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# A Rapidly Relocatable High-Resolution WRF System for Military-Defense, Aviation and Wind Energy

13th Annual WRF Users' Workshop

25 - 29 June 2012, Boulder, CO

**Aijun Deng,**
**David Stauffer, Brian Gaudet and Glenn Hunter**

***Penn State University***

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# Outline

- **Overview of Penn State WRF NWP systems**
  - **Defense Application/Hazard Prediction**
  - **Wind Energy/Turbine Siting**
  - **Aviation Flight Planning**
  - **$CO_2$ Prediction/Monitoring using WRF-Chem-FDDA**
- **NextGen Airport Forecast System (NGAFS)**
  - **Application for a historic snow event on 29 October 2011**
- **Summary and Conclusions**

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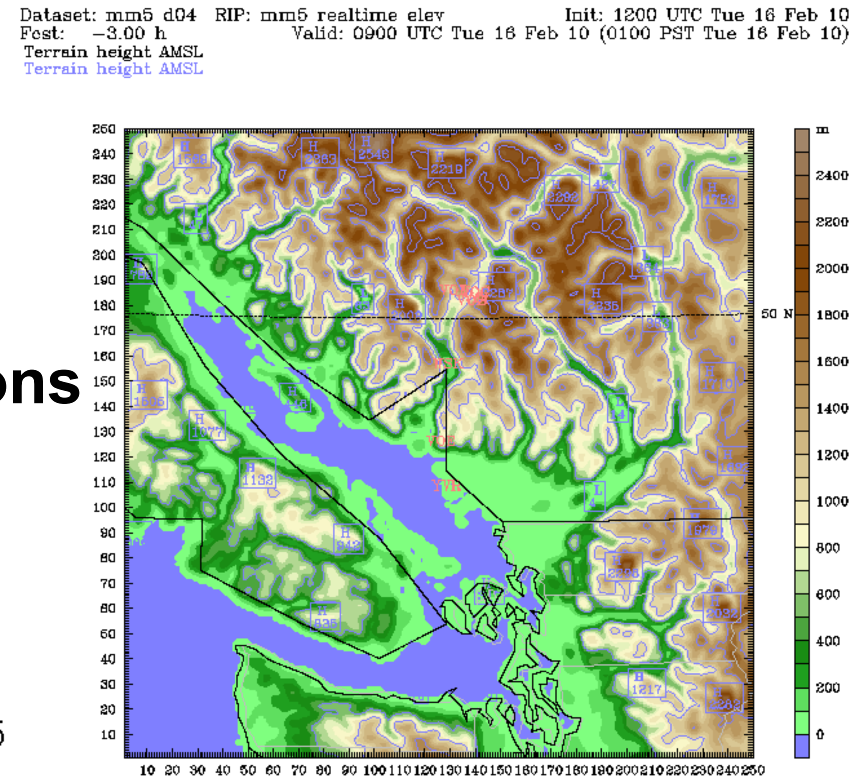
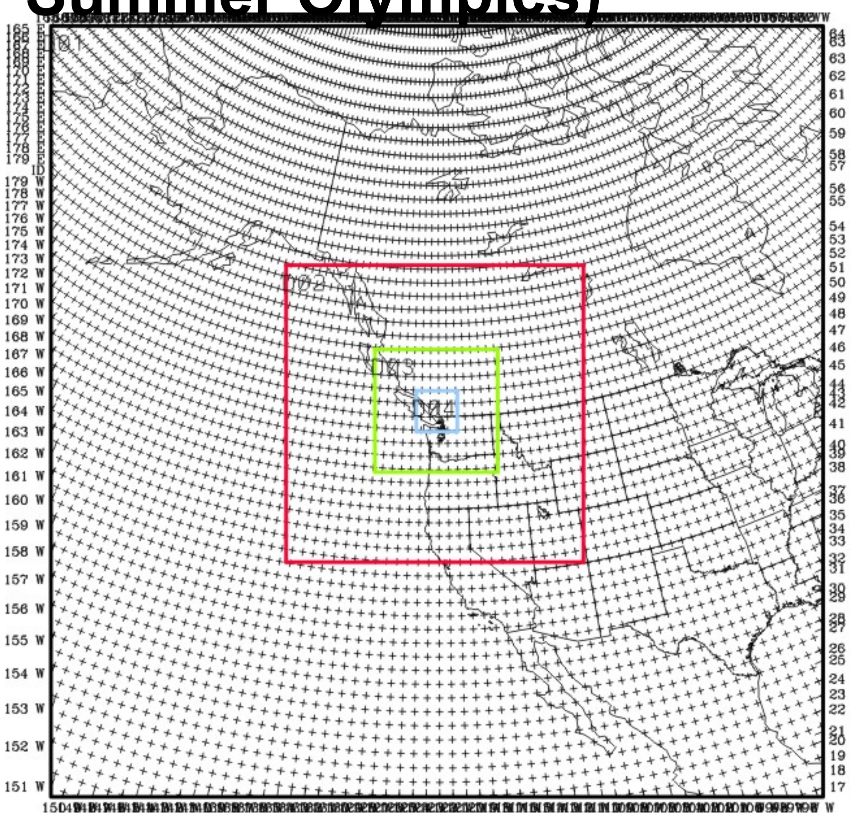
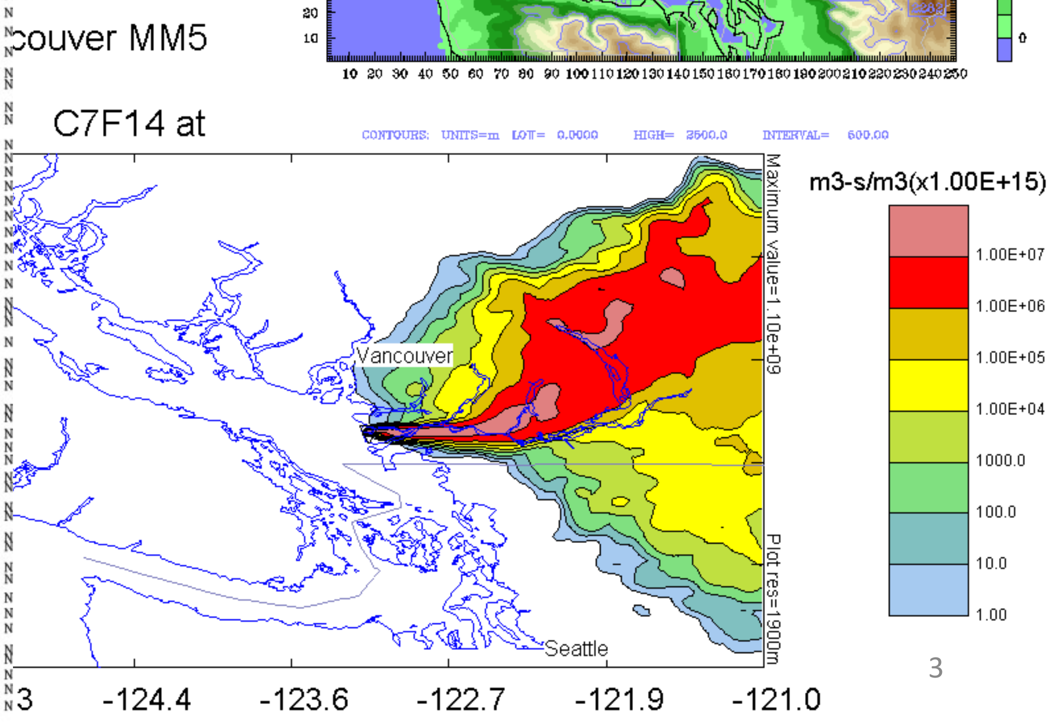
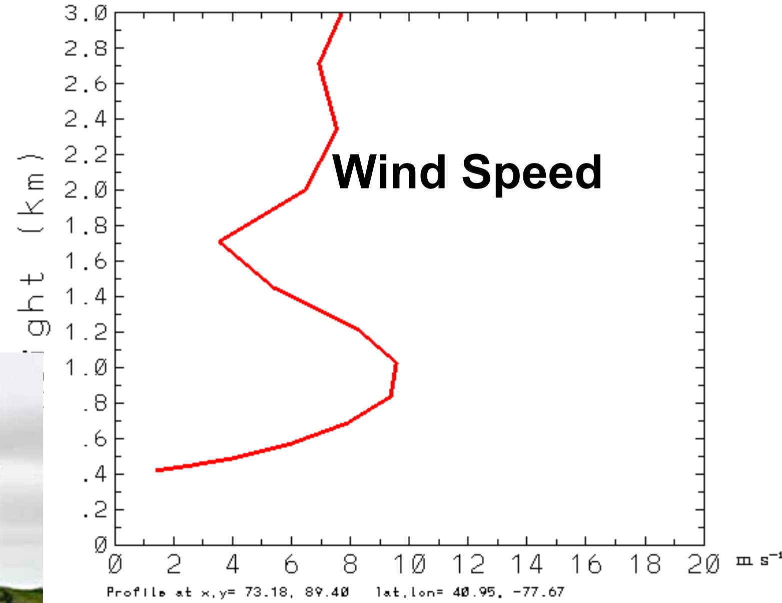
# Penn State WRF-Relocatable On-demand Forecast System (WRF-ROFS) used for defense applications including Vancouver Winter Olympics (and upcoming London Summer Olympics)

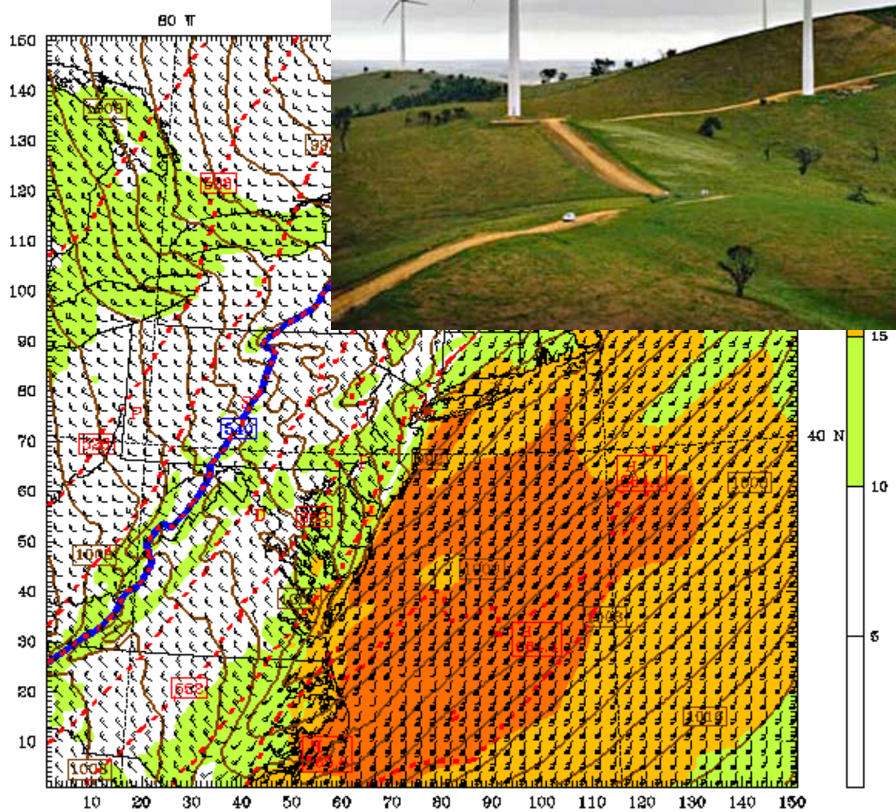


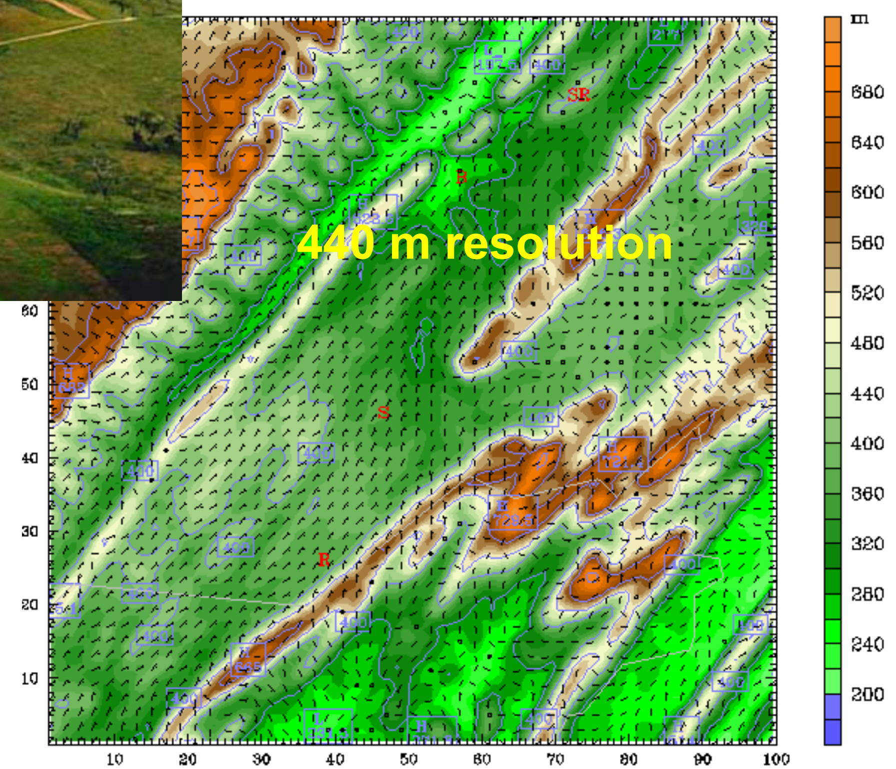



# Penn State WRF NWP System Used for Wind Energy Forecast/ Turbine Siting

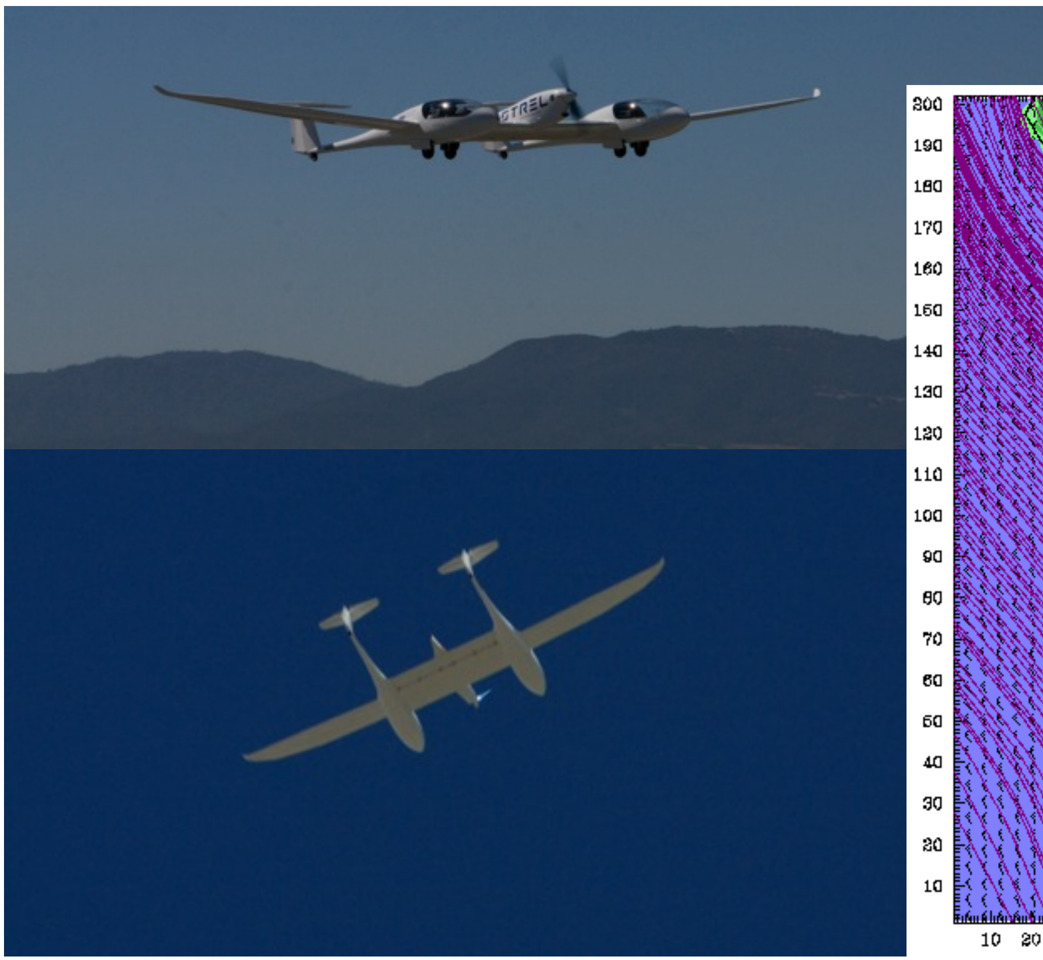


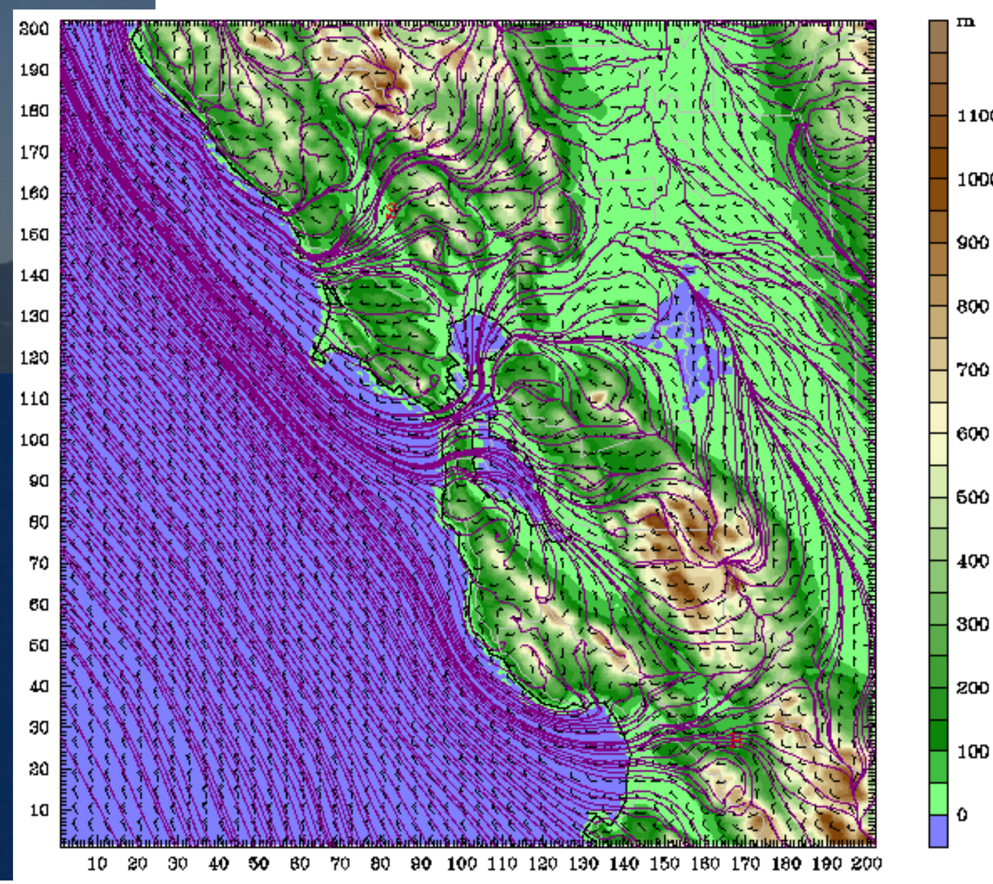



# Penn State WRF NWP System Used for In-Flight Planning for Minimal Fuel Consumption

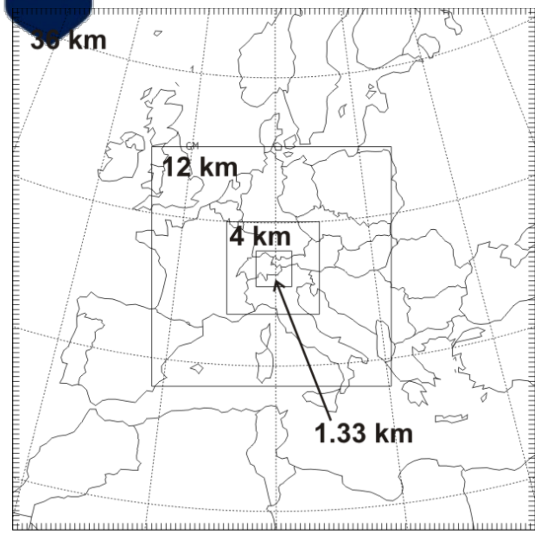
## The 2011 Green Flight Challenge Champion
**(**http://cafefoundation.org/v2/gfc_main.php**)**

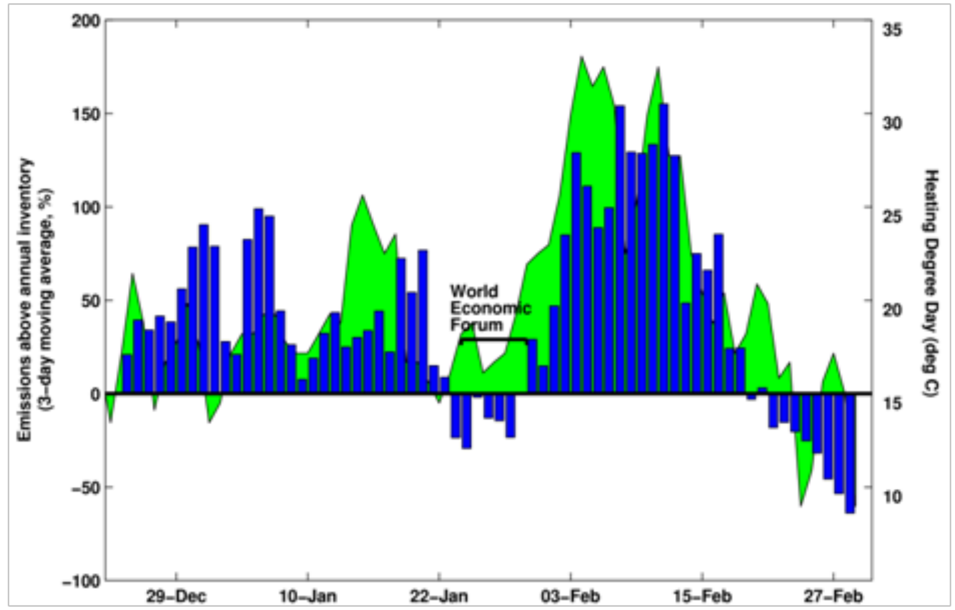


**WRF 1-km Resolution Forecast**



# Penn State WRF-Chem-FDDA Realtime System, Combined with $CO_2$ Observations used for World Economics Forum (WEF) 2012




**WRF-Chem FDDA modeling system**

**- Run twice a day during World Economics Forum (WEF) 2012**

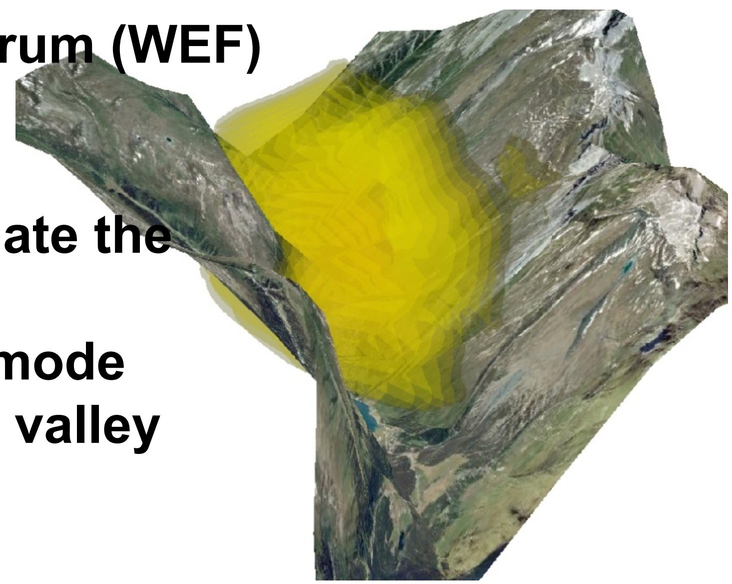
**- Assimilating WMO observations**

**- Daily update of model-obs residuals to estimate the emissions**

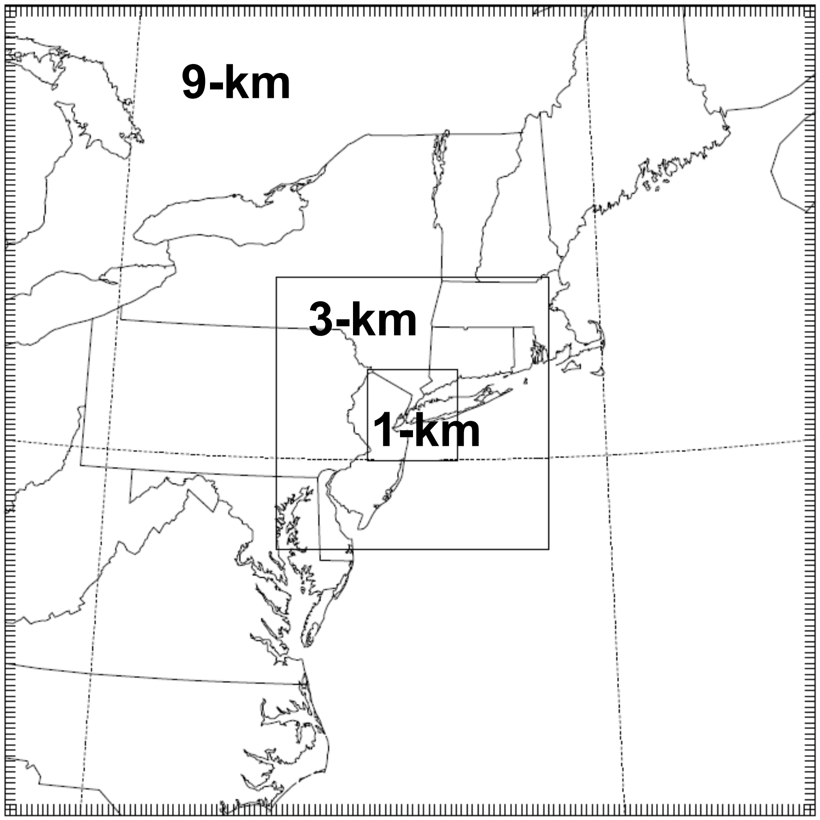
**- 24-hour simulations in time-lagged realtime mode**

**-Daily 3D plume videos for visualization of the valley circulation and the $CO_2$ plume**

**(See details in poster presentation P33)**



# Penn State NextGen Airport Forecast System (NGAFS)





**To be used with the NOAA/NWS/MDL Localized Aviation Model Output Statistics (MOS) Program (LAMP) system**

## NGAFS Evaluation --- Test Case

- Historical event of Oct. 29, 2011 – NYC Central Park, recorded first snowfall accumulation of one inch or more in October since records began in 1869.

- Serious impact on Northeast U.S., fatalities, damaging winds, coastal flooding, 1-2 feet of snow, millions without power for up to one week.

- Rain changing to snow turned out to be difficult problem that was not well predicted (several hours late) at the three NYC area airports.

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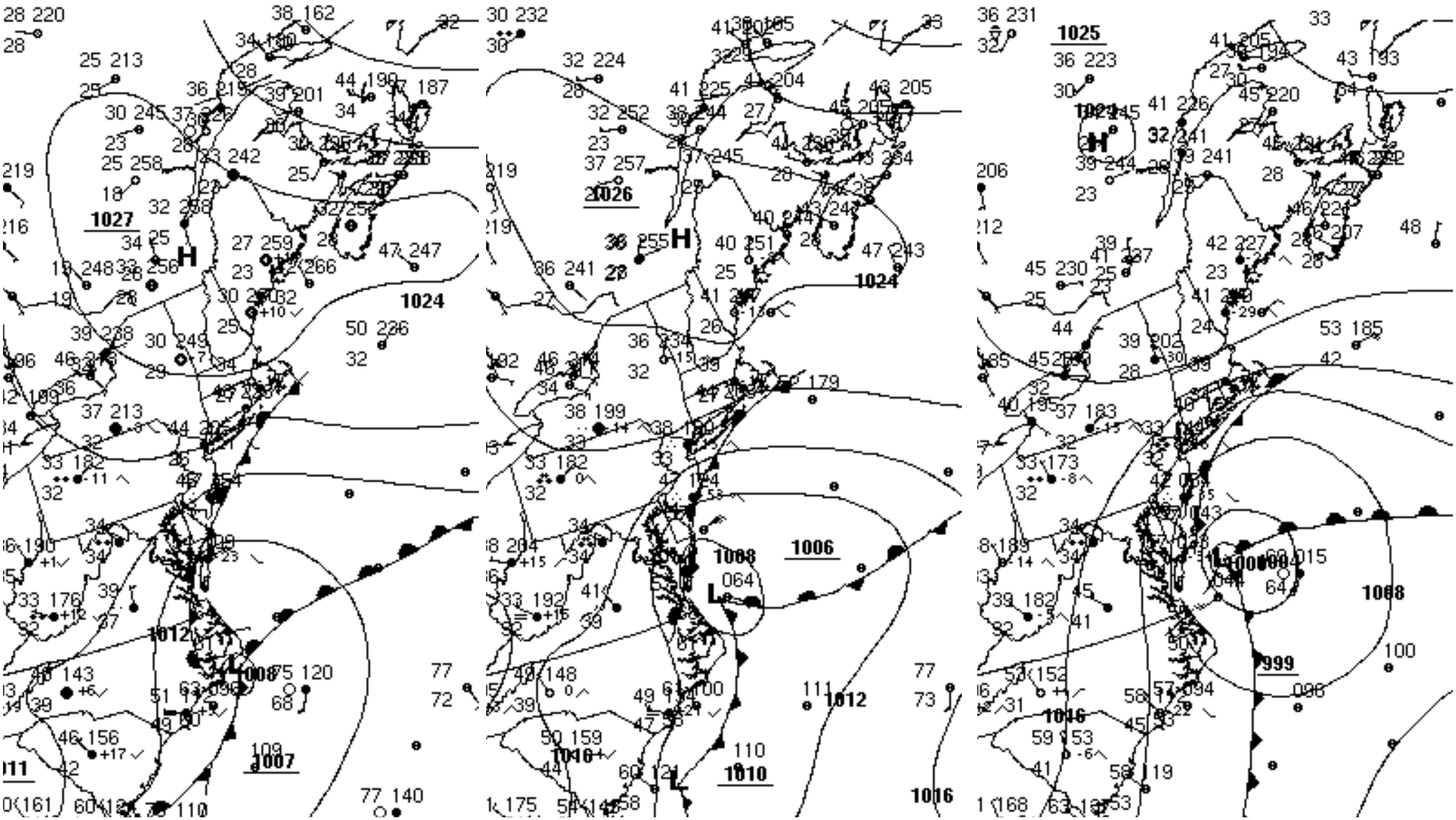
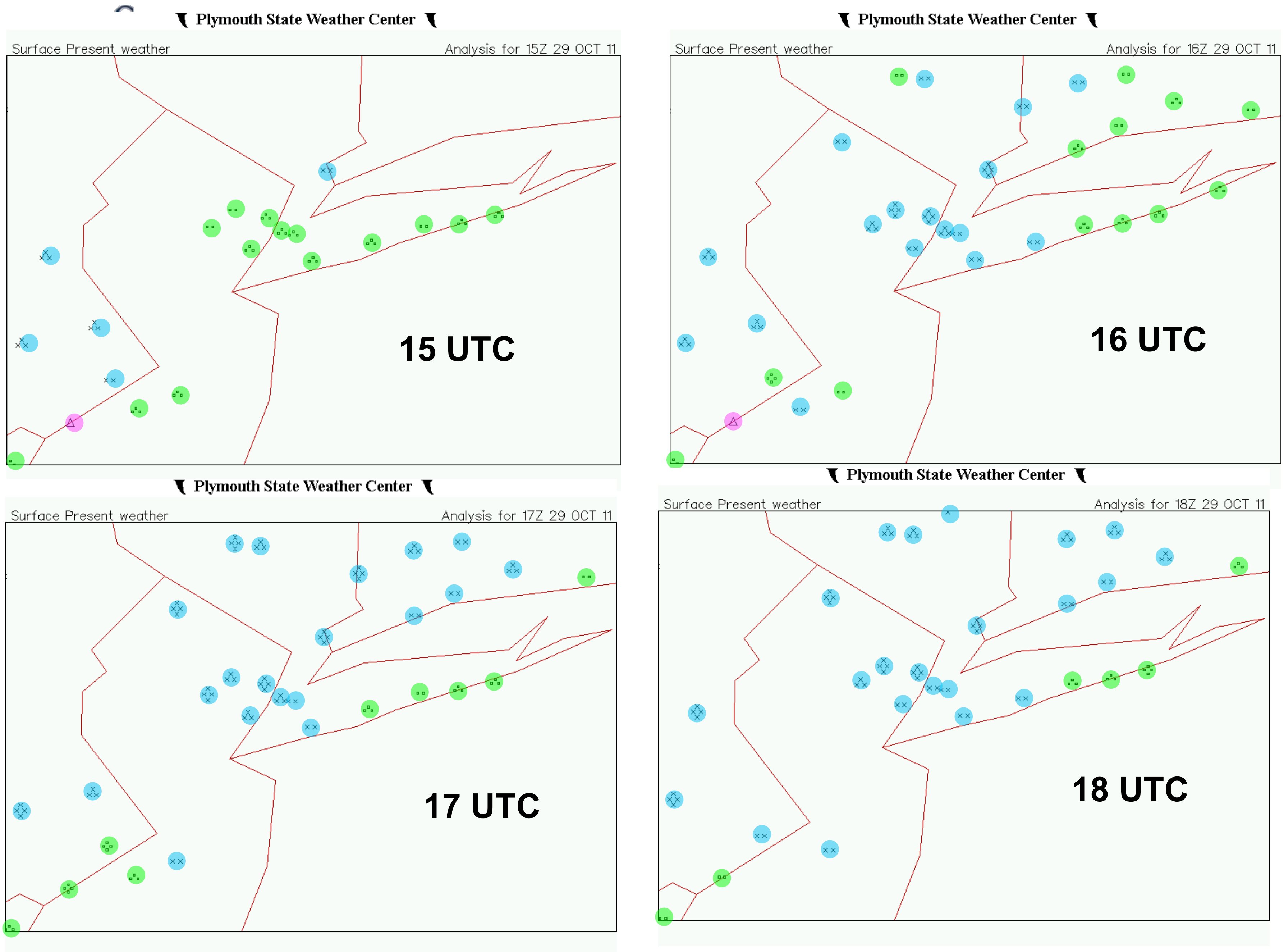


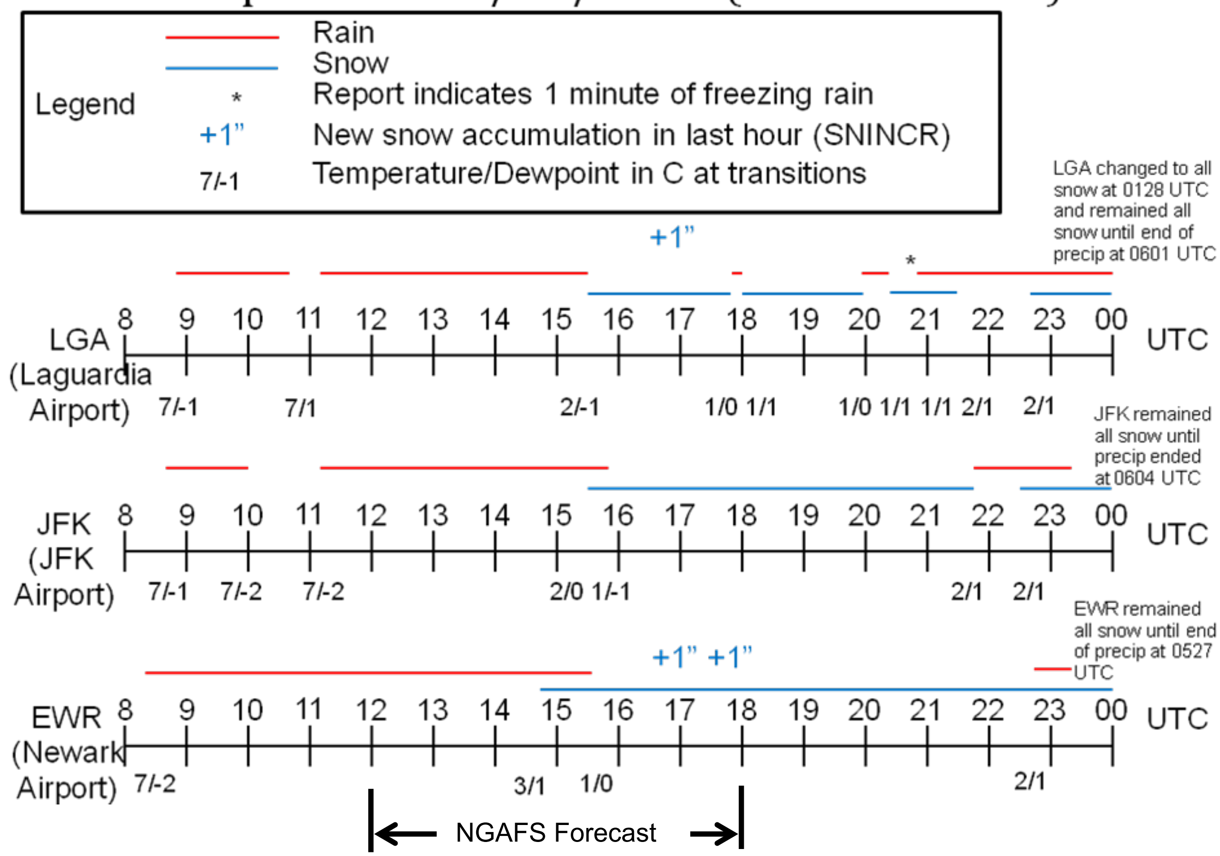
12 UTC　　15 UTC　　18 UTC

**October 29, 2011**


Plymouth State Weather Center
Surface Present weather
Analysis for 15Z 29 OCT 11
15 UTC
Plymouth State Weather Center
Surface Present weather
Analysis for 16Z 29 OCT 11
16 UTC
Plymouth State Weather Center
Surface Present weather
Analysis for 17Z 29 OCT 11
17 UTC
Plymouth State Weather Center
Surface Present weather
Analysis for 18Z 29 OCT 11
18 UTC

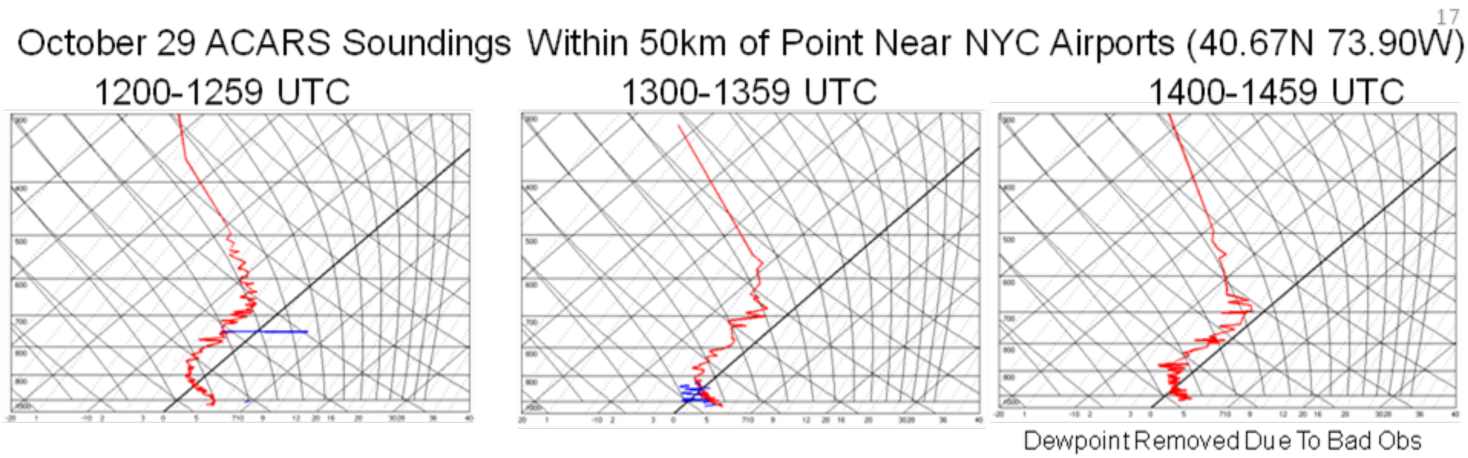
# Observed Precipitation Type Reported on Oct. 29, 2011 at LaGuardia (LGA), John F. Kennedy (JFK), and Newark (EWR) Airports

Timelines of Observed Precipitation Type at NYC-area Airports on 10/29/2011 (from METARs)

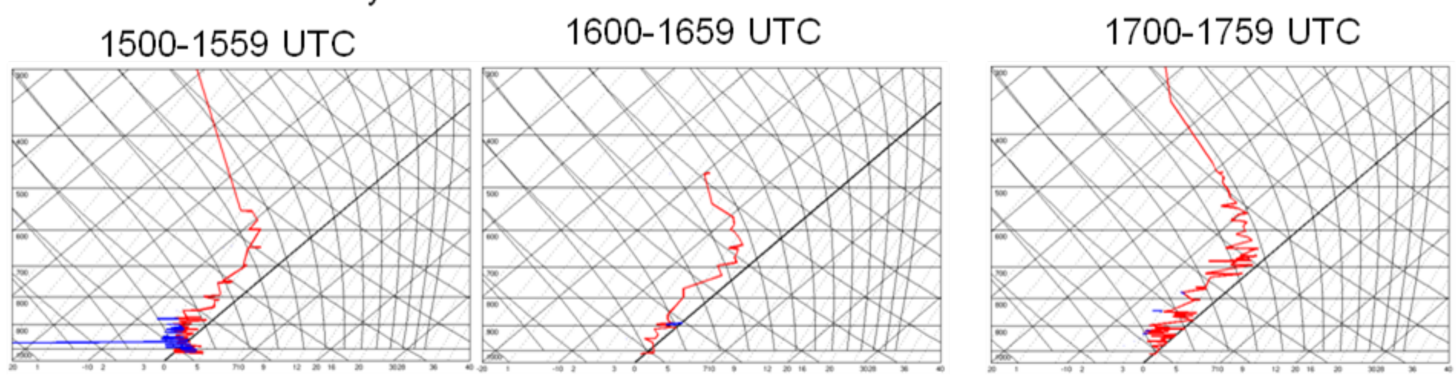



*Red lines above the time lines indicate rain. Blue lines indicate snow.*

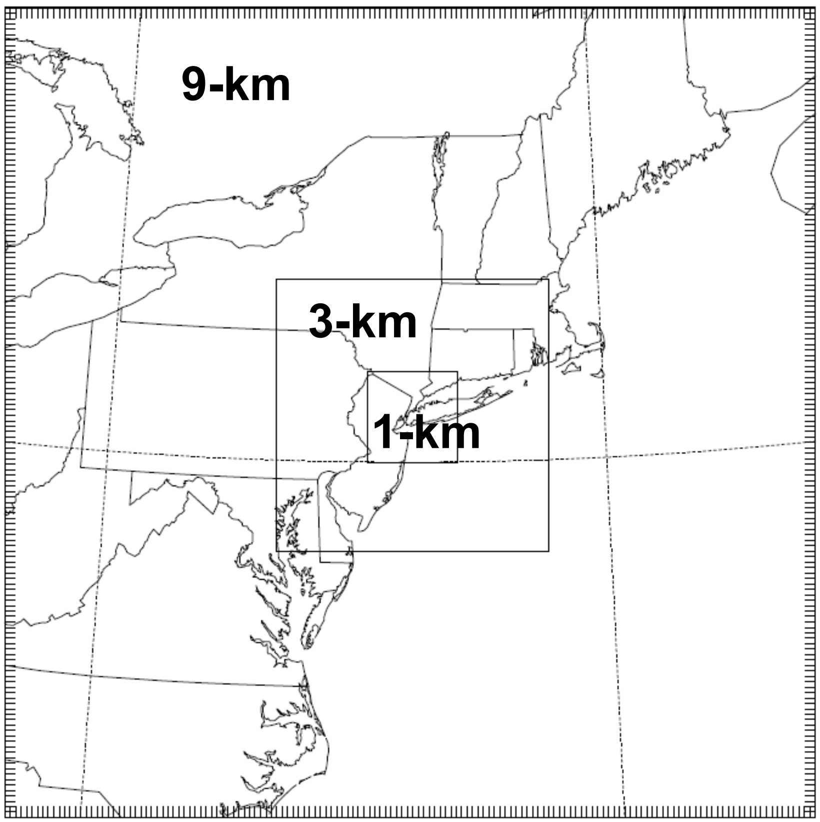
# Six ACARS Composite Temperature Soundings (C) from Aircraft Ascents and Descents in the NYC Area Between 1200 – 1800 UTC, Oct. 29, 2011




1444 UTC -- EWR switches from rain to rain/snow mix
1533 UTC -- LGA switches from rain to snow
1536 UTC -- EWR switches from rain/snow mix to snow only
1531 UTC -- JFK switches from rain to rain/snow mix
1549 UTC -- JFK switches from rain/snow mix to snow only
1752 UTC – LGA briefly switches from snow to rain and back to rain



# Penn State NextGen Airport Forecast System (NGAFS)



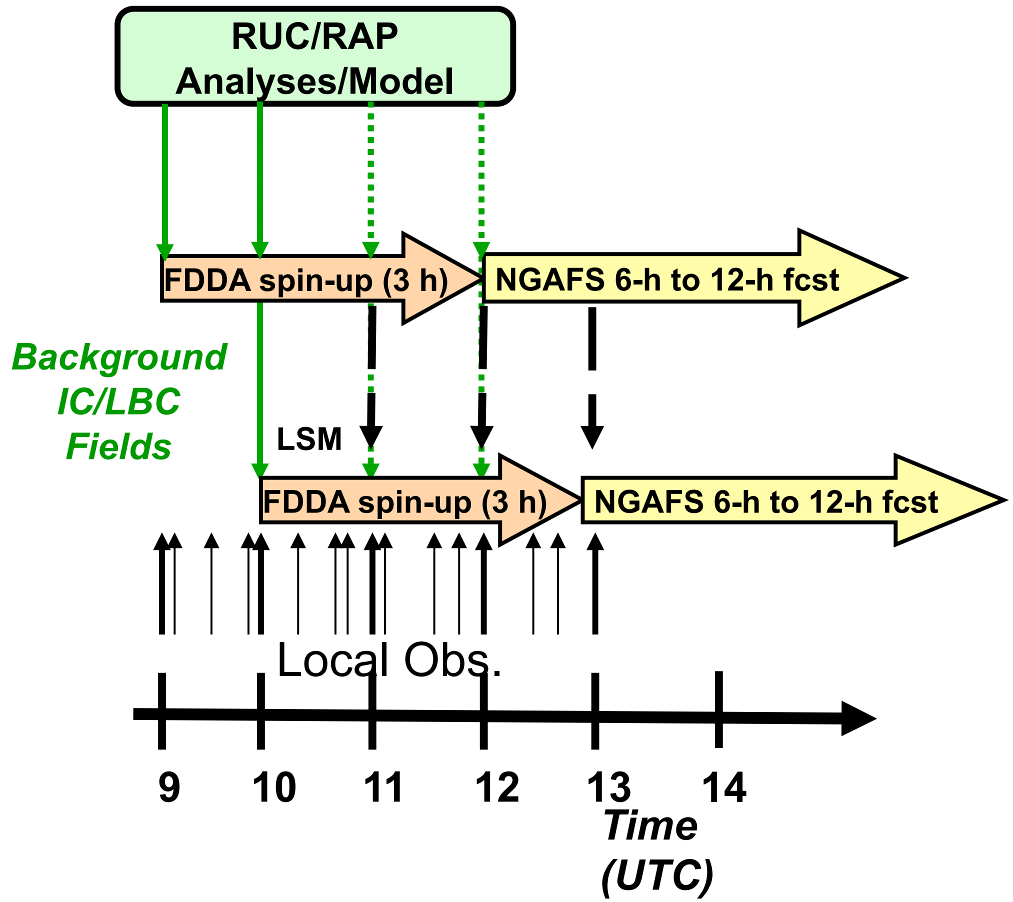

Model Physics as in Rapid Refresh (RAP) or HRRR:

- MYJ TKE PBL
- RUC Land Surface Model (LSM)
- Thompson Mixed-Phase Microphysics
- Grell 3D Ensemble CPS on 9-km grid (ishallow=0)
- RRTM LW / Dudhia SW Radiation

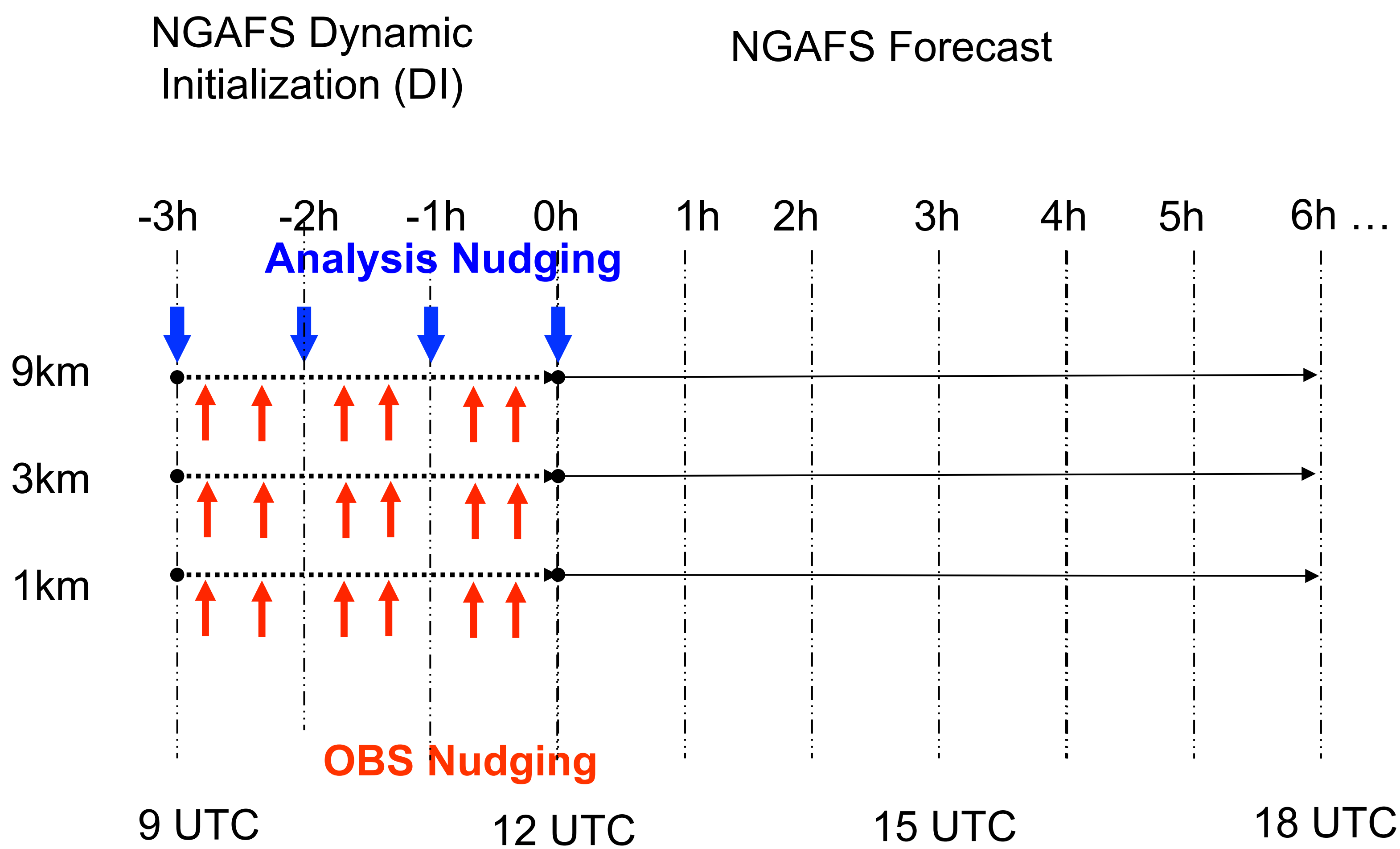
***Nested domains of 9-km, 3-km and 1-km horizontal grid spacings, with 150 X 150 X 50 grid points centered on LaGuardia Airport (LGA). (Innermost domain includes LGA, EWR and JFK.)***

# NGAFS Four-Dimensional Data Assimilation (FDDA)

## Partially Cycled System

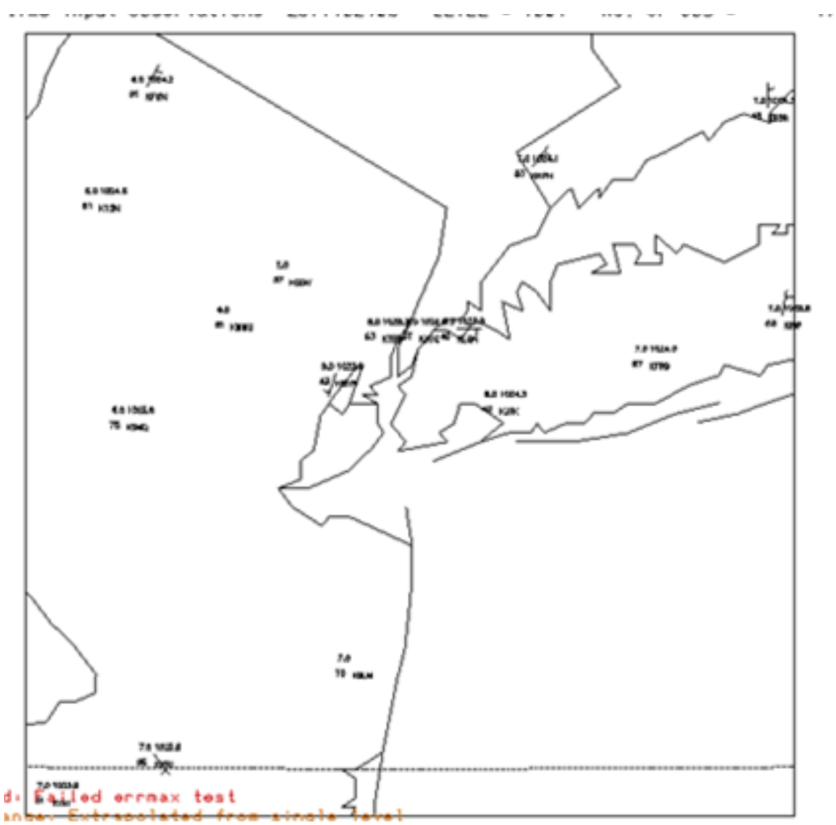


# NGAFS “Running Start” FDDA Scheme

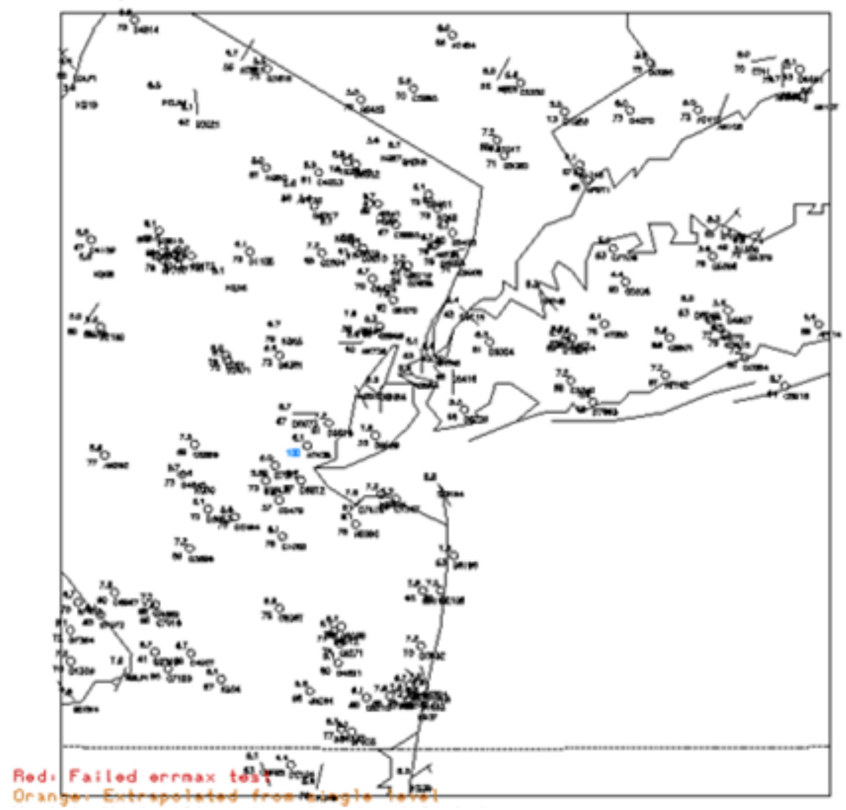


# Surface Obs Assimilated into NGAFS

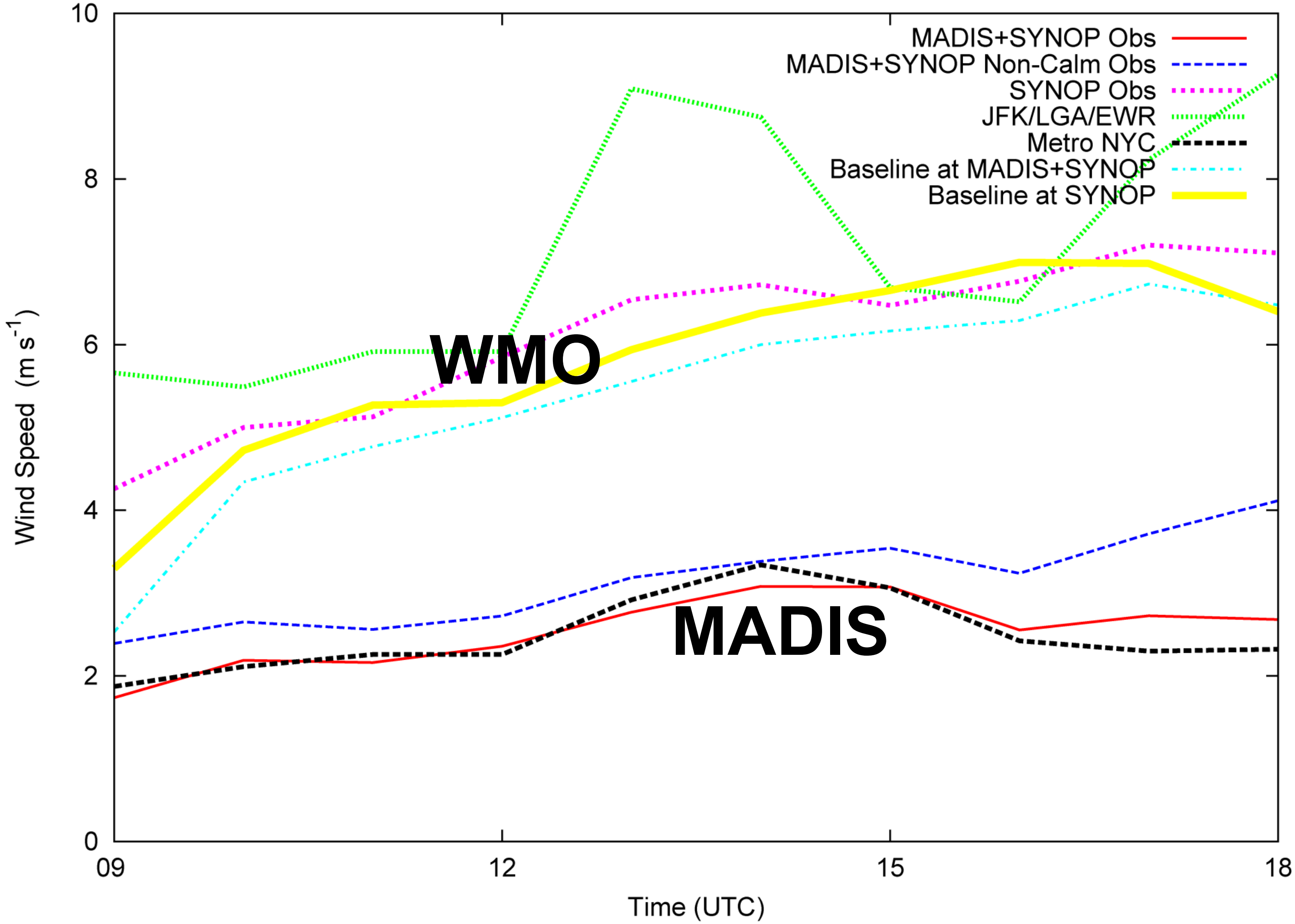
**WMO**




**MADIS**



# Observed Wind Speeds And MADIS Wind Speed Bias: WMO vs. MADIS



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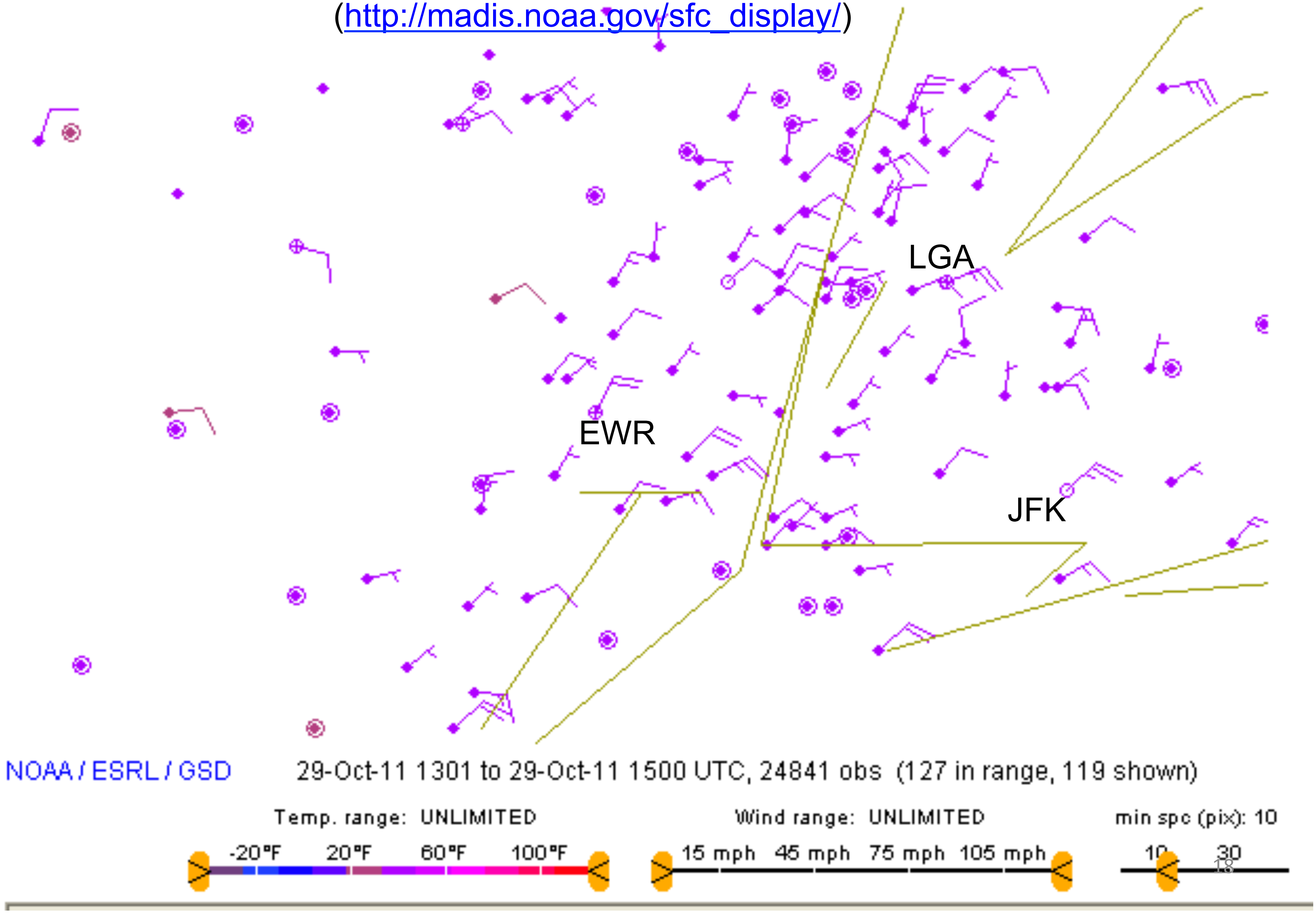
# 10/29/2011 1500 UTC

(http://madis.noaa.gov/sfc_display/)



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# Experimental Design

•**Baseline:** The realtime baseline NGAFS starting from RUC analyses at –3 h using 3-hour pre-forecast DI ICs, assimilating surface and upper-air WMO obs. No mass fields are assimilated within the PBL

•**No FDDA:** No pre-forecast DI, using RUC analysis at 0 h

•**Baseline ACARS**: Same as Baseline except for additional assimilation of aircraft (ACARS, or Aircraft Communications Addressing and Reporting System) obs

•**Baseline ACARS MADIS:** Same as Baseline ACARS except for additional assimilation of surface temperature and moisture fields within the PBL

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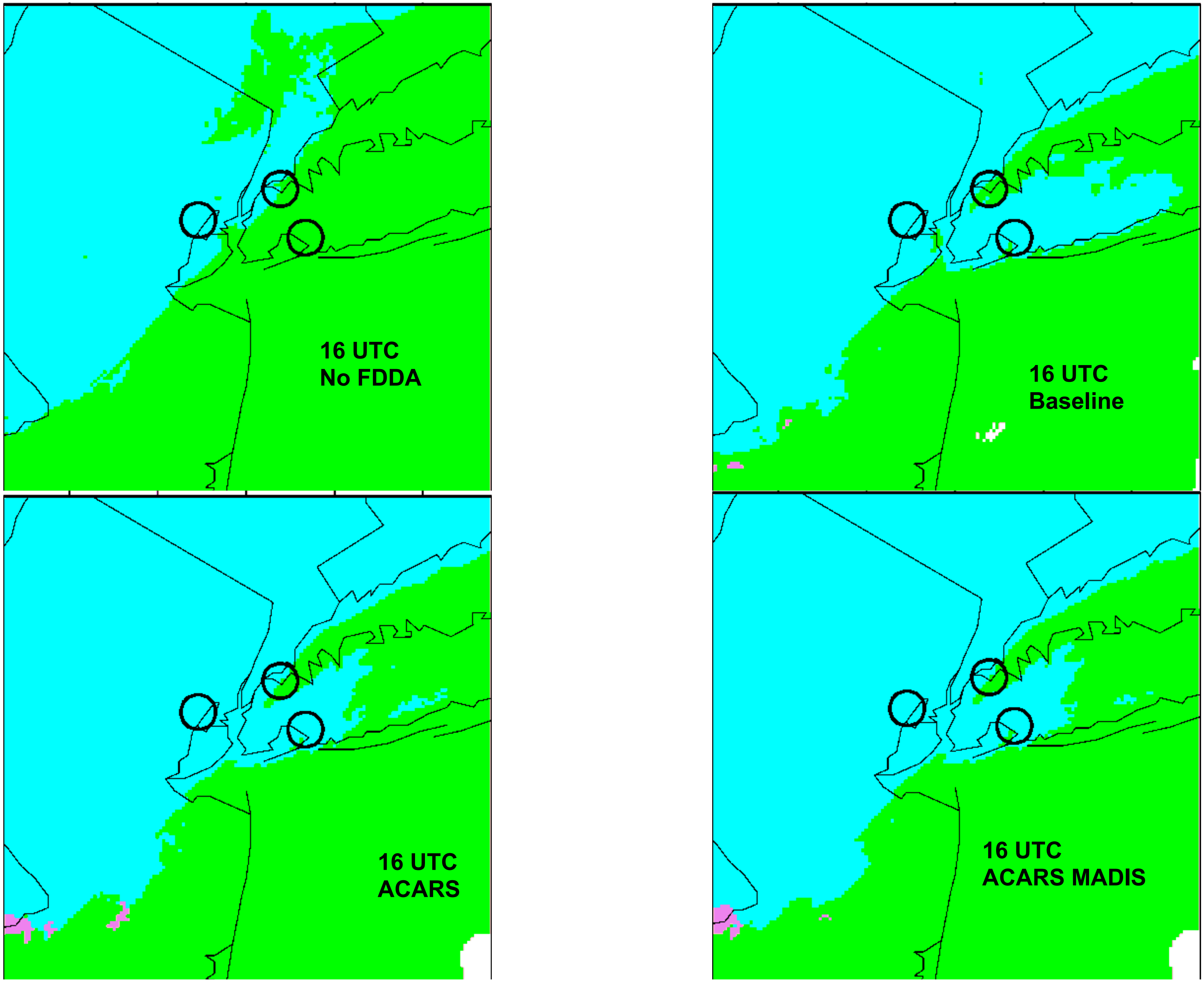
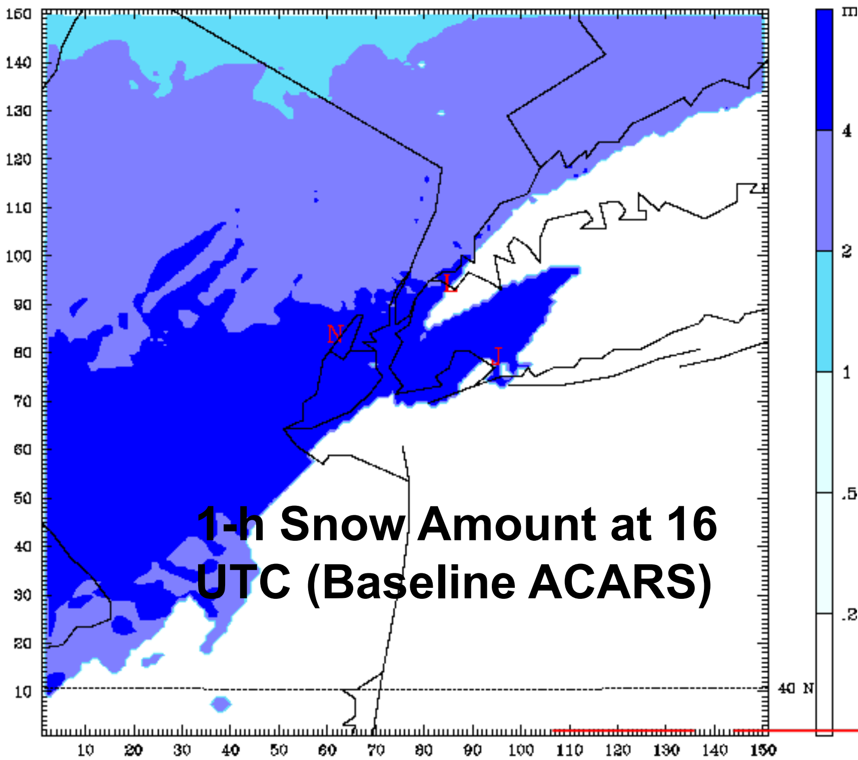
# 4-h Precipitation Type Forecasts on the 1-km grid



# Snow Amount: WRF vs. OBS




1-h Snow Amount at 16 UTC (Baseline ACARS)

# WRF:

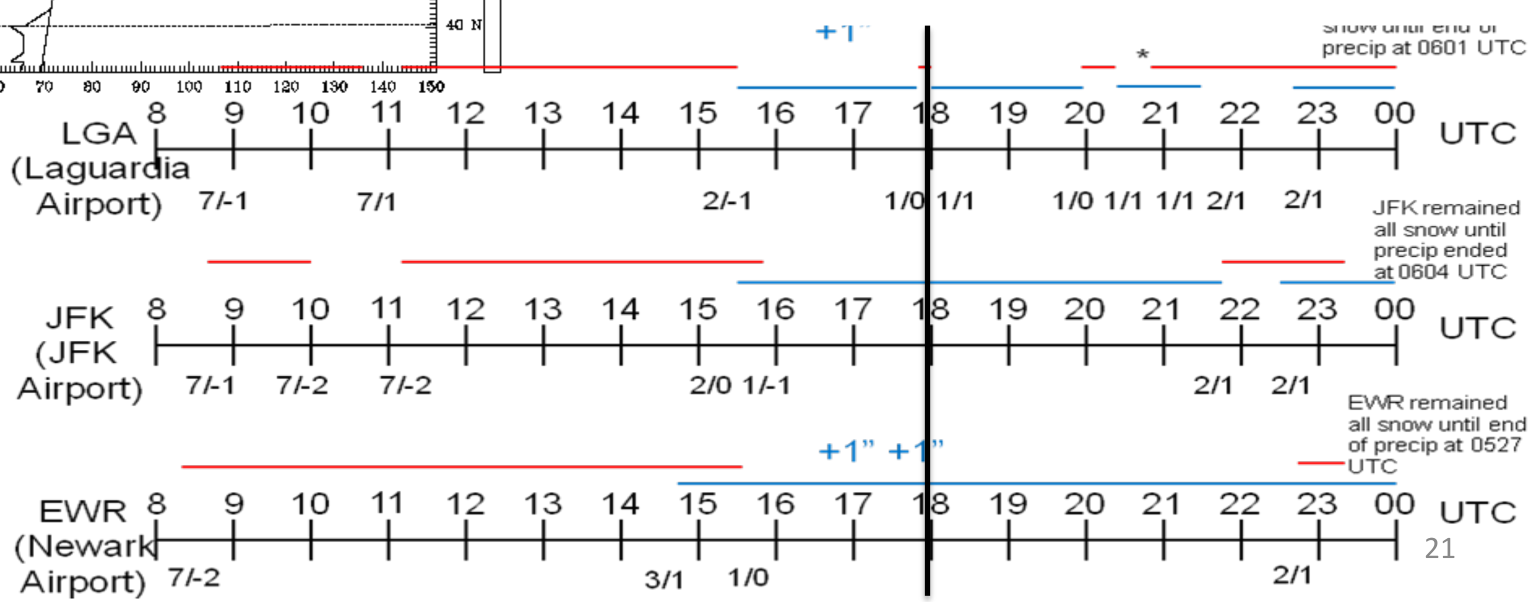
**4 mm/h liquid= 1.5 inch/h snow (assuming 1:10 ratio)**

**Airport Snow total up to 18 UTC:**

**JFK: ~7.66 mm liquid eq. or ~ 3 inch snow**
**EWR: ~18.55 mm liquid eq. or ~7 inch snow**
**LAG: ~15.6 mm liquid eq. or ~ 6 inch snow**

# OBS

**18 UTC**



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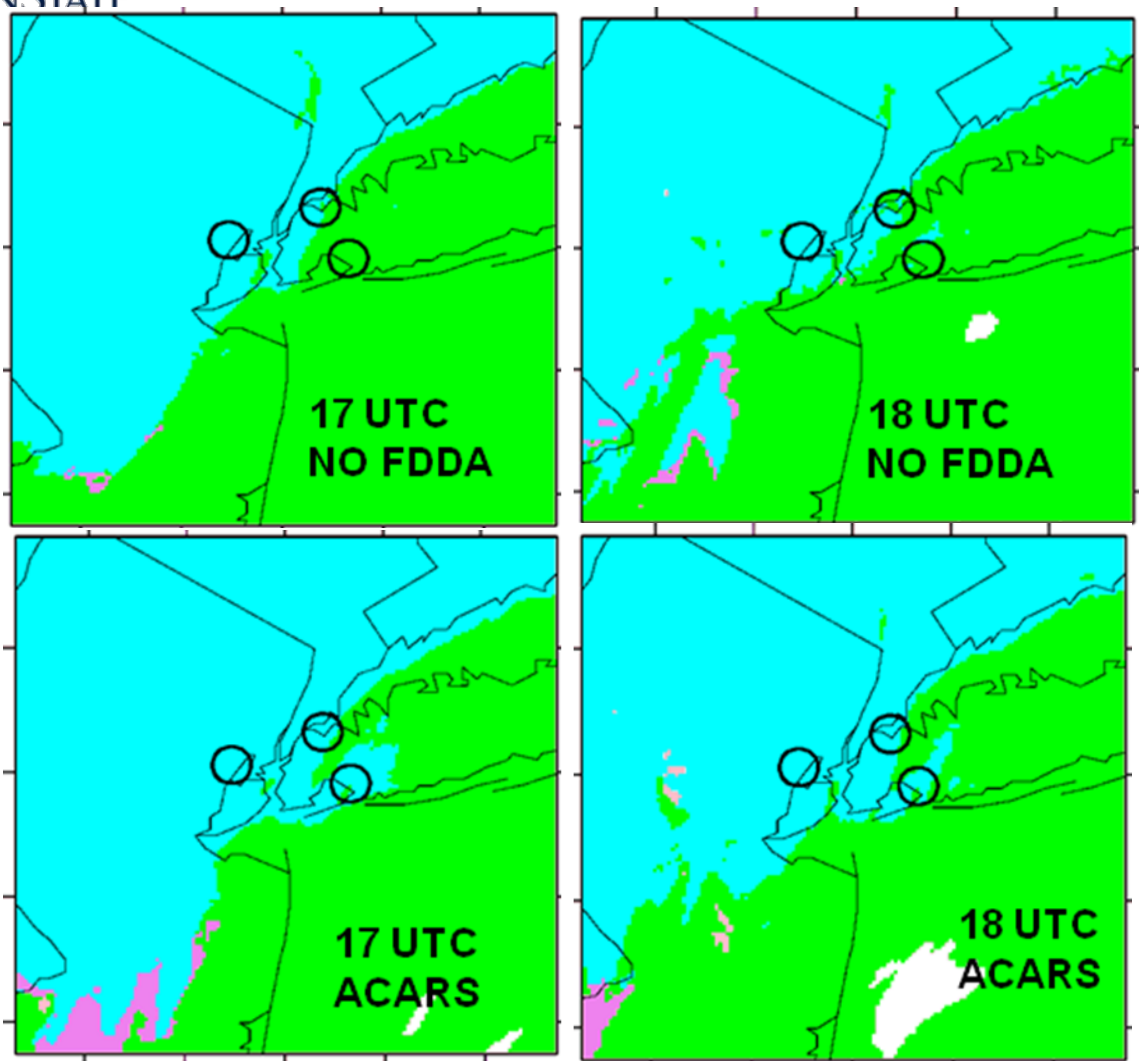
# Precipitation Type Forecasts on the 1-km grid



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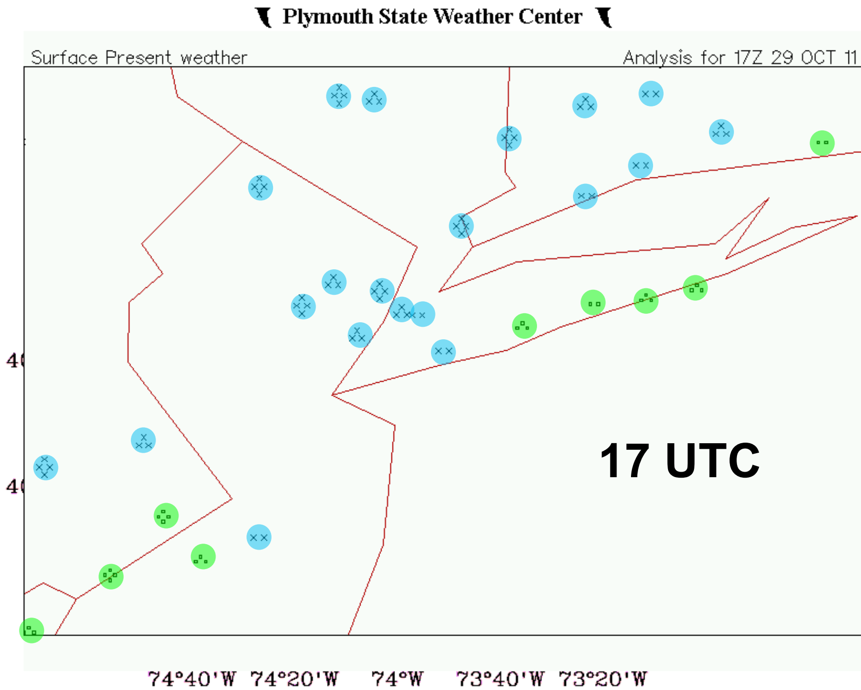
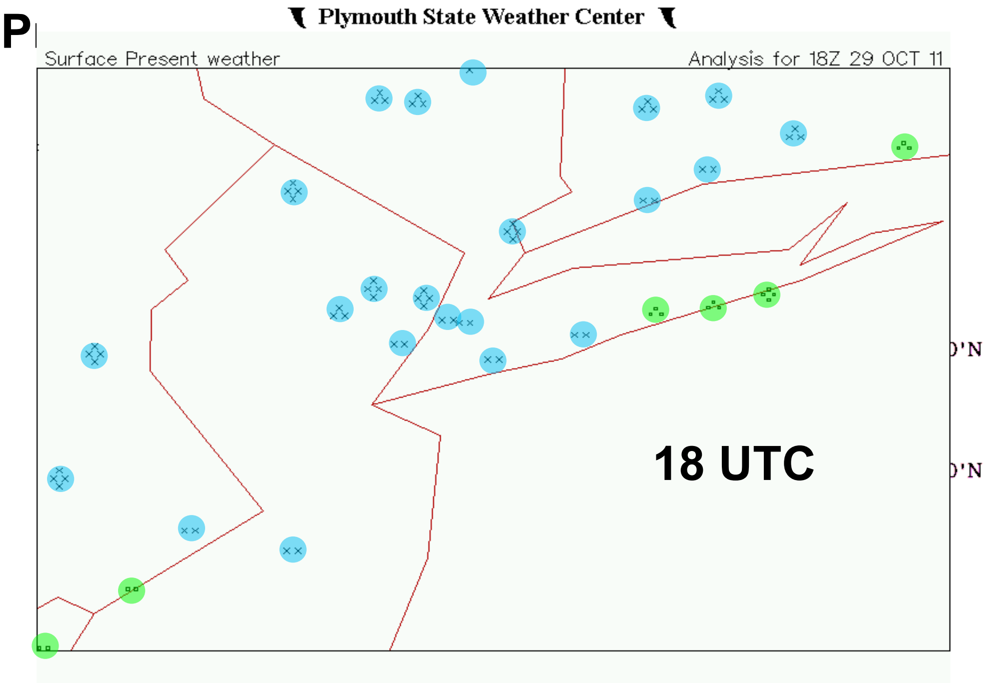
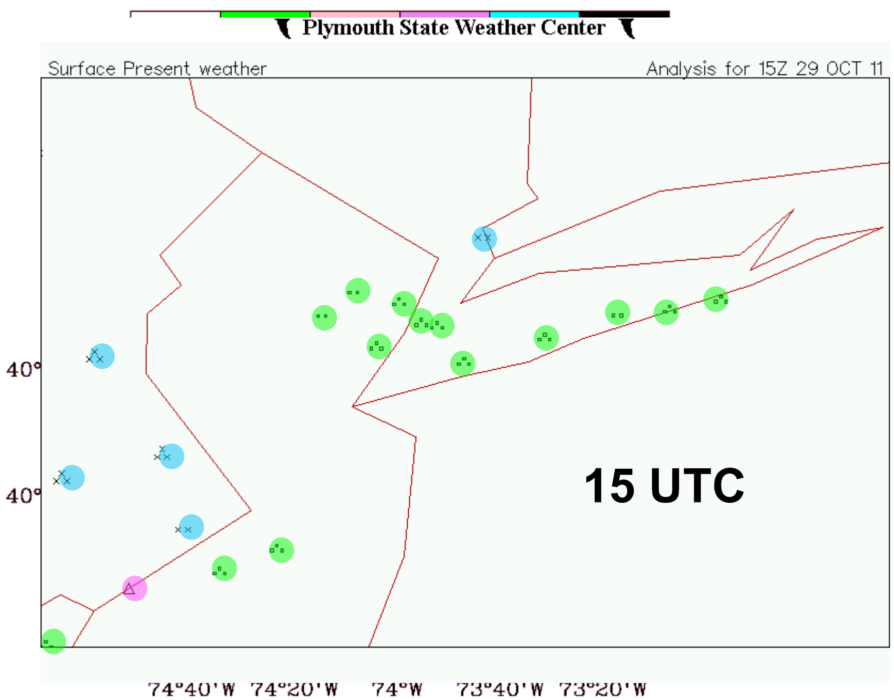
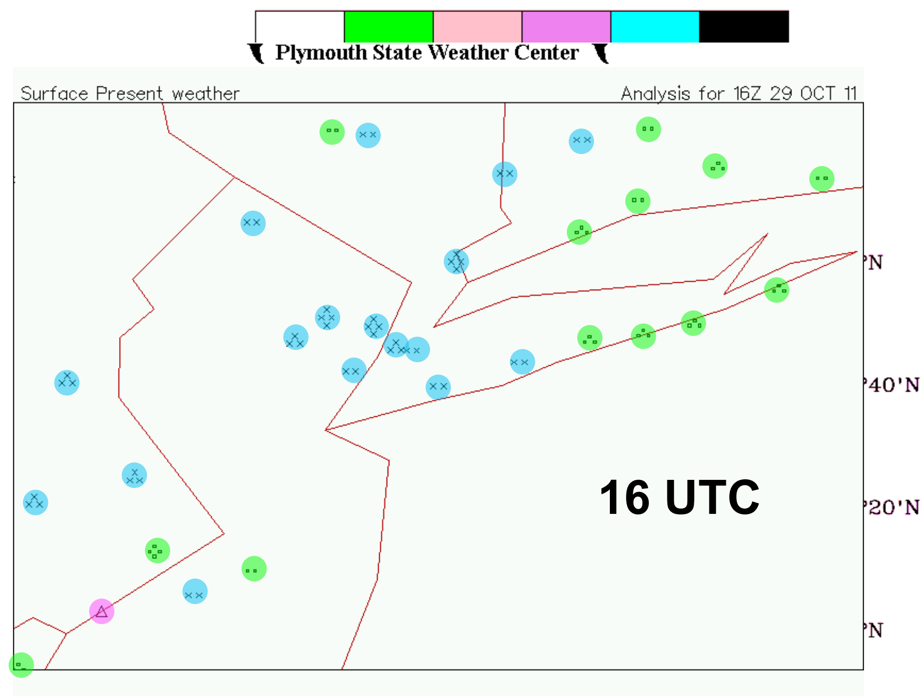

Plymouth State Weather Center
Surface Present weather
Analysis for 17Z 29 OCT 11
17 UTC
74°40'W 74°20'W 74°W 73°40'W 73°20'W

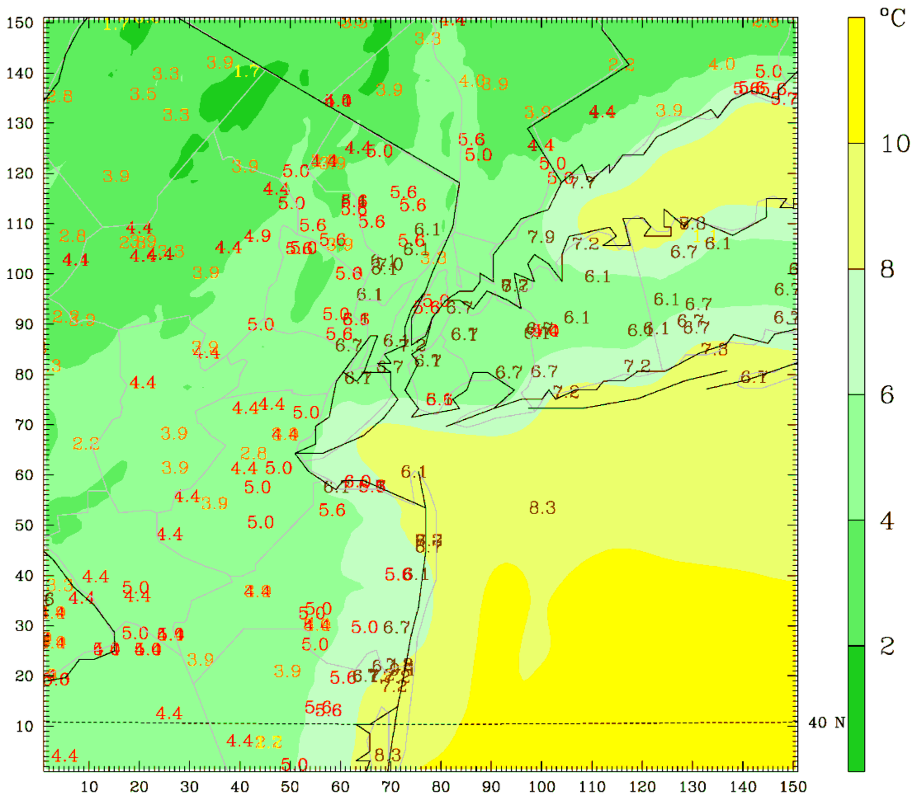

Plymouth State Weather Center
Surface Present weather
Analysis for 18Z 29 OCT 11
18 UTC


Plymouth State Weather Center
Surface Present weather
Analysis for 15Z 29 OCT 11
15 UTC
74°40'W 74°20'W 74°W 73°40'W 73°20'W

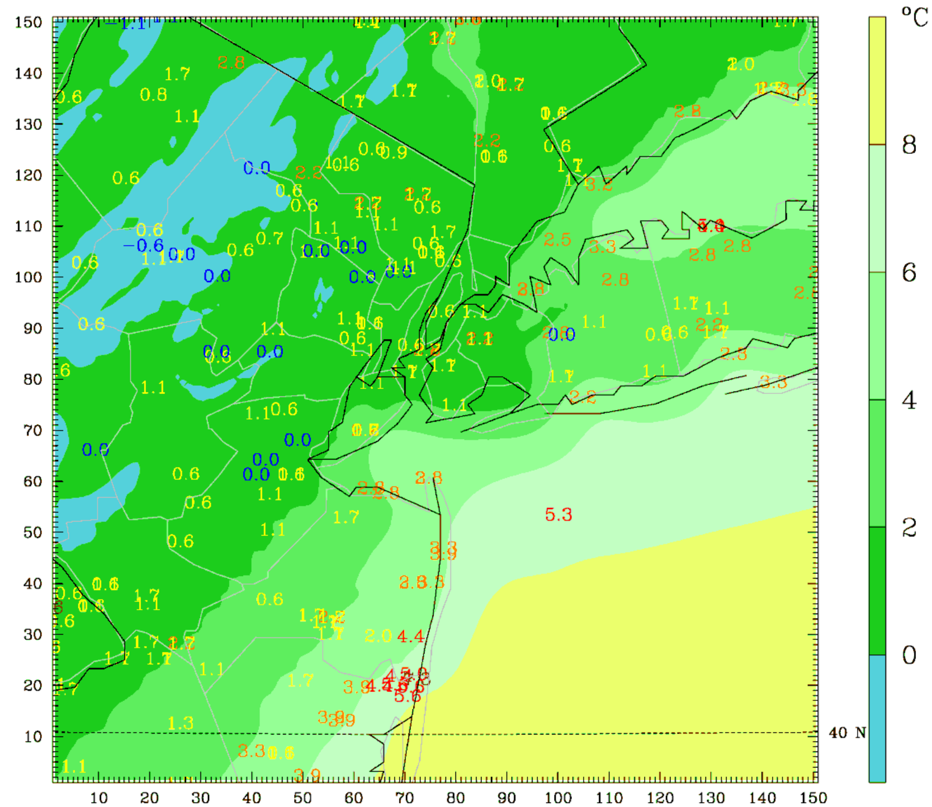

Plymouth State Weather Center
Surface Present weather
Analysis for 16Z 29 OCT 11
16 UTC
40'N
20'N

# RUC Analyses vs. Observations

**12 UTC, 29 OCT 2011**




**16 UTC, 29 OCT 2011**



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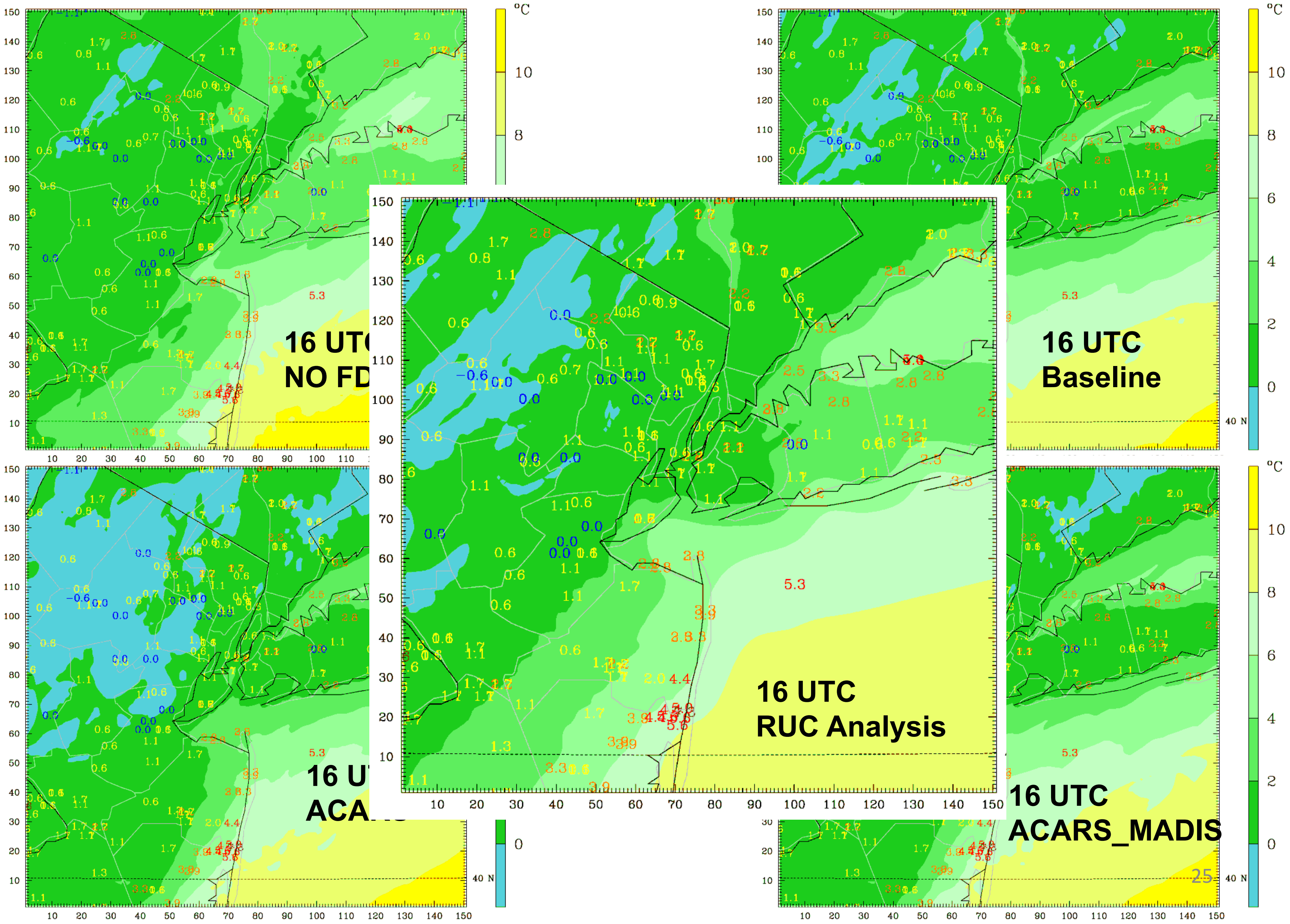
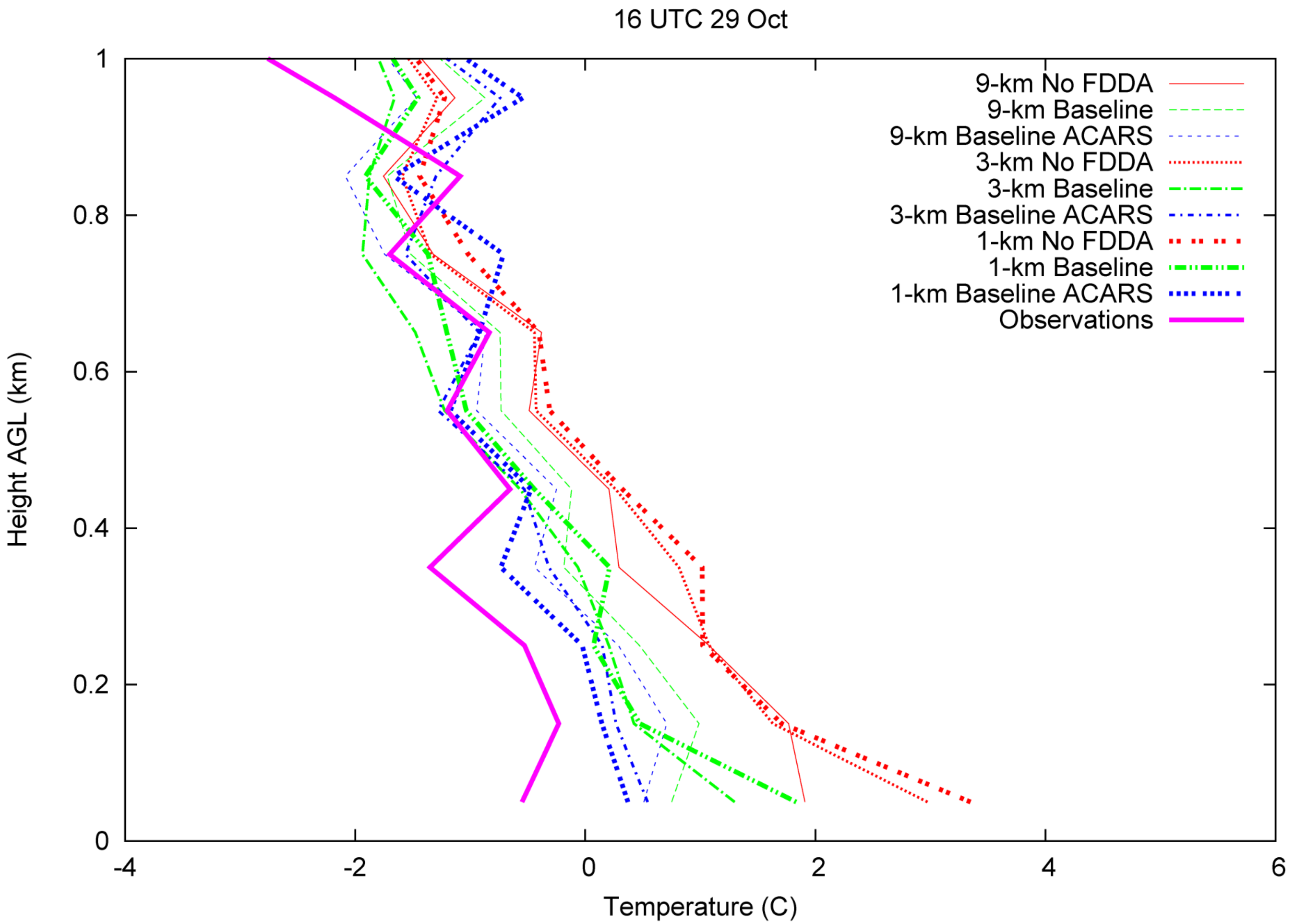
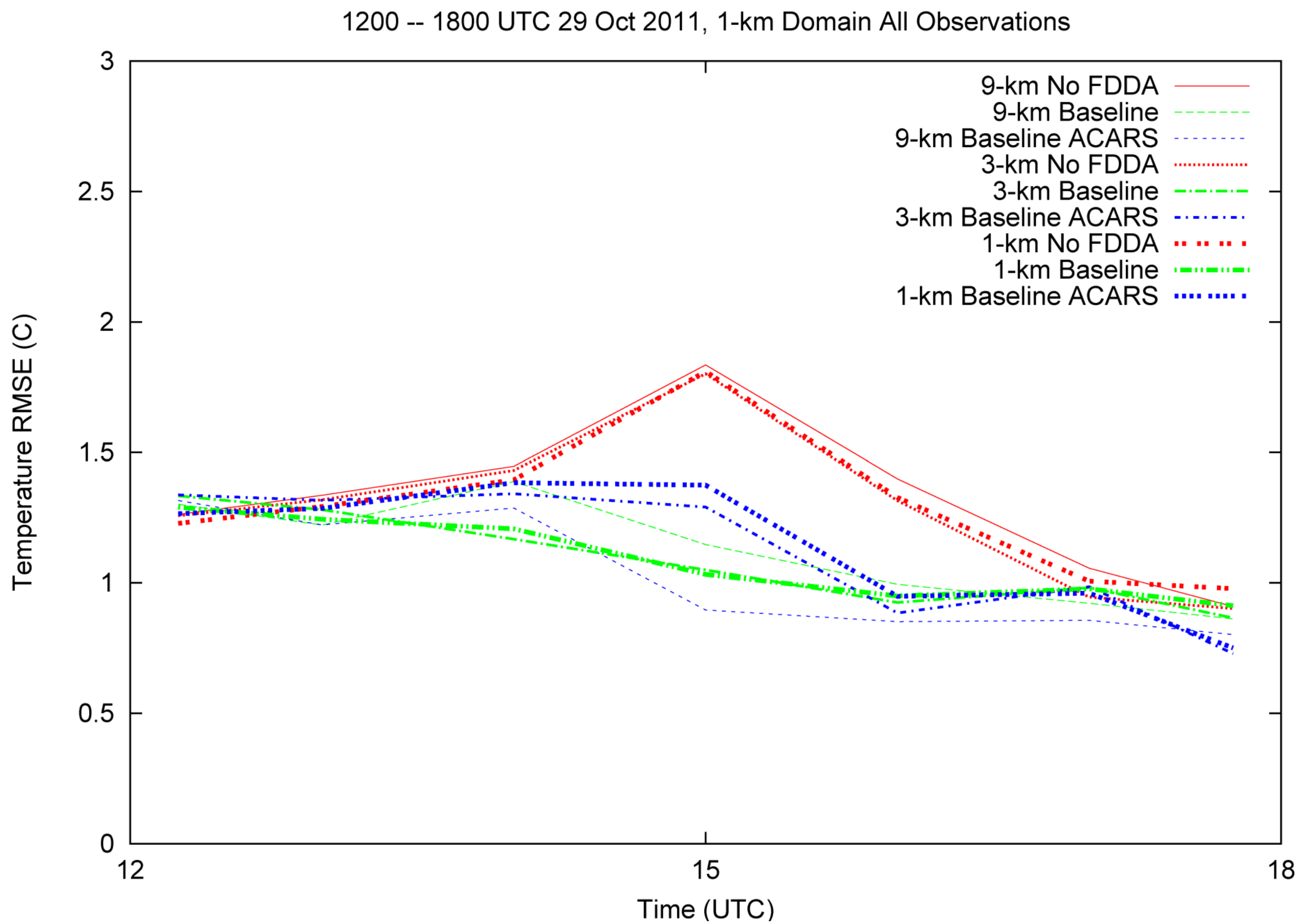
# 1-km NGAFS-Predicted Surface Temperature with Observations



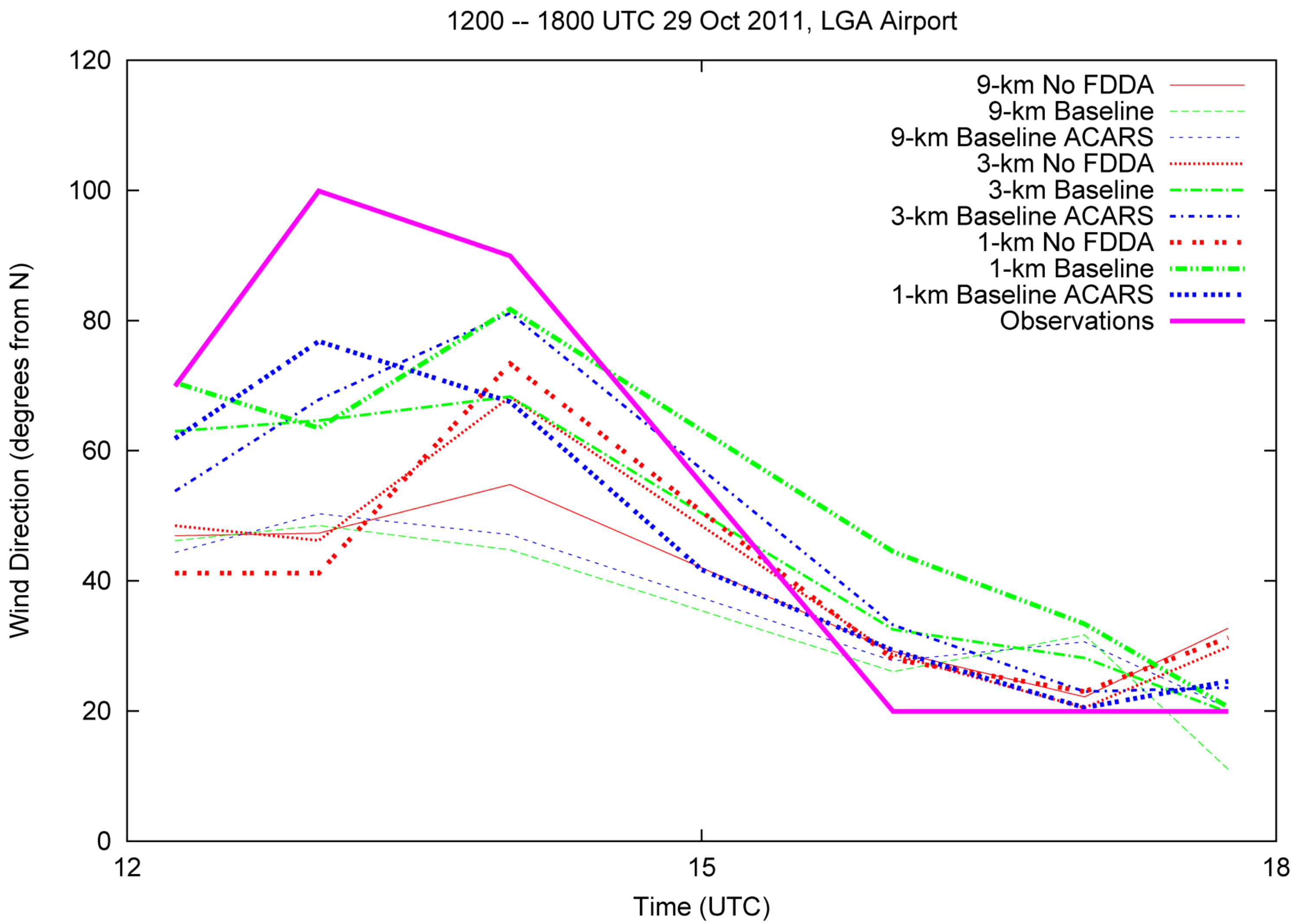
# NGAFS 4-h Forecast of the Low-level Temperature Structure



# RMSE Time Series of NGAFS-Predicted Surface Temperature

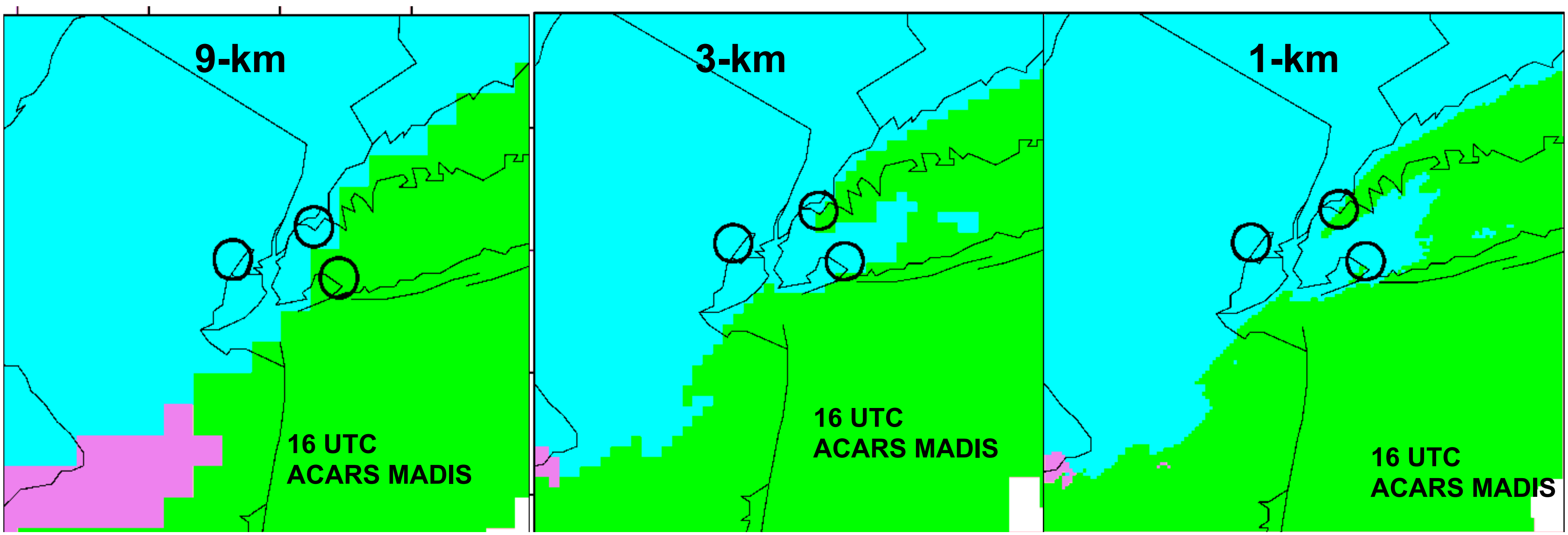


# Observed and NGAFS Wind Direction Forecasts



# 4-h Precipitation Type Forecasts

## Effect of Resolution



# Summary

- Penn State WRF NWP systems applied to military defense, wind energy, aviation and $CO_2$ emission monitoring
- Hourly-cycled Realtime high-resolution Penn State NGAFS Baseline forecast with pre-forecast FDDA for 12 UTC initial conditions (ICs) performed well for precip type (i.e., the timing of the changeover to snow from 15-16 UTC and retaining snow thereafter) at the three NYC airports for the historic Oct. 29, 2011 snow storm event
- Improved precip type results, especially during the 15 – 16 UTC changeover period, were generally obtained with the 1-km and 3-km grids compared to the 9-km grid.
- No FDDA NGAFS using 12 UTC RUC analyses for ICs predicted changeover at Newark and LaGuardia by 16 UTC on finer domains but failed to predict changeover at JFK
- Additional assimilation of ACARS data along with WMO and RUC analysis data in Baseline generally produced colder temperature predictions and better snow forecasts

Acknowledgement

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- DTRA contract HDTRA01-03-D-0010 under the supervisions of Lt. Col. Charles Harris, Dr. Andy Grose and Mr. Jim Miles

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# Supplementary Slides

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## NCEP Manikin Precipitation Type

- The NCEP Manikin scheme (Manikin 2005) diagnoses the dominant precipitation type based on five different diagnostic approaches, including the numerical model's explicit microphysics, but also using algorithms based on such factors as the temperature profile in the atmosphere's lower layers.

- An important advantage of this approach is that it uses multiple diagnostic approaches (currently weighted equally), thereby producing a consensus forecast, which may be more accurate than any single forecast approach.

- Another advantage is that it distinguishes between rain, freezing rain, sleet and snow, although it does not allow for a mix of these types. That is, it only determines the type of precipitation most likely to be observed at the surface at a given time.

## NCEP Manikin Precipitation Type

- Penn State modifications to the Manikin approach used in WRFPOST for precipitation type evaluation.
  - ➢ Adapted the Manikin explicit algorithm to correctly use the new Thompson microphysics.
  - ➢ Changed the definition of measureable precipitation from using a hard-wired threshold of precipitation per time step to using a threshold of roughly 0.01” per hour to give a consistent representation of precipitation for all resolutions.