



Met Office

Verification of FLYSAFE CAT Objects Against Aircraft Turbulence Measurements

Dr Philip G Gill

9th EMS Annual Meeting - Applications of Meteorology, Toulouse, 29 September 2009



Contents

This presentation covers the following areas

- Introduction
- FLYSAFE Weather (Wx) Objects
- Aircraft Data
- Verification Methodology
- Verification Results
- Summary



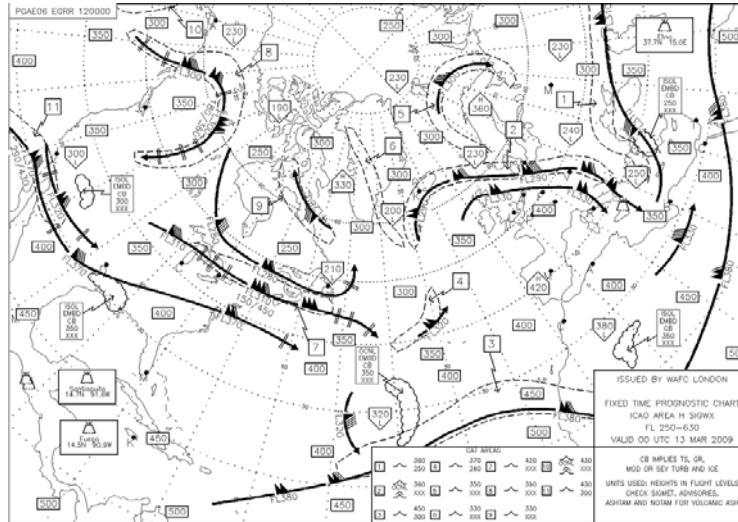
Met Office

Introduction

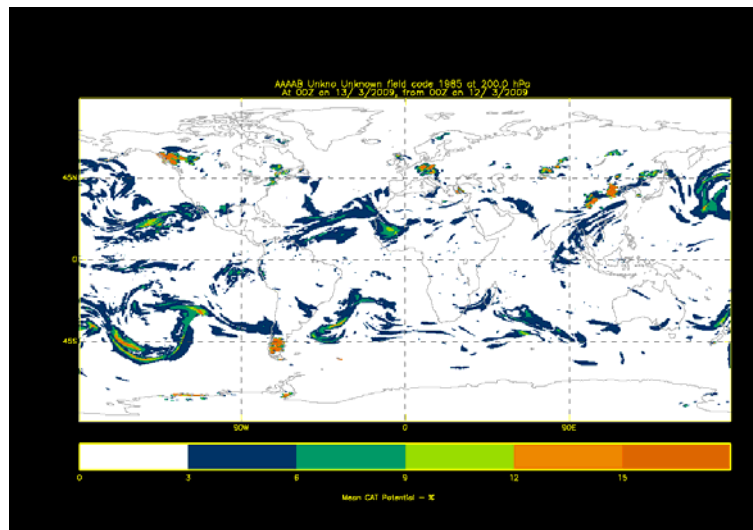
- What – Objective verification of FLYSAFE Clear Air Turbulence (CAT) objects
- When – December 2008 to Mar 2009
- Where – Global verification
- Why – To demonstrate the quality of the FLYSAFE forecasts using objective verification.
- How – Verification against aircraft observations from the Global Aircraft Data Set (GADS)



Current Forecast Products Manual SIGWX BUFR and GRIB CAT forecasts



- Forecaster's SIGWX chart
- Manual production
- Distributed as BUFR features



- Example field from new GRIB forecast
- Automated production
- Distributed as graphical image file



Met Office

FLYSAFE Wx Objects

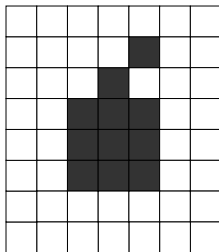
- Objects are contoured regions defining areas of turbulence
- Uses Ellrod turbulence indicator computed from UK Met Office Global Unified Model
- Gridded data become Wx Objects encoded using the Geospatial Mark-up Language (GML) for transmission to an aircraft



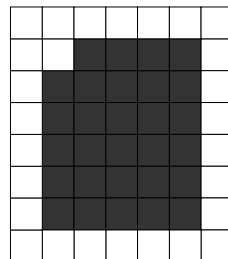
FLYSAFE Wx Objects

Met Office

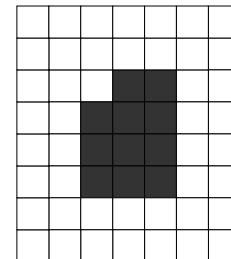
- Gridded fields to Weather Objects (Christian Pagé, Météo France) – methodology adapted for use by FLYSAFE partners: Met Office, Univ Hannover, DLR.
- For 2D gridded field
 - Apply threshold to create a categorical field
 - Add a temporary border of one grid point = 0
 - Apply closing mathematical morphology: to eliminate small features



N x Dilatation

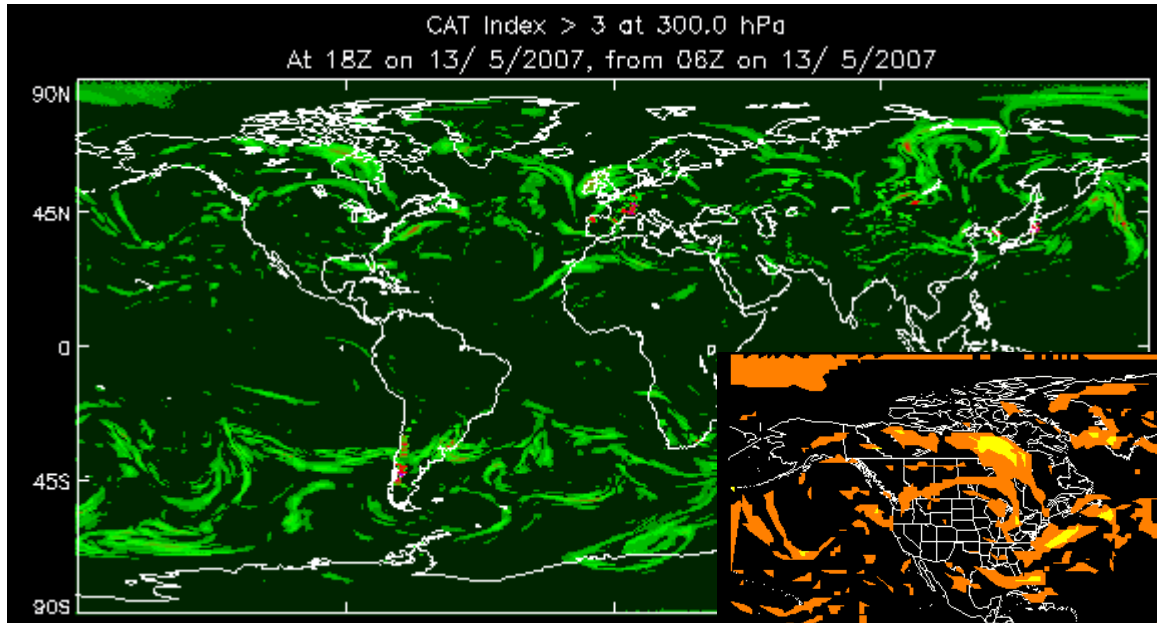


N x Erosion



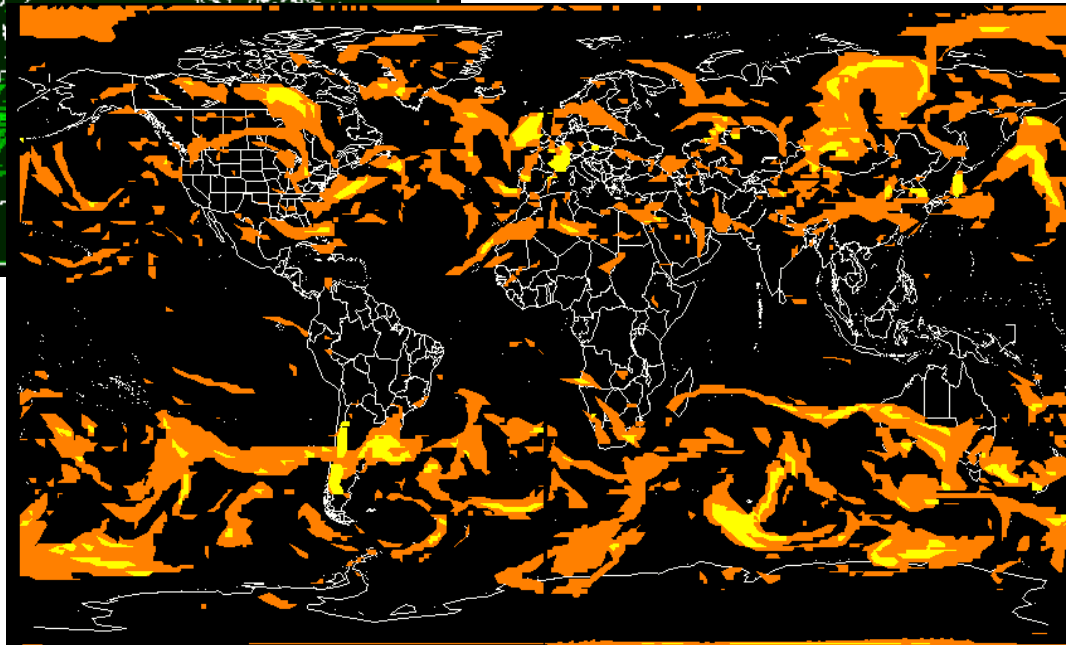
- Apply a flood-fill algorithm to each region to isolate individual objects
- Return a binary mask containing geographic co-ordinates of candidate weather objects

FLYSAFE Wx Objects



The figure below shows CAT objects created from the Unified Model – Global Field shown on the left.

(Andrew Mirza, Met Office)



Each filled (orange, yellow) contour is a discrete “weather object” – when encoded using FLYSAFE’s data model, metadata is added: date and time, intensity, confidence



Met Office

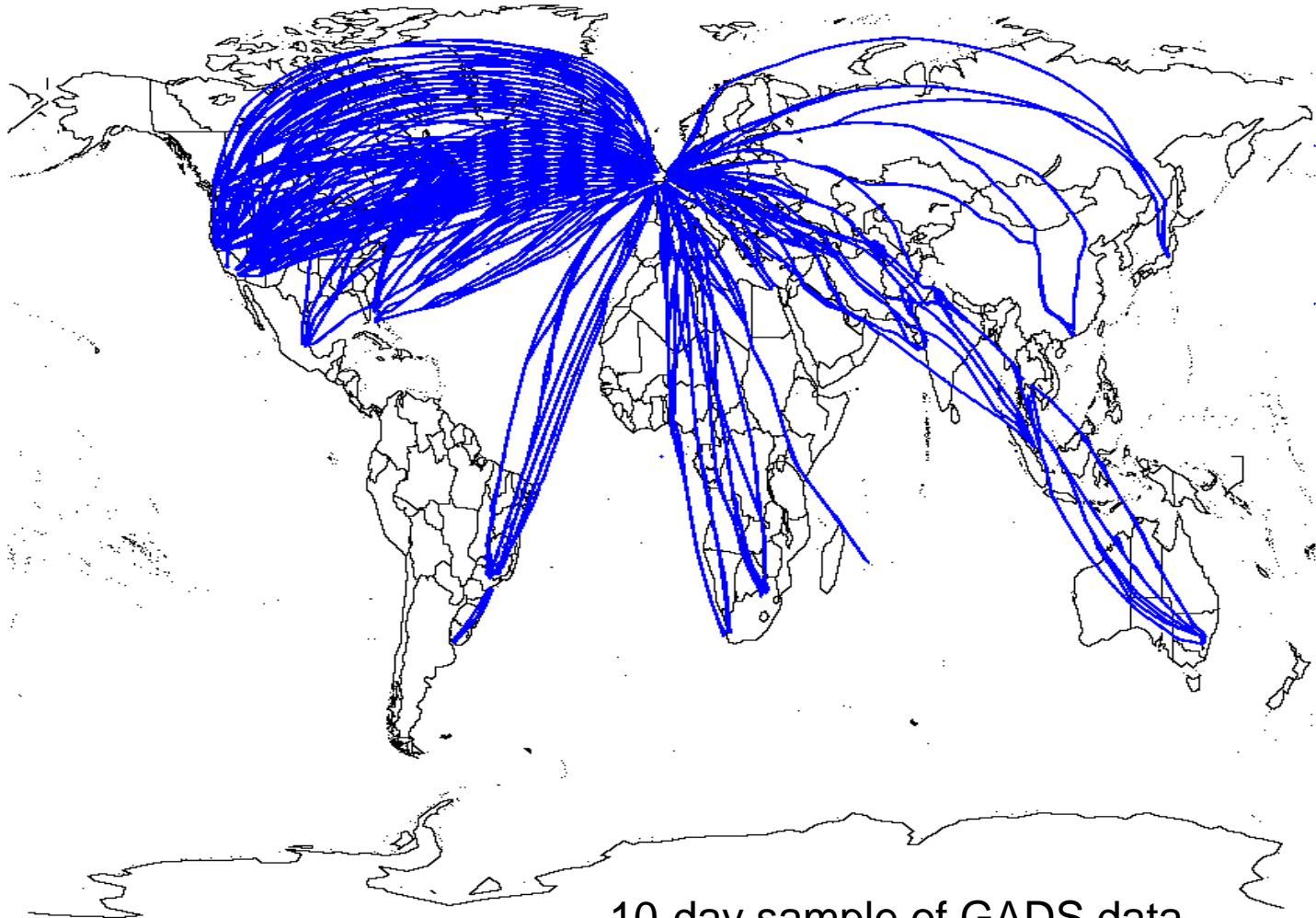
Global Aircraft Data Set

- Archive of aircraft data set up by Joel Tenenbaum (State University of New York)
- British Airways fleet of Boeing 747-400 aircraft
- Global coverage, but flights mainly over northern hemisphere
- Automated aircraft observations every 4 seconds
- Indicator of turbulence derived from vertical acceleration, aircraft mass, altitude and airspeed called the derived equivalent vertical gust (DEVG).



Met Office

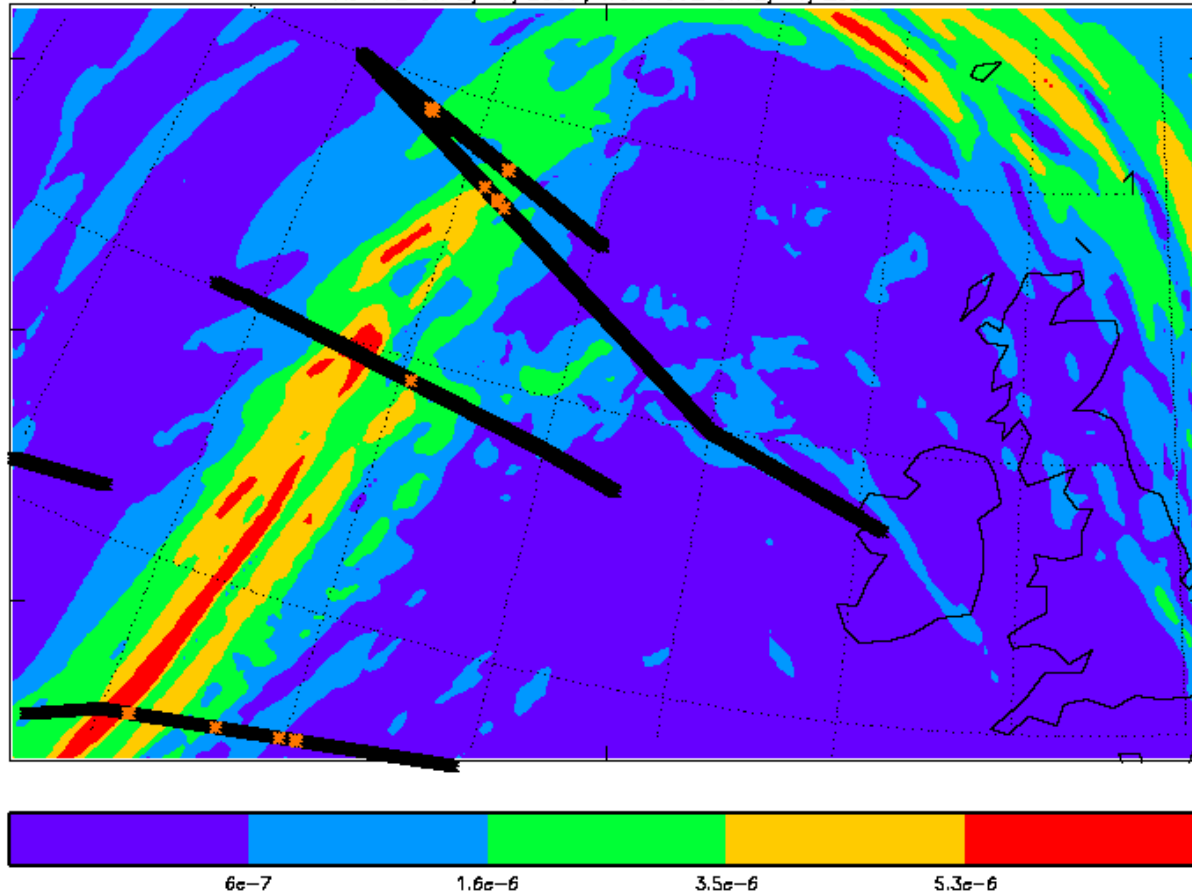
GADS Data Coverage



10-day sample of GADS data

Verification methodology

Atmos 'x' wind component (with respect to grid) at 1.059e+04 metres
At 17Z on 2/ 1/2007, from 06Z on 2/ 1/2007





Met Office

Forecast Assessment

- Turbulent/non turbulent event defined on 10min aircraft track ~120km - approx grid size
- Forecast turbulent event – CAT potential \geq Threshold
- Observed turbulent event: thresholds –
Slight or greater $DEVG \geq 2.0\text{m/s}$
Moderate or greater $DEVG \geq 4.5\text{m/s}$
- Construct 2x2 contingency tables for each threshold
- Sum entries in contingency tables over the verification period
- Produce a Relative Operating Characteristic (ROC) curve by plotting the Hit rate against False-alarm rate for each threshold.

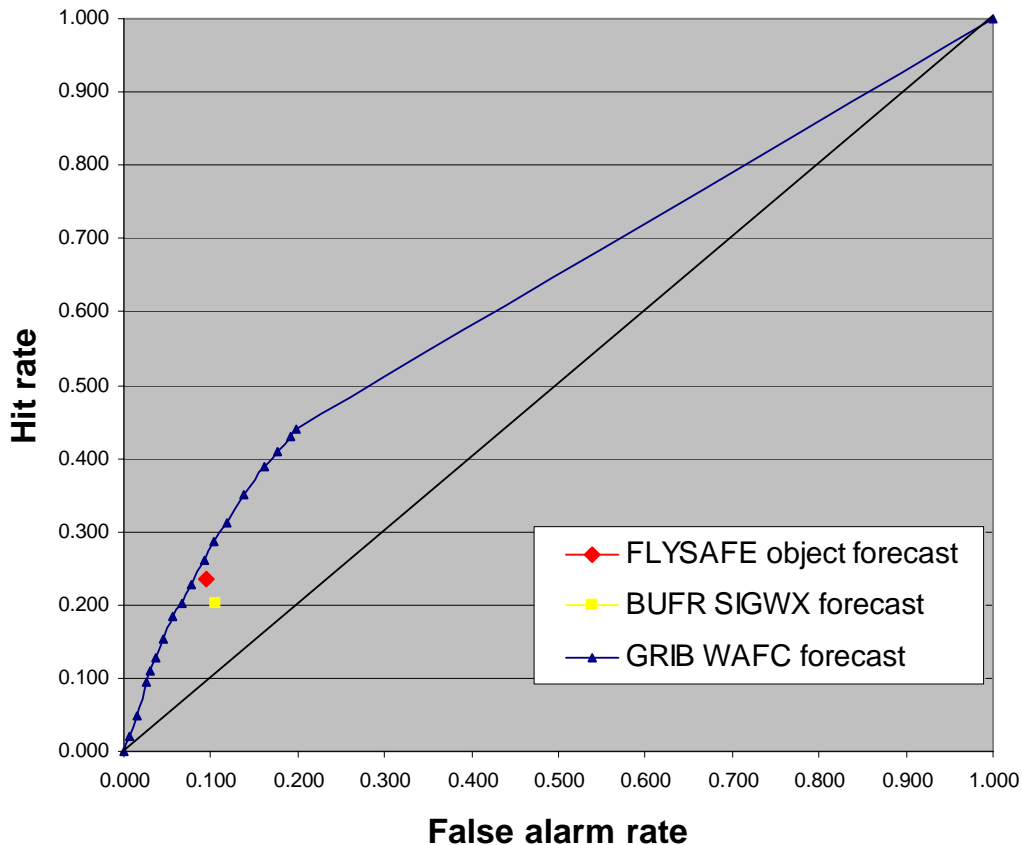
	Turbulence observed YES	Turbulence observed NO
Turbulence forecast YES	Hit	False alarm
Turbulence forecast NO	Miss	Correct rejection

2x2 contingency table



Comparison of CAT forecasts

ROC curve comparing CAT forecasts T+24 Dec 2008 - Mar 2009 against global GADS data light turbulence (DEVG \geq 2m/s)



Recorded
observed
events
~300,000

Classified
observed
turbulent
events
~8,000



Summary

- The FLYSAFE's forecasts expressed as weather objects show slightly more skill than the manual BUFR SIGWX forecasts.
- Fine tuning of the algorithm to create weather objects could increase skill towards that seen for the gridded forecast from which they are derived.
- Obtaining meaningful results at the moderate and severe thresholds will require a larger sample size.



Met Office



Questions and Answers