Use of Direct Broadcast Leo & Geo Soundings for Numerical Weather Prediction

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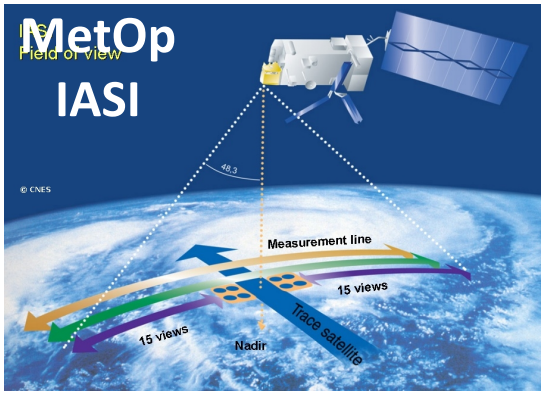
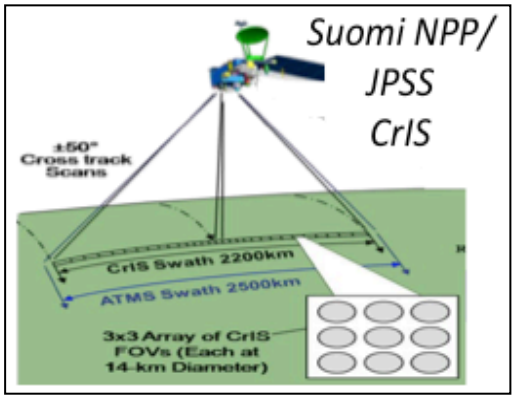
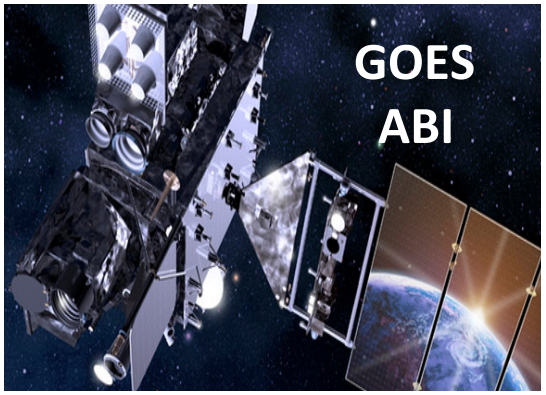
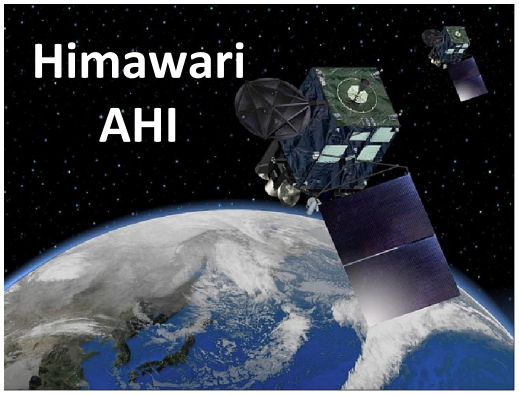
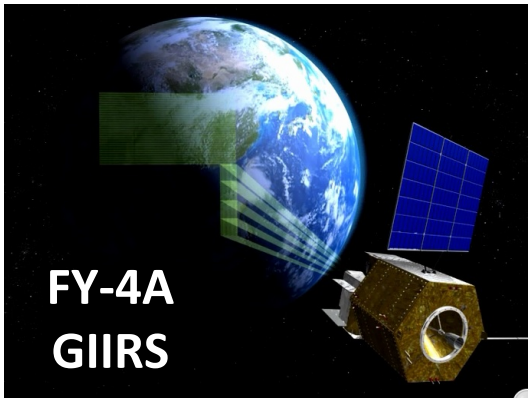
[1]U. of Wisconsin (USA), [2]Hampton U. (USA), [3]Nanjing U. (China)



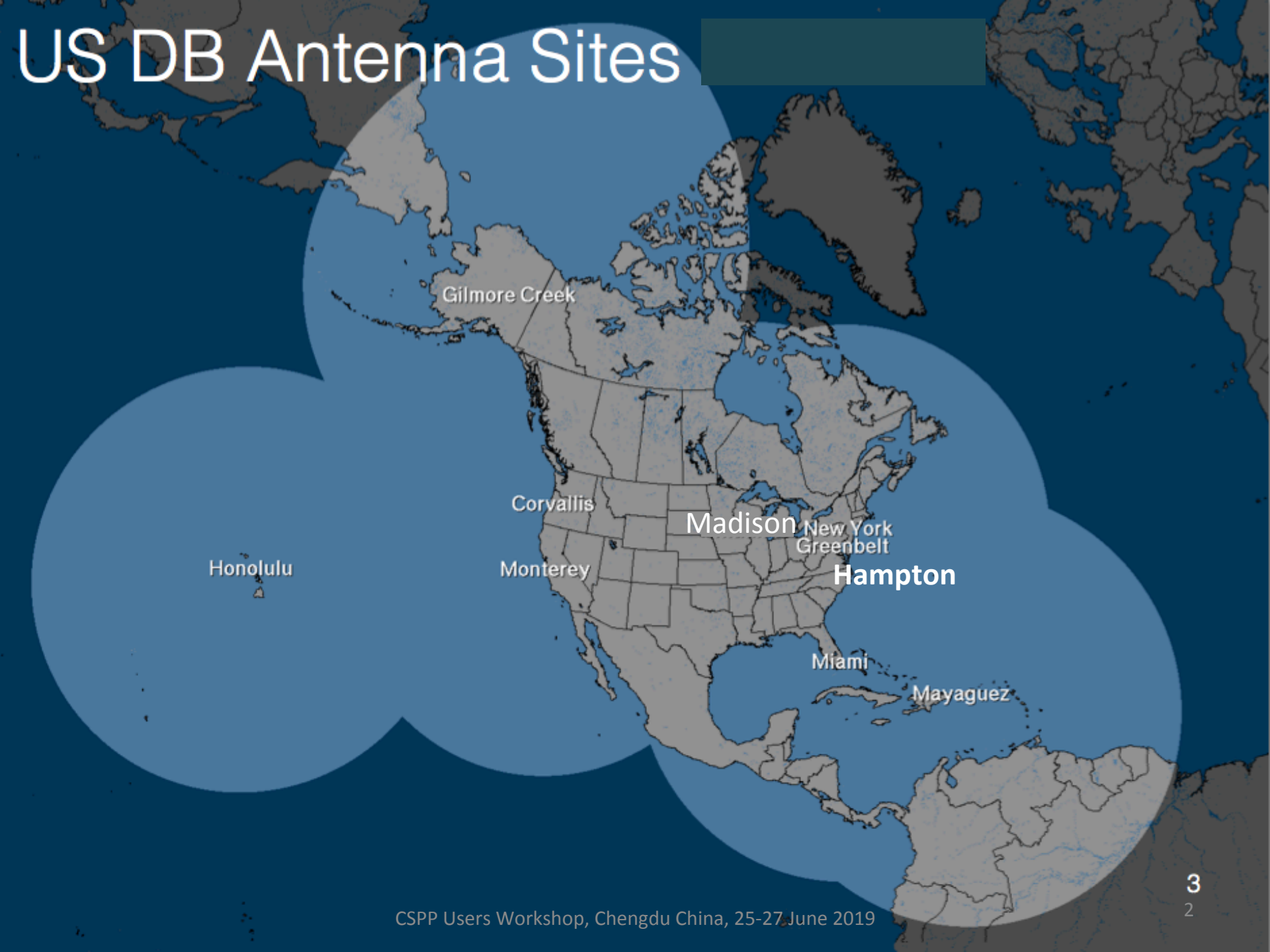




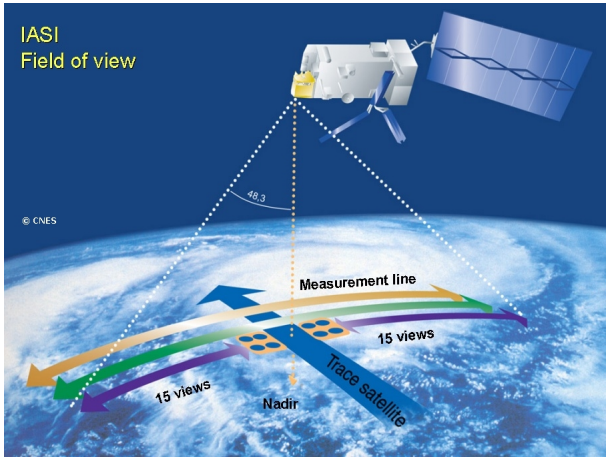


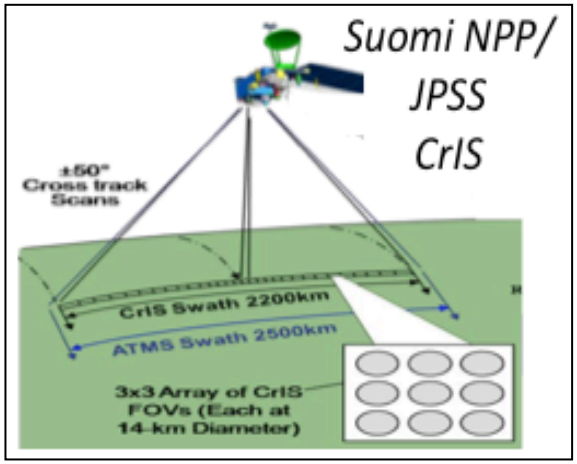


US DB Antenna Sites



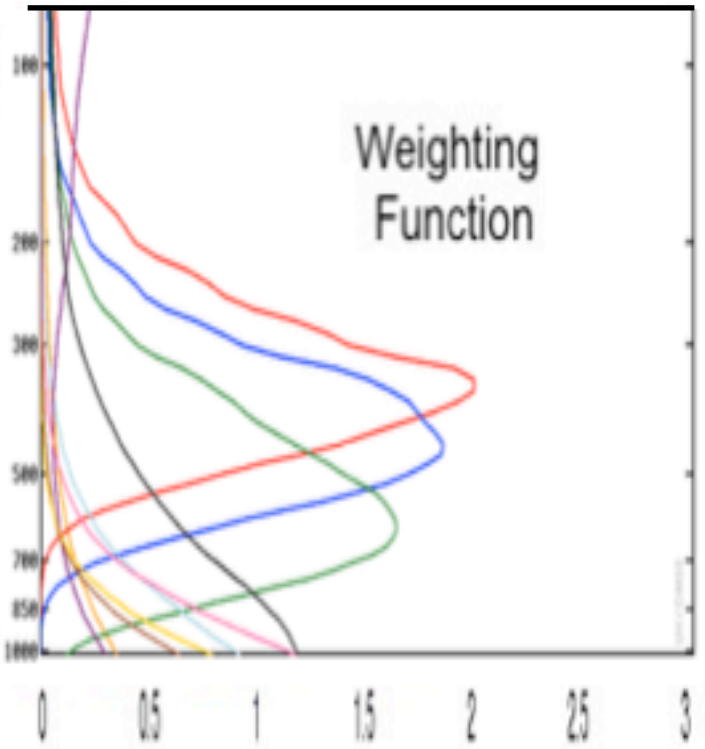
Operational Polar-Orbiting Hyper-Spectral & Geostationary Sounders



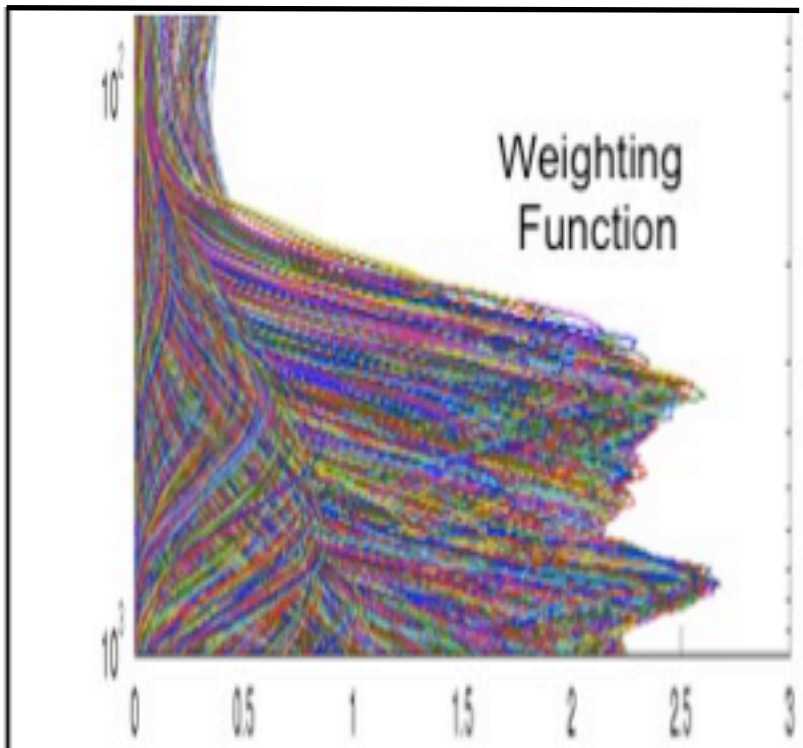


Instrument	IASI	CrIS	ABI
Satellite	Metop-A, Metop-B	Suomi-NPP	**GOES-16**
Type	Michelson Interferometer	Michelson Interferometer	**Radiometer**
Spectral resolution	0.25 cm^{-1}	0.625 (LW), 1.25 (MW), 2.5 cm^{-1} (SW)	**GOES-16**
Spectral range	645 – 2760 cm^{-1} (15.5 – 3.62 µm)	650 – 2550 cm^{-1} (15.4 – 3.9 µm)	**751.9 - 21276 cm^{-1} 0.47 – 13.3 µm**
Number of Detectors/ Channels	12 / 8461	**27 / 2211**	**16 / 16**
NEDT range	0.1 – 0.75 K	0.05 – 0.5 K	**0.01 /0.07**
Spatial Resolution (at nadir)	12 km	14 km	**2 km**
Launched	2006, 2012	2011	**2016**

Optimizing Time and Spatial Resolution

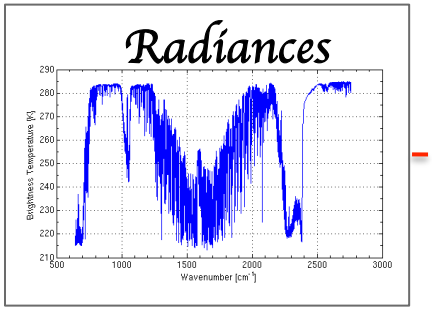


ABI: Vertical Res. 5-10 km
Horizontal Res. 2-km
Time Res. 5-15 min.



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

"Dual-Regression" Retrieval Algorithm* Overview



Global clear soundings

Radiances (clear FM)

Clear-trained regression coefficients

Global cloudy soundings

Radiances (cloudy FM)
Cloud height classes

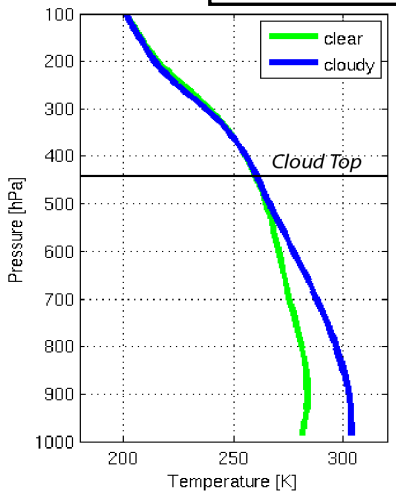
Cloud-trained regression coefficients

Theoretical Statistics

Radiance Observations

Clear-trained EOF regression retrieval

Cloud-trained EOF regression retrieval



Cloud Top Altitude
Level where $T_{cloudy} > T_{clear}$ for $p > p_{cld}$

Final Profile
from cloudy and/or clear retrievals

Temperature, Humidity and Ozone profiles, Surface and Cloud parameter at single FOV (0-2-km) resolution

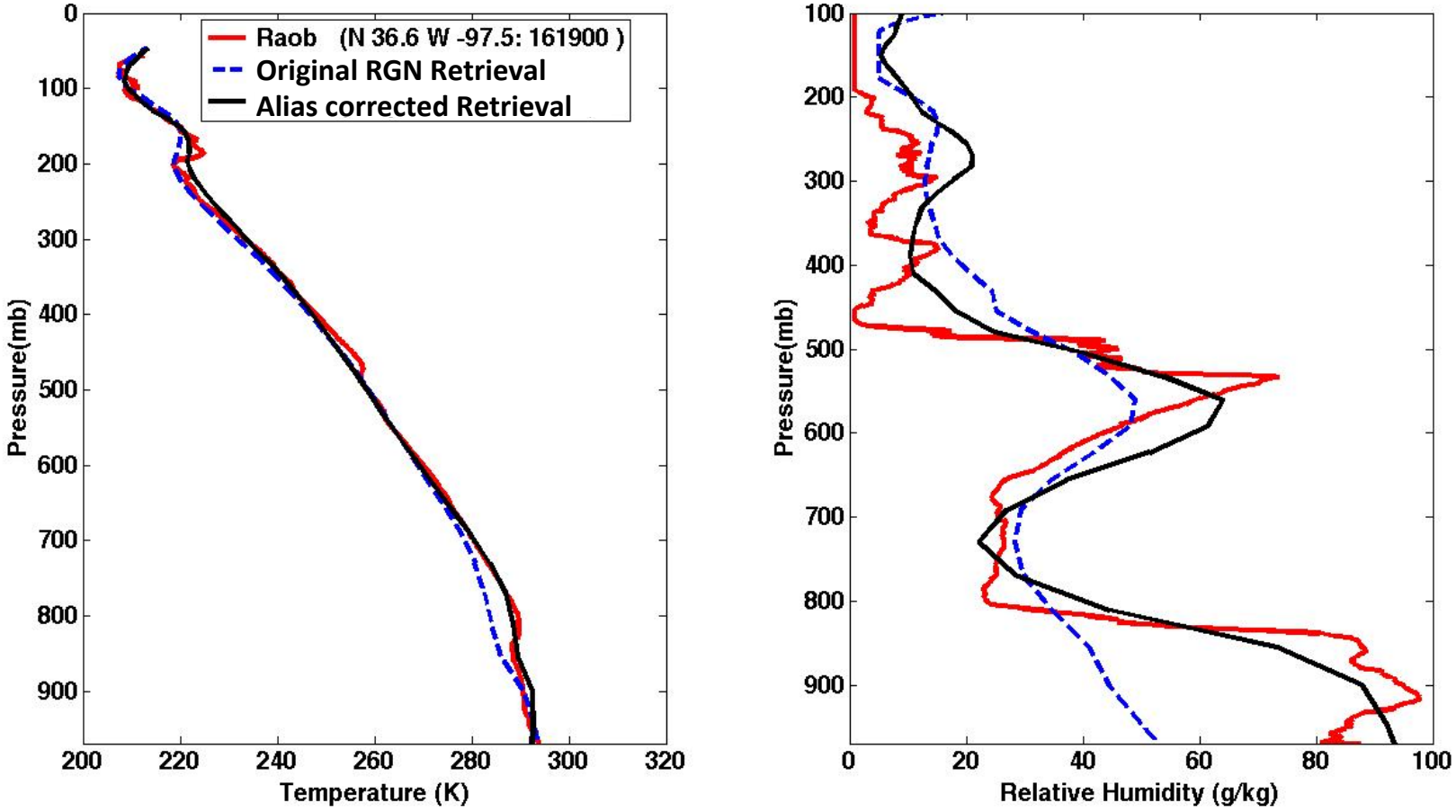
Provides Clear Air Soundings, Including Above Cloud & Below Semi-transparent/Broken Clouds

De-Aliasing Using Forecast Model Profile

Problem: DR method uses a global statistical training data set. Imperfect skill, due to lack of vertical resolution in radiances leads to a vertical aliasing error.

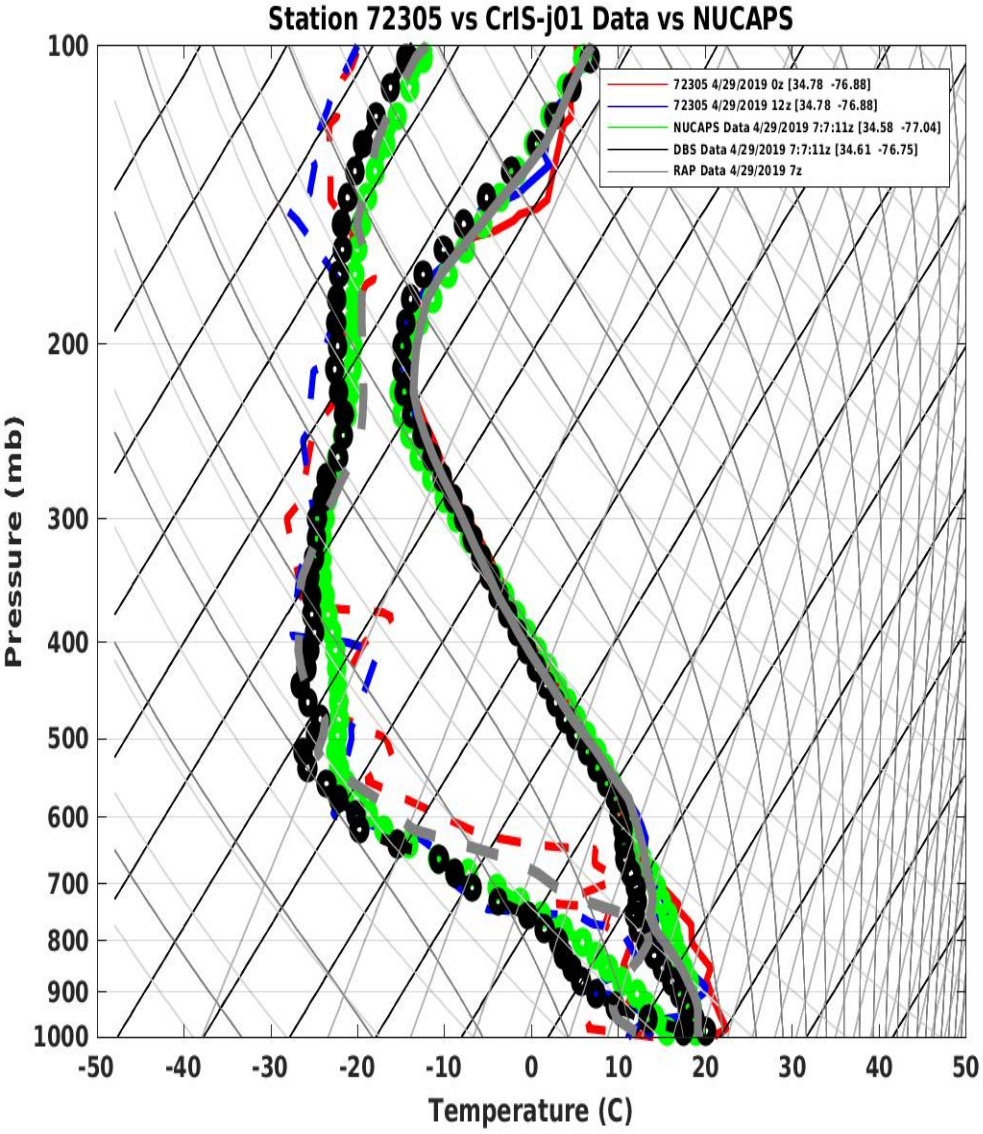
Solution: Calculate radiance spectrum from forecast profile (FP) and perform DR retrieval using simulated forecast radiances.

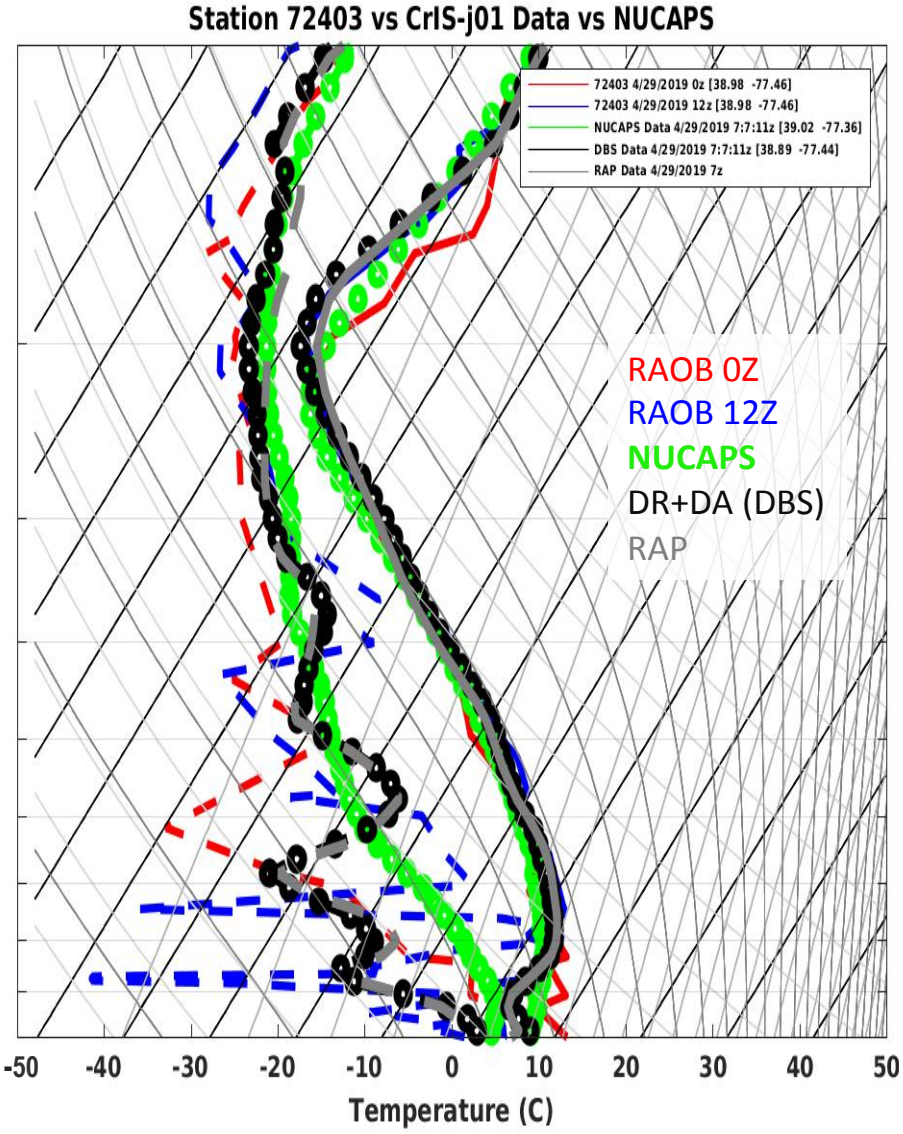
Vertical Alias = Forecast Simulated Retrieval– Forecast Profile



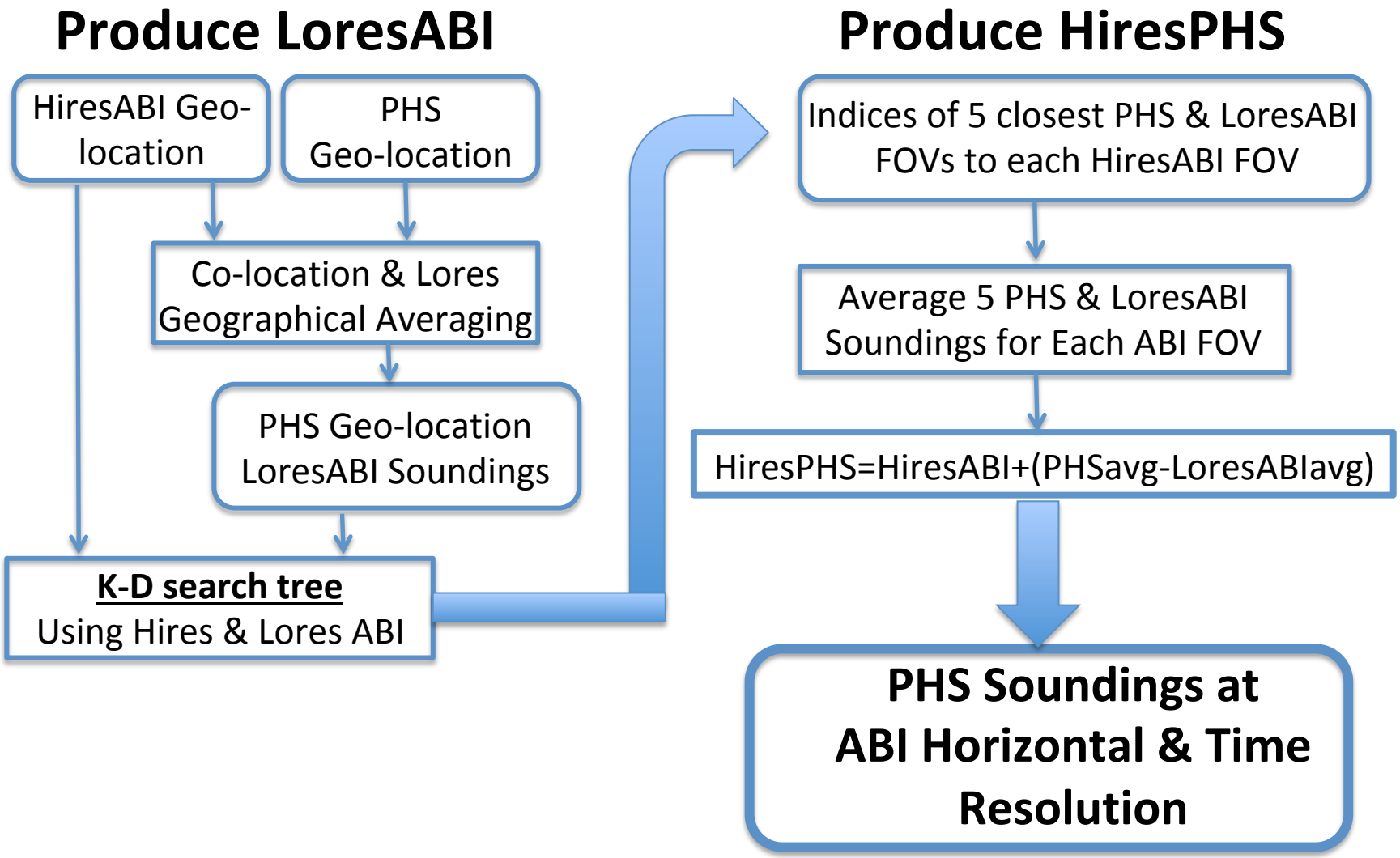
Dual Regression De-Aliased Vs. NUCAPS Vs. Radiosondes

http://cas.hamptonu.edu/dbps_cron/adinorscia/JOBS/AKQ/Ensemble/

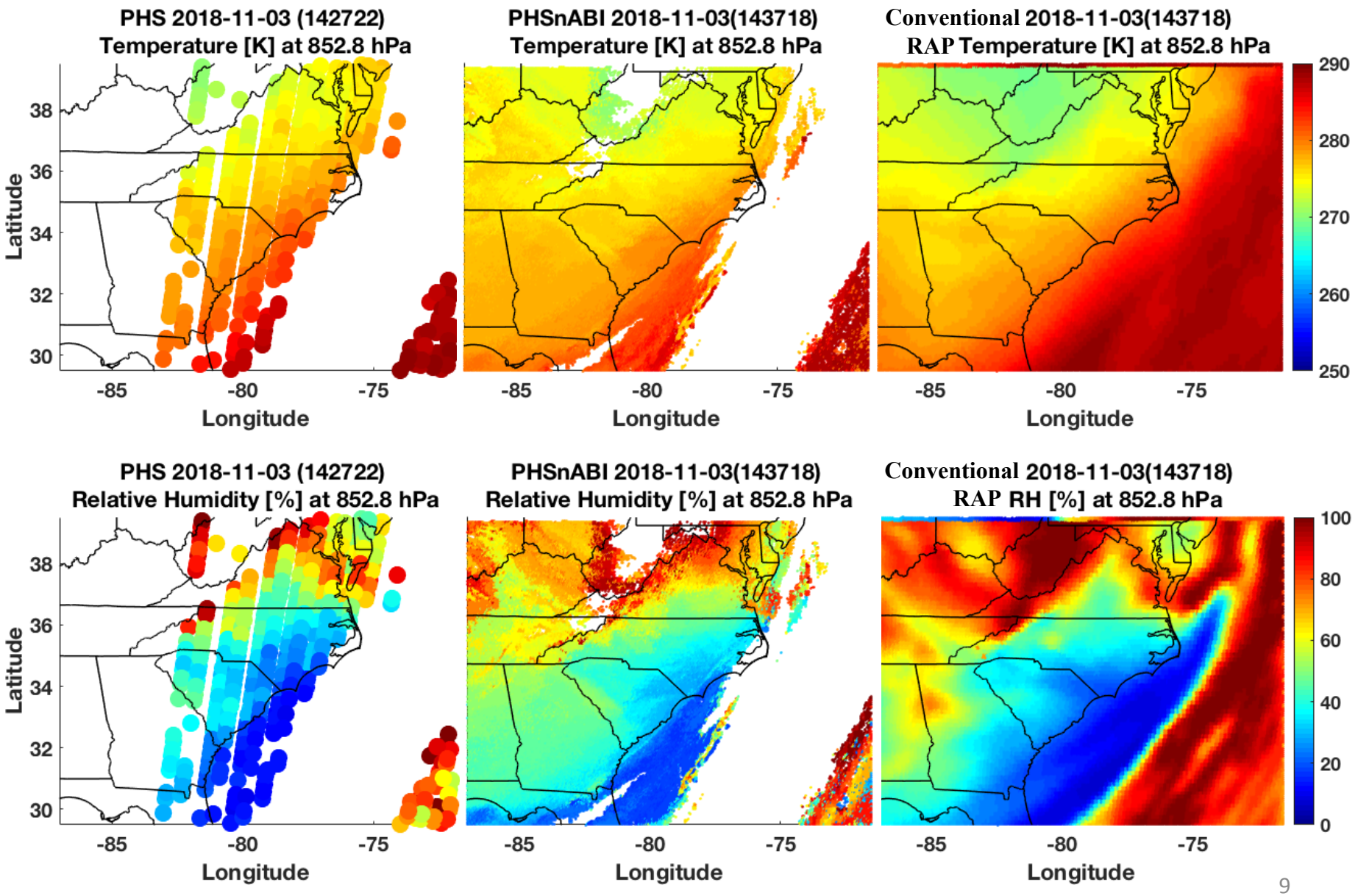




Fusion of PHS and ABI Soundings



PHS + ABI Retrieval Fusion Example

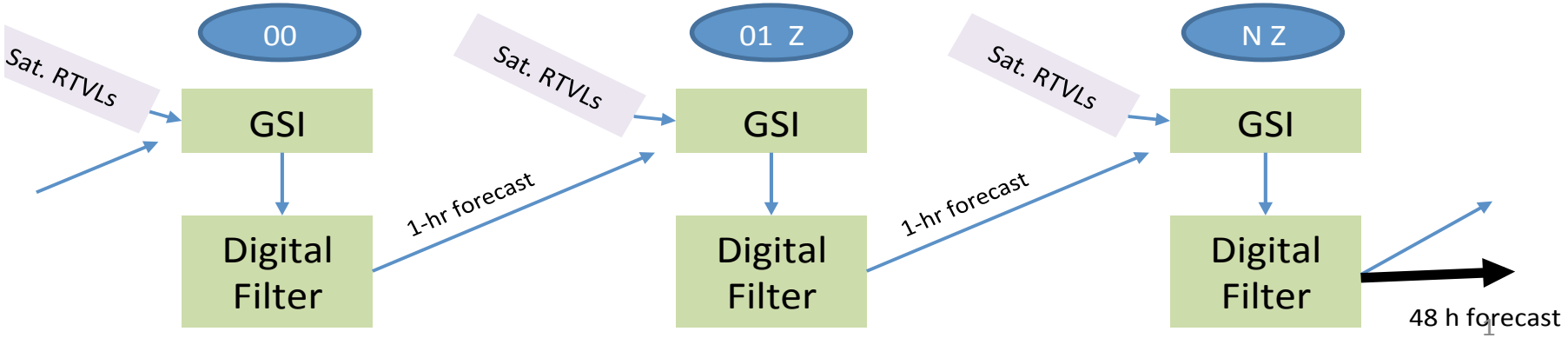


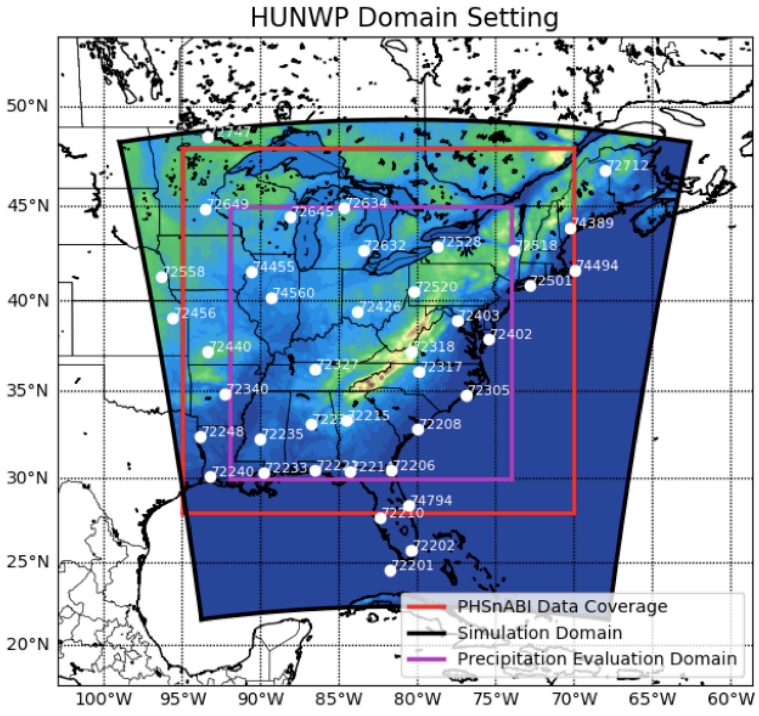
Application to NWP

***Shao, M**. and W. Smith, **"Impact of Atmospheric Retrievals on Hurricane Florence/Michael Forecasts in a Regional NWP Model"** Journal of Geophysical Research – Atmospheres, 2019.*

Model	WRF-ARW 3.9.1/GSI3.6 (3D-Var)
Horizontal Grid	3-km (PHSnABI) and 9-km (PHS)
Vertical Grid	Sigma-Isob Hybrid (50 levels) Pressure top at 10 mb
Background	GFS 0.25° forecasts
Initial Time (Hourly update)	Case 1: 2018091303 Case 2: 2018101012
Physics	LW/SW: RRTMG Microphysics: Thompson Aerosol Cumulus Parametrization: Grell-Freitas PBL: MYNN; LSM: RUC
Data Assimilation interval (window) Model Initialization Period/time step	Mulitple One hour (+/- 30 min) 24-hour/50 seconds

See Poster by Shao at this Workshop

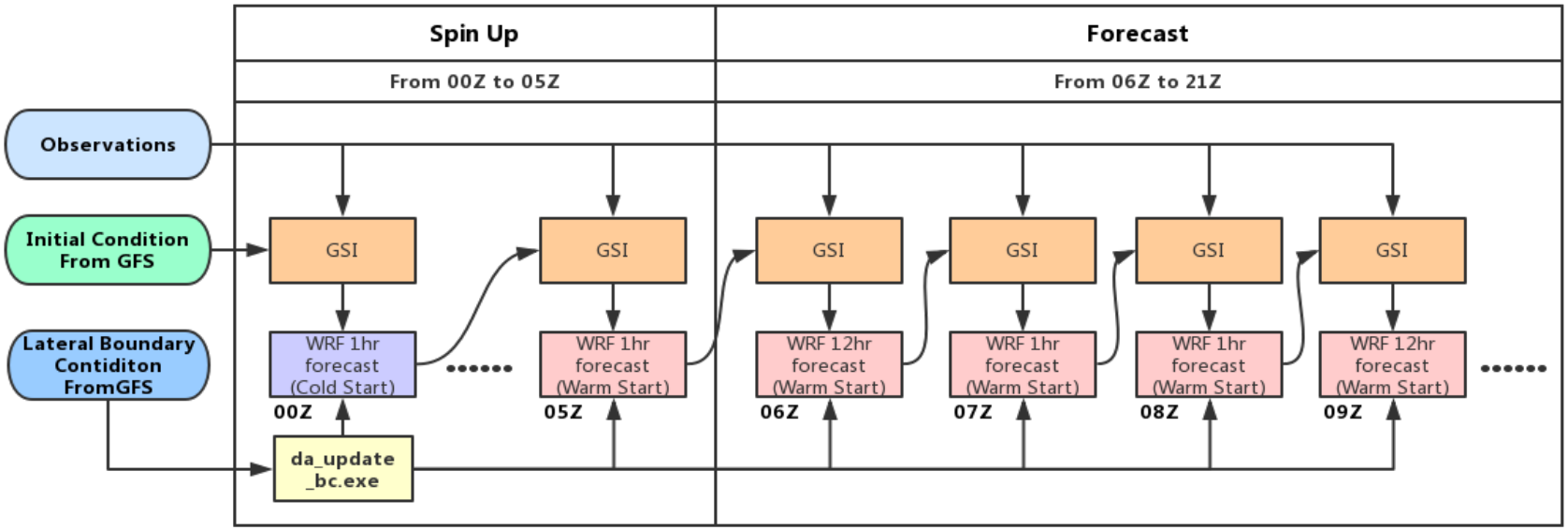




Operational Model for Assimilating PHSnABI

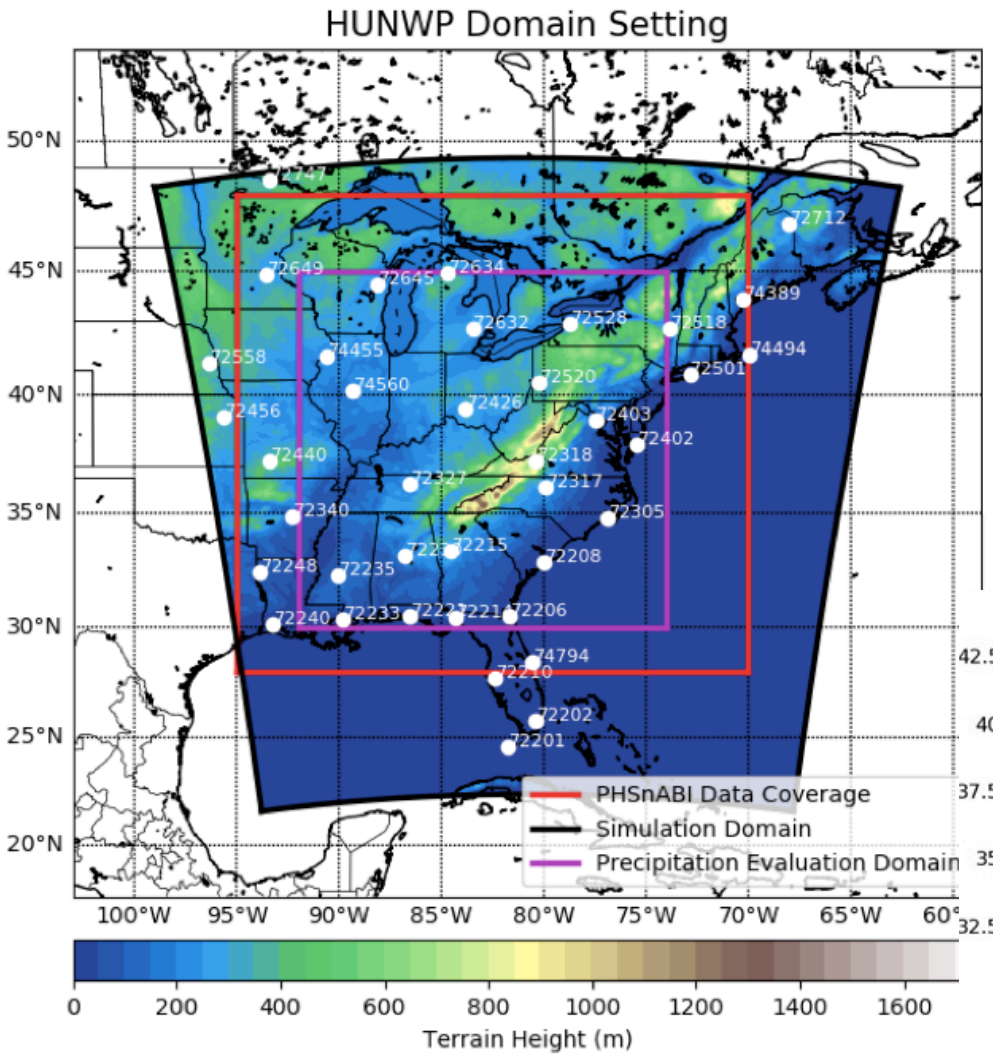
Qi Zhang

NOAA RAP-like Configured 9-Km WRF Model

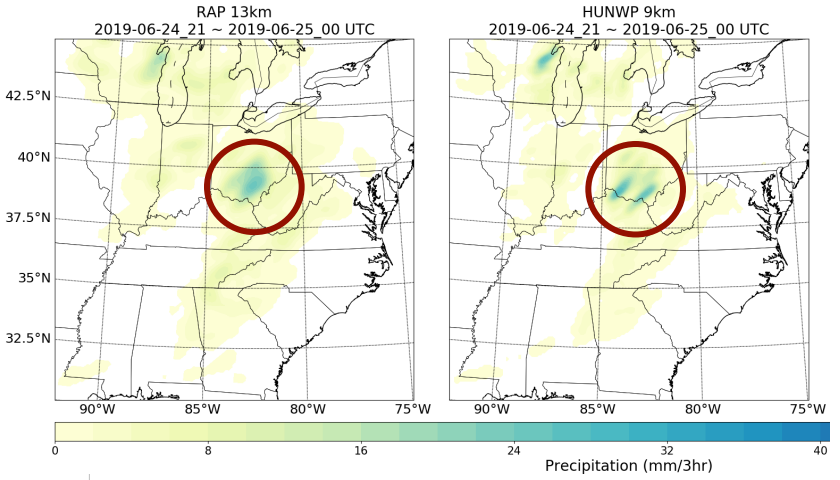


Daily RAP WRF PHSnABI NWP

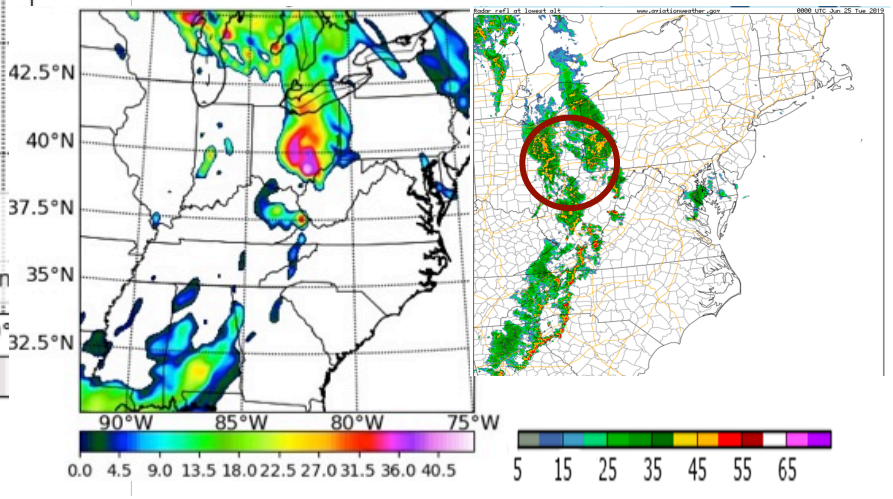
http://cas.hamptonu.edu/~qi.zhang/HUNWP_1.1.0_PHSnABI/



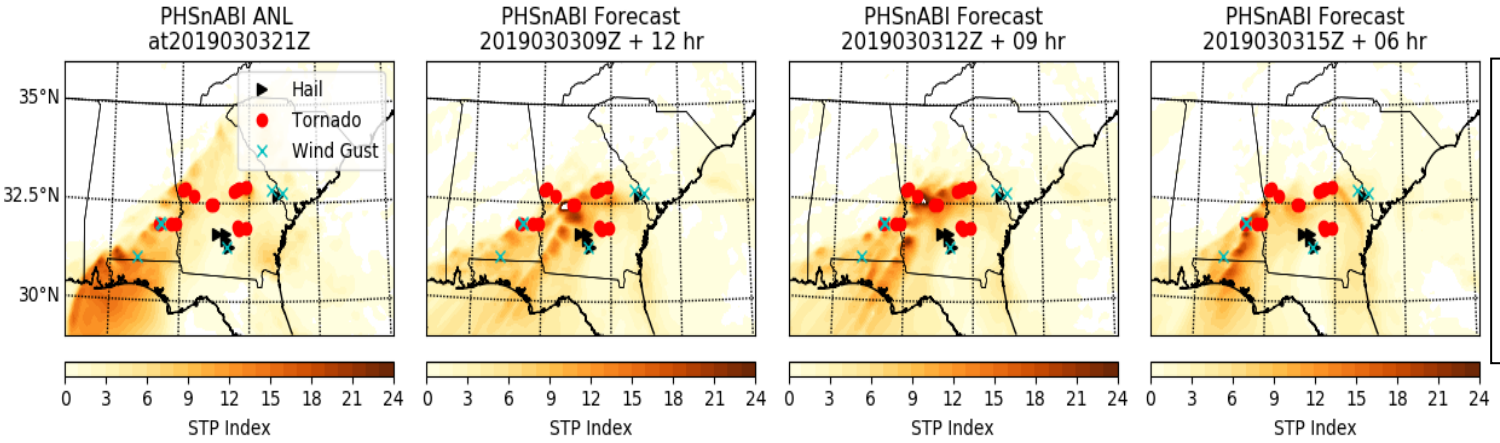
Today's (6/26) 00 UTC Forecast



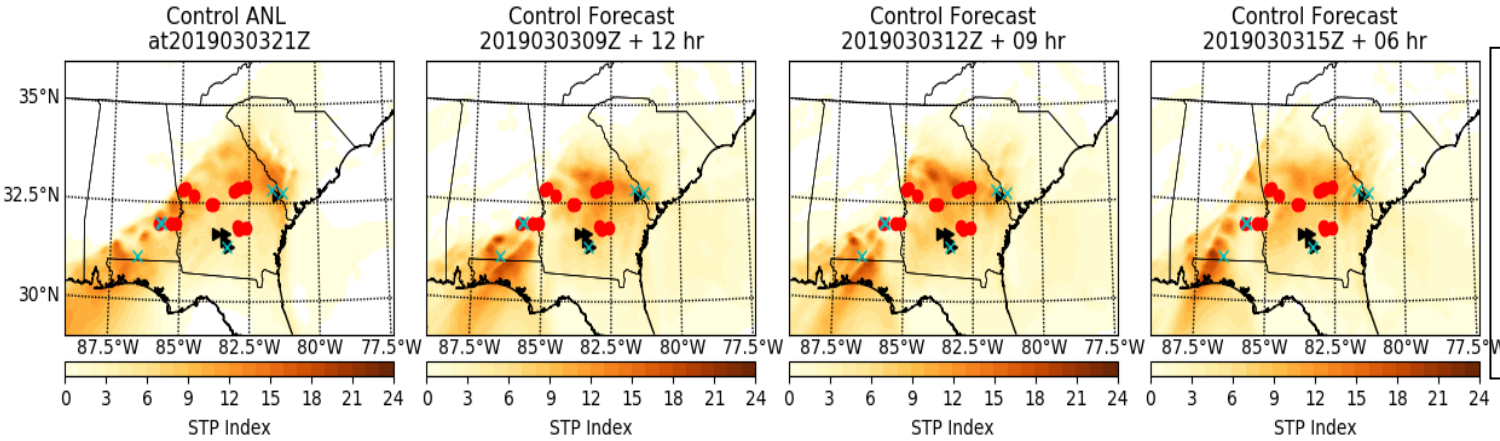
00 UTC FCST Max Ref 00:00 UTC Radar



HU DB Data Improved Forecasts for the SE US March 3, 2019 Tornado Outbreak



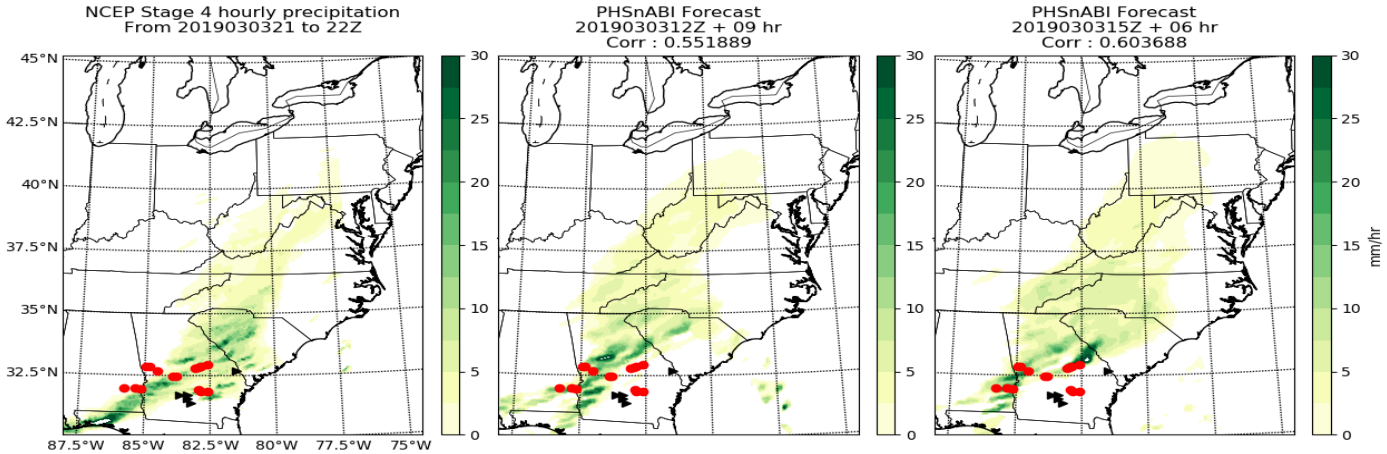
HU STP forecasts using satellite soundings (rust colors). Red dots show locations of 21-22 UTC tornadoes.



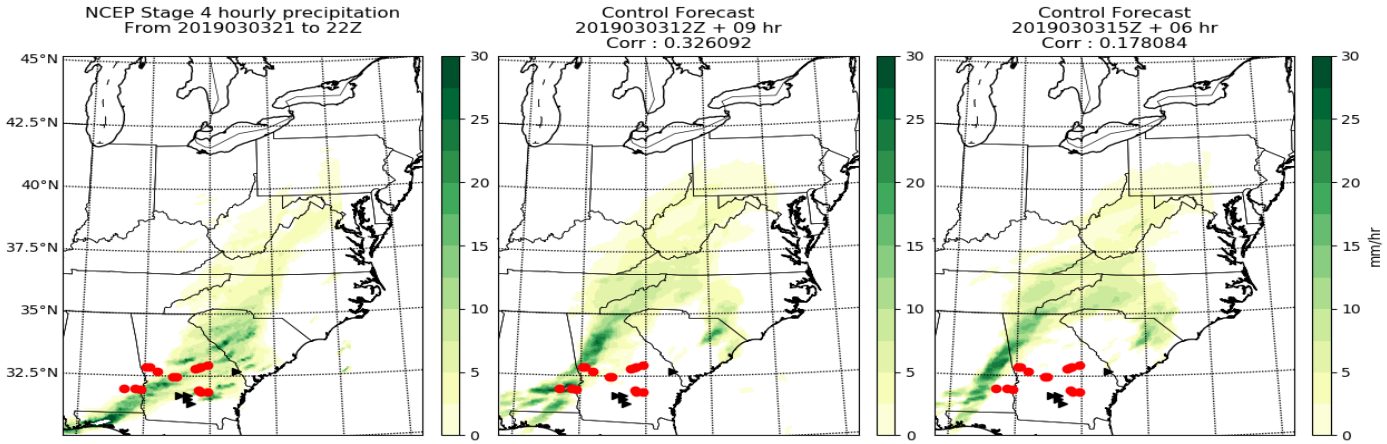
HU STP forecasts Without using satellite soundings (rust colors). Red dots show locations of 21-22 UTC tornadoes.

Tornado outbreak locations shown by red dots and HU 6, 9, and 12-hr forecasts of the Significant Tornado Parameter (STP) (rust colors) defined as the sum of the CAPE, 0-1 km storm relative helicity (vorticity), 0-6 km bulk wind difference, and surface parcel Lifting Condensation Level height. Intense convection and tornadoes can be expected where the STP is high.

HU DB Data Improved Forecasts for the SE US March 3, 2019 Tornado Outbreak



HU precipitation forecasts using satellite soundings (green and yellow colors). Red dots show locations of tornado outbreaks.

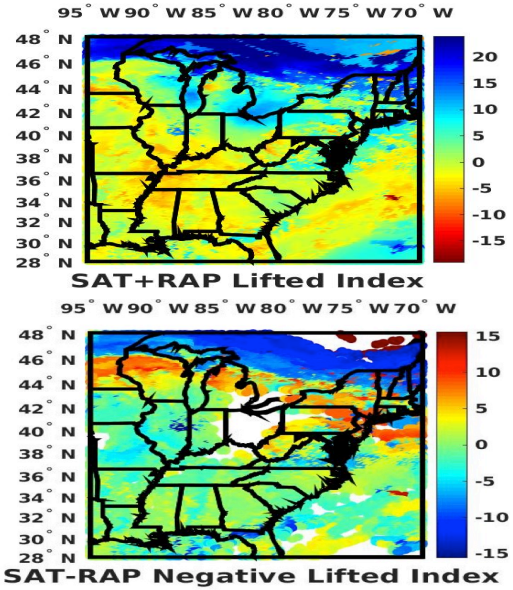


HU precipitation forecasts <u>Without</u> using satellite soundings (green and yellow colors). Red dots show locations of tornado outbreaks.

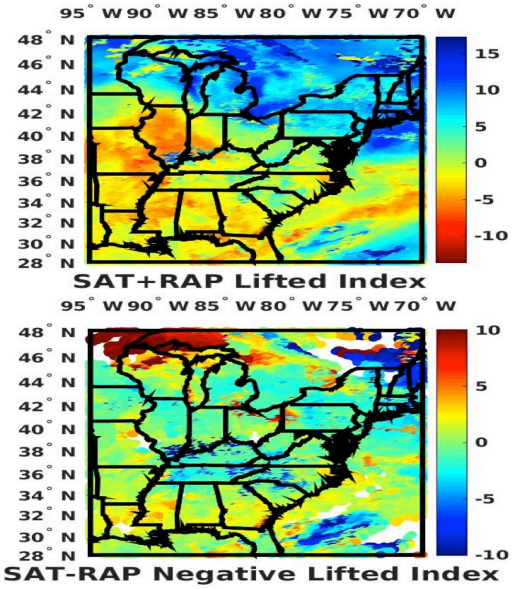
Tornado outbreak locations shown by red dots and HU 6, and 9-hr forecasts of 21 – 22 UTC precipitation (green and yellow colors). The much higher forecast skill of the HU satellite sounding initialized precipitation forecast can be seen by their comparison with surface and radar (Stage 4) hourly precipitation measurements shown by the panels on the left side of this figure.

Nowcasting the May 27/28 Tornado Outbreak

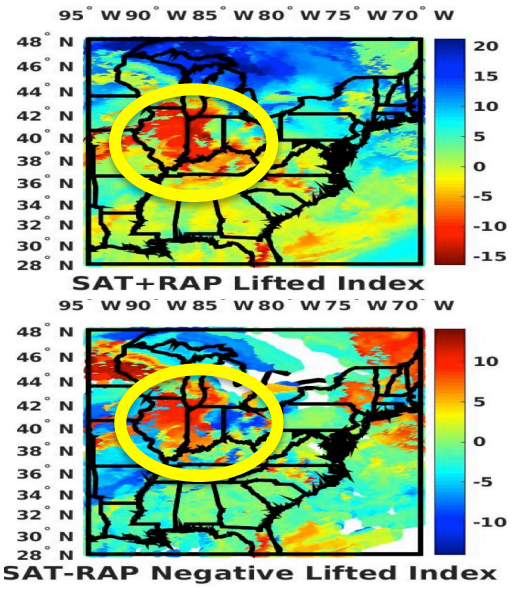
PHSnABI 2019-05-27 (160137 UTC)



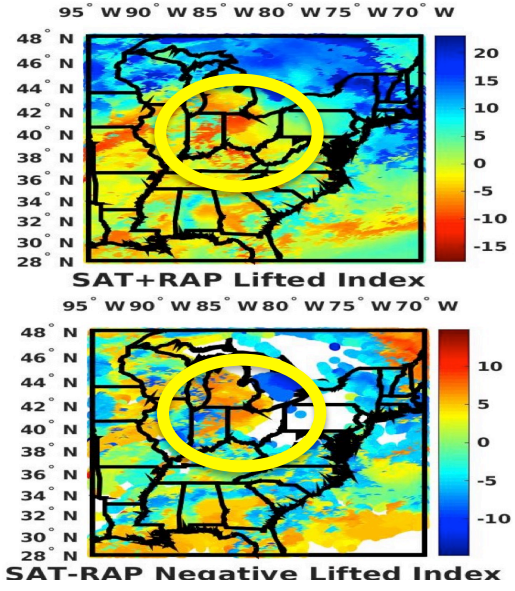
PHSnABI 2019-05-27 (195137 UTC)



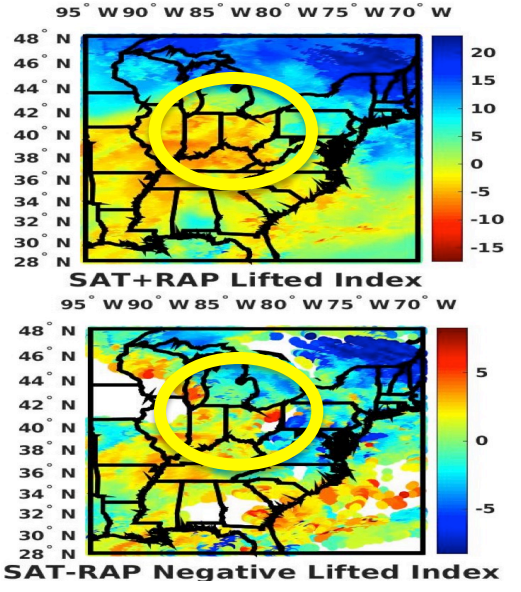
PHSnABI 2019-05-28 (011138 UTC)



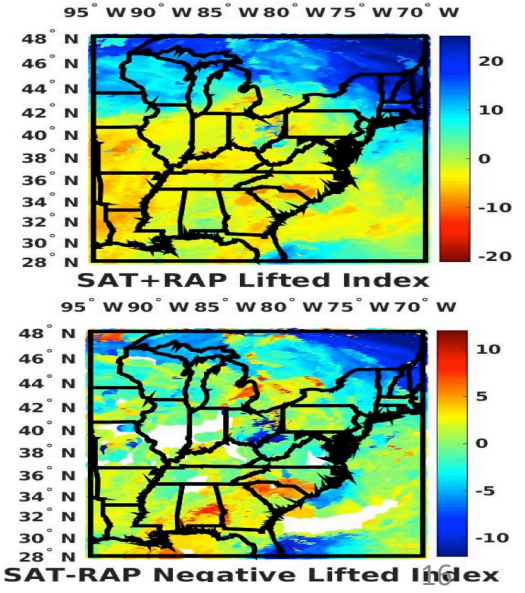
PHSnABI 2019-05-28 (062138 UTC)



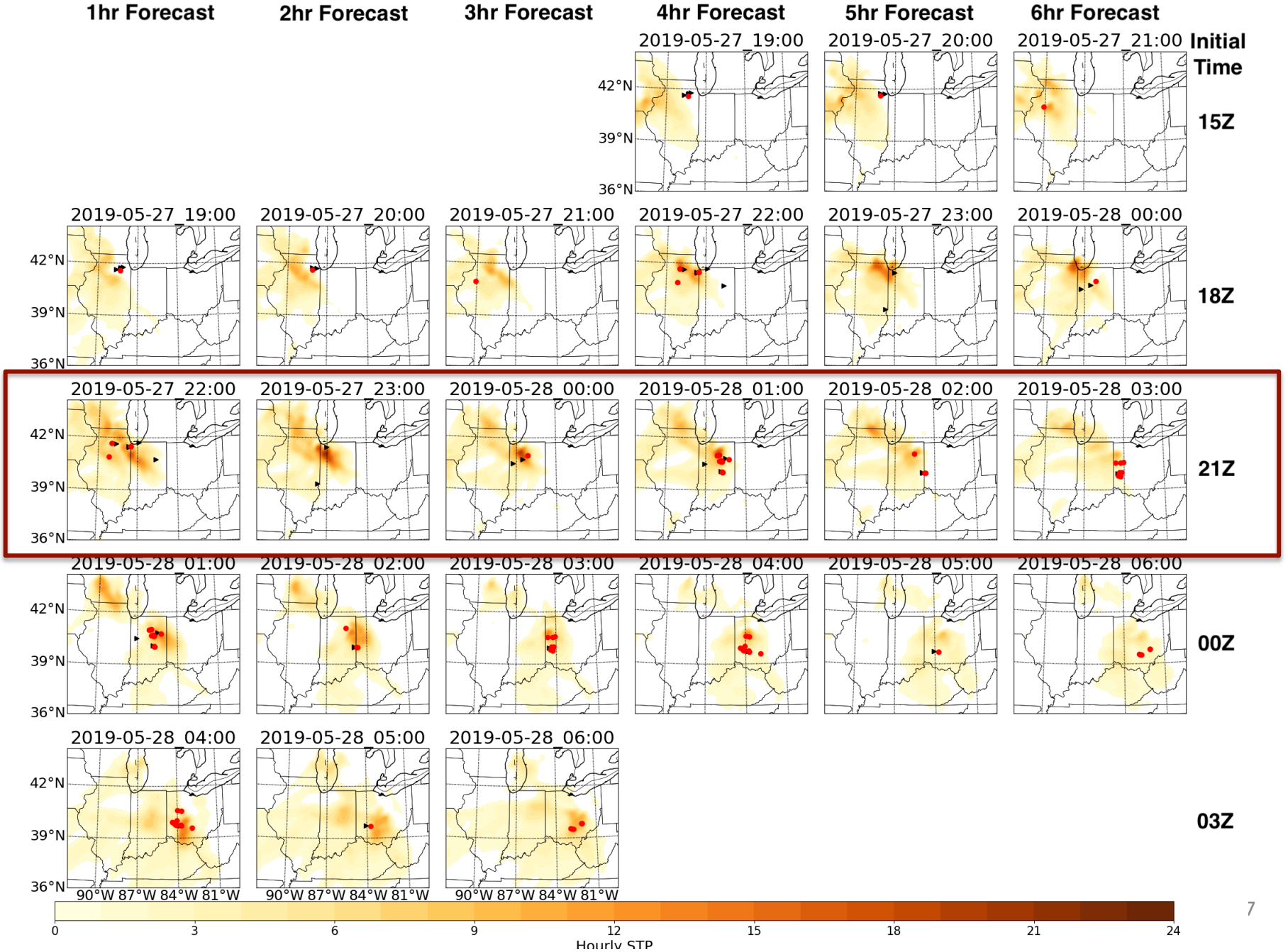
PHSnABI 2019-05-28 (080138 UTC)



PHSnABI 2019-05-28 (135638 UTC)

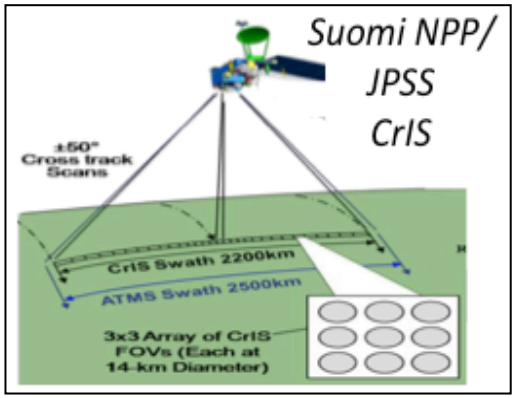


May 27/28 Upper Midwest Tornado Outbreak PHSnABI Forecast STP



Combining Polar & Geo Soundings with AHI Over China

- **PHSnAHI:**



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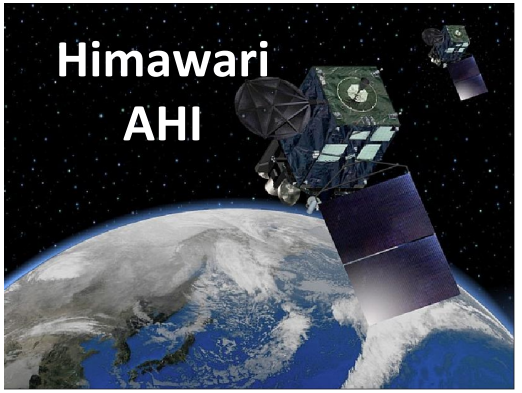
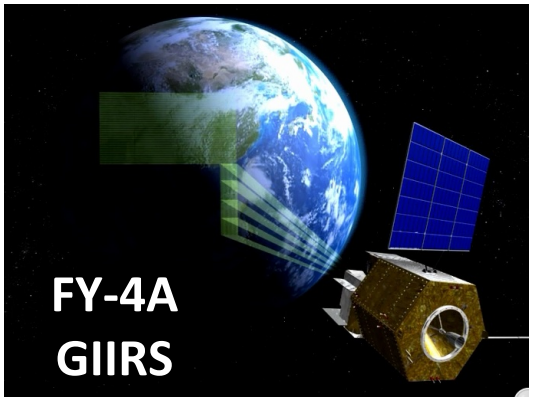


- **GHSnAHI:**



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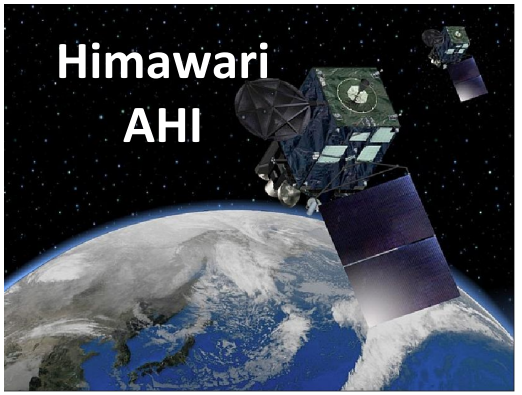


- **PHSnGHSnAHI: Combine 'PHS' with 'GHSnAHI'**

GIIRS

Designed & built at Shanghai Institute of Technical Physics
Launch date: FY4A, 11 December 2016

The First IR Hyperspectral Sounder in GEO!

Geo. Interferometric Infrared Sounder (GIIRS)

GIIRS is the first space-borne interferometer that flies in geostationary orbit to make measurements of three-dimensional atmospheric structure from interference by split light beams. Technically featuring a 32×4 sensor array plane, it is equipped with a Michelson interferometer working over different infrared bands for large-area, continuous, fast, and accurate vertical air sounding of temperature and humidity.

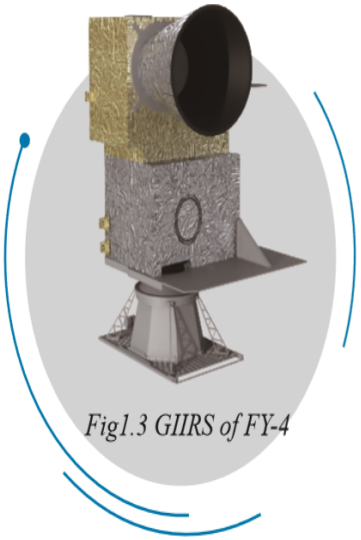


Fig1.3 GIIRS of FY-4

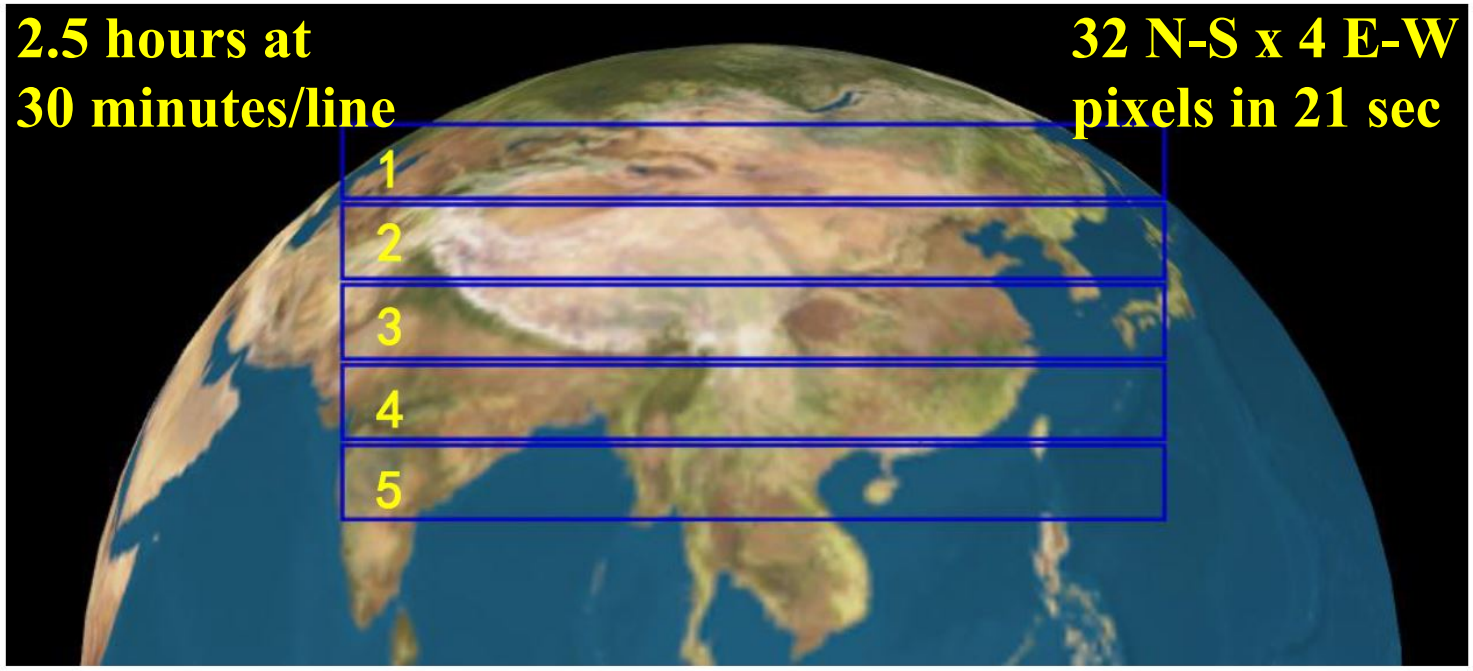
Table 1.4 Specifications of GIIRS

Working bands	**GIFTS-like spectra**	700-1130cm^{-1} (8.85-14.29μm) 1650-2250cm^{-1} (4.44-6.06μm)	
Spectral resolution	0.625cm^{-1} (actual measurement)		
Spectral channels	1650 (actual measurement)		
Spatial resolution	**16 km / pixel**	16km	**128 km E-W**
Temporal resolution	768km×960km (30min.) 4480km×5000km (60min.)		**640 km N-S**
Radiation calibration accuracy	1.5K		**in 21 sec**
Spectral calibration accuracy	10ppm		

from Revercomb SPIE Asia Pacific Remote Sensing, 2018

Sample data

15°N~55°N， 70°E~140°E:China and its surrounding areas

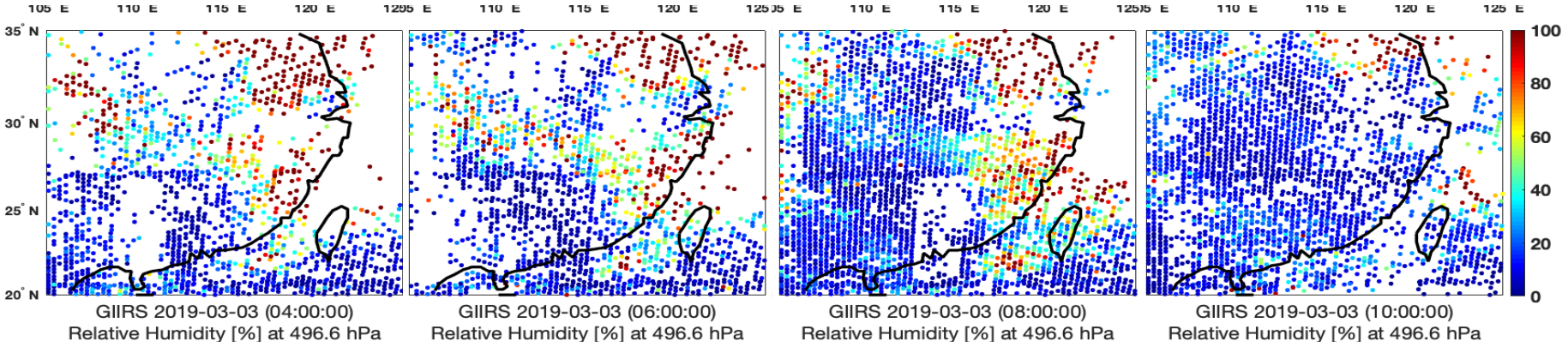


- atmospheric sounding interferometer's motion mode is "big step": There are 5 lines, every lines has 54 dwell points, altogether 270 dwell points;
- Each line is divided into two tasks, the first tasks has 28 dwell points, and the second task has 26 dwell points;
- Each dwell point resident 16 frames ,each frame has 1.3 sec， altogether 21 sec;
- There are 5 lines , 10 tasks. Every task takes 15 minutes,2.5hours。

Qifeng LU (NSMC/CMA)

2-hr interval GIIRS & GIIRS + AHI Combined Soundings March 3, 2019 (04:00 to 10:00 UTC)

GIIRS 500 hPa Relative Humidity



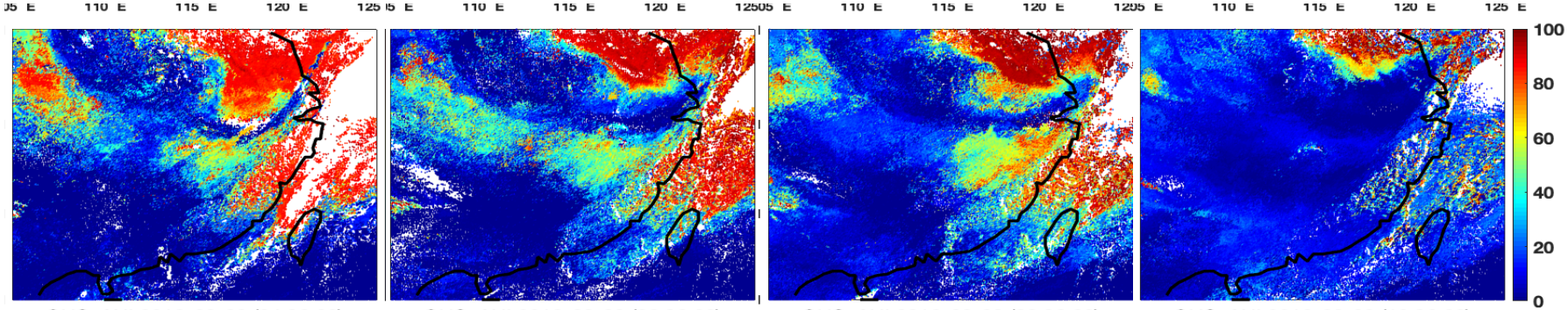
GIIRS 2019-03-03 (04:00:00) Relative Humidity [%] at 496.6 hPa

GIIRS 2019-03-03 (06:00:00) Relative Humidity [%] at 496.6 hPa

GIIRS 2019-03-03 (08:00:00) Relative Humidity [%] at 496.6 hPa

GIIRS 2019-03-03 (10:00:00) Relative Humidity [%] at 496.6 hPa

GIIRS + AHI 500 hPa Relative Humidity



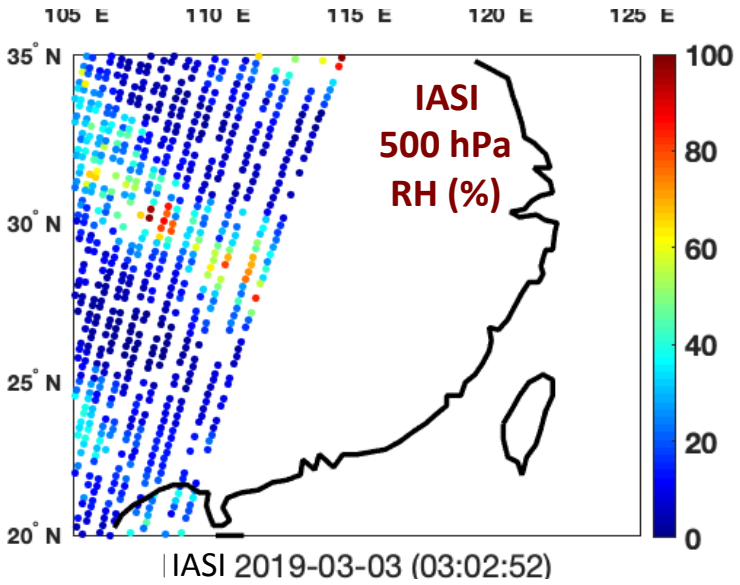
GHSnAHI 2019-03-03 (04:30:00) Relative Humidity [%] at 496.6 hPa

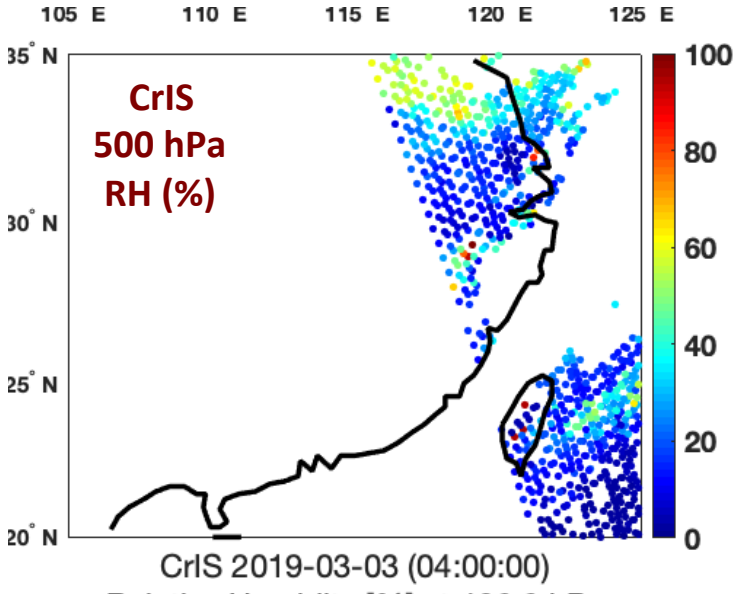
GHSnAHI 2019-03-03 (06:30:00) Relative Humidity [%] at 496.6 hPa

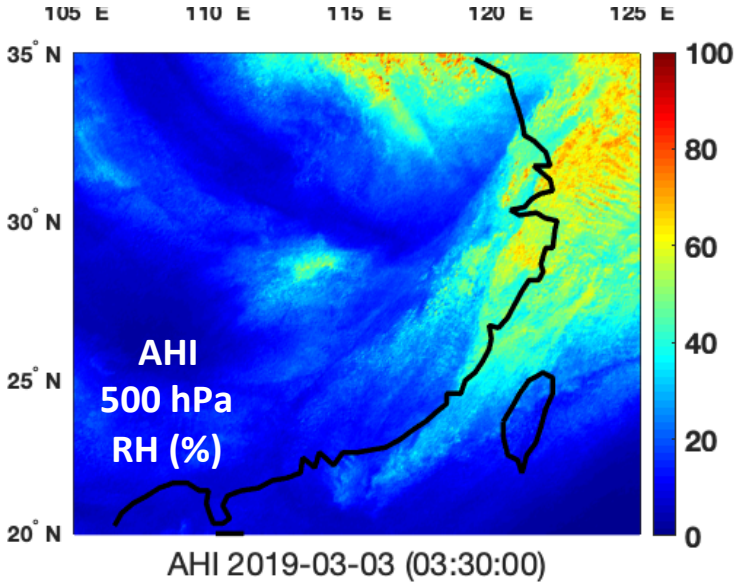
GHSnAHI 2019-03-03 (08:30:00) Relative Humidity [%] at 496.6 hPa

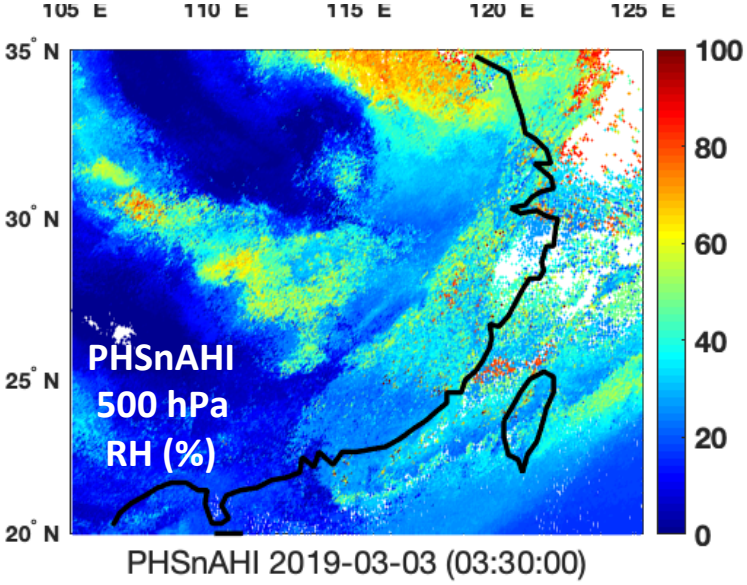
GHSnAHI 2019-03-03 (10:30:00) Relative Humidity [%] at 496.6 hPa

PHSnAHI

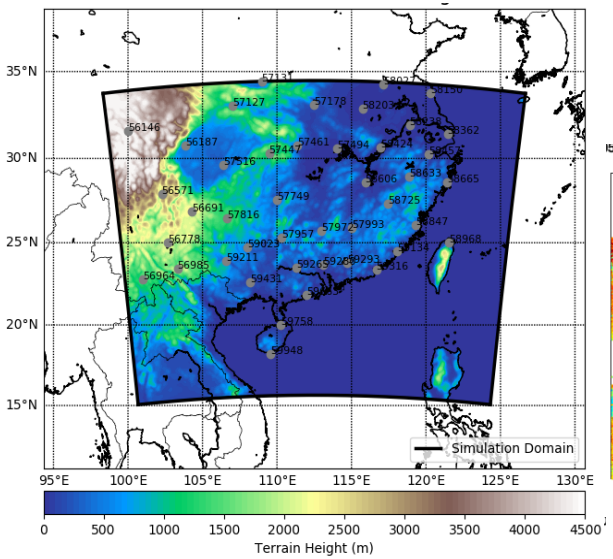

105 E
110 E
115 E
120 E
125 E
35° N
30° N
25° N
20° N
IASI
500 hPa
RH (%)
100
80
60
40
20
0
IASI 2019-03-03 (03:02:52)


105 E
110 E
115 E
120 E
125 E
35° N
30° N
25° N
20° N
CrIS
500 hPa
RH (%)
100
80
60
40
20
0
CrIS 2019-03-03 (04:00:00)

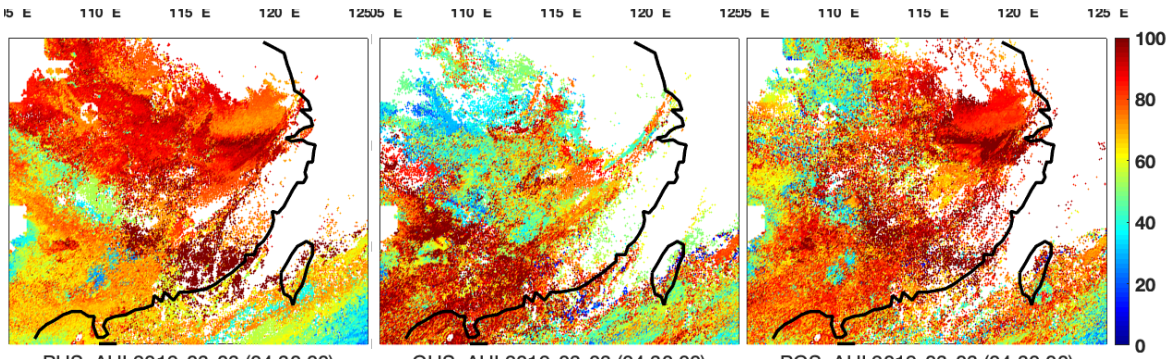

105 E
110 E
115 E
120 E
125 E
35° N
30° N
25° N
20° N
AHI
500 hPa
RH (%)
100
80
60
40
20
0
AHI 2019-03-03 (03:30:00)


105 E
110 E
115 E
120 E
125 E
35° N
30° N
25° N
20° N
PHSnAHI
500 hPa
RH (%)
100
80
60
40
20
0
PHSnAHI 2019-03-03 (03:30:00)

Forecast Model Domain



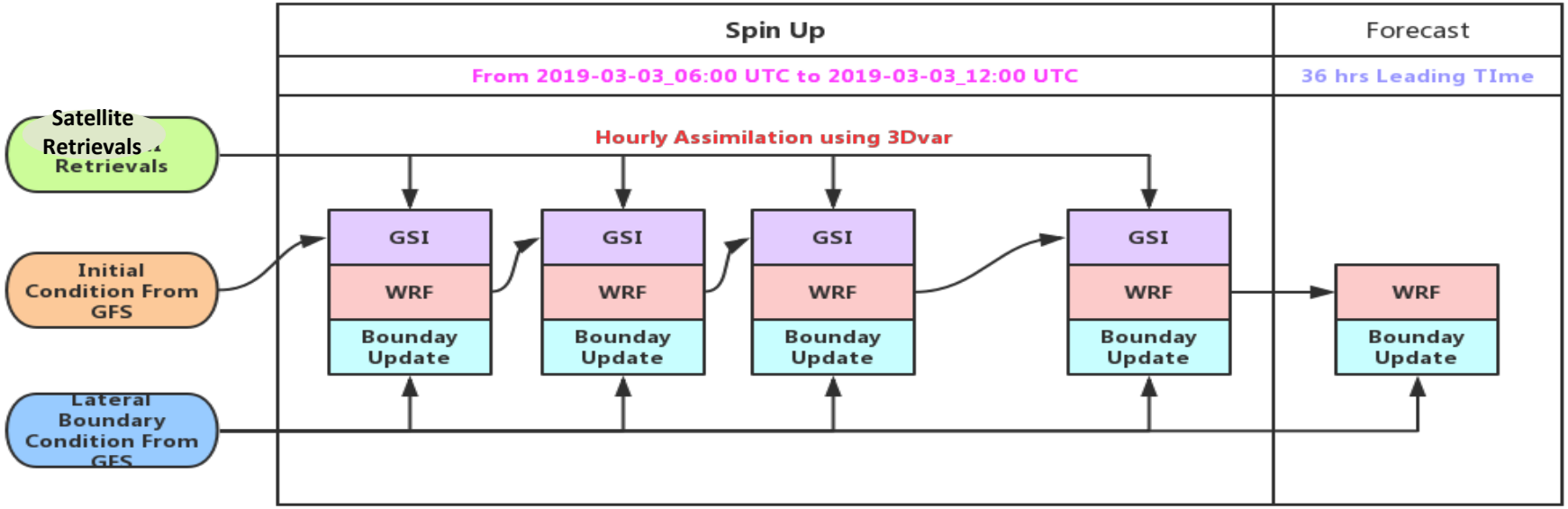
Forecast Model Set-up For March 3-4 Southeast China WRF Model Numerical Forecasts Using Polar + Geostationary Satellite Data



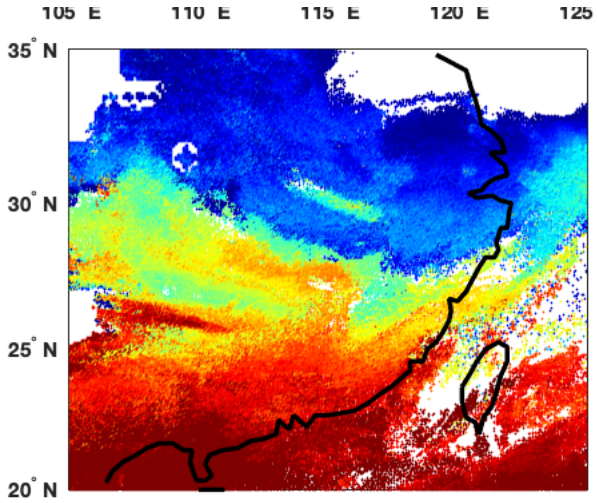
PHSnAHI 2019-03-03 (04:30:00)
Relative Humidity [%] at 852.8 hPa

GHSnAHI 2019-03-03 (04:30:00)
Relative Humidity [%] at 852.8 hPa

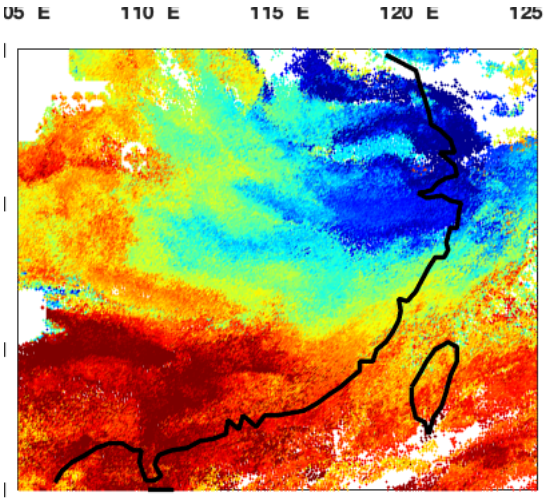
PGSnAHI 2019-03-03 (04:30:00)
Relative Humidity [%] at 852.8 hPa



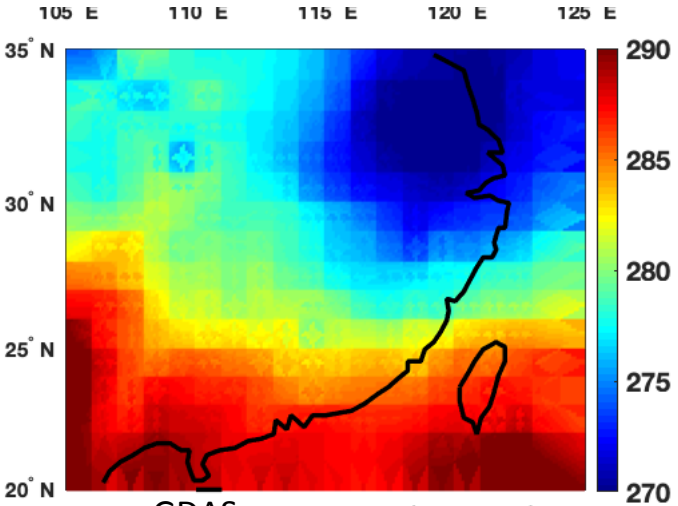
March 3, 2019 11:30 UTC - Latest Soundings Used for WRF Model Initialization @ 12 UTC



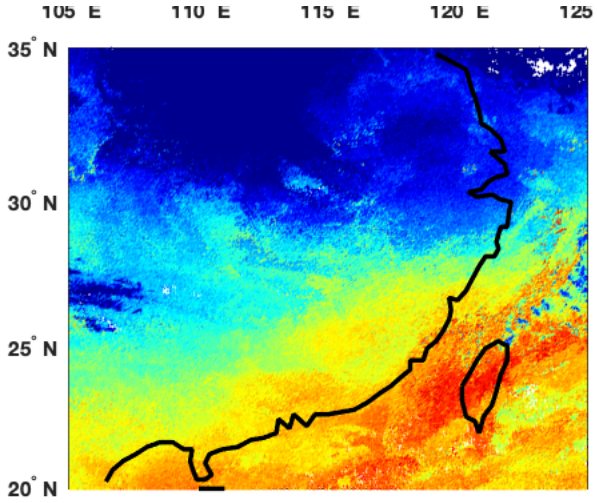
PHSnAHI 2019-03-03 (11:30:00)
Temperature [K] at 852.8 hPa



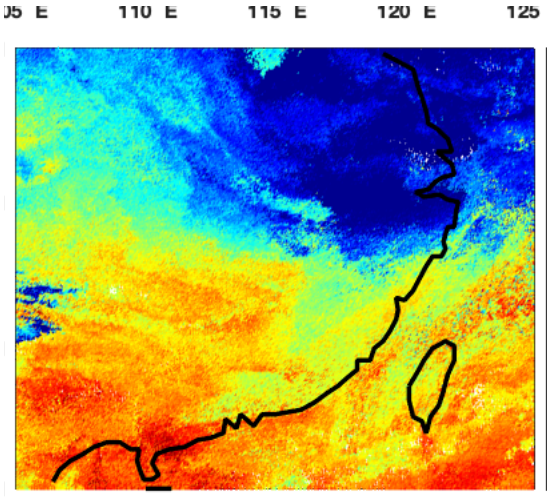
GHSnAHI 2019-03-03 (11:30:00)
Temperature [K] at 852.8 hPa



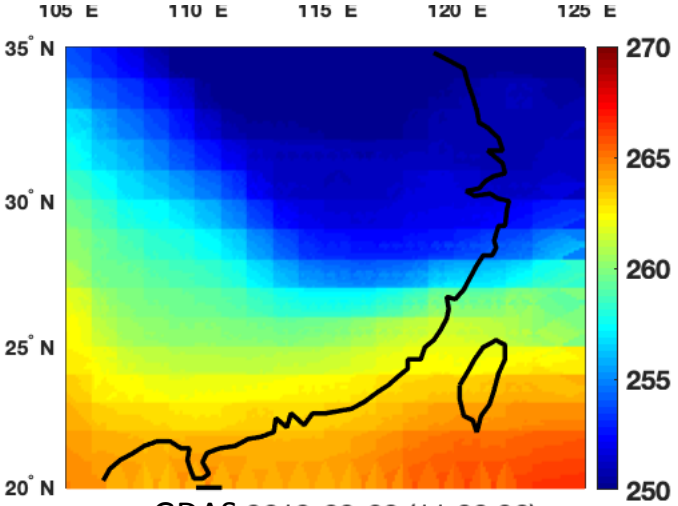
GDAS 2019-03-03 (11:30:00)
GDAS Temperature [K] at 852.8 hPa



PHSnAHI 2019-03-03 (11:30:00)
Temperature [K] at 496.6 hPa

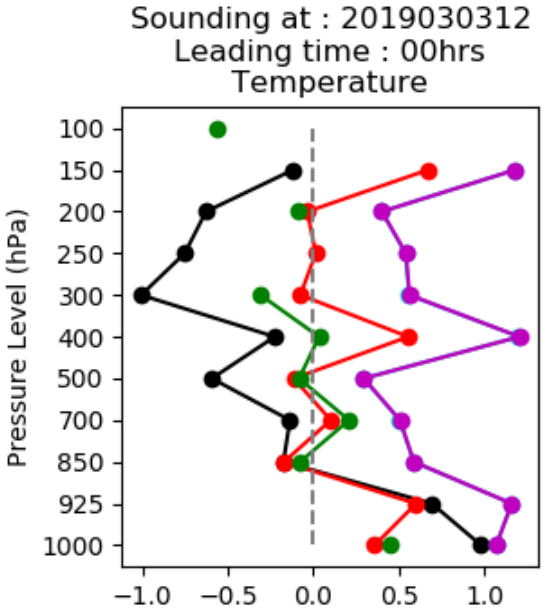


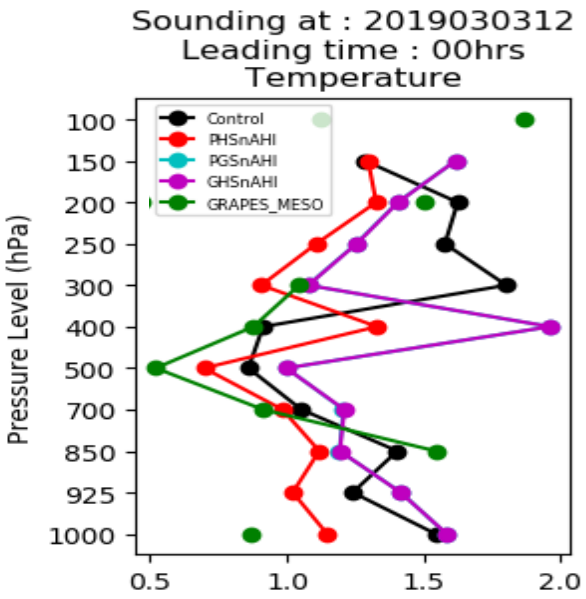
GHSnAHI 2019-03-03 (11:30:00)
Temperature [K] at 496.6 hPa

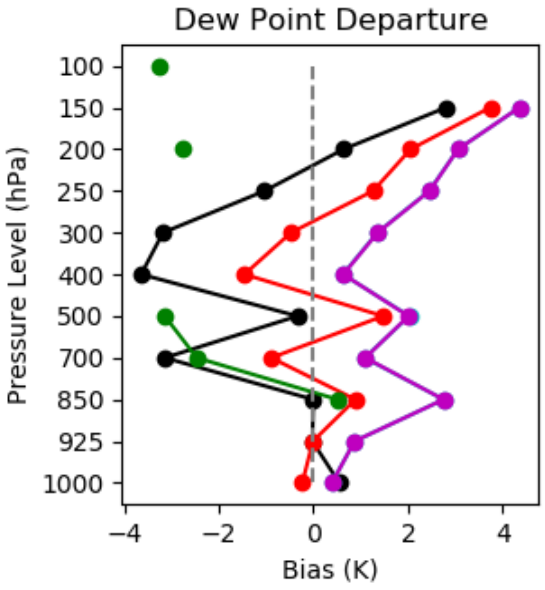


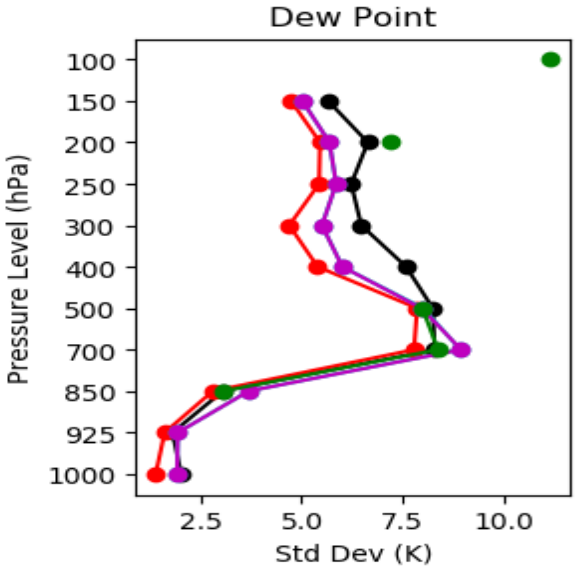
GDAS 2019-03-03 (11:30:00)
GDAS Temperature [K] at 496.6 hPa

Bias & STD From Radiosondes



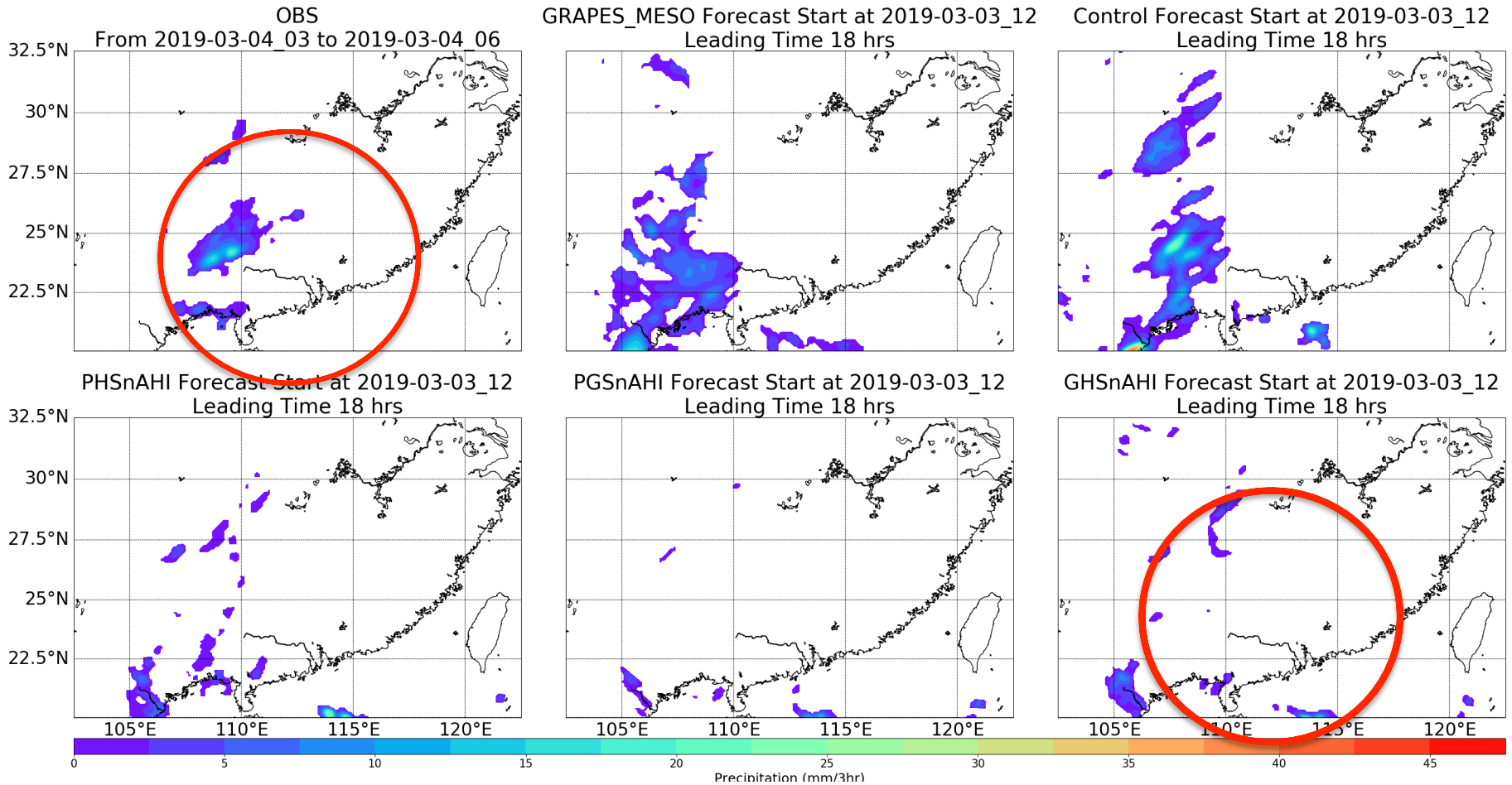






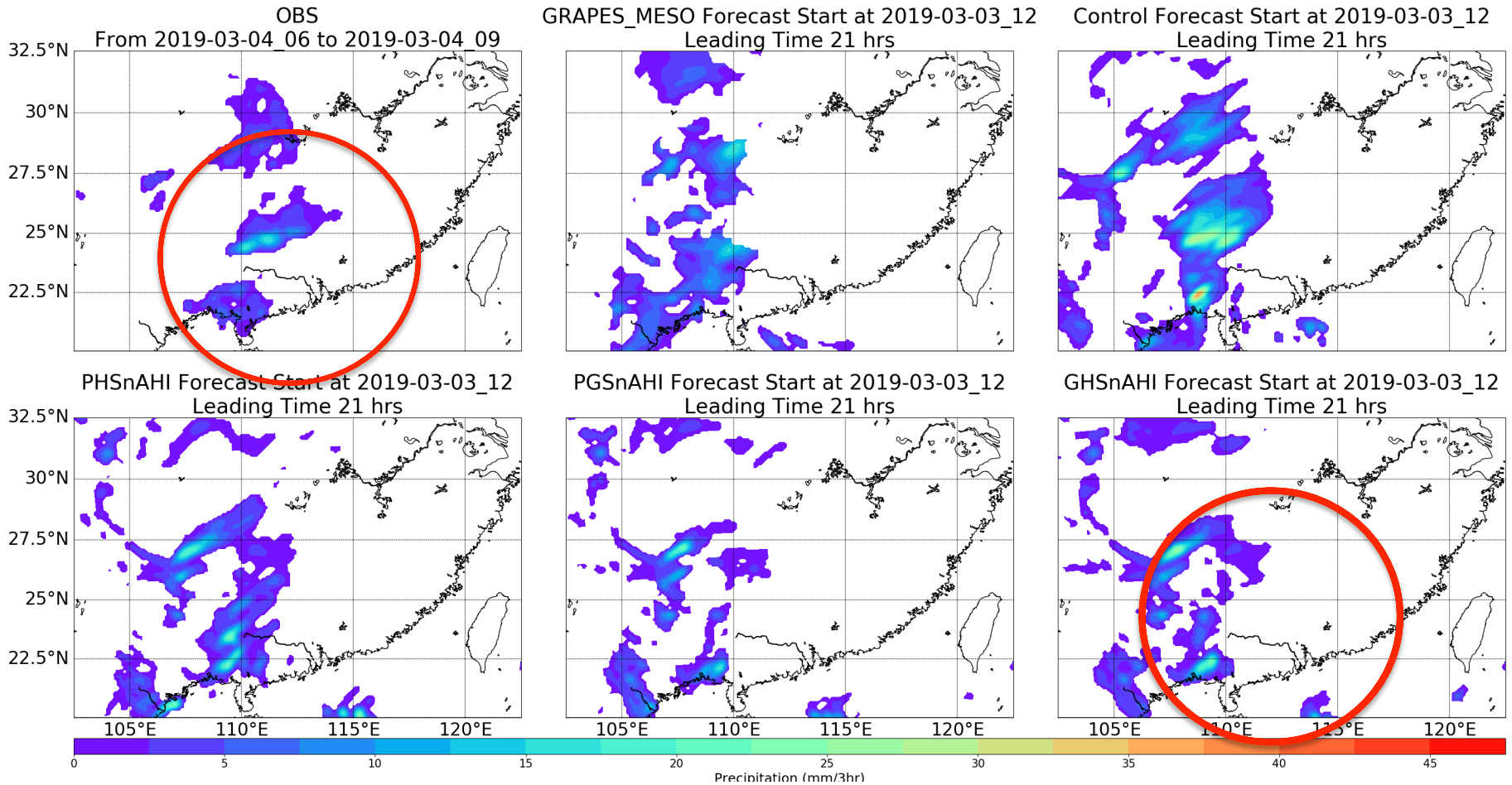
21 Hour Forecast

12 UTC on 3/3/19 to 9 UTC on 3/4/19



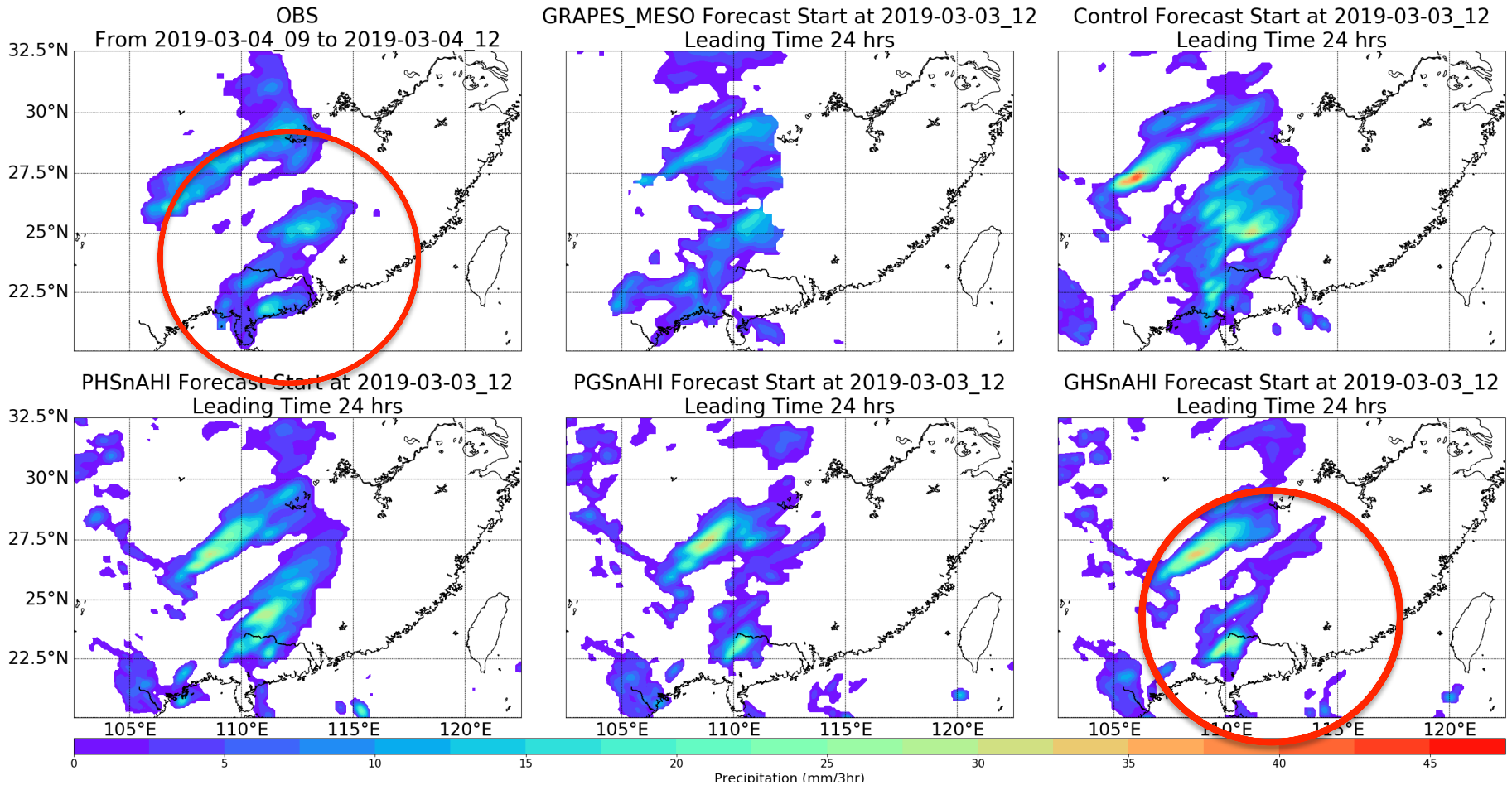
24 Hour Forecast

12 UTC on 3/3/19 to 12 UTC on 3/4/19



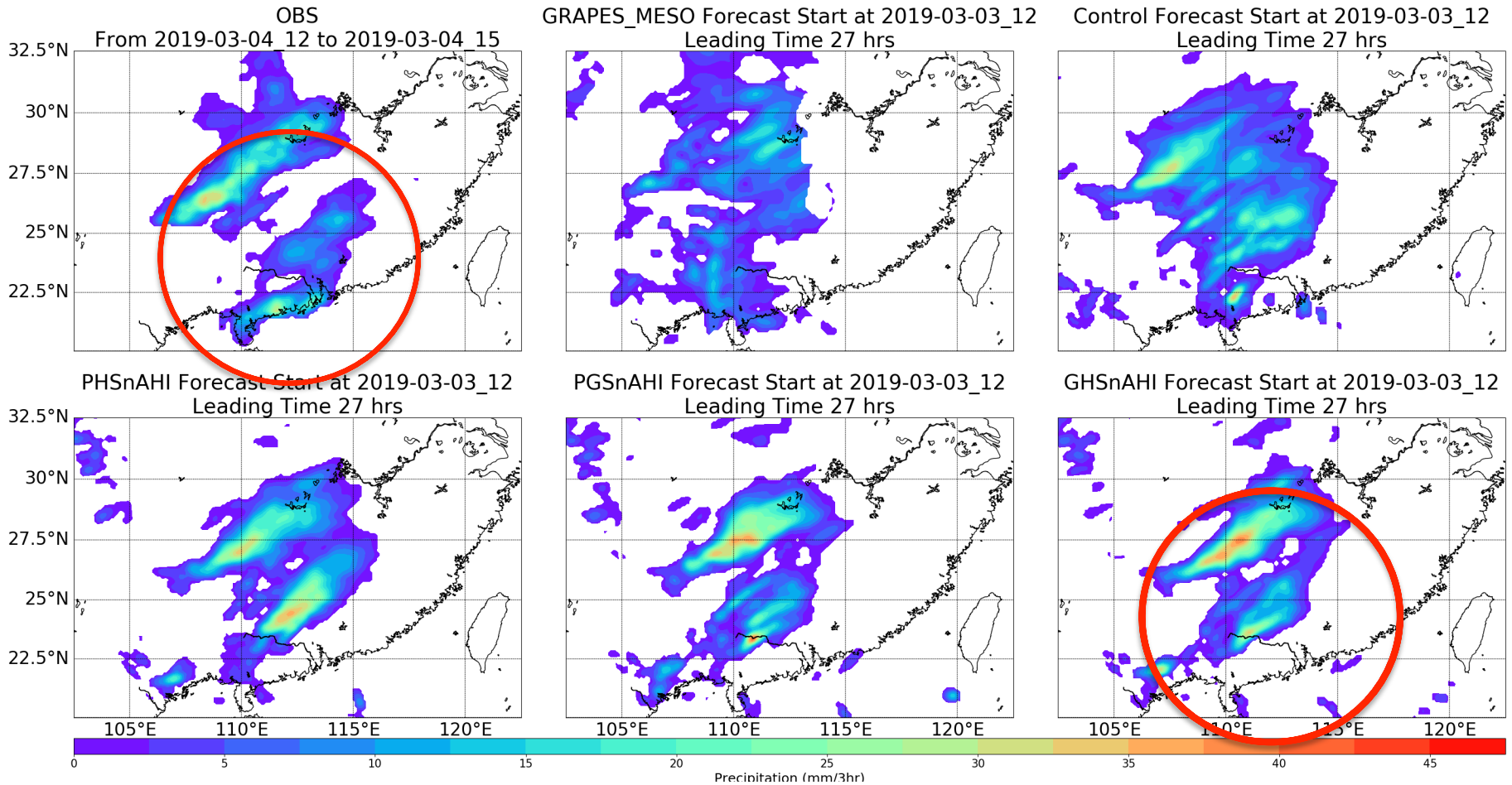
27 Hour Forecast

12 UTC on 3/3/19 to 18 UTC on 3/4/19



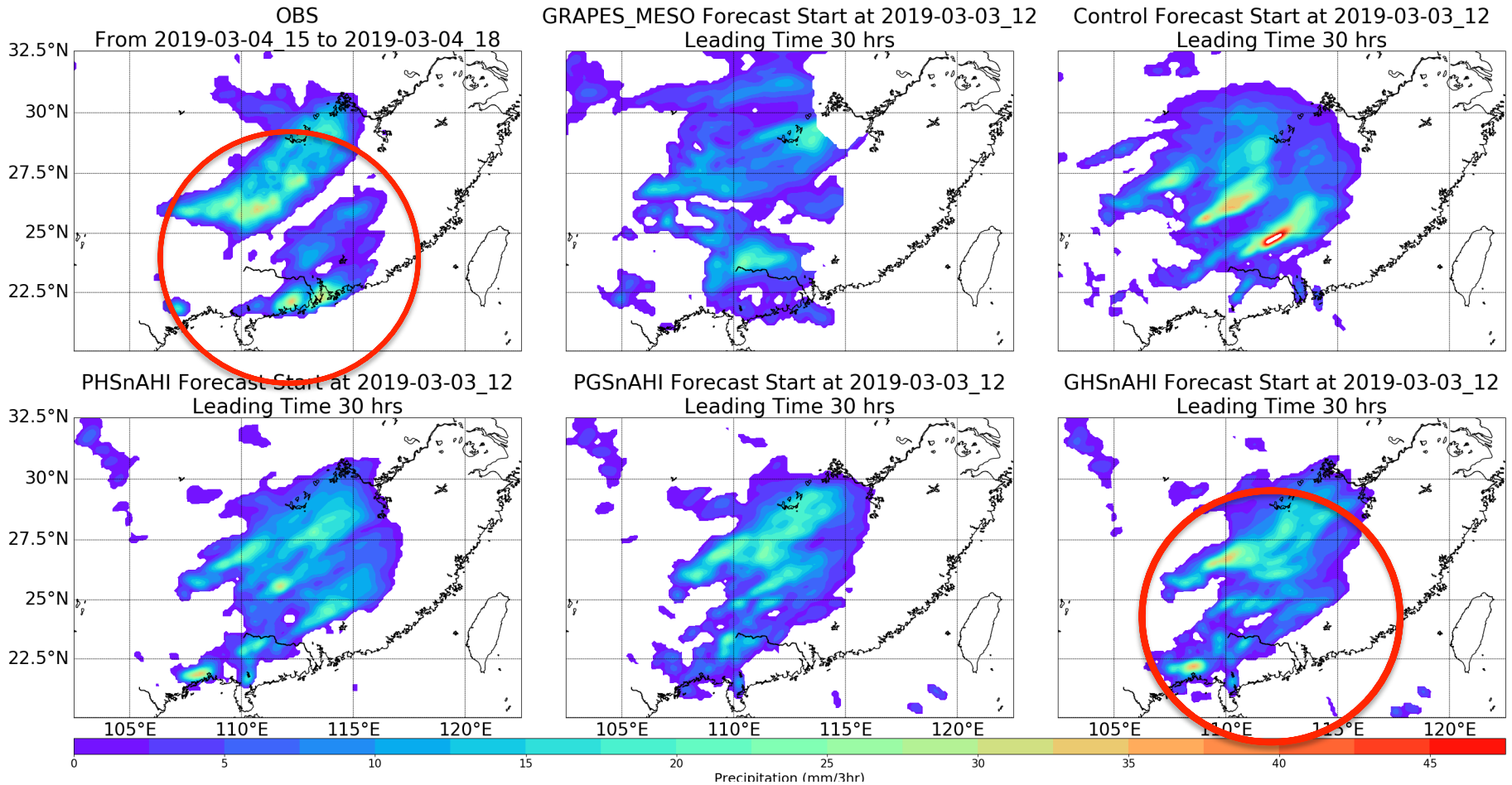
30 Hour Forecast

12 UTC on 3/3/19 to 21 UTC on 3/4/19



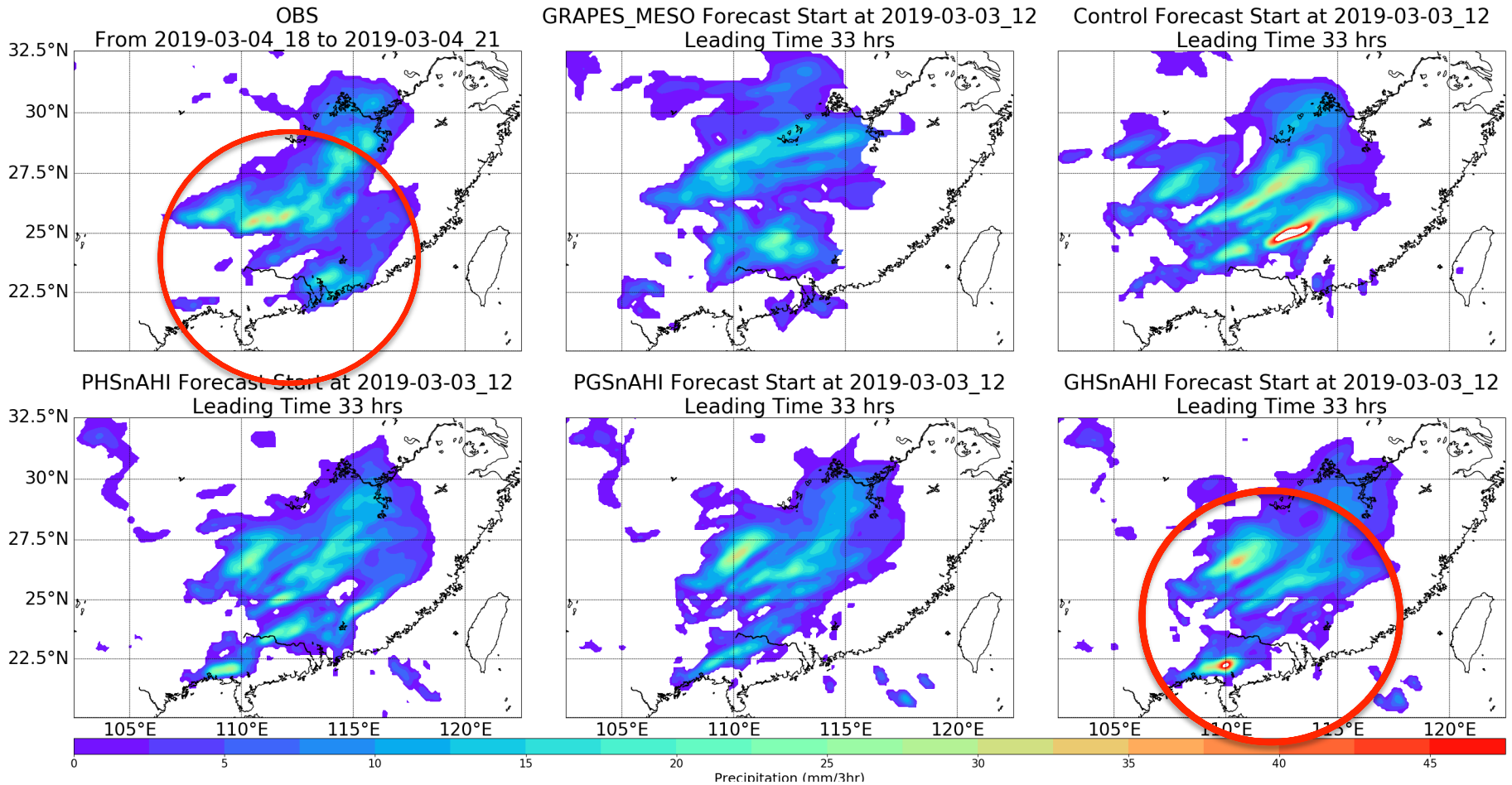
33 Hour Forecast

12 UTC on 3/3/19 to 24 UTC on 3/4/19

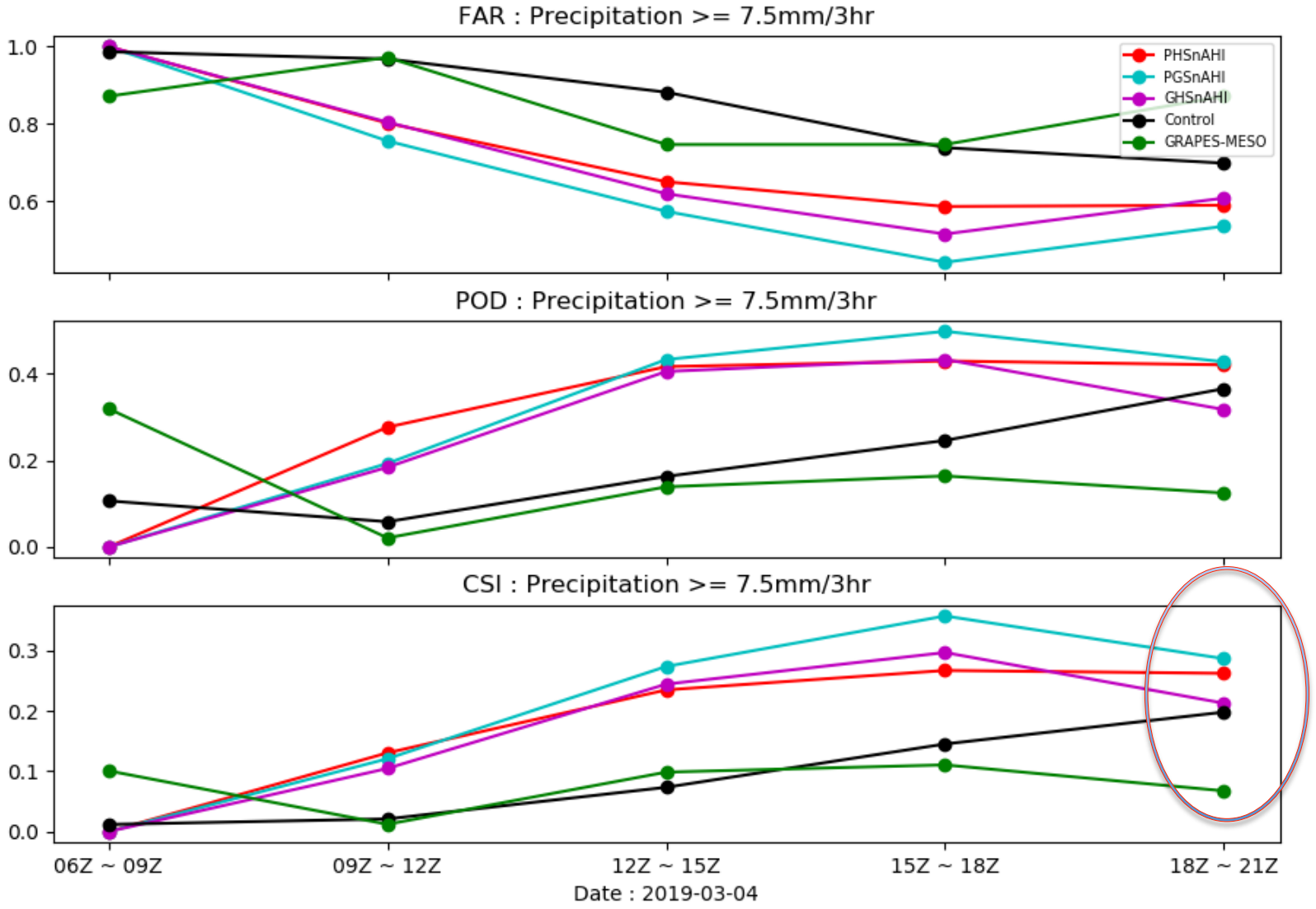


33 Hour Forecast

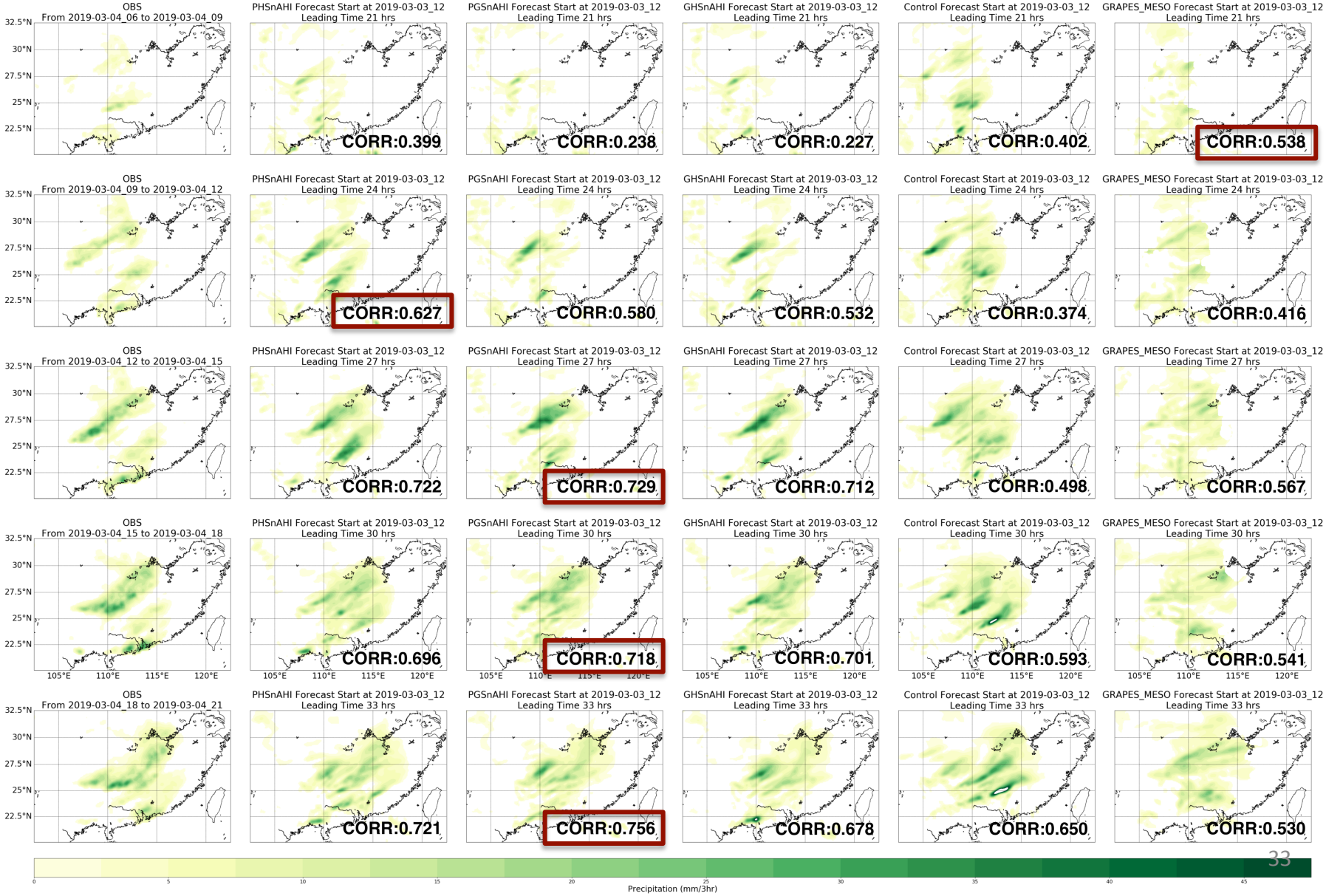
12 UTC on 3/3/19 to 24 UTC on 3/4/19



3-hr Accumulated Precipitation False Alarm (FAR), Probability of Detection (POD) and Critical Success Index (CSI)



Accumulated Precipitation from 09Z to 21Z Vs. 'PHSnAHI', 'PGSnAHI', 'GHSnAHI', 'Control' and 'GRAPES-MESO' forecasts



Summary

- To critically ***benefit convective weather forecasts***, improved atmospheric soundings are derived by combining direct-broadcast (DB) polar hyperspectral (PHS) measurements (i.e., CrIS and IASI onboard JPSS and Metop platforms, respectively) with geostationary multi-spectral ABI imagery observations.
- The high spatial and temporal resolution ***PHSnABI sounding products are being assimilated in NOAA RAP/HRRR-like models*** to demonstrate their value for improving NWP. ***Hurricane, tornado, and daily weather forecast applications show promising results.***
- In order to obtain the full information content advantage of the radiance data, de-aliased **sounding retrievals** obtained using all the spectral channel radiances, for both clear and cloudy conditions, over land as well as over sea, are assimilated.
- ***Refinements of GIIRS Calibration will increase the impact of these data on NWP***
- ***The Imager/Sounder Retrieval fusion technique can be applied to China's FY-3D HIRAS, and FY-4A GIIRS and AGRI data. The Geo-Hyperspectral Data fill in important space and time gaps in the polar hyperspectral data.***