

# Atmospheric Predictability

Some aspects we have recently learned and other aspects  
awaiting our investigation

**Ronald M. Errico**

Goddard Earth Sciences and Technology Center (UMBC)  
Global Modeling and Assimilation Office (NASA)

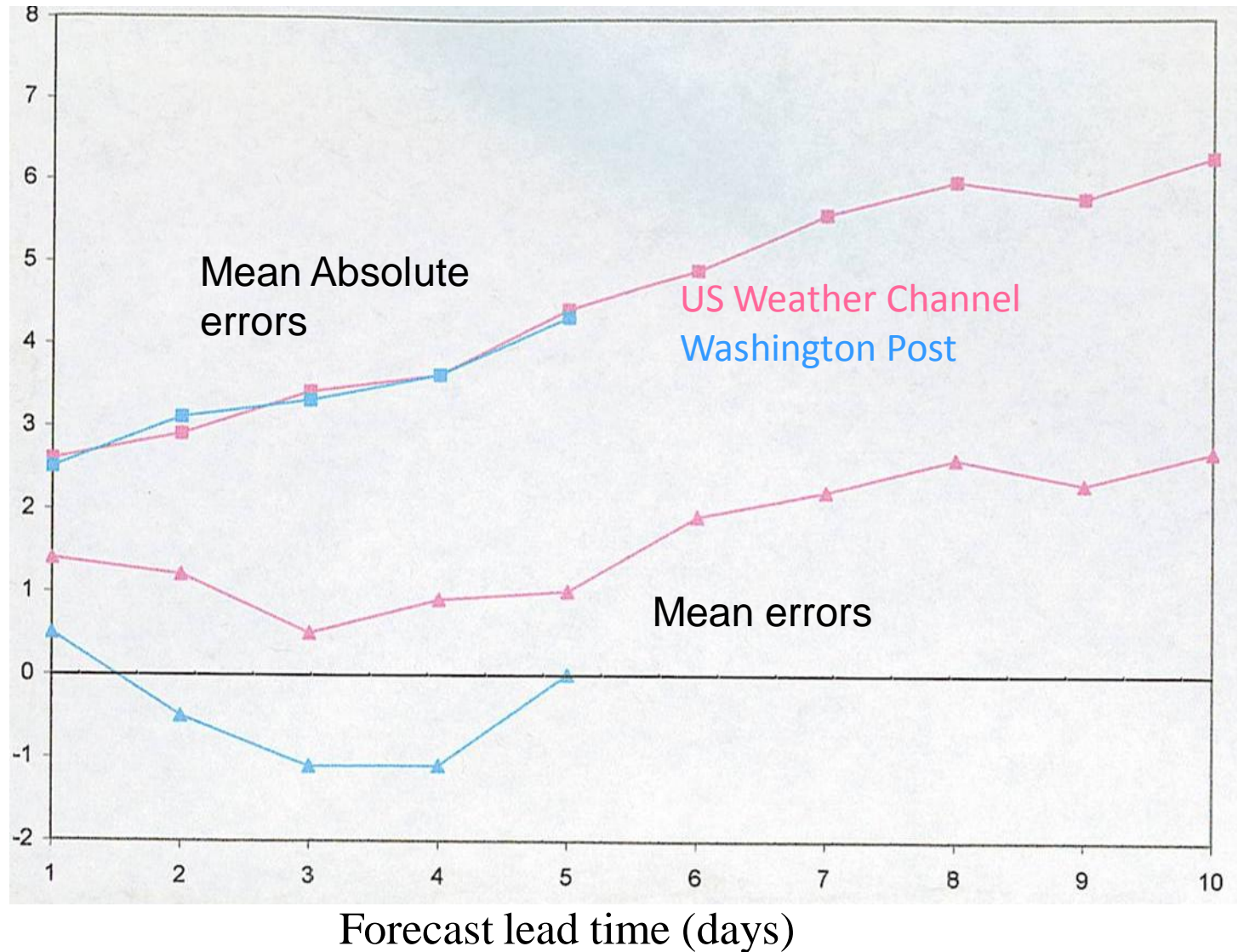
# Ideas from Philip Thompson (*Tellus* 1957)

## Uncertainty of initial state as a factor in the predictability of large scale atmospheric flow patterns

1. Given the (then) present observational network, "...the rms vector wind error may double its initial value after two days, and rise to the error of sheer guessing in about a week."
2. Our understanding of predictability should guide what we attempt to do and guide us regarding what is required to accomplish what we want to do (Errico et al. 2002).
3. Even if details (e.g., instantaneous weather) become unpredictable after some short time, statistical characterizations (e.g., time means) may remain predictable for longer periods (Namias 1947).

# Error scores for forecast low temperatures at Baltimore Maryland averaged for 67 days during Autumn 2002

Error score (deg. F)

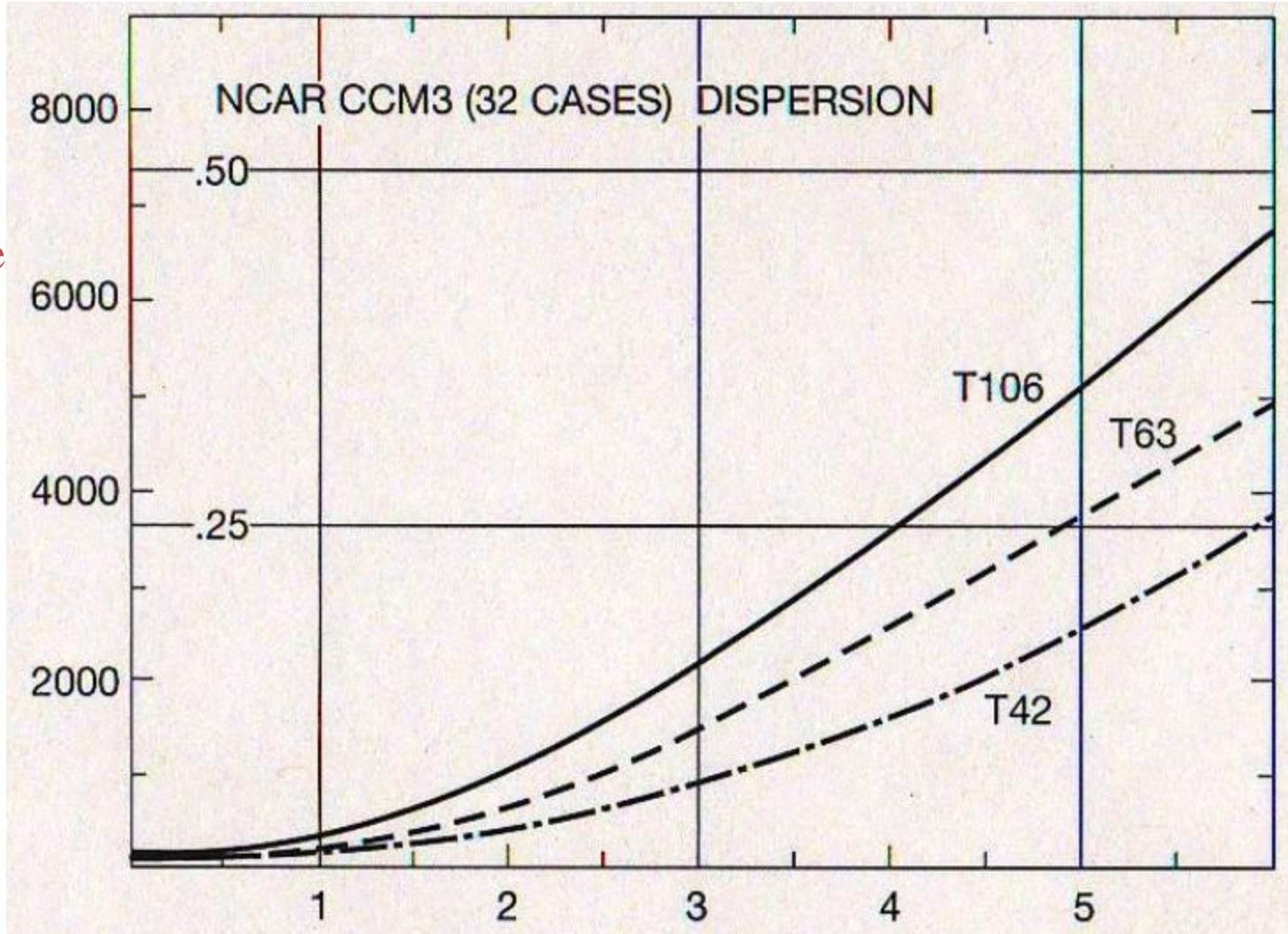


Adapted from B. Errico 2003

# Error growth as a function of model resolution (from D. Baumhefner)

Variations of 500 hPa height differences between ensemble members

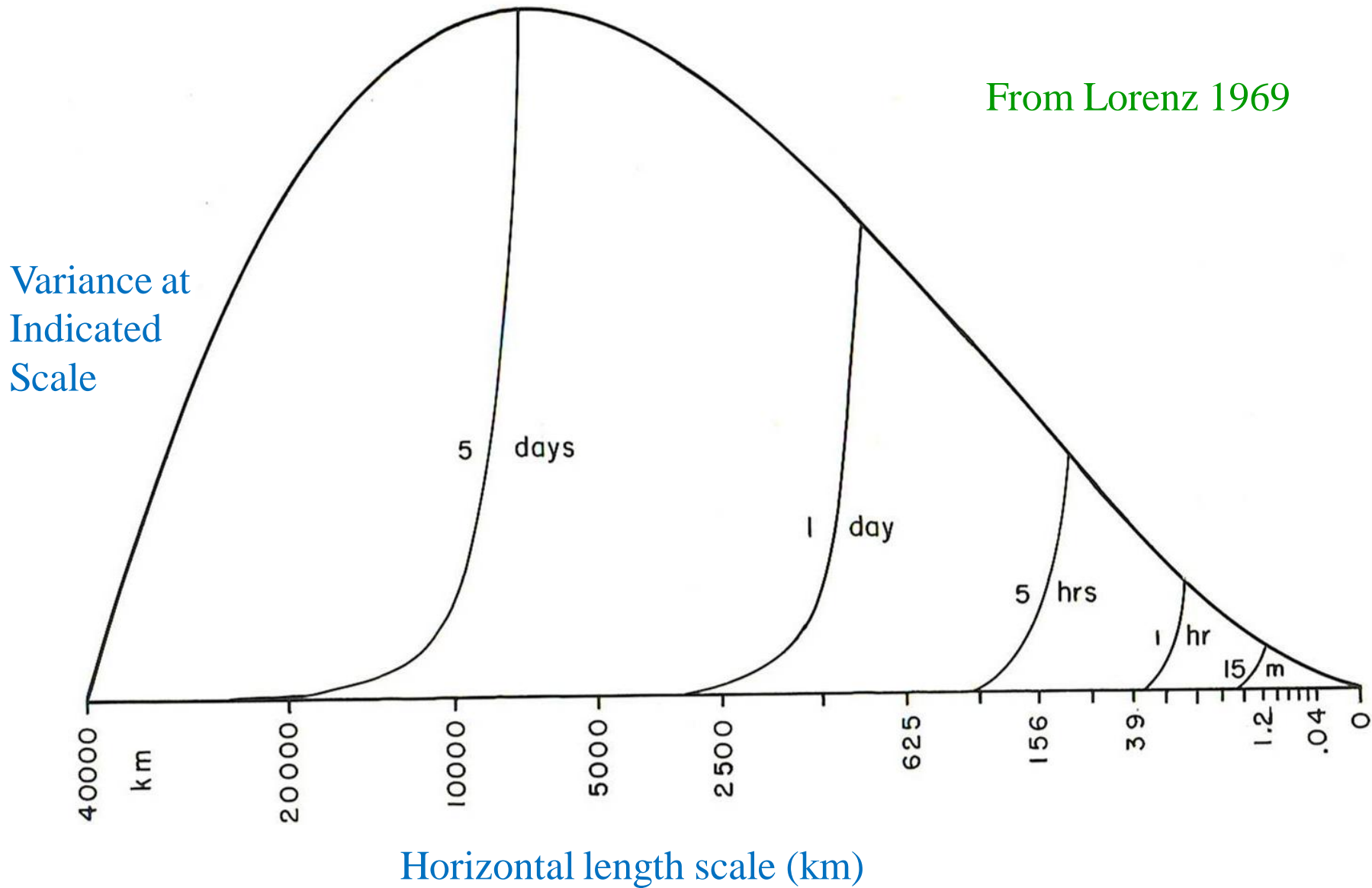
Variance  
(m\*\*2)  
  
(metric  
applied  
at T42)



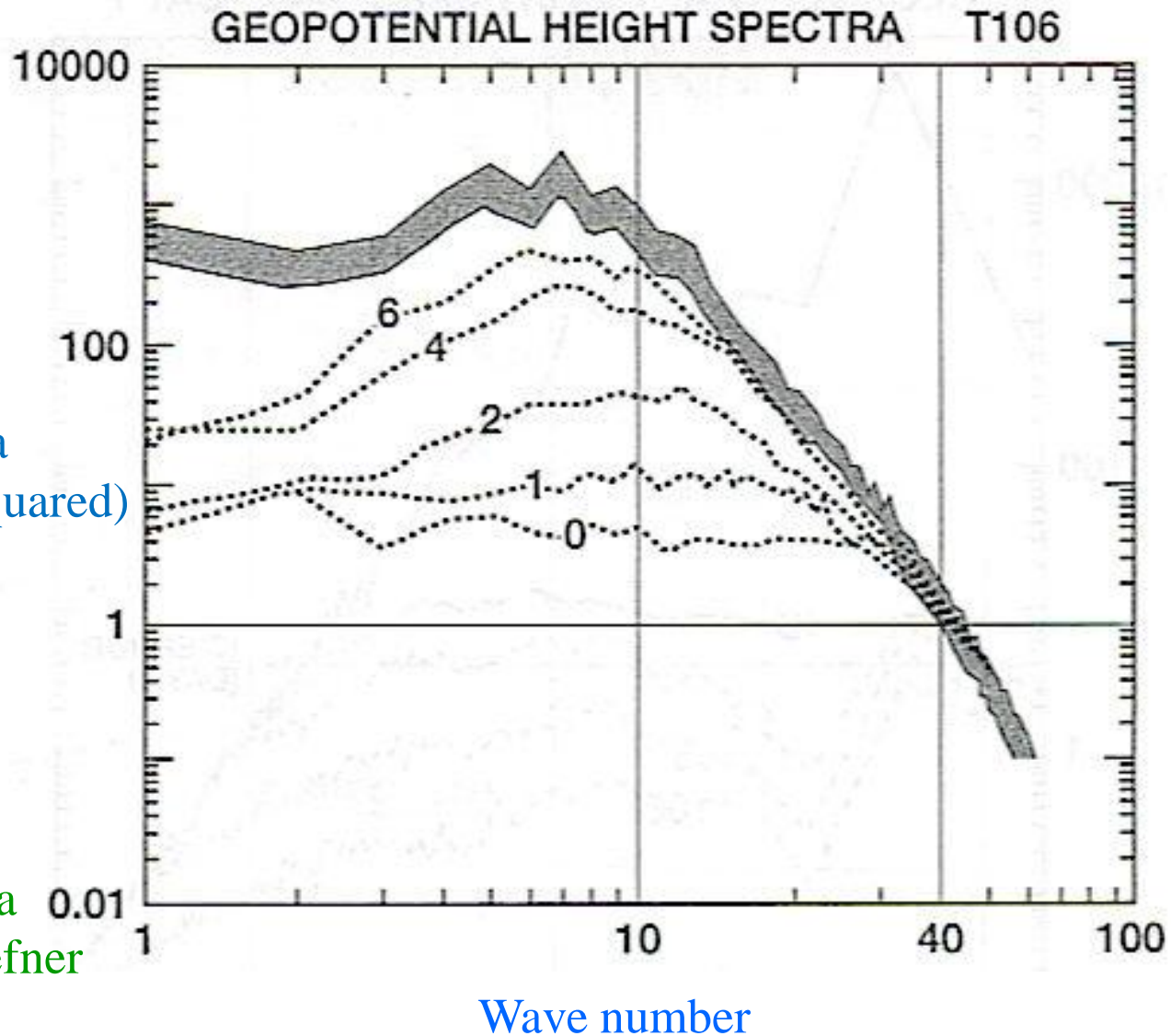
Forecast Day

# Power spectra of forecast differences

From Lorenz 1969



# Predictability experiments with the NCAR CCM



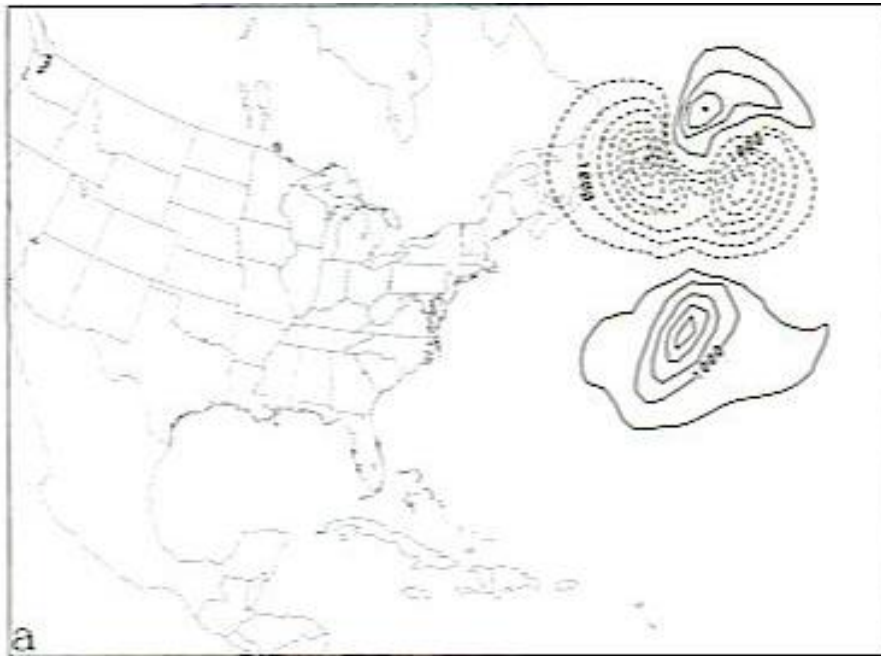
From Tribbia  
and Baumhefner  
*MWR* 2004

# Linear vs. Nonlinear Results in Moist Model

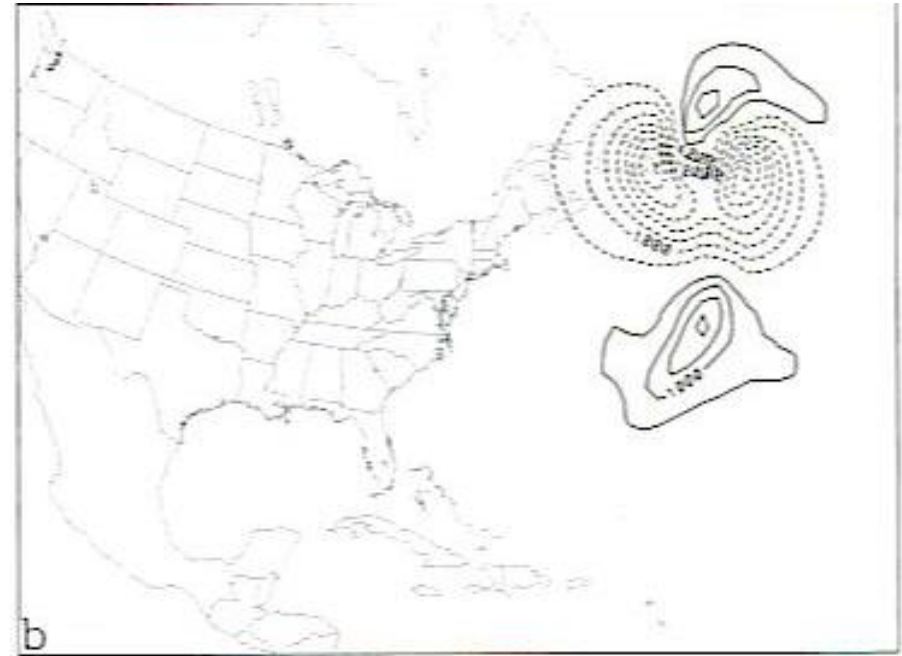
24-hour SV1 from case W1  
Initialized with  $T'=1\text{K}$   
Final ps field shown

Errico and Raeder  
1999 *QJRM*S

Linear Result

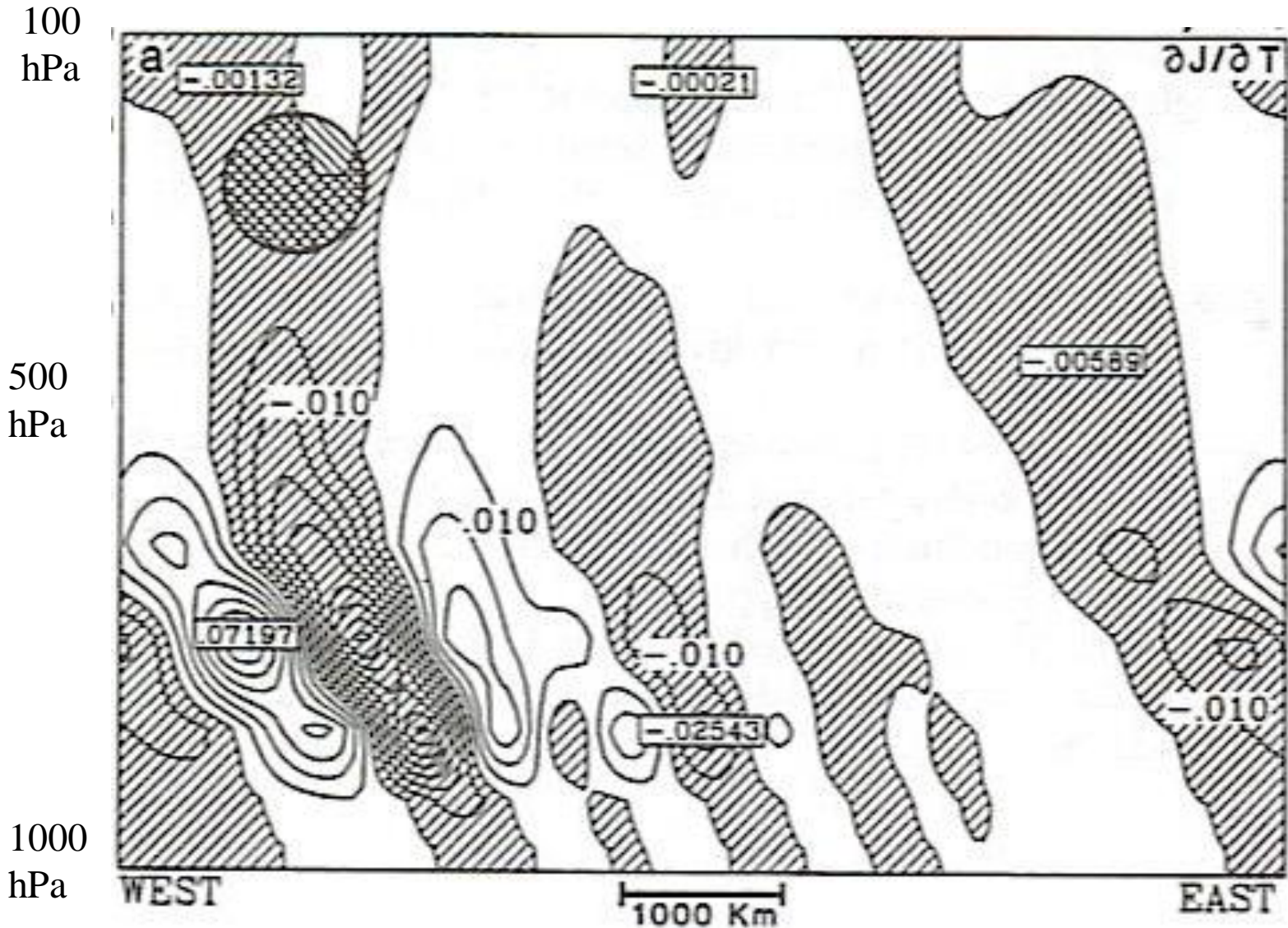


Nonlinear Result



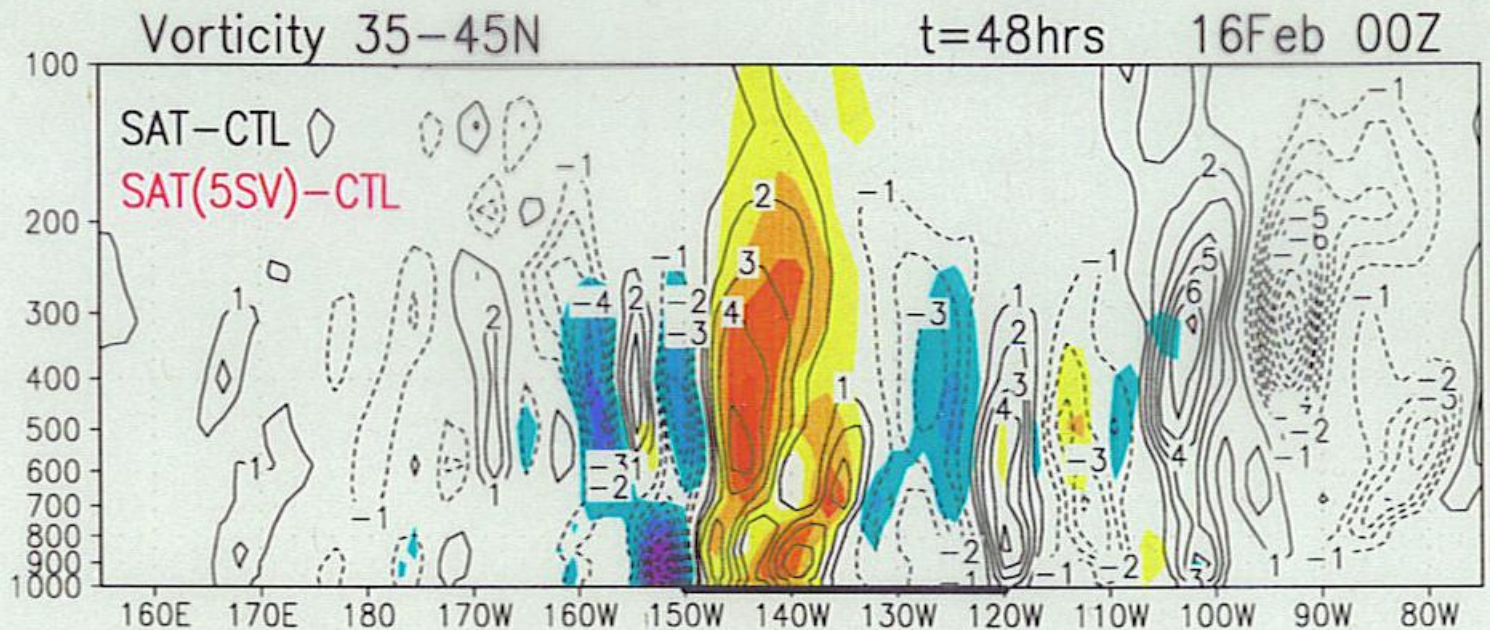
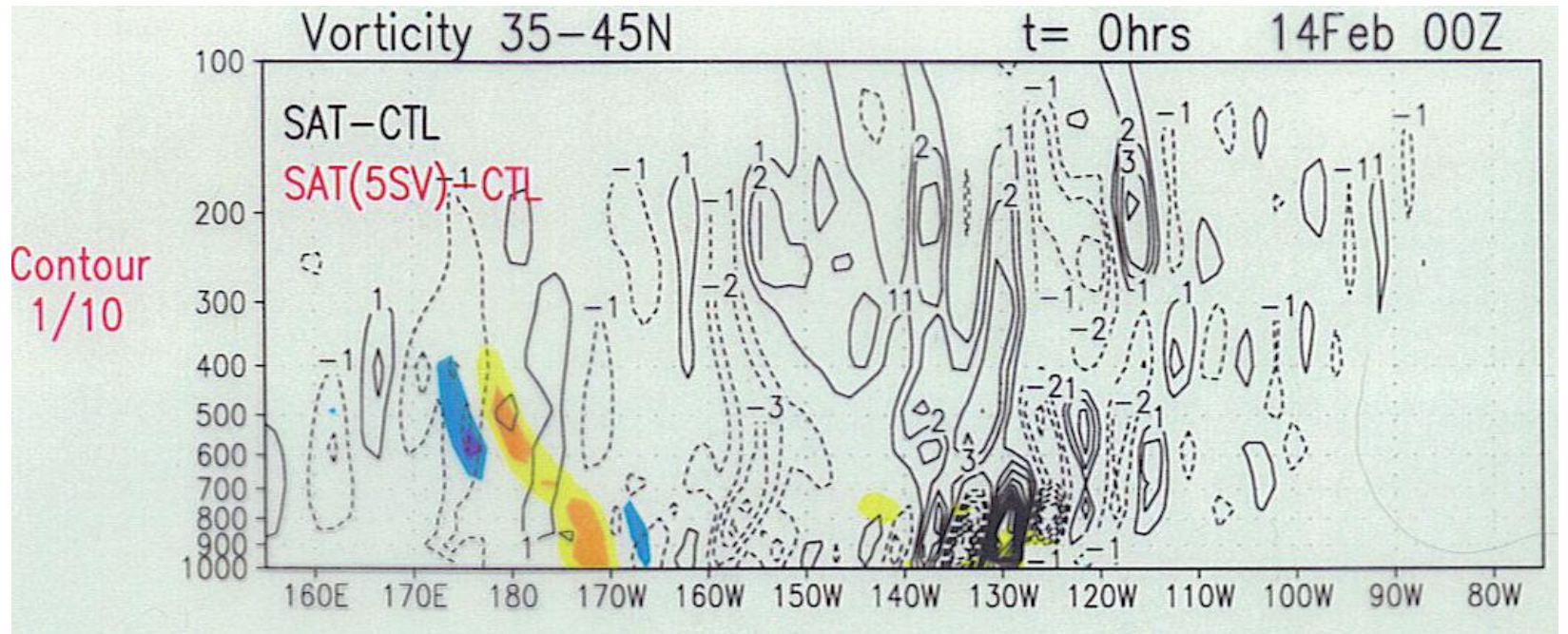
Contour interval 0.5 hPa

# Sensitivity field for $J=p_s$ with respect to $T$ for an idealized cyclone



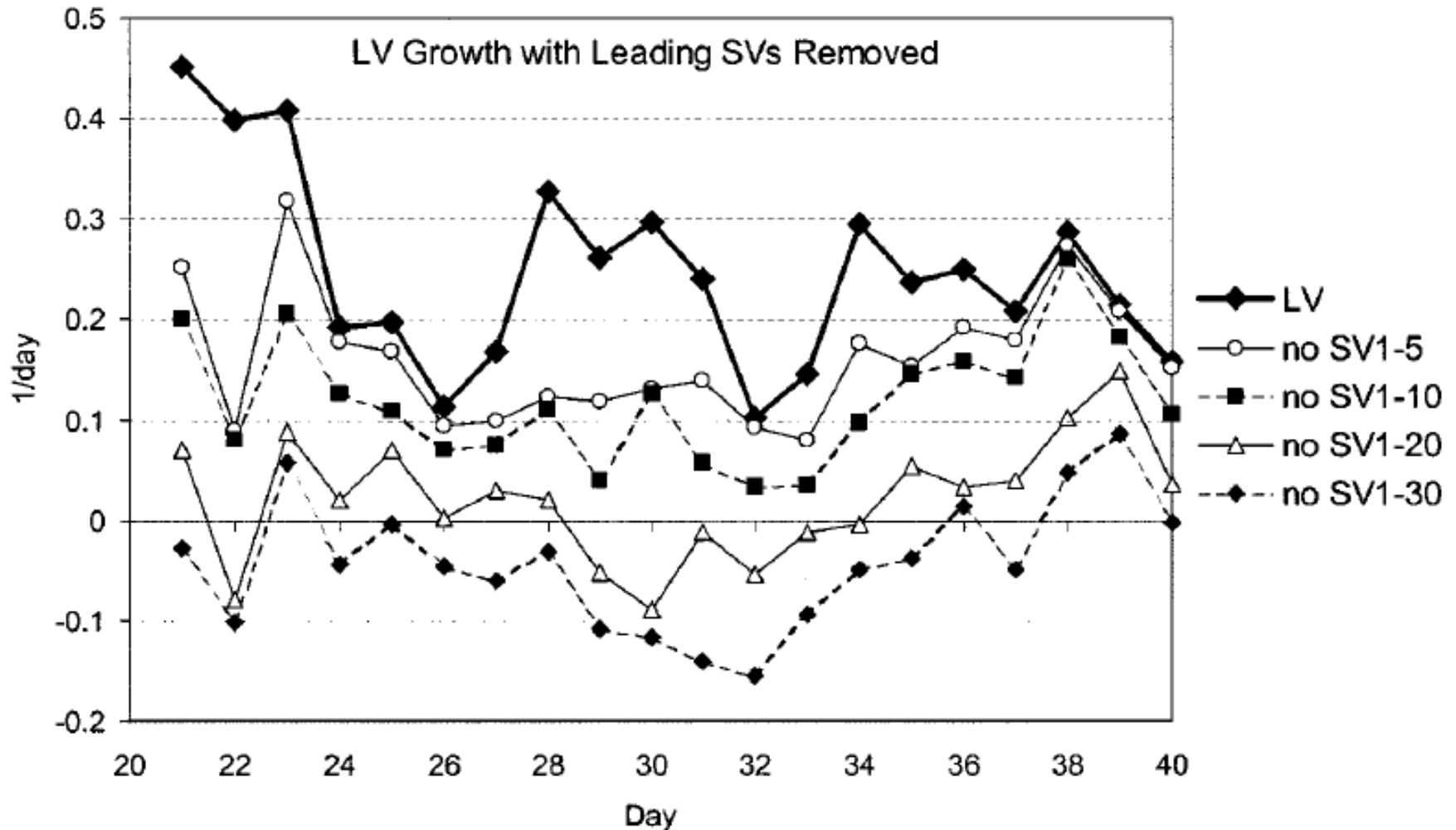
From Langland and Errico 1996 *MWR*





Gelaro et al.  
MWR 2000

## The relationship between LVs and SVs



# NON-LOCAL INITIAL STRUCTURES

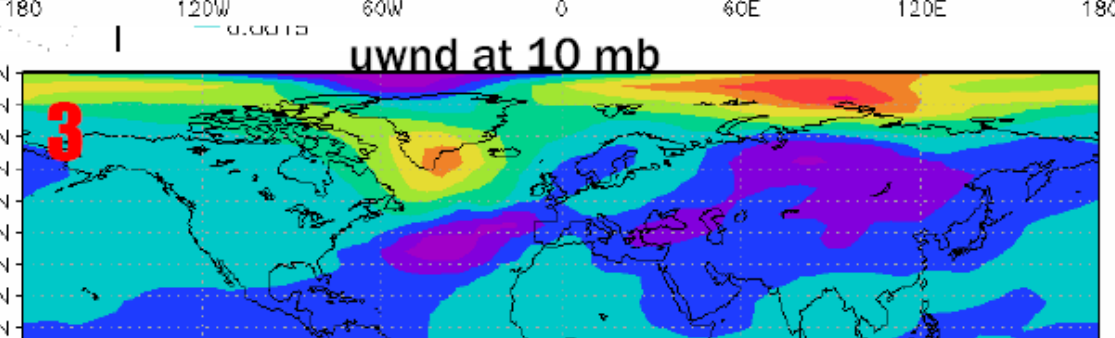
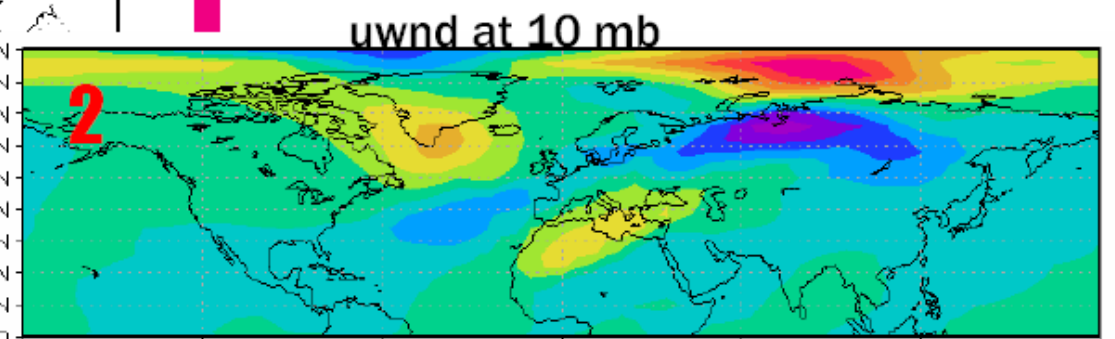
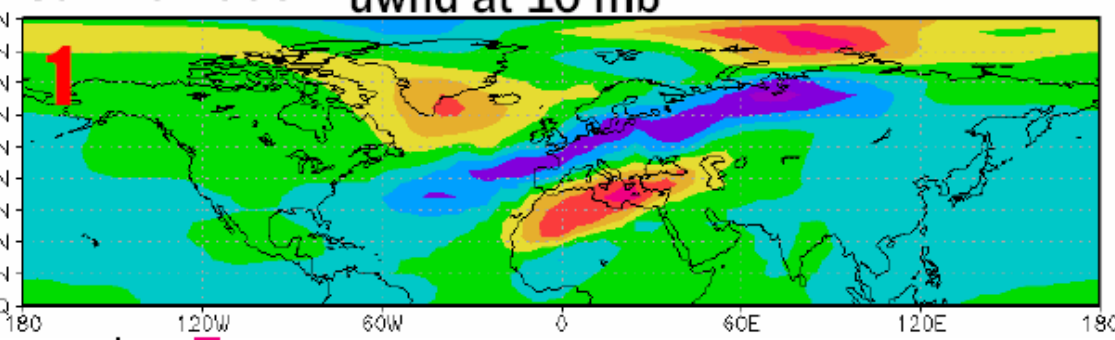
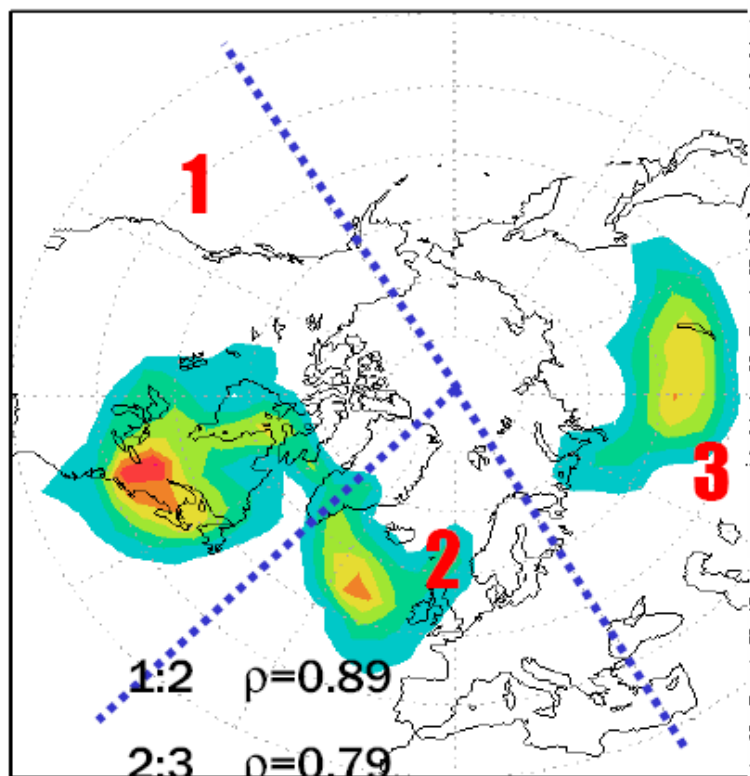
Jan-15-2006

ISVEC#1

Jan-20-2006

uwnd at 10 mb

Vertically Integrated TE



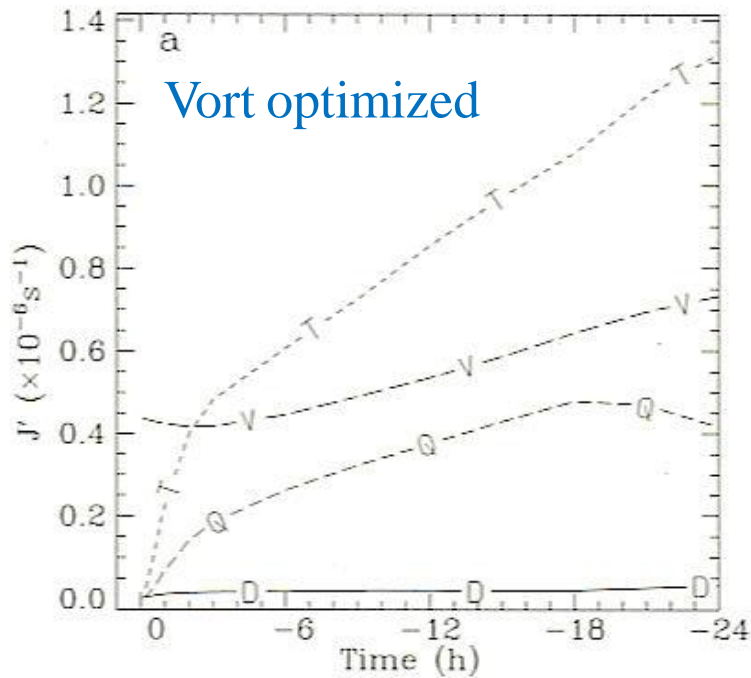
1:2  $\rho=0.89$

2:3  $\rho=0.79$

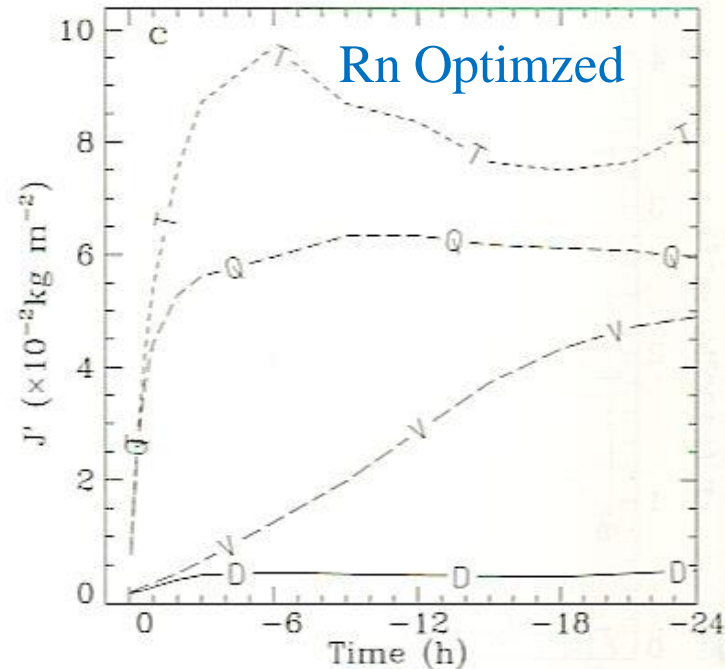
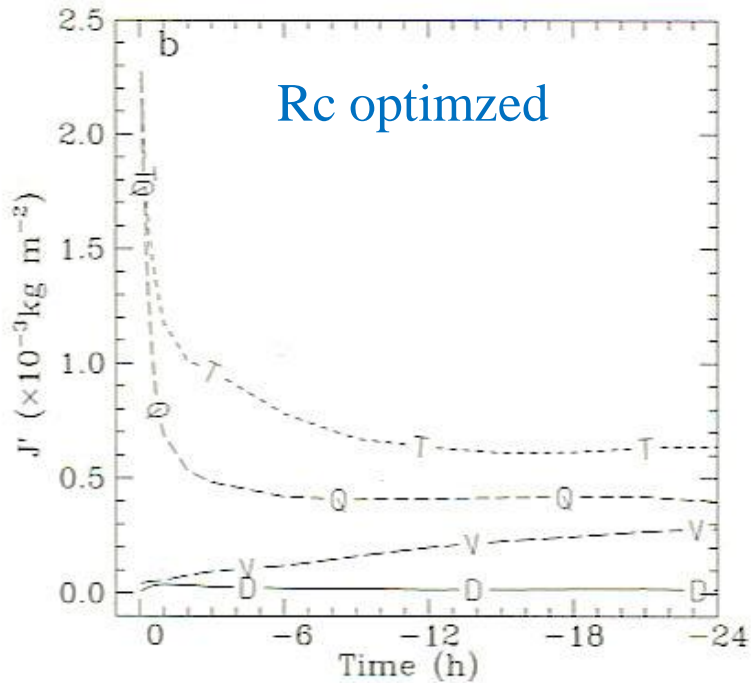
1:3  $\rho=0.59$

From E. Novakovskaia et al.

Errico et al.  
2003 *Tellus*

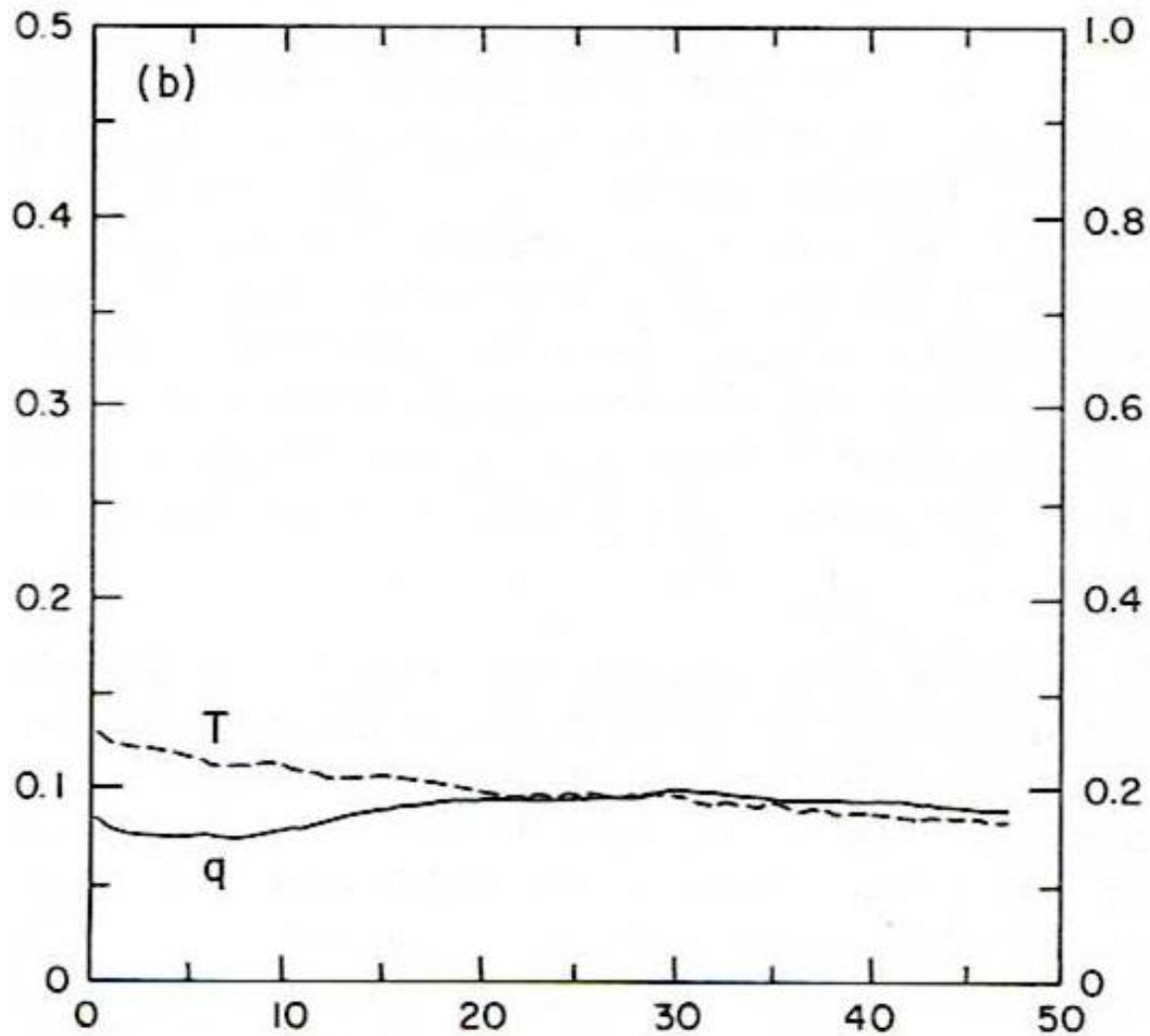


Impacts for adjoint-derived optimal perturbations for forecasts starting indicated hours in the past.



# Predictability Experiments with a NCAR/PSU MM3

rms  
q diff  
(g/Kg)



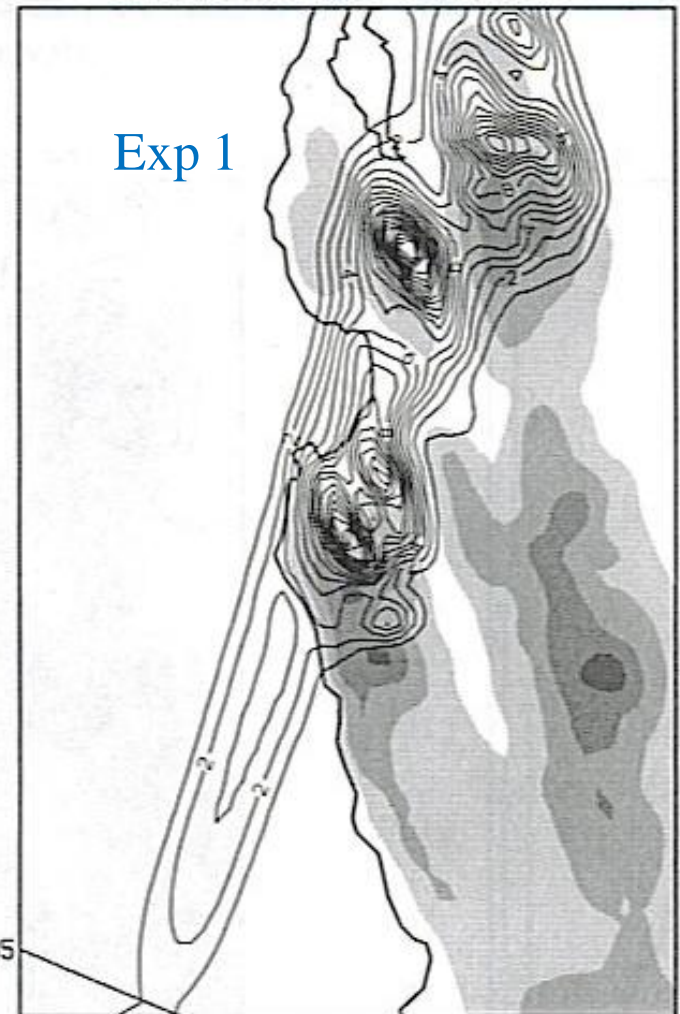
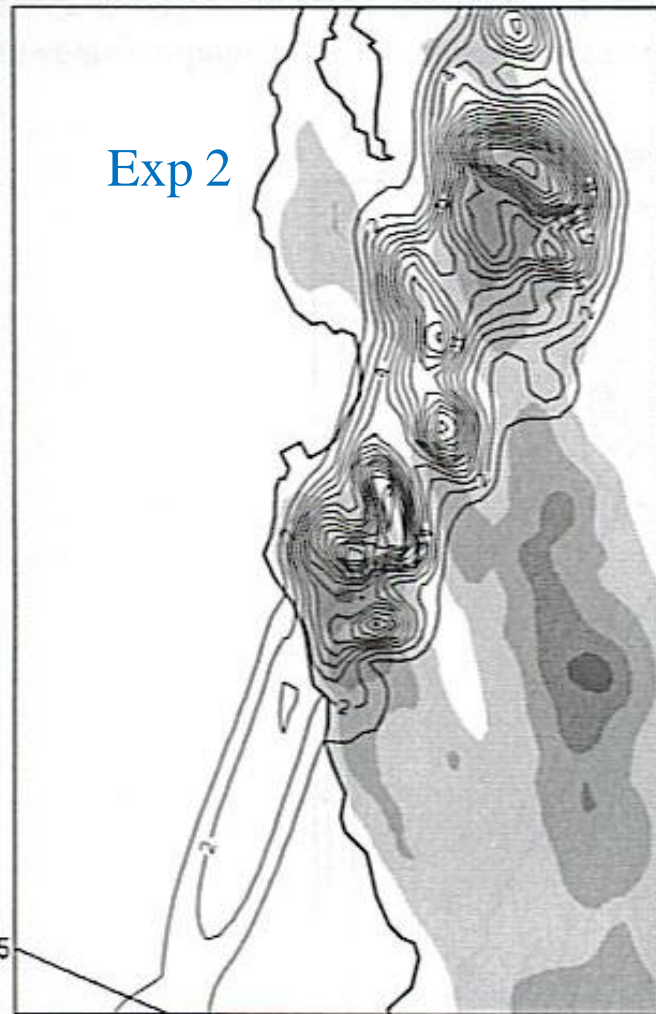
rms  
T diff  
(deg K)

From Anthes  
et al. 1985

Forecast time (hours)

# Mesoscale Predictability with MM5

1-hour accumulated precipitation

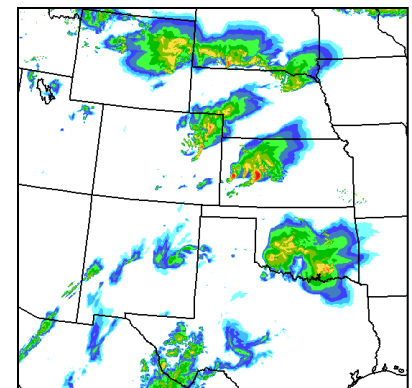
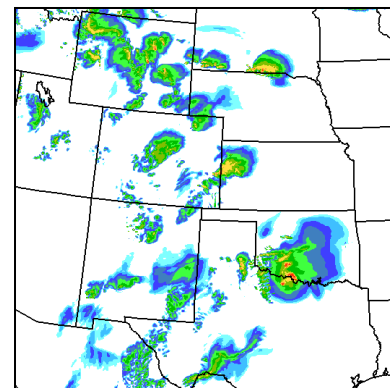
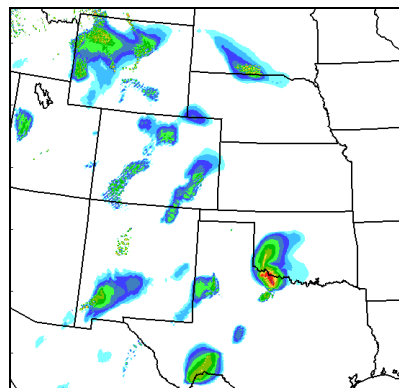
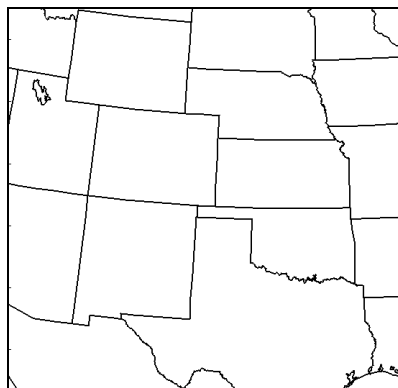
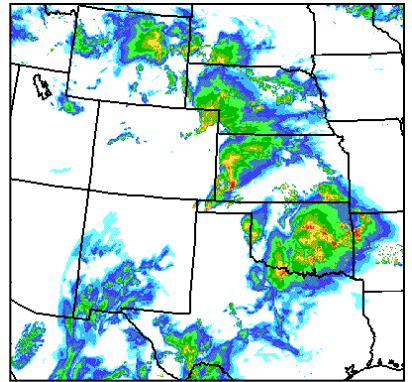
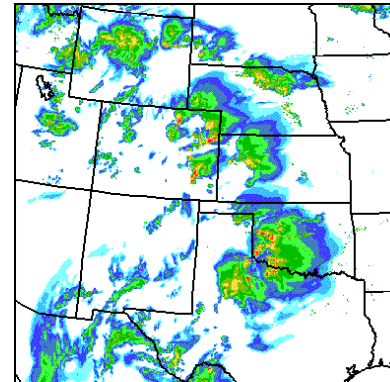
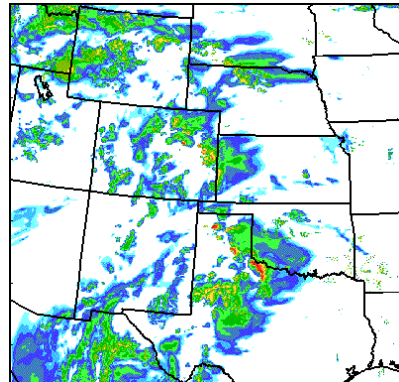
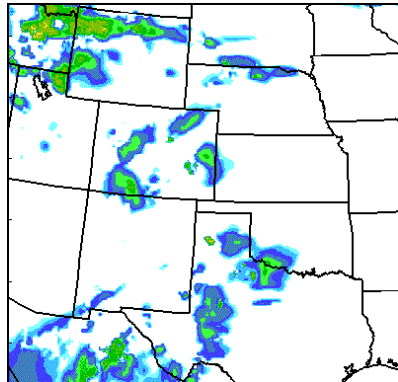
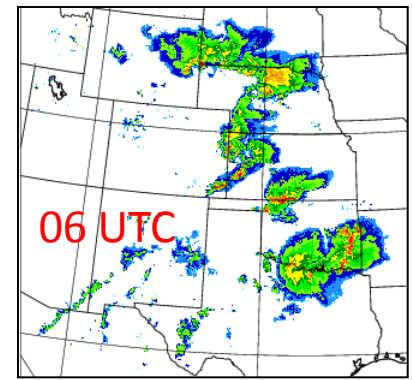
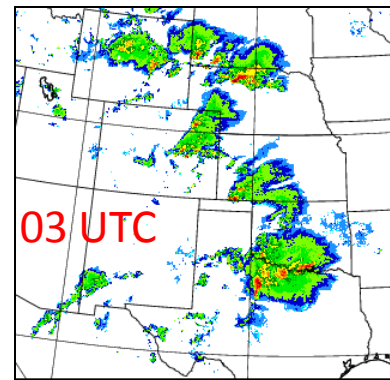
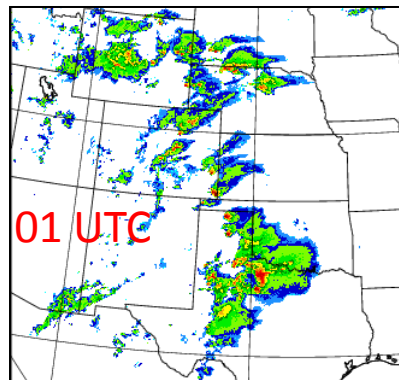
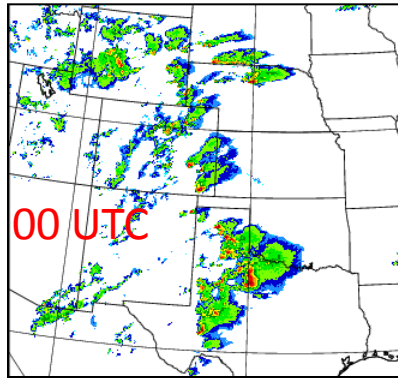


From Nuss &  
Miller 2001

Precipitation contour interval 1mm; topography shade interval 250 m

# 06/14/09 Composite Radar

From Morris Weisman (NCAR)

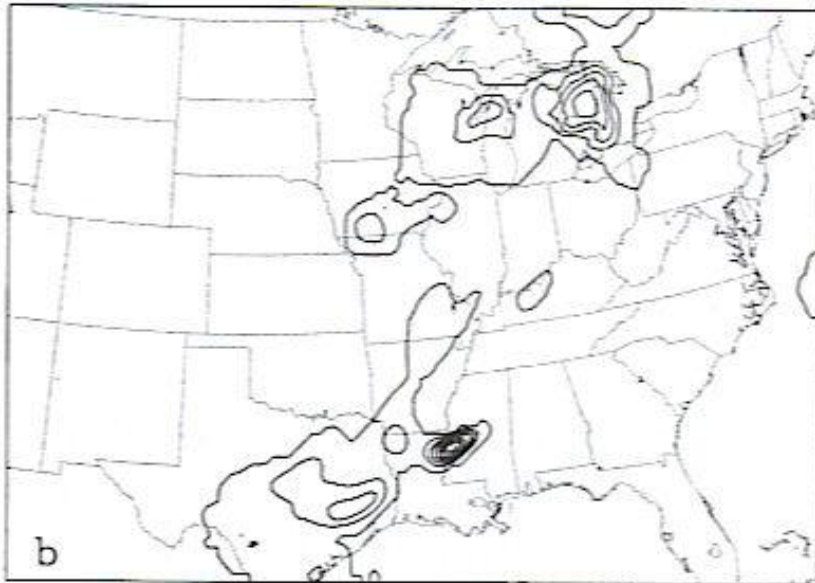


Example of Model Error:  
Errico et al. *QJRM*S 2001

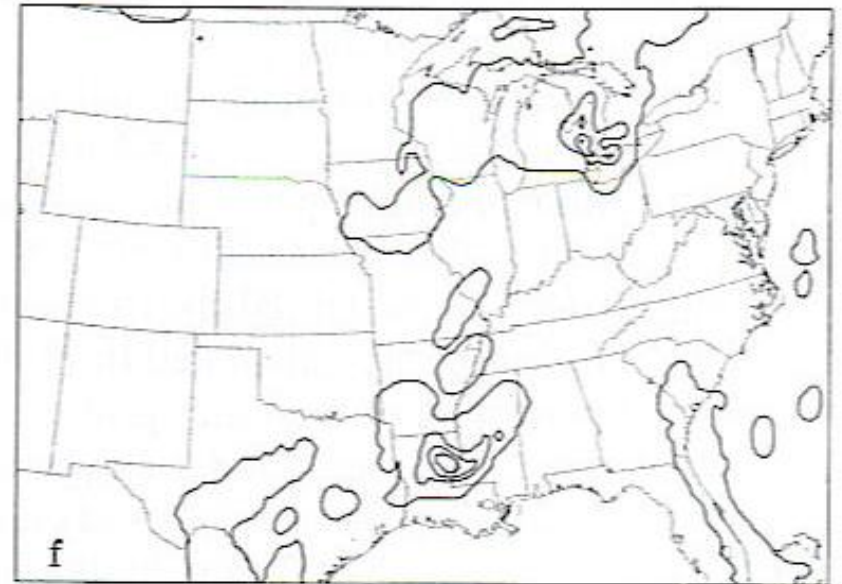
6-hour accumulated precip.  
With 3 versions of MM5  
Contour interval 1/3 cm



Kain - Fritsch



Betts - Miller



Grell



# Outstanding problems

1. How do error doubling times depend on horizontal and vertical scales?
2. On the mesoscale, what are the characteristics of intrinsic error growth?
3. What are reasonable goals for improving quantitative precipitation forecasts?
4. What are the implications of very rapid growth being non-modal?
5. What, if any, are the reasonable intrinsic limits to weather prediction?
6. What must be done to more closely approach these limits?
7. How can we apply our understanding of the limits of predictability to more appropriately utilize the information content of forecasts?
8. What are the characteristics of model error in the best current models?
9. What are the relative influences of model versus initial condition error on the errors produced by the best current forecast systems?
10. How predictable are time-mean fields for various periods?
11. How can we best characterize the “almost” slow manifold?