Flow Dependent Jb in a global grid-point 3D-var

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Overview

- Most current implementations of global variational analysis systems use spectrally defined background error covariances and analysis variables
- The improved specification of the background error covariances is an ongoing goal of data assimilation groups.
- NOAA/NWS/NCEP/EMC is attempting to improve our system by defining the background error covariance and analysis variables in grid-space

Analysis variable and Background error definition

- Spectral
  - Simple definitions of background error covariance straightforward
  - Consistent with spectral model
  - Poles easy to handle
  - Computational cost?
- Grid space
  - Inhomogeneous – anisotropic background errors less complicated (but still not trivial)
  - Local definition of errors
  - Easy to distinguish between land-sea, tropics, mid-latitudes, etc.
  - Consistency between global & regional systems

Grid-point space background

- Two major considerations
  - How to computational perform the background error computations
    - Recursive filters
  - How to define the appropriate background errors
    - Ongoing research

Recursive filters

- Closely related to diffusion operator methods (Derber and Rosati, 1989 and Weaver and Courtier, 2001)
- Most recent references
  - Purser, Wu, Parrish and Roberts, 2003: Numerical Aspects of the application of recursive filters to variational statistical analysis, Part I and II, Mon. Wea. Rev.
  - Wu, Purser and Parrish, 2002: Three-Dimensional variational analysis with spatially inhomogeneous covariances, Mon. Wea. Rev.

Recursive Filters

- 3-D representations from simple 1-D filters
- General 1-D form – two steps

$$q_i = \beta p_i + \sum_{j=1}^{n} \alpha_j q_{i-j}$$ Advancing step

$$s_i = \beta q_i + \sum_{j=1}^{n} \alpha_j s_{i+j}$$ Backing step

$$\beta = 1 - \sum_{j=1}^{n} a_j$$

Recursive Filters

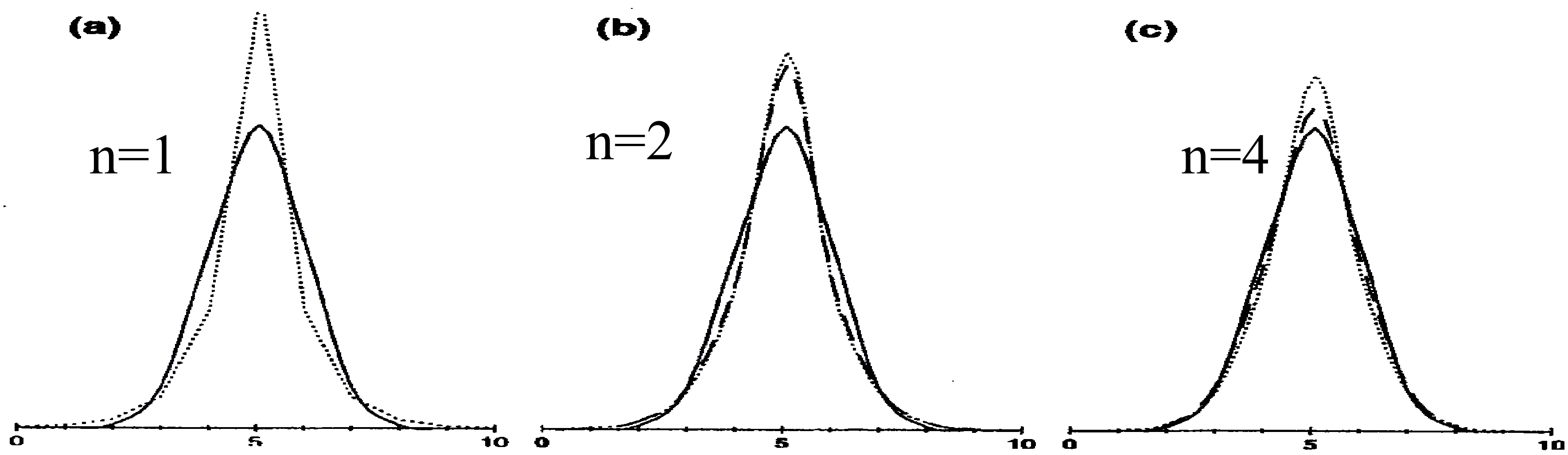
- First order (n=1)

$$q_i = (1-\alpha)p_i + \alpha q_{i-1}$$

$$s_i = (1-\alpha)q_i + \alpha s_{i+1}$$

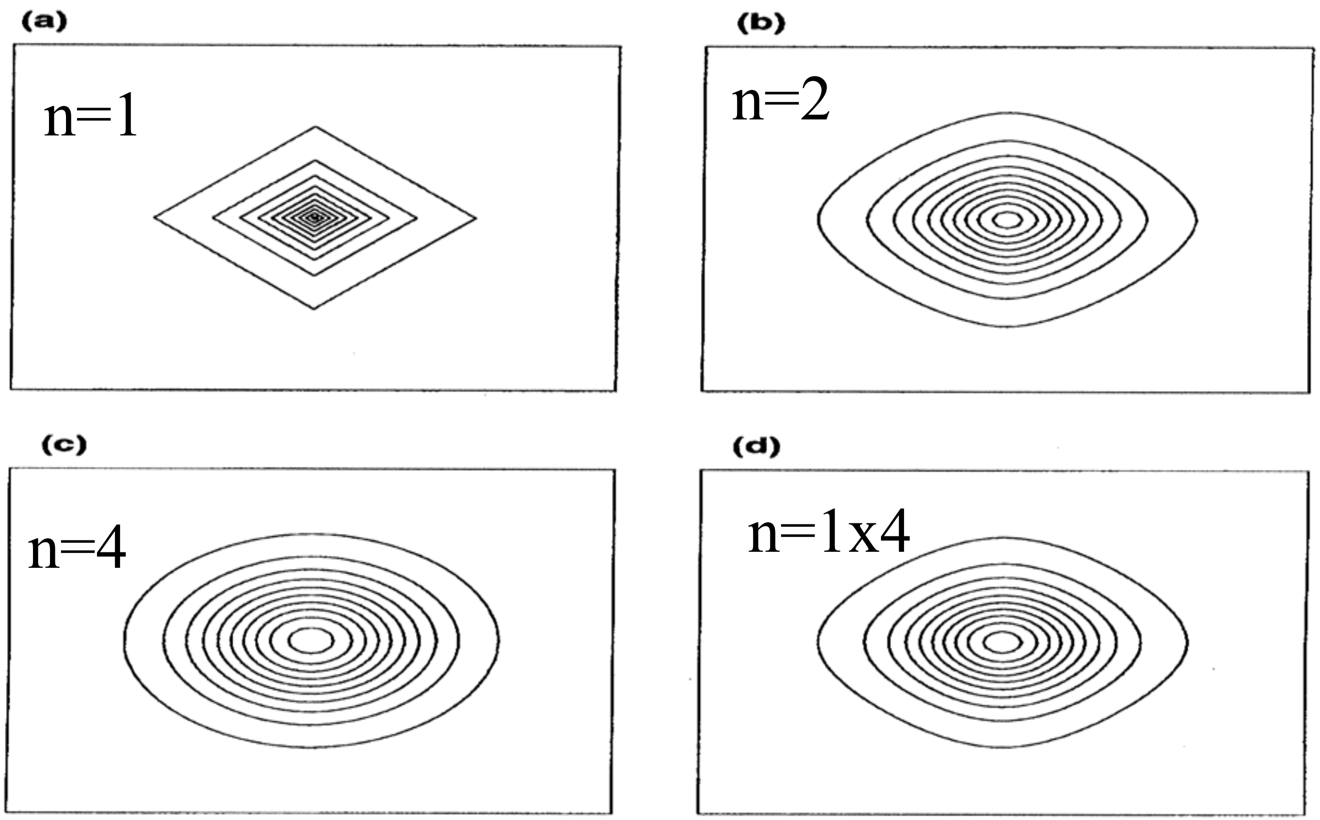
- Note recursive filter is self-adjoint
- Produces a quasi-Gaussian filter response

1-D Response

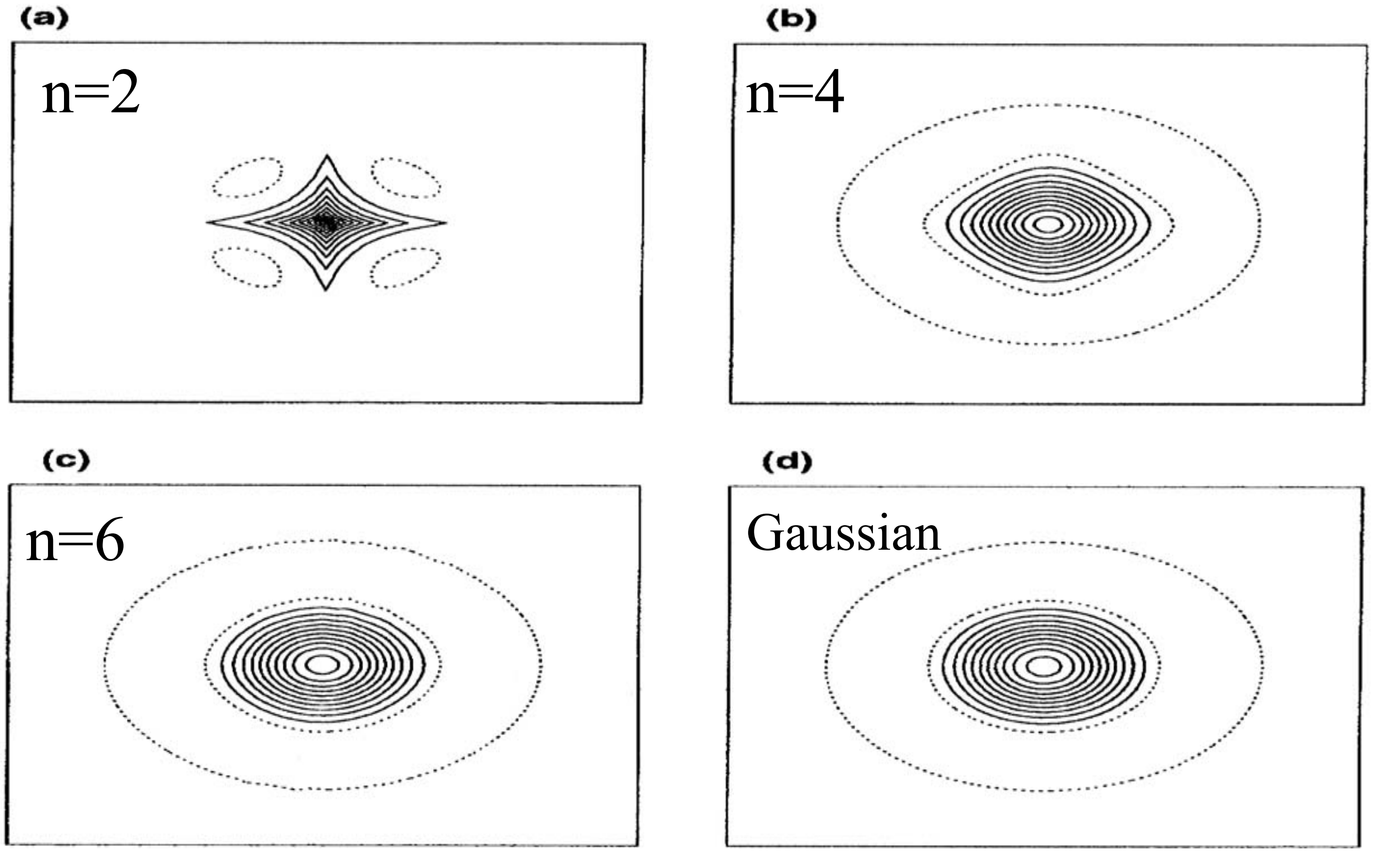


2-D isotropic application

- Successive application in x then y direction

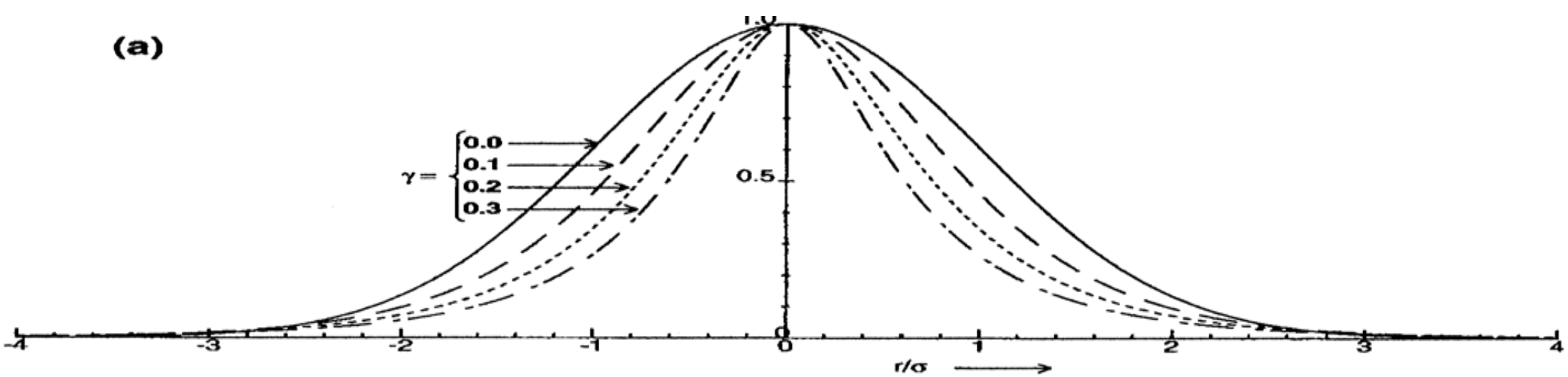


Laplacian of 2-D



Comments on Recursive Filters

- 4^{th} Order minimum
- Non-Gaussian isotropic shapes created by adding Gaussians
- Fat-tailed error covariances



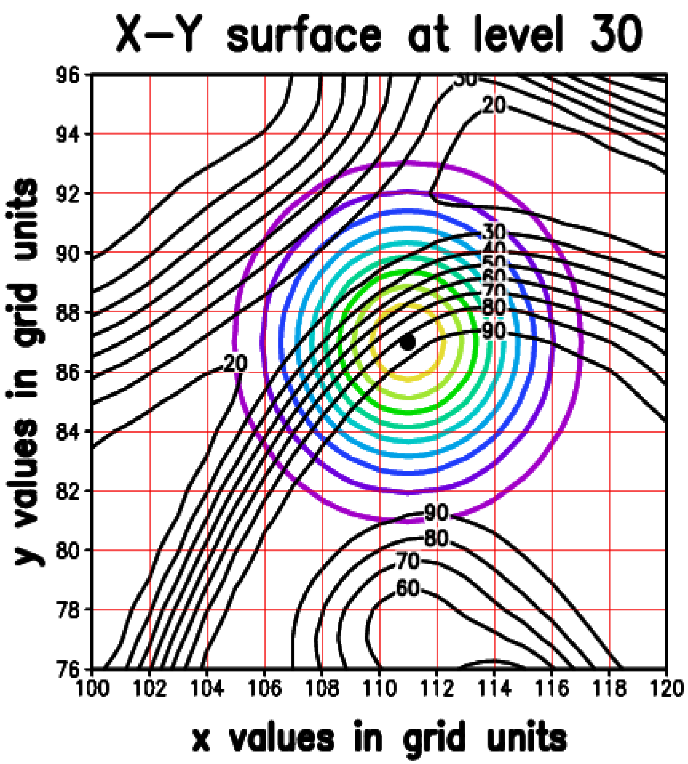
Inhomogeneous anisotropic covariances on a globe

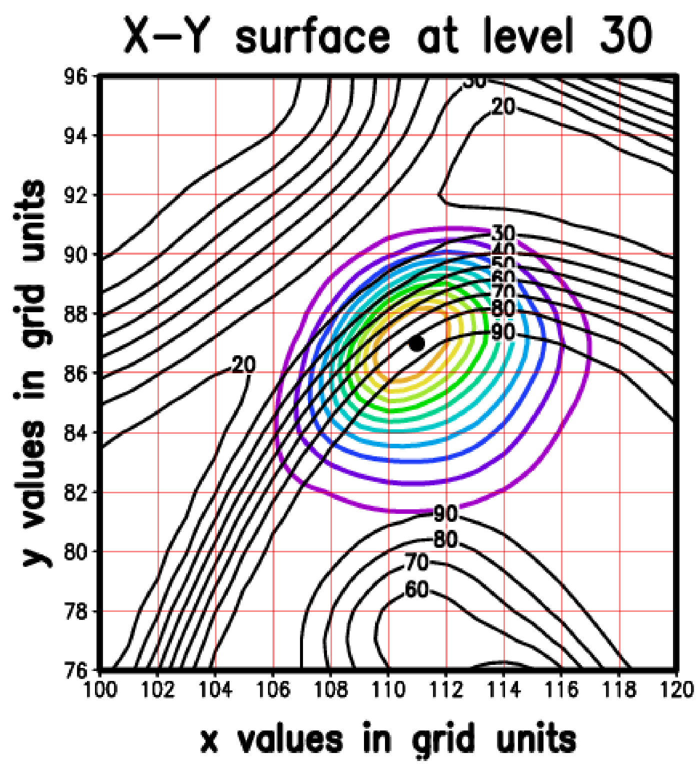
- A bit more complicated.
  - Smoothing must be done not only along x-y-z directions but along other directions as well – triad – hexad algorithms.
  - Transitions can create additional problems (solvable but at a cost)
  - polar problem

Isotropic Model

Anisotropic Model

qlf=20%





Isotropic Model

Anisotropic Model

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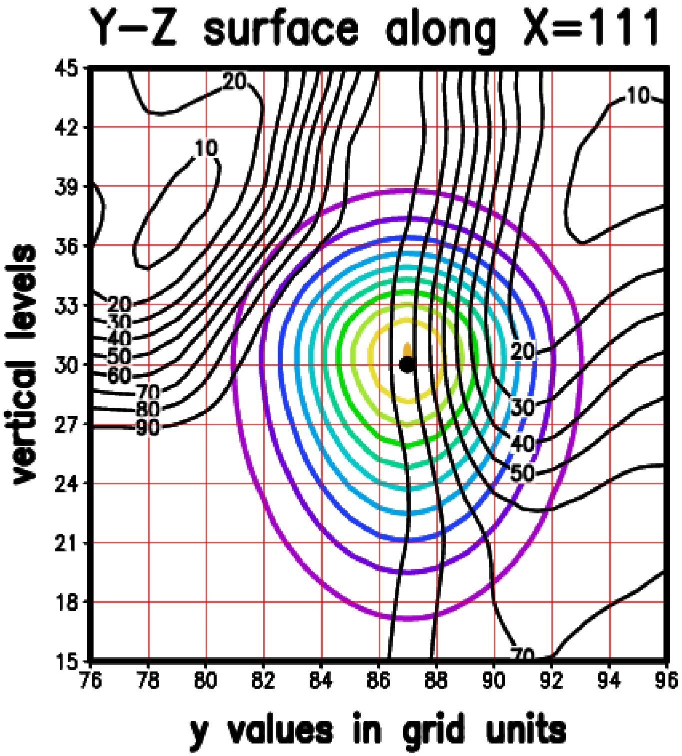
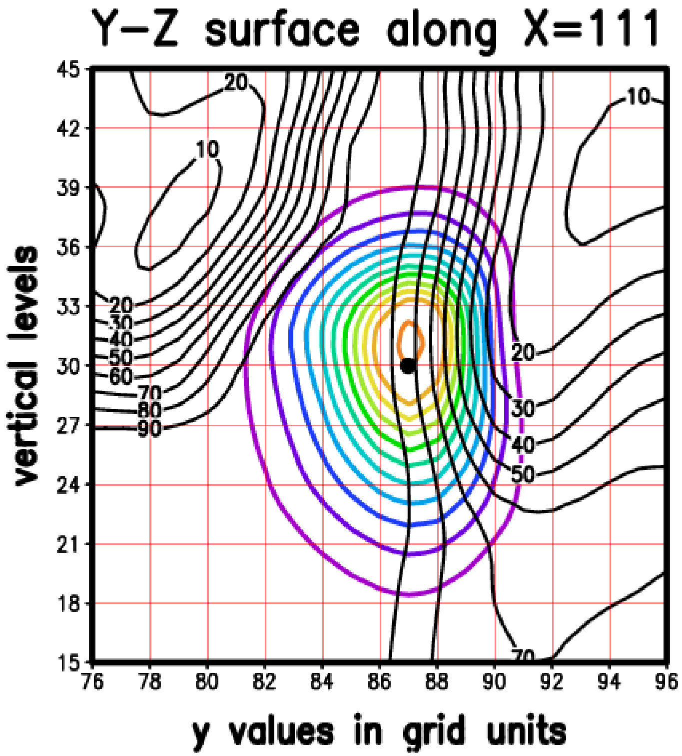
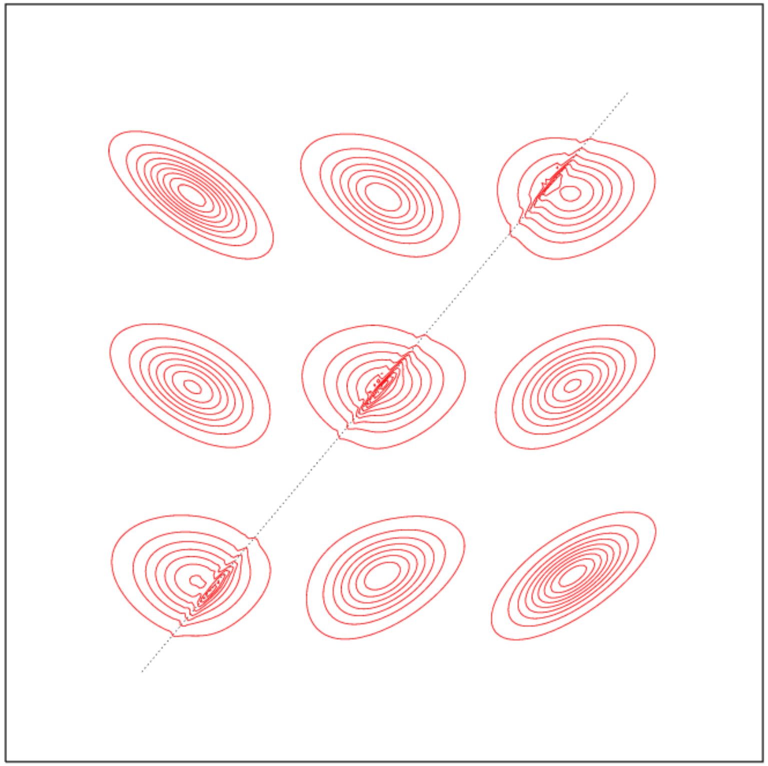


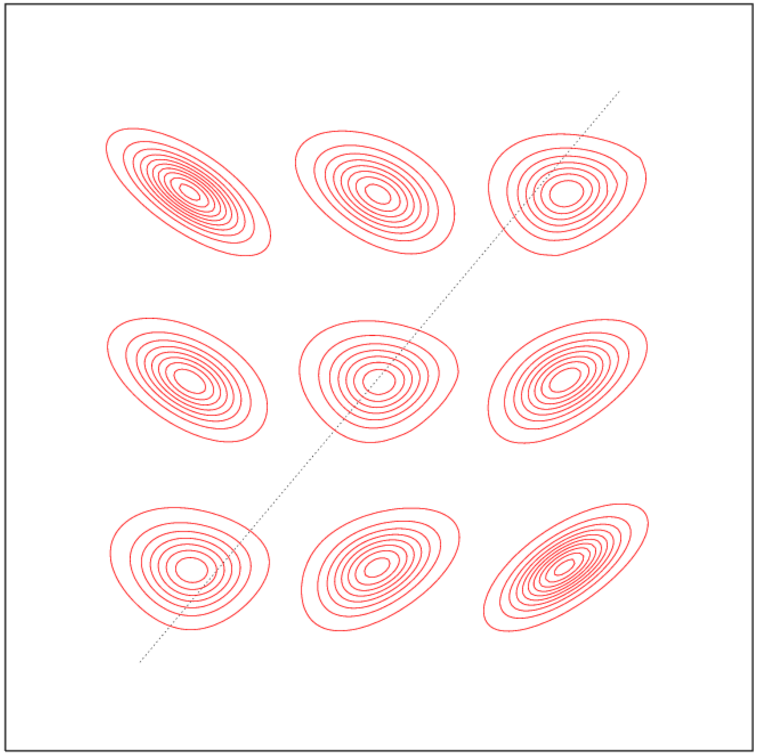


Transition problem

3 color triad
no bridging function
one iteration
transition scale= .250



4 color triad
2^{nd} degree bridging function
one iteration
transition scale= .250



Incorporation in NCEP global system

- Version of NCEP global system developed identical to current experimental spectral system except:
  - Background term estimated using recursive filters
  - Modified error statistics (due to recursive filter form)
  - Balance equation
  - Minimization algorithm
  - No divergence tendency equation constraint (not currently used in spectral version)

Incorporation in NCEP global system

- Initial version attempting to produce similar to spectral version.
- Inner loop performed completely on linear Gaussian grid.

Background Term

- Initially assumes Background of the form:

$$B = B_V^{T/2}(B_H^1 + B_H^2 + B_H^3)B_V^{1/2}$$

- where $B_V^{1/2}$ includes the vertical component of the recursive filter and the balance relationships. This part of the background term is incorporated into the definition of the analysis variables
- and $B_H^1 + B_H^2 + B_H^3$ represents three horizontal applications of the recursive filters

Background Term

- The length scales used in B_H^1 $B_V^{1/2}$ and in the balance equation are calculated using the NMC method
- The length scales in B_H^2 are ½ those in B_H^1 and B_H^3 are ¼ those in B_H^1 this gives fat-tail distribution
- Vertical error terms are defined for each latitude
- Horizontally homogeneous in physical space not grid space

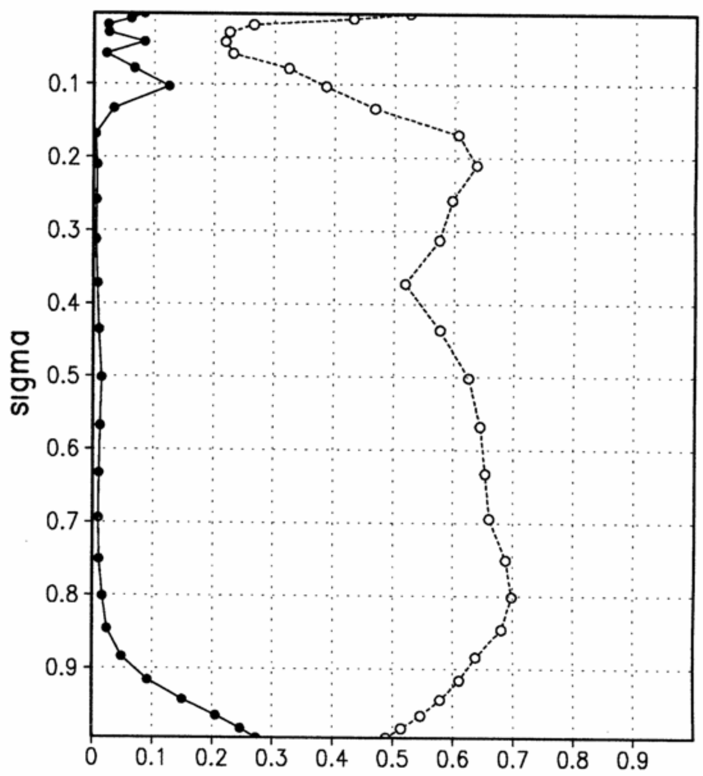
Background Term

- Balance equation
  - function of latitude

$$T = A\psi$$

$$\chi = C\psi$$

$$p_s = D\psi$$



Polar recursive filter problem

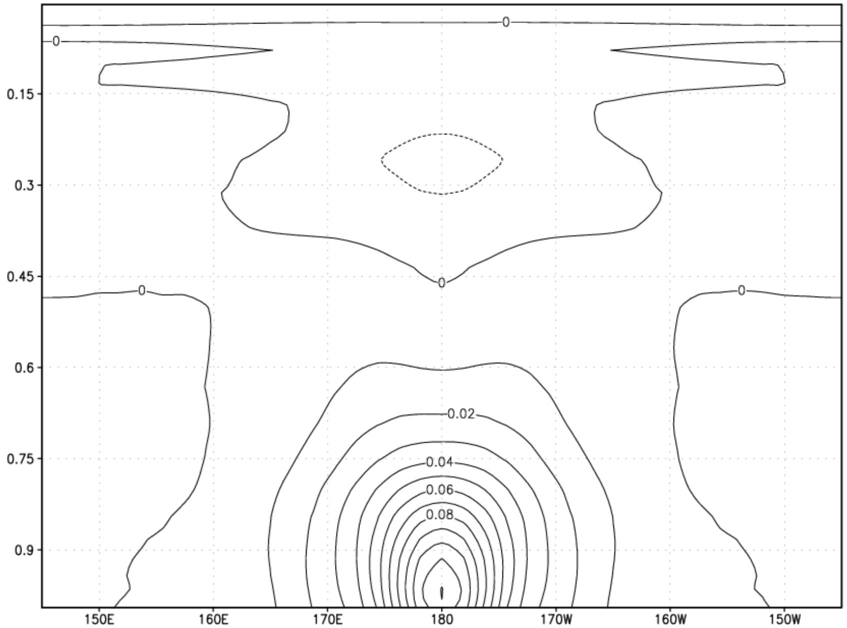
- Define two polar stereographic grids over north and south poles
- Interpolate values from Gaussian grid to polar grids (using blending region)
- Perform recursive filter on three grids (2 polar + 1 rest of globe
- recombine using adjoint of interpolations and blending

Minimization changes

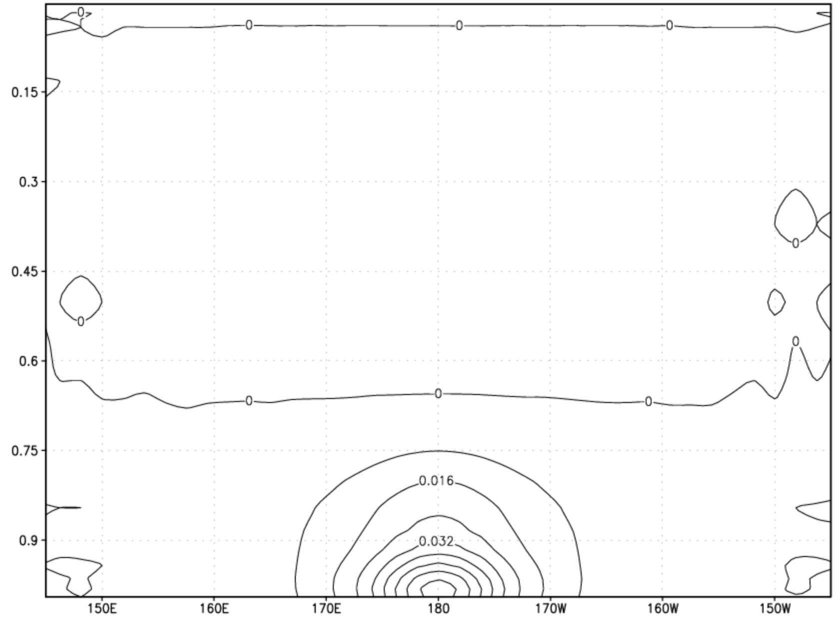
- Since difficult to square-root $B_H^1 + B_H^2 + B_H^3$ use Derber and Rosati (1989) minimization algorithm (only requires B not $B^{1/2}$)
- Requires saving 2 N component vectors (x, $B^{-1}x$)

Single point ob
45N180W T1000hPa

SSI

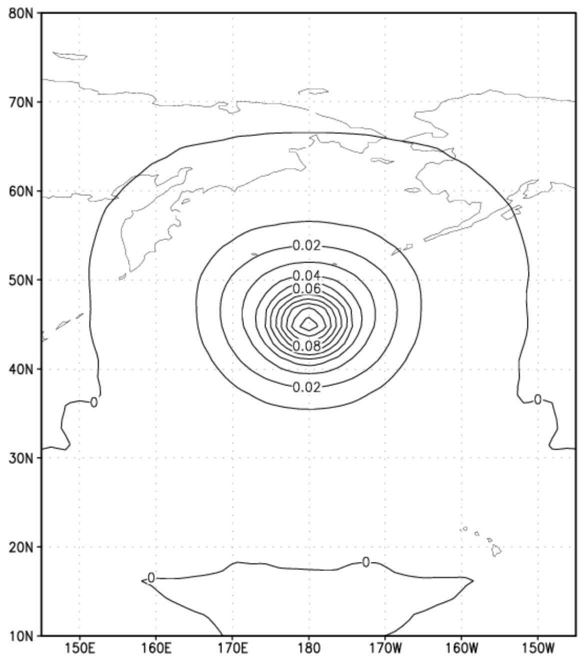


GSI

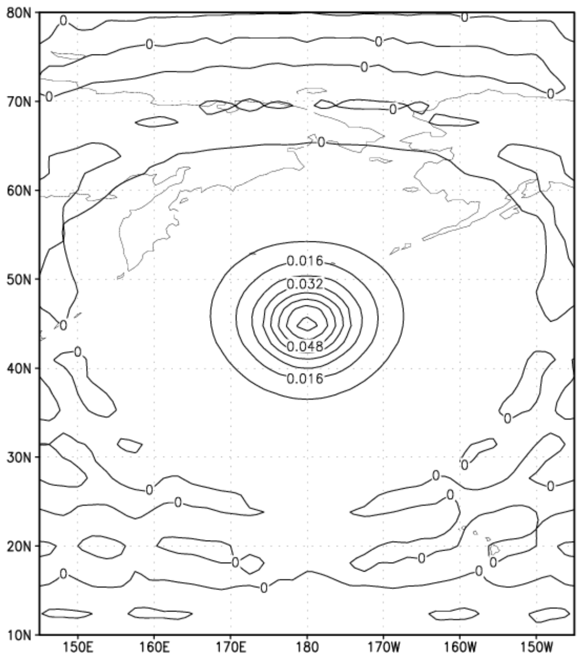


Single point ob 45N180W T1000hPa

SSI



GSI



Single point ob 45N180W T1000hPa

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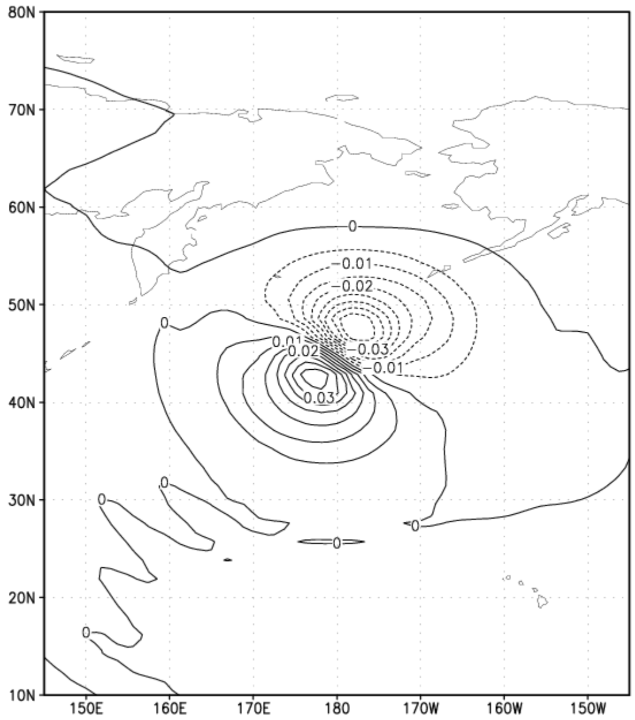
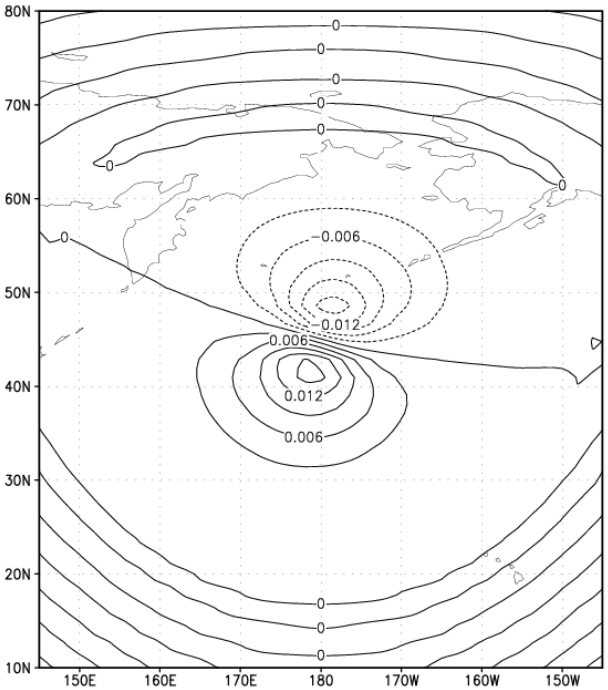
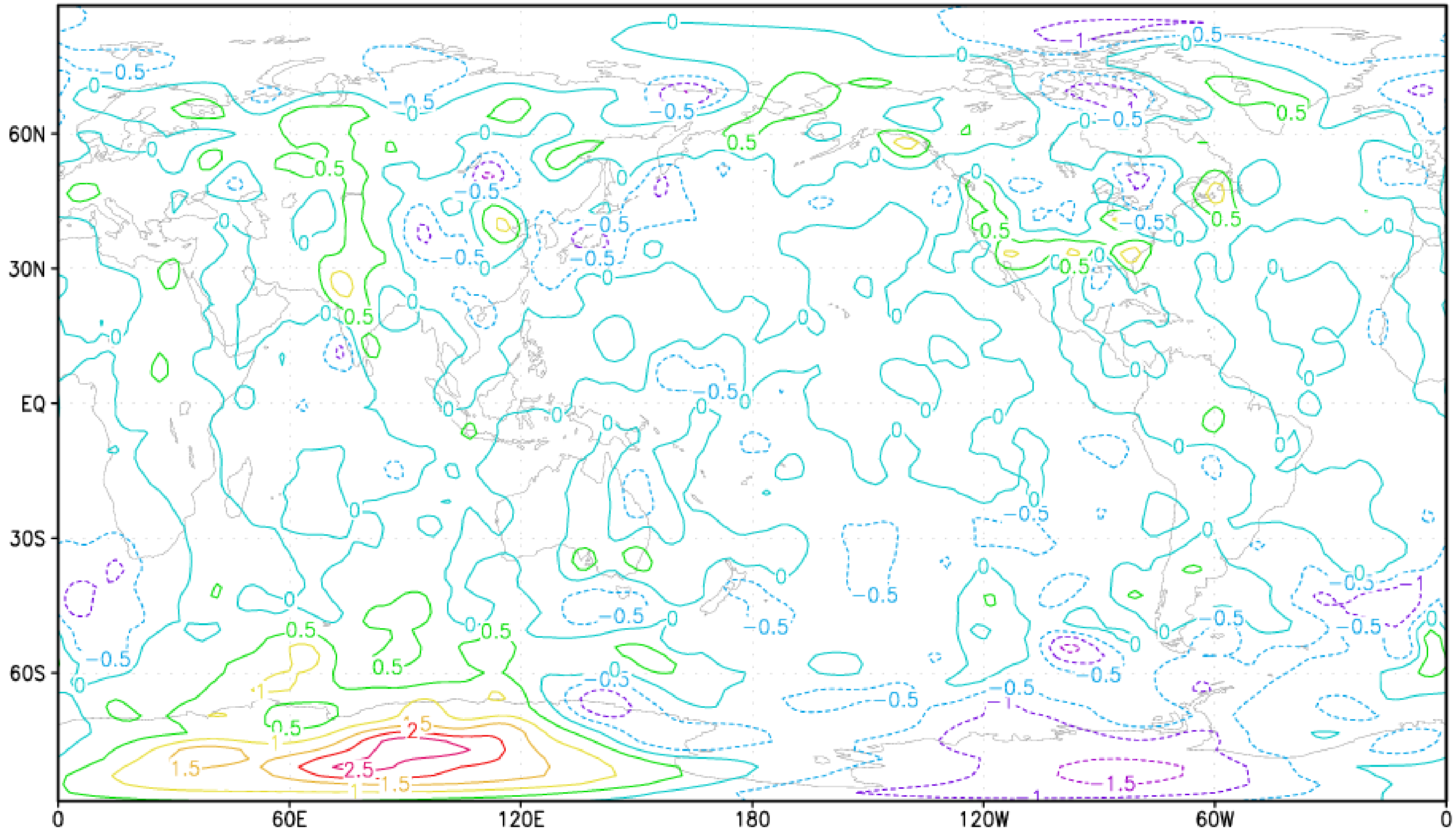


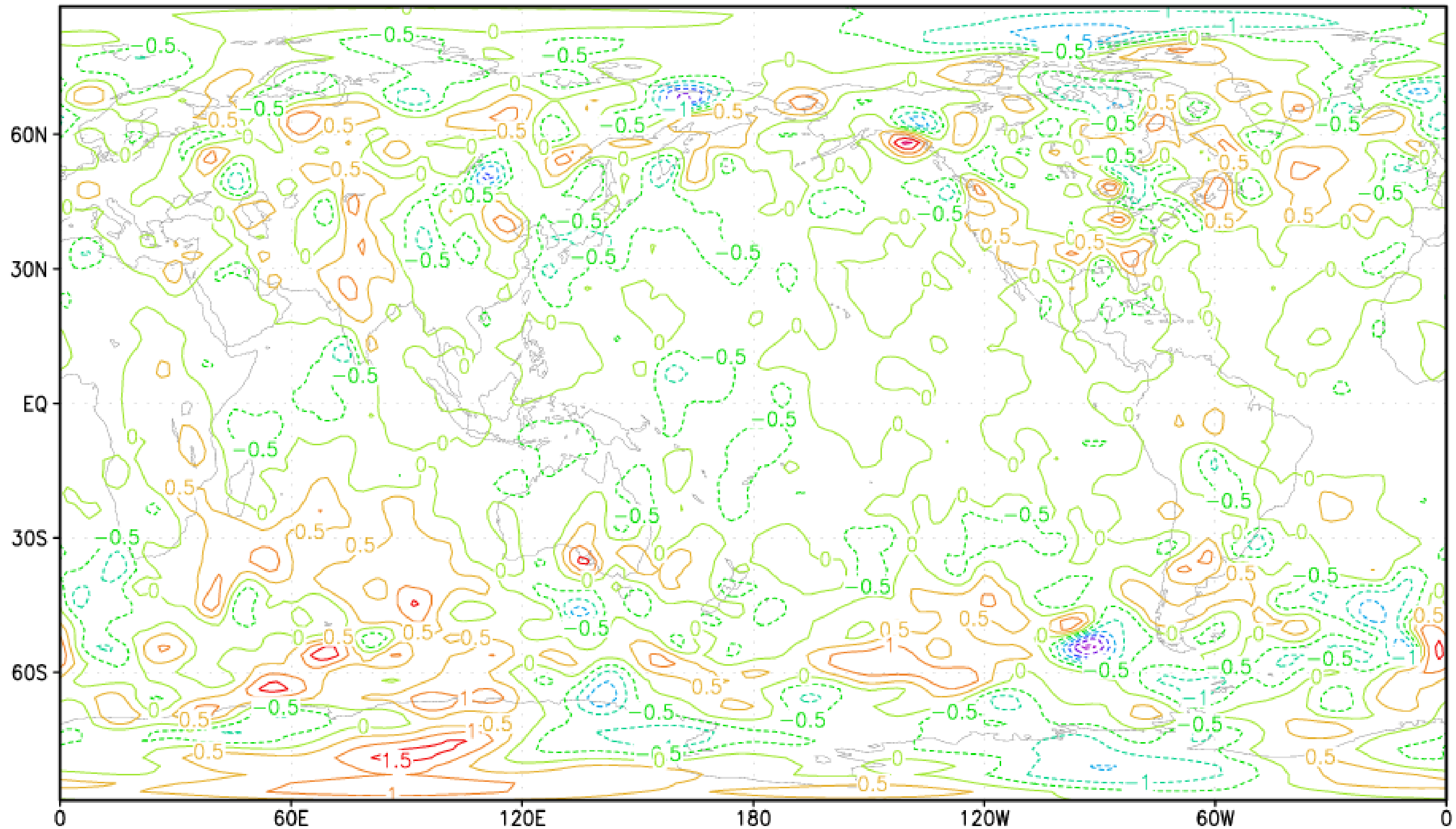
GSI



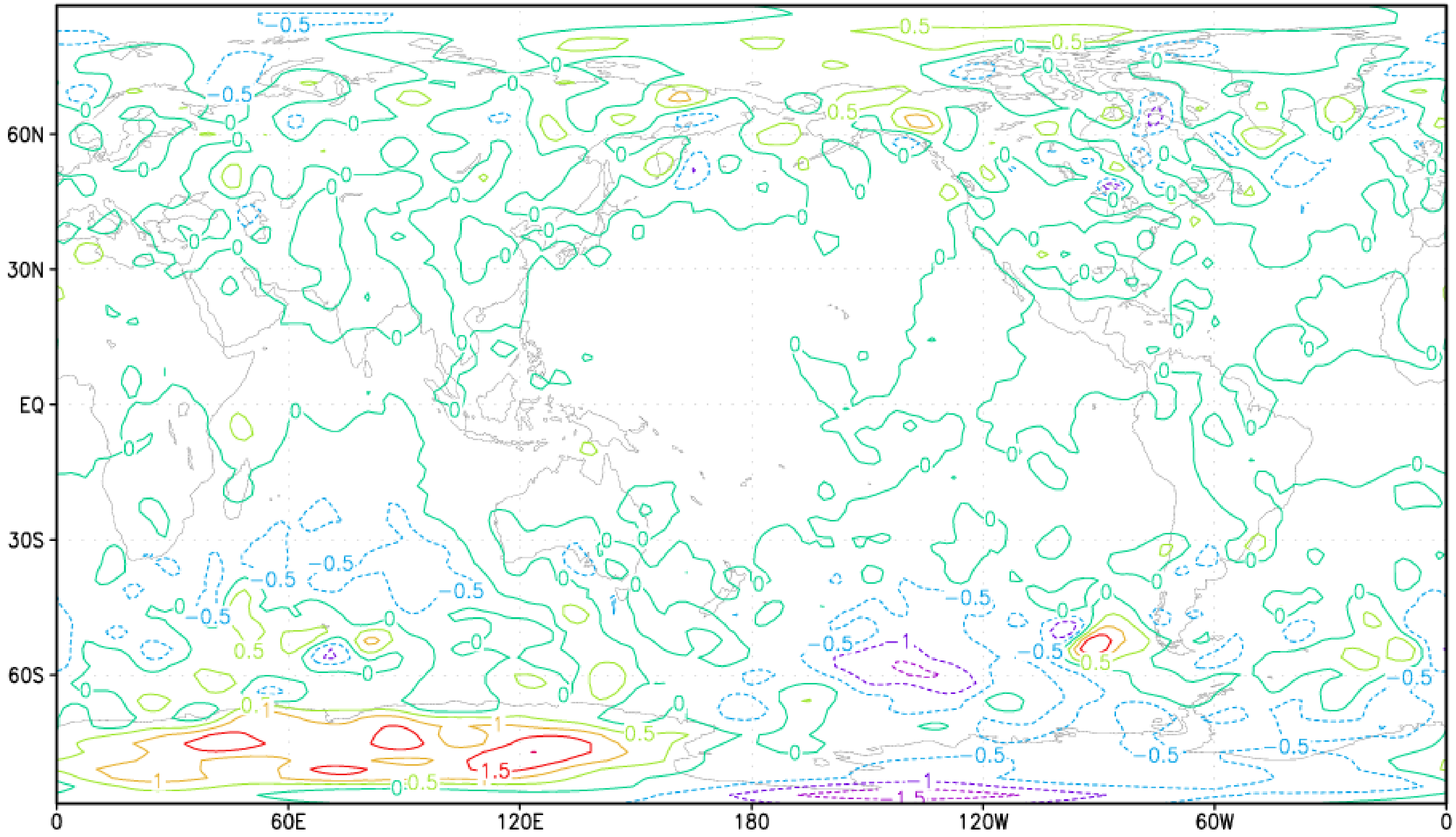
T analysis increment GSI ~500hPa



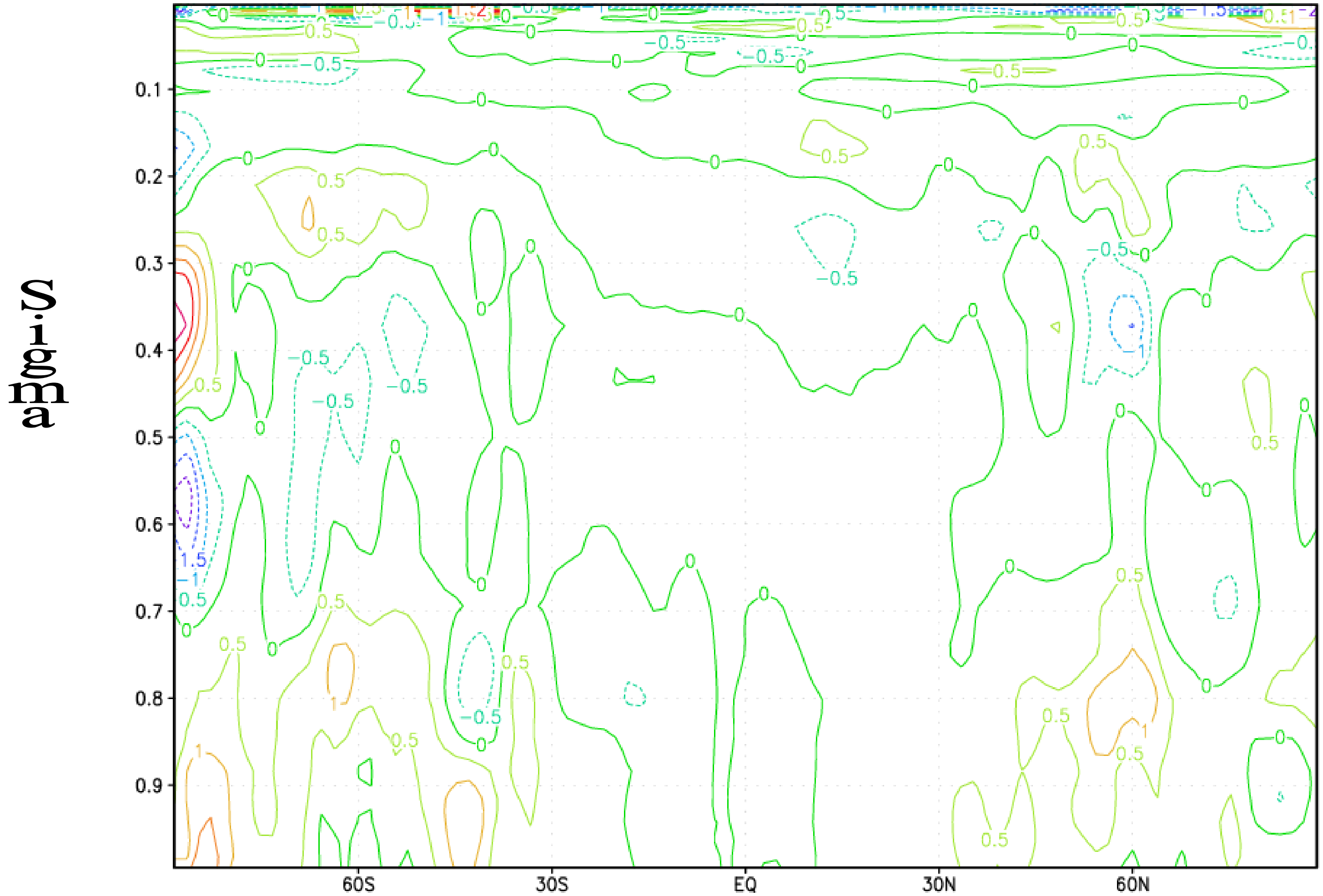
T analysis increment SSI ~500hPa



T GSI-SSI
~500hPa



T GSI-SSI 180W



Final comments

- NCEP is exploring the grid point form of the background error covariance (GMAO collaboration) to allow local definition of background error structure.
  - Need to complete modifications for parallel processing efficiency
  - Test current version to replace spectral version
  - Modification to work on regional and global domains
  - Inclusion of situation dependent covariances

Final comments

- Initial experiments (with some bugs) showed promising results (especially in the tropics)
- Defining the local background error structure remains an ongoing research problem.
  - Possibilities – background structure based, ensemble based, etc.
  - Estimation and validation of statistics based on innovations
- Expectation is that improved specification of background error will result in largest enhancement of analysis quality.