Real Time Data Assimilation at the University of Washington

Ryan D. Torn and Gregory J. Hakim
University of Washington

2005 Pacific Northwest Weather Workshop

March 4, 2005

Most operational centers create ensemble members by perturbing around a deterministic estimate

- ECMWF - singular vectors
- NCEP – bred vectors
- UW – multi-model analyses and/or physics

But, what if we could produce probabilistic analyses, with each ensemble analysis member an equally likely representation?

Ensemble Kalman Filter

Marriage of data assimilation and ensemble forecasting

$$\mathbf{x}^a = \mathbf{x}^b + \mathbf{K}(\mathbf{y} - \mathbf{H}\mathbf{x}^b)$$

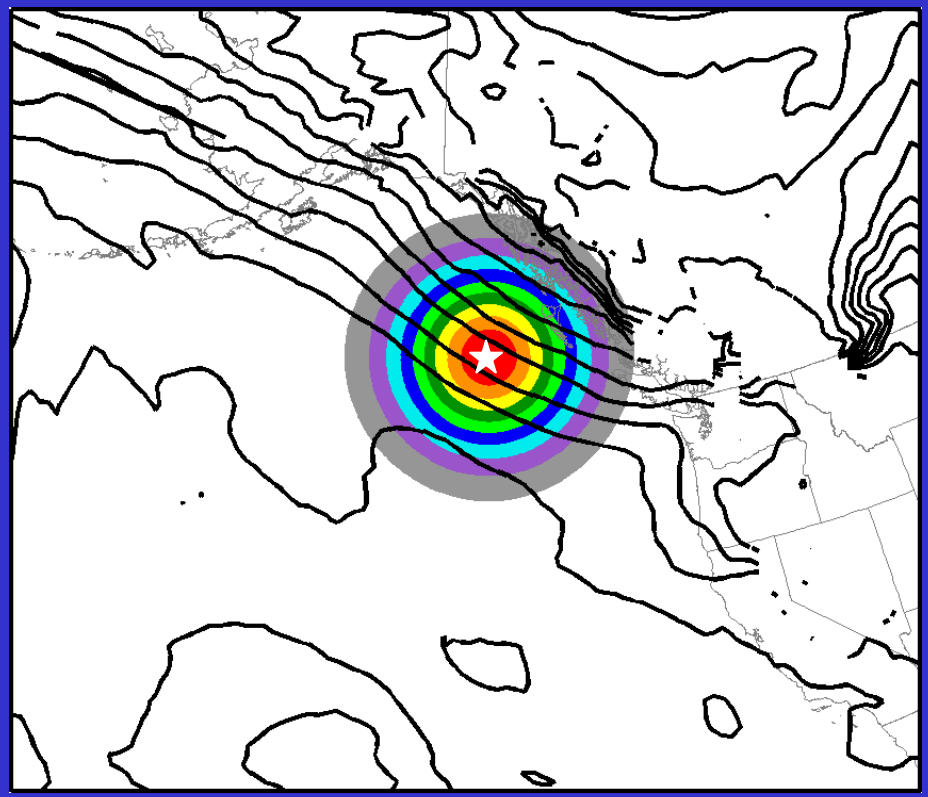
$$\mathbf{K} = \mathbf{P}^b\mathbf{H}^T(\mathbf{H}\mathbf{P}^b\mathbf{H}^T + \mathbf{R})^{-1}$$

$$\mathbf{P}^b \approx \frac{1}{N_e - 1}\mathbf{X}'^b\mathbf{X}'^{bT}$$

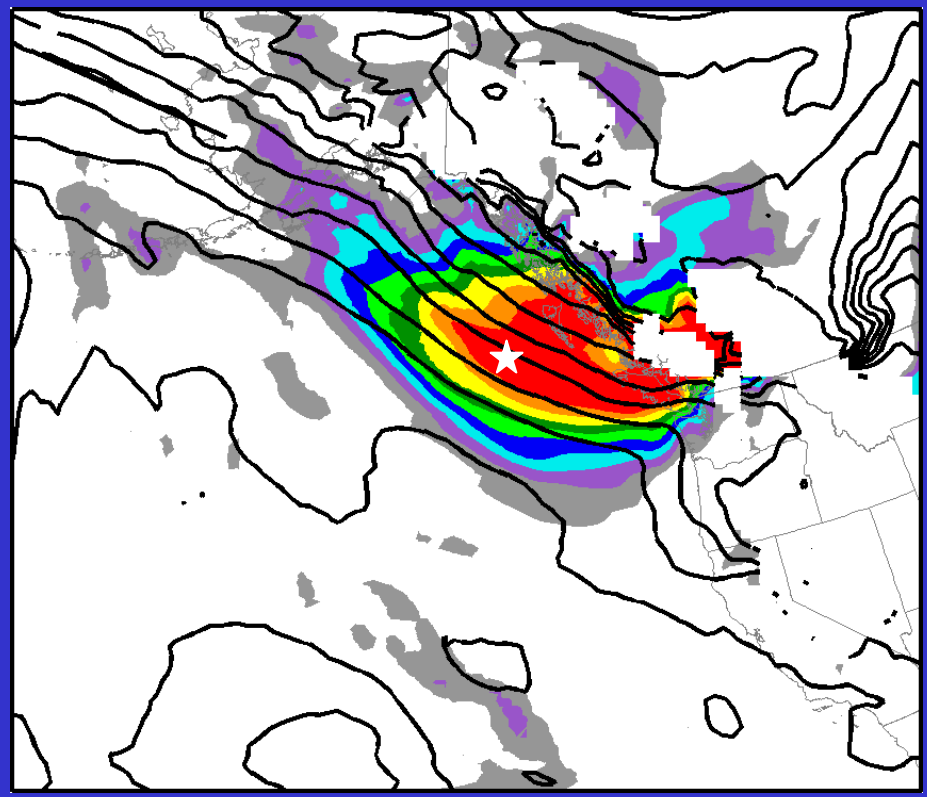
Unlike operational methods, P^b calculated from ensemble!

Ensemble Covariances

3D-VAR covariance

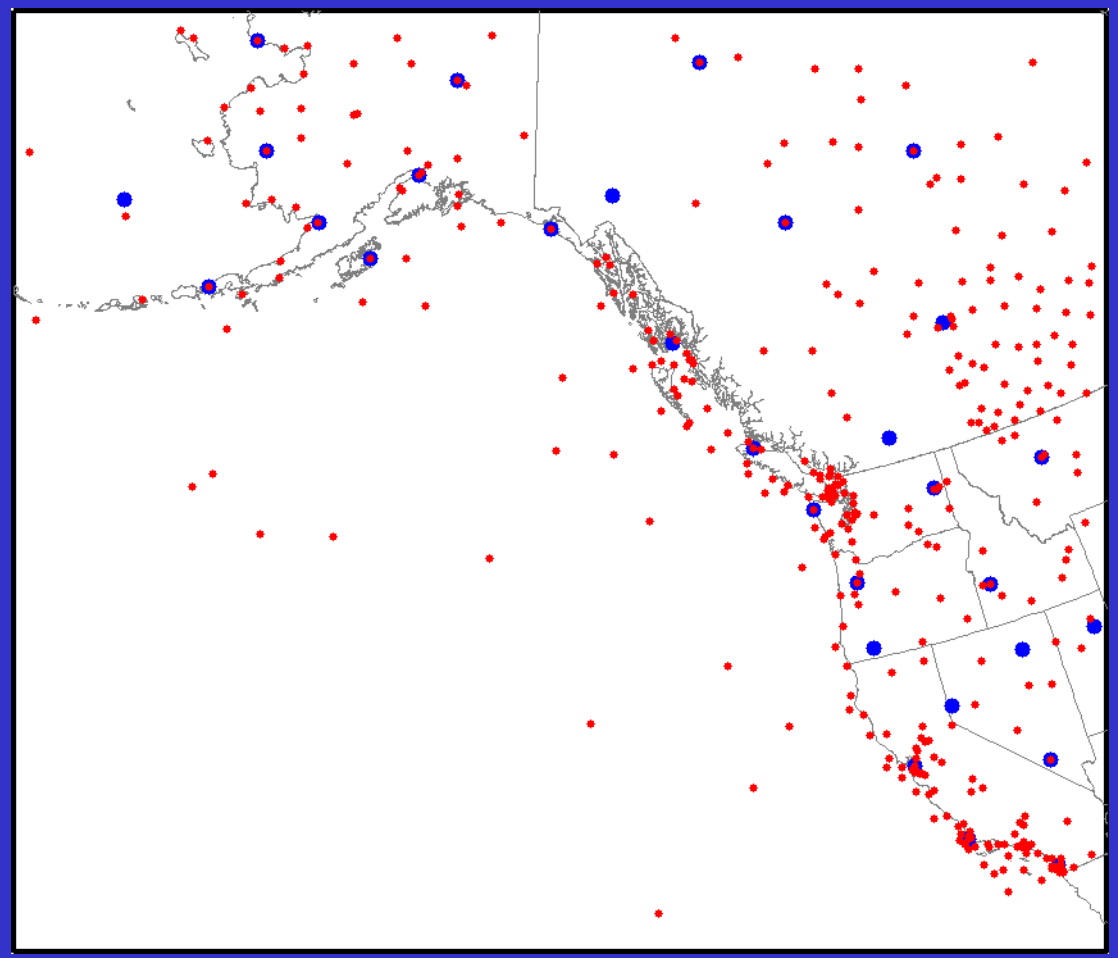


ensemble covariance



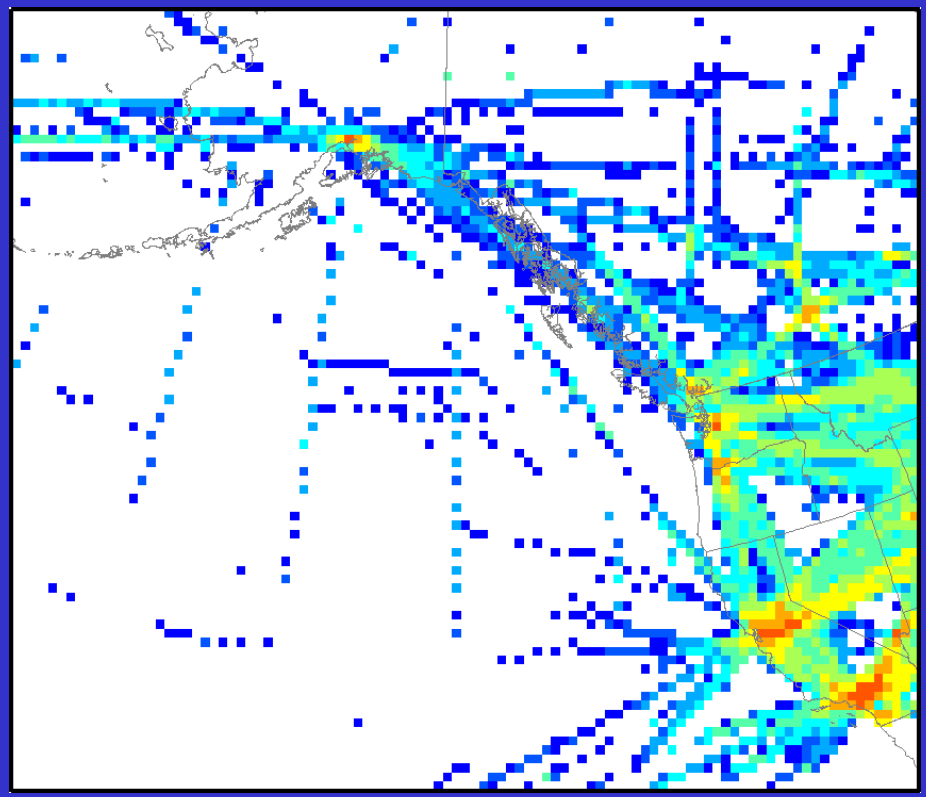
System Specifications

- Weather Research and Forecasting model, (WRF) 45 km resolution, 33 vertical levels
- 90 ensemble members
- 6 hour analysis cycle
- ensemble forecasts to t+24 hrs at 00 and 12 UTC
- assimilate rawindsonde, ACARS, cloud drift winds, ASOS, buoy and ship data

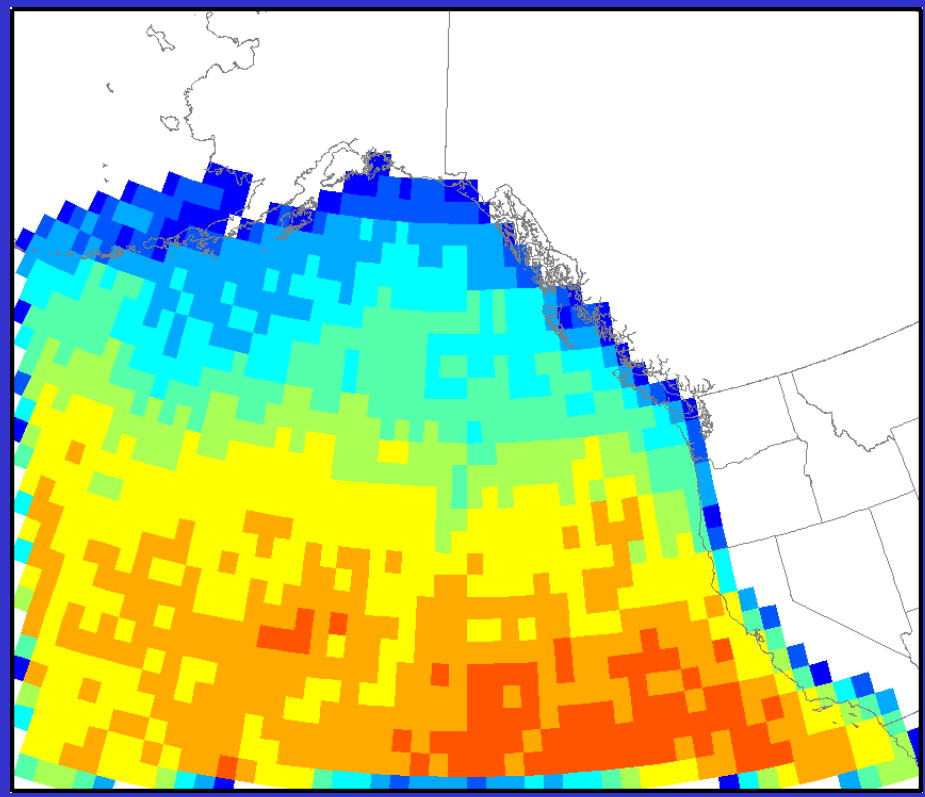


Observation Densities

aircraft obs.



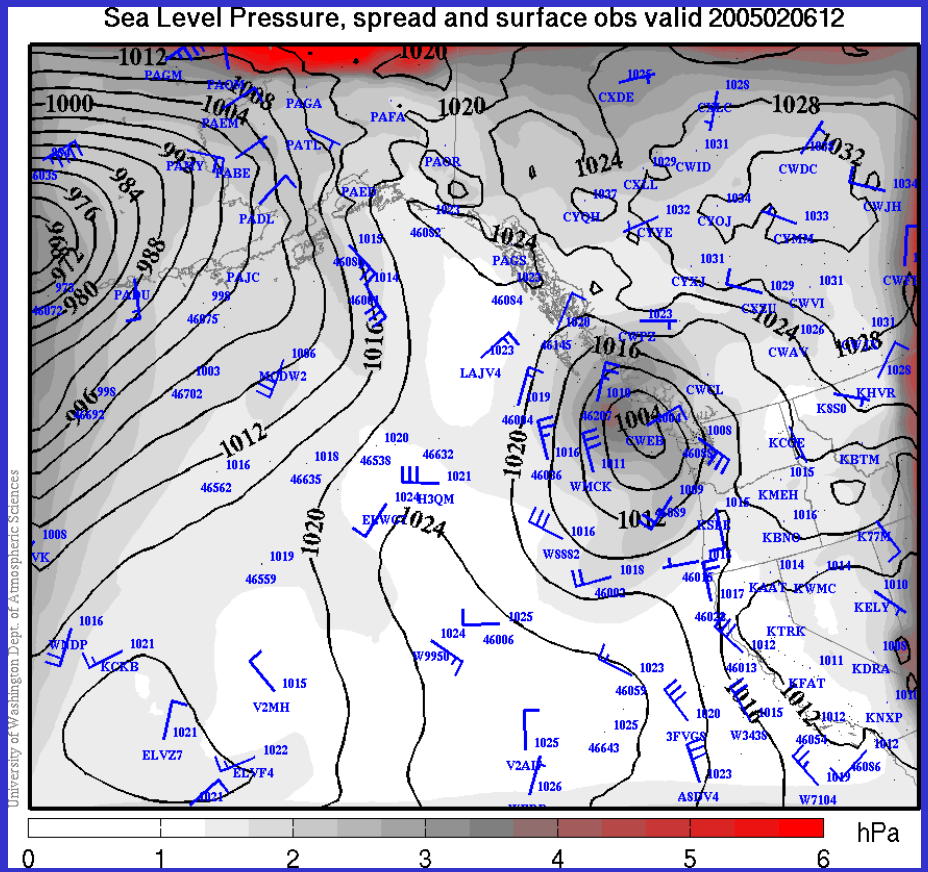
cloud winds

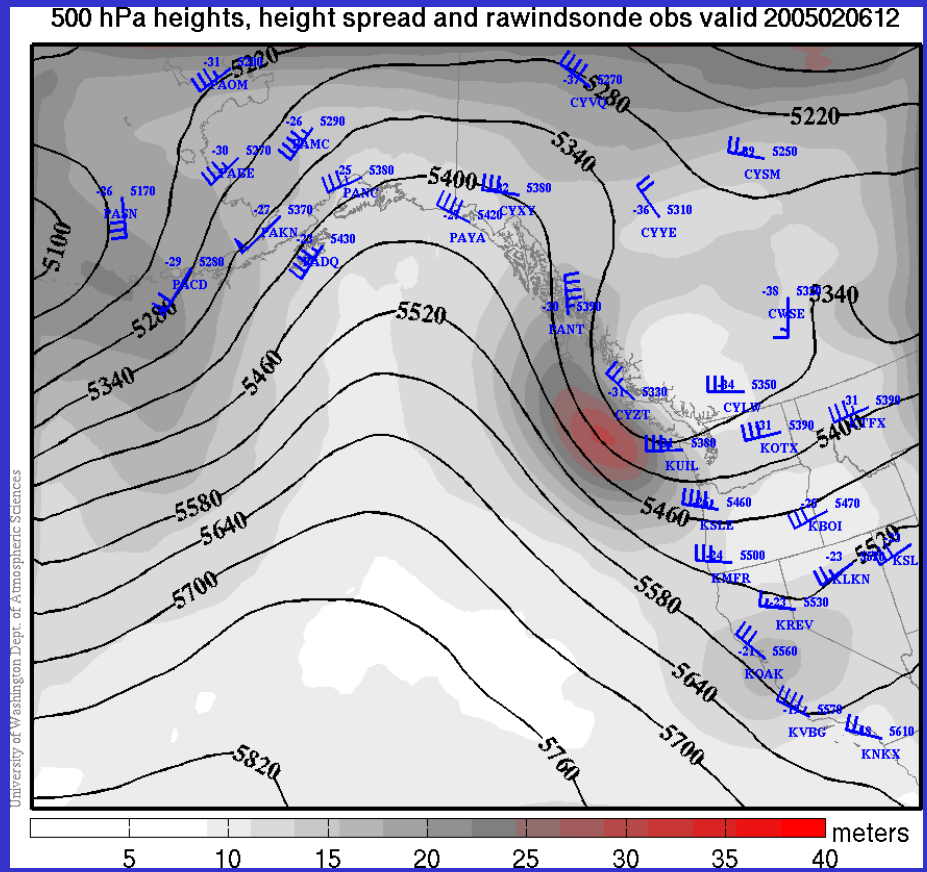


Probabilistic Analyses

sea-level pressure

500 hPa height

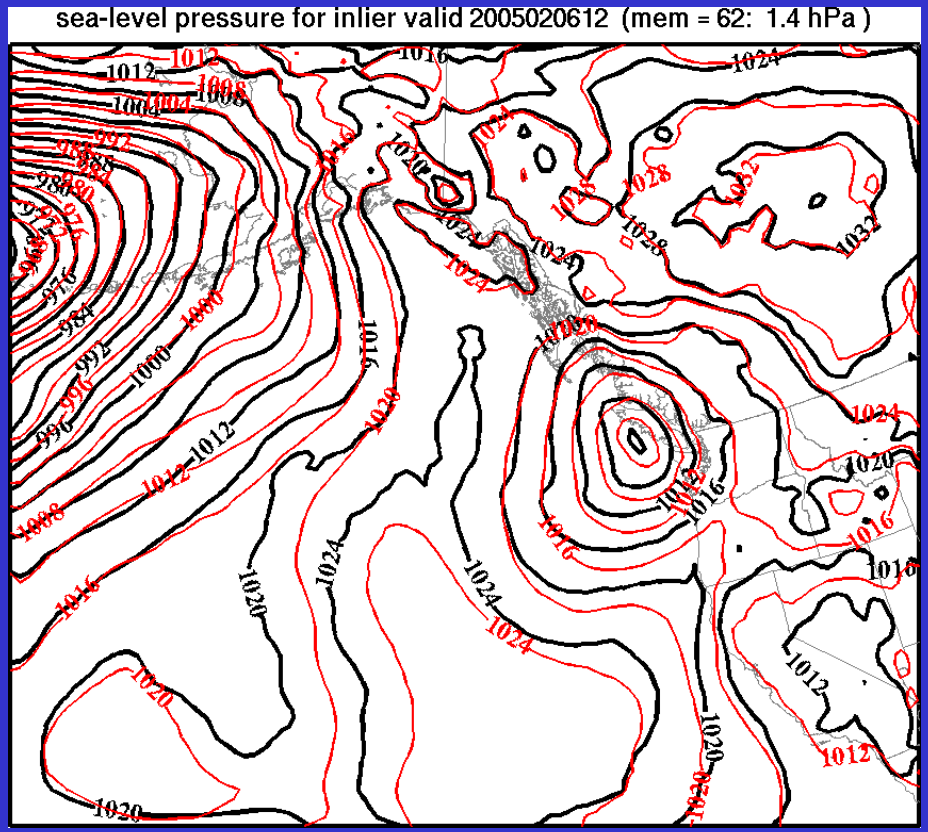




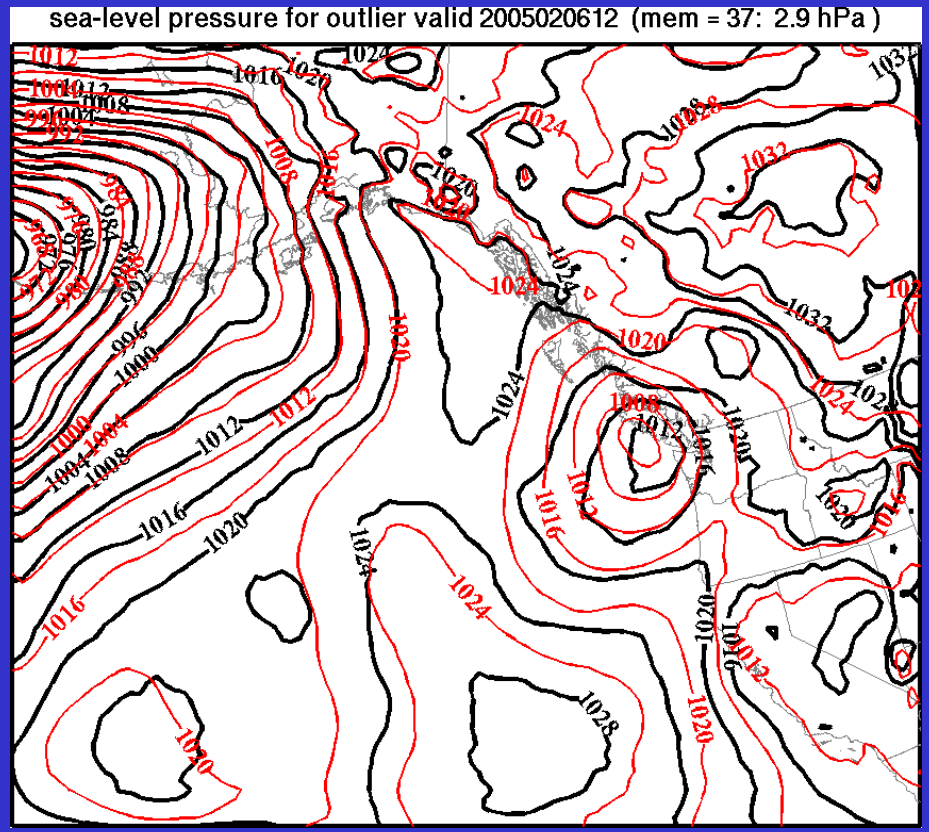
Large uncertainty associated with shortwave approaching in NW flow

Ensemble inliers/outliers

inlier

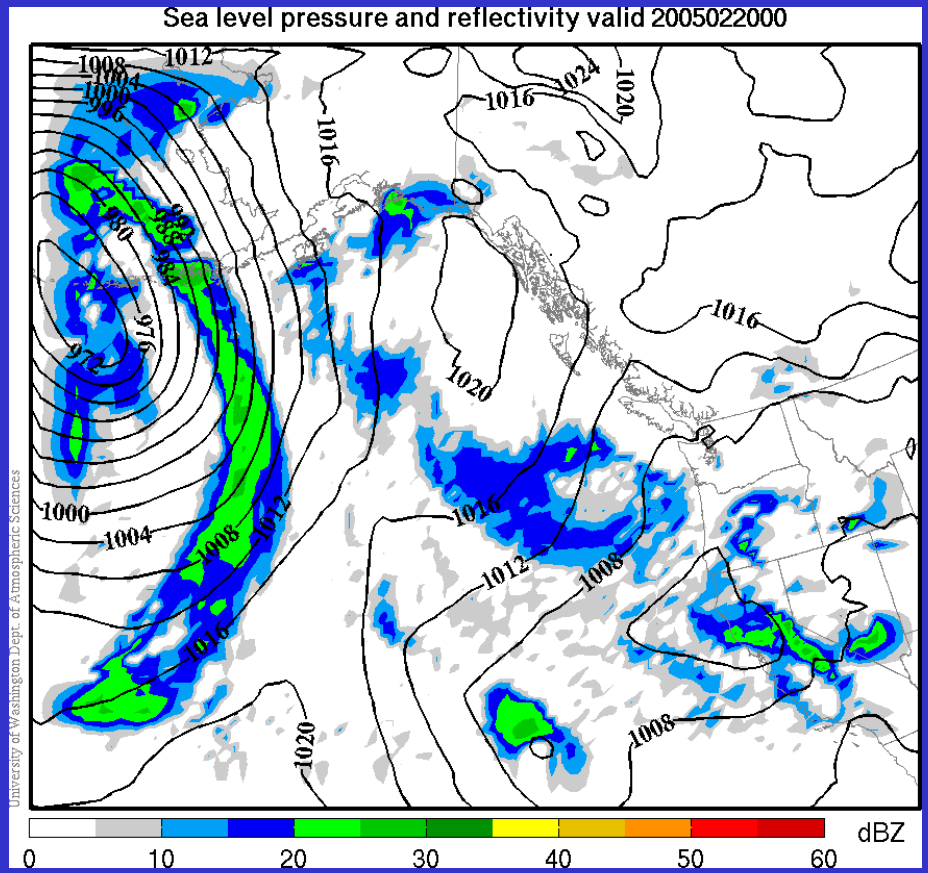


outlier

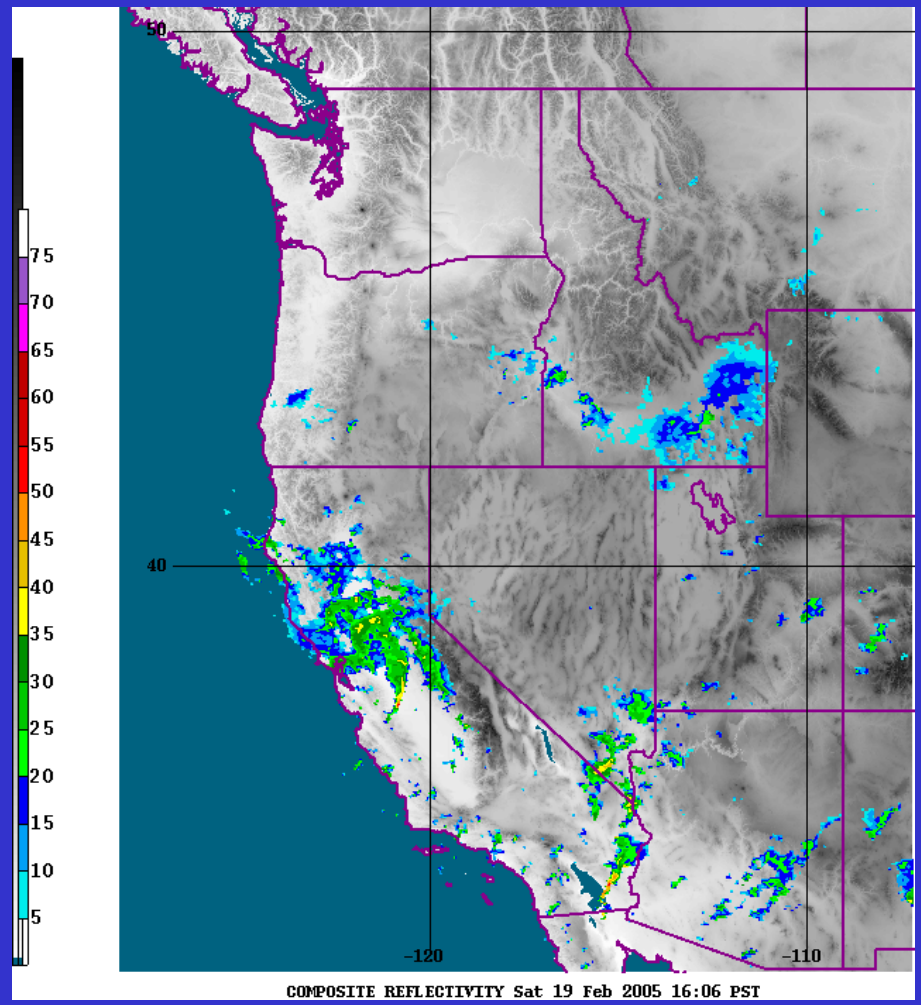


Microphysical Analyses

20 February 2005, 00 UTC



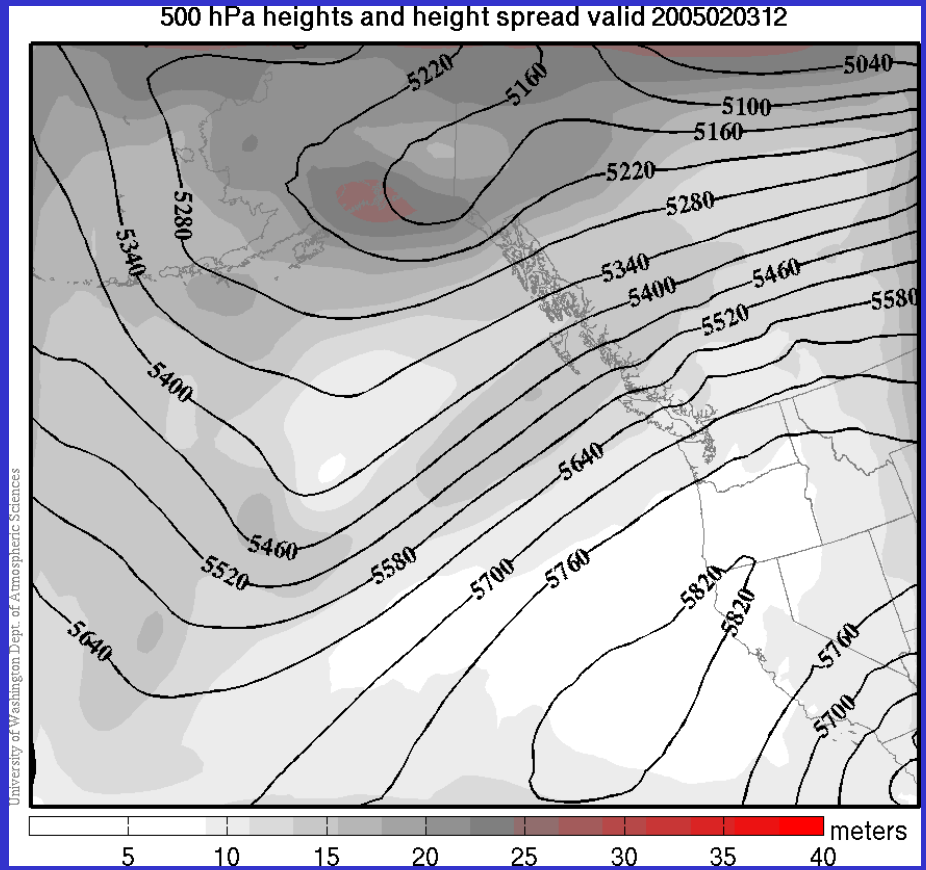
model analysis



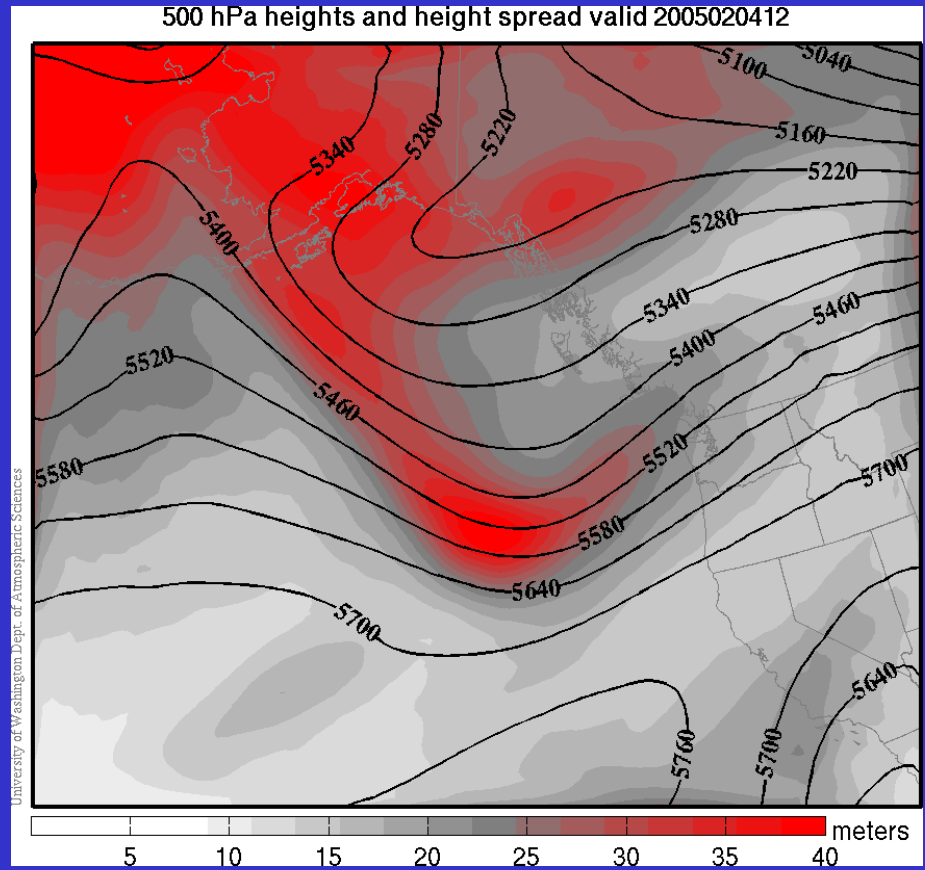
composite radar

Ensemble Forecasts

Analysis



24-hour forecast



Forecast Sensitivity

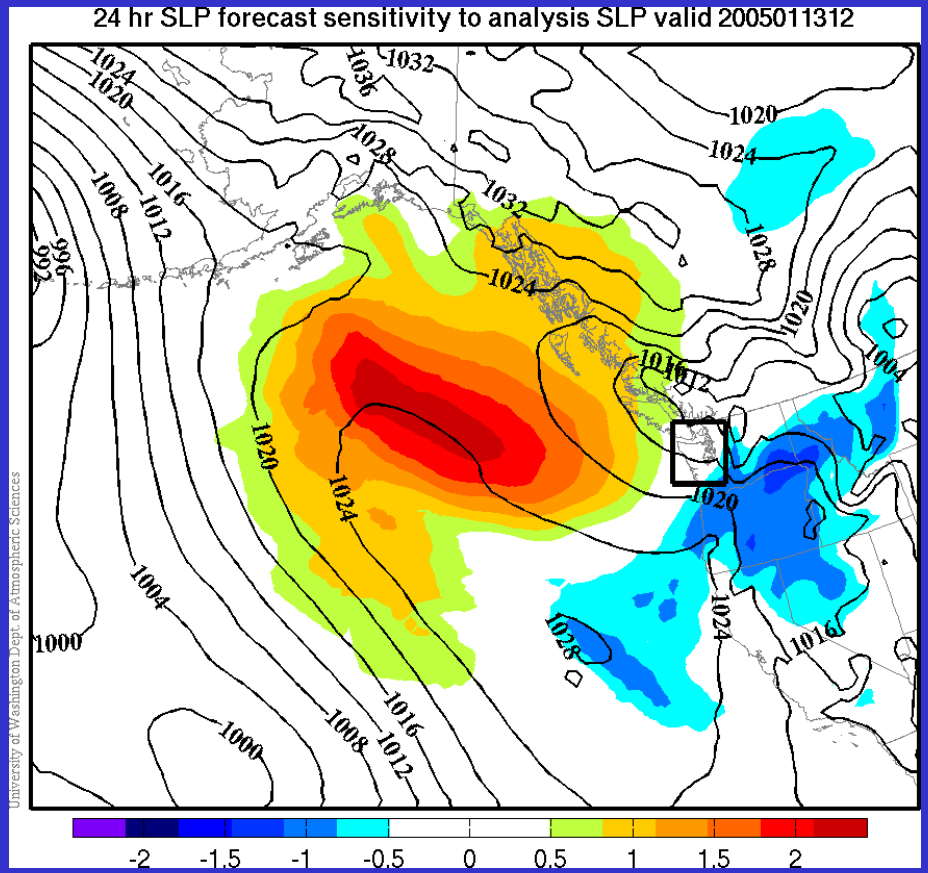
How does a one unit difference in the analysis field at one point alter the forecast of a given field at another point?

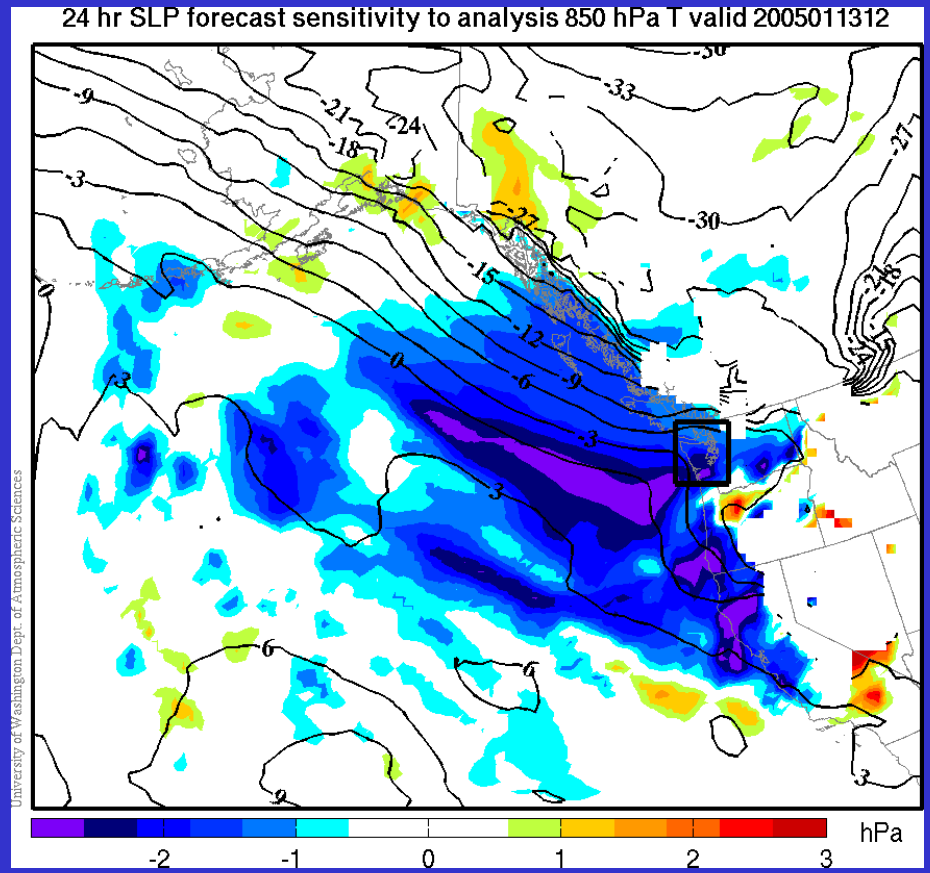
$$\Delta J^{f} = \frac{\mathrm{cov}(X_i^{a}, J^{f})}{\mathrm{var}(X_i^{a})} \times \Delta X_i^{a}$$

Sensitivity Example

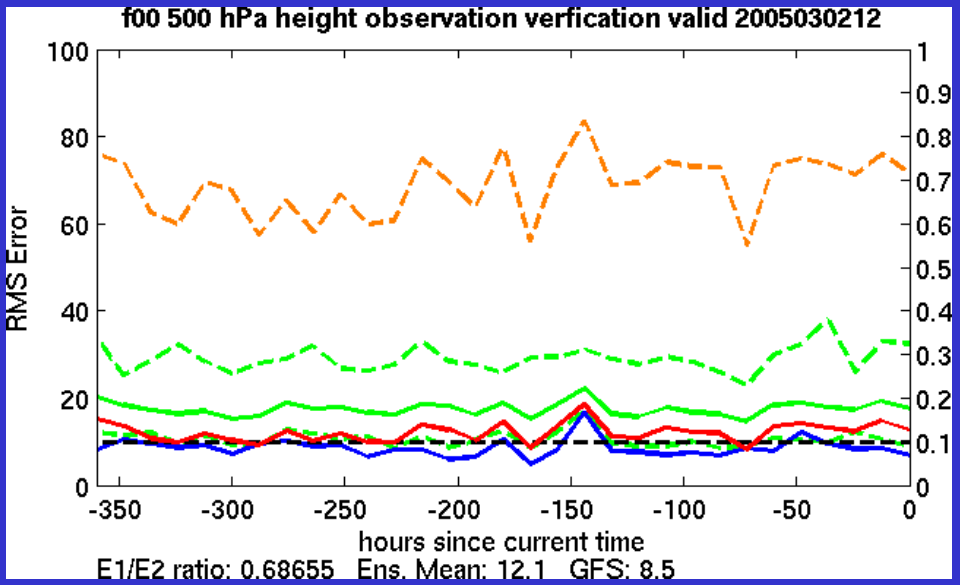
analysis SLP

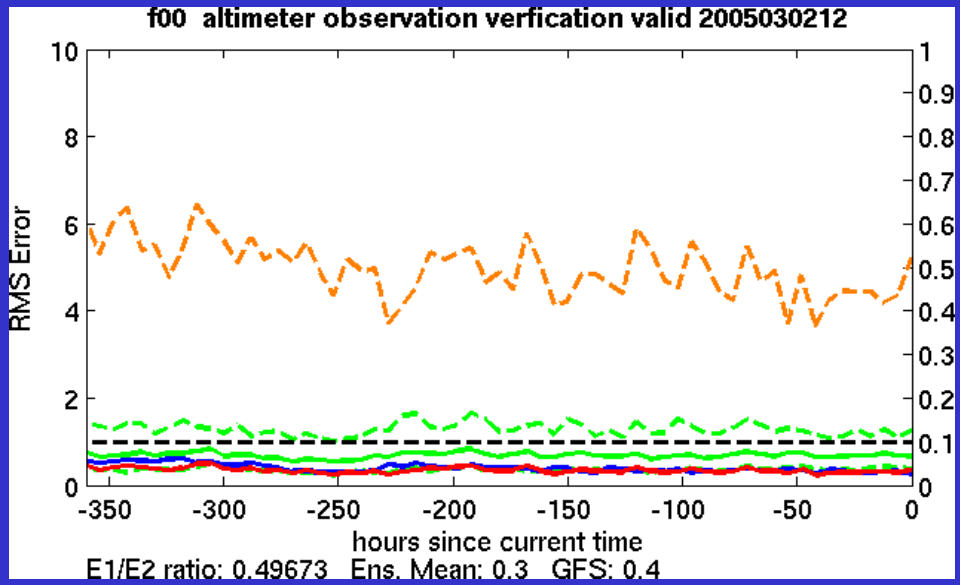
850 hPa temp.

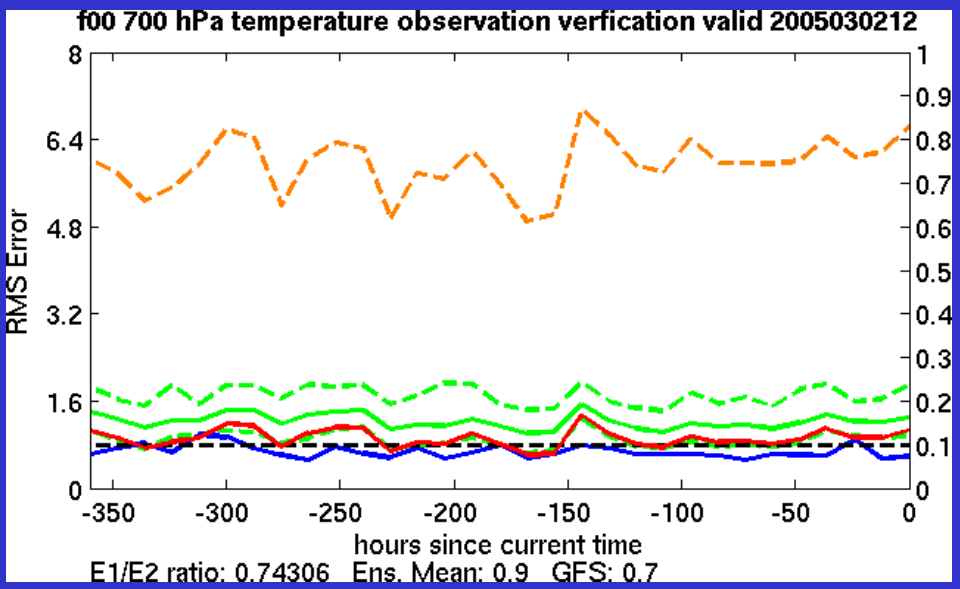


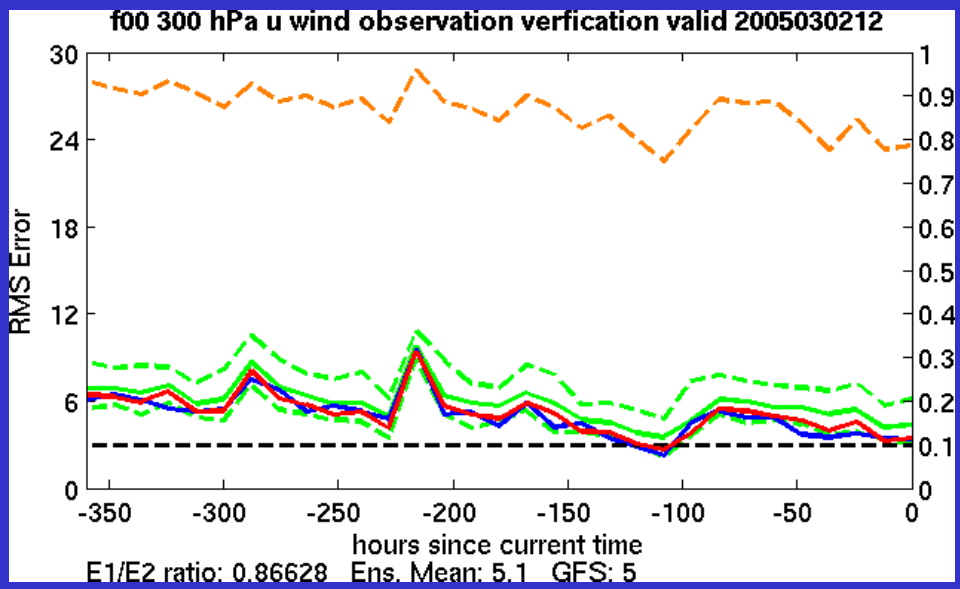


Analysis Verification

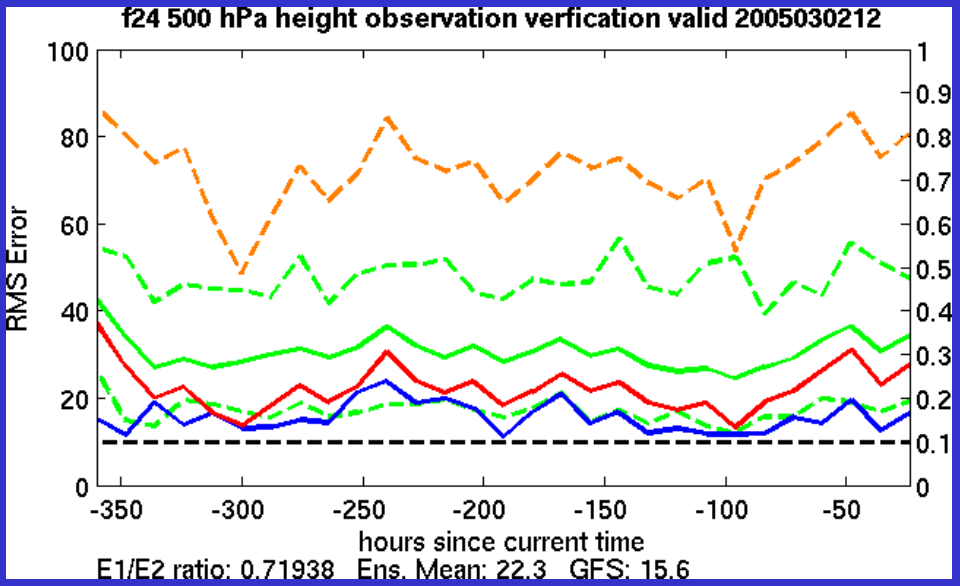


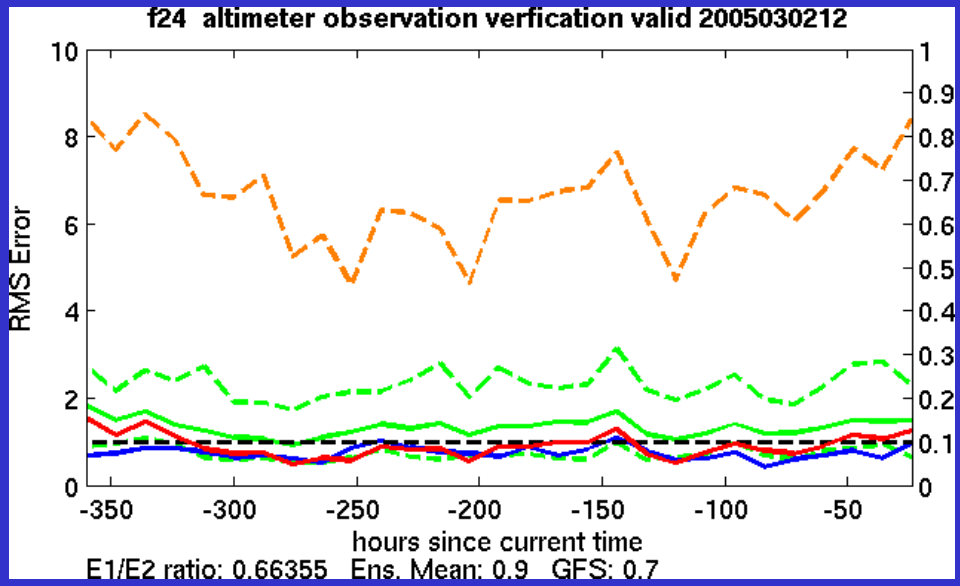


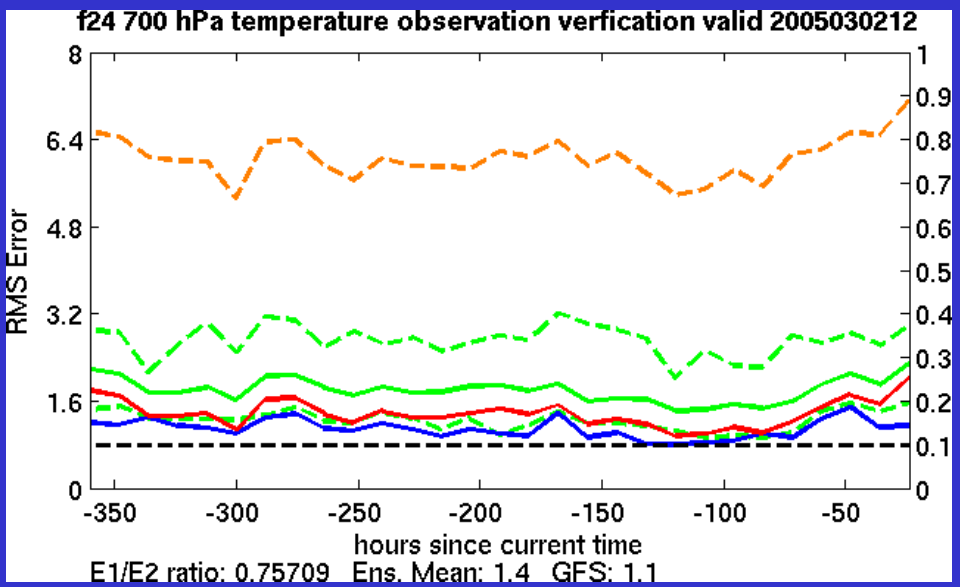


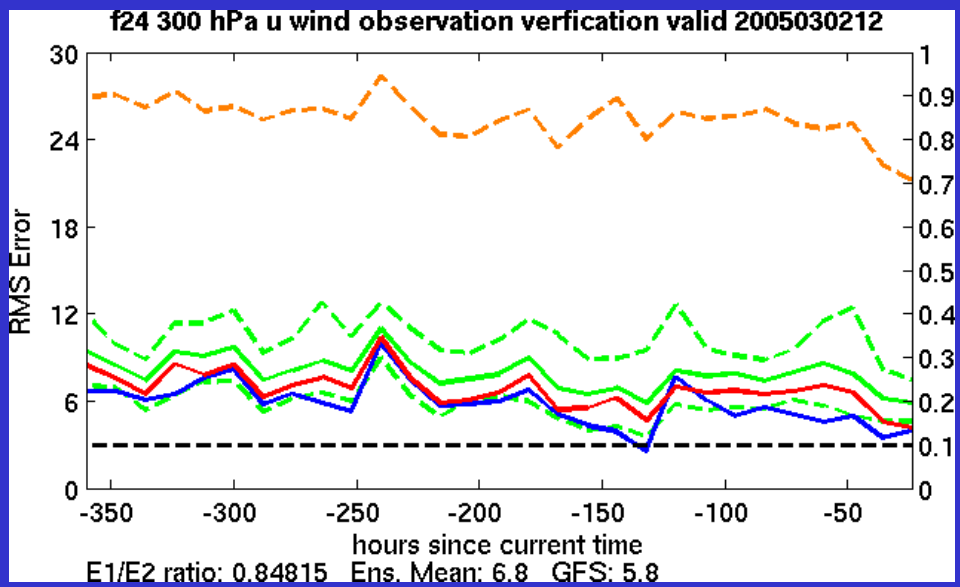


Forecast Verification









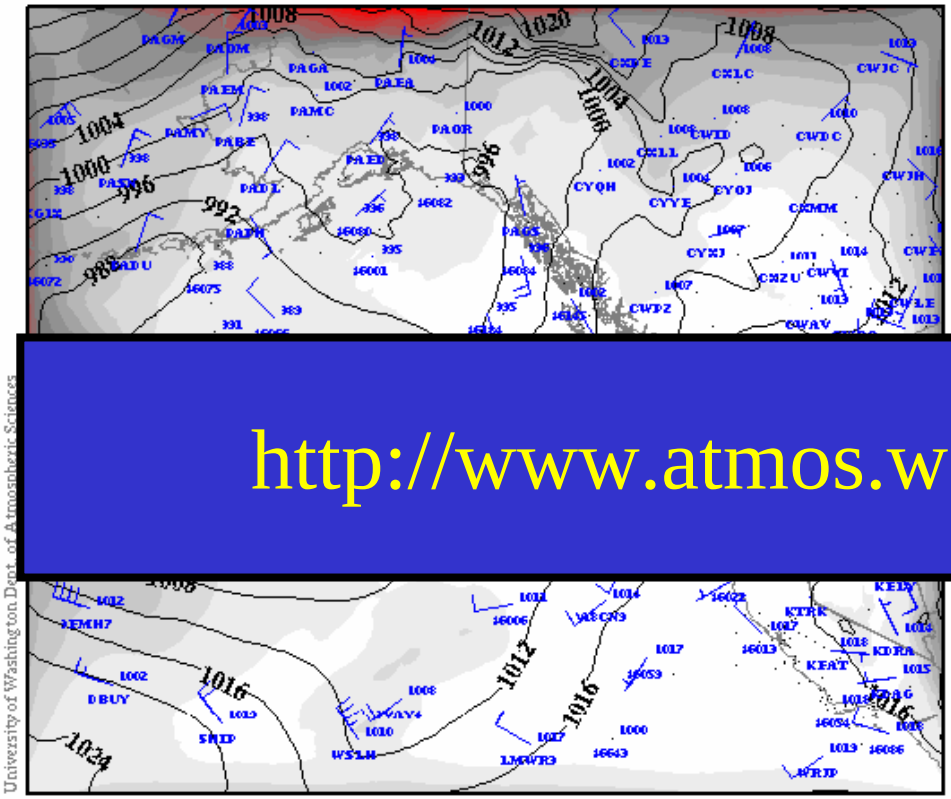
University of Washington Real-Time Ensemble Kalman Filter

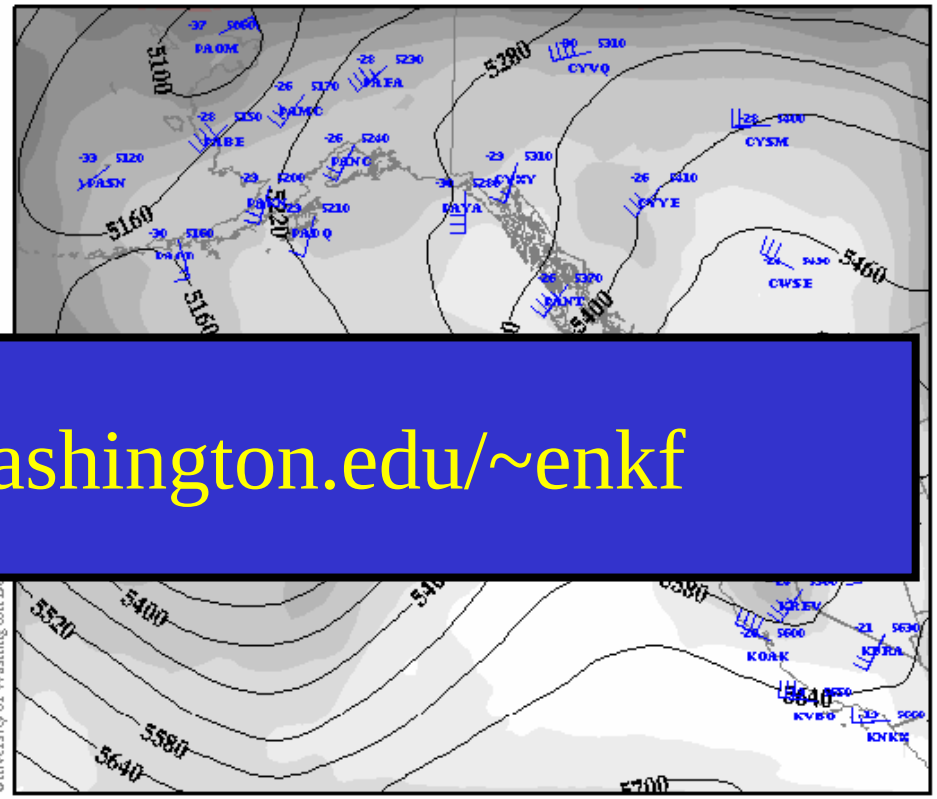
(What? Who? Why?)

| Analyses | Forecasts |

Sea Level Pressure, spread and surface obs valid 2005030212

500 hPa heights, height spread and rawindsonde obs valid 2005030212





http://www.atmos.washington.edu/~enkf

hPa

0 1 2 3 4 5 6

Loop Surface map GO

meters

5 10 15 20 25 30 35 40

Loop 500 hPa map GO

Filter status **Wed Mar 2 09:27:57 PST 2005 :** Analysis completed on: Wed Mar 2 07:16:14 PST 2005

Observations assimilated

Radiosonde verification (00 and 12 UTC)

Filter performance: E1/E2 = 0.758 (LOG)