

Introduction to WRFDA

Zhiquan Liu

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

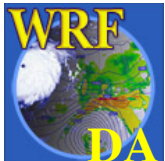
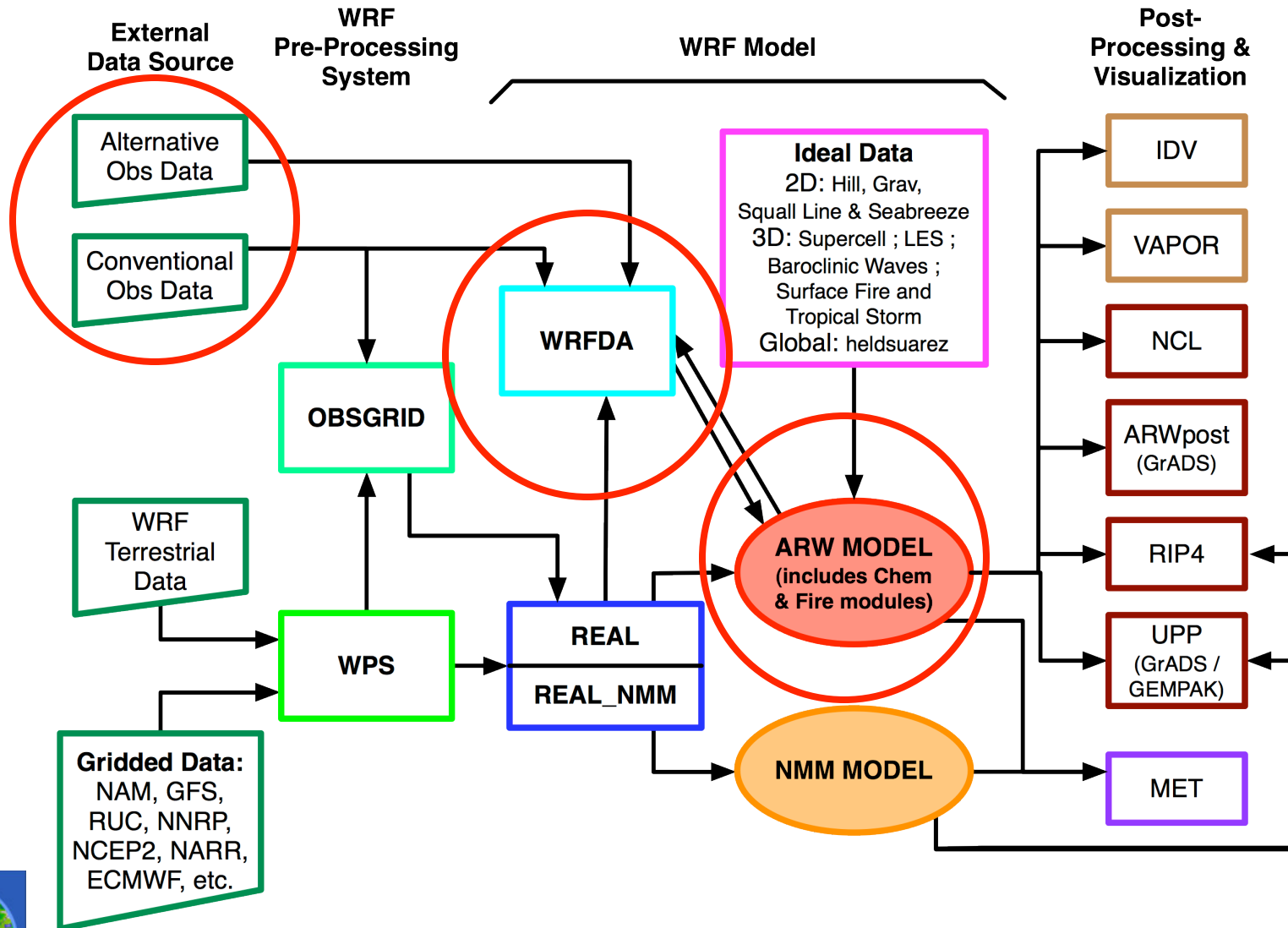
Acknowledge:

WRFDA team and many visitors,

AFWA, NCAR, PWS, NSF-AGS, USWRP, NSF-OPP, NASA, PSU, CWB, BMB, CAA, KMA, EUMETSAT, NUIST



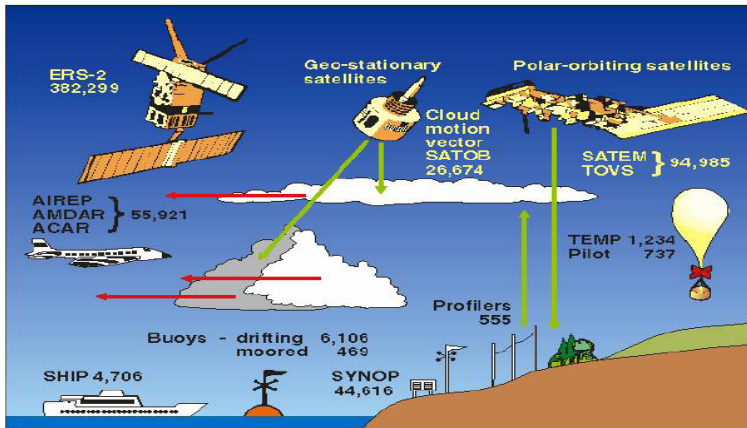
WRFDA in WRF Modeling System



Why data assimilation?

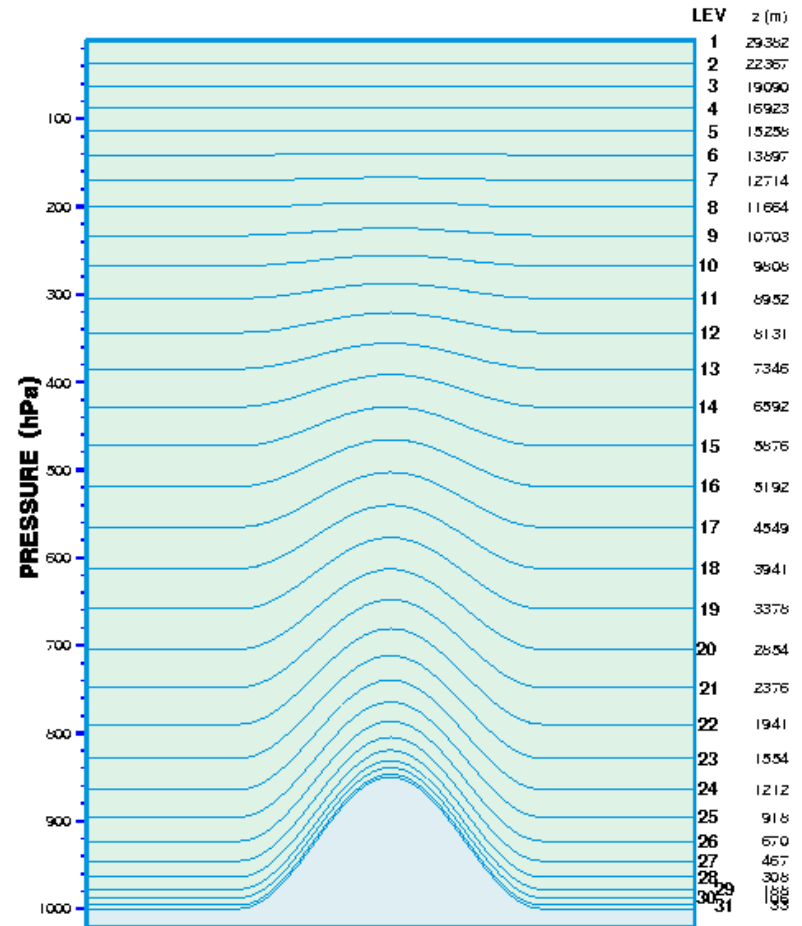
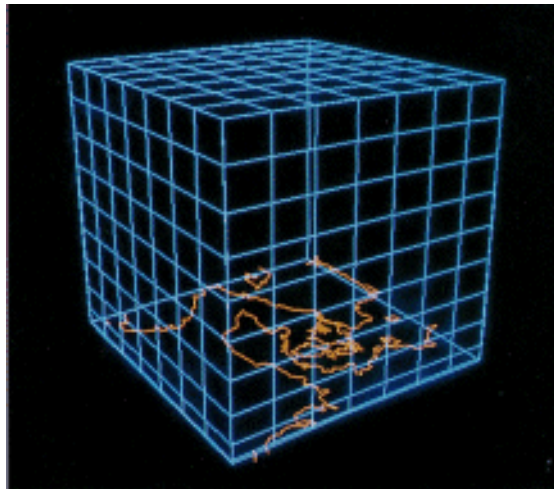
- Initial conditions
- Verification and validation
- Observing system design, monitoring and assessment
- Reanalysis
- Better understanding:
 - Data assimilation methods
 - Model errors
 - Data errors
 - ...



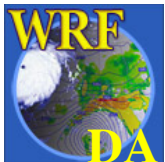


Observations
 $y^0, \sim 10^5 - 10^6$

Model state
 $x, \sim 10^7$



Vertical resolution of the DMI-HIPLAM system



Radiance impact on Hurricane forecasts

(Liu et al. 2012)

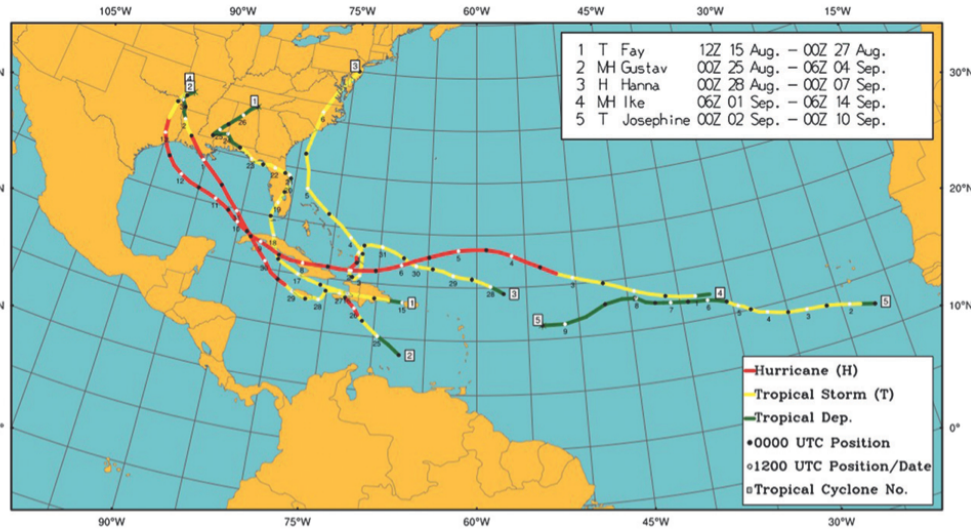


FIG. 1. NHC best track for the five named storms during 11 Aug–13 Sep 2008. See legend for meanings of colors and symbols used in the

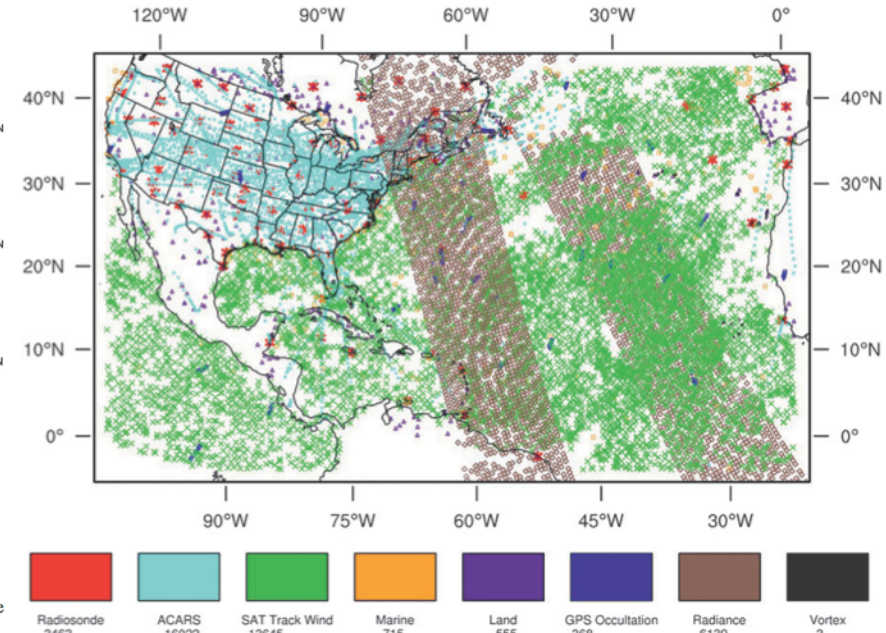


FIG. 2. Snapshot of observations assimilated at 0000 UTC 16 Aug 2008.

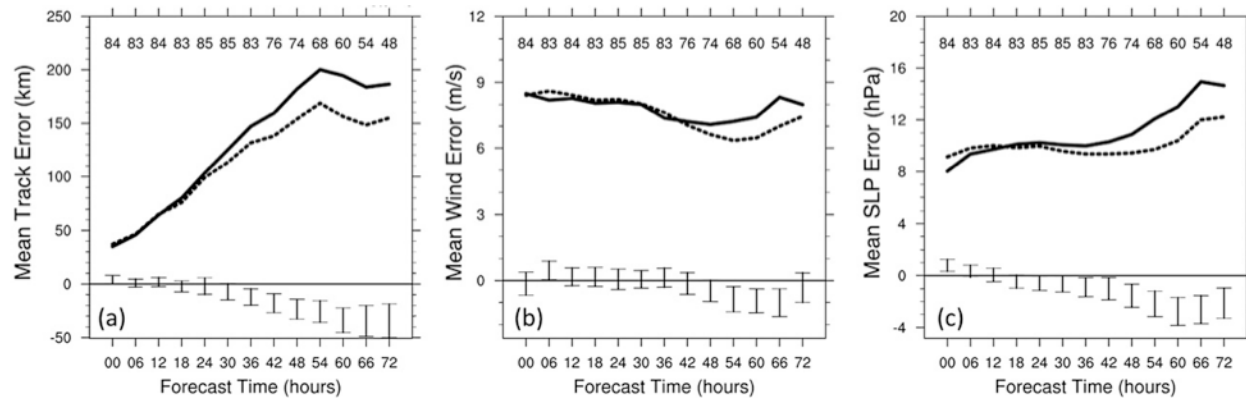
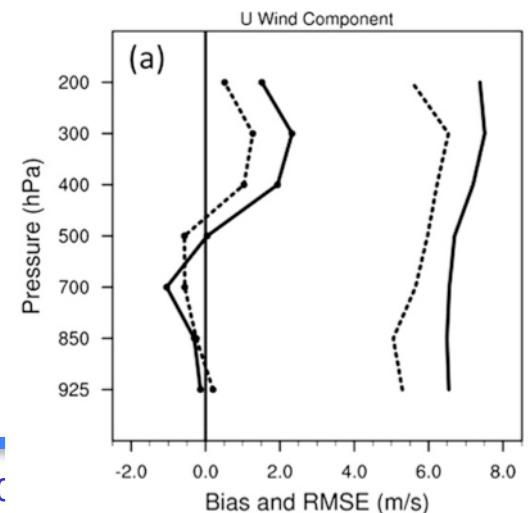
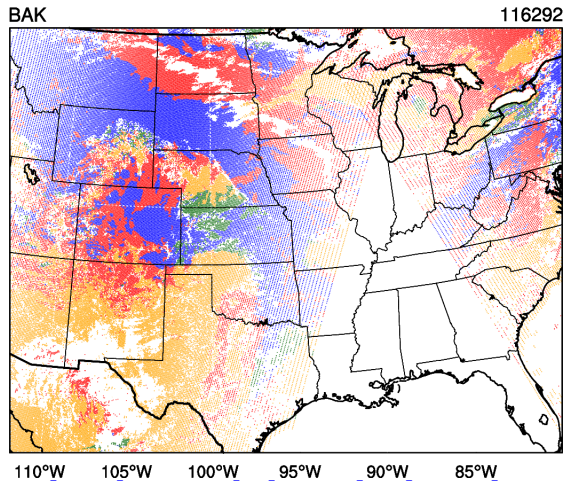


FIG. 5. Mean absolute errors as a function of forecast lead time for (a) track, (b) maximum wind speed, and (c) minimum sea level pressure for all storms. Solid lines denote the results from the NoAMA experiment and dashed lines denote the results from the AMA experiment. Bounds of the 90% confidence interval based upon differences between the two experiments' errors (see section 6b) are also shown.



band 24 (4.46 micron) 2011052418

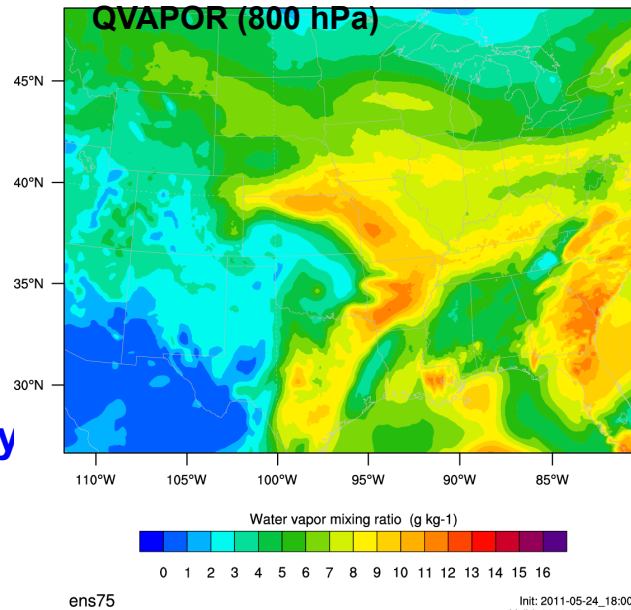


- both model and obs cloudy
- both model and obs clear
- model clear, obs cloudy
- model cloudy, obs clear

3dvar

Init: 2011-05-24_18:00:00
Valid: 2011-05-24_18:00:00
3DVAR Analysis

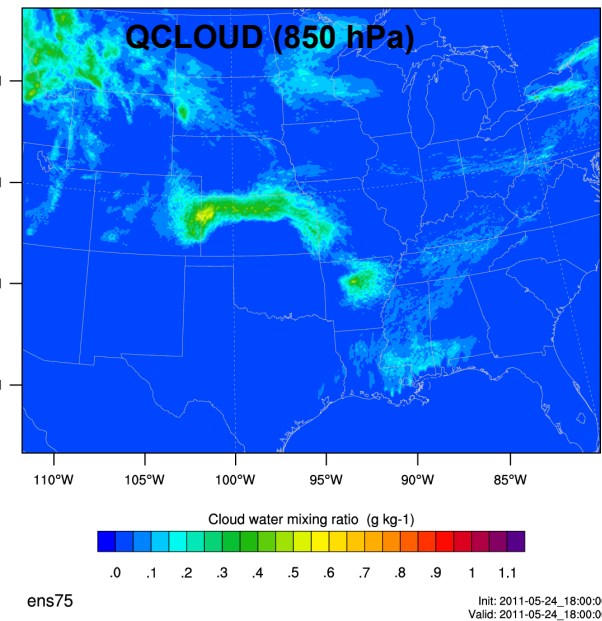
Water vapor mixing ratio (g kg⁻¹) at Eta Level 15



3dvar

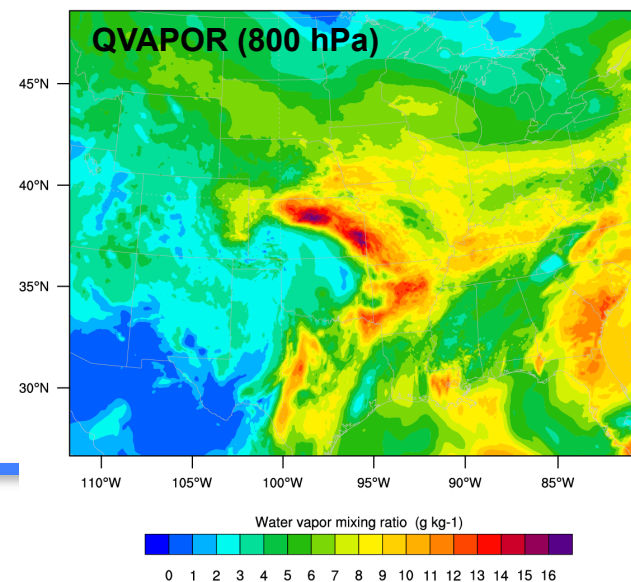
Init: 2011-05-24_18:00:00
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Cloud water mixing ratio (g kg⁻¹) at Eta Level 13

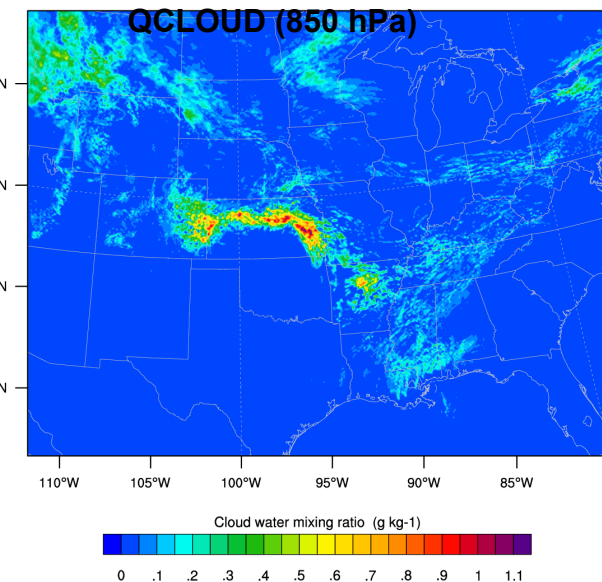


Hybrid-3DVAR Analysis

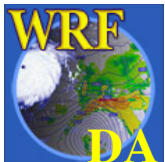
Water vapor mixing ratio (g kg⁻¹) at Eta Level 15



Cloud water mixing ratio (g kg⁻¹) at Eta Level 13



**Impact of hybrid-3DVAR
& all-sky MODIS radiance
DA at 4km resolution
over US with 50 members
of ensemble.**



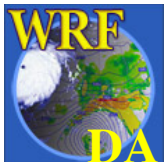
Assimilation methods

- Empirical methods
 - Successive Correction Method (SCM)
 - Nudging
 - Physical Initialisation (PI), Latent Heat Nudging (LHN)
- Statistical methods
 - Optimal Interpolation (OI)
 - 3-Dimensional VARiational data assimilation (3DVAR)
 - 4-Dimensional VARiational data assimilation (4DVAR)
- Advanced methods
 - Extended Kalman Filter (EKF)
 - Ensemble Kalman Filter (EnFK)
 - Hybrid VAR/Ens DA

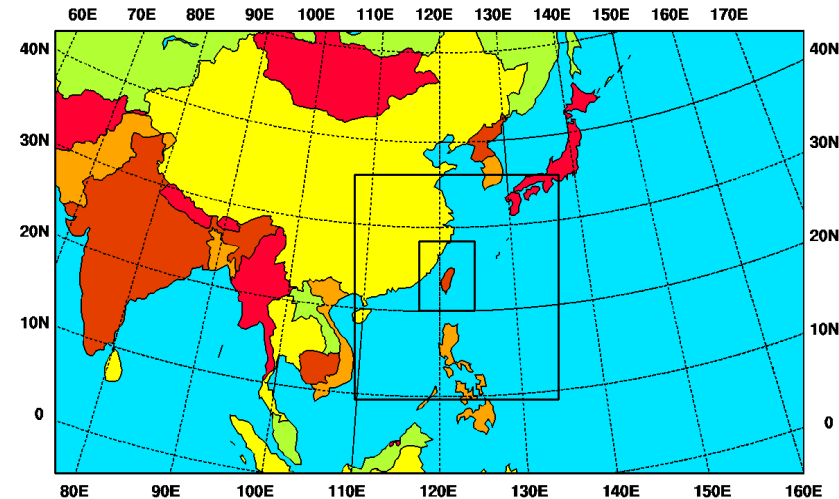


WRFDA is a Data Assimilation system built within the WRF software framework, ...

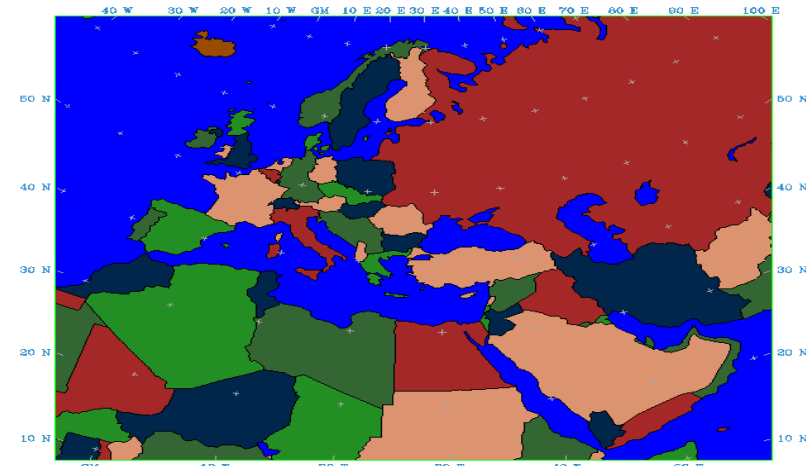
- **Goal:** Community WRF DA system for
 - regional/global,
 - research/operations, and
 - deterministic/probabilistic applications.
- **Techniques:**
 - 3D-Var
 - 4D-Var (regional)
 - Ensemble DA,
 - Hybrid Variational/Ensemble DA.
- **Model:** WRF (ARW, NMM, Global)
- **Support:**
 - NCAR/ESSL/MMM/DAS
- **Observations:** Conv.+Sat.+Radar(+bogus)



Domain area of CWB WRF

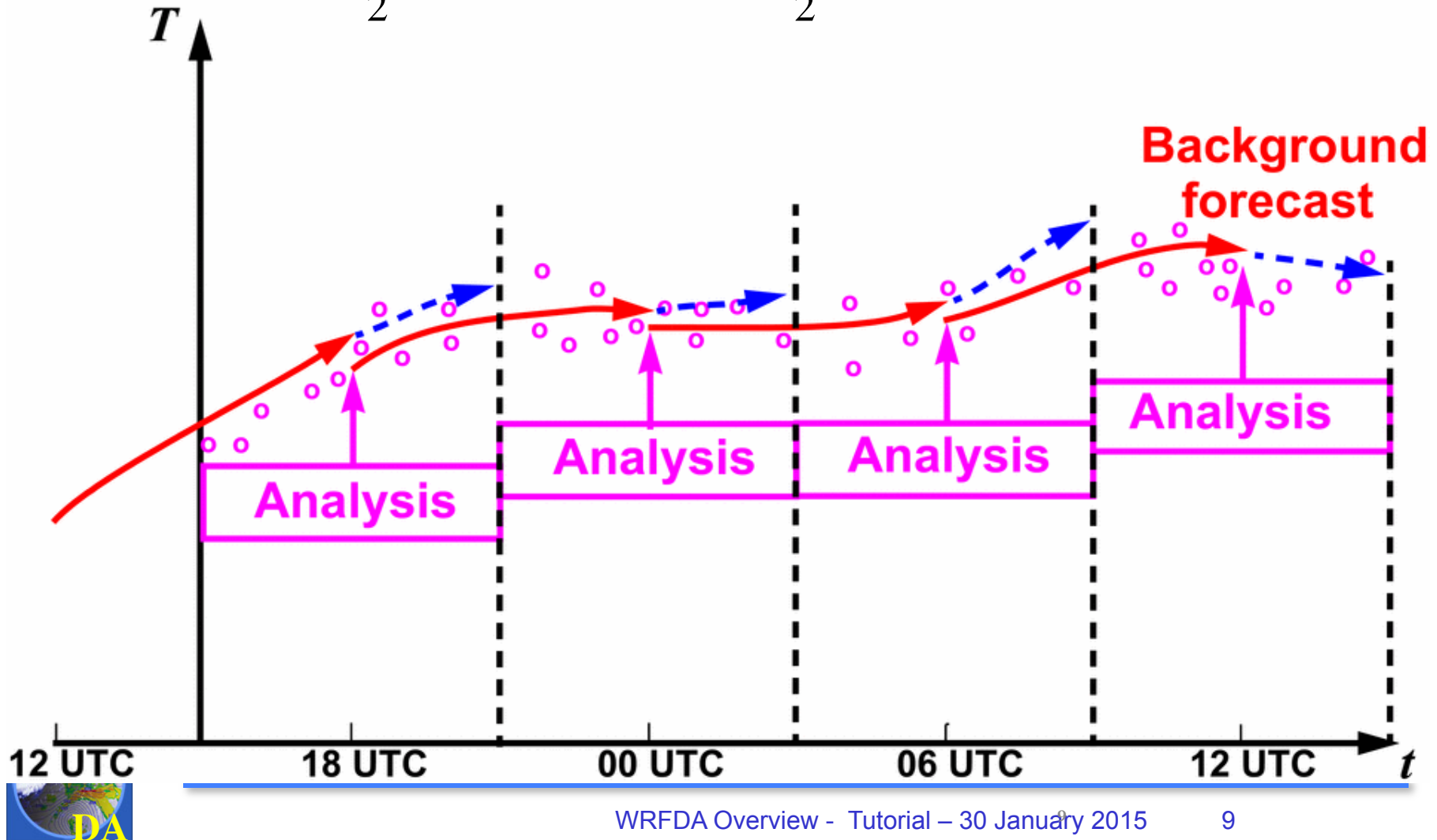


Panasonic European WRF

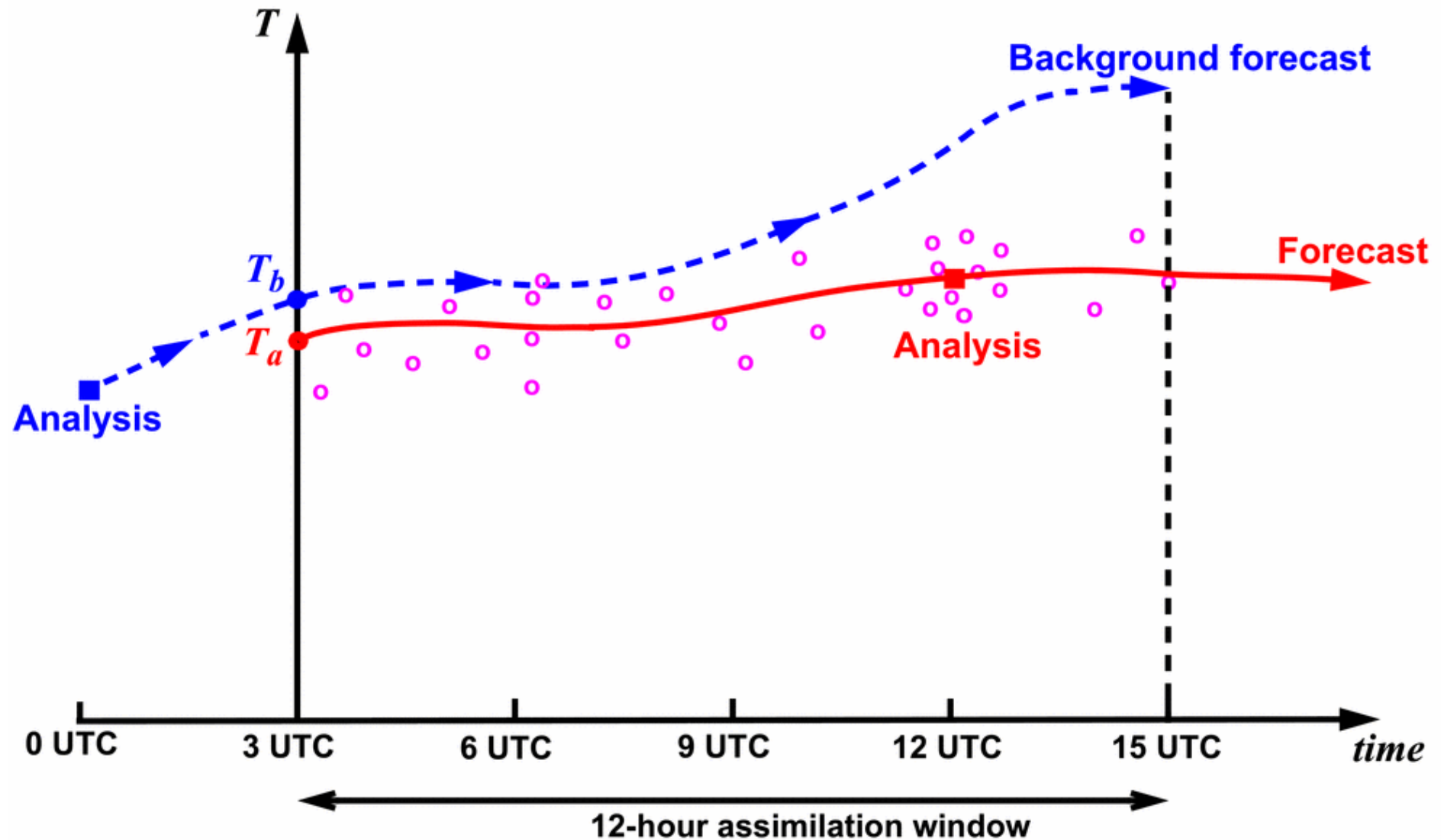


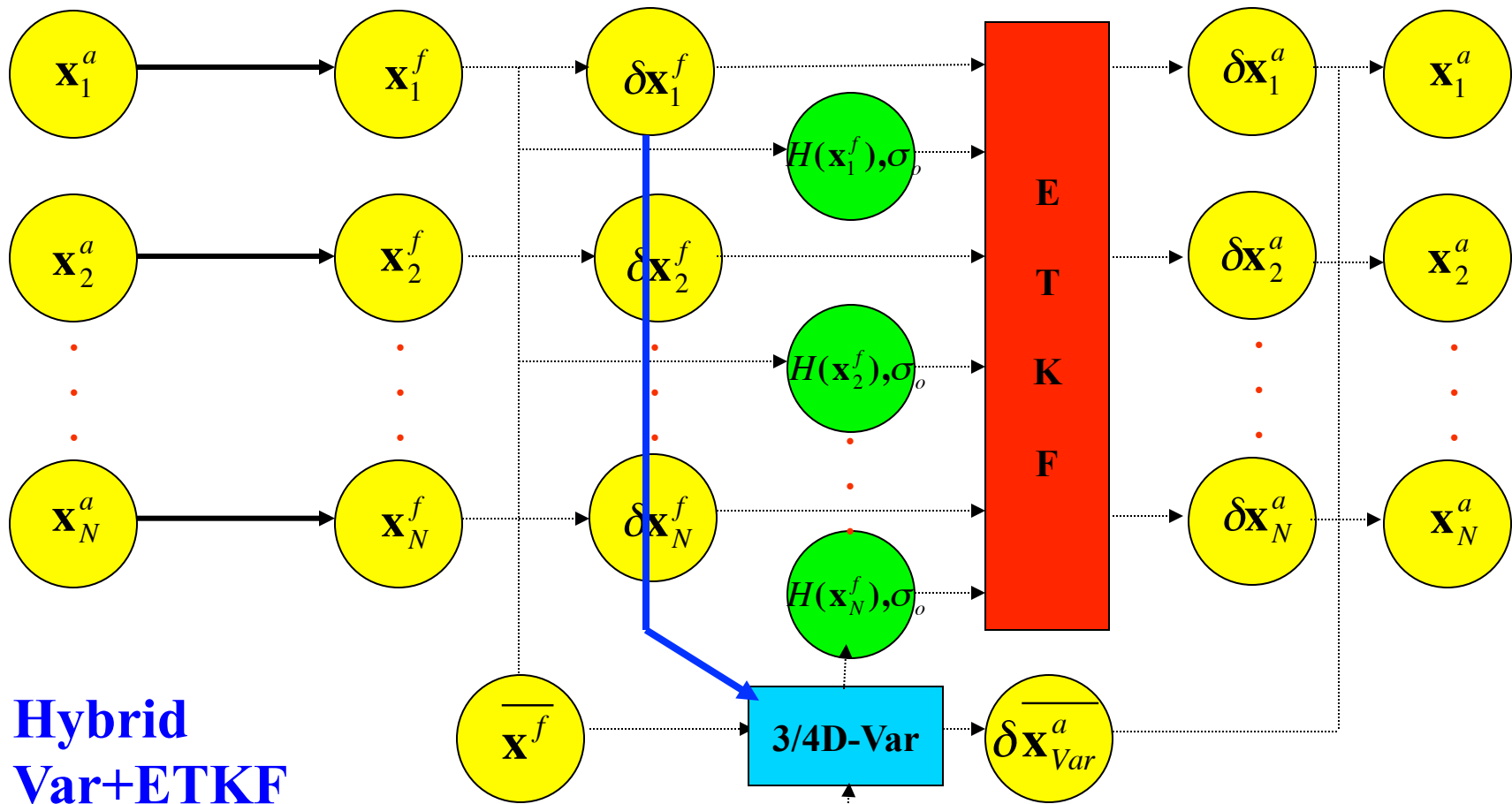
3DVAR (Barker et al. 2004)

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



4DVAR (Huang et al. 2009)

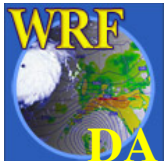




(Wang et al. 2008)

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





■ In-Situ:

- SYNOP
- METAR
- SHIP
- BUOY
- TEMP
- PIBAL
- AIREP, **AIREP humidity**
- TAMDAR



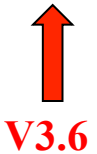
V3.6

■ Bogus:

- TC bogus
- Global bogus

■ Radiative Transfer (RTTOV_11.1 or CRTM_2.1.3):

- HIRS NOAA-16, NOAA-17, NOAA-18, NOAA-19, METOP-A
- AMSU-A NOAA-15, NOAA-16, NOAA-18, NOAA-19, EOS-Aqua, METOP-A, **METOP-B**
- AMSU-B NOAA-15, NOAA-16, NOAA-17
- MHS NOAA-18, NOAA-19, METOP-A, **METOP-B** ← **V3.6**
- AIRS EOS-Aqua
- SSMIS DMSP-16, DMSP-17, DMSP-18
- IASI METOP-A, **METOP-B** ← **V3.6**
- ATMS Suomi-NPP
- MWTS FY-3
- MWHS FY-3
- **SEVIRI METEOSAT** ← **V3.6**



V3.6

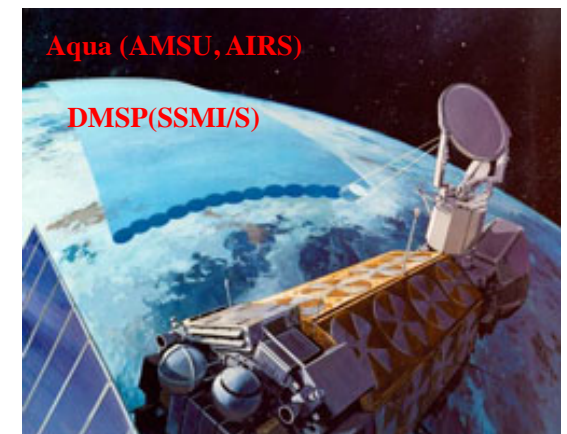
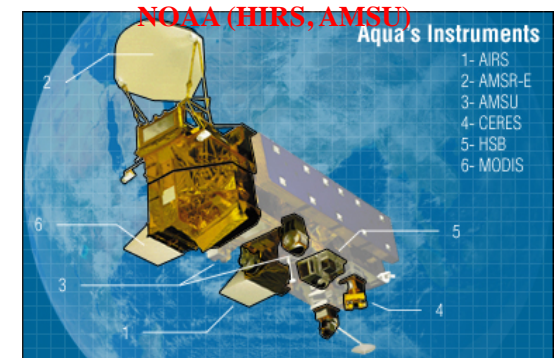
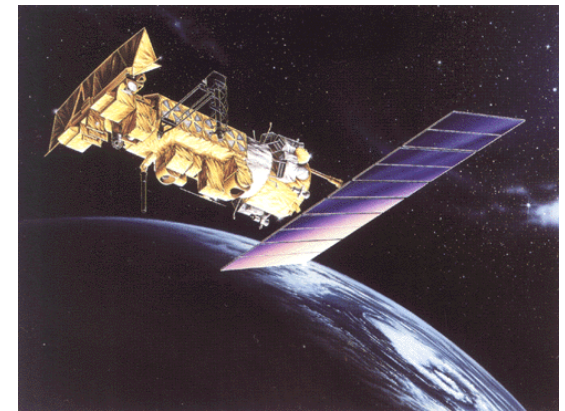
■ Remotely sensed retrievals:

- 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 radial velocities and reflectivities
- Satellite temperature/humidity/thickness profiles
- GPS refractivity (e.g. COSMIC)
- Stage IV precipitation/rain rate data (4D-Var)

WRFDA

Radiance Assimilation

- BUFR 1b radiance ingest.
- **RTM interface (v3.5.1):**
RTTOV (v11.1) or CRTM (v2.1.3)
- NESDIS microwave surface emissivity model
- Range of monitoring diagnostics.
- Quality Control for HIRS, AMSU, AIRS, SSMI/S.
- **Bias Correction:**
Adaptive or Variational
- Variational observation error tuning
- Parallel: MPI
- Flexible design to easily add new satellite sensors
- Cloudy Radiance DA



WRFDA tutorials

21-22 July 2008. NCAR.

02-04 Feb 2009. NCAR.

20-22 July 2009. NCAR.

03-05 Aug 2010. NCAR.

20-21 July 2011. NCAR.

23-25 July 2012. NCAR.

24-26 Jul 2013. NCAR.

28-30 Jul 2014. NCAR

18 April 2009. South Korea.

15-31 Oct 2009. Nanjing, China.

10 April 2010. Seoul, South Korea.

16 April 2011. Busan, South Korea.

10-20 Oct 2011. Bangkok, Thailand.

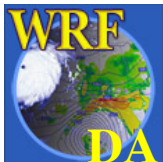
21 April 2012. Seoul, South Korea.

22-24 Sept 2013. Chengdu, China

14-25 Oct 2013. Vienna, Austria.

WRFDA online tutorial and user guide

<http://www2.mmm.ucar.edu/wrf/users/wrfda>



Recent Tutorials at NCAR

1. WRFDA Overview
2. Observation Pre-processing
3. WRFDA System
4. WRFDA Set-up, Run
5. WRFDA Background Error Estimations
6. Radar Data
7. Satellite Data
8. WRF 4D-Var
9. WRF Hybrid Data Assimilation System
10. WRFDA Tools and Verification
11. Observation Sensitivity

Practice

1. obsproc
2. wrfda (3D-Var)
3. Single-ob tests
4. Gen_be
5. Radar
6. Radiance
7. 4D-Var
8. Hybrid
9. Advanced (optional)



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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 computing platform. The WRFDA system is designed to handle data assimilation scales ranging from 100 kilometers to 10 kilometers.

The Mesoscale and support

- WRF S
- Advanc
- grid and
- WRF P
- WRF D
- Numer

LATEST WRFDA RELEASE

[WRFDA Version 3.6](#)
(Released April 18, 2014)

1687 places mapped @ 12:20 pm EST Jun 25

maplogo

