Emerging Aviation Weather Research at MIT Lincoln Laboratory*

Haig Iskenderian

19 November 2015

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

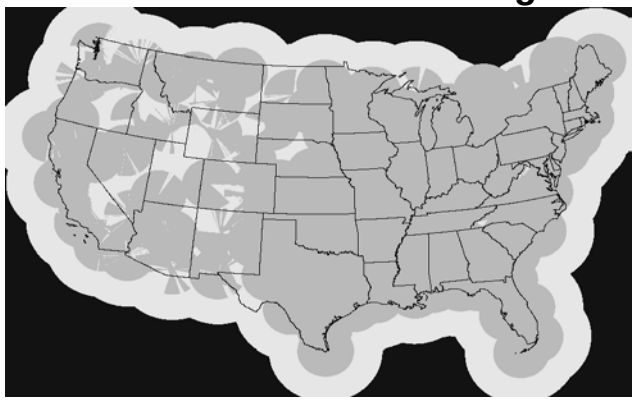
*This work was sponsored by the Federal Aviation Administration under Air Force Contract No. FA8721-05-C-0002. Opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the United States Government.

Outline

- **Offshore Precipitation Capability**
- **Convective Weather Avoidance Polygons**
- **Forecast Confidence**

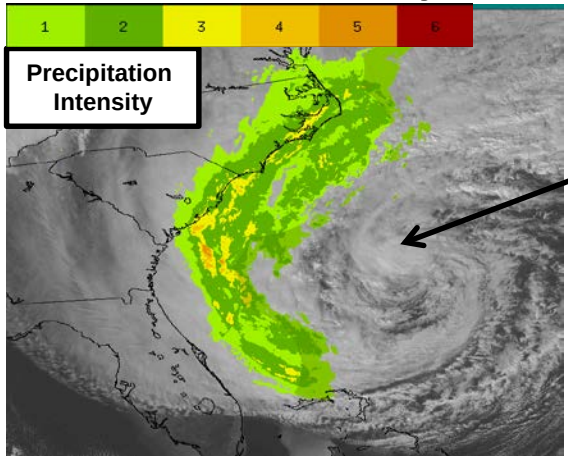
Aviation Weather Information Shortfall:
Limited Offshore Observations and Forecasts

NEXRAD Radar Coverage



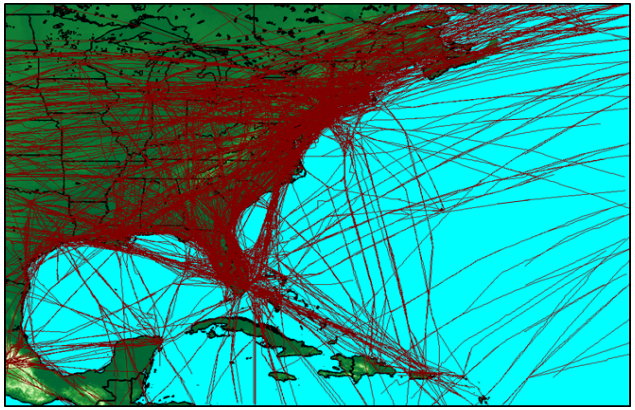
Good Coverage | Degraded Coverage | No Coverage

Current Radar Analysis

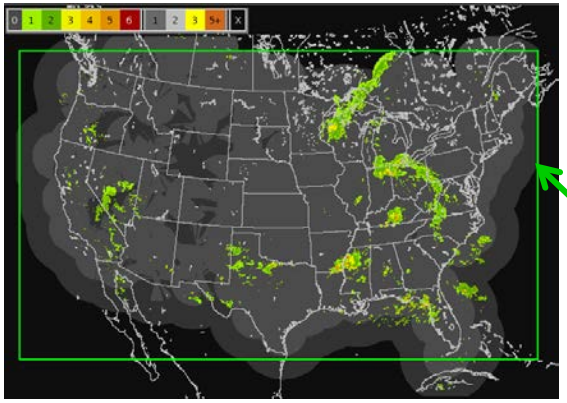


No Weather Radar

Sample Flight Tracks



Current Forecast Domain

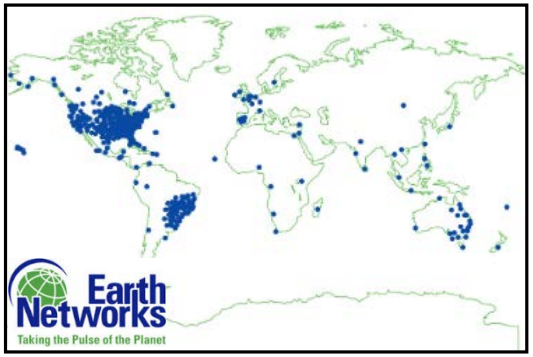


Current Forecast Domain

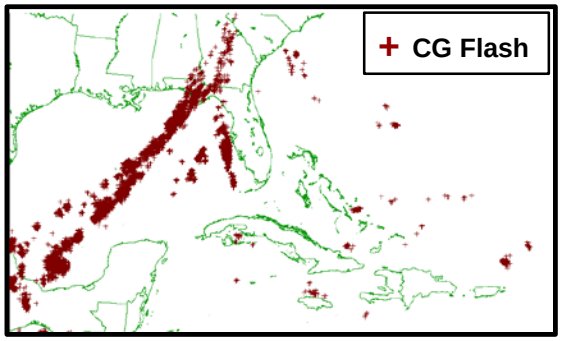
The Offshore Precipitation Capability (OPC) is being developed to provide operational radar-like view of weather beyond radar coverage

OPC Input Data

Lightning



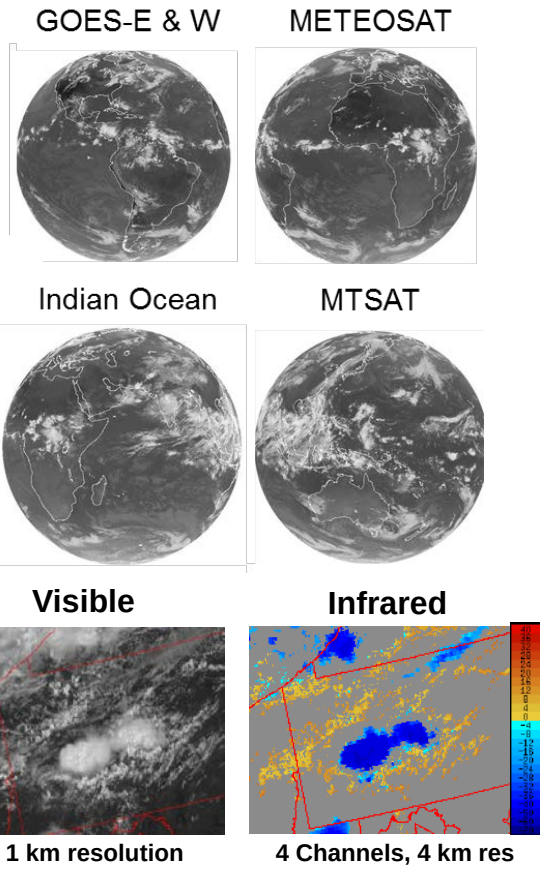
Earth Networks Total Lightning Network Sensor Locations



Lightning Flashes, Oct 14th, 2014

Update rate: Every second

Geostationary Satellite



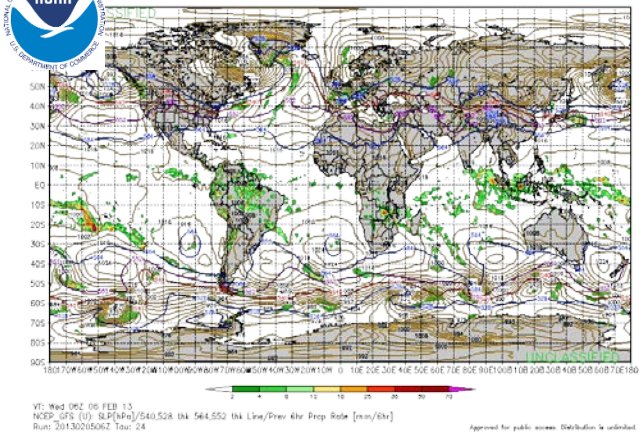
1 km resolution

4 Channels, 4 km res

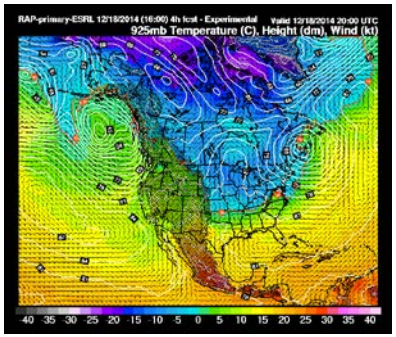
Update rate: ~10 – 30 minutes

Numerical Weather Prediction Models

GFS Forecast



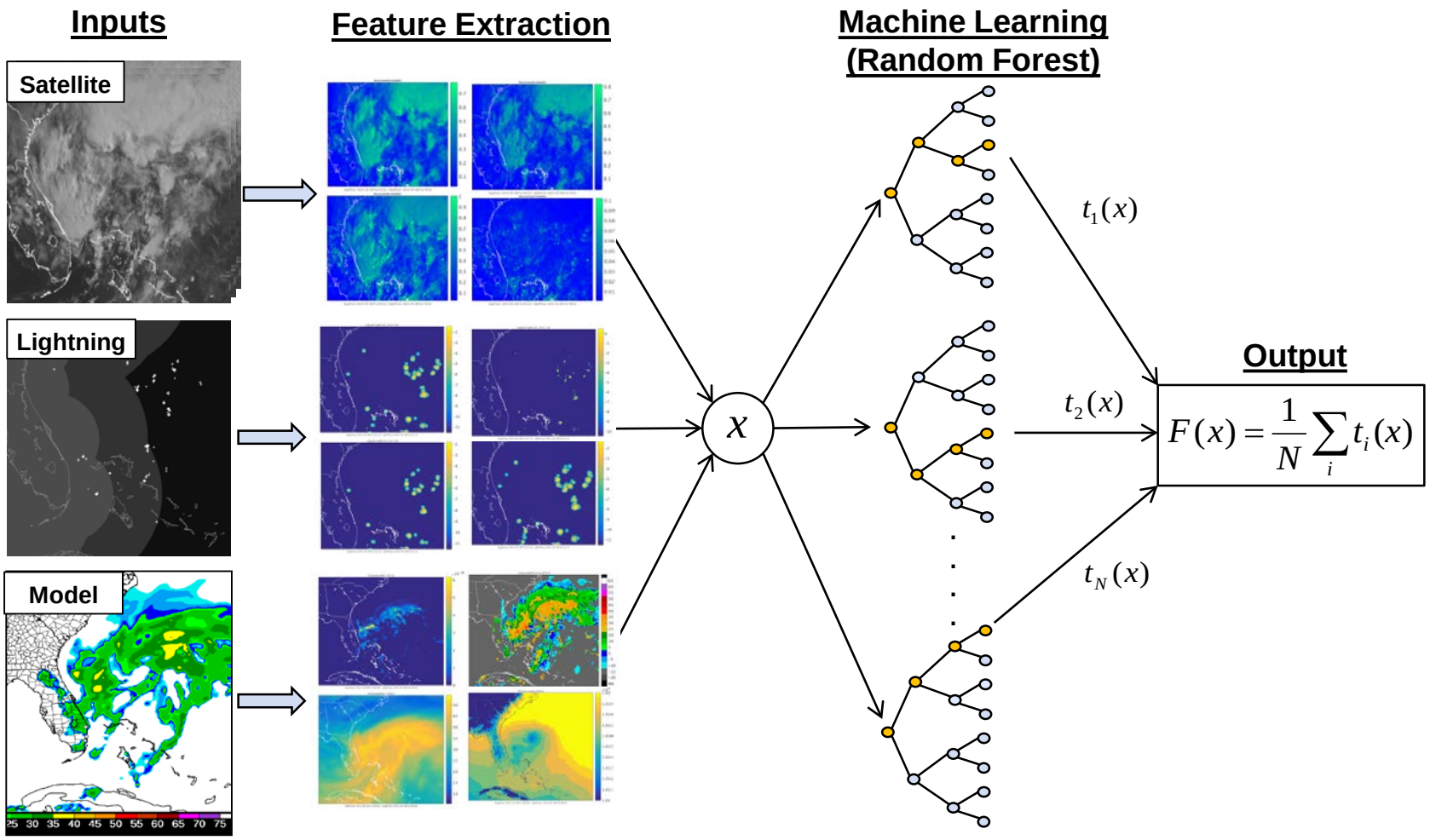
RAP Model



Temperature, Pressure, & Winds

Update rate: Forecasts issued hourly

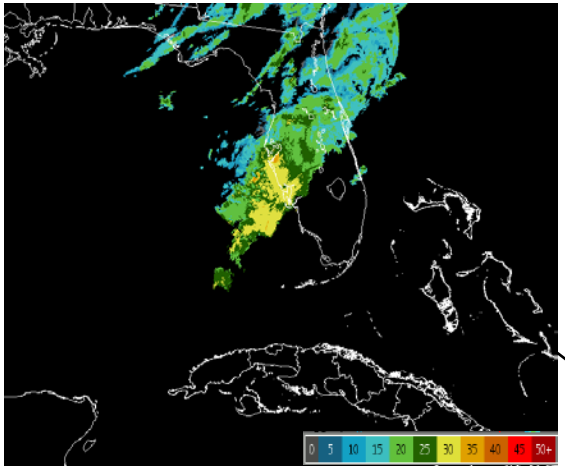
OPC Processing



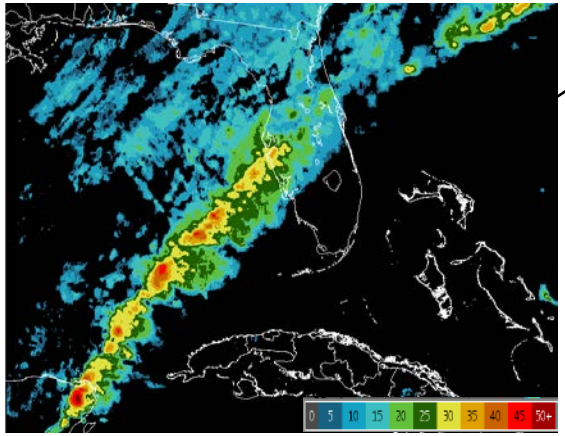
Multiple, heterogeneous inputs are flexibly accommodated and optimally combined

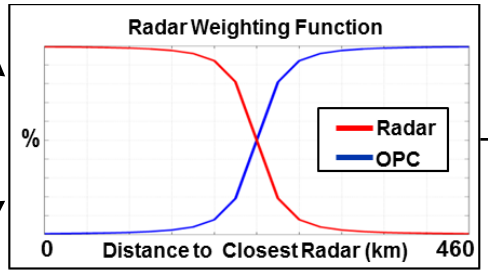
Merging OPC and Radar

Radar

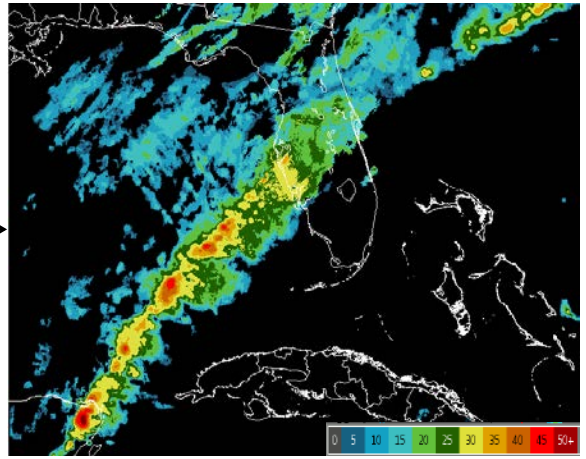


Machine Learning



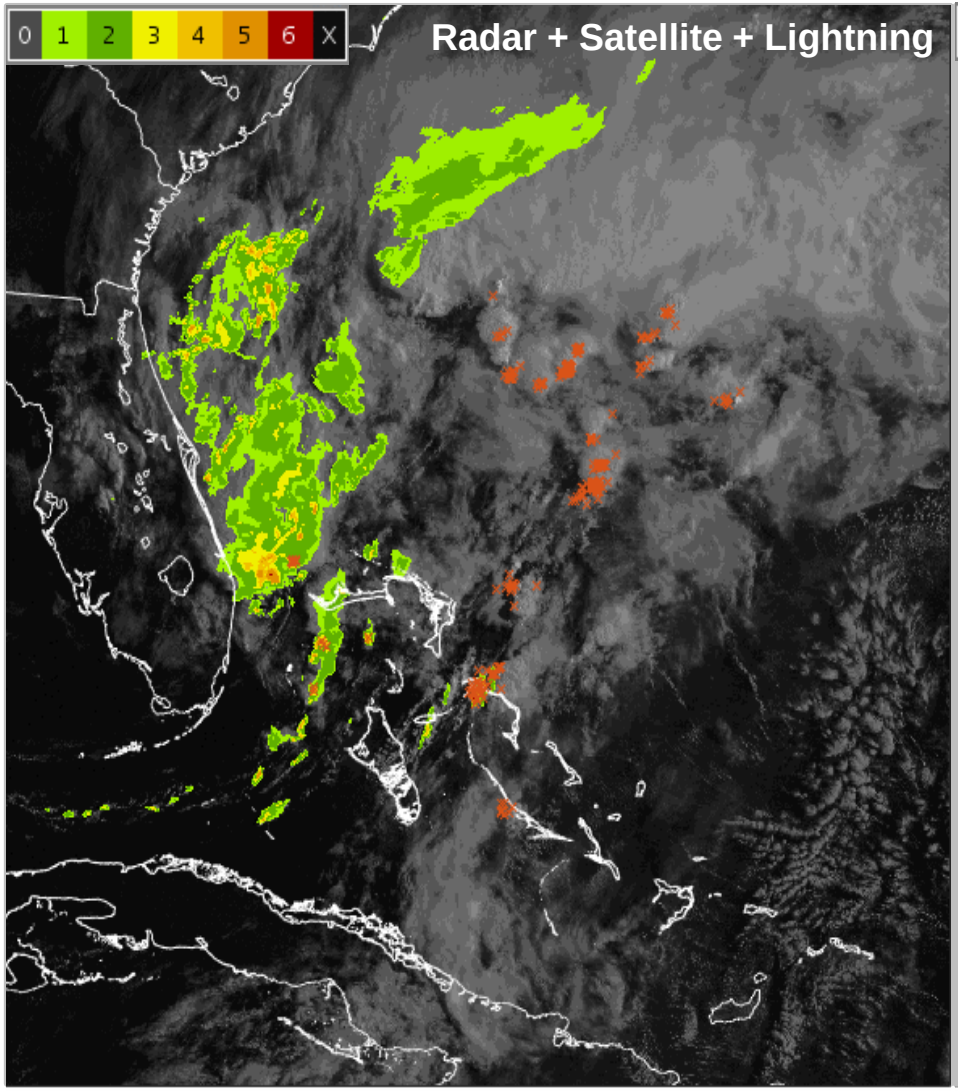


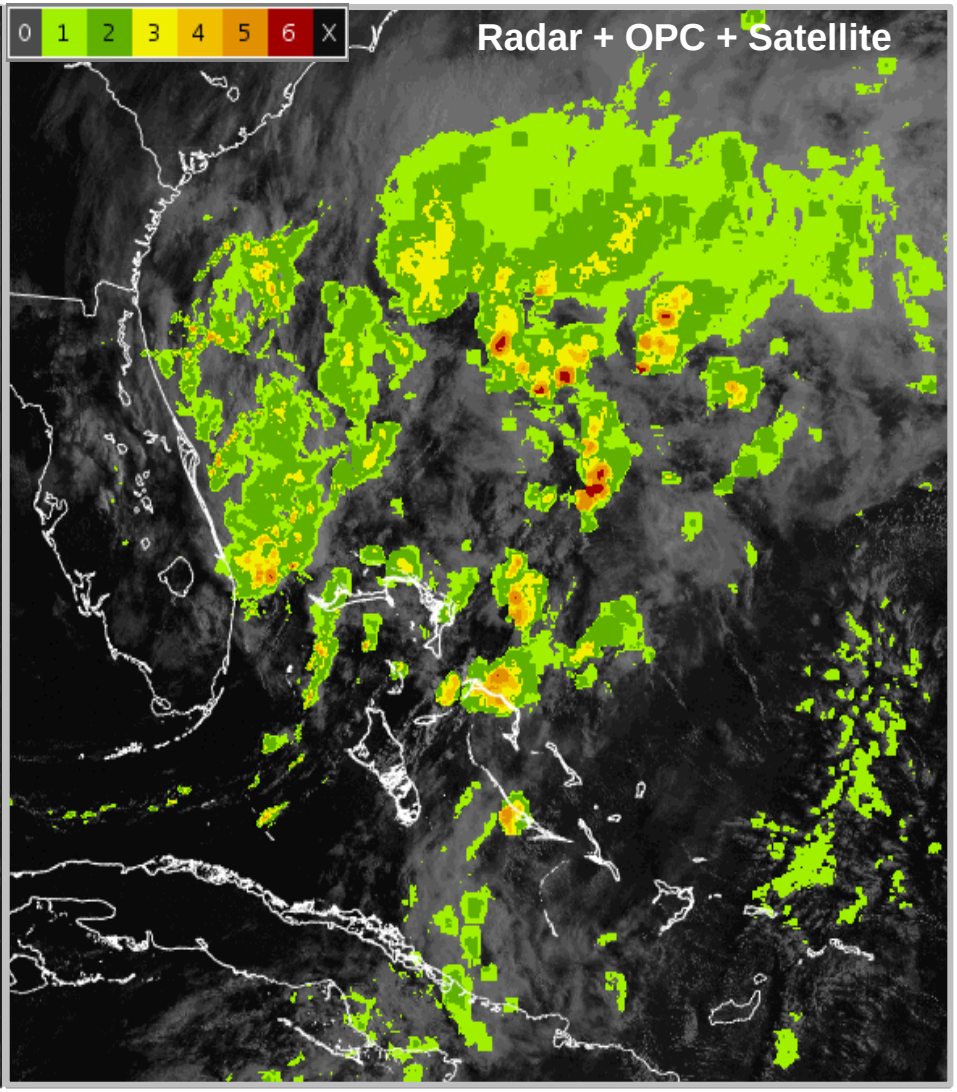
Merged Radar + OPC



OPC is used to fill areas without weather radar coverage

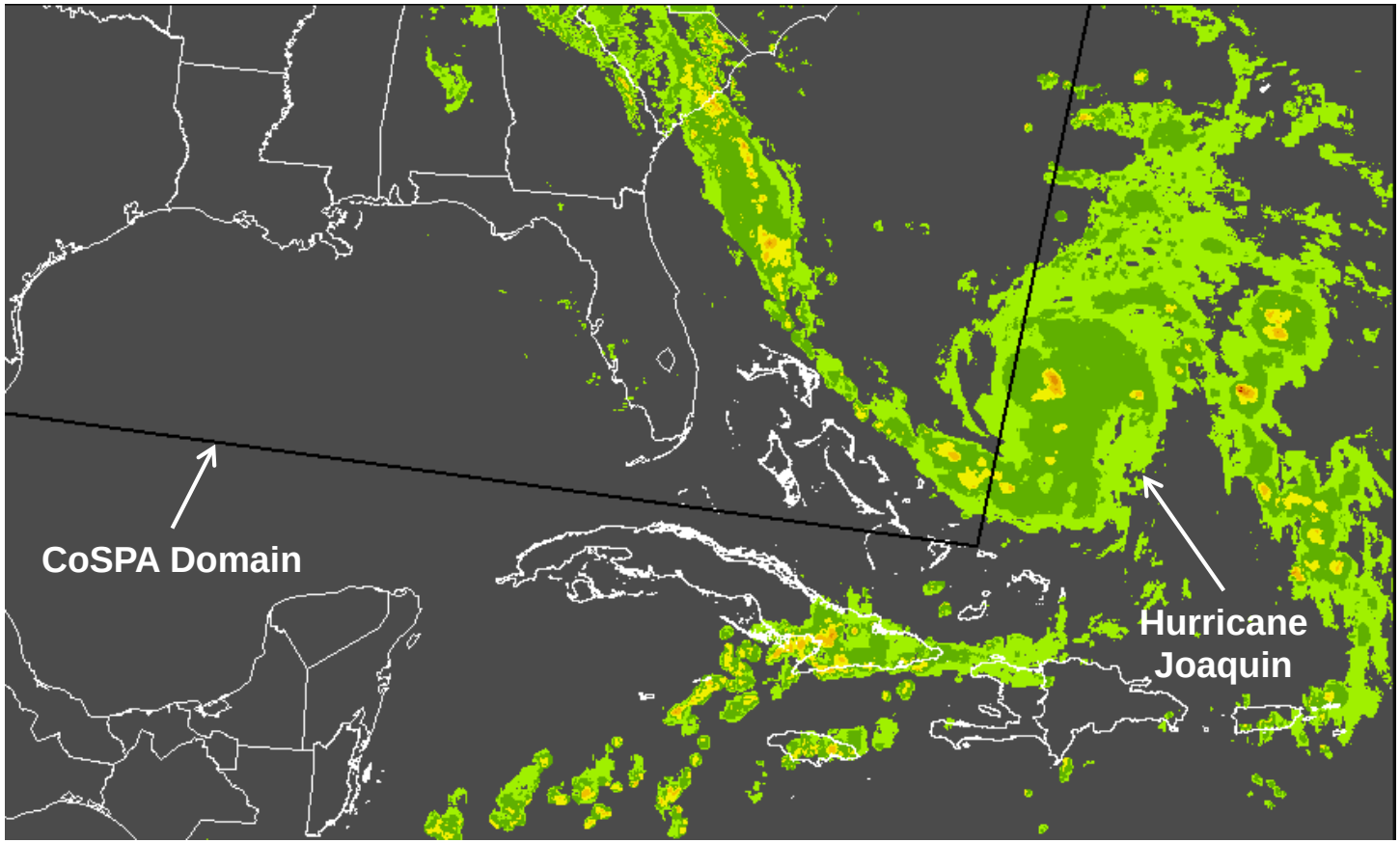
OPC Mosaics and Lightning





Offshore Forecast

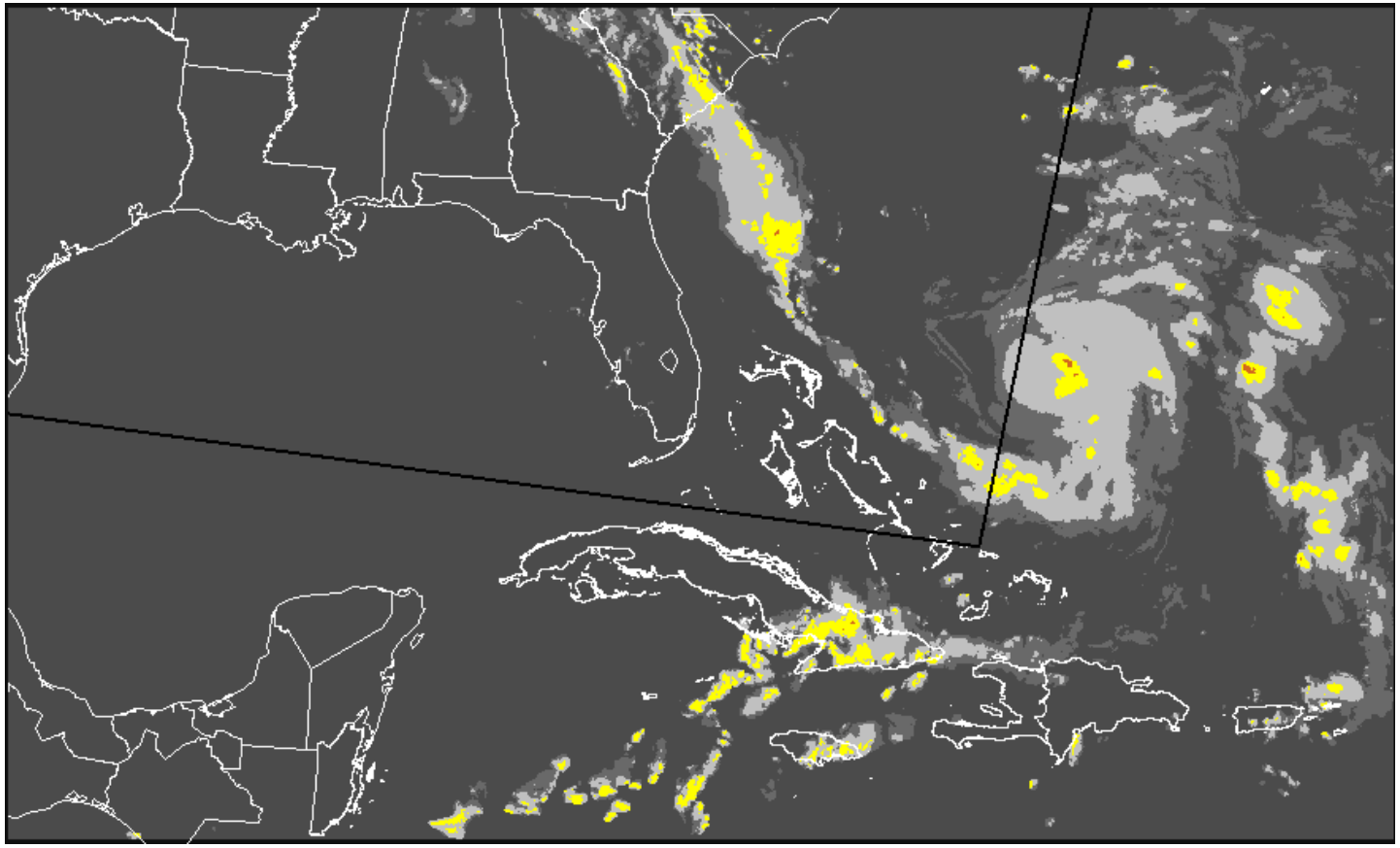
OPC Analysis
17 UTC 3 October 2015



OPC is the starting point for the offshore forecast

1 Hour Offshore Forecast

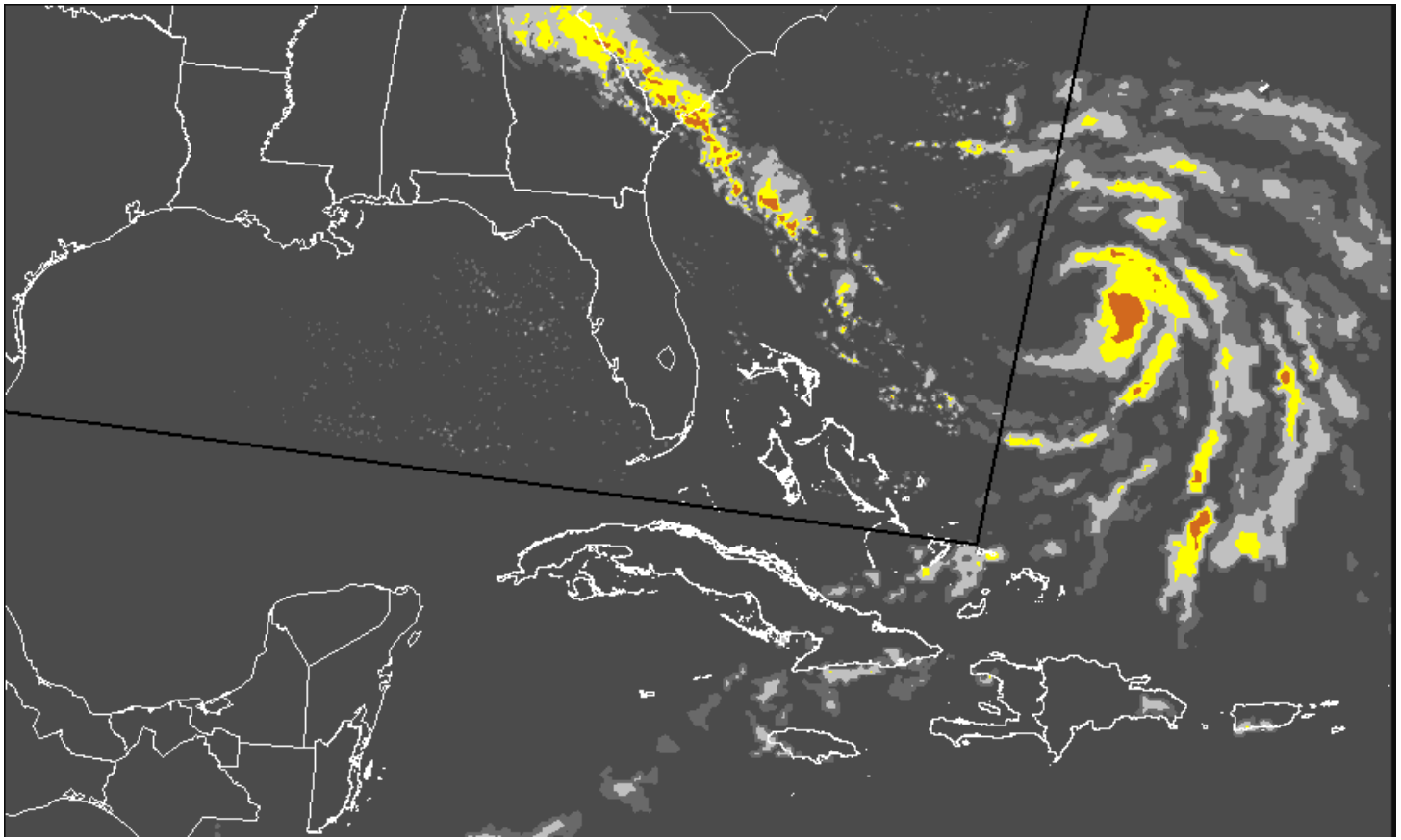
Valid 18 UTC 3 October 2015



Offshore Forecast blends OPC extrapolation with RAP numerical model forecast

8 Hour Offshore Forecast

Valid 01 UTC 4 October 2015

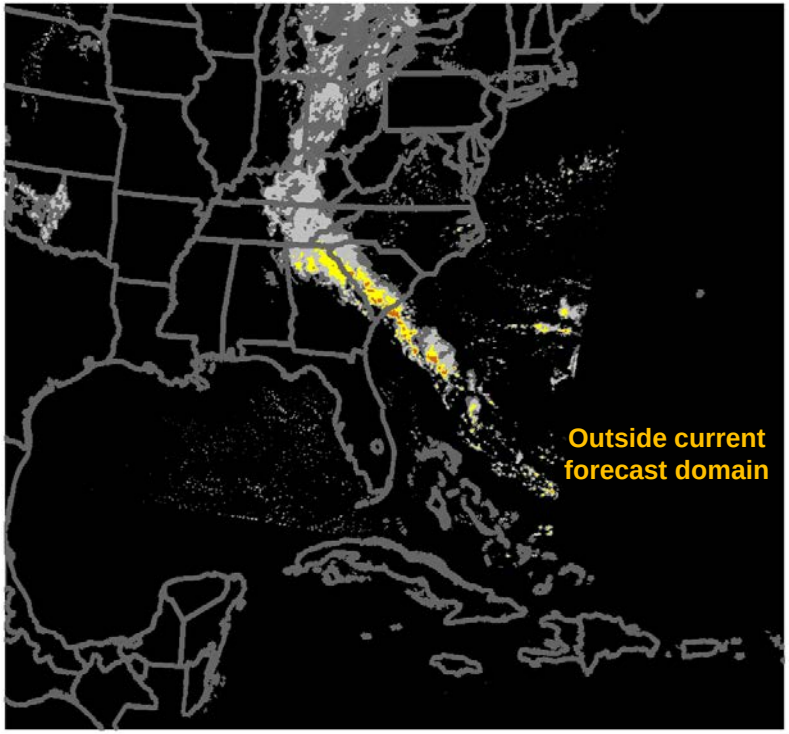


Offshore Forecast blends OPC extrapolation with RAP numerical model forecast

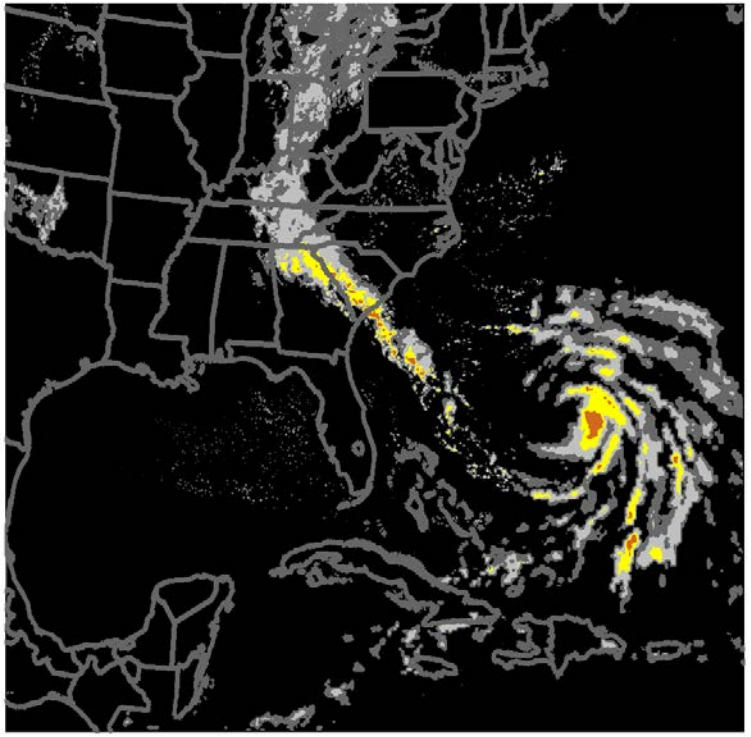
8 Hour Offshore Forecast Comparison

Valid 01 UTC 4 October 2015

Current 8 Hour Forecast



Offshore 8 Hour Forecast



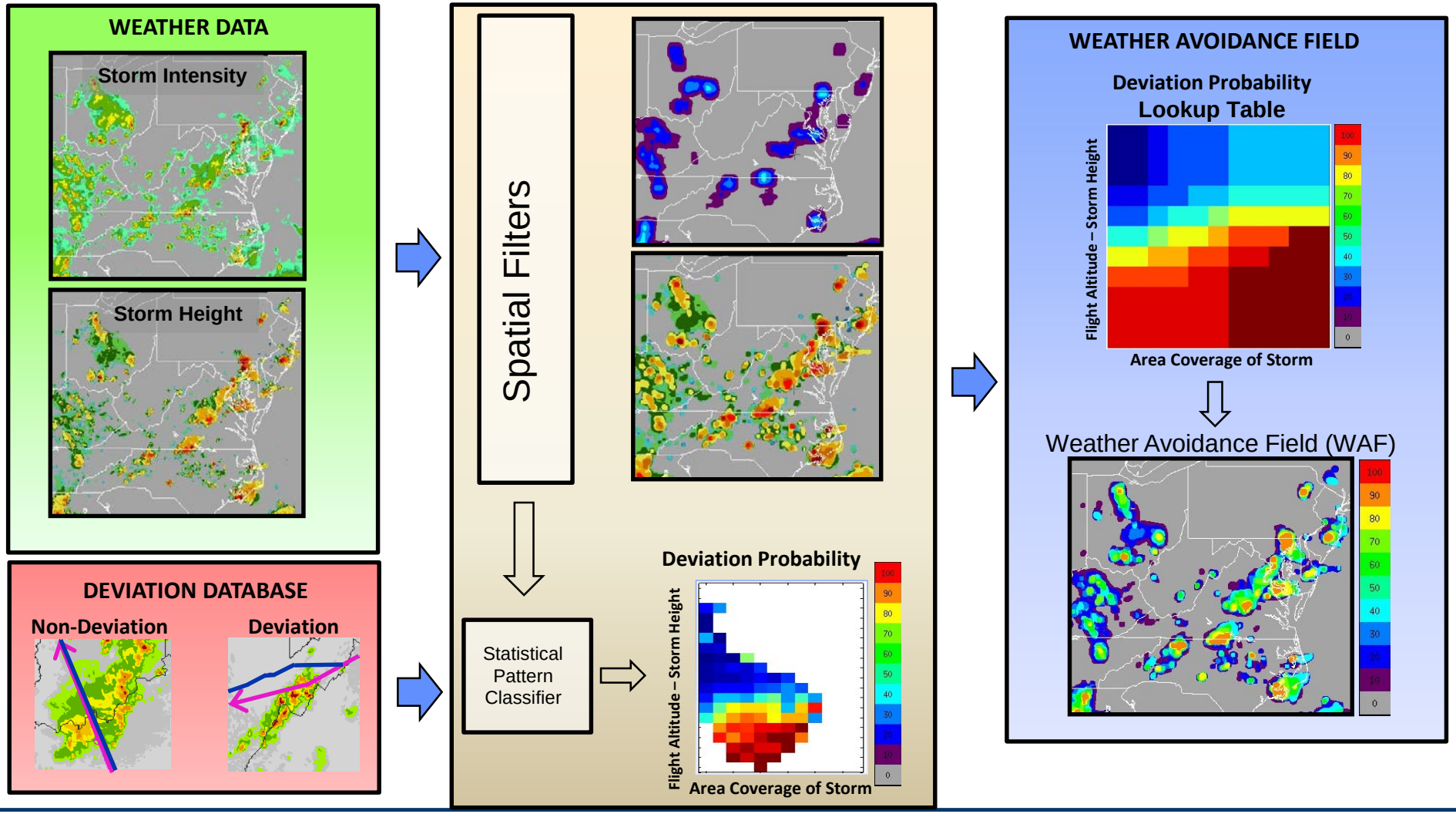
Offshore Forecast extends the range of current forecast

Outline

- **Offshore Precipitation Capability**
- **Convective Weather Avoidance Polygons**
- **Forecast Confidence**

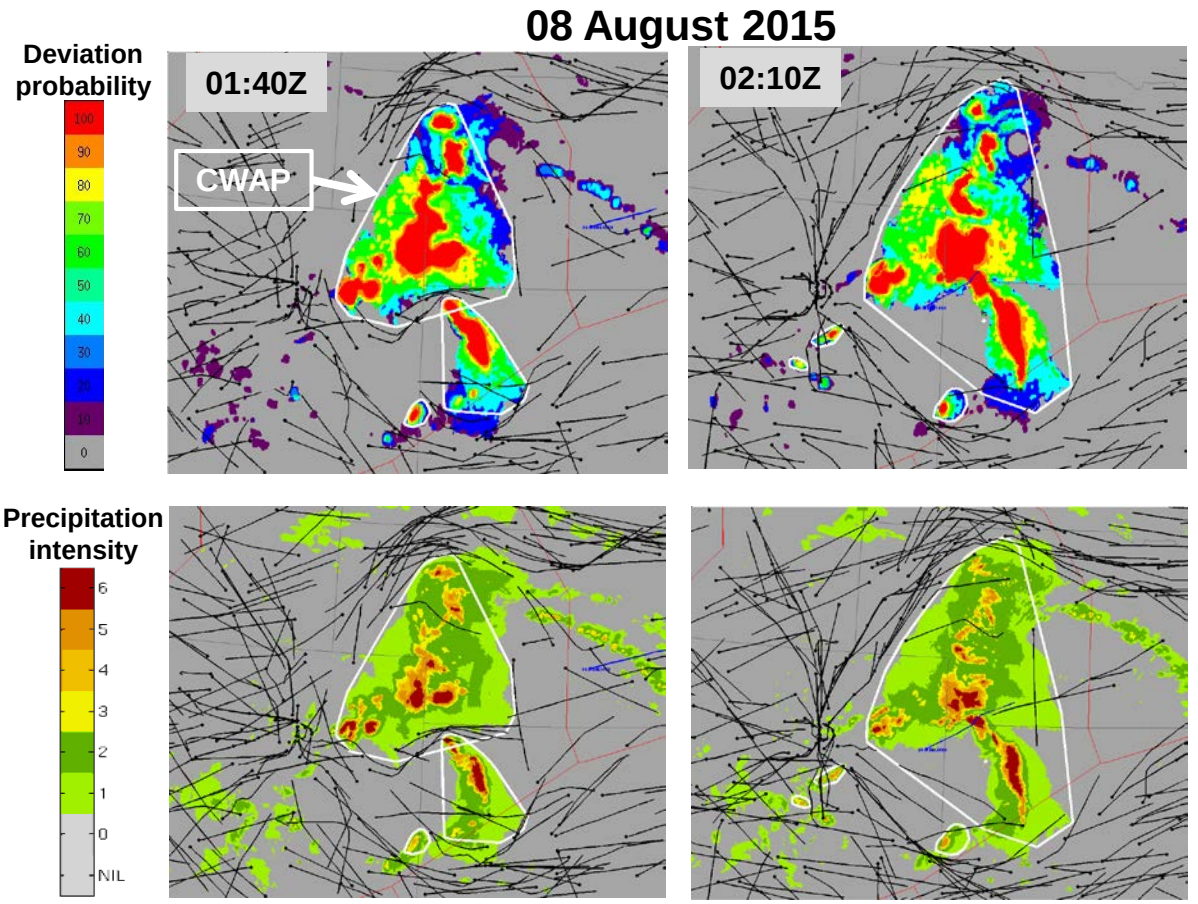
Weather Avoidance Field
Identifying Storms that Pilots Avoid

Convective Weather Avoidance Model



Convective Weather Avoidance Polygons
Identifying Clusters of Storms that Pilots Avoid

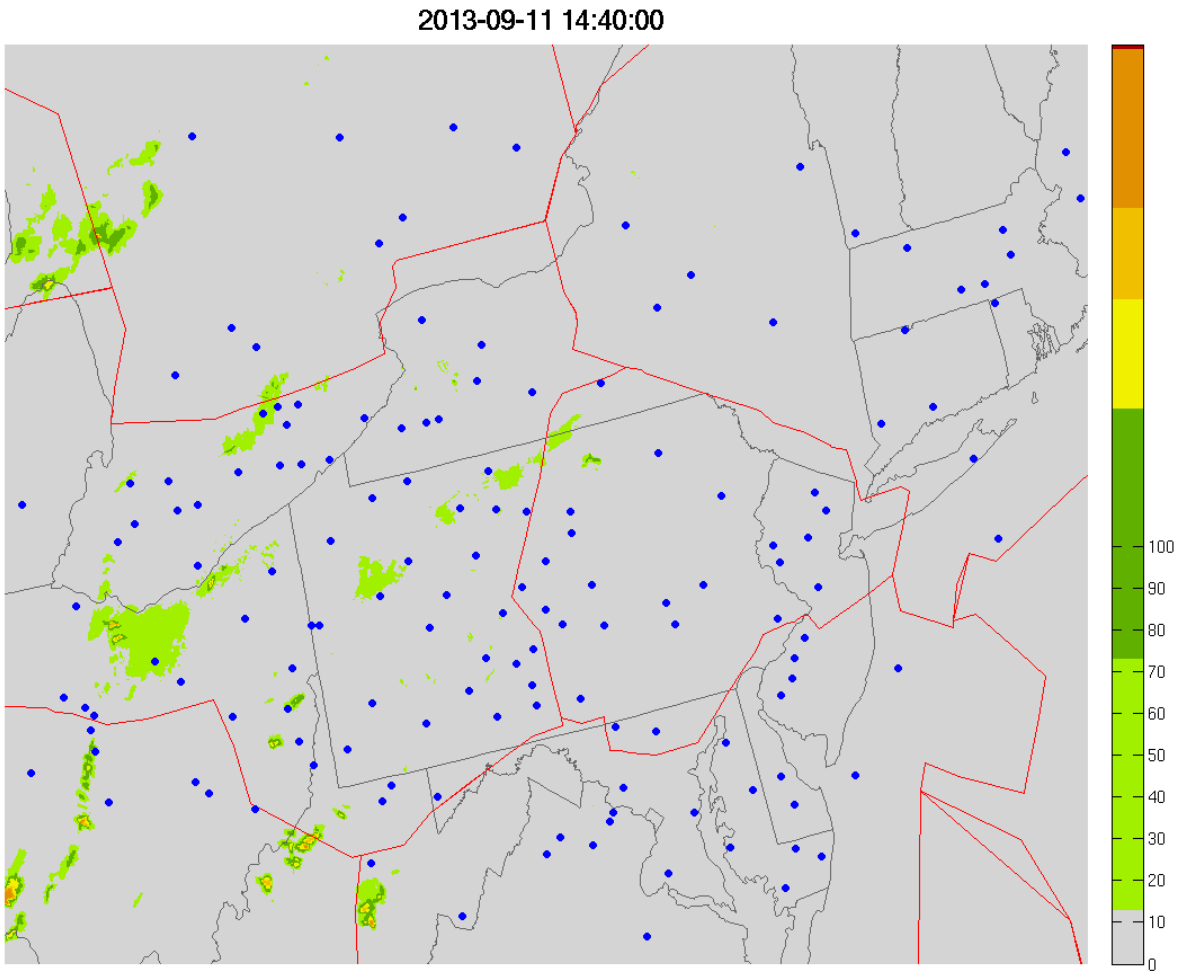
- **In en route airspace, pilots avoid *storms*, not *pixels***
- **Convective Weather Avoidance Polygon (CWAP) combines edges in the echo top field with WAF**
- **Identify the *boundaries of storms that pilots tend to avoid***



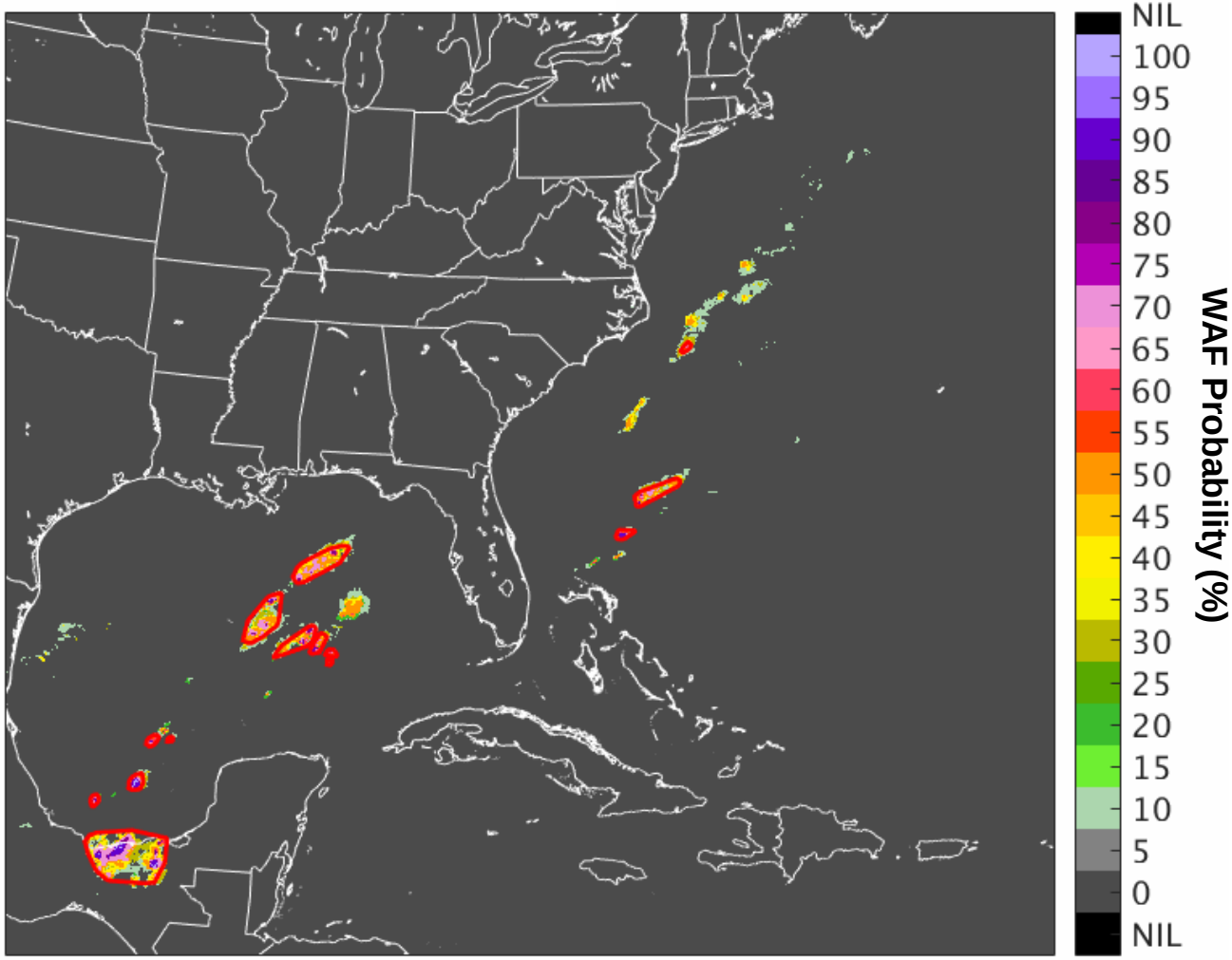
15 – 60 minute forecasts of CWAP can alert dispatchers, pilots, and ATC to growing storms that should be avoided

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CWAPs, Flights and Weather



Offshore CWAPs based on OPC

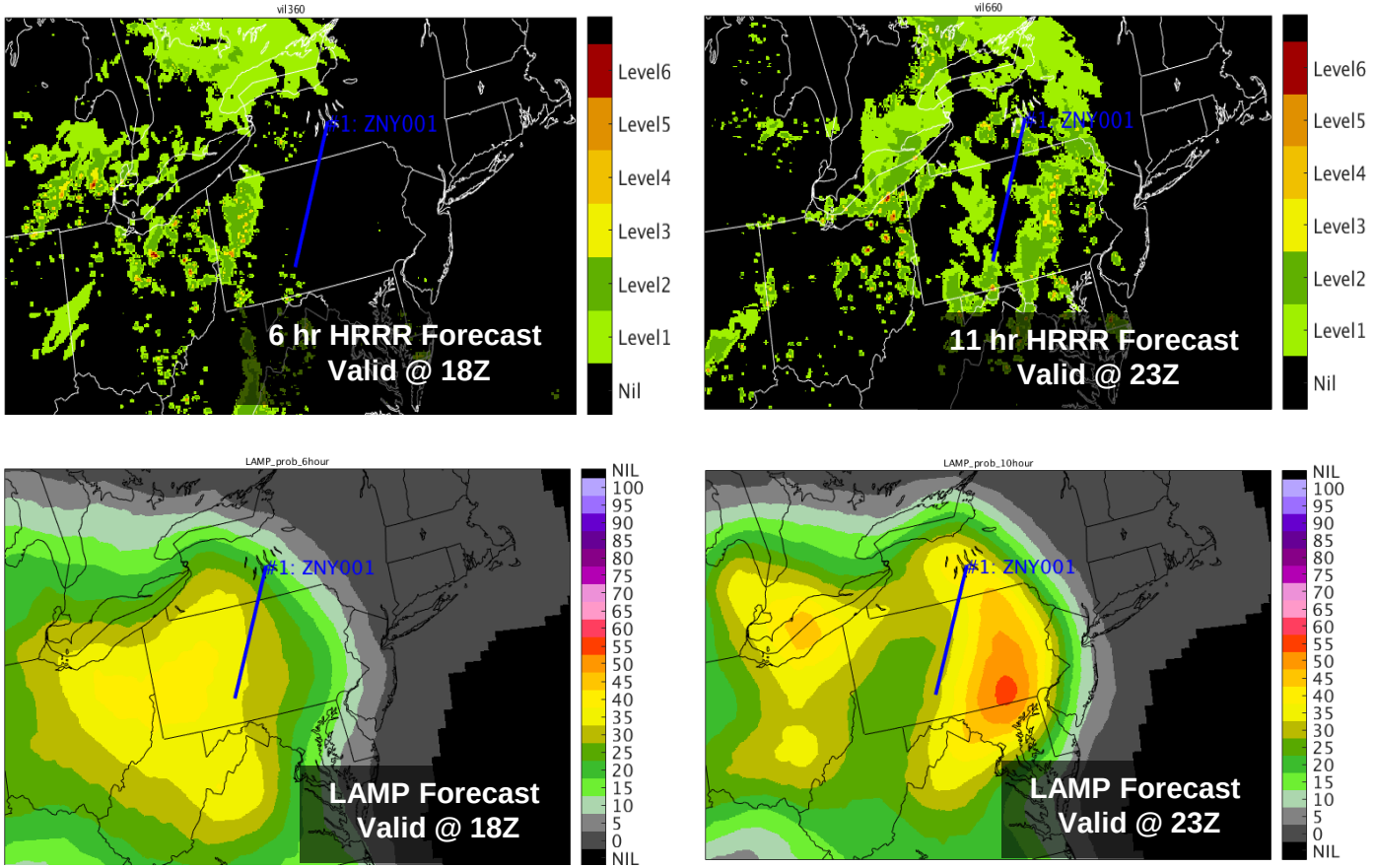


Outline

- **Offshore Precipitation Capability**
- **Convective Weather Avoidance Polygons**
- **Forecast Confidence**

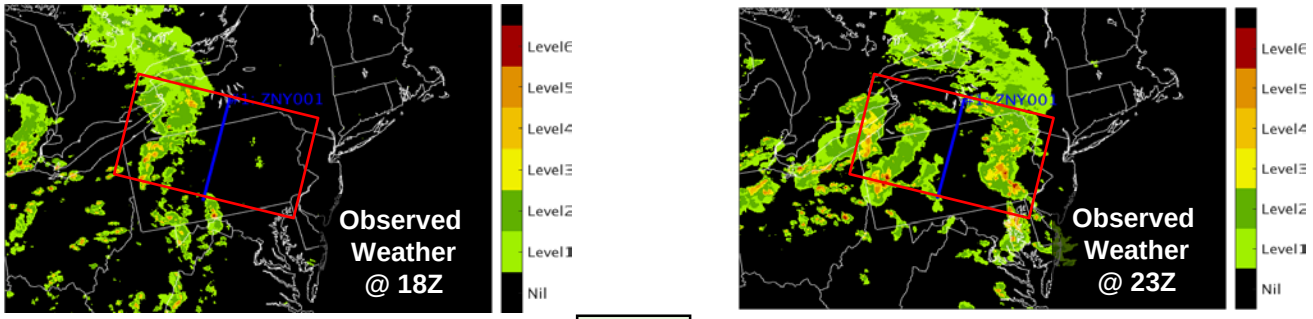
How Much Can I Trust the Forecast?

Forecasts issued 12 UTC 14 June 2015

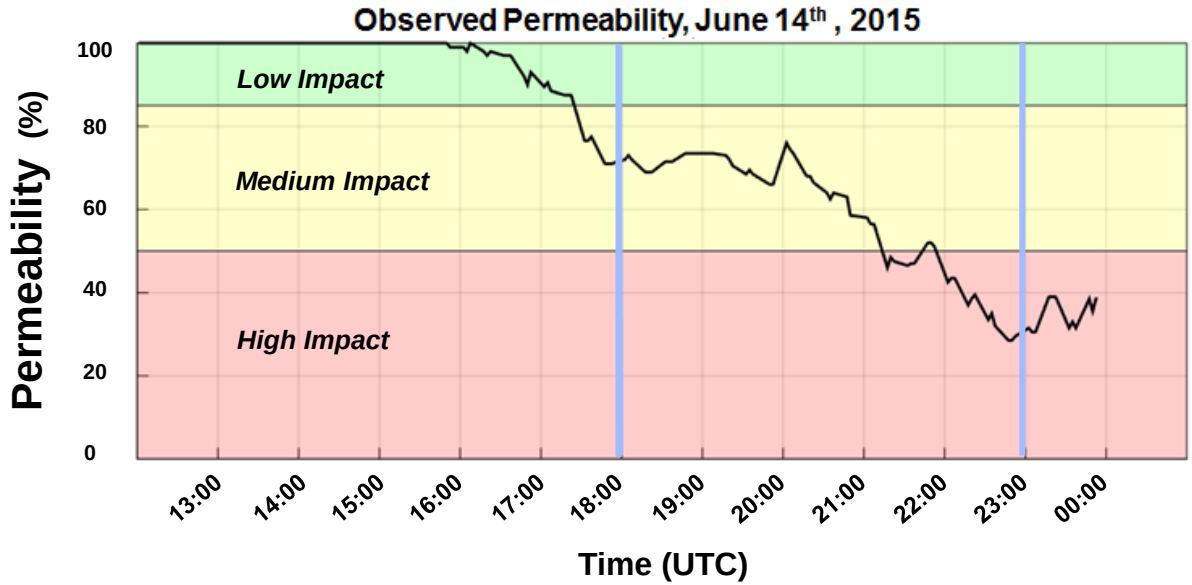


Users often compare and contrast forecasts

Translate Weather to Permeability
Important for Enroute Decisions

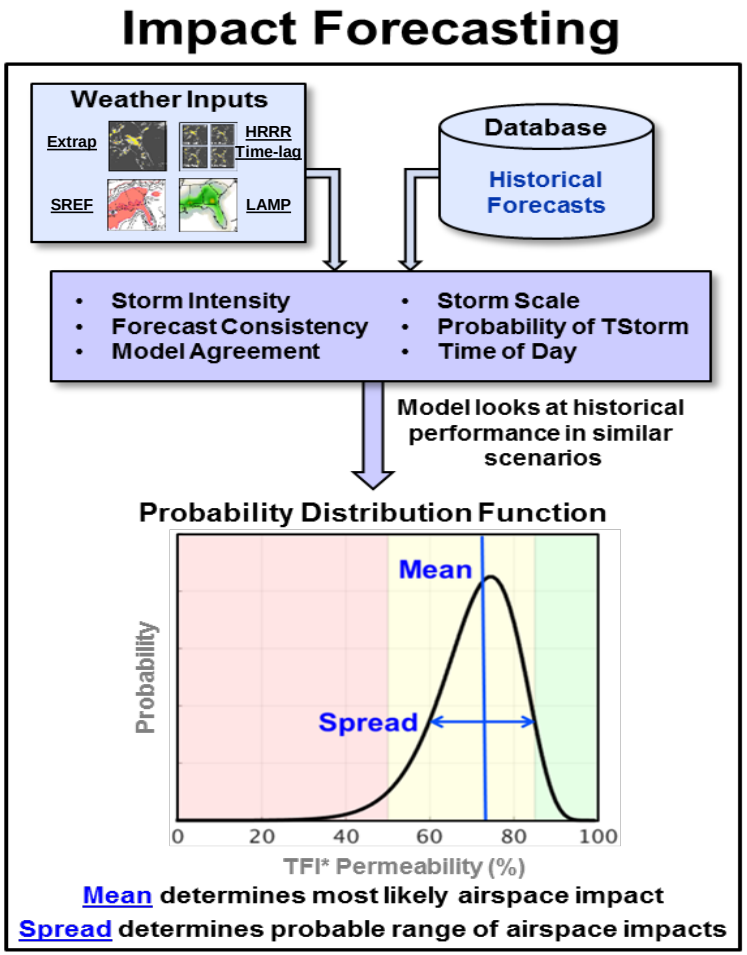


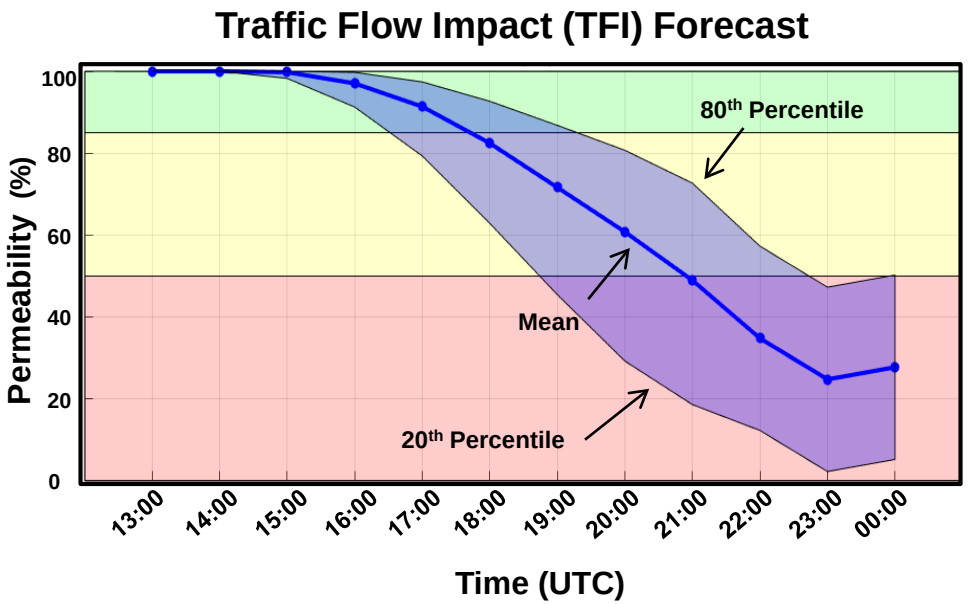
CWAM



Forecast Confidence
Combine Multiple Forecasts

- **Developing machine learning methods to combine multiple forecasts of varying skill to provide the confidence in a permeability forecast**

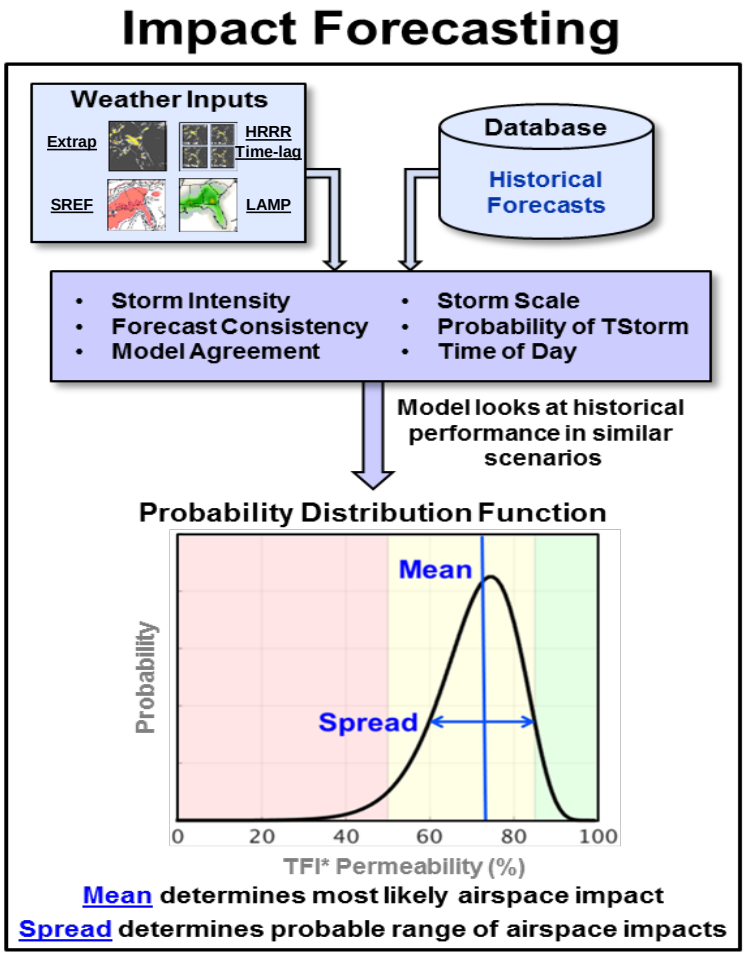


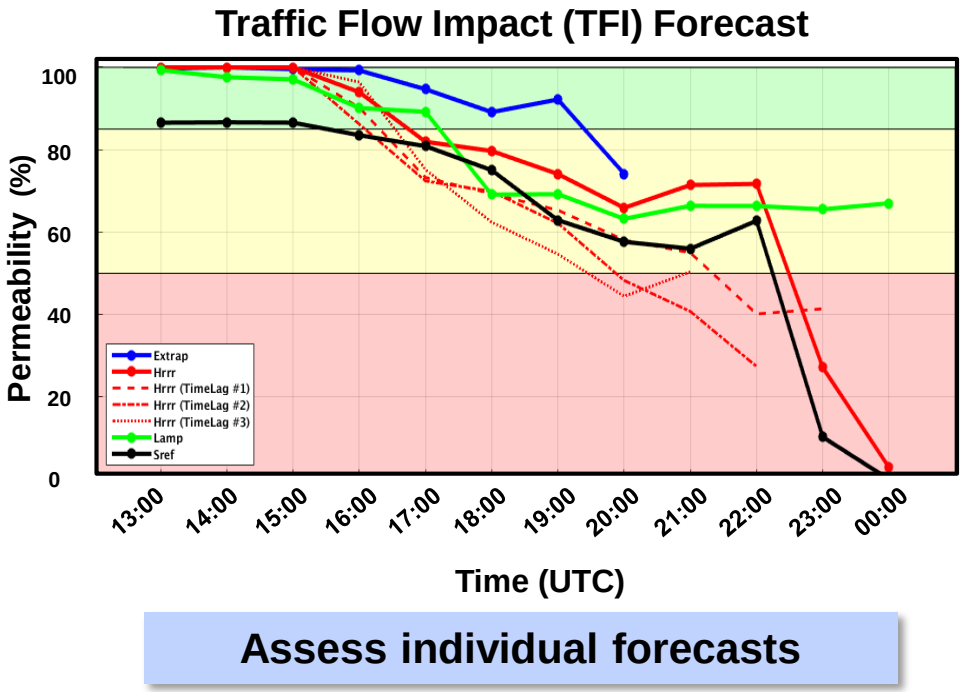


Spread of 80th and 20th percentiles indicates forecast confidence

Forecast Confidence
Combine Multiple Forecasts

- **Developing machine learning methods to combine multiple forecasts of varying skill to provide the confidence in a permeability forecast**

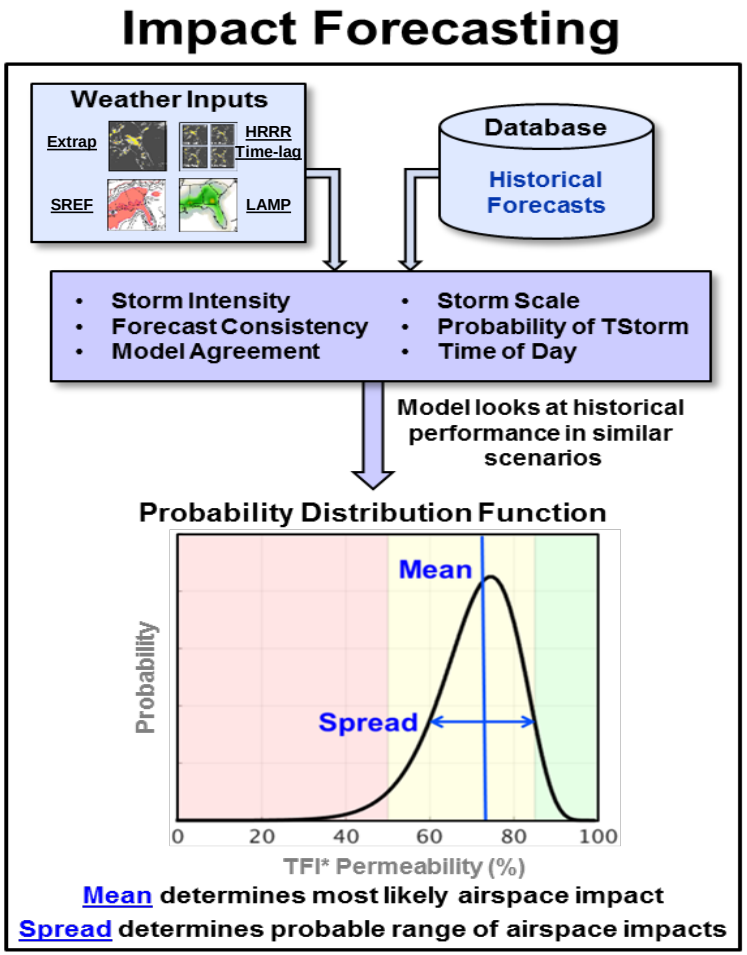


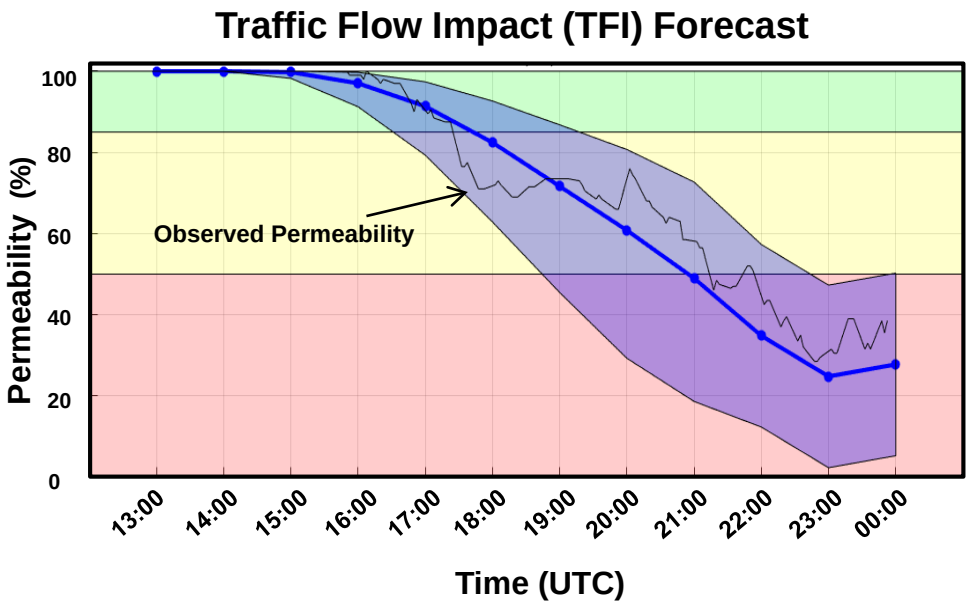


Assess individual forecasts

Forecast Confidence
Combine Multiple Forecasts

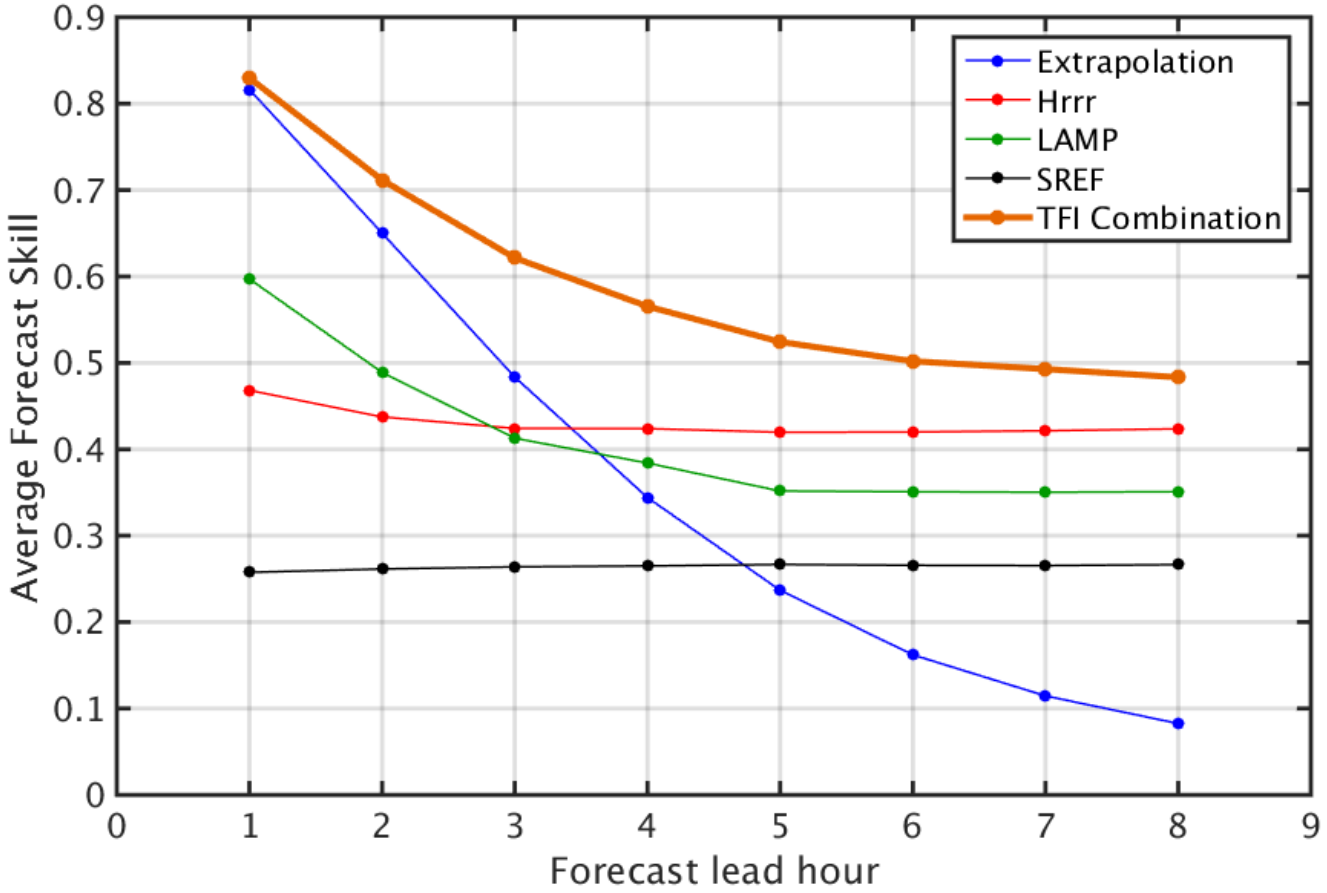
- **Developing machine learning methods to combine multiple forecasts of varying skill to provide the confidence in a permeability forecast**





Observed permeability should tend to fall within shading

Quantified Accuracy of Translated Forecast Components



*Forecast Skill: coefficient of determination (R^2) between forecasted and observed permeability

Combination of forecasts outperforms any single forecast

Summary

- **Offshore Precipitation Capability (OPC)**
  - Creating radar-like analyses for regions beyond radar
  - Forms the starting point for offshore forecast
  - Potential operational platforms for OPC include FAA NextGen Weather Processor and NWS Multi-Radar/Multi-Sensor (MRMS) system

- **Convective Weather Avoidance Polygons (CWAP)**
  - Leverages Convective Weather Avoidance Model
  - CWAP defines a region of airspace that pilots tend to avoid
  - Included as part of NextGen Weather Processor technical transfer

- **Forecast Confidence**
  - Combines multiple forecast models to provide forecast confidence for enroute planning
  - Included as part of NextGen Weather Processor technical transfer