



# WRFDA Overview: Status and Plan

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NCAR/MMM

## **Acknowledge:**

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



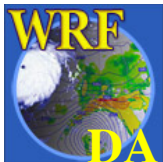
# Outline

- New features in WRFDA V3.7
- Ongoing developments

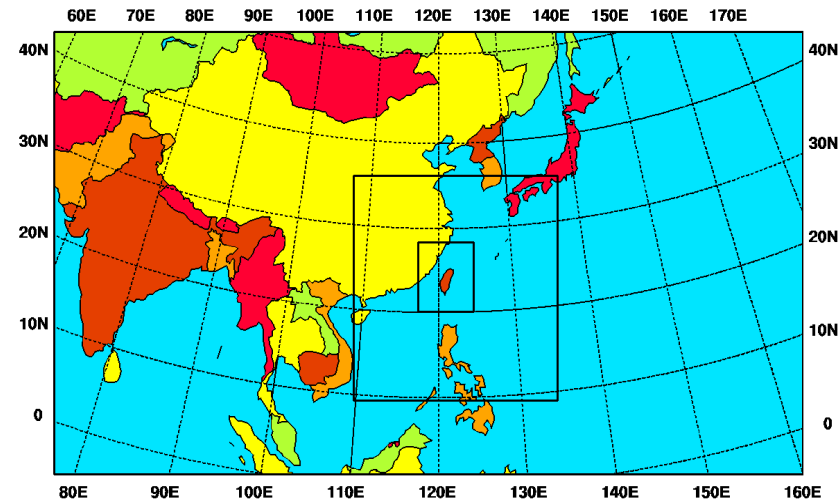


**WRFDA** is a Data Assimilation system built within the WRF software framework, ...

- **Goal:** Community WRF DA system for
  - research/operations, and
  - deterministic/probabilistic applications.
- **DA Techniques:**
  - 3D-Var
  - 4D-Var
  - Ensemble Transformed Kalman Filter
  - Hybrid-3DVAR
- **Support:**
  - NCAR/MMM via [wrfhelp@ucar.edu](mailto:wrfhelp@ucar.edu)
- **Observations:** Conv.+Sat.+Radar(+bogus)

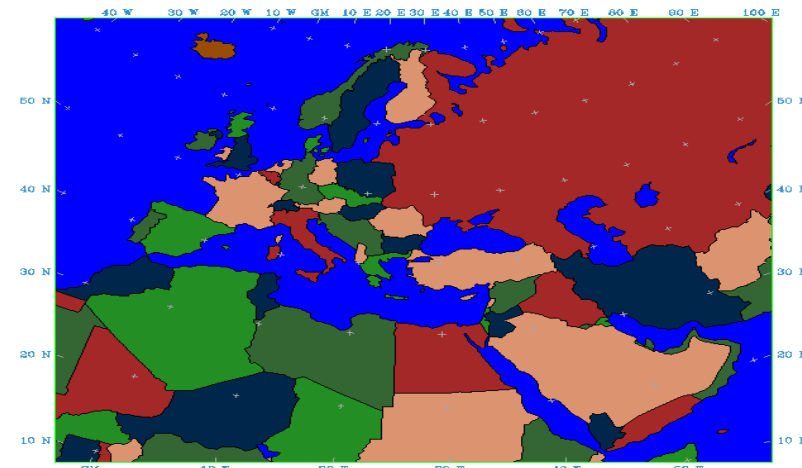


Domain area of CWB WRF



**Both operations run in hybrid-3DVAR mode**

Panasonic Weather Solution European WRF



## WRFDA USERS PAGE

Home System User Support Download Publications & Documentation Links Internal

### WRFDA Home

WRFDA News

Public Domain  
Notice

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WRF Users Page

### 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:

#### LATEST WRFDA RELEASE

##### [WRFDA Version 3.7](#)

(Released April 20, 2015)

#### UPCOMING EVENTS

June 15–19, 2015

[2015 WRF Workshop](#), NCAR Center  
Green Campus, Boulder, CO, USA.  
[Registration is now open!](#)

August 3–7, 2015

[2015 WRFDA New User Tutorial](#), NCAR  
Foothills Laboratory, Boulder, CO, USA.  
**Registration is now full!**

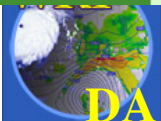
#### WHAT'S NEW

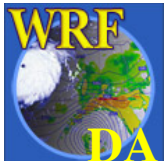
April 20, 2015

[WRFDA Version 3.7](#) has been released.  
[View release notes.](#)

April 3, 2015

Registration is now open for the [WRF Workshop](#) and the [WRFDA tutorial](#).





- **In-Situ:**
  - SYNOP
  - METAR
  - SHIP
  - BUOY
  - TEMP
  - PIBAL
  - AIREP, AIREP humidity
  - TAMDAR
- **Bogus:**
  - TC bogus
  - Global bogus
- **Radiances: can use RTTOV\_11.1 or 11.2 (new in V3.7) 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
  - AIRS EOS-Aqua
  - SSMIS DMSP-16, DMSP-17, DMSP-18
  - IASI METOP-A, METOP-B
  - ATMS Suomi-NPP
  - MWTS FY-3
  - MWHS FY-3
  - SEVIRI METEOSAT
- **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 (enhancements in V3.7)**
  - Satellite temperature/humidity/thickness profiles
  - GPS refractivity (e.g. COSMIC)
  - Stage IV precipitation/rain rate data (4D-Var)

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

- **Little\_r (ascii), HDF, Binary**
- **NOAA MADIS (netcdf),**
- **NCEP PrepBufr,**
- **NCEP radiance bufr**

# CHOICE OF ANALYSIS VARIABLES

| cv_options | Analysis variables                                                           |
|------------|------------------------------------------------------------------------------|
| 3          | $\Psi$ , unbalance X, unbalance t, pseudo rh and unbalance $\log(P_s)$       |
| 5          | $\Psi$ , unbalance X, unbalance t, pseudo rh and unbalance $P_s$             |
| 6          | $\Psi$ and unbalance X, unbalance t, unbalance pseudo rh and unbalance $P_s$ |
| 7          | u, v, t, $P_s$ and pseudo rh <b>(new in WRFDA V3.7)</b>                      |

Pseudo rh defined as Q divided by  $Q_s$  from the background

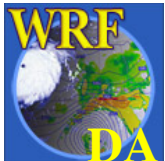
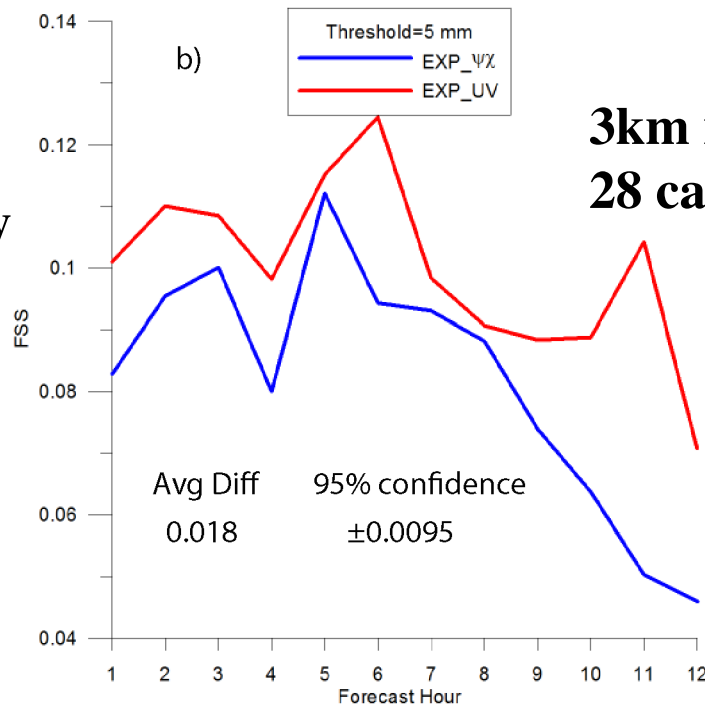


# New Analysis Variable Option

## CV\_Options = 7

- CV7 uses velocity components u/v as momentum control variable – all others use Psi/Chi (stream function/velocity potential)
- No multivariate correlation is considered yet
- By avoiding the u/v -> Psi/Chi conversion, the analysis can better fit to convective-scale observations, such as radar radial velocity
- **Planned future improvement: add correlation between temperature and velocity**

**CV7 is recommended to apply to convective-scale DA.**





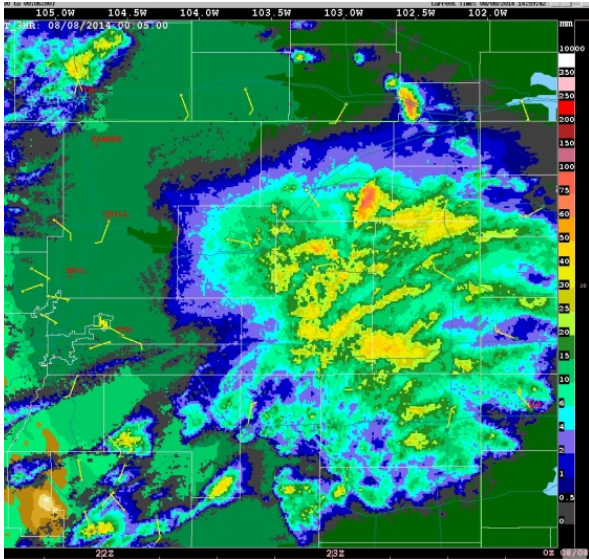
# New capabilities in WRFDA 3.7 for radar DA

- Added separate cloud analysis variables **Qc and Qr** (vs. existing total water analysis variable)
- A new scheme to indirectly assimilate reflectivity by **converting reflectivity to rainwater**
- Added the assimilation **of estimated humidity (from reflectivity) within cloud**
- Making 4DVar radar DA fully compatible with 3DVar
- The new CV option CV7 is recommended for radar DA

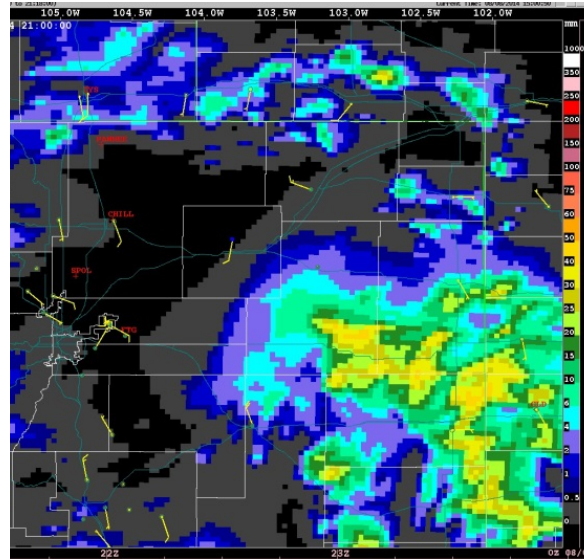
**More details see  
talk by Jenny Sun  
Friday 8:30am**

3H accumulated rainfall in northeastern Colorado  
during STEP 2014 Hydromet summer real time experiment at  $t = 3h$

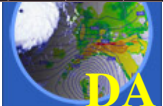
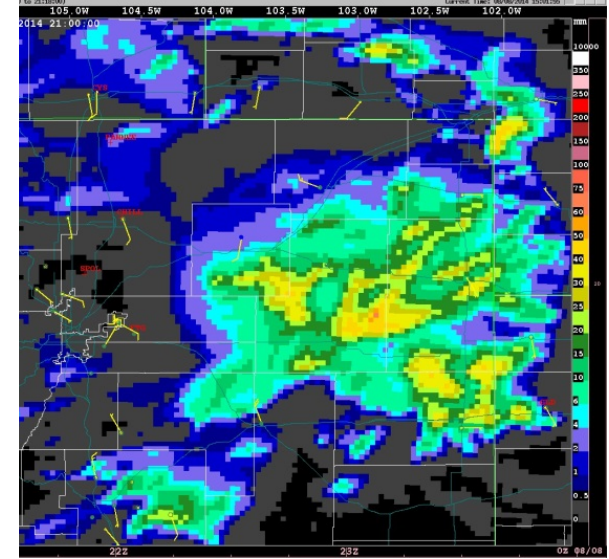
OBS



3DVar without radar



3DVar with radar





# WRFPlus (TL/AD of WRF) code in V3.7

- Upgraded to be consistent with WRF V3.7
- WRFPlus now has two microphysics options for 4DVAR assimilation.
  - &physics  
mp\_physics\_ad =  
98: Use original large-scale condensation  
microphysics (default)  
99: Use new modified Kessler scheme (new in V3.7)



# Outline

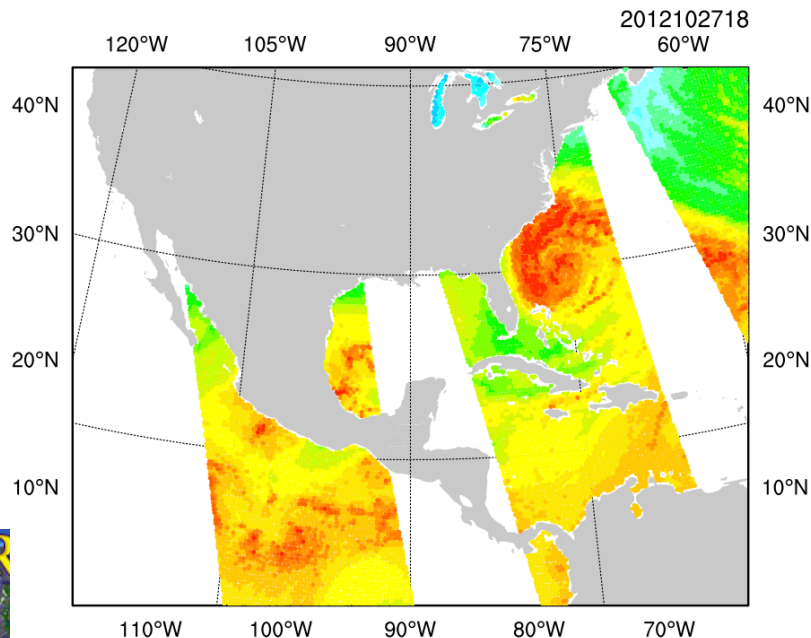
- New features in WRFDA V3.7
- Ongoing developments



# New radiance data (1): AMSR2

| Channel | Frequency | Polarization | Beam Width            | Footprint<br>(along scan* along track) |
|---------|-----------|--------------|-----------------------|----------------------------------------|
| 1,2     | 6.925     | V, H         | $1.8^\circ \pm 15\%$  | 35*61 km                               |
| 3,4     | 7.3       | V, H         | $1.8^\circ \pm 15\%$  | 35*61 km                               |
| 5,6     | 10.65     | V, H         | $1.2^\circ \pm 15\%$  | 24*41 km                               |
| 7,8     | 18.7      | V, H         | $0.65^\circ \pm 15\%$ | 13*22 km                               |
| 9,10    | 23.8      | V, H         | $0.75^\circ \pm 15\%$ | 15*26 km                               |
| 11,12   | 36.5      | V, H         | $0.35^\circ \pm 15\%$ | 7*12 km                                |
| 13,14   | 89.0      | V, H         | $0.15^\circ \pm 15\%$ | 3*5 km                                 |

gcom-w-1-amr2\_ch0009 OBS 10085 / 10085



**Allow clear-sky or all-sky  
radiance assimilation over water**

**See Poster P5 by Chun Yang et al.:**  
Impact of assimilating AMSR-2 radiance  
observations on forecast of Hurricane Sandy

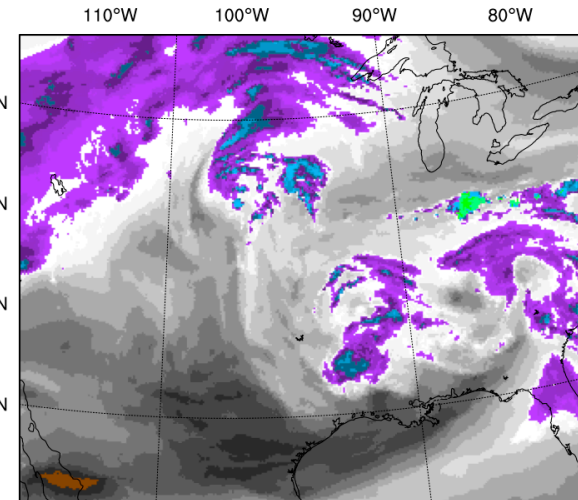
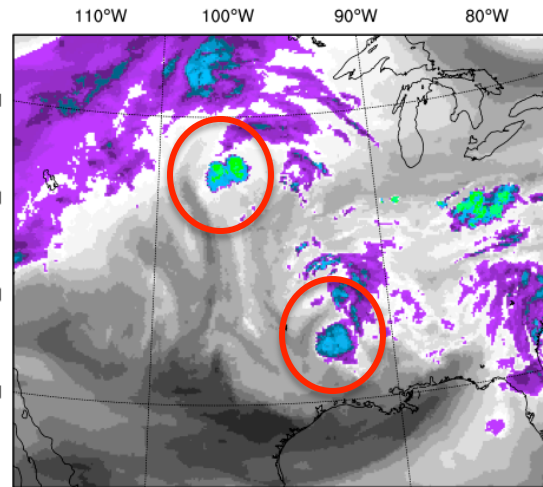
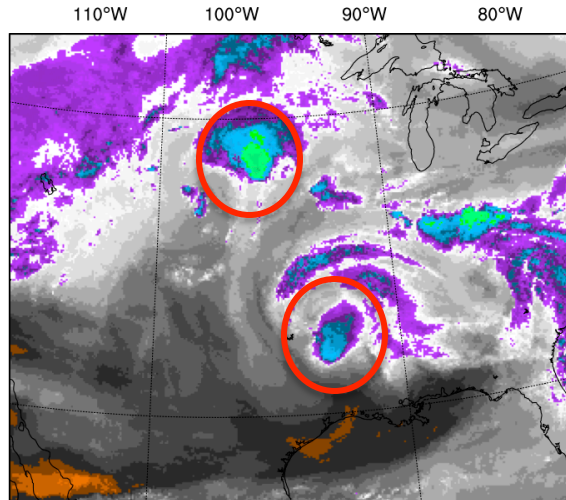


# New radiance data (2): GOES-Imager

goes-13 chan3 obs 2013051618

goes-13 chan3 bak 2013051618

goes-13 chan3 bak 2013051618

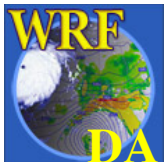


GOES-13 WV Obs

WRF 1-h Forecast with assimilation  
of GOES-13 clear-sky WV Obs

WRF 1-h Forecast w/o assim.  
of GOES-13 WV Obs

**WRF configured at 3-km with hourly cycling 3DVAR assimilation**



# Multi-Incremental 4DVAR

- 4DVAR minimization runs at lower resolutions than WRF model's to allow substantial speed-up
- Now works for `cv_options = 3`
  - Need more development to make it work properly with `cv_options = 5/6/7`

TABLE 2. Computational performance comparison of the full-resolution WRF 4D-Var and multi-incremental WRF 4D-Va on NCAR Yellowstone; Each test has three outer loops with 20 iterations inner loops for each. Unit: Minutes

| <i>Cores</i> | 8   | 16  | 32   | 64   | 128  | 256 | 512 | 1024 |
|--------------|-----|-----|------|------|------|-----|-----|------|
| Full-Res.    | –   | –   | 4191 | 2169 | 1230 | 728 | 392 | 257  |
| Multi-Inc.   | 455 | 217 | 135  | 83   | 53   | 37  |     |      |

12-h vs. ~ 40min!

**15km/15km/15km versus 135km/45km/45km**

Xin Zhang et al., 2014: Development of an Efficient Regional Four-Dimensional Variational Data Assimilation System for WRF. J. Atmos. Oceanic Technol., 31, 2 777–2794.



# Hybrid 4D-EnVar

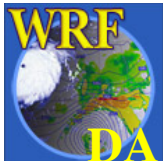
- 4D extension of hybrid-3DVAR
- Need 4D ensemble perturbation input to form 4D flow-dependent background error covariance
- No need for TL/AD version of WRF
- Approximation: time-invariant static part of analysis increment and alpha control variable



# 4DVAR for WRF/Chem

Daven Henze's group at CU

- For aerosol/chemistry data assimilation and forecasting
- Good progress on WRFPlus-Chem
  - J. J. Guerrette and D. K. Henze, 2015, GMDD
  - TL/AD Implementation based on GOCART aerosol scheme
  - Demonstration for emission source inversion,
    - **Also see Poster P68 by J. J. Guerrette and D. K. Henze**
- Working toward WRF/Chem-4DVAR for aerosol/chemistry DA





# Future Plan

- Will focus more on convective-scale DA
  - Radar, all-sky radiances (high spatial-/temporal-res. geostationary sensors), precipitation observations, near surface data, WV from the ground-based GPS
  - Advanced 4D data assimilation techniques
    - 4DVAR, hybrid 4D-EnVar, hybrid-4DVAR
    - Ensemble analysis within Var system.
  - Demonstration with real-time DA/forecast
- Explore new application areas
  - e.g., aerosol/chemistry data assimilation, coupled DA



# Final Remarks

- Most of these new developments are through externally funded projects
  - We will try our best to make them available to the community
  - But delays could occur given resource limitation and pressing project deliverables
- Community contributions are welcome for future release
  - So that your development will be kept updated along with other new capabilities in the future.
  - Doing so may not be trivial for the task like WRF/Chem-4DVAR and also limited by resource available for outside developers and NCAR developers

