The Warner Memorial Symposium
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The NCAR X-FDDA: A Tribute to Tom Warner

Yubao Liu
(National Center for Atmospheric Research)

Thanks: The NCAR RTFDDA team (1999 - )

Tears, Sweat, or Dew?
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<th>Chris Davis</th>
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<td>Hsiao-M. Hsu</td>
<td>Mei Xu</td>
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NCAR/RAL X-FDDA Scientific Modelers (1999 – )
A suite of MM5/WRF based multi-scale continuous data assimilation and forecasting systems for supporting user/mission-oriented weather applications.

**What is X-FDDA?**

Mesoscale deterministic FDDA and forecasting
Mesoscale ensemble FDDA and forecasting
Microscale FDDA and forecasting
Production of regional and/or global micro-climatology
RTFDDA: 4-D Data Assimilation & Forecasting

Regional-scale NWP models
WRF / MM5

All WMO/GTS

GOES

Radars

Wind Prof

MESONETs

ACARS

Etc.

Farm Met

Modified WRF/MM5:
\[
\frac{Dx}{Dt} = ... + GW \left( x_{obs} - x_{model} \right)
\]

where \( x = T, U, V, Q, P1, P2 \ldots \)

\( W \) is weight function

Weather observations

WRF/MM5

Cold start

FDDA

Forecast

NCAR
Effectively and efficiently incorporate observation data into a full-physics MM5/WRF models to produce 4-D synthetic (model and obs) weather on high-resolution grids over the user regions.
A Unique Advantage of RTFDDA

- It assimilates all observations into WRF model equation during the model forward integration ("forecasts"); and thus
- it produces dynamically-balanced, physically-consistent, and cloud "spun-up" 4D continuous analysis and forecasts of all weather variables on high-resolution grids.
NCAR RTFDDA Applications

20+ Mission-oriented Operations
18 Regular Operational RTFDDA Systems

Olympics
Salt Lake City
Goes IR
RTFDDA
17Z cycle
Sep. 23

~200-blade super-cluster
D1  98x84x37, DX = 40.5 km
D2  106x115x37, DX = 13.5 km
D3  91x91x37, DX = 4.5 km
D4  112x154x37, DX = 1.5 km
Comparison of C-FDDA Model and Gage Rain

(Total accumulation of 10 Nov 2008 – 22 Mar 2009)

D1
DX: 40.5km

D2
DX: 13.5km

D3
DX: 4.5km

D4
DX: 1.5km

100x100 km²
Army Ensemble-RTFDDA Forecasts Example
Calibrated Xcel Energy Ensemble-RTFDDA Forecasts for a CO Wind farm

Raw E-RTFDDA output

Calibrated with ANKF+QR

Hub height wind speed (m/s)

7 days (mm/dd), 2011

WRF  MM5  Obs  En Mean  Calibrated members
WRF-RTFDDA-LES (300m grid)

Explicit Simulation of Tornadoes

April 27 2011: A massive devastating tornado outbreak in Southeastern U.S. that caused destructive damage and fatality
Simulated Tornado-bearing MCS (DX = 300m)
27th April 2011, 5:05PM CDT

From: Wanli Wu
An Example of Tornados Simulated

Surface wind and 700hPa W

V10 max: 76.9m/s
W max: 50m/s
Vor max: 1000/s
P-drop: 40 hPa

From: Wanli Wu
RTFDDA: Toward Advanced Capabilities

Next-Gen 4DWX 4D-REKF System

- Incorporate Ensemble Kalman Filter
- Optimize DA and model physics interactions
- DA for microscale weather modeling

Ensemble RTFDDA (Obs-nudging Ensembles)

Improvements:
- Spatial weights
- Temporal weights
- Radar/Sat. data

Hybrids:
- 3DVAR
- VDRAS
- Grid-nudging

WRF/MM5-RTFDDA: Obs-nudging
Hybrid DA for Radar Data Assimilation

All U, V, T, Qv observations and data QC

Upper-air data

Radar radial winds and reflectivity

WRF-based RTFDDA system (Liu et al. 2005 and 2006 WRF Workshop)

Continuous 4-D analyses and forecast cycling

WRF-RTFDDA

Hybrid Engine

Latent heat nudging (DZ)

3DVAR analysis (VR, DZ)

Radar Analysis
Next-Generation FDDA: 4D-REKF

3DDA

**OA**: Simple empirical isotropic (distance) function

**3DVAR**: Historical daily (24h-12h forecast) isotropic weight function

**ENKF**: Ensemble flow-dependent anisotropic weight function

4DDA

Nudging

WRF or MM5

RTFDDA

Constraint

WRF

4D-Var

Nudging

WRF

4D-REKF

4D-REKF: 4-Dimensional Relaxation Ensemble Kalman Filter (FDDA and forecasting)
Thank you Tom, for your 11 years’ oversight and guidance to me and the X-FDDA group.

Your leaving made us sweating, tearing; tearing, sweating...

But now, these drops are more like sweet dew that you left to nurture us to grow toward the future...

And, thank you Mrs. Susan Warner!