EarthCARE Data Exploitation Experiments at NOAA

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NESDIS
National Environmental Satellite, Data, and Information Service

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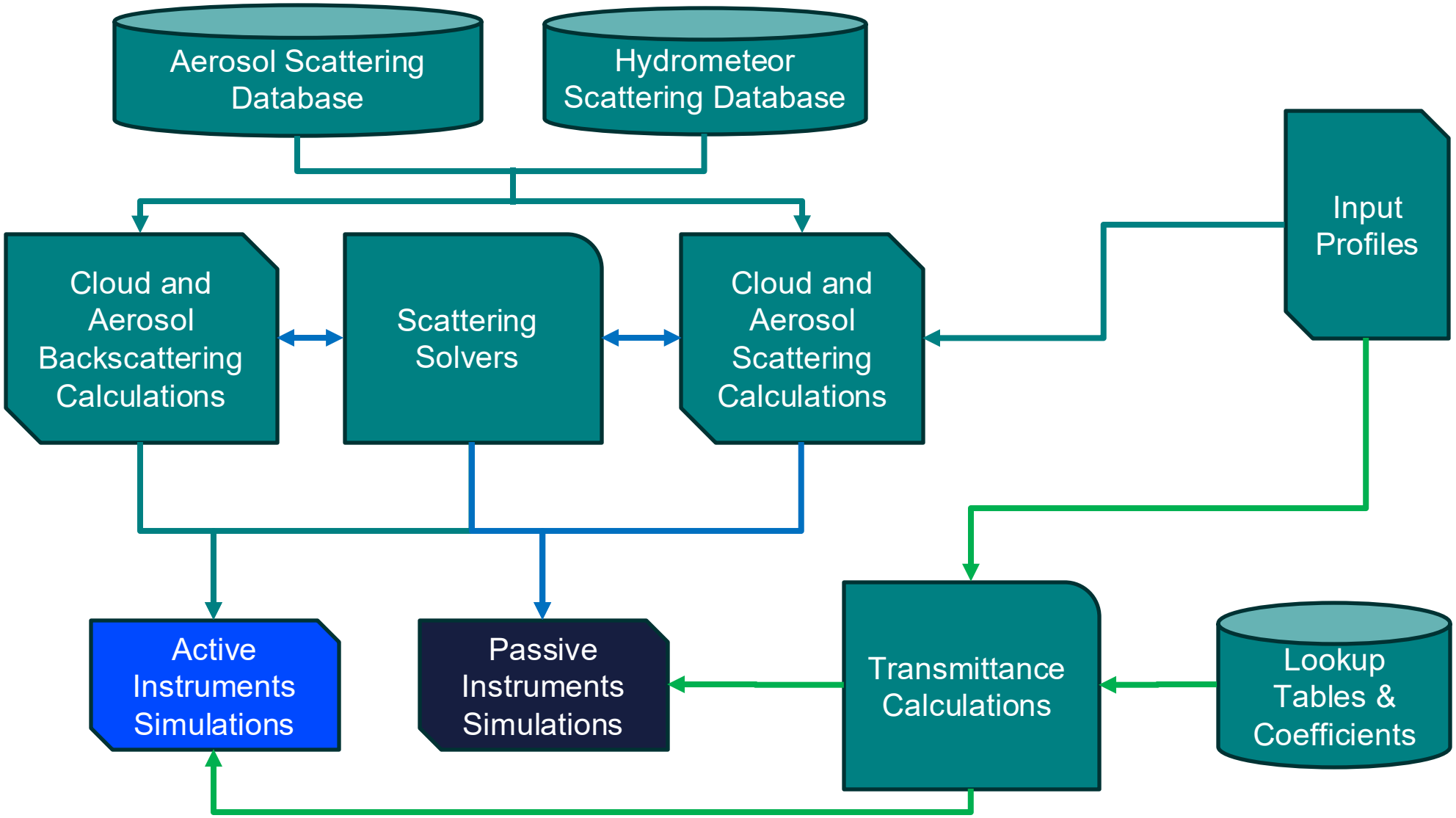
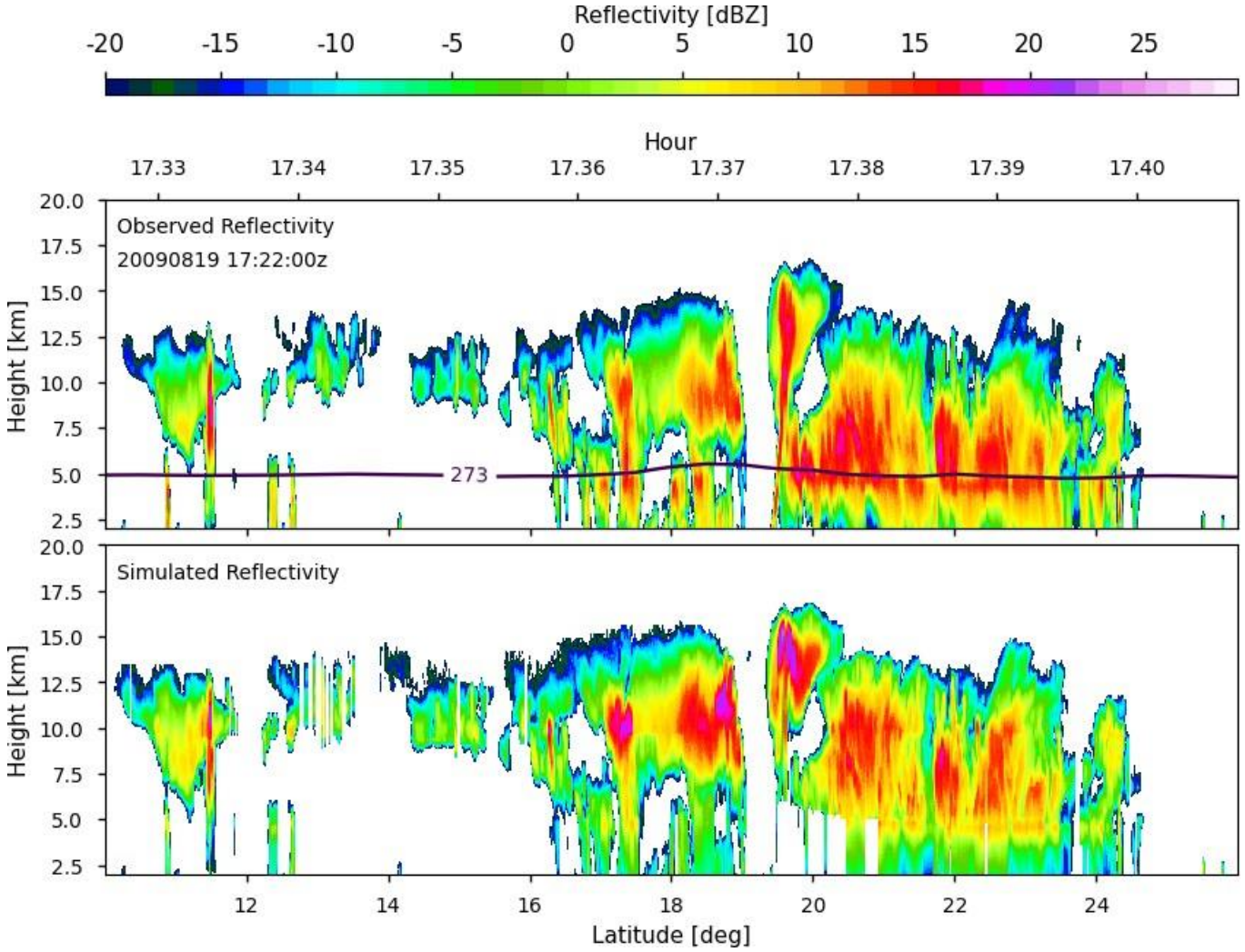
Outline

- EarthCARE CPR applications in NWP
  - Clouds structure in tropical cyclones is a critical indicator of storm intensity and rapid intensification
- EArthCARE ATLID applications in wildfire smoke model verification
  - The HRRR-Smoke (High-Resolution Rapid Refresh Smoke) model is a NOAA atmospheric forecast tool used by meteorologists, firefighters, and the public to predict the movement, height, and concentration of wildfire smoke across North America.
- EArthCARE ATLID applications in satellite cloud and wind product verification
  - LEO and GEO winds are among the top contributors for global NWP models.

CRTM Framework

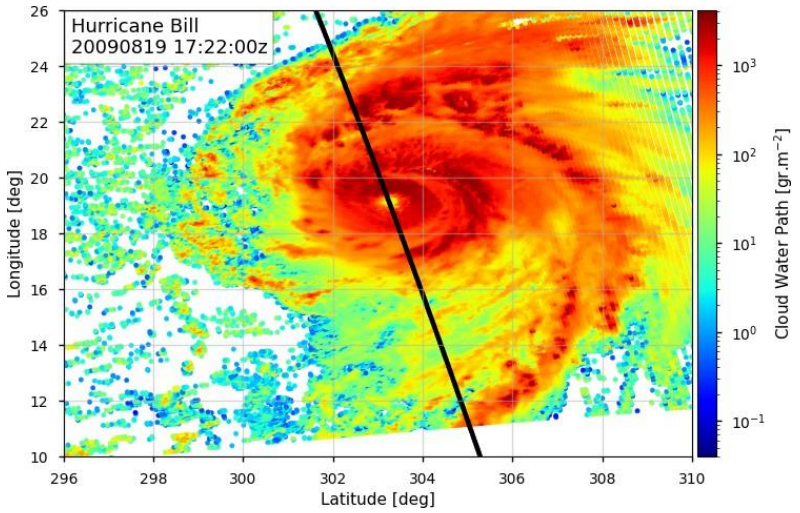


Cloudsat Cloud Profiling Radar (CPR – W-band 94 GHz)



Observed and simulated reflectivities for Hurricane Bill.

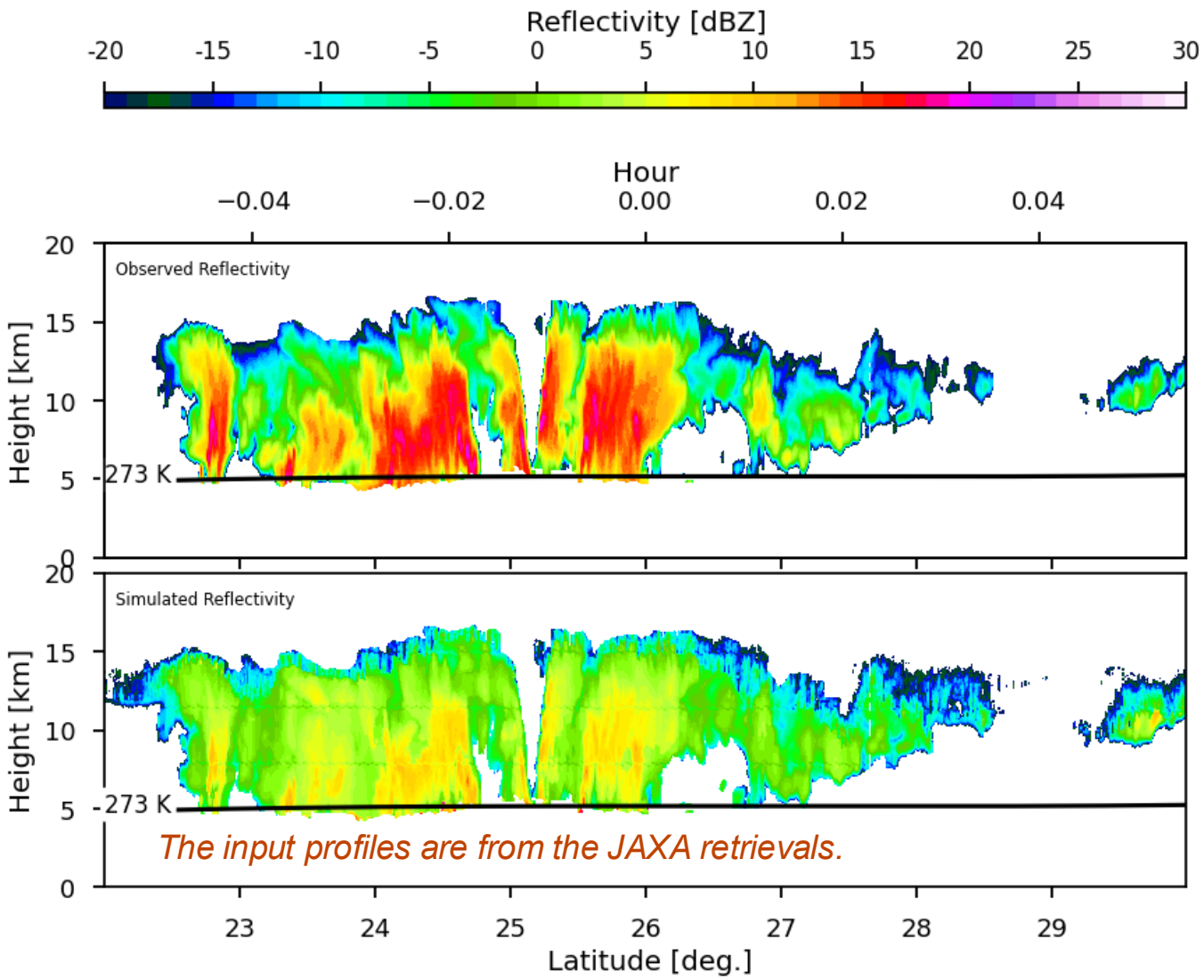
August 19, 2009



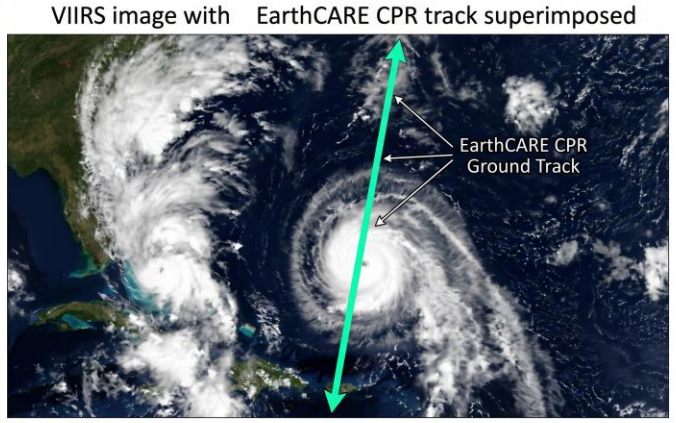
Moradi et al. https://doi.org/10.5194/amt-19-549-2026, 2026

Cloud Profiling Radar (CPR – W-band 94 GHz)

Observed and simulated reflectivities for Hurricane Humberto.

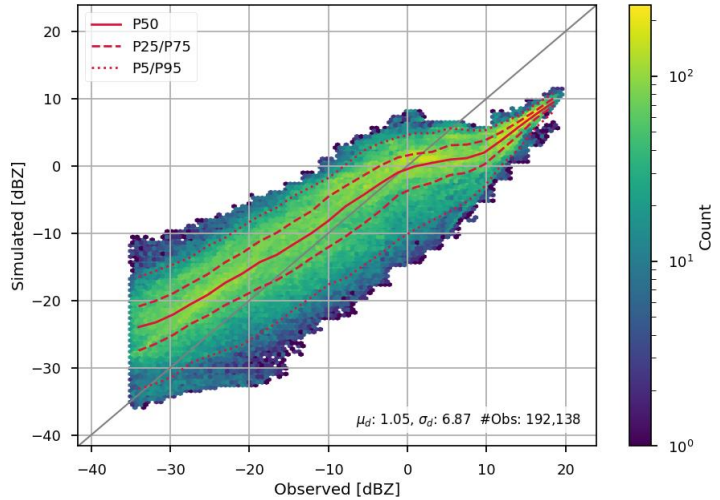


The input profiles are from the JAXA retrievals.



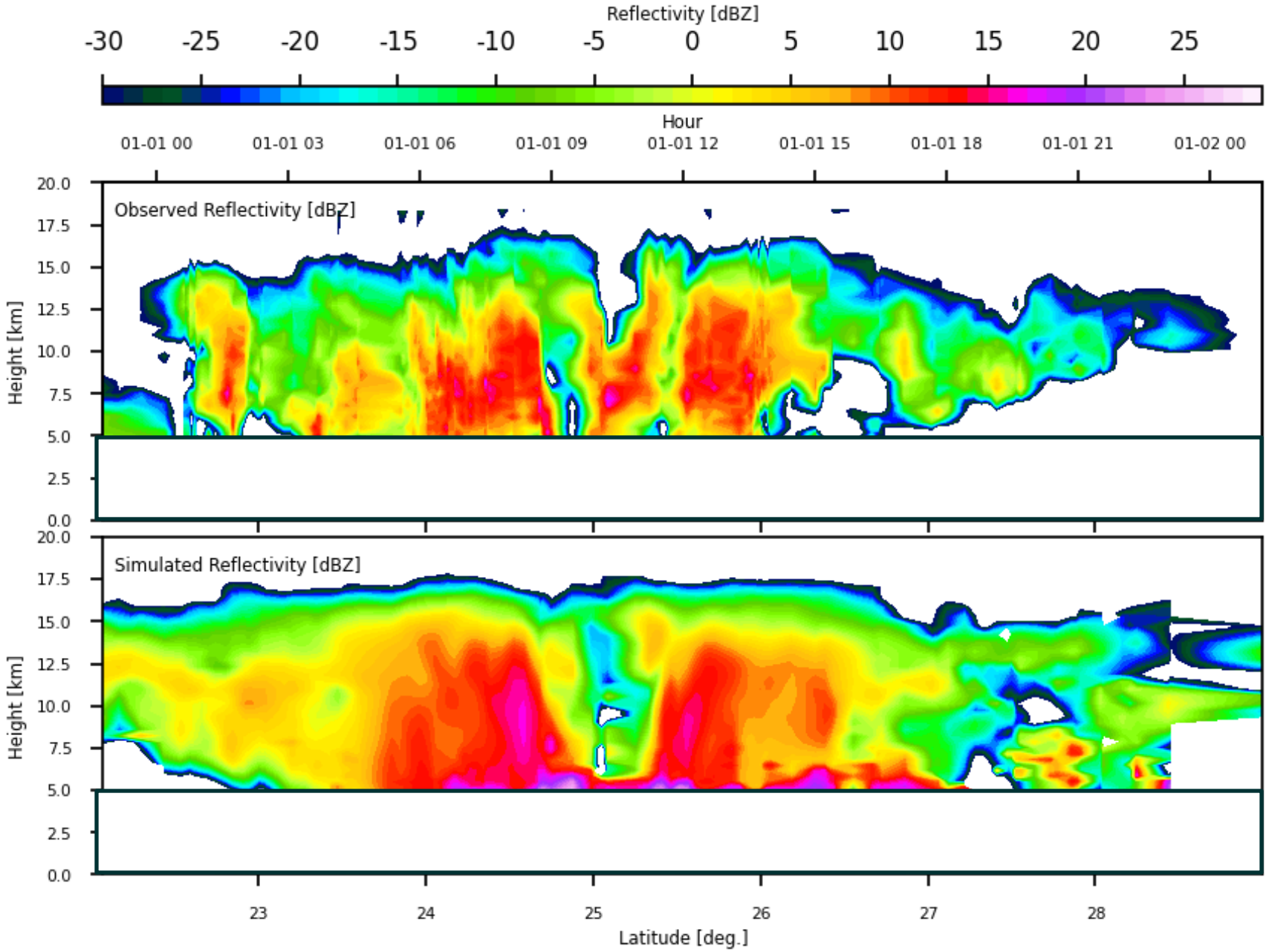
VIIRS image with EarthCARE CPR track superimposed

Sept 28, 2025

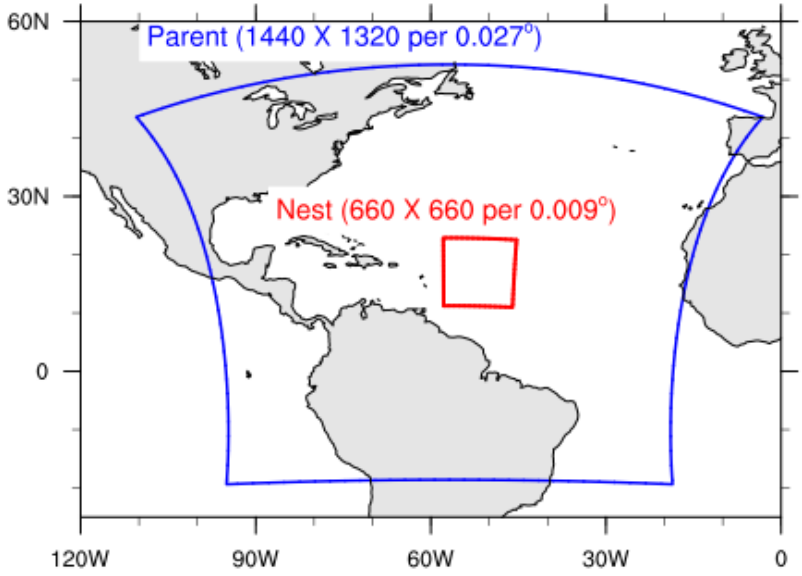


The forward-model simulations using JAXA retrievals as input are approximately 5 dBZ lower than the observations at higher reflectivity values, likely due to biases in the input cloud and hydrometeor profiles.

CPR Simulations Using NWS HAFS – Hurricane Humberto



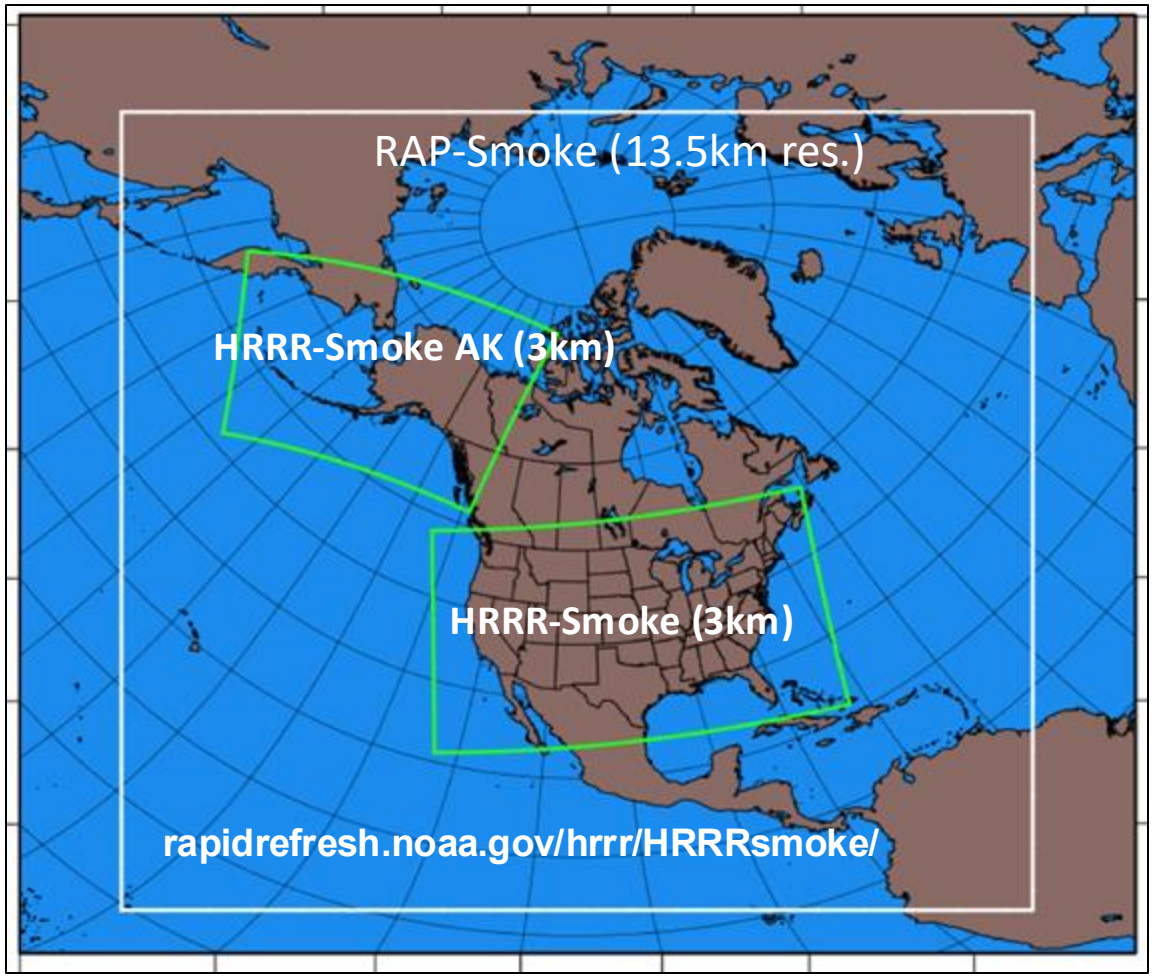
Hurricane Forecast Analysis System (HAFS)



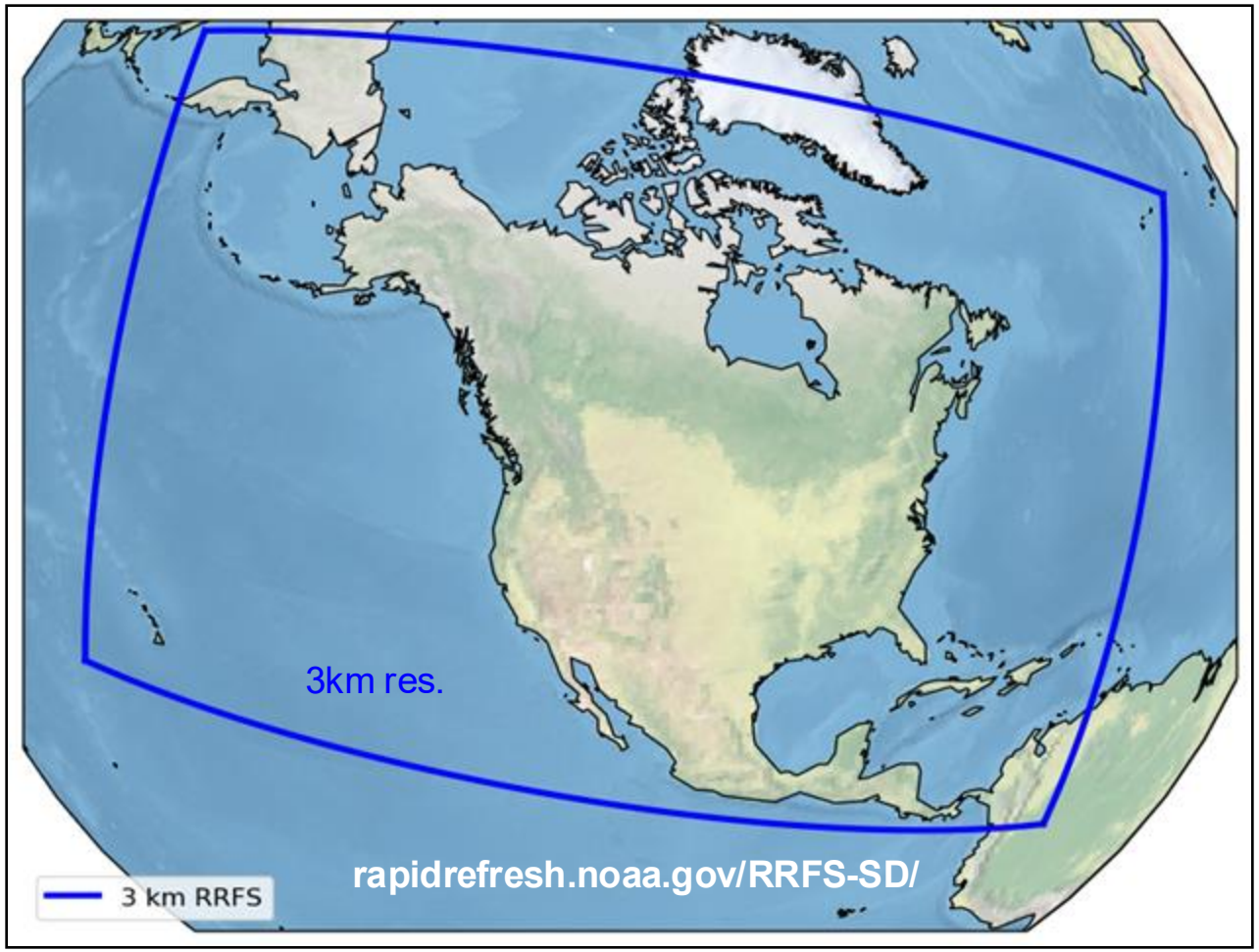
- High-resolution moving nest
- High-resolution physics
- Multi-scale data assimilation (DA)
- 3D ocean coupling,
- Observations to support the DA.

NOAA's operational RAP/HRRR-Smoke models and new RRFS-Smoke-Dust model

NOAA's operational coupled weather-smoke model: Rapid-Refresh/ High-Resolution Rapid Refresh with Smoke



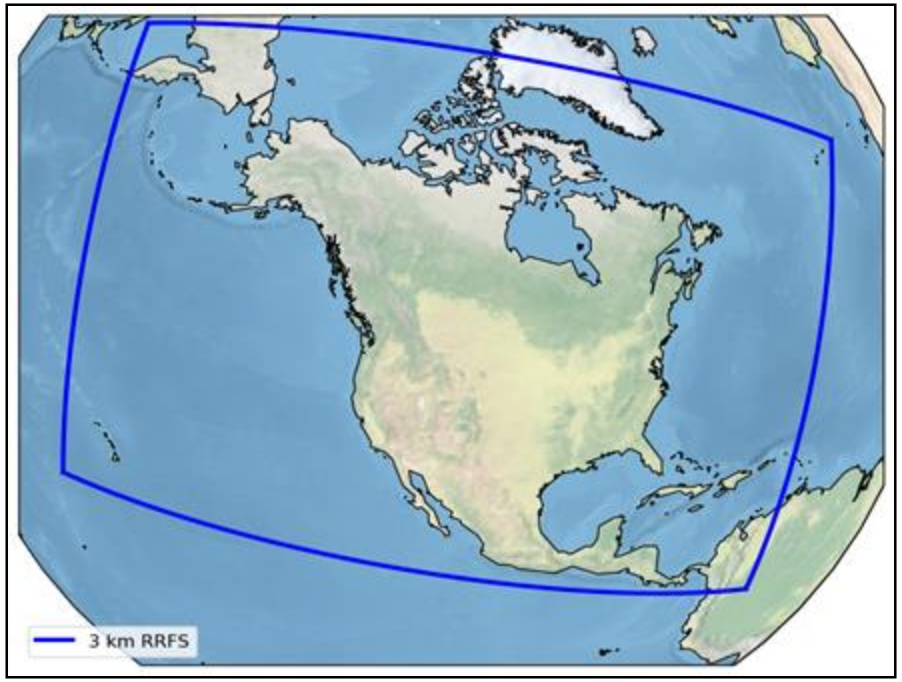
NOAA's new coupled weather, smoke and dust model: Rapid Refresh Forecasting System with Smoke/Dust



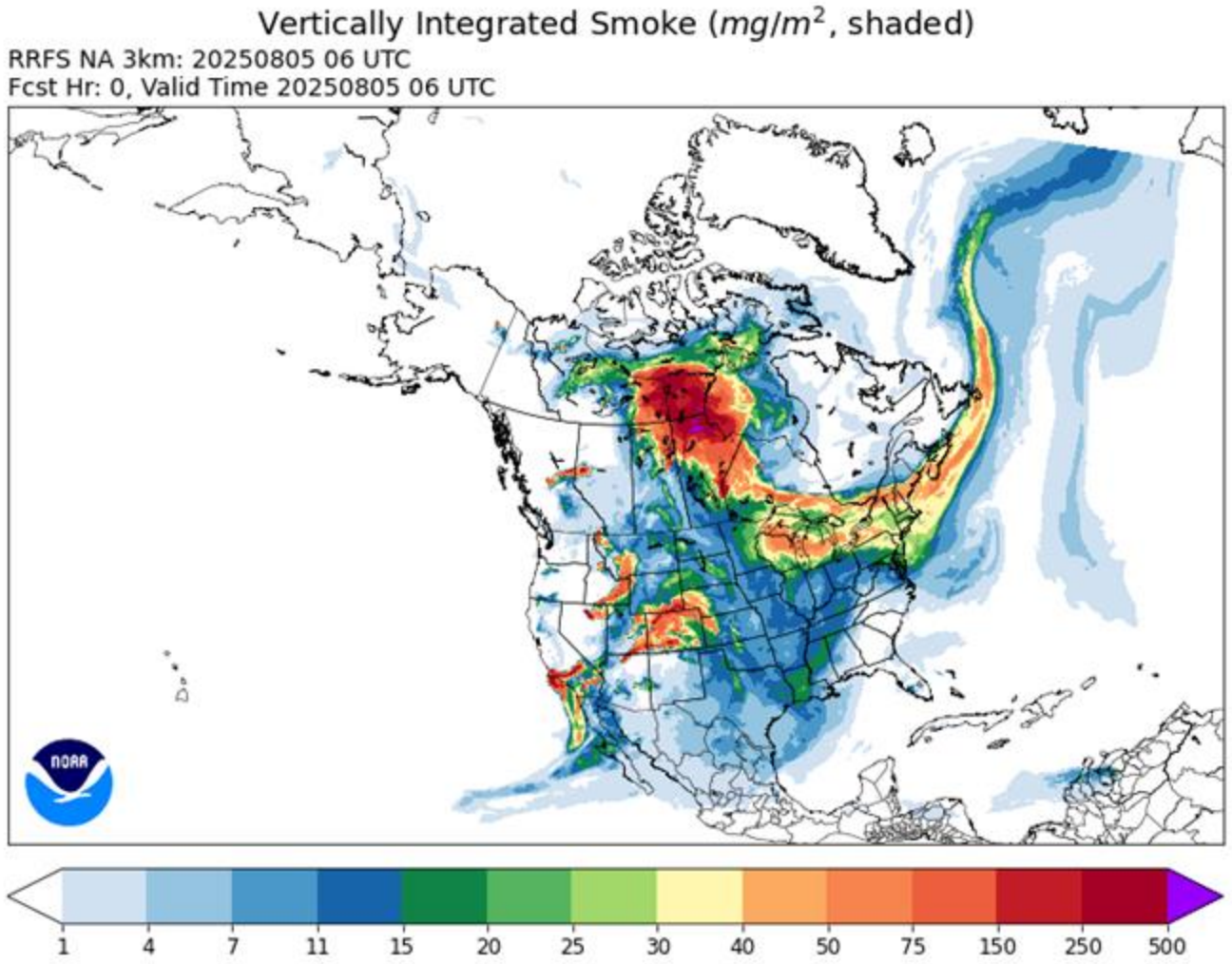
Transitioning of the RAP/HRRR-Smoke models to RRFS-Smoke-Dust (RRFS-SD)

- The model grid: **3km** horizontal resolution, **65** vertical layers
- **Smoke** (primary PM2.5 from wildland fire emissions) and **fine and coarse dust** aerosols are included
- The smoke emissions are based on the real-time **RAVE data**
- A new forecast is generated every hour. It goes out to **84 hours 4 times a day,** 18 hours for other cycles
- Impact of smoke and dust aerosols on radiation and visibility are included
- **A new fire weather index – Hourly Wildfire Potential is provided by the model. HWP is also used to predict wildfire emissions in the model.**
- The RRFS-SD model is scheduled to become operational in 2026
- The fire weather, smoke and dust fields are displayed on a public web-site (https://rapidrefresh.noaa.gov/RRFS-SD/) and DESI (https://sites.gsl.noaa.gov/desi/)

3 km resolution FV3 limited area model domain



Capabilities of the RRFS-SD model



The model grid: **3km** horizontal resolution,

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Smoke (primary PM2.5 from wildland fire emissions) and **fine and coarse dust** aerosols are included.

The smoke emissions are based on the real-time **RAVE data.**

A new forecast is generated every hour. It goes out to **84 hours 4 times a day,** 18 hours for other cycles.

Impact of smoke and dust aerosols on radiation and visibility are included.

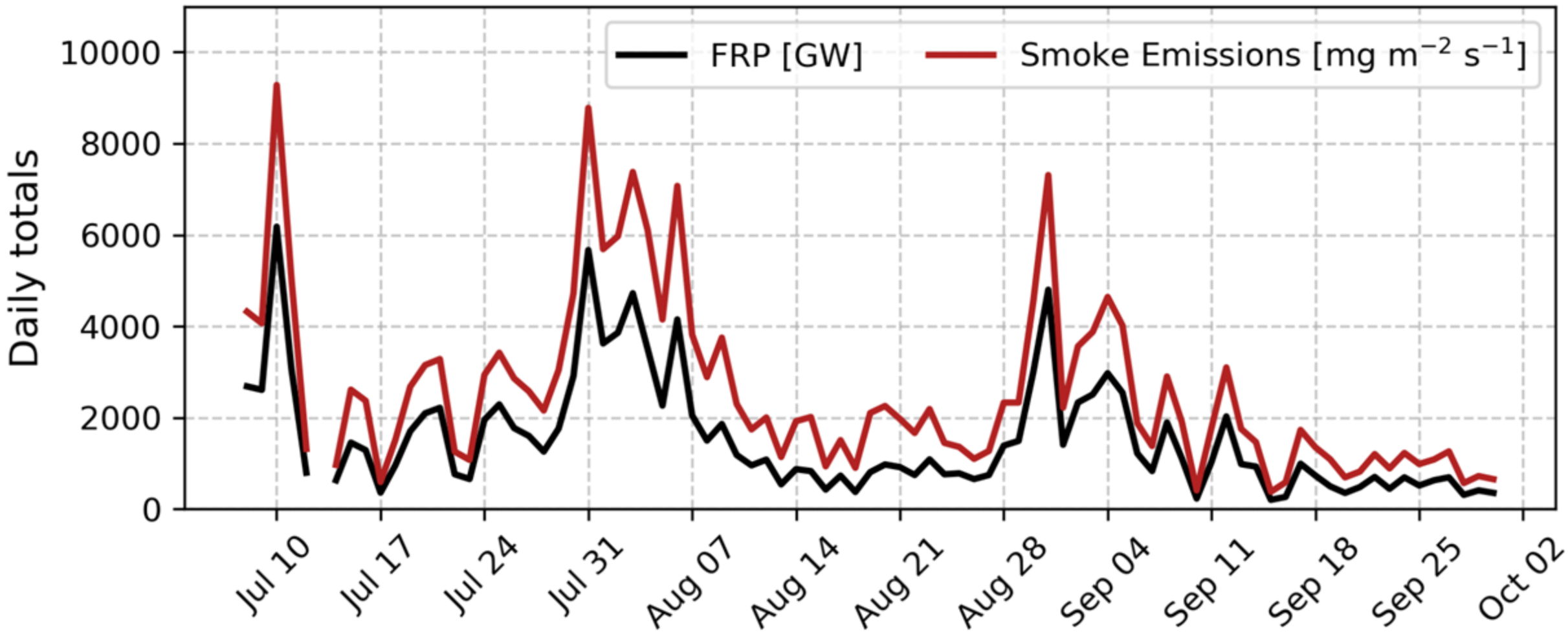
A new fire weather index – Hourly Wildfire Potential is provided by the model. HWP is also used to predict wildfire emissions in the model.

The RRFS-SD model has been extensively tested in real time and for case studies.

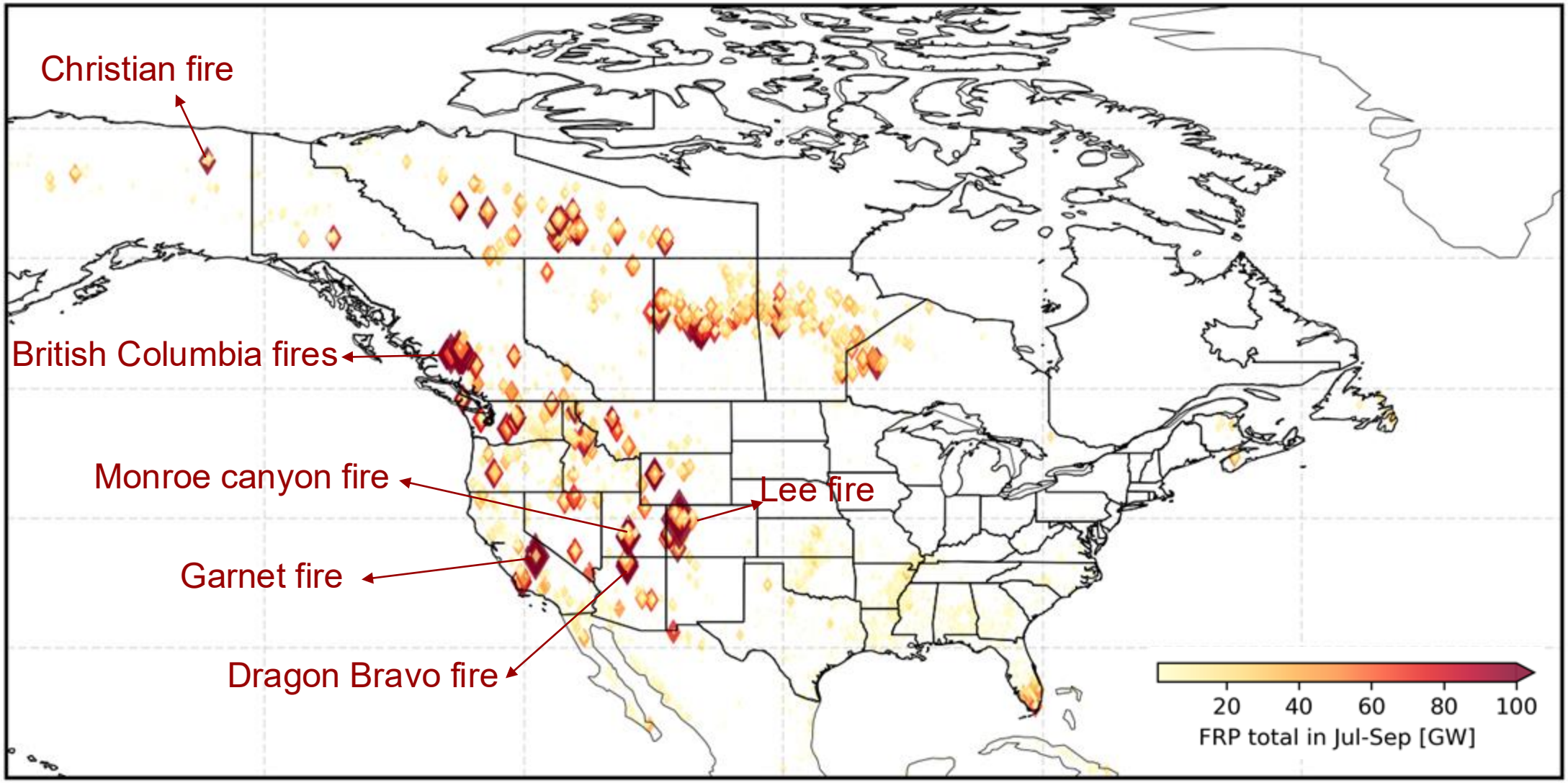
The fire weather, smoke and dust fields are displayed on a public web-site and DESI:

https://rapidrefresh.noaa.gov/RRFS-SD/

2025 Jul-Sep Fire Radiative Power (FRP) as provided by RAVE and Emissions estimated by RRFS-SD



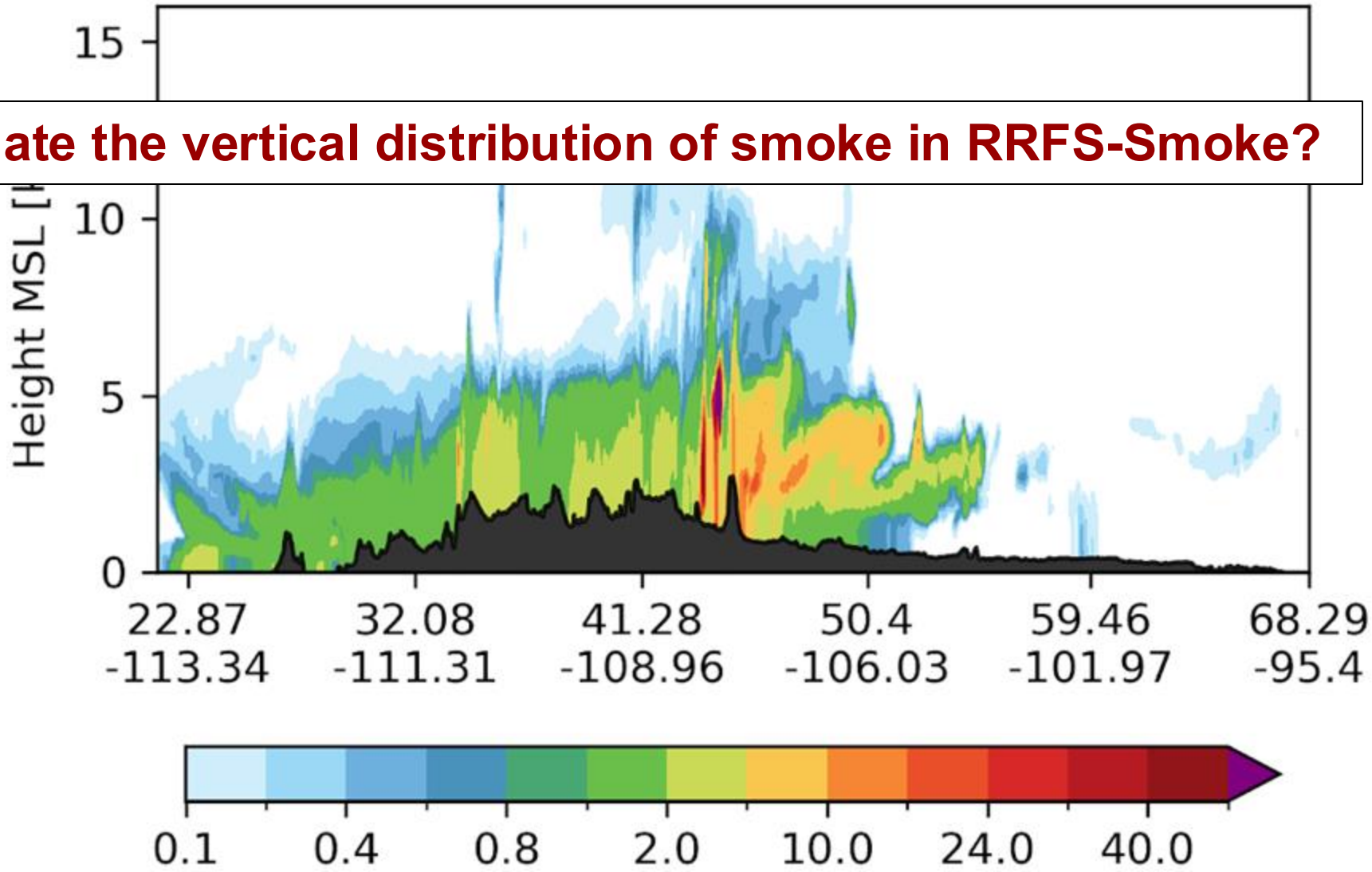
2025 Jul-Sep Fires in the US and Canada



Vertical distribution of smoke in RRFS-Smoke

How can we evaluate the vertical distribution of smoke in RRFS-Smoke?

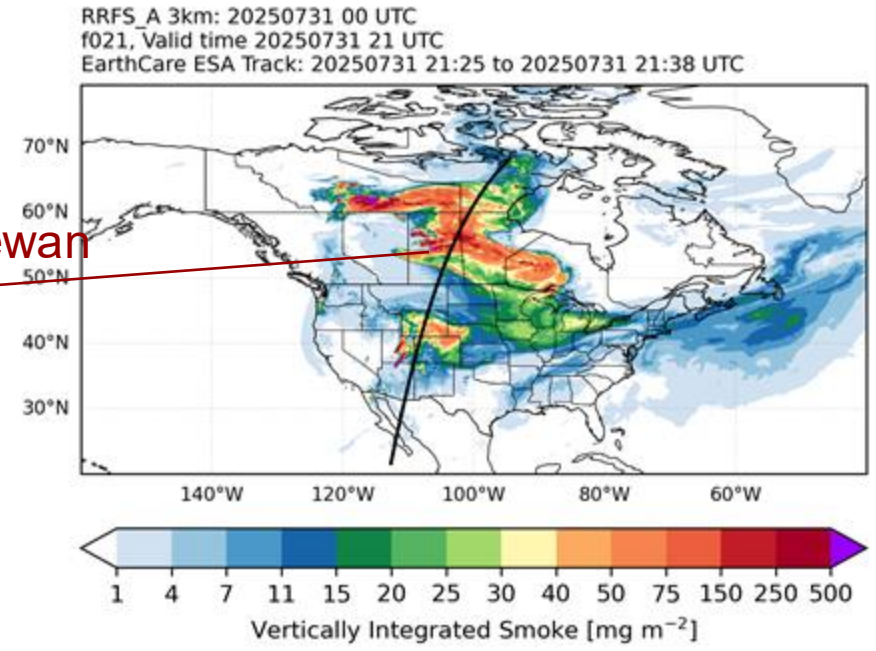
The model does NOT ingest smoke boundary conditions from a global model.

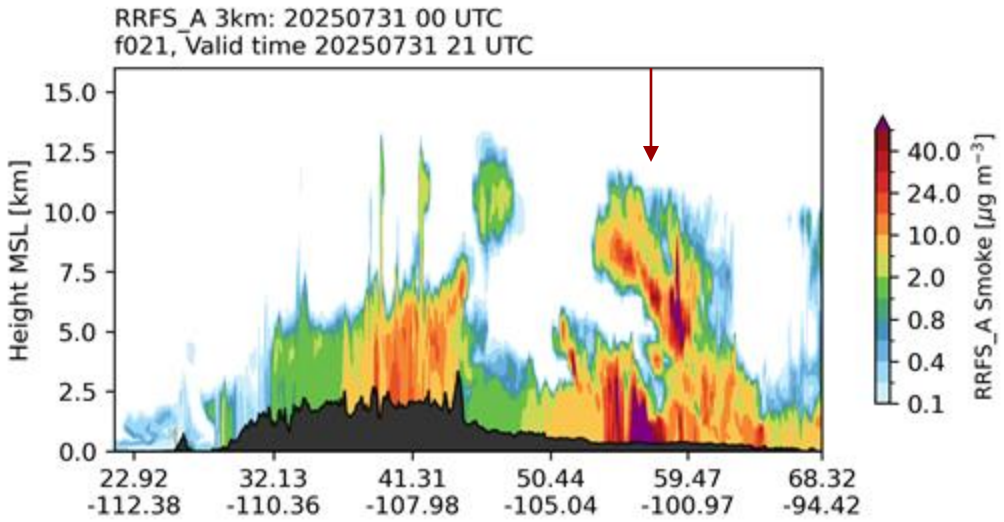


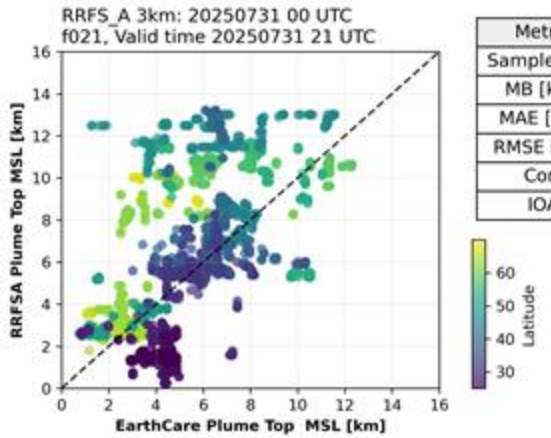
Model vs EarthCare Plumetop height comparison

Saskatchewan fires, Canada

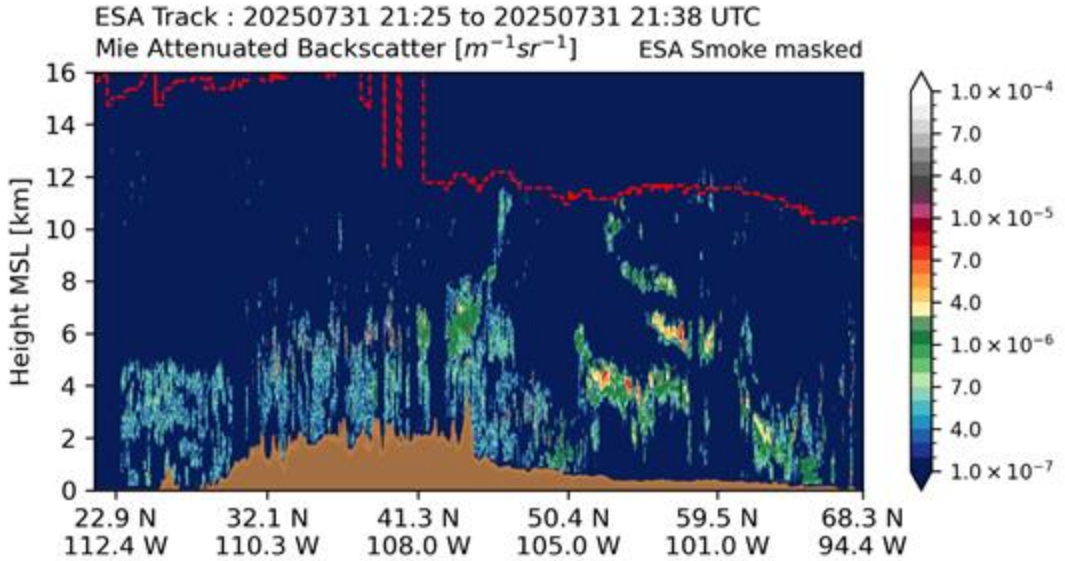
Saskatchewan fires





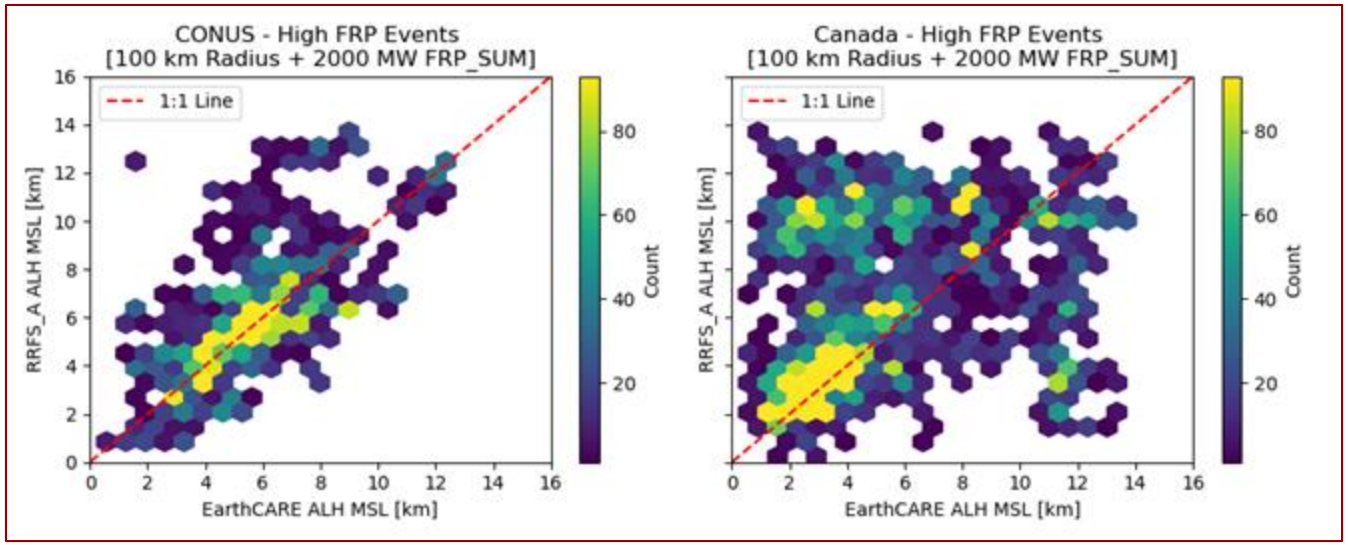


Metric	Value
Sample Size	3895
MB [km]	0.90
MAE [km]	2.25
RMSE [km]	3.03
Corr	0.58
IOA	0.70

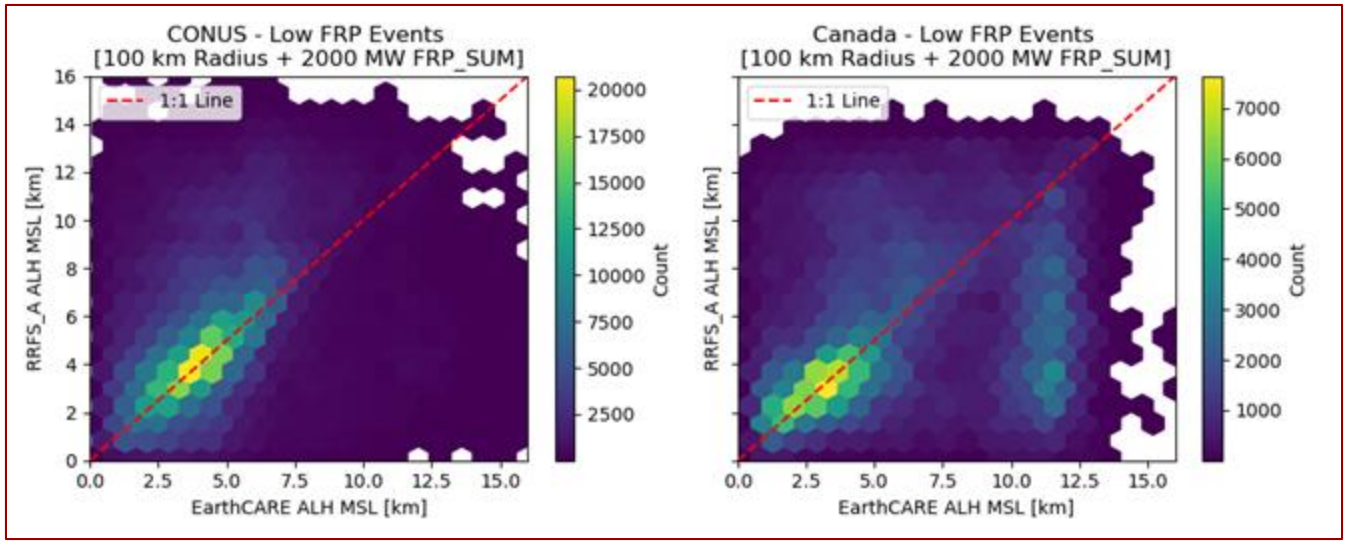


Model vs EarthCare Plumetop height densities

Active fires [Sum of FRP is > 2000 MW] within 100 km radius, smoke layer heights influenced by the model plumerise parameterization



Sum of FRP is < 2000 MW within 100 km radius, smoke advected by the model dynamics



Model vs EarthCare Plumetop height Stats

--- Overall Stats 100km Radius + 2000MW Threshold ---

region	category	Bias	MAE	RMSE	Corr	IOA	Count
CONUS	High FRP	0.314989	1.301738	1.873594	0.695077	0.819436	4383.0
	Low FRP	0.918478	2.143796	3.054900	0.418972	0.622277	679342.0
Canada	High FRP	1.307022	2.926775	4.047009	0.317656	0.591760	9333.0
	Low FRP	-0.689244	3.090859	4.155258	0.278838	0.590545	370479.0

--- Overall Stats 75km Radius + 2000MW Threshold ---

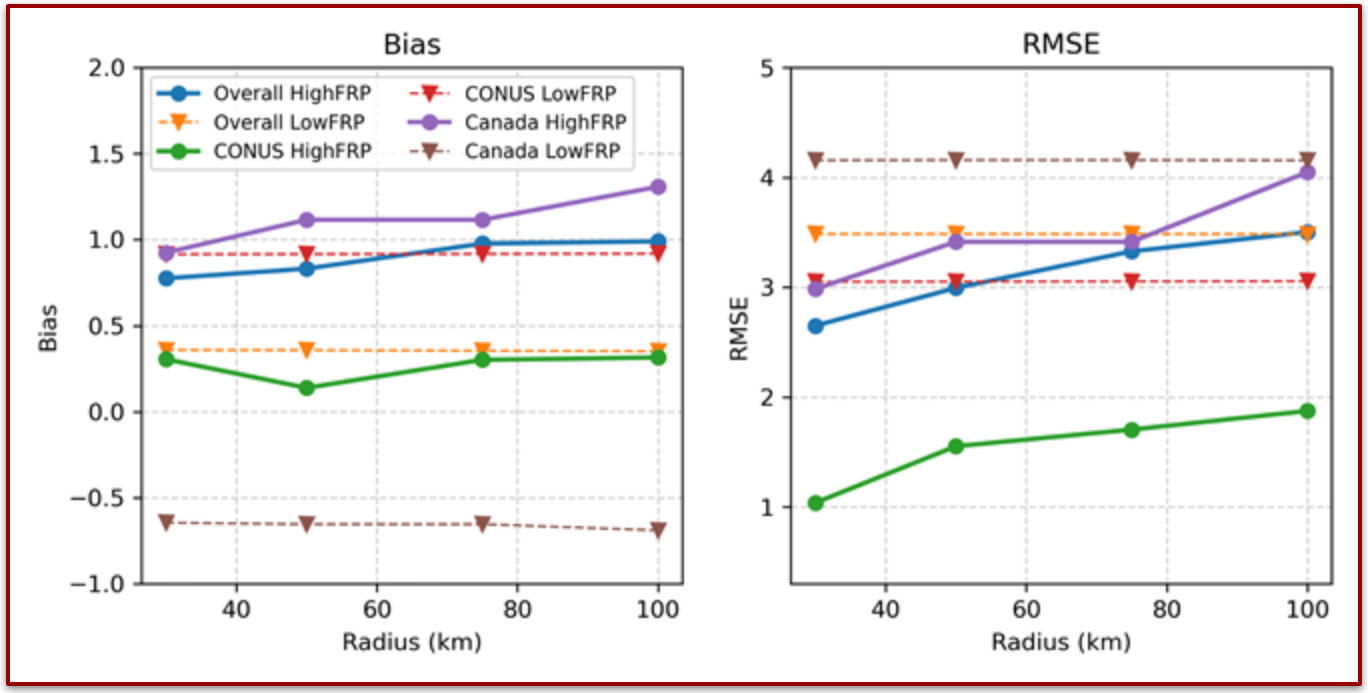
region	category	Bias	MAE	RMSE	Corr	IOA	Count
CONUS	High FRP	0.301487	1.169357	1.703798	0.714800	0.832960	2663.0
	Low FRP	0.917007	2.142187	3.052882	0.419618	0.622814	681062.0
Canada	High FRP	1.287282	2.808932	3.849415	0.359937	0.609462	5795.0
	Low FRP	-0.670055	3.091133	4.157155	0.277524	0.589995	374017.0

--- Overall Stats 50km Radius + 2000MW Threshold ---

region	category	Bias	MAE	RMSE	Corr	IOA	Count
CONUS	High FRP	0.138554	1.029521	1.552422	0.520098	0.719245	1180.0
	Low FRP	0.915951	2.140315	3.050737	0.420473	0.623477	682545.0
Canada	High FRP	1.115200	2.469311	3.413168	0.429371	0.643300	2876.0
	Low FRP	-0.653584	3.091539	4.157768	0.276682	0.589645	376936.0

--- Overall Stats 30km Radius + 2000MW Threshold ---

region	category	Bias	MAE	RMSE	Corr	IOA	Count
CONUS	High FRP	0.304727	0.776616	1.037683	0.502620	0.718472	365.0
	Low FRP	0.914935	2.139126	3.049505	0.420552	0.623599	683360.0
Canada	High FRP	0.924410	2.161604	2.984912	0.525496	0.704747	1151.0
	Low FRP	-0.644946	3.089640	4.155681	0.276662	0.589629	378661.0

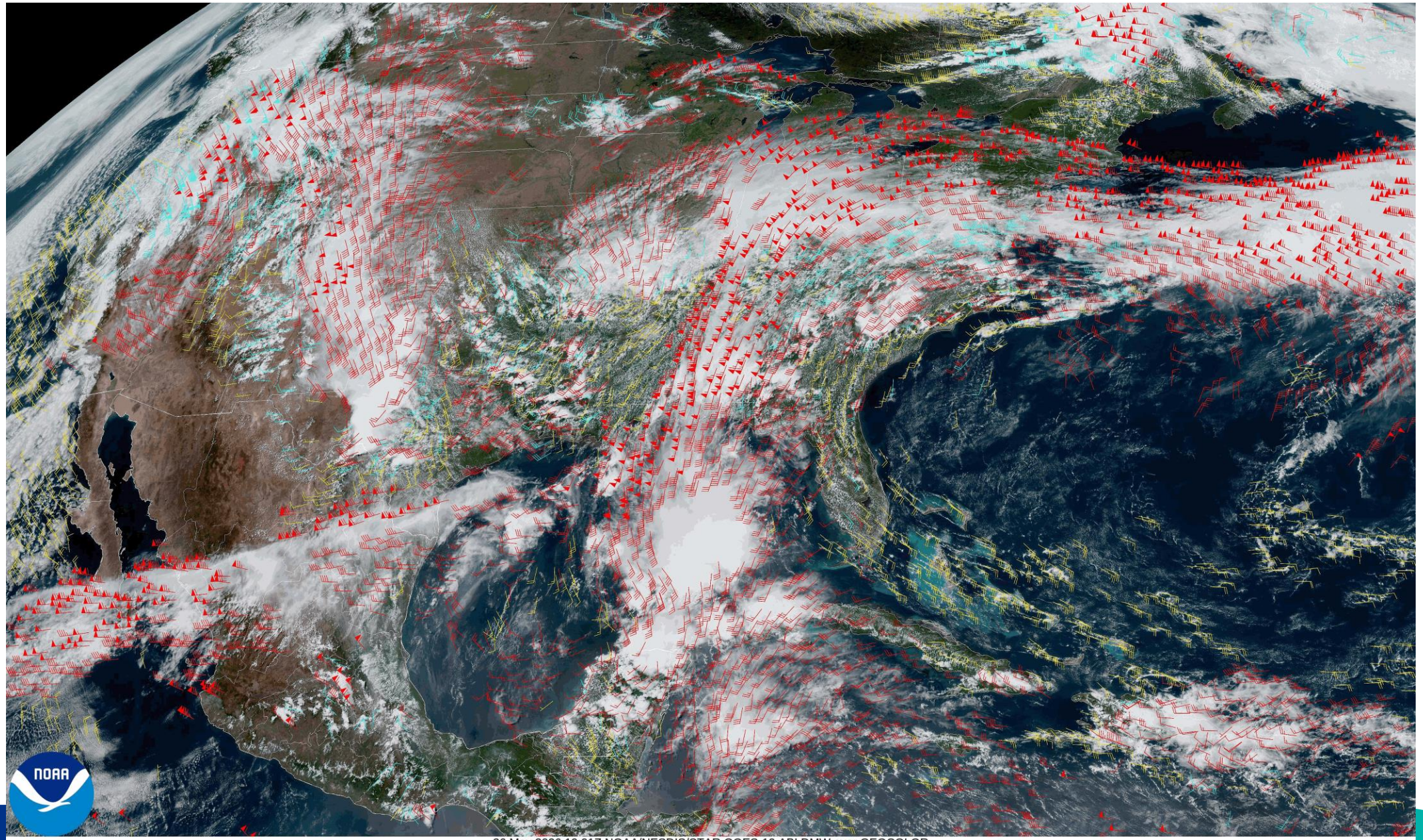


HighFRP and LowFRP = sum of FRP within the radius of influence is >2000MW and <2000MW

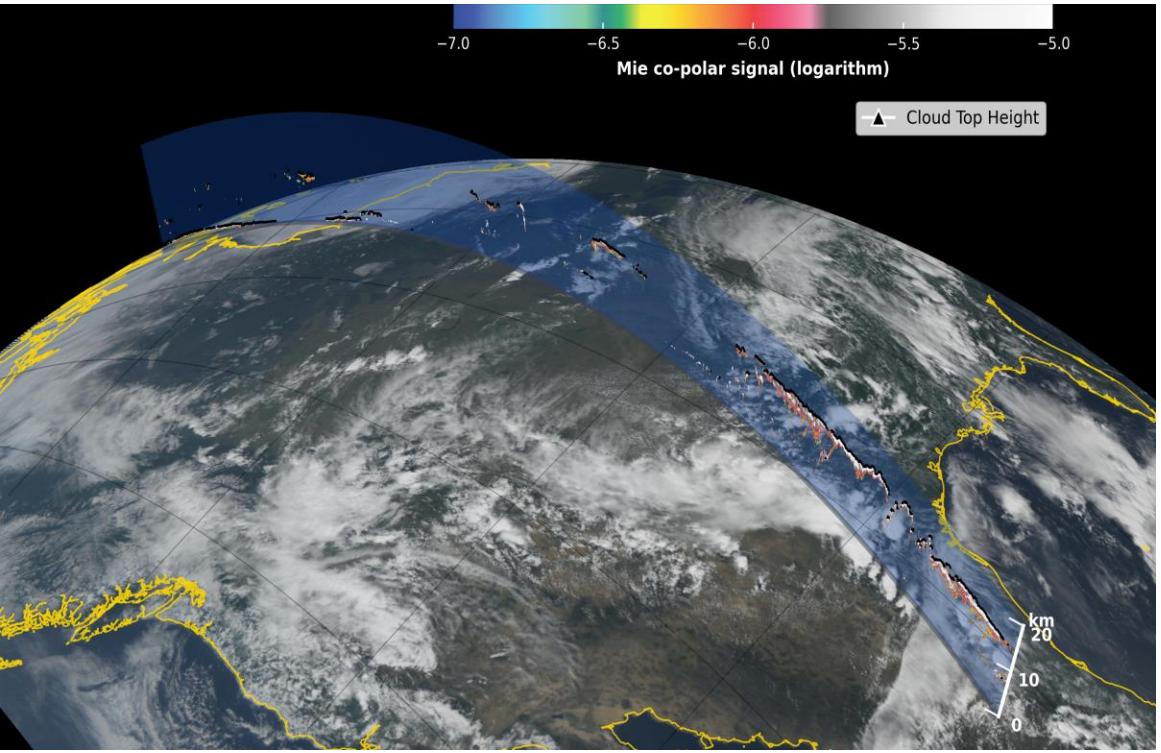
Summary:

- RRFS_A performs **better** over **CONUS** compared to high-latitudes
- Reducing radius of influence from 100 km to 30 km shows consistent improvement in model performance, suggesting that plumerise is **capturing** the injection heights and the **near-source** smoke transport is **well represented**
- RRFS_A **underpredicts** plumetop heights in **high-latitudes** and slightly overpredicts over CONUS

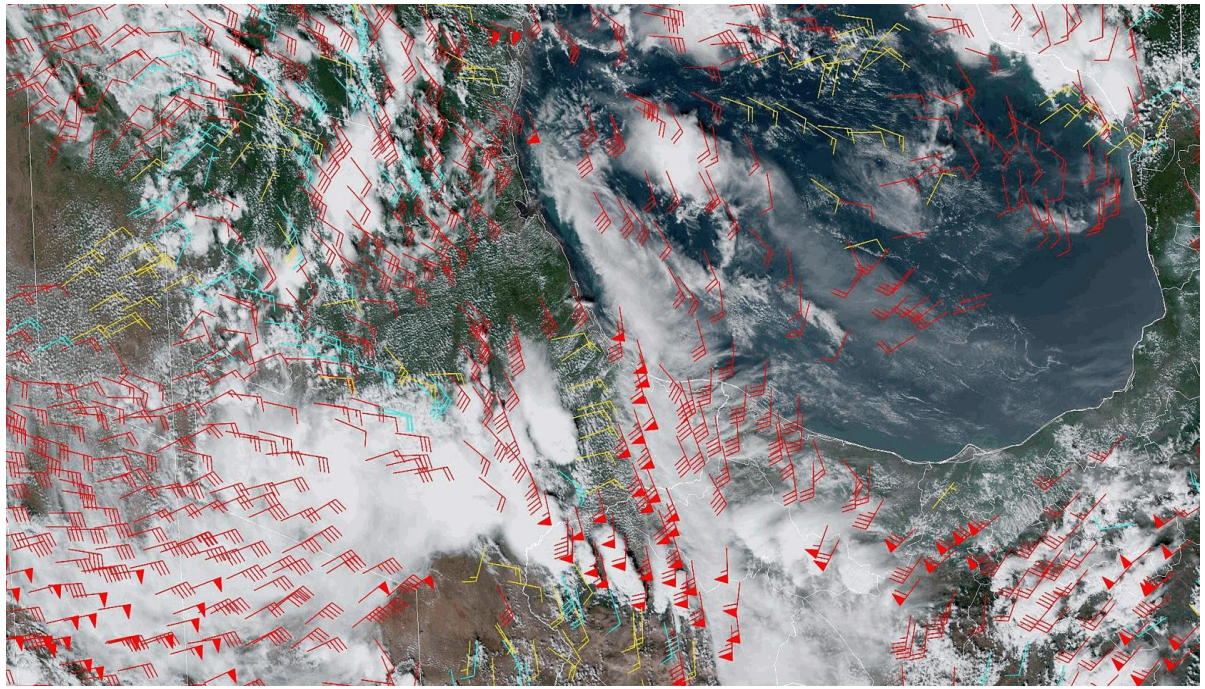
GOES-19 ABI LWIR CONUS Winds (May 26, 2026/21Z)



ABI Wind Height Verification With ATLID



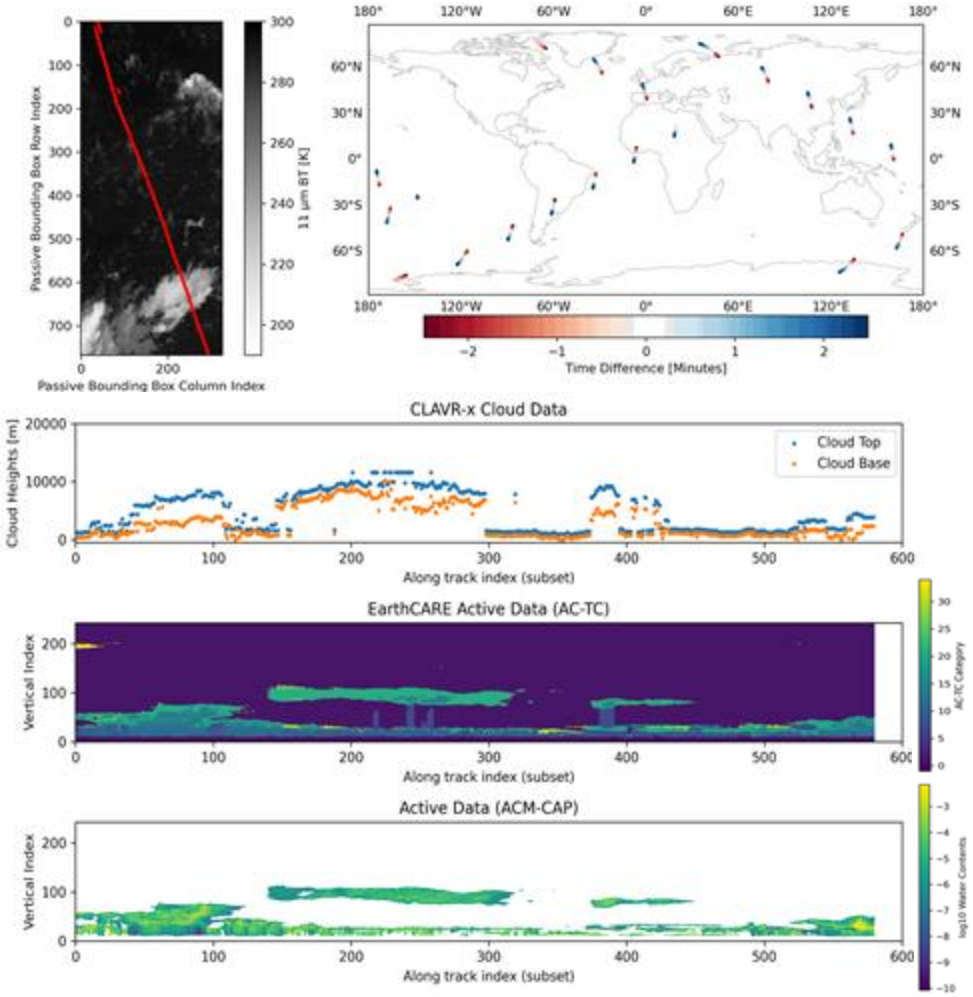
GOES-19 ABI with ATLID curtain
(May 26, 2026)



GOES-19 ABI CONUS winds
(May 26, 2026, 21Z)

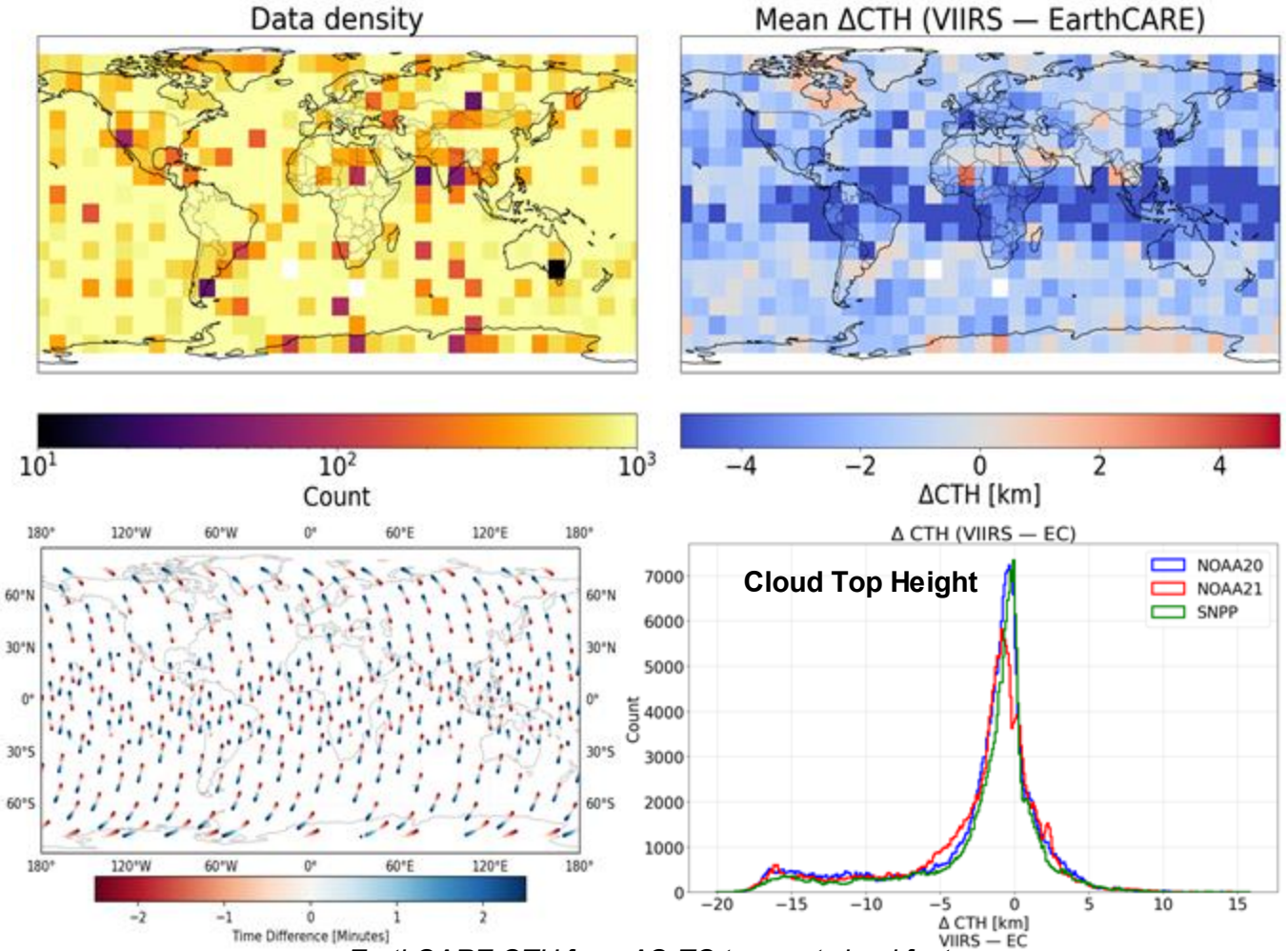
EarthCARE – LEO/ GEO Collocation Data: Cloud Evaluation

Sample Cloud Top/Base Height Comparison using JPSS VIIRS - EarthCARE collocations



Global VIIRS Comparisons for March 1-30, 2026

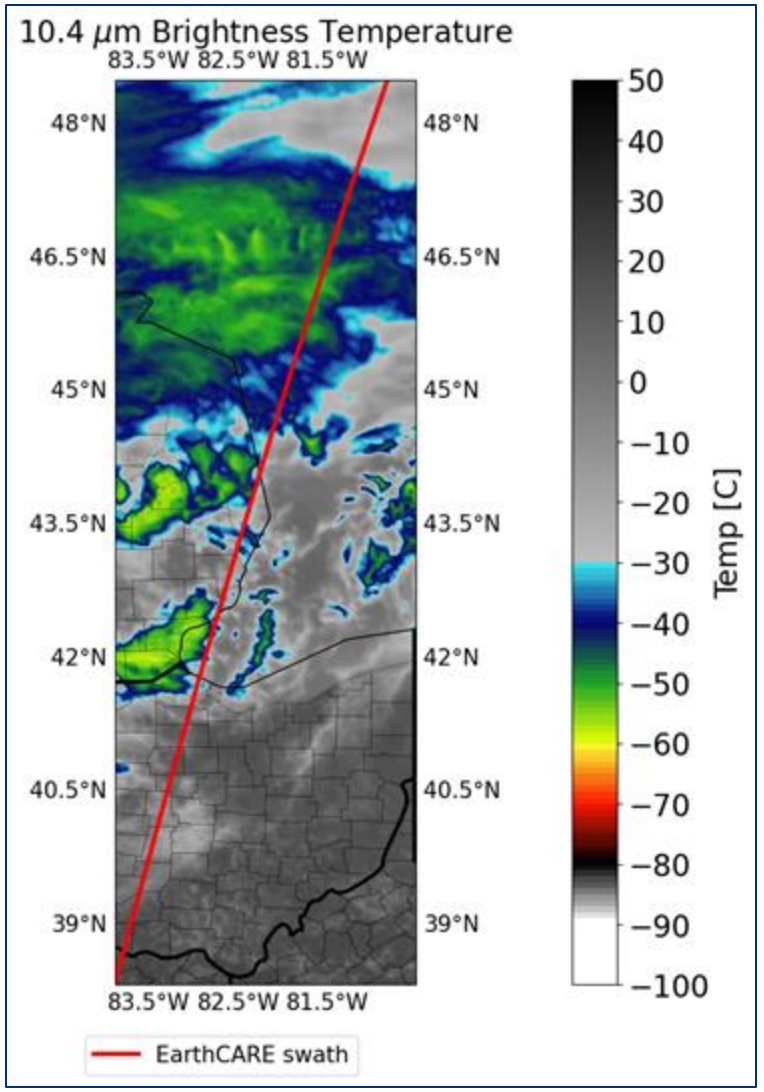
(averaged over 10° x 10° Lat/Lon)



EarthCARE CTH from AC-TC topmost cloud features
VIIRS CTH from CLAVR-x with NOAA Enterprise algorithms

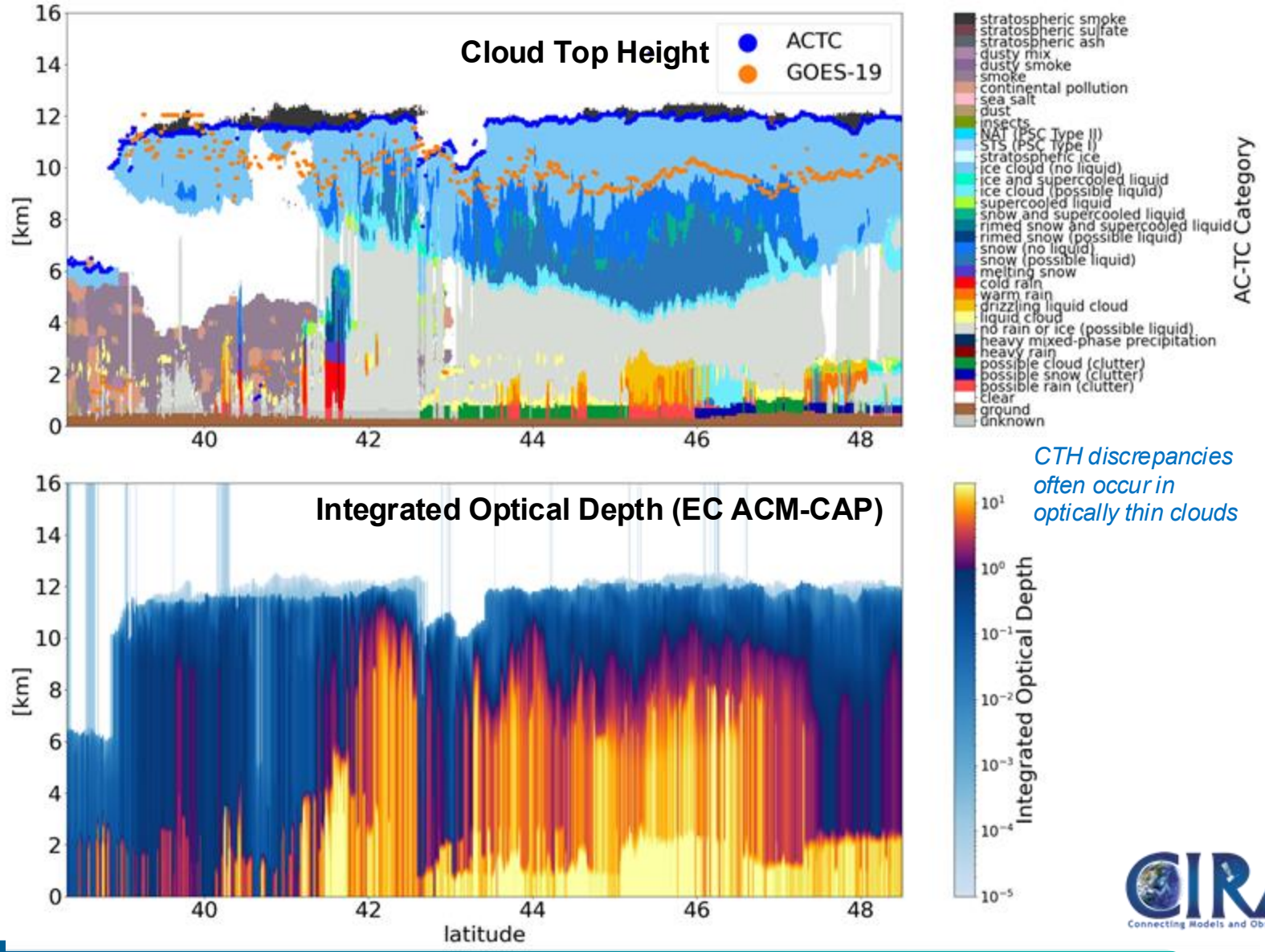
EarthCARE – LEO/ GEO Collocation Data: Cloud Evaluation

GOES-19 ABI - EC collocation



Ohio to Ontario

2026-03-06T19:50:20_10065D



CTH discrepancies often occur in optically thin clouds

Summary

- NOAA NESDIS has developed a robust framework to exploit EarthCARE CPR and ATLID observations to verify LEO and GEO retrievals and model outputs of clouds and aerosols that are critical for several applications such as tropical cyclones, wildfires and NWP.
- The EarthCARE data are easy to access, well documented and are of high quality.
- EarthCARE observations are making a valuable contribution for advancing the verification of NESDIS cloud and atmosphere products.

Thank you!