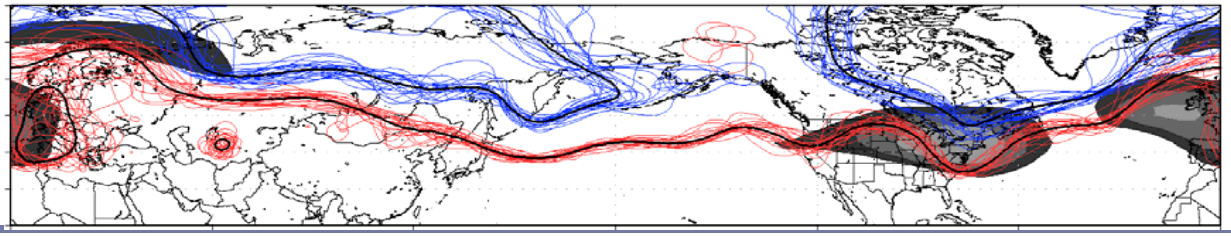
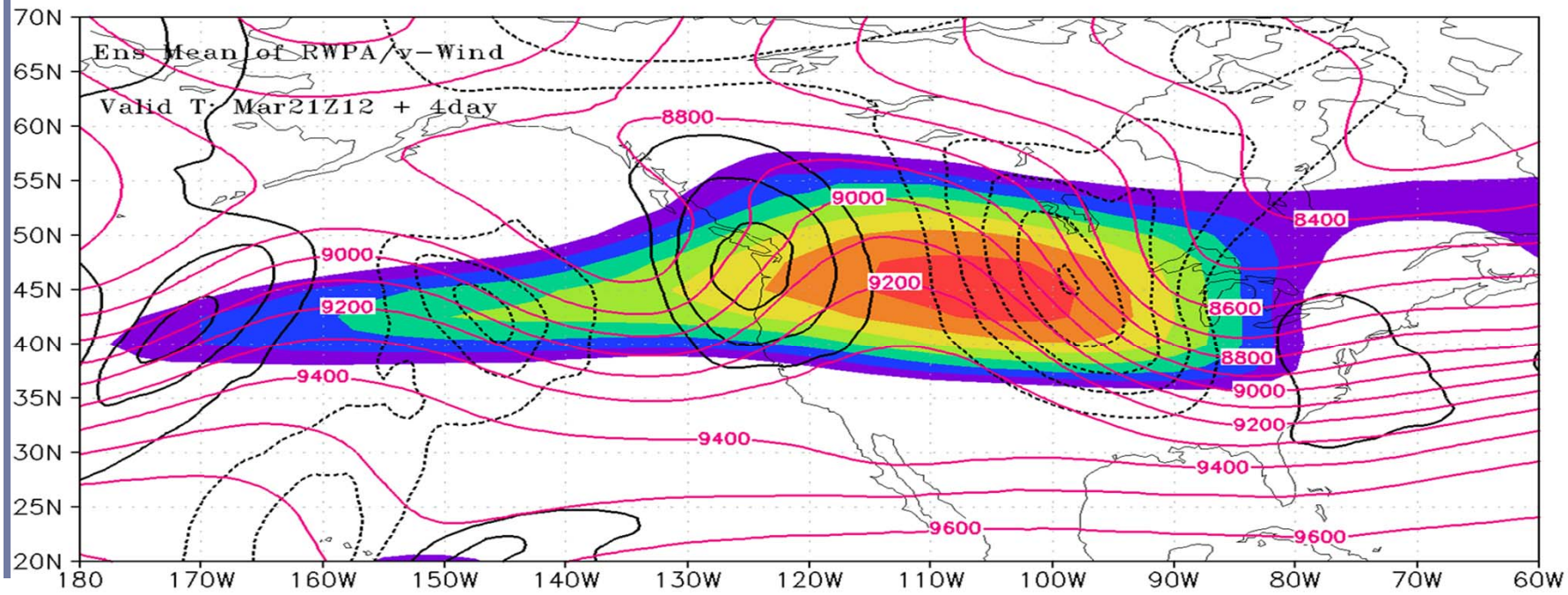


Stony Brook University
School *of* Marine and Atmospheric Sciences

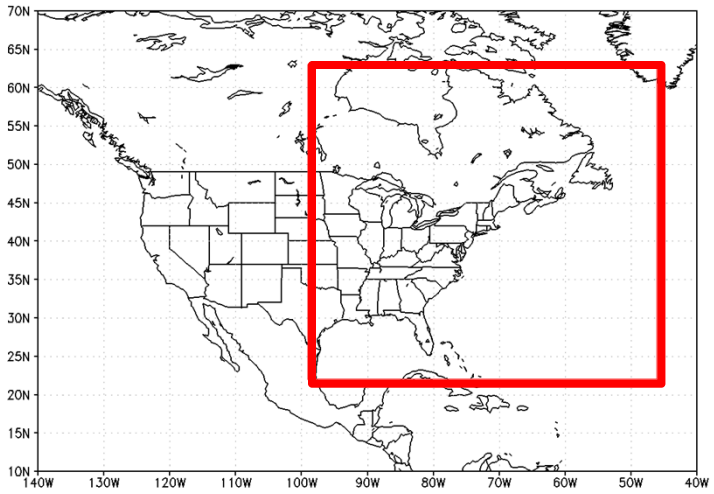
Investigating medium-range forecast uncertainty and large error cases along the East coast using ensemble and diagnostic tools

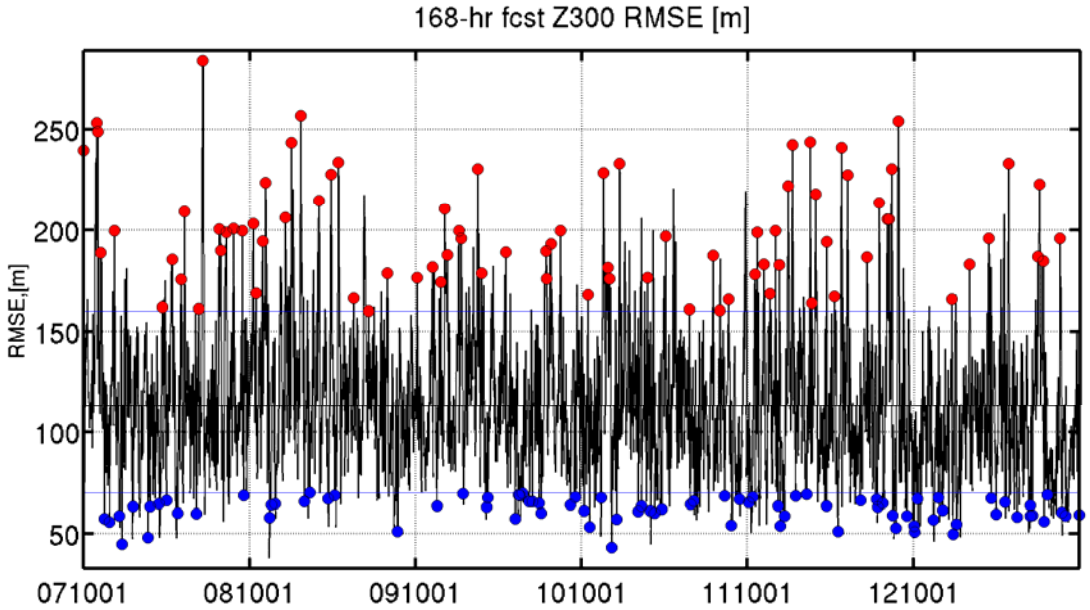
- Minghua Zheng, Brian Colle, and Edmund Chang
- School of Marine and Atmospheric Sciences, Stony Brook Univ.



Sponsor: NOAA/CSTAR

Motivation— Day 7 large errors in the GFS over eastern U.S. and western Atlantic from 2007-2013



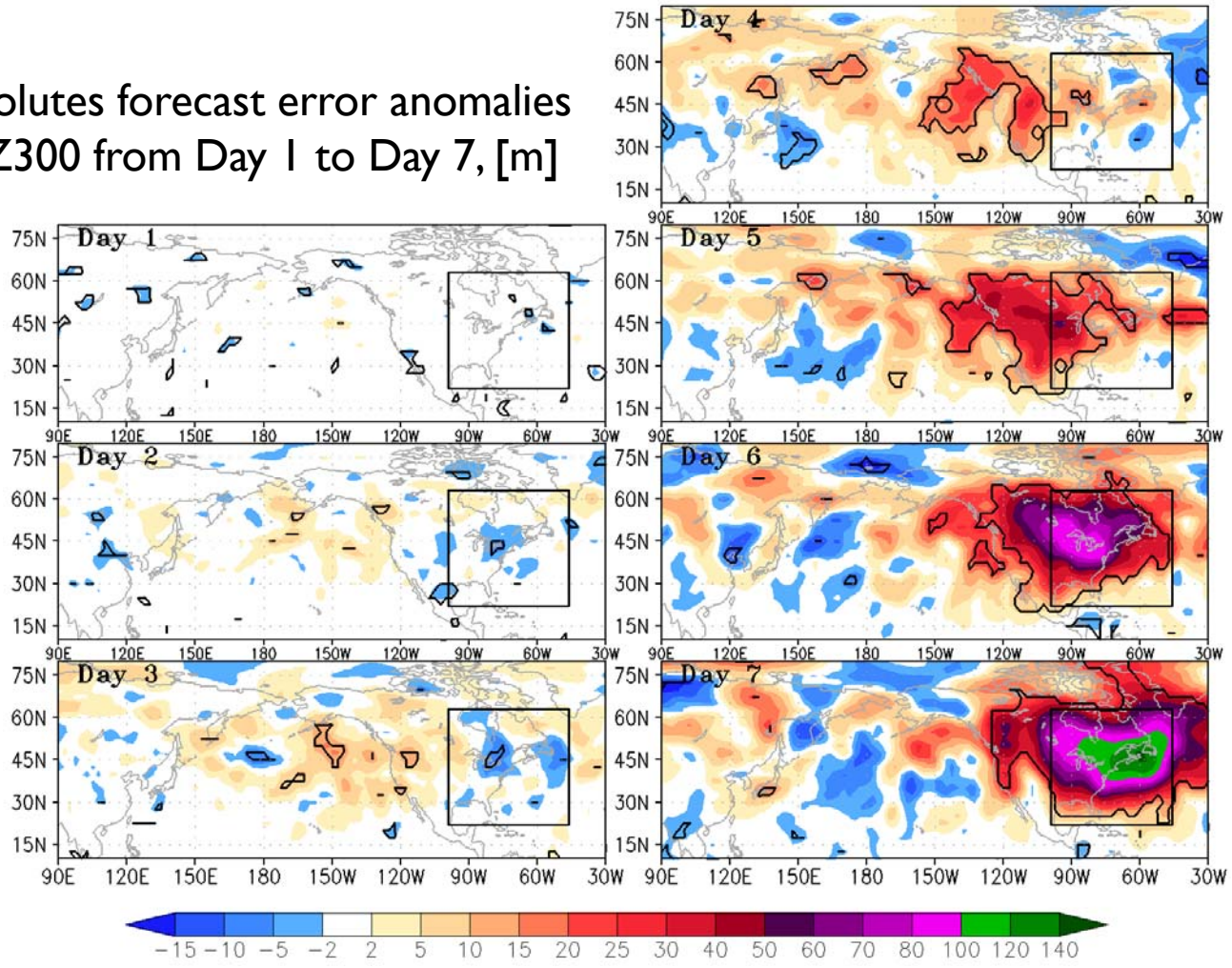


- Definition of dropouts (busts, red dots):
  - i. 7-day RMSE of Z300 over the box > 160m;
  - ii. Spatial anomaly correlation < 0.4
- Data:
  - i. GFS analysis and 7-day control run forecast for 6 cool seasons (2007-2013);
  - ii. Parameter: geopotential height at 300hPa (Z300)

Questions: what upstream features are associated with these errors?
Are there tools to understand the origin of the errors using ensembles?

Composited time evolutions of absolute error anomalies for dropouts

Absolutes forecast error anomalies of Z300 from Day 1 to Day 7, [m]

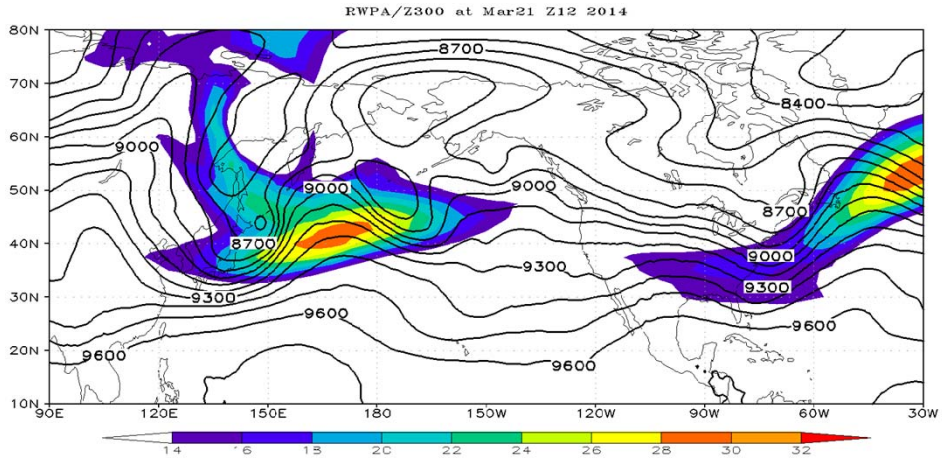


Hypothesis: these errors are associated with upstream systems propagating across eastern Pacific, e.g. Rossby wave packets.

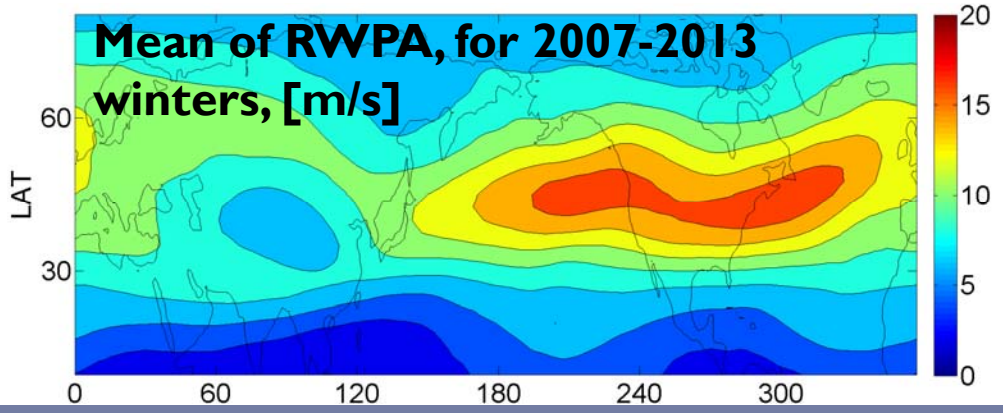
What is Rossby wave packet?

- A wave packet (wave group) refers to a spatially localized region of enhanced wave activity that propagates coherently.
- Mid-latitude baroclinic waves in the atmosphere are organized in Rossby wave packets (RWP).

One RWP example: RWPA(shaded, calculated using v-wind at 300 hPa), Z300 (black contour), [m/s]/[m]



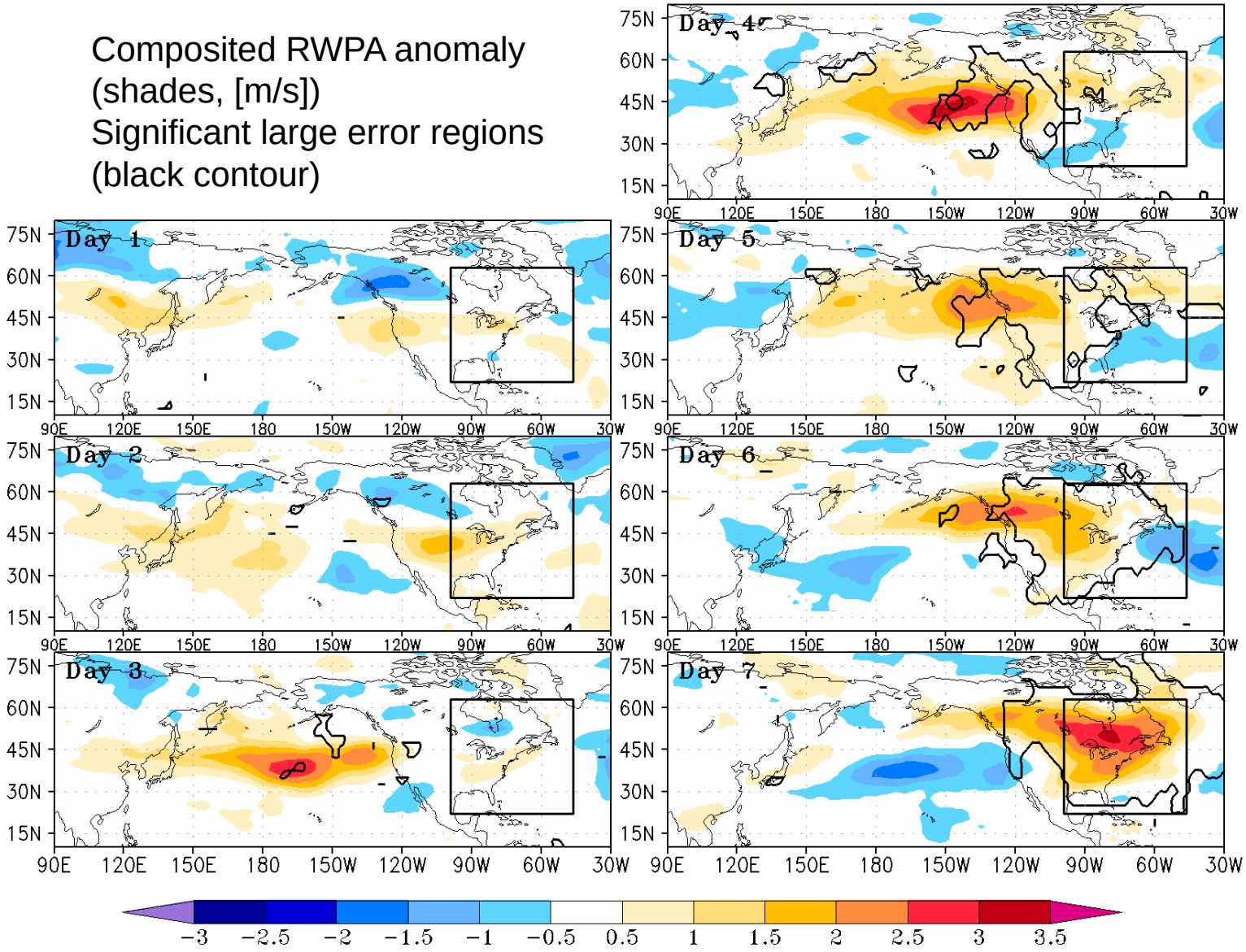
RWPA: RWP amplitude



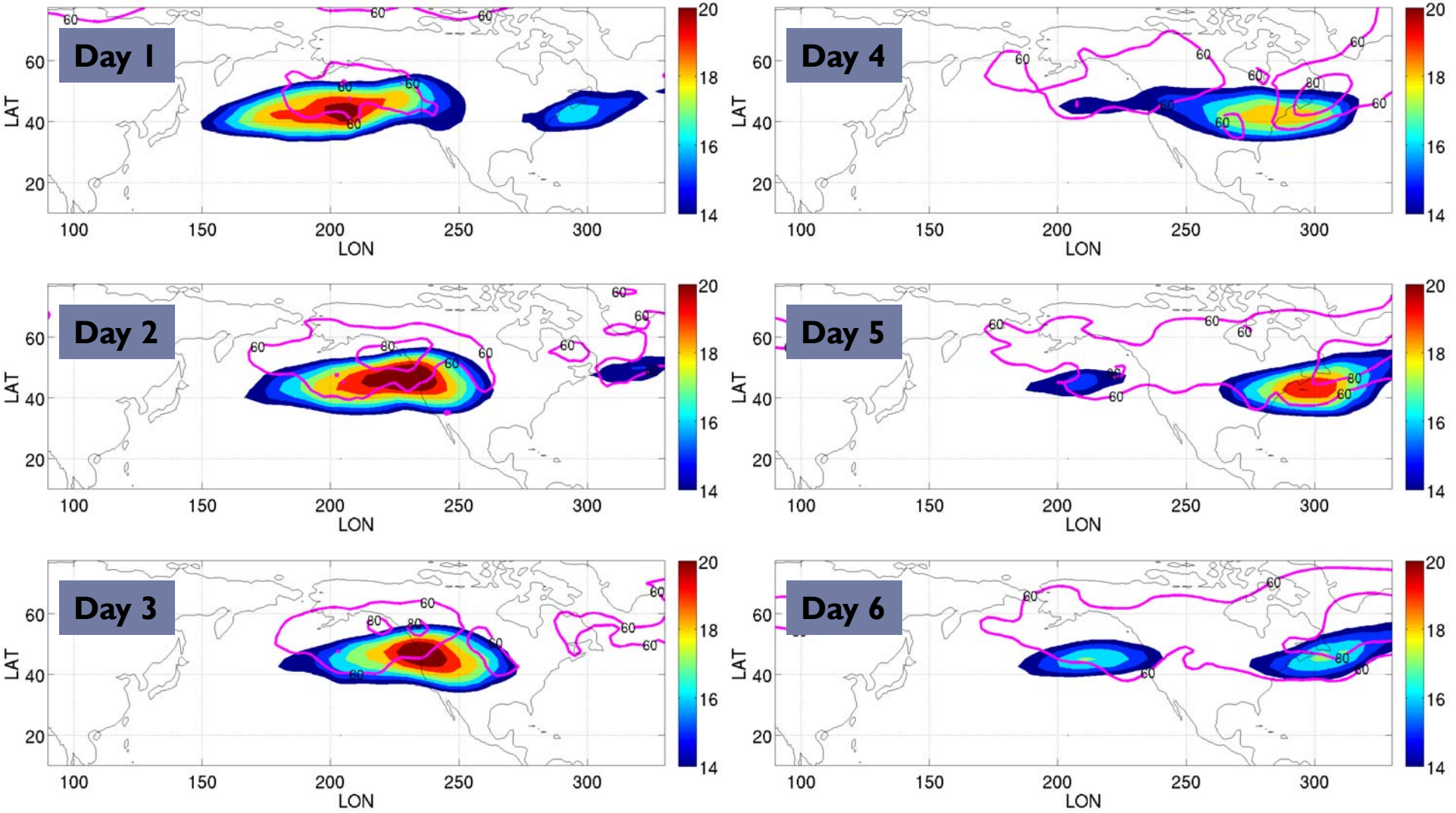
CSTAR GEFS Ensemble Wave Packet website:
Link to http://wavy.somas.stonybrook.edu/wavepackets/home.html

Composited RWPA anomaly and significant large errors for dropouts

Composited RWPA anomaly (shades, [m/s])
Significant large error regions (black contour)



The impact of coherent RWPs on forecast uncertainty of Z300 based on GEFS 20-mem ensemble forecasts from 2007-2013

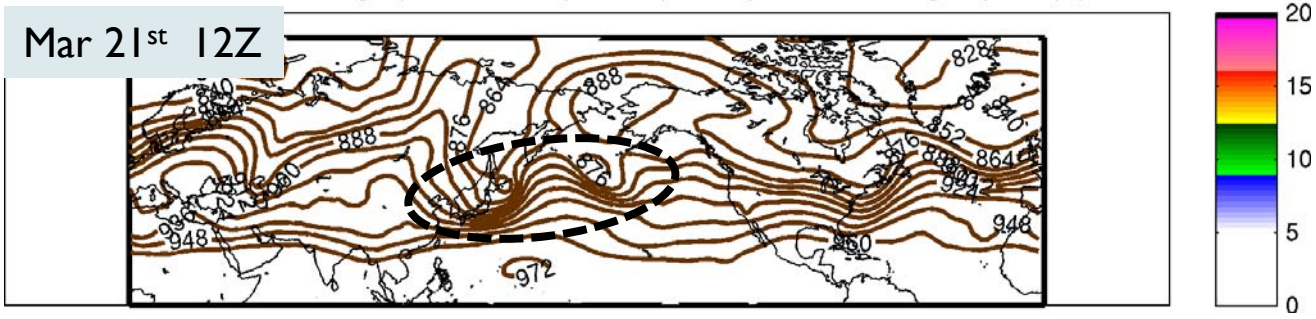


Composited RWPA (shades); normalized ensemble spread (magenta contour); unit: [m/s] and [%]

One example of RWPA and ensemble spread of Z300

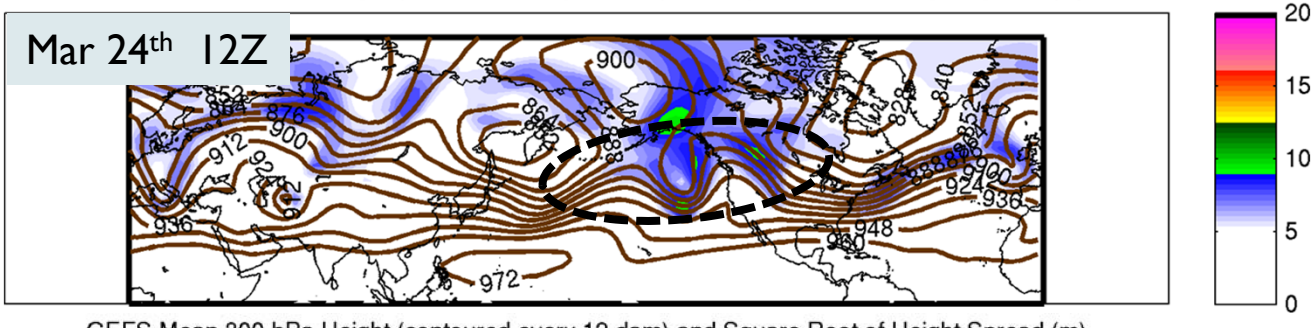
Day 0

GEFS Mean 300 hPa Height (contoured every 12 dam) and Square Root of Height Spread (m)



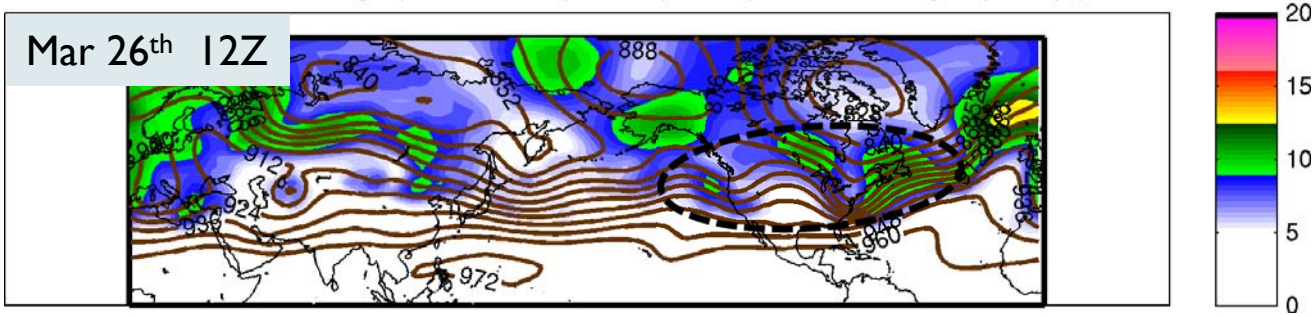
Day 3

GEFS Mean 300 hPa Height (contoured every 12 dam) and Square Root of Height Spread (m)



Day 5

GEFS Mean 300 hPa Height (contoured every 12 dam) and Square Root of Height Spread (m)



http://wavy.somas.stonybrook.edu/wavepackets/archive/2014032112/NH/GEFS.html

An introduction to ensemble sensitivity analysis

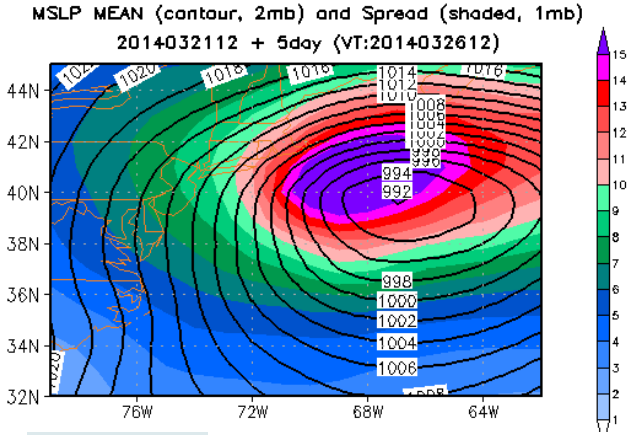
- There is a need of the ensemble tool for the forecasters to investigate upstream structures leading to downstream uncertainties and potential large errors/spread.
- Ensemble sensitivity analysis: (Hakim,2008,2009)

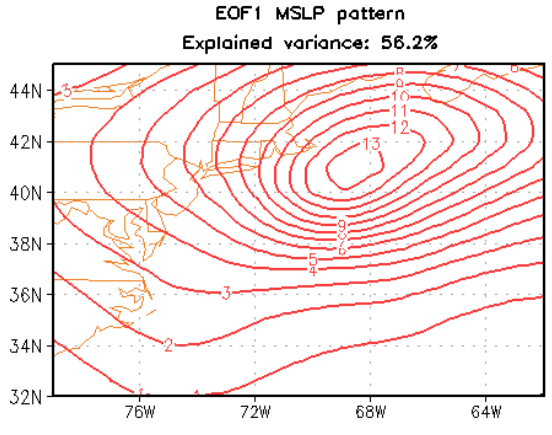
$$\text{sensitivity} = \frac{\text{cov}(\mathbf{J}, \mathbf{X}_i)}{\sqrt{\text{var}(\mathbf{X}_i)}}, \qquad (1)$$

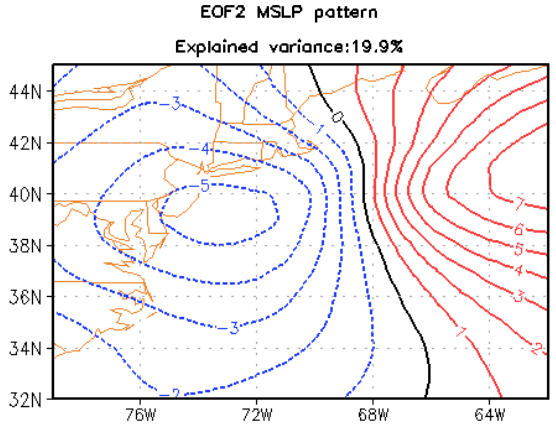
"Sensitivity" = *Corr(J,Xi)* when var(J)=1

- Choices of forecast metrics (*J*): EOF PCs of ensemble forecasts, projection coefficients of forecast jump pattern at valid time, … (ref: Zheng et al 2013)
- Choices of state vector (*Xi*): ensemble geopotential height at 500 hPa, ensemble mean sea level pressure, …

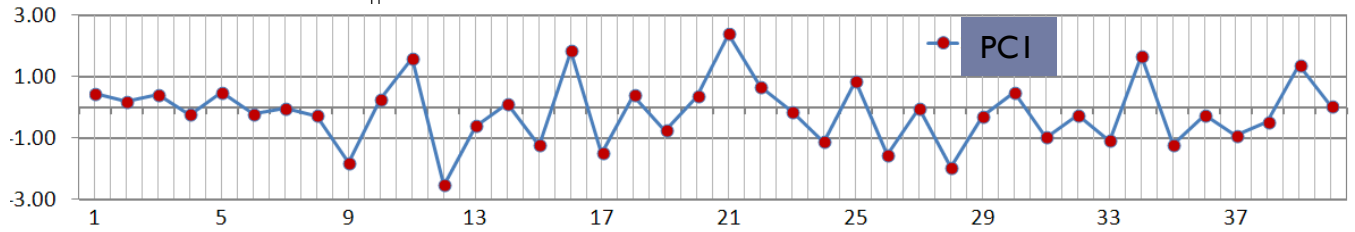
Case study 1: **Mar 26th, 2014 potential Eastern US Winter Storm** using NCEP+CMC 40-mem ensembles





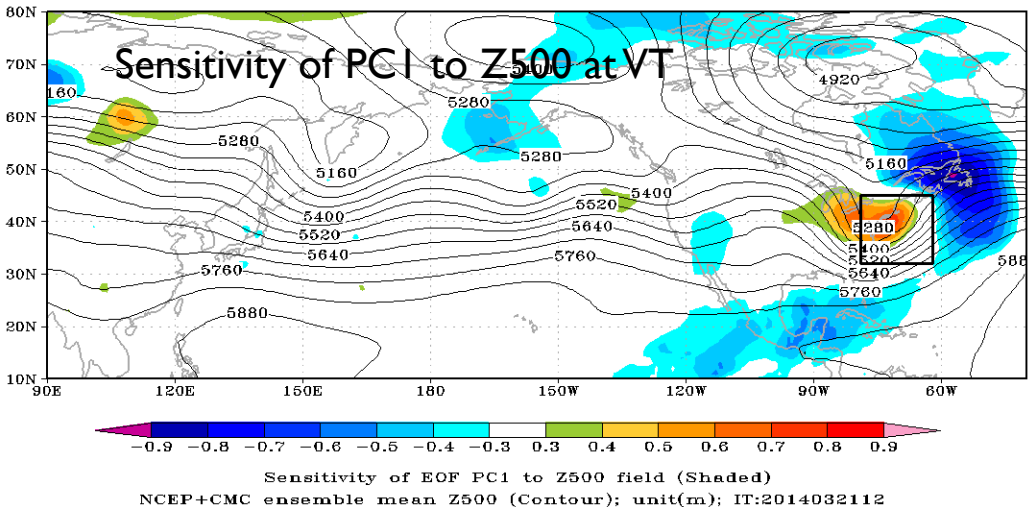


FCST Metric (*J*)



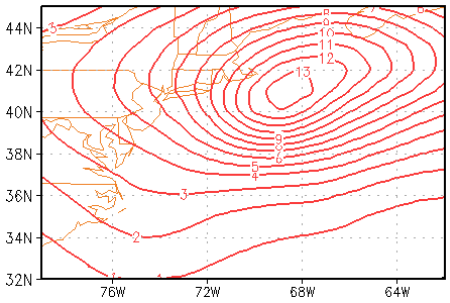
+J➔+EOF1
-J➔-EOF1

Correlation (PC1, Z500 at VT)



The sensitivity of PC1 to Z500 for NCEP+CMC 40-mem ensembles. VT: 2014Mar26Z12, IT: Mar 21Z12; 5-day fcst

EOF1 MSLP



Positive: Z500↑
➔**PC1↑➔Enhancement of weaker cyclone**
Negative: Z500↑
➔**PC1↓➔Enhancement of stronger cyclone**

Summary

Stony Brook University
School *of* Marine and Atmospheric Sciences

- ✓ 7-day forecast large error cases over eastern US and western Atlantic ocean are associated with the existence of enhanced Rossby wave packets propagating across central and eastern Pacific.
- ✓ Forecast errors and ensemble spread grow and propagate following RWP centers; after RWPs become mature, errors/spread tend to be maximized over the leading regions.
- ✓ An ensemble sensitivity tool has been applied to ensembles to diagnose the origin of forecast uncertainty. In the Mar 26th, 2014 potential Eastern US Winter storm case, ensemble sensitivity using EOF PC1 suggest that the weaker (deeper) cyclone solution is associated with the weakening (strengthening) of an upstream ridge over northeastern Pacific.
- ✓ We have developed ensemble sensitivity tool on our CSTAR website (http://dendrite.somas.stonybrook.edu/CSTAR/Ensemble_Sensitivity/EnSense_Main.html) in collaboration with the Environmental Modeling Center (EMC) of NCEP.

Stony Brook University
School of Marine and Atmospheric Sciences

Future work

- ✓ Analyze the forecast errors/spread using GEFS reforecast data, and track RWPs in both forecasts and analysis.
- ✓ Examine the impacts of different types/tracks of RWPs on forecast errors/uncertainty.
- ✓ Investigate the characteristics of sensitivity patterns associated with high impact weather (HIW) events.
- ✓ Develop more ensemble sensitivity products using different forecast metrics (e.g., large-scale precipitation), and using multi-model ensembles. The goal is to improve forecasters' understanding of upstream error/uncertainty sources for HIW events.

Acknowledgements

- This work is supported by NOAA-CSTAR (NA10NWS4680003).

Email: Ming.H.Zheng@gmail.com