WRFDA Overview: Status and Plan

Zhiquan Liu

Jenny Sun, Hui-Chuan Lin, Xin Zhang, Michael Kavulich, Feng Gao,

Craig Schwartz, Syed Rizvi, Hans Huang, Junmei Ban,

Ying Zhang, Dongmei Xu, Chun Yang

NCAR/MMM

Acknowledge:

Former team members and many collaborators and visitors

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, …

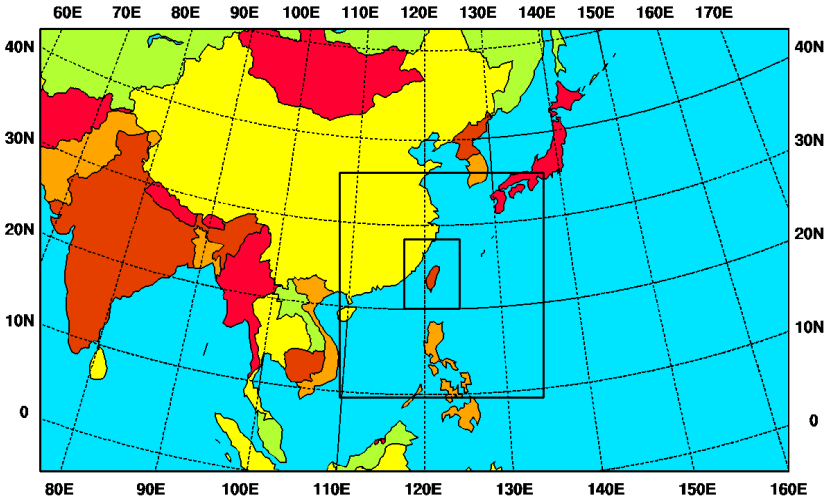
- **Goal:** Community WRF DA system for
  - research/operations, and
  - deterministic/probabilistic applications.

- **DA Techniques:**
  - 3D-Var
  - 4D-Var
  - Ensemble Transformed Kalman Filter
  - Hybrid-3DVAR

- **Support:**
  - NCAR/MMM via wrfhelp@ucar.edu

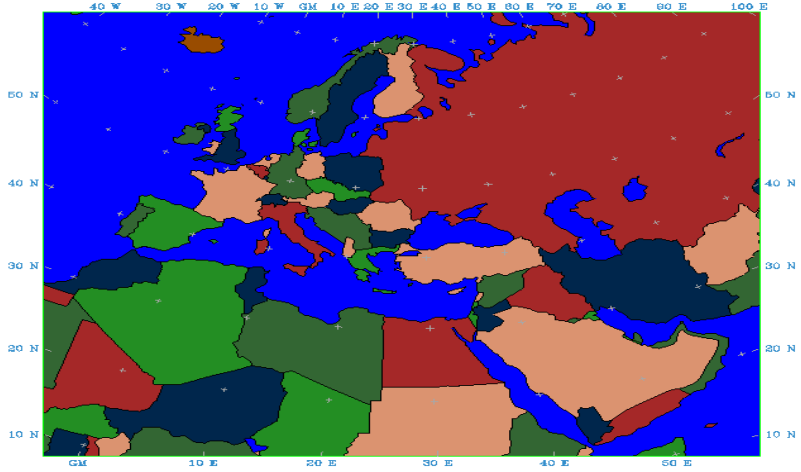
- **Observations:** Conv.+Sat.+Radar(+bogus)

Domain area of CWB WRF

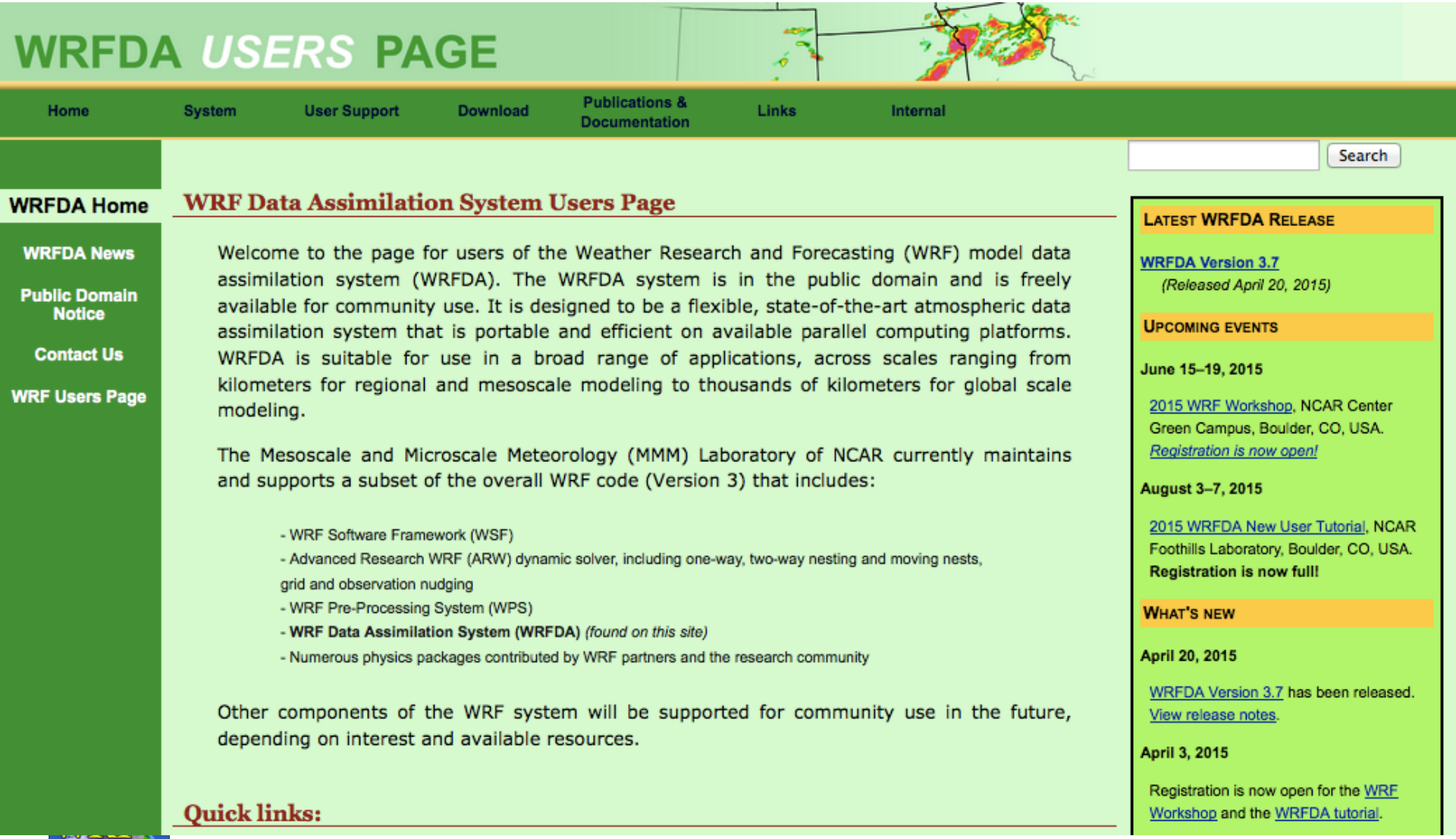


Both operations run in hybrid-3DVAR mode

Panasonic Weather Solution European WRF



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



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 (enhancements in V3.7)**
  - Satellite temperature/humidity/thickness profiles
  - GPS refractivity (e.g. COSMIC)
  - Stage IV precipitation/rain rate data (4D-Var)

- **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

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

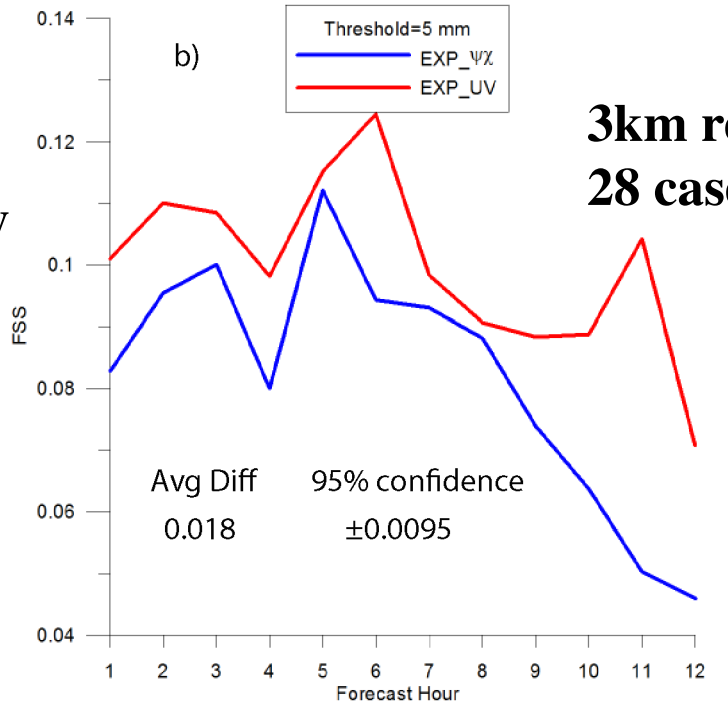
cv_options	Analysis variables
3	Ψ, unbalance X, unbalance t, pseudo rh and unbalance log (P_s)
5	Ψ, unbalance X, unbalance t, pseudo rh and unbalance P_s
6	Ψ and unbalance X, unbalance t, unbalance pseudo rh and unbalance P_s
7	u, v, t, Ps and pseudo rh **(new in WRFDA V3.7)**

Pseudo rh defined as Q divided by Qs 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.



3km resolution
28 cases with 3DVAR

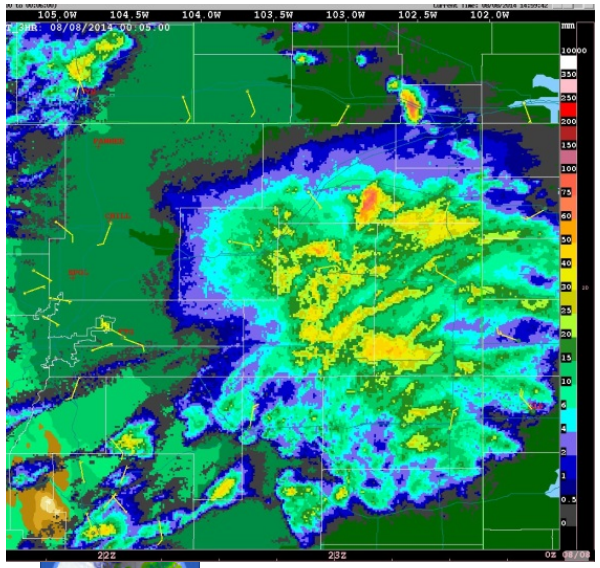
New capabilities in WRFDA 3.7 for radar DA

- 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

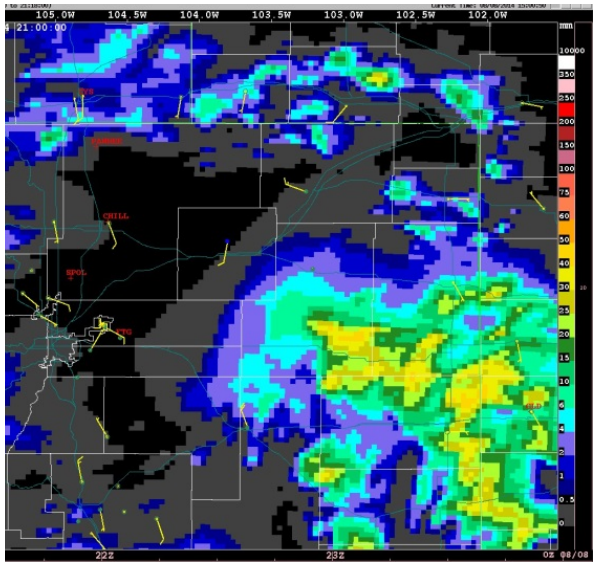
More details see talk by Jenny Sun Friday 8:30am

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

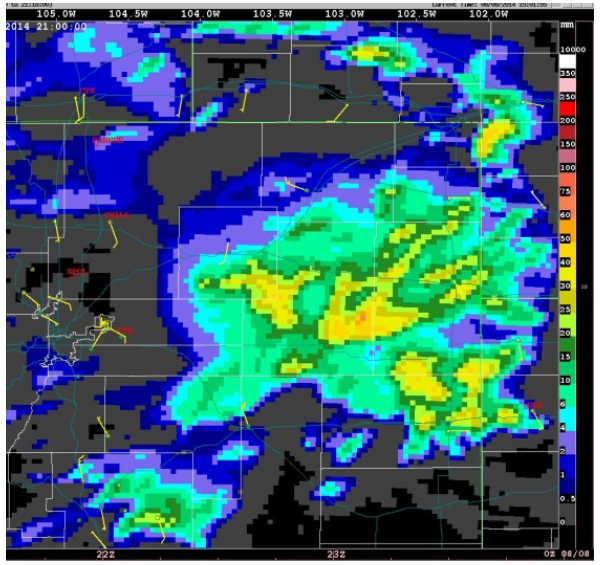
OBS



3DVar without radar



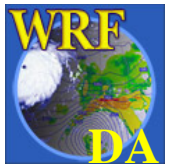
3DVar with radar



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)



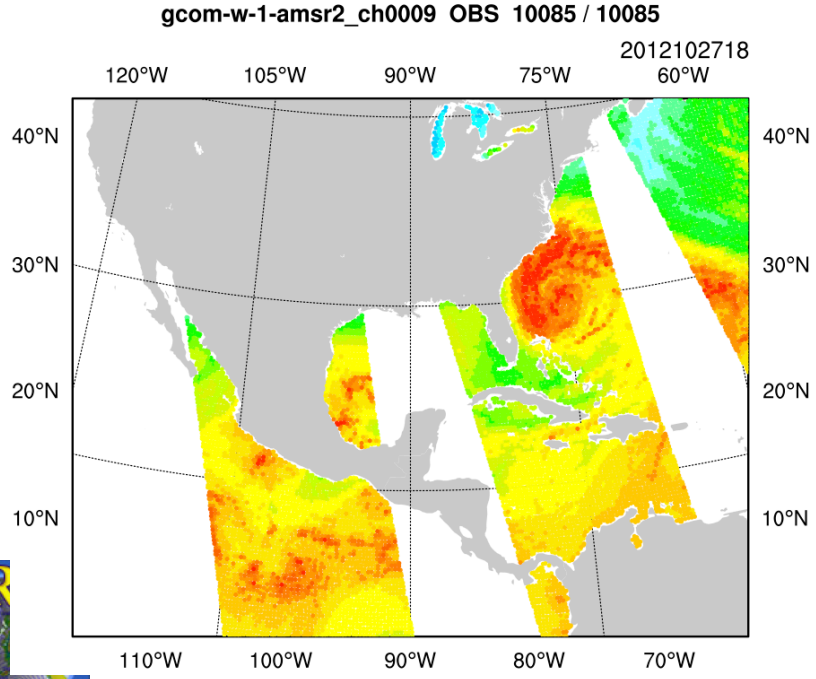
Outline

- New features in WRFDA V3.7

- Ongoing developments

New radiance data (1): AMSR2

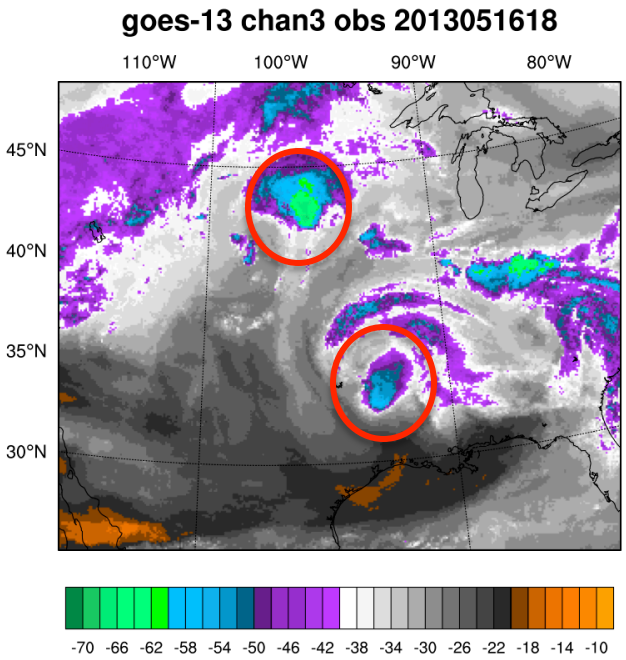
Channel	Frequency	Polarization	Beam Width	Footprint (along scan* along track)
1,2	6.925	V, H	1.8° ± 15%	35*61 km
3,4	7.3	V, H	1.8° ± 15%	35*61 km
5,6	10.65	V, H	1.2° ± 15%	24*41 km
7,8	18.7	V, H	0.65° ± 15%	13*22 km
9,10	23.8	V, H	0.75° ± 15%	15*26 km
11,12	36.5	V, H	0.35° ± 15%	7*12 km
13,14	89.0	V,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



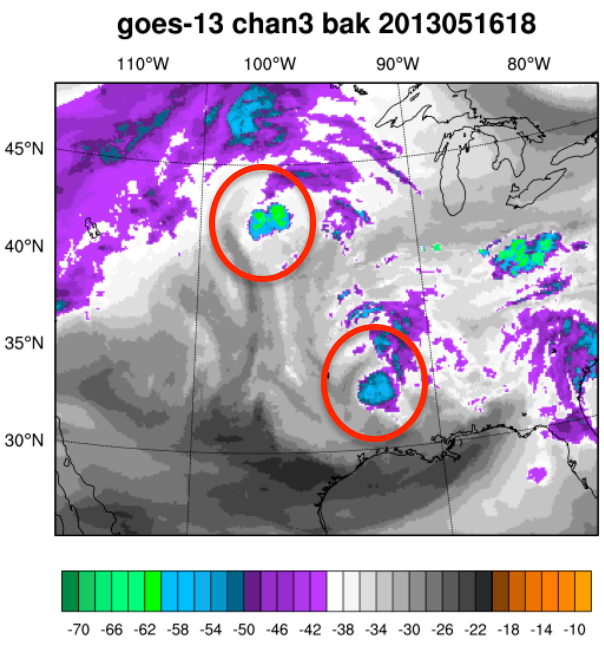
Allow clear-sky or all-sky radiance assimilation over water

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

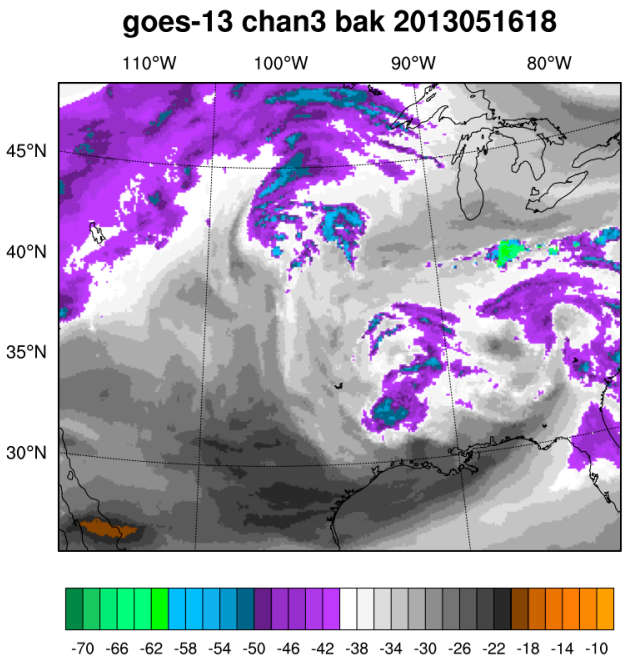
New radiance data (2): GOES-Imager



GOES-13 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

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

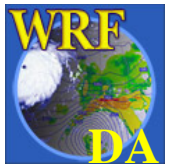
12-h vs. ~ 40min!

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



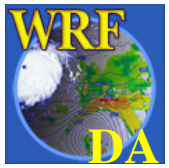
4DVAR for WRF/Chem
Daven Henze's group at CU

- 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