



Introduction to WRFDA

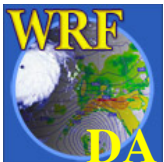
Hans Huang

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

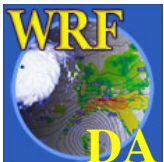
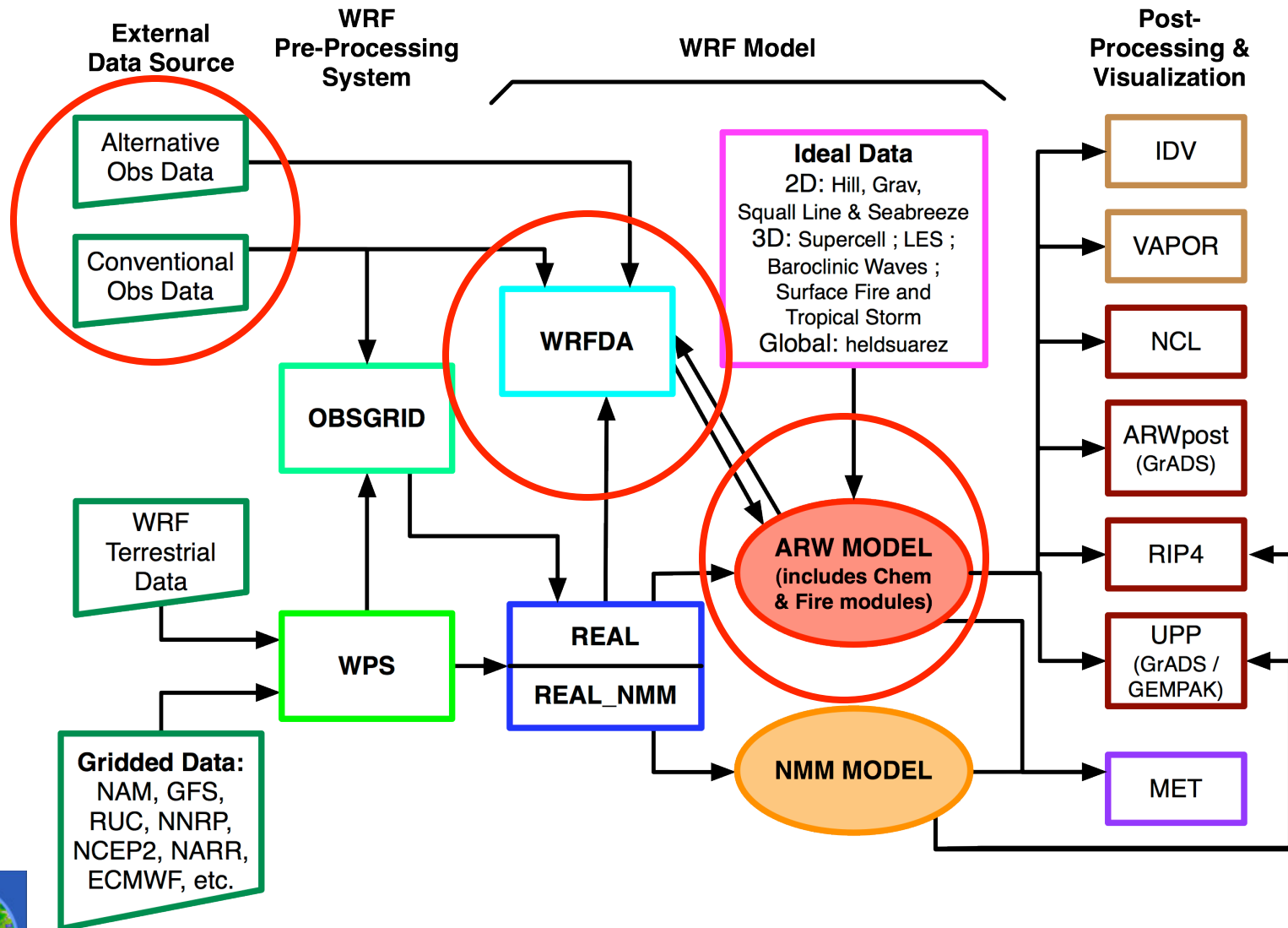
Acknowledge:

NCAR/MMM/DAS

NCAR, AFWA, USWRP, NSF-OPP, KMA, CWB, CAA, NASA,
EUMETSAT, BMB, AirDat

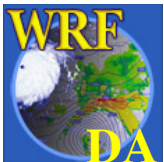


WRFDA in WRF Modeling System



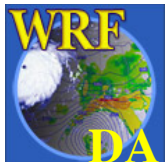
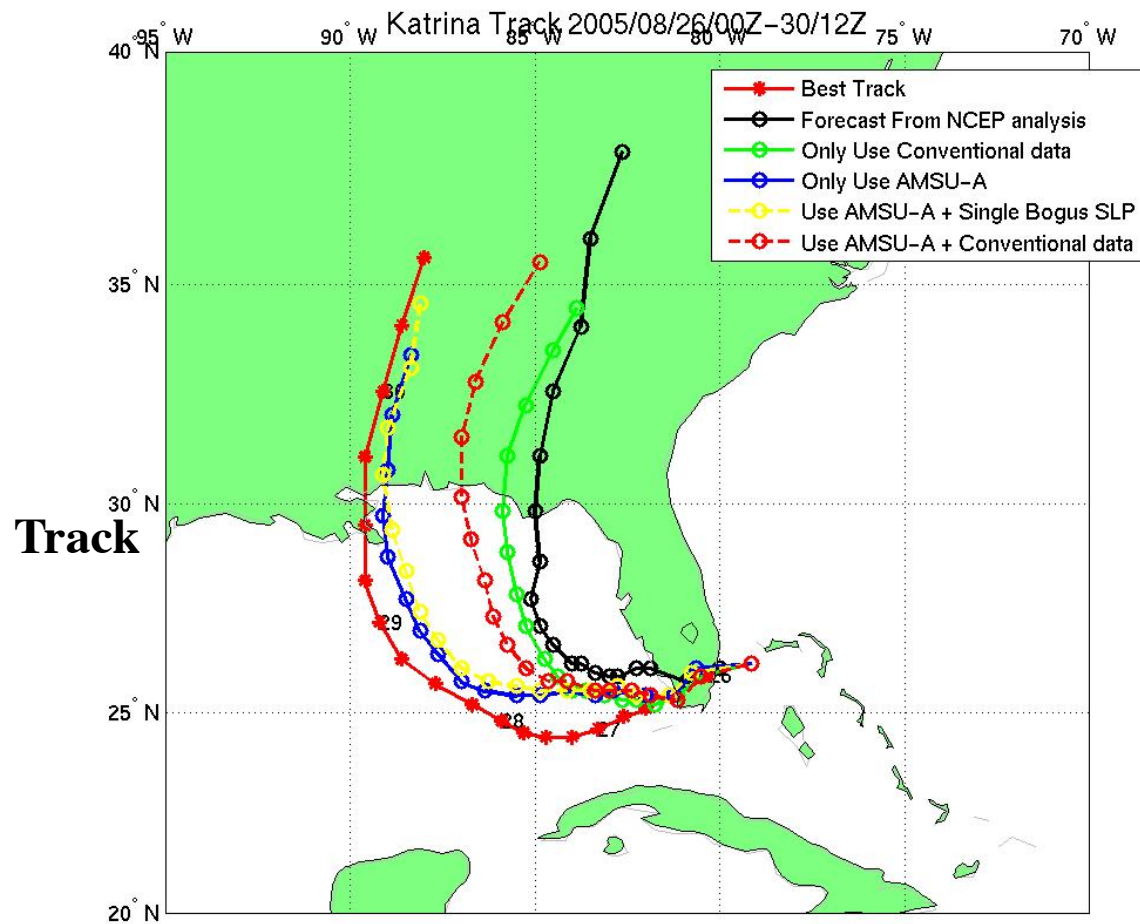
Why data assimilation?

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



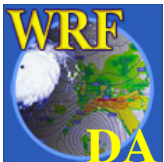
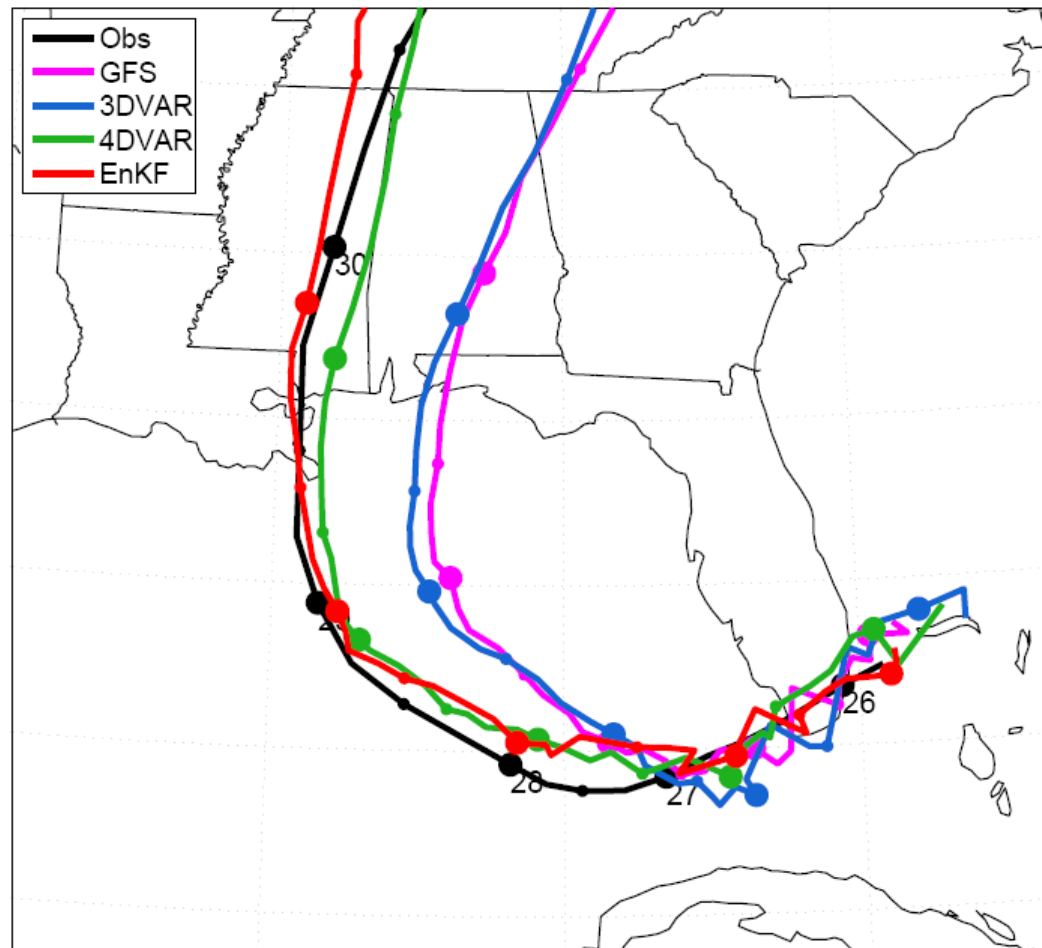
Katrina track forecasts (Zhiquan Liu)

- Impact of data



Katrina track forecasts (Zhang, Zhang, Huang, Zhang)

- Impact of DA methods



Modern weather forecast (Bjerknes, 1904)

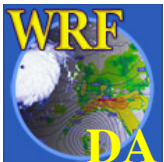
- A sufficiently accurate knowledge of the state of the atmosphere at the initial time
- A sufficiently accurate knowledge of the laws according to which one state of the atmosphere develops from another.

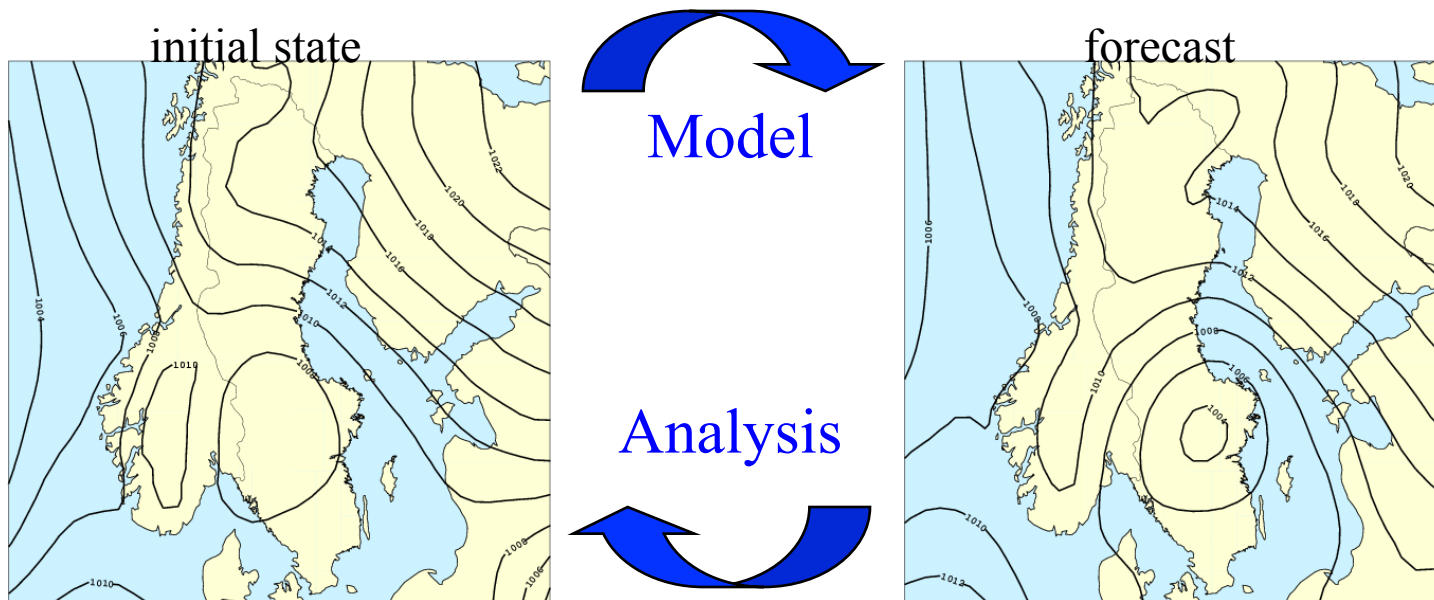


Vilhelm Bjerknes (1862–1951)

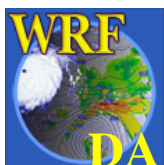
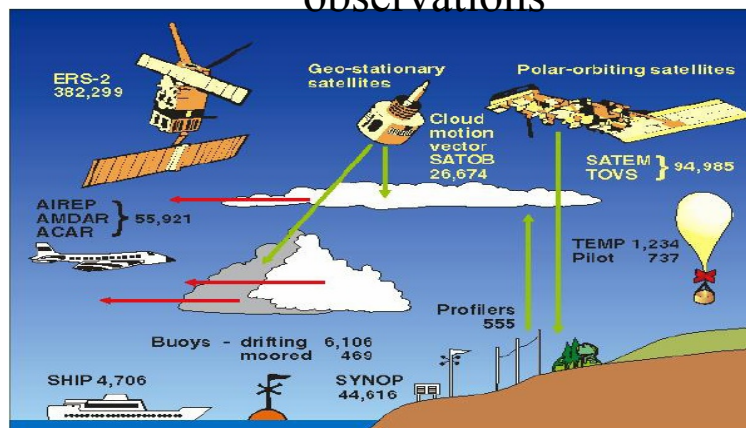
- **Analysis:** using observations and other information, we can specify the atmospheric state at a given initial time: “Today’s Weather”
- **Forecast:** using the equations, we can calculate how this state will change over time: “Tomorrow’s Weather”

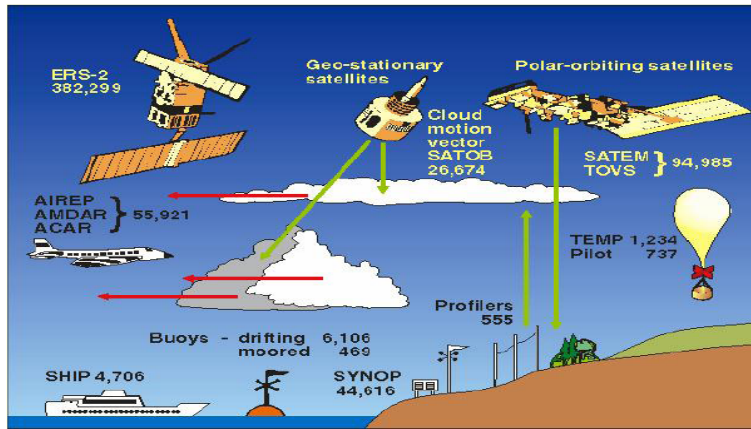
(Peter Lynch)





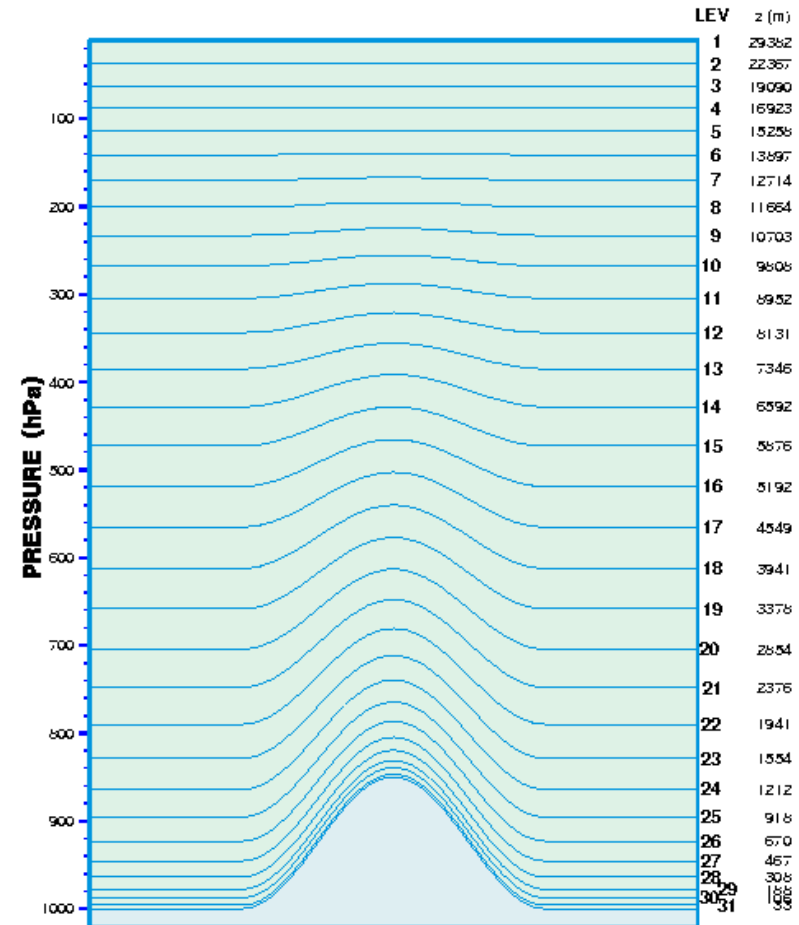
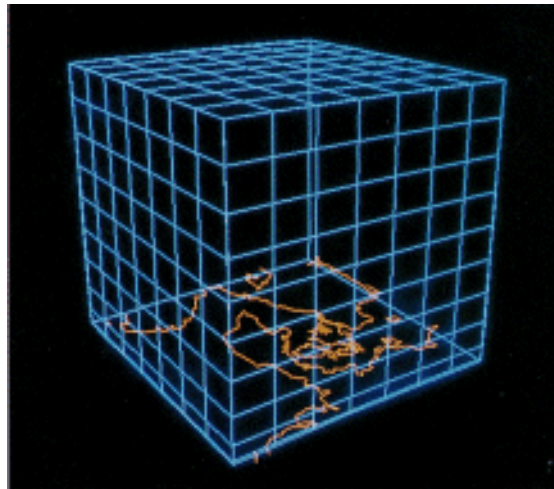
observations



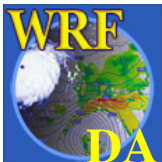


Observations
 $y^0, \sim 10^5 - 10^6$

Model state
 $x, \sim 10^7$

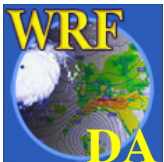


Vertical resolution of the DMI-HIRLAM system



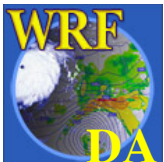
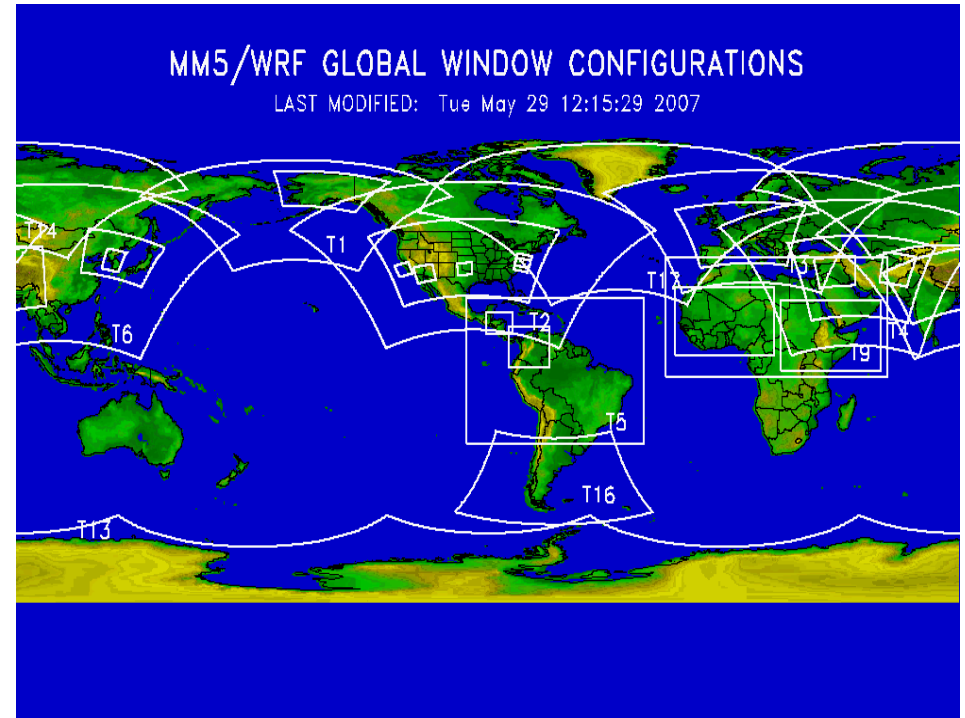
Assimilation methods

- 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

- **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)
- **Observations:** Conv. + Sat. + Radar (+Bogus)
- **Support:**
 - NCAR/NESL/MMM/DAS (Data Assimilation Section, also supporting [WRF/DART](#))

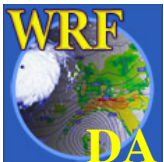
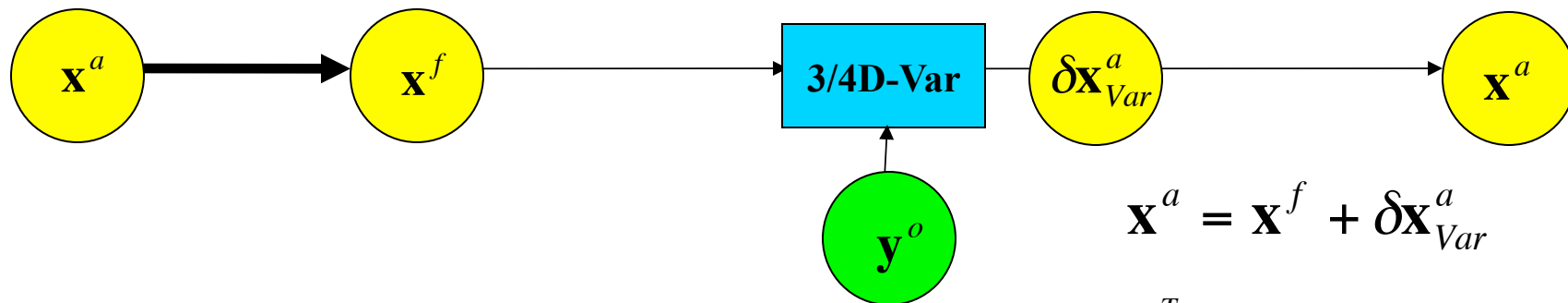


WRFDA

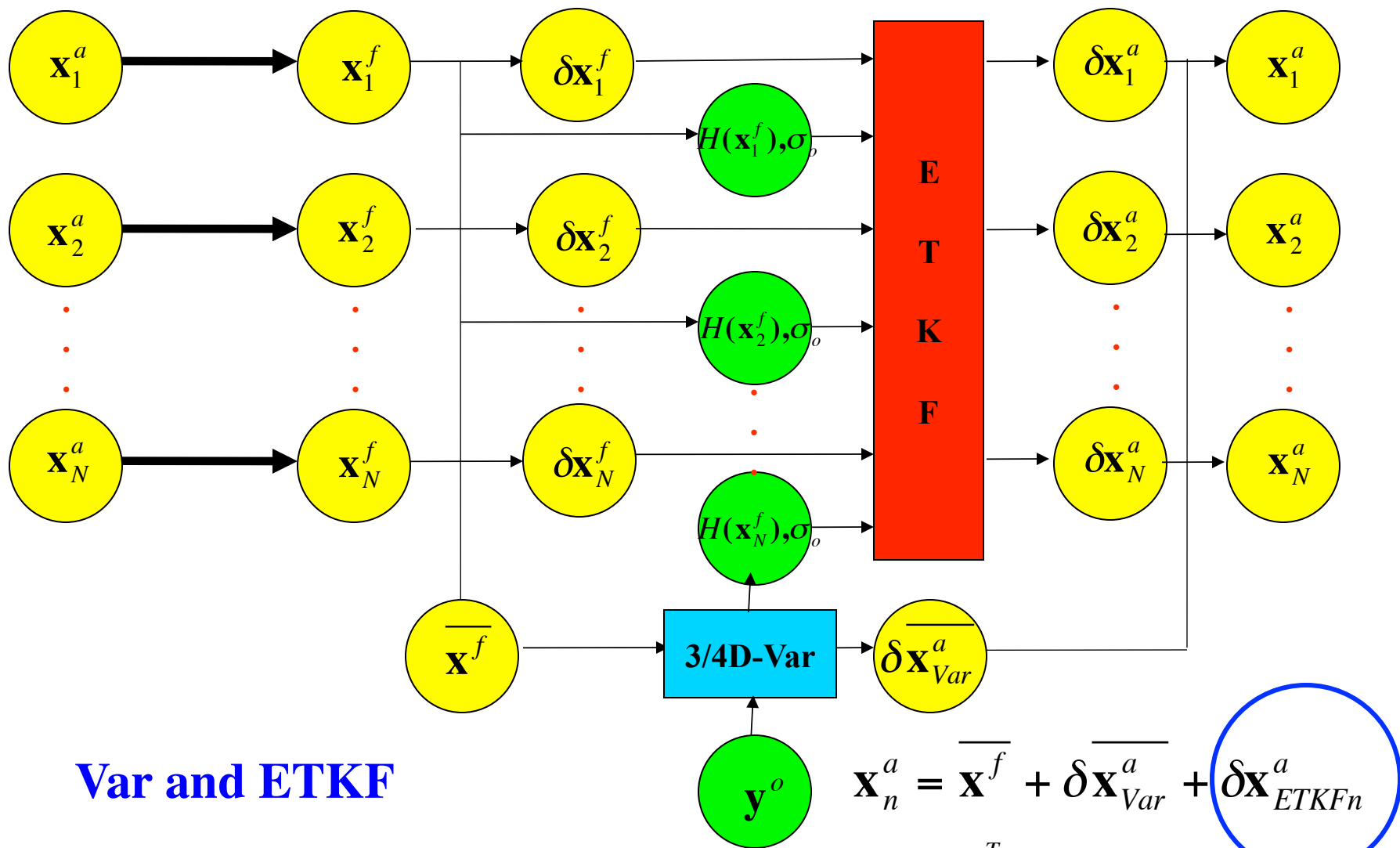
3/4D-Var

3D-Var: Barker et al. 2004

4D-Var: Huang et al. 2009



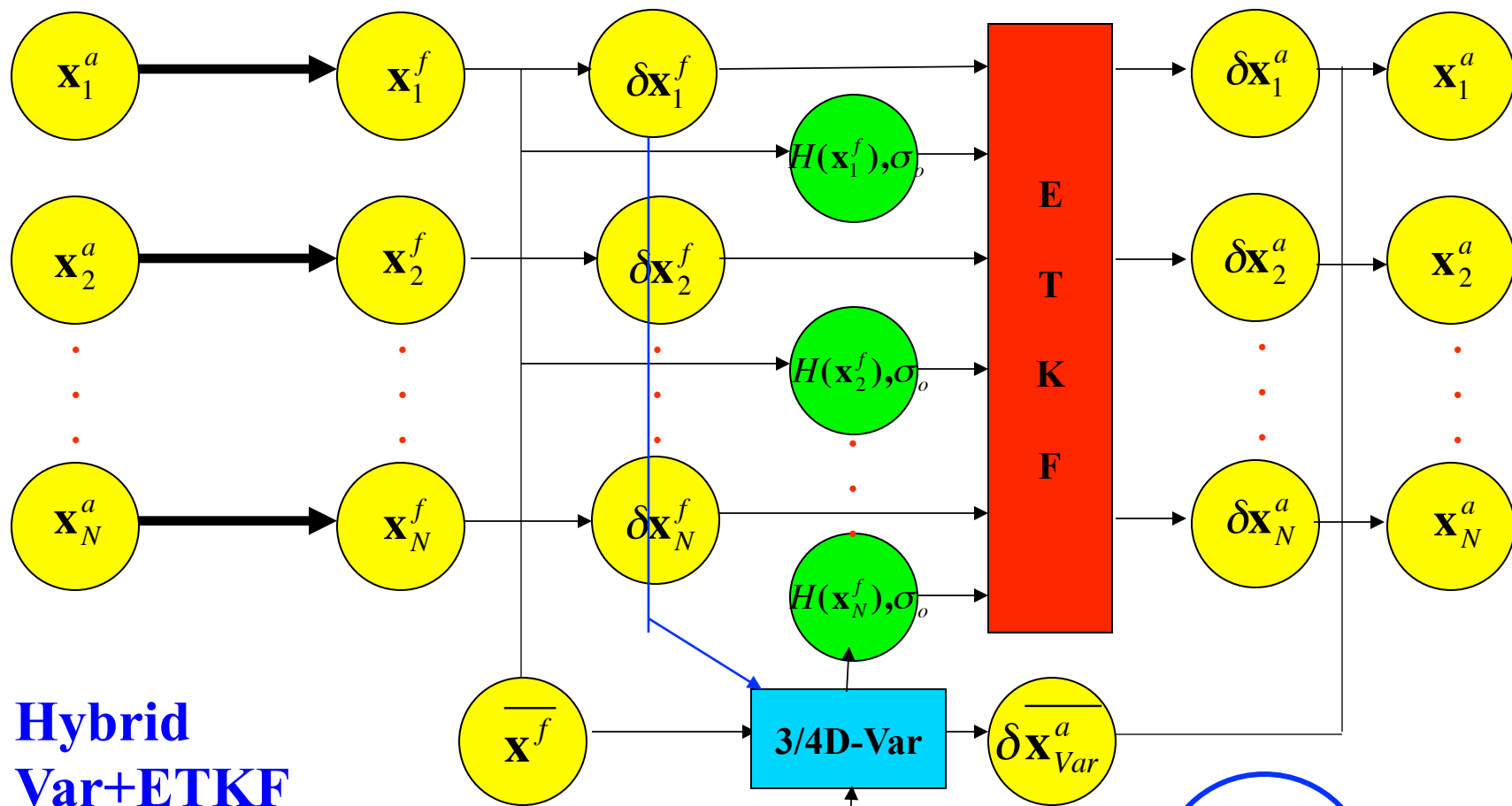
$$J = \frac{1}{2} \delta \mathbf{x}_0^T \mathbf{B}_o^{-1} \delta \mathbf{x}_0 + \frac{1}{2} \sum_{i=0}^n \left[\mathbf{H}_i \delta \mathbf{x}(t_i) - \mathbf{d}_i \right]^T \mathbf{R}_i^{-1} \left[\mathbf{H}_i \delta \mathbf{x}(t_i) - \mathbf{d}_i \right]$$



Var and ETKF

$$J = \frac{1}{2} \delta \mathbf{x}_0^T \mathbf{B}_o^{-1} \delta \mathbf{x}_0 + \frac{1}{2} \sum_{i=0}^n \left[\mathbf{H}_i \delta \mathbf{x}(t_i) - \mathbf{d}_i \right]^T \mathbf{R}_i^{-1} \left[\mathbf{H}_i \delta \mathbf{x}(t_i) - \mathbf{d}_i \right]$$





(Wang et al. 2008)



$$J = \frac{W_b}{2} \delta \mathbf{x}_0^T \mathbf{B}_o^{-1} \delta \mathbf{x}_0 + \frac{W_\alpha}{2} \mathbf{a}^T \mathbf{A}^{-1} \mathbf{a} + \frac{1}{2} \sum_{i=0}^n \left[\mathbf{H}_i \delta \mathbf{x}(t_i) - \mathbf{d}_i \right]^T \mathbf{R}_i^{-1} \left[\mathbf{H}_i \delta \mathbf{x}(t_i) - \mathbf{d}_i \right]$$

WRFDA Observations

■ In-Situ:

- Surface (SYNOP, METAR, SHIP, BUOY).
- Upper air (TEMP, PIBAL, AIREP, ACARS, TAMDAR).

• Remotely sensed retrievals:

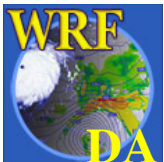
- Atmospheric Motion Vectors (geo/polar).
- SATEM thickness.
- Ground-based GPS Total Precipitable Water/Zenith Total Delay.
- SSM/I oceanic surface wind speed and TPW.
- Scatterometer oceanic surface winds.
- Wind Profiler.
- Radar radial velocities and reflectivities.
- Satellite temperature/humidity/thickness profiles.
- GPS refractivity (e.g. COSMIC).
- Stage IV precipitation/rain rate data (4D-Var)

■ Radiative Transfer (RTTOV or CRTM):

- HIRS NOAA-16, NOAA-17, NOAA-18, NOAA-19, METOP-2
- AMSU-A NOAA-15, NOAA-16, NOAA-18, NOAA-19, EOS-Aqua, METOP-2
- AMSU-B NOAA-15, NOAA-16, NOAA-17
- MHS NOAA-18, NOAA-19, METOP-2
- AIRS EOS-Aqua
- SSMIS DMSP-16, DMSP-17, DMSP-18

•Bogus:

- TC bogus.
- Global bogus.

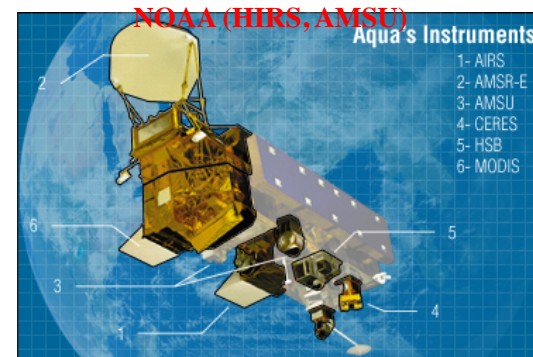
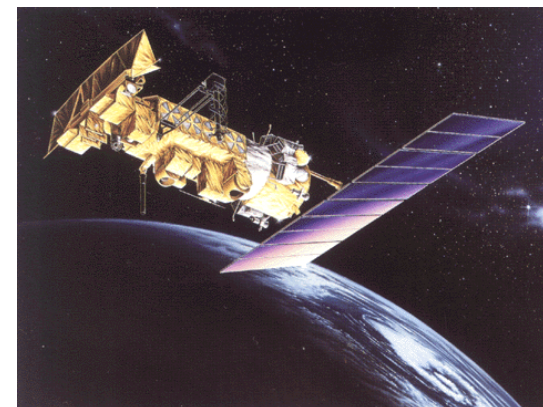


WRFDA

Radiance Assimilation

Liu and Auligne, NCAR

- BUFR 1b radiance ingest.
- **RTM interface:**
RTTOV (v10.1) or CRTM (v2.0.2)
- 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



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.

18 April 2009. South Korea.

15-31 Oct 2009. Nanjing, China.

10 April 2010. Seoul, South Korea.

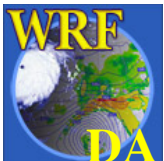
16 April 2011. Busan, South Korea.

10-20 Oct 2011. Bangkok, Thailand.

21 April 2012. Seoul, South Korea.

WRFDA online tutorial and user guide

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

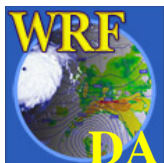


Recent Tutorials at NCAR.

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

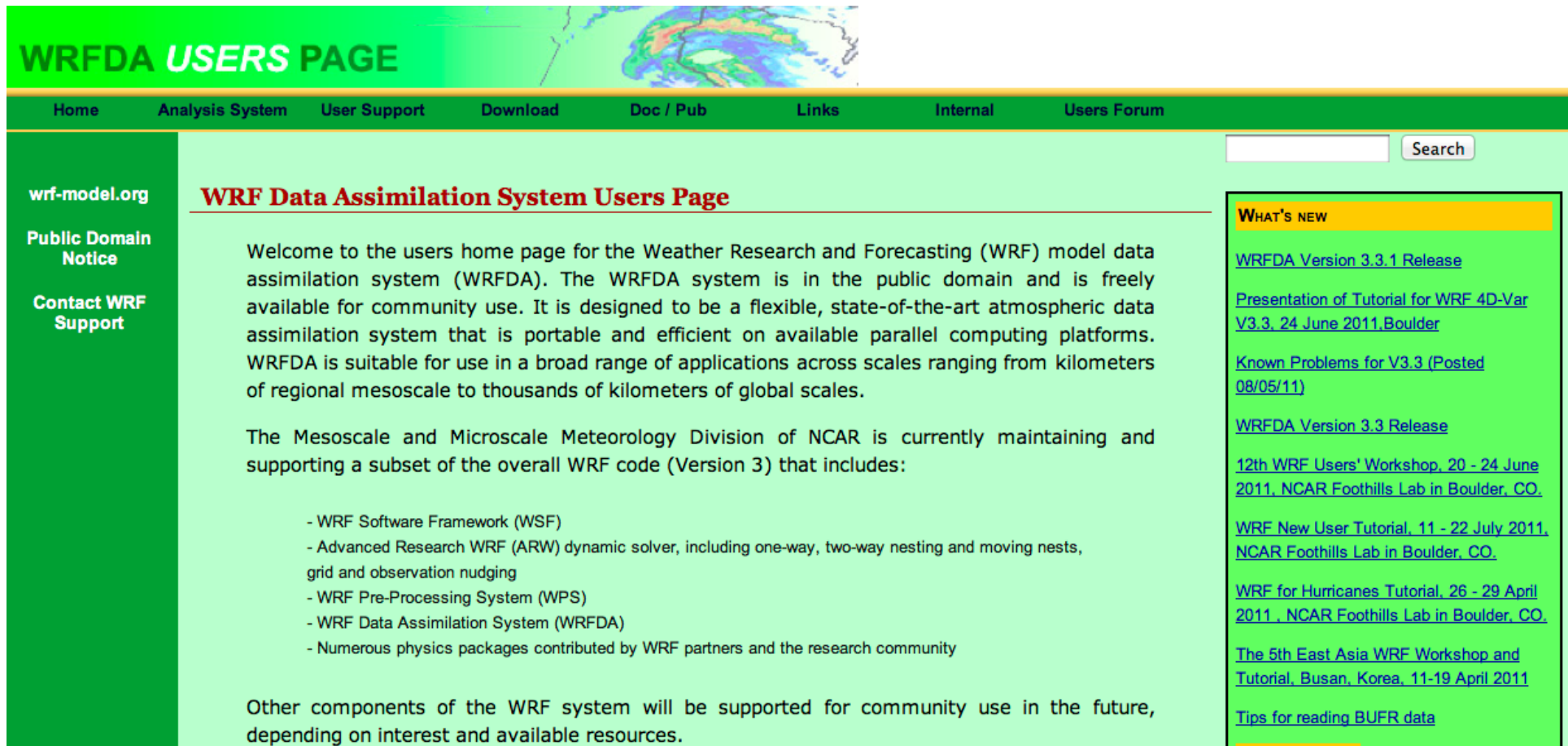
1. obsproc
2. wrfda (3D-Var)
3. Single-ob tests
4. Gen_be
5. Radar
6. Radiance
7. 4D-Var
8. Hybrid
9. Advanced (optional)



The next: 22-24 July 2013

Google WRFDA:

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



The screenshot shows the 'WRFDA USERS PAGE' with a green header and a navigation bar. The main content area is white with a green sidebar on the left. The sidebar contains links to 'wrf-model.org', 'Public Domain Notice', and 'Contact WRF Support'. The main content area has a title 'WRF Data Assimilation System Users Page' and a welcome message. It lists the components of the WRF system: WRF Software Framework (WSF), Advanced Research WRF (ARW) dynamic solver, WRF Pre-Processing System (WPS), WRF Data Assimilation System (WRFDA), and numerous physics packages. A 'WHAT'S NEW' section on the right lists recent releases and tutorials.

WRFDA USERS PAGE

Home Analysis System User Support Download Doc / Pub Links Internal Users Forum

[wrf-model.org](#)

Public Domain Notice

Contact WRF Support

WRF Data Assimilation System Users Page

Welcome to the users home page for 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 of regional mesoscale to thousands of kilometers of global scales.

The Mesoscale and Microscale Meteorology Division of NCAR is currently maintaining and supporting 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)
- 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.

WHAT'S NEW

- [WRFDA Version 3.3.1 Release](#)
- [Presentation of Tutorial for WRF 4D-Var V3.3, 24 June 2011, Boulder](#)
- [Known Problems for V3.3 \(Posted 08/05/11\)](#)
- [WRFDA Version 3.3 Release](#)
- [12th WRF Users' Workshop, 20 - 24 June 2011, NCAR Foothills Lab in Boulder, CO.](#)
- [WRF New User Tutorial, 11 - 22 July 2011, NCAR Foothills Lab in Boulder, CO.](#)
- [WRF for Hurricanes Tutorial, 26 - 29 April 2011, NCAR Foothills Lab in Boulder, CO.](#)
- [The 5th East Asia WRF Workshop and Tutorial, Busan, Korea, 11-19 April 2011](#)
- [Tips for reading BUFR data](#)

