Weather Regimes and Forecast Errors in the Pacific Northwest

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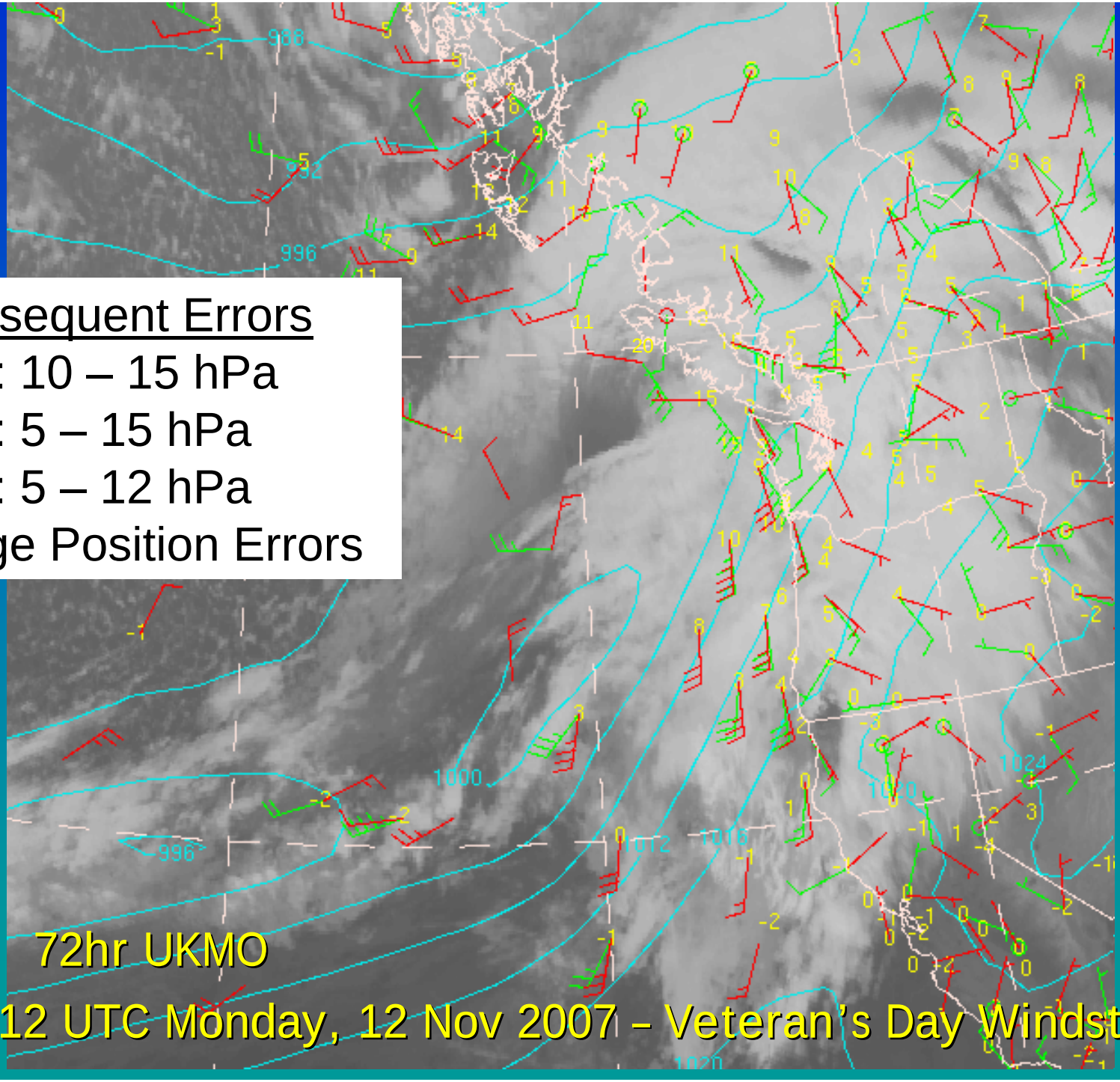
- Numerical weather prediction has improved significantly over the last 20+ years
- Largely due to improvements, such as model physics, model resolution, and data assimilation.
- BUT, large short-term forecast errors still occur ….



Subsequent Errors

36h: 10 – 15 hPa

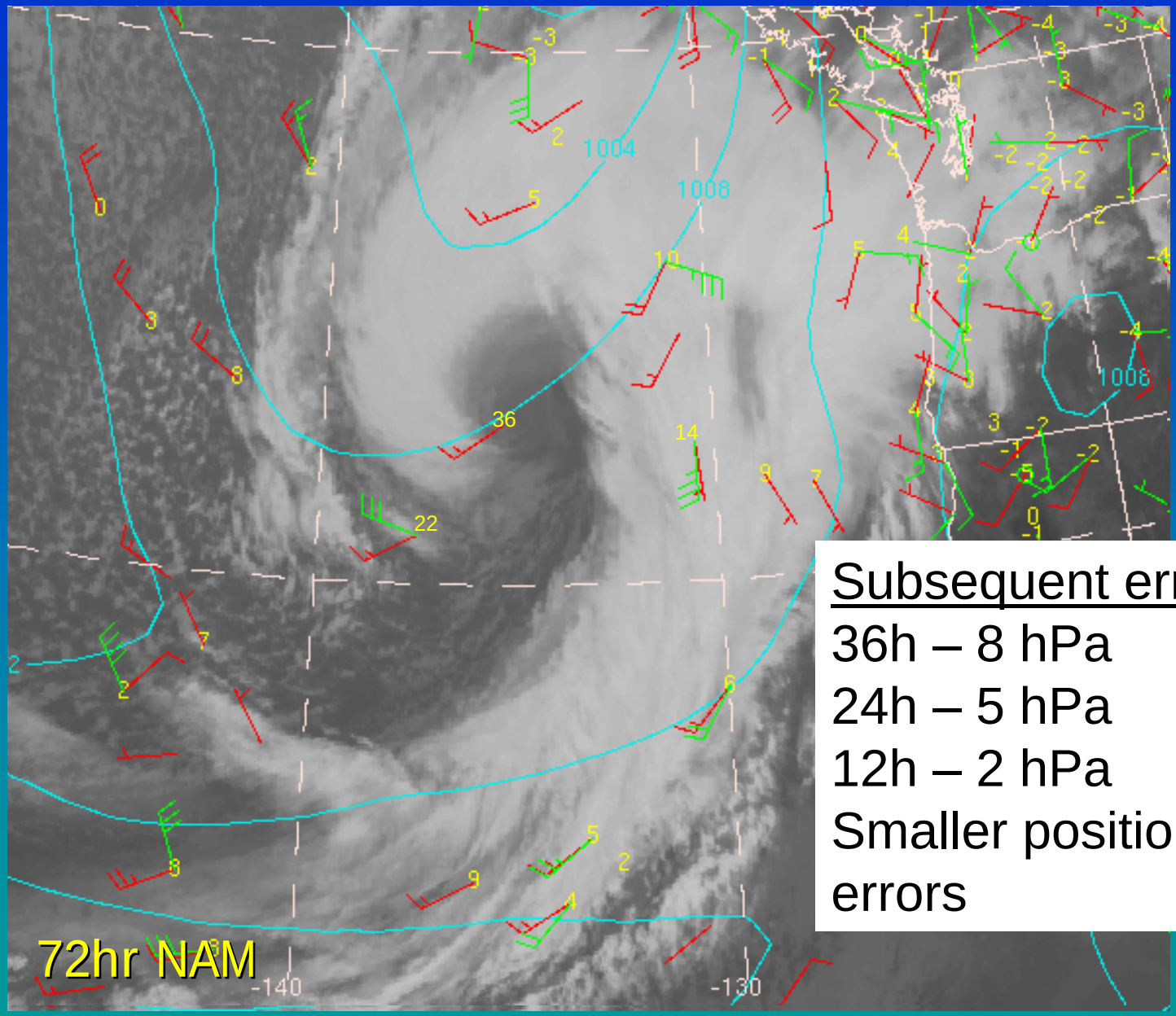
24h: 5 – 15 hPa

12h: 5 – 12 hPa

Large Position Errors

72hr UKMO

12 UTC Monday, 12 Nov 2007 – Veteran's Day Windstorm



Subsequent errors

36h – 8 hPa

24h – 5 hPa

12h – 2 hPa

Smaller position errors

00UTC 9 October 2007 – Rapidly Deepening Cyclone

How Important are these forecast errors?

- Do large forecast errors occur for storms that impact society/property …

Snow

Winds

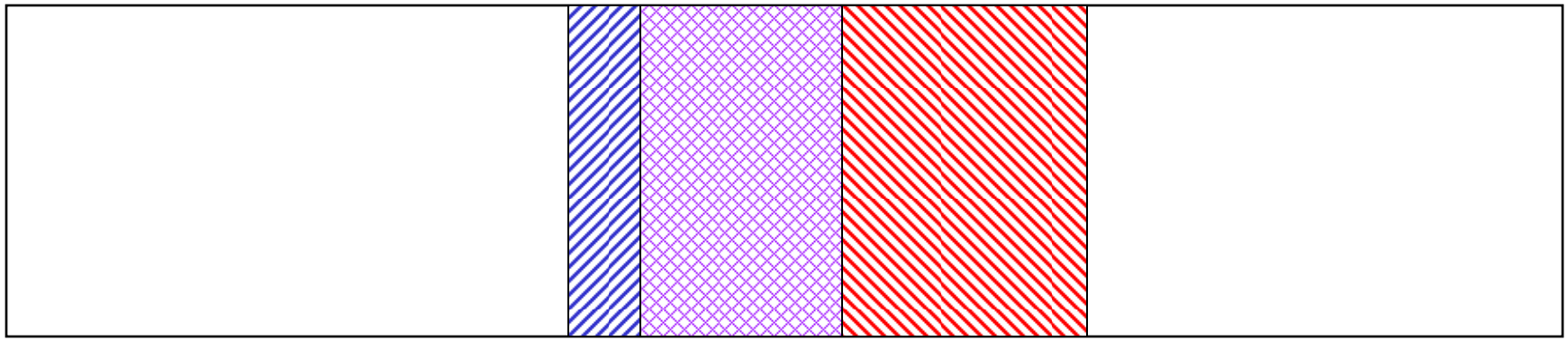
Floods…

High (significant) Impact Event?

- High Impact Event = Any event mentioned in the Storm Data Publications during Oct – Mar of 2002 – 2007, west of Cascades WA & OR, affecting significant area (high wind events, significant rain/flooding, lowland snow)
- Large Error Day = Any day where the forecast of sea level pressure at coastal and offshore stations is large (more than 2*sd) at 2 or more locations
- **Are large error days associated with high impact events?**

High Impact Events ~17%

Large Error Days ~ 25%



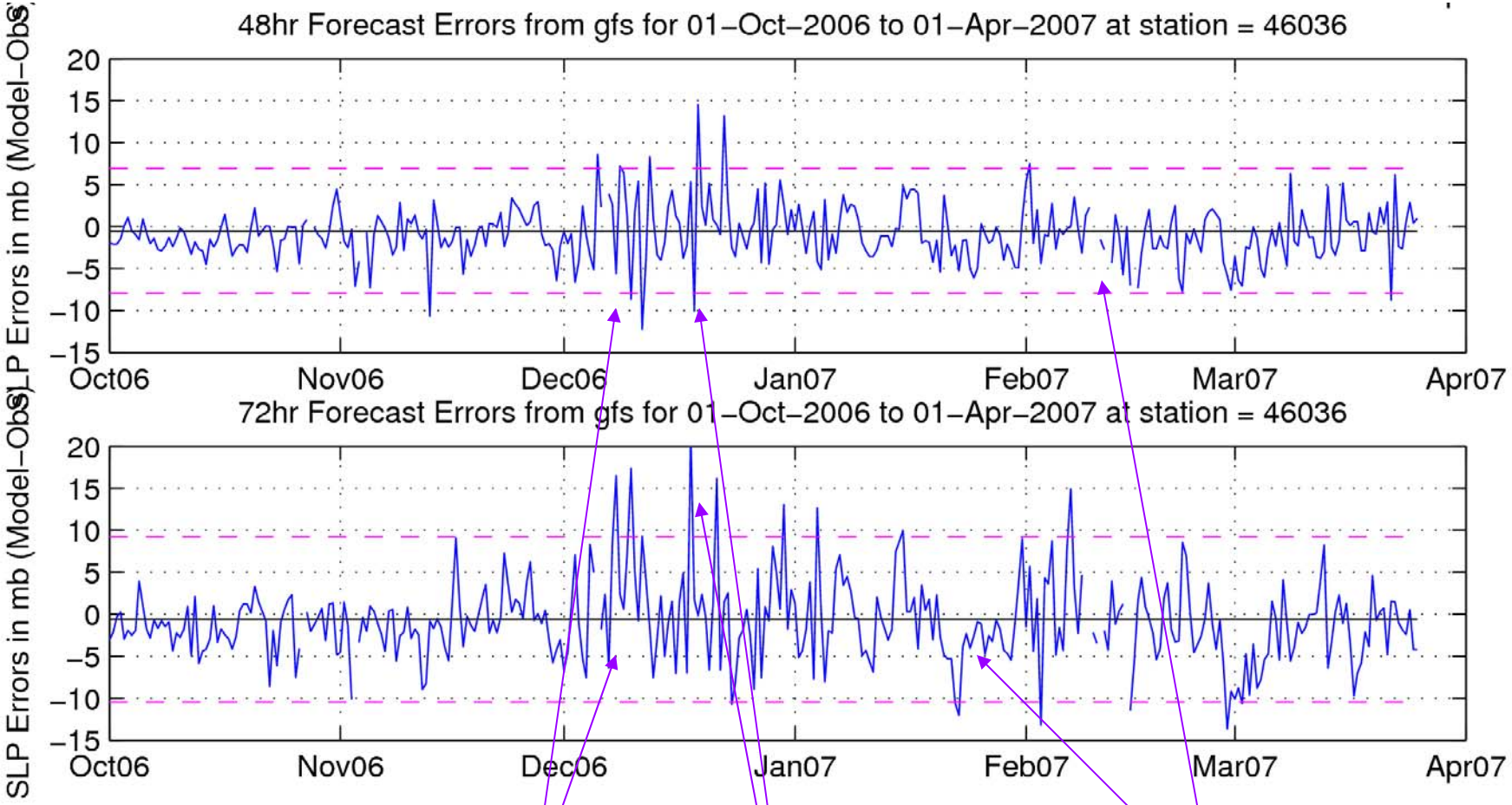
911 Days, 5 winter Seasons

55% of High Impact Events have large errors.

If the large error date lags 1 day or is same day as a high impact event, then 70% of High Impact Events have large forecast errors.

Why do large short-term forecast errors occur?

- Since many ‘high impact events’ are also short-term forecast error events, important to investigate the circumstances under which large forecast errors occur.
- Forecast Errors can be episodic ….



Periods of Large Errors

Periods of Small Errors

Error > 2*sd

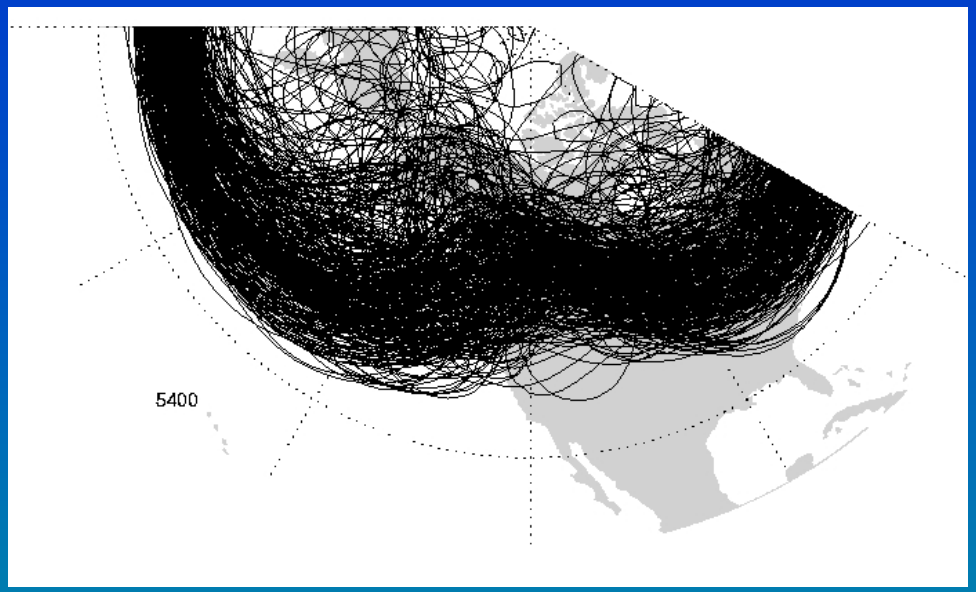
Why do large short-term forecast errors occur?

- Interested in the large-scale environment in which these large short-term forecast error events occur
- **Do large forecast error events occur during particular ‘flow (or weather) regimes’?**

What is a Weather Regime?

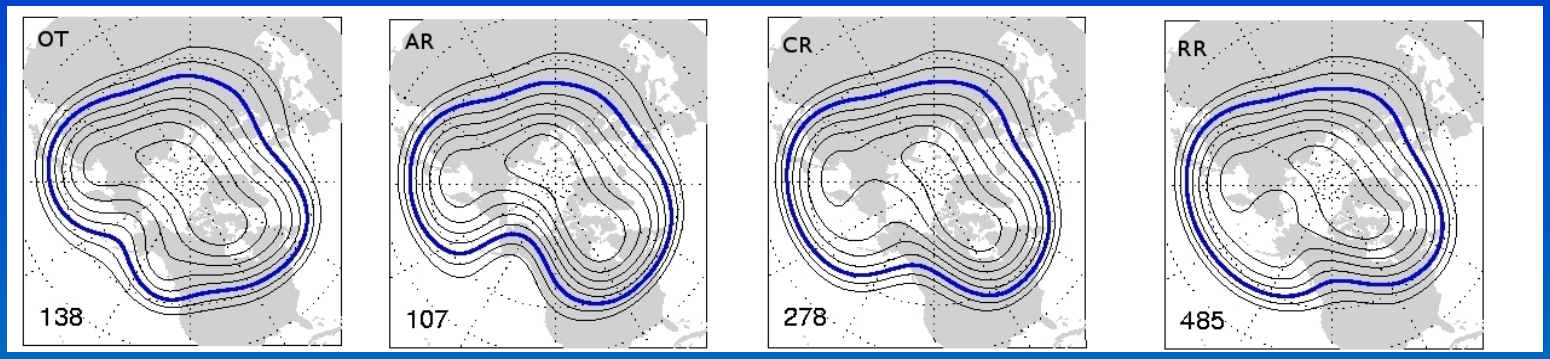
- **Method -** Cluster a **single 500-hPa geopotential height contour** to identify regime patterns that occur in the Pacific sector
- **Motivations –** Using a single contour
  - Appeals to **synoptic intuition**
  - Yields a **simple framework**
- **Data –** Used 5-day average of 540 dm 500-hPa heights from the NCAR reanalysis data from **DJFM 1958-1999, 150°E – 60°W**

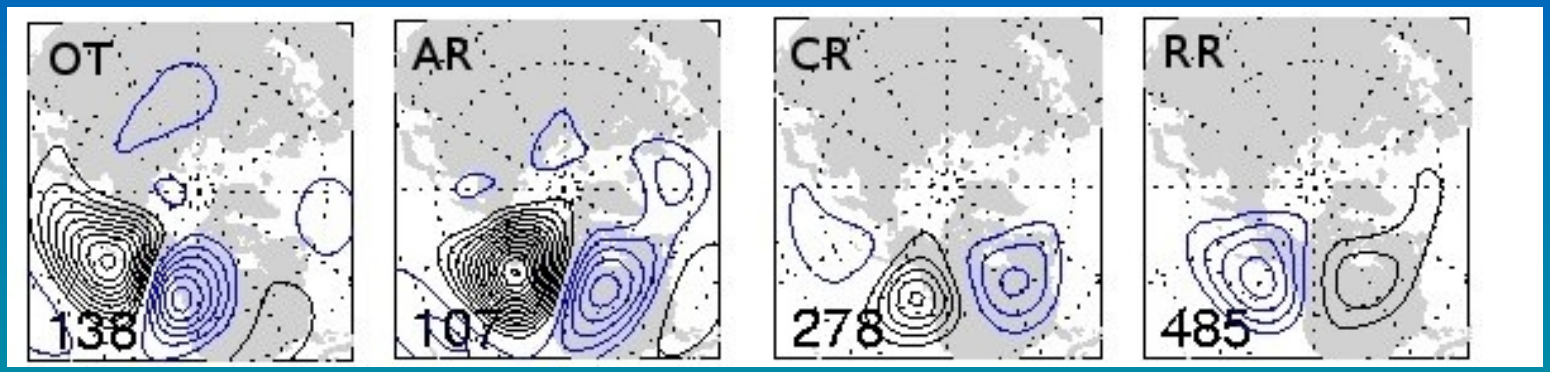
Limited Contours



- 1008 individual spaghetti strands to be clustered
- Each "spaghetti strand" is a **5-day average** of the **540-dam contour** of the 500-hPa geopotential height field, taken from **DJFM 1958-1999, 150°E – 60°W**
- **Casola and Wallace (JAMC, 2007)**

4 Regimes of Interest





Off-Shore Trough **Alaska Ridge** **Coastal Ridge** **Rockies Ridge**

Full Field – 510dam:552dam, 6 dam interval, **540 dam in blue**

Anomalies – 2 dam interval; **(+) in Black; (-) in Blue**

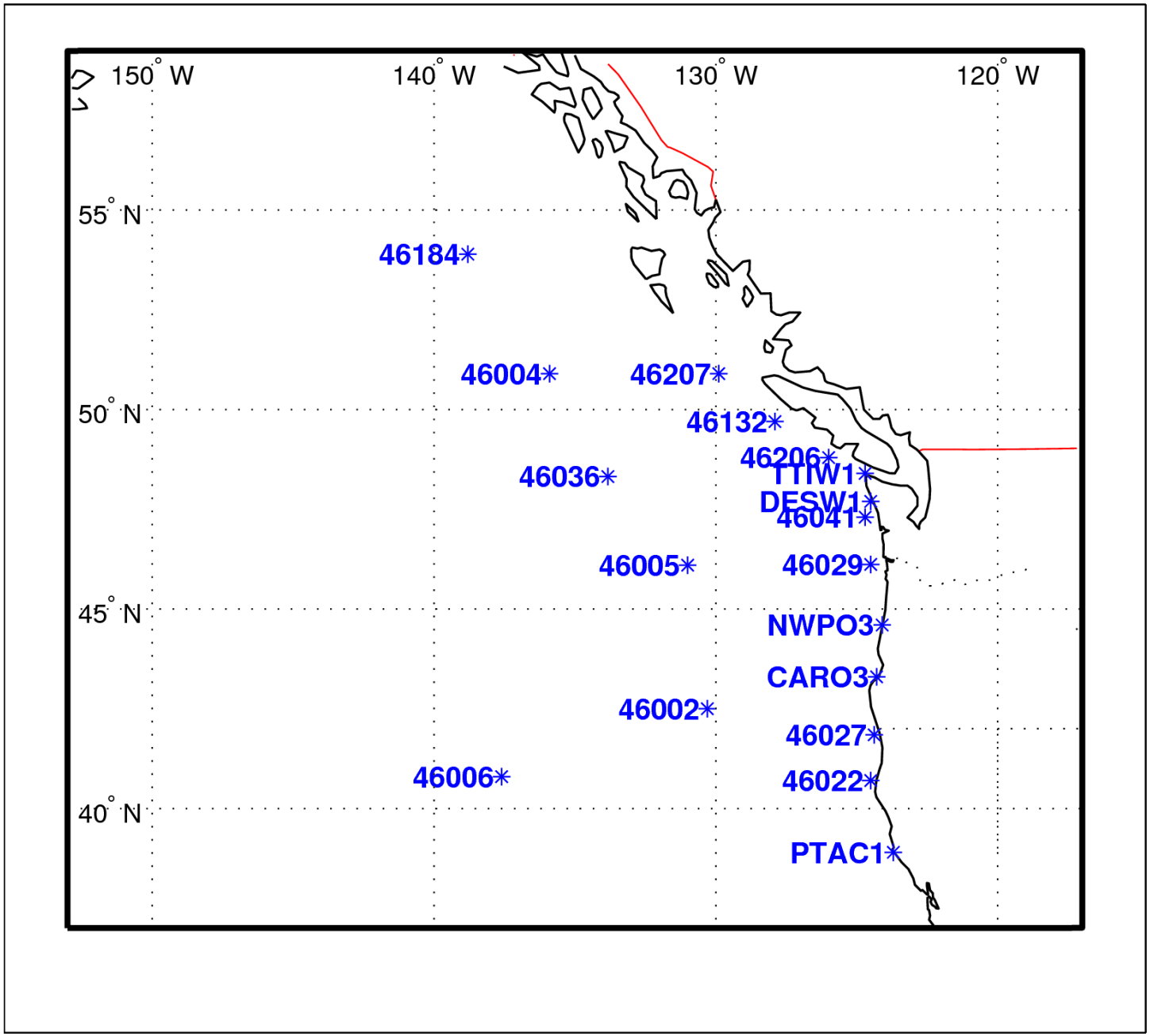
Regimes for This Study

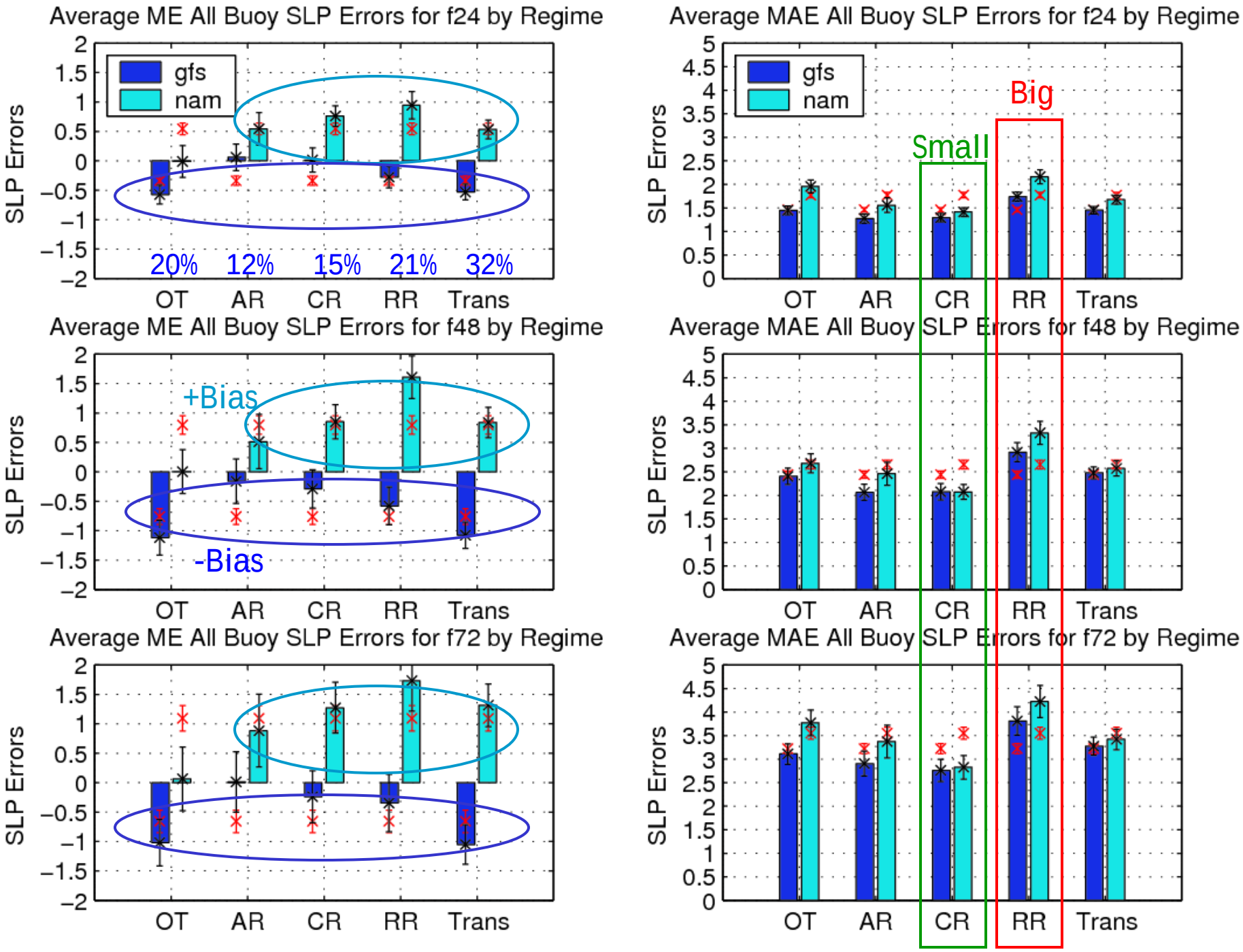
- For the period November 2002 – March 2007 (winter months only), calculated 3-day running mean of 500-hPa 540 dm and matched each day to one of the four regimes that matched the closest.
- If the correlation coefficient was less than 0.5, then there was no match, and that day was called ‘transistion’

Large Forecast Errors

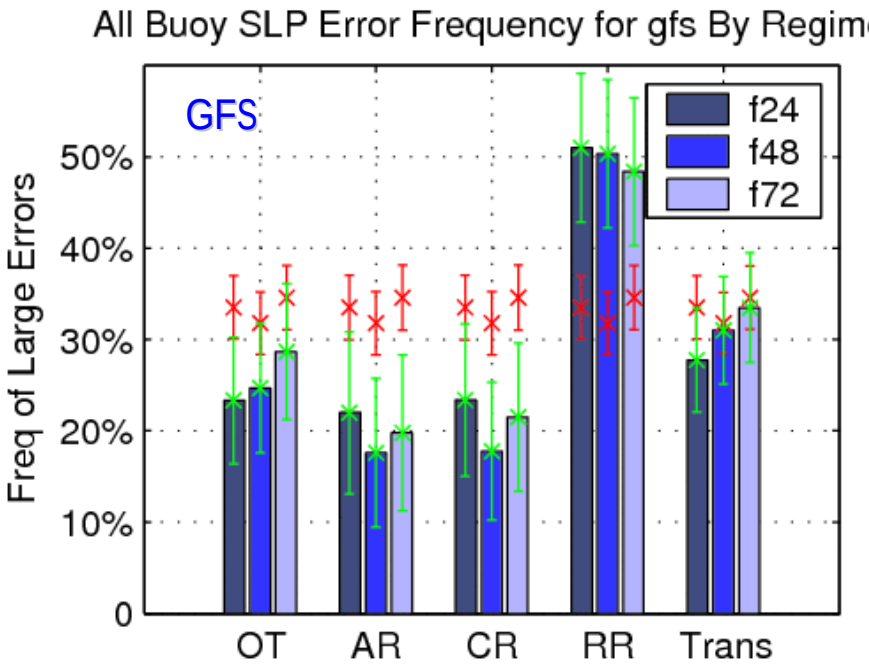
- 24- 48- 72-h **Forecasts of sea level pressure** (slp) by the GFS (and NAM) model(s) for 5 winter seasons (November 2002 – March 2007) were **compared to slp observations** at coastal and offshore stations
- Average error, standard deviation, and Mean Absolute Error (MAE) calculated at each station
- **Daily Error = average MAE for all stations** for each day, each forecast lead time
- If **error > 2*SD** at an individual station, it was a large error day for that station (also used 3*SD)
- **Large Error Day** = **more than 2 stations** experienced errors > 2*SD.

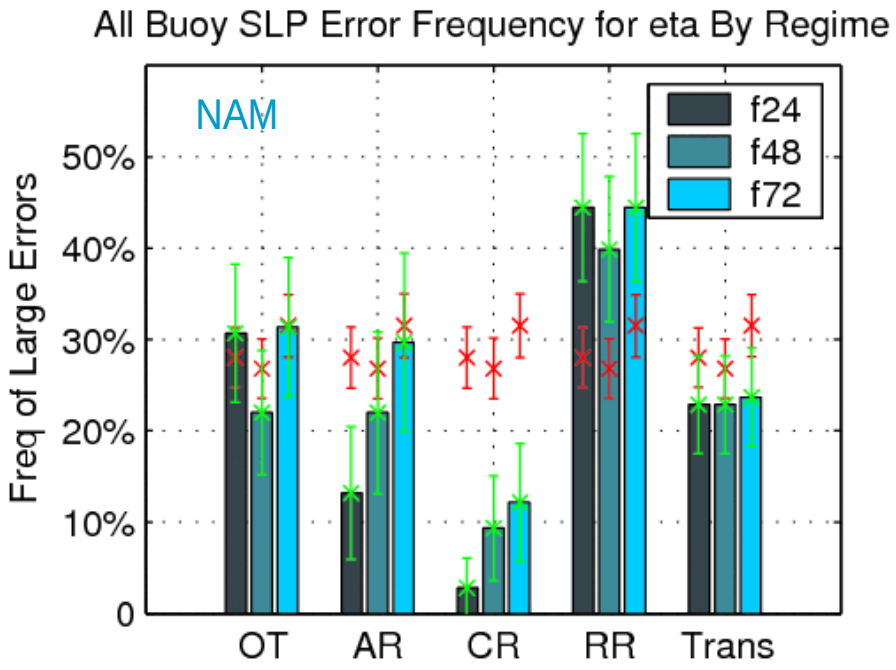
Buoy locations




Average ME All Buoy SLP Errors for f24 by Regime
Average MAE All Buoy SLP Errors for f24 by Regime
Average ME All Buoy SLP Errors for f48 by Regime
Average MAE All Buoy SLP Errors for f48 by Regime
Average ME All Buoy SLP Errors for f72 by Regime
Average MAE All Buoy SLP Errors for f72 by Regime
SLP Errors
gfs
nam
20%
12%
15%
21%
32%
+Bias
-Bias
Small
Big
OT
AR
CR
RR
Trans

Large Error Days

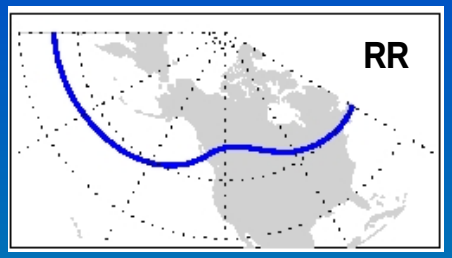


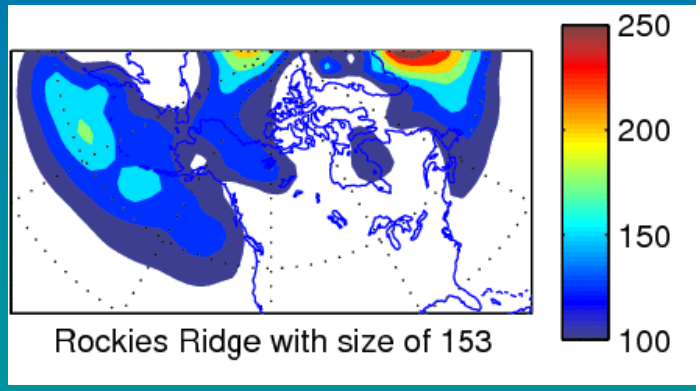


- Rockies Ridge experiences highest frequency of large error days
- Coastal Ridge experiences the lowest
- Offshore Trough has 2nd highest frequency of large error days -- NAM

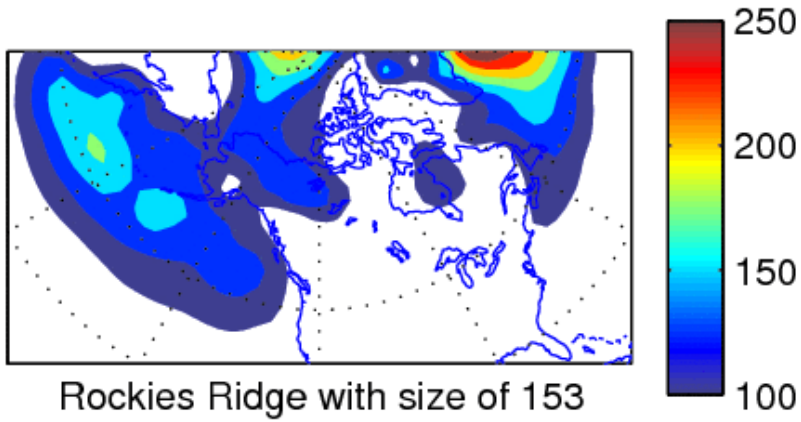
What's so special about Rockies Ridge?

- Has straight jet across Pacific
- Has largest variance of SLP in region closest to the PacNW
- Windstorms and Floods often in this regime
- High Impact events 40% RR (30% OT, 13% Trans, 10% AR, 7% CR)

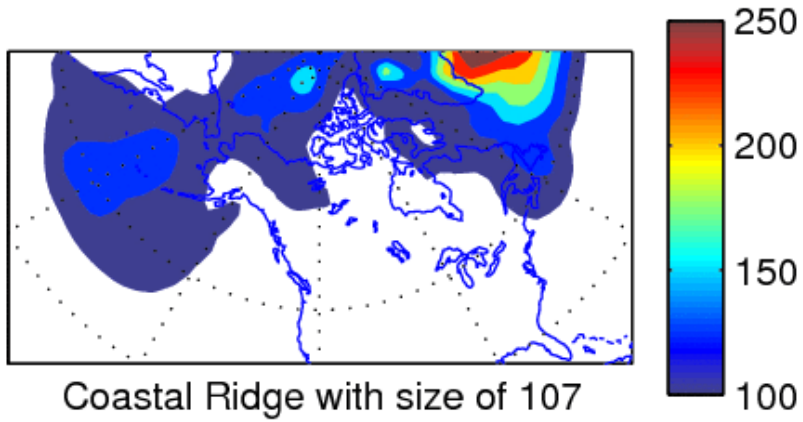




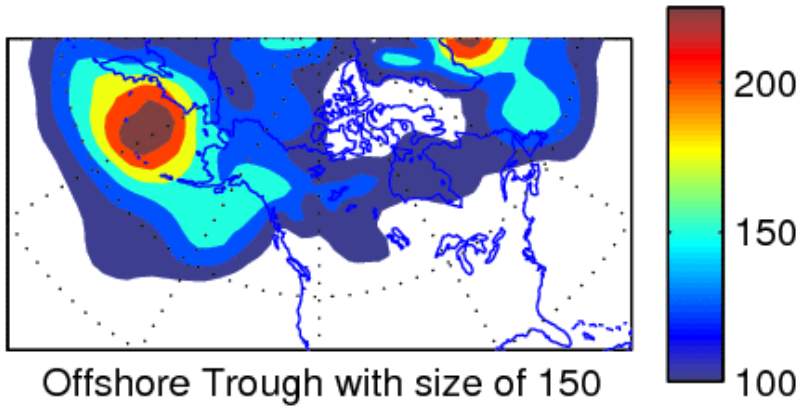
Rockies Ridge with size of 153



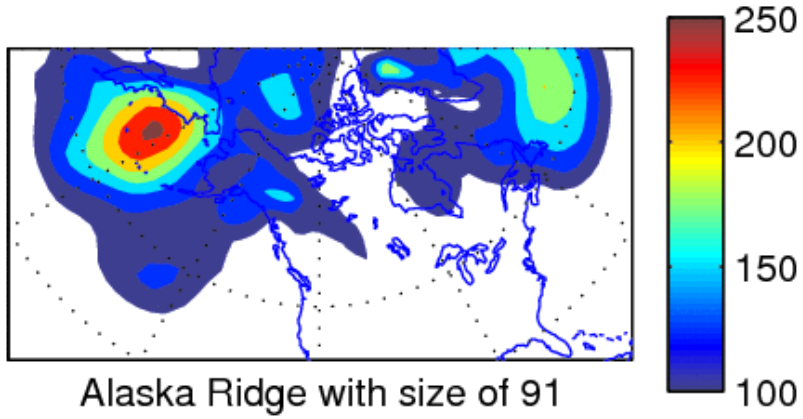
Rockies Ridge with size of 153



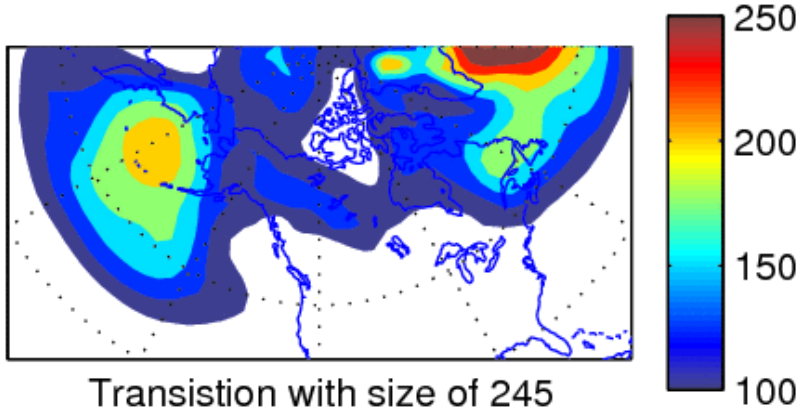
Coastal Ridge with size of 107



Offshore Trough with size of 150



Alaska Ridge with size of 91



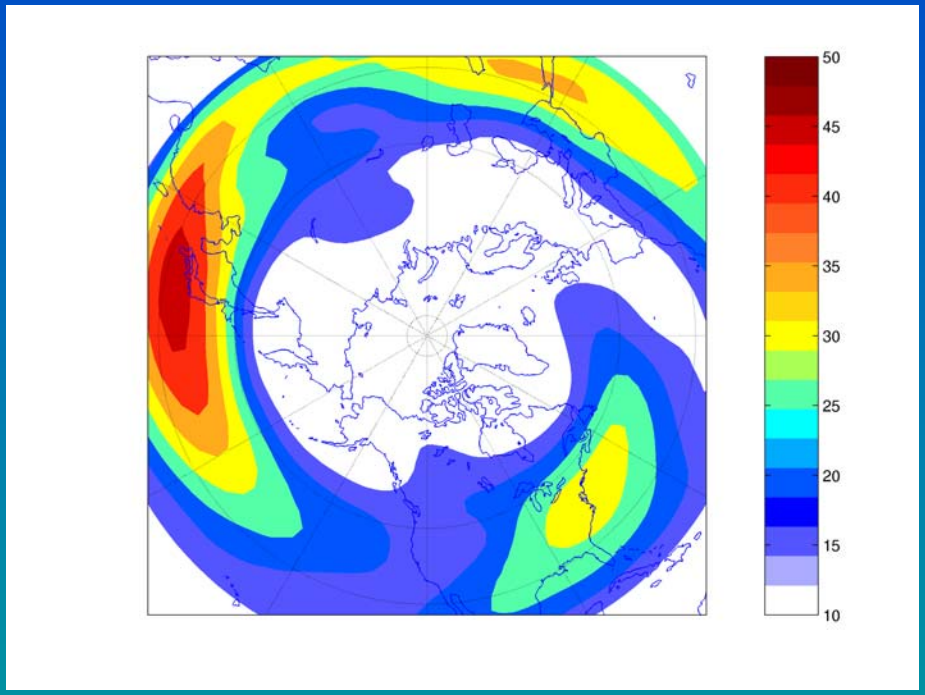
Transistion with size of 245

SLP Variance for the different Regimes 2002-2007

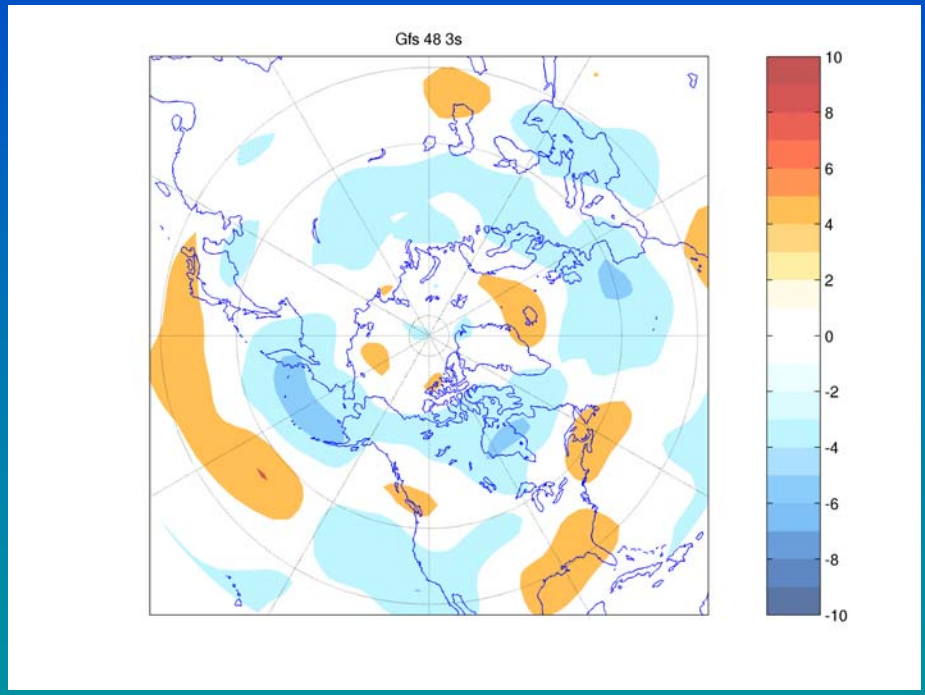
Alternative Weather Regime: Jetstream Strength

- Anecdotal evidence that when there is a strong jet across the Pacific – larger uncertainty in forecasts and larger forecast errors, esp. SLP
- Used 300 hPa windspeed from NCAR reanalysis data to define the Jet
- There are several ways to classify the Pacific Jet …. Principal Component Analysis, jet strength in a box at verification stations, upstream of stations, lagged by a day, composite jet strength for large error days …

Composite Jet for Large Error Events



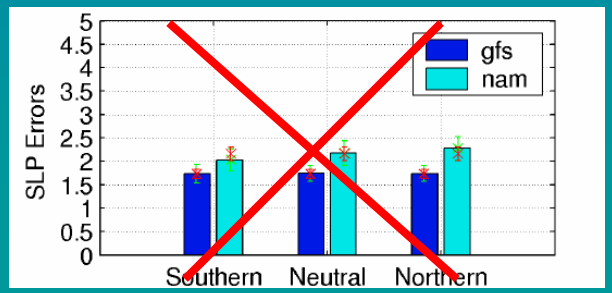
2002-2007 NDJFM Climatology

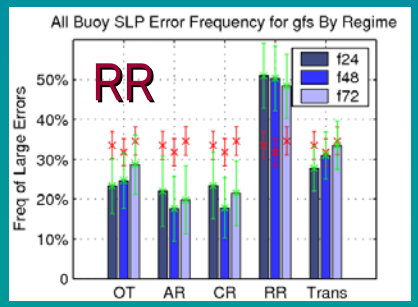


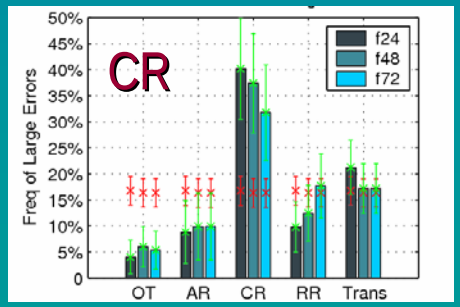
Composite of Jet for Large Error Events

The Take Home Message(s)

- Large forecast errors of SLP in my verification ‘box’ are not a function of the strength of the Pacific jet.
- Large forecast errors of SLP in my ‘box’ are a function of the ‘shape’ of the upper level flow (with the Rockies Ridge regime experiencing the largest average MAE (all models, all lead times) and the Coastal Ridge the smallest.
- Large forecast errors of minimum Temperature over the PacNW are also related to weather regime, with the Coastal Ridge experiencing the largest errors.

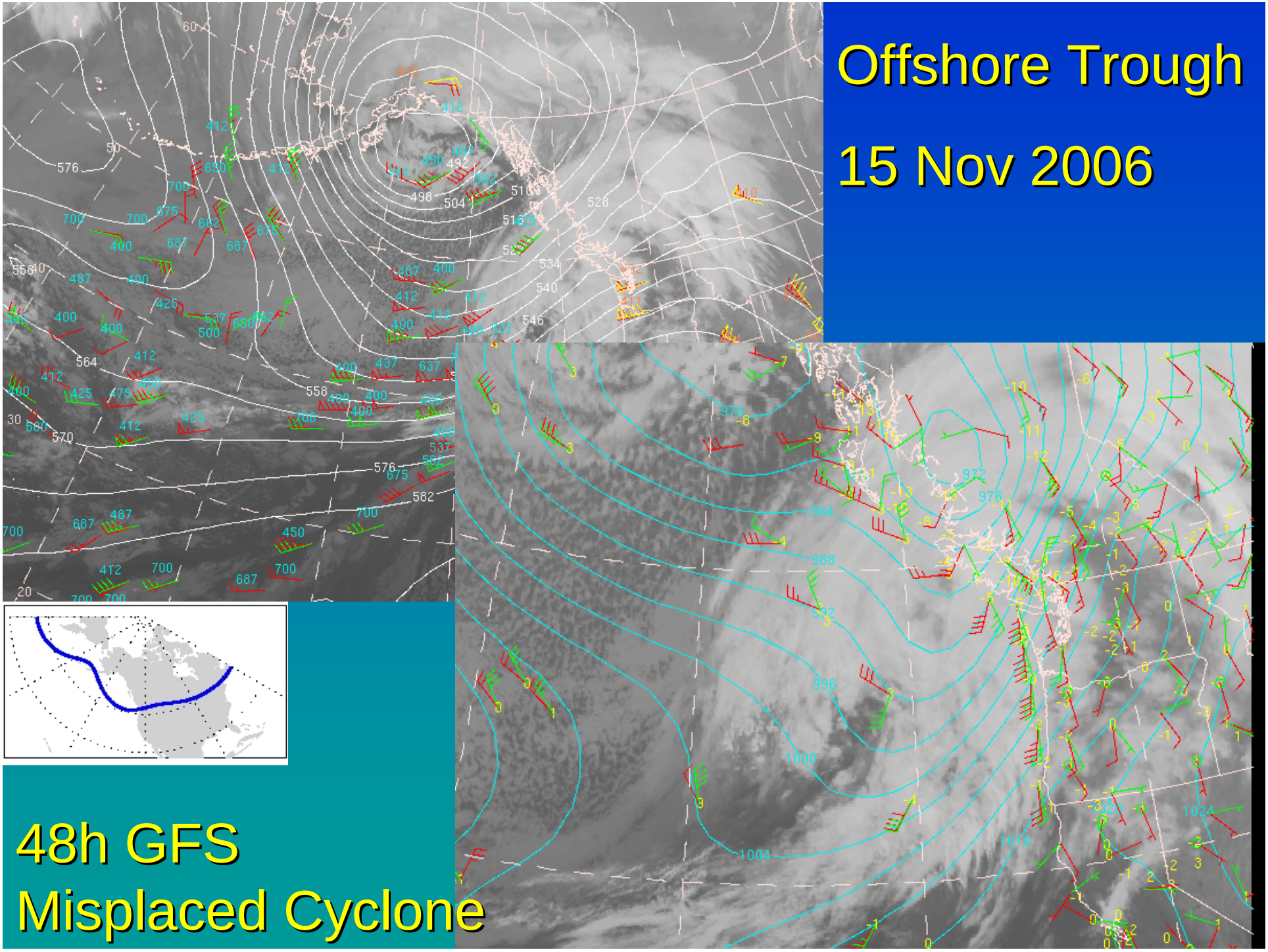


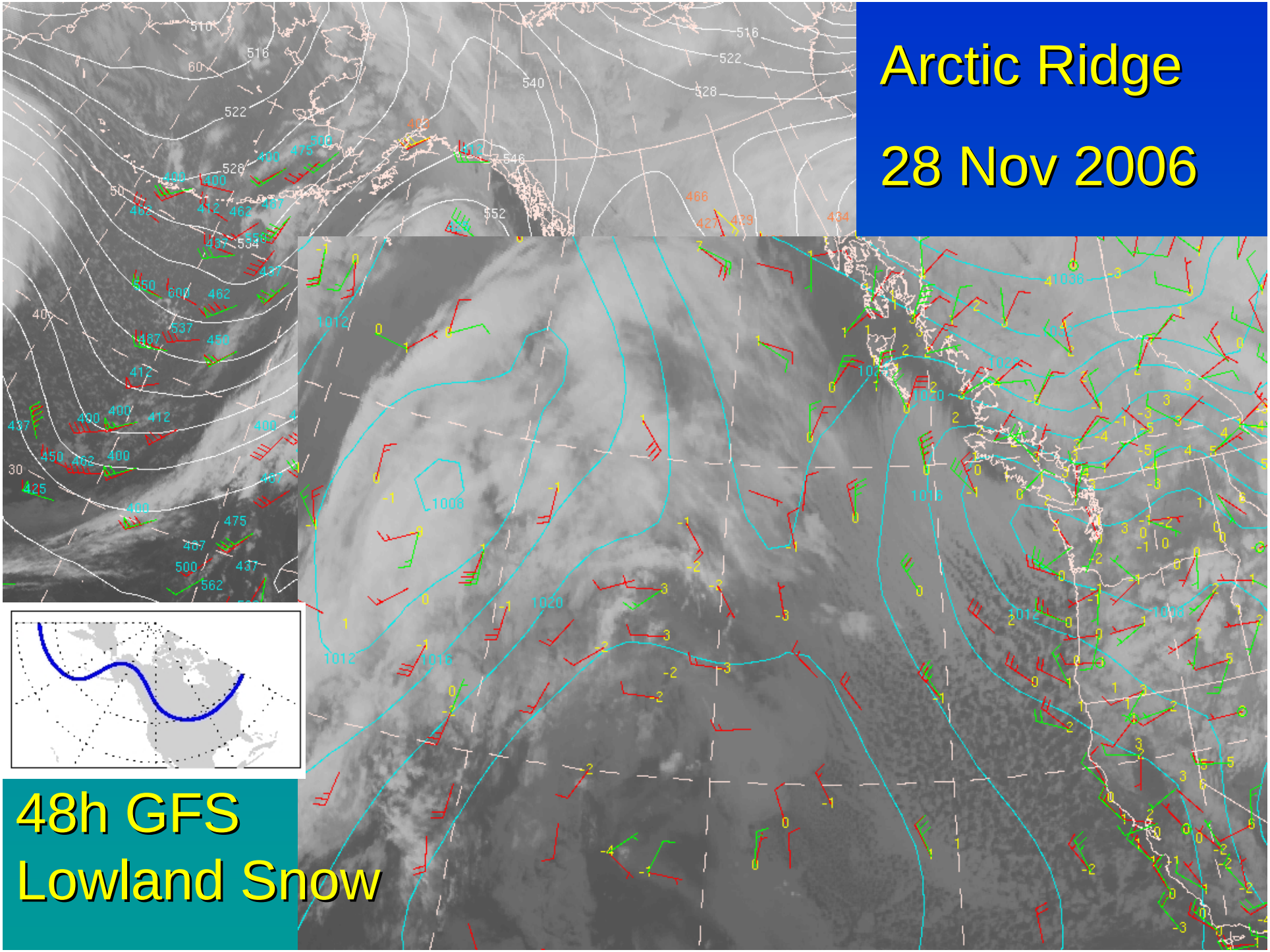


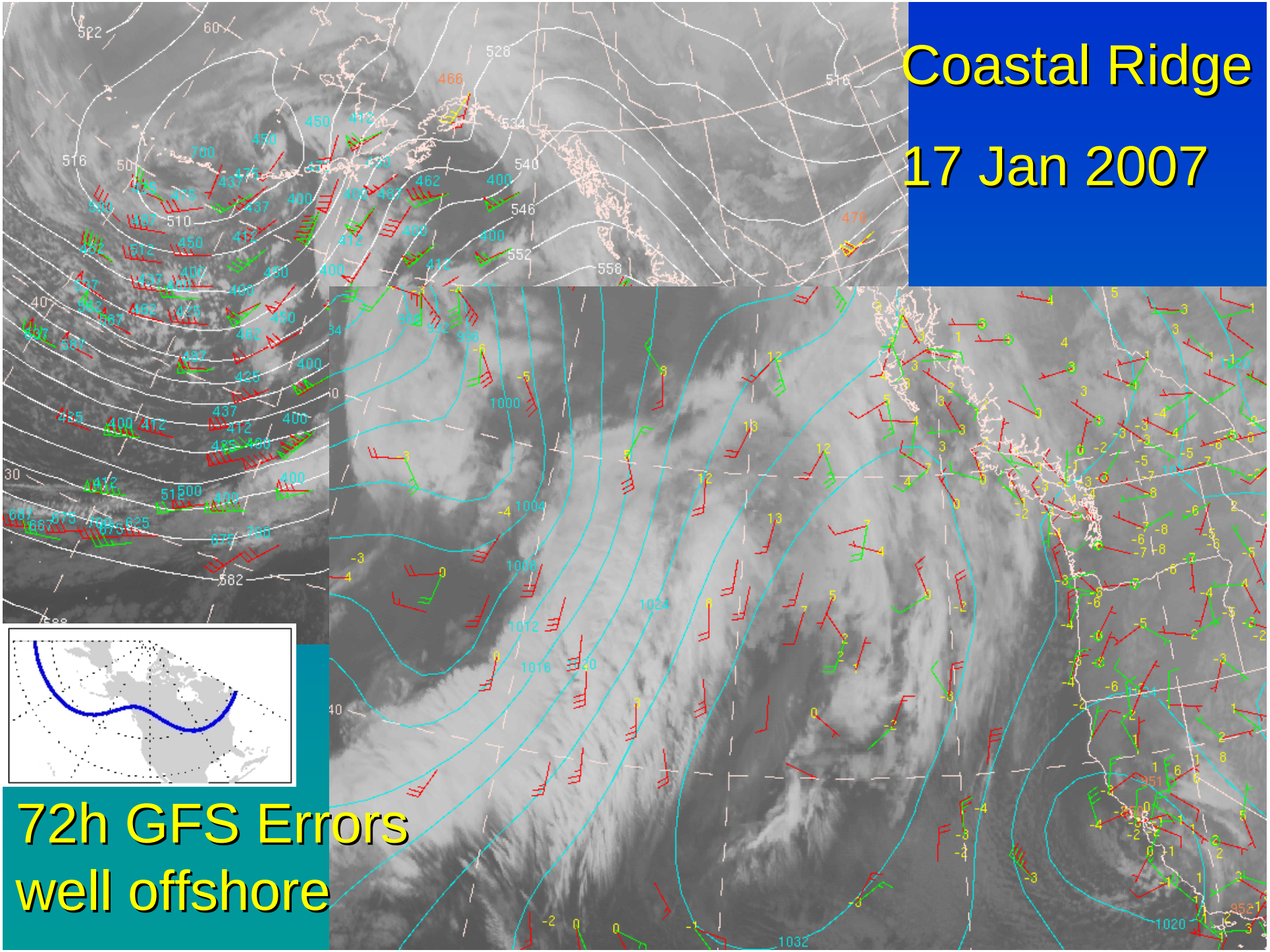


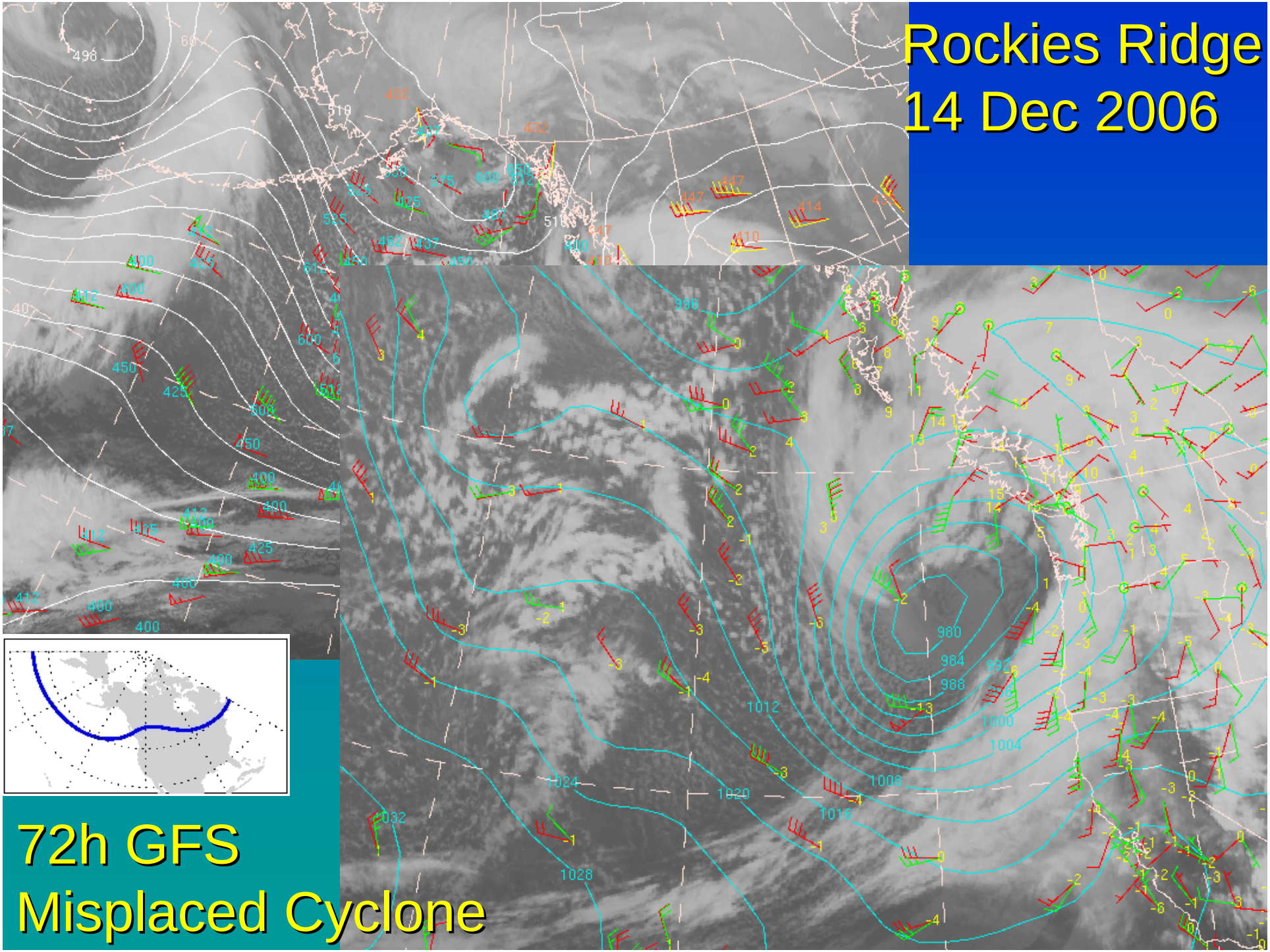
Implications

- The statistical evidence here demonstrates that upper level flow shape modulates the observed forecast errors (i.e. RR regime)
- Processes of downstream development, amplification of jet still contribute to error growth and propagation, but large errors on west coast are not limited to these processes alone – initial condition errors may still dominate
- There are other ways to quantify forecast errors: sensitivity fields, ensemble spread. Can these results be reproduced using these metrics?

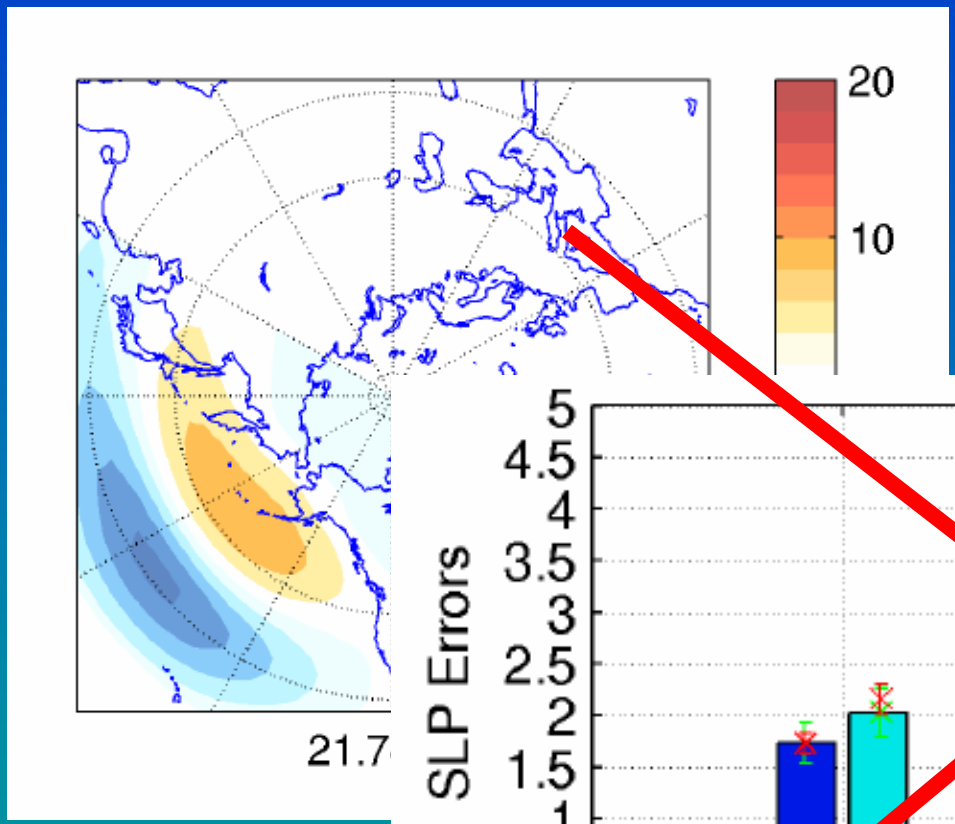

Offshore Trough
15 Nov 2006
48h GFS
Misplaced Cyclone


Arctic Ridge
28 Nov 2006
48h GFS
Lowland Snow

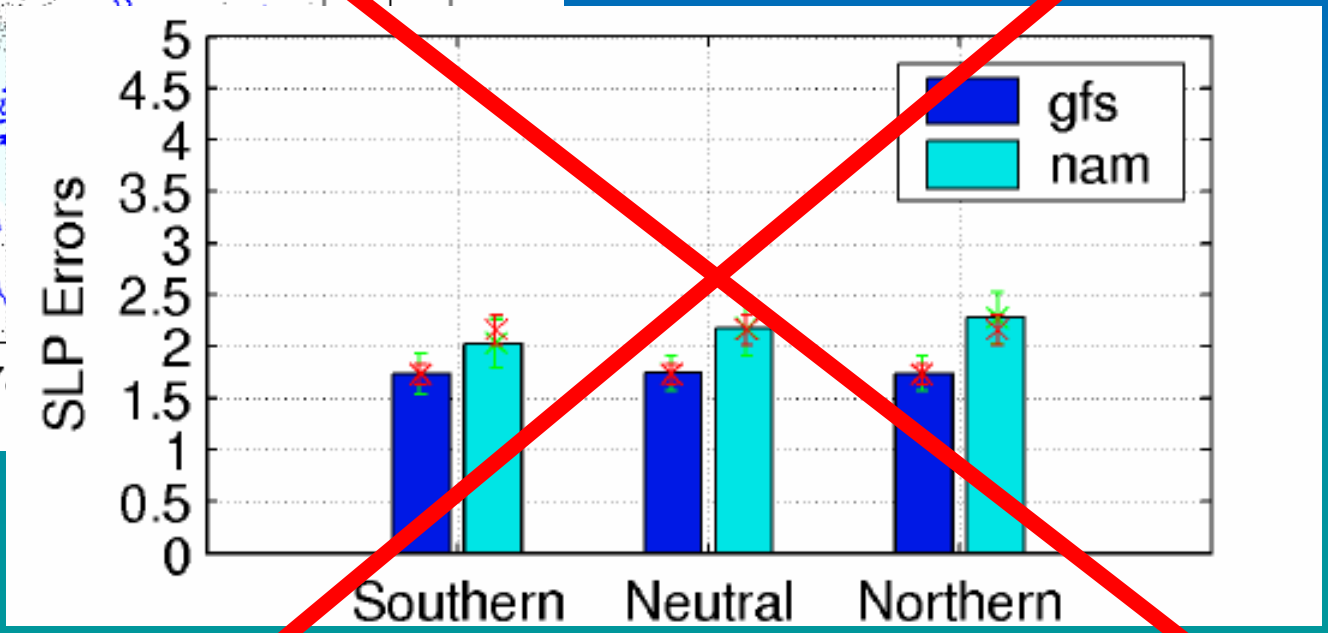

Coastal Ridge
17 Jan 2007
72h GFS Errors
well offshore


Rockies Ridge
14 Dec 2006
72h GFS
Misplaced Cyclone

Principle Component Analysis

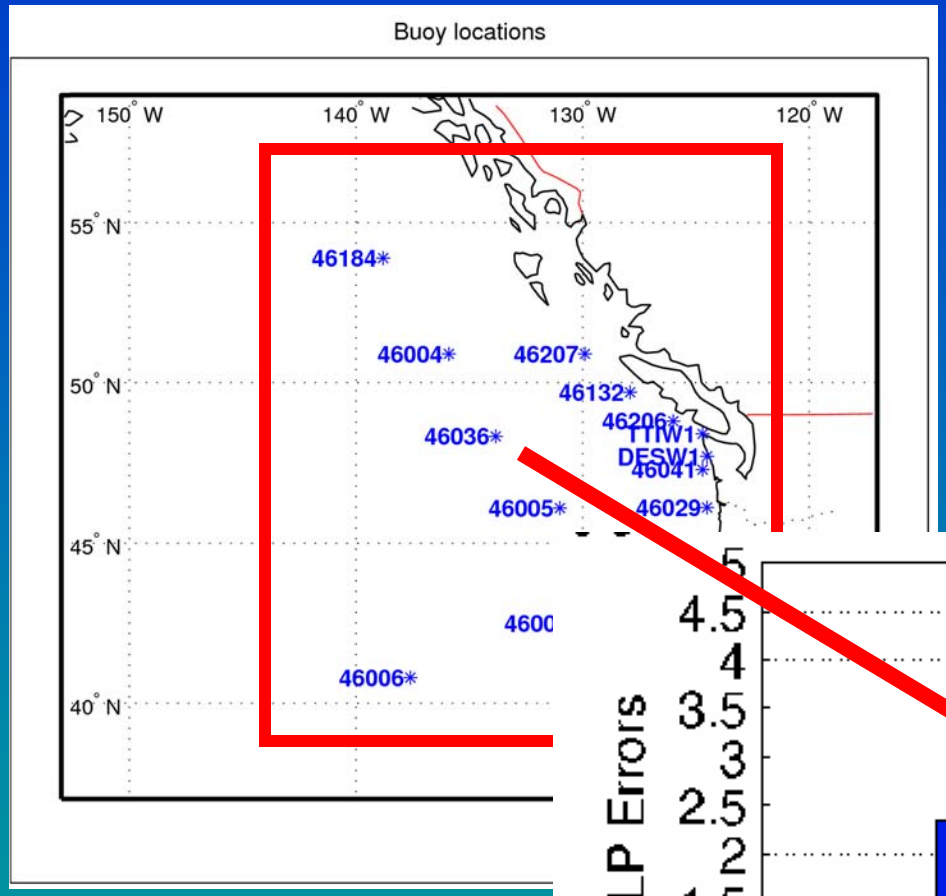


1st EOF
Northern/Southern Jet



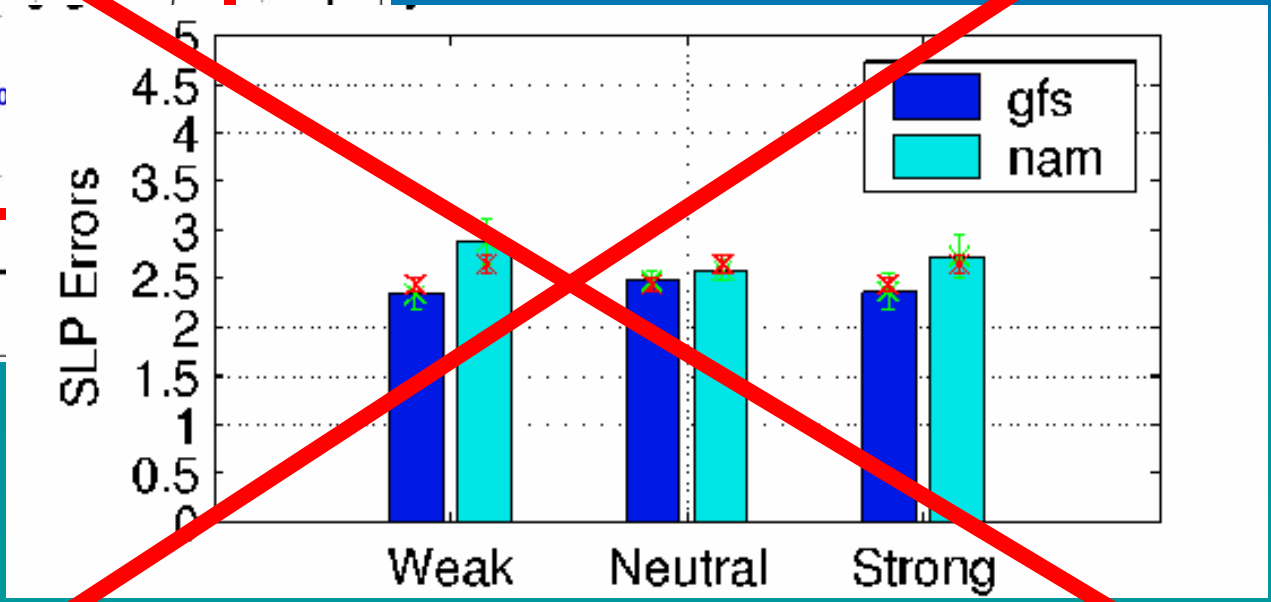
No Difference

Jet strength in Box



Separate dataset into weak/neutral/strong 300 hPa zonal windspeed.

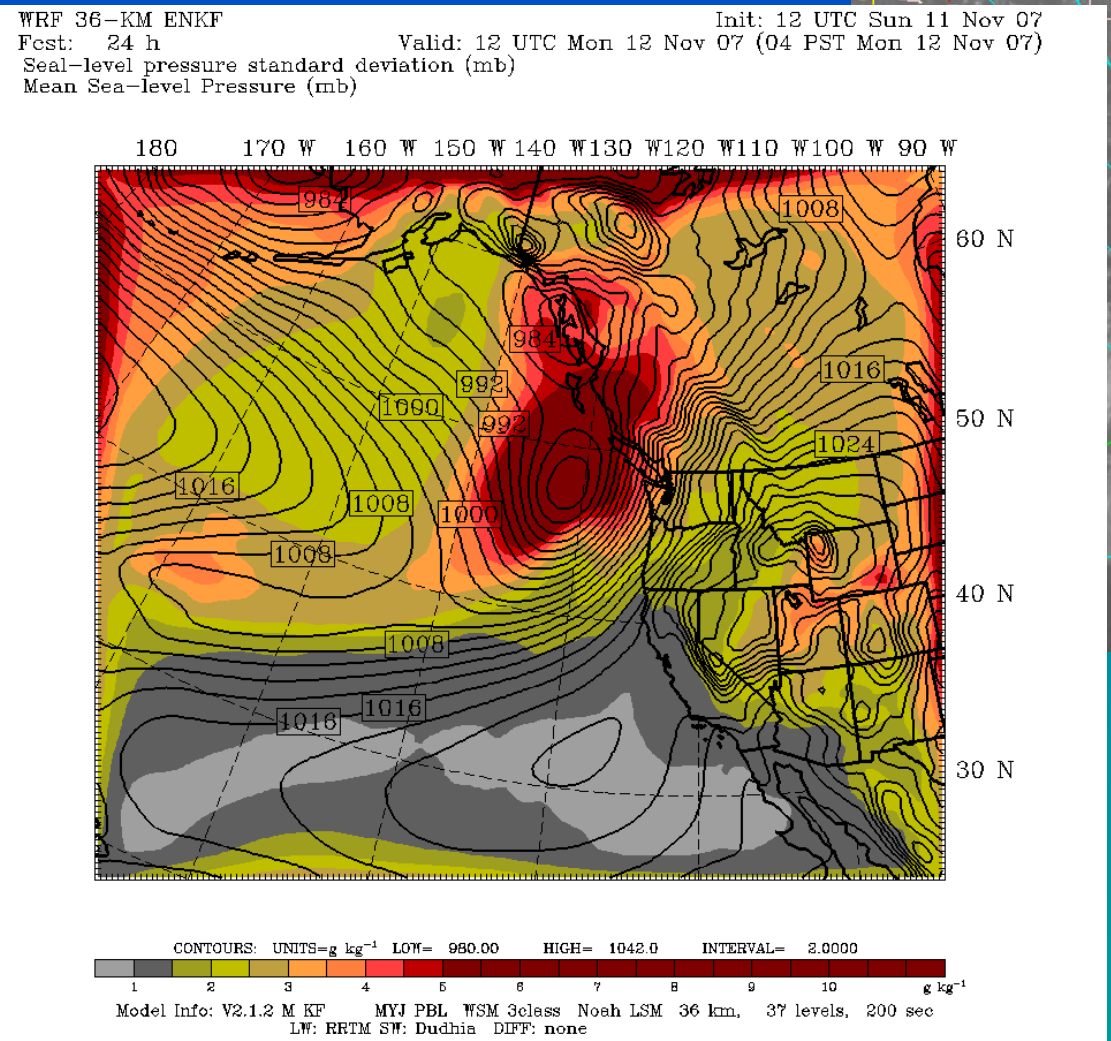
Calculate MAE SLP for each category

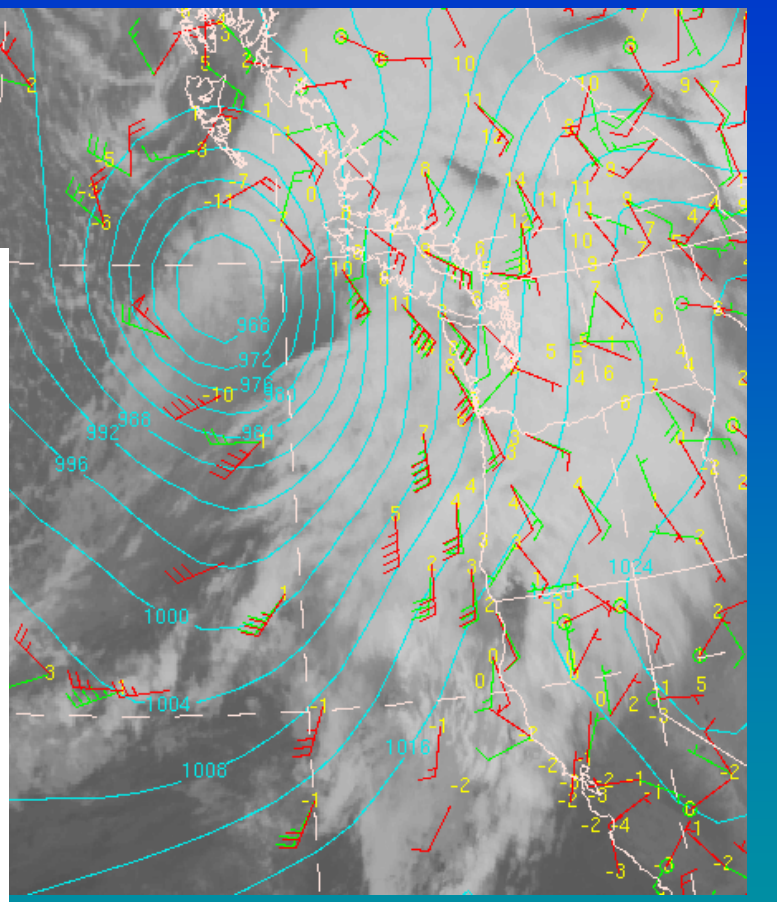


No Difference

48h Forecast GFS 12UTC 12 Nov

48h EnKF SLP spread …





24h Spread

Courtesy of Greg Hakim, Ryan Torn, Brian Ancell