WRFDA Overview

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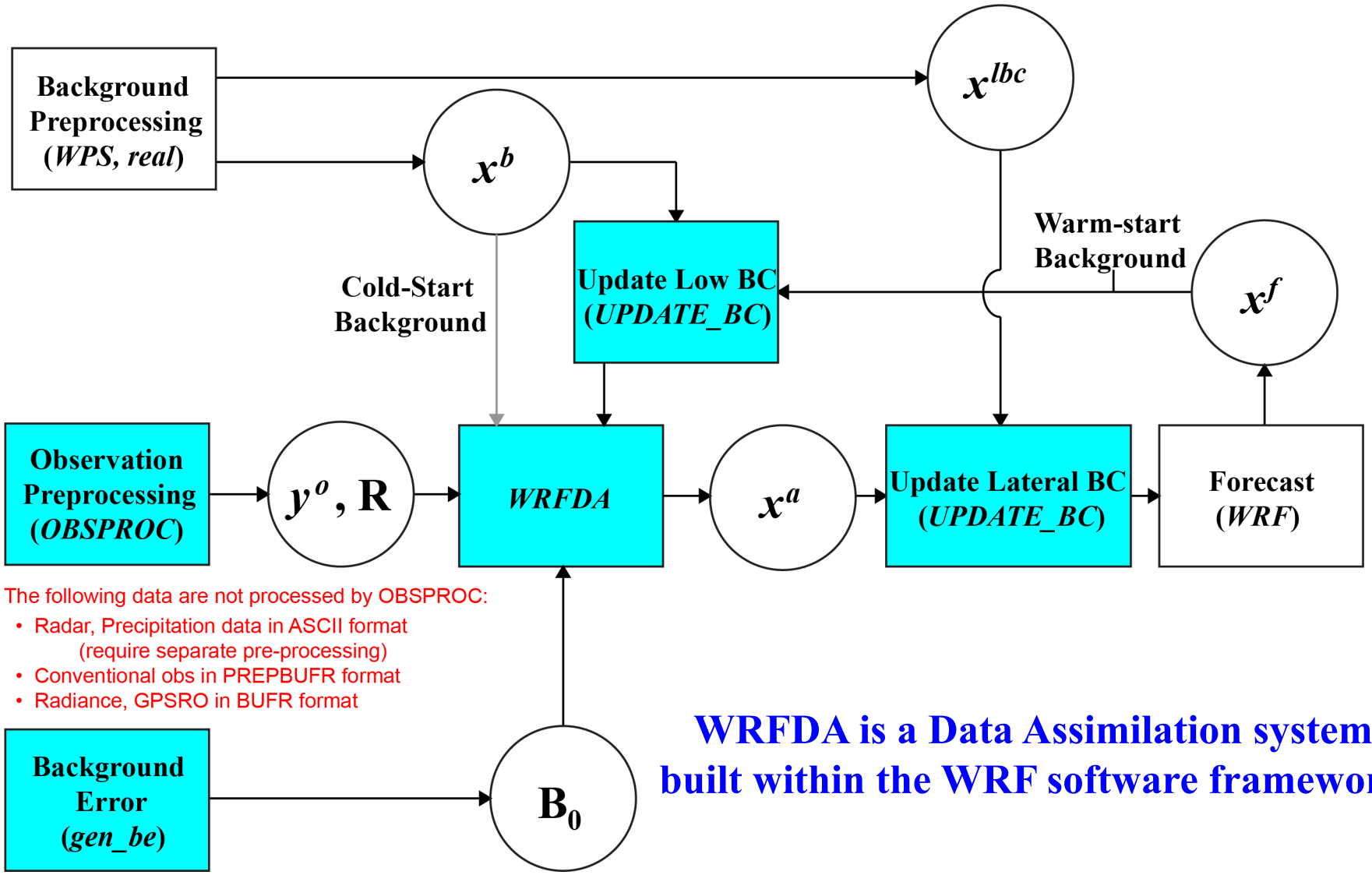
NCAR/MMM

WRFDA is a Data Assimilation system built within the WRF software framework, used for application in both research and operational environments….

WRFDA in the WRF Modeling System

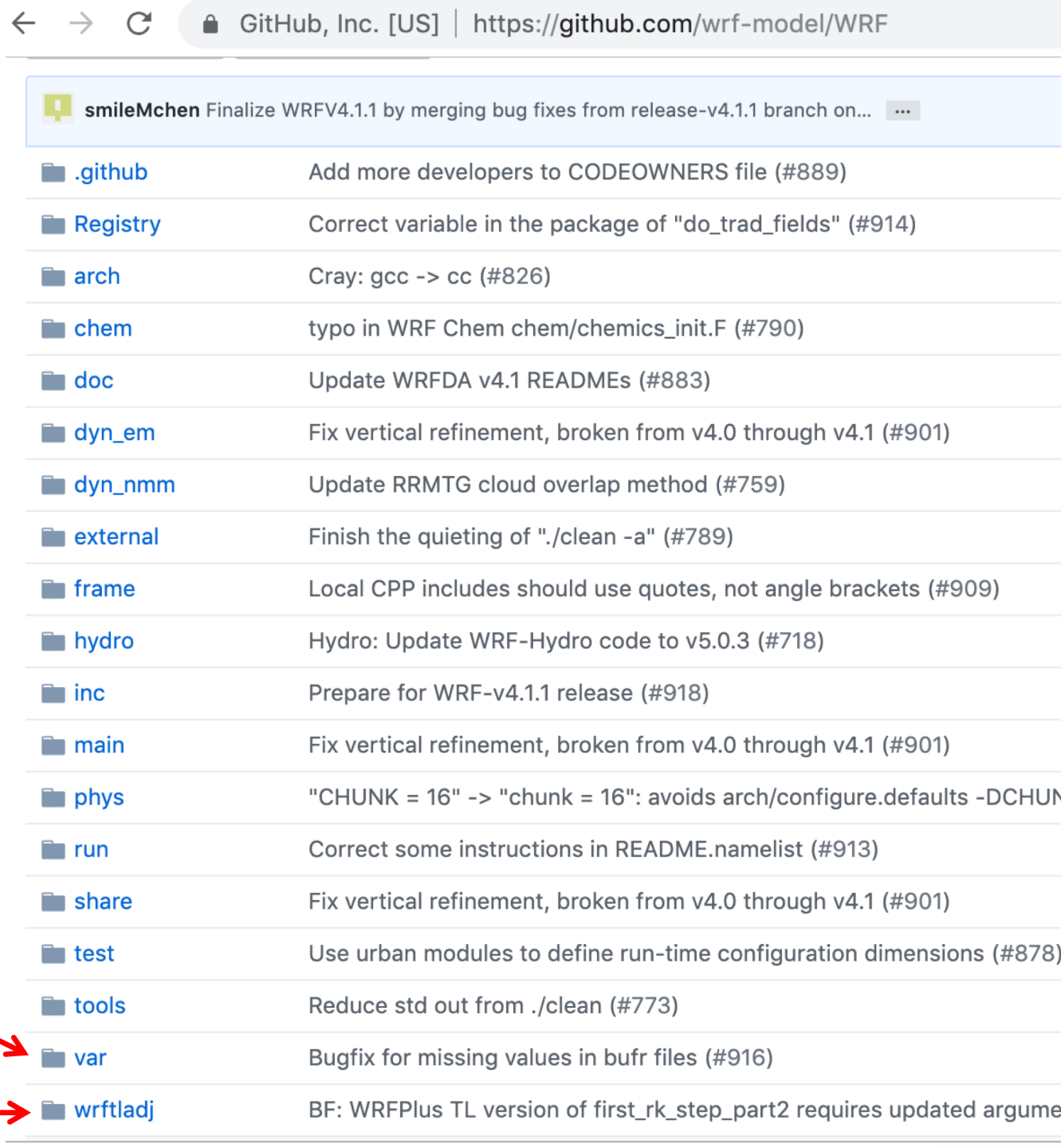


The following data are not processed by OBSPROC:

- Radar, Precipitation data in ASCII format (require separate pre-processing)
- Conventional obs in PREPBUFR format
- Radiance, GPSRO in BUFR format

WRFDA is a Data Assimilation system built within the WRF software framework

WRF code all on a public github repository



WRF Data Assimilation (WRFDA)

WRFPlus

What WRFDA can do?

- Provide Initial conditions for the WRF model forecast
- Verification and validation via difference between obs and model
- Observing system design, monitoring and assessment
- Reanalysis
- Better understanding:
  - Data assimilation methods
  - Model errors
  - Data errors
  - …

History of WRFDA developments

- Developed from MM5 3DVAR beginning around 2002, first version (2.0) released December 2003
- Implemented radar radial velocity DA in 2005
- WRF-Var V3.0, April 2008, merged into WRF repository
- WRF-Var V3.1, April 2009, **4DVAR and Radiance DA**
- WRFDA V3.2, April, 2010, **Hybrid-3DEnVAR**, Adjoint sensitivity
- WRFDA V3.3, April 2011, WRFPlus up to data with WRF
- WRFDA V3.4, April 2012, parallel 4DVAR, precipitation DA
- WRFDA V3.5, April 2013, wind speed/direction DA
- WRFDA V3.6, April 2014, dual-res. Hybrid, aircraft humidity DA
- WRFDA V3.7, April 2015, new radar DA option, cv_options=7, new MP option for WRFPlus TL/AD
- WRFDA V3.8, April 2016, dynamic constraint, AMSR2 radiance
- WRFDA V3.9, April 2017, hybrid-4DEnVar, all-sky radiance DA
- WRFDA V4.0, June 8, 2018, **WRFPlus merged into WRF Github repository (fully public Github repository)**
- **WRFDA V4.1, released in April 12, 2019, work with theta_m**

DA algorithms available in WRFDA

- 3DVAR and FGAT (First Guess at Appropriate Time)
  - Different options for choice of dynamic control variables (e.g., Psi/Chi or U/V) and cloud analysis variables
- 4DVAR
  - Need WRFPlus: TL/Adjoint 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
  - 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

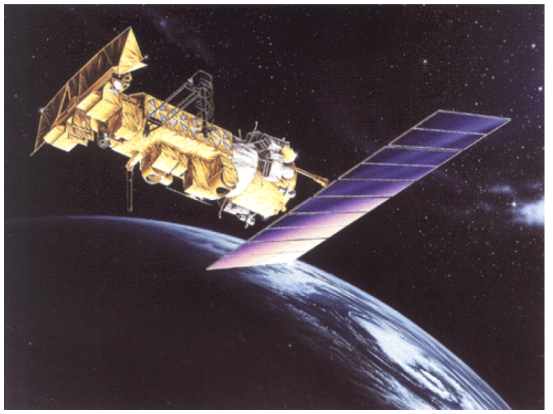
- **Remotely sensed retrievals:**
  - Atmospheric Motion Vectors (geo/polar)
  - SATEM thickness
  - Ground-based GPS TPW or ZTD
  - SSM/I oceanic surface wind speed and TPW
  - Scatterometer oceanic surface winds
  - Wind Profiler
  - Radar data (reflectivity/retrieved rainwater, and radial-wind
    - 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)

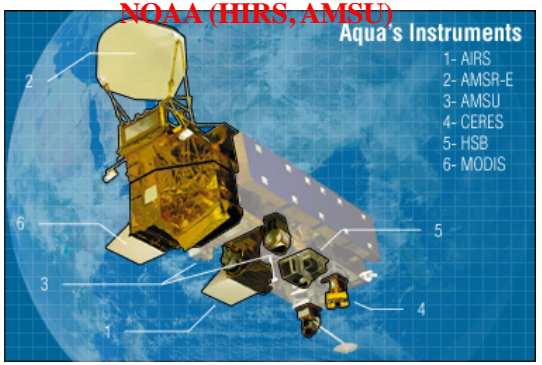
- **Radiances (VarBC, RTTOV & CRTM, All-sky radiance):**
  - HIRS NOAA-16, NOAA-17, NOAA-18, NOAA-19, METOP-A
  - AMSU-A NOAA-15/16/18/19, EOS-Aqua, METOP-A, METOP-B
  - AMSU-B NOAA-15, NOAA-16, NOAA-17
  - MHS NOAA-18, NOAA-19, METOP-A, METOP-B
  - AIRS EOS-Aqua
  - SSMIS DMSP-16, DMSP-17, DMSP-18
  - 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)

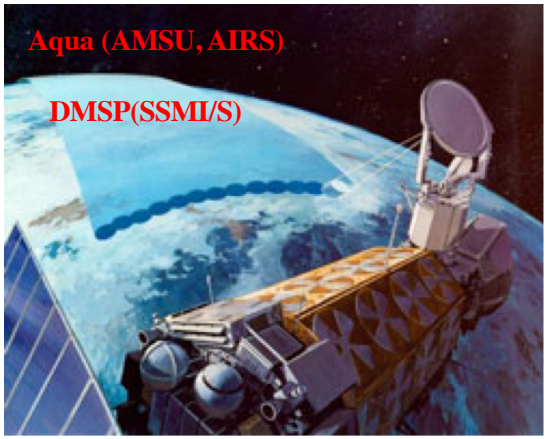
WRFDA is flexible to allow assimilation of different formats of observations:
- Little_r (ascii), HDF, Binary
- NOAA MADIS (netcdf),
- NCEP PrepBufr,
- NCEP radiance bufr

WRFDA
Radiance Assimilation

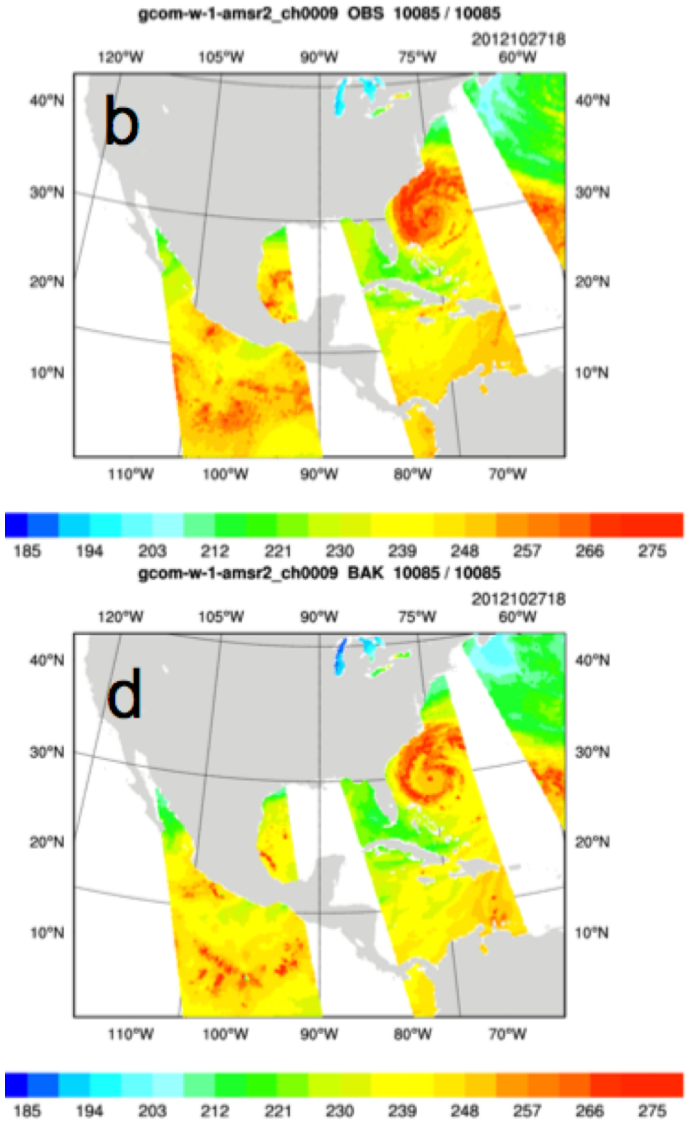
- Two RTM interfaces
  - RTTOV or CRTM
- Variational Bias Correction
- Modular code design to ease adding new satellite sensors
- Capability for cloudy radiance DA



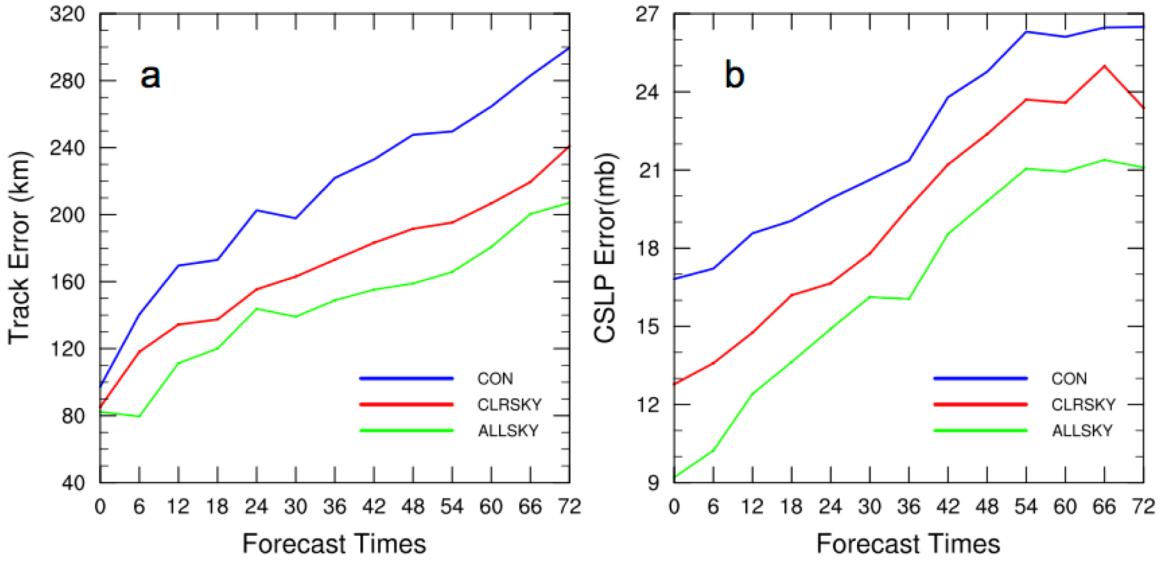




New in V3.9: all-sky radiance DA: AMSR2

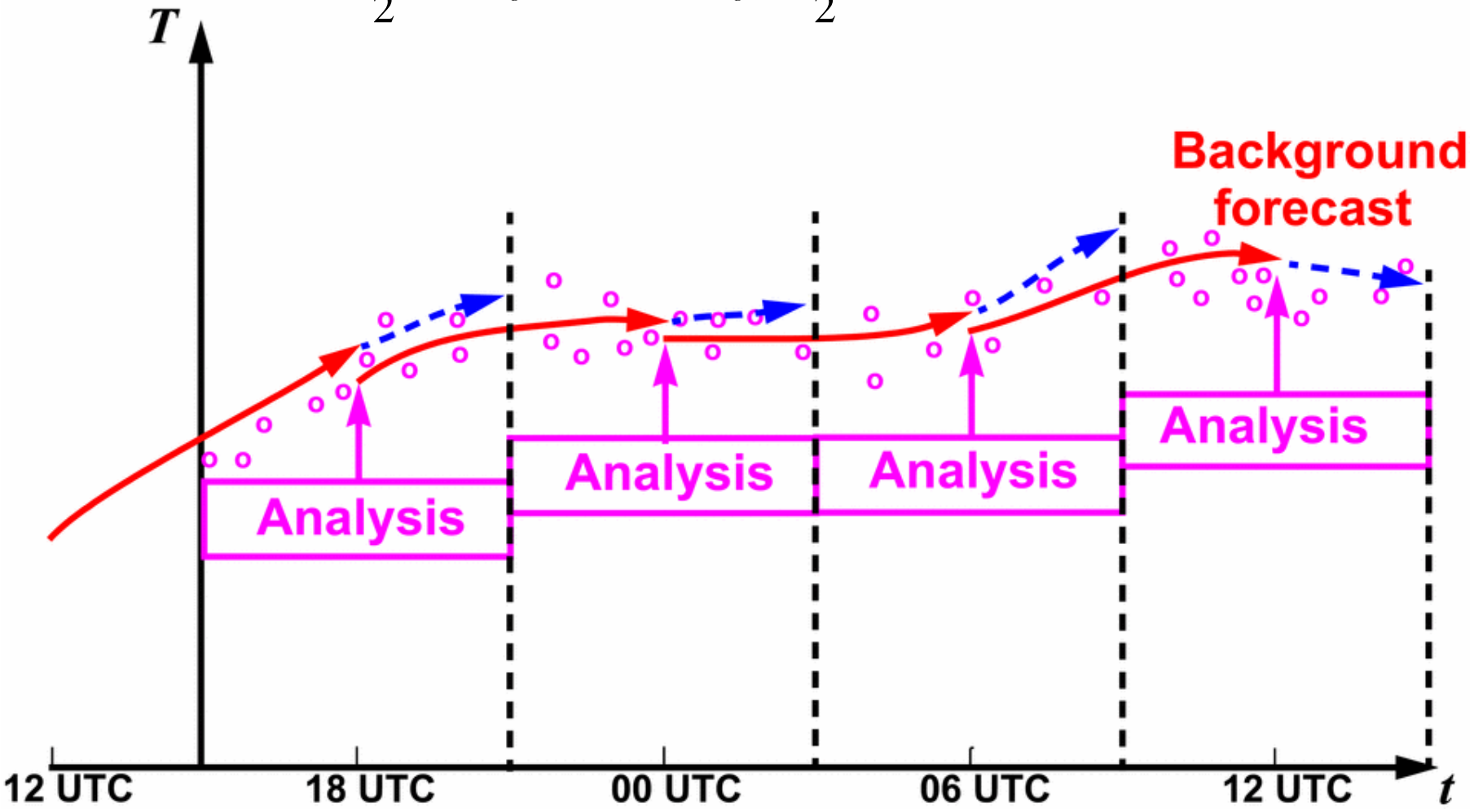


Channel	Frequency (GHz)	Polarization	Footprint (along scan* along track)
1,2	6.925	V,H	35*61 km
3,4	7.3	V,H	35*61 km
5,6	10.65	V,H	24*41 km
7,8	18.7	V,H	13*22 km
9,10	23.8	V,H	15*26 km
11,12	36.5	V,H	7*12 km
13,14	89.0	V,H	3*5 km



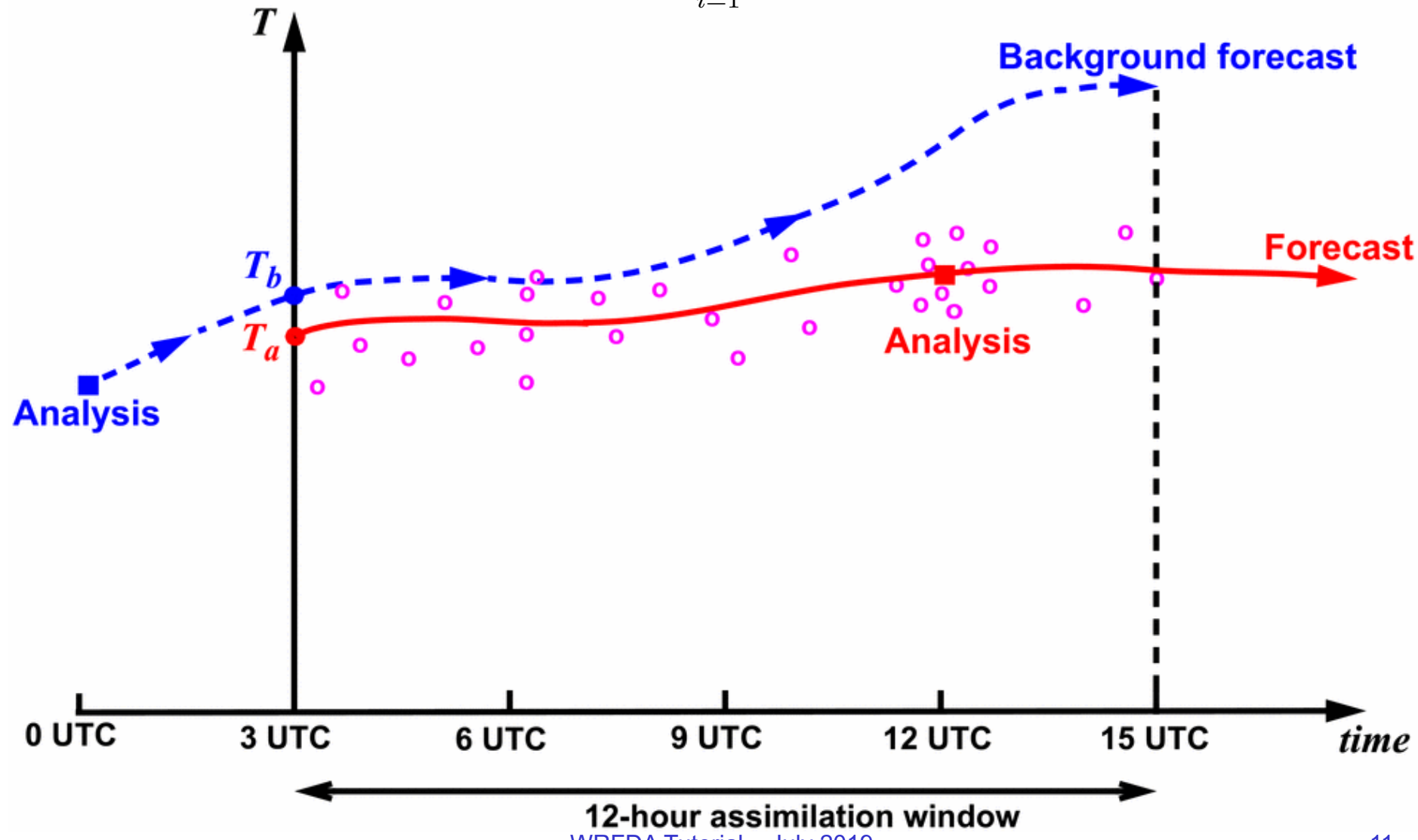
3DVAR (Barker et al. 2004)

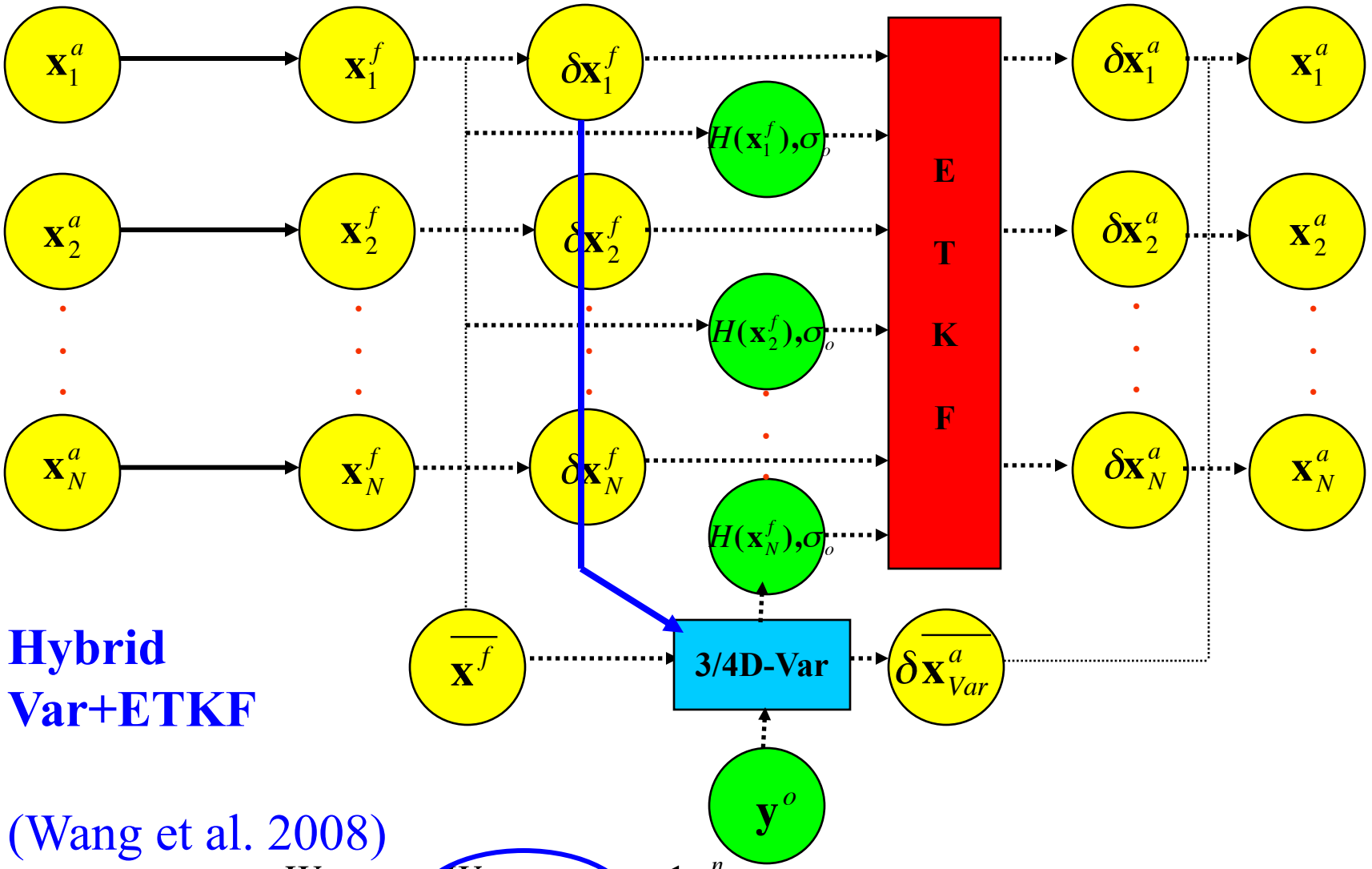
$$J(x) = \frac{1}{2}(x - x_b)^{\mathrm{T}} \mathrm{B}^{-1}(x - x_b) + \frac{1}{2}[H(x) - y]^{\mathrm{T}} \mathrm{R}^{-1}[H(x) - y]$$



4DVAR (Huang et al. 2009)

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

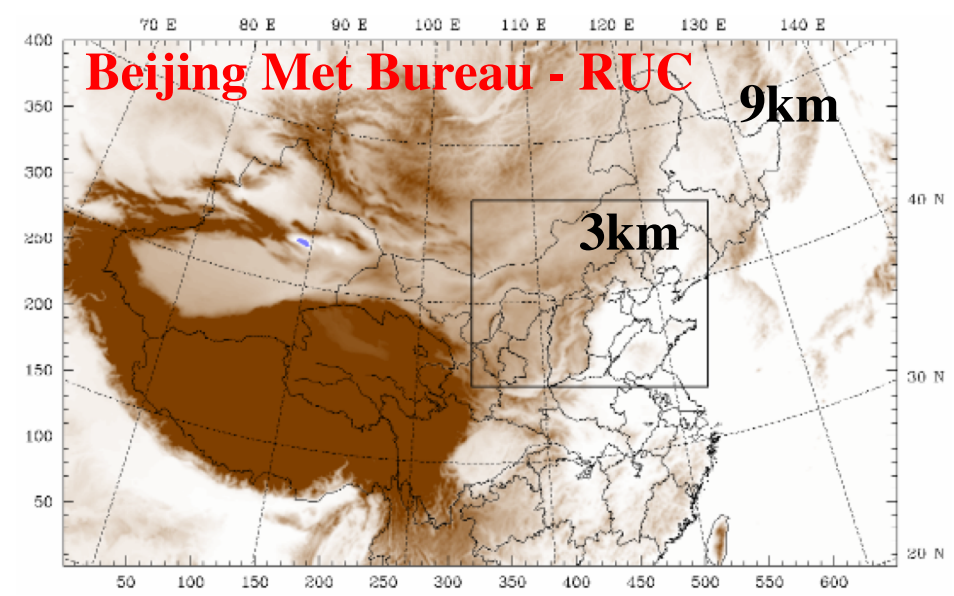


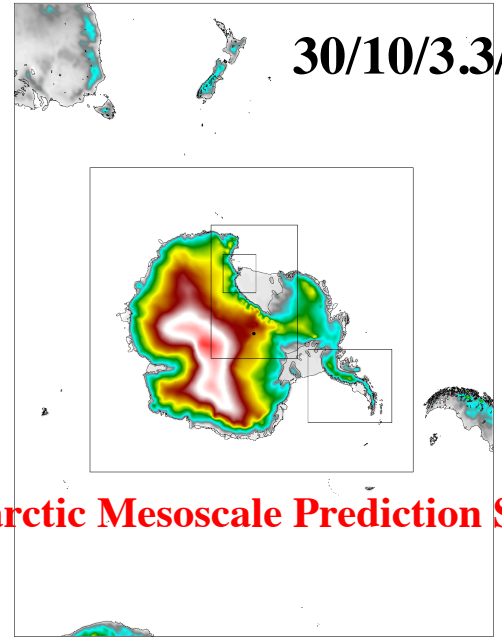


Hybrid Var+ETKF

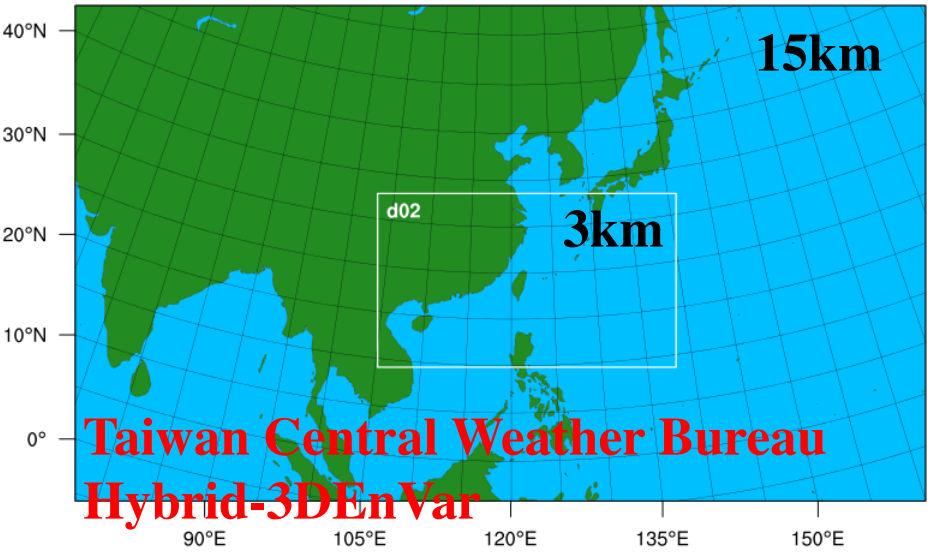
(Wang et al. 2008)

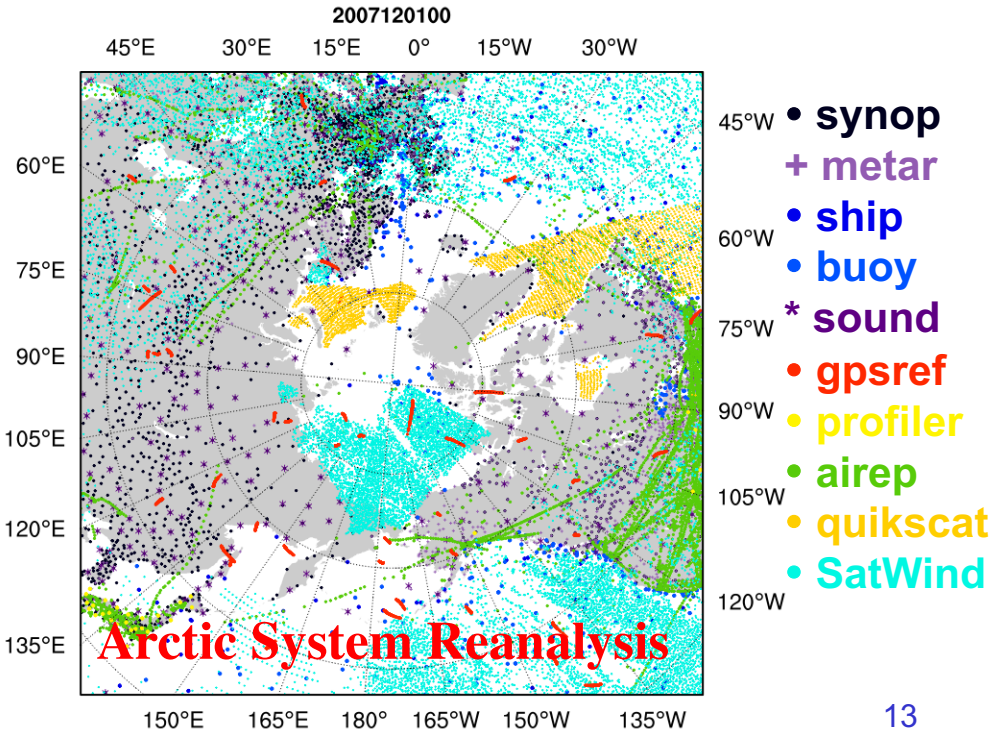
$$J = \frac{W_b}{2}\mathbf{v}^T\mathbf{v} + \frac{W_\alpha}{2}\mathbf{a}^T\mathbf{A}^{-1}\mathbf{a} + \frac{1}{2}\sum_{i=0}^{n}\left[\mathbf{d}_i - \mathbf{H}_i\mathbf{M}_i\mathbf{U}\mathbf{v}\right]^T \mathbf{R}_i^{-1}\left[\mathbf{d}_i - \mathbf{H}_i\mathbf{M}_i\mathbf{U}\mathbf{v}\right]$$





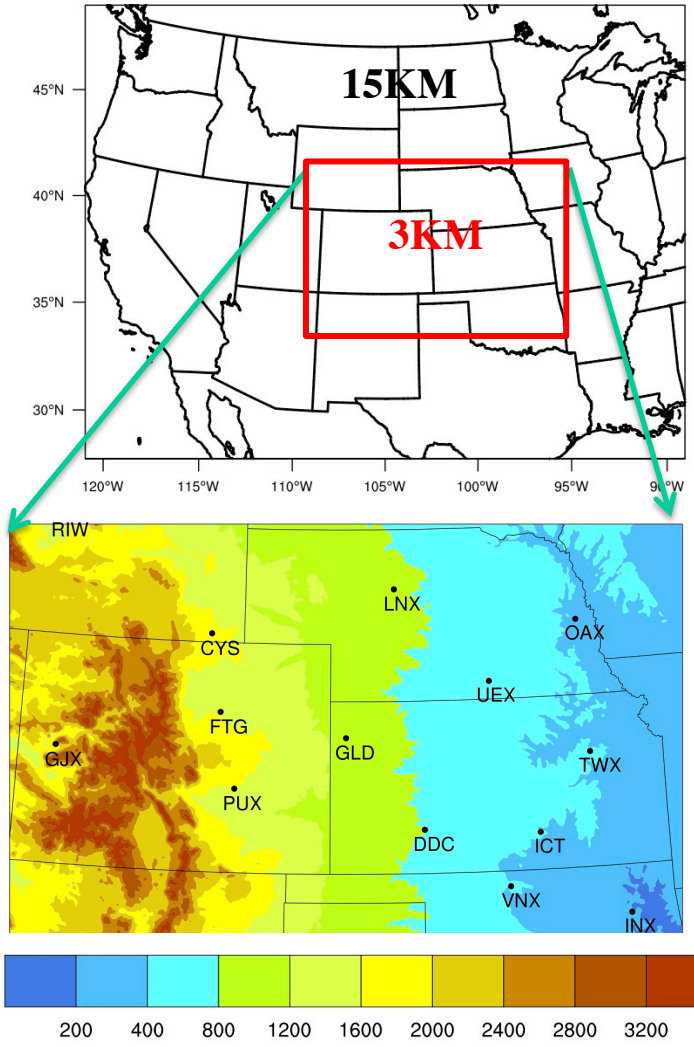
Antarctic Mesoscale Prediction System—AMPS



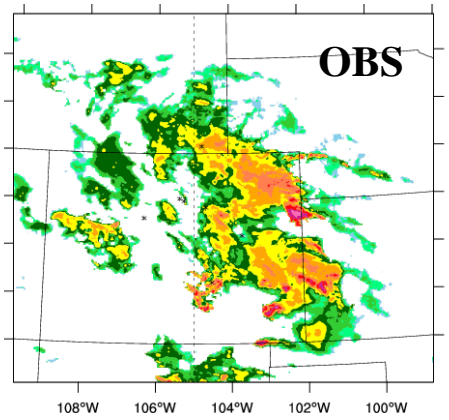


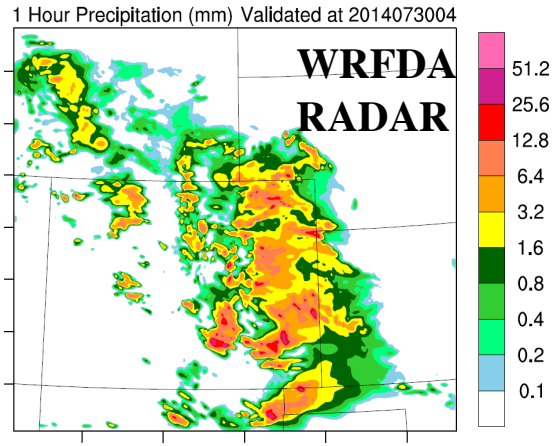
Radar DA for hydrological application

STEP Hydromet Real Time Exp. during spring time

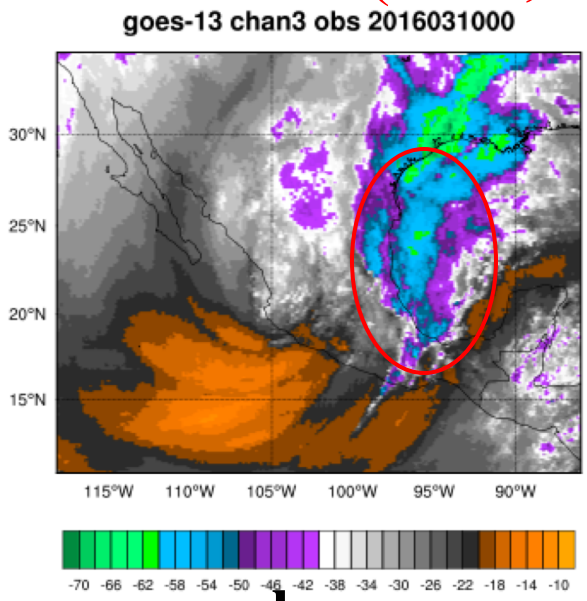


- The goal is to improve lo cal-scale QPF in coupled hydromet system
- < 1 h rapid update
- Radar radial velocity an d reflectivity assimilation
- High resolution vs. ense mble
- Impact of terrain
- Improved results in capt uring localized storms

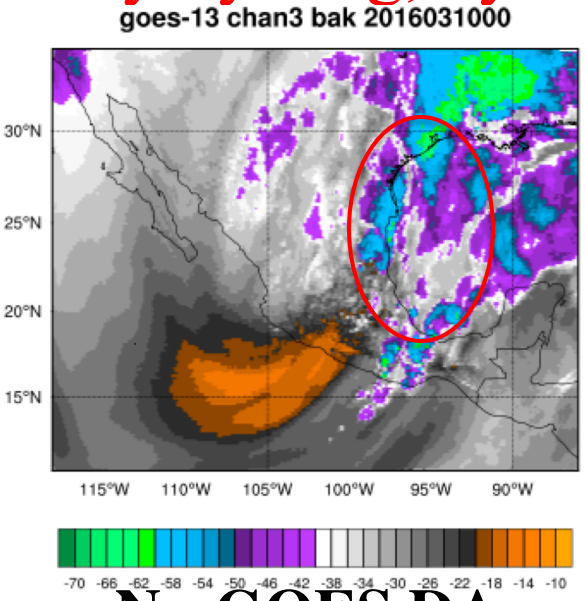




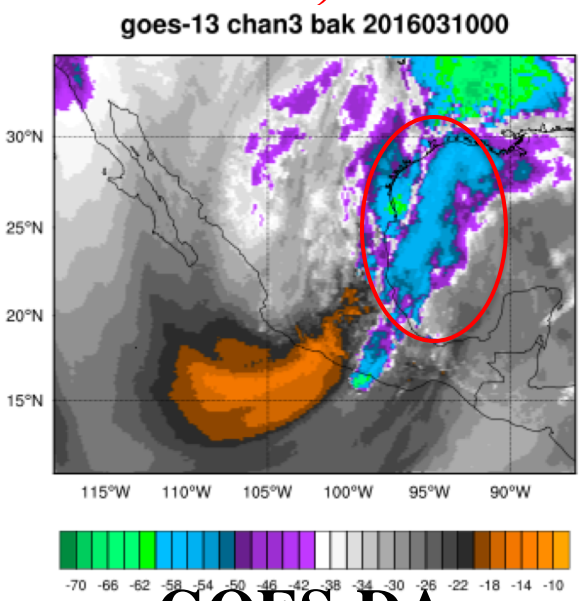
GEOS imager radiance DA at convection-permitting scale (4km, hourly-cycling, hybrid-3DVAR)



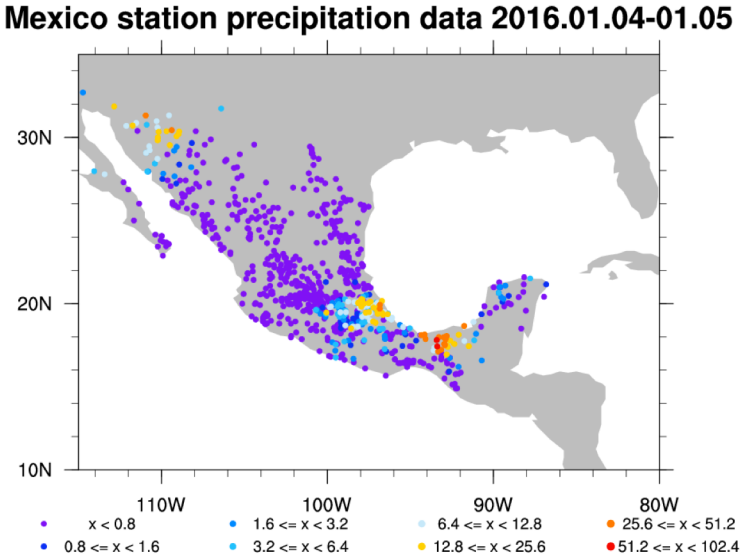
obs

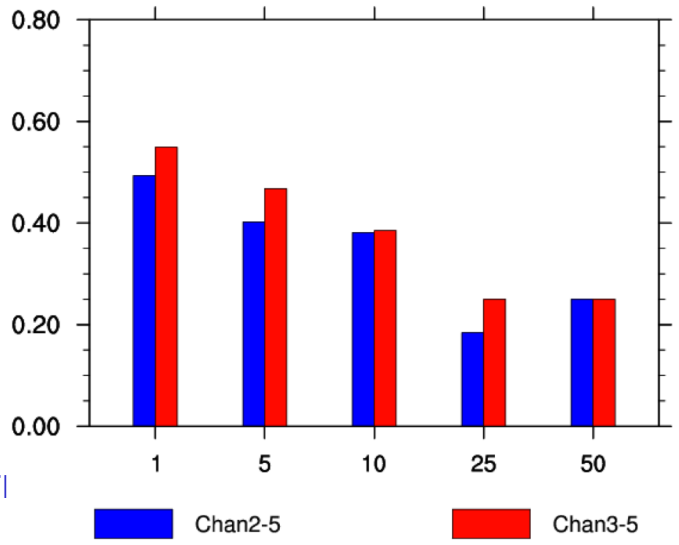


No-GOES DA



GOES-DA

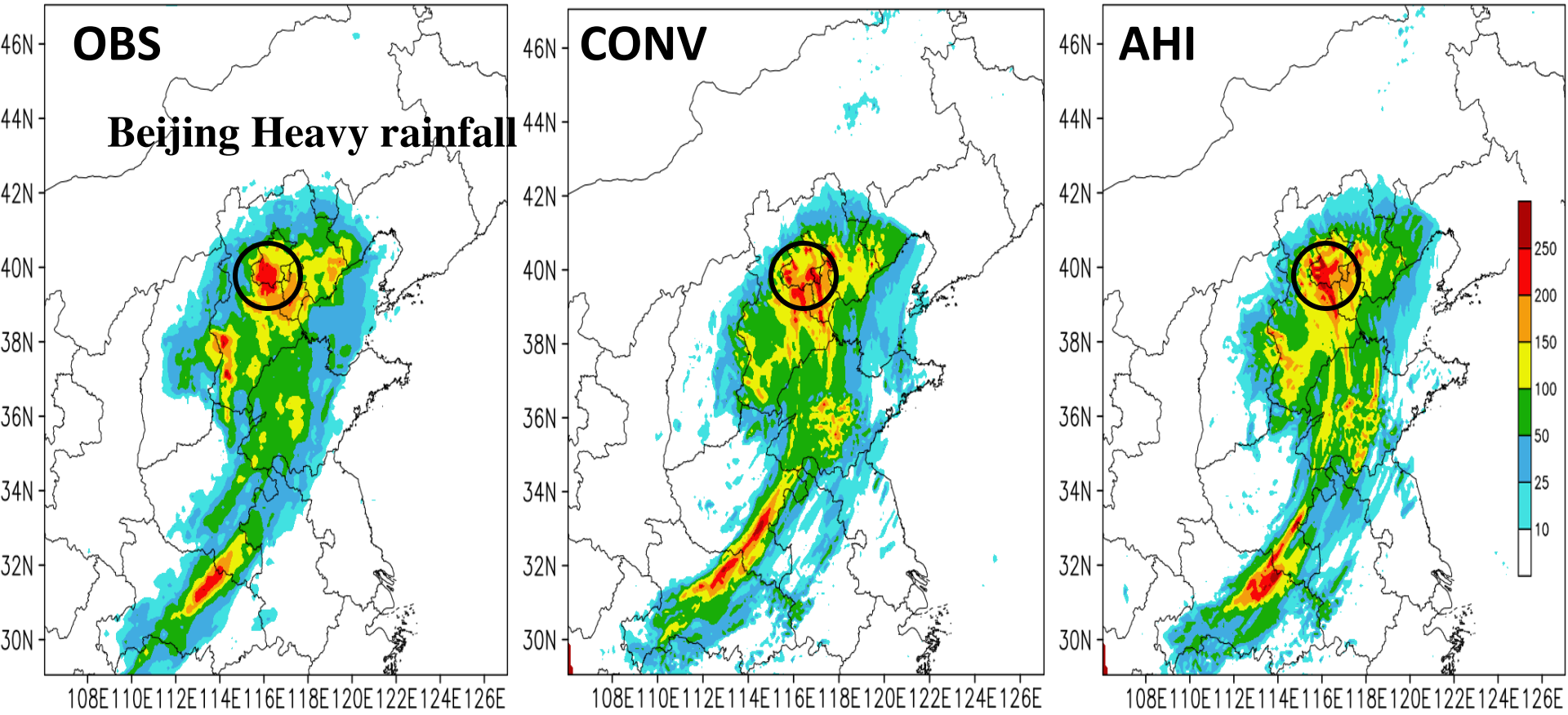




Yang et al., 2017, JGR.

RFI

24h accumulated rainfall field initialized at 2016071912



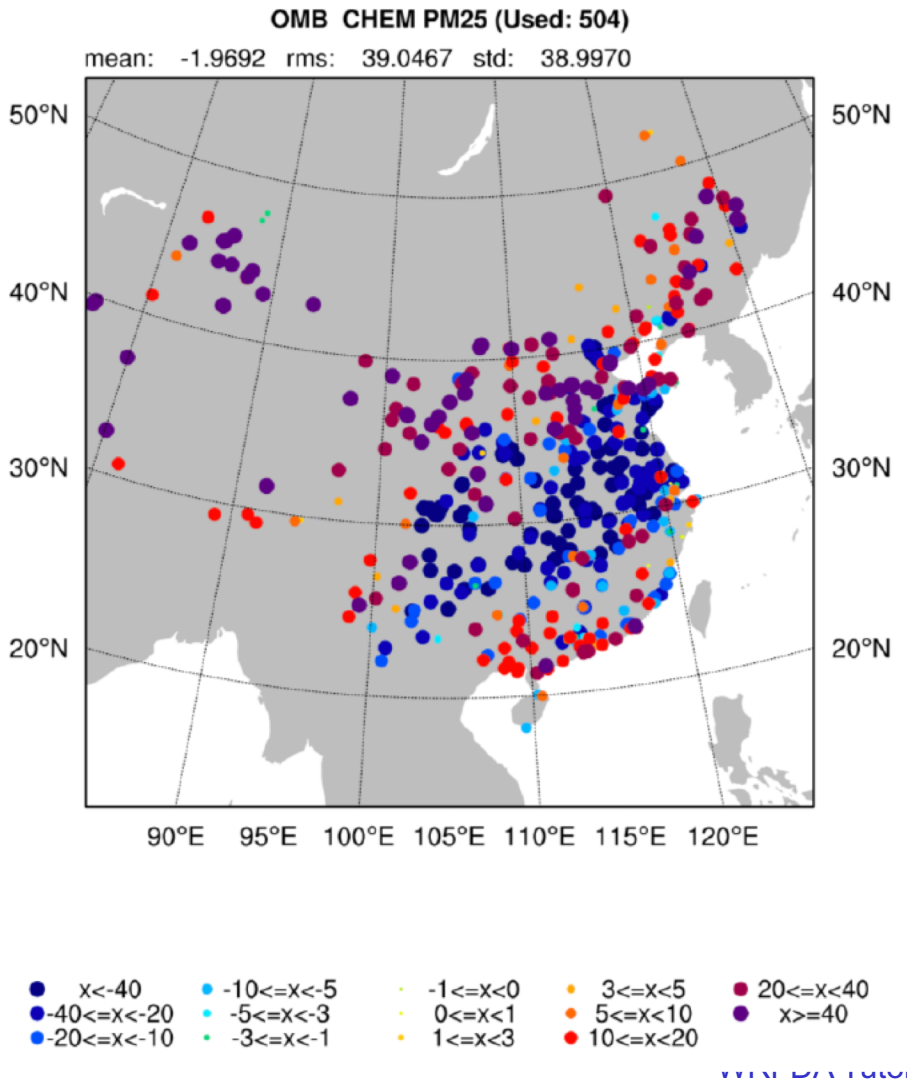
Himawari-8 AHI radiance DA impact

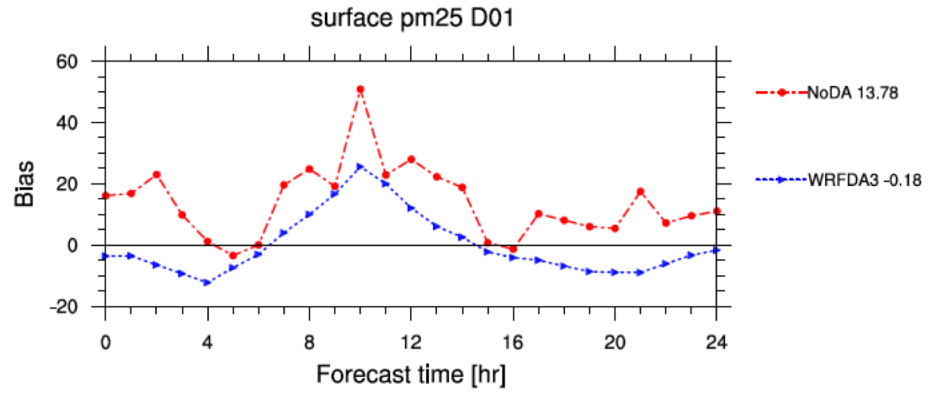
Ongoing R&D

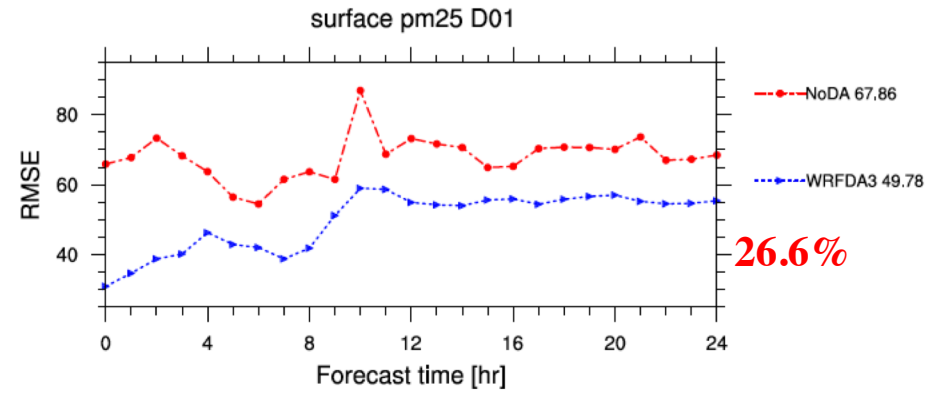
- Multi-Resolution Incremental 4DVAR
- GOES-ABI and Himawari-AHI all-sky radiance DA
- A new radar reflectivity operator with TL/AD for direct assimilation of reflectivity
  - Take into account mixed-phase precip. in melting layer
- Extension for aerosol/chemical DA
  - 3DVAR, can assimilate surface 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)

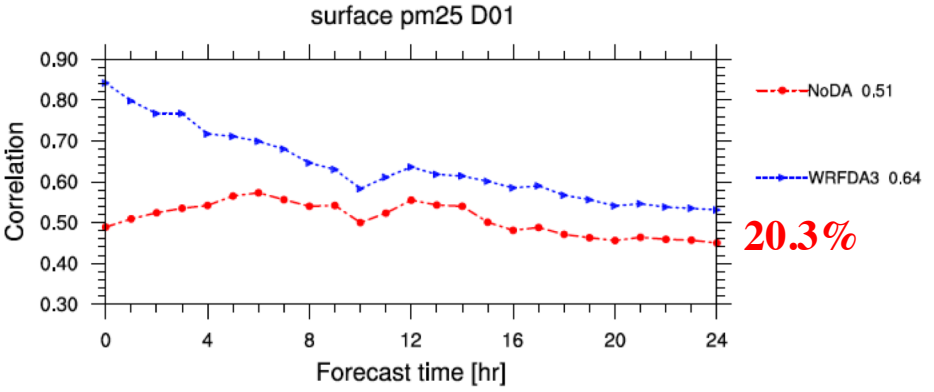
With MOSAIC aerosol scheme







26.6%



20.3%

Preliminary capability of 4DVAR-based emission inversion

Geosci. Model Dev., 8, 1857–1876, 2015
www.geosci-model-dev.net/8/1857/2015/
doi:10.5194/gmd-8-1857-2015

Geoscientific Model Development
Open Access

Development and application of the WRFPLUS-Chem online chemistry adjoint and WRFDA-Chem assimilation system

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Correspondence to: J. J. Guerrette (jonathan.guerrette@colorado.edu)

Received: 26 January 2015 – Published in Geosci. Model Dev. Discuss.: 27 February 2015
Revised: 19 May 2015 – Accepted: 29 May 2015 – Published: 23 June 2015

Atmos. Chem. Phys., 17, 7605–7633, 2017
https://doi.org/10.5194/acp-17-7605-2017

Atmospheric Chemistry and Physics
Open Access
EGU

Four-dimensional variational inversion of black carbon emissions during ARCTAS-CARB with WRFDA-Chem

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Correspondence to: Jonathan J. Guerrette (jonathan.guerrette@colorado.edu)

Received: 1 July 2016 – Discussion started: 17 October 2016
Revised: 24 March 2017 – Accepted: 22 April 2017 – Published: 22 June 2017

Not Secure | www2.mmm.ucar.edu/wrf/users/wrfda/

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WRF Users Page

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: 4.0 *(Released June 8, 2018)*
- WRFDA system requirements Lists the requirements to run WRFDA on your system

Latest WRFDA Release

WRFDA Version 4.0
(Released June 8, 2018)

Upcoming events

July 24–26, 2017

2017 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

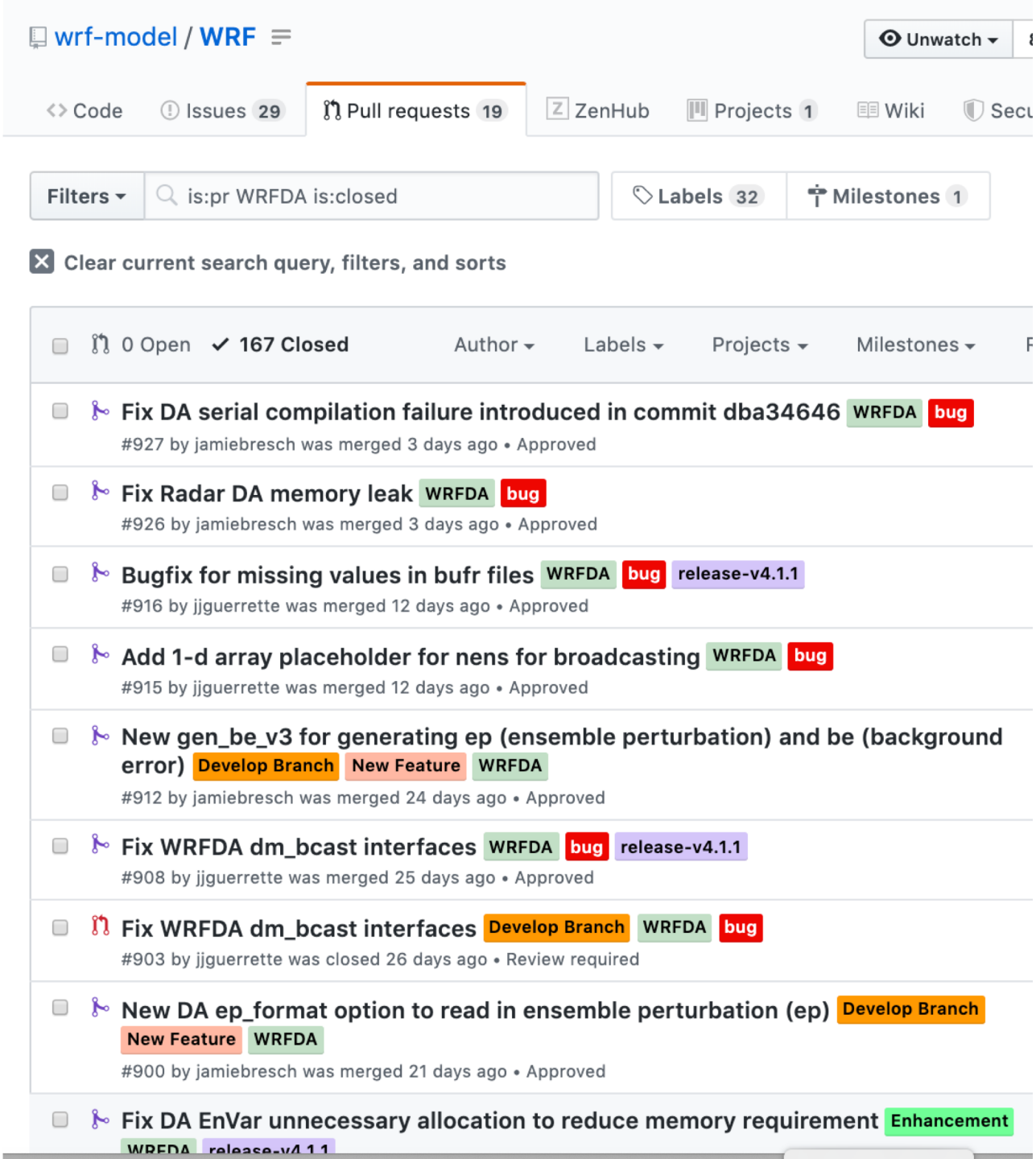
WRFDA Version 3.9.1 has been released. View release notes.

July 10, 2017

The Users Guide and FAQ have been updated.

April 17, 2017

WRFDA Version 3.9 has been released. View release notes.



Welcome your contributions,

Use git/github and follow Pull Request examples

NOT send us your code in tar file