# 16th Weather Squadron
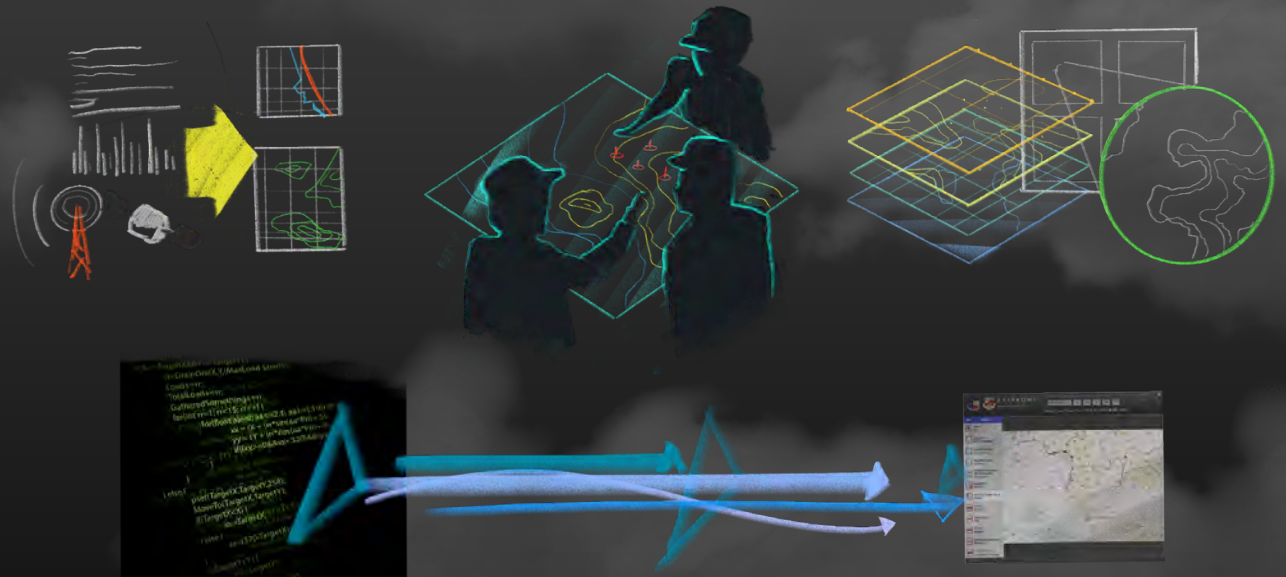


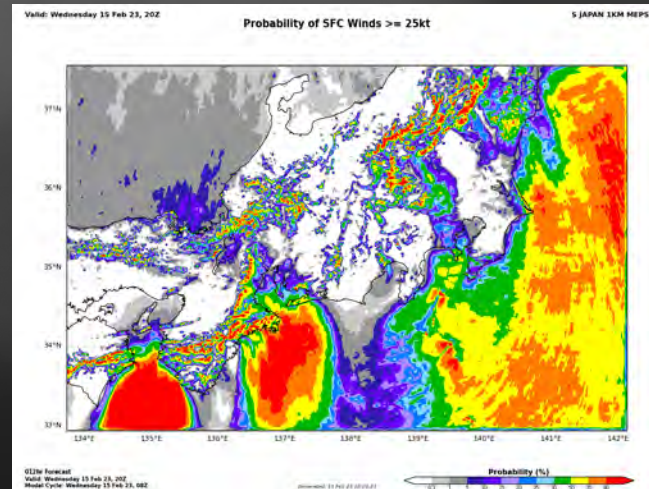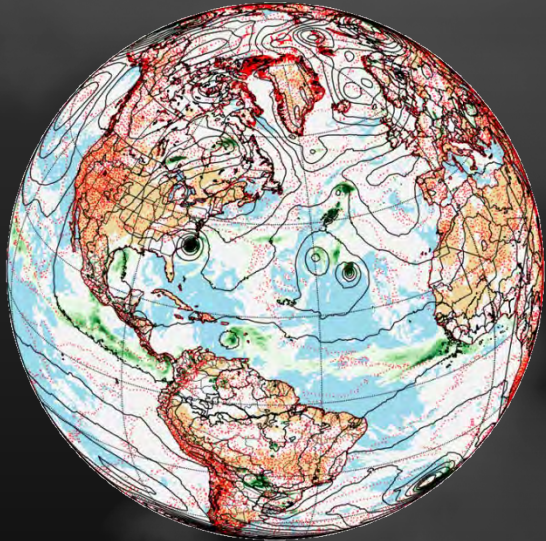September 2023

Source: U.S. Navy / Seaman John Ciccarelli.

**Automate environmental information insights for national security decision advantage**

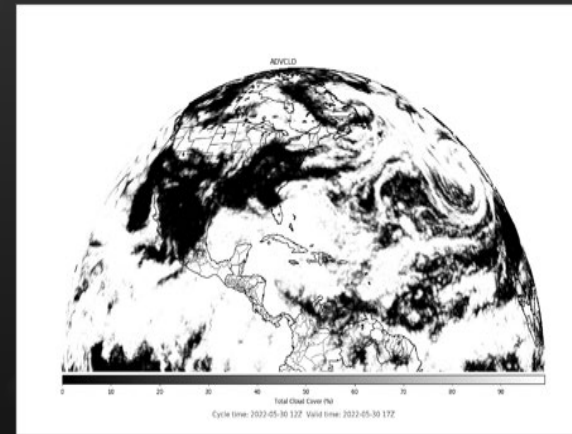# Mission

Global land surface and atmospheric analysis and forecasts to 16 days

Rapidly updating global cloud analysis and forecasts

Fine scale 1 km (30 hrs) and 4 km (72 hrs) regional environment forecast enhancements

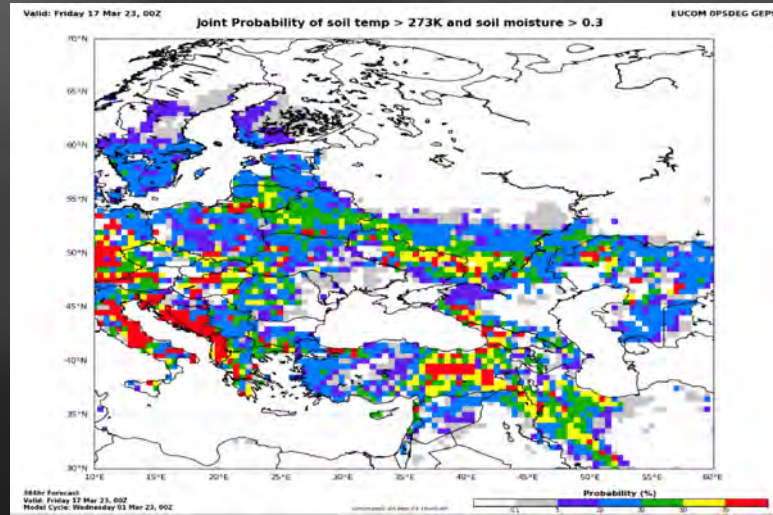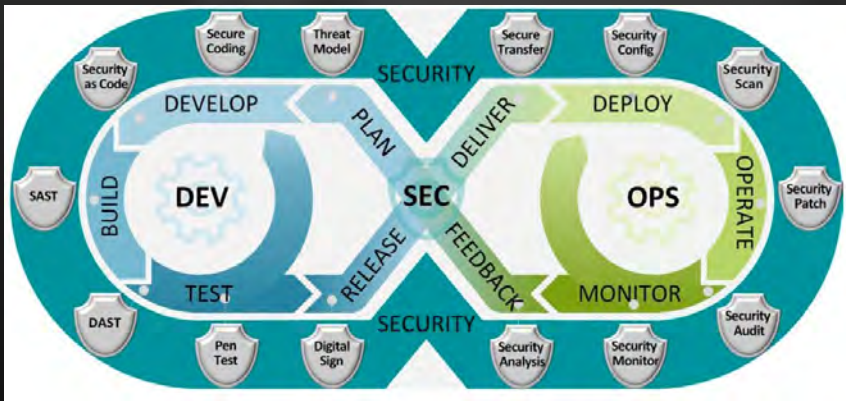Government leaders for operational environmental modeling forecast skill and cyber security

**Foundational secure 24/7 environmental modeling for Joint Forces providing 200 TB of data and 200M products to 20K users annually**

# Mission

Continuous Integration / Continuous Delivery of automated enhancements (transient or permanent) via software DevSecOps







Collaboration of users (via stakeholder engagement team), scientists, and coders to innovate effective operational product adaptations
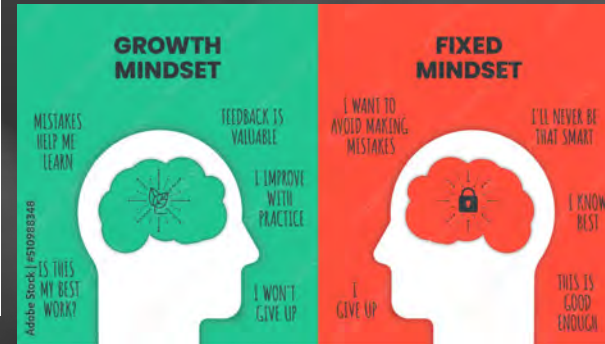
**Operationally responsive model/product adaptations and prototypes for evolving decision needs**
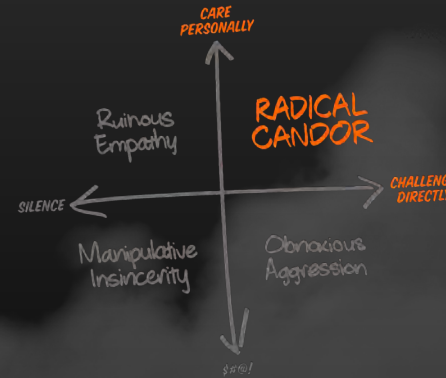
# Mission



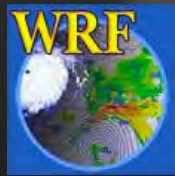Provide operational insights and subject matter expertise to supporting commands/program offices

Educate supported Joint Forces on optimal use of 16 WS capabilities and ways to leverage its resources

Heavy emphasis on hiring and developing the right people/skills for complex and challenging mission

**Environmental science and information technology expertise base for the Air Force Weather enterprise**

# Clouds: History

- We have been doing this for a very long time (Jan 1971)

  - https://apps.dtic.mil/sti/pdfs/ADA290987.pdf

  - This is why we still have separate nowcasting and modeling capabilities—lots of ops tied into the legacy processing

- Support for intelligence, surveillance, reconnaissance safety and mission success

- Icing aviation hazards

- Triggered lightning!

# More on WWMCA

- Product is cut at defined issuance time (every 30 mins) with whatever satellite data is available at that time (best possible product out to ops)

- No later update is made, so WWMCA data at some grid cells may be a few hours old

- Inputs from 16 geostationary and polar orbiting satellites, along with traditional observations, and NWP temperature/moisture/land surface fields

- Note how many variables are defined as "cloud"--what does this mean?

| Parameter | Units | Layers or Grid Cell |
|---|---|---|
| Cloud Amount | Percent | Layers |
| Cloud Type | Enumerated (See Table 4 -74) | Layers |
| Cloud Base | Meters | Layers |
| Cloud Top | Meters | Layers |
| Optical Depth | Dimensionless Stored as *10 | Layers |
| Ice Cloud Fraction | Percent | Layers |
| Cloud Water Path | g/m^2 | Layers |
| Cloud Particle Size | Micrometers | Layers |
| Update Time | Minutes after 0000Z 31 December 1967 | Grid Cell |
| Satellite Merge | Bitmask of GDR sources used in merge (see Table 5 -80) | Grid Cell |
| Satellite ID | ID number of dominant satellite (see Table 5 -81) | Grid Cell |
| Total Cloud Amount | Percent | Grid Cell |
| Number of Layers | Number (1-4) | Grid Cell |
| Quality Index | Percent (reserved for future use) | Grid Cell |

# WWMCA, ADVCLD, DCF
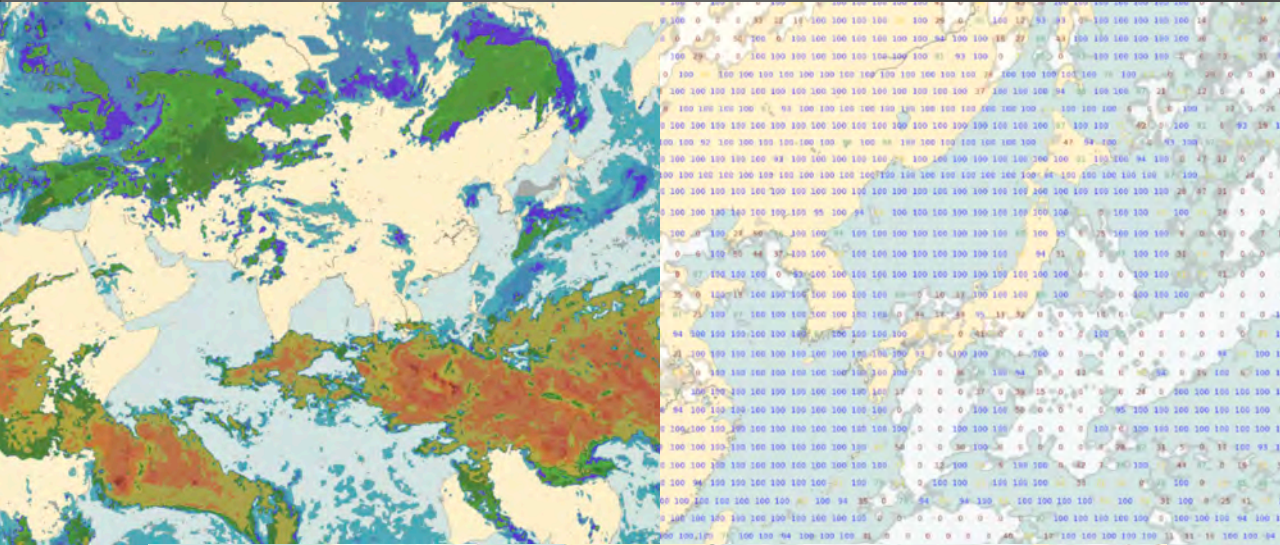
## WorldWide Merged Cloud Analysis

- Inputs from geostationary and polar orbiting satellites, land surface/ice analysis, and numerical weather prediction

- Cloud analysis products produced every 30 minutes

- Satellite inputs human-tuned to mitigate seasonal biases

## ADVection of CLouDs (ADVCLD)

- Uses global model winds to move WWMCA clouds

- Hourly forecasts to 12 hours

## Diagnostic Cloud Forecast

- Statistical correction of global model predictors to create a product with similar characteristics to WWMCA

- 3-hourly forecasts to 144 hours

# GALWEM

## Global Air-Land Weather Exploitation Model

- 4X/day 17 km deterministic run to 240 hours

- 4X/day 20 km 18-member ensemble to 384 hours

- 70 vertical levels, 80 km model top

- Initial conditions provided by UKMO

- Post-processing/tailoring to create ~2500 output variables

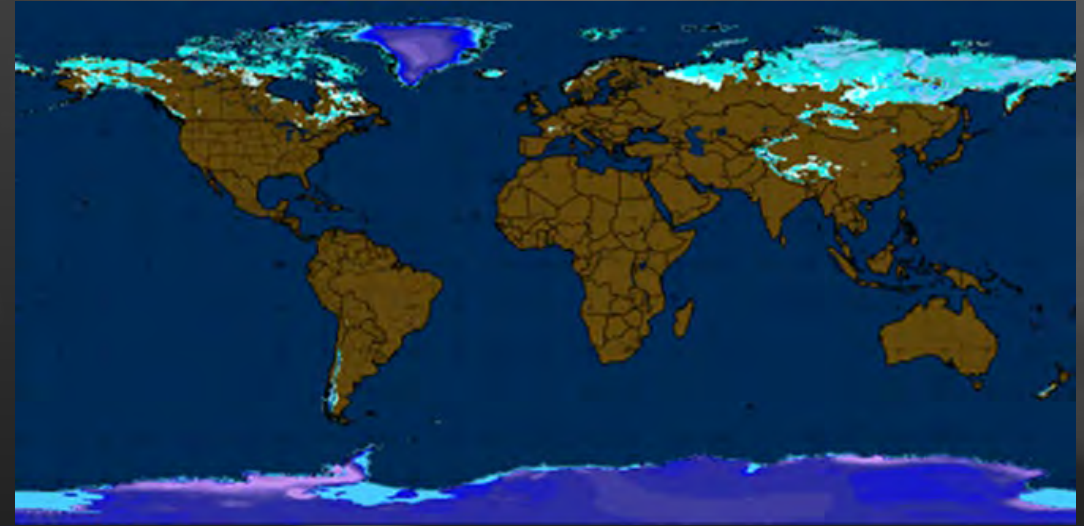- Total cloud cover, cloud fraction, ceiling height, others in development
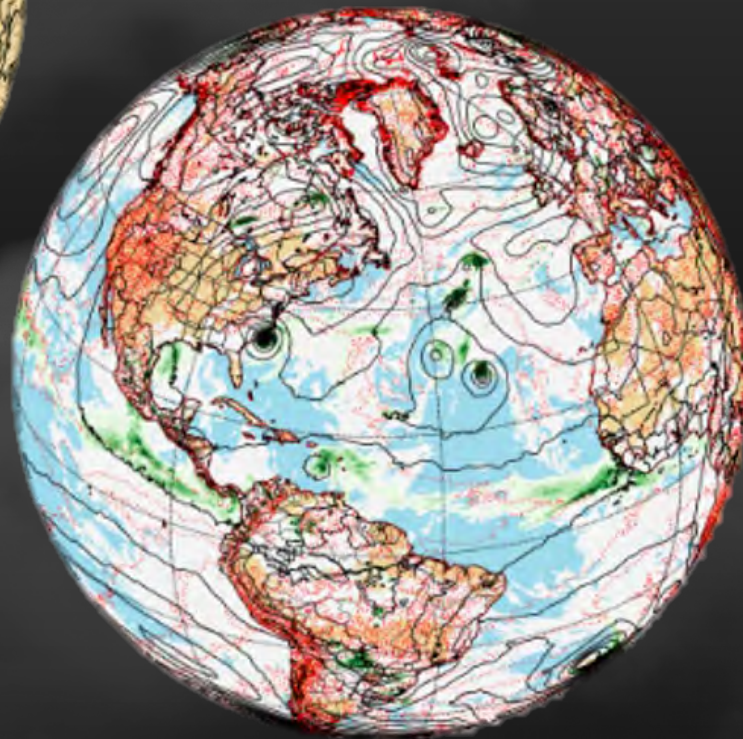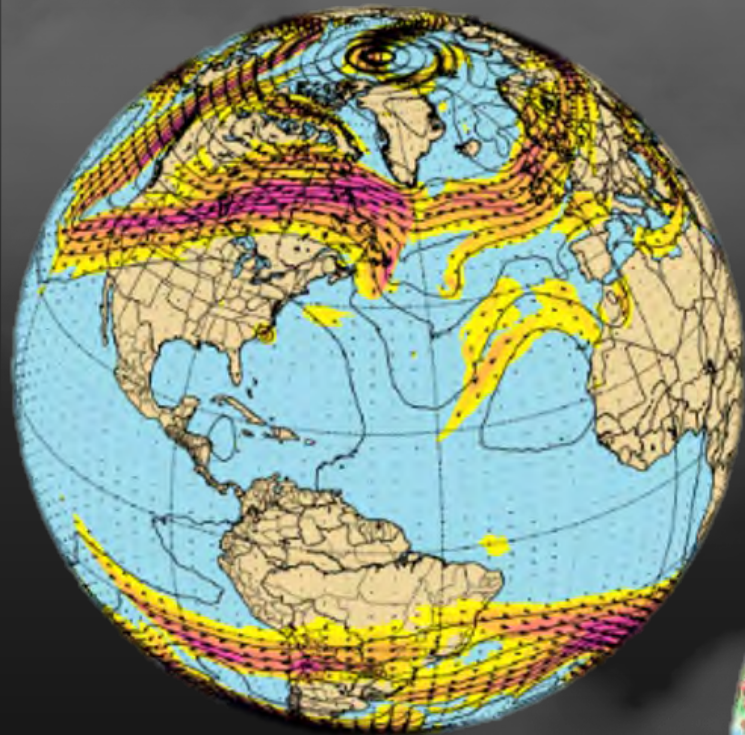
# LIS

## Land Information System

- 4X/day 10-km soil temperature, soil moisture, ice, and snow analysis

- Inputs from satellites, precipitation measurements, WWMCA, and global models

- Advanced assimilation techniques to maximize available data and model outputs

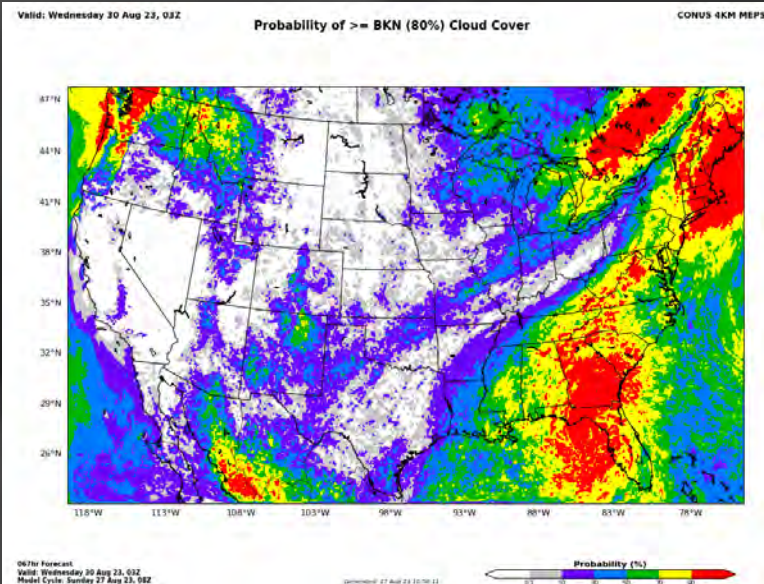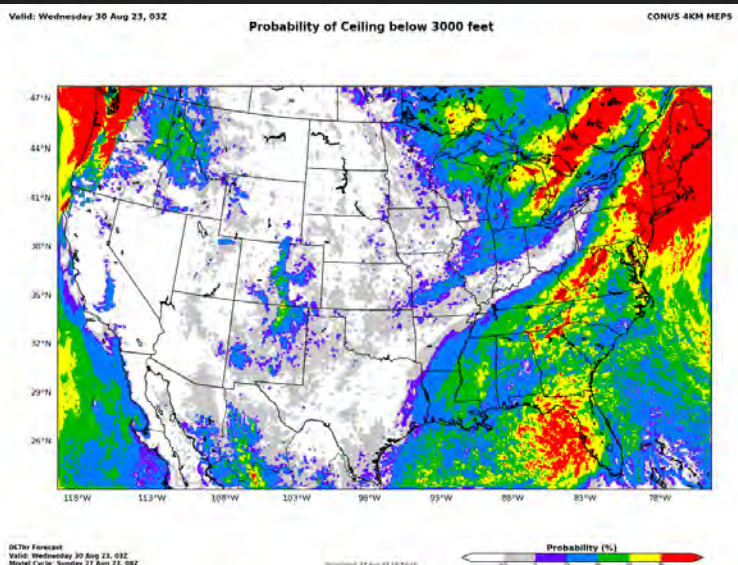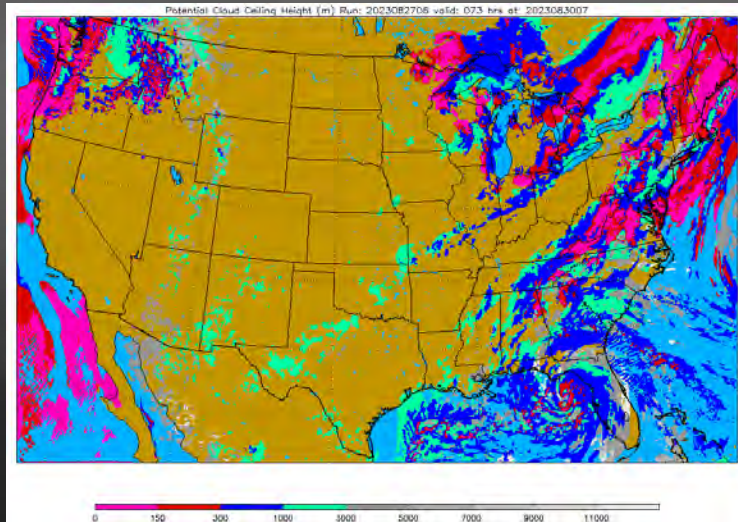- Background for WWMCA (and WWMCA is background for it)

# AFWEPS

## Air Force Weather Ensemble Prediction Suite

- 2X/day half-degree global 63-member ensemble to 384 hours (GEPS)

  - 21 members each from NOAA, CMC, FNMOC

- 12X/day WRF 16-member regional ensembles (MEPS)

  - 20 km to 132 hours, 4 km to 72 hours, 1 km to 30 hours

  - Single runs every two hours, time-lagged 30 hours

  - Each member has unique physics/global background combinations

- Inline diagnostics to calculate algorithms for rapidly changing variables at every model time step

- Regional ensemble domains can be rapidly moved to new areas as decision needs arise

- Simple RH-based computation of cloud presence

- Uncertainty from cloud diagnosis and from flow-dependent ensemble members

- Probabilities computed for ceiling height and total cloud cover (20% and 80% sky coverage)

# Clouds--Philosophy

- Definitions of cloud:

- <u>AMS:</u> A visible aggregate of minute water droplets and/or ice particles in the atmosphere above the earth's surface.

- <u>WMO:</u> A hydrometeor consisting of minute particles of liquid water or ice, or of both, suspended in the atmosphere and usually not touching the ground. It may also include larger particles of liquid water or ice, as well as non-aqueous liquid or solid particles such as those present in fumes, smoke or dust.

- We use the word "cloud" the way we use the word "storm"--there is a general meaning that we all understand but specific definitions vary by situation!

- Imagine if we produced forecasts of "storms"….

# Clouds--Philosophy

## Hydrometeor Space

Particle phase and/or type
Particle mixing ratio
Particle size distribution

Necessary Translation

## Radiation Space

Wavelength dependent
brightness temperature
difference from clear sky
background

Case-specific thresholds

Case-specific thresholds

CLOUDS?

# Clouds—Product Development

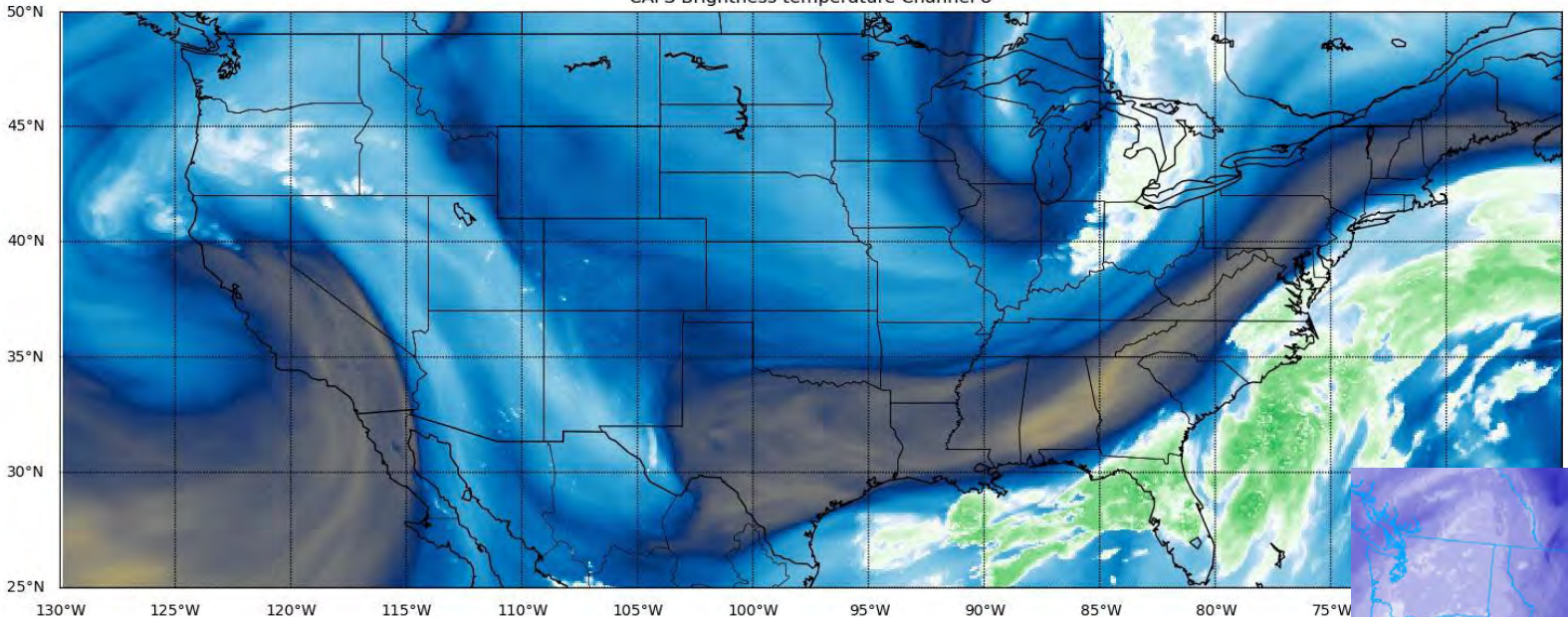- Multiple lines of development effort:

    - NCAR/MMM working on all-sky data assimilation and IR direct radiance insertion

    - 16 WS working to replicate all WWMCA/ADVCLD/DCF variables with GALWEM post-processor

    - 16 WS working to use CRTM with MPAS to create wavelength-specific simulated satellite products

# MPAS/CRTM



CAFS Brightness temperature Channel 8
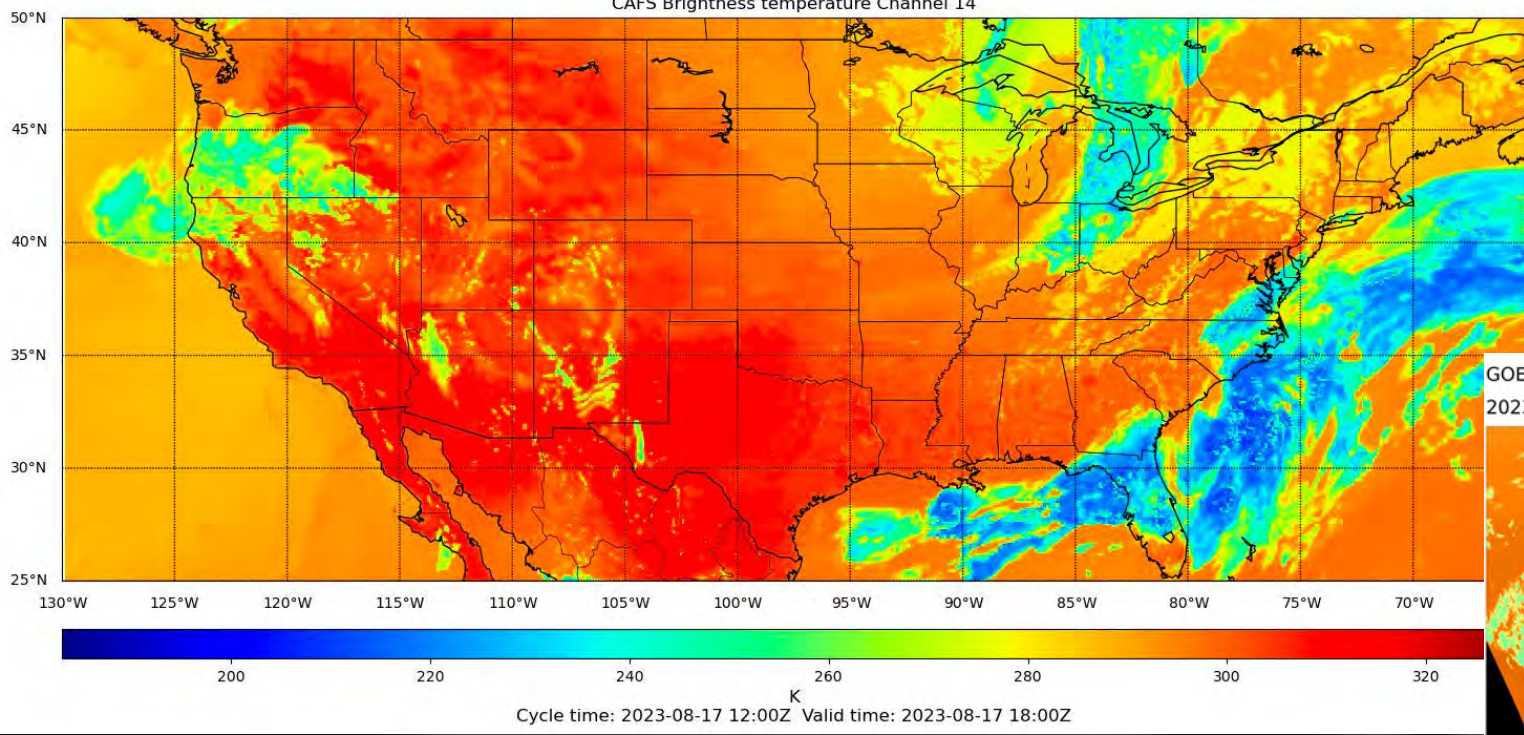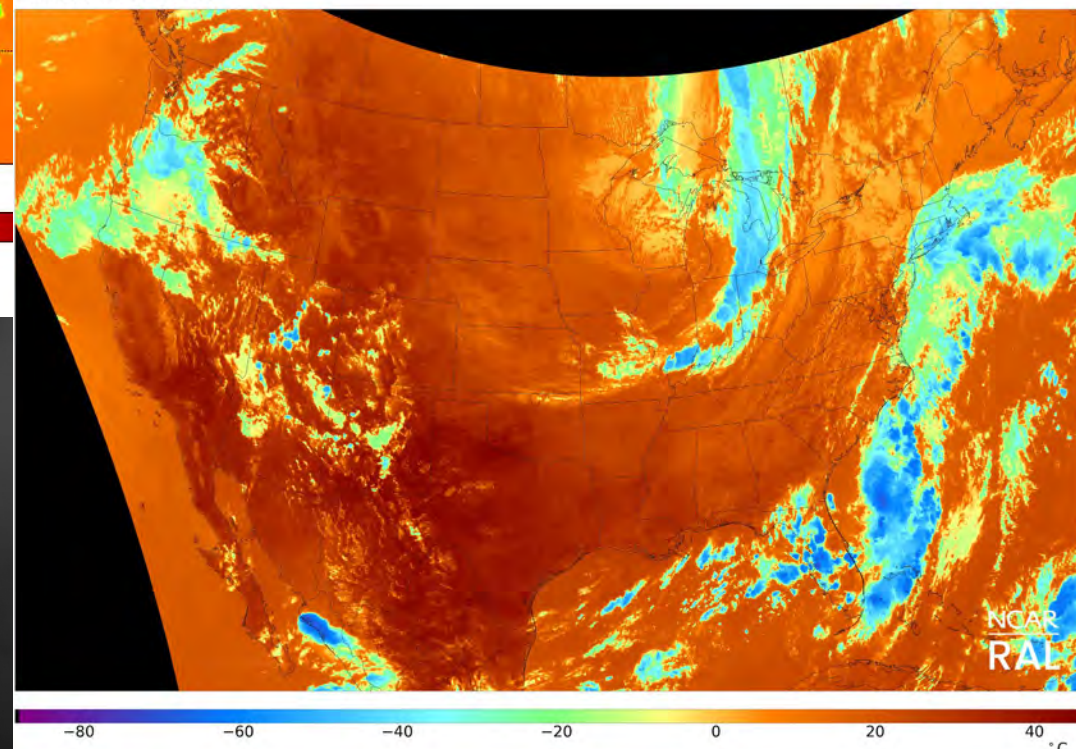
Cycle time: 2023-08-17 12:00Z  Valid time: 2023-08-17 18:00Z
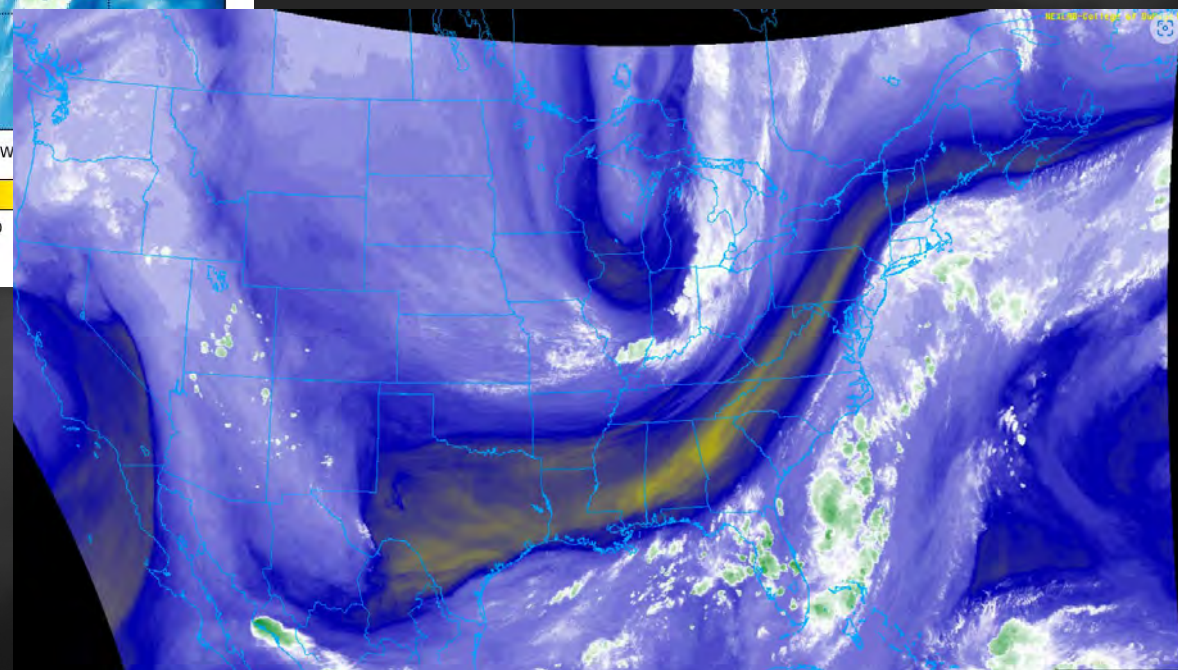
# MPAS/CRTM



CAFS Brightness temperature Channel 14

Cycle time: 2023-08-17 12:00Z  Valid time: 2023-08-17 18:00Z

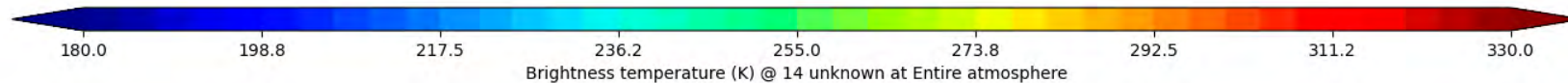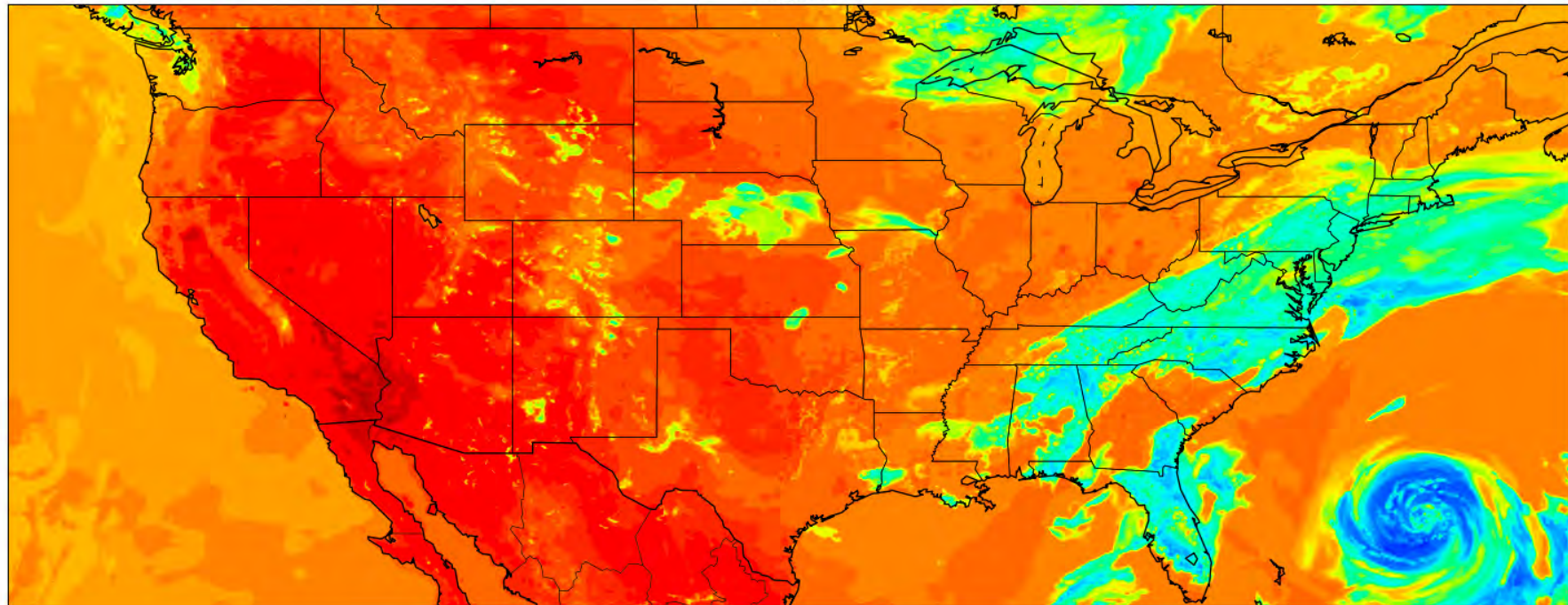GOES-16 channel 14 (11.2 micron) infrared
2023-08-17 17:57:36

# MPAS/CRTM



20 micrometer droplet size

Original

Brightness temperature (K) @ 14 unknown at Entire atmosphere

Cycle: 2023-08-28 @ 18Z Fcst Hr: 120
Valid: 2023-09-02 @ 18Z

USAF 557th Weather Wing

Droplet size from MPAS microphysics

New
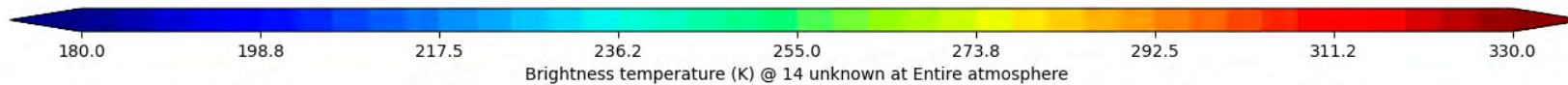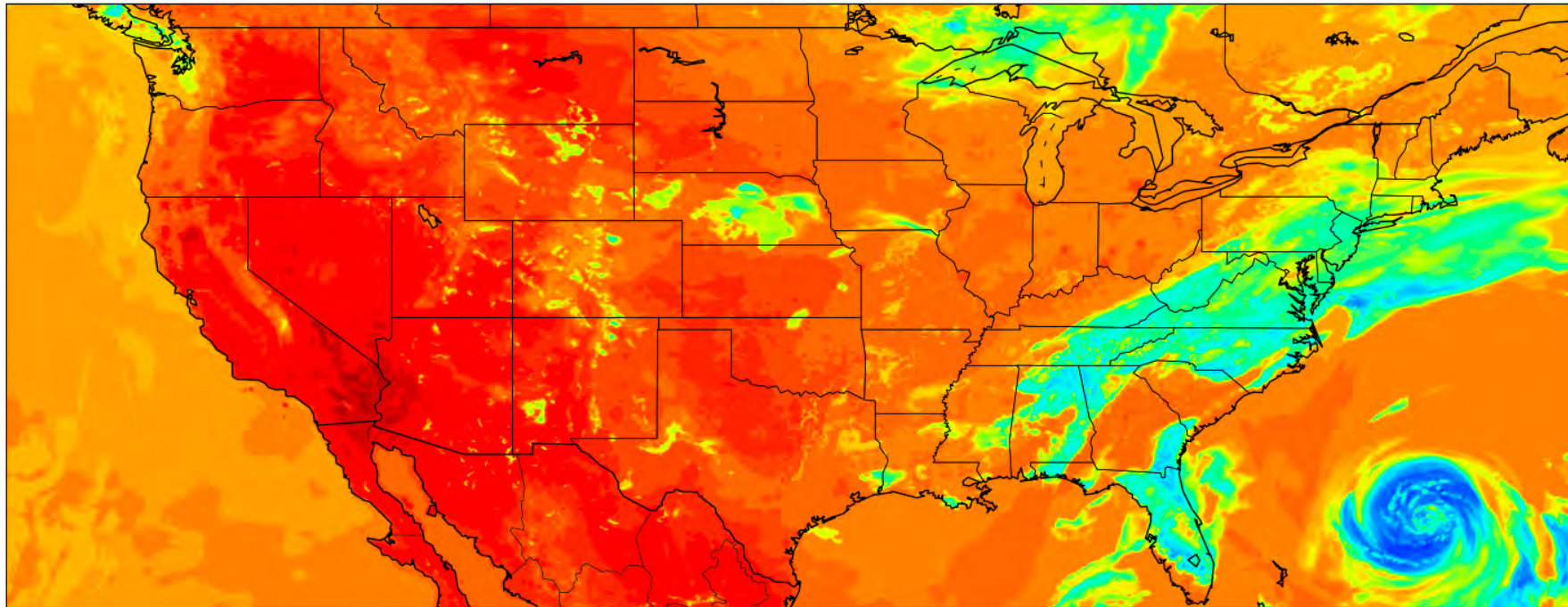
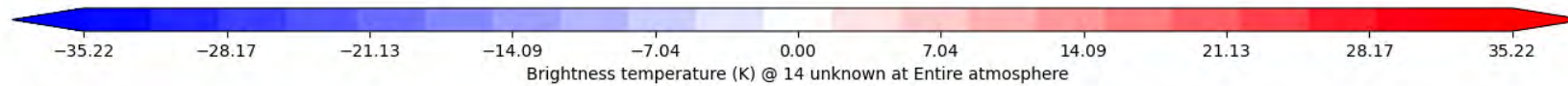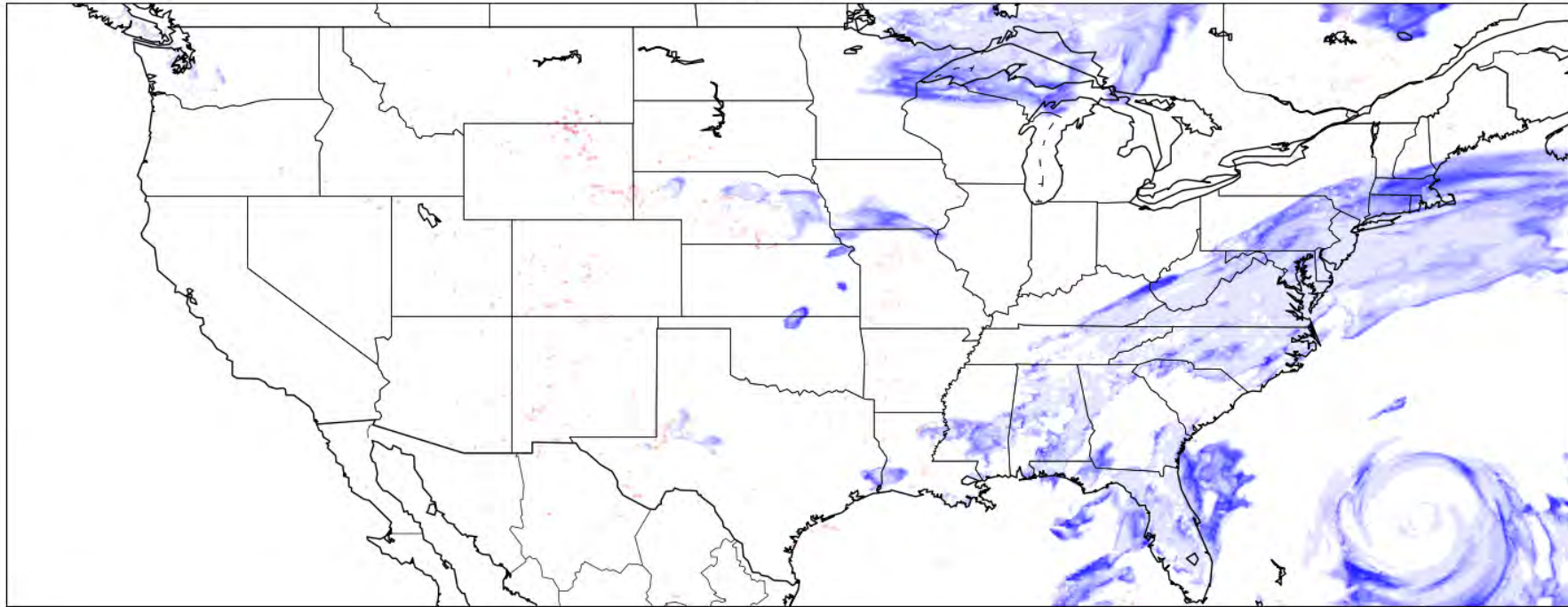Brightness temperature (K) @ 14 unknown at Entire atmosphere

Cycle: 2023-08-28 @ 18Z Fcst Hr: 120
Valid: 2023-09-02 @ 18Z

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UNCLASSIFIED

# MPAS/CRTM



Original - New

Brightness temperature (K) @ 14 unknown at Entire atmosphere

Cycle: 2023-08-28 @ 18Z Fcst Hr: 120
Valid: 2023-09-02 @ 18Z

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# Clouds—Verification Development

- Multiple truth sources
  - Gridded data and representative point data
- Stratification
  - Seasons
  - Cloud level
  - Region and Hemisphere
  - Land vs. Water
- Largely gridpoint-based verification, scorecard statistics
  - Potential for object-based verification

- Climatologies of forecasts and observations
- Thresholding
  - Percentiles
  - Key quantities

- Scorecards can illustrate multiple stratifications simultaneously



- However, a need will still exist for summarizing these disparate metrics to give a go/no-go on a new implementation

# Ideal end state for Clouds

- 3-D gridded physical cloud properties on 1000 ft layers
  - Hydrometeor (by phase) and aerosol mixing ratios
  - Hydrometeor size distributions
  - Short term more important than long term
  - Need to do convection well
- Post-processing to determine wavelength specific "cloud" for use cases
- Verification methods that identify specific characteristics of new NWP or observation systems
  - Specificity enables development and improvement
  - Target improvements toward stakeholder needs

# Future for Clouds

- Rapid refresh modeling
  - Grow OCONUS data assimilation capabilities
  - Merge ADVCLD, DCF, and AFWEPS into one streamlined capability
    - Possible intermediate step of using WWMCA as a cloud mask
    - End state—separate WWMCA and NWM capabilities (full DA)
- On-demand modeling in the cloud
  - Enable more sophisticated model setups as warranted
  - Higher enclave capabilities