Title: Improving very-short-range Forecasts of the Pre-Convective Environment and Heavy Precipitation Events using Legacy GOES T&Q Retrievals

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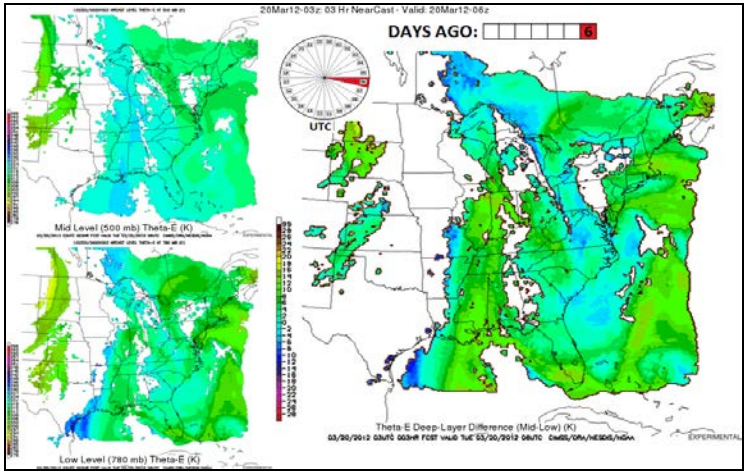
- Topics: Severe Weather and Lightning

- Programs: Funded by GOES-R3, with interactions in Proving Grounds, Training and JPSS RR/PG

Why are GEO-based NearCasts important?

Because they provide unprecedented understanding of the past and future evolution of multi-level Moisture and Stability fields



6 day loop of NearCast Analyses

What are we trying to improve?

Short-range forecasts of timing / location of severe thunderstorms - especially hard-to-forecast, isolated summer-time convection

Basic questions addressed here include:

1 - How can forecasters use NearCasts to improve forecaster awareness and reduce false alarms?

2 – How best can the underutilized GOES Legacy Retrievals be used objectively to improve short-range forecasts of the Pre-Convection Environment ?

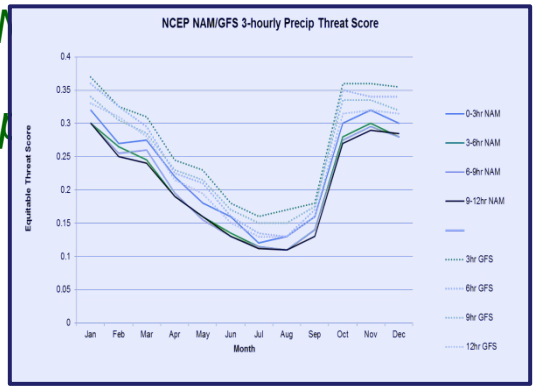
NearCasts are 1-9 hour forecasts specifically designed to monitor conditions where hazardous weather will *(or will not)* form.

NearCasts :

- *Add a forecast component to GOES observation*
- *Are available within minutes of observation times,*
- *Are frequently updated (hourly or sub-hourly), and*
- *Are Data-Driven – Preserve observations more than NWP*
- *Use full-resolution GOES retrievals not included in operational NWP*

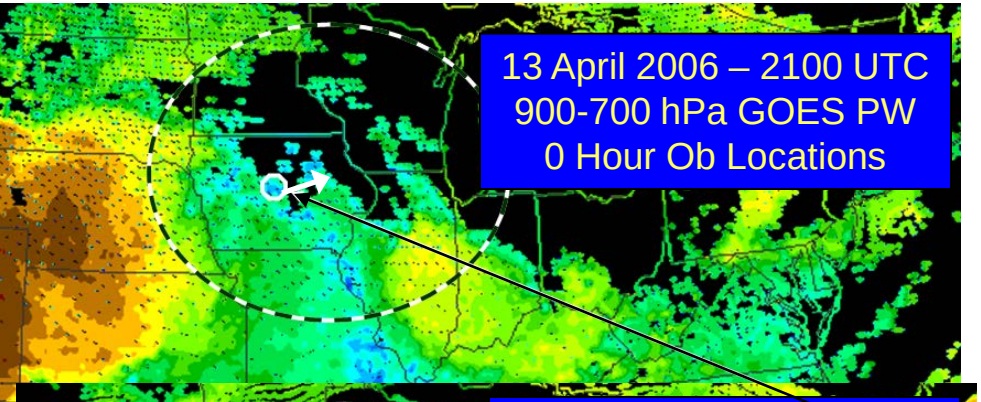
What are we trying to help improve?

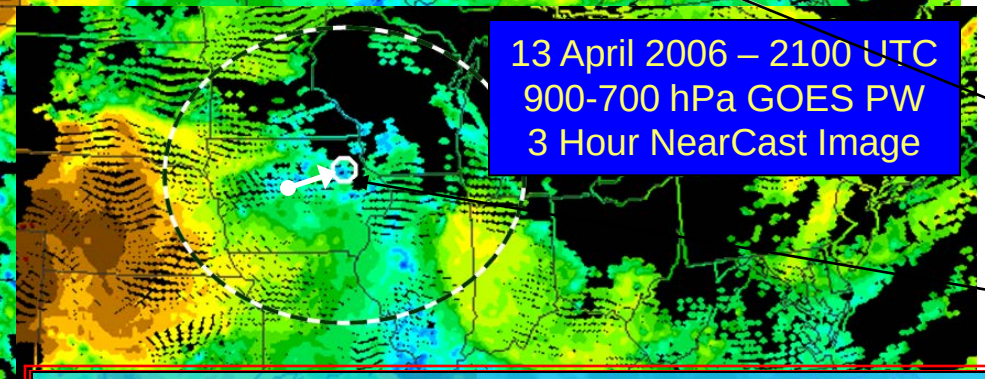
- *Poor warm-season precipitation forecast accuracy in short-range N*
  a time when GOES IR soundings are least impacted by clouds
- *Time lags between observation times and NWP guidance up*
- *Under-utilization of GEO satellite moisture over land in NWP and subjective forecasting*
- *Loss of observed moisture extremes in NWP*
- *Lack of IR satellite information about convective environments after storms begins*

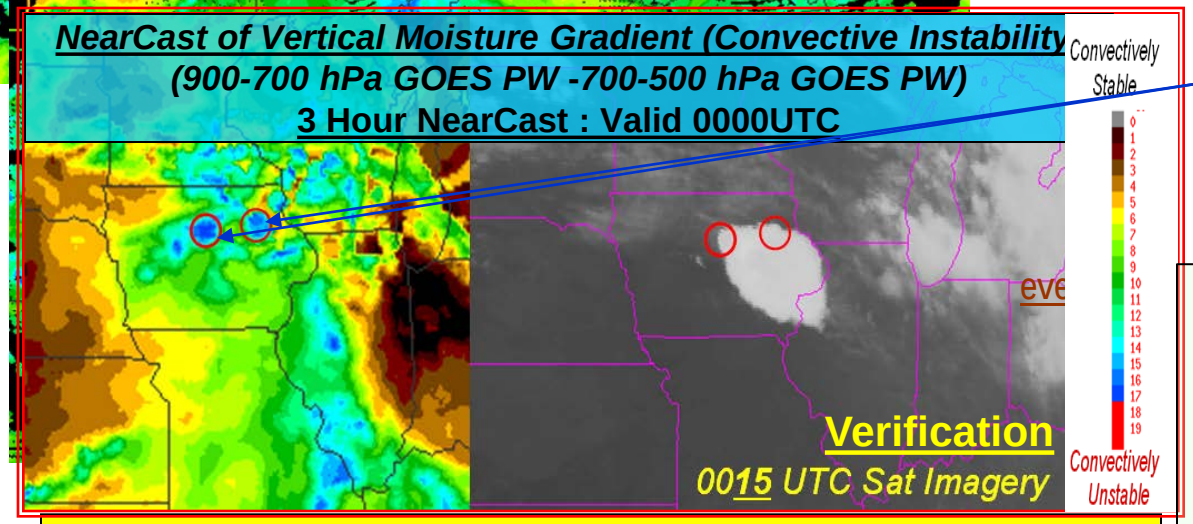


Providing forecasters an objective, observation-based tools to monitor the pre-convective environment

3. Methodology – How the Lagrangian NearCast system works:







Updated Hourly - Full-resolution 10 km data - 10 minute time steps

Differentiating where convection can/cannot develop

Instead of interpolating (smoothing) randomly spaced moisture/temperature observations to a fixed grid and then calculating moisture changes at the grid points (time consuming),

the Lagrangian approach interpolates wind data to locations of full resolution GOES multi-layer moisture & temperature observations **(both as PW and θe) and** then moves these high-definition data to future locations, using dynamically changing winds using 'long' (10 min.) time steps.

The moved 'obs' values from each layer are then both:

1) Transferred back to an 'image' for display as 'predicted DPIs',

2) Combined to produce a variety of derived parameters and

3) Compared between layers to derive various "Stability Indices" that are combined with 'conventional tools' to identify mesoscale areas where severe convective will develop

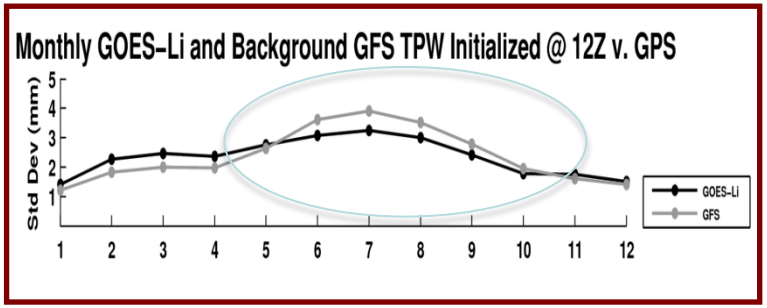
convective clouds appear

We will next show how to remove biases in the GOES retrievals and how the use of Isentropic Coordinates adds further value for forecasters

4. Results – GOES Retrieval Bias Corrections

Evaluation of GOES Precipitable Water Retrievals

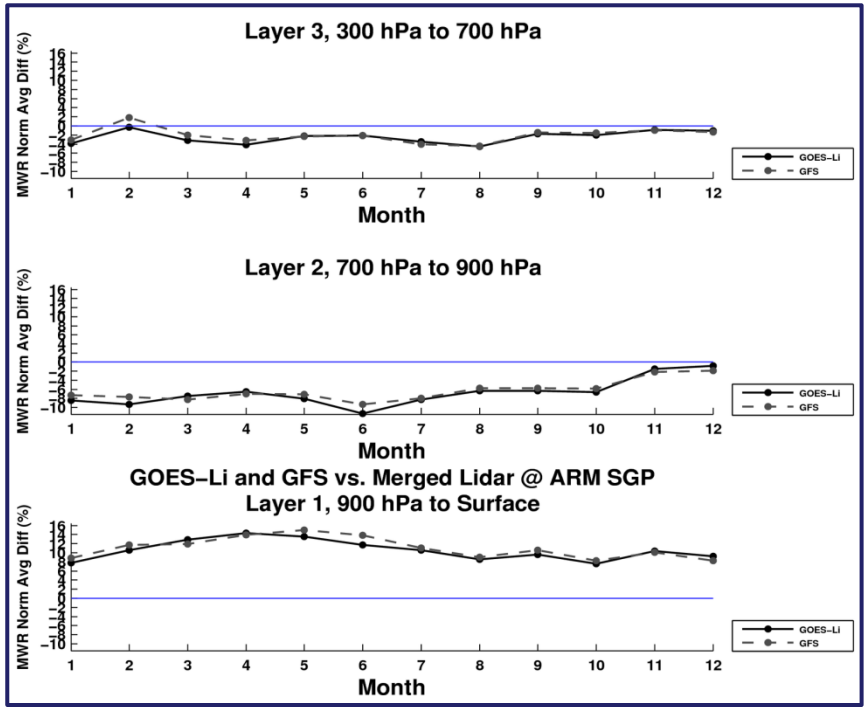
(Retrievals use NCEP GFS as First Guess Background)



Comparisons against GPS TPW observations around the US show:

- GOES TPW data show improvement over GFS First Guess:
  - *In warm months (when NWP precipitation skill is worst) and when using 06Z, **12Z** and 18Z GFS guess fields*
  - GOES TPW (Li retrievals) data have a wet bias
    - *Worst at time of day when GFS has highest precipitation bias*

- *Multi-layer comparisons against Raman Lidar observations from Oklahoma ARM CART site show:*
  - Distinctly different biases in 3 PW layers
    - Match GFS very closely
  - Raw Mixing Ratio Biases have:
    - Significant annual cycles
    - Daily cycles vary by GFS cycle time
  - Normalized Biases:
    - Have smaller annual cycle
    - *Will be used to **correct** retrievals this spring using either annual or monthly bias removals*
    - Will remove run-to-run inconsistency throughout day



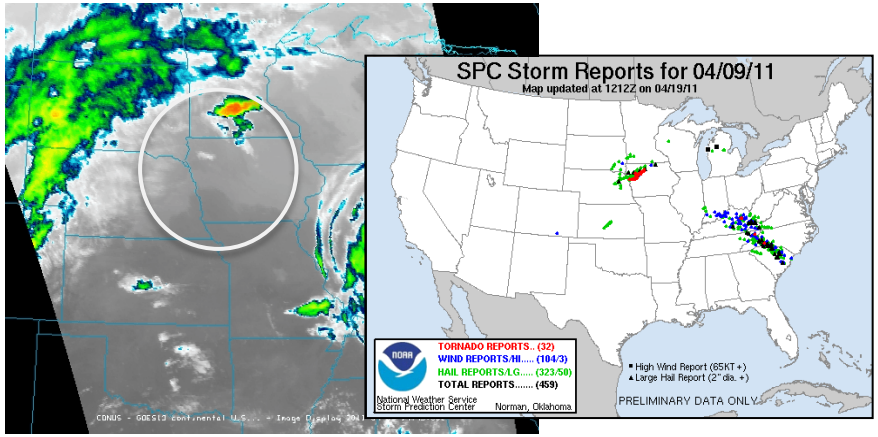
Normalized GOES TPW Bias

Monthly for 2011

4. Results – Impact of Isentropic version of NearCasting Model

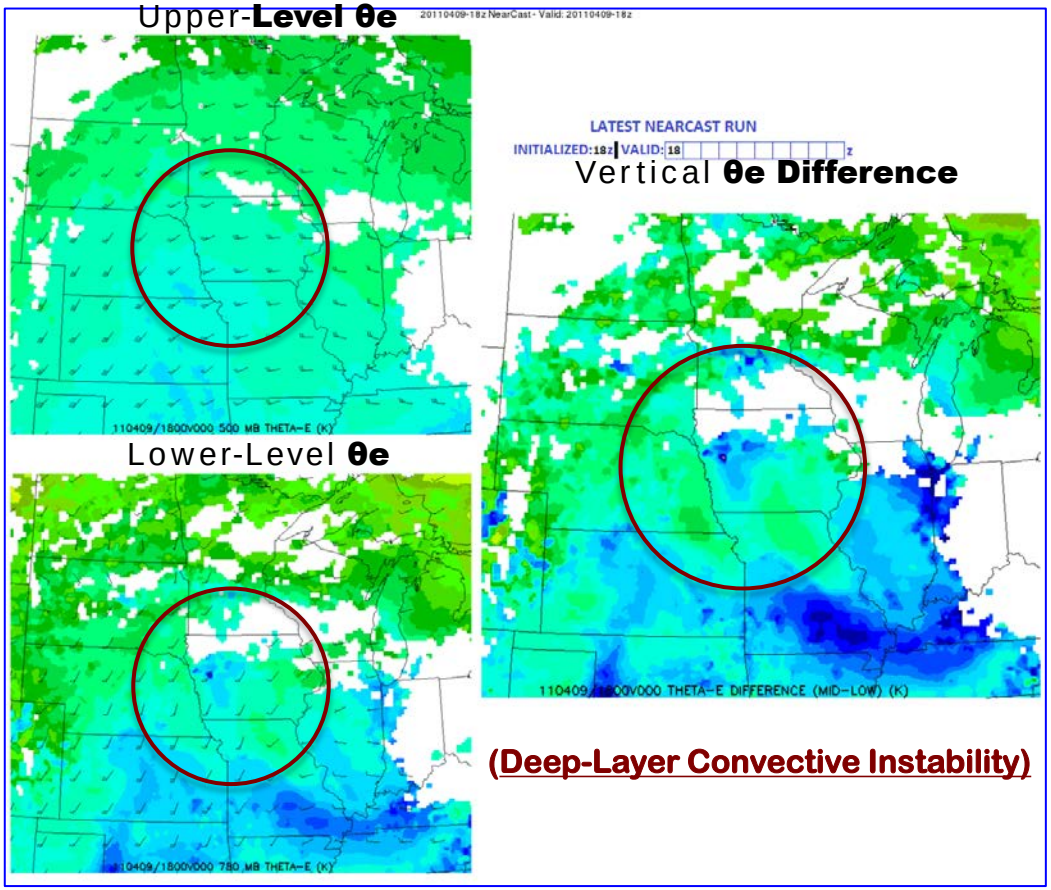
Example from April 9, 2011 – Mapleton, IA

- Tornado struck Mapleton around 00z,
- Convection starts in far eastern Nebraska about 2230Z when as area was predicted to become rapidly unstable as Upper-Level Dryness moves over moist/warm air at lower levels
  - Apparent in 15Z run and enhanced later
- Separate Heavy Precip event followed in SE MN



Conventional Isobaric version of NearCast Model showed:

- Band of Warm/Moist (high θe) air at lower-levels moves central KA, across NE and into western IA as
- Region of upper-level dryness approach moves eastward to same area
- Resulting in rapid destabilization in area that was previously stable
- Severe convection occurred on back side of lower-level moisture band
- No strong differentiation between severe wx & heavy precipitation events



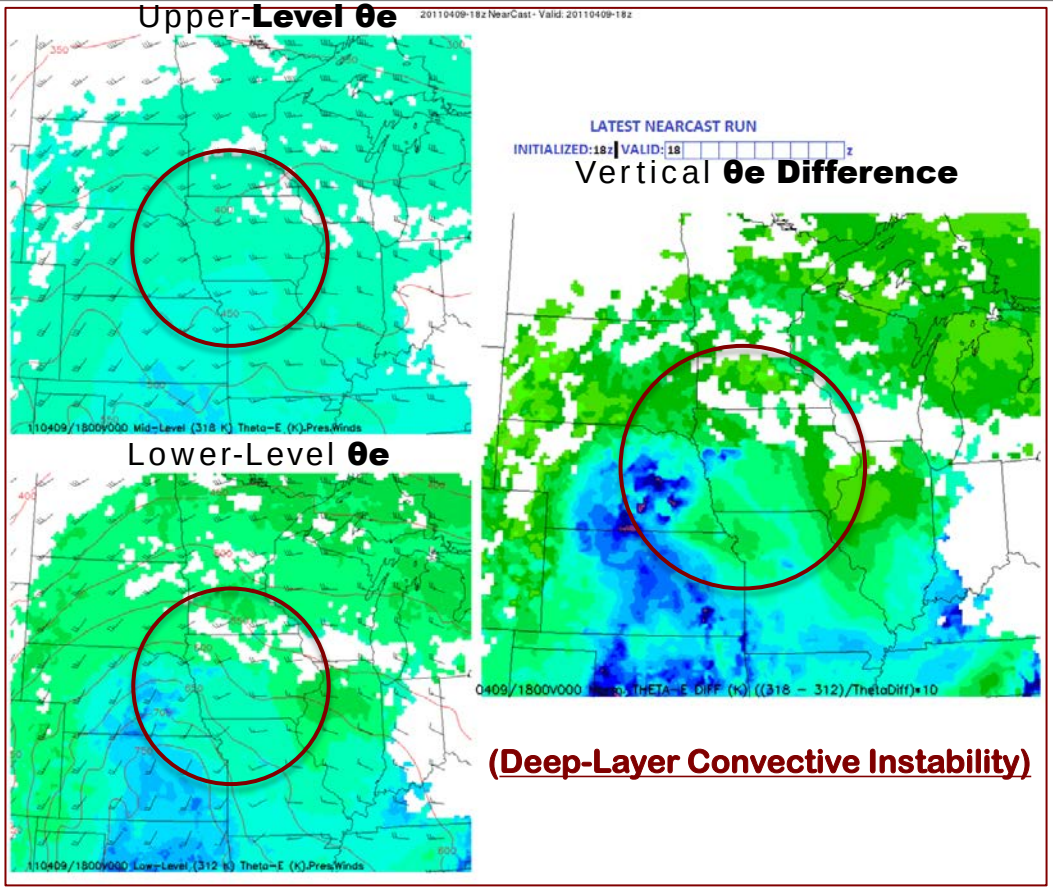
4. Results – Impact of Isentropic version of NearCasting Model

Advantages of posing GOES NearCasts in Isentropic Coordinates:

- Isentropic framework more accurately projects parcels forward in time since flow in clear air (where soundings are available) is along isentropic surfaces, passing through pressure surfaces instead of along them (as in the current model configuration).
- Observations used are above the boundary layer, so diabatic processes AND potential temperature/surface interaction are minimal in areas of interest.
- Because isentropic surfaces can vary with pressure and height, the vertical component of flow is implicitly included in the horizontal component. This means the model will now be able to depict areas of rising and sinking air, further narrowing zones with the most convective potential.
- Improved 'fit' to moisture channel weighting functions

Isentropic version of NearCast Model showed:

- Better defined structure and source of bands of Warm/Moist (high θe) air at lower-levels
- Region of upper-level dryness encroaching from west better defined
- Resulting destabilization is more intense and more isolated
- Movement of moisture along lower isentropic surface suggests lifting mechanism / convective trigger
- Larger moisture supply and weaker Convective Instability associated with heavy precipitation event



4. Results – Impact of Isentropic version of NearCasting Model

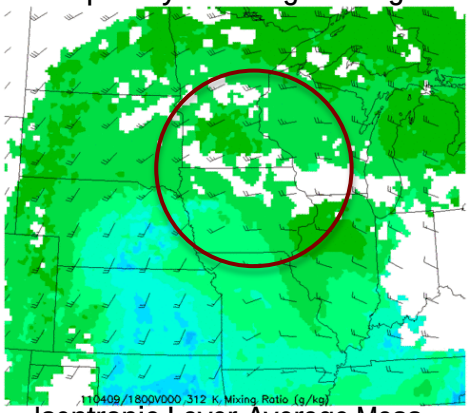
Advantages of posing GOES NearCasts in Isentropic Coordinates:

- Additional diagnostic outputs:
  - The natural inclusion of vertical motions present in flow along sloping isentropic surface allows calculations of both the vertical motion of the Lagrangian parcels that make up the NearCasts and identification of areas of strong subsidence that can inhibit/delay convection.
  - Since the vertical separation between isentropic surfaces represents not only static stability but also the amount of mass contained between isentropic surfaces, the total amount of moisture available for adiabatic transport into areas of potentially heavy precipitation (mixing ratio x mass) can be traced
  - Derived parameters diagnosed using the Isentropic outputs can be transformed back to isobaric levels for easier interpretation -- *but additional Education/Training will be needed for forecasters and SOOs.*

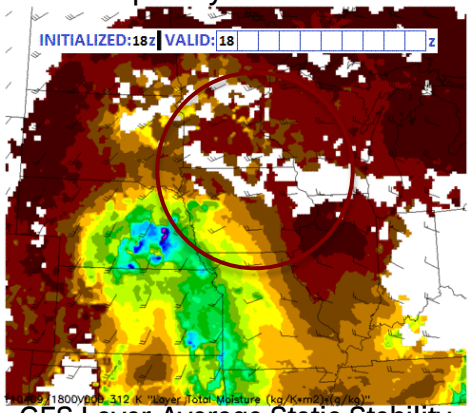
Isentropic version of NearCast Model showed:

- Largest layer-average Mixing Ratio (upper left, moisture per unit geometric volume) remains in IA
- Region of weakest static stability (greatest mass between bounding isentropic surfaces, lower left) moves from SE NE through IA to SE MN – adds info to NWP guidance (lower right)
- When viewed as in terms of the Total Moisture being transported in adiabatically (upper right), the maximum heavy rainfall support focuses on So MN, after and separate from the severe convection in west IA

Isentropic Layer-Average Mixing Ratio

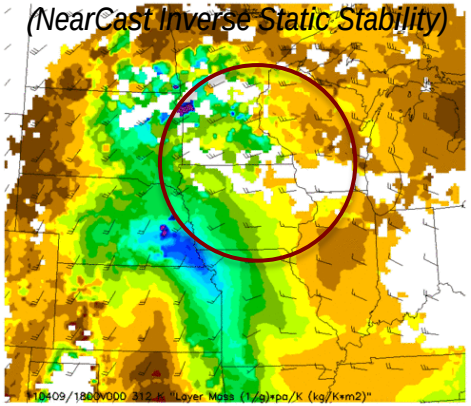


Isentropic Layer Total Moisture

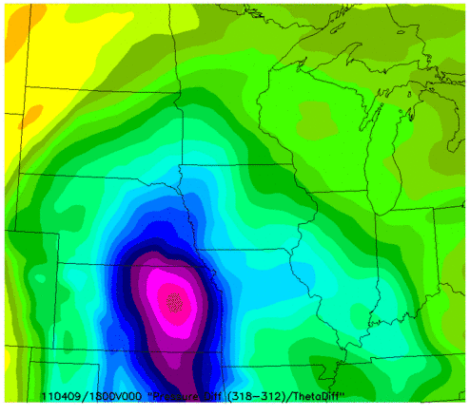


Isentropic Layer-Average Mass

(NearCast Inverse Static Stability)



GFS Layer-Average Static Stability



5. Possible Path to Operations

- NearCast model can be run locally or regionally on a Unix server
- Evaluations have been made at NWS Sullivan and SPC (HWT) and AWC
- 2012 Evaluations showed

1. Forecasters preferred θe difference to a new "Pseudo-CAPE" field – This is good! Is showed that improved training helped forecasters understand the importance of upper-level dryness *and that GOES/SEVIRI observe this well*
2. Provide information about dynamic triggering *(See Isentropic conversion discussion later)*
3. Clouds limit the usefulness of product at times *(Due now to fewer retrievals using improved "Li" retrieval system)*
4. Nearcast fields (especially tendencies) were most helpful when used to compliment NWP & diagnose initial growth and coverage
5. Improved Education and Training material helped forecasters:
   - *Understand* how to use the new products,
   - *Interpret* the NearCast analyses and forecasts and
   - *Absorb* the content of the combined-parameter displays
6. 'New' forecasters still need to be 'exposed' to the new products gradually and repeatedly *(Use of "background displays" to introduce forecasters to products on a daily basis)*

- Continued Proving Grounds testing scheduled in 2013 at SPC, AWC and HPC/OPC
- EUMETSAT is supporting tests of NearCasts using SEVIRI observations as surrogates for GOES-R Legacy Retrievals at European Severe Storms Lab in July

6. Future Plans

- Conversion of NearCast model to use Isentropic coordinates successfully extended the utility of satellite sounding products to forecasters from observations to predictions
  - Enhances value of best clear-air observations from GOES-R – upper-level dryness and mid-to-lower-level moisture
  - Adds additional diagnostic fields to help isolate which area of instability will likely trigger (and not produce) severe convection
- Development of the isentropic version of model will continue.
- Sigma-coordinate and/or sigma-isentropic hybrid version of model may be developed.
  - Will be more useful at the lower levels, especially where orography influences flow.
- New training and testing planned for Proving Grounds at HPC and OPC
  - Will include their NESDIS partners
- Tests of model over Europe and parts of Africa using data from SEVIRI are coordination with EUMETSAT.
- Efforts to adapt model to run over Alaska using polar microwave and hyperspectral IR retrievals are being planned.
  - Use of both forms of retrievals over near-shore oceans will allow model to extend lower in atmosphere and to include effects of near-shore orographic lifting

7. Publication List

- Major effort to publish in refereed journals will occur in last year of project
- Project Publications in past year included:
  - Petersen et al., 2012: USING ANALYSES OF THE INFORMATION CONTENT OF GOES/SEVIRI MOISTURE PRODUCTS TO IMPROVE VERY-SHORT-RANGE FORECASTS OF THE PRE-CONVECTIVE ENVIRONMENT, Proceeding of the EUMETSAT Users Conference, Sopot, Poland.