The Predictability of North American Land-falling Cyclones

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Background

- Atmospheric predictability has been shown to depend on different flow regimes on a variety of scales:

  - Forecast error sensitivity varies with ENSO cycle (Reynolds and Gelaro 2001)

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  - ETKF targeting regions vary with synoptic case (Majumdar et al. 2002)

  - SLP errors vary with large-scale, 500-hPa flow regime (McMurdie and Casola 2009)

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  - Wind
  - Precipitation intensity and type (flooding, water resources, recreation, road weather…)

Research Questions

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2) Are certain levels of cyclone predictability related to synoptic/mesoscale flow patterns or cyclone characteristics?

3) Why is the cyclone predictability for different flow patterns/cyclone characteristics the way it is?

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The "Why" of Cyclone Predictability

- Predictability assessed with forecast uncertainty
  (ensemble forecast spread)

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Ensemble Forecast Spread

Potential for perturbation growth
(Intrinsic predictability)
(Forecast sensitivity!)

Initial ensemble spread

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The "Why" of Cyclone Predictability

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(Forecast sensitivity!)

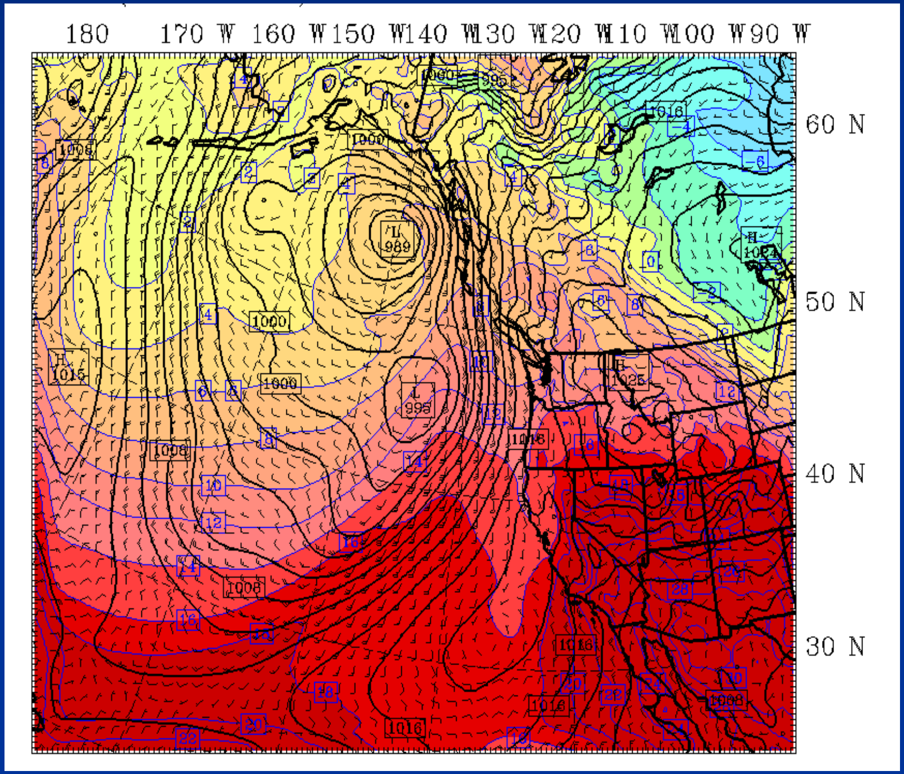
Initial ensemble spread

Eventual links to data assimilation…

Methodology

- Dataset contains EnKF 48-hr forecasts of land-falling cyclones over 3 winters (2008/2009 to 2010/2011) – only 2009/2010 so far…

Methodology - EnKF



36-km Domain

- 80-member WRF-ARW EnKF
- 6-hr update cycle
- Extended forecasts to 48 hours when a cyclone makes landfall
- Extended forecast times chosen from deterministic GFS-WRF forecasts
- Assimilates cloud-track winds, ACARS, radiosonde, and surface data

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→ Characterizes the intrinsic predictability of R

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1) Ensemble sensitivity of the response function R

→ Characterizes the intrinsic predictability of R

2) Ensemble forecast spread of the response function R

→ Characterizes the real predictability of R

Methodology

- Ensemble sensitivity:

$$E = \frac{CV_{R,IC}}{V_{IC}}$$

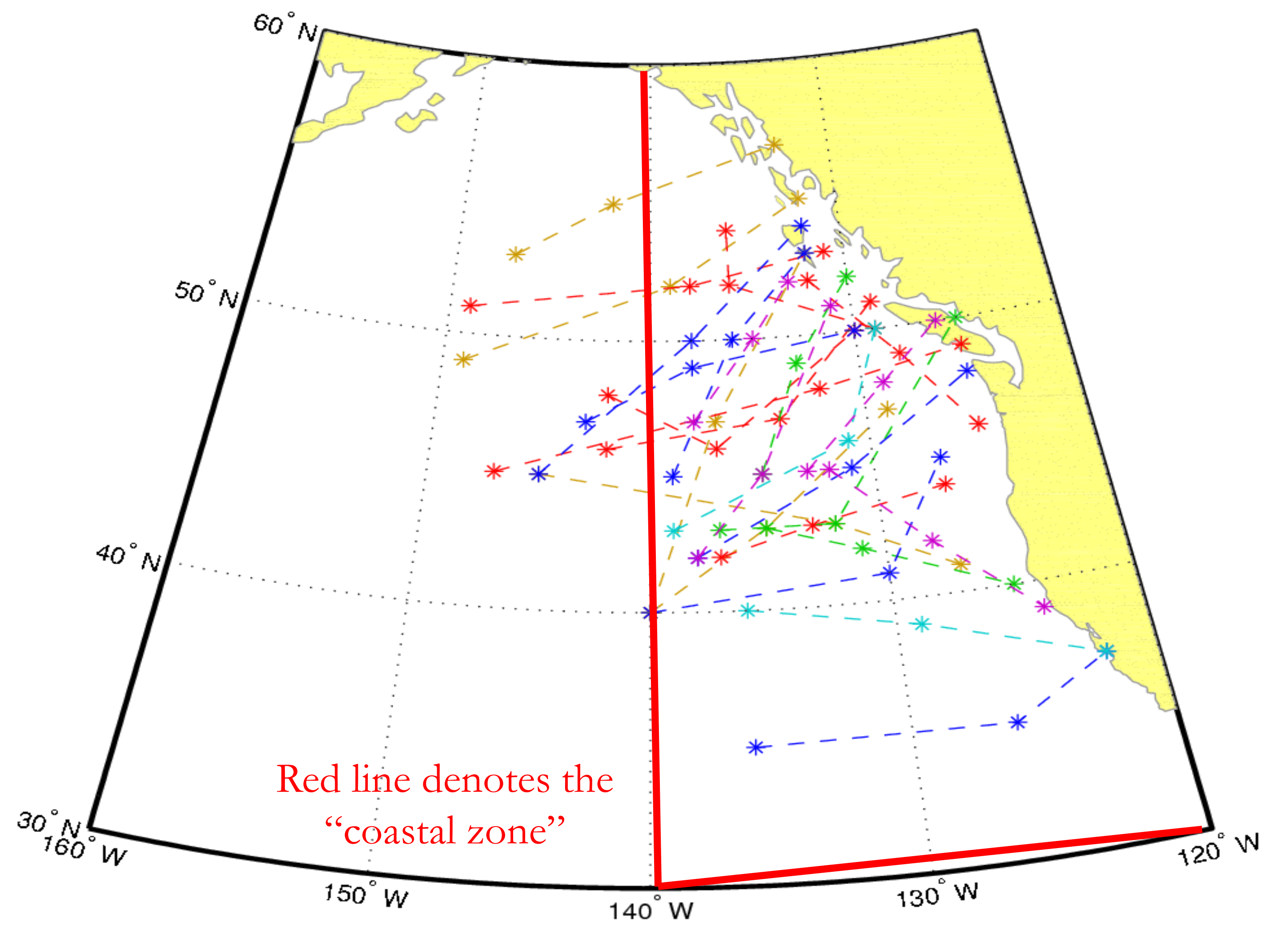
Covariance b/w response function and initial conditions

Variance of initial conditions

Response functions: Average SLP, Average U wind, Average V wind, SLP gradient

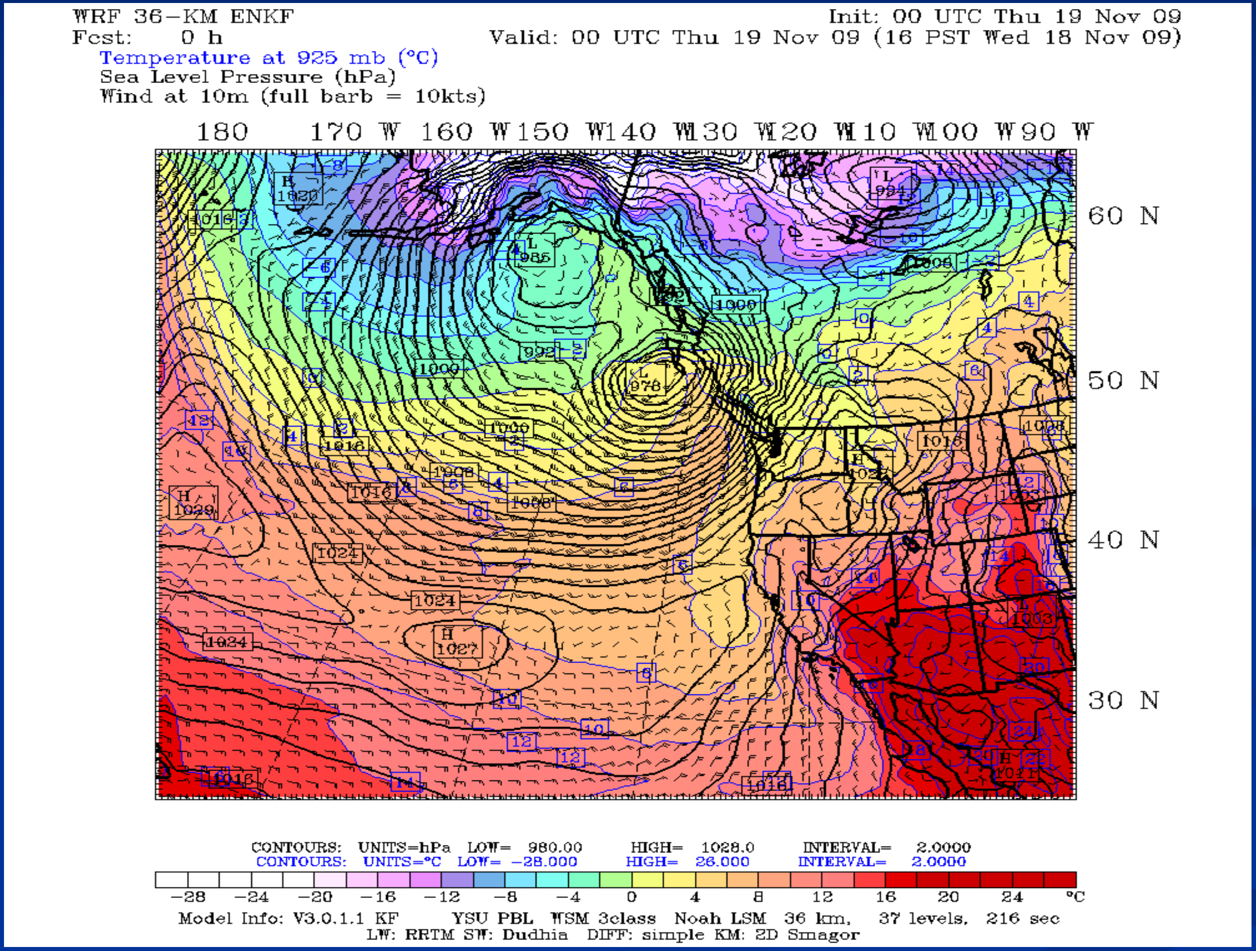
Sensitivity w.r.t.: GPH and Temperature at 300, 500, 700, 850, 925-hPa, and SLP

2009/2010 Season



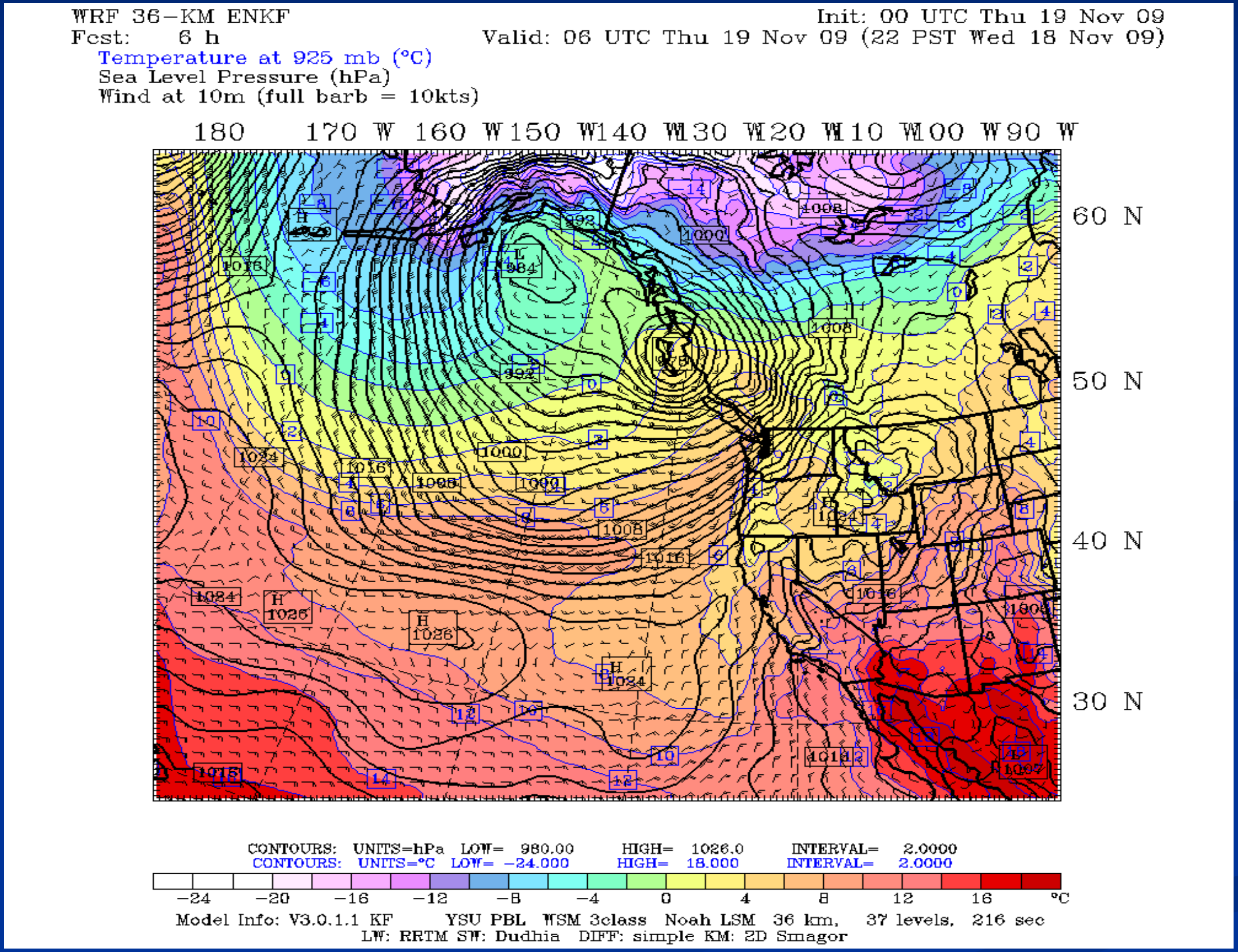
27 Cyclones (cyclones can be in coastal zone at multiple times)

Cyclone Sensitivity Examples – Deepening



Initialized 2009111900 - 00hr Forecast

Cyclone Sensitivity Examples – Deepening



Initialized 2009111900 - 06hr Forecast

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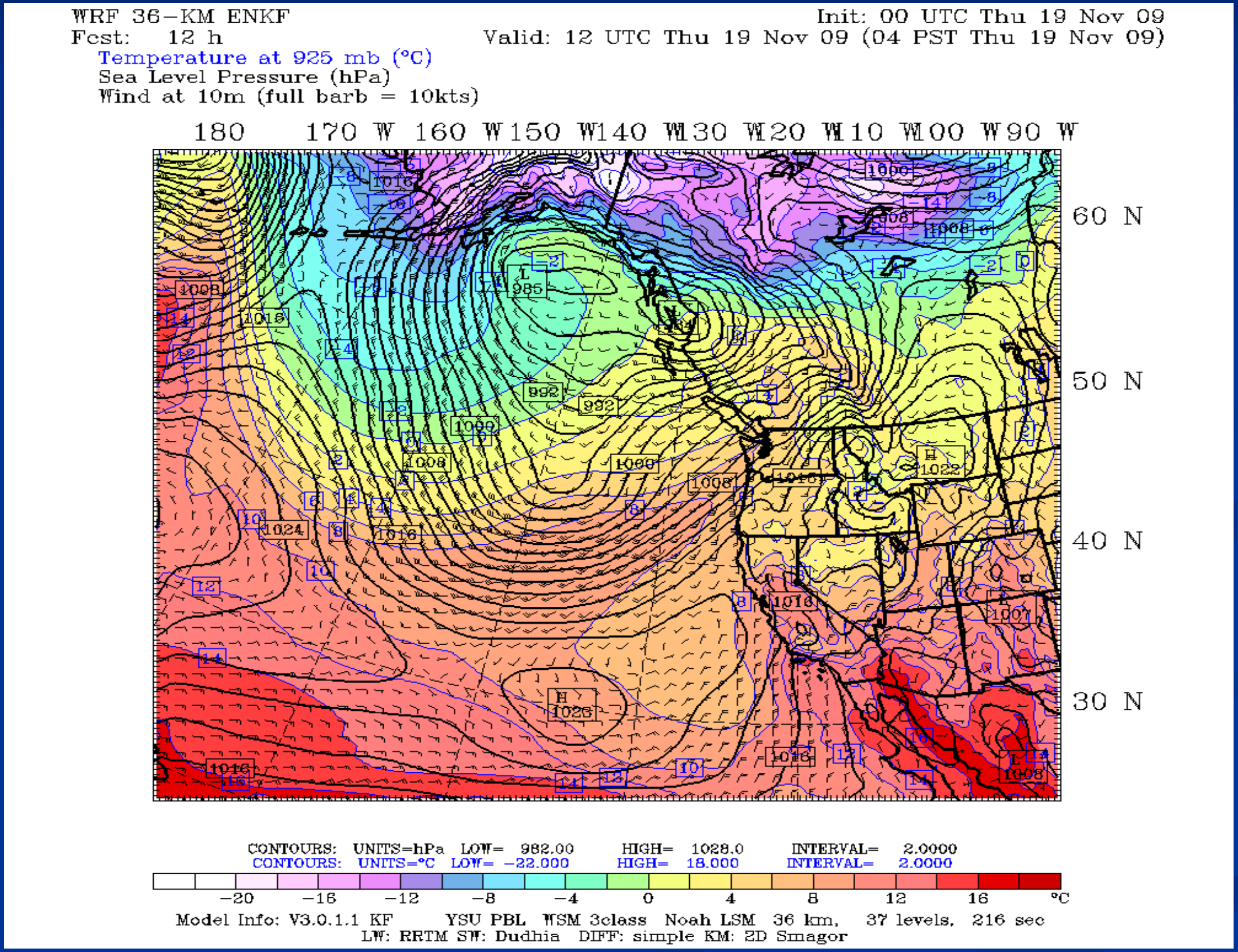
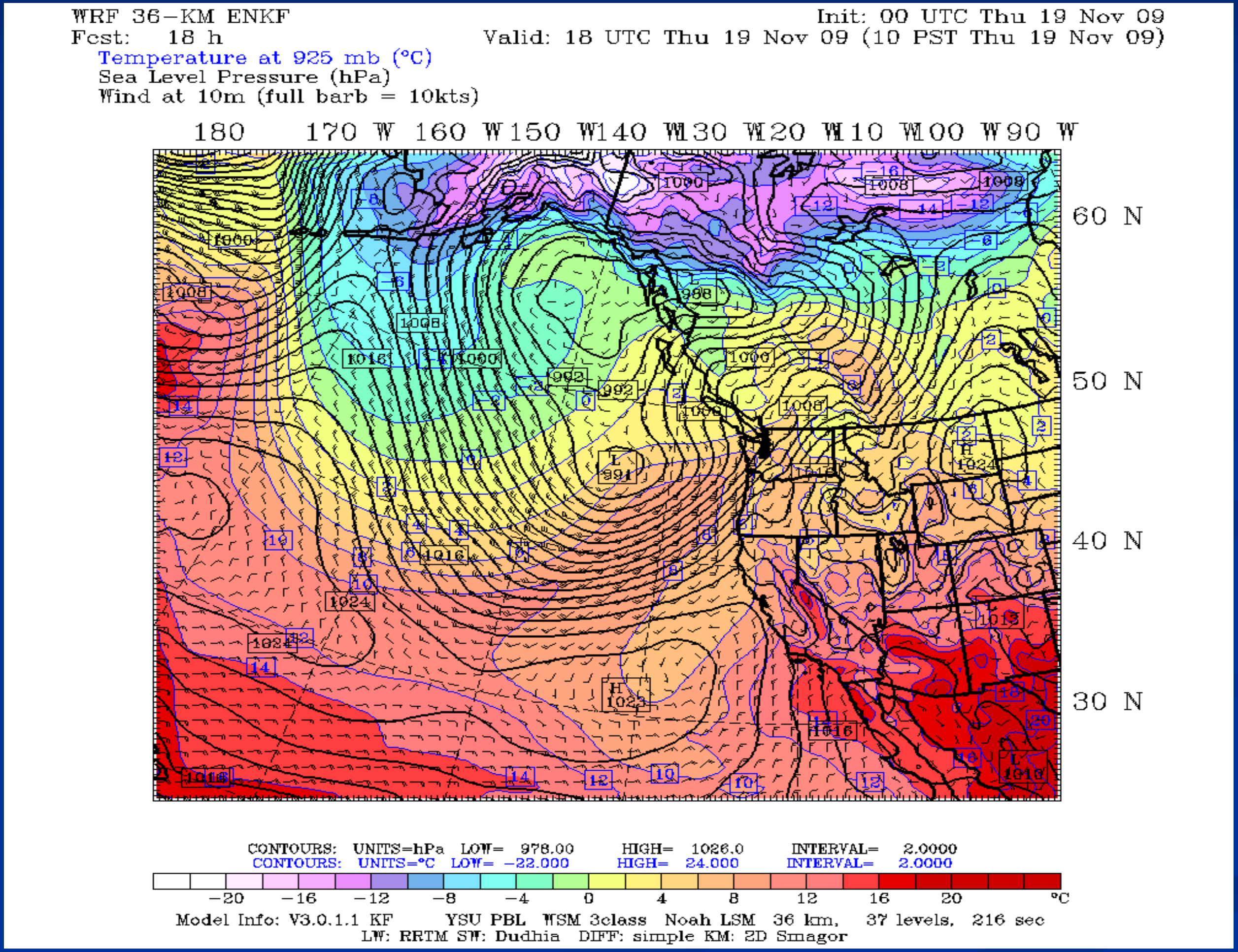


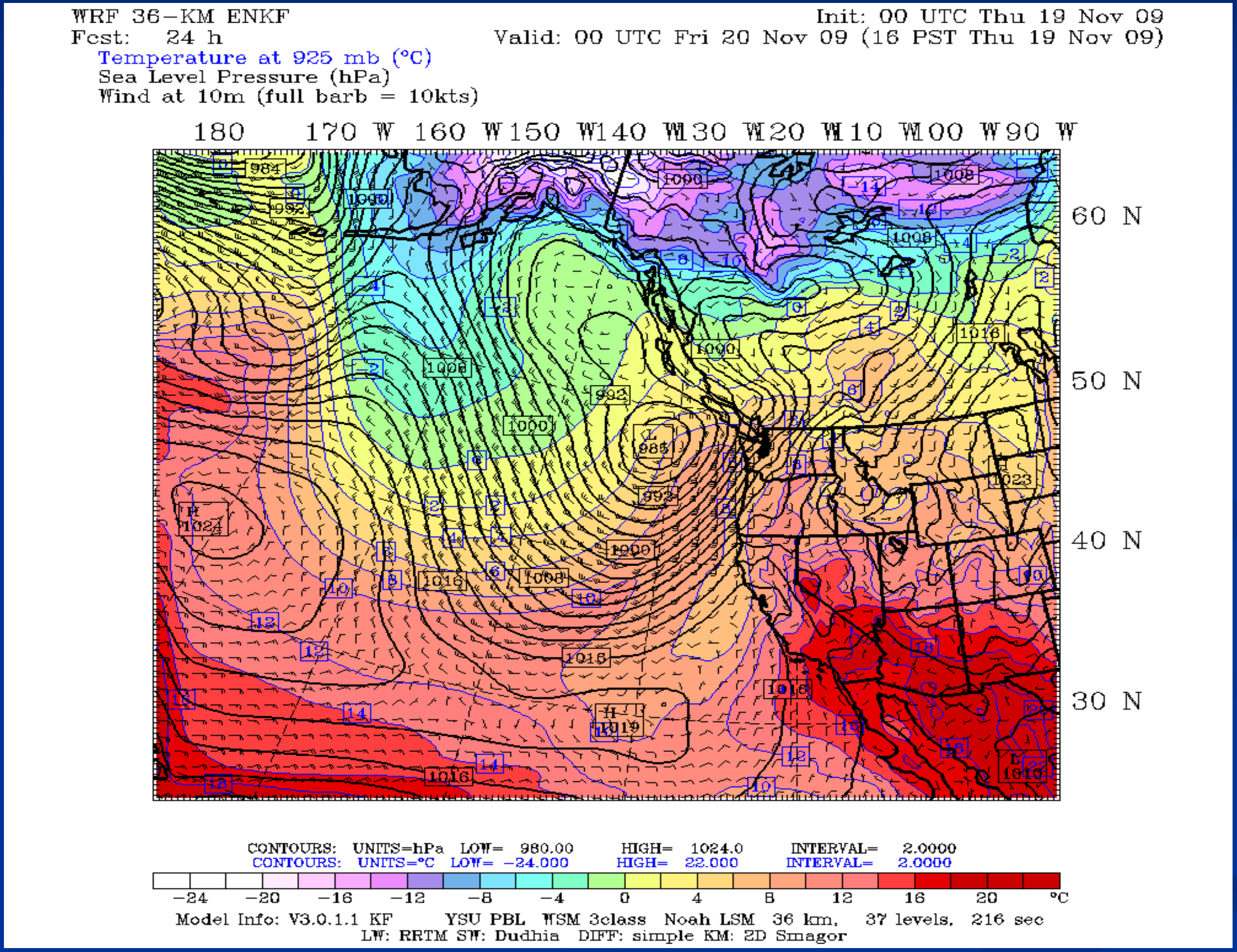
Initialized 2009111900 - 12hr Forecast

Cyclone Sensitivity Examples – Deepening



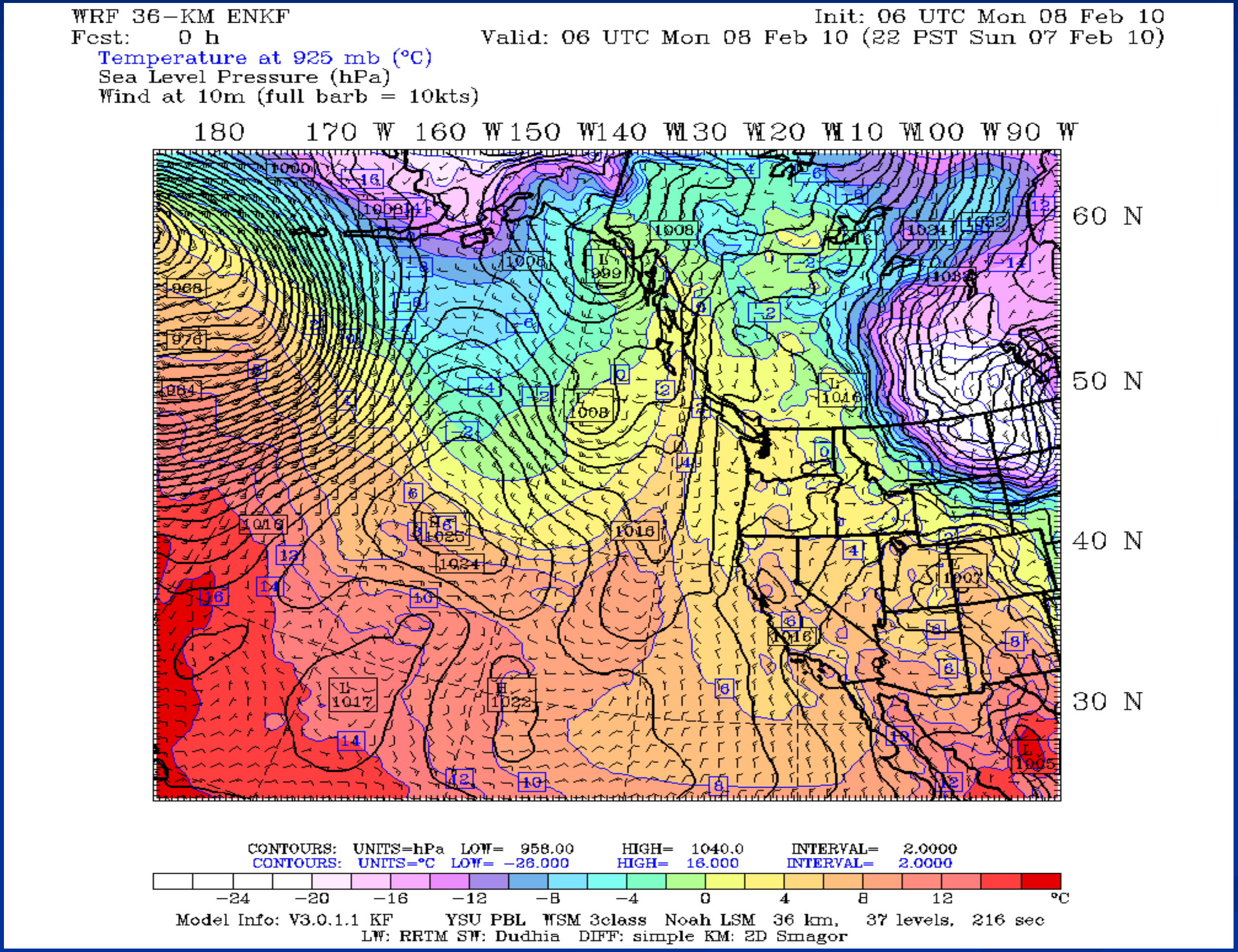
Initialized 2009111900 - 18hr Forecast

Cyclone Sensitivity Examples – Deepening



Initialized 2009111900 - 24hr Forecast

Cyclone Sensitivity Examples – Decaying



Initialized 2010020806 - 00hr Forecast

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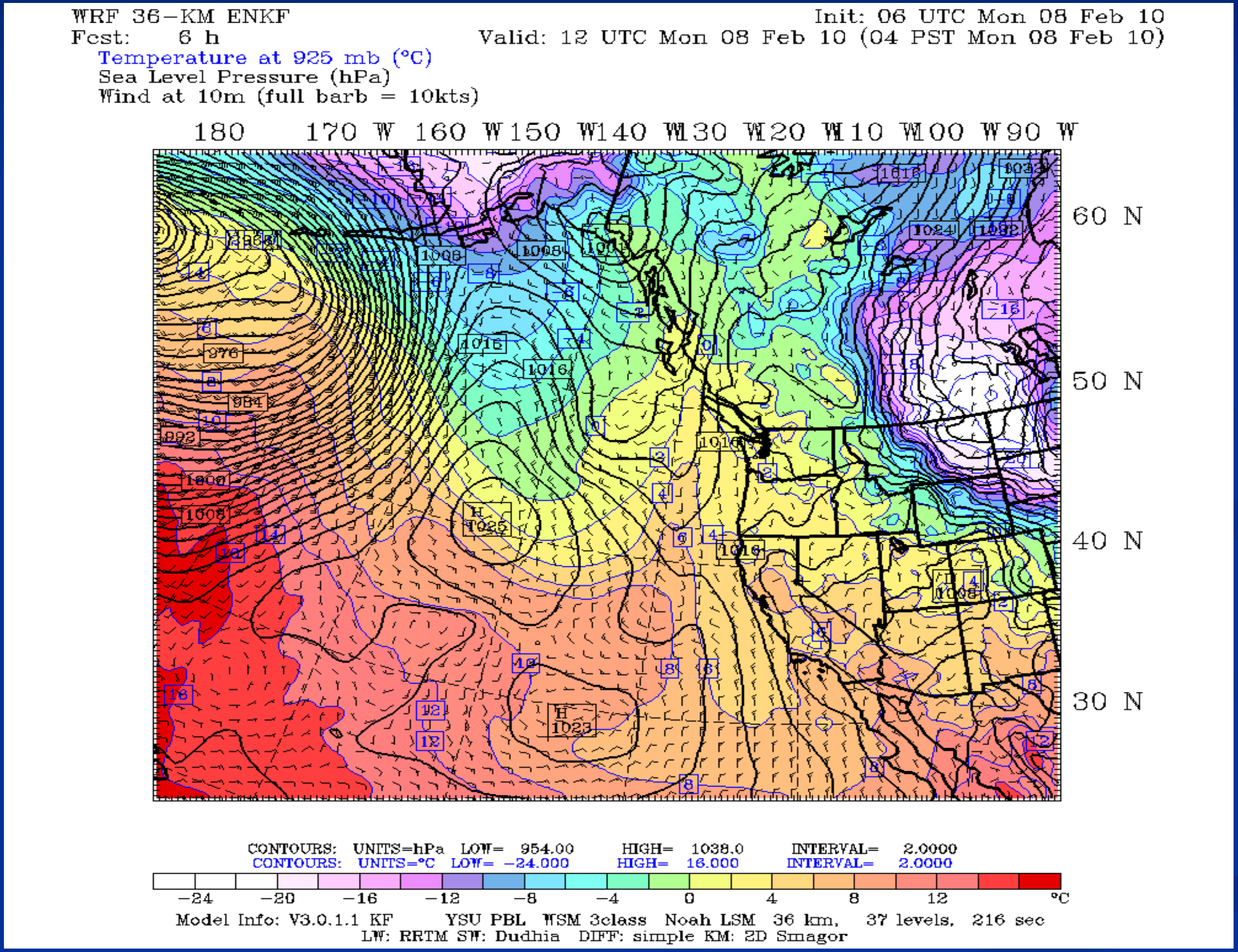

Initialized 2010020806 - 06hr Forecast

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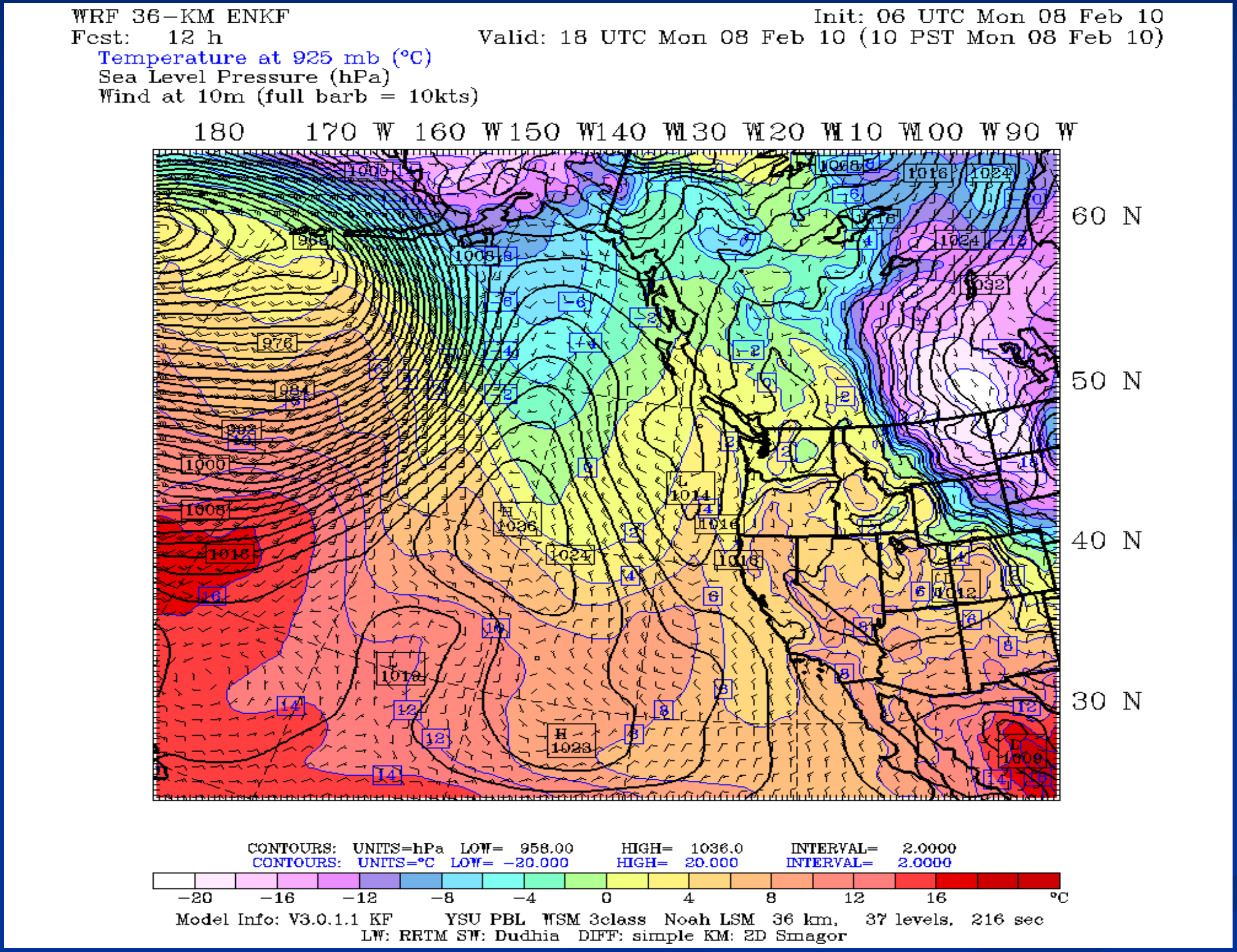

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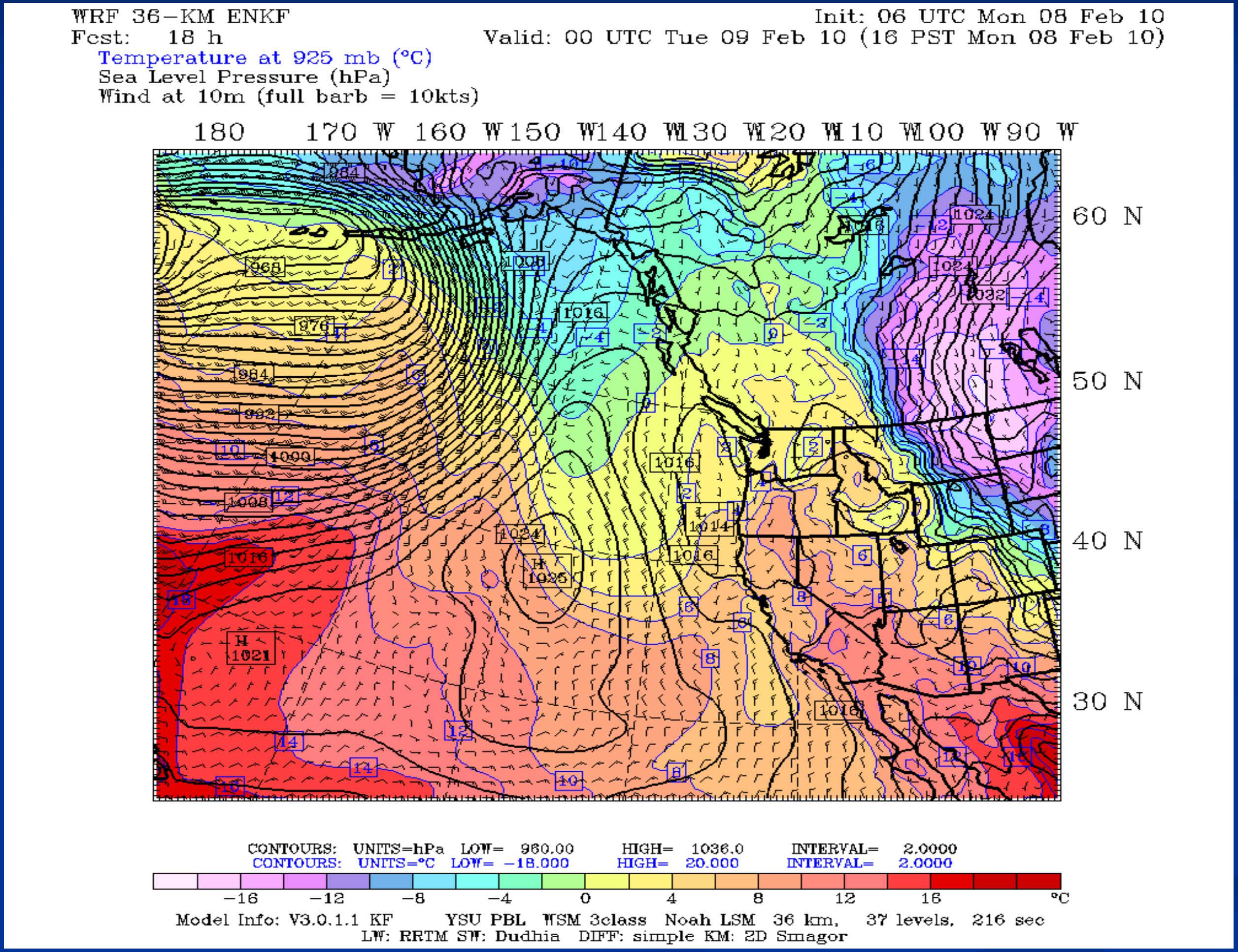

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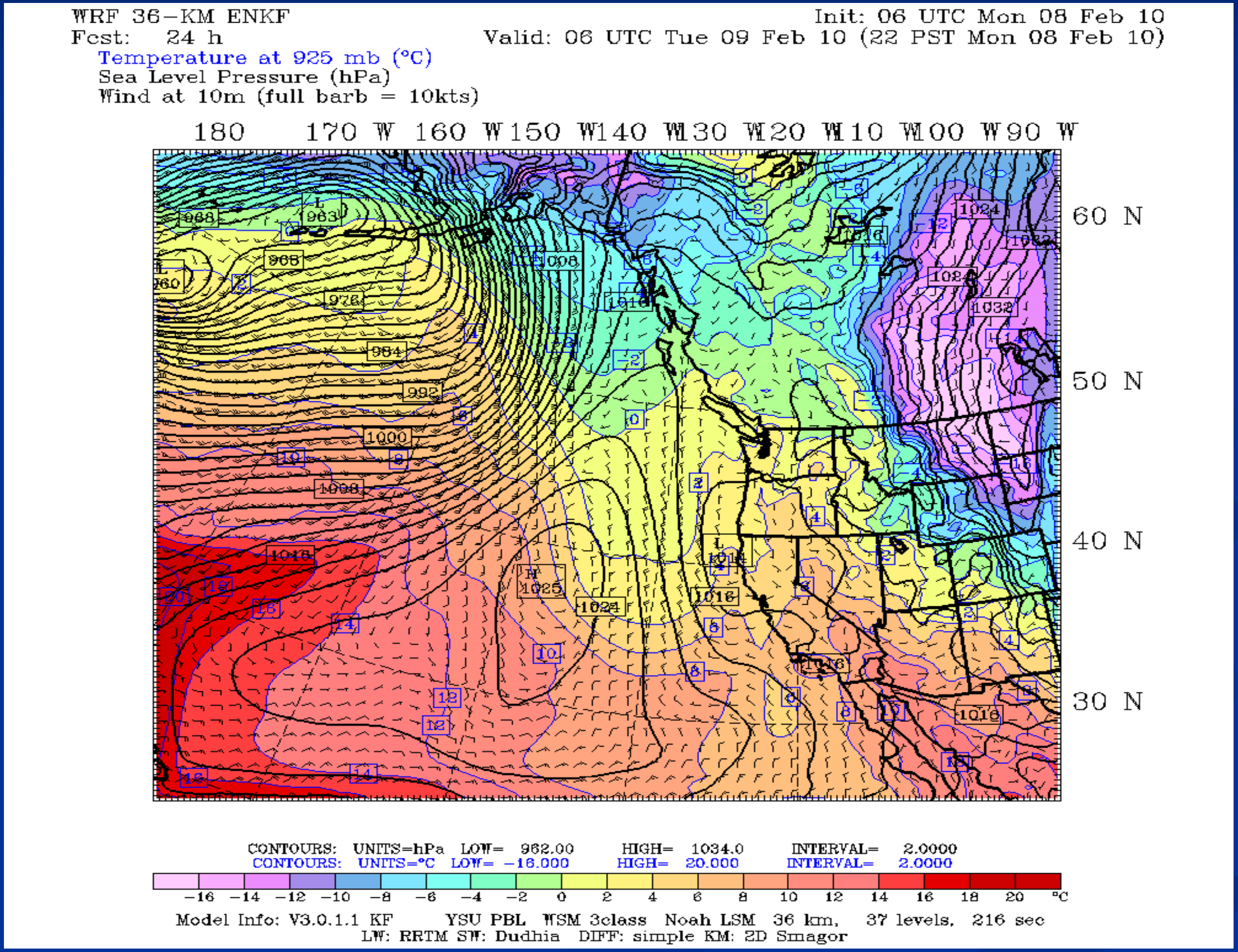

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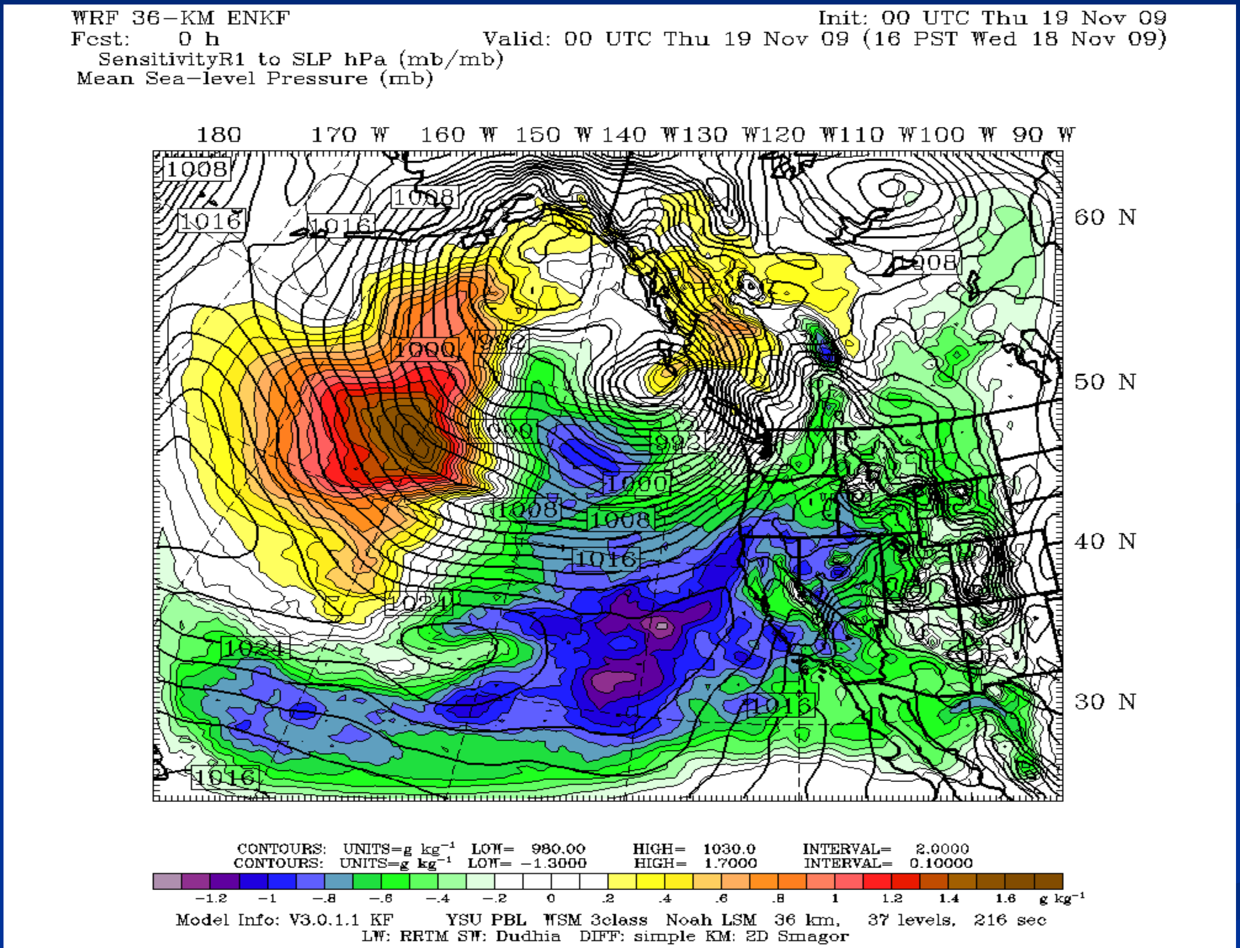
Ensemble Sensitivity – Deepening



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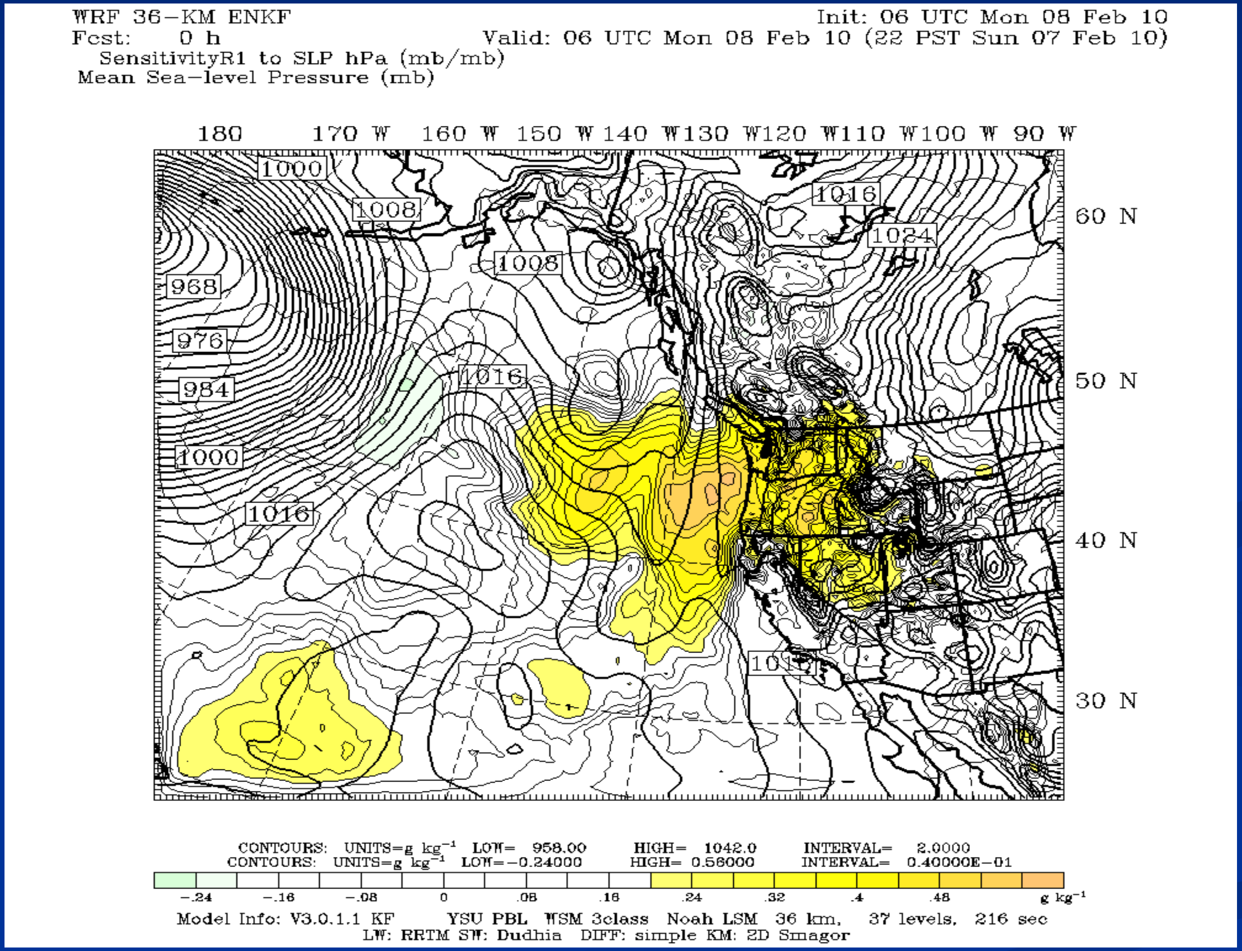
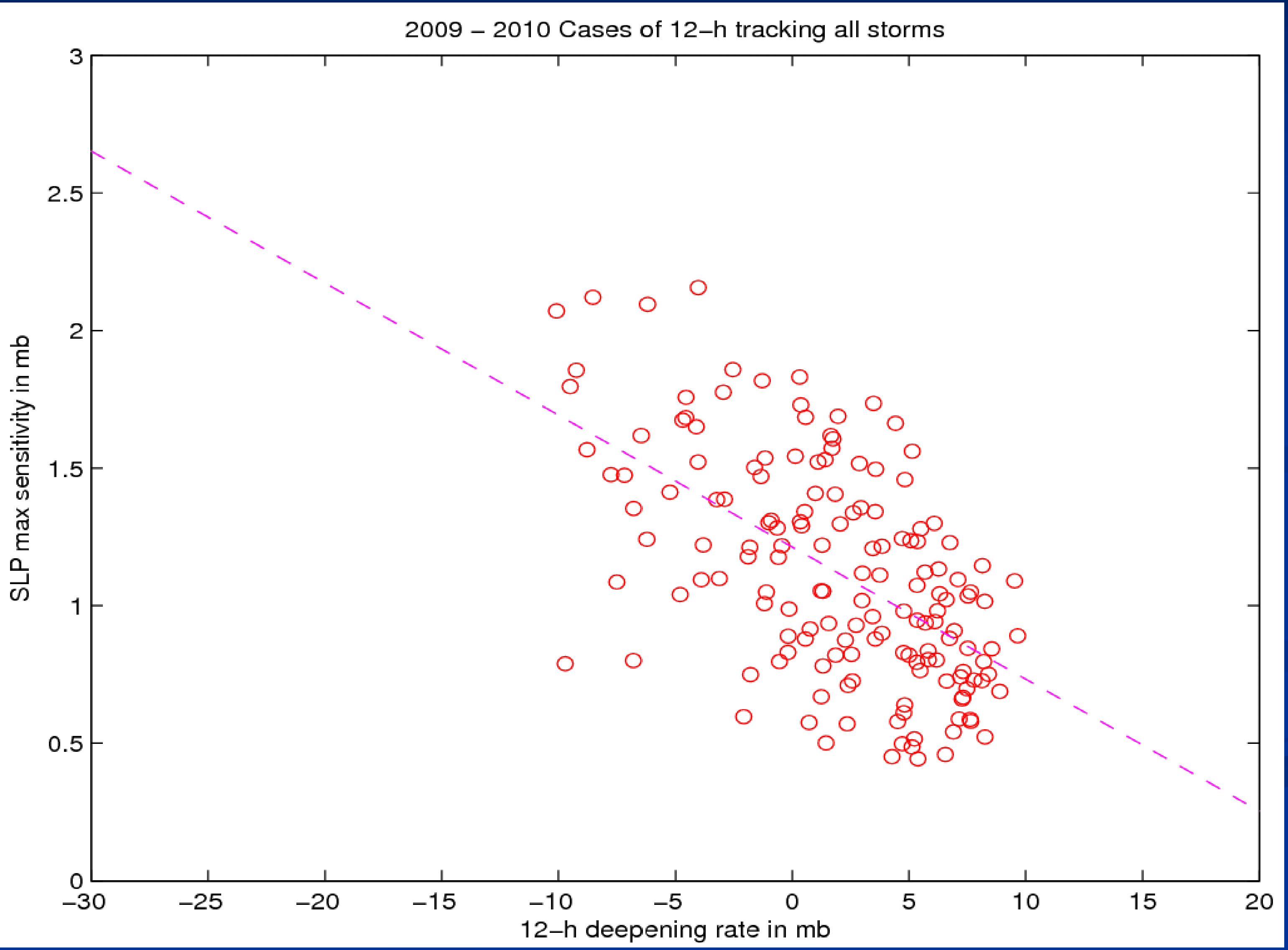
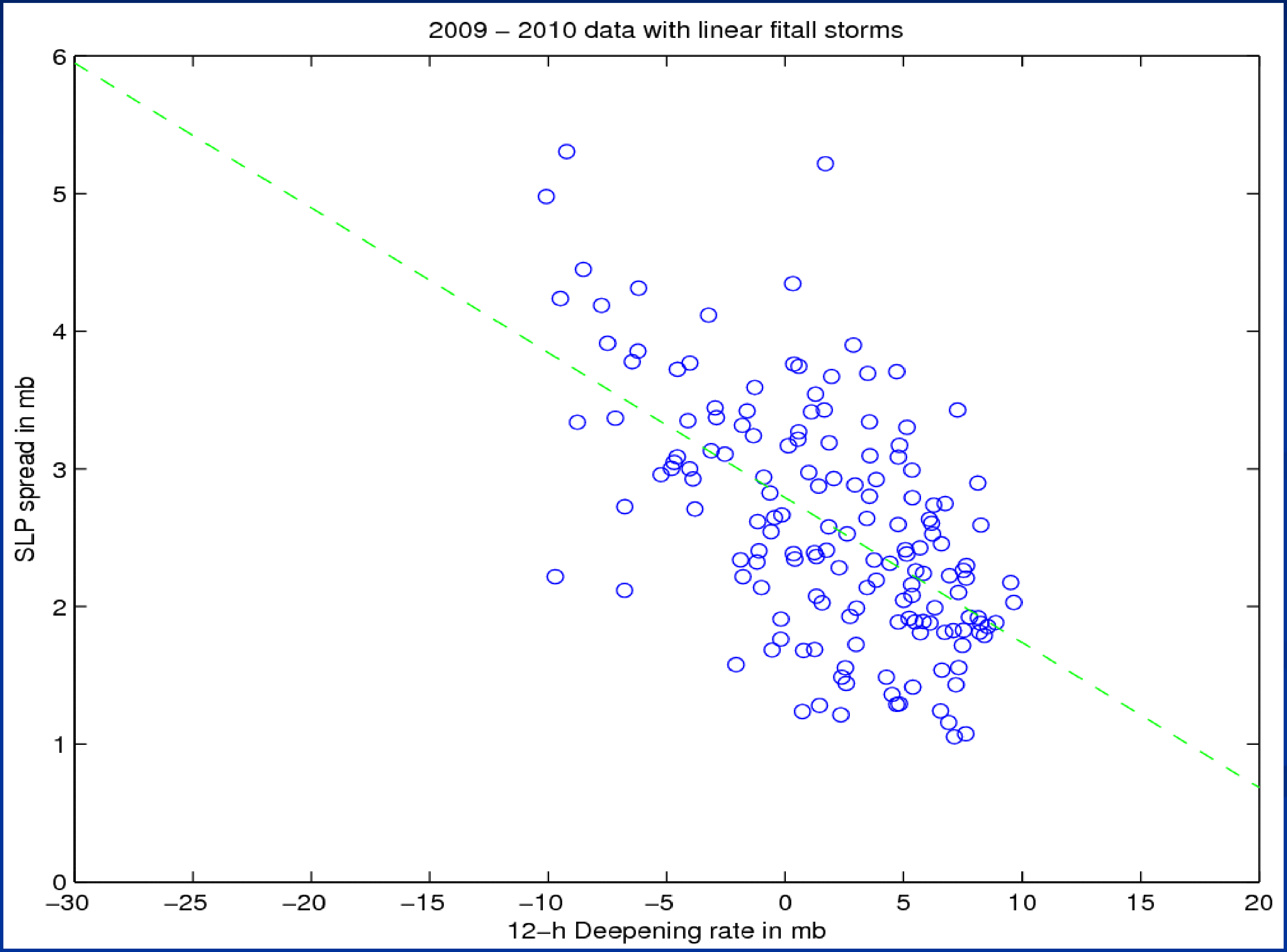


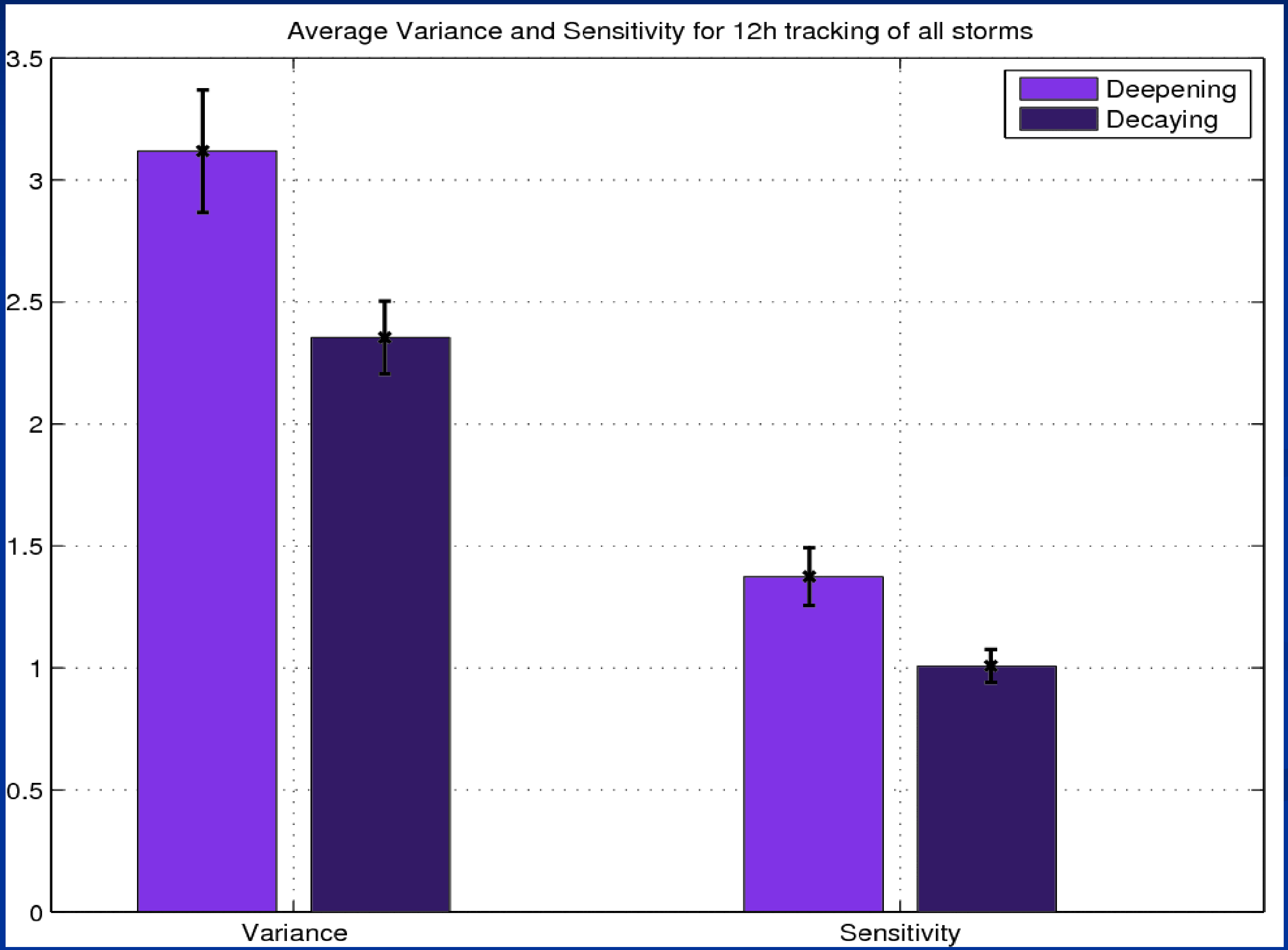
24-hr Sensitivity vs. Deepening Rate



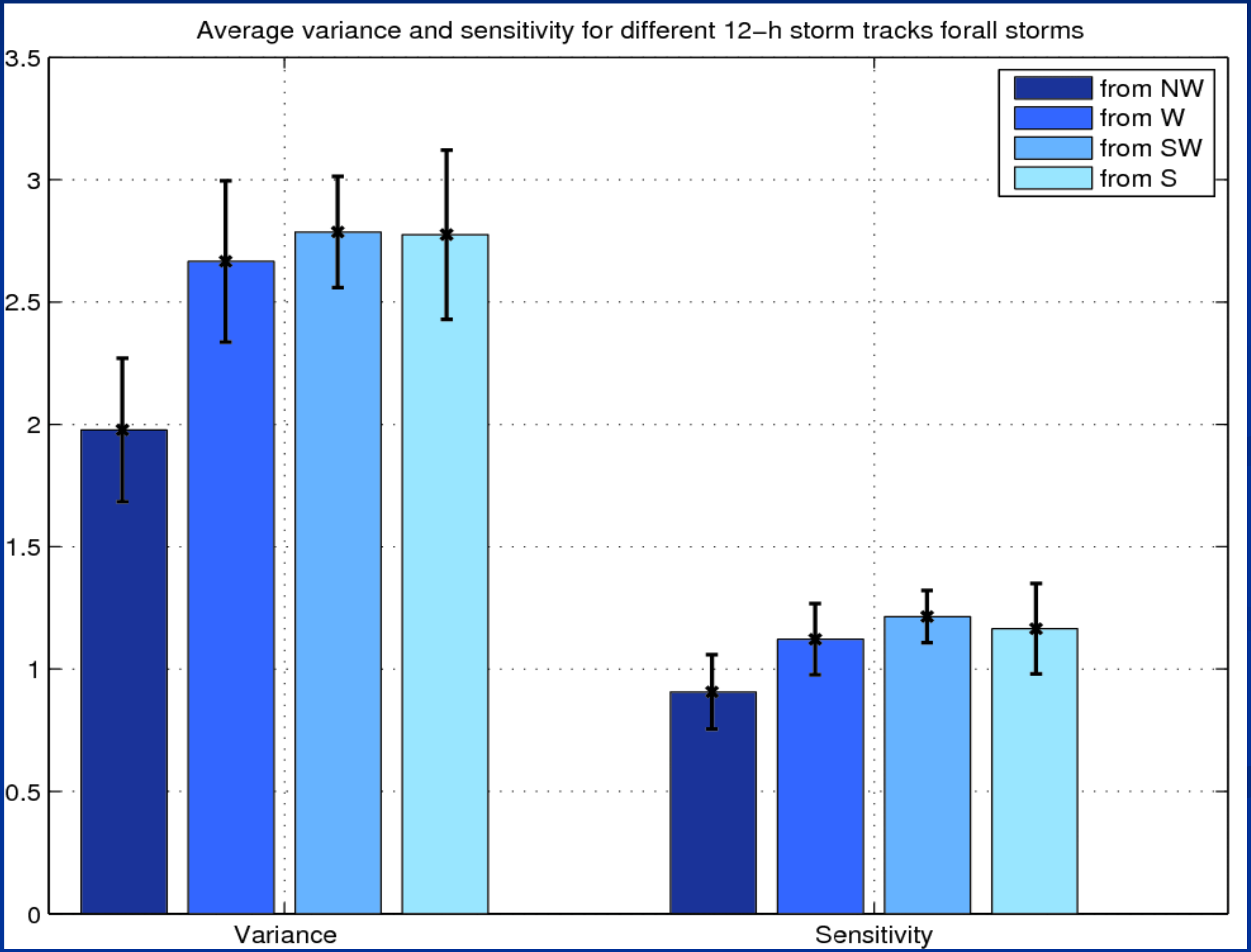
24-hr Spread vs. Deepening Rate



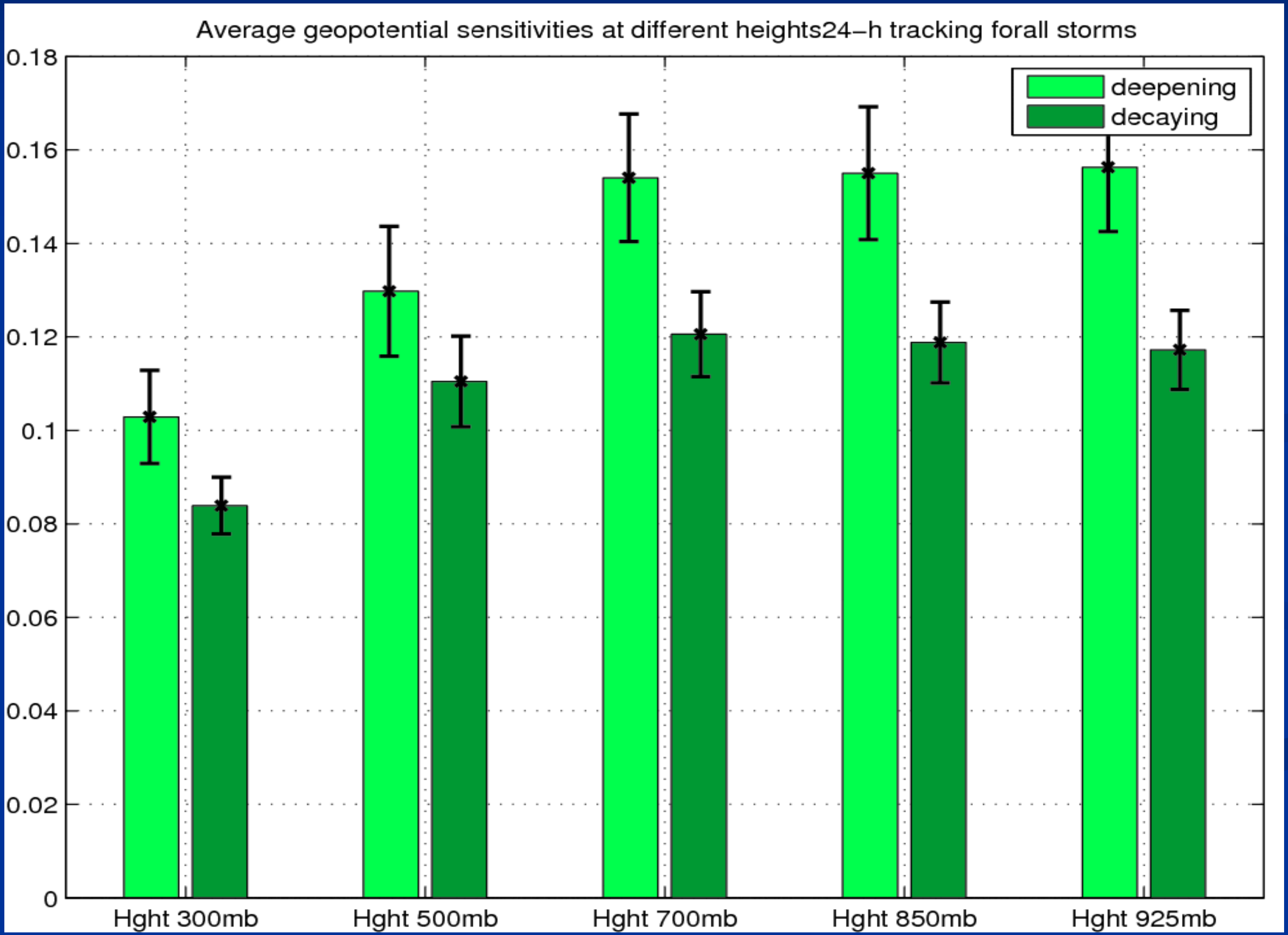
Spread/Sensitivity vs. Deepening Rate



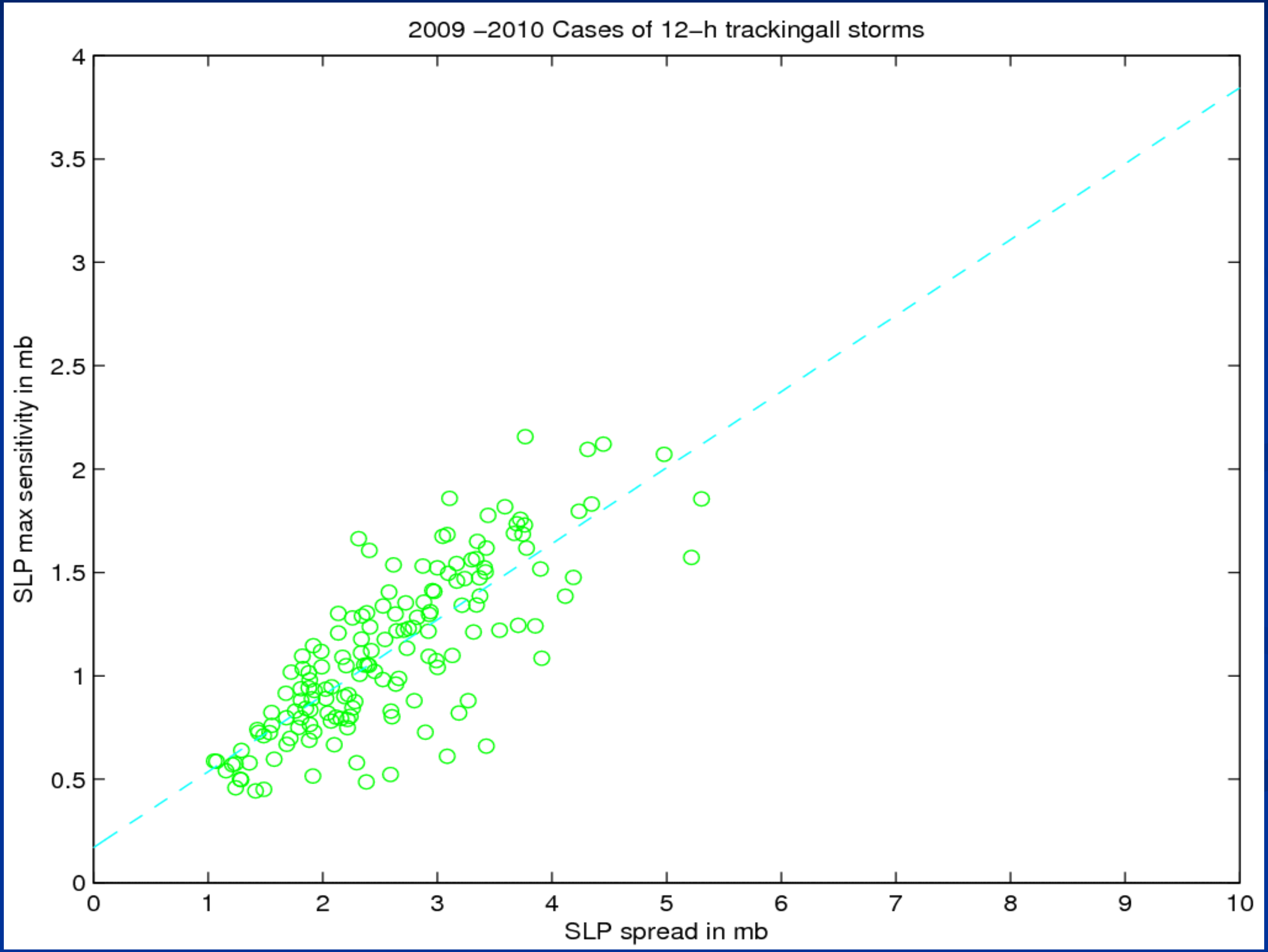
Spread/Sensitivity vs. Storm Track



Sensitivity to GPH vs. Level



24-hr Spread vs. Sensitivity



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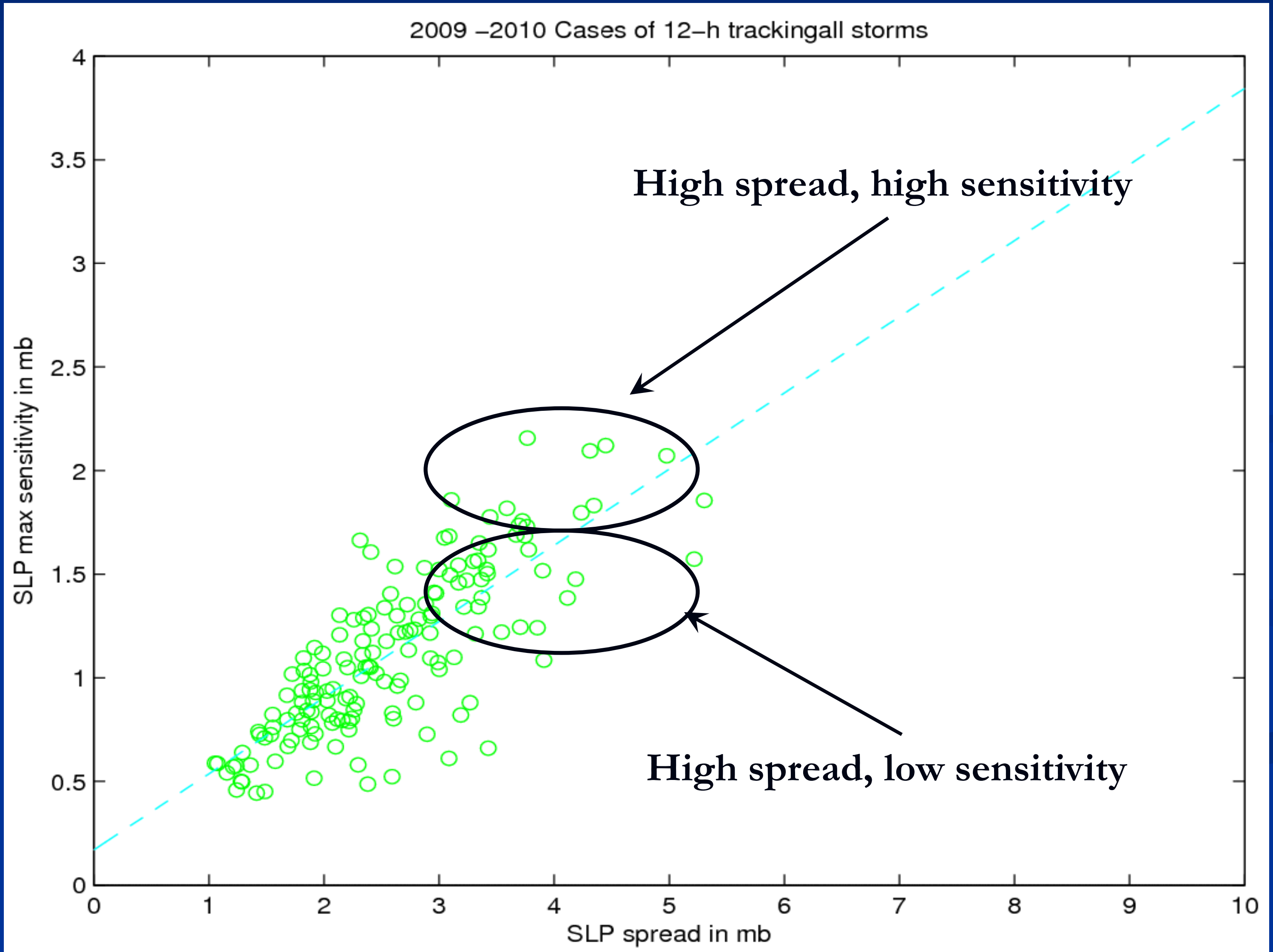
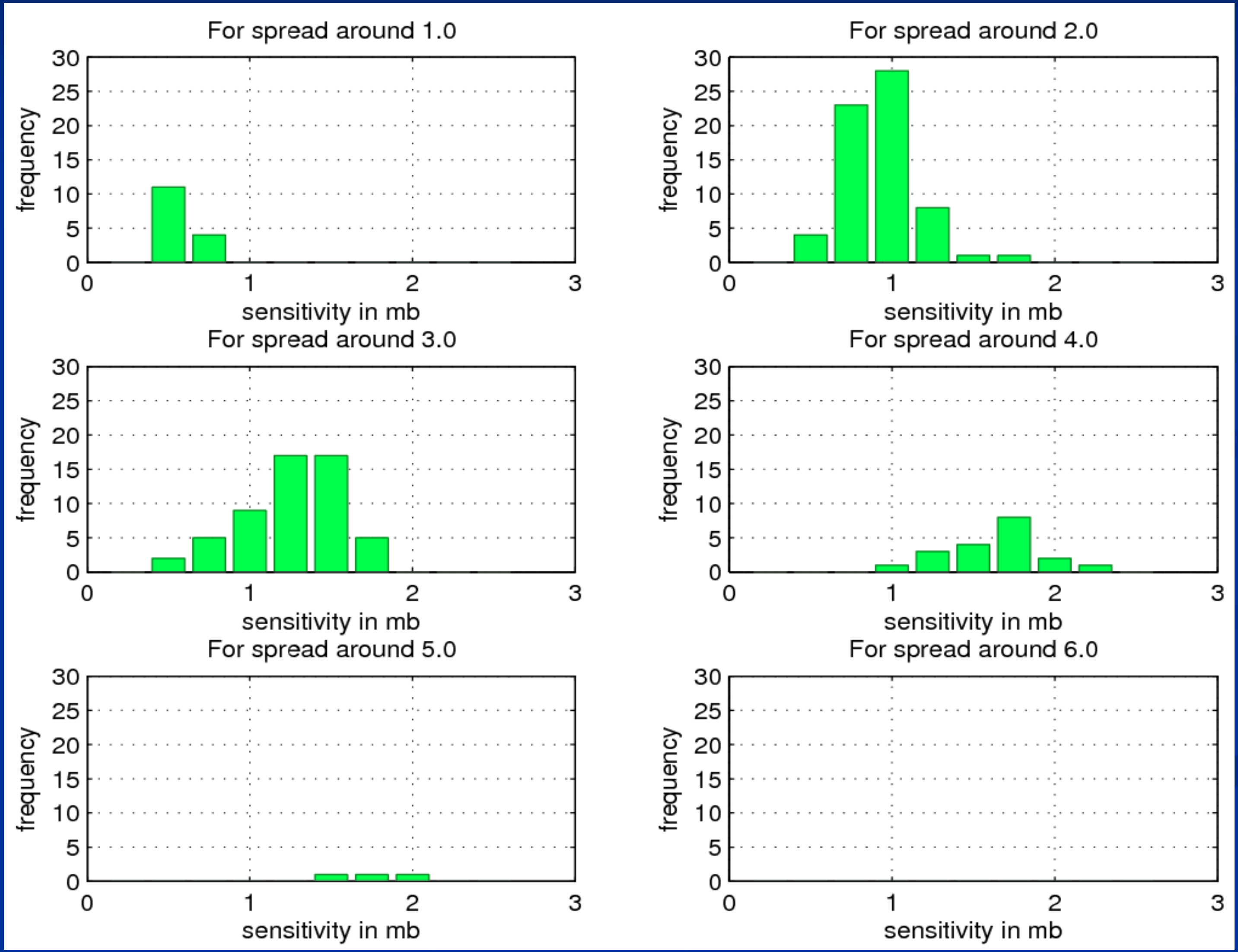
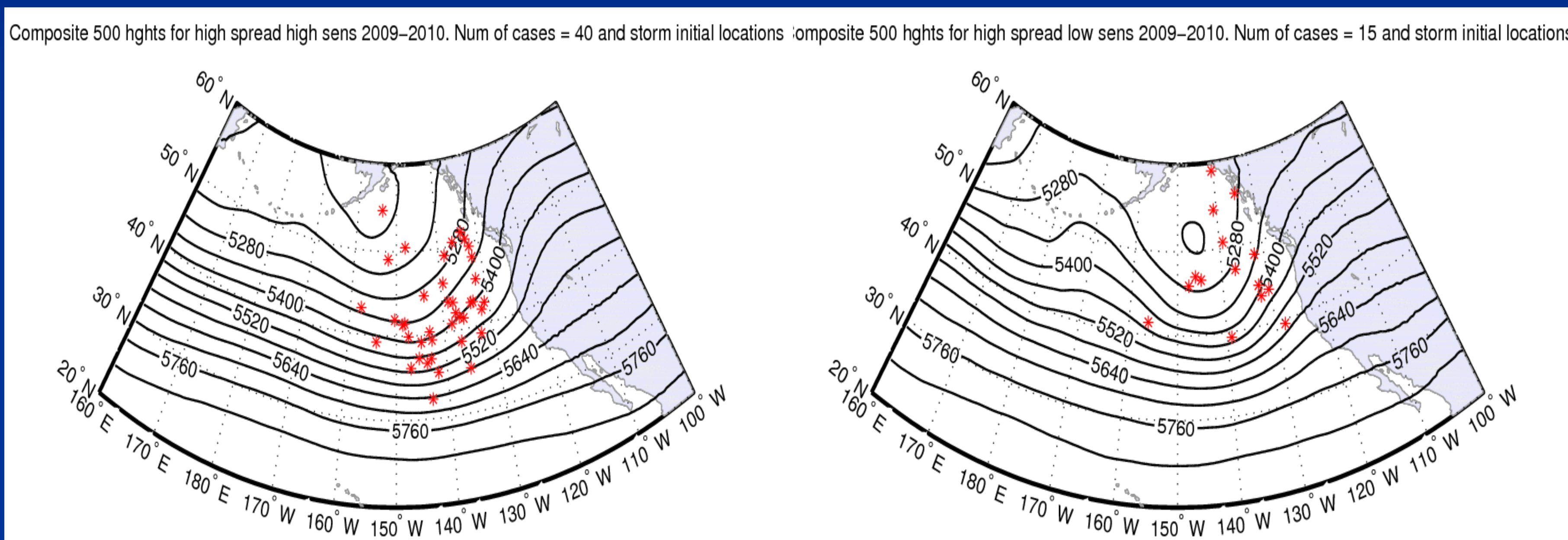


Sensitivity Distribution over Different Spread Values



Composite 500-hPa Flow

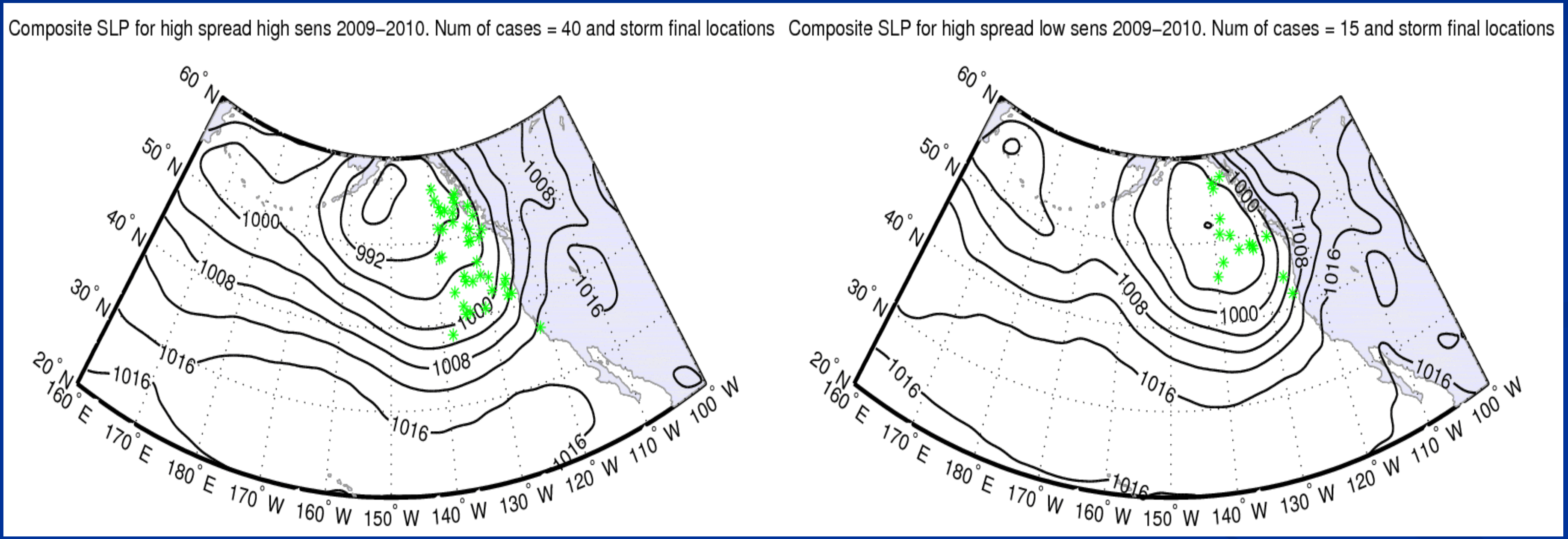


High spread, high sensitivity

High spread, low sensitivity

Red stars = cyclone initial position

Composite SLP



High spread, high sensitivity

High spread, low sensitivity

Green stars = cyclone final position

Summary

- We aim to assess the "what", the "how", and the "why" of North American land-falling cyclone predictability over 3 winters

  What: General characteristics of forecast uncertainty

  How: Link between uncertainty and flow regime

  Why: Intrinsic unpredictability vs. initial condition uncertainty

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- The tools we are using to do this are:

  - Ensemble sensitivity

  - Adjoint sensitivity (upcoming)

  - Ensemble forecast spread

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  - Sensitivity to GPH maximizes in lower troposphere just like adjoint sensitivity

Future Work

- Add other 2 winters to dataset, finish analysis
- Expand results to other response functions, forecast times
- Include adjoint sensitivity in analysis
- Include forecast error in analysis