

Assimilation of Lightning In WRF Using 1-D + 4-D VAR

H. Fuelberg, I. Navon, R. Stefanescu, M. Marchand
Florida State University

- Strong relation between max updraft speed and total flash rate at model resolution of 1 km (Barthe et al. 2010)
- W_{\max} related to CAPE (must account for entrainment)
- CAPE related to vertical temperature profile
- Proxy for model state variable is temperature profile
- 1-D + 4-D VAR technique (Mahfouf et al. 2005; Bauer et al. 2006)
- 1-D VAR Problem

Let $X = (t; Ps; q)$ where X is a vector representing atmos. state

Let F_{oi} be a set of observations with errors σ_{oi}

Let $F_i(x)$ be an observation operator generating flash rate

- The optimum profile X minimizes a cost function of the form:

$$J(X) = \frac{1}{2}(X - X_b)^T \mathbf{B}^{-1}(X - X_b) + \frac{1}{2} \sum_{i=1}^n \left(\frac{F_i(X) - F_{oi}}{\sigma_{oi}} \right)^T \mathbf{R}^{-1} \left(\frac{F_i(X) - F_{oi}}{\sigma_{oi}} \right),$$
$$\nabla J(X) = \mathbf{B}^{-1}(X - X_b) + \sum_{i=1}^n \mathbf{F}_i^T \mathbf{R}^{-1} \left[\frac{F_i(X) - F_{oi}}{\sigma_{oi}^2} \right],$$

- Use 1-D VAR to adjust temperature profile to modify CAPE

- The 1-D VAR temp. profiles considered new observations and then are assimilated using 4-D VAR
- Our scheme currently is being coded
- Will be completed in \approx 2 months
- Also will consider 3-D VAR and 4-D VAR without 1-D VAR
- Our schemes and two nudging schemes will be tested on four cases with copious lightning
 - Nor'easter (tentatively the 10-11 Feb. 2010 storm)
 - North Pacific mid-latitude cyclone (17-19 Dec. 2009 storm)
 - Tropical cyclone (Hurricane Karl, 2010)
 - Severe thunderstorm/tornado outbreak in U. S.
- Currently coding the schemes of Fierro et al. and Pessi and Businger



Preparing Fierro et al. Scheme

- WRF Model Specifications
 - 6 km parent domain, 2 km nested domain, 60 vertical levels
 - No cumulus parameterization
 - WRF Single Moment 6-Class scheme
 - WWLLN lightning data assimilated at 10 min intervals over a 6 h period. Poor detection efficiency—only detects strongest flashes. Plan to use GLD360 data in the future
 - Fierro et al. used WTLN total lightning observations.
 - When WWLLN lightning was observed in a grid cell, we saturated the mixed phase region.
 - Fierro et al. supersaturated the region up to 5%, depending on the flash rate
- Come see early results at our poster