2013 realtime WRF-DART analysis and ensemble forecasts

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14th WRF User’s Workshop  24-28 June 2013
Springtime convection permitting forecasts at NCAR

10th consecutive year of realtime forecasts with the WRF model

Demonstrates WRF capabilities
Support for MMM associated field programs
Contributes to predictability studies of convection

BAMEX – 2003

MPEX – 2013

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MPEX – Mesoscale Predictability Experiment

Goals
1) Improve convection permitting forecasts by reducing initial condition uncertainty through targeted sub-synoptic observations upstream of anticipated convective events
2) Sample the near storm environment to better understand how developing convection impacts subsequent predictability

Ops from 15 May – 15 June 2013, 15 flights, 18 upsonde missions

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MPEX flight operations example – 05/23/13  Water Vapor @ 14 UTC

Blue (green) dots dropsonde (operational sounding) locations
Black (white) flight level (500 mb) wind vectors

Flight level 40k ft, ~180 mb
~28 drops/mission
Takeoff 0900 UTC
MPEX upsonde operations example
– 20 May 2013 (Moore, OK tornado event)

Purdue, NSSL, CSU and Texas A&M participated in upsonde mission. ~ 20 upsondes per event.

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Courtesy Russ Schumacher CSU
WRF and DART configuration options

**WRF V3.3.1**
- 415x325x40 (E-W)x(N-S)x(B-T), model top 50 mb
- 15 km grid spacing
- Key physics options: Tiedtke, RRTMG, Thompson, MYJ, NOAH
- Ensemble forecasts – 10 (30) member from 00 (12) UTC, 3 km grid spacing nest

**DART development branch (approx. Kodiak release)**
- 50 member ensemble
- 6 hourly continuous cycling assimilation
- adaptive prior inflation, sampling error correction, adaptive localization
- conventional obs (ACARS, METAR, Radiosondes, Marine, Profiler, CIMMS motion vectors), ~180k obs/day
**Ensemble Sensitivity**

\[
\frac{\partial J_e}{\partial x_j} \equiv \text{cov}(\delta J, \delta x_{o,j})D_j^{-1} = \frac{\text{cov}(J, X_j)}{\text{var}(X_j)}
\]

Ancell and Hakim 2007, Torn and Hakim 2008

- Ensemble-based method of computing the sensitivity to the initial conditions (or prior forecast states)
  - Above equation is linear regression based on ensemble:
    - Dependent variable is ensemble estimate forecast metric (e.g. average accumulated precipitation over an area)
    - Independent variable is ensemble estimate of state variable (e.g. mid-tropospheric humidity)
  - Works best when the forecast metric is more continuous
  - Can also compare subset of members that have particular metric properties (e.g. max – min metric groups)
Sample ensemble sensitivity:

Warm (cool) colors – increase (decrease) in field at 12 UTC associated with more precip in area at right from Fhr 35-38

Theta-e tongue further east, trough further east leads to more precipitation in box
Hypothetical observation impact

• Ensemble-based method allows for estimate of observation impact
  – Can get change in metric value if you know observation properties, ensemble metric values and observation value itself
  – Can get reduction in variance knowing first two above (no need for observation)

\[
\delta J = J(HX^b)^T(HP^bH^T + R)^{-1}[y - \mathcal{H}(x^b)]
\]

\[
\delta \sigma = -J(HX^b)^T(HP^bH^T + R)^{-1}HX^bJ^T
\]

Change in Forecast metric slope innovation covariance innovation

Change in forecast metric variance Forecast metric observation covariance x inverse innovation covariance

See Torn and Hakim 2008, MWR
Highest impact associated with synoptic features, mid-troposphere theta-e, surface theta-e, and the sampled mid-troposphere disturbance in NM/AZ.
Fractions Skill Score

50 km radius of influence, by Fhr for NCAR ensemble vs. GFS IC

\[ FBS = \frac{1}{N} \sum_{i=1}^{N} (f_i - o_i)^2, \quad \text{FBS}_{\text{worst}} = \frac{1}{N} \sum_{i=1}^{N} (f_i^2 + o_i^2), \quad \text{FSS} = 1 - \frac{FBS}{FBS_{\text{worst}}} \]
Areal coverage by rain rate threshold, ensemble (green), GFS (red), and ST4 observed (black). Day 1 NCAR ens early peak in diurnal, GFS especially higher bias day 1 [but both too wet day 1, better day 2].
F1-12 ROC diagrams

Relative operating characteristic curves, skill when left of diagonal

F1-12 Reliability diagrams

Over (under) dispersive left (right) of diagonal

A neighborhood approach would lead to ‘improved’ stats
Forecast errors are more like each other than the observations, but generally both compare well.
Mean difference (5/14-6/15) between WRF DART analysis and downscaled GFS analysis temperature on nest domain for 12 UTC initial conditions – WRF physics related drift?

Will need to evaluate both against obs

May need to include climatological covariances in continuously cycled assimilation to control drift

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Probability of organized convection from 12 Z fcsts, storm reports

30 member, 50 km neighborhood, 6-15 Fhr
High POD but also high FAR

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2013-05-31 12 Z ensemble fcst, reflectivity > 45 dBZ, mem 1-10 (color) and obs (black)

21 UTC

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Summary, future work

• 2013 marked 10th consecutive season of NCAR realtime spring convection permitting (CP) forecasts – first season with ensembles, 3rd with WRF-DART initial conditions

• Ensemble forecasts during MPEX provided useful guidance of significant severe weather hazards during day 1 of the forecast (many strongly forced events)

• Further evidence of ‘drift’ in continuously cycled WRF model forecasts – unique manifestation this season, will compare both analyses to obs

• Ensemble sensitivity application to targeted observing strategies will be further explored

• We will be assimilating MPEX sondes in retrospective studies with WRF-DART with subsequent CP ensemble forecasts (data denial obs impact experiments)
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