio
```

After the first build, launch `target/release/wx-studio` directly.

LICENSE KEY

The first time WX Studio opens, it asks for your license key (it starts with `WXS1-`). Paste it and press **Activate**. The key is checked on this computer and remembered; no internet connection is needed. **Settings** → **Station** → **Licence** shows who it is licensed to and until when, and takes a renewal key. Subscriptions show a reminder in the top bar during their last 14 days; a license is only checked at start-up, so it never stops the program mid-show. Replaying a recorded event works without a key.

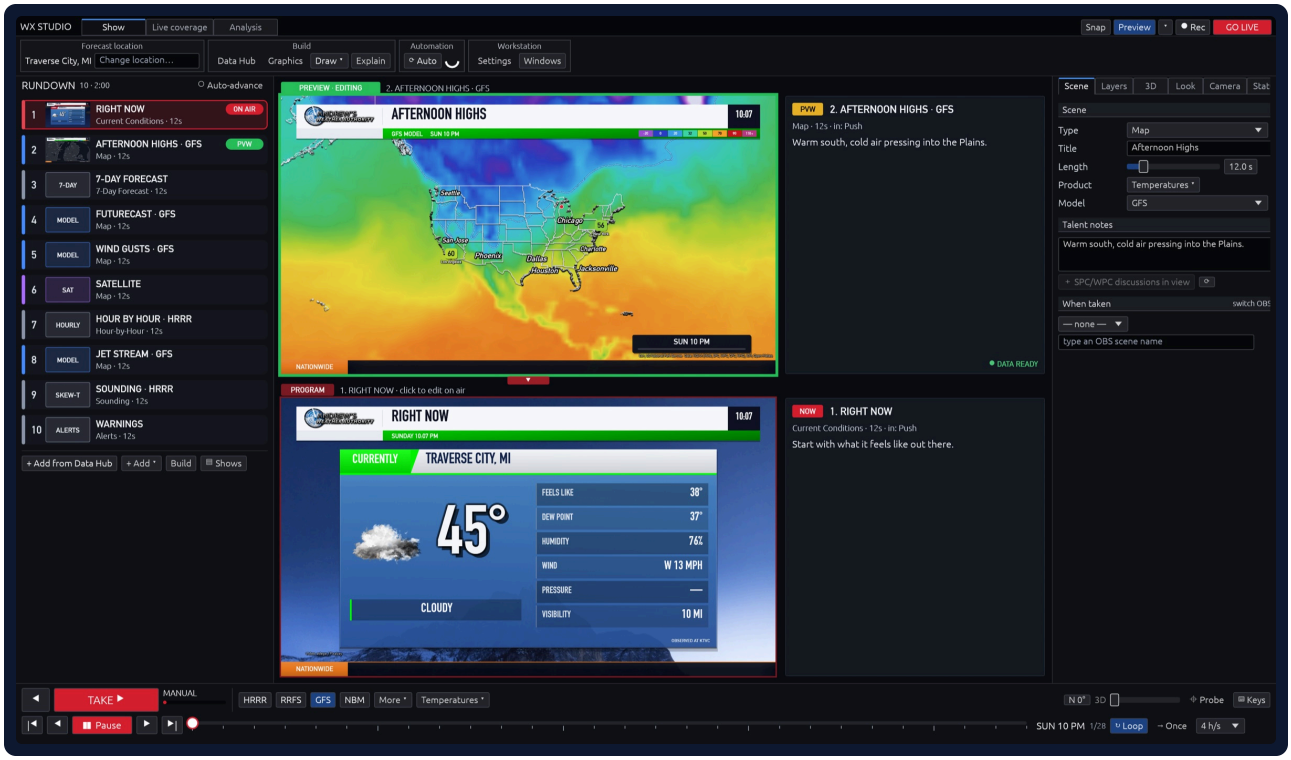
FIRST-RUN CHECKLIST

1. **Location.** Type your city, ZIP code or `lat,lon` in the search box at the top left and pick a result. This sets the forecast point, the nearest radar and the home region that models preload for.
2. **Station.** Open **Settings** (top right) and enter your call letters. They appear in the title graphics and the corner bug.
3. **Logo** (optional). In the **Graphics** window (G), next to **Logo**, click **Choose…** and pick a PNG or JPEG. It replaces the call letters in every title style and the bug.
4. **A show.** Click **Shows** under the rundown and pick a template (Morning Show, Evening Forecast, Severe Weather, Winter Storm, Live Severe Coverage, Tropical Update…), or use **Build** to make one (see Coverage Builder).
5. **Contact.** In Settings, enter a contact email for the NWS User-Agent. The NWS asks every app to identify itself.

The first run downloads radar, satellite and HRRR, GFS and NBM data in the background. While anything is loading, a spinner shows in the top bar; hover it to see how many feeds and map tiles are still on their way (the **Status** tab has the details).

> **TIP** Leave WX Studio running for a few minutes before your first show so the preloaded models finish their first download. Later launches read them from disk.

02 THE OPERATOR SCREEN



The operator screen: the rundown on the left, Preview over Program in the middle with the NOW and NEXT cards, the inspector on the right.

The operator screen is laid out like a control room: what is coming up on the left, what is on air in the middle, and the controls for the selected scene on the right.

AREA	WHAT IT IS
Top bar	The title row holds the work mode (**Show**, **Live coverage**, **Analysis**) on the left and what goes out on the right: **Snap**, **Preview** ▾, ● **Rec** and **GO LIVE**. Below it, a ribbon of labeled groups: **Forecast location** (**Change location…**); **Build**: **Data Hub**, **Graphics**, **Draw** ▾ (the telestrator and **Forecast drawing**) and **Explain**; **Automation**: ⟳ **Auto** (with a spinner while data loads); **Workstation**: **Settings** and **Windows**.
Rundown (left)	Your scenes in order. The scene on air is outlined and marked **ON AIR**; the next one is marked **NEXT**.
Program (center)	Exactly what goes to air, at 16:9. Beside or under it, the **NOW / NEXT** cards show each scene's type, length, transition and talent notes. With **Preview** on, a second monitor shows the scene you are preparing (see Preview and Program).
Inspector (right)	Settings for the selected scene, one tab per job (below).
Control strip (bottom)	**TAKE NEXT**, previous scene, auto-advance, loop playback and quick controls for the scene on air (radar products, satellite sectors, model and product).

The inspector's tabs:

TAB	WHAT LIVES THERE
Scene	What the scene shows: type, title, product and the product's own choices (radar product, tilt and site, model, forecast hour), length and talent notes.
Layers	What is drawn over the map: basemap, warnings, overlays, cities, lightning, cameras, day and night, and the layer order.
3D	3D radar and model volumes, cross sections, the storm box and the spotlight.
Look	The on-air graphics: title graphic, which elements show, page layout and text layers.
Camera	Framing, tilt and heading, the transition in, and the camera path.
Status	**Feed health** for every feed the show uses, then the feeds of this scene.

Each tab is a short form in titled sections. Settings marked *all map scenes* apply to every map, and rarely used detail (exact framing, show-wide transition rules, layer order) stays folded until you open it. Hover a tab name to see what it holds. To drag text layers on the picture, use **Look → Text layers → Drag on the preview**.

Feed health lists every feed in use (warnings, forecast, observations, radar, satellite, lightning, preloaded models and the map grids on screen, point forecasts, HRRR 15-minute, MOS, soundings, the new-run checker and NWWS-OI) with its state (**OK**, **Late**, **Stale** or **Error**), the age of its newest data and its last download time. When a feed turns stale or fails, an alert pops up and a red ⚠ **FEEDS** chip appears in the top bar; click it to open Feed health.

Station red always means *live*: it is used only for **GO LIVE**, **ON AIR**, **TAKE NEXT**, the **NOW** tag and **Rec** while recording. Selected tabs and options use a neutral slate highlight, so nothing else on the screen can be mistaken for an on-air control.

WORK MODES: SHOW, LIVE AND ANALYSIS

The work mode sets how takes, graphics and alerts behave. Switch with the buttons in the top bar; **N** toggles Analysis and **C** toggles Live Coverage.

- **Show**: a produced show. Scenes play in order with their own transitions; turn on **Auto-advance** (A) to run hands-free.
- **Live**: severe-weather coverage. Takes are fast dissolves, new warnings pop up, the crawl carries calls to action, and storm tracks and timing boxes are on. **C** jumps into Live Coverage.
- **Analysis**: your own forecasting. Show graphics (title, bug, lower third, crawl) are hidden, every take is instant, and the cursor reads out the value and lat/lon under it.

PART II

BUILDING A SHOW

03 THE RUNDOWN

A show is a rundown: an ordered list of scenes, each with its own data, framing, length, transition and talent notes. This chapter covers taking, editing, saving and generating rundowns.

WORKING WITH SCENES

- **Take a scene**: click its card, or press **TAKE NEXT**, → or Page Down. ← or Page Up goes back. With Preview on, a click puts the scene in Preview instead (see Preview and Program).
- **Reorder**: drag a card. **Undo/redo**: ⌘Z / ⇧⌘Z.
- **Add scenes**: **+ Add** ▾ for any scene type or map product, or **+ Add from Data Hub** (H). The Data Hub is a floating window over the operator screen; anything you pick is inserted as **NEXT** and never goes straight to air.
- **Scene length**: the seconds slider on the Scene tab; used by auto-advance.
- **Talent notes**: on the Scene tab. They show in the NOW / NEXT strip, the prompter and the producer panel.
- **Shows**: save the rundown as a named show, load one, or export/import `.wxshow` files from **Shows**.
- **Thumbnails**: each card shows the scene as it last went to air (hover for a larger picture). A thumbnail is taken from the program a few seconds after a scene is taken, once its data is in, and again every 15 minutes it stays on air; scenes that haven't aired yet show an empty frame. Turn them off under **Shows → Thumbnails on the cards**.
- **Versions**: saving over a show keeps the version it replaces, and the working rundown is kept every 10 minutes while it changes (30 versions each). **Shows → Versions** lists them by show and time; loading one keeps the current rundown as a version first, so a roll-back can itself be rolled back. They live in the WX Studio settings folder and survive restarts.

SAVING SHOWS

From the rundown, **Shows → Save "name"** (or ⌘S) saves the rundown back over the show it was loaded from, in the same place in the list. **Save as** makes a new one. Loading a template and saving it gives you an edited copy of that template. A dot on **Shows** • means the rundown has changes you haven't saved. Every save keeps the version it replaces under **Shows → Versions**.

COVERAGE BUILDER

Build under the rundown opens the Coverage Builder:

1. Pick a template: routine forecast, live severe coverage or analysis.
2. Tick the scenes to include, choose framing and scene length.
3. Pick a transition look (Smooth, Clean dissolves, 3D moves, Hard cuts) and the mode to run in.
4. **Replace rundown**, **Append to rundown** or **Save as show**.

Undo (⌘Z) brings back the previous rundown.

04 SCENE TYPES



The 7-Day Forecast page, from the NWS forecast, in the station's look.

Every scene is either a **map** (any radar, satellite, model or overlay product) or a **page** (a designed graphic such as the 7-day forecast). Pick the type at the top of the Scene tab.

Pick the type at the top of the Scene tab.

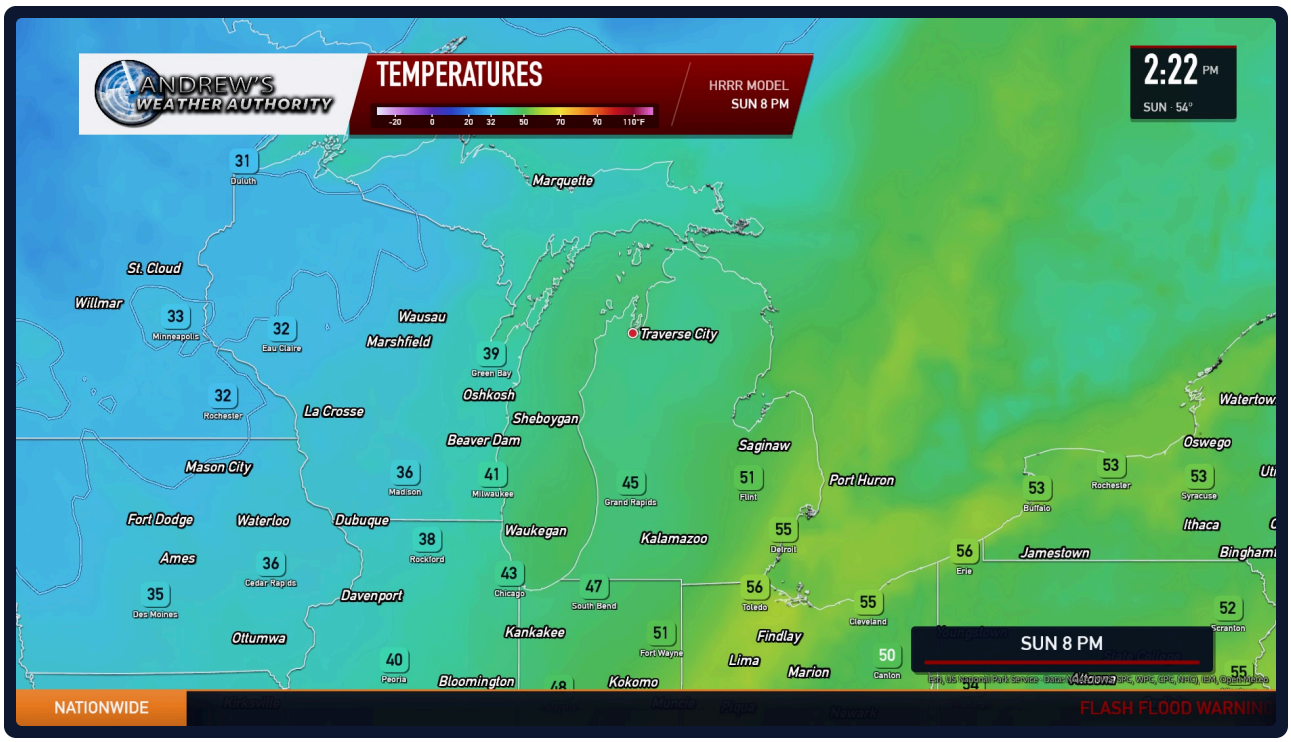
TYPE	WHAT IT SHOWS	OPTIONS ON THE SCENE TAB
Map	Any map product (radar, satellite, models, overlays).	Product, model, camera framing, tilt.
Current Conditions	Current weather at your location, or at up to nine places.	**Locations**: + Home, + Nearby towns (largest towns within 150 km), or search. Layout: **Cards** or **Table**.
7-Day Forecast	NWS 7-day forecast (model fallback outside the US).	Day overrides in Graphics.
Hour-by-Hour (Data Hub → Forecast, or + Add)	Meteogram of temperature, dew point, rain chance, clouds and wind.	Model (NBM uses the NWS hourly forecast; **HRRR 15-min** shows every 15 minutes for 18 hours). **Time shown**: when it starts (now, or 1-168 hours ahead, with Next 6 AM / noon / 6 PM / midnight buttons) and how many hours, to narrow in on this evening or tomorrow morning.
MOS Guidance	NOAA's statistical station guidance for the observing site nearest home, as a table: temperature, dew point, high / low, sky, wind, chance and type of precipitation, thunder.	**GFS MOS (MAV)** every 3 h to 3 days, **extended GFS MOS (MEX)** to a week, **LAMP** hourly to a day, **NBM text** (NBS, NBE). From the Iowa Environmental Mesonet's MOS archive.
Hourly Forecast (Data Hub → Forecast)	The 7-day page's cards, one per hour: time, icon, temperature, rain chance, sky and wind.	Model (including **HRRR 15-min**); **Time shown** as above, and the step between cards (1-6 hours, or 15-90 minutes with HRRR 15-min). Up to eight cards.
Model Comparison	Every model at your location.	Products (temperature, feels like, dew point, precip, snow, precip chance, wind, gusts, clouds, pressure, CAPE), models, 24–168 hours, consensus, **Charts** or **Table** layout.
Ensemble Plumes	Every GEFS member's running rain and snow total at your location for 7 days, with the mean, the middle 80% and the chance of 1" of rain / 6" of snow.	—
Sounding	Skew-T, hodograph and parameters, with the latest observed sounding from the nearest launch site.	Model and forecast hour; **Observed sounding** and **use for stats**.
Alerts	Watches and warnings for your location.	—
Tropical Update	Summary cards for active storms.	—
Tropical Models	Intensity guidance for one storm or invest.	System and model set.
Drive Times	Travel times on key routes.	Routes (automatic or your own).

TYPE	WHAT IT SHOWS	OPTIONS ON THE SCENE TAB
Sun & Moon	The sun's path across today's sky, dawn, sunrise, sunset and dusk, daylight and its change from yesterday, the moon's phase, rise and set, and the next four phases. Uses the moon images in your icon pack's `Weather Icons IV/moon` folder when present.	—
Space Weather, **Tsunami Status**, **Model Timing**, **Overview**	Data pages.	—

MULTIPLE LOCATIONS ON CURRENT CONDITIONS

Each place shows the nearest NWS observation when it is less than two hours old, with model data filling gaps and today's high and low. Rename a place by editing its name; reorder with ↑; remove with ✕.

05 BRANDING AND PAGE DESIGN



The Blade title style over an HRRR temperature map, with the legend in the title.

Your station's look lives in one package: title graphics, logo, fonts, colors and page templates. Each scene can override it.

TITLE GRAPHICS

Pick the show's style in **Graphics** → **Title style**; each scene can override it on the Scene tab under **Title graphic**.

STYLE	LOOK
Card	Rounded card with an accent rail.
Blade	Station tab and a slanted gradient slab: title over its color key on the left, model and time stacked on the right.
Arrow	Solid slab with a pointed end.
Slab	Wide band across the top with an angled cut.
Wedge	Dark slab led by an angled color wedge, subtitle on an offset tab.
Banner	Full-width bar with the station block, legend and clock.
Studio	White bar: logo block, dark title, tag or clock on the right, color strip with the day and time and a boxed legend.
Pinpoint	Dark glass bar with a boxed logo, title over subtitle and boxed legend bins.

- **Legend inside the title**: on by default for styles that support it; the bottom-left legend then stays off.
- **Own colour** per scene, with Winter, Severe, Heat and Tropics presets.
- **Info box**: talking points under the title, one per line, like `Mountains: 4-10"`.
- **Tag**: right-hand text on the Studio bar (a hashtag or sponsor). Blank shows the clock.
- Banner and Studio carry the clock, so the corner bug is hidden while they are on screen.

LOGO

Graphics → **Logo** → **Choose...** (PNG or JPEG; transparent PNGs look best). The logo replaces the call letters in the titles and the bug. **Clear** goes back to the call letters.

Animated logos loop in the titles and the bug: **APNG** and **GIF** play on their own frame timing, and **WebM**, **MOV** or **MP4** play through ffmpeg (install it with `brew install ffmpeg`), keeping a WebM's transparency. Every frame shares one crop, so the artwork does not jump; up to 360 frames are kept. **Clear background** removes a flat background from files without transparency.

FONTS

Graphics → **Headline font** and **Label font** take a TrueType or OpenType file (`.ttf`, `.otf`, `.ttc`) for every graphic: the headline face (titles, big numbers) and the label face (subtitles, values). **Built-in** goes back to the DIN pairing. A file that is not a font is named in red and the built-in face stays.

A DIFFERENT LOOK FOR EACH SCENE

Every page scene can have its own look, so the 7-Day can be in **Local sky** while Current Conditions stays in **Aero glass**. Open the scene's **Look** tab; under **Page layout**:

- **Theme**: Aero glass, Network blue, Local sky or Classic cards. **Station (...)** follows the station theme in Settings.
- **Icons**: Classic flat or Shaded, or **Station**.
- **Layout**: any Template Designer layout for that page, **Built-in layout**, or **Station (...)** for the one marked On air. Map scenes have this row too, for the map frame.

The choice is saved with the scene and goes everywhere it does: output windows, recordings, thumbnails and saved shows. Only the scene on air changes; the rest of the window keeps the station theme.

PAGE TEMPLATES (TEMPLATE DESIGNER)

Open it from the **Look** tab of any 7-Day, Current Conditions, Hour-by-Hour, Alerts, Drive Times or Model Comparison scene (**Page layout** → **Open Template Designer**, which also shows the layout on air), or from **Graphics** → **Package** → **Template Designer...**. It lays out the **7-Day Forecast**, **Current Conditions**, **Hour-by-Hour**, **Alerts**, **Drive Times** and **Model Comparison** pages your way, saved for the station (its call letters).

The designer works like a slide editor: each page is a canvas of **elements** you add, move, size, turn, layer and style, over a background of your choosing.

1. Pick the page from the tabs at the top (a ● on a tab means one of your templates is on air for it). A page with no template yet offers **Start from the built-in layout** (7-day: today large with the rest of the week in two rows; current: hero temperature with a location bar; hourly: eight 3-hour cells over the chart; alerts: a card per alert; drive times: a row per route; model comparison: the chart) or **Start from a blank page**. Later templates come from **+ New ▾** in the template bar (built-in layout, blank page, or a copy of the one open). The **ON AIR** switch in the template bar puts the template on air in place of the built-in page (click again to go back).
2. Add elements from the **INSERT** group of the toolbar (**EDIT** has undo, redo, duplicate and delete; **LAYOUT** has arrange, align and snap): * **Text**: a free text box. Text takes live values (see the variables below); **Insert live value** in its properties adds one. * **Data**: text bound to one value (temperature now, condition, today's high, a day's name, an alert, a route…) with optional text before and after (`°`, `%`, `HIGH`). * **Shape**: rectangle, ellipse, triangle, diamond, arrow, star or line. * **Picture…**: a picture, logo or animation from a file (PNG, JPEG, GIF; MP4, MOV and WebM through ffmpeg). * **Icon**: a live weather icon (conditions now, or any forecast day) or a fixed one (sunny, rain, snow, thunder and the rest). * **Chart**: a data chart (temperature line, temperature with rain chance, the week's highs and lows, rain chance bars, wind and gusts) that you can then restyle. * **Widgets**: the ready-made pieces: one forecast day, a single hour, an alert card, a drive route row, the station logo, the built-in 7-day columns, current panel, hourly chart, alert board, drive-times table and model chart, and the map-frame legend, info box, valid time and timeline. Alert and route slots with nothing in them draw nothing (an empty first alert slot shows "No watches or warnings").
3. On the canvas: * Click an element to select it; **Shift-click** adds or removes one, or drag a box around several on empty canvas. **⌘A** selects all. * Drag to move. Pink **guides** show and snap when an edge or center lines up with the page's edges and center or with another element (**Snap** in the toolbar; hold **Alt** to move freely). Arrow keys nudge (Shift for 1% steps). * Drag any of the eight white **handles** to size it; corners keep the shape with **Shift** (pictures and icons always keep theirs). With several selected, the handles scale the whole group. * Drag the round **knob** above the box to turn it (Shift for 15° steps; it settles on 0°, 90°, 180° when Snap is on). Anything turns, text and charts included. * **Arrange** (or **⌘]** / **⌘[**, with Shift for all the way) brings it forward or sends it back; **Align** lines the selection up left, center, right, top, middle or bottom (one element aligns to the page) and **distributes** three or more evenly across or down. * **Duplicate** (**⌘D**), **Delete** (Delete key), copy / cut / paste (**⌘C ⌘X ⌘V**), **Undo** / **Redo** (**⌘Z** / **⇧⌘Z**). * **Layers** on the left list every element, top first: click to select (Shift for more), the dot hides or shows it. **Lock** in its properties keeps it from being picked or moved.
4. The **properties** panel on the right edits the selected element: * **Content**: the text, data value, shape, picture, icon or chart. * **Position and size** in % of the page, and the **turn** in degrees. * **Fill**: none, the theme's card, the station accent, any color, or a two-color **gradient** at any angle; **corners**; a **border** (width, color, dashed); a soft **shadow** (color, offset, blur); **opacity**. * **Text**: color, font, size, alignment, capitals. * **Animation** (see below). With several elements selected, **Copy this element's style to the others** gives them all the primary one's fill, border, corners, shadow, opacity and text style.
5. **Charts**: pick **Hourly** (any number of hours from now, a point every 1 to 12 hours) or **7-day** data, then add **series**: each has a value (temperature, feels like, dew point, rain chance, rain amount, snowfall, wind, gusts, cloud cover, pressure, CAPE; or the day's high, low and rain chance), a type (**line**, **bar** or **area**), a color, line width, fill opacity, dots, values over each point, smoothing and a legend name. For the chart: time and value **axes**, a **legend**, **gridlines** and their color, the label font, size and color, and a

fixed y range or one that starts at zero. A built-in hourly chart becomes a custom one with **Make it a custom chart**.

6. **Background**: with nothing selected the panel shows the page. Choose the station backdrop, a **colour**, a **gradient**, a **picture** or a **video loop** (MP4, MOV, WebM through ffmpeg, or an animated GIF; up to 16 seconds loop), with **cover** or **fit**, **blur** and **darken** so text reads over it. Each template has its own background, so each page can look different. (The map frame has none: the map shows through.)
7. Text takes live variables: `{city} {temp} {cond} {hi} {lo} {time} {date} {station}`; per day `{d1_name} {d1_hi} {d1_lo} {d1_pop} {d1_text}` through `{d7_…}`; per hour ahead `{h0_temp} {h3_time} {h3_pop} {h3_wind}` (h0 to h48); alerts `{alert_count} {a1_event} {a1_until} {a1_area} {a1_headline}`; routes `{r1_name} {r1_time} {r1_delay} {r1_miles}`.
8. Tick **Use on air**: the page now draws from the template whenever this station is on air. Untick it (or delete the template) to go back to the built-in page.

Templates made before the canvas editor open as they were: their panels become rectangles and a text block that showed one value becomes a data field, with nothing moved or restyled.

File → Duplicate template makes a variation; templates from another station can be copied in from the template list. Current Conditions with several places keeps its own cards or table.

Map frame: the **Map frame** page lays out what sits over every map scene: the **legend** (of whatever the scene shows), the **info box**, the **valid time**, the loop **timeline** and any text, panel or logo, placed anywhere on the picture (the preview shows a stand-in map). Text takes `{title} {model} {valid}` besides the usual variables. With **Use on air**, map scenes draw it instead of the built-in legend, timeline and info box; the title graphic stays. It opens from the Look tab of any map scene.

Animated blocks: every block on every page can **come on** when the scene is taken: fade in, slide from any side, grow or wipe, after a delay and over a time you set; and **go off** before the next take (fade, slide off, shrink, wipe off), timed to finish as the scene ends when the rundown auto-advances. A **path** of keyframes moves, scales and fades a block over time after the take: each key has a time and a move (% of the page), size and opacity, and the block eases between them. Set keys by dragging, with the **timeline** under the preview:

- Drag the red **playhead** to a time (the preview holds there), press ● **Record**, and drag the selected element on the preview to where it should be at that moment; its corner sizes it. That makes (or updates) the key at the playhead; the first one also pins the element's resting place at 0 s, so it moves from where you laid it out.
- Each key is a ◆ on the timeline: drag it sideways to change its time, click it to hold the preview there. ◆ **Key here** adds a key at the playhead, ✕ **Delete key** removes the one shown.
- On the canvas each key also shows as a numbered box on the path: drag its dot to move it, its corner to size it.
- ▶ **Play** plays entrances, paths and exits in the preview, which loops them. Opacity is set in the key list in the properties panel.

In the layers list, ◆ marks elements with keyframes and ▶ those with an entrance.

Sharing between stations: in the **File** menu, **Export this template...** saves it as a `.wxtemplate` file and **Export all of this station's...** saves every template of the station in one; **Import...** adds templates from such files (several at once). Imported templates belong to this station and start off air.

COLORS AND THE REST OF THE PACKAGE

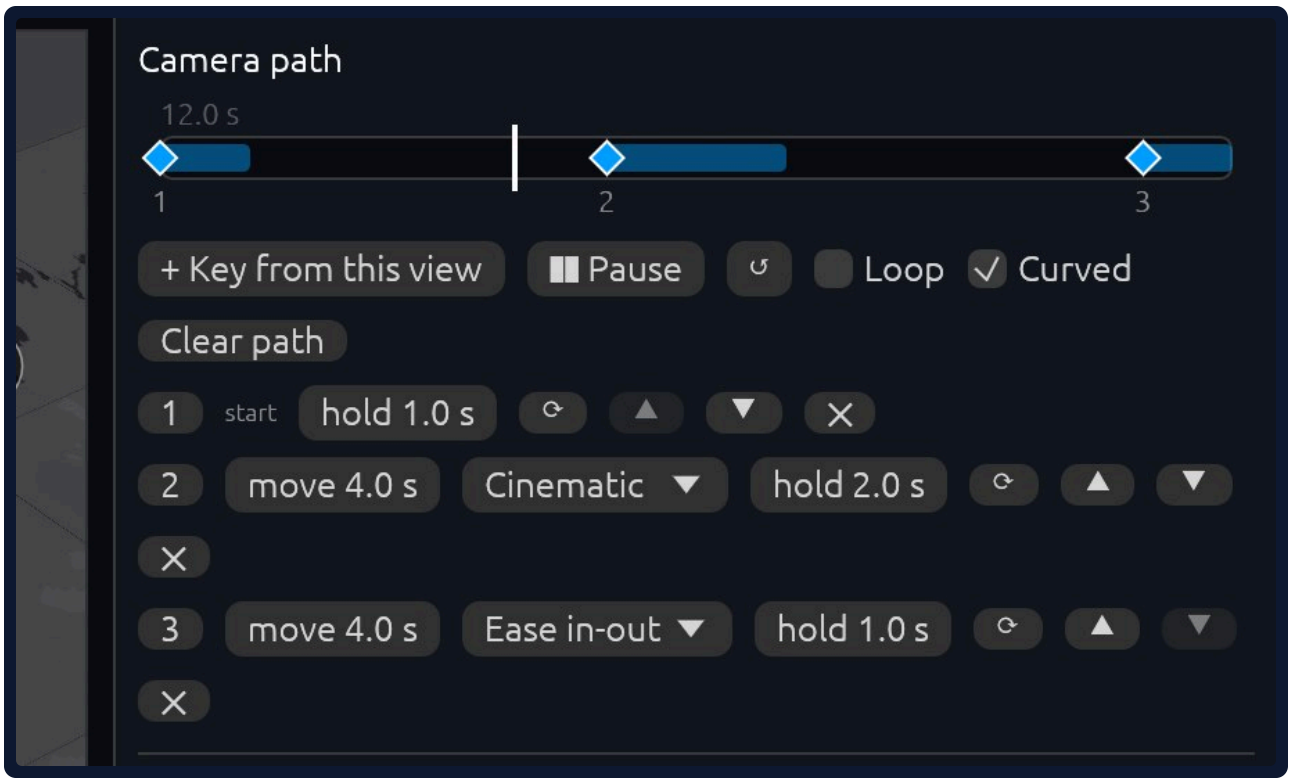
- **Accent** and **surface hue** in Graphics.
- **Look tab** per scene: which on-air elements show (title, bug, legend, timeline, crawl) and text layers.
- **Graphics Editor**: color tables for radar, model products, warnings and SPC outlooks; import `.pal` files.
- **Talent lower third** (L): its accent rule draws across, the panel wipes open and the name rises in; pressing L again plays it out in reverse. Exports draw it fully in.
- The **crawl** (custom messages or alerts).

CUSTOM BANNER IMAGES

Pick **Custom image** as a title style (for the show in Graphics, or one scene in its Title graphic) to put your own art behind the title. The art is a full-frame PNG, 1920×1080 on a transparent background, so it can sit anywhere on the frame; WX Studio still draws the live title, the product line, the clock (or your tag) and, if you like, the logo, in fixed zones.

- **Banner image** (Look tab, under Title graphic) sets this scene's own PNG, and **Show's banners by product** sets one each for radar, satellite, model maps, forecast pages, severe & warnings, tropical, soundings and a default. A scene uses its own image, else its product's, else the default. Save over the PNG in your editor and the program picks it up in a moment.
- **Dark text** draws the title, product line and clock in dark ink for light art; **Draw the station logo** puts your logo in the logo zone (turn it off when the logo is part of the art).
- **Save the banner template (PSD)** writes a layered Photoshop file and an example PNG. Design on **Your banner art**; **Safe zones** marks where the logo, title, product line and clock go and the title-safe frame; **Reference program** is a backdrop to judge contrast against. Hide those two layers and export PNG.

06 TRANSITIONS AND CAMERA MOVES



A keyframed camera path on the Camera tab.

How each scene comes to air, and how the camera moves while it is there.

TRANSITIONS

- **Per scene** on the **Camera** tab: Fly, Cut, Dissolve, Wipe, Push, Zoom, and 3D Swing, Cube, Flip and Fly away, with their length.
- **House rules**: what to use when a scene says Fly but there is no map move (pages), the transition used in Live mode, and how the chips animate in.
- Map flies keep model fields drawn the whole way: the field is colored for the whole trip when the scene is taken.

CAMERA PATHS (KEYFRAMED MOVES)

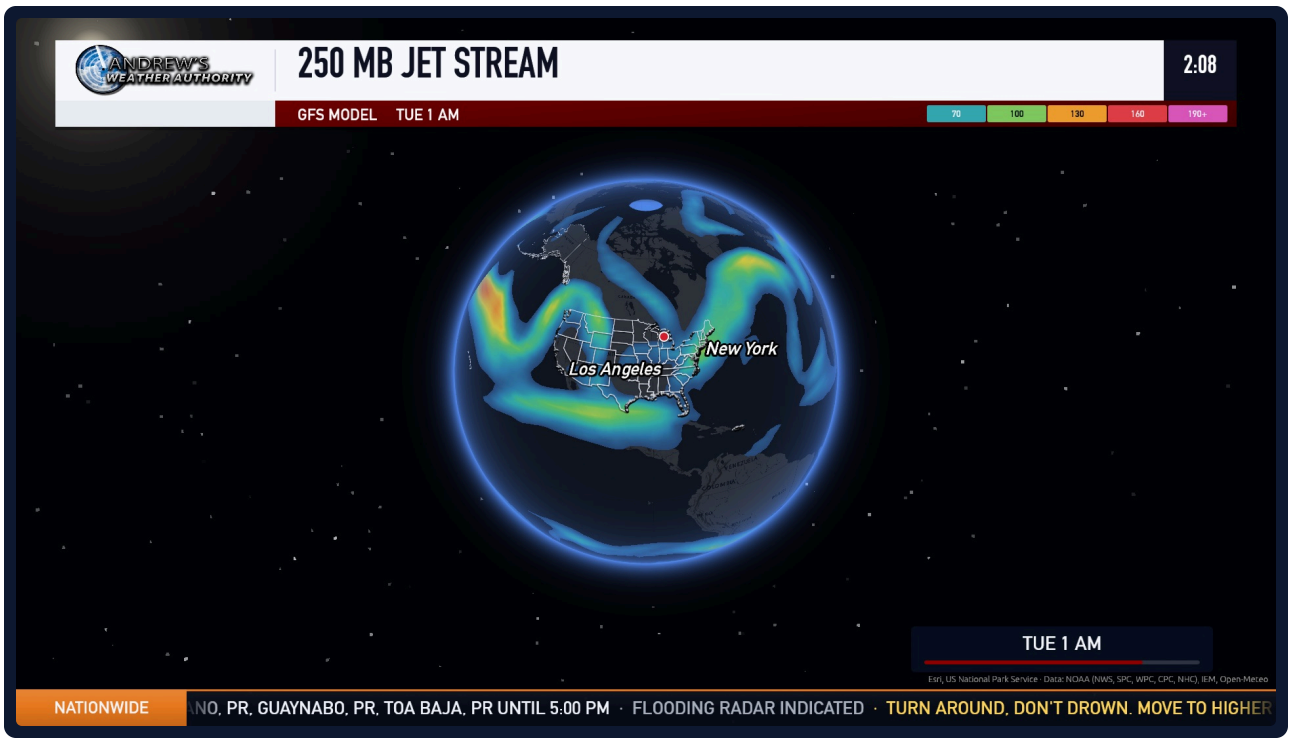
A map scene can carry a path through any number of camera keys, each a full framing (position, zoom, tilt and heading). On the **Camera** tab under **Camera path**:

- Frame the map and press **+ Key from this view**; repeat for each stop.
- The **timeline** has a ruler in seconds, each move as a span labeled with its time and easing, each hold as a block and each key as a numbered ◆. Drag a ◆ sideways to change when the camera arrives there (the later keys move with it), drag the white end of a hold to hold longer, click or drag anywhere else to scrub the map, click a ◆ to jump to it.
- Each key is a card with its place, zoom, tilt and time: **fly** (seconds to travel there), the **easing** (Ease in-out, Cinematic, Ease in, Ease out, Linear) and **hold**. **Go** shows the key on the map, **Use this view** replaces it with the map as framed now, ▲ ▼ reorder and ✕ removes.
- While the Camera tab is open and you are not live, the program shows the path over the map: the flight as a dashed line, each key as a numbered marker with a frame of what that key's view takes in, and a crosshair where the camera is at the playhead (preview only, never on air).
- **Curved** runs a smooth curve through all the keys instead of straight hops; **Loop** goes back to the first key and starts again.
- When the scene is taken, the map flies to the first key and the path plays: **▶ Play / ▮▮ Pause**, **↺ Start** back to the beginning. Dragging the map stops the path.

PART III

WEATHER DATA

07 MAPS



Zoomed out, the GPU map becomes a globe: the jet stream from the GFS.

Every map in WX Studio is drawn in true 3D on the graphics card, with a choice of basemaps, map looks and layers that apply across radar, satellite and model scenes.

PICKING A PRODUCT

Click the product button on the Scene tab (or in the bottom control strip). The menu has eight sections:

SECTION	PRODUCTS
Radar & Satellite	Radar, Storm Velocity, Satellite, Visible Satellite
Observations	Current Observations (station plots), Storm Reports, Map Only (overlays)
Surface	Temperatures, Feels Like, Dew Points, Humidity, Wind Flow, Wind Gusts, Surface Pressure, Cloud Cover, Visibility, 24-Hour Temp Change, plus catalog surface and cloud products
Precipitation	Futurecast, Simulated Radar, Rainfall Totals, Precipitable Water, 3–120 h QPF
Severe	CAPE, CIN, Lifted Index, 0–1 and 0–3 km Helicity, Updraft Helicity, Lightning Threat, Nadocast, plus instability, shear and composite products
Winter	Snowfall Totals, Snow Depth, Freezing Level, 10:1 and Kuchera snowfall windows, depth-change snowfall, freezing rain, column max temperature, Kuchera ratio
Upper Air	250 mb Jet Stream and the catalog's height, temperature, humidity, vorticity, vertical velocity, advection and frontogenesis products, and the dynamic tropopause (2 PVU) maps
Tropical	Tropical Tracker

The section holding the current product is marked with •.

CAMERA

On the Camera tab: **National / Regional / Local / Metro** framings, **This view** (save what you are looking at), **Free** (the map stays where you leave it), **Preview**, and the **3D tilt** slider. Fly the map with the mouse: drag to pan, scroll to zoom.

Tilt and heading belong to the scene. Set them on the Camera tab (**3D tilt**, **Heading**, **Flat**) and they are saved with that scene, even a **Free** one; a scene with nothing set comes up flat and north up, so a tilt from one scene never carries into the next. Tilting live (right-drag, or the **3D** slider in the control strip) lasts until the next scene. **Show 3D** tilts its scene to 50° when you turn it on; change it from there as you like.

THE 3D MAP

The program map is drawn in true 3D on the graphics card (Layers tab → **3D map (GPU)**, on by default):

- **Globe**: zoom out past state level and the map curves into the Earth, with its atmosphere and stars behind it. Keep zooming out to see the whole planet (zoom 1); zoom back in and it flattens smoothly into the local map (fully flat from zoom 5). Untick **Globe** to keep the map flat at every zoom.
- **Terrain**: mountains and valleys from the public AWS Terrain Tiles, with the basemap draped over them and shaded by the relief. **relief** sets the vertical exaggeration (3× by default; the real relief barely shows at regional zooms). Terrain tiles are downloaded as you fly and kept on disk like basemap tiles.
- **Colours on the GPU**: model maps and single-site radar are colored by the graphics card from the raw data. Changing a color table, an opacity curve, the reflectivity floor, smoothing or storm motion shows on the next frame, zooming in never waits for re-coloring (the data is sampled at screen resolution), model playback blends the values between hours, and model fields lie on the terrain like the radar. **Single satellite bands** (IR, water vapor, visible up to 1 km on CONUS and Meso sectors) are sampled on the satellite's own fixed grid in the shader, so they stay sharp at any zoom without re-rendering, and NOAA **raster overlays** (MRMS rainfall, smoke, dust, PM2.5, ozone) are colored from their values, so a new color ramp or opacity shows at once without downloading again. **Every GOES product**, RGB composites (GeoColor, True Color, Airmass and the rest), full disk and the 0.5 km visible band included, is drawn as tiles on the satellite's own grid: only the tiles in view are made, at the detail the zoom needs, over a coarse overview of the whole scan, so panning and zooming never wait for a re-render. Himawari, GK2A and Meteosat, the vector outlooks (SPC, WPC, CPC...), the radar spotlight, the 2D map (`--painter-map`) and the OpenGL renderer color on the CPU.
- **Tilt and turn** freely (right-drag or shift-drag), as on the flat map; distant ground fades into haze when tilted.
- Radar, satellite, model shading, NOAA overlays, traffic and basemap labels are all laid on the 3D ground. Warnings, contours, town names, values, storm tracks, titles and legends draw on top, kept in the right place by the same 3D camera. Labels round the back of the globe are hidden.
- The **Level II 3D volume** is ray-traced through the reflectivity volume rather than drawn as stacked slices, so it reads as solid from any angle and hides behind mountains. It still uses the reflectivity color table and the **3D** opacity curve, and the storm box still loops with the radar.

Untick **3D map (GPU)** for the earlier 2.5D map (tilt and turn, no globe or terrain). On a computer without a working GPU driver for wgpu, WX Studio starts with the OpenGL renderer and the 2.5D map automatically; `--glow` forces that, and `--painter-map` uses the 2.5D map for one run.

MAP LOOK: STANDARD OR BROADCAST

Graphics Editor → Package → **Map look** (or Layers → **Map look, basemap, radar source & 3D**) switches the whole map's style at once:

- **Broadcast**: Esri's physical terrain basemap (tan land, blue water, relief), heavy black state lines raised with a drop shadow, model maps in flat color bands (5 °F for temperature) at near-full opacity, big white slanted town names with a dark outline, and a sun glare in the sky beside the globe. The terrain basemap is made for national and regional maps (it has no detail past zoom level 8).
- **Standard**: the dark canvas, thin light borders and smooth shading.

Each part can still be changed on its own afterwards (basemap, **Model maps in flat color bands**, **Sun glare**, the state-line style, the town-name style).

BASE LAYER EDITOR

Graphics Editor → Package → **Base layer** (or Layers → **Map look, basemap, radar source & 3D**) → **Custom base layer** builds the map under the weather from parts, each in your own color, instead of a ready-made basemap:

- **Land** and **Water** colors.
- **Terrain** shading: its color and strength (shadows from a hillshade; 0 turns it off).
- **Roads**: on or off, color and opacity.
- **States** and **Counties**: on or off, color and width.

Start from sets everything at once: Classic dark, TV green & blue, Tan & teal, Night, Light or Satellite-like. Town names stay WX Studio's own (Graphics Editor → City names). The recoloring happens on the 3D map; the flat map shows a tinted approximation.

BUILT-IN MAP (INSTANT, OFFLINE)

WX Studio carries its own map: land, water, lakes, country, state and US county lines are drawn on your machine from outlines shipped inside the app, so the map appears at once and needs no internet. It is an option; the online basemaps stay as they were.

- **Basemap** → **Built-in Dark**, **Built-in Light** or **Built-in Tan & Blue**.
- With the custom base layer: tick **Built-in map (instant, offline)** in the base layer editor. Land and water take your colors as before.
- State and county lines (Graphics Editor → Layers) are then drawn from the same outlines, in their own color and width, instead of being fetched again each time the view moves.

The outlines are Natural Earth (1:10 million) and US Census county lines. They are sharp for national, regional and metro views; zoomed in to street level the coast and lakes are plainer than the online maps, and small lakes are missing. Terrain shading and roads in the custom base layer still come from the internet (and are kept on disk after the first view).

LAYERS TAB

Basemap, radar source, opacity, city values, warning polygons and which warnings show, wind particles and barbs, isobars on futurecast, playback speed, **Traffic cameras**, **Live traffic flow**, **Lightning flashes**, **Day / night shading**, **Sunrise / moon chip**, overlays (SPC, WPC, CPC, NHC, hydro, winter, air quality, boundaries) and the per-scene layer order.

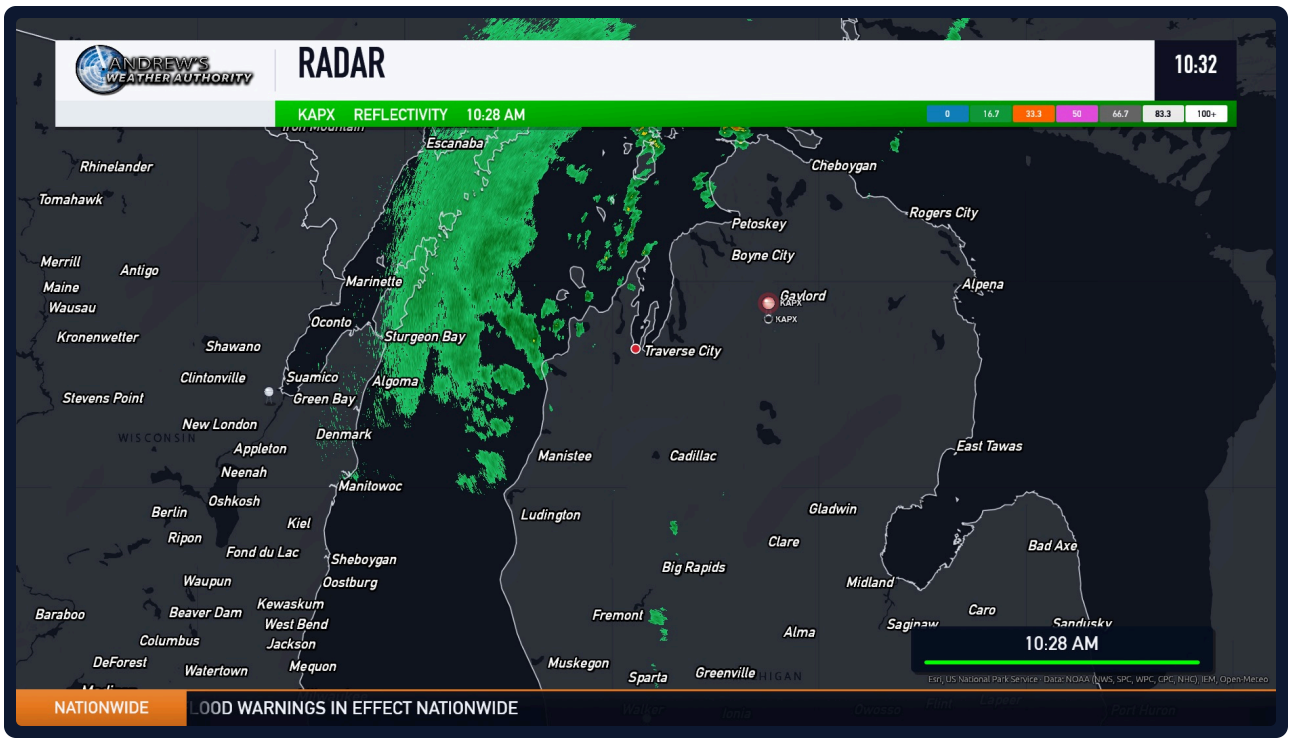
NOAA overlays (Layers tab or Data Hub), drawn from NOAA's own data on the workstation:

- **Watches and discussions** (Layers → warnings, on by default): SPC's tornado and severe thunderstorm **watch boxes** as SPC draws them, hatched in the watch color (yellow tornado, pink severe thunderstorm) with a heavy dashed edge and a "TORNADO WATCH 278 · UNTIL 10:03 PM" tag (PDS when it is one); and **mesoscale discussions** (SPC MDs and WPC precipitation discussions) as a dotted blue outline tagged "MD 2134 · WATCH 80%". Warnings stay solid outlines with a light fill, so the three never look alike. (The NWS alert feed gives watches only as county lists, which is why watch boxes come from SPC through the Iowa Environmental Mesonet.)
- **WPC**: **Surface Analysis** (the current fronts, troughs, highs and lows with pressures, from WPC's coded surface bulletin every 3 hours, drawn with standard front symbols); National Forecast Chart days 1, 2 and 3; QPF next 6 hours, days 1, 2, 3, 4-5, 6-7, 1-3, 1-5 and 1-7; Excessive Rainfall days 1-3; Significant River Flood Outlook; WSSI and probabilistic WSSI; probabilistic winter precipitation; the Winter Weather Outlook days 4-7.
- **CPC**: 6-10 and 8-14 day temperature and precipitation; monthly and seasonal (next 3 months) temperature and precipitation; monthly and seasonal drought outlooks; 3-7 and 8-14 day hazards; GFS precipitation anomalies for weeks 1 and 2; the weekly sea-surface temperature anomaly.
- **Also**: NOHRSC snow depth and snow water equivalent, RFC flash-flood guidance (1 and 3 h), MRMS observed precipitation, SPC outlooks, NHC, air quality and boundaries.
- Snow analysis, flash-flood guidance, the CPC anomalies and the Winter Weather Outlook come in NOAA's own colors; the rest are colored and styled in WX Studio.

DAY AND NIGHT

Day / night shading (Layers tab) shades the night side of the Earth at the time of the frame on air: the valid hour on model maps, the frame time on radar and satellite, now otherwise. Twilight fades in from sunset to the end of astronomical twilight, a thin warm line marks the terminator and a sun marks where it is overhead. It drapes on the 3D globe like any map image. Move **Day / night shading** in the layer list to put it over or under the data. **Sunrise / moon chip** adds today's sunrise, sunset and moon phase at your location under the title. The **Day & Night** module in the Data Hub starts a zoomed-out map with both on.

08 RADAR



Single-site radar, decoded in the app.

WX Studio decodes NEXRAD Level III and Level II, TDWR and MRMS itself, so every product is colored with your tables, re-rendered at screen resolution, and available in 3D.

PRODUCTS AND SOURCES

- **Single-site NEXRAD** (Level III), decoded in WX Studio: reflectivity at several tilts, velocity, **storm-relative velocity**, correlation coefficient, ZDR, KDP, hydrometeor classification, echo tops and one-hour rainfall. Pick products with the buttons in the control strip (REF, VEL, SRV, CC, ZDR, KDP, HC, TOPS, RAIN) or keys **1–9** in Live mode.
- **More products** (the **More** row on the Scene tab, **More** ▾ in the control strip, and the Live panel): **VIL** (digital vertically integrated liquid), **DHR** (hybrid scan reflectivity: the lowest unblocked tilt everywhere), **HHC** (hybrid hydrometeor class), **STA** (storm-total rainfall), **3HR** (three-hour rainfall) and **24HR** (24-hour rainfall ending at 12Z). Velocity also comes at four tilts: 0.5°, 0.9°, 2.4° and 3.4°.
- **Rotation and debris**, computed by WX Studio from the lowest scans (guidance, not NWS detections):
- **AZSH**, azimuthal shear: how fast velocity changes across the beam, from a least-squares fit over about 2 km at every gate, in 10^{-3} s^{-1}. Cyclonic rotation only.
- **NROT**, normalized rotation: that shear divided by a threshold that eases with range (beam spreading weakens measured rotation), so **1.0 means mesocyclone strength** at any range and 2–3 is strong. Kept only inside storms (20 dBZ or more), from 8 km out.
- **TDS**, tornado debris signature: gates with correlation coefficient of 0.82 or less in 35 dBZ or more, with ZDR near zero and NROT 1 or more within about 2 km, inside 150 km of the radar, colored by their CC (whiter = lower = more debris-like). Low CC alone also shows hail, birds and clutter; the rotation requirement is what separates debris.
- **Radar site**: nearest by default; pick another in Settings, or show radar sites on the map and click one.
- **TDWR airport radars**: the 45 Terminal Doppler Weather Radars (ids starting with T, marked **TDWR** in the site list) can be picked like any site. They are C-band: finer and faster than a WSR-88D near the airport but weakened behind heavy rain. Reflectivity comes from the long-range scan (300 m gates to about 410 km); velocity and storm-relative velocity from the short-range scans (150 m gates to about 90 km). TDWRs send no other products, and the nearest-site default always stays a WSR-88D.
- Level II (the full volume, in 3D) also gives **spectrum width** and **differential phase** (PHI) at every tilt.
- **Mosaics**: Layers tab → **Basemap, radar source & 3D** → **Radar**:
- **NEXRAD Mosaic (MRMS, in-app)**: NOAA's Multi-Radar Multi-Sensor mosaic (every NEXRAD and Canadian radar merged at 1 km, every 2 minutes), decoded in WX Studio onto 2.5 km cells (each cell keeps the strongest echo inside it) and colored on the GPU with your radar color table, so it matches single-site radar and any zoom stays sharp to regional scale. The loop is the last 10 scans, 6 minutes apart, and refreshes every 2 minutes; frames are labeled with clock times. More mosaic products are under **Product** → **Radar mosaic**: composite and base (lowest-scan) reflectivity, 18 dBZ echo tops (kft), hail size (MESH, inches), 60-minute rotation tracks and rain rate.
- **Product** → **MRMS (all products)** has the rest of MRMS, in groups:

- **Reflectivity**: low-level composite, lowest altitude, merged base, 1-hour maximum composite and base, at 0, -10 and -20 °C, layer composites (low, high, super) and constant-altitude slices at 1 to 12 km.
- **Dual-Pol**: merged ZDR and correlation coefficient.
- **Heights & Tops**: 30, 50 and 60 dBZ echo tops, high-res enhanced echo tops, heights of the composite and base reflectivity, 50 and 60 dBZ heights above 0 and -20 °C, the bright band, and the RAP freezing level, surface temperature and wet-bulb MRMS uses.
- **Hail**: hail size (MESH) maxima over 30 minutes to 24 hours, probability of severe hail and the severe hail index.
- **Rotation**: 0-2 km and 3-6 km azimuthal shear, and rotation tracks over 30 minutes to 24 hours at both layers.
- **VIL & Ice**: VIL, high-res VIL, VIL density, 2 and 24-hour VIL maxima and vertically integrated ice.
- **Precipitation**: precipitation type, warm-rain probability, radar quality, radar-only rainfall (15 minutes to 72 hours, and since 12Z) and multi-sensor rainfall (pass 1 and pass 2, 1 to 72 hours).
- **Lightning**: cloud-to-ground density over 1 to 30 minutes, 30 and 60-minute lightning probability and lightning jumps.
- **Flash Flooding**: recurrence intervals (30 minutes to 24 hours and maximum), rain as a percent of flash-flood guidance (1, 3, 6 hours and maximum), soil saturation and unit streamflow from the CREST, SAC-SMA and hydrophobic models.

Each decodes on the same 2.5 km grid as the mosaic and gets a color bar for its units. Products MRMS hasn't updated recently (some hail, lightning and flood grids stay empty in quiet weather) load as an empty map. * **NEXRAD Mosaic (IEM)** or **Global (RainViewer)**: ready-made image tiles. * Options: hide below a dBZ, mask velocity by reflectivity, smoothing, despeckle, the sweep and range rings, and manual storm motion for SRV.

OPACITY CURVES

3D tab → Radar tools → **Opacity curve** sets opacity by value, GR2-style, for the product on the map and (with 3D on) for the volume. The graph shows the color bar faded by the curve over a checkerboard. Drag a point to move it (it stays between its neighbours); press empty space to add one and drag it into place; right-click a point to remove it. The graph follows the pointer every frame; the map catches up a few times a second while you drag and exactly when you let go. Presets: **Solid**, **Hide light**, **Ramp**, **Cores only** (reflectivity) and **Ramp**, **Fade middle** (other products). Example: 0% up to 10 dBZ and 100% from 21 dBZ hides light echo and keeps the rest solid. The 3D curve is opacity for 2 km of echo, so thin and deep parts of a storm read correctly.

DATA PROBE

⌖ **Probe** in the control strip (or **P**) shows the value under the cursor for whatever the map shows: single-site radar (any product and tilt, velocity in knots and storm-relative where the product is), satellite (cloud-top temperature in °C, or visible reflectance) and model fields. Click the map to pin a value box there; pins belong to the scene, so they are saved with the show, go to air, and their values follow the loop frame by frame. Click a pin to remove it, or ✕ **pins** in the control strip to clear the scene's pins.

SPOTLIGHT

Radar controls → **Spotlight** puts a lens on the radar map: inside the circle you see velocity (at the same tilt, Level II or Level III), or reflectivity when the map shows velocity. It follows the cursor over the program map and stays where you leave it on air; set its radius in km.

TURNING THE MAP

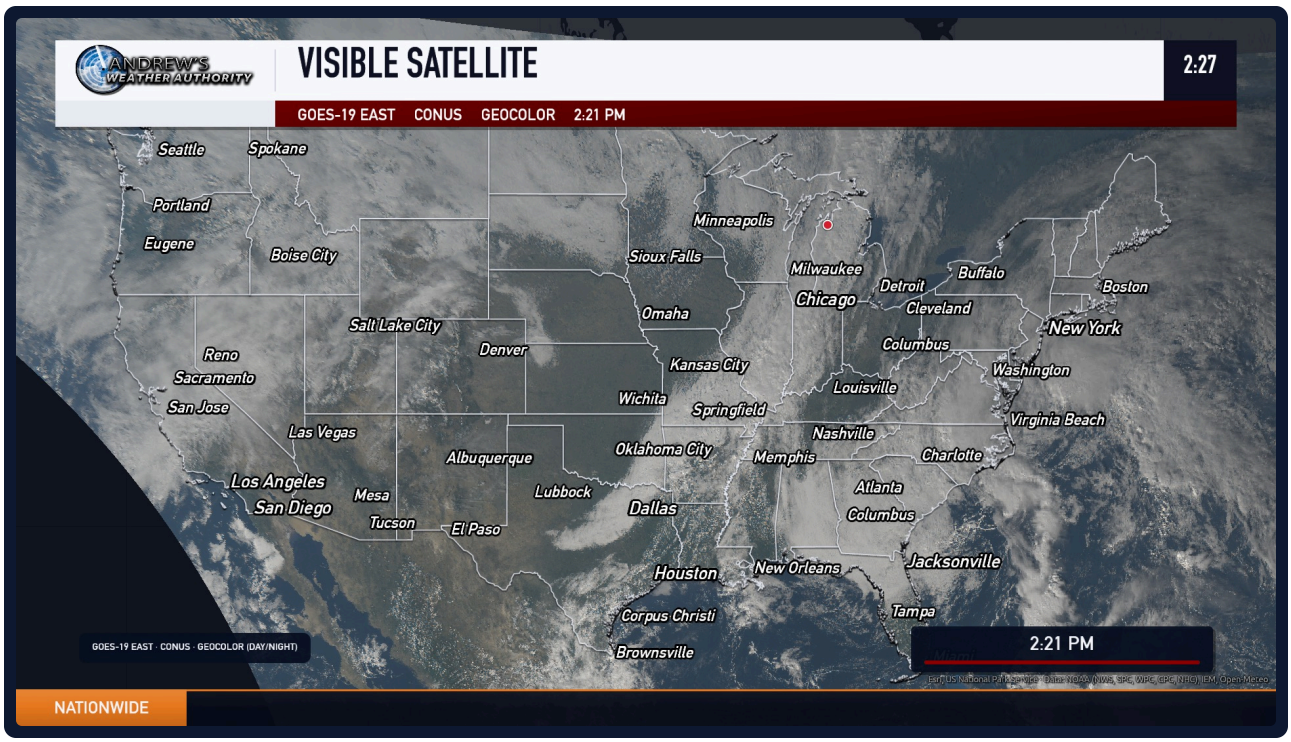
Right-drag (or shift-drag) sideways to turn the map; up and down still tilts. Two-finger rotate works on a trackpad. Within 6° of north the map snaps to north, so it is easy to get back; keep turning and it lets go. The **Heading** slider and **North up** button are under the map controls, and a north arrow appears on the map whenever it is turned. Saved views keep their heading.

LEVEL II: EVERY MOMENT, EVERY TILT, CROSS SECTIONS AND 3D

NEXRAD **Level II** is the full volume scan: every moment at every tilt (9 to 15 depending on the scan mode), downloaded from NOAA's public archive for the radar in use. Volumes reach the archive about 10 minutes after the scan; Level III is faster but has fewer tilts and products.

- **Level II products**: in the radar controls, switch **Level III / Level II**. Level II offers **REF, VEL, SRV, SW** (spectrum width, kt), **ZDR, CC** and **PHI** (differential phase), with a button for every elevation angle in the current volume plus ▲ / ▼ to step tilts. Loops use up to six volumes (each is about 10 MB, cached on disk for 6 hours). Non-reflectivity moments are masked by reflectivity from the same volume at the nearest angle; SRV uses the same storm motion as Level III SRV. Color tables are shared with the matching Level III product.
- **Cross section**: on a single-site radar map, on the 3D tab click **Draw A → B**, then click two points on the program map. The line appears on the map and a panel at the right shows the vertical slice of reflectivity from the ground to 52,000 ft, with height in feet and distance in miles. **Clear** removes it. The slice is saved with the scene.
- **Storm box** (3D tab → **Box a storm**, then click two opposite corners): the volume inside the box is rebuilt at up to 140 cells across (no coarser than 300 m), the view flies in and tilts, and a wireframe box with height ticks frames the storm. The 3D volume **loops with the radar**: the last 6 Level II volumes (4 in Live mode) are kept, and each radar frame shows the volume closest in time. **Whole radar** drops the box.
- **3D volume** (Data Hub → Severe → 3D Radar, or **Show 3D** on the 3D tab of any radar map): the reflectivity volume stands up over the map itself (ray-traced in 3D on the GPU map, see The 3D map), with a height pole at the radar marked every 10,000 ft. Turning it on tilts the scene gently (30°) if it was nearly flat (saved with the scene; the **Tilt** slider changes it). Zoomed out to the globe the volume is hidden until you zoom back in. Heights are stretched a fixed 7× so the storm keeps its shape as you zoom; **height ×** stretches or flattens that. It combines with the cross section, the 2D radar underneath, warnings and every other map layer. (Older rundowns with the separate 3D Radar scene still play.) **Speed:** the newest volume stands up within seconds while the rest of the loop downloads, then the loop fills in. 3D scenes coming up in the rundown are built ahead (and the Level II download starts as soon as any scene in the show uses 3D), and the last few loops are kept, so cutting between 3D scenes is instant. Panning or zooming never rebuilds the volume; it only refreshes when a new scan comes in (every 4 to 5 minutes).
- **3D Radar scene time-lapse**: on a 3D Radar scene, **Loop the last 8 volumes** plays the newest Level II volumes (about the last half hour) one after another, holding on the newest, with a dot per volume along the bottom. **Storm-relative** follows the selected storm (or the most threatening one) along its radar-tracked motion: each volume is cut from a 90 km box moved back along the storm's track to where it was at that scan, and the camera orbits the storm, so it stays centered and you watch it grow while the ground, towns and radar slide past. The title says which storm it follows; with no tracked moving storm it shows the whole radar.
- Beam geometry uses the standard 4/3-earth model; echoes under 10 dBZ are left clear. Far from the radar the lowest beam is high (about 5 km at 230 km), so low-level detail fades with distance, as it does on any single radar.

09 SATELLITE

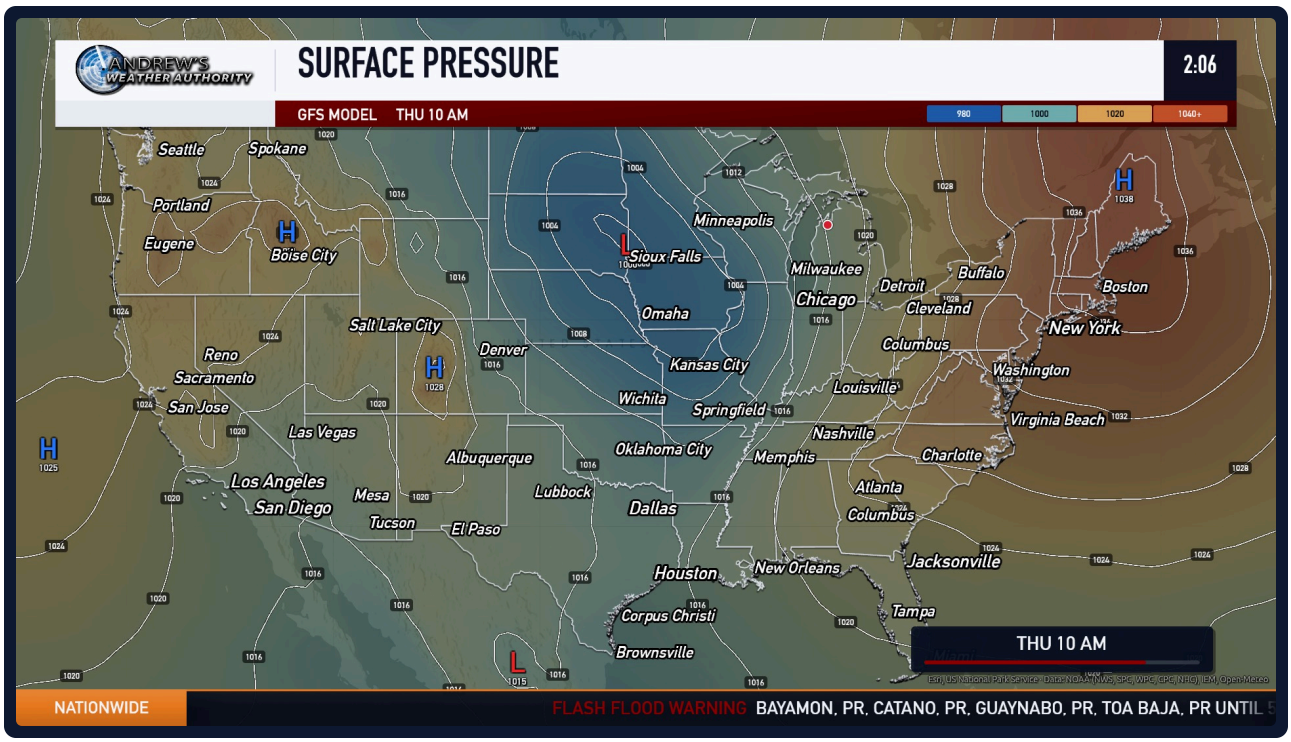


GOES-19 GeoColor, decoded in the app and drawn on the satellite's own grid.

GOES-East and GOES-West imagery is decoded in the app from NOAA's raw files, and Himawari, GK2A and Meteosat complete the ring around the globe.

- **GOES-19 East** and **GOES-18 West**, sectors **CONUS/PACUS**, **Full Disk**, **Meso 1** and **Meso 2**.
- **Himawari-9** (Japan, 140.7° E), **GK2A** (Korea, 128.2° E) and **Meteosat-12** (Europe and Africa, 0°) complete the ring around the globe. They are full disk only, every 10 minutes:
- Himawari-9 and GK2A are decoded in the app at 2 km: infrared, water vapor, Airmass and the infrared RGBs (Night Microphysics, Dust, Simple Water Vapor) use the same enhancements as GOES. Visible and true color are not available from them.
- **Meteosat-12 with a Data Store account** (Settings → Maps & radar → **EUMETSAT Data Store**, the consumer key and secret from your free account at eoportal.eumetsat.int): every FCI channel raw from the Data Store, calibrated in the app (brightness temperature for the infrared, reflectance for the visible, 1 km visible averaged to 2 km), so **true colour**, the visible and every infrared product and RGB work as on GOES. Each 10-minute disc comes in 40 strips of about 17 MB; only the strips over your area (your latitude ±25°) download, once per image for all channels, and are kept on disk for 6 hours.
- **Meteosat-12 without an account**: the 10.5 µm infrared image from EUMETSAT's EUMETView, turned back into temperatures for WX Studio's IR enhancement. Infrared only; it covers 70° N to 70° S and 70° W to 70° E.
- Full disks are large (GK2A about 35 MB a frame): a long loop takes a minute or two to load the first time. Lower **loop frames** for a quicker start.
- All 16 ABI bands with broadcast enhancements; **True Color** (IR at night) and **Airmass**.
- **Derived RGBs**: Day Cloud Phase, Night Microphysics (fog), Dust, Day Convection, Fire Temperature, Natural Color, Day Snow-Fog, Sandwich (visible with cold IR tops in color), Simple Water Vapor, **Volcanic Ash**, **SO_2**, **Differential Water Vapor**, **Day Cloud Type** and **Day Cloud Convection**.
- **Satellite-derived products** (Product → **Satellite-derived**), NOAA's GOES Level 2 retrievals resampled to about 4 km: **cloud-top height** (kft), **precipitable water**, **land** and **sea surface temperature**, the clear-sky stability indices (**CAPE**, **lifted index**, **K index**, **total totals**, **Showalter**), **fire temperature**, **smoke & dust** (aerosol optical depth), the **cloud mask** and **rain rate**. GOES-19 is used, or GOES-18 for western regions. Retrievals that need clear sky are blank under cloud; rain rate and sea temperature come from the full disk.
- Full Disk is limited to 2 km bands; visible and color products need CONUS or a Meso sector.
- **Keep preloaded** (⍰) downloads and decodes a product in the background so it is instant on air. Loop length is set with **loop frames**.

10 MODELS



GFS sea-level pressure with styled isobars and H / L markers.

Model data comes straight from NOAA NOMADS, ECMWF open data, Environment Canada and Open-Meteo, cropped to the view and decoded on your machine.

MODELS AND DOWNLOADS

- **Models**: HRRR, RRFS, GFS and NBM come straight from NOAA NOMADS as GRIB2. ECMWF, ICON, GEM and UKMET come through Open-Meteo, as do **ICON-EU** (7 km, to 5 days) and **ICON-D2** (2 km, to 2 days) over Europe, **ARPEGE** (Météo-France, to about 4 days), **JMA GSM** (to 11 days) and **CMA GRAPES** (to 10 days). Pick the model with the buttons in the control strip (**More** ▾ has the rest).
- **Model timing alerts** (Settings → Models, on by default): every few minutes (2-60, default 5) WX Studio checks the newest run of each model on air, coming up or preloaded. When one lands you get a note ("GFS 12Z Nov 9 is in"; several at once in one note), and optionally a desktop notification; the model's map grid reloads from the new run, the preloaded area refreshes and the point forecasts follow. The last few arrivals are listed under the setting.
- **NOAA's AI models** (More ▾, maps):
- **AIGFS (NOAA AI)**: NOAA's operational AI GFS, four runs a day to 16 days every 6 hours at 0.25°: temperature, wind, pressure and precipitation, from NOMADS.
- **GraphCast, FourCastNet, Pangu-Weather and Aurora (AI)**: the AI models NOAA's research office runs from the GFS analysis twice a day, to 10 days every 6 hours at 0.25° (temperature, wind and pressure; GraphCast also precipitation). Each run is a single 5 GB file on AWS; WX Studio reads only the pieces a map needs by byte range (about 10 seconds for two days). These are experimental research output, credited on air with their maker ("Experimental AI: GraphCast (Google DeepMind), run by NOAA OAR"). The GraphCast and Pangu-Weather model weights are licensed for non-commercial use; check before using their maps commercially.
- **AIGEFS mean (NOAA AI)** and **HGEFS mean (hybrid)**: the means of NOAA's AI ensemble (31 members, to 16 days) and of its hybrid ensemble (the GEFS and AIGEFS together, to 10 days), every 6 hours: temperature, wind, pressure and precipitation.
- The HREF, SREF and CONUS HiresW have ended (HiresW now runs for Guam only), so they aren't offered.
- **GEM from Environment Canada**: the Canadian GEM global model (15 km) is read straight from the MSC Datamart under Environment and Climate Change Canada's open license (commercial use allowed; "GEM: Environment and Climate Change Canada" goes on air), hourly to 48 hours then every 3 hours to 10 days, from the 00 and 12 UTC runs. Each step's fields (about 1 MB each) download once per run and are kept on disk; the first week at a point takes a couple of minutes and loads beside the other models. Settings → Models → **Direct sources** switches back to Open-Meteo, which is also used if the Datamart can't be reached.
- **GEM Regional (RDPS) and HRDPS**: Canada's regional GEM (10 km over North America, hourly to 84 hours) and high-resolution HRDPS (2.5 km over Canada and the northern US, hourly to 48 hours), both four runs a day from the same Datamart, credited the same way. They're in the model menus for maps, the hour pages and Model Comparison. A full HRDPS run is large (about 1.4 GB for a 48-hour map), so its first load takes a few minutes; after that it comes from disk.
- **Whole runs for the long-range models**: GFS, NBM, ECMWF, ICON, GEM and UKMET maps load every frame of the run, not just the first days: the GFS hourly to 120 hours then every 3 hours to 384 (about 210 frames), the NBM hourly to 48, 3-hourly to 192 and 6-hourly to 264, ECMWF to 15 days, GEM to 10, ICON to 7½ and UKMET to 7, every 3 hours after the fifth day. While a new GFS or NBM run is still

posting, the map uses as far as it has got (the newest data first); the loop grows on the next refresh. The preloaded first day shows at once while the rest loads. Rain and snow totals weight each frame by its step, so a 3-hourly frame counts three hours.

- **How runs download**: the map on screen goes first. It starts at once, uses twelve connections, and preloads pause their requests until it is done. Only the fields the product needs are fetched, so surface products like temperature and rain come quickest. Once a surface map is in, the remaining (upper-air) fields for the same area download quietly in the background, so switching to a jet, vorticity or Q-vector map reads from disk in a few seconds instead of downloading the run again.
- Hours come in coarse first: the next 12, then every 6th across the run, then every 3rd, then the rest. The whole loop is on the map early and fills in. While it fills, rain and snow totals are rough, since each frame stands for the hours around it.
- The area loaded is the view with a wide margin, snapped to fixed steps, so panning and zooming nearby reuse the hours already on disk instead of starting a new download.
- A request NOMADS sits on for more than 15 seconds is asked for again, and the first answer wins, so one slow hour doesn't hold up the finish.
- All NOMADS downloads share one pace (100 requests a minute, under NOAA's limit of about 120), so the app never trips NOAA's temporary block. A new GFS run takes about two minutes to arrive in full; any view or product after that comes from disk in seconds.
- **NOMADS-only map models** (Scene tab → Model, or **More** ▾):
- **RAP**: the 13 km Rapid Refresh, hourly to 21 hours (51 hours from the 03/09/15/21Z runs).
- **HRRR 15-min**: HRRR's sub-hourly output, a 6-hour futurecast in 15-minute steps (24 frames). Simulated radar, temperature, dew point, wind, gusts and precipitation; rainfall totals count each step as a quarter hour.
- **RRFS**: the 3 km Rapid Refresh Forecast System, operational since November 2026, which replaced the NAM, NAM 3 km and HiresW: hourly runs to 18 hours, and to 84 hours from the 00/06/12/18Z runs. RRFS has no cropping service, so WX Studio reads only the messages it needs from each file by byte range.
- **WOOF-NAM** (More ▾): a NAM-style 12 km model run by Recast four times a day to 84 hours on the NAM's own grid, with the NAM's fields and pressure levels, made from the GFS. It keeps a NAM-like 12 km model on the map now that NOAA's NAM has ended. WX Studio reads only the fields it needs from each hour's file. Free under CC BY 4.0: "WOOF-NAM by Recast" is added to the on-air credit line whenever a scene shows it. It is not an official NOAA or NWS forecast. CONUS stations only. These are map-only, except HRRR 15-min, which also drives Hour-by-Hour and Hourly Forecast.
- **ECMWF from ECMWF**: the ECMWF (IFS, 0.25°) and the **ECMWF AIFS** (ECMWF's AI model) are read straight from ECMWF open data, free for commercial use under CC BY 4.0 ("ECMWF open data (CC BY 4.0)" goes on air with them), so they need no Open-Meteo key. The IFS runs at 00 and 12 UTC to 15 days (3-hourly to 6 days, then 6-hourly) and at 06 and 18 UTC to 6 days; a loop longer than 6 days uses the newest 00 or 12 UTC run. The AIFS runs four times a day to 15 days every 6 hours. Each step's surface fields (about 3.5 MB) download once per run from the cloud mirror or ECMWF and are kept on disk, then cut to any map or point; maps, point pages and Model Comparison all use them. ECMWF point forecasts load beside the others and join them when ready. If ECMWF can't be reached,

the last run found is used from disk, as NOMADS models do. Settings → Models → **Direct sources** switches back to Open-Meteo; if ECMWF can't be reached, Open-Meteo is used automatically. Gusts, CAPE and precipitation type are IFS only.

- **Alaska, Hawaii and Puerto Rico**: NOAA runs separate grids there, and WX Studio picks the station's region from its location (Change location): the RRFS (3 km in Alaska, 2.5 km in Hawaii and Puerto Rico), the NBM and the REFS everywhere; the HRRR and its 15-minute output in Alaska; the RAP in Alaska (11 km) and Puerto Rico (32 km); and the radar mosaic from MRMS Alaska, Hawaii or Caribbean. NOAA doesn't run the HRRR or RAP over Hawaii, or the HRRR over Puerto Rico; a scene on one of those says so and suggests the RRFS, NBM or GFS. Moving the station to another region reloads the model grids.
- **Retired models**: NOAA stopped the NAM, NAM 3 km, HREF and SREF on 3 November 2026. Scenes and saved shows that used the NAM open on the RRFS (surface products) or the GFS (upper air); NAM 3 km scenes open on the HRRR. HREF scenes load the REFS products that replaced them.
- **Preloading**: Settings → Models chooses which models download their whole domain in the background and how many hours. Each forecast hour is cached on disk, so restarts are fast. Models download one or two at a time in the order the show needs them: the scene on air first, then the scenes coming up, then the rest of the list.
- **Preloading ahead** (**scenes ahead**, 3 by default): the data of the next scenes in the rundown loads before they are taken: model runs (including a model that isn't in the list, such as the RAP, for as long as a coming scene uses it), mesoanalysis, ensembles, hydro, Nadocast, soundings, Level II for 3D radar (the 3D grid is built ahead too), plumes, tropical guidance, drive times and the market's current conditions. The NEXT card shows **DATA READY**, **LOADING** with a percentage, or **QUEUED**, and Settings lists each coming scene's state.
- **The catalog** adds about 70 products. Upper-air products draw height contours with labels and wind barbs; QPF and snowfall come in 3, 6, 12, 24, 48 and 120-hour windows ending at the hour shown.
- **Playback**: the loop row under the take buttons works for model hours, radar and satellite frames: **|◀** first frame, ◀ step back, ▶ **Play / ▮▮ Pause**, ▶ step forward, **▶|** last frame, then the scrubber (a tick per frame; click or drag to pick a time, which pauses; hover to see that frame's time), the valid time and frame number, **↻ Loop** or → **Once** (play to the last frame and stop), and for models the speed in hours per second. Keys: Space play / pause, **,** and **.** step, Home and End first and last frame. Hours are colored on a background thread and cross-faded on the GPU.
- **Contour and label styling**: Graphics Editor → Effects → **Contours & labels**. Pick a contour (isobars, the freezing line, or any catalog field's heights, temperatures or thicknesses) and set its interval, smoothing, line color and width, halo, label font (headline, label or regular face), size, color, background (box, halo or plain), spacing and decimals, and H / L markers with their spacing (the strongest center wins). A changed contour is marked • in the list; **Reset to built-in look** undoes it.
- **Upper-air products read best on the GFS**, which carries every pressure level. The first time you open them the extra levels download, so the first load is slower.

MODELS IN 3D

3D satellite (3D tab of an infrared satellite scene → **Cloud tops in 3D**, or the Data Hub's **3D Satellite**): the infrared image stands up as cloud, each top at the height its temperature gives against the clear ground near it, colored by the IR enhancement, with shadows; **height ×** stretches it.

Any map scene can stand a model field up in 3D over the map: 3D tab → **3D model** (or the Data Hub's **3D Jet Stream**, **3D Clouds** and **3D Wind Flow** cards). It needs the 3D map.

- **Where**: the box is the area on the map when you turn it on (up to 50° wide); **Use this view** moves it. It plays through the run (**hours**, **s per hour**) while you tilt and orbit; **height ×** stretches it.
- **Model**: **GFS** (0.25°, anywhere on Earth, every 3 hours) or **RAP** (13 km over North America, hourly to 21 hours; no cloud, rain or ozone fields).
- **Fields**: clouds, cloud water, cloud ice, rain / snow / graupel, relative humidity, dew point, mixing ratio, wind speed, temperature, potential temperature, theta-e, rising / sinking air, vorticity, potential vorticity and ozone.
- **See-through** shows every layer at once, colored and shaded by value. **Solid surface** pulls out one value as a lit shape (100 kt wind, 2 PVU for the tropopause, 0 °C for the freezing level, 90% humidity…), with **Colour by** painting a second field on it and an optional **shadow** on the ground. The quick picks (Jet stream, Wind flow, Tropopause, Clouds, Rain & snow, Moisture, Updrafts, Ozone) set these up.
- **Wind**: **Flow** (animated, colored by speed), **Arrows** and **Barbs** on a level plane at the height you choose.
- **Cross section…**: click two points on the program map; the field's vertical slice between them shows in a panel with wind barbs through it, and follows the loop.

Each forecast hour is one small download cut to the box on NOAA's side and kept on disk for the run, so changing field or look afterwards is quick. A 3D model with no box of its own (it follows the view) is built for a whole sector around the map (as large as a 3D model box goes) and keeps it: panning, swiveling, tilting and zooming never download again. A new sector is built only when you move the map's center out of it.

MORE MODEL PARAMETERS

The product menu's catalog groups now carry over a hundred more fields, from any NOMADS model that publishes the inputs (GFS, RAP, HRRR, RRFS and NAM-style models; regional models skip the stratosphere):

- **Surface changes and moisture**: MSLP change (6, 12, 24 h), temperature change (6, 12 h), 6- and 12-h highs and lows, the run's highest gust, wet-bulb temperature, dew point depression, mixing ratio, vapor pressure deficit and moisture convergence.
- **Upper air**: 250 mb height and wind, 200 and 300 mb vorticity, relative vorticity (850 to 200 mb), divergence (850, 200 mb), 925 mb vertical velocity, 700 and 500 mb dew point, 300 mb temperature advection, 0 °C lines at 925, 850 and 700 mb, 1000-500 mb thickness, mean 700-300 mb RH, moisture transport (925 to 500 mb), integrated water vapor transport, dew point depression (850 to 500 mb) and the stratosphere (100, 50, 10 mb temperature and wind).
- **Severe**: bulk shear from the surface to 925, 850, 700 and 500 mb, 0-1 km helicity, storm motion, mixed-layer CAPE and CIN, most-unstable CIN, 0-3 km lapse rate, boundary layer height, warm cloud depth, Craven-Brooks, the fixed-layer Significant Tornado Parameter and 0-1 km EHI; 1 km reflectivity.
- **Winter**: rain and sleet by window and in total, 3- and 48-h snow (10:1 and Kuchera), freezing rain by window, snow depth change (6 to 48 h), categorical rain, snow, sleet and freezing rain, the highest freezing level and the dendritic growth zone's depth.
- **Fire Weather** (its own section): Fosberg index, hot-dry-windy index and 925 / 850 mb vapor pressure deficit. **Tropical**: 200-850, 500-850, 700-850 and 200-500 mb shear.
- **Isentropic** (Upper Air): the 290 to 320 K surfaces every 5 K, each shaded by relative humidity with its pressure contoured (50 mb) and the wind on it, and **Isentropic Lift**: air sliding up (green to purple) or down (brown) the surface, in μb/s, the same scale as vertical velocity.
- **Isentropic PV**: potential vorticity on the 310, 320 and 330 K surfaces in PVU (2 PVU is the dynamic tropopause), with pressure and wind.
- **Q-Vectors**: at 850, 700 and 500 mb, **Q-vector convergence** (warm colors force rising air, blues sinking) and **magnitude**, from the geostrophic wind and temperature smoothed over about 100 km, with heights contoured.

These fields come with each model's full download, which now includes 800, 600, 400 and 150 mb as well, so a model's first full load takes a little longer.

MESOANALYSIS

Mesoanalysis in the product menu has SPC-style fields for the current hour: surface-based, mixed-layer, most-unstable and 0-3 km CAPE, CIN, 0-1 and 0-3 km storm-relative helicity, 0-6 km shear, the 700-500 mb lapse rate, LCL height, precipitable water, dew point, lifted index, and the significant tornado, supercell composite and energy-helicity indices. SPC publishes its mesoanalysis only as pictures, so WX Studio computes the same fields from the NOAA RAP (the model SPC's analysis starts from): the loop is the last five hourly analyses plus the newest 1-hour forecast, refreshed every 15 minutes. STP is the fixed-layer version; SCP uses 0-3 km SRH and 0-6 km shear in place of the effective layer.

ENSEMBLE MEMBERS, LOW TRACKS, CROSS SECTIONS AND TIME-HEIGHTS

- **Ensemble Members** (Data Hub → Models, or a scene of that type): a small map for each of the 31 GEFS members (and their mean) of **Snow** (at **10:1** or by the **Kuchera** ratio, which uses the warmest temperature in the column), **Freezing rain**, **Sleet** (at 3:1) or **Rain**, over a **6-hour** or **24-hour** window every 6 hours to 7 days, with each member's amount at home in its corner. Below, a **box and whisker** of every window at home (box 25–75%, whiskers 10–90%, line the median, dot the mean) with the window on show lit. Play through the run or pick the window's end on the Scene tab. The first load of a run reads every member's files (several minutes); the run then stays in memory until the next.
- **Member low tracks** (Layers → **GEFS member low tracks**, or the Data Hub card): every member's surface low tracked every 6 hours, dots colored by central pressure, the control in white, the deepest point of each track labeled.
- **Model Cross Section**: a model field (any of the 3D fields: humidity, clouds, wind, temperature, theta-e and so on) from the ground into the stratosphere between two towns (Scene tab → **From (A)** and **To (B)**, typed and picked), or west to east through home. Isentropes, the 0 °C line and wind barbs on top, a locator map of the line beside it, playing through the run. **GFS** anywhere, **RAP** over North America.
- **Model Time-Height**: the same over home, through the run (days across, height up).

ENSEMBLES

Ensembles in the product menu:

- **REFS: 24-h Rain > 1"**, **REFS: 6-h Snow > 6"**, **REFS: Updraft Helicity > 75** and **REFS: Storms > 40 dBZ**: neighborhood probabilities (the chance within about 40 km of a point) from the RRFS Ensemble Forecast System, NOAA's replacement for the HREF since 3 November 2026: the RRFS and five RRFS members plus the HRRR, current and 6-hour-old runs, to 60 hours from the 00/06/12/18Z cycles. Rain is shown for day 1, day 2 and hours 36-60; snow for each 6-hour window (the members' forecast snow depth); updraft helicity is the highest hourly probability of each day; storms are every hour. Scenes saved with the HREF products load these.
- **GEFS: Rain > 1"**, **GEFS: Snow > 6"**, **GEFS Mean Precipitation**, **GEFS Mean Snowfall**: from all 31 GEFS members, totals from the start of the run through each 6-hour step out to 7 days. Snow is each member's precipitation at 10:1 while it is snowing.
- **Ensemble Plumes** (a scene type) draws every GEFS member's totals at your location. The GEFS run downloads once (about 90 MB, 15-30 seconds) and is shared by the maps and plumes.

ANOMALIES

Anomalies in the product menu show how far the GEFS ensemble mean is from normal, daily to 16 days, blue below normal and red above:

- heights at 1000, 700, 500 and 250 mb, in dam;
- temperature at 2 m, 850, 500 and 250 mb, and the day's high and low, in °F;
- sea-level pressure (mb), 10 m wind speed (mph) and the west-east wind at 850, 500 and 250 mb (kt: positive is a stronger westerly than normal).

These are all the fields NOAA computes anomalies for. The departures are computed by NOAA (the North American Ensemble Forecast System) against NCEP's reanalysis climatology for the date and hour, so WX Studio needs no climatology of its own. Each day is a whole 5 MB global file (NOMADS can't crop these), downloaded once per run and kept on disk.

DYNAMIC TROPOPAUSE (2 PVU)

Upper Air → Dynamic Tropopause (2 PVU) maps the GFS's 2 PVU surface: its **potential temperature** (cold, low-tropopause troughs in purple and blue; warm ridges in orange and red), its **pressure** (where the tropopause folds down), and its **wind** with pressure contours, all with wind barbs. A median filter removes the speckle the GFS gives where the surface is barely defined. GFS only.

HYDRO

Hydro in the product menu shows NOAA MRMS: **1, 6, 24 and 72-hour rainfall** (radar corrected with rain gauges), **Rain vs Flash Flood Guidance** (percent of the guidance that has fallen), **Rainfall Recurrence Interval** (how rare the rain is, in years) and **Flash Flood Streamflow** (the CREST model's peak flow per km²). They refresh every 10 minutes.

Layers → River gauges (any map scene) adds NWS river forecast points and USGS stream gauges:

- Each NWS gauge is colored by its flood category: green below flood stage, yellow action, orange minor, red moderate, purple major. A ring in a worse color means the official forecast goes higher.
- Gauges in or forecast to flood are always labeled with the stage, its trend (▲▼ over 6 hours), the category and the forecast crest; zoom in to label the rest.
- Zoomed out, only gauges at action stage or worse are shown. USGS gauges without an NWS forecast appear as small blue dots on regional and local maps.
- The talent data panel counts gauges in flood and forecast to flood.

NADOCAST

Severe → Nadocast shows Nadocast's machine-learning day-1 probabilities (tornado, wind, hail and their significant versions). Nadocast was trained on the HREF and SREF, which NOAA retired in November 2026, and its runs stopped on 3 November 2026. The scene now says so instead of showing an old forecast; use **REFS: Updraft Helicity > 75** or the SPC outlook. Pick the hazard on the Scene tab.

11 FORECAST DRAWING



Explain the forecast: the worked nor'easter drawing in Preview, with the Forecast drawing editor open.

Draw a forecast chart over any map, the way a forecaster would by hand: fronts, pressure centers, weather areas and symbols, with an automatic first guess and WPC's own chart as starting points.

Draw ▾ → **Forecast drawing…** opens the editor; you draw on the program map.

- **Fronts**: cold, warm, stationary, occluded, trough, dryline, squall line and outflow boundary. Click along the front (or drag freehand) and double-click, right-click or press Enter to finish; the symbols face the left of the way you drew (**Flip** turns them).
- **Highs and lows** with their pressure, **hurricane**, **tropical storm** and **depression**, and weather symbols (snow, rain, thunderstorms, freezing rain, sleet, fog, wind, tornado, hail, fire, flooding, sun, cloud).
- **Areas** with a **solid**, **hatched** or **gradient** fill and a label, **lines** and **arrows** (solid or dashed), **boxes**, **ellipses** and **text boxes**.
- **Select** an item to change its colors, fill, line, smoothing and label; drag it, or drag one of its points; **Raise**, **Lower**, **Duplicate**, **Delete** (or the Delete key).
- **Products**: name it and **Save**; **Open** ▾ reloads (or deletes) saved drawings, kept in the settings folder under `forecast drawings`. **On this scene** puts the drawing on the current map scene; any map scene can also pick one on its Layers tab. The **Caption** shows as a chip on air.
- ➕ **Save as new scene** saves the drawing, adds it to the rundown as NEXT (with the view and product on screen), and closes the editor so you can carry on with the rest of the app. To change it later, select that scene and choose **Draw** ▾ → **Edit this scene's drawing**.
- **Smart analysis** draws the weather map's main features for you, from the scene's model at the frame on screen (pause the loop on the time you want; show a model map on the scene first). Tick what you want and press ✦ **Analyse**:
- **Highs & lows**: pressure centers from sea-level pressure, labeled with their pressure. Only centers that stand out from their surroundings, at least about 9° apart.
- **Jet stream**: jet axes from 250 mb winds where the core reaches **Jet cores** (100 kt by default), each a ribbon labeled with its peak speed plus chevrons showing which way it blows.
- **Troughs & ridges**: axes at 500 mb (troughs as trough lines, ridges as orange lines).
- **Fronts (first guess)**: from 850 mb temperature and wind, kept only where they lie in a sea-level pressure trough; cold, warm or stationary from the wind across the line. Treat them as a starting point.

Everything it adds is an ordinary item: move it, drag its points, restyle or delete it. Running it again (say at another frame) replaces the analyzed items you haven't touched; anything you've edited stays. **Clear analysis** removes the untouched ones. Upper-air fields the map on screen doesn't hold are read from the model run in the background (from disk when already downloaded). Models without upper-air fields (most Open-Meteo models) give highs and lows only. * **Smart areas** make editable areas from the scene's model (show a model map on the scene first), over a window **through** a day or **for** a number of hours: * **Condition**: any mix of conditions that must all hold, each **at any time**, **the whole time**, **in total**, **at its highest** or **at its lowest** — for example temperature < 32 °F the whole time through Monday, gusts ≥ 40 mph at any time, snow ≥ 1" in total. Quick picks: Below 32°, Hard freeze, Gusts 40+, Heat 95+, Snow 1"+. * **Amounts**: snow or rain totals in bands (1, 3, 6, 12, 18" by default), each a colored, labeled area ("3-6\""). * **Lake effect**: from the GFS over the map in view, where the water is at least 13 °C (adjustable) warmer than the air at 850 hPa across at least 60 km of open water upwind, with moist air and a steady wind.

EXPLAIN THE FORECAST

Explain in the ribbon's **Build** group adds a map scene called *Explain the forecast* as **NEXT**, with a ready-made explainer drawing on it, and opens the drawing editor. The first time, the drawing is a worked nor'easter example: colder and warmer air, the jet stream, cold air pouring south, the low's track and callouts. Edit it like any drawing; your edited version is what **Explain** uses from then on.

The editor's **Explain the forecast** tools draw the same kind of graphic from scratch:

- **Jet stream**: a wide ribbon with its name along it. Click along the jet, double-click to finish.
- **Flow arrows**: chevrons showing which way the air moves.
- **Callout**: a labeled box with an arrow. Click where the box goes, then the point it explains.
- **Warm and cold air**: draw an **Area** and set its fill to **Soft wash**.
- **Nor'easter template** replaces the drawing with the worked example.

WPC'S FORECAST CHART

WPC forecast chart in the Forecast drawing window loads the Weather Prediction Center's National Forecast Chart as drawing items. Pick **Day 1**, **Day 2** or **Day 3**, tick what you want (**Fronts**, **Highs and lows**, **Rain/Thunderstorms**, **Rain**, **Mixed Precipitation**, **Snow**, **Severe Thunderstorms Possible**, **Heavy Rain/Flash Flooding Possible**, **Critical Fire Wx Possible**, **Freezing Rain Possible**, **Heavy Snow Possible**), choose **Weather as Areas**, **Icons** or **Areas and icons**, and press **Load from WPC**. The layers download at the same time.

Everything loaded is an ordinary item: move a front, restyle an area or delete an icon like anything you drew. WPC's areas go under your own items, its fronts and symbols on top. **Reload from WPC** replaces only what came from WPC; **Remove WPC items** clears it.

THE DRAWING'S TIMELINE

Timeline... opens the drawing's timeline in its own window, with one row per item, like an After Effects layer stack. On air the drawing plays this timeline from the take; in the editor, the map shows the drawing at the playhead.

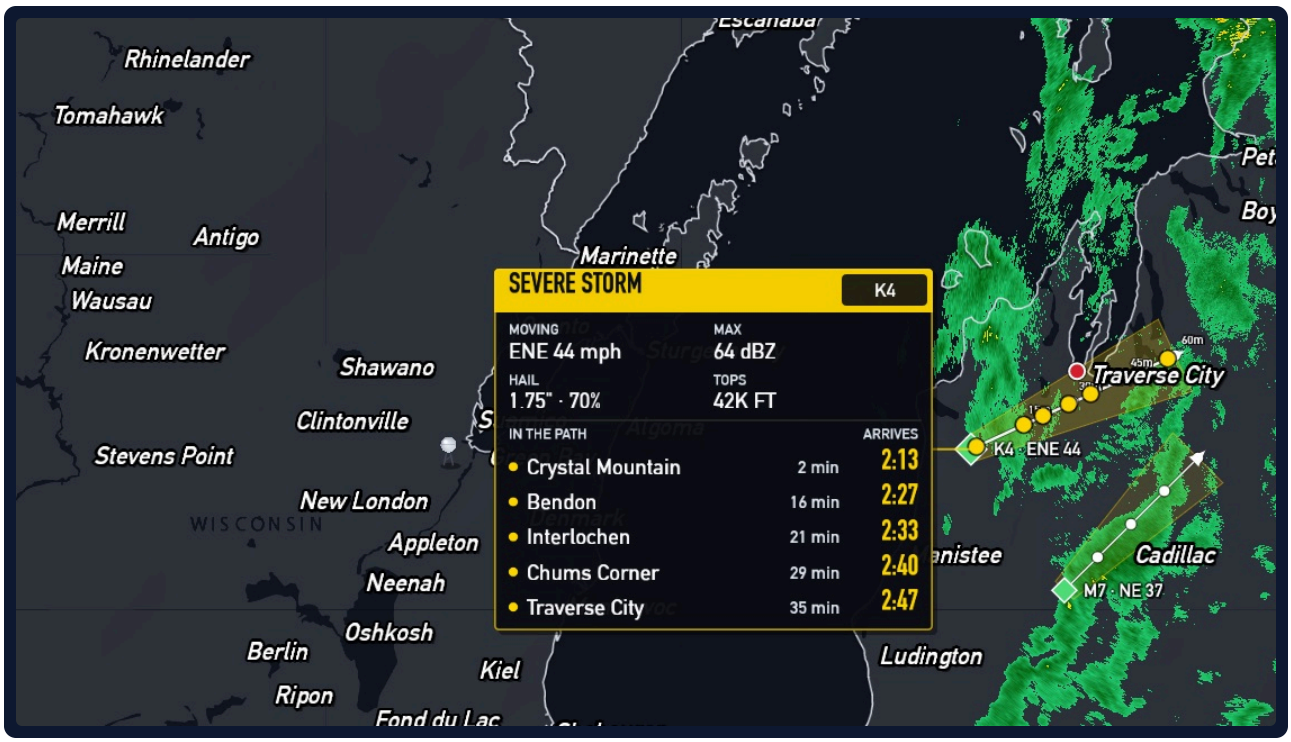
- Each row's bar runs from the item's **in point** (white diamond) to its **out point** (red diamond, or the end). The slope and gold diamond show it coming on.
- Drag the white diamond to change when it starts, the gold one to change how long it takes, the bar's end to make it go off early (double-click the end: it stays), or the bar itself to slide the item. Times snap to 0.1 s.
- **Comes on with**: **Fade**, **Draw on** (fronts and lines draw along their length), **Pop** (symbols and text grow in) or **Cut**.
- Drag on the ruler to scrub; ▶ **Play**, ⟲ **Start** and **Loop** play it on the map. **Show all** leaves the timeline so every item is fully on while you draw.
- **Stagger** brings the items on one after another, a set number of seconds apart, in list order (areas, then fronts, then symbols). **All come on with** sets every item's entrance; **All at once** puts every item on at the start. **Auto length** sizes the timeline to fit, or set a length.

With Preview on, the drawing you're editing shows in Preview only.

PART IV

SEVERE WEATHER AND LIVE COVERAGE

12 SEVERE WEATHER TOOLS



Storm timing: threat, motion, hail, tops and town arrival times.

Storm tracking with town arrival times, lightning, and model and observed soundings.

STORM TRACKS AND TOWN TIMING

On single-site radar, every tracked cell gets a track, a cone and 15-minute ticks. Severe cells (adjustable) also get a **timing box**:

- threat (strong, severe, rotation, tornadic) and storm ID
- motion, max reflectivity, hail size and probability, cloud tops, rotation
- the next towns in the path with minutes and clock arrival time

Dots on the track mark where each town is reached. Click a storm for the lower-third callout. The track cone lies on the ground, so it keeps its shape on a tilted or turned map.

Moving boxes: drag a timing box, the storm callout or a camera card anywhere on the program map. It locks to that spot of the map (and travels with its storm), so it stays put as you pan, zoom, tilt or turn. Double-click a box to let it place itself again. **Graphics Editor → Radar → Storm tracks & arrival times** controls which cells show, track length, arrival-time range, path width, towns per storm, **Town timing boxes** and which threats get a box. Boxes no longer pop up by themselves: click a storm to show its box and click it again to put it away, or tick **Auto-show boxes** to box every qualifying storm.

LIGHTNING

Layers → Lightning flashes shows every GOES Geostationary Lightning Mapper flash, about 20 seconds behind real time:

- **Icon**: Glow, Bolt, Dot or Cross.
- **Light burst**: each new strike blooms and flickers.
- **3D pillars**: a column of light rises from each strike; **Keep pillars up** leaves a slimmer column for as long as the strike is on the map.
- **Merge dense areas**: strikes within the chosen pixel distance become one icon with a count.
- **Minutes shown** (2–30) and **size**. Strikes age from white to yellow, orange and red.

SOUNDINGS AND SEVERE PARAMETERS

The Sounding scene shows model soundings with surface-based, mixed-layer and most-unstable parcels, shear, Bunkers storm motion, SRH, STP and SCP.

Where the model soundings come from: the NWS's own models, read from their GRIB2 files on NOAA NOMADS: the **RAP** (hourly, every 25 hPa) and the **GFS**, each cropped to a small box around the point. The next six hours come up within seconds; the rest of the 48 fill in behind them, and every download is cached. **HRRR** soundings (pick HRRR as the scene's model) come from the HRRR's full pressure-level files on NOAA's AWS bucket: WX Studio reads each file's index and downloads only the temperature, humidity, height and wind messages (about 88 MB an hour, eight at a time), for the first 18 hours. The first hour takes about 25 seconds; the decoded profiles are cached, so reopening takes under a second. **RRFS** soundings (pick RRFS) come the same way from NOMADS, which has no crop for the RRFS: per hour, one request for the surface values in its 2D file and one batched multi-range request for temperature, humidity and wind every 25 hPa to 700 hPa and every 50 hPa above, about 95 MB, for the first 18 hours (about 30 seconds an hour the first time, cached after). NOAA hasn't posted the operational RRFS on AWS yet; WX Studio checks each run, and once the files appear there it reads them from AWS instead (no NOMADS rate limit) and shows the run's whole length, 84 hours on the 00, 06, 12 and 18 UTC runs. **ECMWF** and **ECMWF AIFS** soundings come from ECMWF open data's pressure levels (1000 to 100 hPa: temperature, humidity, height and wind) with the surface pressure and 2 m / 10 m values, every 3 hours (6 for the AIFS), about 20 MB a step, cached per run. Heights are worked out from the temperatures (hydrostatic), within a few meters of the model's own; that halves the download. (The NWS public API at api.weather.gov has no vertical profiles.)

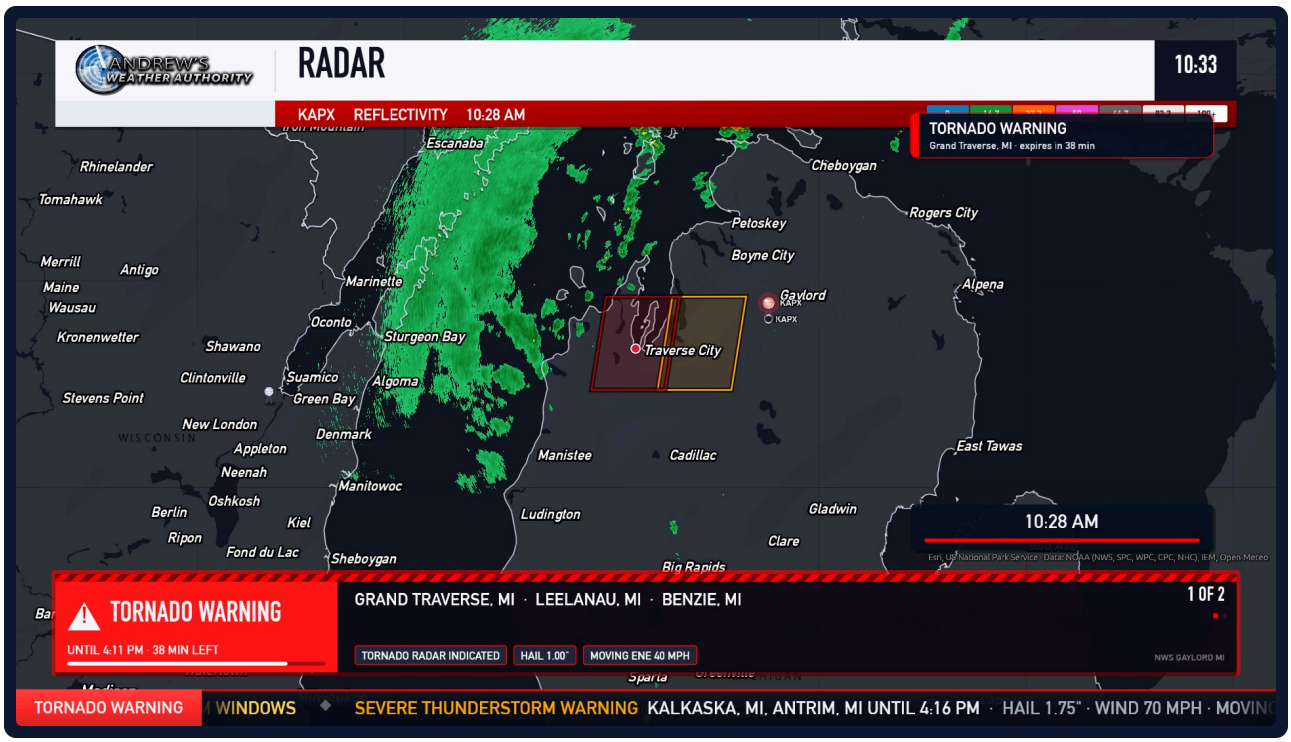
Observed soundings: the newest weather-balloon flight (00Z or 12Z) from the launch site nearest your location is drawn in gold with the model soundings, from the Iowa Environmental Mesonet RAOB archive. Tick **use for stats** to make the observation the main sounding (its parcel, hodograph and parameters) with the model in its color for comparison. The Scene tab names the site, the flight time and how far away it is. Under **Observed (RAOB) → Site** pick any launch site (nearest first, with the distance); **Nearest to the sounding** goes back to the automatic choice. If a site has no flight in the last two days the Scene tab says so.

Where the sounding is (Scene tab → **Where**):

- **Home**: the forecast location.
- **Point**: any place. Type a city, ZIP or `lat,lon` in **Move to** and pick a result, or right-click any map and choose **Model sounding here** (a Sounding scene for that point is added as NEXT).
- **Area mean**: the models sampled on a grid across a box (2×2 to 6×6 points) and averaged level by level into one mean profile, so one grid point's noise doesn't drive the forecast. Set the box with **100 / 200 / 400 / 800 km** around the place, **Use the map view**, or right-click a map and choose **Area sounding of this view**. The Skew-T shades the spread between the points (10th to 90th percentile of temperature in red and dew point in green), and the table where the hodograph usually sits shows each severe parameter's **mean, low and high** across the points (SB/ML/MU CAPE, ML CIN, 0-6 km shear, 0-1 and 0-3 km SRH, PWAT, 700-500 mb lapse rate, STP and the supercell composite). Each grid cell is the mean of the model's own points inside it, from one NOMADS download per forecast hour; an area averages the scene's model (RAP, HRRR or GFS).

Map products include CAPE, CIN, LCL, lifted index, shear, SRH, EHI, the supercell composite, updraft helicity and lapse rates.

13 WARNINGS AND ALERTS



A tornado warning on air: the polygon, the banner and the alert stack.

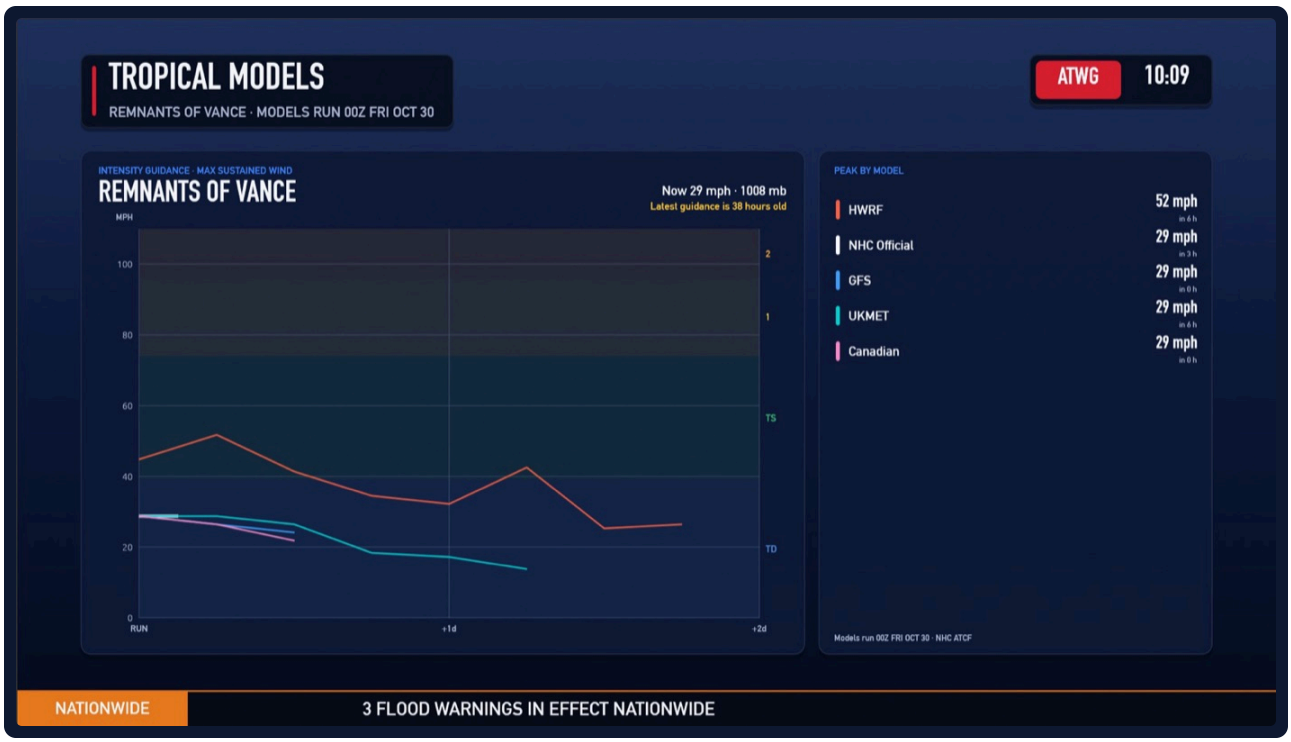
Warnings arrive from the NWS API or straight off the NOAA Weather Wire, and drive pop-ups, banners, map polygons, threat colors and Live mode.

- **Push warnings**: Settings → Alerts & crawl → **Push warnings** takes warnings straight off the NOAA Weather Wire (**NWWS-OI**, with your NWS account's user name and password) or a **NOAAPORT** receiver's product folder, seconds after issue instead of on the NWS API's polling. Tornado, severe thunderstorm, flash flood, special marine, extreme wind, snow squall and dust storm warnings and their follow-up statements (SVS, FFS, MWS) are read for their polygon, VTEC, storm motion and hail / wind / tornado tags, and join the same list as the API's: banners, pop-ups, threat mode and Live follow all react at once, and a cancellation on the wire clears the warning even if the API still lists it. NWWS-OI reconnects on its own; its state shows under the setting and in **Status → Feed health**.
- **Watches, discussions and storm reports from the wire** come in the same way:
- **SPC watches** are drawn with their watch box (from the SAW product) and times. A watch SPC calls a particularly dangerous situation (in its SEL text) reads **PDS Tornado Watch** or **PDS Severe Thunderstorm Watch**, in its own color, with a PDS badge. A watch cancelled on the wire (WOU) leaves at once.
- **Mesoscale discussions** from SPC (MCD) and WPC (MPD) join the discussions in the prompter and on the Scene tab's **+ SPC/WPC discussions in view**.
- **Local storm reports** (LSR) from every NWS office add their tornado, hail and wind reports to the **Storm Reports** map within seconds, before SPC's own list includes them (the same report isn't shown twice).
- **Polygons** from the NWS draw on radar and futurecast (or on every map, in Settings).
- **Pop-ups** appear only when a warning is newly issued or upgraded; routine updates don't repeat them. Set the scope in Settings → Alerts: **Nationwide**, **Near me** (radius), **Area** (drawn box) or **States**. They gather in one compact stack at the top right: the newest in full, the others one line each, with **Dismiss all** at the top. Cards stay up for the time you set, and a warning that expires leaves the cards, banners and map at once.
- **Warnings, PDS and emergencies** read differently everywhere a warning is named (banners, pop-ups, the Live list, map labels, the Alerts page, the crawl, the prompter and the producer panel): **Tornado Emergency** and **Flash Flood Emergency** (damage threat catastrophic), **PDS Tornado Warning** (considerable), and the plain warning. Each has its own color (purple, pink and magenta by default, editable in the Graphics Editor), the Live list adds an **EMERGENCY** or **PDS** badge, and nationwide counts list them apart from the plain warnings.
- **Click a warning on the map** (where polygons are shown) to open its box right there on the map: the name (with an EMERGENCY or PDS badge), the area, hail / wind / motion tags and the time left, with **Read**, **Zoom & radar**, **Banner** and **On air**. In Live mode the warning is also pulled to the top of the sidebar's warning list and outlined in its color. Where warnings overlap, the most serious one opens; a click elsewhere on the map, ✕ or Esc puts the box away.
- **Polygon fills** stay steady and light so the radar under them reads true; tornado warnings pulse their outline only (Graphics → warning style).
- **Read** (on a pop-up or in the Live dock's warning list) opens the warning's full NWS text: headline, area, the description and what to do, in a window you can keep open. While it is open the warning also leads the **talent prompter** in its color (untick **In the prompter** to keep it off).
- **Zoom & radar** frames the warning and switches to the single-site radar nearest to it, entering Live Coverage if the scene on air isn't single-site radar. The Live dock shows when a radar was picked for a

warning; **Back to home radar** (or a new location) returns to yours.

- **Warning banners** (Settings → Warning banners): a banner on air whenever a chosen warning is in effect: tornado, severe thunderstorm, flash flood, extreme wind and snow squall by default, with special marine, hurricane and blizzard available and watches optional. It shows the headline (PDS, emergency, observed), the counties, expiry with minutes left and a countdown bar, hazard tags, storm motion and the issuing office. Several warnings rotate with a "1 of 3" counter. Choose our area, the pop-up area or nationwide, top or bottom, and seconds per warning. Legends and timelines move up out of its way. **B** in Live mode pins one warning.
- **Threat mode** (Settings → Threat mode): live scenes take the color of the worst warning in your area, starting at the level you choose.
- **Accent follows the highest warning**: tick **Every scene's accent follows the highest warning** and choose **Our broadcast area** or **Nationwide**.
- **Live mode keys**: **B** toggles the warning banner, **Z** zooms to the newest warning, **D** toggles the dual pane.

14 TROPICAL



Tropical intensity guidance for an active system.

Active storms, invests, model guidance and intensity forecasts from NHC.

- **Tropical Tracker** (map): NHC storms with their symbol, winds and pressure, the cone, and the **spaghetti** of model tracks with a dot every 24 hours. Invests that NHC is running models on are shown with their latest position.
- **System**: buttons for every active storm and invest and every system NHC updated this week, plus **All**; ◀ ▶ step to the previous or next storm. Hover a storm for when NHC last updated it.
- **Take turns on air** (Tropical Models, following all storms): each storm gets the page for the set number of seconds in turn. The page names the other active storms under the current one.
- **Producer panel and buttons**: the **TROPICAL · STORM ON AIR** section (shown while a tropical scene is on air) has Previous, Next, All storms and a button per storm; Stream Deck, Companion and MIDI buttons have **Next storm**, **Previous storm** and **All storms**.
- **Models**: Key models, Global models, Hurricane models, Consensus + official, or Every aid. Named sets show one line per model family, labeled "GFS", "Euro" and so on.
- **Tropical Models** page: each model's maximum wind against forecast hour over the Saffir-Simpson bands, the peak by model, the system's latest fix, and when the models ran (with a warning when the guidance is more than 18 hours old).

15 TRAFFIC: CAMERAS AND DRIVE TIMES

Live DOT cameras as 3D cards on the map, and drive-time pages with optional live traffic.

CAMERAS

1. On a map scene, open **Layers** and tick **Traffic cameras**.
2. Zoom to regional or closer: camera pins appear (teal = video, gray = snapshot only).
3. Click a pin. Its feed rises out of the map as a tilted 3D card with a light stem to the pin. Click the pin again to put it away. Up to four feeds can be on air. Drag a card to move it; it stays locked to that spot of the map (double-click to reset).
4. **Nearest cameras** on the Layers tab adds cameras near the middle of the view.

Badges: **LIVE** for video, **CAMERA** for a snapshot that refreshes every 10 seconds. Some agencies require their own sign-in for video (Texas, Georgia, Arkansas, Indiana and others); those cameras fall back to their snapshot, and cameras with neither show "offline". Video needs ffmpeg.

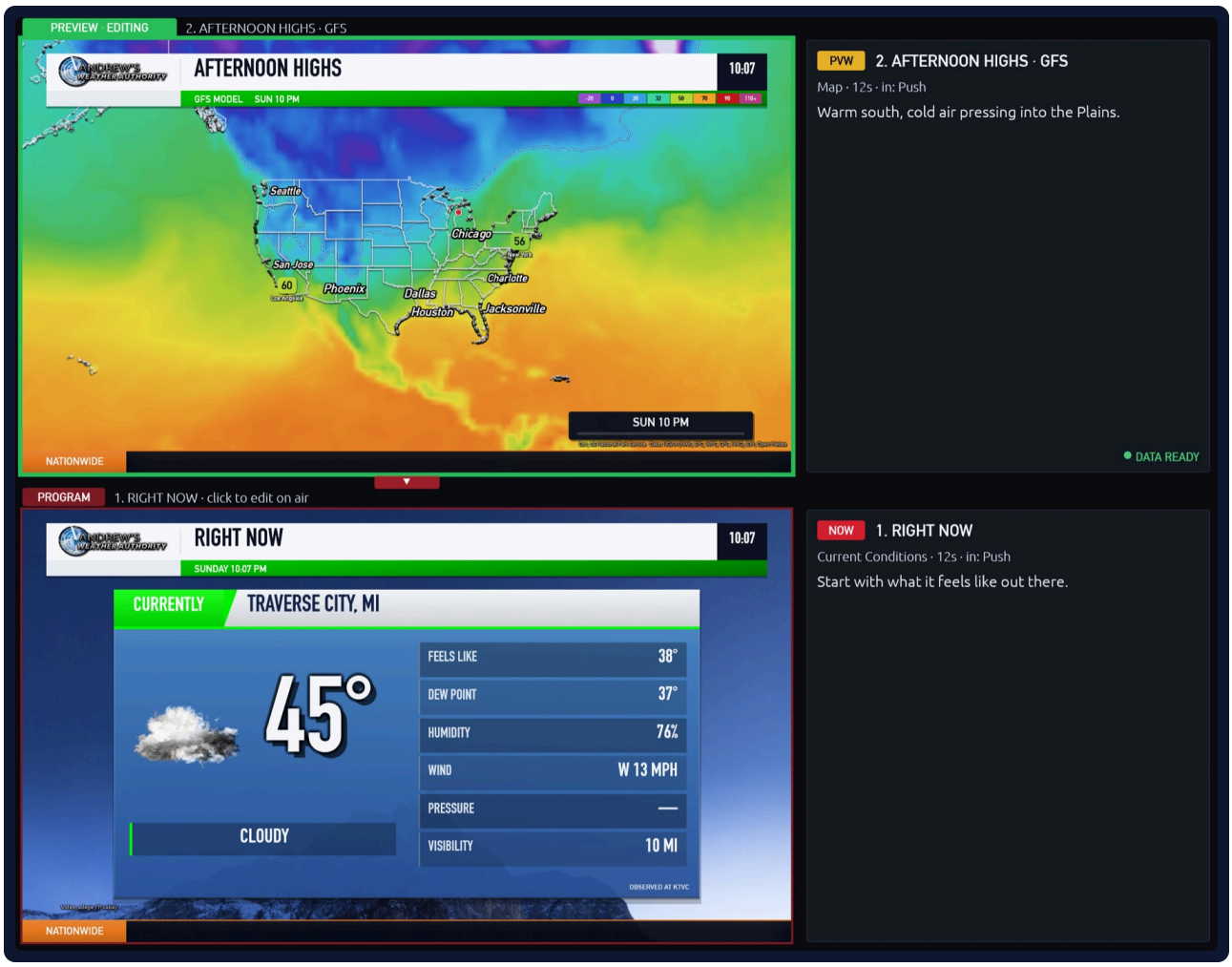
DRIVE TIMES

- Add a **Drive Times** scene. With no routes of its own it picks them automatically: the biggest towns within five hours, one per direction, skipping trips that wind around lakes or mountains.
- **Edit these routes** copies the automatic picks into the scene so you can rename, reorder or add to them. **Back to automatic** clears your routes.
- **Add a route**: type From and To and click **+ Add route**.
- Without a key, times are typical free-flow times from OpenStreetMap routing. Add a **TomTom key** in Settings for live traffic: the time now, the delay (clear, yellow or red) and the **Live traffic flow** layer on maps.

PART V

GOING TO AIR

16 PREVIEW, PROGRAM AND OUTPUTS



Preview and Program: prepare the next scene while the program stays on air. DATA READY means its data is loaded.

WX Studio works like a vision mixer: you prepare the next scene in Preview and take it to Program. Program then feeds every output: full screen, OBS, NDI, SDI, live streams, recordings and scheduled renders.

PREVIEW AND PROGRAM

Preview (top right, on by default) splits the screen into two monitors, like a vision mixer: **PREVIEW** (green), where you prepare the next scene, and **PROGRAM** (red), what is on air. By default Preview sits above Program; the layout is yours to change (below). Only Program goes to the outputs: the Program Output window, OBS, NDI, SDI, streams and recordings.

- Everything you change works on Preview by default: the inspector, the quick controls in the bottom bar and the map you drag. Its tag reads **PREVIEW · EDITING**.
- Click **Program** to edit what is on air instead: its tag turns to **PROGRAM · EDITING**, and dragging its map or changing the inspector goes out live and is kept in the rundown. The bottom bar's quick controls stay on Preview. Clicking Preview, putting a scene in Preview or the next **TAKE** switches editing back to Preview.
- Click a scene in the rundown to put it in Preview (it gets a green **PVW** tag); double-click takes it straight to air.
- **TAKE** (the button, the → key or the red ▶ between the monitors) sends Preview to Program with the scene's transition, framed as it was in Preview. Preview then moves to the next scene. ◀ steps Preview back a scene.
- Program keeps a copy of each scene as it was taken. Put the scene that is on air in Preview to change it: Program keeps showing it unchanged until you TAKE it again.
- Automation and auto-advance still take scenes on their own; Preview follows along when it was holding the scene they took.
- Preview always uses the flat map, even when Program uses the 3D map. A model map in Preview shows the data Program has already loaded when both use the same model, so Program's data is never reloaded for Preview.
- The ▾ next to **Preview** picks the layout: **Stacked** (Preview over Program, the default), **Side by side**, or **Automatic** (whichever gives bigger pictures in the window). **Preview in its own window** pops Preview out into a window you can put on another screen, with its own **TAKE** ▶ and ◀ ▶ to step Preview through the rundown; the main window then shows Program alone. Closing that window puts Preview back.
- Click **Preview** again to go back to a single program monitor that you edit directly.

FULL SCREEN, SNAPSHOTS AND RECORDING

- **On air** (F): the program fills the screen. Esc leaves.
- **Windows**: pop-out program output for a second monitor or capture.
- **Snap** (S): saves a still of the program. **Rec**: records the program.
- **Chroma key**: Settings → a green background behind pages for keying.

OBS

- **OBS**: enter the OBS websocket address and password in Settings; each scene can switch OBS to a named scene when it goes to air (Scene tab → **When taken**).

NDI AND SDI

- **NDI output** (Settings → Output): **Send the program as NDI** makes the program an NDI source on the network ("COMPUTER (WX Studio Program)"), at 1280×720, 1920×1080 or 3840×2160 and 29.97, 30, 59.94 or 60 fps. **Also send graphics with alpha** adds a second source, "WX Studio Graphics (Key)": titles, legends, warning banners, the crawl, the lower third and page cards on transparency, with the map and page backgrounds left out, for keying over cameras in vMix, TriCaster, OBS (with its NDI plugin) or an NDI-to-SDI converter. The output is drawn separately at the chosen size (the map renders again at that size), so it doesn't depend on the window, and frames are read back without making the operator screen wait. The settings show how many receivers are connected and frames sent and dropped. It needs the free **NDI Tools** or NDI runtime installed; without it the setting says so and links to the download. (NDI® is a registered trademark of Vizrt NDI AB.)
- **SDI output** (Settings → Output → SDI, or `--sdi`): the program out of a Blackmagic DeckLink card, in 720p, 1080i, 1080p or 2160p at 25 to 59.94. **Program** sends the whole picture. **Fill + key (external)** sends the graphics on one SDI output and their key (alpha) on its pair, for a switcher's downstream keyer; **Shaped fill** suits a keyer set to pre-multiplied (ATEM: Pre Multiplied Key on), off sends straight fill. **Keyed over SDI input (internal)** has the card key the graphics over the video coming into it. **Key level** fades the whole key. Options the card can't do are grayed out. It needs Blackmagic's free Desktop Video driver; on multi-channel cards, pick a profile with fill and key in Desktop Video Setup. If the card is busy or unplugged, WX Studio keeps trying. The producer panel's **OUTPUT** section turns SDI on and off too.

LIVE STREAMING AND HEADLESS PLAYOUT

- **Live stream** (Settings → Output → Live stream, or `--stream URL`): the program, drawn offscreen like the NDI output, encoded by ffmpeg as H.264 with a silent audio track at 30 fps (720p or 1080p, bitrate of your choice) and pushed to an RTMP or SRT address: YouTube, Twitch, Facebook, any RTMP ingest, or a local MediaMTX for a browser player. If the server or network drops, it reconnects on its own. The producer panel's **OUTPUT** section (engineers) turns the stream and NDI on and off and shows the stream's state.
- `scripts/live-stream.sh` (macOS or Linux) sets the whole thing up from the command line: `scripts/live-stream.sh start` downloads MediaMTX (a small streaming server), starts it, and starts WX Studio streaming to it; viewers on your network open `http://THIS-MACHINE:8888/wx/`. Add `--tunnel quick` for a free public trycloudflare.com address (changes each start), or `--tunnel-token TOKEN` for your own Cloudflare Tunnel with a fixed name (create it in Cloudflare Zero Trust → Networks → Tunnels and point its public hostname at `http://localhost:8888`). `--panel` also tunnels the producer panel (quick tunnels only; think twice). `--no-app` leaves WX Studio alone (turn the stream on yourself), `--headless` runs it headless. `scripts/live-stream.sh status` prints the addresses, `stop` stops it all. The browser player uses HLS (a few seconds behind); on the local network `http://THIS-MACHINE:8889/wx/` plays with lower delay (WebRTC, which Cloudflare's tunnel can't carry).
- **Headless playout** (`--headless`): the program fills the window as on air, the rundown auto-advances and the producer panel listens on the network, so a rack server or a Proxmox VM or container without a monitor plays out on its own with NDI and / or the stream, run from the producer panel. `scripts/headless.sh` on Linux: `setup` installs the virtual display (Xvfb), Mesa's software Vulkan for machines without a GPU, ffmpeg and the window libraries (Debian / Ubuntu); `run [--stream URL] [--detach]` starts it on the virtual display; `install-service` makes it a systemd service that starts at boot and restarts if it stops; `link` prints the producer panel's link with its access token (kept in a private file, never in the logs). For NDI, install the free NDI SDK for Linux and give the VM or container a bridged network so NDI discovery reaches the station.

SCHEDULED RENDERS

- **Scheduled renders** (Windows → **Scheduled renders...**): a rundown scene written to a file on a timer for the web and social, as an **MP4** (H.264, 30 fps, needs ffmpeg), a **PNG** still (the loop's last frame) or a **PNG sequence**, at 1920×1080 or 1280×720, every 5 minutes to every day. A render takes the scene to the program with no transition for its length (the scene's own length unless set), with auto-advance paused, waits for its data, records through the same offscreen renderer as NDI (so files match air), then goes back to the scene you were on. **Off air only** (on by default) waits while you're on air or in live coverage. Files are named `<name>-<date>-<time>` with a `<name>-latest` copy refreshed each time for a web page or uploader; **keep** prunes old ones. **Render now** runs a job at once. **Then send it**: after each render the file can be **PUT** to a URL (`{name}` becomes the file name; WebDAV folders, presigned S3 URLs and most web hosts' upload endpoints take this), with an optional header such as `Authorization: Bearer …`, and / or a **command** run with `{file}` as its path (rclone, scp, or a script that posts to social accounts). The result shows under the job.

17 REMOTE CONTROL AND THE PROMPTER

Run the show from a browser, a Stream Deck, Bitfocus Companion or MIDI hardware, with per-person roles and an audit log, and give talent a scrolling prompter.

PRODUCER PANEL, USERS AND AUDIT LOG

- **Producer panel**: a web page on your network (default port 8790) with a live preview, drag-to-reorder rundown, text layers and styles. It is protected by its access token; keep it on a trusted network.
- **Users and roles** (Windows → **Users, buttons & audit log...**): give each person their own panel link with a role. A **producer** runs the rundown and the on-air text (titles, crawl, banners, warnings, overlays, location); **talent** steps through their own show (takes, auto-advance, prompter, telestrator, storm callouts, the tropical storm, radar product, snapshot); an **engineer** can do everything, including settings, styles and the program window. The owner link in the Windows menu is an engineer. The panel hides what a role can't do, and the server refuses it anyway. **New link** retires a person's old link; removing them ends their access. When someone other than the owner takes a scene, the operator sees a note naming them.
- **Audit log**: every command from the panel, a button or MIDI, with the time, who sent it, their role, how (panel, button, MIDI) and whether it was allowed. The last 40 are in the panel for producers and engineers, the last 200 in the window, and all of them in `audit.log` (one JSON line each) in the app's settings folder.

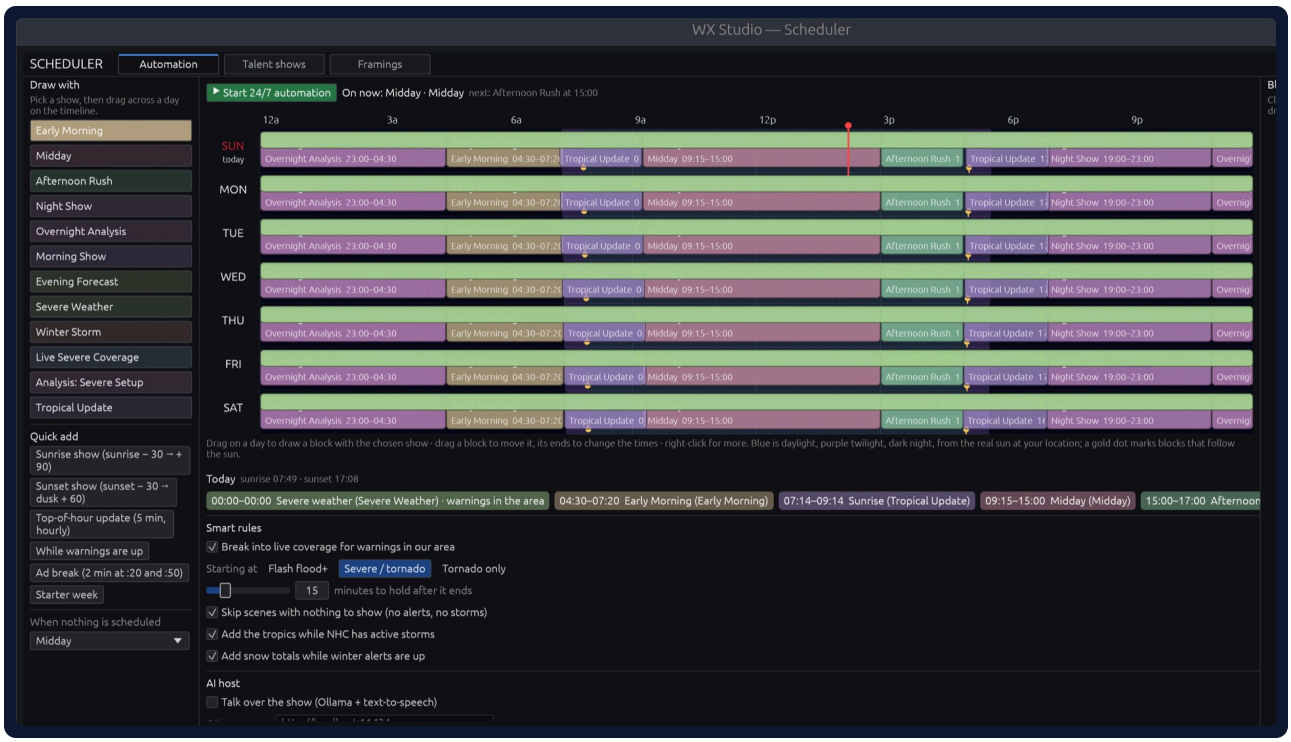
STREAM DECK, COMPANION, TALLY AND MIDI

- **Stream Deck, Companion and hardware buttons**: the same window builds a URL for any action (take next, back, auto-advance, live coverage, telestrator, prompter, next / previous storm, hide banner or lower third, sweep, snapshot, go to scene N), carrying the link of the person pressing it. Stream Deck: the **Website** action with "GET request in background". Bitfocus Companion: the **Generic HTTP** connection, a GET action. Any button that fetches `http://HOST:8790/api/press?cmd=next&token=…` works; every panel command takes the same form.
- **Companion module**: `integrations/companion-module-wx-studio` is a native Bitfocus Companion module (Companion 3.4 or later): actions for every panel command with dropdowns filled from WX Studio (scenes, radar products, warning presets, overlays, storms), tally feedbacks (scene on air in red, next in amber, live coverage, auto-advance, telestrator, prompter, stream, NDI, SDI), variables for button text (`$(wx:on_air_title)`, `$(wx:scene_3_title)` …) and ready-made buttons. Build it with `npm install && npm run package` and import the package on Companion's Modules page; the connection asks for the WX Studio computer's address and the panel's access token (or a user's link, so buttons follow that user's role).
- **Tally (button feedback)**: `http://HOST:8790/api/tally?token=…` answers with the scene on air and next (number, title, type), live coverage, auto-advance and the telestrator; `&index=N` (from 0) adds whether that scene is on air or next. A Companion Generic HTTP feedback on `scene.on_air`, or Stream Deck's API Ninja polling the URL, lights the button of the scene on air. The window copies the URL with the right link.
- **MIDI buttons**: tick **Listen to MIDI controllers**, **+ Add MIDI button**, pick the action and press the pad, key or button (**Learn**). Notes and controllers both work (a held controller presses once); every connected MIDI input is heard.

TALENT PROMPTER

- **Talent prompter** (Windows menu): this scene's notes and what's next. Below the notes it shows every active **SPC Mesoscale Discussion** and **WPC Mesoscale Precipitation Discussion** whose area overlaps the map on air: number, valid time, watch probability, concern, areas and the summary, plus a count of the others. On the Scene tab, **+ SPC/WPC discussions in view** adds those summaries to the talent notes. Discussions refresh every 5 minutes while the prompter is open.
- **Prompter scrolling**: the text rolls up on its own at the set speed, from the top at each take, and stops at the end. The bar at the bottom of the prompter has **Pause / Scroll**, **Top** and the speed; the mouse wheel or trackpad moves it by hand at any time. The producer panel's **PROMPTER** section does the same from a phone or tablet: open or close the prompter, play / pause, top, ▲ / ▼, the speed slider, and a pad to drag, swipe or wheel the text by hand (moving it by hand pauses the roll).

18 AUTOMATION AND TALENT SHOWS



The Scheduler: a week of shows that follow the sun, with inserts and smart rules.

The Scheduler runs a 24/7 channel from a weekly timeline and builds talent shows without touching the program on air. Open it with ⟳ **Auto** in the top bar.

Open ⟳ **Auto** in the top bar (or start the app with `--scheduler`, or `--scheduler talent`). The Scheduler is its own window, so it can sit on a second screen. It has two parts: **Automation**, which sets up and runs the 24/7 week, and **Talent shows**, which builds the shows themselves. When automation is running the Auto button turns green and reads **AUTO**. It keeps running after a restart, so a 24/7 channel comes back on its own.

THE WEEK TIMELINE (AUTOMATION)

The week is seven rows of 24 hours, today first. Each row is shaded with the real sun at your location: blue for daylight, purple for twilight, dark for night, with gold marks at sunrise and sunset. A red line marks now.

- **Draw a block**: pick a show under **Draw with** on the left, then drag across a day. The block runs that show on that day; snap is 5 minutes. A short click-drag makes a one-hour block.
- **Move or resize**: drag a block to move it, or drag either end to change when it starts or ends. Right-click for **Duplicate**, **Every day** and **Delete** (Delete / Backspace works too).
- **Edit**: click a block to open it on the right:
- **Name**, **Show**, the **days** (with **Every day**, **Weekdays** and **Weekends**), and **On** to pause it without deleting it.
- **Starts** and **Ends**: a **Set time**, or minutes before or after **Dawn**, **Sunrise**, **Solar noon**, **Sunset** or **Dusk**. For example, a night show from 30 minutes before sunset to 60 minutes after dusk moves with the season on its own. A gold dot on the timeline marks blocks that follow the sun. The inspector shows today's real times.
- **Layer**: **Base** blocks fill the day. An **Insert** breaks into the base block and hands back when it ends. An insert can **repeat**: for example, every 60 minutes for 5 minutes as a top-of-the-hour update.
- **Runs when**: **Always**, **Warnings in the area**, **No warnings**, **Tropical storms active** or **Winter alerts up**.
- **When it starts / ends**: switch **OBS** to a scene when the block starts (an ad break, a camera, a slate) and, when it ends, to another scene or **back to what was on**. Connect OBS under Settings → Output → OBS; its scenes appear in the list, or type a name. **Call at start** and **Call at end** send an HTTP GET to any URL, for vMix, Bitfocus Companion, a switcher or a webhook.
- **Show → keep graphics running** leaves the rundown on air untouched underneath, which is what a break wants.
- ▲ / ▼ set priority: when blocks overlap, an insert beats a base block, and among blocks of the same layer the one lower in the list wins.
- **Ad break** (Quick add) is an insert at :20 and :50 for 2 minutes that switches OBS to your break scene (one with "ad", "break" or "commercial" in its name, else "Ads") and comes back. Change the times, length or scene in the inspector.
- **Quick add** makes a sunrise show, a sunset show, an hourly top-of-the-hour insert, or a block that runs only while warnings are up. **Starter week** replaces the schedule with the five day parts below.
- **When nothing is scheduled** picks the fallback show.
- **Today** lists today's running order with real times. The status line shows what is on now and what comes next.

Schedules saved before this version keep their times; open a block to switch it to sun times.

The **Starter week** day parts:

BLOCK	TIME	SHOW
Early Morning	04:30–09:00	Commute radar, temperatures, wind chill, fog, morning drive times, traffic cameras, today's futurecast, hour by hour, today's highs, 7-day
Midday	09:00–15:00	Satellite, temperatures, gusts, the afternoon, an analysis segment (500 mb pattern, model check), 7-day
Afternoon Rush	15:00–19:00	Live Doppler, evening commute drive times, traffic cameras, rush-hour futurecast, storm fuel and shear, tonight's lows, 7-day
Night	19:00–23:00	Observations, radar, satellite, overnight futurecast, tonight's lows, "Behind the Forecast" analysis (500 mb, jet, 850 mb advection, models), tomorrow's highs, 7-day
Overnight	23:00–04:30	Overnight Analysis: satellite, radar, 500 mb, 700 mb vorticity, 850 mb advection, moisture, instability, shear, rain totals, model table, sounding, 7-day

When a block starts, its show replaces the rundown and auto-advances. ⌘Z brings back the rundown you had before automation started.

TALENT SHOWS

The **Talent shows** tab builds and edits shows without touching the program on air. Pick a show on the left: your saved shows first, then the built-in templates.

- **Storyboard**: the show as cards in running order. Each card shows its picture (the last time it aired, or its type and product), title and length, with the move into the next scene between cards. The bar under it shows each scene's share of the time; click a card or a segment to pick a scene. **+** adds a scene after the selected one: a map with any product, or any page.
- **Scene settings** (left): title, type, product and model for maps, **On air for** (seconds), **Comes in with** (the transition and how long it takes), talent notes for the prompter, and ◀ **Earlier / Later** ▶, **Duplicate**, **Delete**.
- **Framing** (right, map scenes): a live map of exactly what goes to air, with a title-safe guide. Drag to move, scroll to zoom, right-drag to tilt and turn, or use the **zoom**, **tilt** and **heading** sliders. The **Framing** chips above it (National, Regional, Local, Metro and your own presets) frame the scene in one click. **Use program view** copies the program map, and **Follow program** clears the framing so the scene keeps whatever the program shows.
- **Camera moves** (under the map): fly the map through several framings while the scene is on air. Frame the map and press **+ Key from the map**, or pick **+ Key at preset** (for example National, then Regional, then Local). Each key has **fly** (seconds to get there), an easing and **hold** (seconds to stay). Drag a diamond on the timeline to change when the camera gets there, or the end of a hold to hold longer. Click a key's number to frame that key on the map instead of the scene; **Back to scene framing** returns. ▶ **Play** runs the moves on the map, **Curved** smooths the path and **Loop** repeats it. The total turns orange if the moves run longer than the scene is on air.
- **Save** writes the show back under its own name. Saving under a template's name keeps an edited copy that automation and the Shows menu use instead; **Revert to built-in** drops it. **Save as** makes a new show.
- **Put on the rundown** loads the show on air (⌘Z undoes it). **Schedule it** switches to Automation with this show ready to draw.

FRAMING PRESETS

The **Framings** tab keeps the station's shots so every show uses the same ones. It starts with **National** (a fixed view of the lower 48), **Regional**, **Local** and **Metro** (centered on your home location). For each preset set the zoom, tilt and heading, or drag the map. **Centred on: Home location** moves the shot with the station; **This spot** always shows the same place. **+ Add** saves the program map as a new preset, and the ▲▼ buttons set the order the chips appear in.

Scenes remember the preset they were framed with. Change a preset and every scene using it, in the rundown and in every saved show, moves to the new framing. So do camera-move keys made from it. A scene you have reframed by hand since is left alone. The same presets appear in the inspector's **Camera → Framing** row and in the Coverage Builder's **Maps framed** choice.

SMART RULES

- **Break into live coverage** when a warning at the chosen level (flash flood and up, severe and tornado, or tornado only) touches your area, and return to the schedule a set number of minutes after the last one ends.
- **Skip scenes with nothing to show**: an Alerts page with no alerts, tropical scenes with no storms, a tsunami page with no messages.
- **Add the tropics** while NHC has active storms, and **snow totals** while winter alerts are up.

AI HOST

The host writes two to four spoken sentences for each scene from the data on screen (the observation, the NWS forecast, alerts, storms, places, drive times and your talent notes) and speaks them.

1. Install Ollama and pull a model, for example `ollama pull llama3.2`.
2. In the Scheduler's Automation tab tick **Talk over each scene**, check the Ollama address and model, and pick a persona.
3. **Voice**: **System** uses the macOS voice (pick one) or `espeak` on Linux. **Command** runs any program that reads text on its input, such as Piper piped to an audio player. **Off** writes scripts without speaking (handy with **Test on this scene**).
4. **Keep talking** (on by default): when a line ends and the scene has time left, the host adds a new point about the same scene; it is told what it already said so it does not repeat itself. **Lines per scene** caps it.
5. **Talk over scenes I take by hand too**: the host follows the scene on air even without automation. A new scene stops the old line and starts a new one.
6. **Let the host steer** (only while automation runs) allows it to keep the scene, move on, jump to a scene by title, start live coverage, or add a ticker headline. Live coverage still needs a qualifying warning, and anything outside those actions is ignored. Scenes stay up at least 8 seconds.
7. **Stretch each scene until the host finishes its sentence**: a scene stays on air while the voice is speaking or its first line is still being written, up to a minute past its length.

What the host knows about each scene: the title and subtitle on screen, your info box, values at the biggest towns in view (or which towns have precipitation), the radar site and tracked storms with their next towns, the satellite product, lightning counts, the next 12 hours, each model's high and rain total, the 7-day periods, alerts, current observations and your talent notes.

If a small model answers with just "stay" or a fragment, WX Studio asks again; replies follow a strict format so the action never ends up in what is spoken.

The log at the bottom of the window shows each block change, takeover, added scene and what the host said. The voice plays through the computer's audio output; capture it in OBS for the stream.

19 OFFLINE EVENTS AND PERFORMANCE

Record a real event and replay it later with no network, and measure how much of each frame's time budget the program uses.

OFFLINE EVENTS: RECORD AND REPLAY

Record a real event once, then replay it later with no network: for training, demos and rehearsing a severe-weather show on a quiet day.

- **Record**: Windows menu → *Offline events* → name the event → ● **Record**. Every feed the show uses (radar, satellite, models, alerts, observations, basemap tiles…) is saved as it arrives. A red ● **REC** chip at the bottom of the operator screen shows the running time and size; it never appears on the program output. ■ **Stop recording** closes it. Events are saved in `Documents/WX Studio Events` (set `WX_EVENTS_DIR` to use another folder).
- **Size**: recording skips the disk cache so the event is complete, which means model runs are downloaded again: an HRRR home region alone is over 1 GB. Leave it running long enough for every scene you want to replay to load fully (radar and satellite loops, model hours); anything that never loaded while recording is missing on replay.
- **Replay**: pick an event in the same menu → ▶ **Replay**. WX Studio restarts and serves every feed from the recording. The clock starts where the recording started and runs in real time, so the on-air clock, warning countdowns, "minutes ago" ages and loops all match the event. A blue ▶ **REPLAY** chip shows the event clock. The *event time* slider jumps around in the event; feeds pick up the new time on their next refresh. **Back to live** restarts with live feeds.
- A replay never saves the show and never writes the live caches. Requests that weren't recorded fail as if offline. `WX_REPLAY_LOG=1` prints each hit and miss to the terminal.
- From the command line: `--record [NAME]` starts recording at launch; `--replay FOLDER` replays an event.

FRAME-TIME BUDGET OVERLAY

Press **F12** (or start with `--frame-budget [FPS]`) for a live overlay in the top-right corner: average and worst CPU time per frame against the budget for the chosen rate (29.97, 30, 50, 59.94 or 60 fps), how many of the last 240 frames went over, a bar per frame (green under ¾ of the budget, amber under budget, red over), and the ten most expensive parts of the frame. Press F12 again to hide it. `WX_PROFILE=1` prints the same breakdown to the terminal every 3 seconds.

PART VI

REFERENCE

20 SETTINGS

Settings (top right) has five pages, one per job. Hover a page name to see what it holds.

PAGE	WHAT IT HOLDS
Station	License (holder, expiry, renewal key), call letters, talent, colors, the weather icon folder.
Maps & radar	Radar site, NWS contact, layer rendering, and the Mapbox, TomTom and EUMETSAT keys.
Alerts & crawl	Push warnings (NWWS-OI, NOAAPORT), threat colors, warning banners and the crawl.
Models	NOMADS, ECMWF and GEM direct sources, the Open-Meteo key, preloading, new-run alerts, the model cache and **Clear model cache**.
Output	NDI, live stream, SDI, OBS, chroma key, safe areas and the export folder.

The settings you will use most:

SETTING	WHERE	WHAT IT DOES
Location / radar site	Location search; Maps & radar	Forecast point; the nearest radar or a fixed ICAO ID.
Call letters	Station	Used in title graphics and the corner bug.
NWS contact	Maps & radar	The email address in the NWS User-Agent. The NWS asks every app to send one.
Mapbox token	Maps & radar	Enables the Mapbox basemaps.
TomTom key	Maps & radar	Live traffic delays and the traffic-flow layer.
EUMETSAT Data Store	Maps & radar	Full Meteosat-12 channels (see Satellite).
Open-Meteo key	Models	Commercial Open-Meteo access (required for commercial broadcast of Open-Meteo models).
Models	Models	NOMADS on or off, models to preload, hours, domain or home region, refresh interval, scenes to preload ahead, new-run alerts.
Model cache	Models	Size on disk and **Clear model cache**.
Alerts	Alerts & crawl	Pop-up scope, sounds and card times.
Threat mode	Alerts & crawl	Live scenes take the worst warning's color, from a starting level; the accent can follow the highest warning (area or nationwide).
Warning banners	Alerts & crawl	Which warnings get an on-air banner, where, and for how long.
Storm tracks	Graphics Editor → Radar	Which cells, track and timing range, path width, towns, timing boxes.
Producer panel	Windows → **Producer web panel (LAN)**	On or off, address and access token. Users and roles: Windows → **Users, buttons & audit log…**.
Export folder	Output	Where snapshots and recordings go.

21 KEYBOARD SHORTCUTS

Single-letter keys work whenever the operator screen has focus and you are not typing in a text field.

SHOW CONTROL

KEY	ACTION
→ or Page Down	Take the next scene
← or Page Up	Previous scene
A	Auto-advance on / off
N	Analysis mode on / off
C	Live Coverage on / off
F	On air, full screen
Esc	Leave full screen; close a warning's map box
⌘Z / ⇧⌘Z	Undo / redo rundown changes
⌘S	Save the show

LOOP PLAYBACK

KEY	ACTION
Space	Play / pause
, and .	Step back / forward one frame (pauses)
Home / End	First / last frame

TOOLS AND WINDOWS

KEY	ACTION
H	Data Hub
G	Graphics window
L	Talent lower third in / out
P	Data probe
S	Snapshot of the program
T	Telestrator. Backspace or Delete clears; ⌘Z undoes a stroke
F12	Frame-time budget overlay

LIVE MODE

KEY	ACTION
1–9	Radar product (REF, VEL, SRV, CC, ZDR, KDP, HC, TOPS, RAIN)
B	Warning banner
Z	Zoom to the newest warning
D	Dual pane

TEMPLATE DESIGNER

KEY	ACTION
⌘A	Select all
Arrow keys	Nudge (⇧ for 1% steps)
⇧ while dragging	Keep proportions; turn in 15° steps
⌥ while dragging	Move without snapping
⌘] / ⌘[	Bring forward / send back (with ⇧: to front / back)
⌘D	Duplicate
⌘C / ⌘X / ⌘V	Copy / cut / paste
Delete	Delete
⌘Z / ⇧⌘Z	Undo / redo

FORECAST DRAWING AND SCHEDULER

KEY	ACTION
Enter (or double-click, right-click)	Finish the front or line being drawn
Delete	Delete the selected drawing item
Delete or Backspace	Delete the selected Scheduler block

22 COMMAND LINE AND ENVIRONMENT

Start WX Studio from a terminal to pass options:

```
target/release/wx-studio [OPTIONS]
```

Options fall into two groups. **Operating options** change how this run behaves; settings you change during the run are saved as usual. **Render and test options** run on your saved settings but never save them, so they are safe to use on a production machine.

OPERATING OPTIONS

OPTION	WHAT IT DOES
`--headless`	Headless playout: the program fills the window, the rundown auto-advances and the producer panel listens on the network (see Live streaming and headless playout).
`--stream URL`	Stream the program to an RTMP or SRT address.
`--sdi`	Turn the SDI output on for this run.
`--web`	Turn the producer panel on.
`--web-bind ADDR:PORT`	Producer panel address.
`--scheduler [talent]`	Open the Scheduler, on the Talent shows tab with `talent`.
`--record [NAME]`	Start recording an offline event at launch.
`--replay FOLDER`	Replay a recorded event with no network. A replay never saves the show.
`--frame-budget [FPS]`	Start with the frame-time budget overlay on (60 fps by default).
`--glow`	Start with the OpenGL renderer (no GPU 3D map). `WX_RENDERER=glow` does the same.

BATCH RENDERING

These render scenes to PNG files and quit. On macOS keep the window visible while they run; App Nap slows hidden windows.

OPTION	WHAT IT DOES
`--export-rundown DIR`	Render every rundown scene to PNG and quit.
`--export-hub`, `--export-radar`, `--export-pages`, `--export-models`	Render every Data Hub module, radar product, page or model product.
`--l2`	With `--export-radar`: render the Level II moments instead of Level III.
`--radar-ref-only`	Keep only reflectivity scenes in the rundown.
`--rundown FILE`	Replace the rundown with a JSON array of scenes for this run.
`--batch-wait SECS`	With `--export-rundown`, wait at most this long for each scene's data.
`--scene JSON`	Add and take a scene given as JSON.
`--box W,S,E,N`	With `--export-radar`: add a boxed, looping 3D storm volume with a spotlight.
`--at LAT,LON`	Retarget a batch render to a place.
`--zoom N`, `--tilt DEG`, `--bearing DEG`	Map zoom, 3D tilt and heading.
`--radar ICAO`	Use that radar for the run.
`--pal FILE`	Import a color table at launch.
`--painter-map`	Use the 2.5D painter map instead of the GPU 3D map.

LOOK AND DESIGN CHECKS

OPTION	WHAT IT DOES
`--logo FILE`	Try a logo.
`--title-style NAME`	Try a title style.
`--lightning-style JSON`	Try a lightning look.
`--font FILE`	Try a headline font.
`--contour KEY=JSON`	Try a contour style, for example `--contour 'mslp={"interval":2,"label_bg":"Halo"}'`.
`--look broadcast|standard|relief`	Switch the map look.
`--base PRESET`	Turn on the custom base layer from a preset.
`--page-style NAME`, `--icon-style NAME`, `--backdrop JSON`	Page theme, icon style and page backdrop, for example `--page-style Sky --icon-style Shaded`.
`--designer PAGE[:N]`	Open the Template Designer on a page (`7day`, `current`, `hourly`, `alerts`, `drive`, `model`, `map`), with element N selected.
`--template JSON`	Put a page template on air (`starter:7day` uses the starter layout).

TEST AND DEMONSTRATION OPTIONS

OPTION	WHAT IT DOES
`--shot-ui FILE [SECONDS]`	Screenshot the whole window after SECONDS and quit.
`--take TYPE`	Open a scene type.
`--inspector N`, `--inspector-width N`	Open an inspector tab; pin the inspector's width.
`--settings [TAB]`	Open Settings, optionally on a page (0 Station, 1 Maps & radar, …).
`--builder`	Open the Coverage Builder.
`--web-token T`	Producer panel on with a throwaway token. Combine with another test option so nothing is saved.
`--control-test`	Add a throwaway talent user (link token `talent-test`) to check roles on the producer panel.
`--noaaport DIR`	Read wire products from a folder.
`--output-test DIR`	Write the NDI program and key frames to DIR as PNGs instead of sending them.
`--render-test DIR`	Render the scene opened with `--take` to DIR once, as an MP4 and a PNG.
`--warning-demo`	A tornado and a severe thunderstorm warning over home. Add `--emergency` to make the tornado warning an emergency, `--map-card` to open its map box, `--read-warning` to open its text.
`--watch-demo`	Draw the SPC watch boxes of 21 May 2024.
`--storm-demo`	Two synthetic severe storms near home. `--storm-callout` turns on the automatic storm callout.
`--tele-demo`	Draw a sample telestrator sketch.
`--pgen-demo [explainer|wpcload]`	Open forecast drawing with a sample drawing. `--pgen-analyse` runs Smart analysis; add `--pgen-to-scene` to save it as a scene.
`--run-alert-test`	Treat the first new-run check as new runs, to show the model timing note.
`--auto-test URL`	Run automation with the AI host pointed at URL and the voice off.
`--switch-test A,B`	Time a scene change from scene A to scene B.
`--live-test`	Enter Live after 4 s, return to Show after 14 s, quit at 24 s.
`--pvw-take`	Edit the scene on air in Preview, then TAKE once.
`--zoom-test`	Zoom toward a point in small steps and log how far the ground under it moves.
`--pick-test X,Y`	Hold the pointer at X,Y and log the GPU pick beside the CPU estimate.

OPTION	WHAT IT DOES
`--press-test X,Y`	Click once at X,Y five seconds in.
`--check-glyphs`	List interface symbols no installed font can draw, and quit.

ENVIRONMENT VARIABLES

VARIABLE	WHAT IT DOES
`WX_EVENTS_DIR`	Folder for recorded offline events (default `Documents/WX Studio Events`).
`WX_REPLAY_LOG=1`	Print each replay hit and miss.
`WX_PROFILE=1`	Print the frame-time breakdown every 3 seconds.
`WX_TIMING=1`	Print download and decode timings.
`WX_RENDERER=glow`	Use the OpenGL renderer.
`WX_GPU_COLORMAP=0`	Color model, radar, satellite and raster overlay fields on the CPU instead of in the 3D map's shader.
`WX_BASEMAP=studio-dark|studio-light|studio-terrain`	Use a built-in basemap for this run without changing the saved setting.
`WX_LICENSE_KEY`	A license key to use instead of the saved one.
`WX_STREAM_HOME`	Working folder for `scripts/live-stream.sh` (default `~/.wx-studio-stream`).

FOR DEVELOPERS

COMMAND	WHAT IT DOES
`cargo test --workspace`	Unit and integration tests.
`cargo test -p wx-studio --test ui_snapshots`	UI snapshot tests: runs the app on a replayed event with a fixed rundown and compares 480×270 frames with `apps/wx-studio/tests/snapshots/` (2% pixel tolerance). `WX_UPDATE_SNAPSHOTS=1` records new references; `WX_NO_UI_TESTS=1` skips them on machines without a display.
`cargo bench -p wx-data --bench decoders`	Decoder benchmarks (Level III and Level II radar, HRRR GRIB2, GOES ABI). Add `-- --fetch` once to download the sample files. See BENCHMARKS.md.

23 TROUBLESHOOTING

Common problems and what to do about them.

PROBLEM	WHAT TO DO
A model map says "Loading…" for a long time	The first load of a model or of upper-air levels downloads the whole domain. Watch the progress on the Layers tab; later loads come from the disk cache.
NOMADS can't be reached (outage, its CDN refusing requests, no network)	WX Studio retries each request, then keeps showing the newest run already on disk, so preloaded models still draw. New runs download again once NOMADS answers.
"isn't available from this model"	Not every model has every field. Upper-air and severe products are on GFS, RRFS, RAP and HRRR; NBM is surface only.
A camera shows its snapshot, not video	The agency requires its own sign-in for video, or ffmpeg isn't installed.
A camera says offline	Neither its video nor its snapshot answered. Try a nearby camera.
Drive times show "—" in the delay column	No TomTom key: times are typical. Add a key in Settings for live delays.
No storm timing boxes	Click a storm to show its box (or tick **Auto-show boxes**). They need single-site radar, tracked cells at or above the chosen threat, and towns in the path.
No lightning	There may be no storms in view. Lightning shows the last 15 minutes by default.
Exports are slow on macOS	Keep the window visible; App Nap slows hidden windows.
Model, radar or satellite colors look wrong on the 3D map only	The 3D map colors model fields, radar, single satellite bands and NOAA raster overlays on the GPU. Start with `WX_GPU_COLORMAP=0` to color them on the CPU instead, and report the graphics card.
A ⚠ **FEEDS** chip in the top bar	A feed has gone stale or is failing. Click it for **Status** → **Feed health**: each feed in use with its state, how old its newest data is and how long its last download took. Hover a feed for the error.

24 DATA SOURCES AND LICENSING

Where each feed comes from and what its license asks of you. Credits required on air are drawn automatically.

DATA	SOURCE	NOTES
Radar	NOAA NEXRAD Level III and Level II (AWS), NOAA MRMS mosaic (AWS), IEM, RainViewer	Public; RainViewer has its own terms.
Satellite and lightning	NOAA GOES-19/18 ABI and GLM (AWS)	Public domain.
Himawari-9 and GK2A	NOAA's AWS copies of JMA and KMA full disks	Redistributed by NOAA; credit JMA / KMA.
Meteosat-12	EUMETSAT Data Store (with the station's account) or EUMETView (WMS)	© EUMETSAT; check EUMETSAT's data policy before commercial use.
Mesoanalysis	Computed from the NOAA RAP (NOMADS)	Public domain.
SPC MDs and WPC MPDs	National Weather Service API	Public.
Observed soundings	Iowa Environmental Mesonet RAOB archive	Free; credit IEM.
Ensembles	NOAA REFS (NOMADS) and GEFS (AWS)	Public domain.
MRMS rainfall and flash-flood products	NOAA MRMS (AWS)	Public domain.
River gauges	NWS National Water Prediction Service; USGS Water Services	Public.
AI models	NOAA NOMADS (AIGFS); NOAA OAR MLWP on AWS (GraphCast, FourCastNet, Pangu-Weather, Aurora)	NOAA data; experimental research output. GraphCast and Pangu-Weather weights are non-commercial (CC BY-NC-SA); Aurora is MIT. Credited on air.
MOS	NOAA MDL via the Iowa Environmental Mesonet	Public; credit IEM.
WPC surface analysis	NWS coded surface bulletin (tgftp.nws.noaa.gov)	Public domain.

DATA	SOURCE	NOTES
Models	NOAA NOMADS; ECMWF open data; Open-Meteo; WOOF-NAM by Recast	NOMADS is public domain. ECMWF open data (IFS, AIFS) is CC BY 4.0, free for commercial use, credited on air automatically. Open-Meteo (ICON, ICON-EU/D2, GEM, UKMET, ARPEGE, JMA, CMA GRAPES, ECMWF soundings) is free for non-commercial use; use a paid key for commercial broadcasts. WOOF-NAM is CC BY 4.0, credited on air automatically.
Alerts, forecasts, observations	National Weather Service API	Public; send a contact in Settings.
Outlooks and hazards	SPC, WPC, CPC, NHC, NWS map services	Public.
Tropical guidance	NHC ATCF a-decks and b-decks	Public.
Nadocast	data.nadocast.com (Brian Hempel)	Credit Nadocast on air.
Towns	US Census gazetteer and population estimates	Public.
Cameras	Community `maps-data` collection of DOT and weather cameras	Downloaded at runtime, not bundled. The collection has no license file; each camera belongs to its agency.
Routing and traffic	OSRM / OpenStreetMap; TomTom (your key)	OSM data is © OpenStreetMap contributors. TomTom needs your own account.
Basemaps	Esri, Mapbox (your token)	Attribution is drawn on air.