# Adaptive Observation Strategies for Advanced Weather Prediction


**David P. Bacon, Zafer Boybeyi**

**Center for Atmospheric Physics**

**Science Applications International Corporation**

**Michael Kaplan**

**Dept. of Marine, Earth, & Atmos. Sci.**

**North Carolina State University**


**October 30, 2001**


**David P. Bacon**
**(703)676-4594**
**david.p.bacon@saic.com**

# Weather Forecasting – A Primer

- **Weather forecasting relies on a system of systems:**
  - ***In-situ* observations (surface, balloon, & aircraft)**
  - **Remotely-sensed observations (satellite-based)**
  - **Data assimilation (creating a physically consistent 3-D dataset)**
  - **Prognostic models (extrapolation into 4-D)**

# *In-situ* Observations

- **Irregular spatial distribution**
  - **Where the people (and planes) are**
- **Quasi-regular temporal distribution**
  - **Surface observations**
    - **Hourly *with special reports for significant weather***
  - **Balloon observations**
    - **Twice-daily at 0000Z & 1200Z**
  - **Aircraft observations**
    - **Regular intervals**

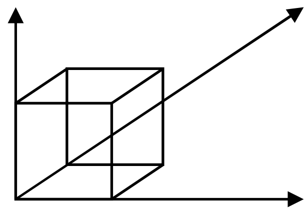
# Remote Sensing Observation Strategies

- The beginning:
  - TIROS-1 (April 1, 1960)
    - » Television and InfraRed Operational Satellite
  - ATS-1 (December 6, 1966)
    - » Applications Technology Satellite – Geostationary
    - » Communications system test bed
- Raster based systems
  - Vidicon tubes to CCDs

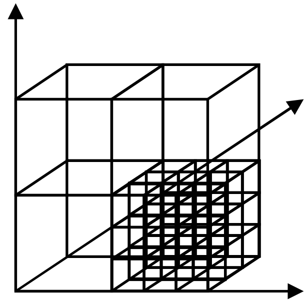
# Data Assimilation

- **Goal: A physically consistent 3-D representation of the atmosphere at an instant of time**
- **Requirements: Rationalize a disparate set of data that is a mix of irregular and grid point information at synoptic (0000Z & 1200Z) and asynoptic times**
- **Modify large-scale effects to reflect small-scale features**
  - **Capture steep gradients critical to severe weather**

# Prognostic Models



- Most models are based on a rectangular grid structure
  - Intuitively obvious
  - Simplest tiling
  - Simple operator decomposition
- Higher resolution is obtained by nesting
  - Conceptually easy
  - Numerically tricky
    - » Reflective internal boundaries
    - » Differing surface conditions
    - » Scale interactive information exchange
- Initial conditions obtained from data assimilation system
  - Generally at synoptic times

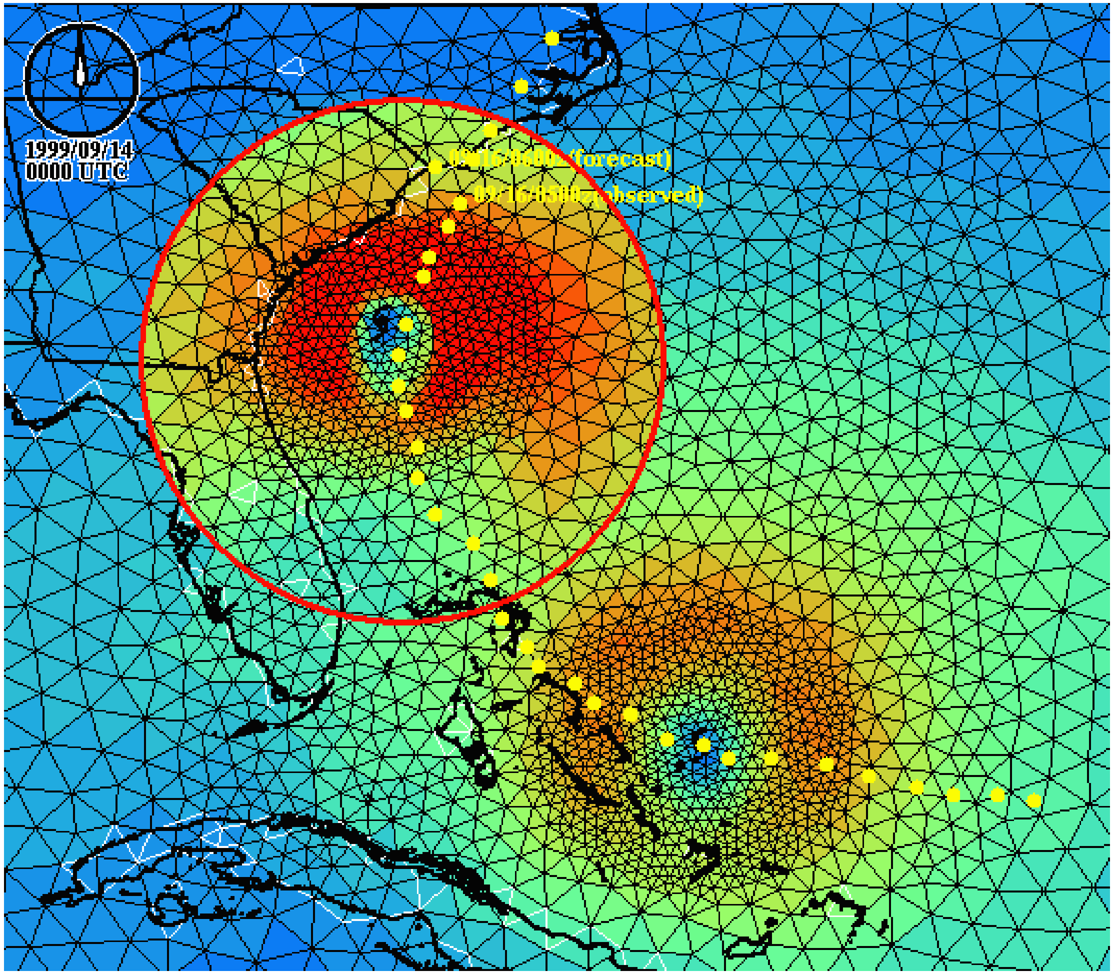


# A Vicious Circle

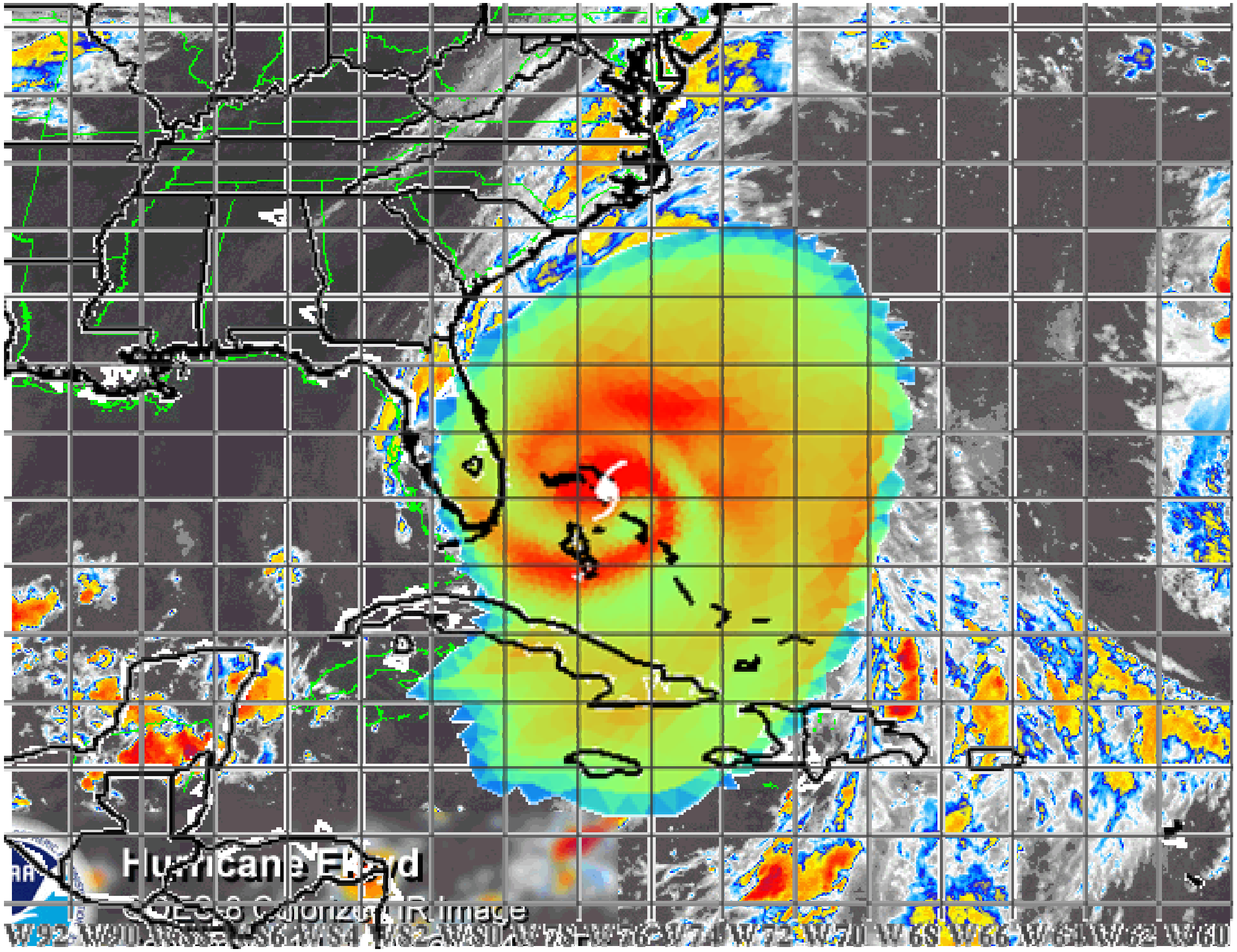
- **Increased horizontal ($\alpha$) and vertical ($\beta$) resolution in models leads to:**
  - **Higher resolution initial conditions:** $\alpha^2\beta$
  - **Increased run-time:** $\alpha^2\beta$
  - **Increased output volume:** $\alpha^2\beta$ **max($\alpha$, $\beta$)**
- **Higher resolution ICs requires higher resolution observations**

# Dynamic Adaptation of Data Assimilation and Model Resolution

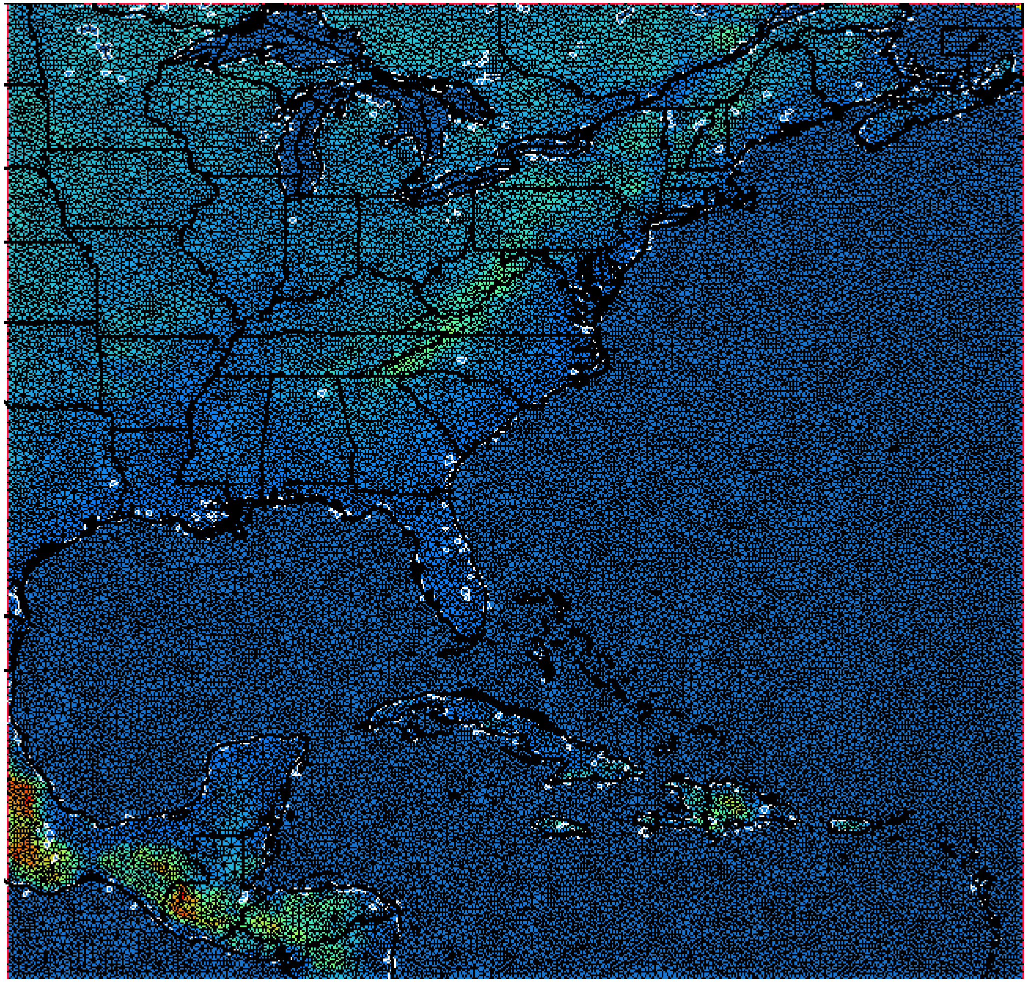
- **Initial grid for an OMEGA simulation of Hurricane Floyd and the grid (inset) at 72 hours**



# OMEGA Forecast of Hurricane Floyd

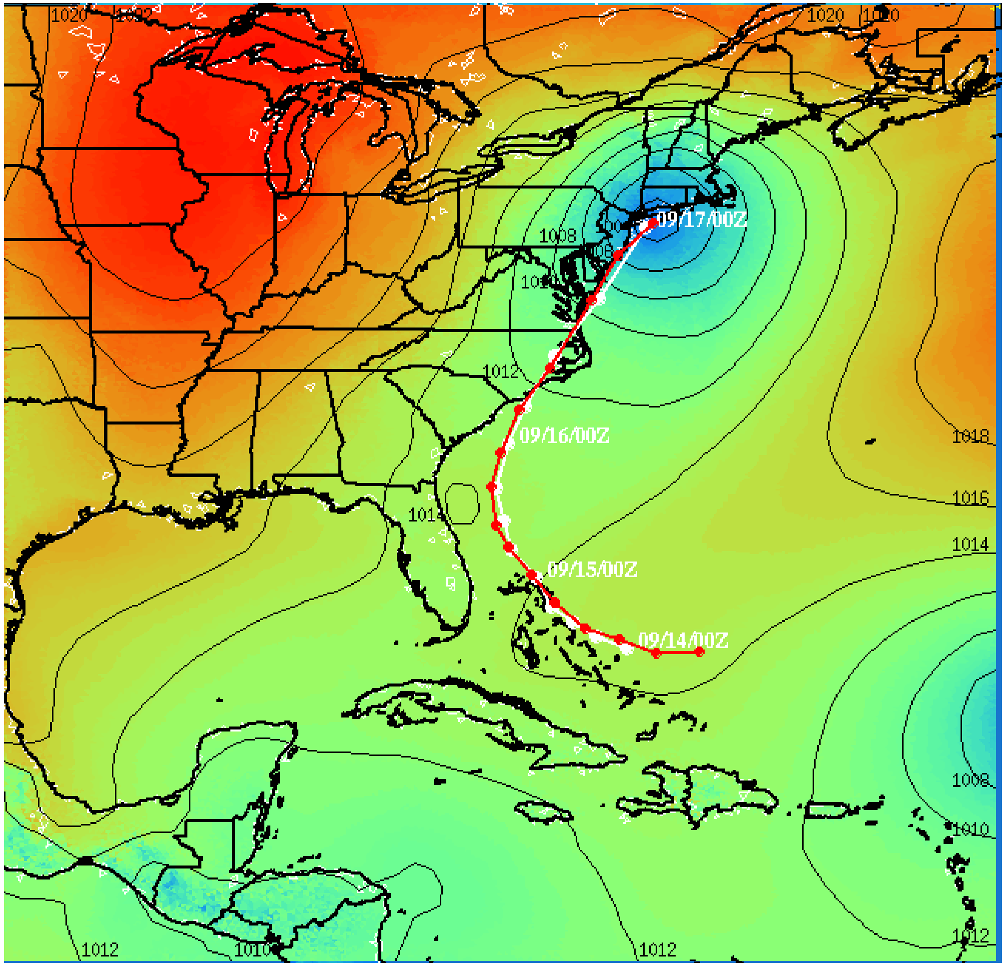


# Control Simulation



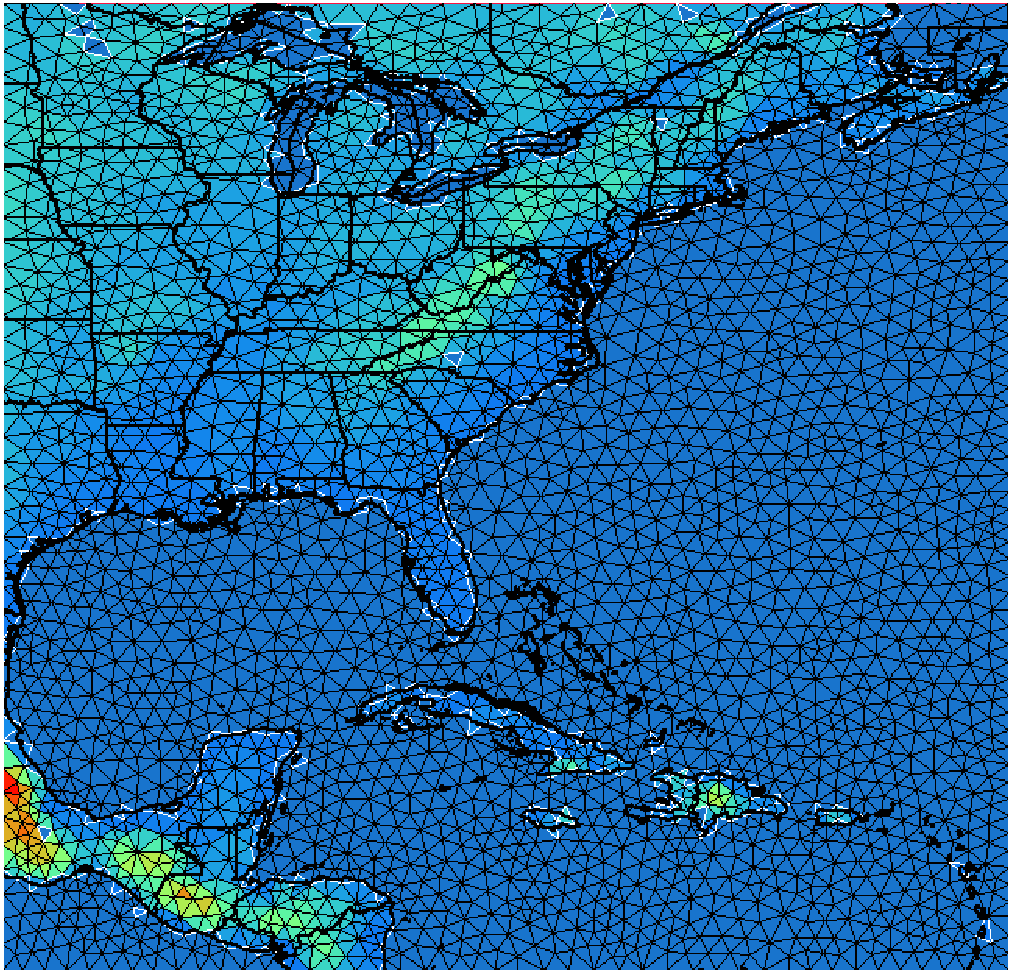
- **Initialization:**
  - **1200Z September 13**
  - **NOGAPS Analysis**
- **Boundary Conditions:**
  - **NOGAPS Forecast**
- **Grid Resolution:**
  - **5 - 15 km**

# Verification of Control Simulation



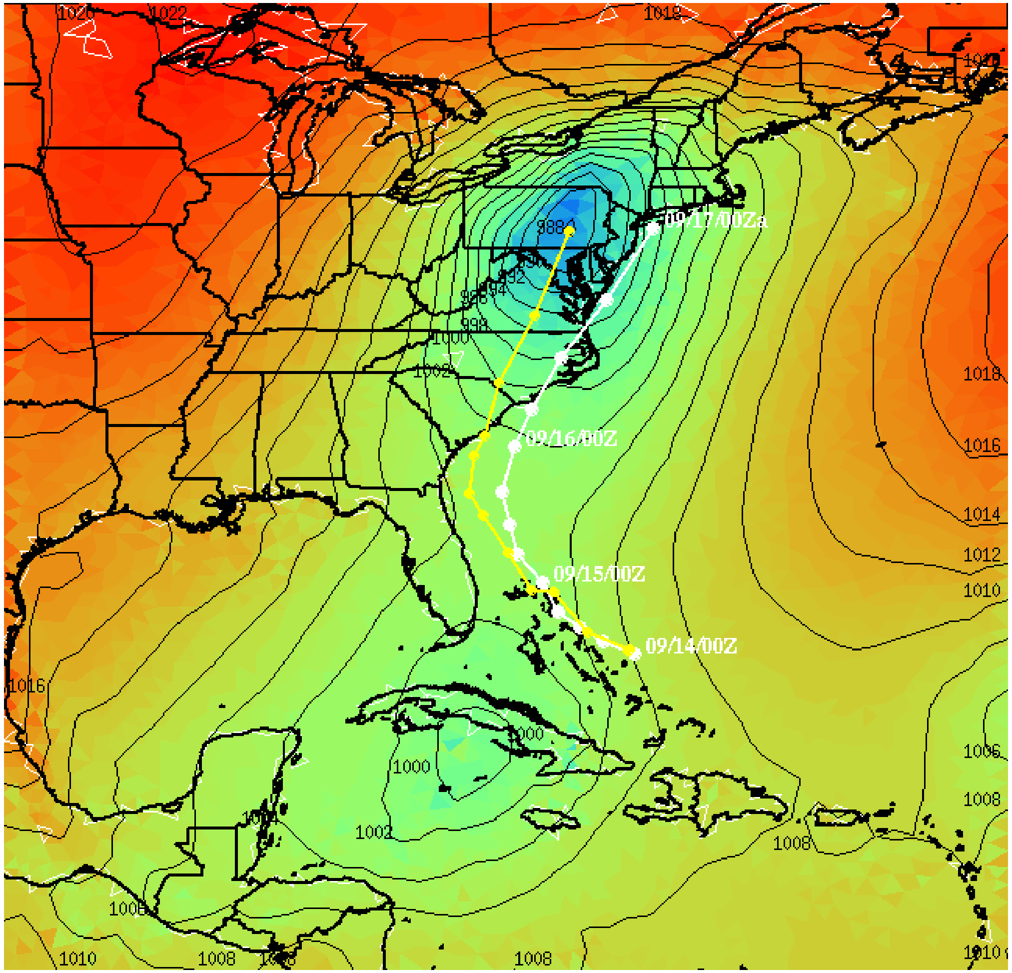

- **Storm Tracks**
  - **White: Observations**
  - **Red: Control**

# Coarse Resolution Simulation



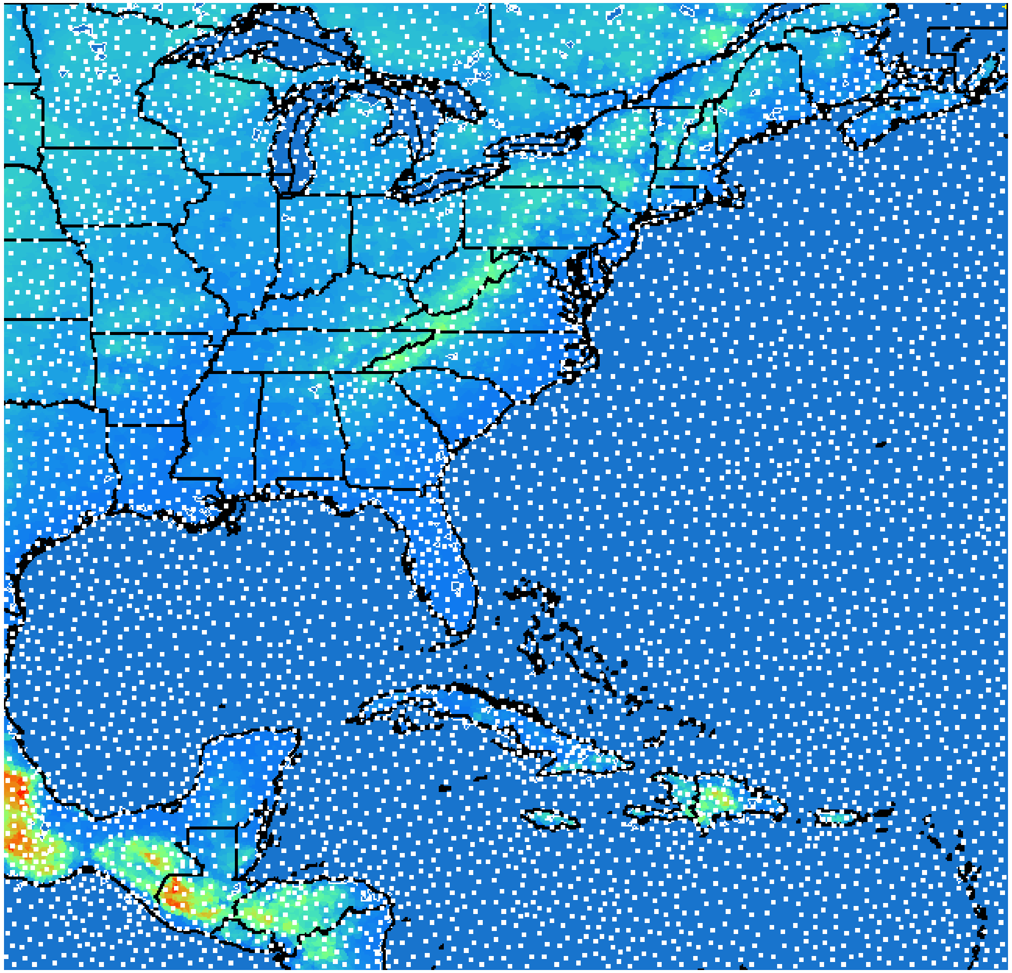
- **Initialization:**
  - **0000Z September 14**
  - **NOGAPS Analysis**
- **Boundary Conditions:**
  - **NOGAPS Forecast**
- **Grid Resolution:**
  - **75 - 120 km**

# Verification of Coarse Resolution Simulation



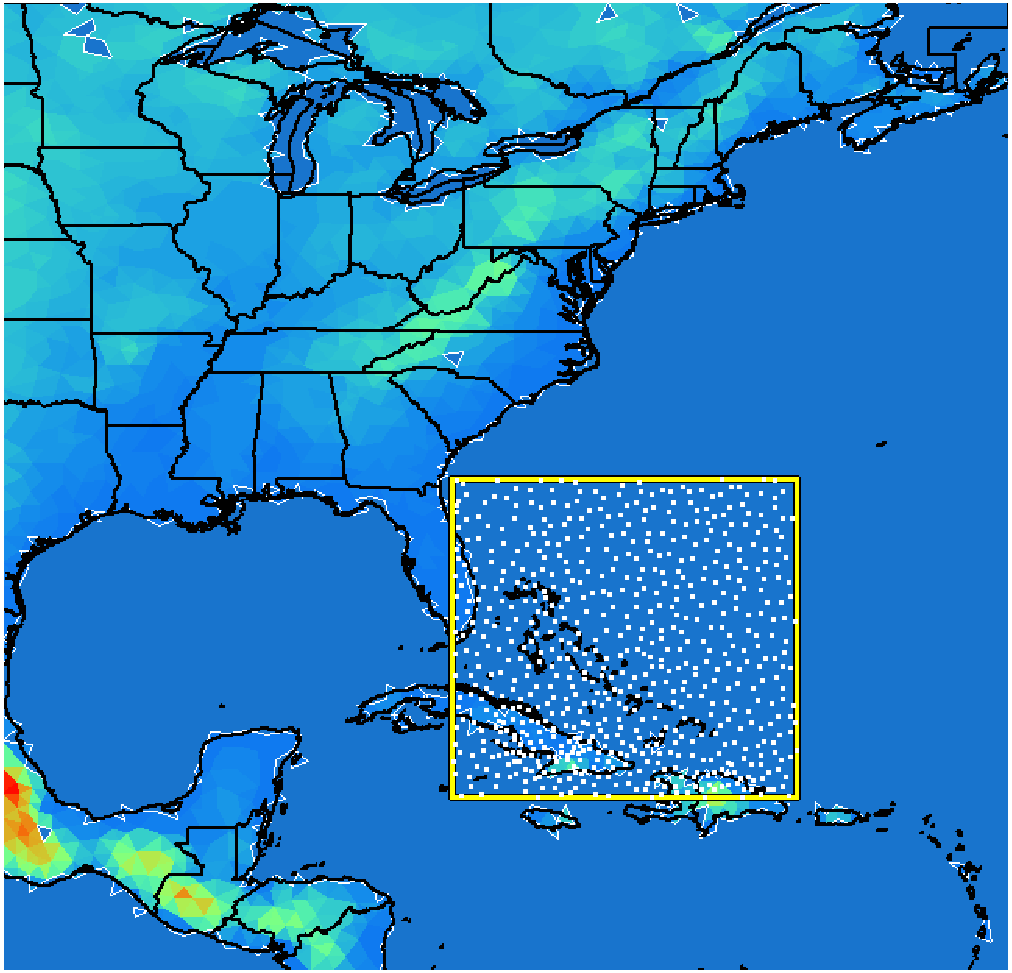

- **Storm Tracks**
  - **White: Observations**
  - **Red: Control**
  - **Yellow: Coarse Res**
- **Significant westward track deviation**

# Adaptive Observations



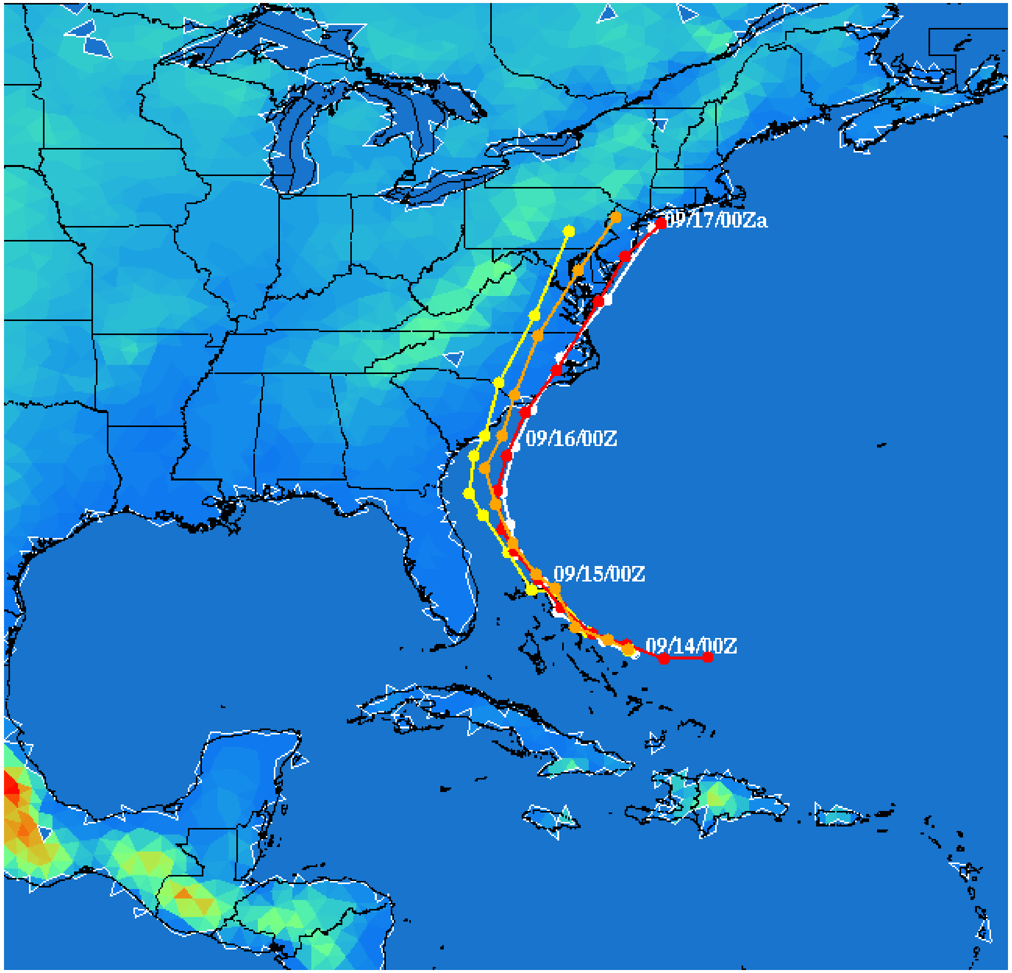
- **Control Run provides a source of *pseudo*-observations for OSSEs**
- **Control cell centroid closest to the Coarse cell centroid used to provide *pseudo*-sounding**

# Case #1:  654 Targeted Observations



- **Coarse Resolution Configuration**
- **Added 654 observations**
  - **All cell centroids in box around storm**

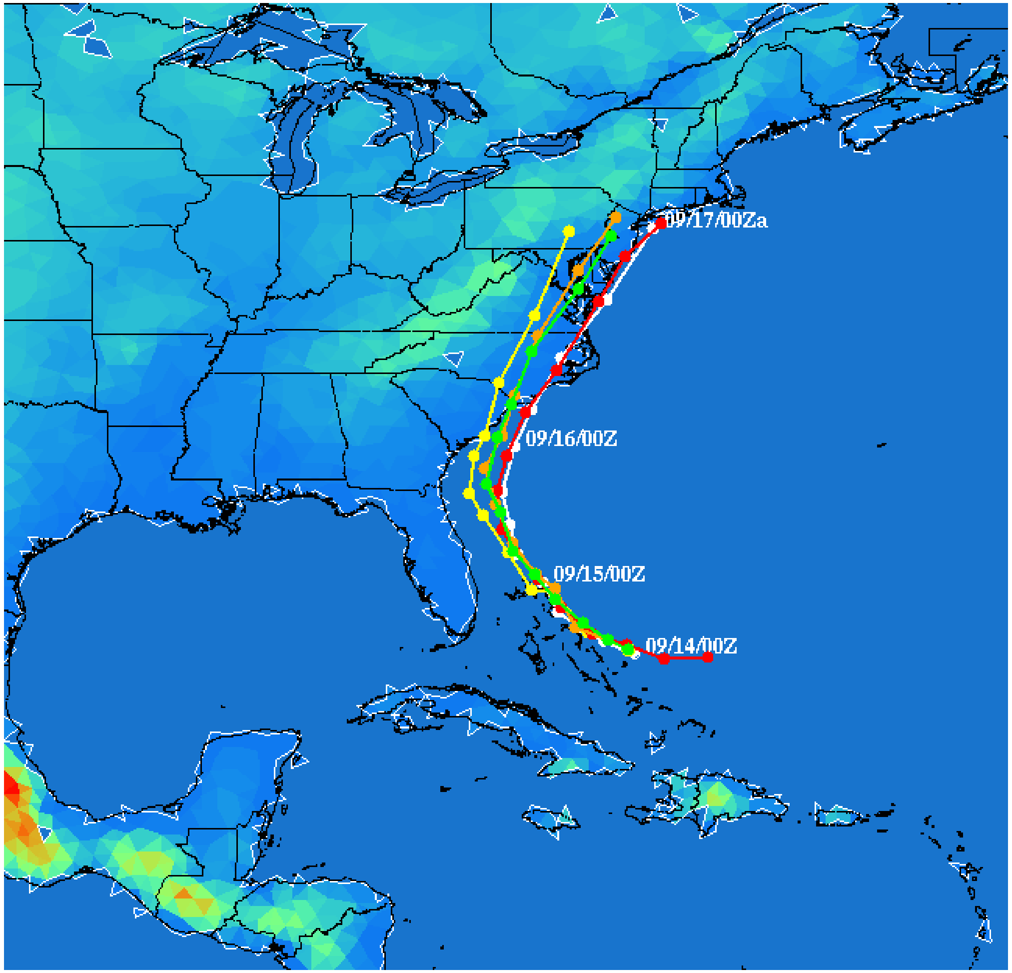
# Verification of Case #1 (654 Targeted Observations)




- **Storm Tracks**
  - **White: Observations**
  - **Red: Control**
  - **Yellow: Coarse Res**
  - **Orange: Case #1 (654)**

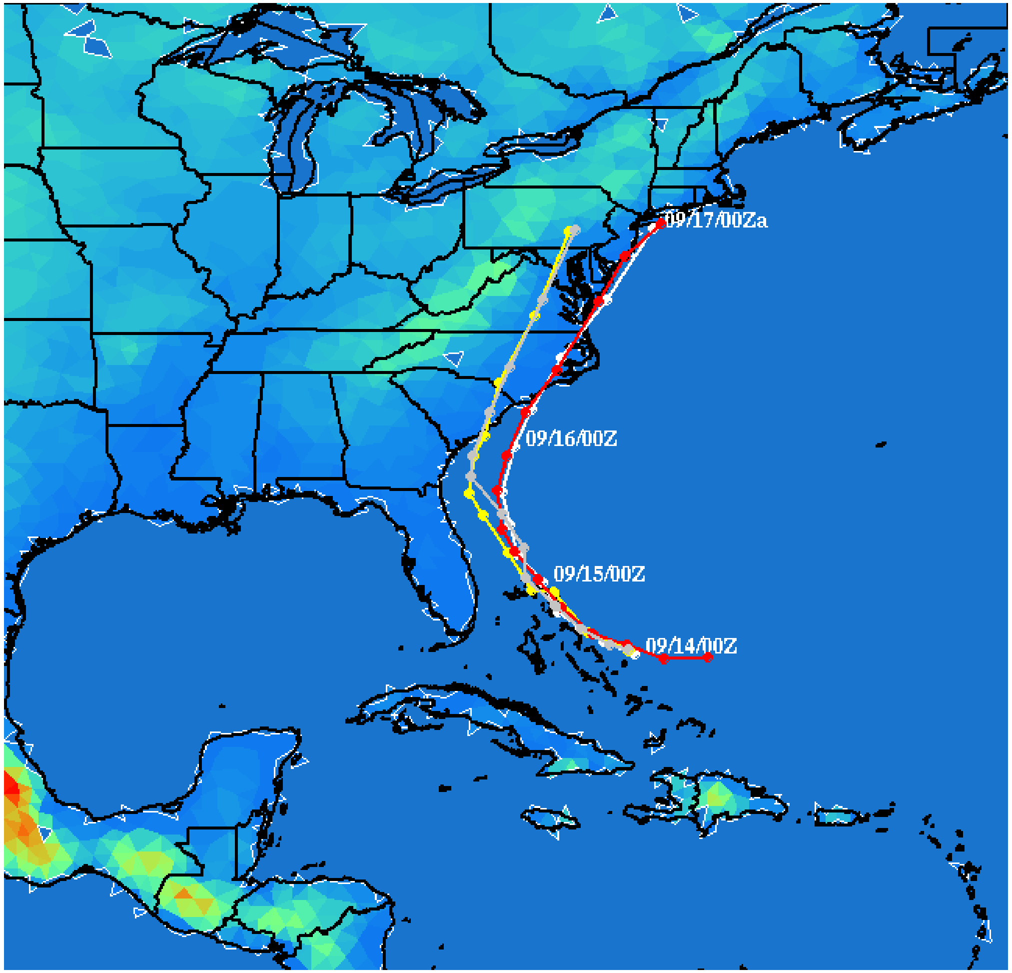
- **Noticeable improvement in forecasted track**

# Case #2: 100 Targeted Observations



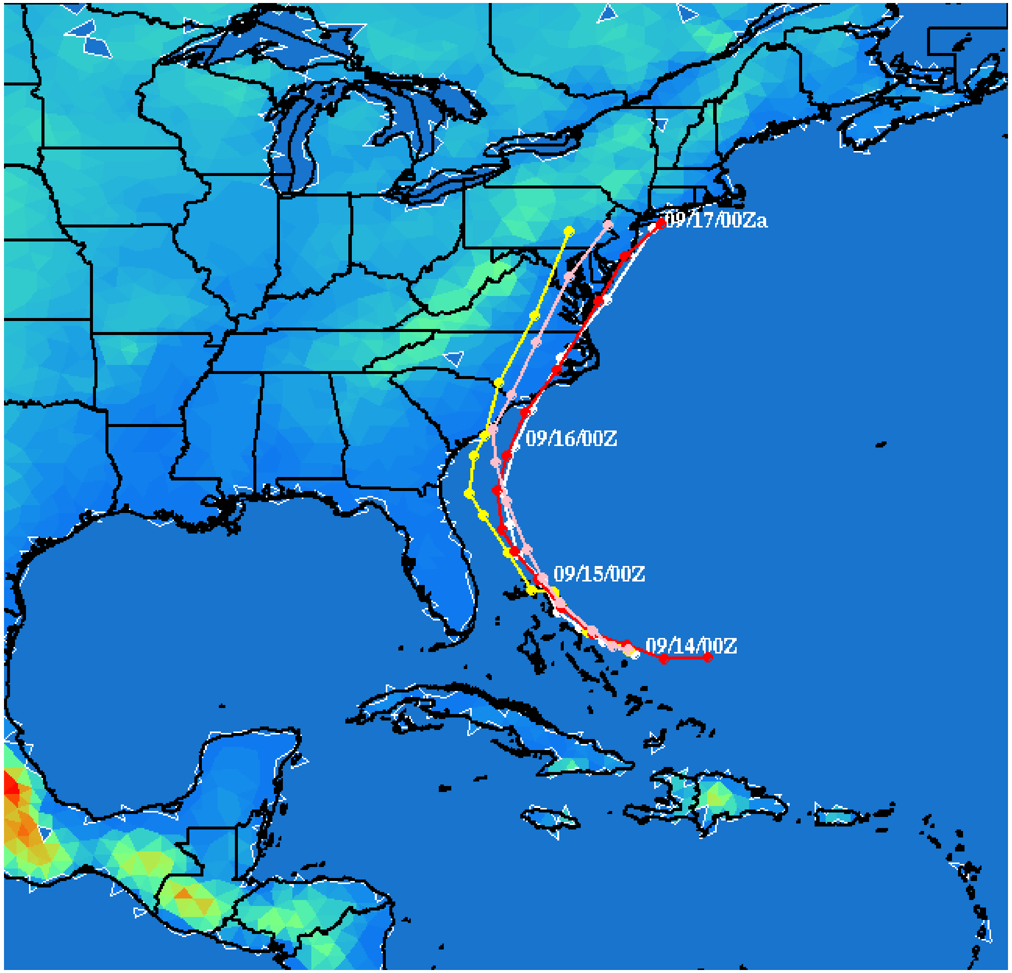

- Coarse Resolution Configuration
- Added 100 observations
  - Regular 10 x 10 array around storm
- Storm Tracks
  - White: Observations
  - Red: Control
  - Yellow: Coarse Res
  - Orange: Case #1 (654)
  - Green: Case #2 (100)
- Virtually identical track to Case #1 with only 20% of the targeted observations

# Case #3:  11 Targeted Observations




- **Coarse Resolution Configuration**
- **Added 11 observations**
  - **Around initial storm location**
- **Storm Tracks**
  - **White: Observations**
  - **Red: Control**
  - **Yellow: Coarse Res**
  - **Cyan: Case #3 (11)**
- **Very minor difference from Coarse resolution simulation**

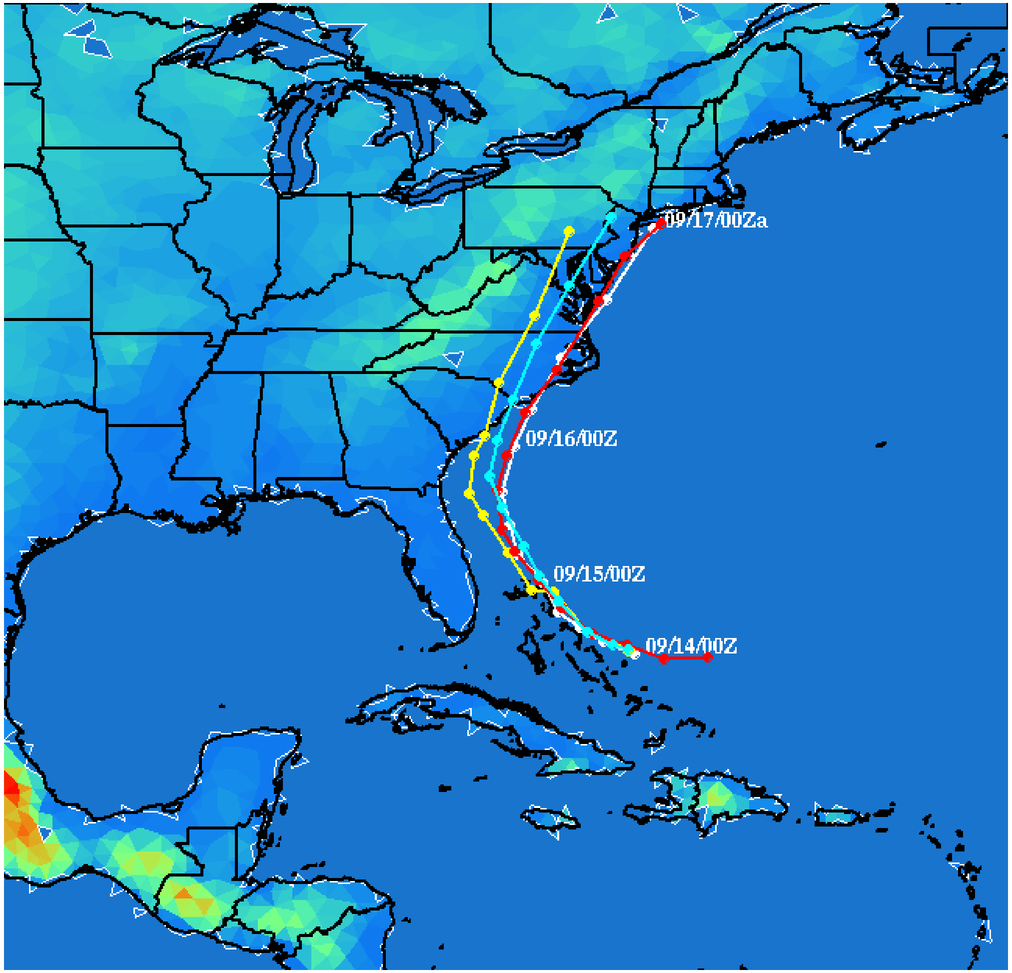
# Case #4:  50 Targeted Observations




- Coarse Resolution Configuration
- Added 50 observations
  - Along forecasted track
- Storm Tracks
  - White: Observations
  - Red: Control
  - Yellow: Coarse Res
  - Pink: Case #4 (50)

- While this case improved the forecast early on, it did not improve the track at later times as much as Case #1 or Case #2

# Case #5:  25 Targeted Observations




- Coarse Resolution Configuration
- Added 50 observations
  - Along forecasted track
- Storm Tracks
  - White: Observations
  - Red: Control
  - Yellow: Coarse Res
  - Cyan: Case #5 (25)
- Track nearly identical to Case #4.

# Conclusions and Ramifications

- Targeted observations can have a dramatic impact on storm forecasts
  - Improvement in initial storm conditions has the largest payoff
  - Other scenarios may have different requirements
- Greatest improvement will come in identifying and obtaining key observations for *developing* convective storms
  - The critical scales are so small and hence the volume of regular arrays of observations is so large that either the communications become a dominant problem *or* the extraction of a "signal" from the "noise" of data bits prevents utilization
- The routine utilization of targeted as opposed to general satellite observations has significant impact on satellite operations
  - Timeliness is key $\Rightarrow$ Communication & data mining issues
- A tightly linked forecast and observational system can address these issues as well