A Validation of a Modified Fog Algorithm at WFO Miami using NASA SPoRT Satellite Imagery and Surface Observations

Alannah Irwin[1], Jeral Estupiñán[2], Brad Diehl[2],J.C. Maloney[2] and A. Kennedy[2]

[1]Florida International University Department of Earth and Environment, 11200 SW 8th Street, AHC-5 360, Miami, FL, 33199
[2]NOAA/NWS Miami Weather Forecast Office, 11691 SW 17th Street Miami, FL 33165
Contact Info: jeral.estupinan@noaa.gov

Introduction

Validate and test the accuracy of the modified fog algorithm used by WFO Miami

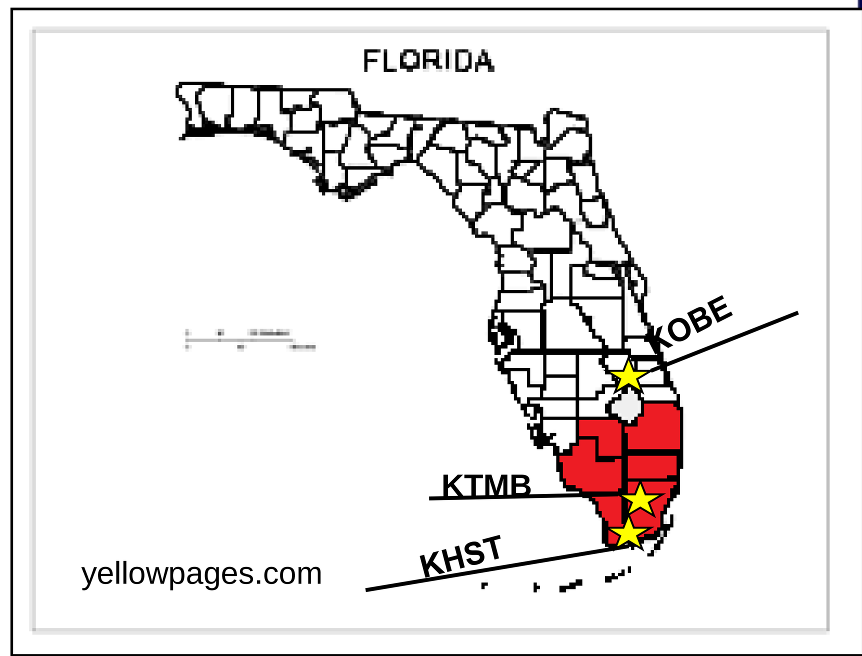
- A new fog detection algorithm was developed at WFO Miami (Fischer et. al. 2013).
- The new algorithm, which is a modified version of the United Parcel Service (UPS) Airlines crossover technique (Baker et. al. 2002), uses the crossover temperature in conjunction with a 15-knot maximum threshold of 925mb winds.
- The advantage of the modified crossover technique is the standalone nature of the algorithm, not relying on the modified Richardson number for boundary layer instability measures since Florida nights are not typically turbulent during fog season.
- The algorithm was tested using METARs from the chosen sites Kendall-Tamiami Executive Airport (KTMB) and Homestead General Aviation Airport (KHST), using Okeechobee County Airport (KOBE) as a control for the reanalysis.
- Aside from METARs, fog events were monitored using the NASA Short-Term Prediction and Research Transition (SPoRT) Nighttime Microphysics Image and the GOES Hybrid Spectral Difference (11µm minus 3.9µm).

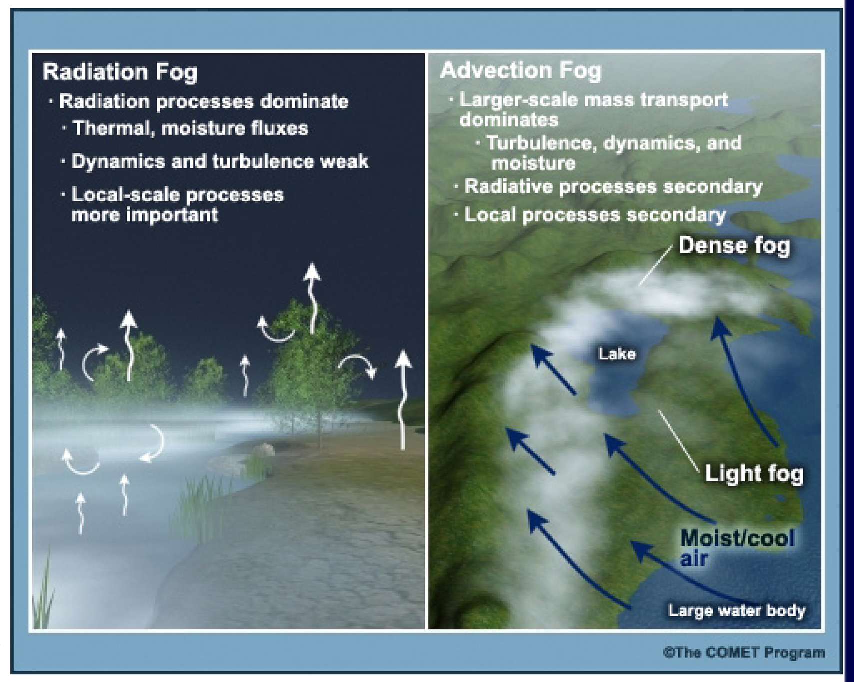
South Florida Fog Events

Model Descriptions, Forecasting, and Forecast Areas

Models Used by WFO Miami and their Description

- **ECMWFModifiedCrossover** – 16km gridpoint resolution with 90 layers; result of the fog algorithm using WFO Miami's crossover temperature and forecast minimum temperature w/ECMWF's 925mb winds
- **GFSModifiedCrossover** – 27km gridpoint resolution with 64 layers; result of the fog algorithm using WFO Miami's crossover temperature and forecast minimum temperature w/GFS40's 925mb winds
- **NAMModifiedCrossover** – 4km gridpoint resolution with 60 layers; result of the fog algorithm using WFO Miami's crossover temperature and forecast minimum temperature w/NAM12's 925mb winds
- **EnsembleModifiedCrossover** – Percentage grid based on the success rate of fog prediction from the three models using the 925mb winds, crossover temperature, and minimum forecast temperature from each
- **ModelECMWFModifiedCrossover** – Uses the 925mb winds, crossover temperature, and the forecast minimum temperature from the ECMWF model
- **ModelGFSModifiedCrossover** – Uses the 925mb winds, crossover temperature, and the forecast minimum temperature from the GFS40 Model
- **ModelNAMModifiedCrossover** – Uses the 925mb winds, crossover temperature, and the forecast minimum temperature from the NAM12 model
- **ModelEnsembleModifiedCrossover** – Percentage grid based on the success rate of fog prediction by the ECMWF, GFS, and NAM using the 925mb winds from each model, but uses the crossover temperature and forecast minimum temperature from WFO Miami's models
- **PureCrossover** – Uses the crossover temperature and WFO Miami's forecast minimum temperature, but does not consider the 925mb winds
- **Conditions for Fog Formation:** Relative humidity close to 100% at the surface, the temperature and dewpoint are within 4°F, calm winds (AMS Glossary)
- **What is considered fog?:** Visibility reduced below 1km (0.62mi). Fog is considered ground fog when <60% of sky is covered. Shallow fog occurs when vertical visibility is obstructed less than 6ft above the surface. Haze does not reduce visibility; could be a preliminary sign of fog. Mist is an intermediate between haze and fog, having suspended particles more than haze but less than fog. (AMS Glossary)





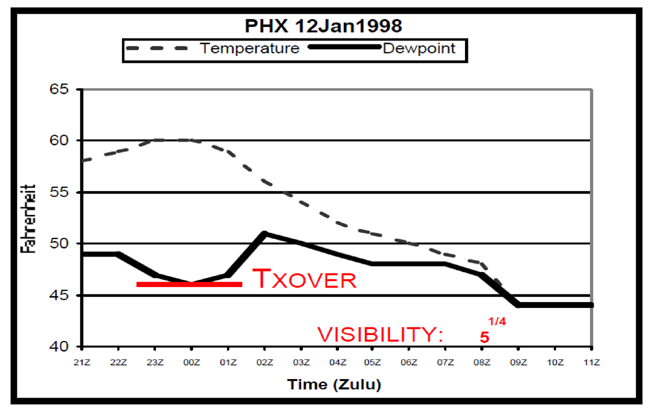
South Florida Fog Season

Fog Season: Typically ranges from November 1 to April 30. Fog formation correlates with the passage of cold fronts. From the late fall to late winter months, fog forms due to radiative cooling. The surface will radiate heat to space when cloud cover is limited. If the relative humidity is high along the surface and the wind is less than 4kt, water vapor will condense, forming clouds. As the waters along the peninsula warm around early March, a frontal passage in this area could cause advection fog. Warm air moves across the cold surface, causing condensation to occur.

Parameters of Analysis

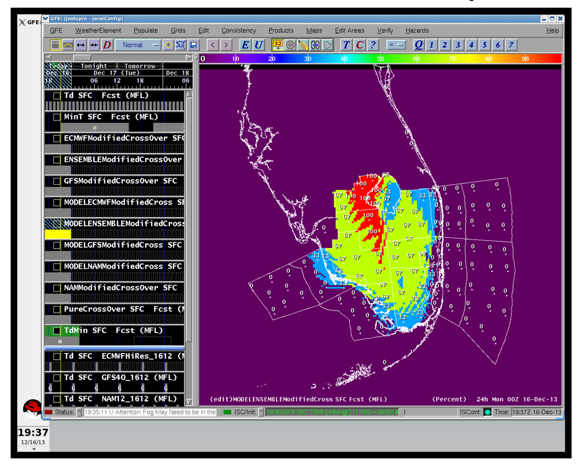
A modified crossover technique that combines the original crossover temperature methodology with a 15-kt maximum 925 mb wind threshold

a.) UPS Airlines Crossover Variables – Crossover Temperature and Modified Richardson Number

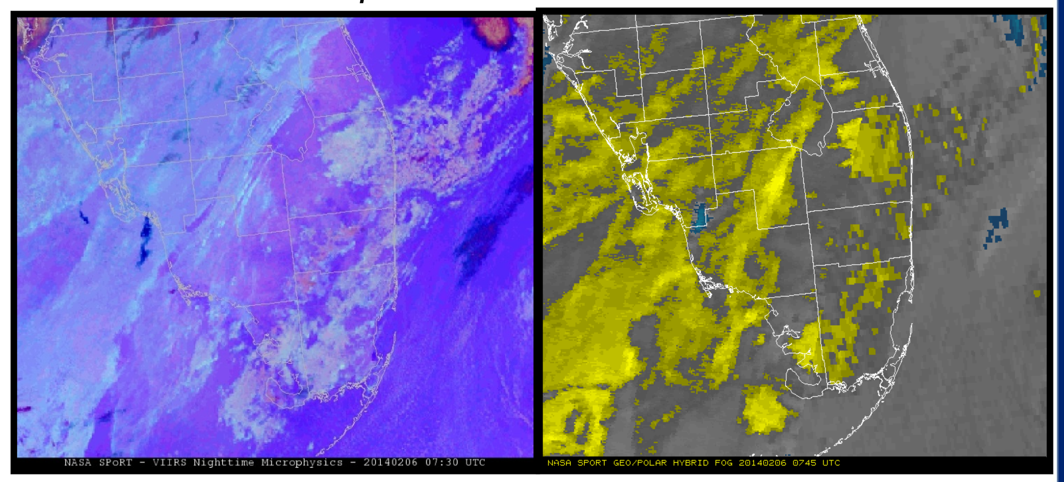


Modified Richardson Number
$MRi = (T_b - T_{sfc}) / (u)^2$
Where $T_b = T_1$ or T_3 (whichever is warmer)
T_{sfc} = forecast minimum T (°C)
u = boundary layer wind speed (kt)

b.) WFO Miami Fog Algorithm – the Modified Crossover Technique



c.) NASA SPoRT Nighttime Microphysics and GOES Spectral Difference



Analysis Design and Overview

a. UPS Airlines Crossover Temperature and Modified Richardson Number

- Crossover temperature is the dew point temperature observed during the day prior to fog events. Fog is forecast to form when the nighttime temperature is expected to cool to the crossover temperature. In order to use the UPS technique, it must be assumed that no advection is present, thus the forecast of radiation fog is most common with this application.
- A Modified Richardson Number is used to forecast turbulence within the boundary layer. There are three characteristics of the surface boundary layer that the MRi measures: mixy, marginal, or decoupled
  - **MRi values < 0.025 = mixy boundary layer; stratus expected**
  - **MRi values between 0.025 and 0.04 = marginal boundary layer; variable fog**
  - **MRi values > 0.04 = stagnant air; definite fog development**

b. WFO Miami Fog Algorithm – the Modified Crossover Technique

- Combination technique that uses the UPS Airlines Crossover Temperature and a 15kt-maximum threshold of 925mb winds. This technique caters to the climate of Florida as there is not a strong correlation between daytime and nighttime mixing in the boundary layer. Versions of the algorithm have been created at WFO Miami based on the following models: NAM, GFS, ECMWF, and an Ensemble of each.
  - **The algorithm was captured for 25 days beginning Nov. 2013 and ending Apr. 2015**
  - **18 Dense Fog Events recorded at KTMB (main station)**
  - **21 Dense Fog Advisories issued between 01DEC2013 and 09MAR2014**
  - **Note: analysis based on days when algorithm is available; does not include all SFL events**

c. NASA SPoRT Nighttime Microphysics and GOES Spectral Difference

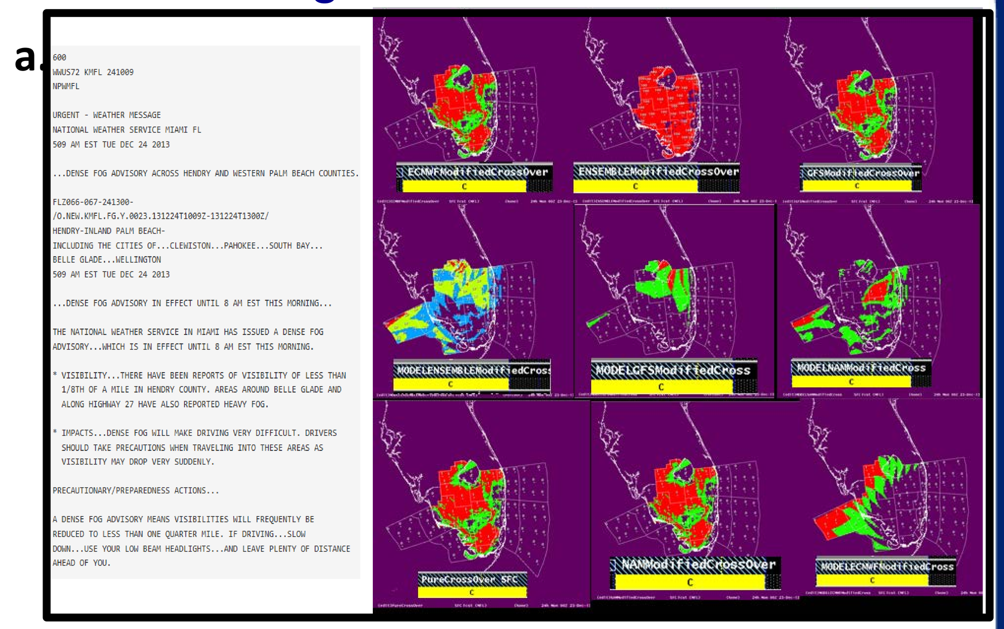
- Nighttime Microphysics imagery from NASA SPoRT is important to help distinguish between low lying clouds and fog in specific environments. It uses the difference between the 10.8 and 3.9 µm channels to determine the depth of the clouds and the composition of the clouds (ice vs. water). The 10.8 µm channel also determines the temperature at the surface. Fog at the surface of a warm climate identified in a light blue/purple color.
- The GOES Hybrid Spectral Difference (also called the MODIS Fog Product) is a 1km resolution model. This model is a hybrid of the GOES Fog Product and the MODIS Low Cloud Base Model. Low cloud base colors are indicated in yellow, while higher cloud bases are shown in blue.
- The combination of these two products help determine the accuracy of the WFO Miami Fog Algorithm. This imagery verifies fog formation in the interior regions of Florida where no METAR reports are available.

Validation

The WFO Miami modified fog algorithm has a high accuracy of forecasting dense fog events, but is too sensitive for forecasting minor or localized fog events.

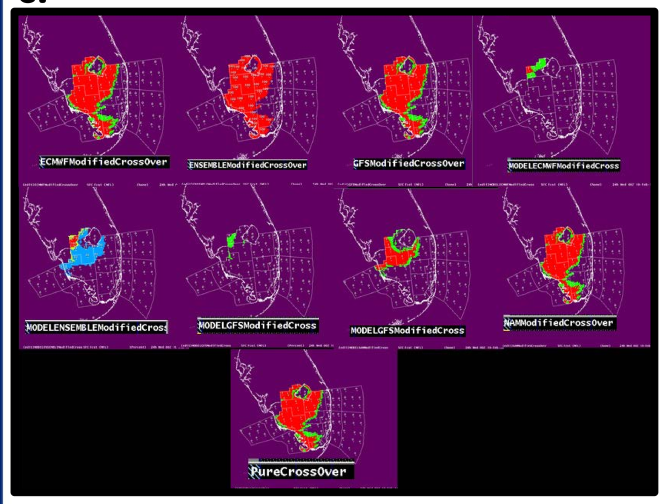
- The fog algorithm was most accurate with dense fog events 24DEC2013, 28JAN2014, 01FEB2014, 06FEB2014, and 08FEB2014 and no fog events such as 18JAN2014, 08APR2014, 10APR2014, and 18APR2014.
- There was higher confidence amongst models for dense fog events (Figure a.)
- NASA SPoRT imagery and METAR data were able to confirm algorithm accuracy. There were limitations to these methods at times. In some events, SPoRT imagery was unavailable and METAR data could not verify fog formation in the interior, such as 09MAR2014 (Figure b). Fog is highlighted in black, while low clouds are highlighted in yellow.
- During minor and localized fog events, there was a large forecast range between models, such as 20FEB2014 and 22FEB2014. Amongst all model outputs, the most accurate WFO Miami modified fog algorithm was a combination of the Model NAM Modified Crossover and Model Ensemble Modified Crossover (Figure c.). The models displayed the most certainty during dense fog events and decreased the amount of "false alarm" fog events from the previous study.

a.



b.

c.



Results

25 total algorithm days; 5 no forecast fog (4 correct); 5 dense fog events (5 correct)
15 minor/localized events - the accuracy varied amongst models, but the Model Ensemble was able to precisely forecast the fog within 33% for most areas (areas that were forecast to have 66% fog wound up having trace amounts of fog form), and it was entirely accurate for all areas forecast to have 100% fog events. The Model NAM was most accurate in terms of forecast area, being between 75-80% accurate with fog forecast areas (sometimes it would over-forecast fog).

Future goals

- Continue to evaluate the current algorithm and make the necessary changes to ensure accuracy in future fog forecasts.

Aknowledgments

The NASA SPoRT team, especially Kevin K. Fuell and Kevin M. McRath for providing a data feed for the satellite images.

References

Fischer, Michael and J.E. Estupiñán, 2013: A Modified Fog Detection Algorithm Developed at the Miami Weather Forecast Office, Presented at the The 38th Annual National Weather Association Meeting in Charleston South Carolina.
Baker, R., J. Cramer, and J. Peters, 2002: Radiation fog: UPS Airlines conceptual models and forecast methods. Preprints,10th *Conf. on Aviation, Range, and Aerospace*, Portland, OR, Amer. Meteor. Soc., 5.11. [Available online at http://ams.confex.com/ams/pdfpapers/39165.pdf.]