Jobsheet

GOES-R Convective Development Nearcasting Model

Objectives:

- Obtain and demonstrate an understanding of the NearCast analysis and short-range forecast processes and the temperature and moisture data derived by the GOES sounder that drive the system.
- Understand how lower-level NearCasts of GOES observations can be used to anticipate the evolution of the pre-convective environment 1-9 hours into the future.
- Understand how mid-level NearCasts of GOES observations can be used to help isolate areas conducive for deep-layer convective destabilization 1-9 hours into the future.
- Understand how lower- and mid-level NearCasts of GOES temperature and moisture observations can be used to help identify areas conducive for development of deep-layer convective destabilization 1-9 hours into the future.

Product Overview:

NearCasts are <u>Near</u>-term fore<u>Casts</u> which are intended to help fill the information gap between 0-1 hour long Nowcasts and longer-range NWP, covering the period 1-9 hours into the future. The overall goal of NearCasts is to provide forecasters with new, data-driven tools to help identify areas of enhanced moisture transport and convective destabilization using products from current and future Geostationary Satellites. The NearCasting system uses a trajectory-based approach which preserves large gradients and maxima and minima observed in the GOES data, as well as using successive temporal data insertions to revalidate/revise previous projections every hour.

NearCasts were developed as a means of allowing forecasters to extend the utility of the GOES sounder observations by increasing situational awareness and increasing thunderstorm prediction skill both by 1) filling gaps in the GOES infrared data sets in areas where clouds have already formed and 2) adding a forecast component to the detailed GOES moisture observations. The primary source of data for the NearCasting system is Moisture and Temperature observations made hourly at ~10km resolution by the GOES sounder. Although the GOES moisture observations are only available for 3 layers of the troposphere (nominally from the surface to 900 mb, from 900-700 mb, and from 700-300 mb), the data provide greater detail (both horizontally and in time) than any other operational NWS data system. These moisture products are probably the variables that the GOES sounder observes best. The Total Precipitable Water (TPW) measurements from these GOES data exceed the accuracy of GFS forecasts and add important small-scale details in many situations, especially during the warm season.

The NearCasts predictions are made using dynamical trajectory techniques that are significantly different than traditional NWP. This process is done for every GOES observation and at every observing time as follows:

1. Wind data from short-range RUC forecasts are interpolated to the location and layer of each 10 km spaced GOES observation. Observed GOES data types used in the

NearCasts include temperature, mixing ratio and calculated equivalent potential temperature.

2. The observed data are then projected forward to future locations using dynamically changing winds. At the end of each time step, the velocity of each parcel is changed using accelerations calculated from the Coriolis force of the parcels and pressure gradient fields (also obtained from the RUC) that have been interpolated to each of the parcel locations. The locations and values of each of the parcels are saved at 30 minutes intervals out to 9 hours in the future.
   Note: *The parcel-following Lagrangian trajectory method retains all maxima and minima in the observed data sets throughout the full integration period. It also allows the model to use 10-15 minutes time steps, which is much more efficiently than the 20-30 seconds time steps that would be required at this resolution in conventional Eulerian grid-point models.*
3. The observed values and locations of each data projection are then merged with information about the trajectories generated from the previous 9 NearCast runs to create rectangular grids. These grids are then used to generate output graphics and/or for diagnostic calculations. In this process, the most recent trajectories receive the highest weighting. In areas where clouds may have developed and prevented the retrieval of IR-based soundings, data from previous model runs can fill many of the gaps left in the most recent data sets, especially after convection develops near the area of interest. This same procedure if followed by all forecasts and analyses.

Jobsheet Overview:

This jobsheet is broken out into four sections, one of each objective listed above. There are 23 questions to be answered along the way. Answers to these questions will be provided in the answer key document.

Objective #1: Obtain and demonstrate an understanding of the NearCast analysis and short-range forecast processes and the temperature and moisture data derived by the GOES sounder that drive the system.

WES Instructions:

1. If AWIPS D2D is not currently open, double-click on the Launch AWIPS D2D icon to start up an AWIPS D2D session.

2. Left click on the D2D clock in the lower-right corner of D2D.

3. Inside the “Set Time” window, set the D2D clock to **2011 May 24 18:00** UTC (don’t bother changing the seconds) and check the “Freeze Time at This Position” box.

4. Set the map scale to **CONUS**.

5. Set the frame count to **64**.

6. Load the 900-700mb Precipitable Water (PW) product by doing the following:
    a. Launch the Volume Browser GUI by selecting **Volume → Browser…**
    b. Under the **Edit** dropdown menu, select **Clear All**
    c. In the **Sources** section, select **LOCAL → NRCAST**
    d. Under the **Fields** section, select **Sfc/D2D →Misc → Precipitable H2O**
    e. In the **Planes** section, select **Local → PW: Sigma Layers → 900-700mb (Low)**
    f. A product should populate the **Product Selection List** at the bottom of the GUI. Right-Click on this product and select **Change to NRCAST 900-700mb Precipitable H2O Img(K)** and click on the **Load** button.

7. Look back at the 1300 UTC PW product.

    Since there was no GOES data available at 1200 UTC, the 1300 UTC product is simply a display of the observations.

8. Move forward to look at the 1400 UTC PW product.

    Here, the GOES observations from 1400 UTC are combined with 1-hour trajectory locations and values from the Nearcast 1300 UTC run. Note that using a combination of the most recent observations with previous trajectories not only provides data in areas which had previously had been cloud covered, it also allow the trajectories from previous, upwind observations both to validate the new data and to be transported into areas that continue to be cloud covered.

9. Move forward to 1800 UTC PW product.

    Notice the missing areas of data due to cloud cover were significantly reduced.

10. Look at the full PW dataset from 1300 UTC – 1800 UTC and answer the following questions below:

    Question 1: What area show an increase in 900-700 mb PW in the 4 hours since the analysis cycle began?

    Question 2: Where is does the PW increase most rapidly?

    Question 3: Is the increase in PW over central OK and NE TX due to transport of previous observations into this area or new observations?

Question 4: What is the magnitude of the change in PW across the 'dryline' forming in north-central TX?

In addition to using moisture data, the moisture and temperature data from the GOES sounder retrievals can be combined to determine the Equivalent Potential Temperature (θe) for each of the GOES observations. The θe is a conservative property and measures the total thermal as air parcels' total thermal energy content (both sensible and latent heat) and it a very good parameter to use to differentiate air masses.

11. Next, we'll load the 780mb low-level θe product by doing the following:
    a. Click to enable the **Toggle Image Combination** button on the D2D display
    b. Launch the Volume Browser GUI by selecting **Volume → Browser…**
    c. Under the **Edit** dropdown menu, select **Clear All**
    d. In the **Sources** section, select **LOCAL → NRCAST**
    e. Under the **Fields** section, select **Basic → Equiv Pot Temp**
    f. In the **Planes** section, select **Local → Theta-e Pres Lvls → 780 MB (Low)**
    g. A product should populate the **Product Selection List** at the bottom of the GUI. Right-Click on this product and select **Change to NRCAST 780MB Equiv Pot Temp Img(K)** and click on the **Load** button.
    h. You can fade between these two products using the +/- keys on the number pad. You can switch directly between products using the decimal button on the number pad or by left-clicking on the product title in the D2D legend.

12. In a new D2D pane, load up the GOES IR satellite product from the **Satellite → IR Window** menu at the top of the D2D window.

13. Toggle back and forth between the PW and θe product at 1800 UTC and answer the following questions:

Question 5: What is the magnitude of the change in θe across the 'dryline' forming in north-central TX?

One of the primary contributing factors for this θe gradient to be more distinct than the PW field in the same areaas the day progresses is due to diurnal heating.

Question 6: Even though the PW that moved into eastern AK between 1300 and 1800 UTC was notably larger than that in north-central TX, how much greater or less is the θe here compared to in TX?

Question 7: What is the θe in the area ahead of this convection in MO/IA (look at the IR product to find this area)? What would you expect to happen to these storms if they continue to move farther east?

Question 8: From 1800 – 2330 UTC, what is the θe of the air mass moving across Lake Erie into PA?

Objective #2: Understand how lower-level NearCasts of GOES observations can be used to anticipate the evolution of the pre-convective environment 1-9 hours into the future.

WES Instructions:

1. If AWIPS D2D is not currently open, double-click on the Launch AWIPS D2D icon to start up an AWIPS D2D session.

2. Left click on the D2D clock in the lower-right corner of D2D.

3. Inside the “Set Time” window, set the D2D clock to **2011 May 24 18:00** UTC (don’t bother changing the seconds) and check the “Freeze Time at This Position” box.

4. Set the map scale to **CONUS**.

5. Set the frame count to **36**.

6. Load the 780mb low-level θe product by doing the following:
    a. Click to enable the **Toggle Image Combination** button on the D2D display
    b. Launch the Volume Browser GUI by selecting **Volume → Browser…**
    c. Under the **Edit** dropdown menu, select **Clear All**
    d. In the **Sources** section, select **LOCAL → NRCAST**
    e. Under the **Fields** section, select **Basic → Equiv Pot Temp**
    f. In the **Planes** section, select **Local → Theta-e Pres Lvls → 780 MB (Low)**
    g. A product should populate the **Product Selection List** at the bottom of the GUI. Right-Click on this product and select **Change to NRCAST 780MB Equiv Pot Temp Img(K)** and click on the **Load** button.

7. In a new D2D pane, load up the GOES IR satellite product from the **Satellite → IR Window** menu at the top of the D2D window.

8. Loop through the lower-level θe Nearcast data from 1800 to 0300 UTC.

This loop shows the predicted evolution of the lower-tropospheric θe fields in the 9 hours between 1800 UTC on the 24th and 0300 UTC on the 25th. Due to the efficiency of the model, the output fields were available to forecasters before 1900 UTC, which is within 10 minutes of when the GOES sounder observations over the area were completed and the temperature and moisture retrieval became available.

Remember that the NearCasting system is designed to preserve details from the observation to a greater degree than more smoothed fields found in conventional NWP systems. It should also be noted that, even though the integrated Precipitable Water derived from the GOES sounder improve upon GFS data used as a first-guess in the retrieval process, none of the GOES information that drive the NearCasts shown here are used in any operational NWS NWP system.

9. Continue looking at both the θe and IR data and answer the following questions:

Question 9: What is predicted to happen to the band of high θe that extended south-to-north across central TX in the 1800 UTC analysis?

Question 10: Where is the dryline located at 2200 UTC?

Question 11: How have the values of θe across the dryline changed between 1800 UTC and 2200 UTC? How has the gradient changed?

Question 12: What is predicted to happen to the area of enhanced θe initially in western NE?

Question 13: Where should the area of cool-dry air (low values of θe) over the Great Lakes moved between 1800 and 2200 UTC? Should the threat for convective storm development be increasing or decreasing across northern PA and why?

Question 14: Is the lower-level supply of warm-moist air (represented by higher values of θe) over eastern IA and western IL likely to support continued growth and

movement of the storms moving into the area from MO and IA?

Objective #3: Understand how mid-level NearCasts of GOES observations can be used to help isolate areas conducive for deep-layer convective destabilization 1-9 hours into the future.

WES Instructions:

1. If AWIPS D2D is not currently open, double-click on the Launch AWIPS D2D icon to start up an AWIPS D2D session.

2. Left click on the D2D clock in the lower-right corner of D2D.

3. Inside the “Set Time” window, set the D2D clock to **2011 May 24 18:00** UTC (don’t bother changing the seconds) and check the “Freeze Time at This Position” box.

4. Set the map scale to **CONUS**.

5. Set the frame count to **36**.

6. Load the 780mb low-level θe product by doing the following:
    a. Launch the Volume Browser GUI by selecting **Volume → Browser…**
    b. Under the **Edit** dropdown menu, select **Clear All**
    c. In the **Sources** section, select **LOCAL → NRCAST**
    d. Under the **Fields** section, select **Basic → Equiv Pot Temp**
    e. In the **Planes** section, select **Local → Theta-e Pres Lvls → 780 MB (Low)**
    f. A product should populate the **Product Selection List** at the bottom of the GUI. Right-Click on this product and select **Change to NRCAST 780MB Equiv Pot Temp Img(K)** and click on the **Load** button.

7. Load the 500mb low-level θe product by doing the following:
    a. Click to enable the **Toggle Image Combination** button on the D2D display
    b. Launch the Volume Browser GUI by selecting **Volume → Browser…**
    c. Under the **Edit** dropdown menu, select **Clear All**
    d. In the **Sources** section, select **LOCAL → NRCAST**
    e. Under the **Fields** section, select **Basic → Equiv Pot Temp**
    f. In the **Planes** section, select **Local → Theta-e Pres Lvls → 500 MB (Mid)**
    g. A product should populate the **Product Selection List** at the bottom of the GUI. Right-Click on this product and select **Change to NRCAST 500MB Equiv Pot Temp Img(K)** and click on the **Load** button.
        i. You can fade between these two products using the +/- keys on the number pad. You can switch directly between products using the decimal

button on the number pad or by left-clicking on the product title in the D2D legend.

8. In a new D2D pane, load up the GOES IR satellite product from the **Satellite → IR Window** menu at the top of the D2D window.

9. Toggle off the 780mb θe product and look only at the 500mb θe product. Loop through the data window.

   This loop shows the predicted evolution of the mid-tropospheric θe fields in the next 9 hours. Ever since geostationary satellite imagery of mid-level moisture have been available to forecasters, it has been observed that convection tends to form along both edges of dry bands, especially along the leading edge of these features. In the next sections, we will test the hypothesis that areas in which upper-level dryness (represented by low values of θe) overtakes regions with warm/moist air at lower levels (represented by low values of θe) are conducive for rapid development of convection. This process creates environments that have Deep-Layer Convective Instability. This parameter can be shown to be similar the Lifted Index (LI), but with the threshold between stable and unstable conditions shift from 0 to -4.

10. Look at both the low-level (780mb) and mid-level (500mb) products, along with the IR window data from 1800 – 2330 UTC and answer the following questions:

    Question 15: Where are the two major sources of mid-level dry air (low θe) located in the 1800 UTC analysis?

    Question 16: How do these areas of mid-level dry air change between 1800 and 2200 UTC?

    Question 17: Are the areas of mid-level dryness in general moving faster or slower than the areas of lower-level moisture we investigated earlier?

Question 18: Are the areas of mid-level dryness in general moving in the same or different directions than the areas of lower-level moisture we investigated earlier?

Objective #4: Understand how lower- and mid-level NearCasts of GOES temperature and moisture observations can be used to help identify areas conducive for development of deep-layer convective destabilization 1-9 hours into the future.

WES Instructions:

1. If AWIPS D2D is not currently open, double-click on the Launch AWIPS D2D icon to start up an AWIPS D2D session.
2. Left click on the D2D clock in the lower-right corner of D2D.
3. Inside the “Set Time” window, set the D2D clock to **2011 May 24 18:00** UTC (don’t bother changing the seconds) and check the “Freeze Time at This Position” box.
4. Set the map scale to **CONUS**.
5. Set the frame count to **36**.
6. Right-click on the D2D window and select **Four Panel Layout**.
7. Populate the 4-panel window with the following products:
   a. Upper-Left window – 780mb low-level θe :
      i. Right-click in the upper-left window and select **Load to this Panel**
      ii. Launch the Volume Browser GUI by selecting **Volume → Browser…**
      iii. Under the **Edit** dropdown menu, select **Clear All**
      iv. In the **Sources** section, select **LOCAL → NRCAST**
      v. Under the **Fields** section, select **Basic → Equiv Pot Temp**
      vi. In the **Planes** section, select **Local → Theta-e Pres Lvls → 780 MB (Low)**
      vii. A product should populate the **Product Selection List** at the bottom of the GUI. Right-Click on this product and select **Change to NRCAST 780MB Equiv Pot Temp Img(K)** and click on the **Load** button.
   b. Upper-Right window – 500mb mid-level θe:
      i. Right-click in the upper-right window and select **Load to this Panel**

ii. Launch the Volume Browser GUI by selecting **Volume → Browser…**
iii. Under the **Edit** dropdown menu, select **Clear All**
iv. In the **Sources** section, select **LOCAL → NRCAST**
v. Under the **Fields** section, select **Basic → Equiv Pot Temp**
vi. In the **Planes** section, select **Local → Theta-e Pres Lvls → 500 MB (Mid)**
vii. A product should populate the **Product Selection List** at the bottom of the GUI. Right-Click on this product and select **Change to NRCAST 500MB Equiv Pot Temp Img(K)** and click on the **Load** button

c. Lower-Left window – **EMPTY**
d. Lower-Right window – GOES Vertical θe difference :
    i. Right-click in the lower-right window and select **Load to this Panel**
    ii. Launch the Volume Browser GUI by selecting **Volume → Browser…**
    iii. Under the **Edit** dropdown menu, select **Clear All**
    iv. In the **Sources** section, select **LOCAL → NRCAST**
    v. Under the **Fields** section, select **EWP →CIMSS Nearcast → GOES Vertical Theta-e Difference**
    vi. All other fields will populate, so click the **Load** button at the bottom of the GUI

8. Loop through these 3 products from 1800 UTC to 0300 UTC. Read through the information below and answer the following questions:

The loops in the top two panels of the display can be used subjectively to identify areas where differential advection is forcing upper-level dry/cool air to override lower-level warm/moist air. Comparing the changing θe in the two image loops, an overlap is clearly occurring in TX and OK as the dry/cool mid-level air overtakes the band of moisture moving across central OK and north-east TX

As a more quantitative means of identifying these area where mid-level dry/cool air is moving over the evolving lower-level warm/moist air, the two images on the left can be subtracted to create a depiction of the <u>Deep-Layer Convective Instability</u> ($\Delta\theta e/\Delta P$).

Remember that this index is comprised of variables that the GOES sounder (as well as the future GOES-R ABI) observes very well. Now let's look at the NearCast of Convective Instability (lower-right panel) more closely.

Note that although the ranges of θe in the mid- and lower-level NearCasts are conserved and do not vary during any particular NearCast, the magnitude of the derived Convective Instability can increase (or decrease) during the 9-hour long NearCast period due to differential advection between the lower- and mid-levels.

<u>Additional Notes:</u>

a. *It can be shown that this Deep-layer Convective Instability is equivalent to a*

Modified Lifted Index, where the stable/unstable threshold is shifted from 0° to -4°.)

b. *Although Convective Instability is observed over many parts of the country (e.g., under subsidence under slow-moving anti-cyclones in the southeastern U.S. during summer, as shown in this case over southern GA), the instability well only be released in areas where low-level lifting is also present.*

Question 19: Looking at GOES Vertical θe difference, what 2 areas are showing the greatest destabilization throughout the NearCast period?

Question 20: Looking at GOES Vertical θe difference, at what time is the Convective Instability near OKC largest? How does this compare with when the area of instability reaches Dallas?

Question 21: What effect does the intrusion of mid-level dry air from the Great Lake over the decreasing lower-level moisture over PA have on the likelihood of convection in this area?

Question 22: Why is the destabilization over western KS more pronounced than that over OK and eastern TX?

Question 23: What can be inferred from the rapid transition from very stable to very unstable environments occurring over northeast KS at the end of the NearCast period?