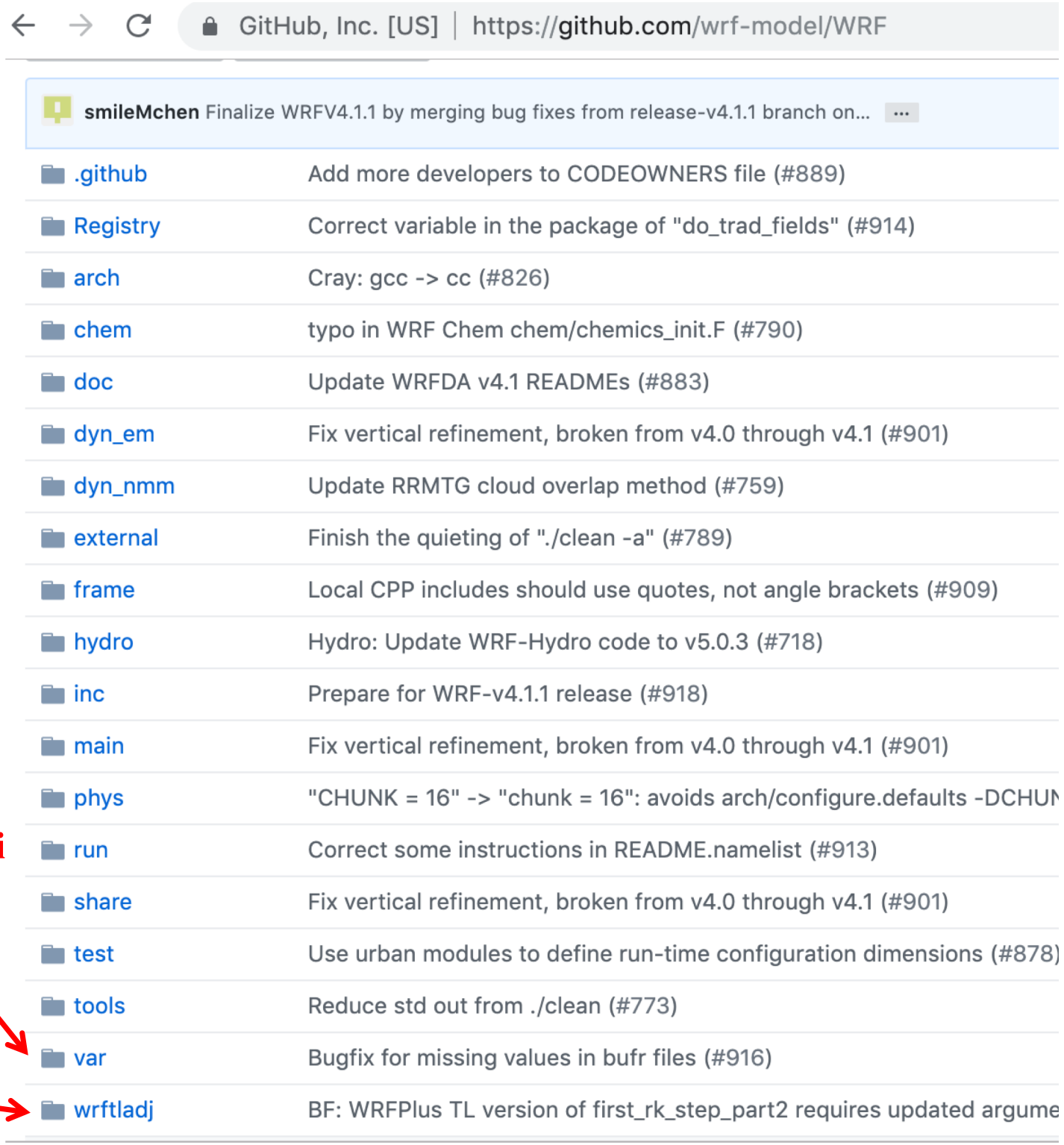
Introduction to WRFDA

Jake Liu

NCAR/MMM

WRFDA-related code all within the same WRF repository



WRF Data Assimilati (WRFDA)

WRFPlus (tangent linear and adjoint code of WRF)

DA algorithm finds the minimum of a cost function

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x}-\mathbf{x}^b)^{\mathrm{T}}\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}^b) + \frac{1}{2}[H(\mathbf{x})-\mathbf{y}]^{\mathrm{T}}\mathbf{R}^{-1}[H(\mathbf{x})-\mathbf{y}]$$

J is just a scalar

x: Gridded analysis variables (a column vector), u,v,t,q,Ps, clouds.

what we're trying to find!

$\mathbf{x}^b$: Background of x (previous forecast, prior information)

B: Background error covariance (fixed or flow-dependent, can have horizontal /vertical correlation and multivariate correlation)

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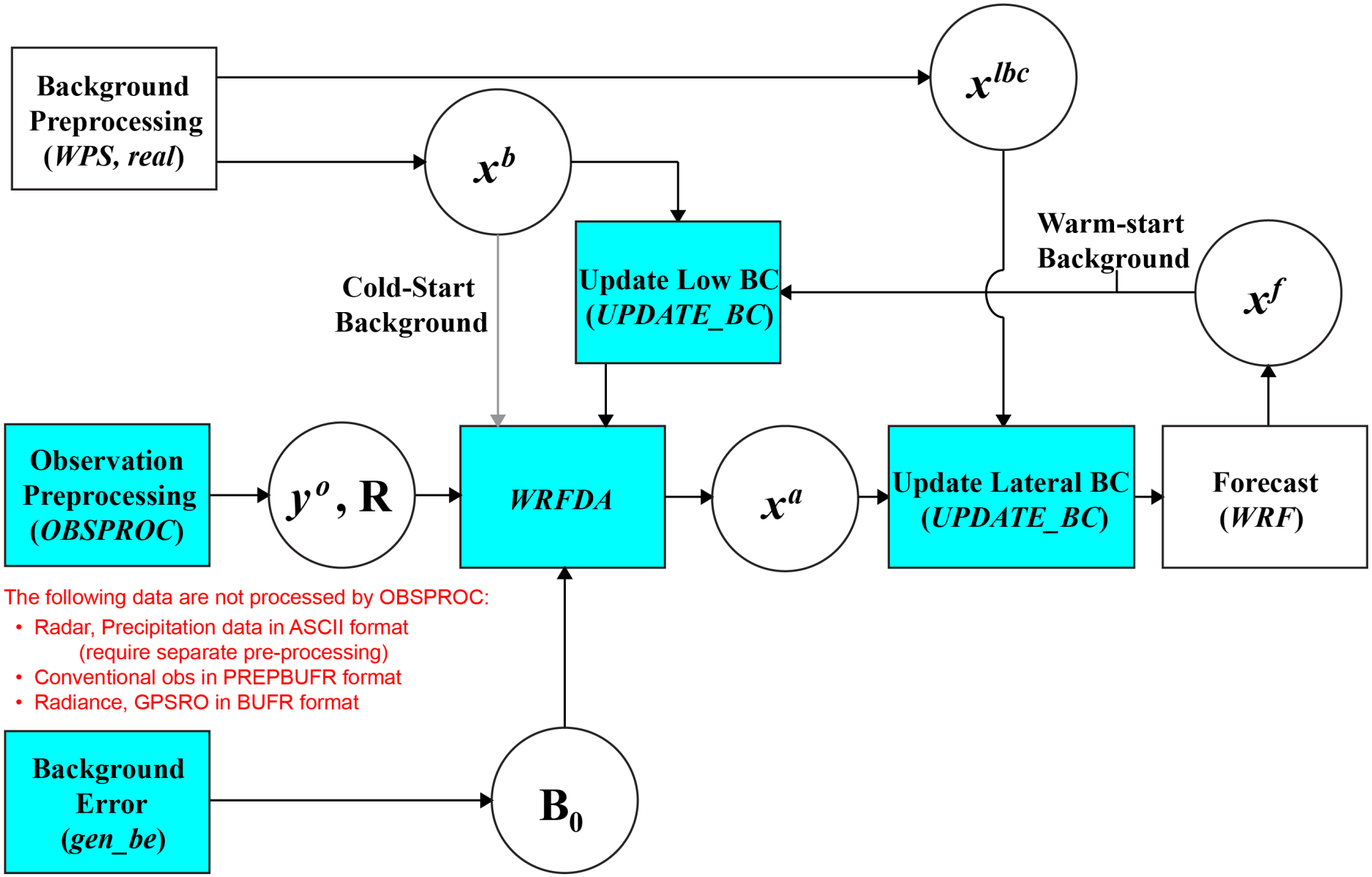
y: Irregularly-distributed observations (can be same or different variables from model)

***H*: Observation operator (interpolate x to observation location and then convert x to observed quantity)**

R: Observation error covariance (usually assume diagonal, so no correlation)

WRFDA in the WRF Modeling System



DA algorithms available in WRFDA

- 3DVAR
  - Different options for choice of non-cloud analysis variables (e.g., Psi/Chi or U/V) and cloud analysis variables
- 4DVAR
  - Need WRFPlus: Tangent Linear & Adjoint code of WRF model
  - Can calculate adjoint-based forecast sensitivity to obs (FSO)
- Hybrid-3D/4DEnVar
  - Can run in dual-resolution mode
  - Can ingest ensemble from global or regional sources
- Ensemble analysis
  - ETKF (Ensemble Transform Kalman Filter) w/o covariance localization
  - EDA: Ensemble of hybrid-EnVar with perturbed observations

WRFDA Observations

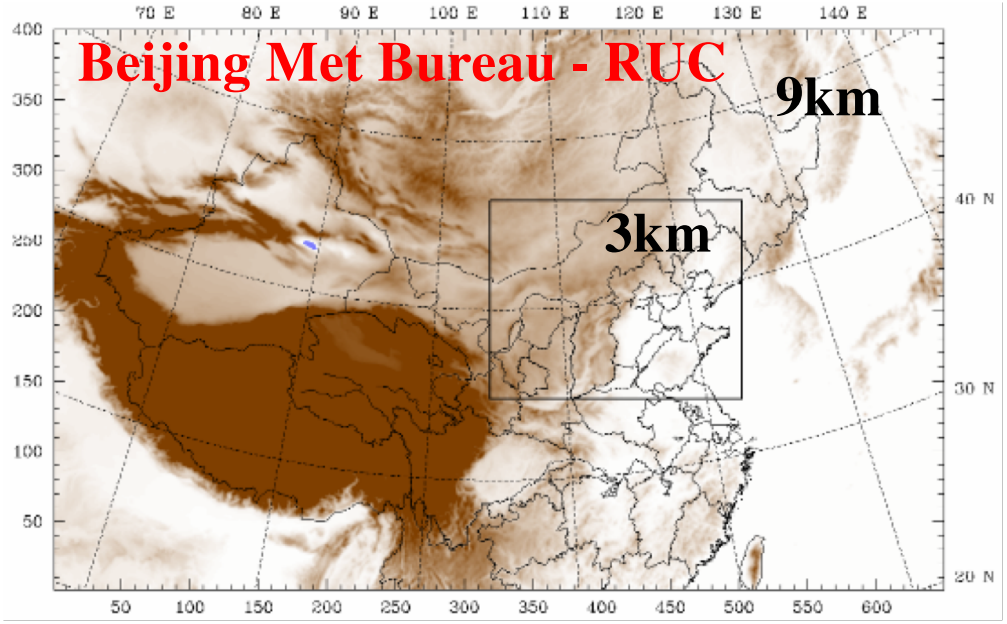
- **In-Situ:**
  - SYNOP
  - METAR
  - SHIP
  - BUOY
  - TEMP
  - PIBAL
  - AIREP, AIREP humidity
  - TAMDAR
- **Bogus:**
  - TC bogus
  - Global bogus

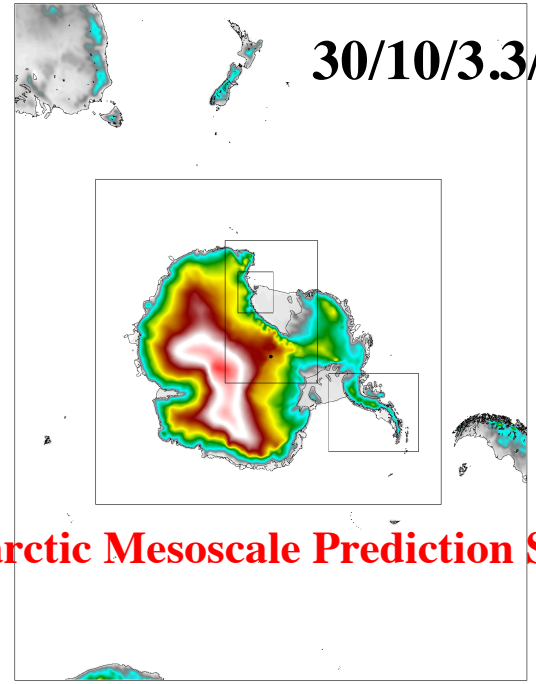
- **Remotely sensed retrievals:**
  - Atmospheric Motion Vectors (geo/polar)
  - SATEM thickness
  - Ground-based GPS TPW or ZTD
  - SSM/I oceanic surface wind speed and TPW
  - Scatterometer oceanic surface winds
  - Wind Profiler
  - Radar data (reflectivity/retrieved rainwater, and radial-wind
    - V3.9: No-rain echo radar DA (from KNU)
  - Satellite temperature/humidity/thickness profiles
  - GPS refractivity (e.g. COSMIC)
  - Stage IV precipitation/rain rate data (4D-Var only)

- **Radiances (VarBC, RTTOV & CRTM, All-sky radiance):**
  - HIRS NOAA-16, NOAA-17, NOAA-18, NOAA-19, METOP-A
  - AMSU-A NOAA-15/16/18/19, EOS-Aqua, METOP-A, METOP-B
  - AMSU-B NOAA-15, NOAA-16, NOAA-17
  - MHS NOAA-18, NOAA-19, METOP-A, METOP-B
  - AIRS EOS-Aqua
  - SSMIS DMSP-16, DMSP-17, DMSP-18
  - IASI METOP-A, METOP-B
  - ATMS Suomi-NPP
  - MWHS2 from FY-3 C/D (new in 4.1)
  - SEVIRI METEOSAT
  - AMSR2 GCOM-W1 (all-sky microwave radiance DA)
  - GOES-Imager, Himawari-AHI (new in 4.1)

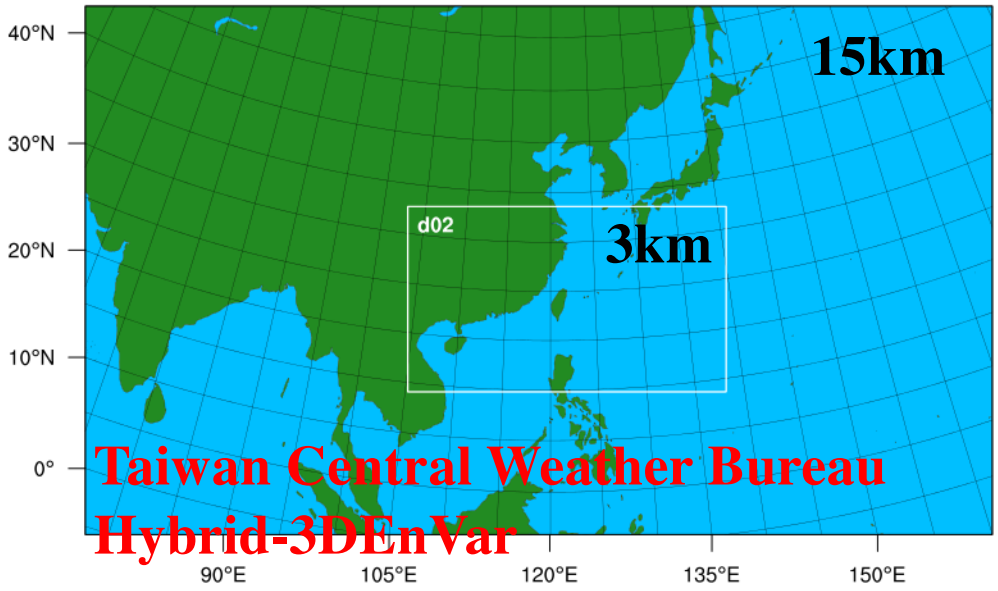
WRFDA is flexible to allow assimilation of different formats of observations:

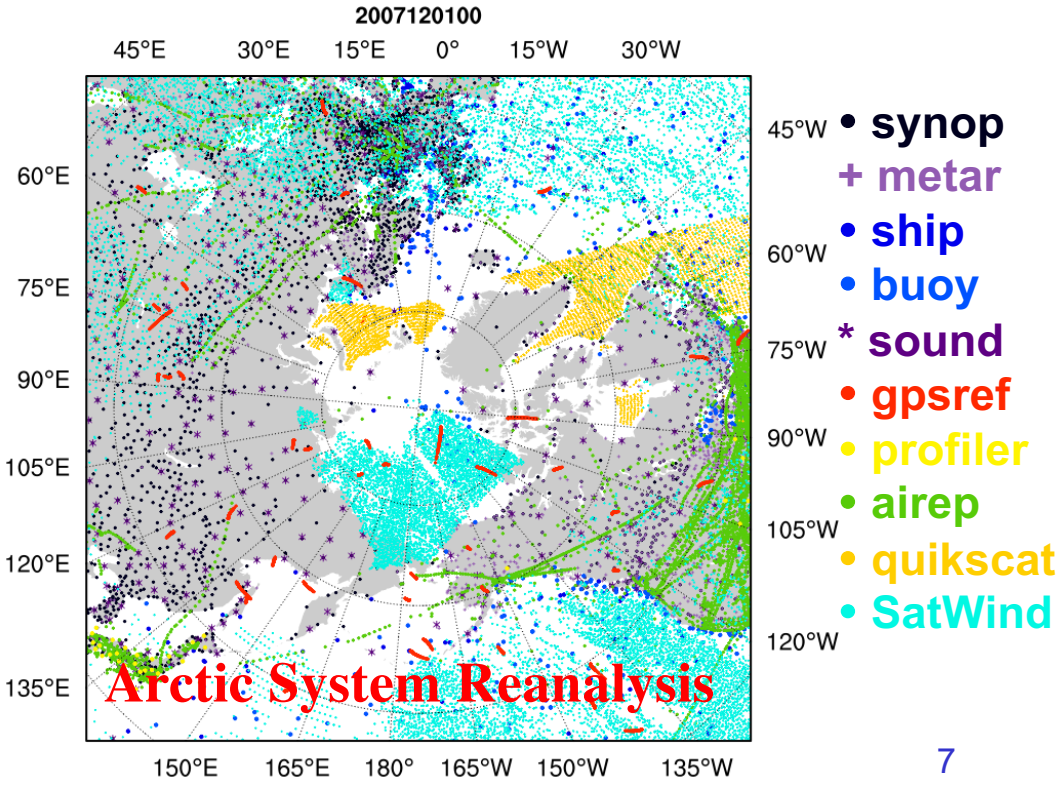
- Little_r (ascii), HDF, Binary
- NOAA MADIS (netcdf),
- NCEP PrepBufr,
- NCEP radiance bufr





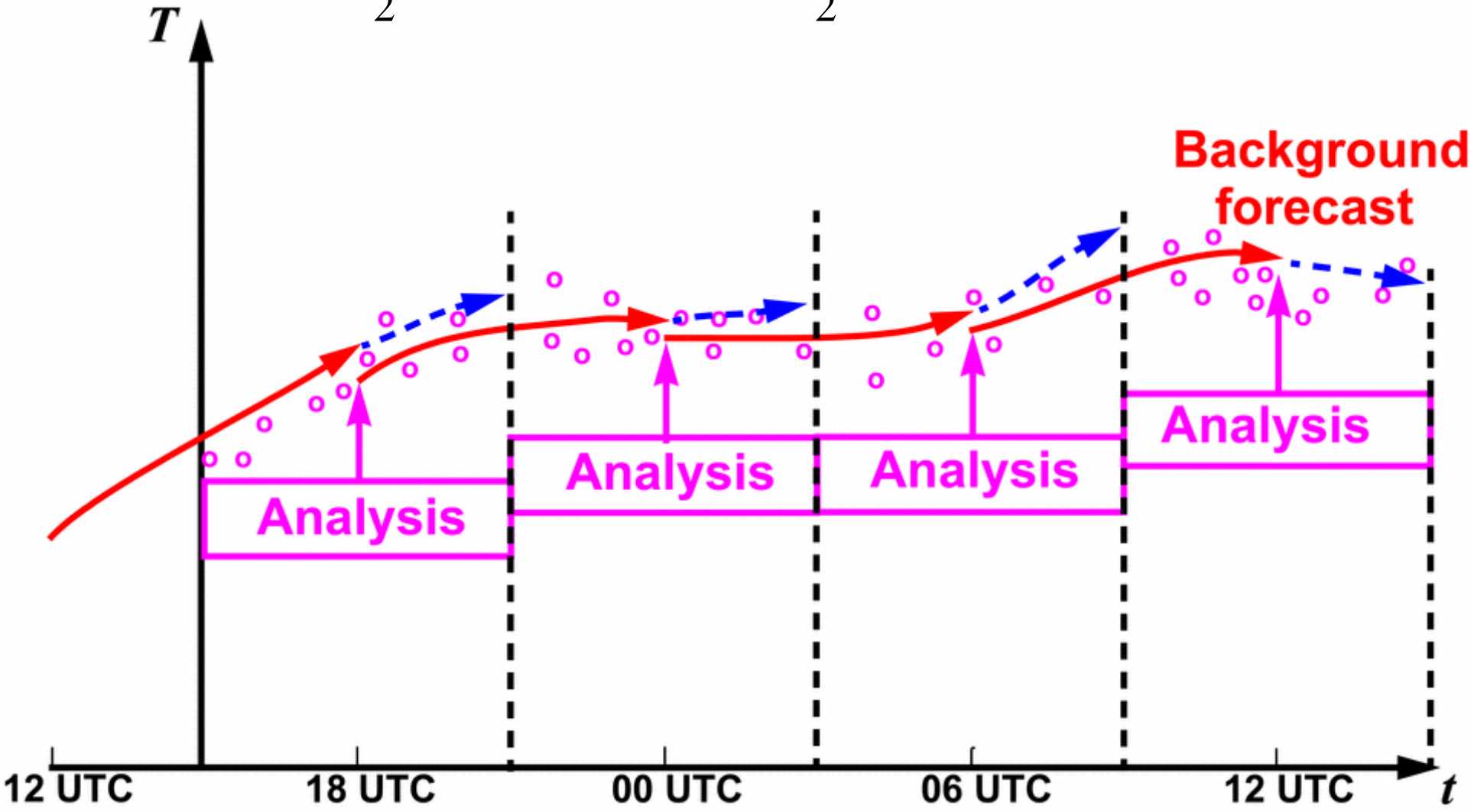
Antarctic Mesoscale Prediction System—AMPS





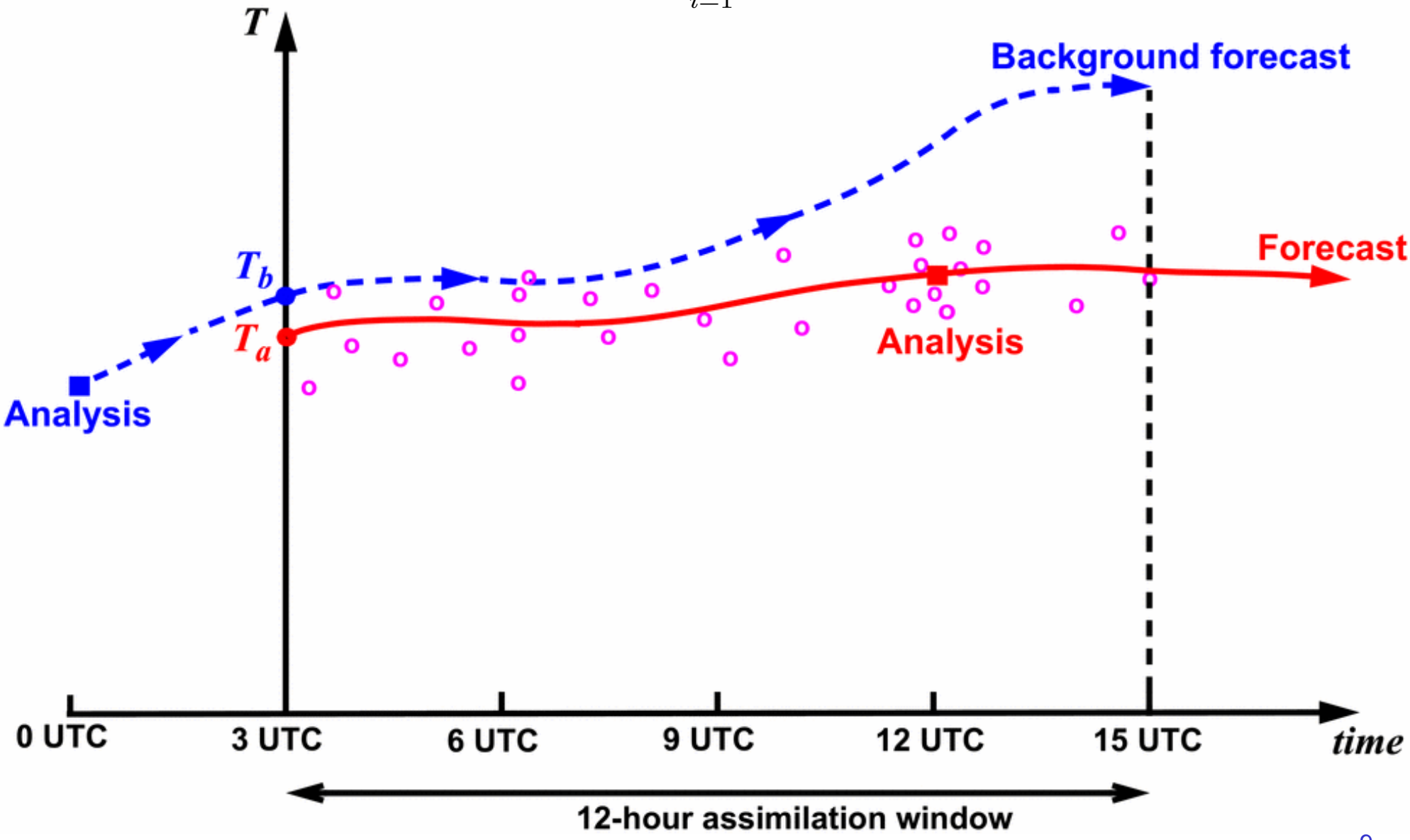
3DVAR (Barker et al. 2004)

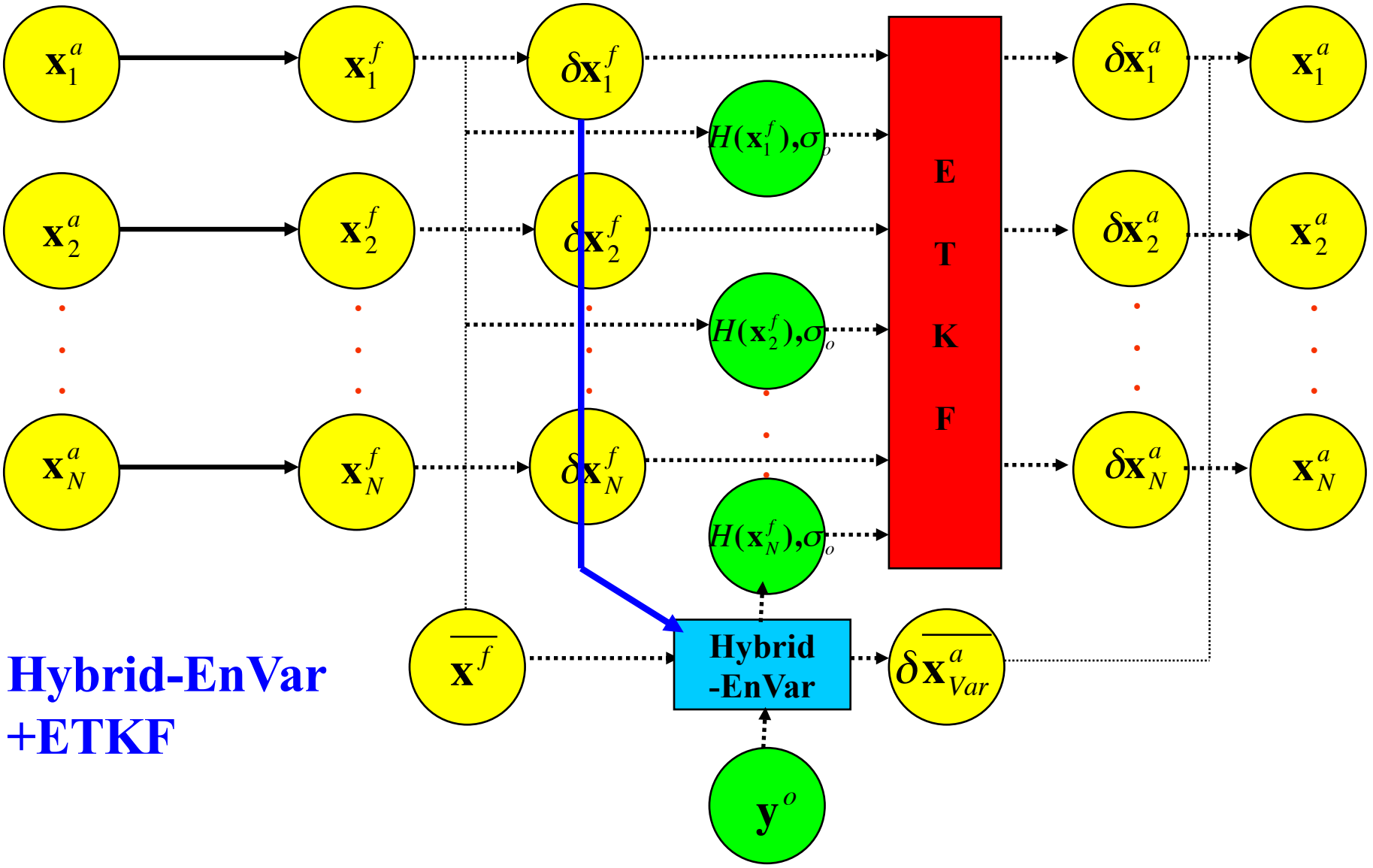
$$J(x) = \frac{1}{2}(x - x_b)^{\mathrm{T}} \mathrm{B}^{-1}(x - x_b) + \frac{1}{2}[H(x) - y]^{\mathrm{T}} \mathrm{R}^{-1}[H(x) - y]$$



4DVAR (Huang et al. 2009)

$$J(\mathbf{x}_0) = \frac{1}{2}(\mathbf{x}_0 - \mathbf{x}_0^b)^{\mathrm{T}}\mathbf{B}^{-1}(\mathbf{x}_0 - \mathbf{x}_0^b) + \frac{1}{2}\sum_{i=1}^{N}[H_i(M_i(\mathbf{x}_0)) - \mathbf{y}_i]^{\mathrm{T}}\mathbf{R}_i^{-1}[H_i(M_i(\mathbf{x}_0)) - \mathbf{y}_i]$$

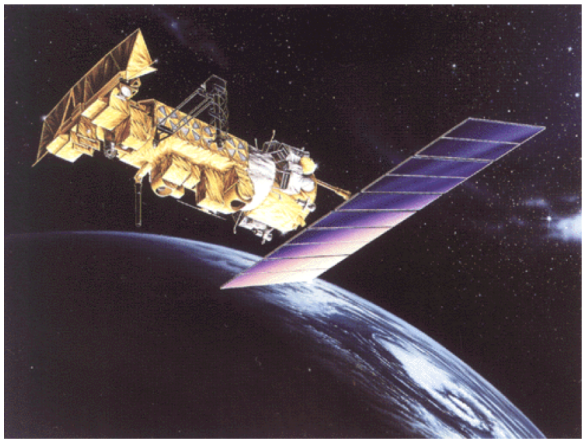


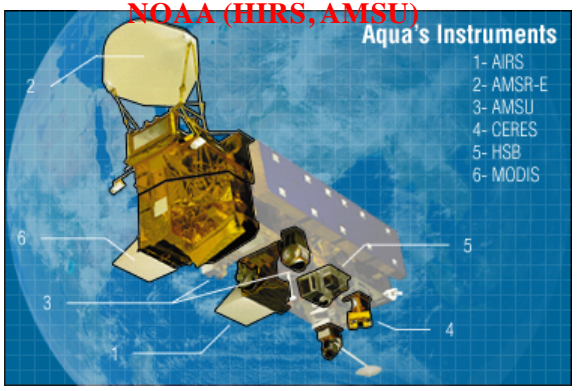


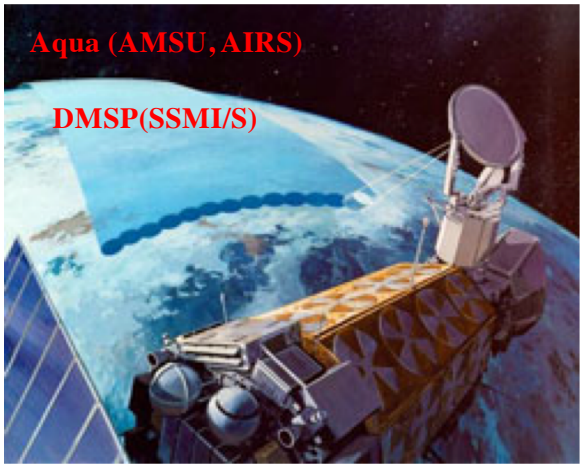
Hybrid-EnVar +ETKF

WRFDA
Satellite Radiance DA

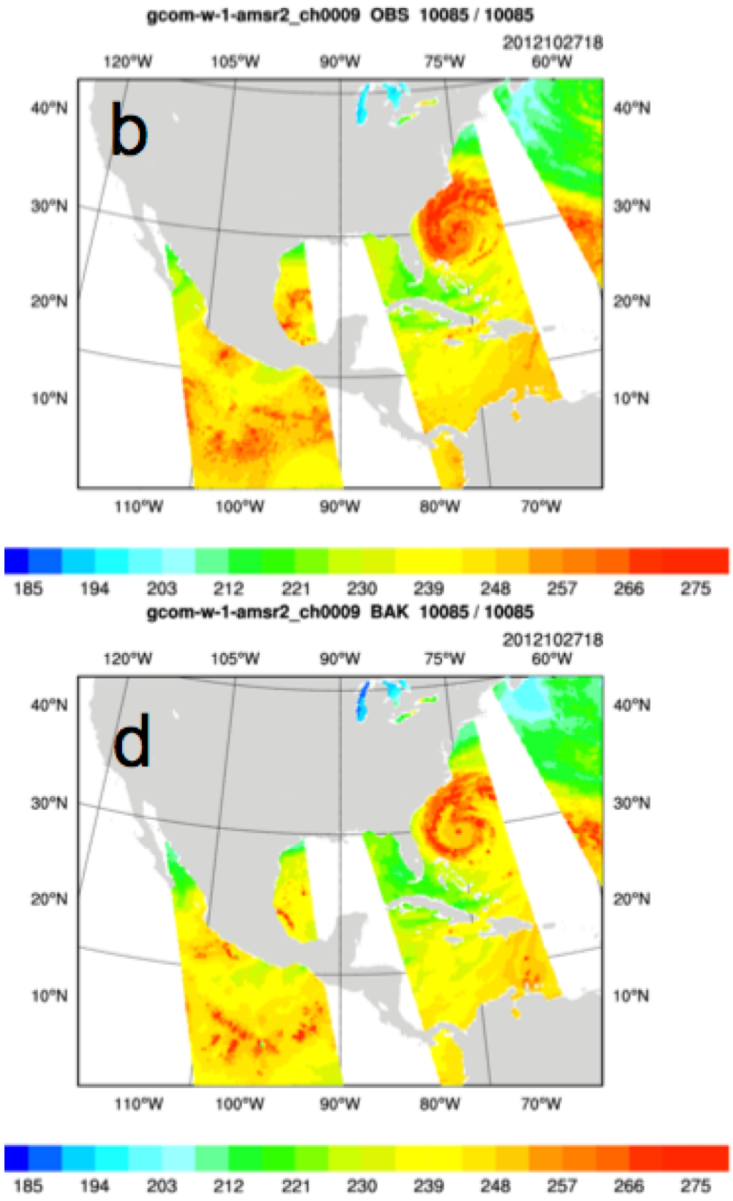
- Two RTM interfaces
  - RTTOV or CRTM
- Variational Bias Correction
- Modular code design to ease adding new satellite sensors
- Capability for cloudy radiance DA



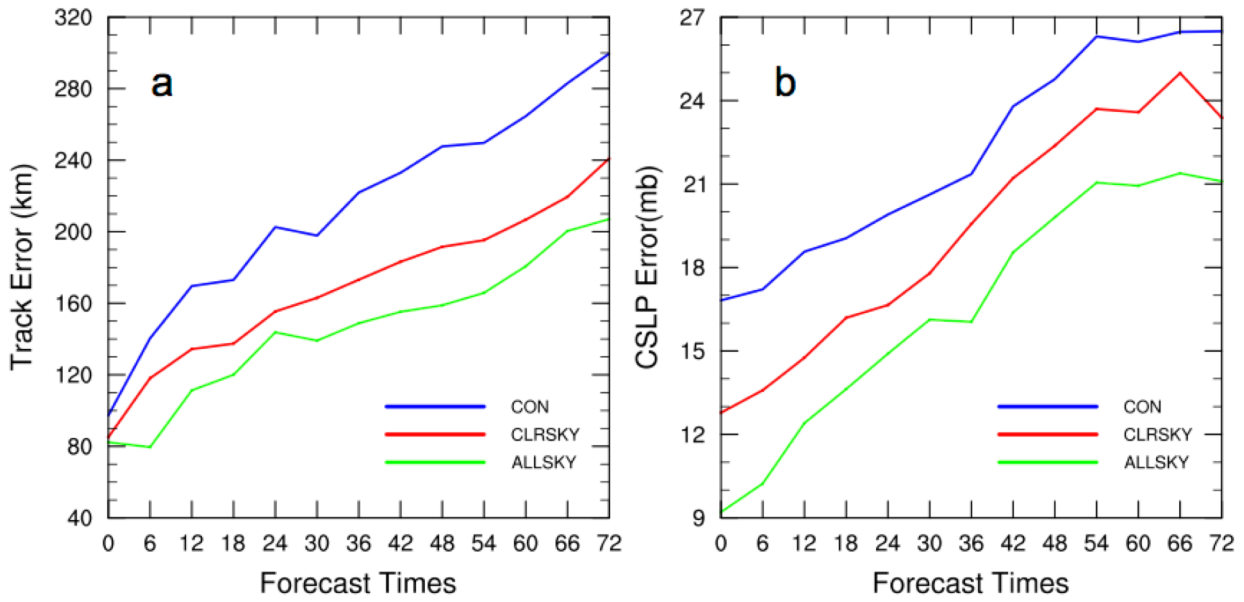




All-sky AMSR2 radiance DA for hurricane Sandy

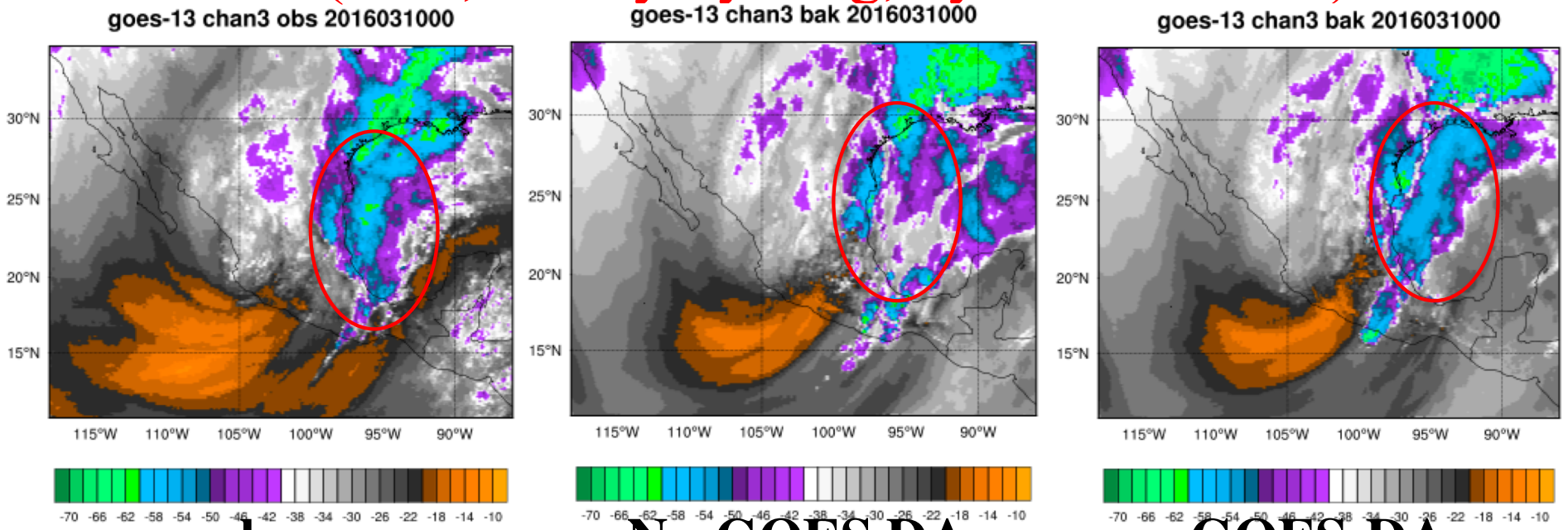


Channel	Frequency (GHz)	Polarization	Footprint (along scan* along track)
1,2	6.925	V,H	35*61 km
3,4	7.3	V,H	35*61 km
5,6	10.65	V,H	24*41 km
7,8	18.7	V,H	13*22 km
9,10	23.8	V,H	15*26 km
11,12	36.5	V,H	7*12 km
13,14	89.0	V,H	3*5 km

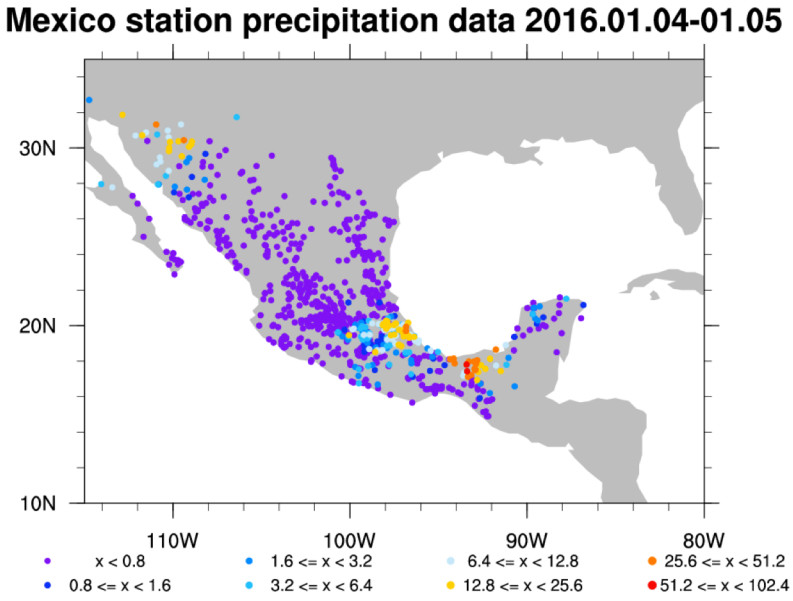


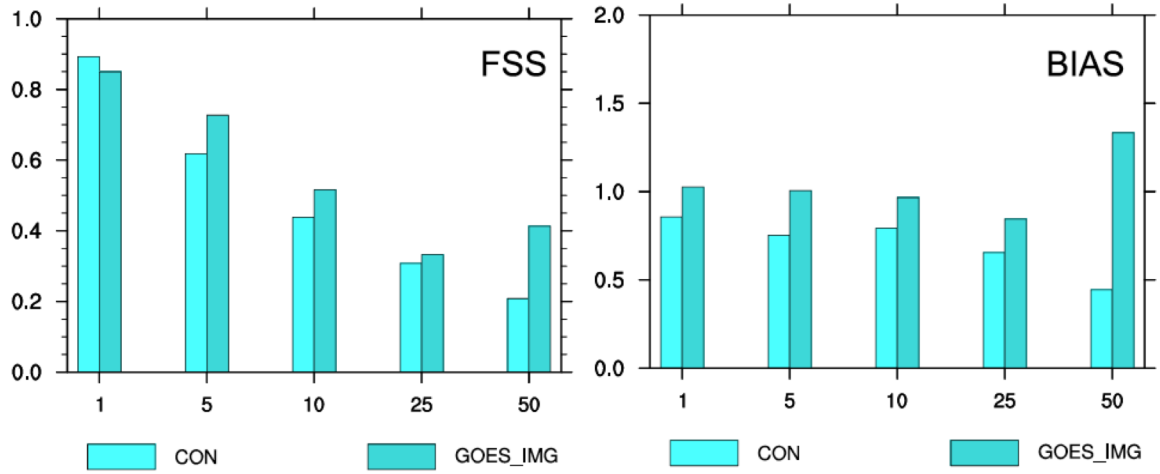
Yang et al., 2016, Tellus.

GEOS imager radiance DA at convection-permitting scale (4km, hourly-cycling, hybrid-3DVAR)



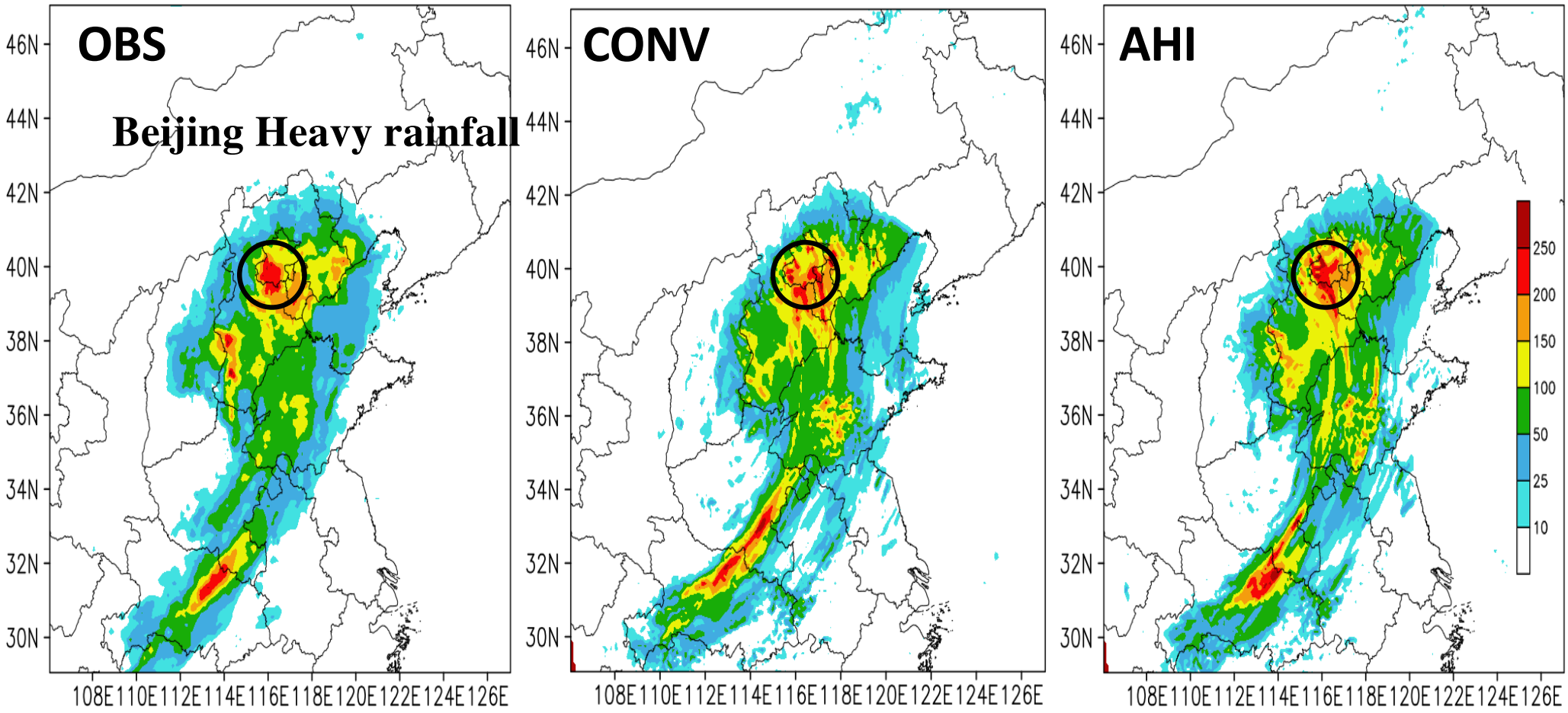
obs **No-GOES DA** **GOES-DA**





Yang et al., 2017, JGR-A.

24h accumulated rainfall field initialized at 2016071912



Himawari-8 AHI radiance DA impact

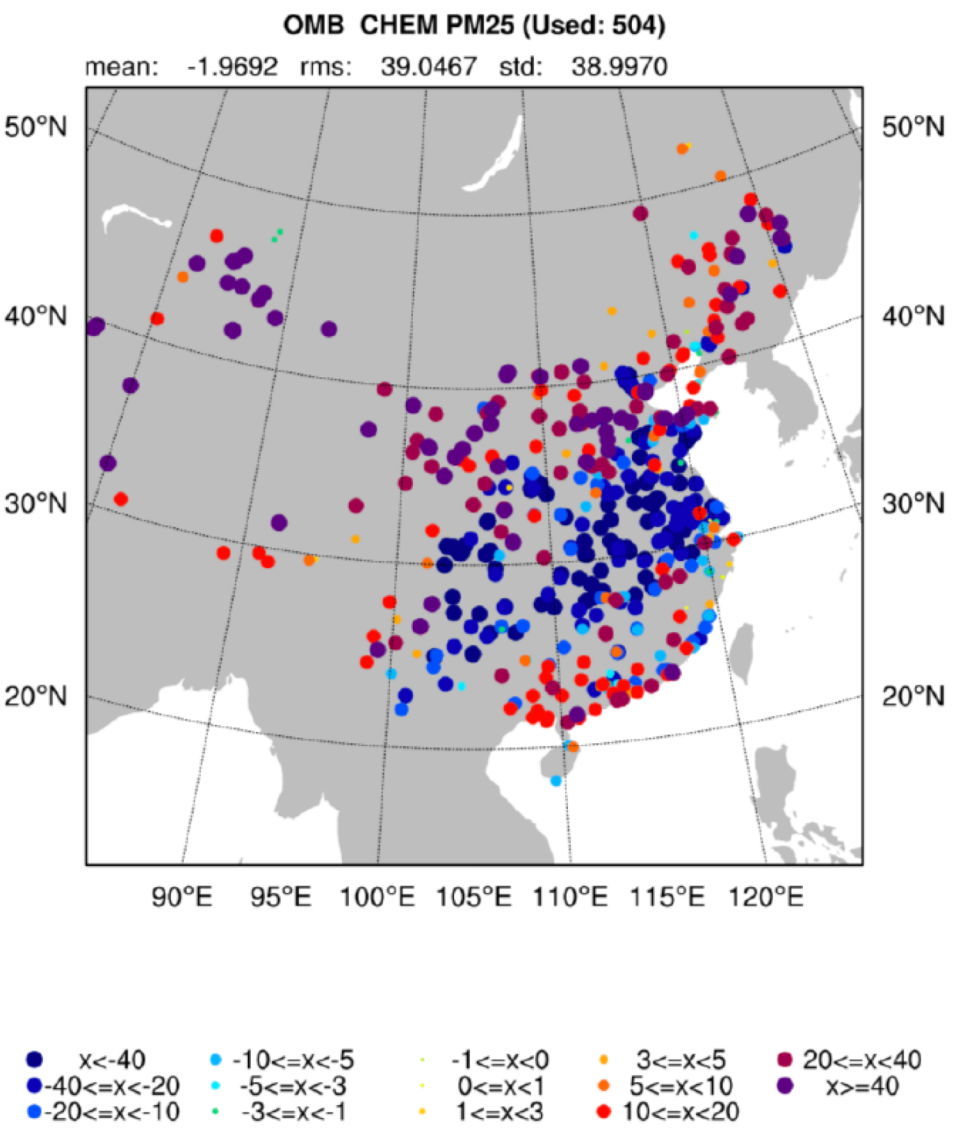
Wang et al., 2018, JGR-A

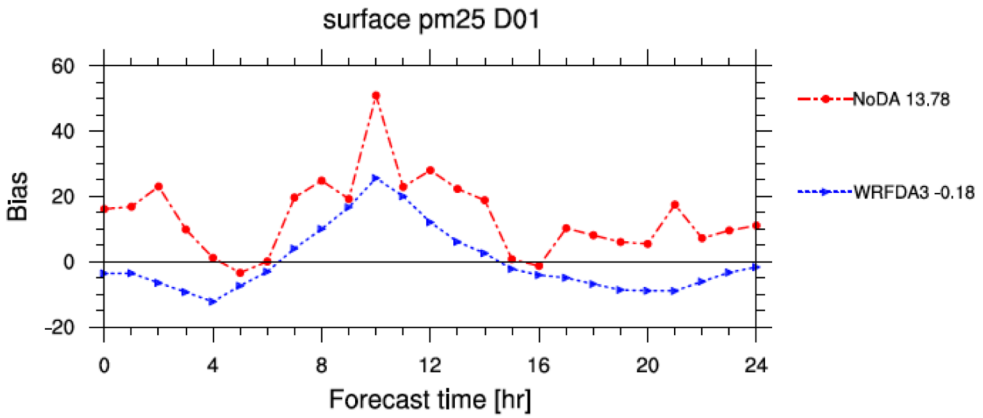
Ongoing R&D

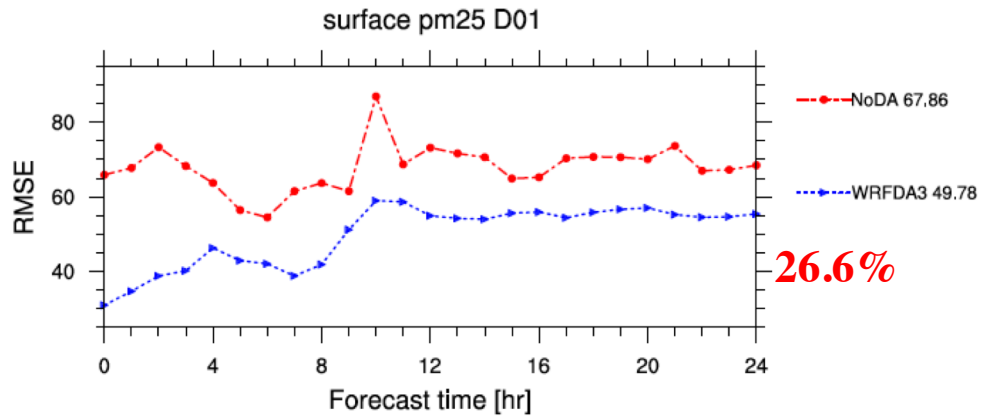
- Multi-Resolution Incremental 4DVAR
- GOES-ABI and Himawari-AHI all-sky radiance DA
- A new radar reflectivity operator with TL/AD for direct assimilation of reflectivity. Wang&Liu, 2019, GMD
  - Take into account mixed-phase precip. in melting layer
- Extension for aerosol/chemical DA
  - 3DVAR, can assimilate surface PM2.5, PM10, SO2, NO2, O3, and CO observations for WRF/Chem initialization
  - Some flexibility to use different aerosol/chemical options

PM2.5 DA impact over East China (Jan. 2015)

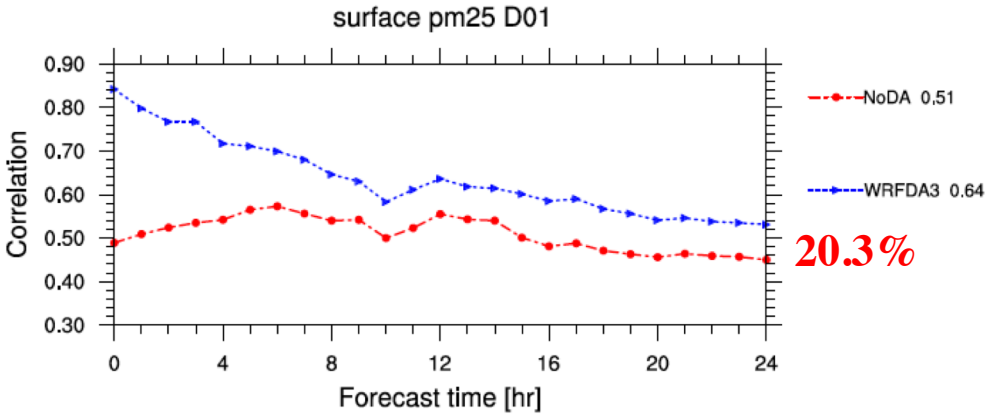
With MOSAIC aerosol scheme



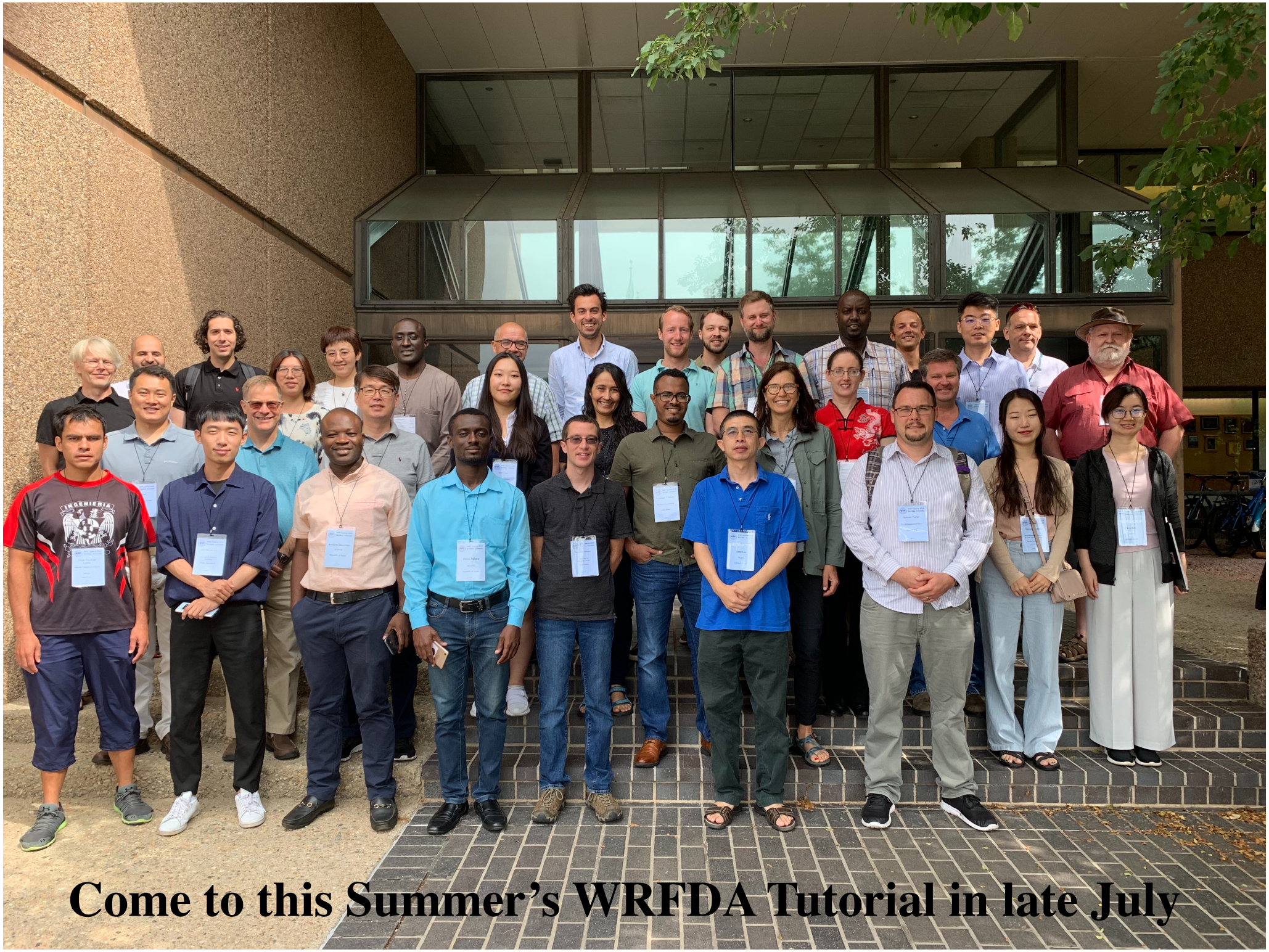




26.6%



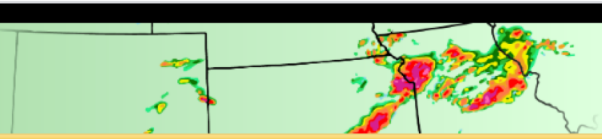
20.3%



Come to this Summer's WRFDA Tutorial in late July

www2.mmm.ucar.edu/wrf/users/wrfda/

WRFDA *USERS* PAGE



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Have questions? Try our FAQ first!

WRF Data Assimilation System Users Page

Welcome to the page for users of the Weather Research and Forecasting (WRF) model data assimilation system (WRFDA). The WRFDA system is in the public domain and is freely available for community use. It is designed to be a flexible, state-of-the-art atmospheric data assimilation system that is portable and efficient on available parallel computing platforms. WRFDA is suitable for use in a broad range of applications, across scales ranging from kilometers for regional and mesoscale modeling to thousands of kilometers for global scale modeling.

The Mesoscale and Microscale Meteorology (MMM) Laboratory of NCAR currently maintains and supports a subset of the overall WRF code (Version 3) that includes:

- WRF Software Framework (WSF)
- Advanced Research WRF (ARW) dynamic solver, including one-way, two-way nesting and moving nests, grid and observation nudging
- WRF Pre-Processing System (WPS)
- **WRF Data Assimilation System (WRFDA)** *(found on this site)*
- Numerous physics packages contributed by WRF partners and the research community

Other components of the WRF system will be supported for community use in the future, depending on interest and available resources.

Quick links:

- Download WRFDA Latest version: 4.1 *(Released April 12, 2019)*
- WRFDA system requirements Lists the requirements to run WRFDA on your system
- WRFDA Users' Guide Instructions on installing and running the latest version of

Latest WRFDA Release

WRFDA Version 4.1
(Released April 12, 2019)

Upcoming events

July 22–24, 2019

2019 WRFDA New User Tutorial, NCAR Foothills Laboratory, Boulder, CO, USA.
Registration is now open!

What's new

August 25, 2017

A new Online Tutorial page on setting up GEN_BE forecast input is now available.

August 17, 2017

WRFDA Version 3.9.1 has been released. View release notes.

July 10, 2017

The Users Guide and FAQ have been updated.

April 17, 2017

WRFDA Version 3.9 has been released. View release notes.

April 13, 2017