Emerging Aviation Weather Research at MIT Lincoln Laboratory*

Haig Iskenderian

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Outline

- Offshore Precipitation Capability
- Convective Weather Avoidance Polygons
- Forecast Confidence
Aviation Weather Information Shortfall: Limited Offshore Observations and Forecasts

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

<table>
<thead>
<tr>
<th>Lightning</th>
<th>Geostationary Satellite</th>
<th>Numerical Weather Prediction Models</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Earth Networks Total Lightning Network Sensor Locations" /></td>
<td><img src="image" alt="GOES-E &amp; W" /> <img src="image" alt="METEOSAT" /> <img src="image" alt="Indian Ocean" /> <img src="image" alt="MTSAT" /> <img src="image" alt="Visible" /> <img src="image" alt="Infrared" /></td>
<td><img src="image" alt="GFS Forecast" /> <img src="image" alt="RAP Model" /></td>
</tr>
<tr>
<td><strong>Lightning Flashes, Oct 14th, 2014</strong></td>
<td><strong>Update rate:</strong> Every second</td>
<td><strong>Update rate:</strong> Forecasts issued hourly</td>
</tr>
<tr>
<td><strong>Update rate:</strong> ~10 – 30 minutes</td>
<td><strong>Temperature, Pressure, &amp; Winds</strong></td>
<td></td>
</tr>
</tbody>
</table>
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

Radar + Satellite + Lightning

Radar + OPC + Satellite

2015-05-06T12:40:00

2015-05-06T12:40:00
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

Outside current forecast domain

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

WEATHER DATA
- Storm Intensity
- Storm Height

Spatial Filters

DEVIAION DATABASE
- Non-Deviation
- Deviation

Statistical Pattern Classifier

WEATHER AVOIDANCE FIELD
- Deviation Probability Lookup Table
- Flight Altitude – Storm Height
- Area Coverage of Storm

Weather Avoidance Field (WAF)
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
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

Observed Weather @ 18Z

Observed Weather @ 23Z

CWAM

Observed Permeability, June 14th, 2015

Permeability (%)

Low Impact

Medium Impact

High Impact

Time (UTC)

13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00
Developing machine learning methods to combine multiple forecasts of varying skill to provide the confidence in a permeability forecast.

**Impact Forecasting**

- Storm Intensity
- Forecast Consistency
- Model Agreement
- Storm Scale
- Probability of TStorm
- Time of Day

Model looks at historical performance in similar scenarios.

**Traffic Flow Impact (TFI) 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.

Impact Forecasting

Weather Inputs
- Extrapolation (Extrap)
- SREF
- HRRR
- Time-lag

Database
- Historical Forecasts

- Storm Intensity
- Forecast Consistency
- Model Agreement
- Storm Scale
- Probability of TStorm
- Time of Day

Model looks at historical performance in similar scenarios

Probability Distribution Function
- Mean determines most likely airspace impact
- Spread determines probable range of airspace impacts

Traffic Flow Impact (TFI) Forecast

Assess individual forecasts
Developing machine learning methods to combine multiple forecasts of varying skill to provide the confidence in a permeability forecast.
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