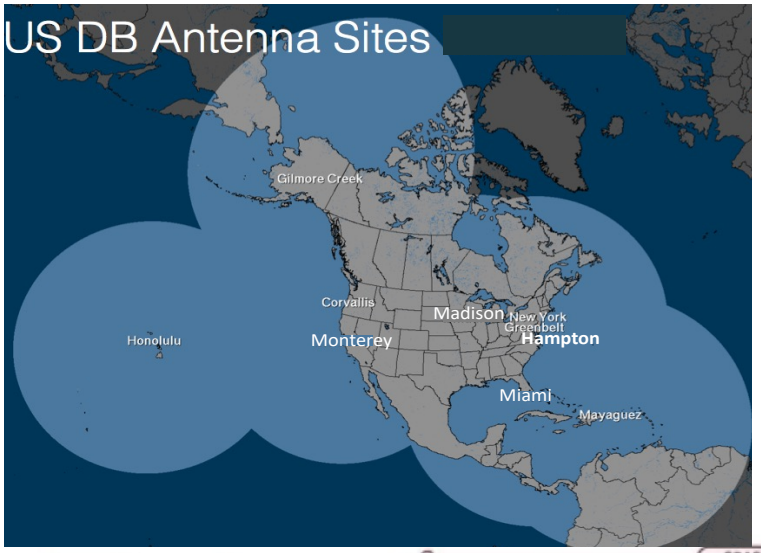
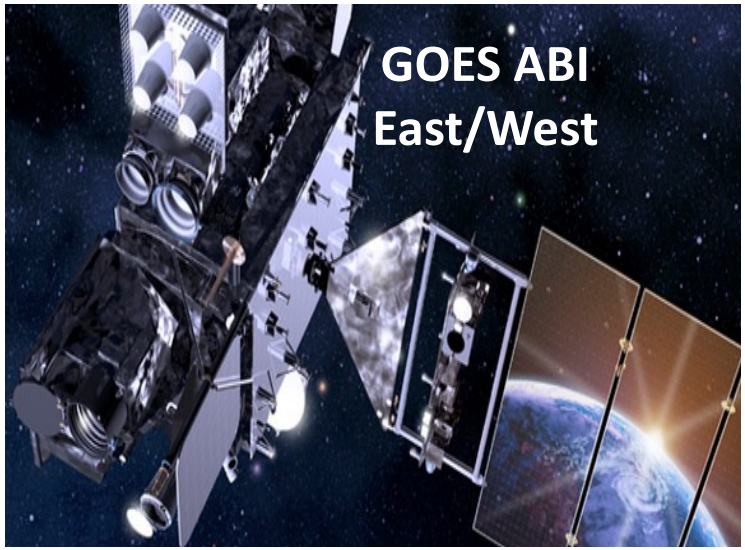
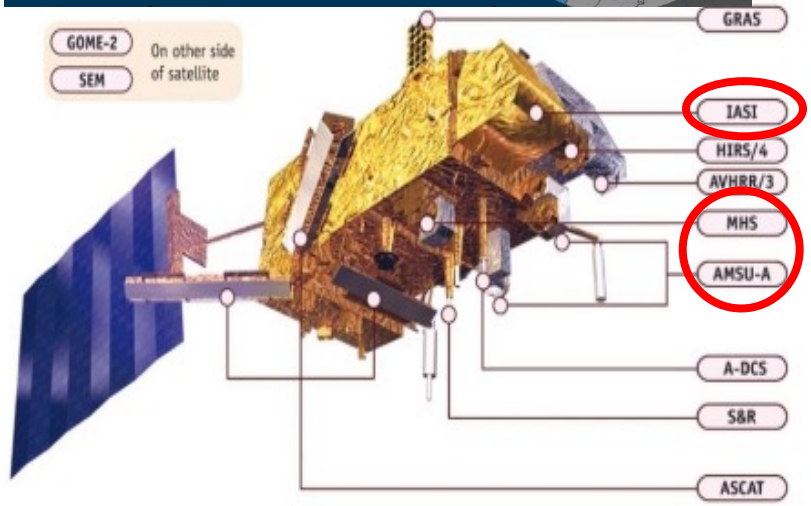
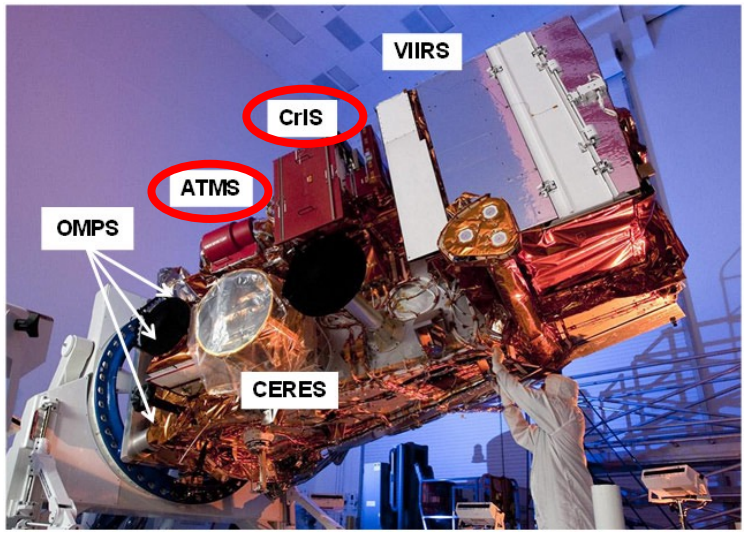
The Use of CSPP For NWP Assimilation of Direct Broadcast Satellite Data

W. Smith Sr. (UW), Q. Zhang (HU), A. DiNorscia (HIS), W. Smith Jr. (NASA), S. Lindstrom (UW)



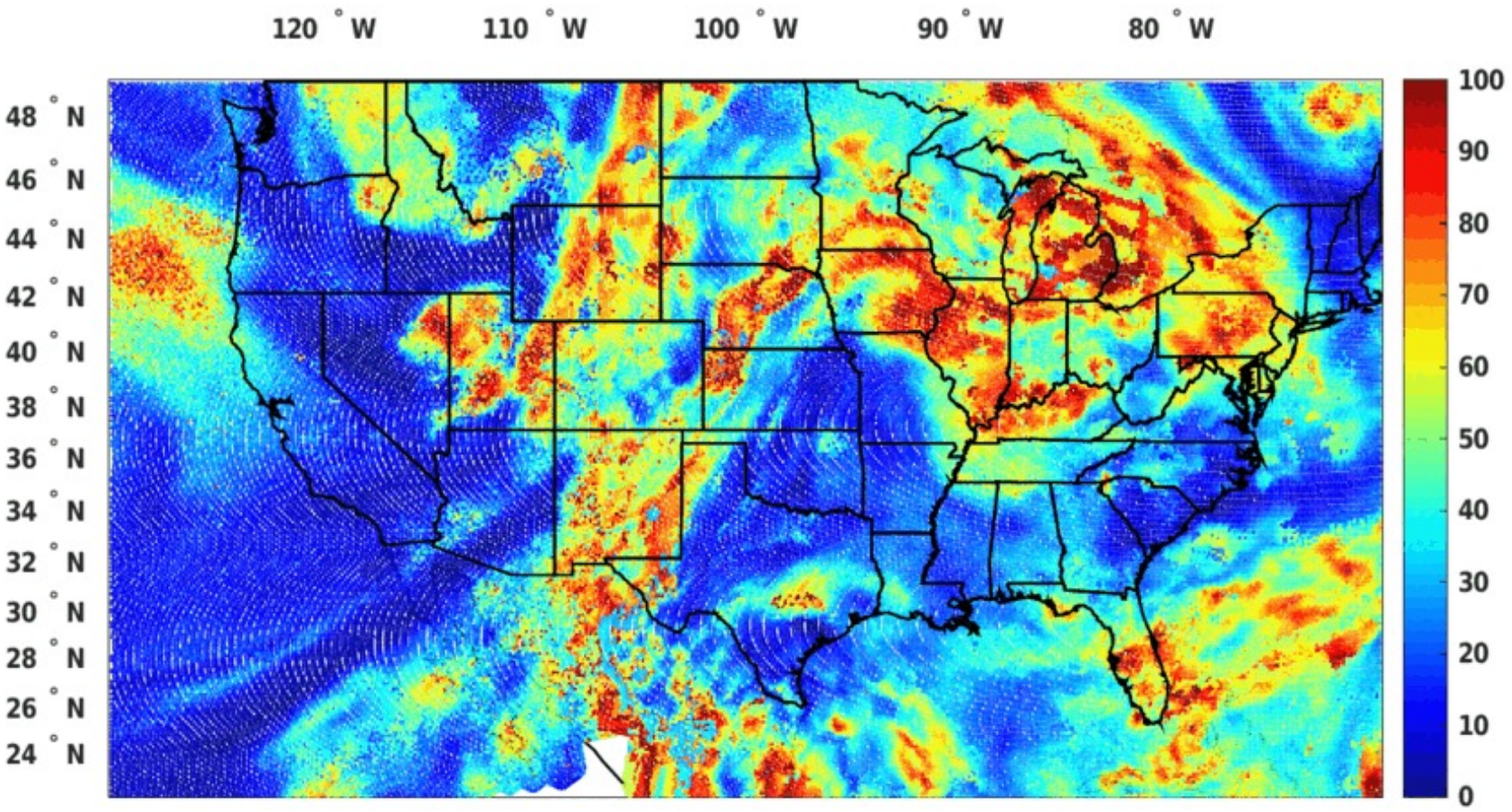






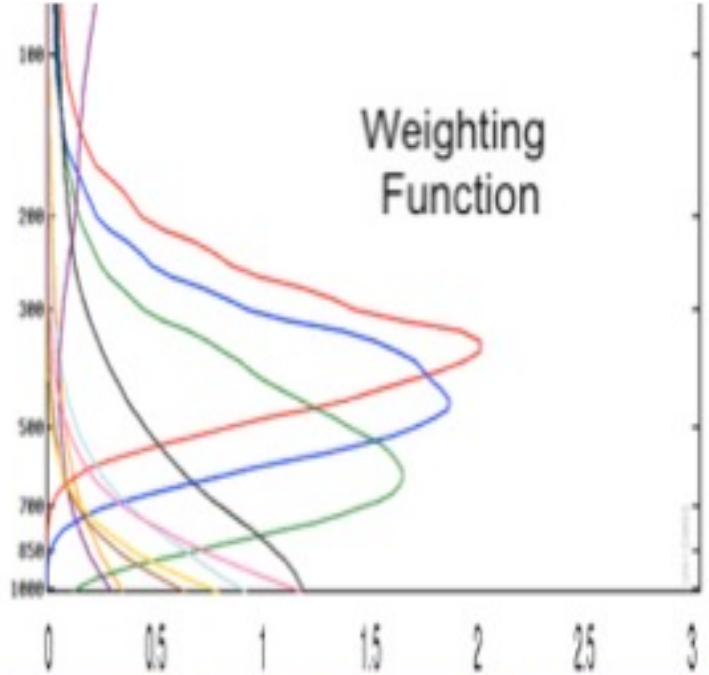
PHS+ABI – A GeoHyperspectral Proxy

12 Hour Movie Loop of Polar Plus Geo Satellite Sounding 500 hPA Relative Humidity

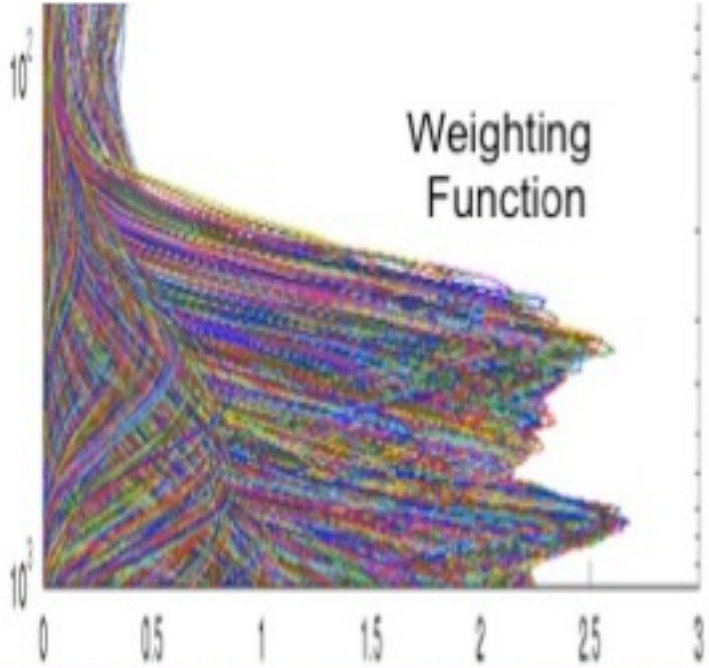


June 14, 2022 CONUS 500 RH (00 to 12 UTC)

Optimizing Vertical and Spatial Resolution

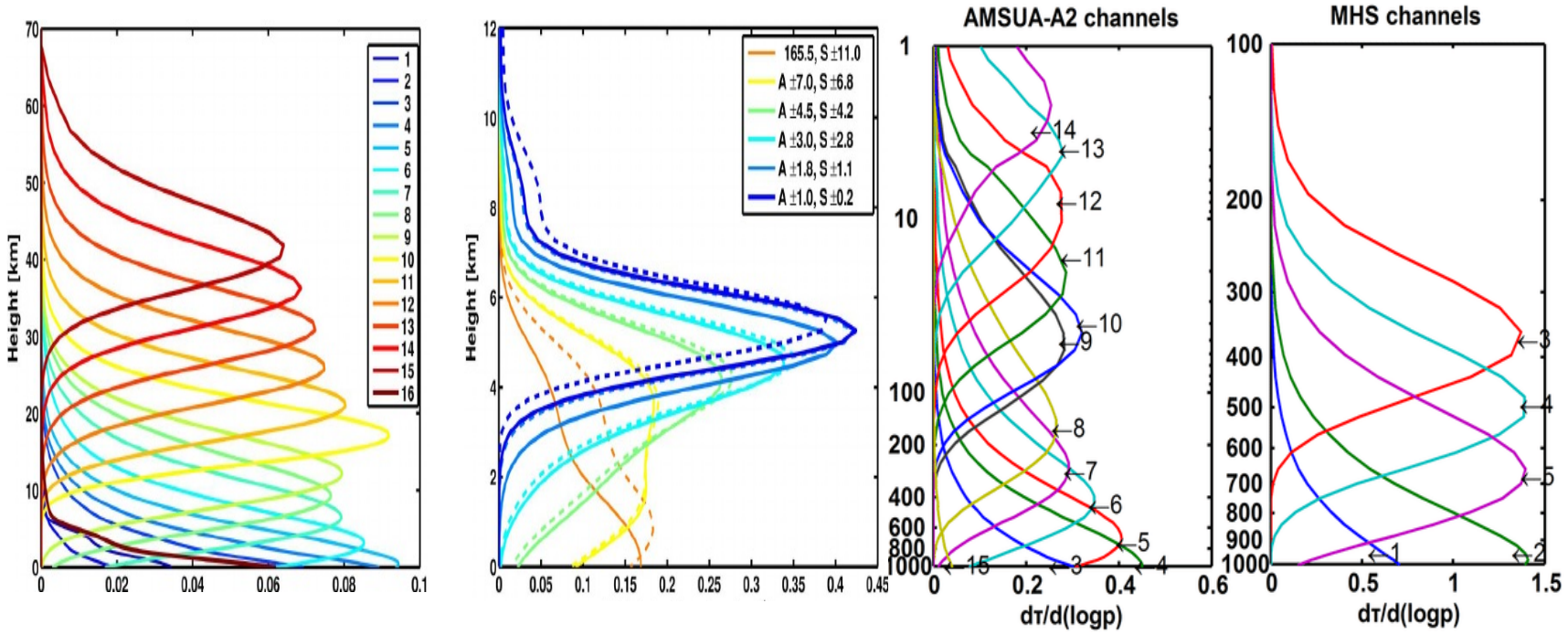


ABI: Vertical Res. 5-10 km
Horizontal Res. 2-km
Time Res. 5-15 min.



IASI/CrIS: Vertical Res. 1-2 km
Horizontal Res. 14-km
Time Res. 50 min-7 hr.

Optimizing All-sky Spatial Coverage

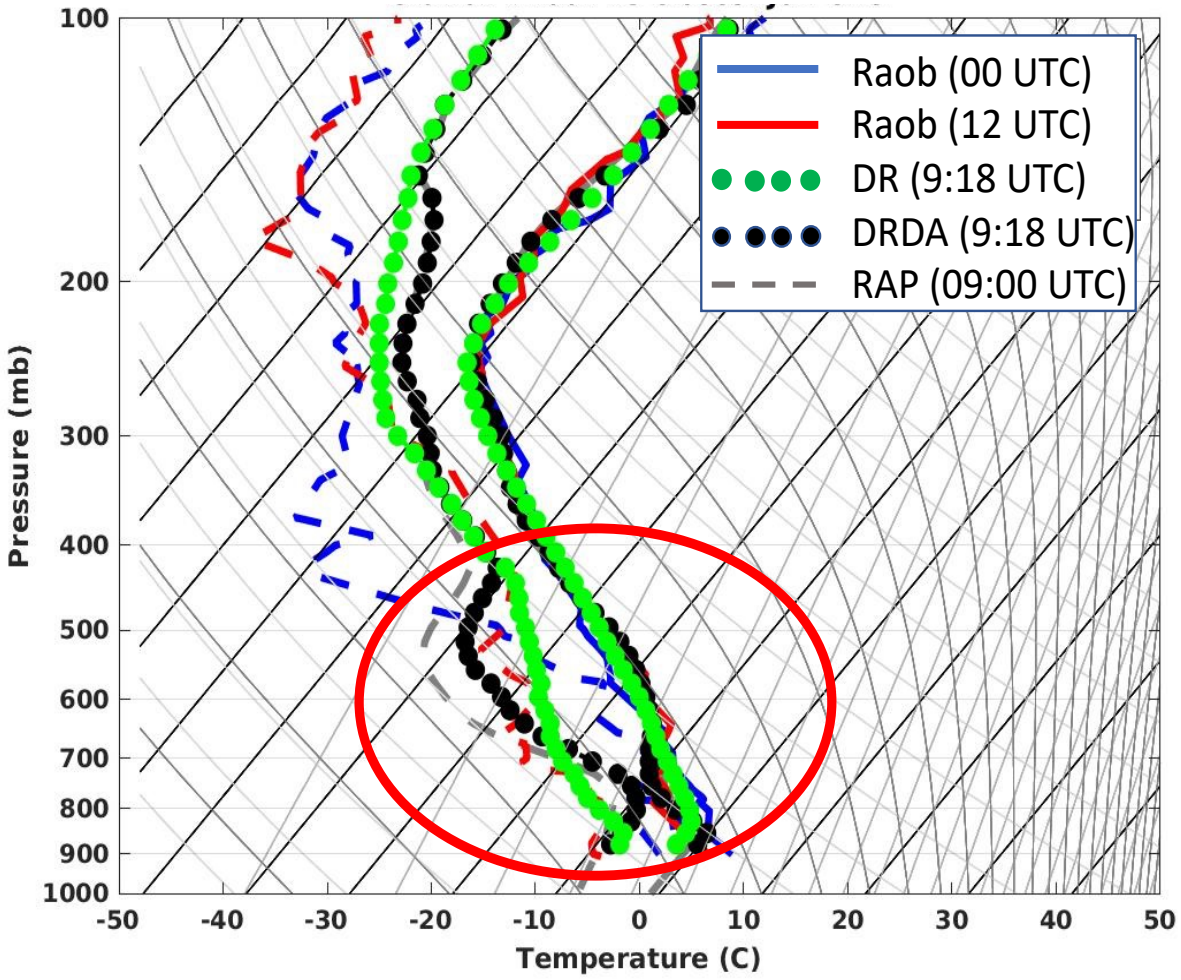


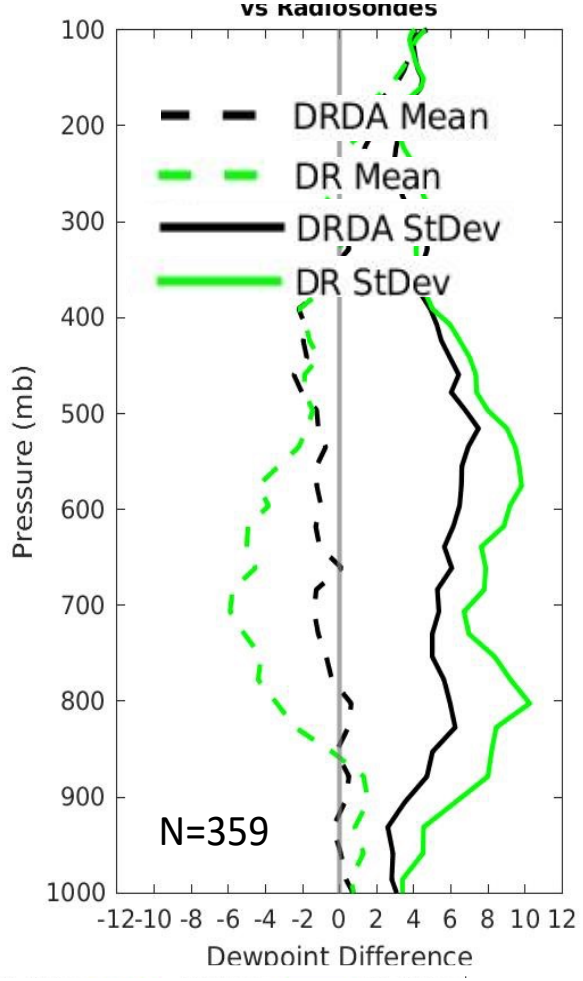
ATMS: Vertical Res. 5-10 km
H_2O Horizontal Res. 15-km
Time Res. Same as CrIS

AMSU/MHS: Vertical Res. 5-10 km
H_2O Horizontal Res. 15-km
Time Res. Same as IASI

Sounding Retrieval (DRDA)

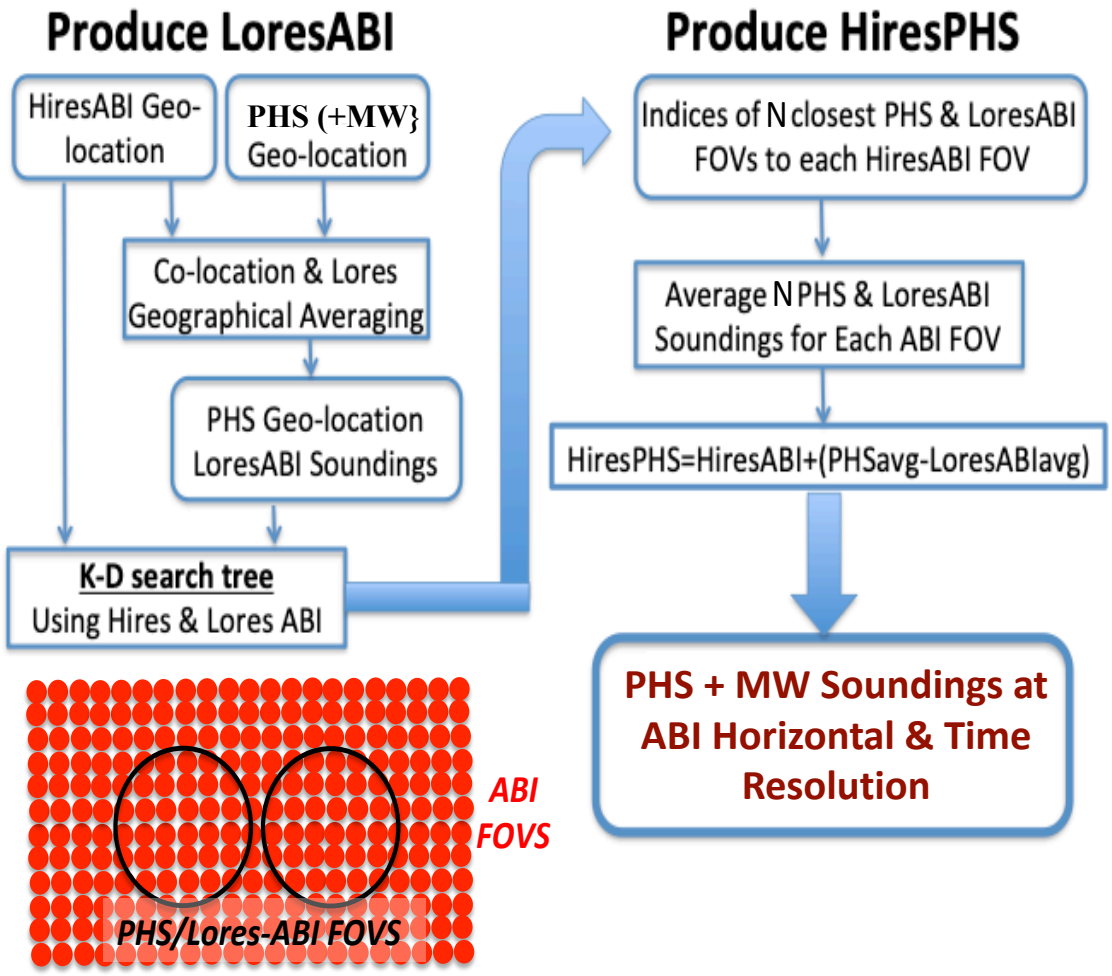
- CSPP Dual Regression (DR) retrieval used down cloud top and MW retrieval below cloud
- Rapid Refresh Model (RAP) 2-hr forecast used to vertically De-Alias (DA) retrieval to insure NWP model vertical resolution consistency for the data assimilation process
- DRDA Retrieval Process Corrects RAP Model Profile Errors to Improve forecast





*CrIS & IASI DRDA + ABI DRDA Retrieval Data Fusion Technique**

Polar Hyperspectral Sounding (PHS) + Advanced Baseline Imager (ABI) = PHSnABI



(1) The first step of the fusion process is to spatially average the high horizontal resolution ABI soundings to the footprints of the CrIS and IASI polar hyperspectral sounding instruments. This provides a paired low-resolution ABI and coincident polar hyperspectral sounding training data set to be used to predict polar hyperspectral soundings at the locations and times of every full resolution multispectral ABI data point.

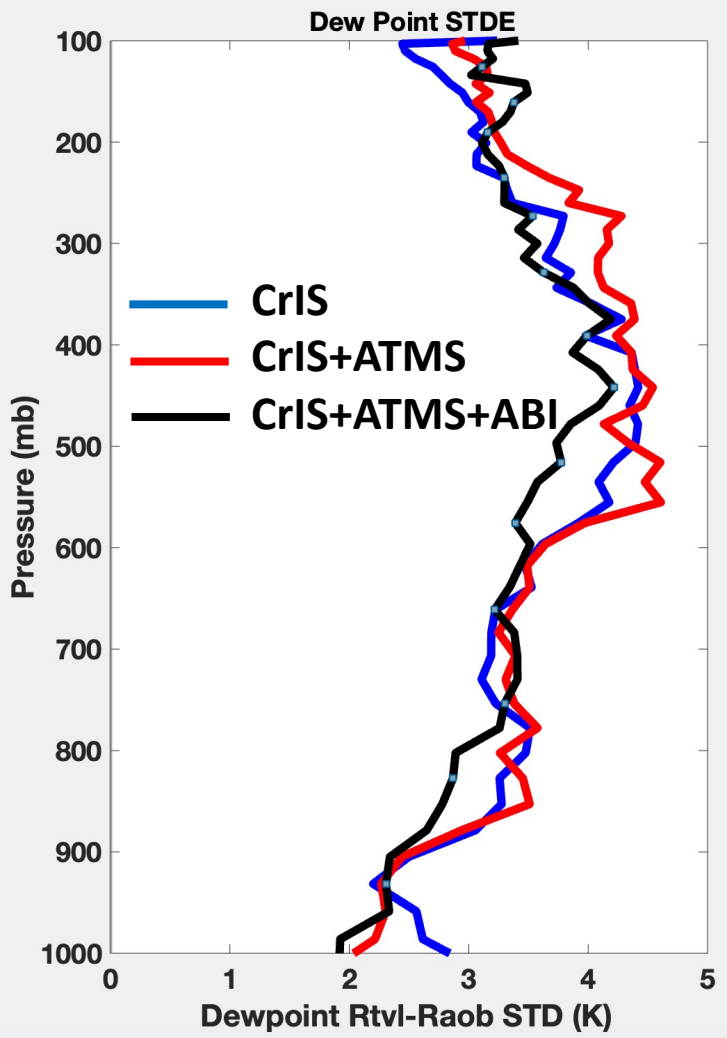
(2) Using a K-D search tree, the N <= 25 LoresABI soundings in the training data set that provide an optimal estimate of each full resolution ABI sounding are selected. The value of 'N' is restricted by maximum allowable time and location differences between the PHS observations in the training data sample and each full resolution ABI observation.**

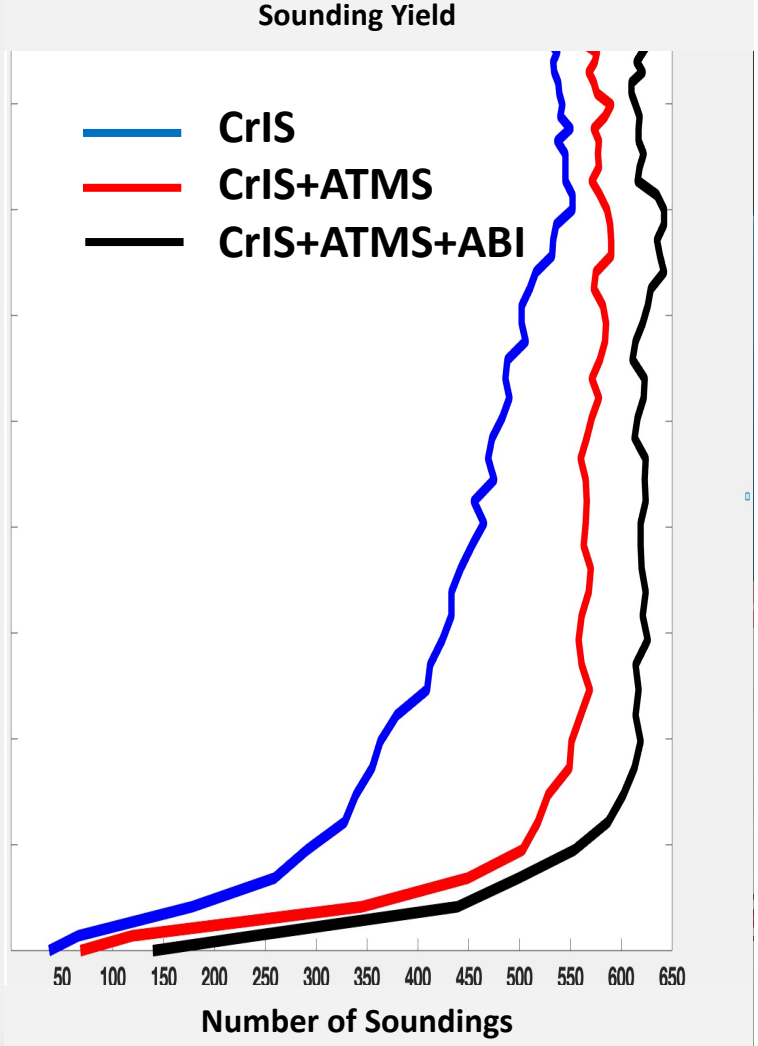
(3) Average differences between the 'N' paired original PHS soundings and the optimal LoresABI soundings in the training data set, as determined in (2), are then calculated for each ABI observation location and time. This average PHS/LoresABI sounding difference is then added to each ABI sounding estimate to predict a Hires PHS sounding at each ABI radiance measurement location and time.

- W. L. Smith, Q. Zhang, M. Shao, and E. Weisz, "Improved Severe Weather Forecasts Using LEO and GEO Satellite Soundings," *J. Atmos. Oceanic Technol.*, vol. 37, pp. 1203–1218, Jul. 2020

** E. Weisz, B. A. Baum, and W. P. Menzel, "Fusion of satellite-based imager and sounder data to construct supplementary high spatial resolution narrowband IR radiances," J. Appl. Remote Sens., 11 (3), 036022 (2017).

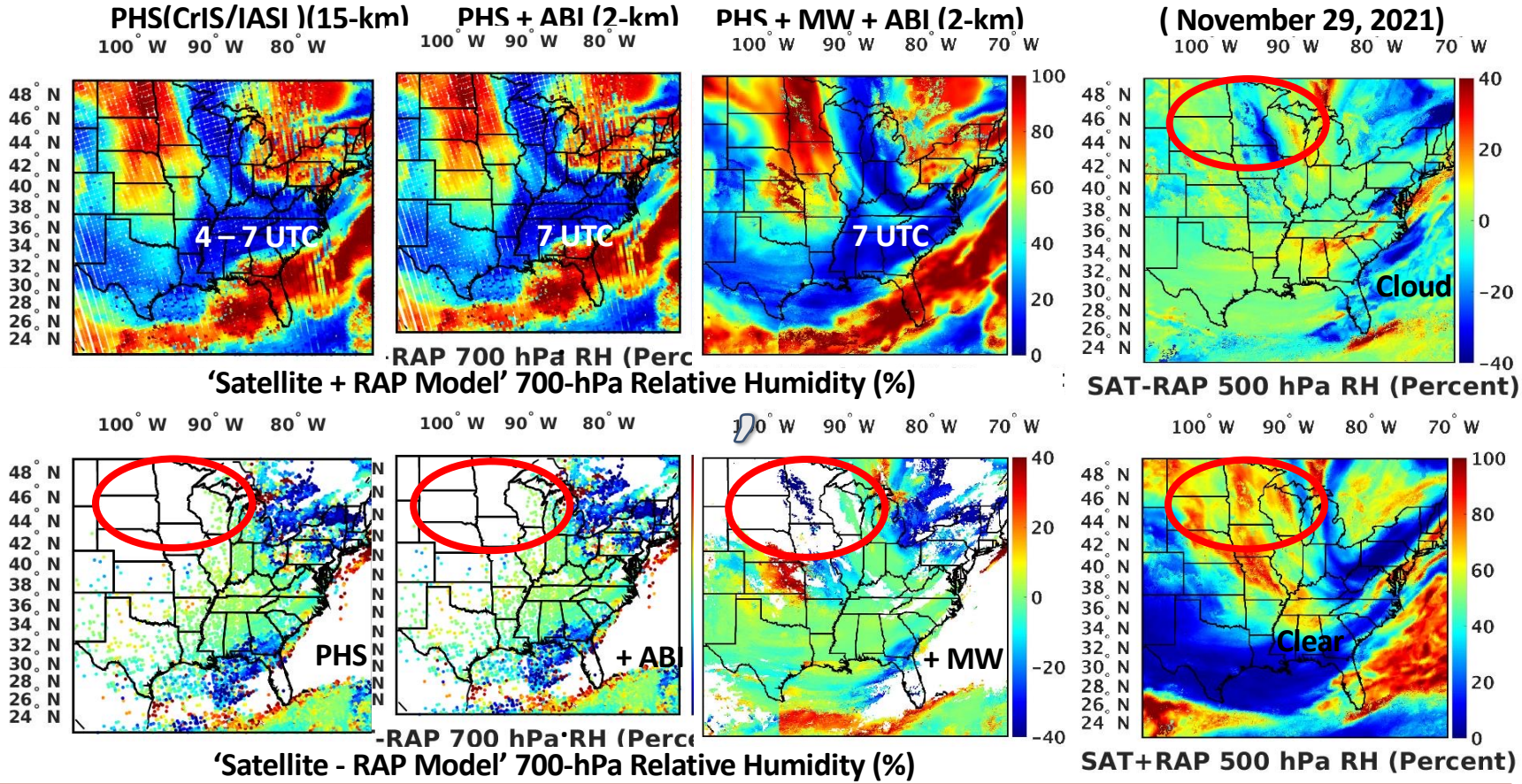
Sounding Accuracy and Yield





Differences in STDE Due to Satellite Observation/Radiosonde Time Difference
Differences in Sounding Yield Due To Clouds (MW Below and ABI Between)

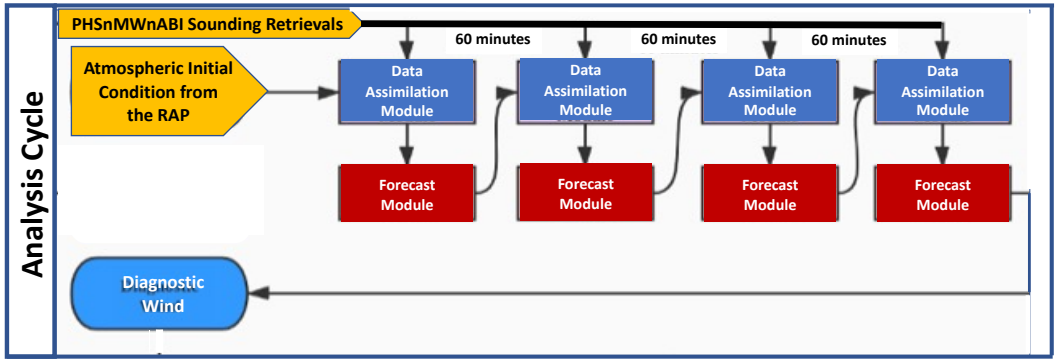
Cloudy Tropospheric And Above Cloud Information

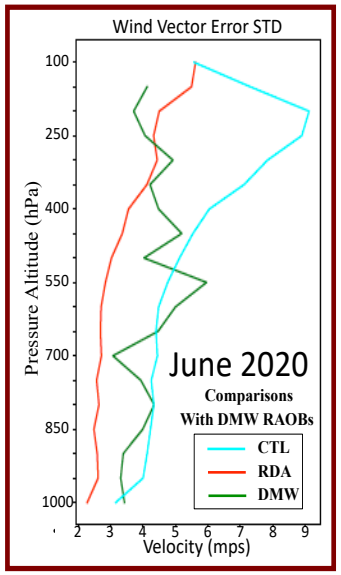


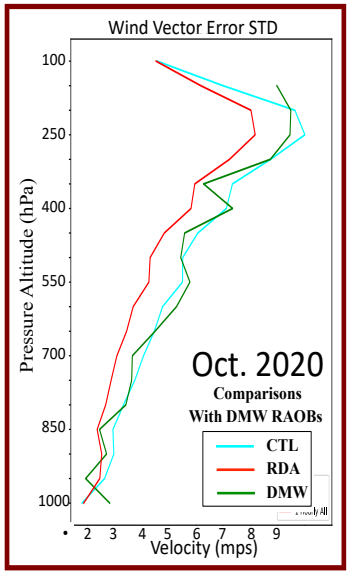
High Spatial Resolution and Above Cloud Radiance Information Crucial For Forecasting Active Weather Regions

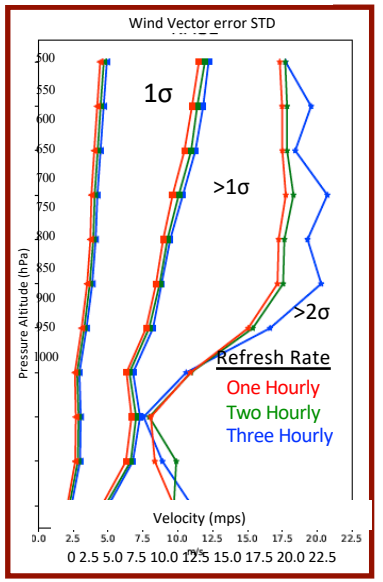
High Spatial and Temporal Resolution Needed to Resolve 3-D Winds Through Continuous Assimilation of Profile Information

- **Winds Are Diagnosed by the Quasi-Continuous Assimilation of High-Resolution Satellite Thermodynamic Profiles or Radiance Spectra**
- **Forecast Model Primitive Equations of Motion Force the Model's Dynamical Processes (i.e., 3-D Winds) to Conform to the Spatial and Temporal Changes in the Thermodynamic Observations Being Assimilated.**
- **Radiosonde Wind Comparisons Show Satellite Radiance Data Assimilated (RDA) Errors Are Less Than Control (CTL) & Derived Motion Wind (DMW) Errors**



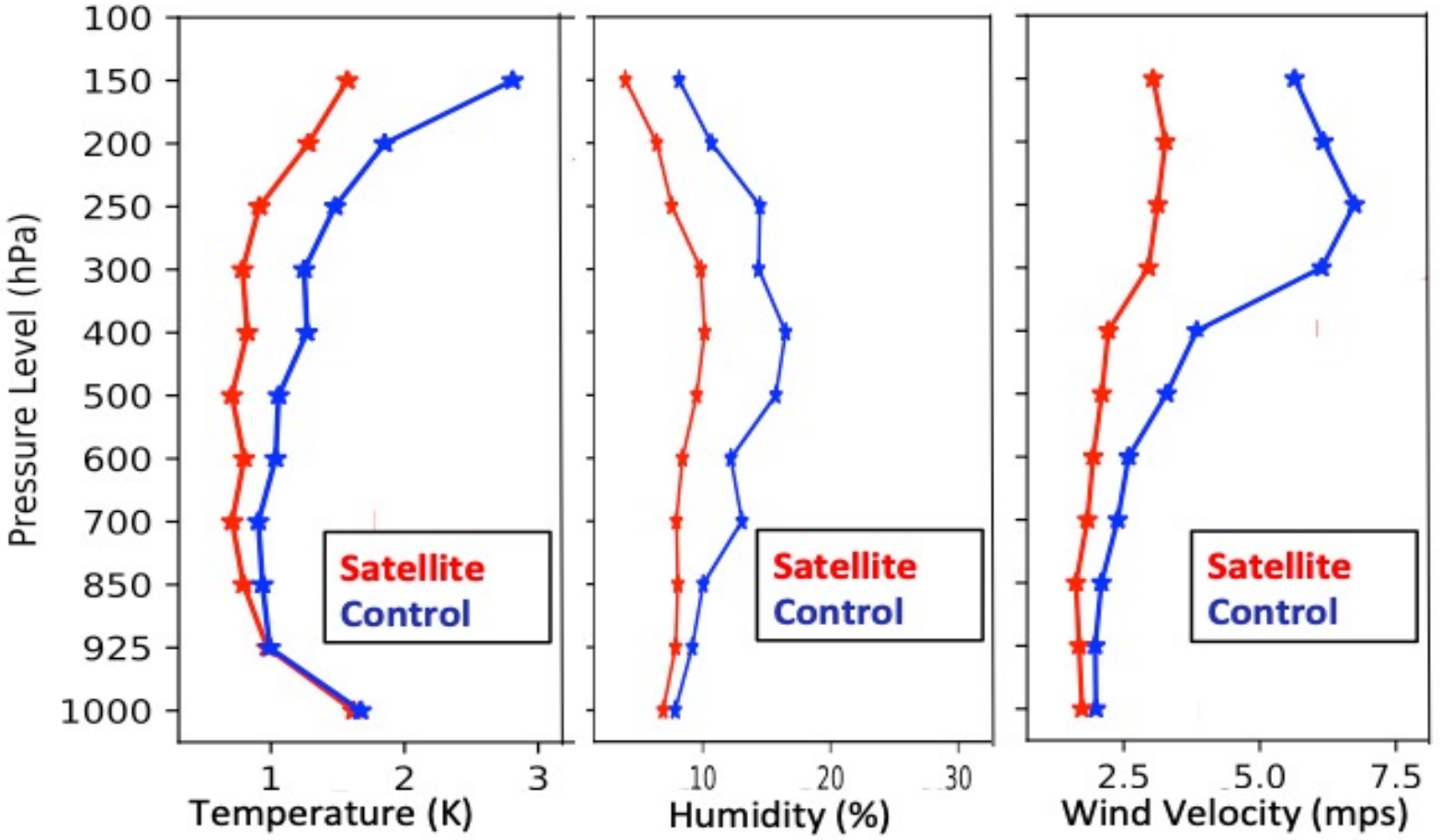






Satellite Sounding Information Assimilation Shows that the Accuracy of Model Diagnosed Wind Determinations Improves with the Increasing Temporal Frequency of the Satellite Information

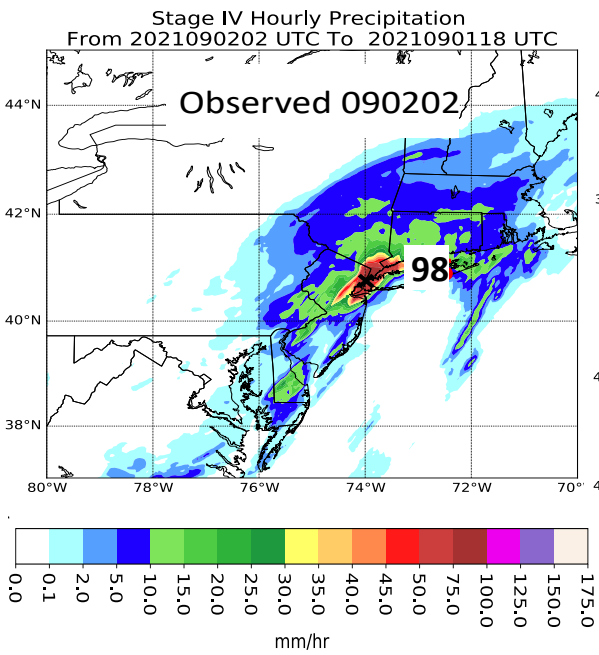
Standard Deviations Between USA Radiosondes and 6-hr Forecast Temperature, Humidity, and Wind Velocity Initialized With Vs Without (Satellite Vs Control) for Feb & Mar 2021

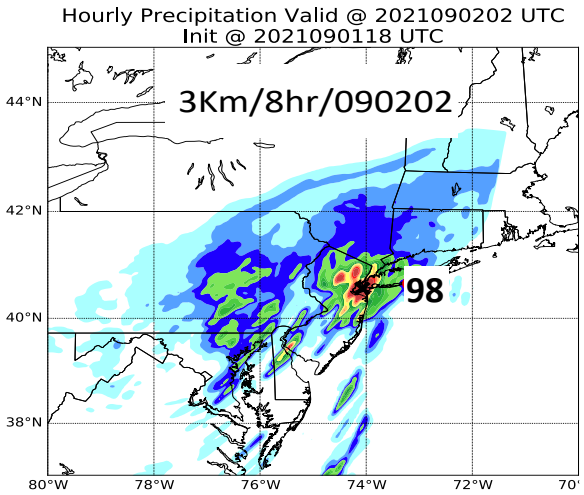


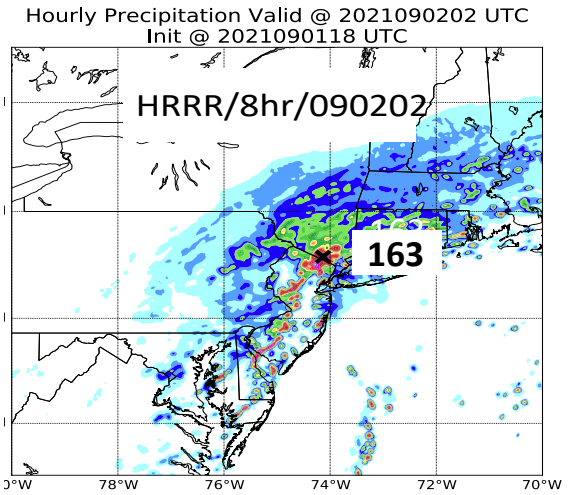
NWP Improved By Assimilating Satellite Sounding Data

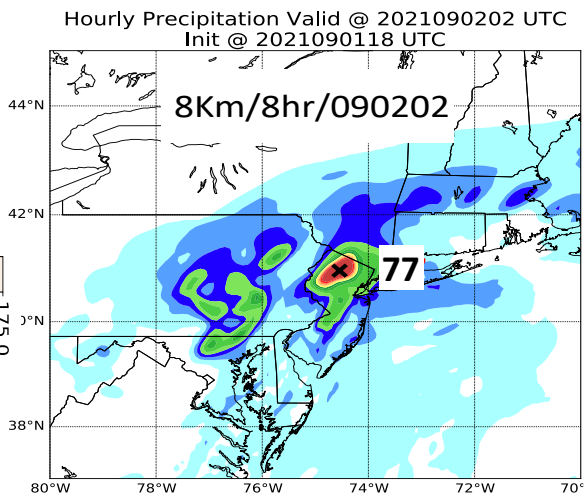
Resolving Convection Processes

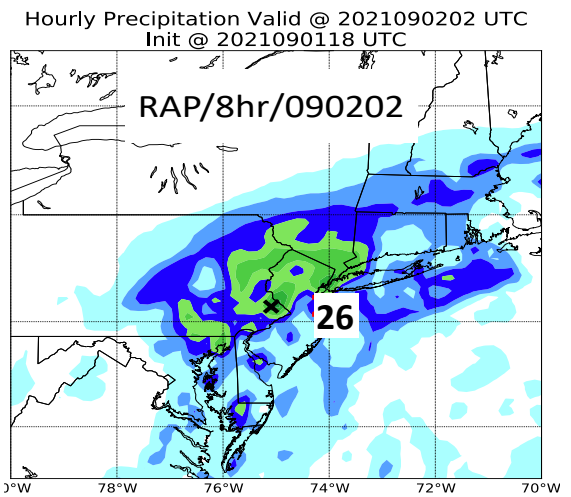
Sept. 1, 2021
Deadly New York
Flash Flood
10 to 11 PM EDT





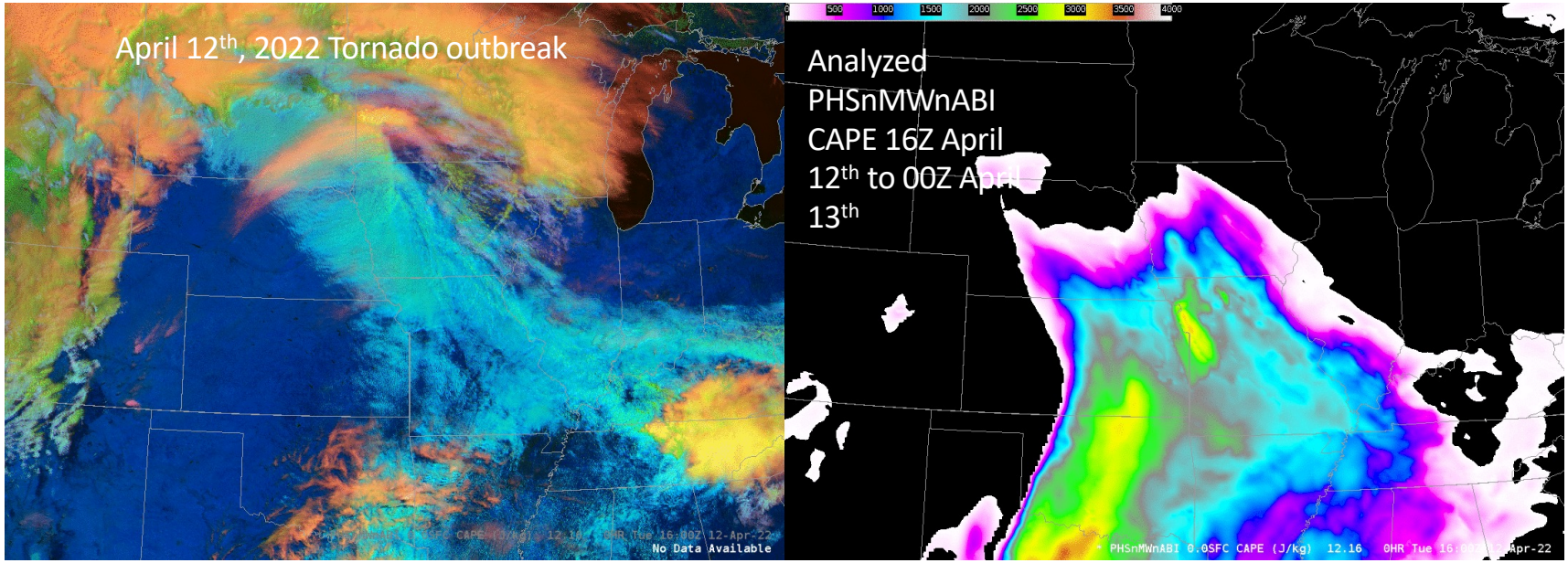






Higher Horizontal Resolution Satellite Data and Forecast Models Provide More Accurate Convective Weather Precipitation Forecasts

PHSnMWnABI Demonstration Within NWS AWIPS System

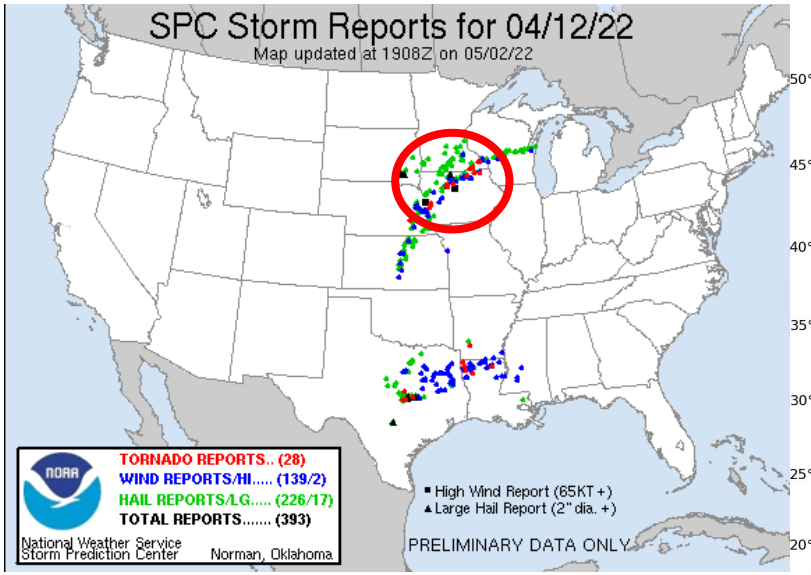


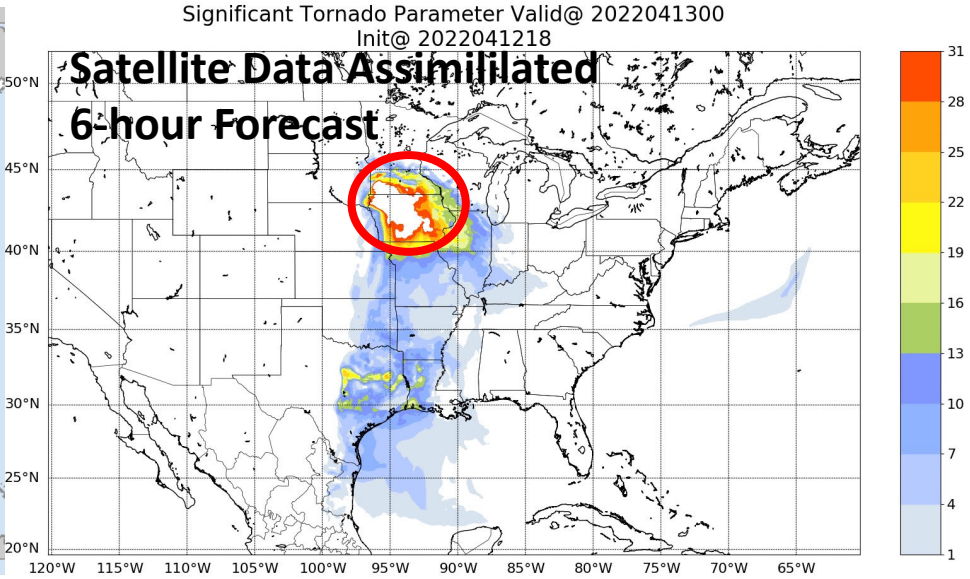
High temporal resolution hyperspectral retrievals determine timing and location of convection (*situational awareness*).

Courtesy of Pierce and Lindstrom

Significant Tornado Parameter

Significant Tornado Parameter (STP) combines most unstable convective available potential energy (MUCAPE), effective storm-relative helicity (SRH), effective bulk vertical wind shear, lifting condensation level (LCL), and the mean parcel convective inhibition (CIN) to distinguish between significantly tornadic (F2 or greater damage) and non-tornadic supercells





Geo- hyperspectral retrievals constrain predictions of the strength and evolution of hazardous weather (***nowcasting***). outbreak beginning at 23:31Z over Northern Iowa on April 12th, 2022

Courtesy of Pierce and Lindstrom

Examples of Forecaster Comments

- ***The 'PHS' CAPE forecast appeared to be a noteworthy improvement from the CAPE fields on the SPC Meso-analysis***
- *The PHS model was very useful today ahead of convective initiation. Instability parameters were observed as ongoing severe storms moved SW toward the established instability gradient….This provided useful information about the existence of a boundary and the motion of the storms along with the pre-conditioned environment.*
- *PHS was already highlighting the area of concern along a tongue of instability where storms were ongoing as of the 19Z 1-hour forecast. In subsequent frames, it shows the instability being maintained as storms move toward my DSS area despite thick cloud cover overhead. Based on previously discussed trends in observed lightning, it seemed it was accurately showing areas of marginal but sufficient instability.*
- ***I found the PHS products useful for seeing the corridors of enhanced severe risk. They correctly showed that hail (or wind) was the highest risk compared to tornadoes.***
- *I didn't look at this PHS Significant Tornado Parameter in real time when warnings were being issued, just completely spaced it. But went back to see how it fared during the Tornado Warnings, it didn't do too bad. The comparison below is from 21z and even though the tornado warning was already issued before the PHS STP was available, it was a nice "confirmation" tool of the Tornado Warning. The units of the STP were nearly 10 at the time of the strong couplet north of Clifton, WI and it was in the right location at the time of warning*
- *The PHS SigTOR parameter also further supported the tornado risk during the 2000Z hour. The image below shows the PHS SigTOR parameter [2-h forecast] at 2000Z with ProbTOR percentages overlaid on top. The cell which produced the likely tornado east of Shelbyville, IN is sampled in the image with the ProbTOR only at 9%.)*
- ***After overlaying Prob Severe with the PHS CAPE and Visible Satellite imagery, you can see your strongest storms along the CAPE gradient which tracks well.***
- *Interesting item to note when analyzing PHS forecast CAPE over western South Dakota. This may be terrain induced, but the sharp gradient of CAPE values noted up and and down the western border of South Dakota. This correlated fairly well with a strong storm or two in the western UNR CWA.*

Summary and Conclusions

- ***The PHSnMWnABI observations serves as a proxy for the next generation Polar- and Geo- Hyperspectral sounding data***
- ***The continuous NWP model assimilation of PHSnMWnABI data provides significantly improved temperature, moisture, and wind observations, which improve forecasts of precipitation and severe weather, including tornadoes***
- ***The nowcasting capability of short-term (2- to 3-Hr forecasts initialized through the with assimilation of PHSnMWnABI soundings was demonstrated during the 2002 NOAA Hazardous Weather Testbed (HWT)***
- ***The PHSnMWnABI research system geographical domain will be expanded to cover the entire CONUS region and integrated into the new generation of Unified Forecast System weather models in preparation for use with data from the next generation of Geostationary and Polar Orbiting Satellite systems***