University of Wisconsin-Madison Space Science and Engineering Center

Cooperative Institute for Meteorological Satellite Studies

NearCasting Severe Convection using Objective Techniques that Optimize the Impact of Sequences of GOES Moisture Products

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Improving the utility of GOES products in operational forecasting

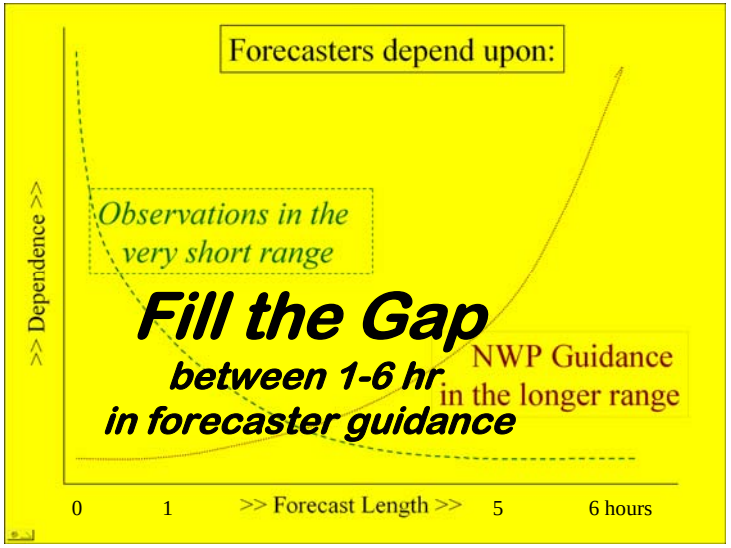
Basic premises - NearCasting Models Should:

Update/Enhance NWP guidance:

Be Fast (valid 0-6 hrs in advance)

Be run frequently

- ***Can avoid 'computational stability' issues of 'traditional' NWP methods***



Use all available observation quickly:

"Draw closely" to good data

- ***Avoid 'analysis smoothing' issues of longer-range NWP***

Be used to anticipate rapidly developing weather events:

"**Perishable**" guidance products – need rapid delivery

- ***Avoid 'computational resources' issues of longer-range NWP***

Run Locally? – Few resources needed beyond comms, users easily trained

We will focus on the "pre-storm environment"

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

Goals: ***- Increase the length of time that forecasters can make good use of frequent, quality GOES observations to supplement NWP guidance in 1-6 hour forecasts***

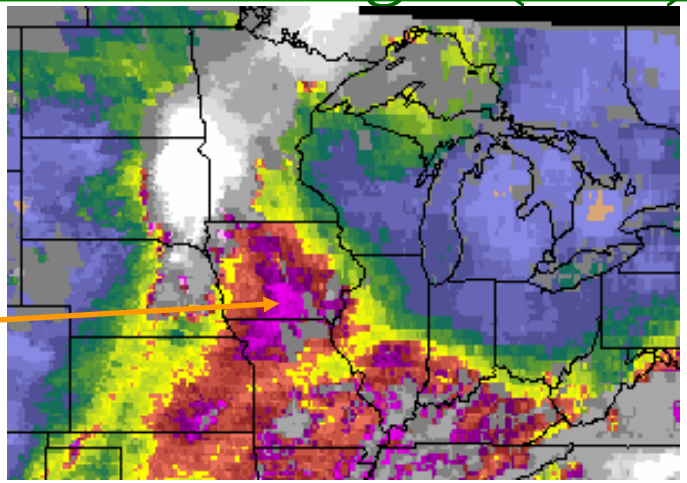
- Provide objective tools to help them do this

A Specific Objective: Expand the benefits of valuable ***Moisture Information*** contained in GOES Sounder Derived Product Images (DPI)

GOES Sounder products images already are available to forecasters

Products currently available include:

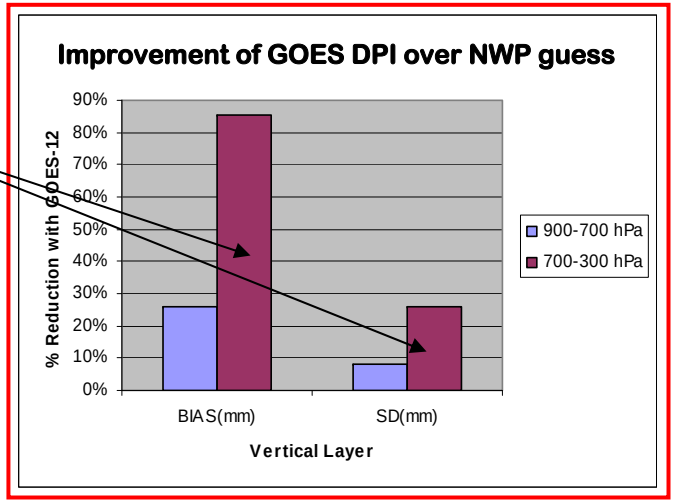
- *Total column Precipitable Water (TPW)*
- *Stability Indices, . . .*
- ***3-layers Precipitable Water (PW) . . .***



GOES 900-700 hPa PW - 20 July 2005

DPI Strengths and Current Limitations

+ **Image Displays speed comprehension of information in GOES soundings**, and
+ **Data Improve upon Model First Guess**,



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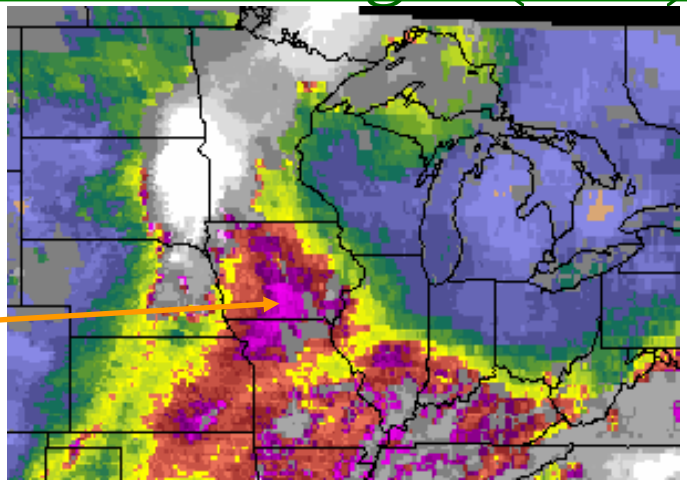

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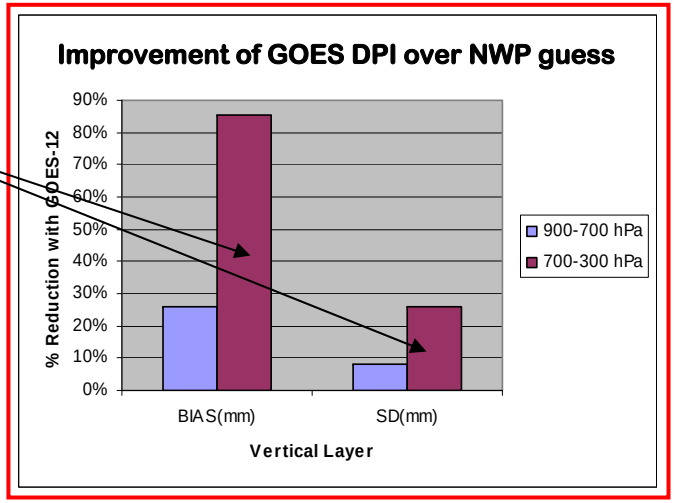


BUT

- **Products used *only* as observations, and**
- **Currently have no predictive component**
  - ***Data not used in current NWP models***

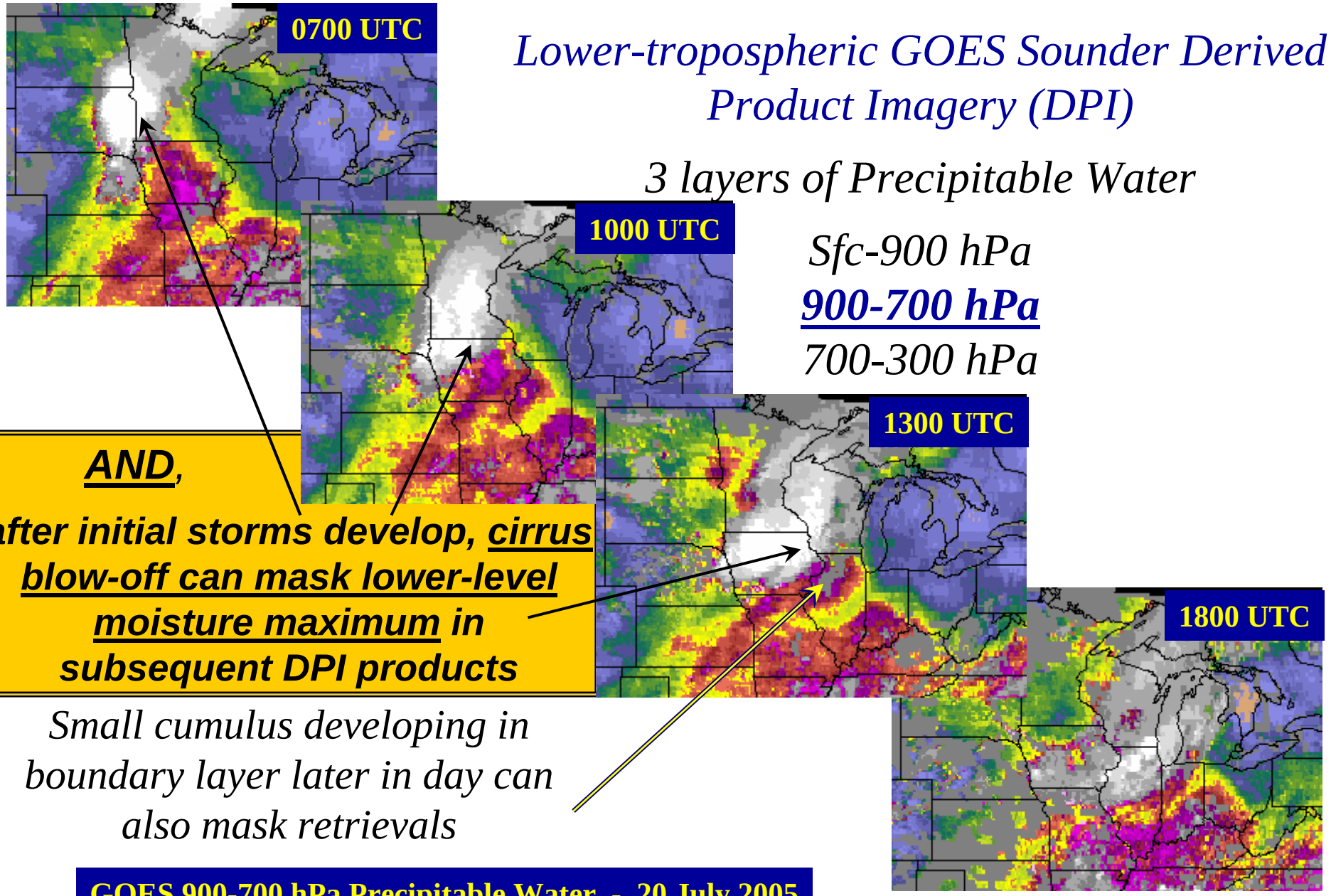
Lower-tropospheric GOES Sounder Derived Product Imagery (DPI)

3 layers of Precipitable Water

Sfc-900 hPa

900-700 hPa

700-300 hPa



AND,

after initial storms develop, cirrus blow-off can mask lower-level moisture maximum in subsequent DPI products

Small cumulus developing in boundary layer later in day can also mask retrievals

GOES 900-700 hPa Precipitable Water - 20 July 2005

Lower-tropospheric GOES Sounder Derived Product Imagery (DPI)

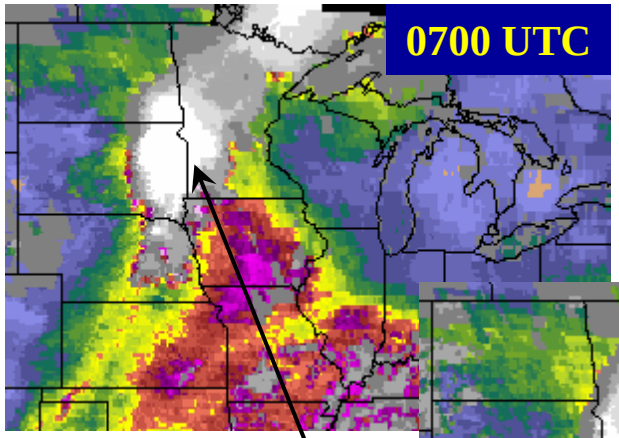
3 layers of Precipitable Water

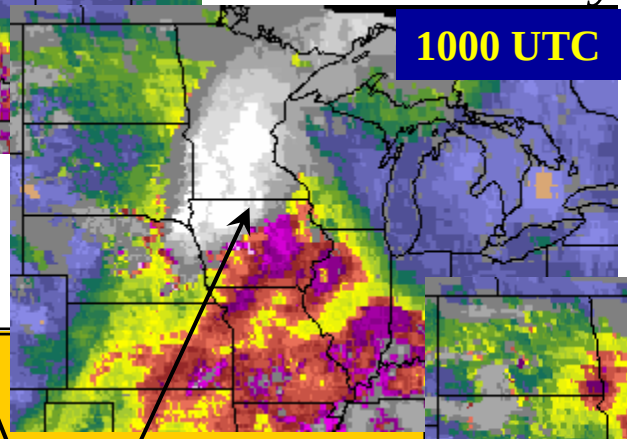
Sfc-900 hPa

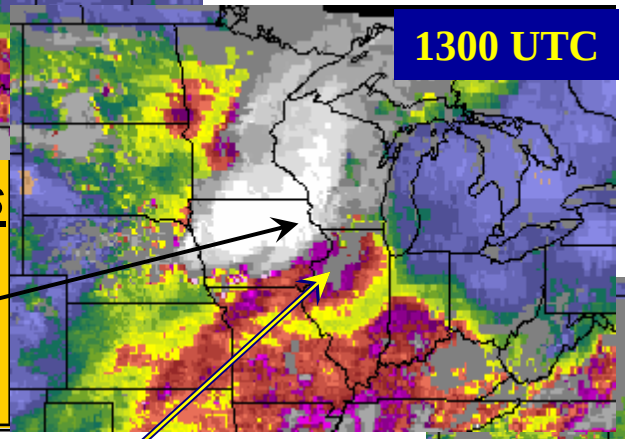
900-700 hPa

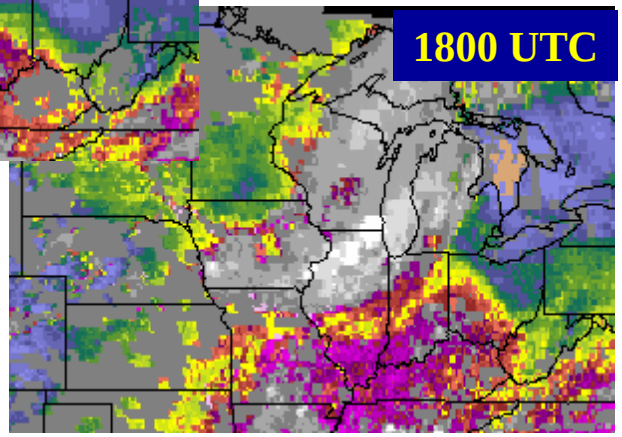
700-300 hPa

Forecasters need new tools that both preserve high-resolution data and show the future distribution of moisture









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GOES 900-700 hPa Precipitable Water - 20 July 2005

What are the benefits of a Lagrangian NearCasting approach?

Extending a proven diagnostic approach to prediction

- It is Quick – ***and these forecasts are VERY parishable***

- (10-25 minute time steps) and minimal resources needed

- Can be used 'stand-alone' or to 'update' other NWP guidance

It is DATA DRIVEN

- Data are used directly - no 'analysis smoothing'

– Retains observed maxima and minima and extreme gradients

- Variable Spatial resolution

- Automatically adjusts to available data density

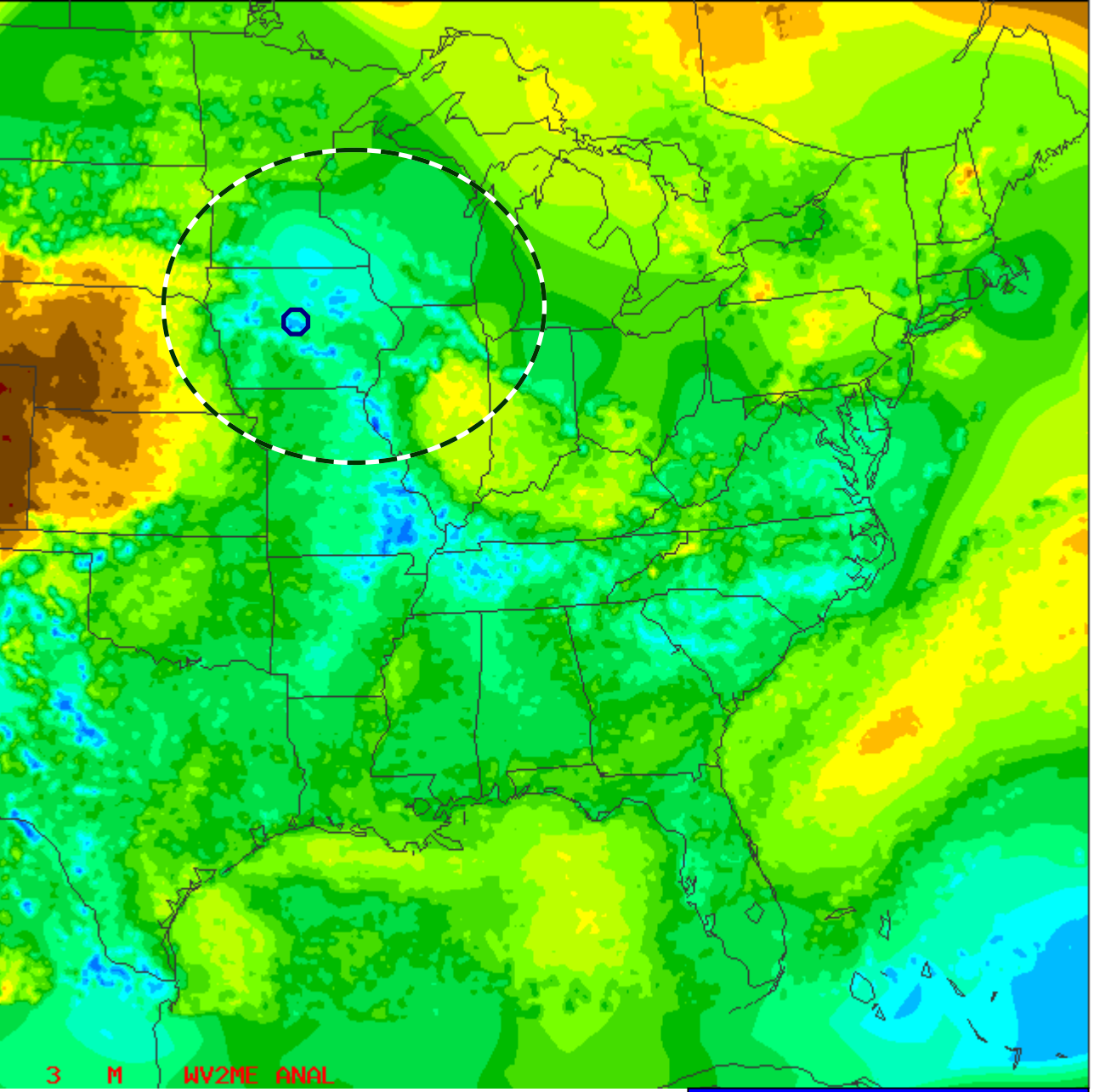
- GOES products can be projected forward <u>at full resolution</u>

- NearCast products exist even after clouds form and subsequent IR observations are no longer available

- New data are added <u>at time observed</u>

- NearCasts updated as soon as GOES sounder products are available

- Data combined over multiple observation times

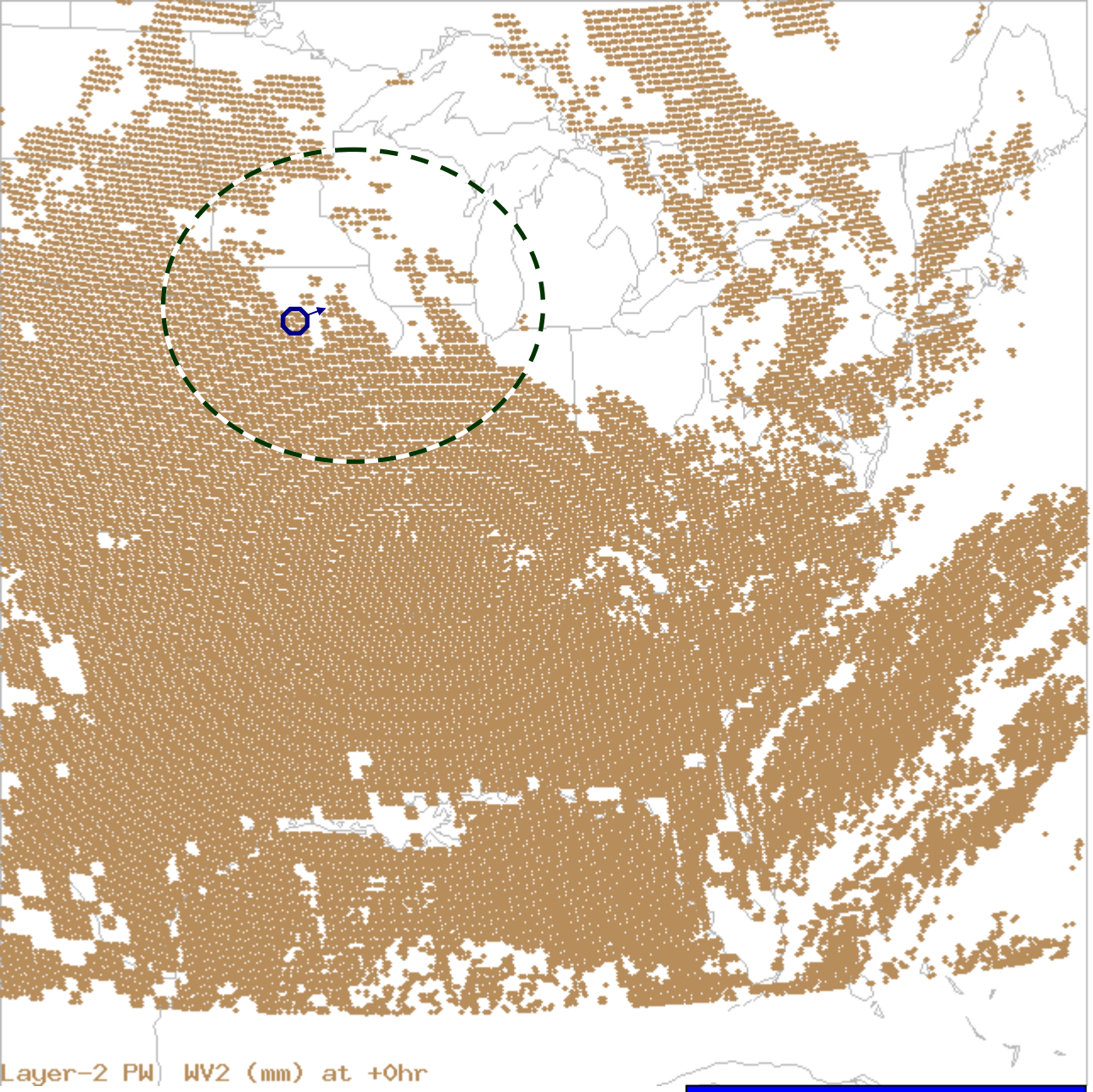


13 April 2006 – 2100 UTC
900-700 hPa GOES PW
0 Hour NearCast

Lagrangian NearCast

How it works:

Instead of interpolating randomly spaced moisture observations to a fixed grid (and smooth data) and then using gridded wind data to determine changes of to calculating moisture changes at the fixed grid points, in the Lagrangian approach ***winds are interpolated to every moisture observation.***



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900-700 hPa GOES PW
0 Hour Ob Locations

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The 10 km data are then moved to new locations, using dynamically changing wind forecasts *using 'long' (10-15 min.) time steps*

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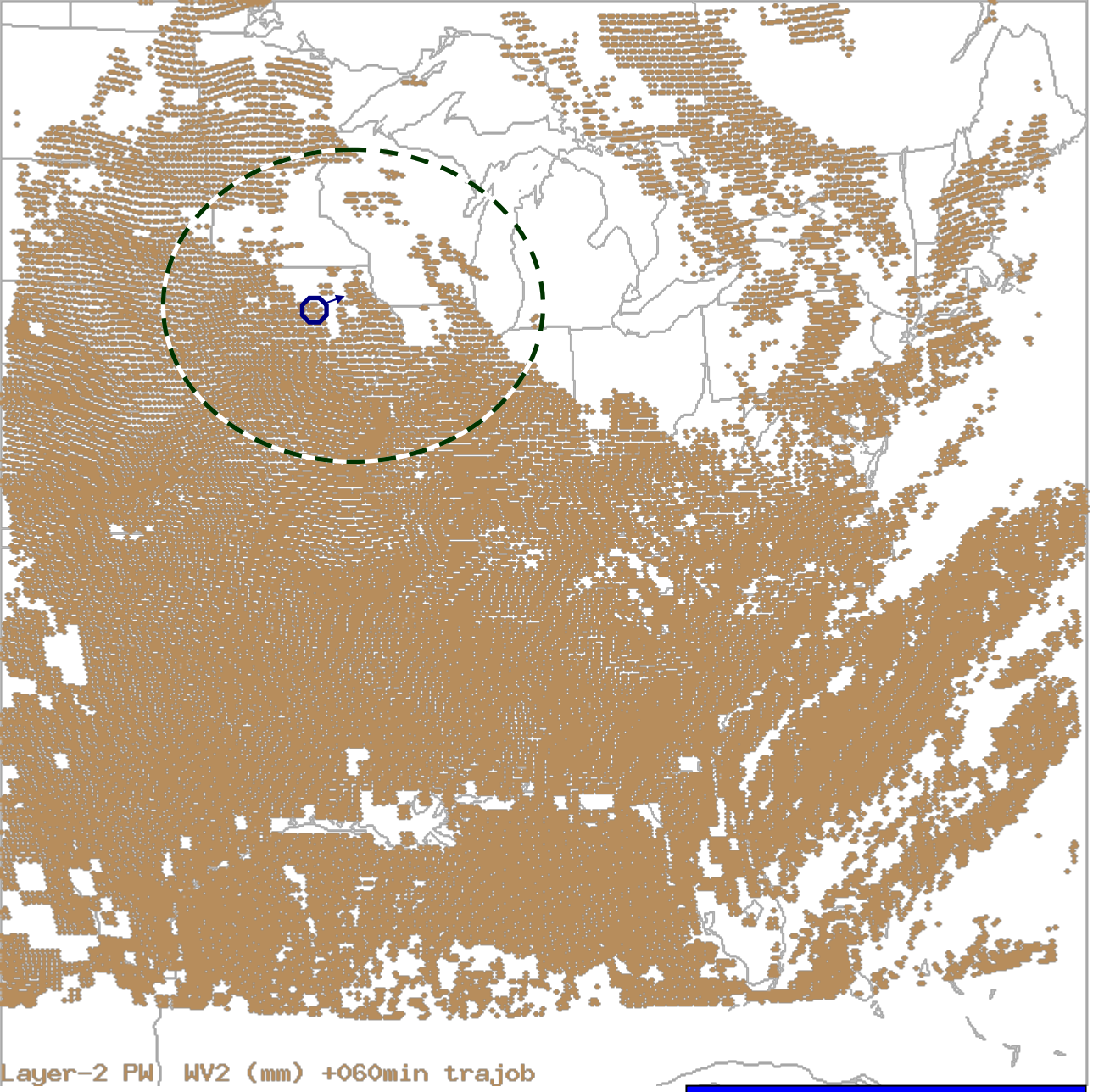

13 April 2006 – 2100 UTC
900-700 hPa GOES PW
1 Hour NearCast Obs

Lagrangian NearCast

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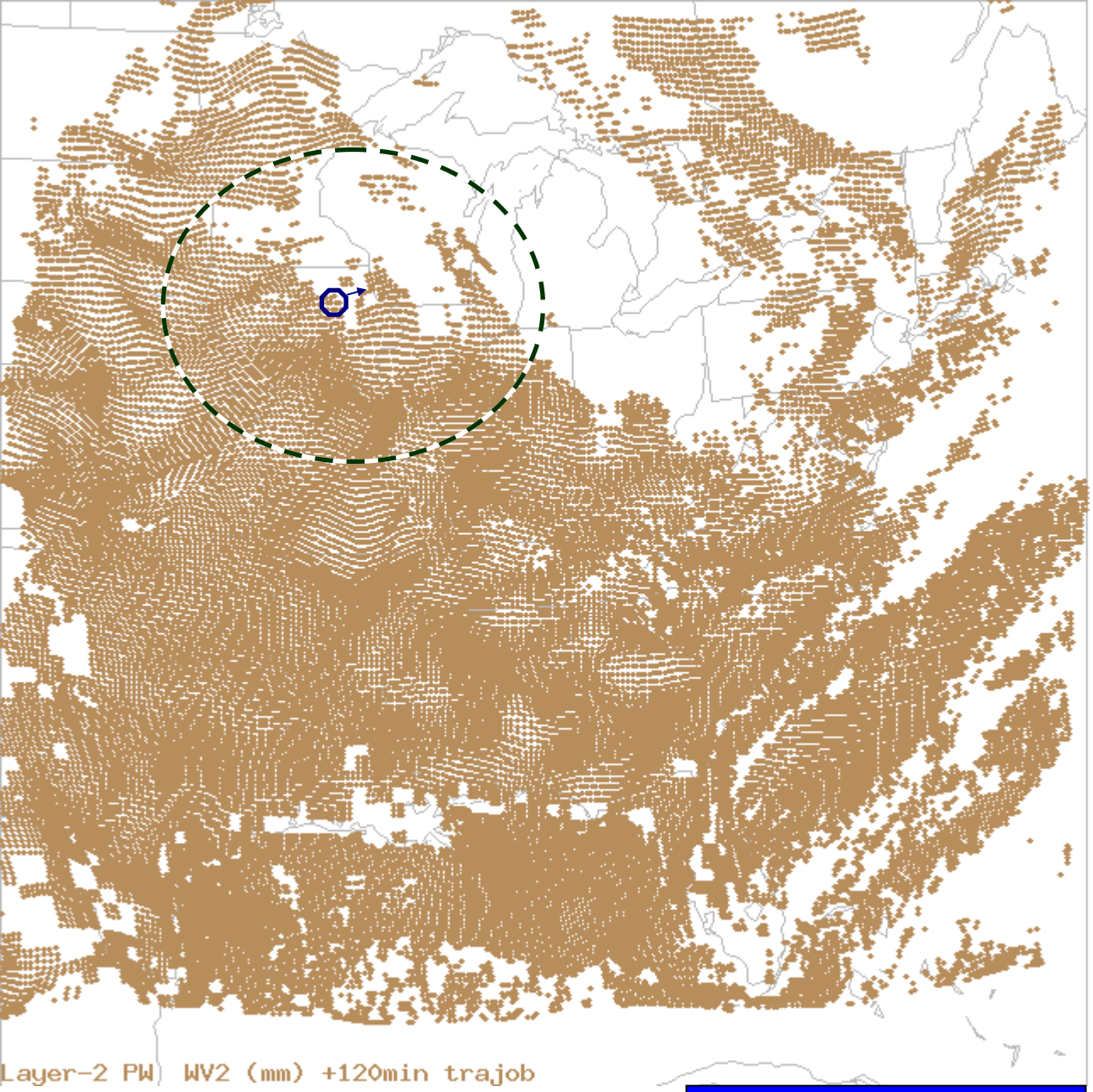

13 April 2006 – 2100 UTC
900-700 hPa GOES PW
2 Hour NearCast Obs

Lagrangian NearCast

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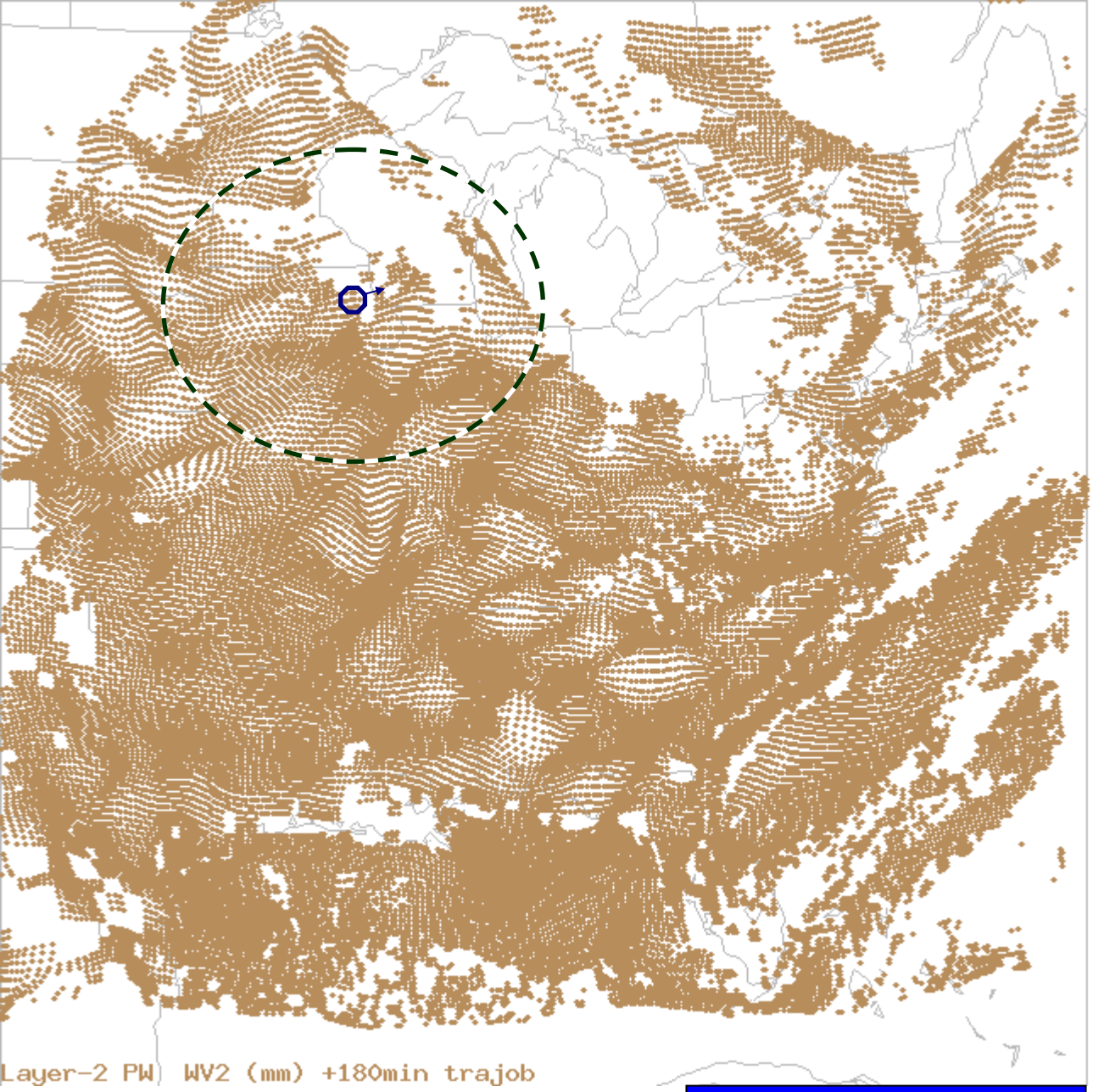

13 April 2006 – 2100 UTC
900-700 hPa GOES PW
3 Hour NearCast Obs

Lagrangian NearCast

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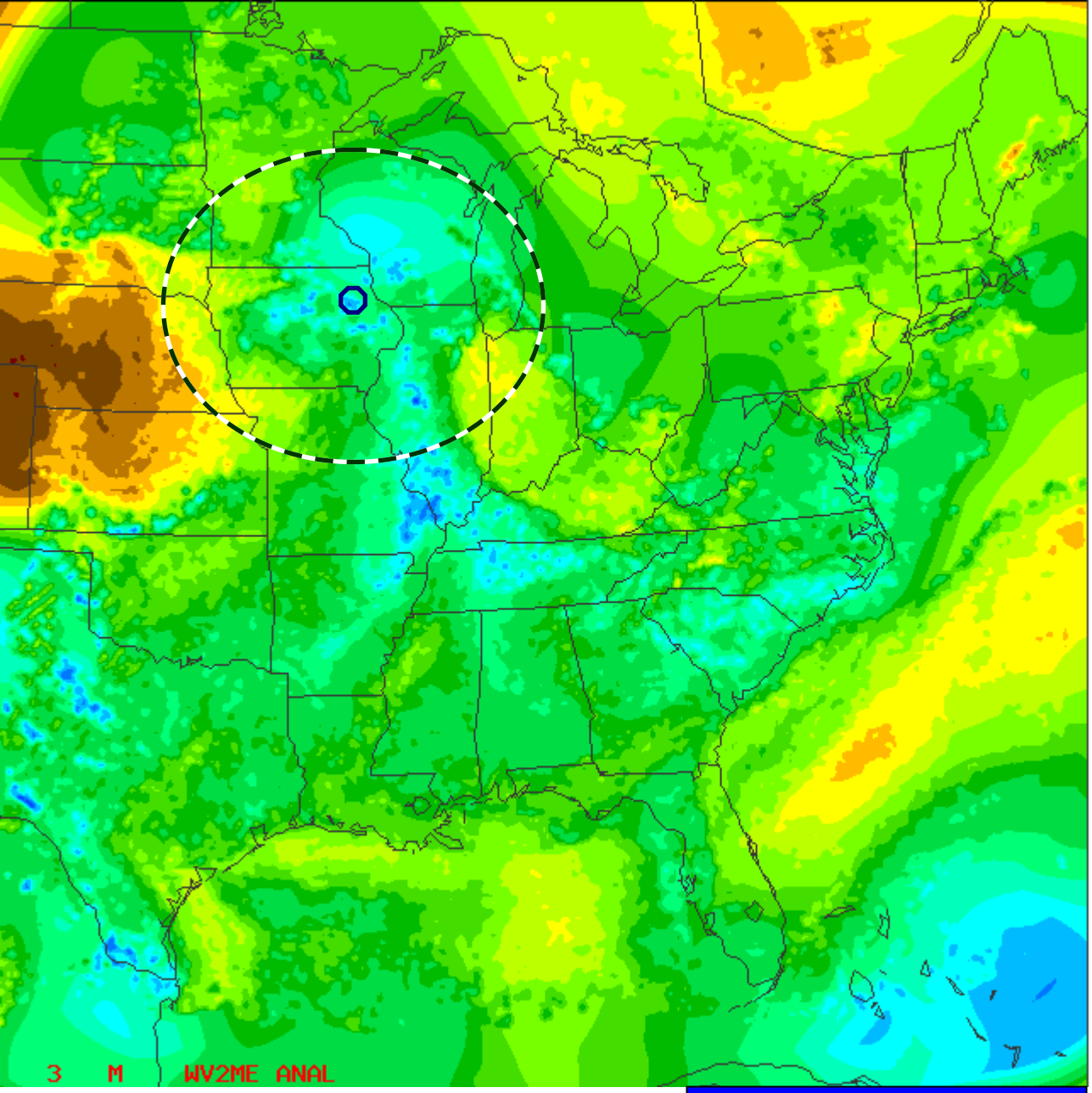

10 km data, 10 minute time steps

13 April 2006 – 2100 UTC
900-700 hPa GOES PW
3 Hour NearCast Image

Lagrangian NearCast

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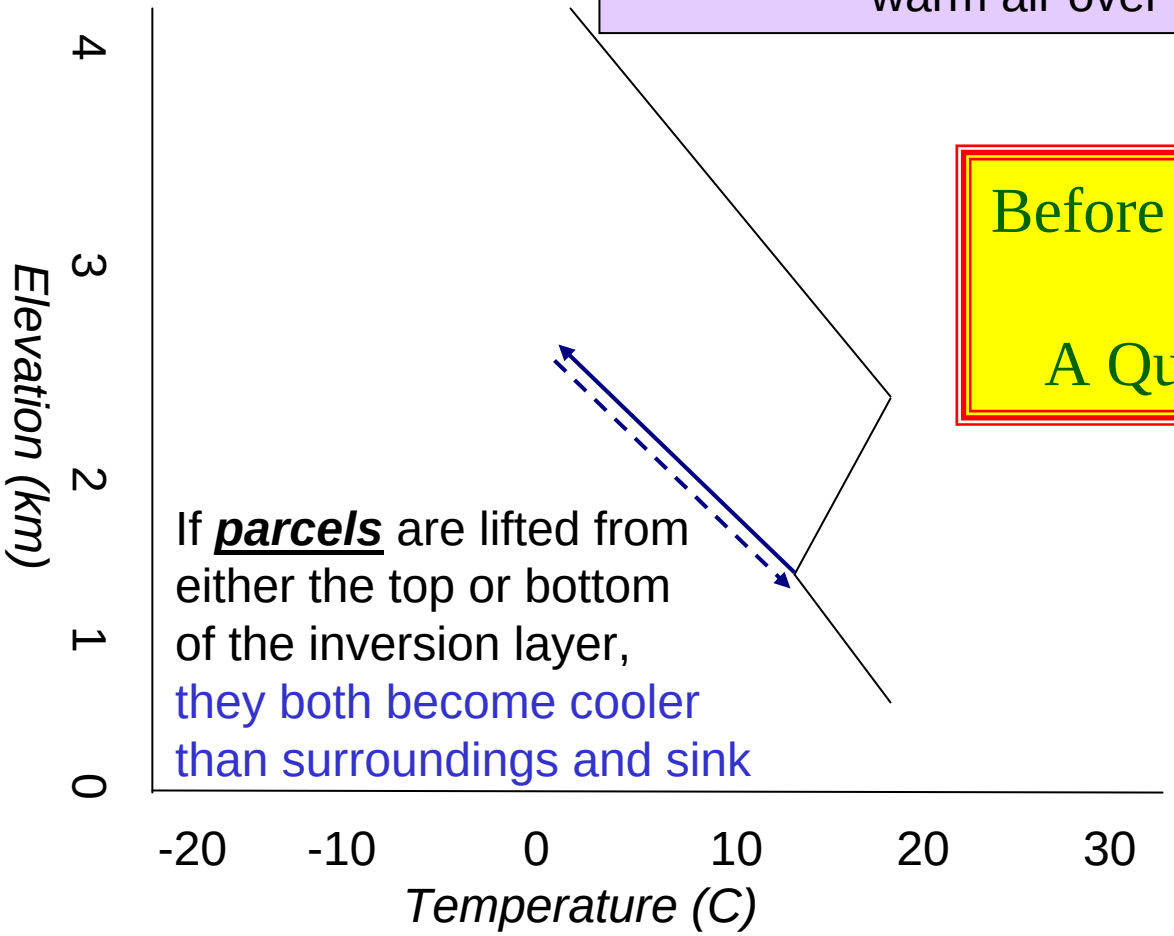
The forecast moisture 'observations' are then periodically transferred back to an 'image' grid, ***but only for display.***

Determining if the atmosphere is conducive to convective storms

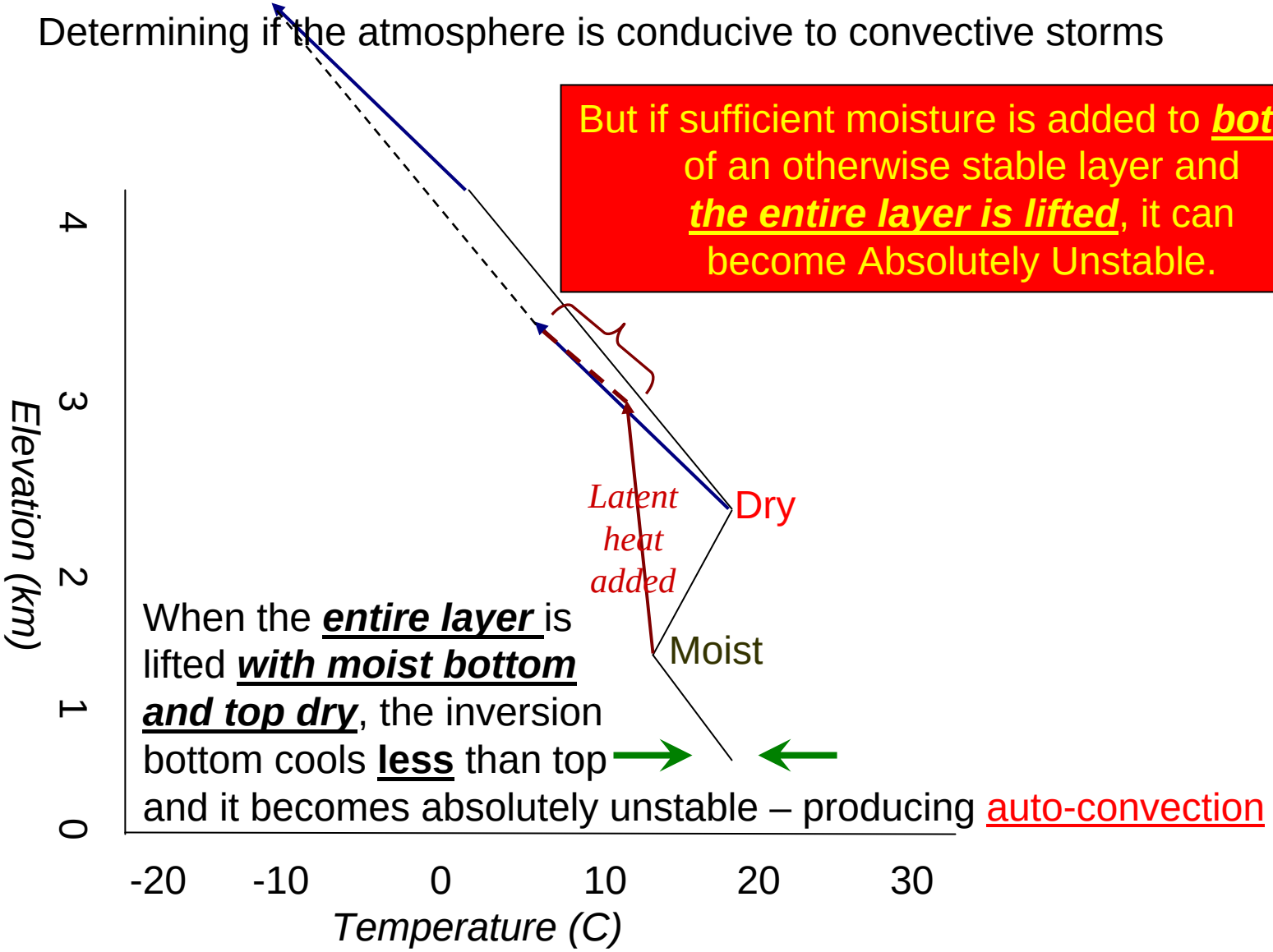
STABLE Vertical Temperature Structure shows warm air over colder air



Before we go farther,

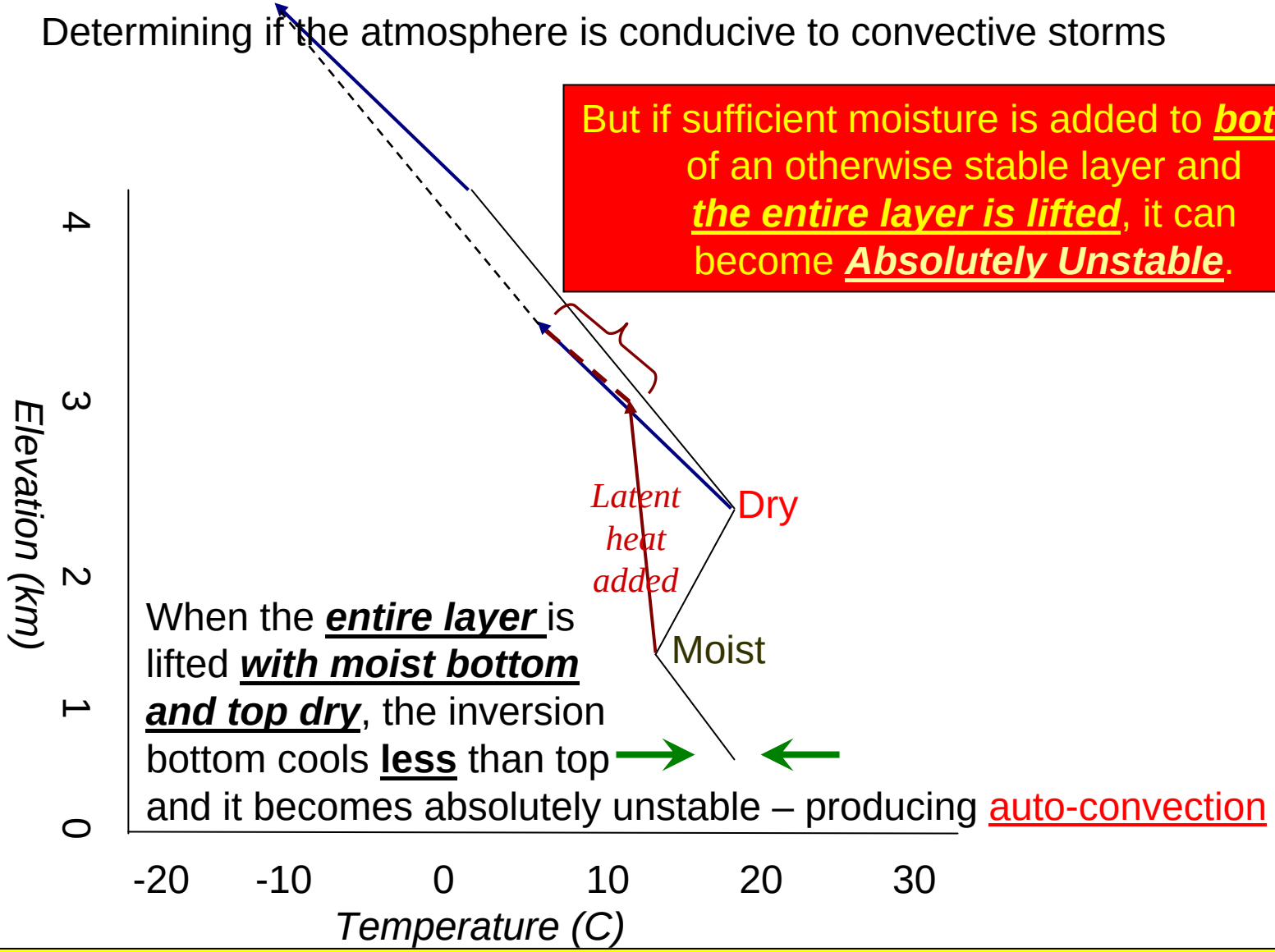
A Quick Tutorial

Determining if the atmosphere is conducive to convective storms



Determining if the atmosphere is conducive to convective storms

But if sufficient moisture is added to ***bottom*** of an otherwise stable layer and ***the entire layer is lifted***, it can become ***Absolutely Unstable***.

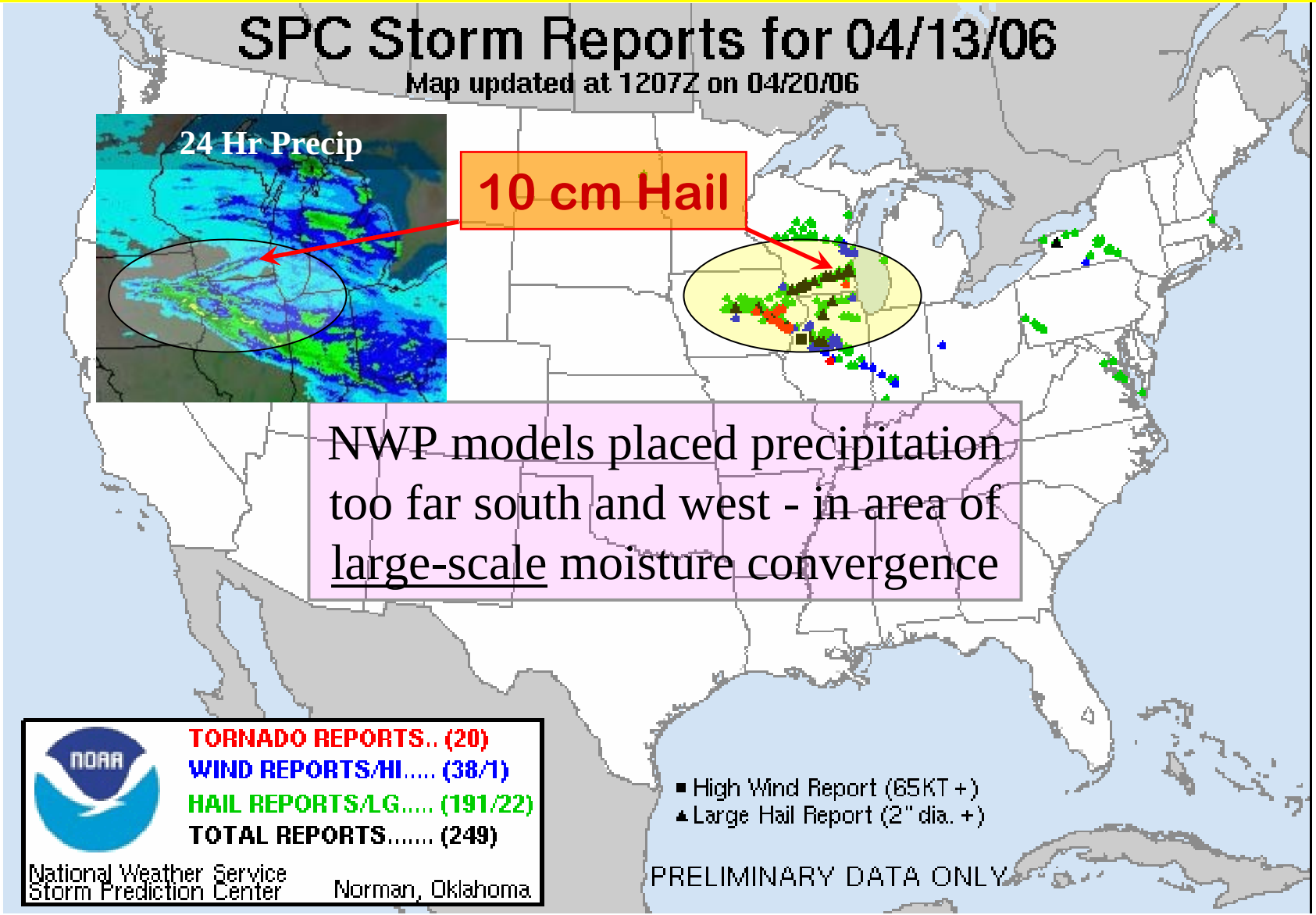


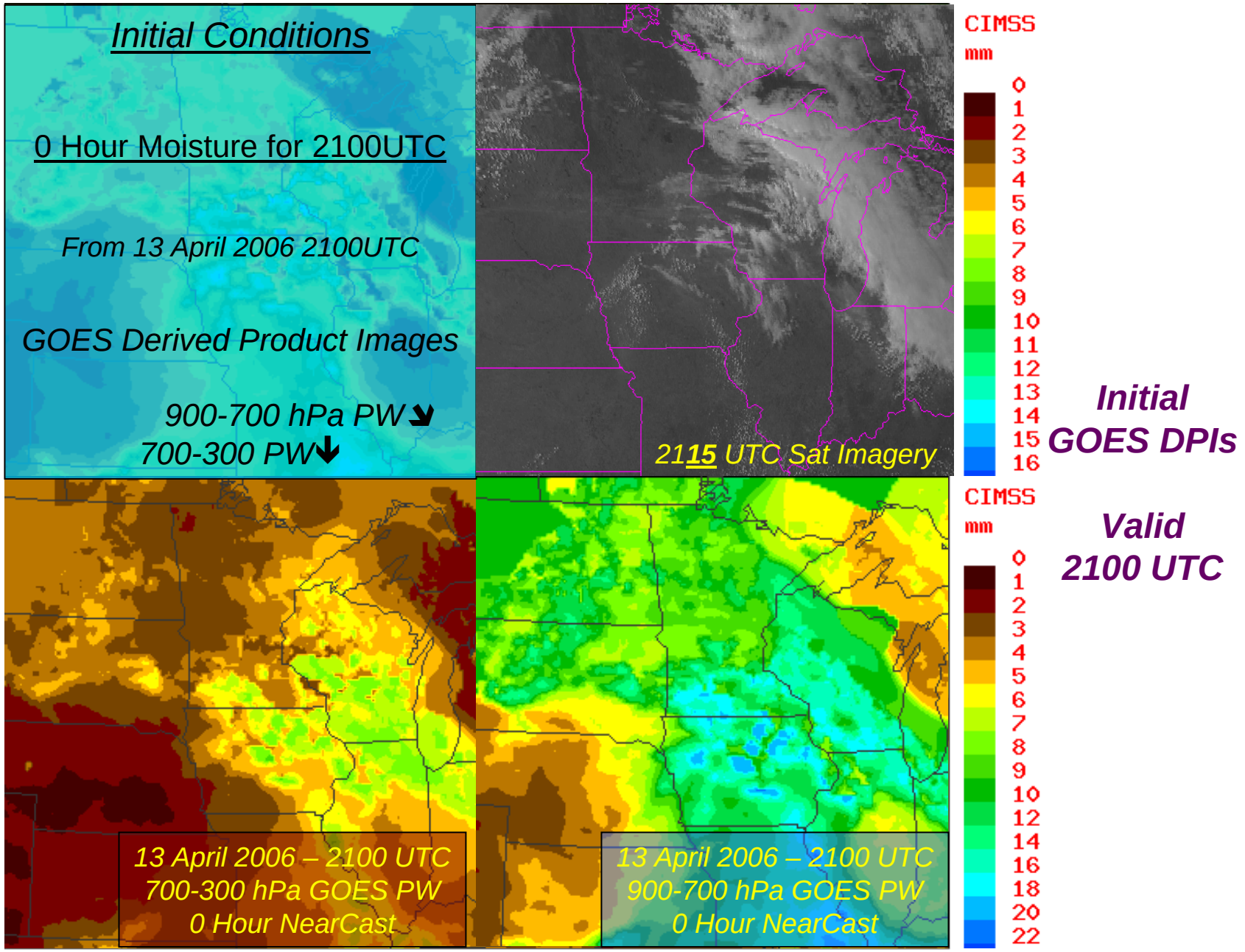
When the ***entire layer*** is lifted ***with moist bottom and top dry***, the inversion bottom cools **less** than top and it becomes absolutely unstable – producing auto-convection

So, we really need to monitor not only the increase of low level moisture, but ,more importantly, to identify areas where Low-level Moistening and Upper-level Drying will occur simultaneously

A case study was conducted for the hail storm event of 13 April 2006 that caused major property damage across southern Wisconsin

The important questions are both where and when severe convection will occur, and Where convection will NOT occur?




Initial Conditions
0 Hour Moisture for 2100UTC
From 13 April 2006 2100UTC
GOES Derived Product Images
900-700 hPa PW
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GOES DPIs
13 April 2006 – 2100 UTC
700-300 hPa GOES PW
0 Hour NearCast
13 April 2006 – 2100 UTC
900-700 hPa GOES PW
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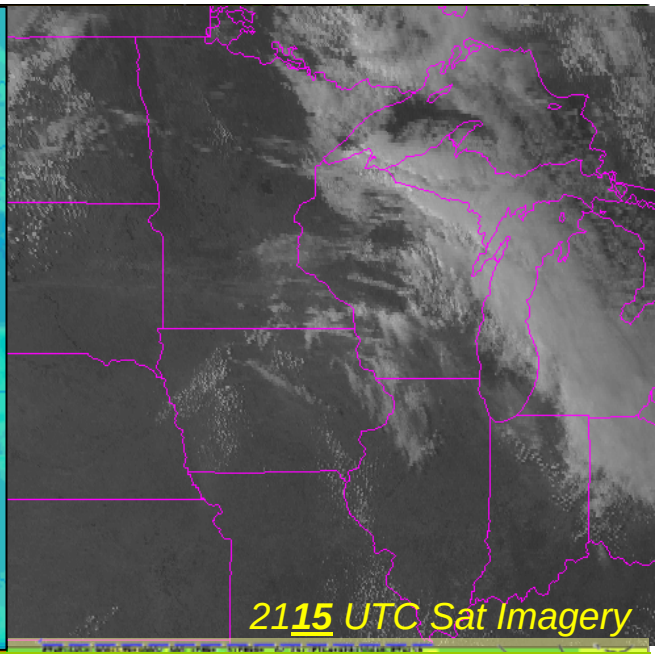
Initial Conditions

0 Hour Moisture for 2100UTC

From 13 April 2006 2100UTC

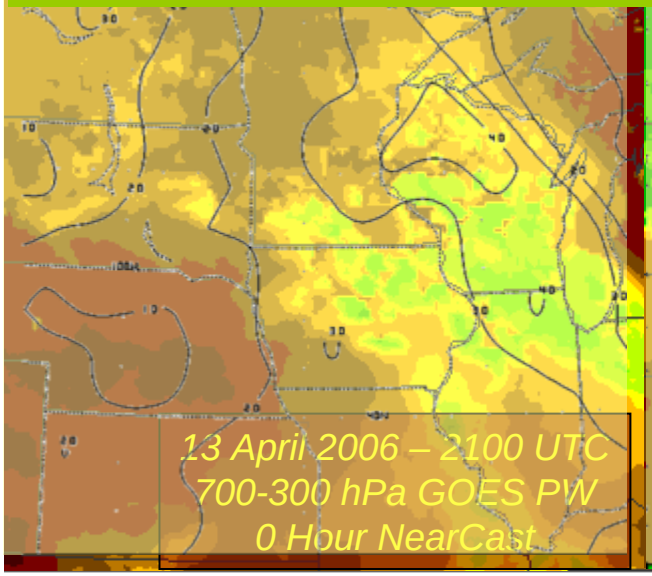
GOES Derived Product Images

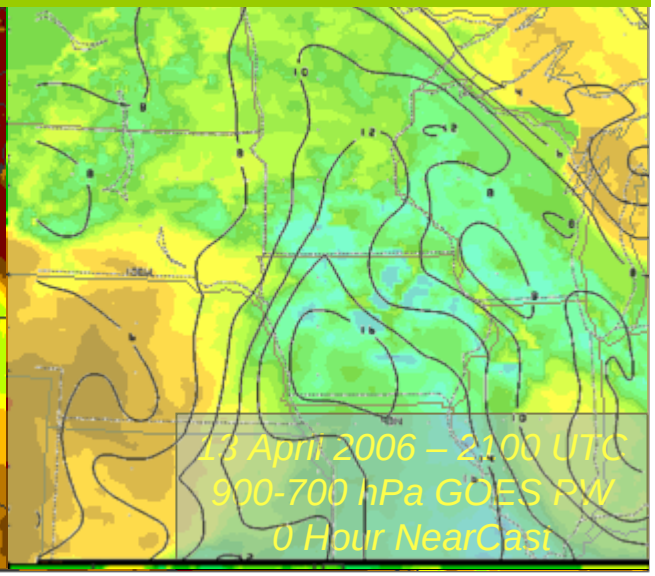
900-700 hPa PW ↘
700-300 PW ↓



Initial GOES DPIs

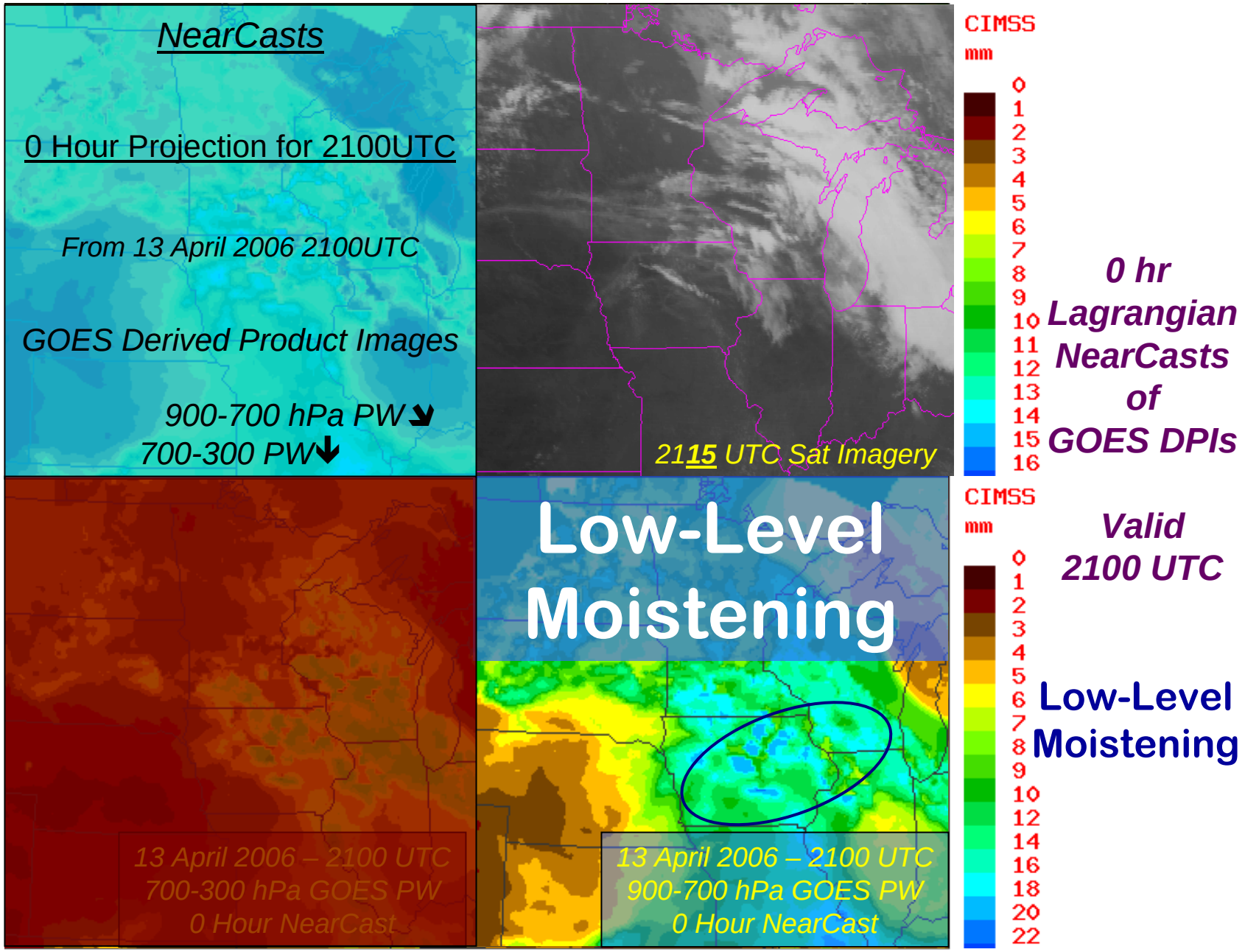
NAM 03h Forecast of 700-300 hPa and 900-700 hPa PW valid 2100 UTC





Valid 2100 UTC

Comparison with NWP conditions


NearCasts
0 Hour Projection for 2100UTC
From 13 April 2006 2100UTC
GOES Derived Product Images
900-700 hPa PW
700-300 PW
2115 UTC Sat Imagery
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0 hr Lagrangian NearCasts of GOES DPIs
Low-Level Moistening
13 April 2006 – 2100 UTC
700-300 hPa GOES PW
0 Hour NearCast
13 April 2006 – 2100 UTC
900-700 hPa GOES PW
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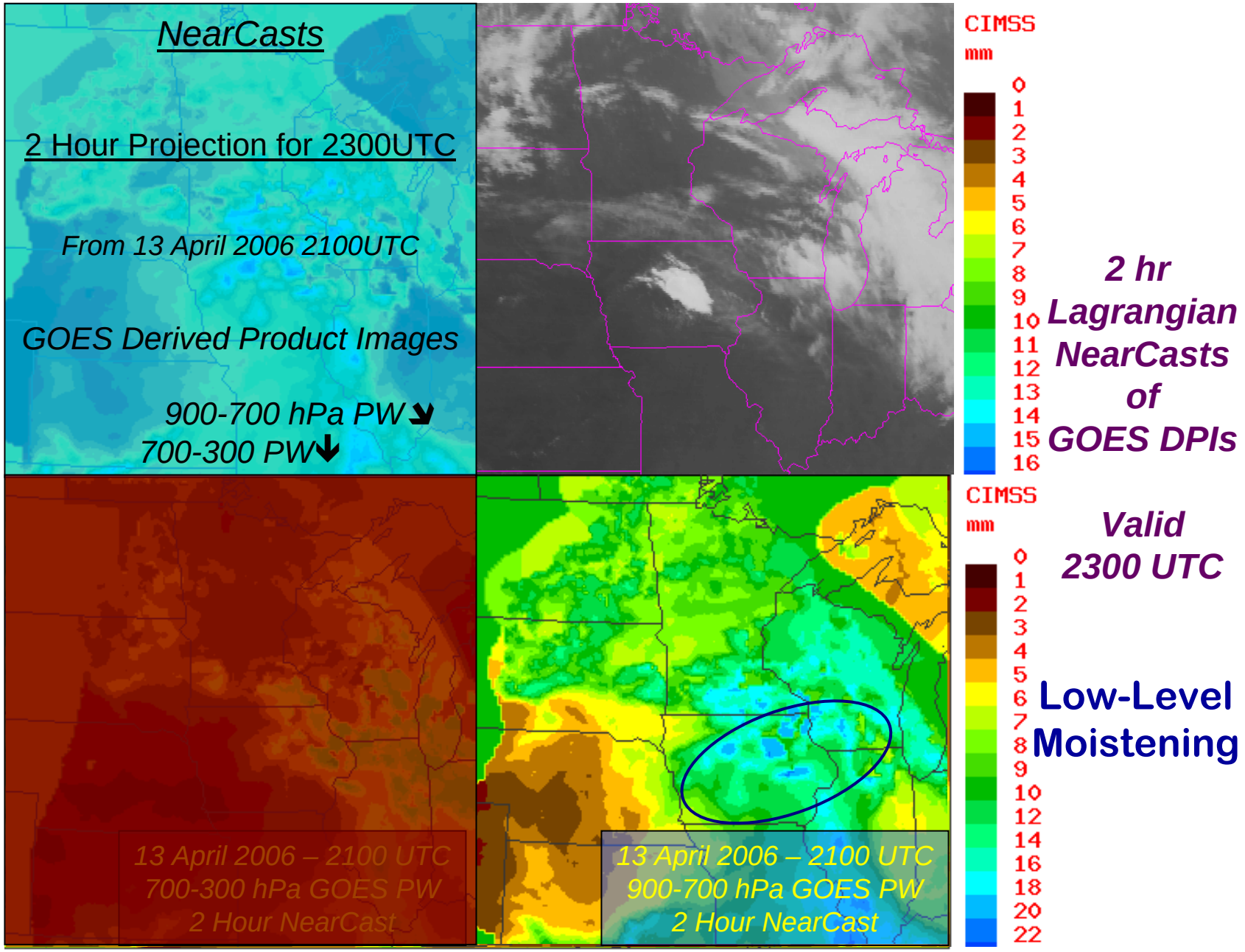
Low-Level Moistening


NearCasts
2 Hour Projection for 2300UTC
From 13 April 2006 2100UTC
GOES Derived Product Images
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2 hr Lagrangian NearCasts of GOES DPIs
13 April 2006 – 2100 UTC
700-300 hPa GOES PW
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13 April 2006 – 2100 UTC
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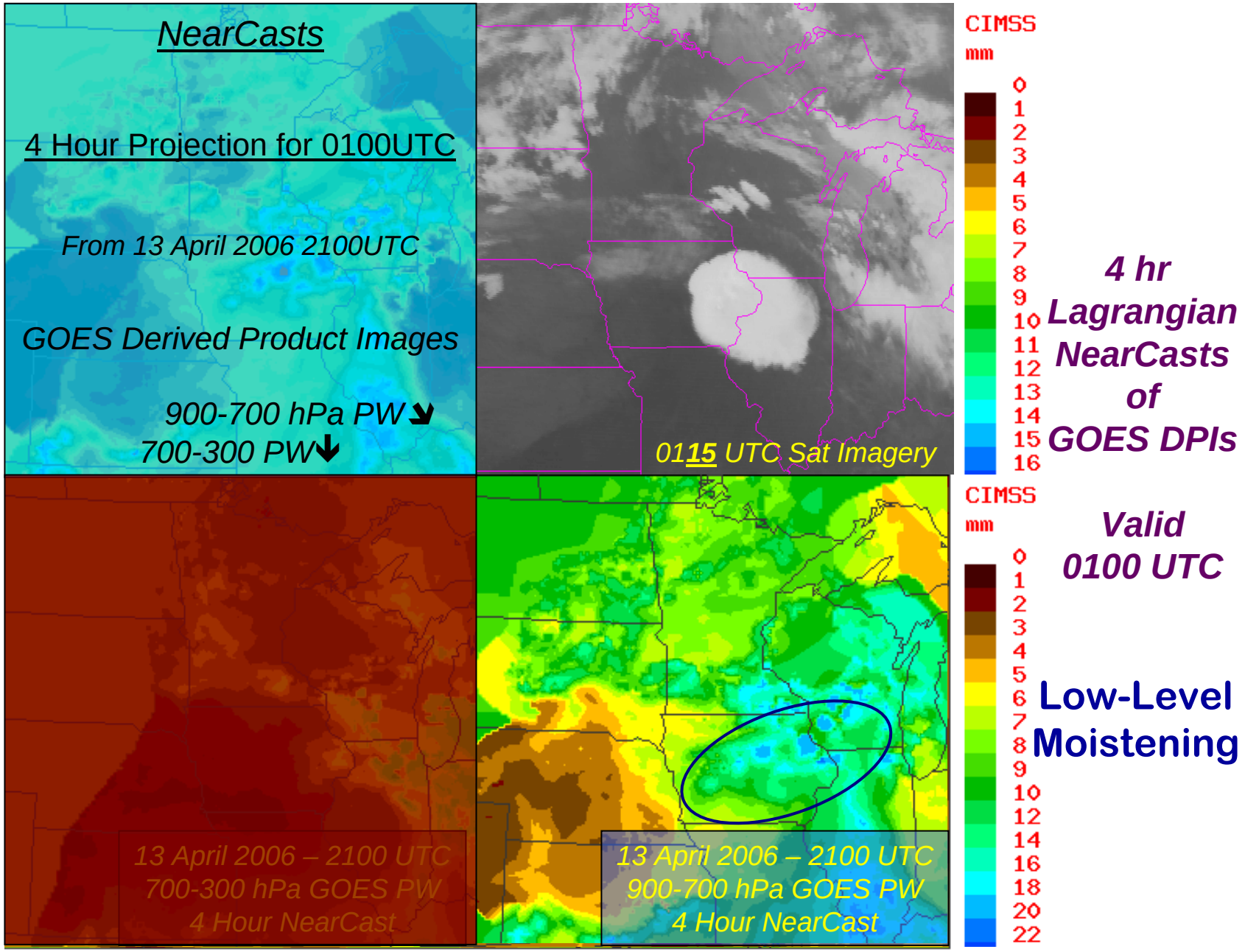
Low-Level Moistening


NearCasts
4 Hour Projection for 0100UTC
From 13 April 2006 2100UTC
GOES Derived Product Images
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700-300 PW
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4 hr Lagrangian NearCasts of GOES DPIs
13 April 2006 – 2100 UTC
700-300 hPa GOES PW
4 Hour NearCast
13 April 2006 – 2100 UTC
900-700 hPa GOES PW
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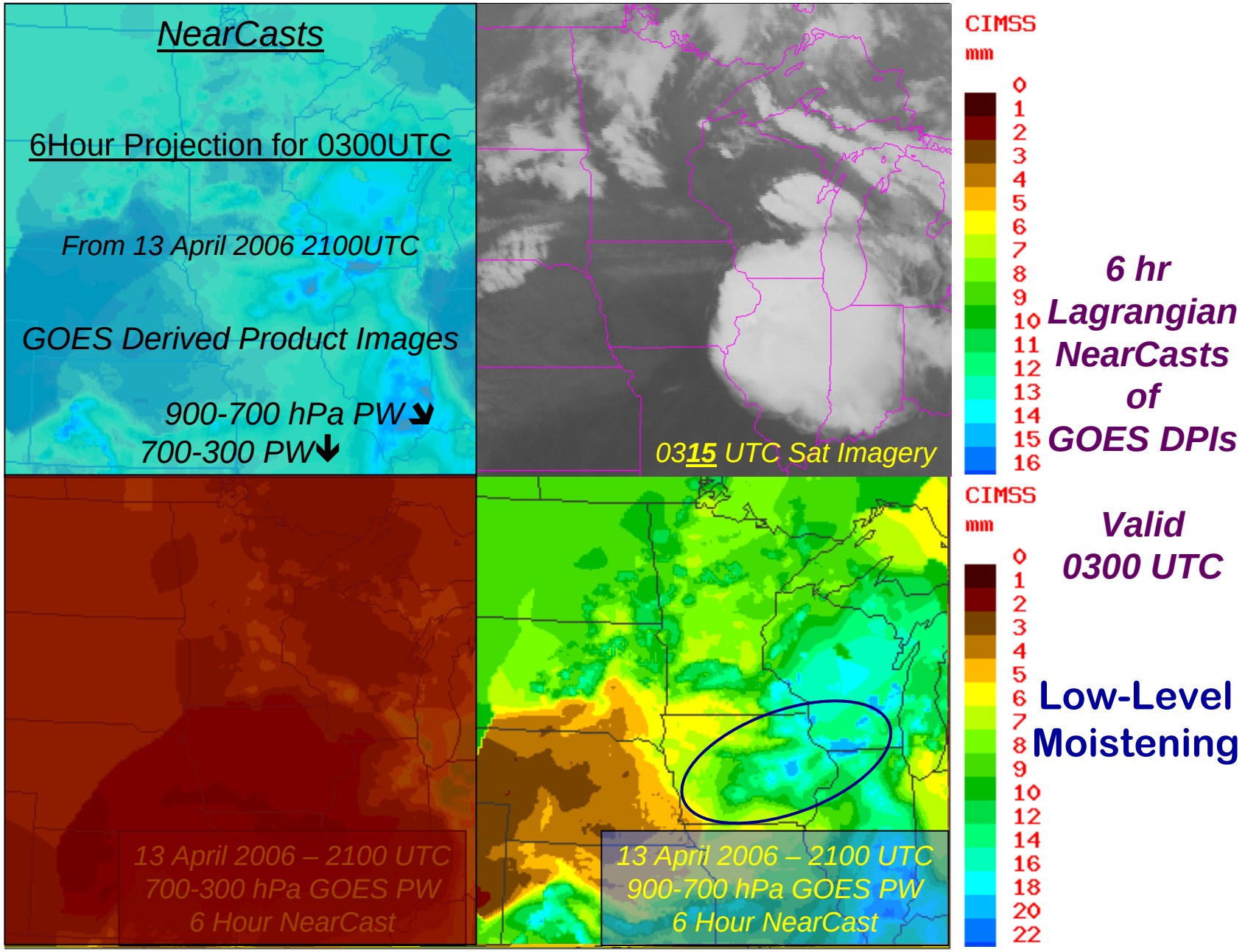
Low-Level Moistening


NearCasts
6Hour Projection for 0300UTC
From 13 April 2006 2100UTC
GOES Derived Product Images
900-700 hPa PW↘
700-300 PW↓
0315 UTC Sat Imagery
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6 hr Lagrangian NearCasts of GOES DPIs
13 April 2006 – 2100 UTC
700-300 hPa GOES PW
6 Hour NearCast
13 April 2006 – 2100 UTC
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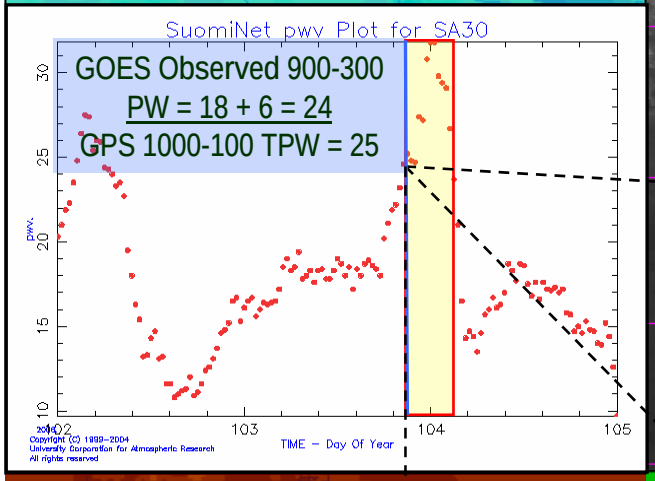
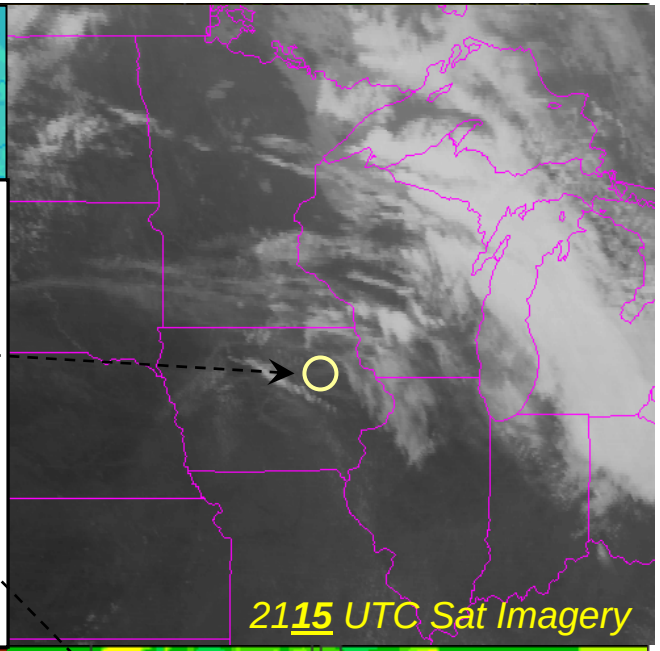
Low-Level Moistening

NearCasts

Validation of rapid moisture change in NE Iowa using GPS TPW data





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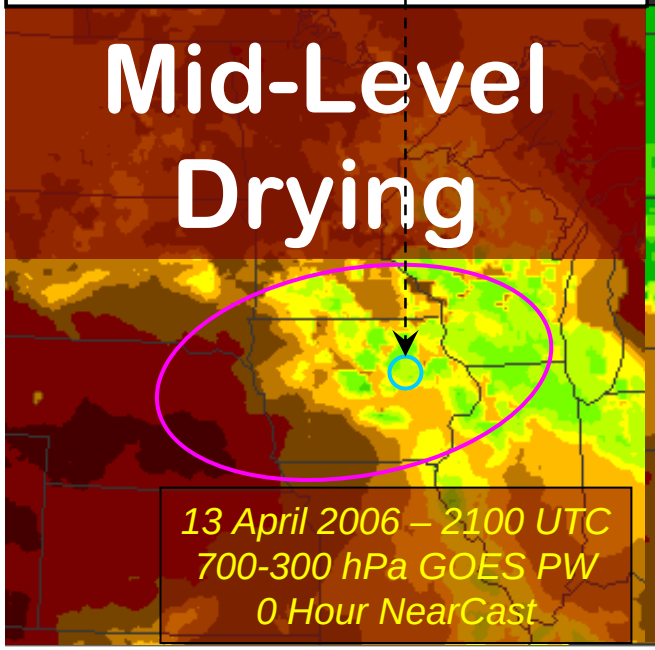
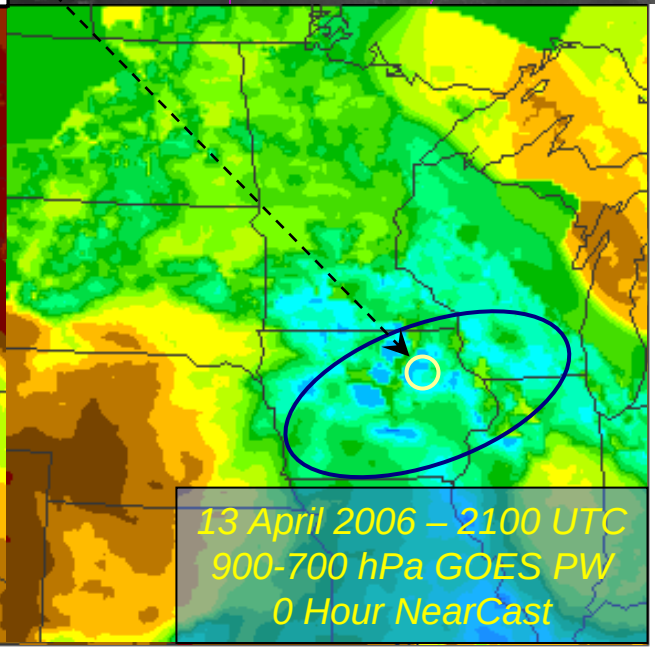
0 hr Lagrangian NearCasts of GOES DPIs

Mid-Level Drying





CIMSS
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Valid 2100 UTC

Mid-Level Drying

NearCasts

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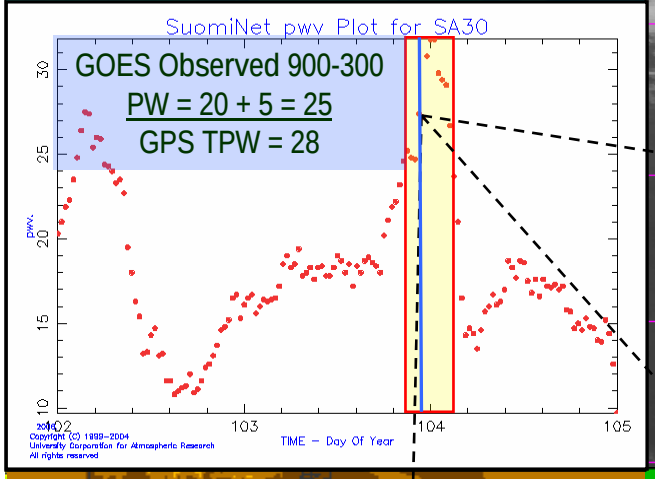

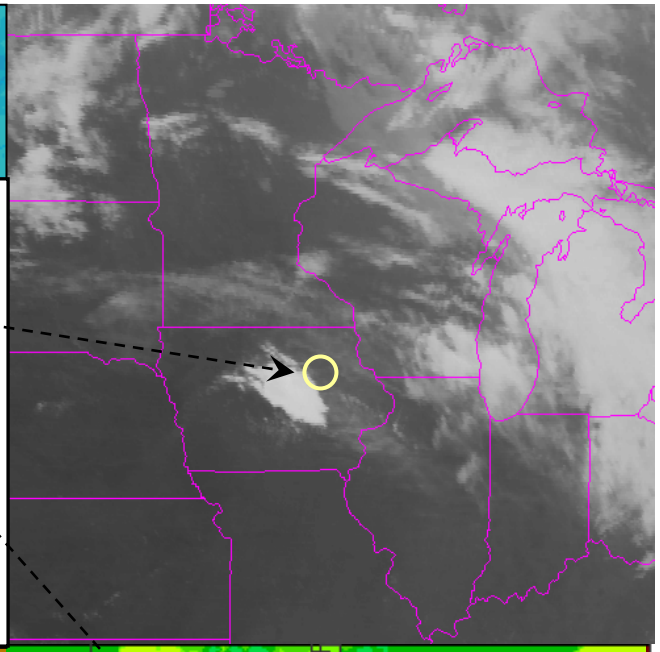

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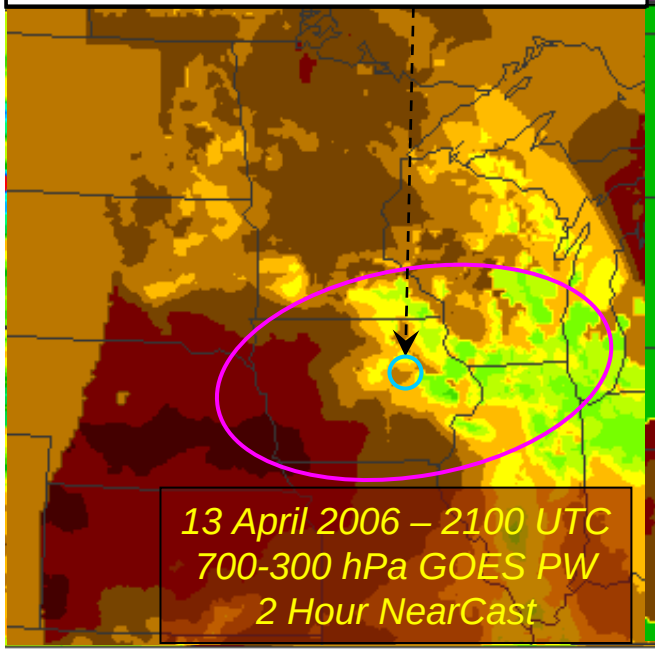
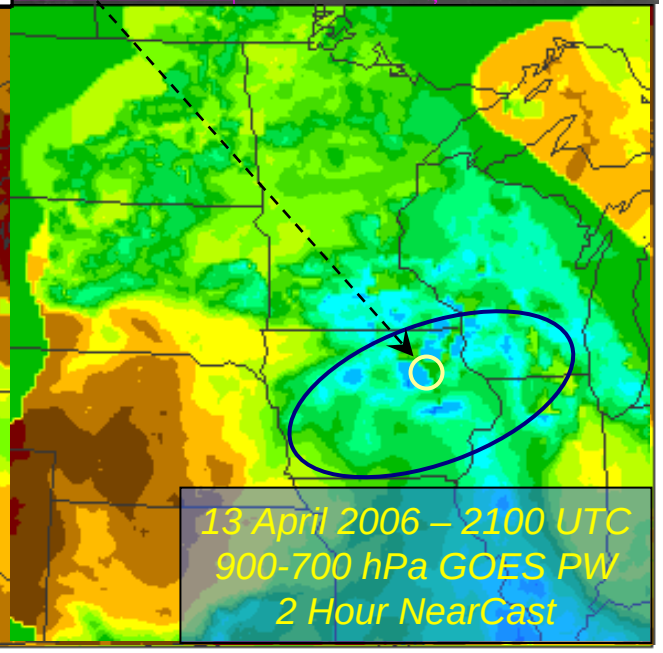
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

2 hr Lagrangian NearCasts of GOES DPIs





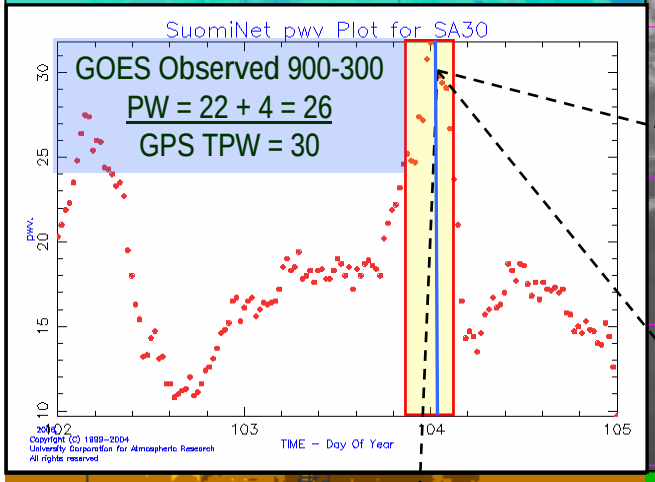
CIMSS
mm
0 1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22

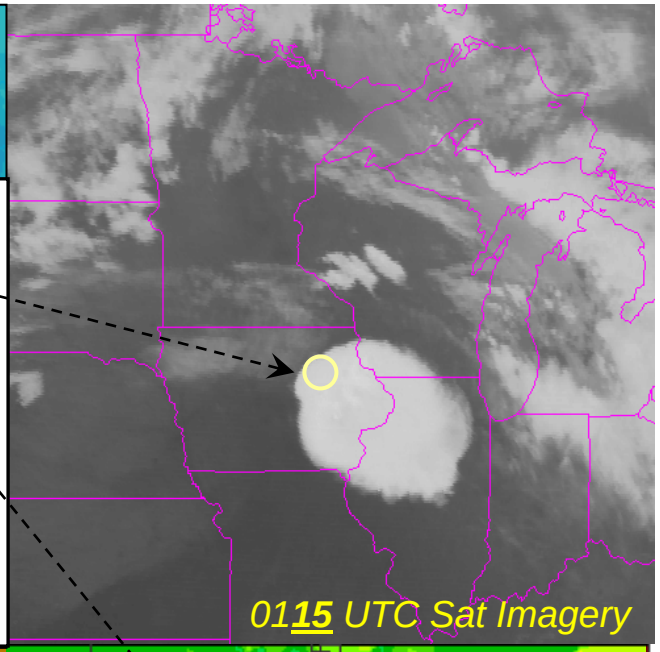
Valid 2300 UTC

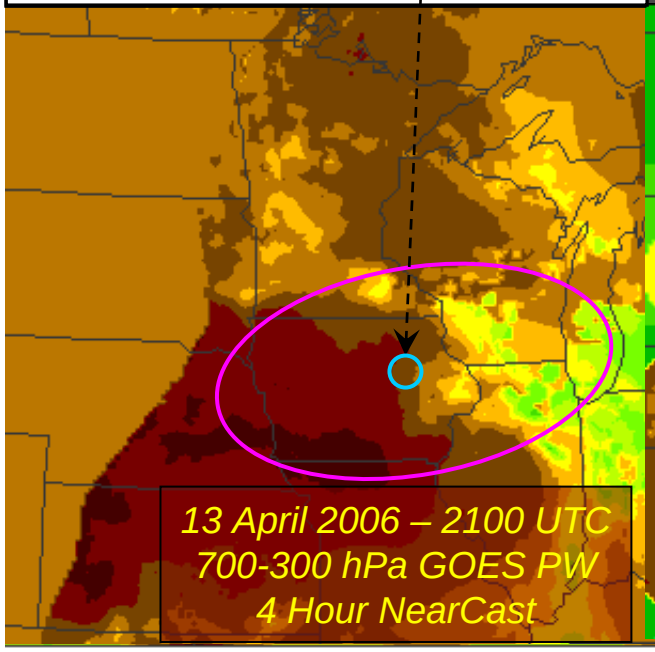
Mid-Level Drying

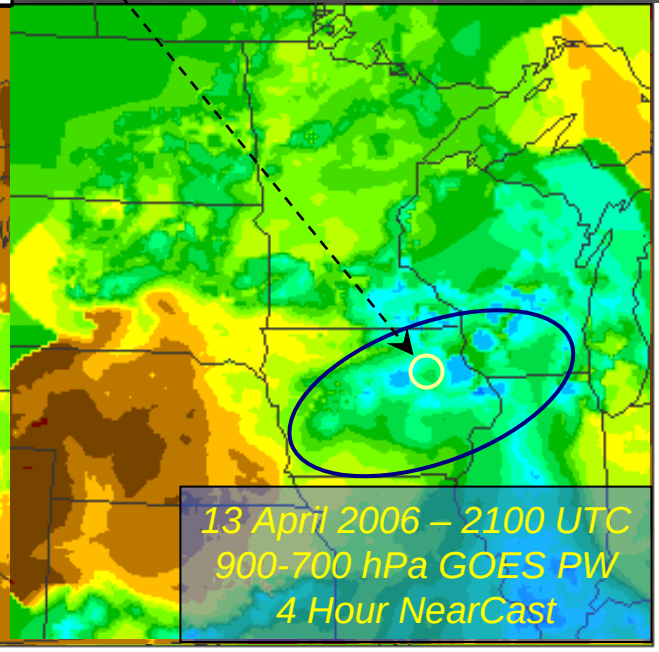
NearCasts

Validation of rapid moisture change in NE Iowa using GPS TPW data









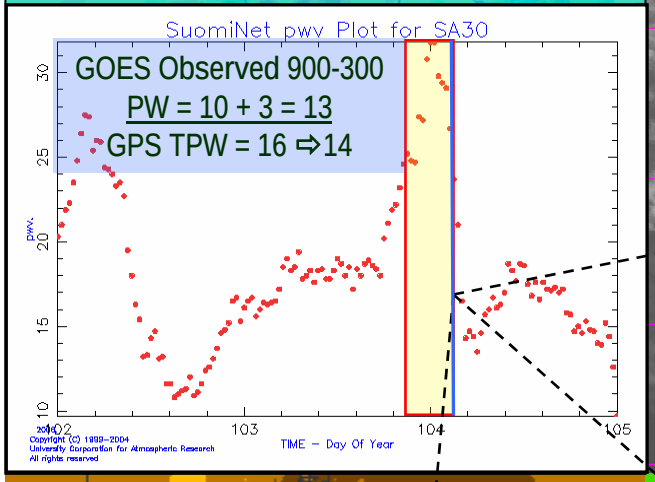
4 hr Lagrangian NearCasts of GOES DPIs

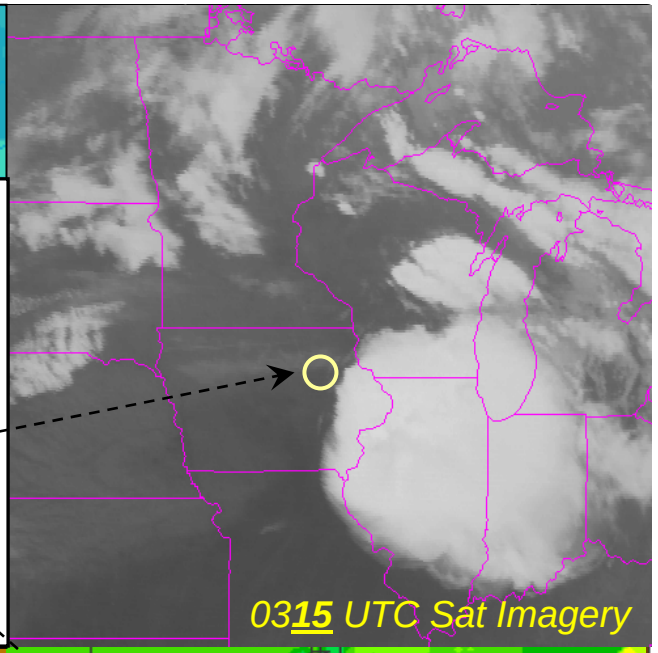
Valid 0100 UTC

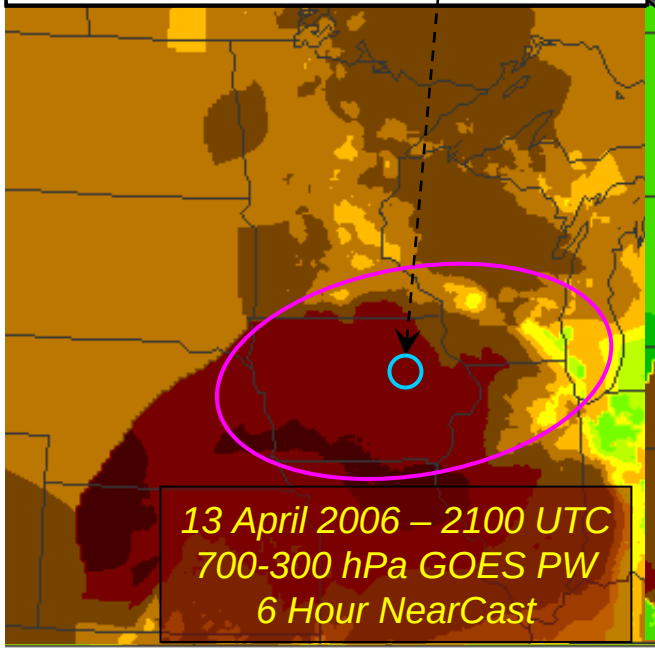
Mid-Level Drying

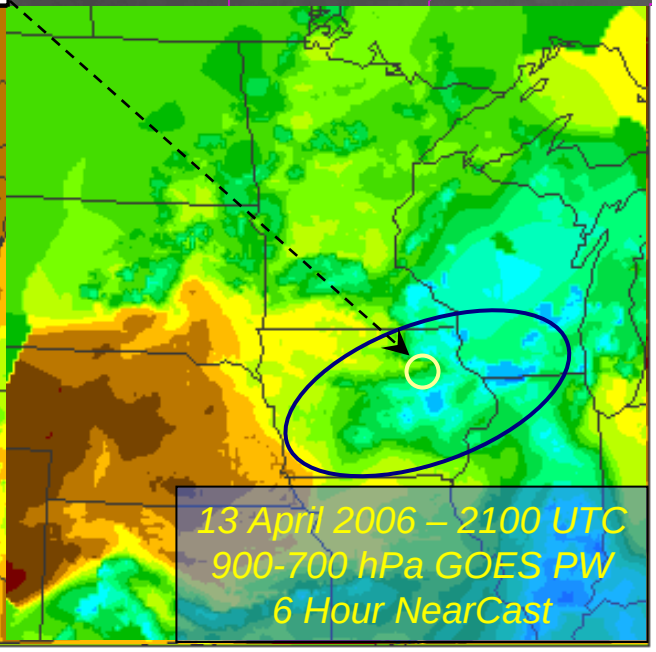
NearCasts

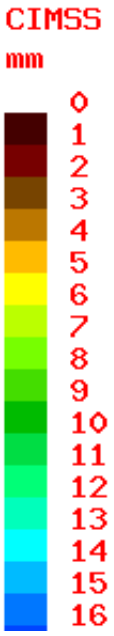
Validation of rapid moisture change in NE Iowa using GPS TPW data







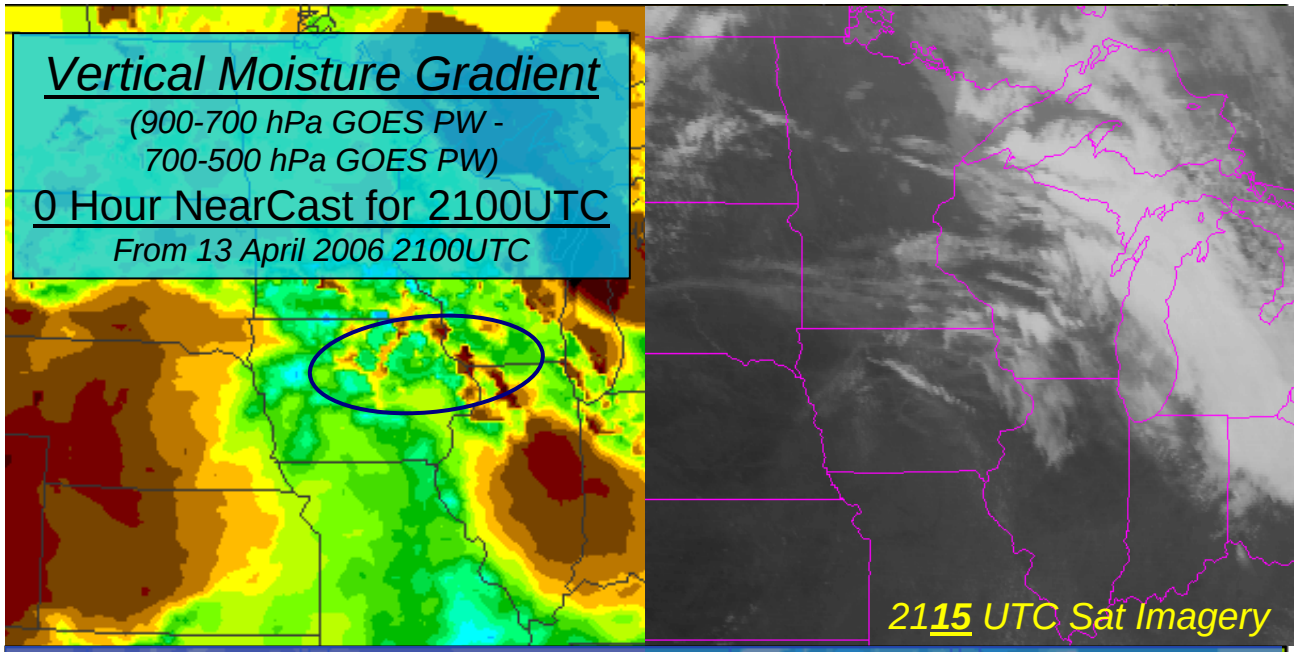




6 hr Lagrangian NearCasts of GOES DPIs

Valid 0300 UTC

Mid-Level Drying

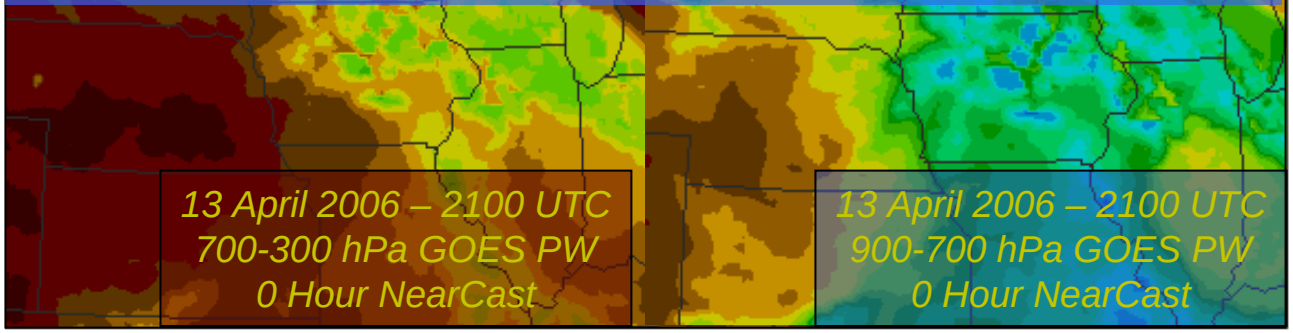


CIMSS
mm
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Formation of Convective Instability

0 hr Lagrangian NearCasts of GOES DPIs

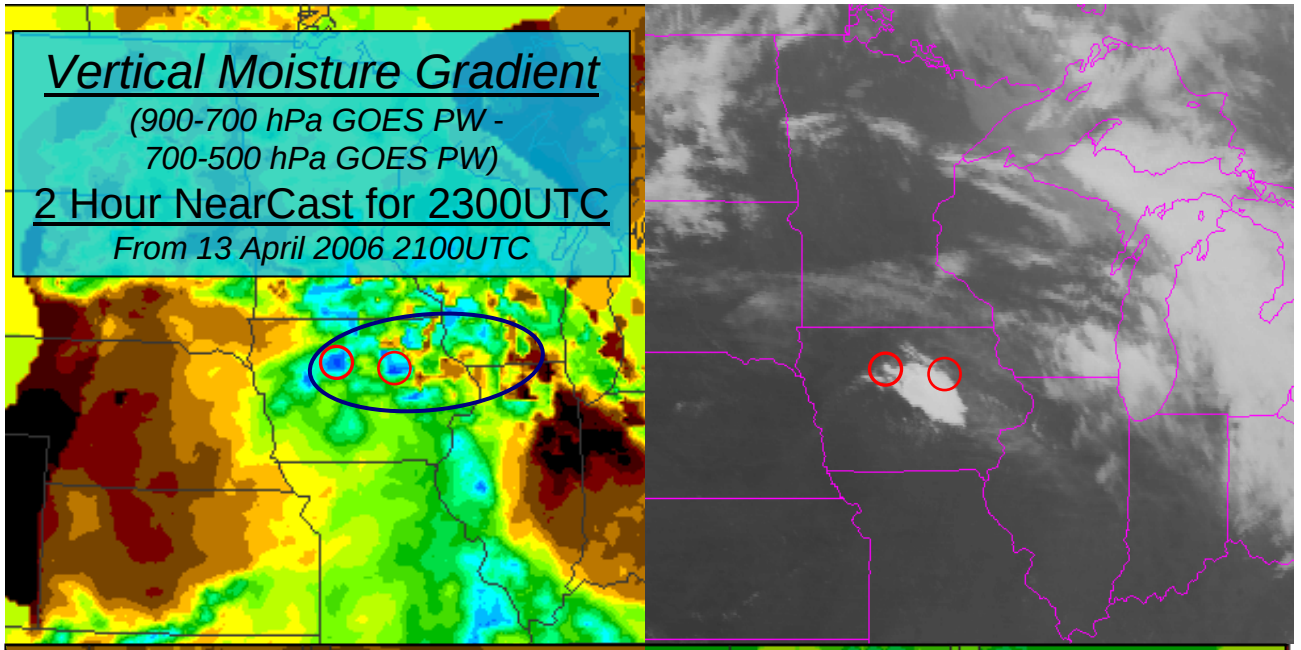
Differential Moisture Transport *Creates* Convective Instability

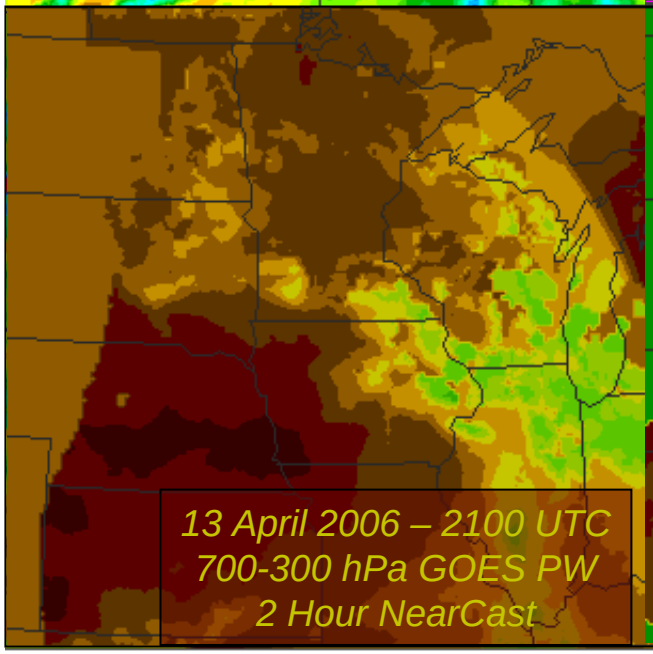


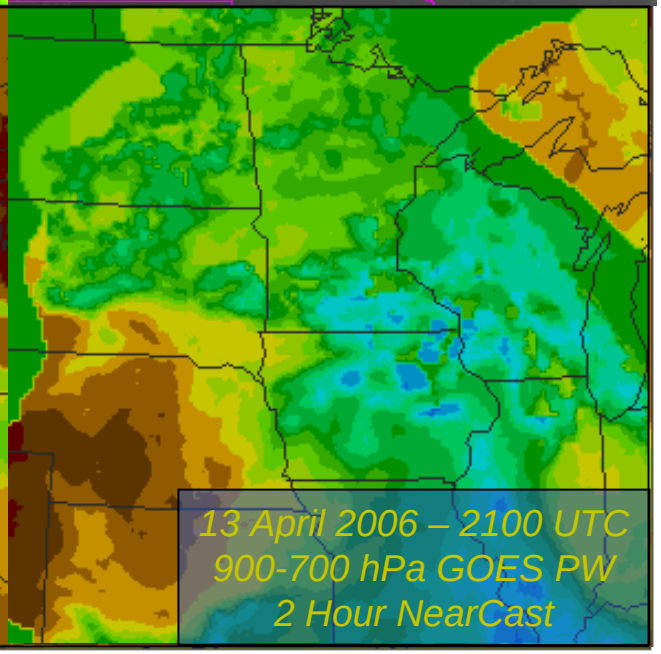
CIMSS
mm
0 1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22

Valid 2100 UTC

Differential Moisture Transport *Creates* Vertical Moisture Gradients

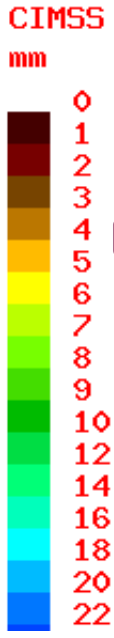






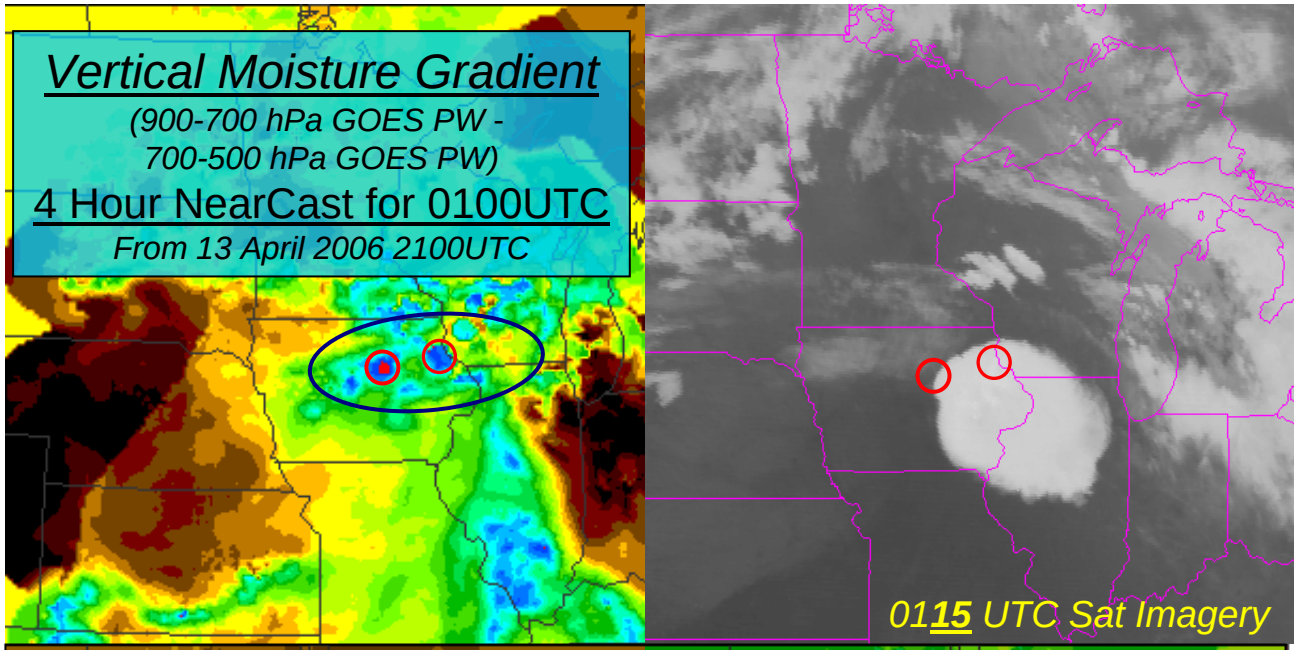
Formation of Convective Instability

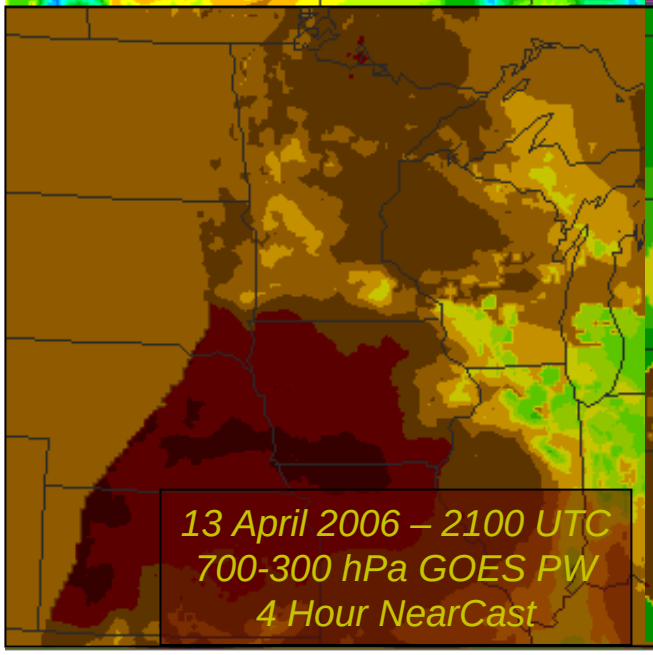
2 hr Lagrangian NearCasts of GOES DPIs

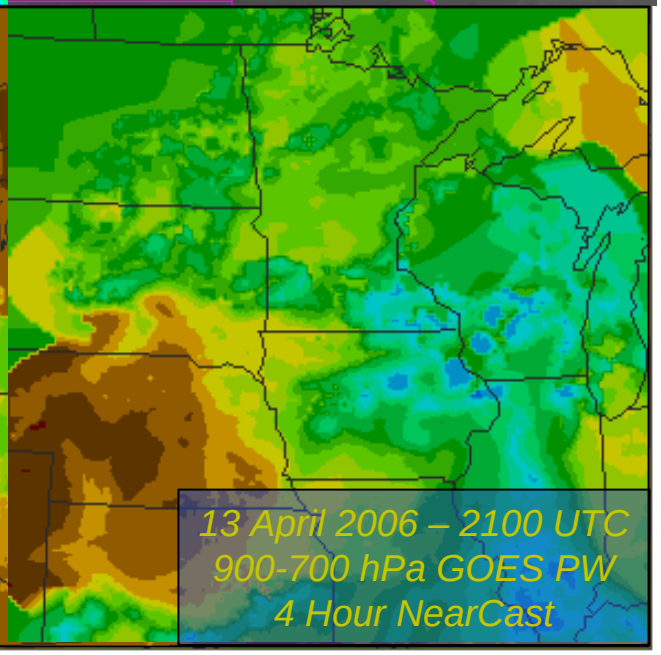


Valid 2100 UTC

Differential Moisture Transport *Creates* Vertical Moisture Gradients





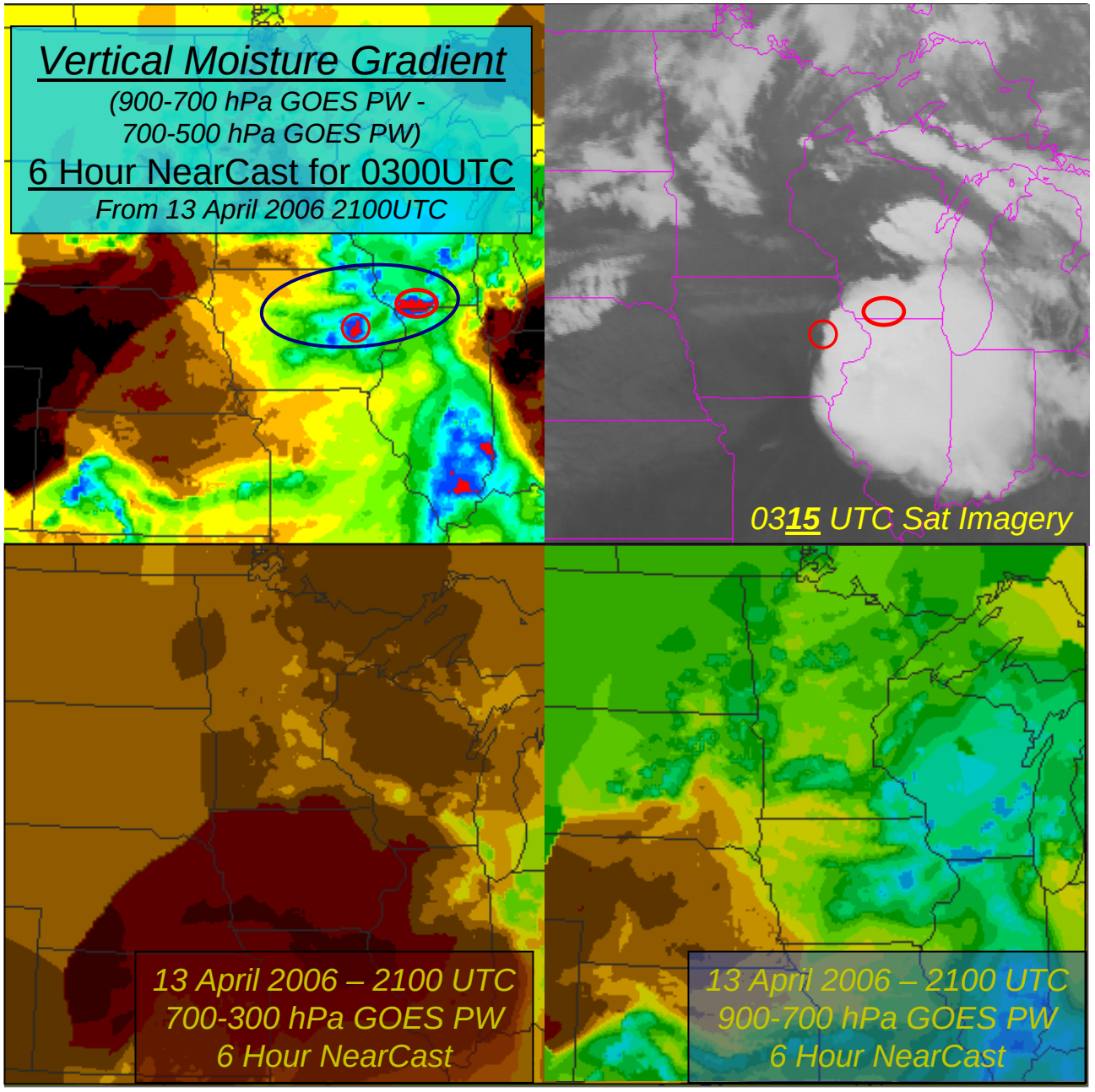


Formation of Convective Instability

4 hr Lagrangian NearCasts of GOES DPIs

Valid 2100 UTC

Differential Moisture Transport *Creates* Vertical Moisture Gradients


Vertical Moisture Gradient
(900-700 hPa GOES PW -
700-500 hPa GOES PW)
6 Hour NearCast for 0300UTC
From 13 April 2006 2100UTC
0315 UTC Sat Imagery
13 April 2006 – 2100 UTC
700-300 hPa GOES PW
6 Hour NearCast
13 April 2006 – 2100 UTC
900-700 hPa GOES PW
6 Hour NearCast
CIMSS
mm
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Formation of Convective Instability
6 hr Lagrangian NearCasts of GOES DPIs
CIMSS
mm
0 1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22
Valid 2100 UTC
Differential Moisture Transport Creates Vertical Moisture Gradients

Examples like this show that:

- The GOES DPI moisture products provide good data

- The Lagrangian NearCasts produce useful and frequently updates about the *FUTURE* stability of the atmosphere

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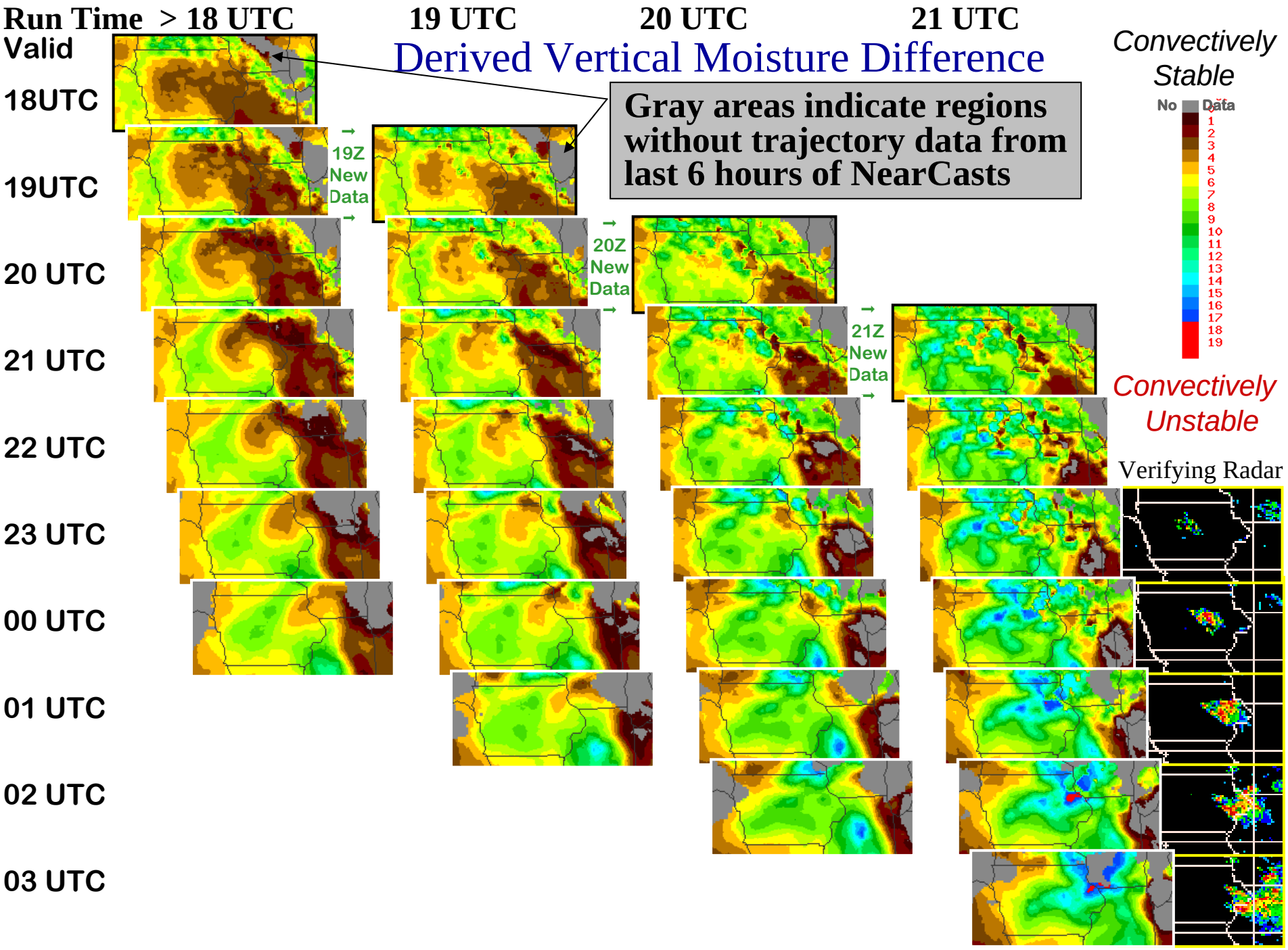
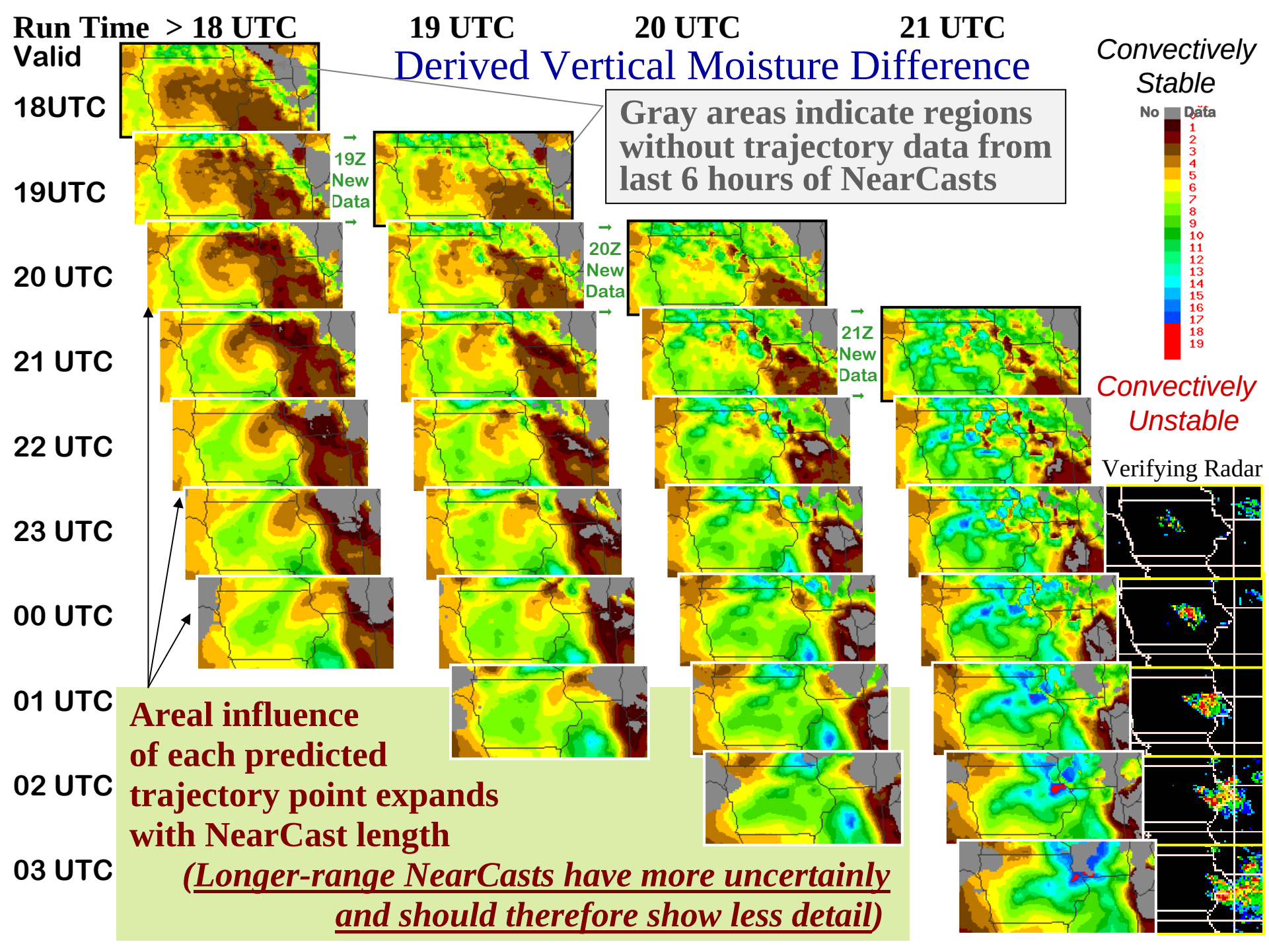
A number of additional modifications have been made to make the image products more useful to forecasters:

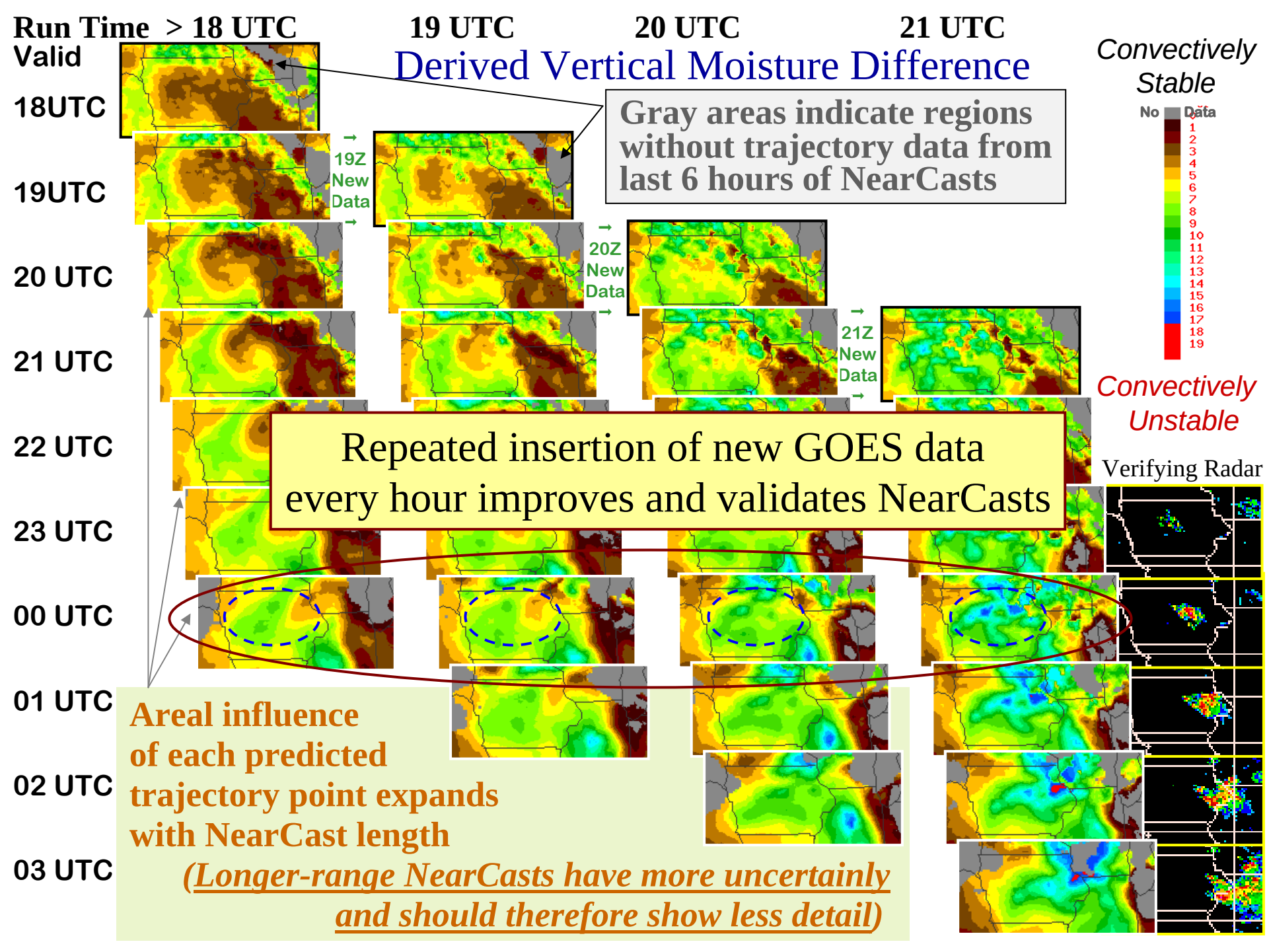
- **Eliminate displays in areas without NearCast 'data'**
  - ***Makes output "looks" more like satellite observations***
- **Add "uncertainty" into longer NearCast images**
  - ***Add 'smoothing' to longer-range NearCasts images***

Also:

- **Sequence image from successive NearCasts to highlight the impact of frequent data updates available only from GOES**


Run Time > 18 UTC
19 UTC
20 UTC
21 UTC
Valid
18UTC
19UTC
20 UTC
21 UTC
22 UTC
23 UTC
00 UTC
01 UTC
02 UTC
03 UTC
Derived Vertical Moisture Difference
Gray areas indicate regions without trajectory data from last 6 hours of NearCasts
19Z New Data
20Z New Data
21Z New Data
Convectively Stable
No Data
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Convectively Unstable
Verifying Radar


Run Time > 18 UTC
19 UTC
20 UTC
21 UTC
Valid
18UTC
19UTC
20 UTC
21 UTC
22 UTC
23 UTC
00 UTC
01 UTC
02 UTC
03 UTC
Derived Vertical Moisture Difference
Gray areas indicate regions without trajectory data from last 6 hours of NearCasts
19Z New Data
20Z New Data
21Z New Data
Convectively Stable
No Data
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Convectively Unstable
Verifying Radar
Areal influence of each predicted trajectory point expands with NearCast length
(Longer-range NearCasts have more uncertainly and should therefore show less detail)


Run Time > 18 UTC
19 UTC
20 UTC
21 UTC
Valid
18UTC
19UTC
20 UTC
21 UTC
22 UTC
23 UTC
00 UTC
01 UTC
02 UTC
03 UTC
Derived Vertical Moisture Difference
Gray areas indicate regions without trajectory data from last 6 hours of NearCasts
19Z New Data
20Z New Data
21Z New Data
Convectively Stable
No Data
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Convectively Unstable
Verifying Radar
Repeated insertion of new GOES data every hour improves and validates NearCasts
Areal influence of each predicted trajectory point expands with NearCast length
(Longer-range NearCasts have more uncertainly and should therefore show less detail)

Summary – An Objective Lagrangian NearCasting Model

- Quick and minimal resources needed

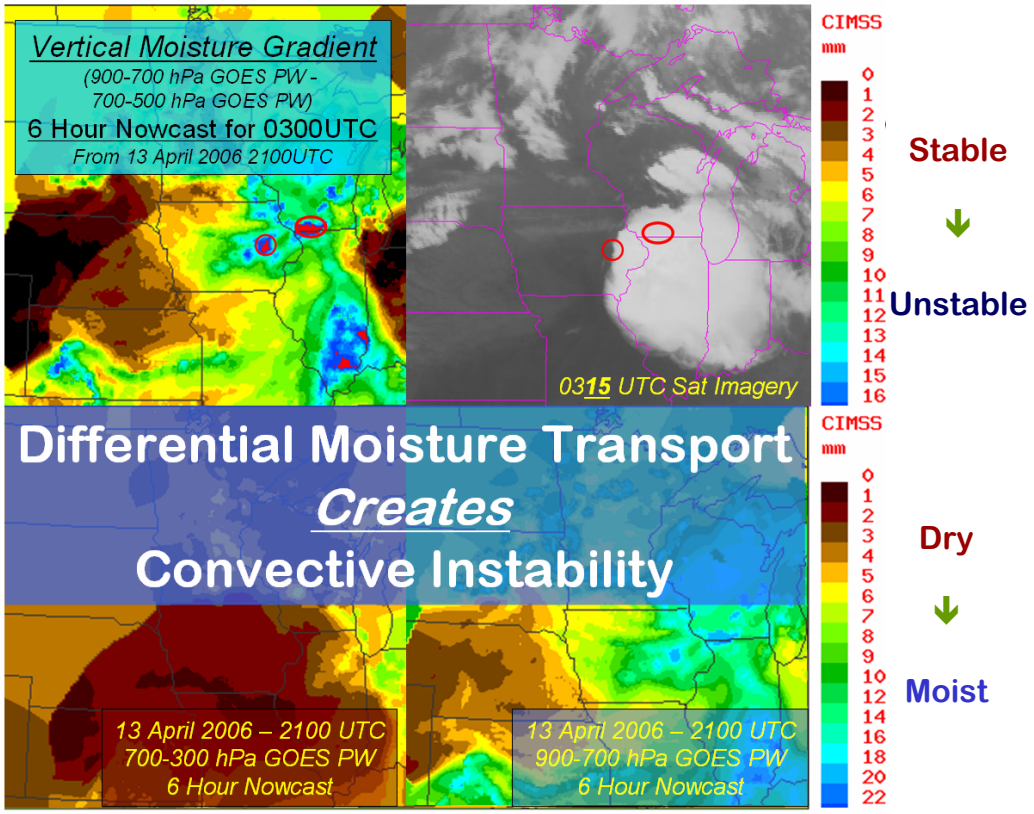
- Can be used 'stand-alone' or to 'update' other NWP guidance

DATA DRIVEN at the MESOSCALE

- Data can be inserted (combined) directly retaining resolution and extremes

- NearCasts retain *useful* maxima and minima – image cycling preserves old data

Forecast Images agree with storm formations and provide accurate/timely guidance



Goals met:

- *Provides objective tool to increase the length of time that forecasters can make good use of detailed GOES moisture data in their short range forecasts (augments smoother NWP output)*
- *Expands value of GOES moisture products from observations to short-range forecasting tools*
- *Testing planned at NWS offices*
- *Adaptable to MSG data*