UW/HU Severe Weather Project Fact Sheet

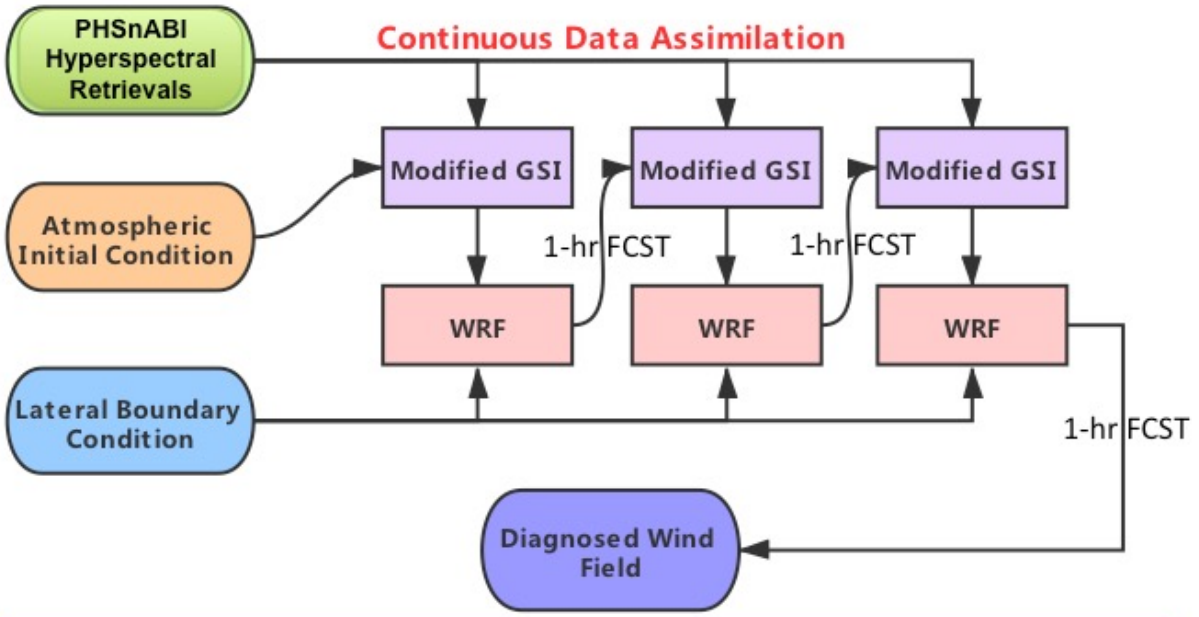
Objective: To produce High-resolution Satellite Upper Air Observations for Improving Numerical Forecasts of Severe Weather

Characteristics:

- Real-time sounding radiance observation receiving sites
  - University of Wisconsin (UW), Hampton University (HU), and Miami Direct Broadcast Satellite (DBS) polar satellite data reception
  - NOAA Amazon Web Service (AWS) and UW geostationary satellite data reception
- High Spatial (2-km) and Temporal (30- to 60-min) resolution temperature and moisture vertical profiles, called 'PHSnABI' are produced and available at hourly intervals (24/7)
- Satellite thermodynamic soundings are continuously assimilated Into 8-km (HU) and 3-km (UW) high-resolution Numerical Prediction Weather (NWP) models to diagnose high-resolution wind profiles.
- Satellite atmospheric profiles are combined With operational weather observations to Initialize a convective weather NWP Weather Research and Forecast (WRF) model predictions.
- Observation and forecast variables Include:
  - Atmospheric profiles of temperature, humidity, wind
  - Surface-skin Temperature
  - Cloud-top height (retrieval), hourly accumulated precipitation (forecast)
  - Convective instability parameters, Significant Tornado Parameter (STP), and updraft velocity at level of free convection (forecast)

Atmospheric Profiling Algorithm

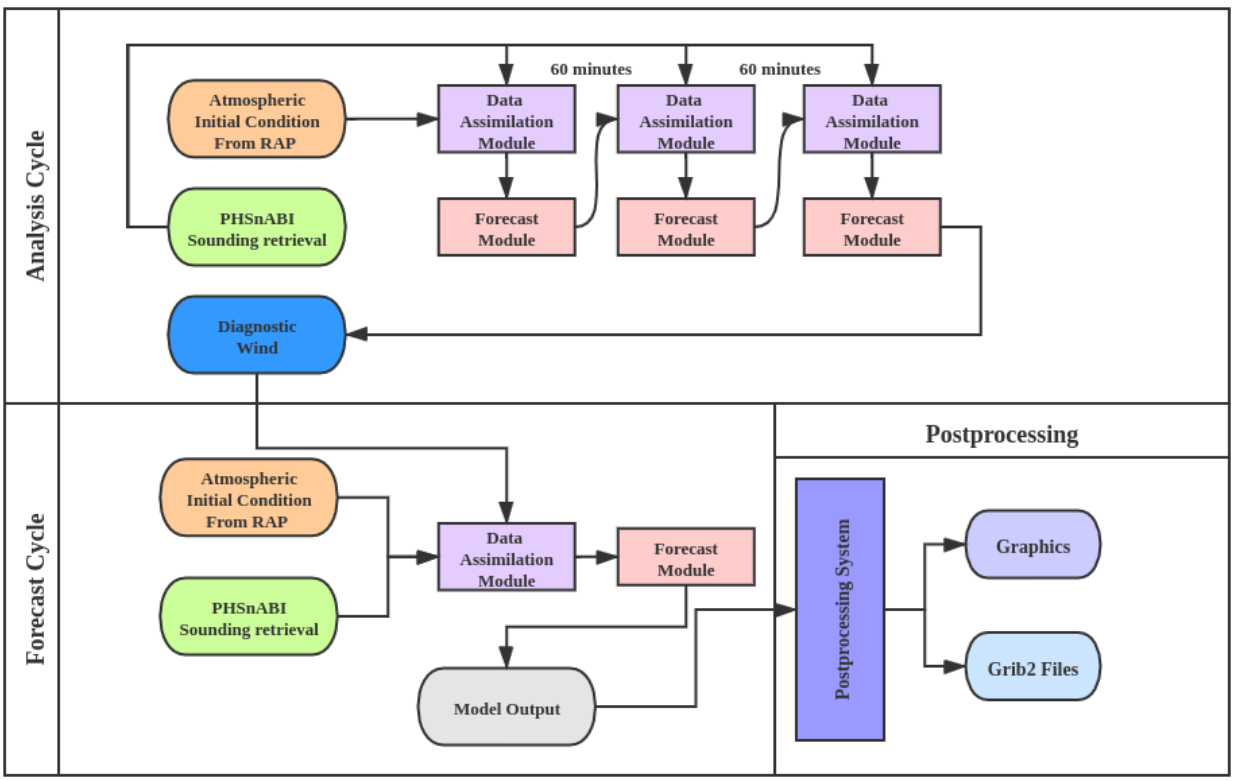
- Combines high vertical resolution (1 to 2-km) clear air atmospheric temperature and humidity profiles, derived by Dual-Regression (DR), from US and European polar orbiting satellite infrared hyperspectral radiance measurements [1], combined with profiles below clouds derived from polar satellite microwave radiance observations [2].
- The 15-km horizontal resolution polar satellite soundings are combined with high horizontal (2-km) and temporal (5 to 15-min) resolution surface-skin temperature, cloud altitude, and moisture profiles derived from multispectral geostationary satellite (ABI) radiance measurements to produce thermodynamic profiles with 2-km spatial, and 30 to 60-min temporal resolution [3].
- The vertical resolution of the satellite atmospheric profiles are transformed to a forecast model vertical resolution using a radiative transfer model driven De-Aliasing (DA) procedure [4]
- A RAP-like 8-km WRF model is initialized with the NOAA Operational RAP analysis and then used to continuously assimilate the 'PHSnABI' satellite retrieval sounding data continuously over a 3-hour time period to produce model diagnosed wind profiles (see figure below)
- The resultant satellite moisture and 3-hr data assimilated model diagnosed wind profiles are then used to enhance the operational RAP model background analysis to initialize a satellite data assimilated a WRF model forecast cycle.



Forecast Model System

Forecast Model System Design:

The forecast system consists of three parts: (1) **Analysis cycle** in which four-dimensional 'PHSnABI' thermodynamic profiles are used to specify their associated wind profiles for initializing a **Forecast cycle.** The wind profiles are specified through the numerical integration of the forecast model equations of motion, using 'PHSnABI' soundings assimilated at hourly intervals over a three-hour period; (2) **Forecast cycle** in which the latest 'PHSnABI' thermodynamic soundings are used together with their associated wind profiles to adjust the NOAA operational RAP model background atmospheric state to produced high-resolution satellite data enhanced NWP model forecasts; (3) **Postprocessing** in which 'PHSnABI' dependent WRF model forecasts are converted to RAP-like grib2 files and displays are produced for the project website. A detailed workflow diagram is presented below.



Forecast Products:

As a research system, the HU-SWRC/UW-SSEC forecast system currently generates three types of forecast results for performance comparison: (1) **PHSnABI Water Vapor Assimilation**, which only assimilates PHSnABI water vapor profiles in analysis and forecast cycles; (2) **PHSnABI Temperature and Water Vapor assimilation**, which assimilates PHSnABI temperature and water vapor profiles in both the analysis and forecast cycles; (3) **Control**, which doesn't assimilate any 'PHSnABI' profile observations (i.e., only NOAA operational RAP model observations are used). The major difference between (1) and (2) is: in (1) the 'PHSnABI' thermodynamic profile associated wind profiles result from assimilating only PHSnABI water vapor information while in (2) the 'PHSnABI' wind profiles result from the assimilation of both temperature and moisture profiles.

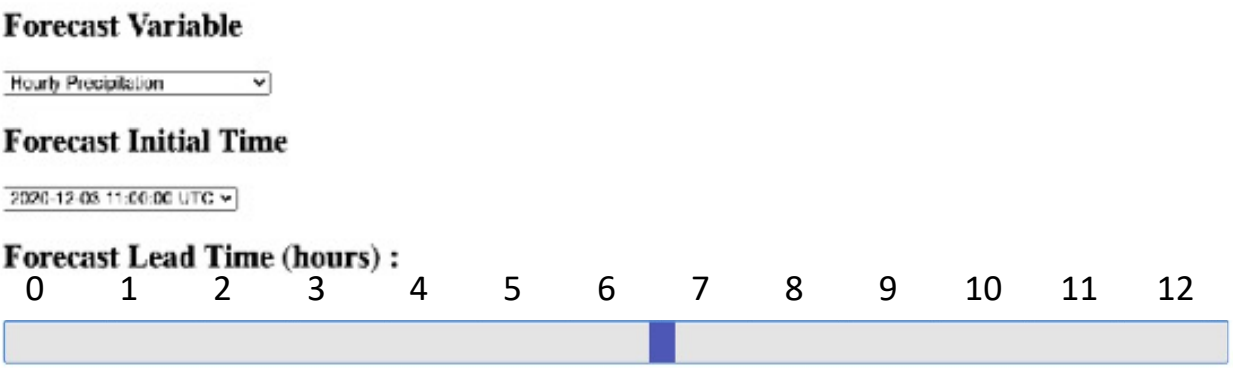
PHDSnABI Sounding Observation Web-site Addresses:

http://dbps.cas.hamptonu.edu/development/

- ***Infrared Sounding Data Products:*** ***http://cas.hamptonu.edu/~adinorscia/ABInPHS_plots/TotalDomain-HU/***
- ***Infrared plus Microwave Sounding Data Products:*** ***http://cas.hamptonu.edu/~adinorscia/ABInPHS_plots/TotalDomain-Exp/***
- ***Radiosonde Comparisons:*** ***http://cas.hamptonu.edu/~adinorscia/InteractiveMap/interactive-map.html***
- ***Users Guide:*** ***http://dbps.cas.hamptonu.edu/development/WebsiteUsersGuide.pdf***

Forecast Display Web-site Address:
http://cas.hamptonu.edu/~qi.zhang/home_2.0/ForecastShow.html

Display Interface: Users can find the 0 - 12 hours lead-time forecasts generated by the forecast system. Currently, only "Hourly Precipitation", "Significant Tornado Parameter", "Most Unstable CAPE", "Lifted Index", "Updraft Velocity at Level of Free Convection", and "Basic Variables" (wind, temperature and relative humidity) at 850hPa, 700 hPa, and 500 hPa are shown. In order to retrieve the desired variable for display, users must first select the "Forecast Variable" and then choose the "Forecast Initial Time". Once the "Forecast variable" and "Forecast Initial Time" are selected, users can view any lead-time between 0- to 12-hours by dragging the slider below:



User define area on the website showing the lead-time slider

In the display area, user can check the product they've selected. The result shown in the first figure (starting from left) on first row is RAP result for the user's selection, the second figure on the first row is PHSnABI Water Vapor Assimilation and Temperature result, the first figure on the second row is Control result (i.e., no PHSnABI data assimilated), and the last figure is PHSnABI water vapor data assimilation result.

References:

[1] W. L. Smith, E. Weisz, S. V. Kireev, D. K. Zhou, Z. Li, and E. E. Borbas, "Dual-Regression Retrieval Algorithm for Real-Time Processing of Satellite Ultraspectral Radiances," *J. Appl. Meteor. Climatol*., vol. 51, pp. 1455–1476, Aug. 2012, doi: 10.1175/JAMC-D-11-0173.1.

[2] Boukabara, S.-A., et al. (2013), A physical approach for a simultaneous retrieval of sounding, surface, hydrometeor, and cryospheric parameters from SNPP/ATMS, *J. Geophys. Res. Atmos.*, 118, 12,600– 12,619, doi:10.1002/2013JD020448.

[3] 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, doi: https://doi.org/10.1175/JTECH-D-19-0158.1.

[4] W. Smith Sr., E. Weisz, and H. Revercomb, "The Retrieval of Atmospheric Profiles From Satellite Radiances For NWP Data Assimilation" ITSC-XX: Lake Geneva, Wisconsin, USA, 28 October-3 November 2015 : https://library.ssec.wisc.edu/research_Resources/publications/pdfs/ITSC20/smith06_ITSC20_2015.pdf

Forecast Training Module:
https://www.youtube.com/watch?v=A9_TDWhKxIw

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