NSF Collaborative Research: Ensemble-Based Predictability, Sensitivity and Data Assimilation in PREDICT

Sharan Majumdar (U.Miami) synoptic-scale

Ryan Torn (SUNY at Albany) mesoscale

Collaborator: Fuqing Zhang (PSU) convective scale

Objectives stated in NSF proposal

1. To diagnose the dominant sensitivities and influence of observations on TC genesis on synoptic, meso- and convective scales.
2. To provide a seamless real-time ensemble prediction, adaptive sampling and data assimilation capability for use in mission planning during PREDICT
3. To provide numerical model output for other PREDICT PIs for their hypothesis testing

PREDICT hypothesis 1: TD formation is favored in the critical-layer region of the synoptic-scale, pre-depression wave trough in the lower troposphere. We suggest that the initialization of this region is crucial (H5). Primary focus: how large scales precondition the smaller scales.

Year 1: prepare ensemble-based products in support of field phase ('dry run' in 2008, Fay → Josephine)

Years 2 & 3: use ensemble sensitivity and data assimilation to

- diagnose important physical processes
- identify scales & variables that curtail prediction error
- prepare reanalysis

Hypotheses on initial fields

For "top-down" genesis, forecast is sensitive to

Mid-tropospheric vortex
Magnitude (and direction?) of vertical shear
Relative humidity in inner core

- For "bottom-up" genesis, VHT theory depends on

  Vortex

  CAPE

  mid-level moisture (downdrafts)

  vertical shear (and others)

Marsupial-specific fields

- Ensemble products that capture the variability (uncertainty) of processes critical to the formation of a pouch and its evolution:
  - Shear vorticity
  - Jet structure

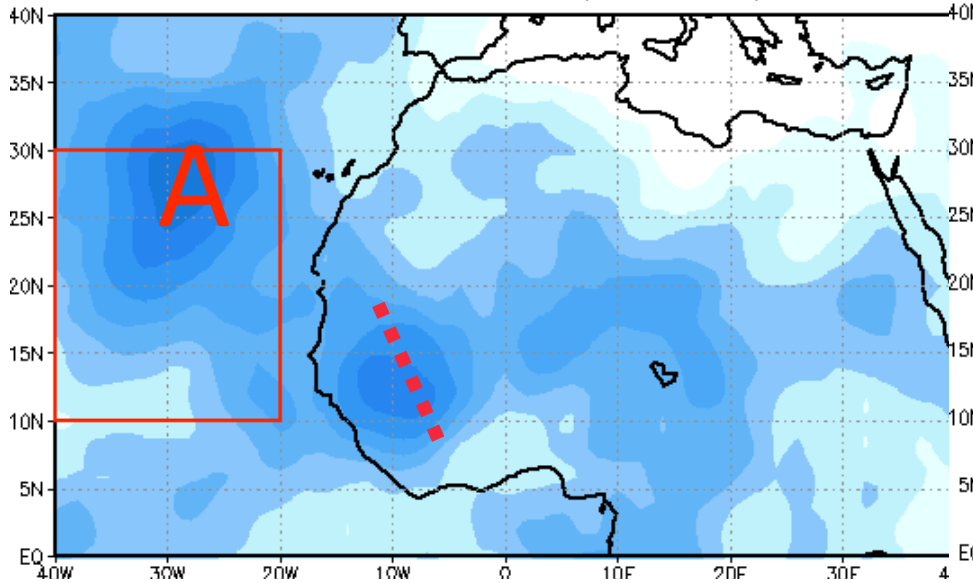
Metrics (pouch relative)

- Mid-level vorticity
- Depth of pouch
- Thickness anomalies (building of warm core)
- Precipitation
- Kinetic energy
- ?

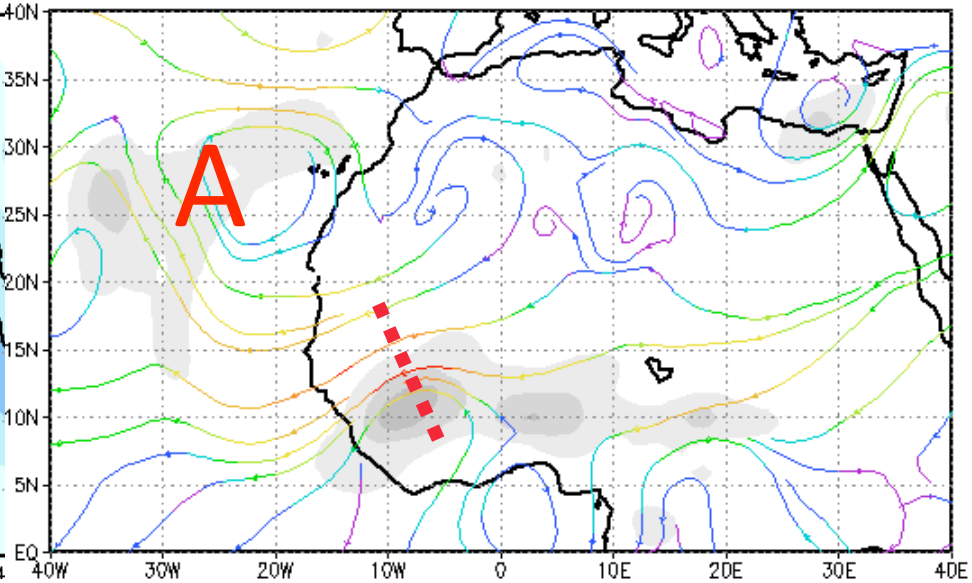
Global products to support decision-making: longer-range (2-7 days in advance)

- ETKF guidance for adaptive sampling
- Ensemble variance
- Probabilities of critical vorticity values, shear thresholds, moist instabilities, jet location
- Pouch probabilities (ensemble critical layers, quantitative estimation of dividing streamline)?
- Other diagnostics?
- e.g. http://catalog.eol.ucar.edu/cgi-bin/tparc_2008/model/date_browse?dateUTC=20080910
- Ensemble sensitivity (Torn)
  - Covariance structure

ETKF Wind SigVar at 700 hPa due to adaptive obs of (u,v,T) at 200/500/850 hP
144-member NCEP+ECMWF+CMC ensemble initialized at 2006090900.
Obs 2006091100, Verif 2006091300. UMiami/NASA N-AMMA/NOAA THORPEX



Ensemble mean streamlines and wind variance (shaded) at 700 hPa
144-member NCEP+ECMWF+CMC ensemble initialized at 2006090900, 48-hr forecast



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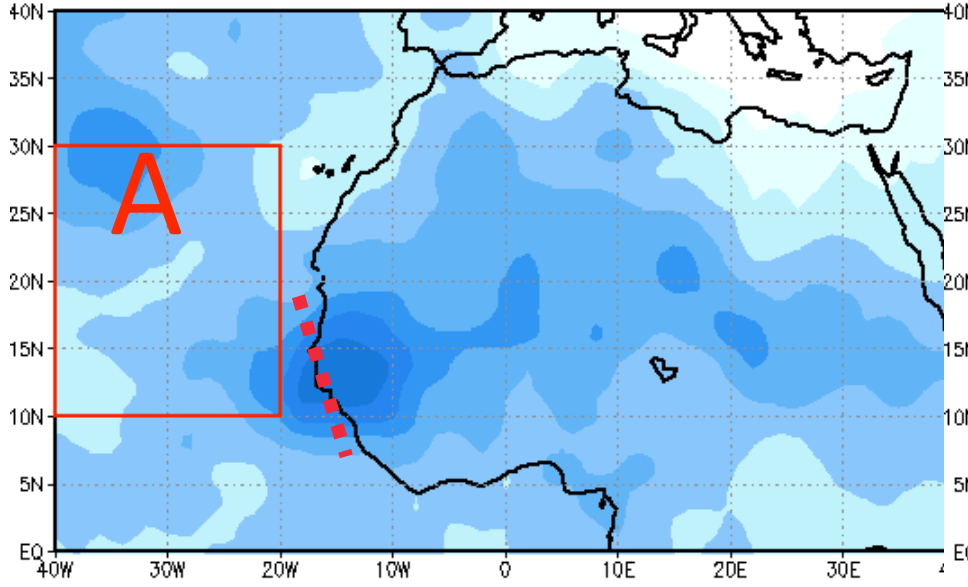

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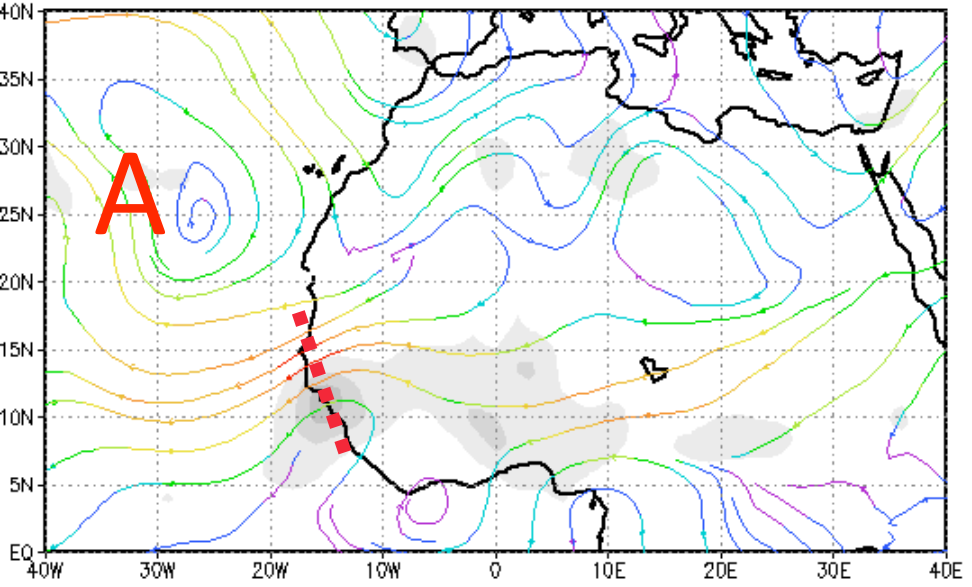

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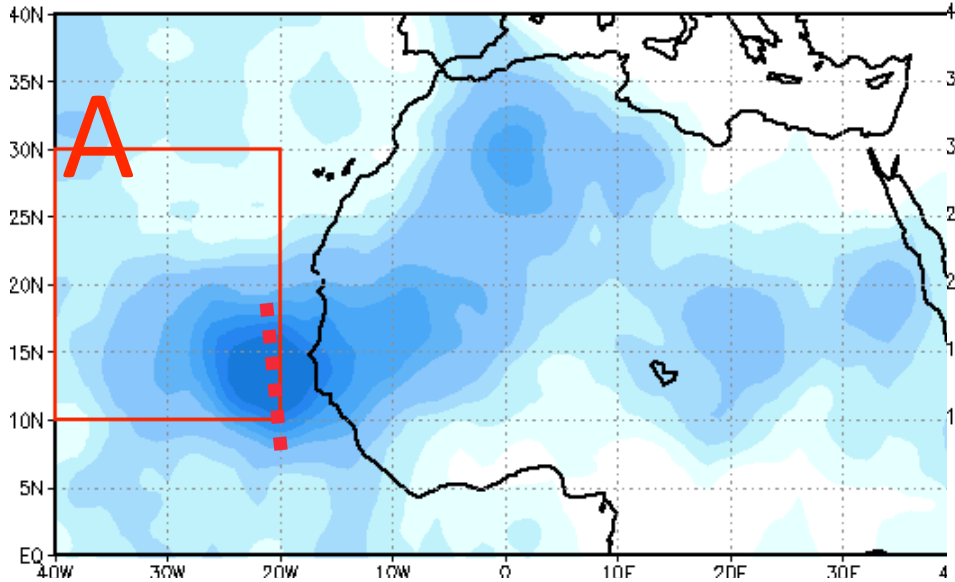

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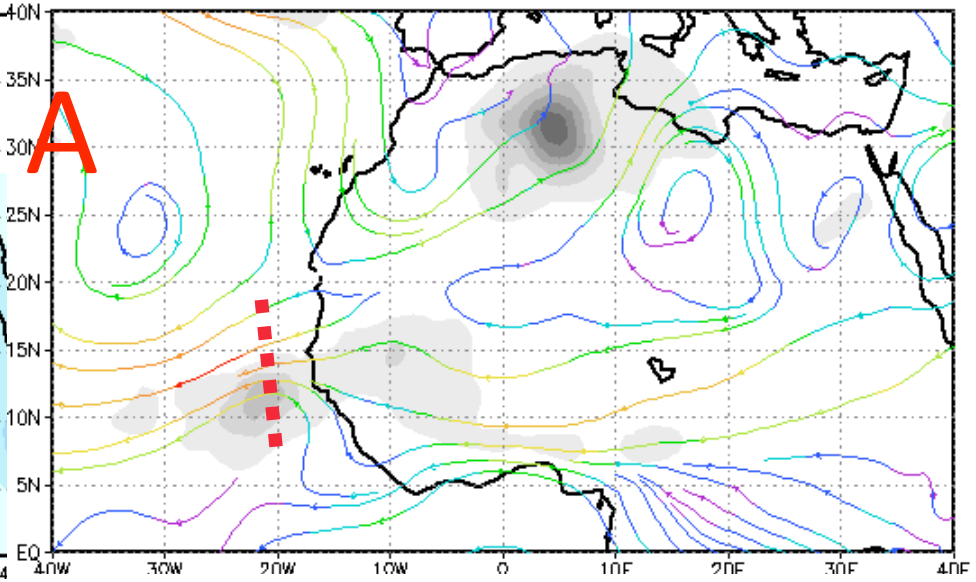

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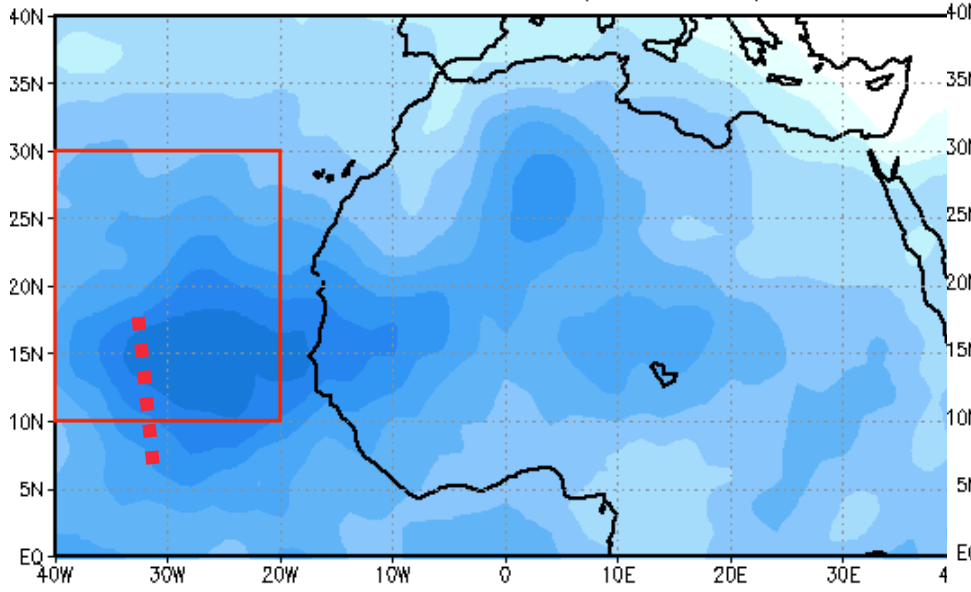

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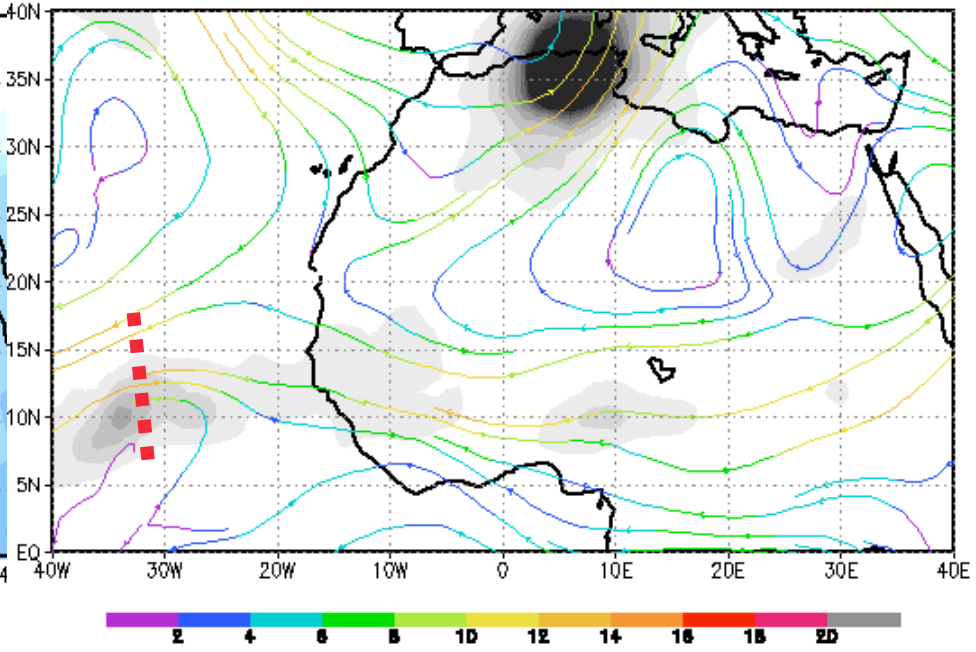
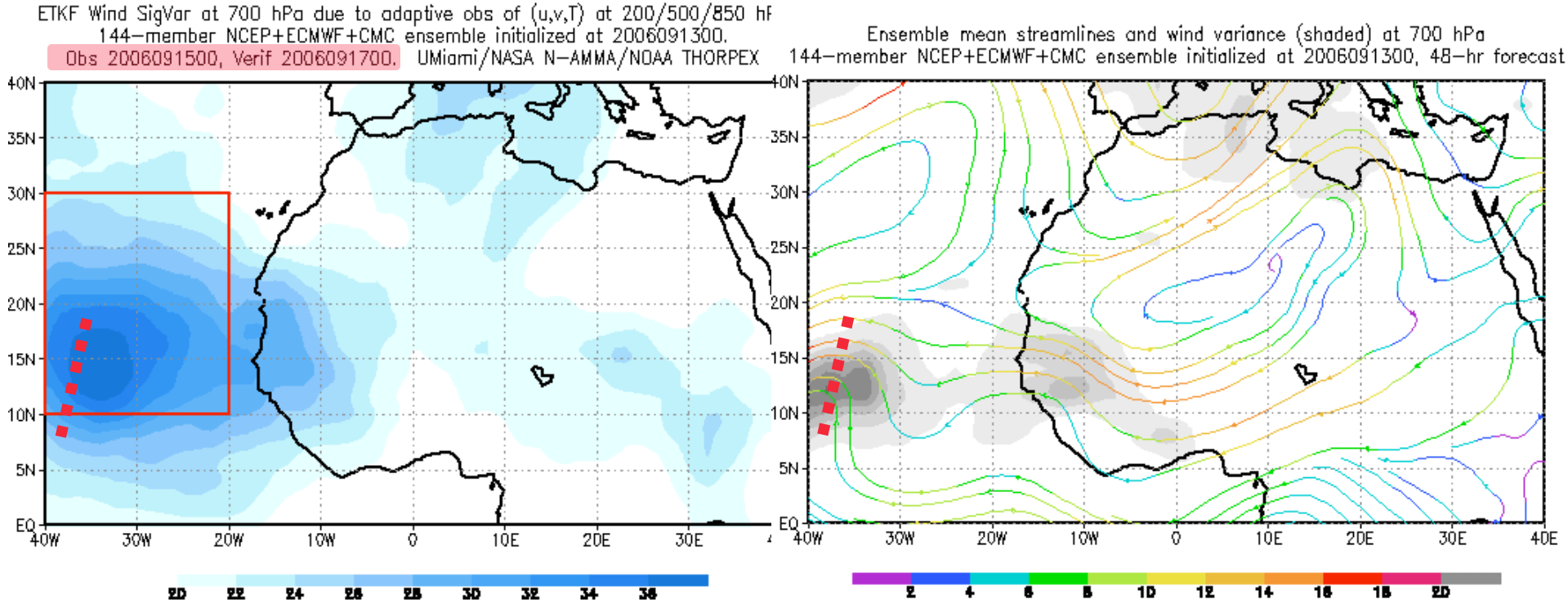


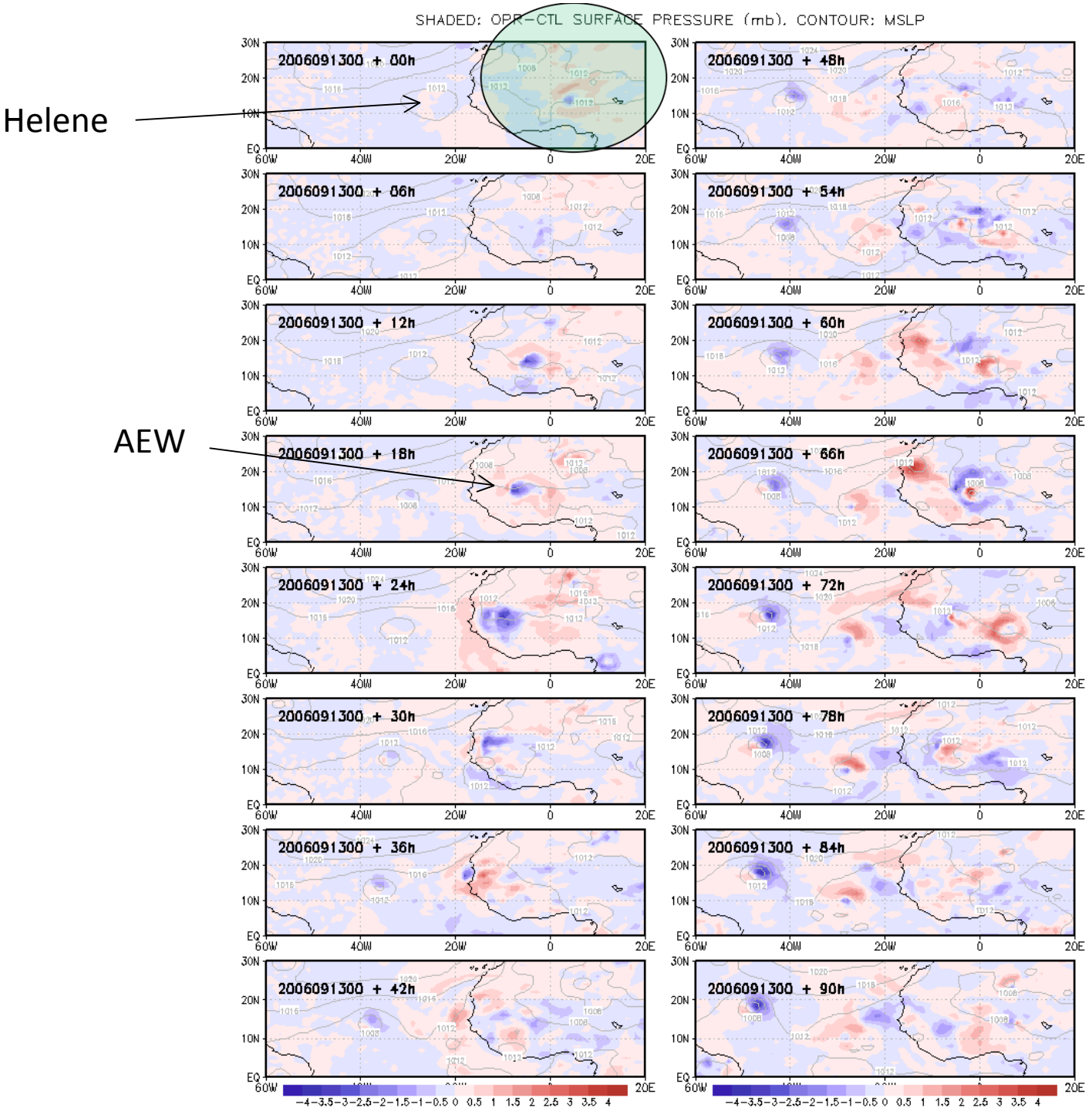


Target areas: local uncertainty in wind field

(1) Easterly Wave

(2) Anticyclone to north A

(3) African Easterly Jet region behind wave



SURFACE PRESSURE SIGNAL IN NCEP GFS MODEL: 0-90h

Blue: radiosondes acted to decrease pressure

Red: radiosondes acted to increase pressure

Global Model Ensembles

- ECMWF (~40km res, generally superior)
  - Co$t for real-time access?
  - Supportive of field experiments (TCS08/T-PARC)

- NCEP, UKMET, CMC ensembles all less skilful for tropical cyclones

Ensemble Sensitivity

$$\left[\frac{\partial J}{\partial \mathbf{x}_o}\right]^{\mathrm{T}} = cov(\delta J, \delta \mathbf{x}_o)\mathbf{P}^{a\,-1}$$

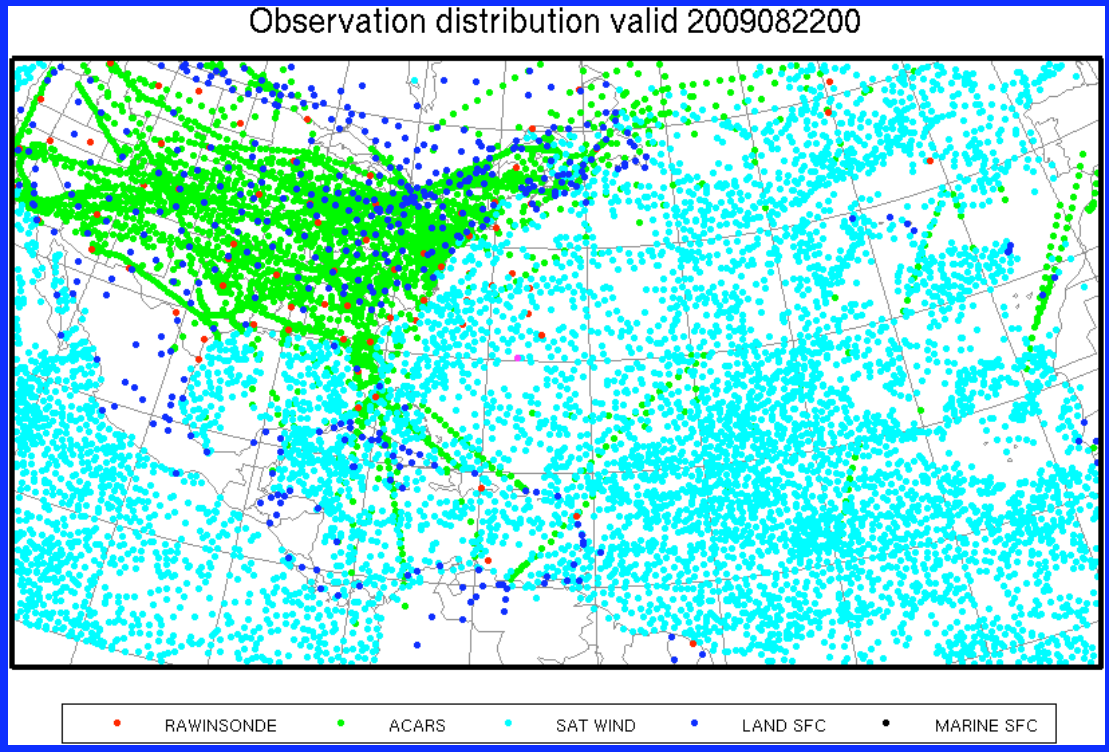
$$\frac{\partial J_e}{\partial x_j} \equiv cov(\delta J, \delta \mathbf{x}_{o,j})\mathbf{D}_j^{-1} = \frac{cov(\mathbf{J}, \mathbf{X}_j)}{var(\mathbf{X}_j)}$$

Ancell and Hakim 2007

- Above equation is linear regression
  - Dependent variable is forecast metric
  - Independent variable is element of state vector
- Can also obtain confidence bounds on sensitivity value

Assimilation System

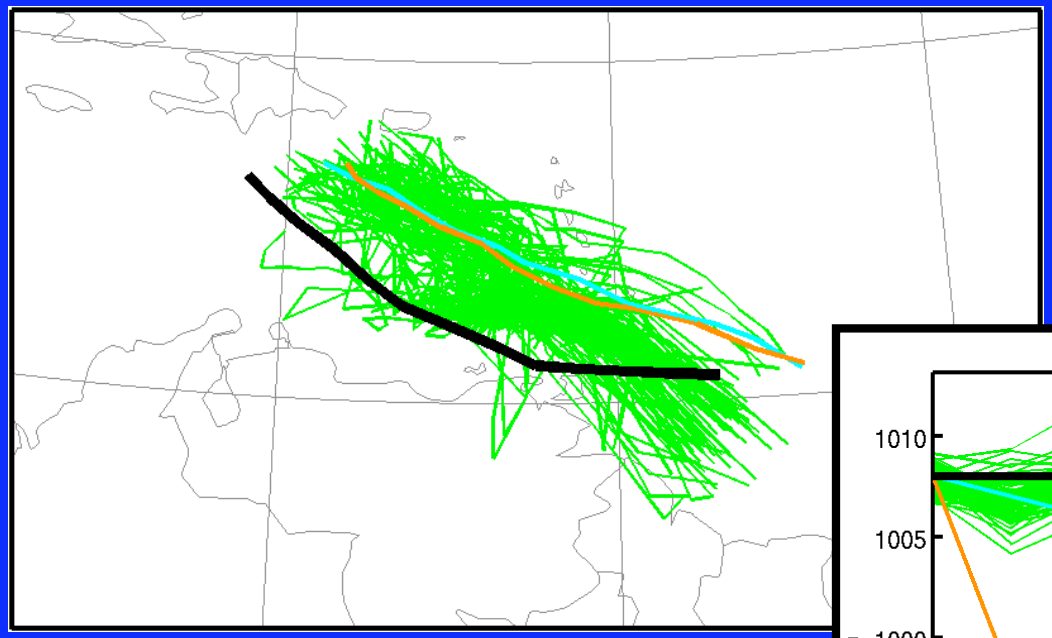
- WRF ARW (v3.1), 36 km horizontal resolution, 96 ensemble members, DART assimilation system.
- Observations assimilated each six hours from surface and marine stations (P_{sfc}), rawinsondes, synoptic dropsondes, ACARS, sat. winds, TC position and minimum SLP
- Initialized system at one time during the TC season, continue to cycle forward in time using GFS LBCs

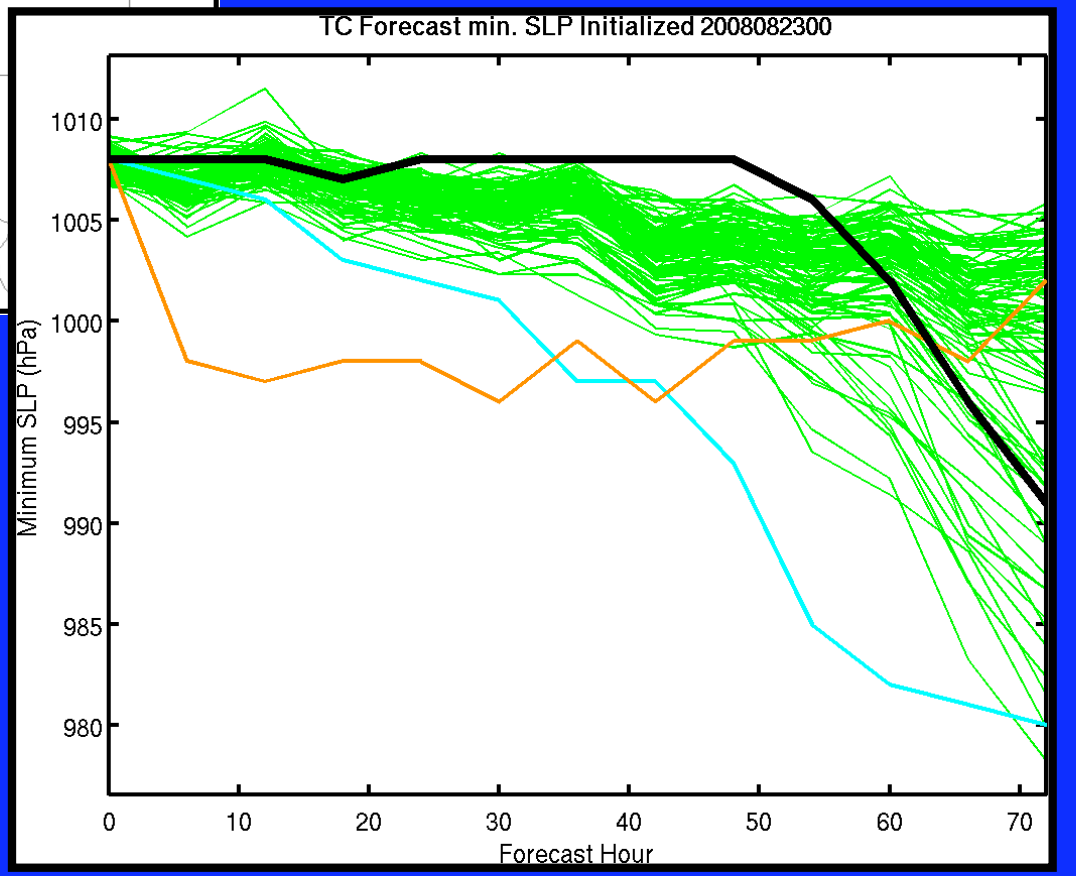


PREDICT Changes

12 km nest for >= TD storms, only use in model advance	12 km nest for INVEST and >= TD storms, cycling of nest
Remove all data near TC core due to potential representativeness errors	Assimilate core data due to increased resolution
Do not assimilate GPS data	Assimilate GPS occultation data (gives information on T, q)
6 hour assimilation interval	3 hour assimilation interval (depends on timing)
Only advance one member forward in time at high resolution	Advance all ensemble members forward, but without convection-resolving

Example Forecast

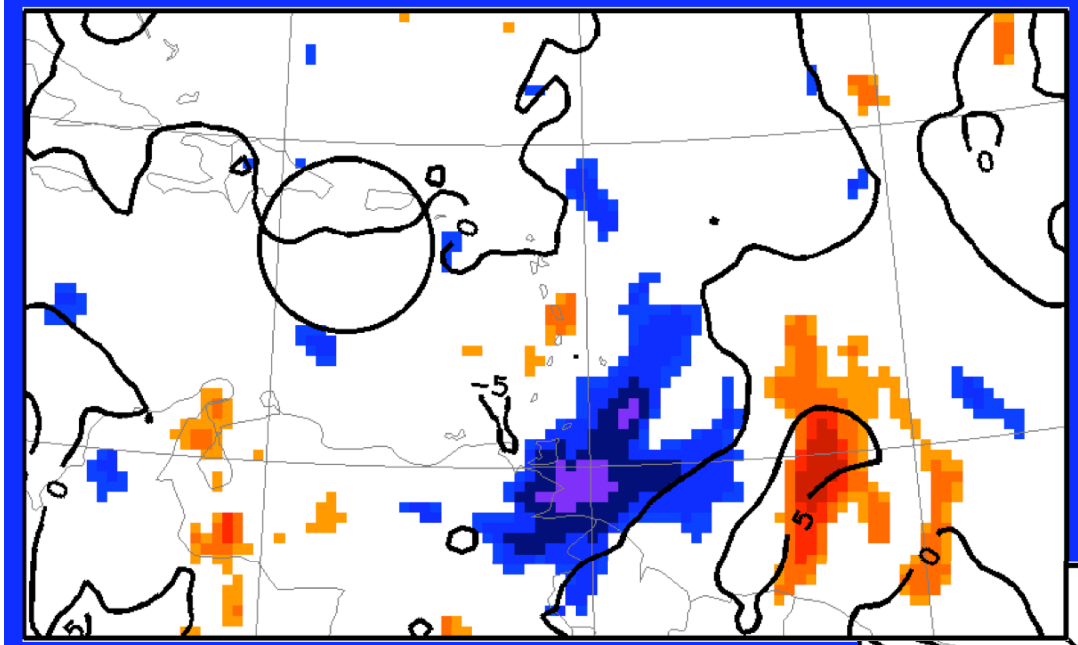




0000 UTC 23 August 2008
(Gustav Genesis)

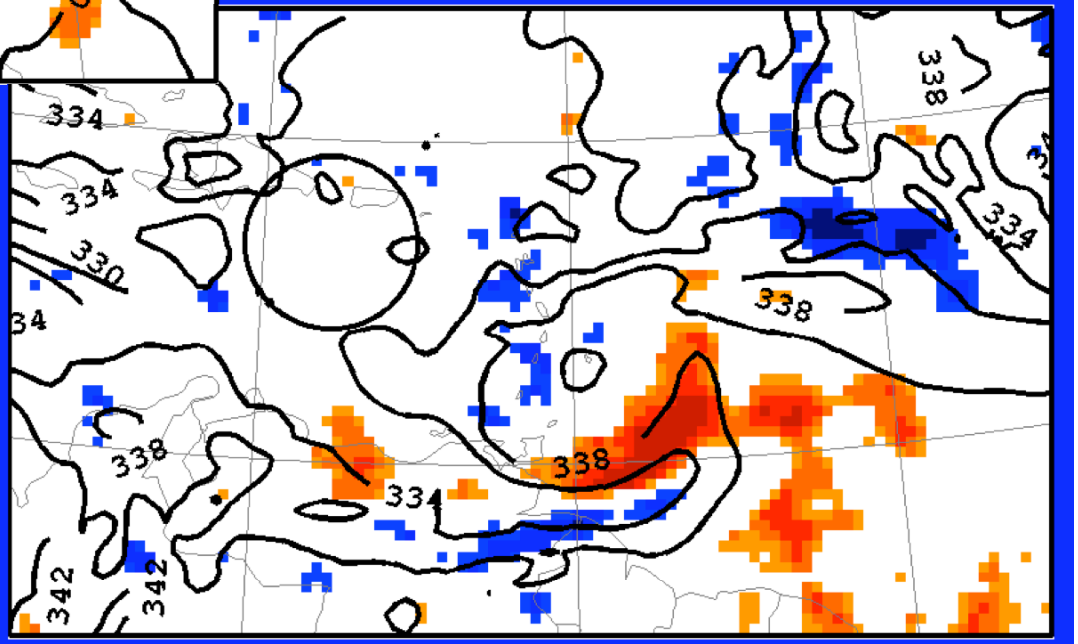
EnKF BEST
HWRF GFDL

Forecast Sensitivity



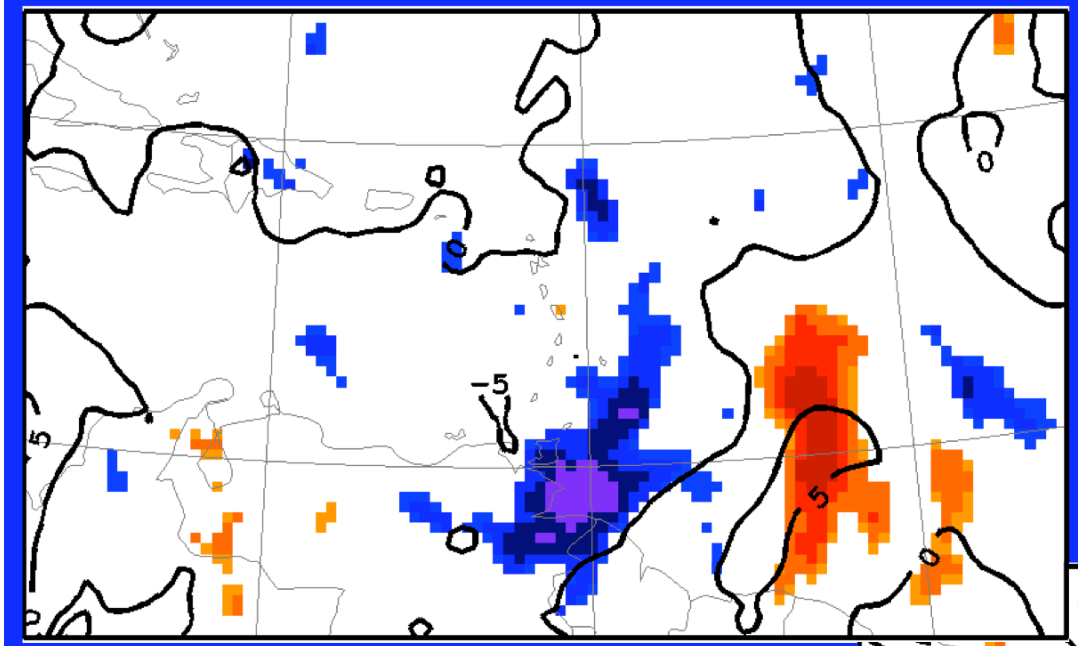
600-800 hPa v-wind

mid-tropospheric θ_e



600-800 hPa Vorticity

Forecast Sensitivity



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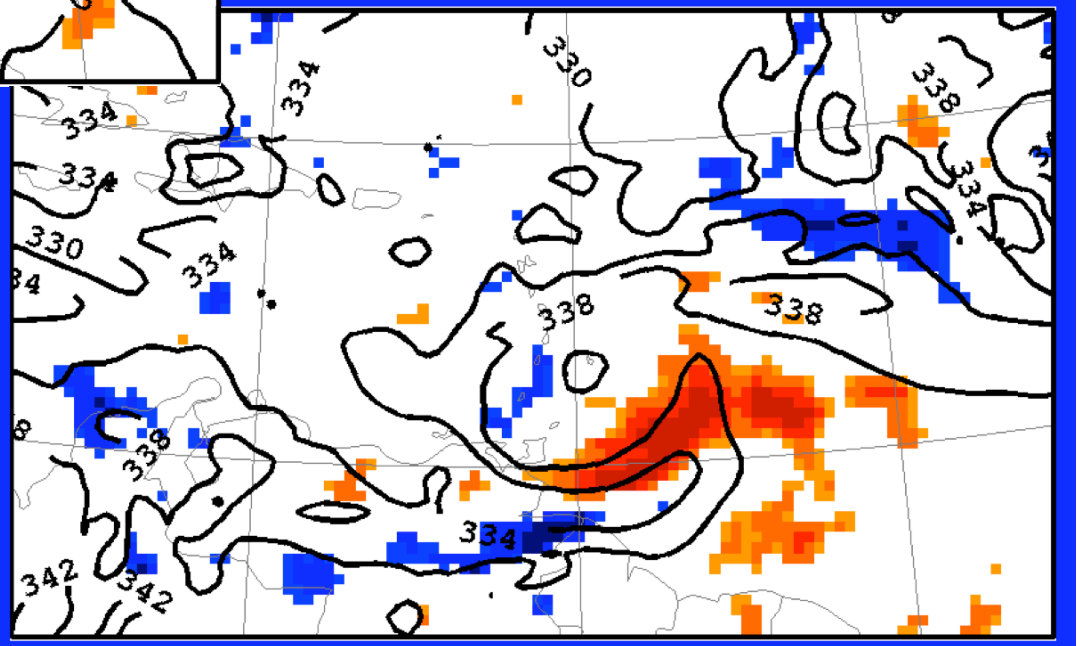

Precipitation

Discussion Points

- What other forecast metrics are other PIs interested in?
- Plan to upload images to PREDICT field catalog. Is there a desire to have gridded data in real-time?