Localized MLEF + WRF regional model

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Hurricane Katrina (landfall at 12Z on AUG 29, 2005):

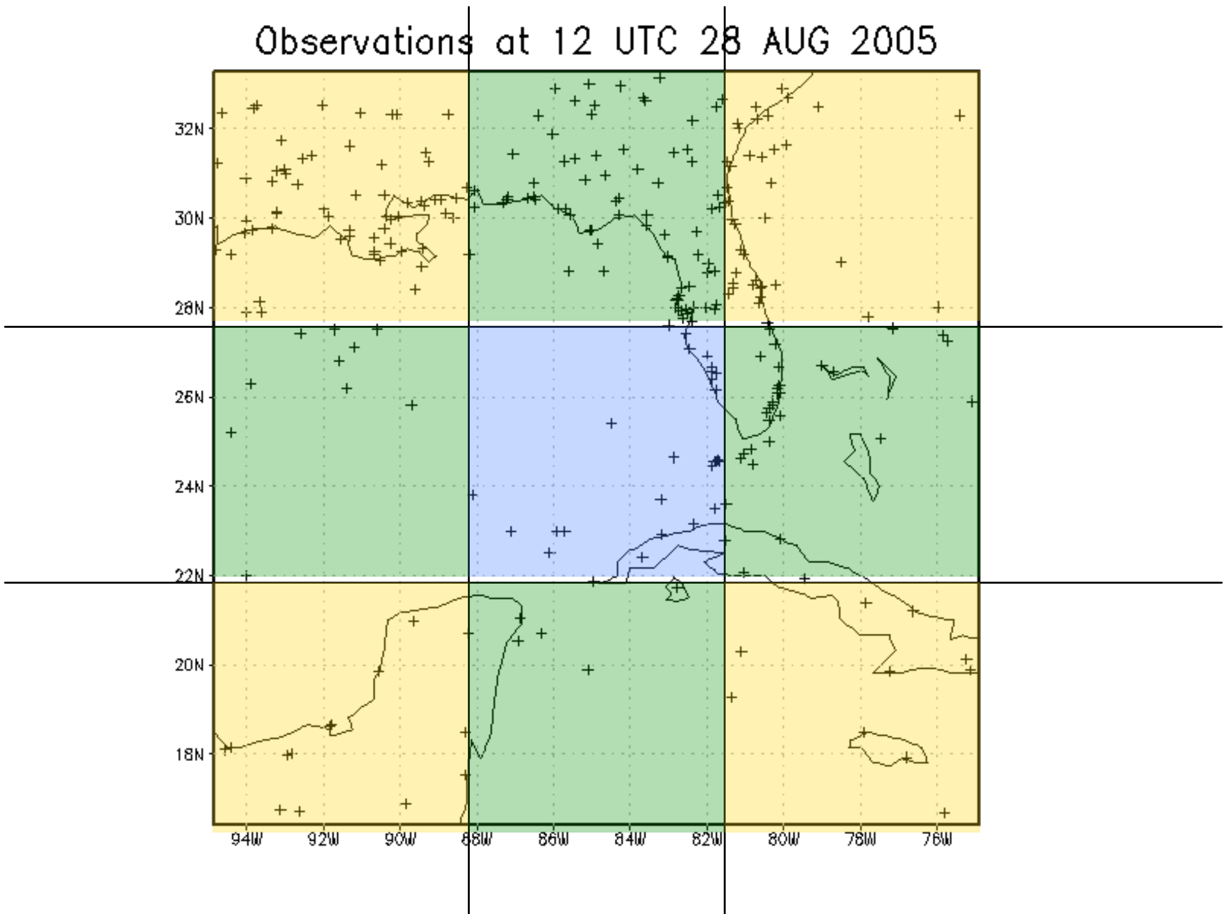
- *Model resolution*: 30 km horizontal, 28 vertical levels (75x70x28)
- 6-hour old boundary conditions from the NCEP GFS model
- *Observations*: NCAR upper-air and surface observations (p_s, T, q, u, v)
- *Assimilation*: 6-hour interval, from 26 Aug 00Z - 31 Aug 00Z (5 days)
- *Control variables*: $u, v, \delta\theta, \delta Z, q_v$
- *State vector dimension* ~700,000
- 32 ensembles
- Error covariance localization based on a *modified* local domains approach

Reference:

Zupanski, M., D. Zupanski, S. J. Fletcher, M. DeMaria, and R. Dumais, 2008: Ensemble data assimilation with the Weather Research and Forecasting (WRF) model: The hurricane Katrina case. *J. Geophys. Res.*, submitted.

Local domains

Independent analysis in each local domain



- **9 local domains (3x3)**
- **Each local domain contains 23x25 horizontal grid points**

Error covariance localization: Modified local domains approach (1)

Work with the observation "weight" matrix, rather than with the analysis directly (motivated by Yang et al. 2008, QJRMS)

$$\boldsymbol{W}_{orig} = \left(\boldsymbol{Z}(\boldsymbol{x}^f)\right)^T \boldsymbol{Z}(\boldsymbol{x}^f) \qquad \left[\boldsymbol{Z}(\boldsymbol{x}^f)\right]_i = \boldsymbol{R}^{-1/2}\left[H(\boldsymbol{x}^f + \boldsymbol{p}_i) - H(\boldsymbol{x}^f)\right]$$

$$\boldsymbol{W}_{new} = diag\left(\boldsymbol{T}^T \boldsymbol{W}_{orig} \boldsymbol{T}\right) / diag\left(\boldsymbol{T}^T \boldsymbol{T}\right) \qquad \boldsymbol{T} = \begin{pmatrix} \gamma_0 & -\gamma_1 & \cdots & -\gamma_K & 0 \\ \gamma_1 & \gamma_0 & -\gamma_1 & \cdots & -\gamma_K \\ \cdots & \gamma_1 & \gamma_0 & -\gamma_1 & \cdots \\ \gamma_K & \cdots & \gamma_1 & \gamma_0 & -\gamma_1 \\ 0 & \gamma_K & \cdots & \gamma_1 & \gamma_0 \end{pmatrix}$$

EVD and inversion done after the observation matrix transformation

Error covariance localization: Modified local domains approach (2)

$$\boldsymbol{W}_{new} = \begin{pmatrix} \boldsymbol{W}_{new}^{1} & 0 & 0 & 0 \\ 0 & \boldsymbol{W}_{new}^{2} & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \boldsymbol{W}_{new}^{L} \end{pmatrix}$$

New observation weight matrix is a linear interpolation from neighboring local domains:

$$\boldsymbol{W}_{new}^{i} = \frac{\gamma_K^2 \boldsymbol{W}_{orig}^{i-K} + \cdots + \gamma_1^2 \boldsymbol{W}_{orig}^{i-1} + \gamma_o^2 \boldsymbol{W}_{orig}^{i} + \gamma_1^2 \boldsymbol{W}_{orig}^{i+1} + \cdots + \gamma_K^2 \boldsymbol{W}_{orig}^{i+K}}{\gamma_0^2 + 2\gamma_1^2 + 2\gamma_2^2 \cdots + 2\gamma_K^2}$$

Enforced correlation between local domains, simulating dynamical dependence in the global domain

Hurricane Katrina position error (km)

Date/Time (UTC)	DA cycle	NOOBS	MLEF (L-3x3) (32 ens)	GLOBAL (96 ens)
26 / 0600	**1**	85	85	85
26 / 1200	**2**	71	79	80
26 / 1800	**3**	95	**84**	110
27 / 0000	**4**	166	**131**	145
27 / 0600	**5**	190	**132**	193
27 / 1200	**6**	220	**163**	206
27 / 1800	**7**	213	**147**	213
28 / 0000	**8**	187	**103**	207
28 / 0600	**9**	176	**71**	160
28 / 1200	**10**	183	**58**	145
28 / 1800	**11**	140	**40**	111
29 / 0000	**12**	129	**27**	97
29 / 0600	**13**	109	**16**	90
29 / 1200	**14**	157	**145**	157

Positive impact of error covariance localization