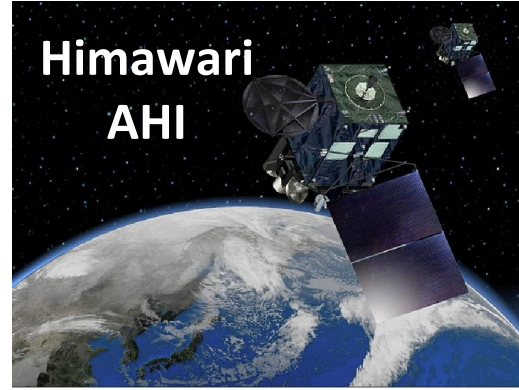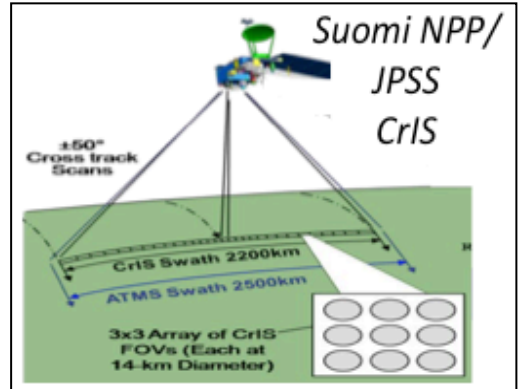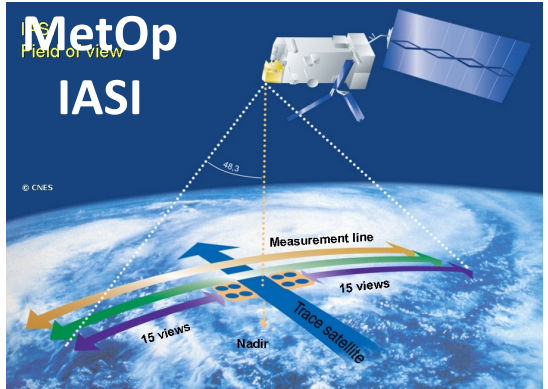# Combined Polar Hyper-spectral (PHS) and Geo-multispectral (ABI) Data - Demonstration of the Need for a Geo-Hyperspectral Sounder

W. Smith Sr.[1,2], R. Knuteson[1], H. Revercomb[1], E. Weisz[1,], Q. Zhang[3]
[1]U. of Wisconsin (USA), [2]Hampton U. (USA), [3]Nanjing U. (China)
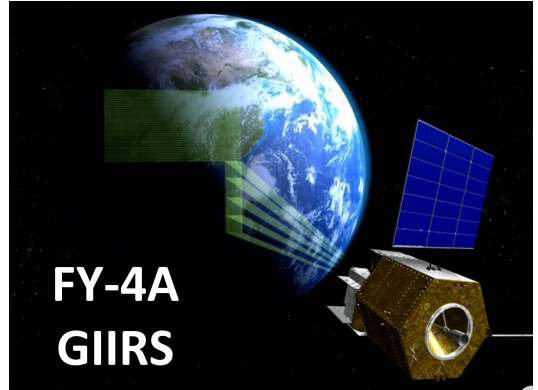
Optimizing Time and Spatial Resolution
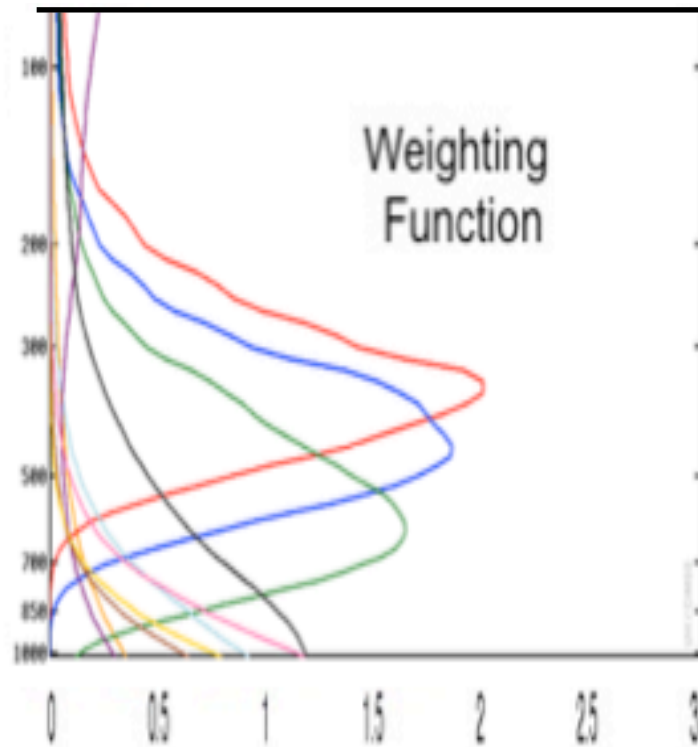
Geo-Multi-spectral ABI
Vertical Res. 5-10 km
Horizontal Res. 2-km
Time Res. 5-15 min.
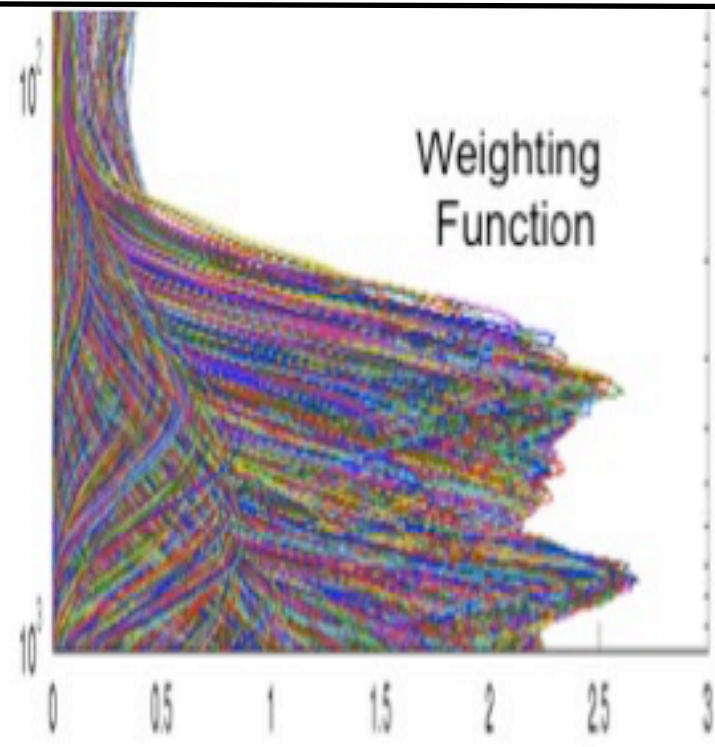
PHS IASI/CrIS
Vertical Res. 1-2 km
Horizontal Res. 14-km
Time Res. 50 min-7 hr.

Single FOV Retrieval Methodology

Dual EOF Regression (DR) for PHS (15-km)

- Accounts for Trace Gases, Clouds, Surface Emissivity/Skin-temperature in the regression training

- Uses "all" spectral channels (i.e., 50 PCs) to optimize S/N

- Accurate cloud heights, profiles above cloud & below thin and scattered cloud (Effective OPD<1.5)

- Vertical de-aliasing for NWP Data Assimilation

    (Alias=FB Calc. Radiance Retrieval − FB Profile)

Clear-sky Regression for Multi-spectral ABI (2-km)

- Clear 2-km FOVs only

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 = Simulated Radiance Retrieval Profile − Forecast Profile

Final Retrieval = DR Retrieval − Vertical Alias
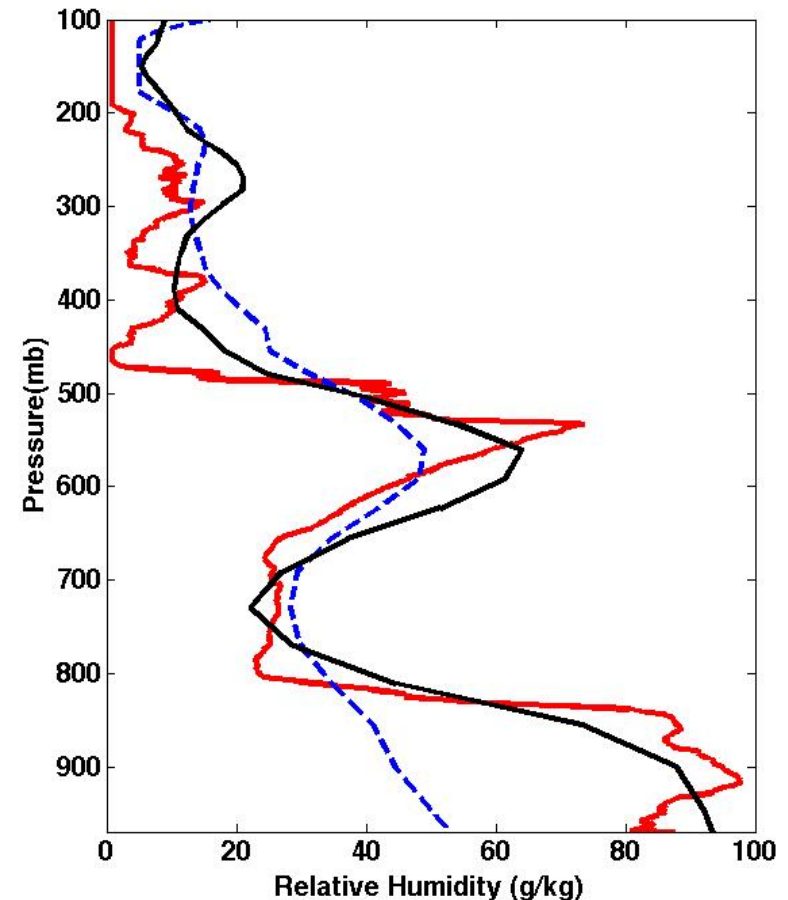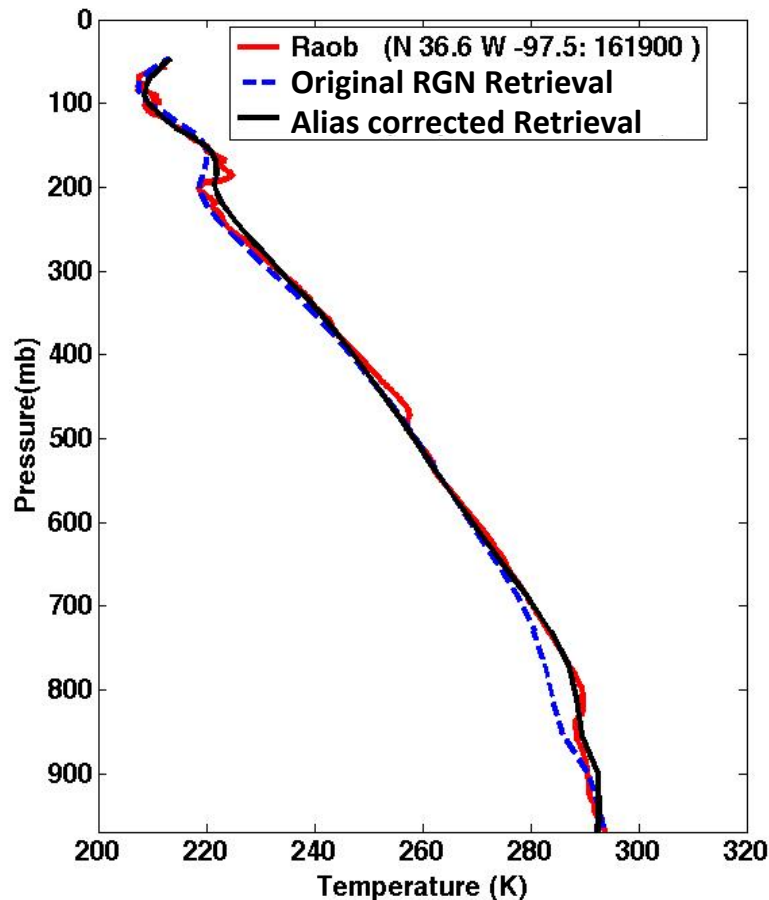
Fusion of PHS and ABI Soundings

Produce LoresABI

HiresABI Geo-location

PHS Geo-location

Co-location & Lores Geographical Averaging

PHS Geo-location LoresABI Soundings

K-D search tree *
Using Hires & Lores ABI

Produce HiresPHS

Indices of 5 closest PHS & LoresABI FOVs to each HiresABI FOV

Average 5 PHS & LoresABI Soundings for Each ABI FOV

HiresPHS=HiresABI+(PHSavg-LoresABIavg)

**PHS Soundings at
ABI Horizontal & Time
Resolution**

*Weisz, E., B. Baum, and W. P. Menzel, 2017a: 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)

PHS + ABI Retrieval Fusion Example

Polar Hyper-spectral 700 hPa Relative Humidity

PHS 2019-10-21 (07:24:39) Relative Humidity [%] at 706.6 hPa — Oct 21, 2019 07:30UTC

PHS 2019-10-21 (14:46:22) Relative Humidity [%] at 706.6 hPa — Oct 21, 2019 14:40UTC — Oct 21, 2019 14:30 UTC
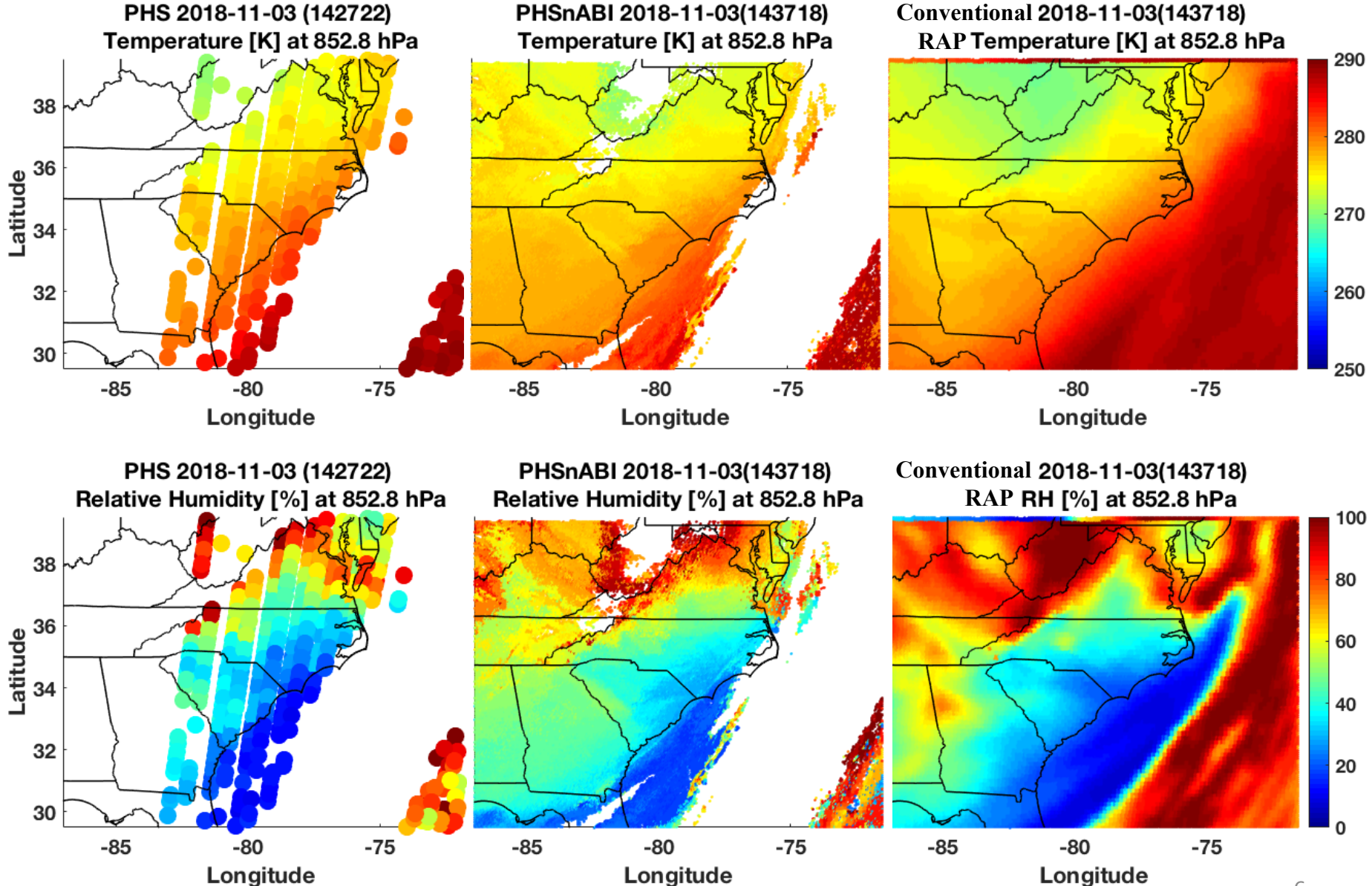
PHS 2019-10-22 (07:56:31) Relative Humidity [%] at 706.6 hPa — Oct 22, 2019 08:00 UTC

PHSnABI 2019-10-21 (07:21:31) Relative Humidity [%] at 706.6 hPa — Oct 21, 2019 07:21UTC

PHSnABI 2019-10-21 (14:21:31) Relative Humidity [%] at 706.6 hPa — Oct 21, 2019 14:21UTC

PHSnABI 2019-10-22 (07:46:32) Relative Humidity [%] at 706.6 hPa — Oct 22, 2019 07:45 UTC

Fused Past Polar (PHS) & Geo (ABI) 700 hPa Relative Humidity

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Application to NWP

Combining Polar & Geo Soundings with AHI Over China

- **PHSnAHI:**

&

Suomi NPP/ JPSS CrIS

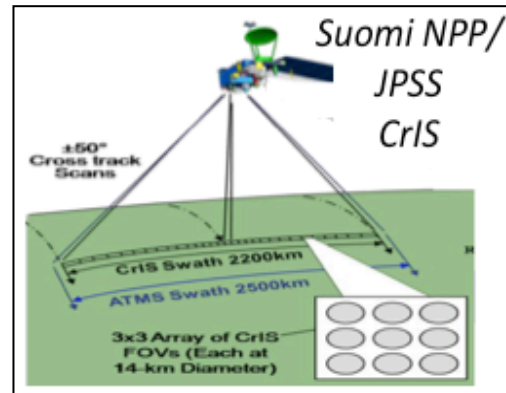±50° Cross track Scans

CrIS Swath 2200km
ATMS Swath 2500km

3x3 Array of CrIS FOVs (Each at 14-km Diameter)

Himawari AHI

- **GHSnAHI:**

FY-4A GIIRS

&
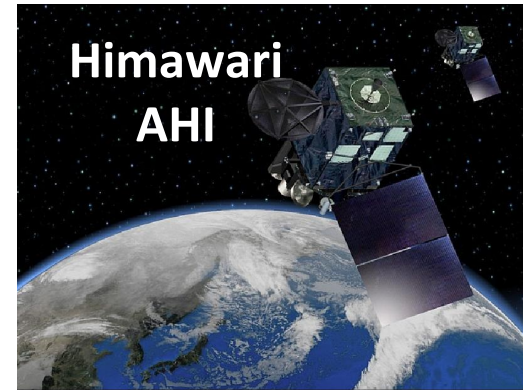
Himawari AHI

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

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
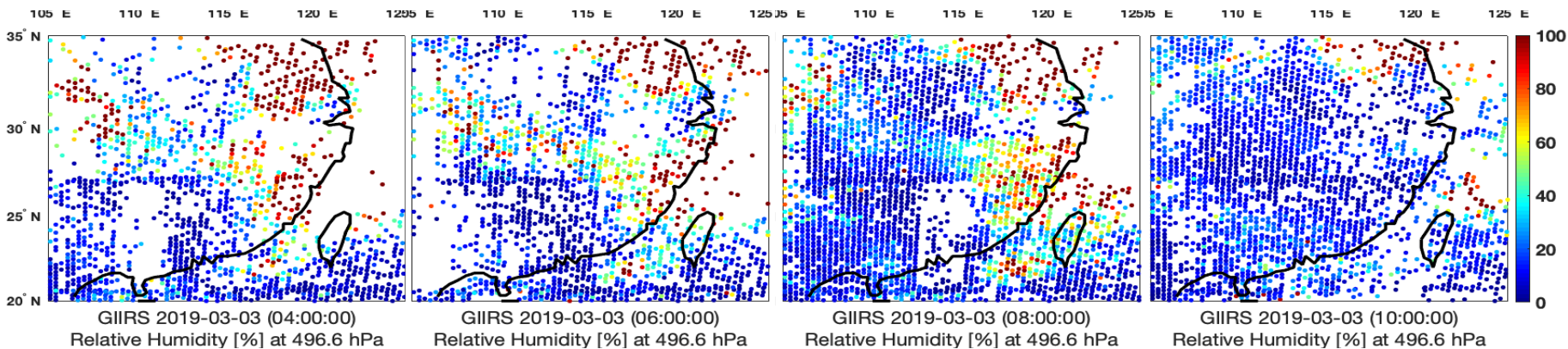
GIIRS + AHI 500 hPa Relative Humidity

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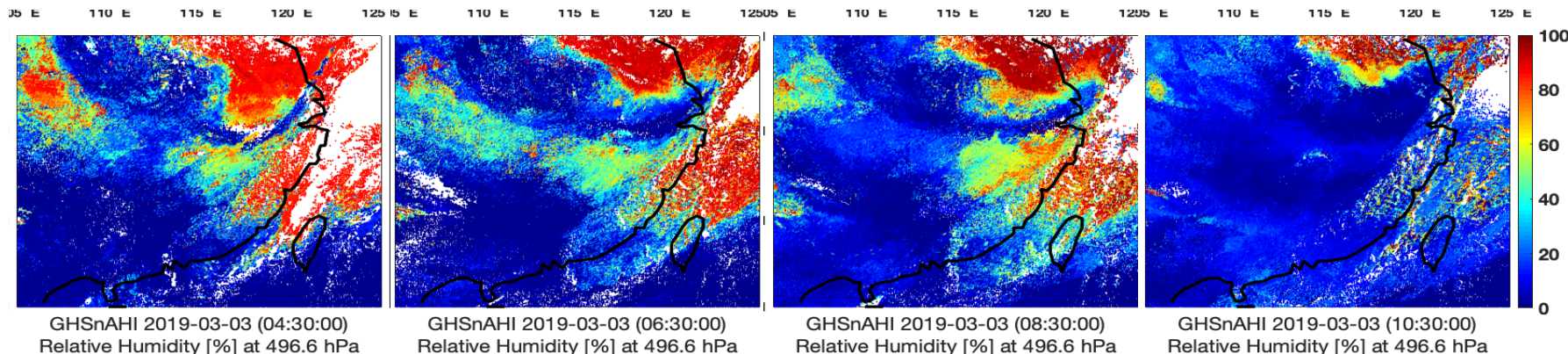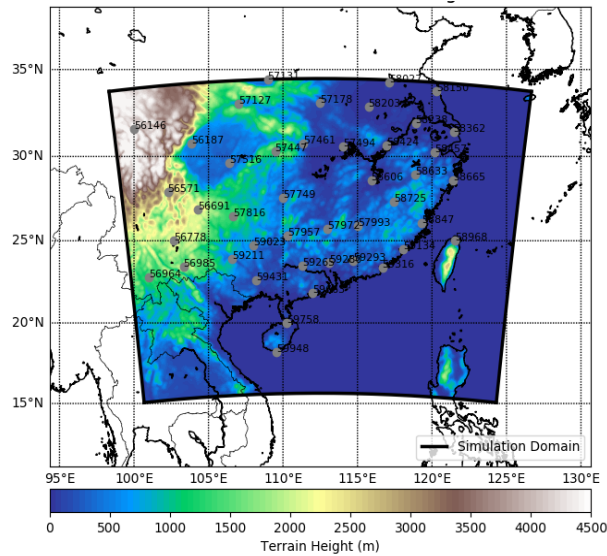
Forecast Model Set-up For March 3-4 Southeast China WRF Model Numerical Forecasts Using Polar + Geostationary Satellite Data

IrIS 2019-03-03 (04:00/05:00) Temperature [K] at 496.6 hPa

GIIRS 2019-03-03 (04:30:00) Temperature [K] at 496.6 hPa

PHSnAHI 2019-03-03 (04:30:00) Temperature [K] at 496.6 hP

GHSnAHI 2019-03-03 (04:30:00) Temperature [K] at 496.6 hP

PGSnAHI 2019-03-03 (04:30:00) Temperature [K] at 496.6 hPa

IrIS 2019-03-03 (04:00/05:00) Relative Humidity [%] at 852.8 hPa

Simulation Domain

Height (m)

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

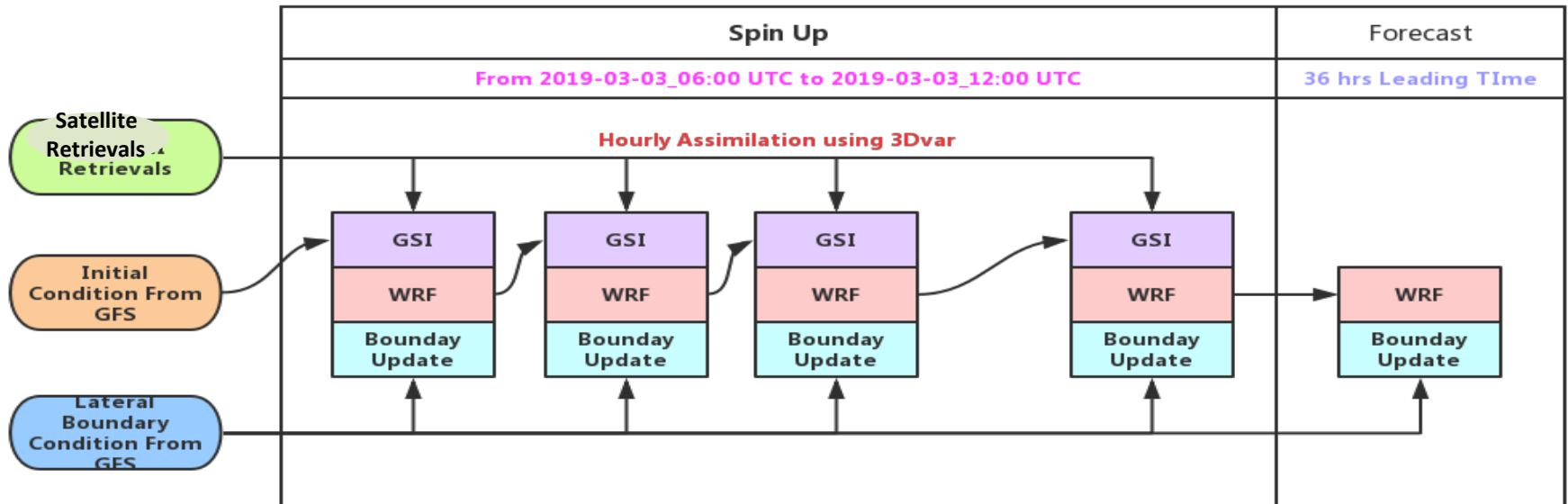PGSnAHI 2019-03-03 (04:30:00) Relative Humidity [%] at 852.8 hPa

Satellite Retrievals

IrIS 2019-03-03 (04:00/05:00) Relative Humidity [%] at 496.6 hPa

Spin Up | **Forecast**

From 2019-03-03_06:00 UTC to 2019-03-03_12:00 UTC | 36 hrs Leading TIme

Hourly Assimilation using 3Dvar

GSI — WRF — Bounday Update

Initial Condition From GFS

Lateral Boundary Condition From GFS

27 Hour Forecast
12 UTC on 3/3/19 to 18 UTC on 3/4/19

OBS
From 2019-03-04_09 to 2019-03-04_12

GRAPES_MESO Forecast Start at 2019-03-03_12
Leading Time 24 hrs

Control Forecast Start at 2019-03-03_12
Leading Time 24 hrs

PHSnAHI Forecast Start at 2019-03-03_12
Leading Time 24 hrs

PGSnAHI Forecast Start at 2019-03-03_12
Leading Time 24 hrs

GHSnAHI Forecast Start at 2019-03-03_12
Leading Time 24 hrs

Precipitation (mm/3hr)
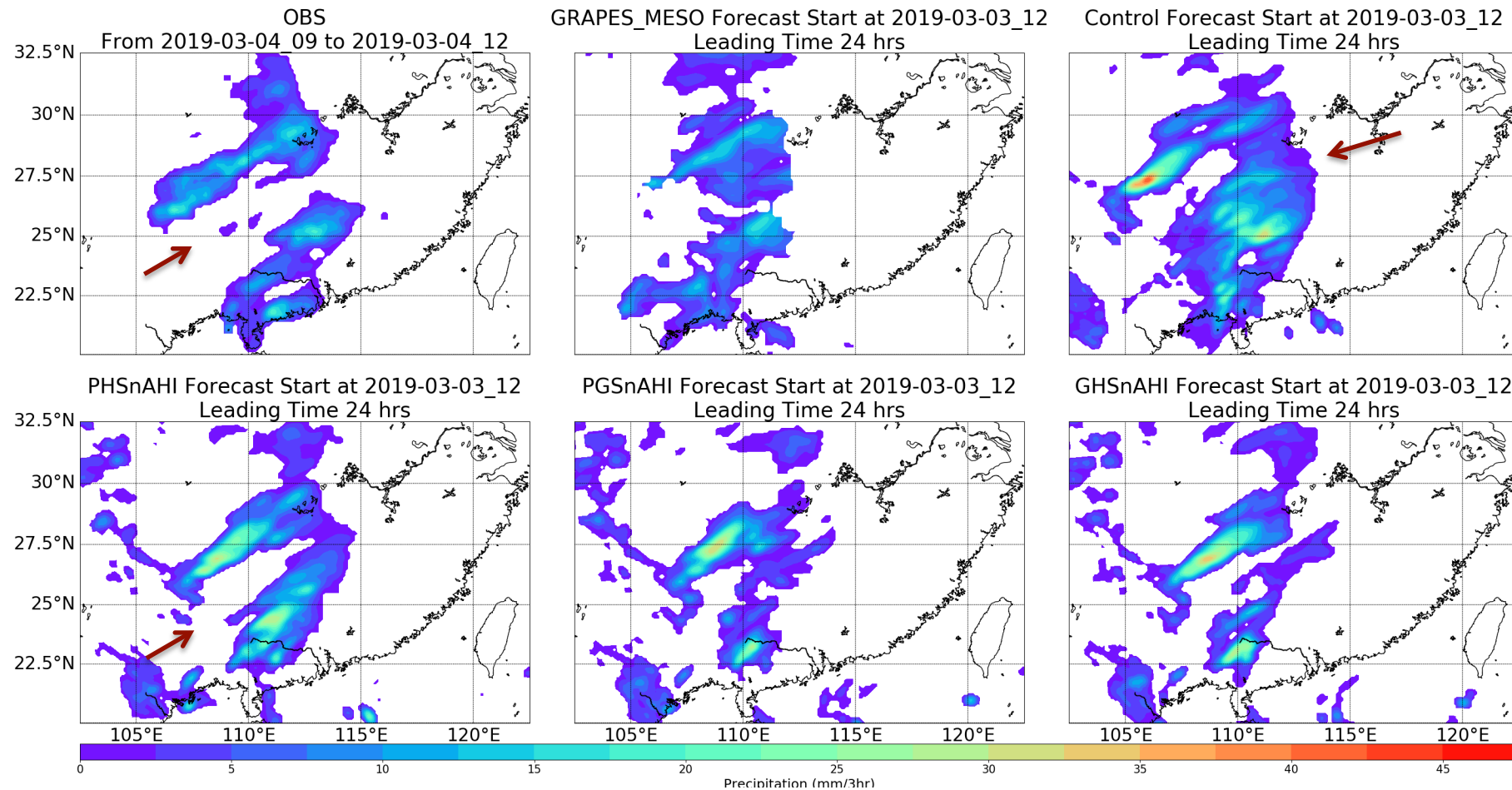
33 Hour Forecast
12 UTC on 3/3/19 to 24 UTC on 3/4/19

OBS
From 2019-03-04_18 to 2019-03-04_21

GRAPES_MESO Forecast Start at 2019-03-03_12
Leading Time 33 hrs

Control Forecast Start at 2019-03-03_12
Leading Time 33 hrs

PHSnAHI Forecast Start at 2019-03-03_12
Leading Time 33 hrs

PGSnAHI Forecast Start at 2019-03-03_12
Leading Time 33 hrs

GHSnAHI Forecast Start at 2019-03-03_12
Leading Time 33 hrs

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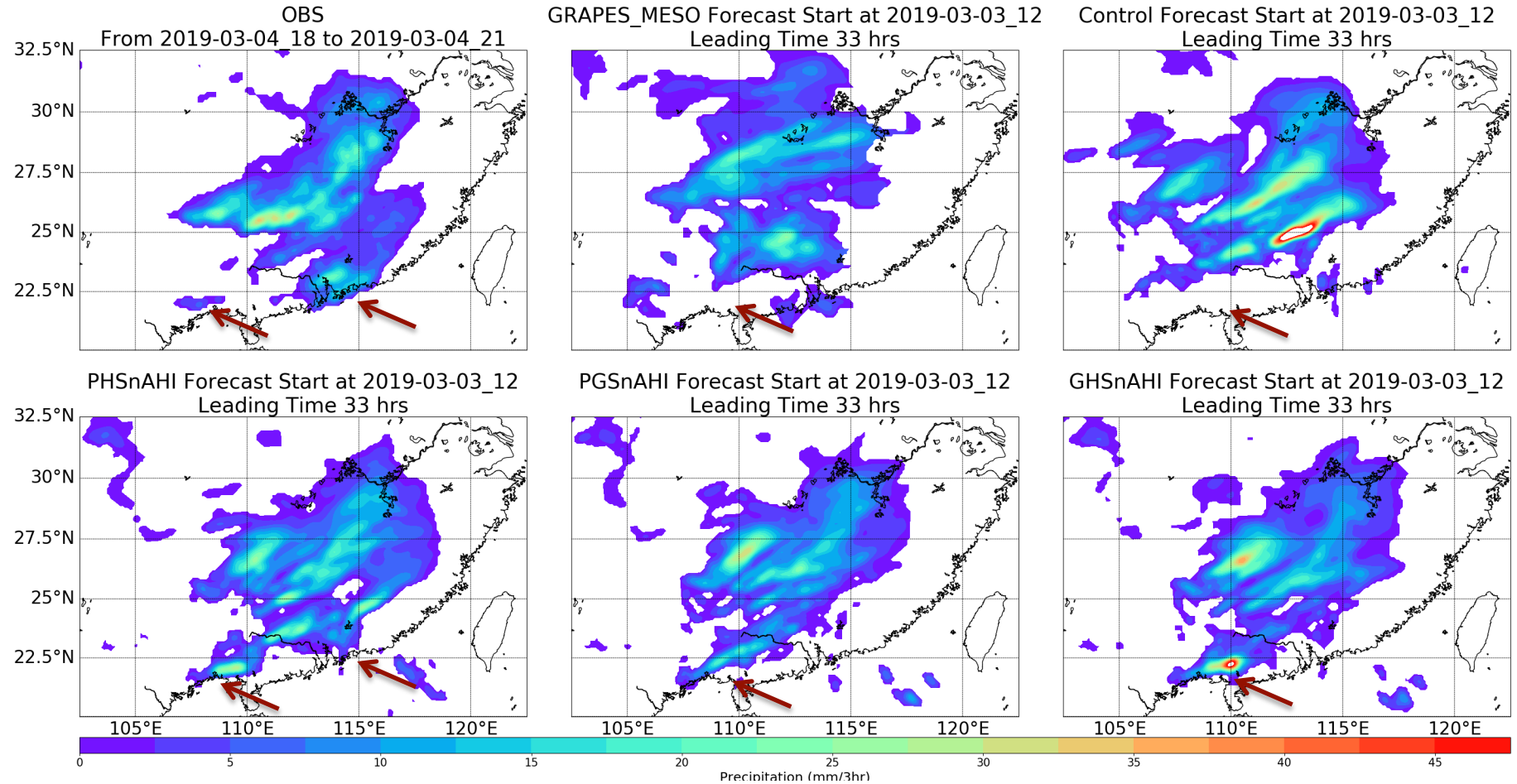
3-hr Accumulated Precipitation False Alarm (FAR), Probability of Detection (POD) and Critical Success Index (CSI)
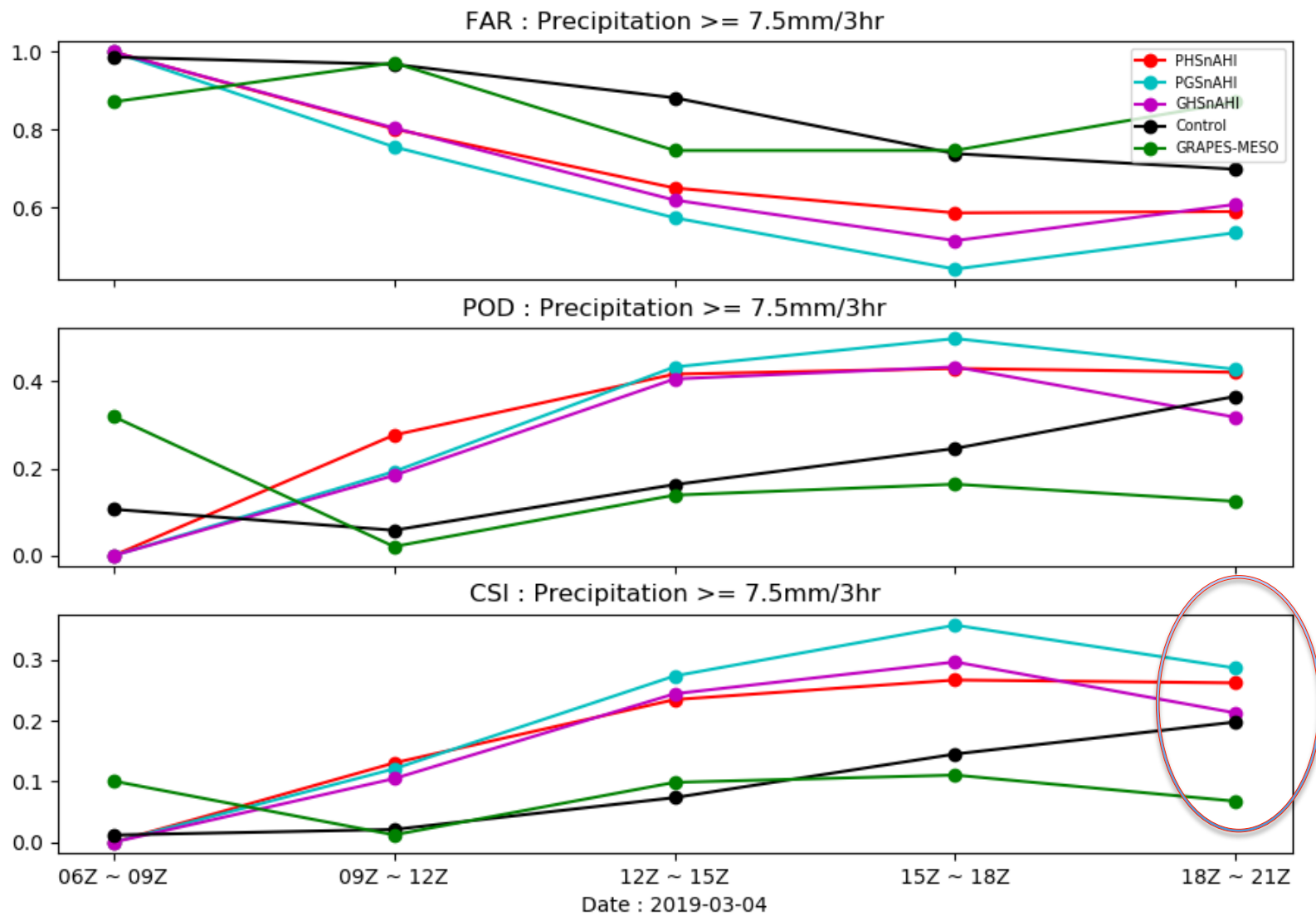
Summary and Conclusion

- To Geo-Hyperspectral soundings are being simulated 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 improved forecasts with geo-hyperspectral-like sounding retrievals..*

- The Imager/Sounder Retrieval fusion technique has been applied to FY-4A GIIRS Geo-Hyper-spectral and Himawari multi-spectral AHI data. The Geo-Hyperspectral Data fill in important space and time gaps in the polar data. It has been demonstrated that the *GIIRS real Geo-Hyperspectral retrievals improve precipitation forecasts provided using PHSnAHI retrievals.*

- *The results show that <u>real </u>Geo-hyperspectral sounder measurements are needed to obtain accurate vertical soundings at high space and time resolution as needed to benefit high impact weather forecasts.*

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