Assimilation of satellite data in regional NWP - progress and challenges

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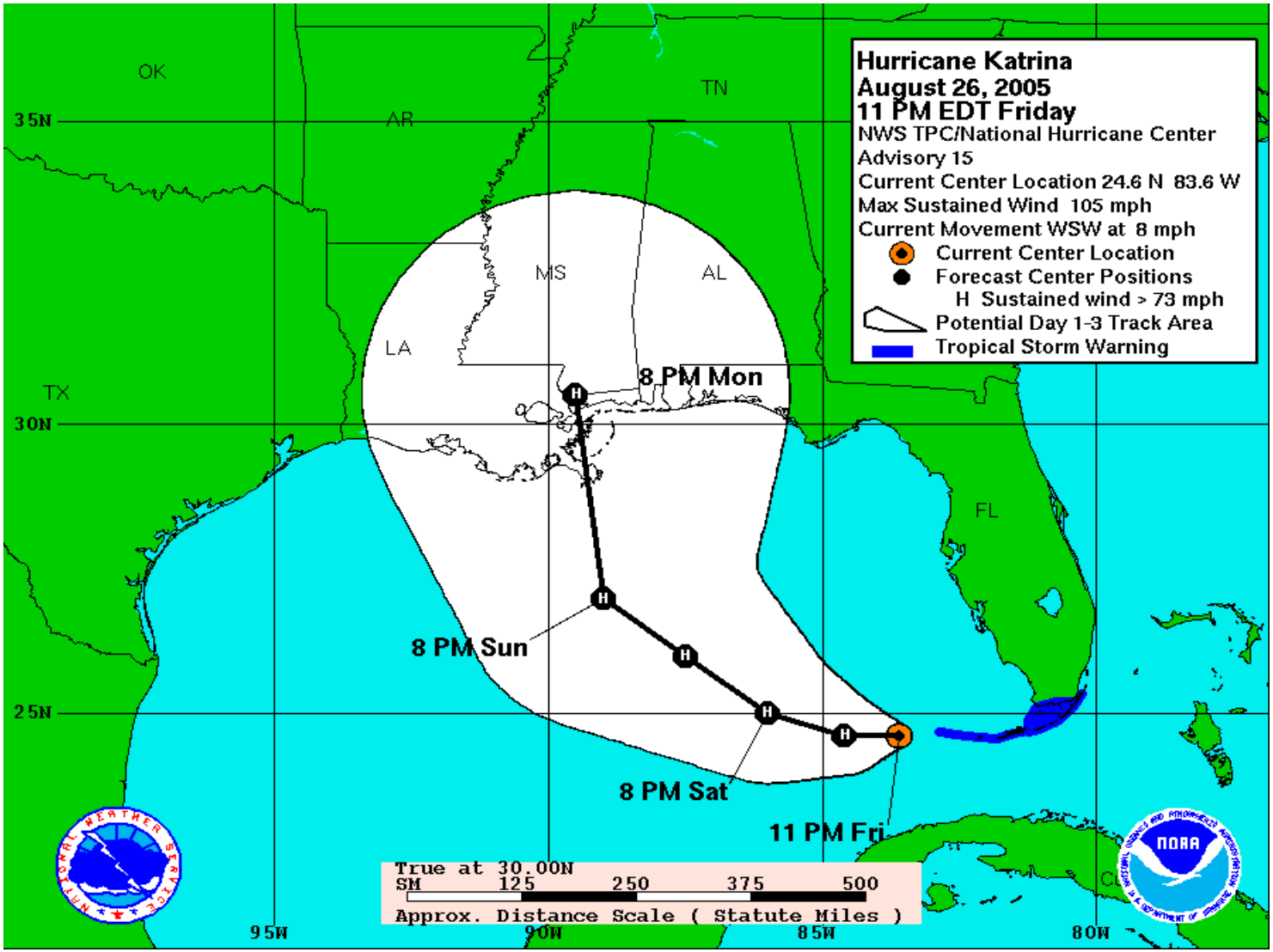
Outline

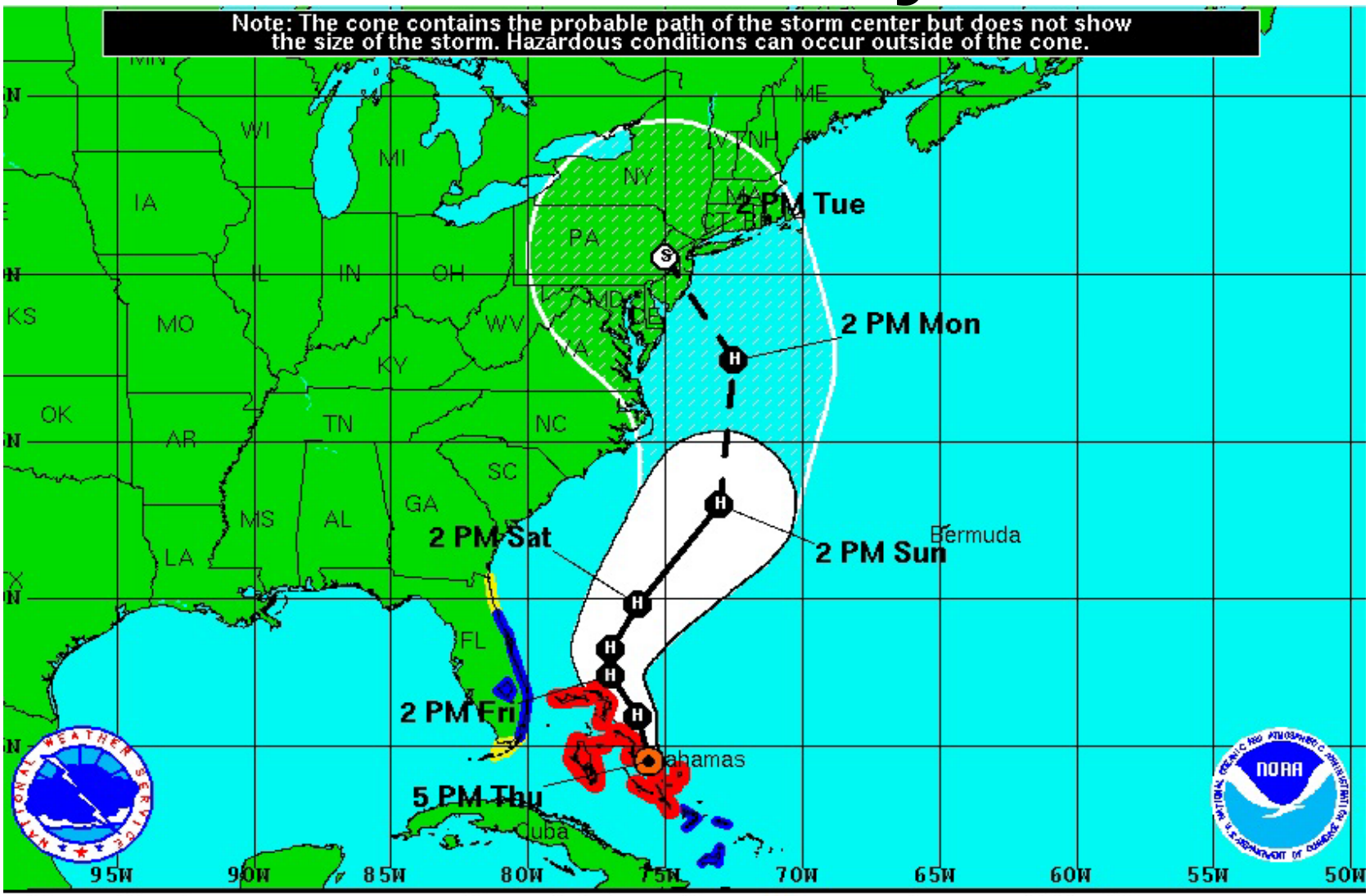
- **How far have we progressed in predicting hurricanes? Why satellite data?**
- **Challenges on regional NWP use of satellite data**
- **Requirements on data and computer for regional NWP applications**
- **Research and demonstration needed for improving utilization of satellite data in regional NWP**

Hurricane Katrina 2005



Warning lead time for actual landfall location, ~72 hours

Hurricane Sandy 2012



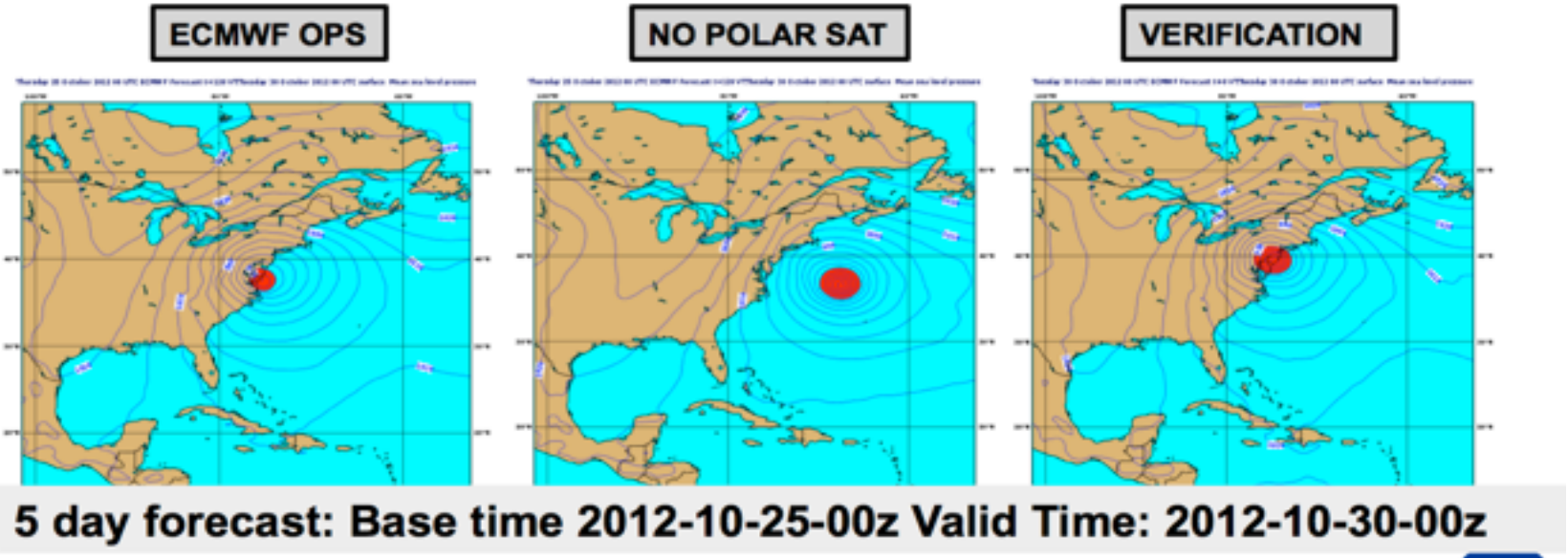
Lead time for accurate landfall location, ~120 hours!!

Why the tremendous improvement in 20 years?

One big reason: Better Assimilation of Satellite Data

Forecast skill without polar satellites ?

Forecasts of Mean Sea Level Pressure, 5 days in advance of the 30th October 2012 for the landfall of Hurricane Sandy. Forecasts from an assimilation system with no polar satellites fails to predict the correct landfall of the storm that caused widespread damage and loss of life to the US east coast.



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Challenges on assimilating satellite data in regional NWP

- Higher resolution of NWP needs high resolution data;
- Requirement on computer resource for assimilating high temporal and spatial resolution observations;
- Inconsistency between NWP model states and observations in rapid weather changing situations;
- Contemporary assimilation strategies/schemes in global NWP might not applicable for regional applications;
- Background error covariance matrix is difficult to be estimated due to large spatial and temporal variation in regional NWP, bias correction is also more difficult;
- Data latency is difficult to meet for real time applications.

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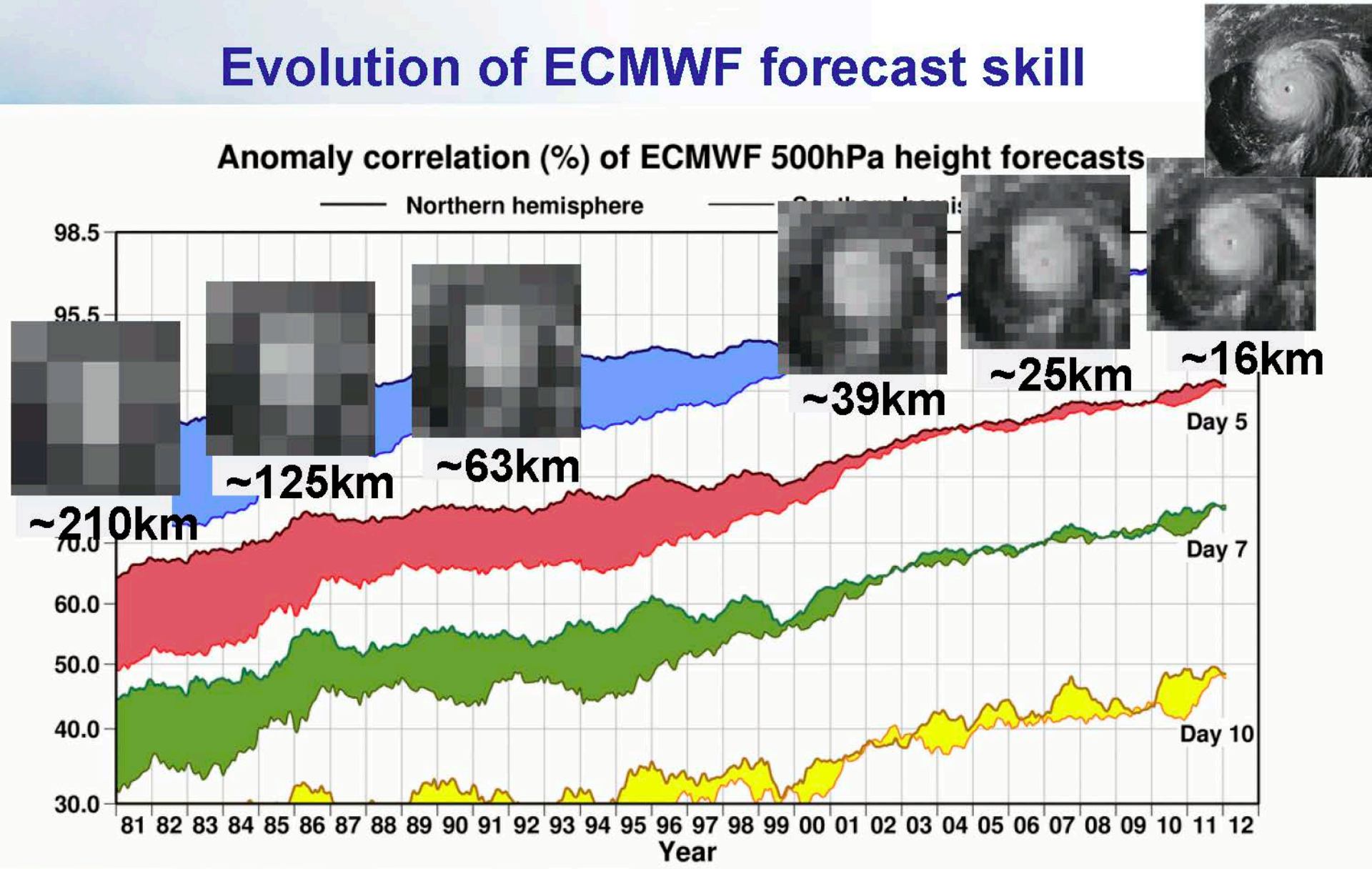
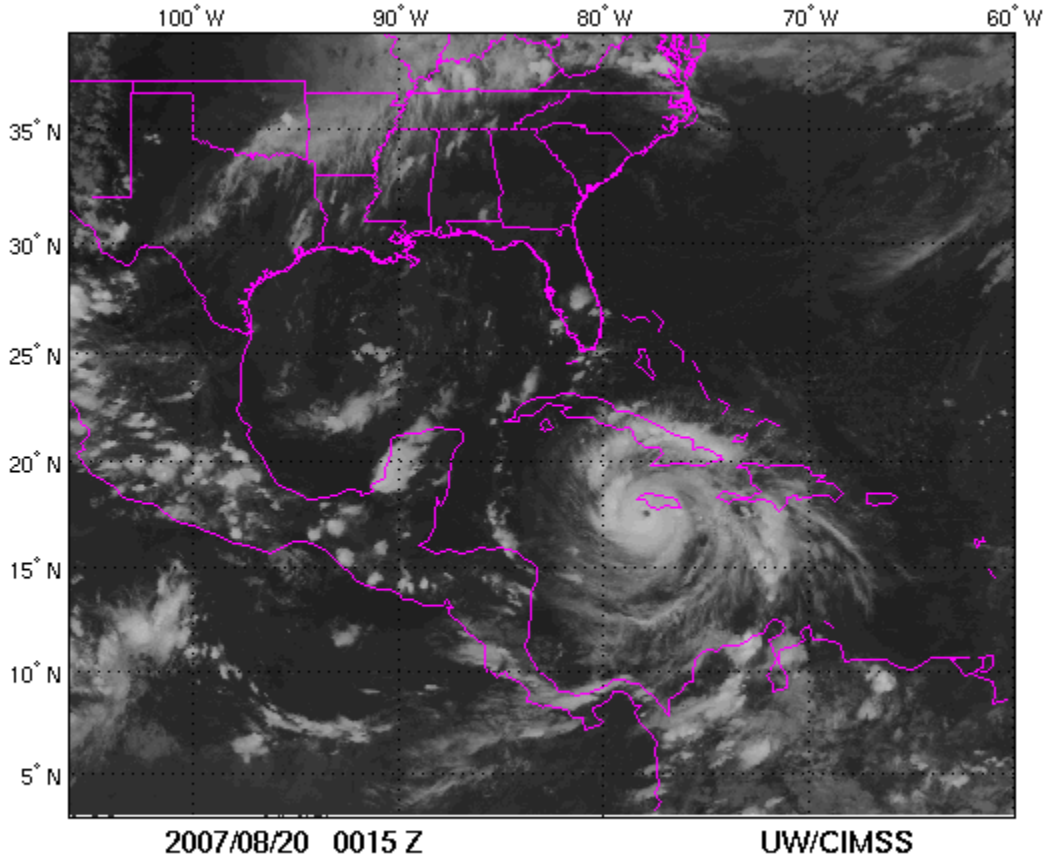
Evolution of ECMWF forecast skill



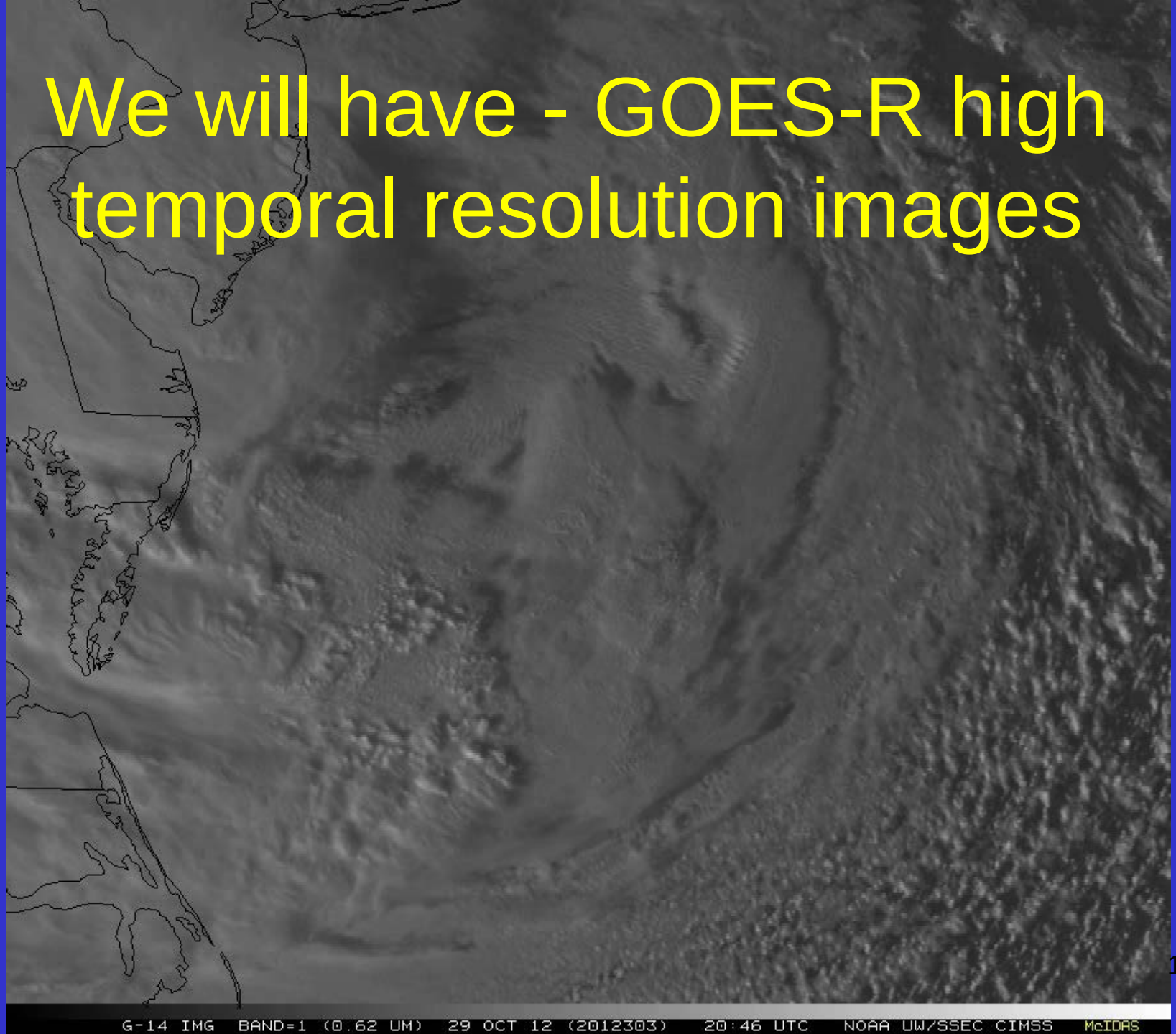
Why GEO advanced sounding measurements in regional NWP?

- The data have good temporal coverage to assure the data availability within each assimilation window;
- The assimilation window can be narrowed (i.e., ±0.5 hour) in order to keep consistency between NWP model's atmospheric states and the observations in a rapid changing weather situation;
- More frequent assimilation of data (i.e., 3 hourly even hourly instead of 6 hourly) is possible.

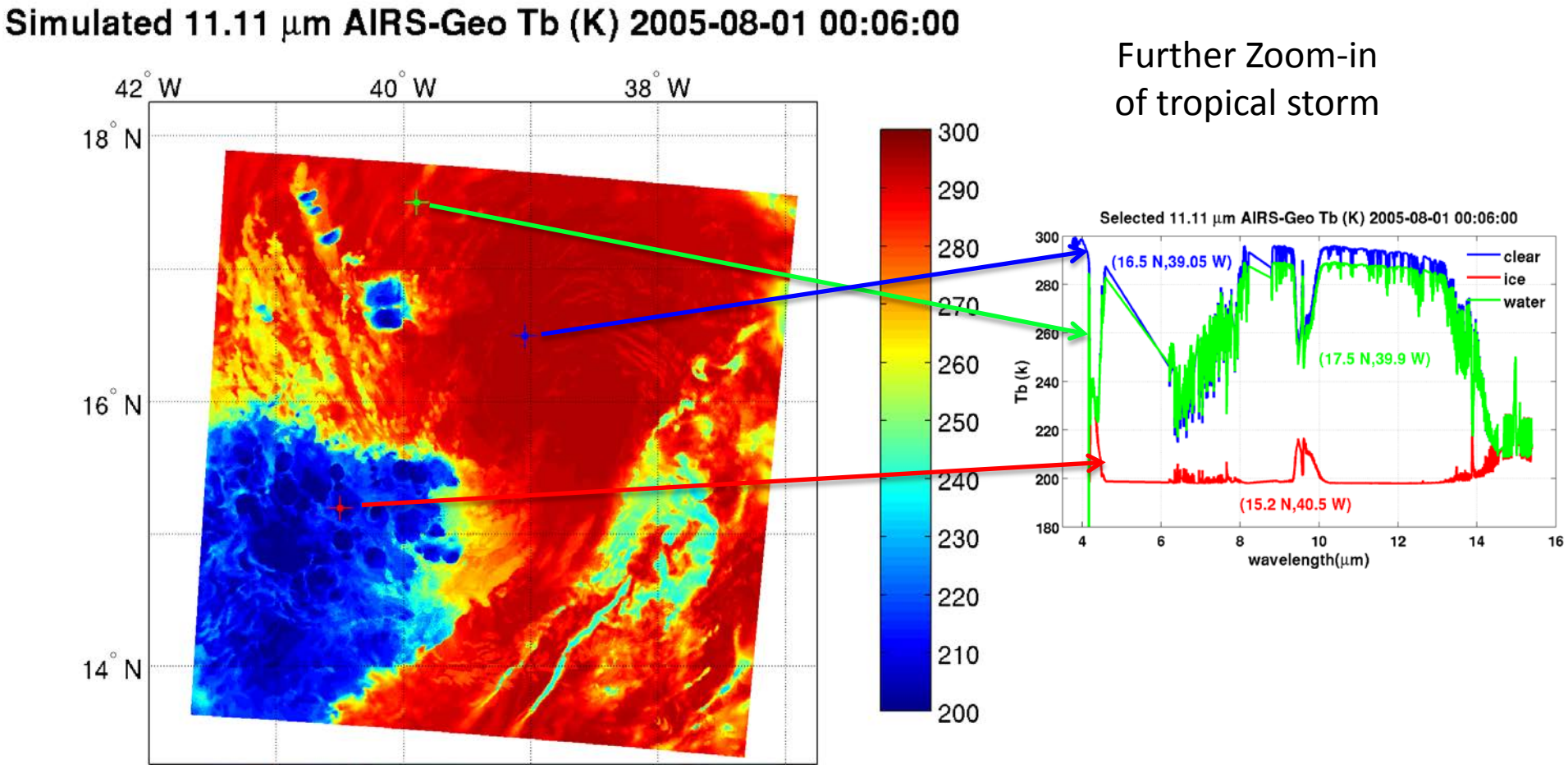


Half-hourly GEO observations (B/W) along with observations (color) from one polar orbit satellite

We will have - GOES-R high temporal resolution images



But we miss - GEO sounding capability



Further Zoom-in of tropical storm

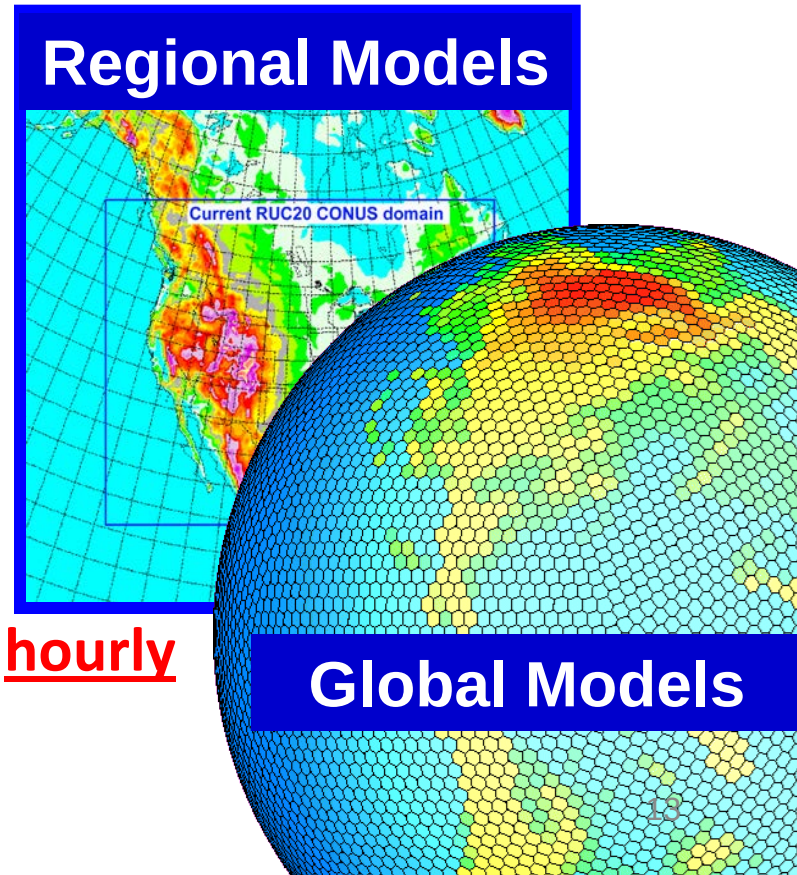
Very fine scale features, such as Individual convective cells are well identified!

Resolution = 1 km

Every 6 minutes

Future NWP Computing Requirements

- Improvements in forecast skill are dependent on super-computing resources
- 100,000 to 200,000 CPU cores required for:
  - **Global cloud resolving**
    - NIM **@2KM** resolution, **2x/day**
  - **Regional Models**
    - North American (NA) Domain
    - HRRR **@<1KM**, **hourly**
  - **Ensembles**
    - HRRR **@3KM** NA, 100 members, **hourly**



ECMWF Model is evolved to an urgent need of Spatially & Temporally coupled 4-D data that only Next Generation of satellite sensors can provide

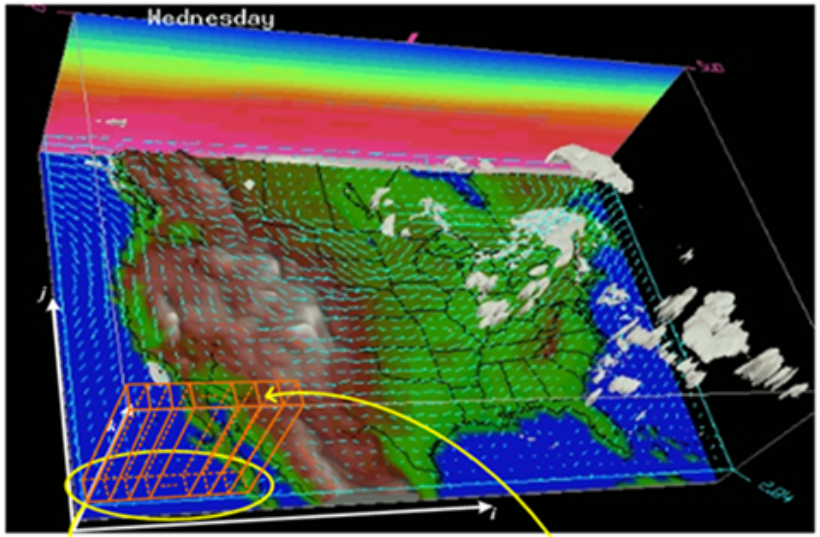
ECMWF is planning to improve model resolution from

- From 16 km to 10 km and to ~5 km in 10 years (~2020) and
- To 2.5 km in 15 years (~2025)

- In addition the temporal resolution (time step) are to be increased accordingly:
  - T1279 H (2012) - 16 km; 600 seconds
  - T2027 H (2015) - 10 km; 450 seconds
  - T3999 NH (2020) - 5 km; 240 Seconds
  - T7999 NH (2025) - 2.5 km; 30-130 Seconds

SSEC Developed GPU-Based WRF model (Huang et al.)

High-Performance GPU NWP Model Infrastructure >100 Speedup



WRF Module name	Speedup
Single moment 6-class microphysics	500x
Eta microphysics	272x
Purdue Lin microphysics	692x
Stony-Brook University 5-class microphysics	896x
Betts-Miller-Janjic convection	105x
Kessler microphysics	816x
New Goddard shortwave radiance	134x
Single moment 3-class microphysics	331x
New Thompson microphysics	153x
Double moment 6-class microphysics	206x
Dudhia shortwave radiance	409x
Goddard microphysics	1311x
Double moment 5-class microphysics	206x
Total Energy Mass Flux surface layer	214x
Mellor-Yamada Nakanishi Niino surface layer	113x
Single moment 5-class microphysics	350x
Pleim-Xiu surface layer	665x

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What are the necessary conditions for a good TC forecast?

- A high resolution numerical weather prediction (NWP) model;
- Realistic microphysics and cloud schemes;
- Powerful computer system;
- Inclusion of coupled ocean model;
- Temporally/spatially coupled observations;
- Data assimilation methodology and schemes that fit the model dynamics and physics;
- Efficient and accurate operator (radiative transfer model and linear model);
- Advanced data analysis and visualization tool;
- Good team work and coordination;
- Dedicated research, followed by demonstration are needed for operation improvement (contemporary global data assimilation strategies/schemes do not necessary fit the regional NWP applications).

Hurricane Sandy (2012) - 72 hour track forecasts on path

(Forecasts start from 12 UTC 25 Oct, valid 18 UTC 30 Oct 2012)