6

An Algorithm for Diagnosis of Aircraft Engine Icing Conditions

George P. McCabe, Julie A. Haggerty, Gary M. Cunning, Frank McDonough, Jennifer Black

National Center for Atmospheric Research, Boulder, CO

Goal

Translate a complex algorithm that determines the risk of ice ingest into aircraft engines to a real-time system that is flexible, configurable, and maintainable by combining simple software components in a data-driven chain of execution.

Background

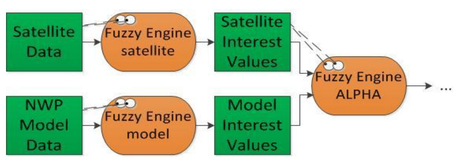
A prototype system called ALPHA (Algorithm for Prediction of HIWC Areas) has been developed to diagnose High Ice Water Content (HIWC) conditions (Haggerty et.al., 2012). ALPHA uses satellite, NWP model, and radar data to evaluate weather conditions related to power loss events of commercial aircraft due to accumulation of ice in jet engines. Deep convective clouds have been a common factor in over 100 cases that create safety issues and cause expensive damage to the aircraft. The algorithm relies on a fuzzy-logic approach that is used to manage spatial and temporal uncertainty in the data.

An aircraft operated by a NASA contractor for HIWC will sample parts of thunderstorms laden with large numbers of small ice crystals. (Image courtesy NASA Glenn Research Center.)

Jet engines are hypothesized to be susceptible to high concentrations of small ice crystals http://nasa-spacestation-info.blogspot.com/2011/08/airplane-plus-heat-plus-ice-equals.html

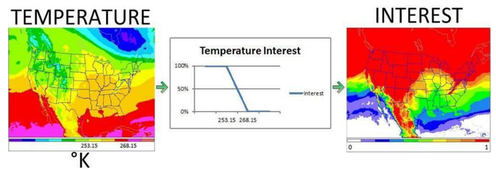
Data Flow

Each application watches a data directory. When a new dataset arrives, the application processes that dataset along with other datasets that are valid at that time. The output dataset is written to another data directory that is watched by another application, creating a chain of execution.



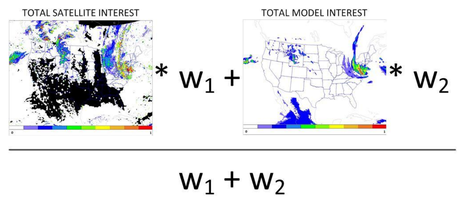
Fuzzy Logic

Fuzzy logic methodology is applied as a means of blending information from multiple routinely available meteorological datasets. A membership function is applied to each field, converting them to non-dimensional interest values.



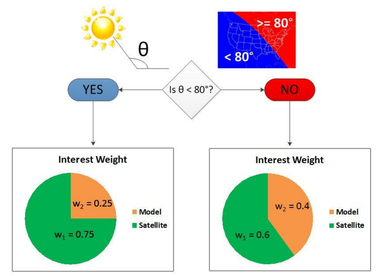
Combining Data

Each interest field is given a weight value (w_i) because certain fields should have more influence on the total interest. Fields can be combined geometrically or algebraically.



Variable Interest

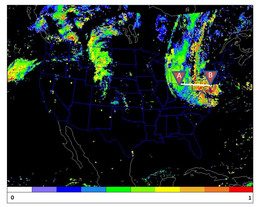
Because there is no visible channel from the satellite data at night, the weight of this dataset is reduced during certain hours. The solar zenith angle is used to determine whether a grid point at a given time should use the daytime or nighttime formula.



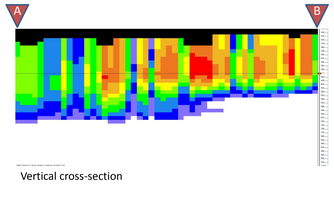
In some cases, the interest map applied to a data set is not static. For example, the map applied to cloud top height at each grid point is based on the tropopause height at that location.

Products

The final output of ALPHA is a 3D gridded product that gives the likelihood of HIWC conditions.



Horizontal view at 350mb



Vertical cross-section

Static image files of the output are generated automatically using NCL (NCAR Command Language) scripts. These images are uploaded to an online data catalog so that they can be accessed by others.

Future Work

ALPHA was designed to be expandable. New datasets can be incorporated into the algorithm with little modification.

A playback system is being developed so that case studies with interesting weather conditions can be easily rerun. This will also allow scientists to test their modifications to the algorithm.

ALPHA will be tested in a planned field campaign in Darwin, Australia. Airborne measurements will be acquired and used for verification.

Acknowledgements:

Rod Potts of the Australian Bureau of Meteorology and Louis Nguyen of NASA Langley Research Center provided data sets for input to ALPHA. This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA. NCAR is sponsored by the National Science Foundation

References:

Haggerty, J., F. McDonough, J. Black, G. Cunning, G. McCabe, M. Politovich, and C. Wolff, "Nowcasting atmospheric conditions associated with jet engine power loss and damage due to ingestion of ice particles," AIAA 4th Conference on Atmosphere and Space Environment, New Orleans, LA, 25-28 June 2012.