Some aspects of Aviation Forecasting at the Met Office

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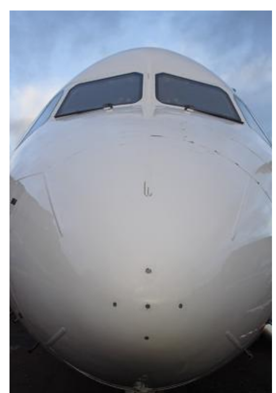
30th September – 03rd October 2013 Antalya, Turkey

Introduction

Purpose of aviation forecasting

- **Safety** - regulated services
- **Economy** of flight - commercial services



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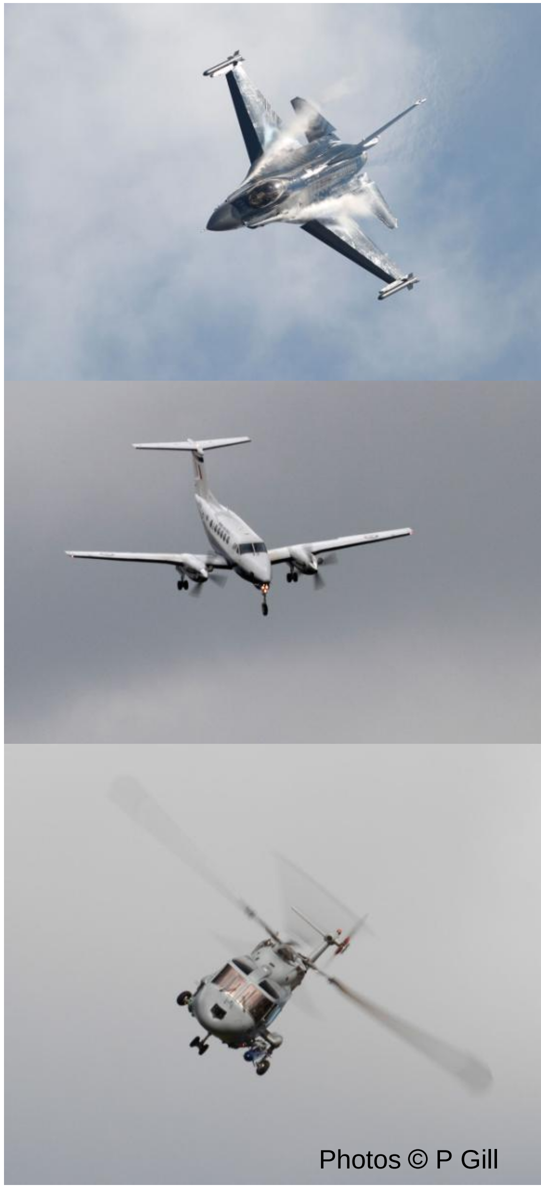
Aviation customers

- Civil aviation authorities
- Defence
- Air traffic control
- Airport authorities
- Airlines
- Flight planning companies



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Met Office

Aviation forecasts

“Snow Chaos”
21 December 2010

“Fog causes massive delays”
21 November 2011

“Ash cloud silences Heathrow skies”
15 April 2010

Terminal area forecasts

- TAFs, visibility, cloudbase, wind, temperature, snow, ice

National & International

- Wind, temperature, pressure (QNH)
- Significant weather – turbulence, Cb, icing
- Tropical cyclones, volcanic ash

Forecast range

- Minutes (eg high resolution wind forecasts for continuous decent approach)
- Hours (eg significant weather)
- Days (eg winds for flight planning, snow)

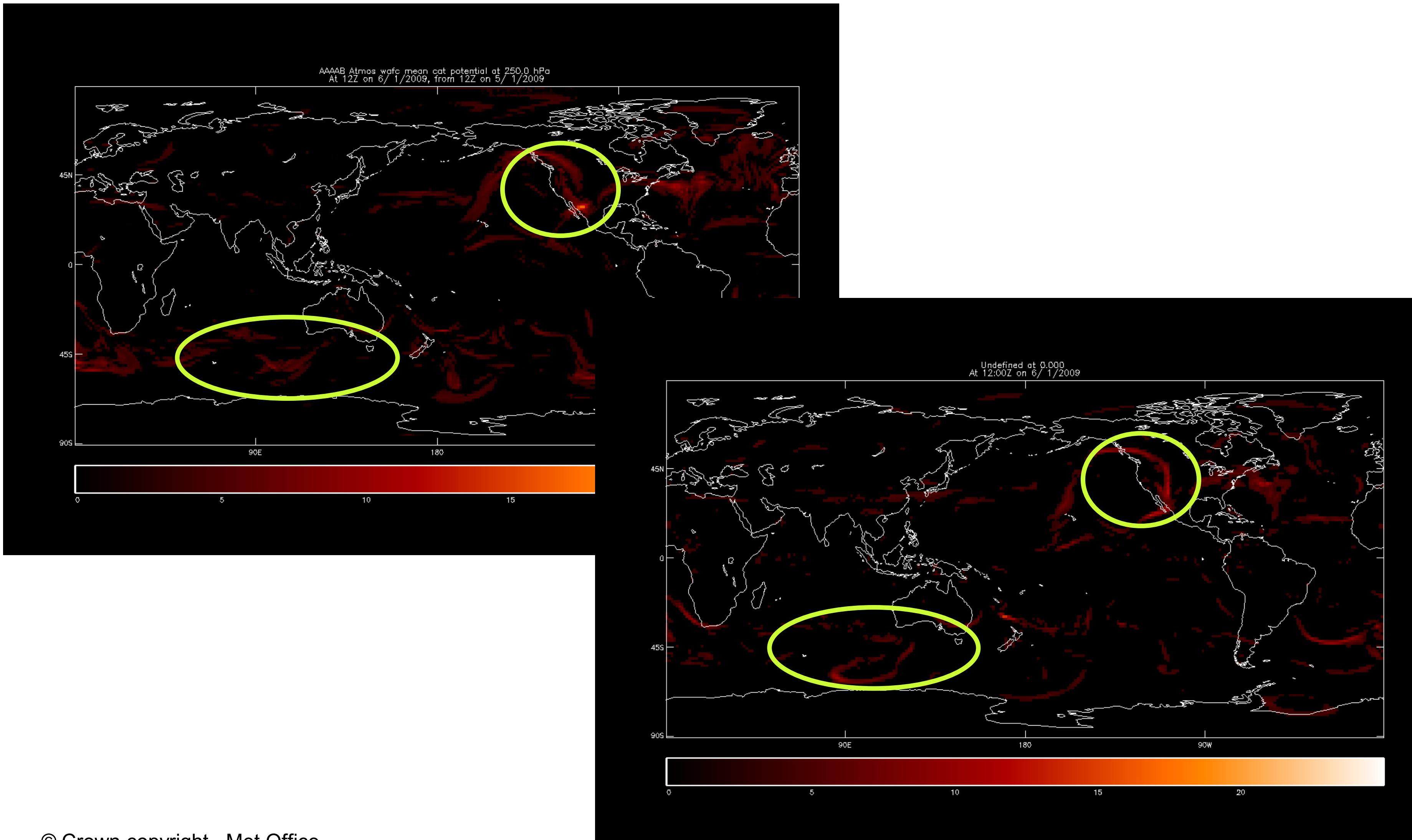
WAFC Blending

Paul Maisey, Met Office, Exeter, 12 October 2011

Background

- Forecasts routinely produced by UK Met Office - World Area Forecast Centre (WAFC) service (along with WAFC Washington, USA)
- Production of gridded hazard forecasts since 2006, covering CAT, Cb, in-cloud turbulence and icing
- Concerns raised around compatibility of US & UK WAFC gridded hazard forecasts, following verification
- To be expected, given basis of different NWP
- Agreement to develop a blended hazard forecast

Example of inconsistency



Methodology

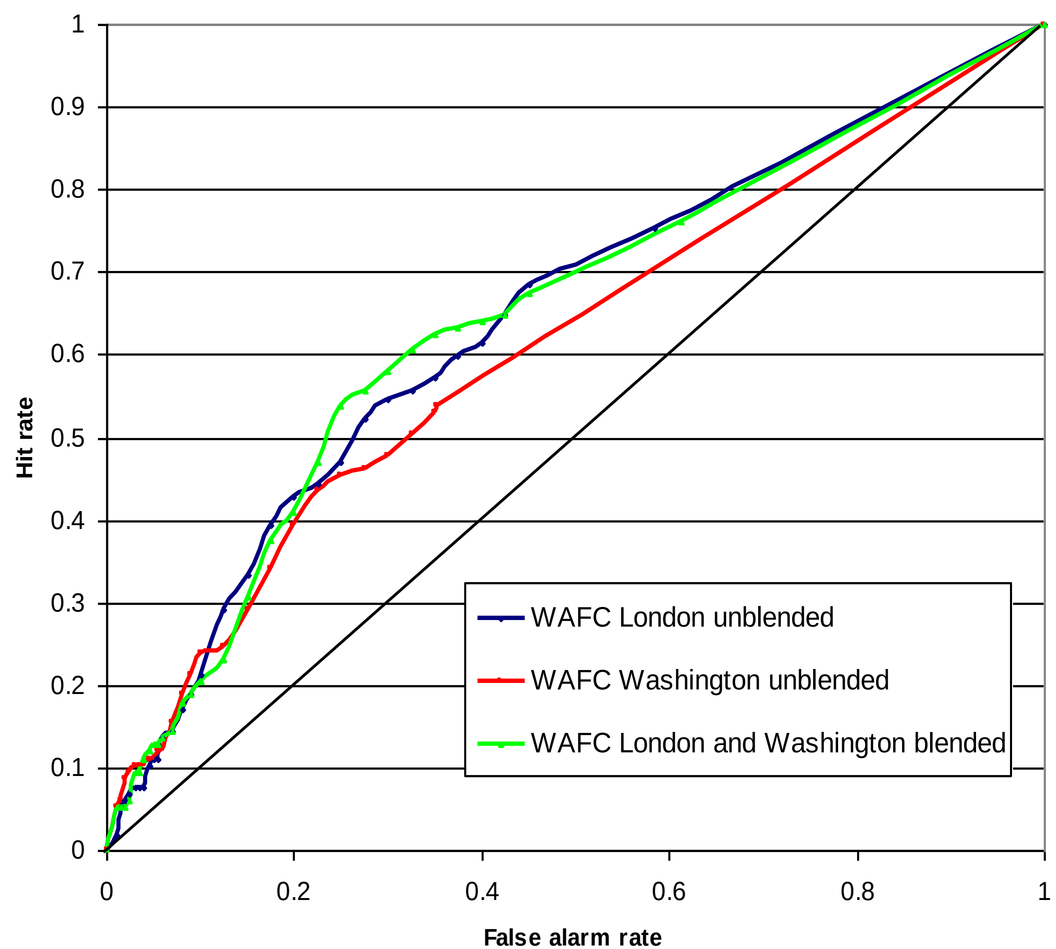
Forecast element	**Blending method between UK & US forecasts**
Mean CAT, icing, ICT, Cb horizontal extent	Arithmetic mean at each gridpoint
Maximum CAT, icing, ICT	Maximum of two forecasts at each gridpoint
Cb cloud base height	Minimum of two forecasts at each gridpoint
Cb cloud top height	Maximum of two forecasts at each gridpoint
Missing data	For one value missing: use available unblended point value For both values missing: set to missing data

Verification of CAT

Comparison of unblended and blended CAT forecasts

Nov 2010-Feb 2011

50N-90N



Turbulence forecasting

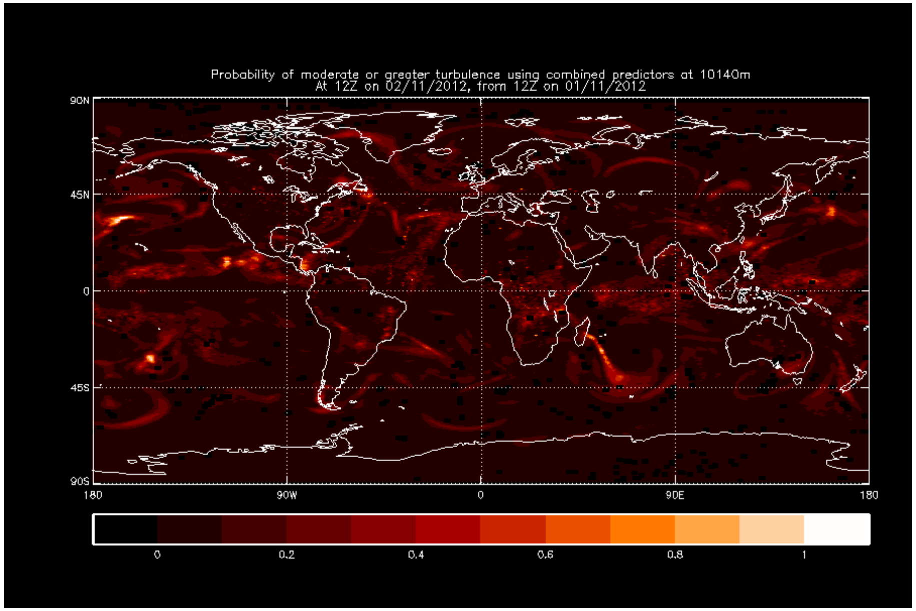
Turbulence predictors

Turbulence can come from different sources – wind shear, convection, (mountain-wave)

- **Windshear related:**
- Ellrod TI1, Ellrod TI2
- Brown
- Dutton
- Lunnon
- **Convection related:**
- Convective rainfall rate
- Convective rainfall accumulation
- **Both wind shear and convection:** Richardson number
- **Turbulence climatology**
  - Gridded field of observed turbulence frequency produced from aircraft observations from previous year
  - Light or greater and moderate or greater turbulence climatology produced

Combining predictors

- Combining turbulence predictors has been shown to increase forecast skill (**Sharman** *et al*, 2006)
- We use weights derived from verification using ROC area
- Predictors combined using a weighted sum



Combined probabilistic predictors

Probabilistic turbulence forecasts from ensemble models and verification

Philip Gill and Piers Buchanan

NCAR Aviation Turbulence Workshop, Boulder, 28 August 2013

Introduction

Met Office

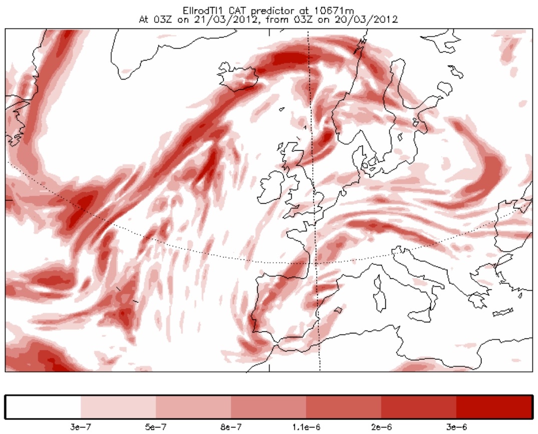
- Turbulence - major cause of aviation incidents & active area of research
- Forecasts routinely produced by UK Met Office - World Area Forecast Centre (WAFC) service (along with WAFC Washington, USA)
- Operational forecasts currently derived from deterministic models
- There is always a degree of uncertainty in deterministic forecasts
- Ensembles are a way of communicating that uncertainty

Photos © P Gill

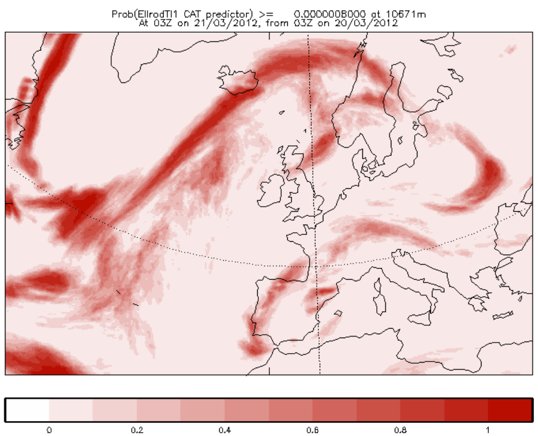
Ensemble Turbulence Forecasts

Deterministic turbulence forecast shows the value of a given turbulence indicator

Ensemble turbulence forecast shows the probability of a turbulence indicator exceeding certain chosen values



Deterministic



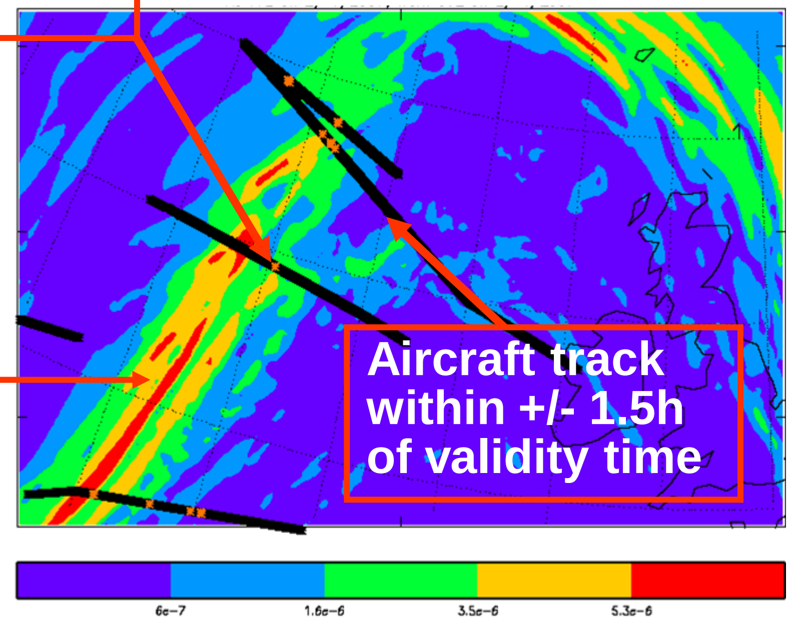
Probabilistic

Ensemble turbulence trial

- **Objective** verification of deterministic and probabilistic model forecasts
- **Global** verification to assess T+24h MOGREPS-G forecasts of turbulence
  - T+24 chosen because this is a typical product time range
- Verification against **automated** aircraft observations from the Global Aircraft Data Set (GADS)
- **12-month** trial from November 2010-October 2011
- **Eight** numerical predictors and climatology verified
- **Five** thresholds used on each predictor to generate probability forecasts
  - Thresholds designed to cover light to moderate to severe turbulence

Verification methodology

- Turbulent/non turbulent event defined on **10min aircraft track** ~120km - approx grid size of WAFC grid
- **Deterministic:** Forecast turbulent event – CAT potential >= Threshold
- **Ensemble:** Probability of exceeding a certain threshold for given turbulence indicator
- Observed (moderate or greater) turbulent event - **DEVG>=4.5m/s**
- Derived Equivalent Vertical Gust (DEVG) – Measurement of observed turbulence derived from **vertical acceleration**, **aircraft mass, altitude and airspeed**
- Construct 2x2 contingency tables for each threshold

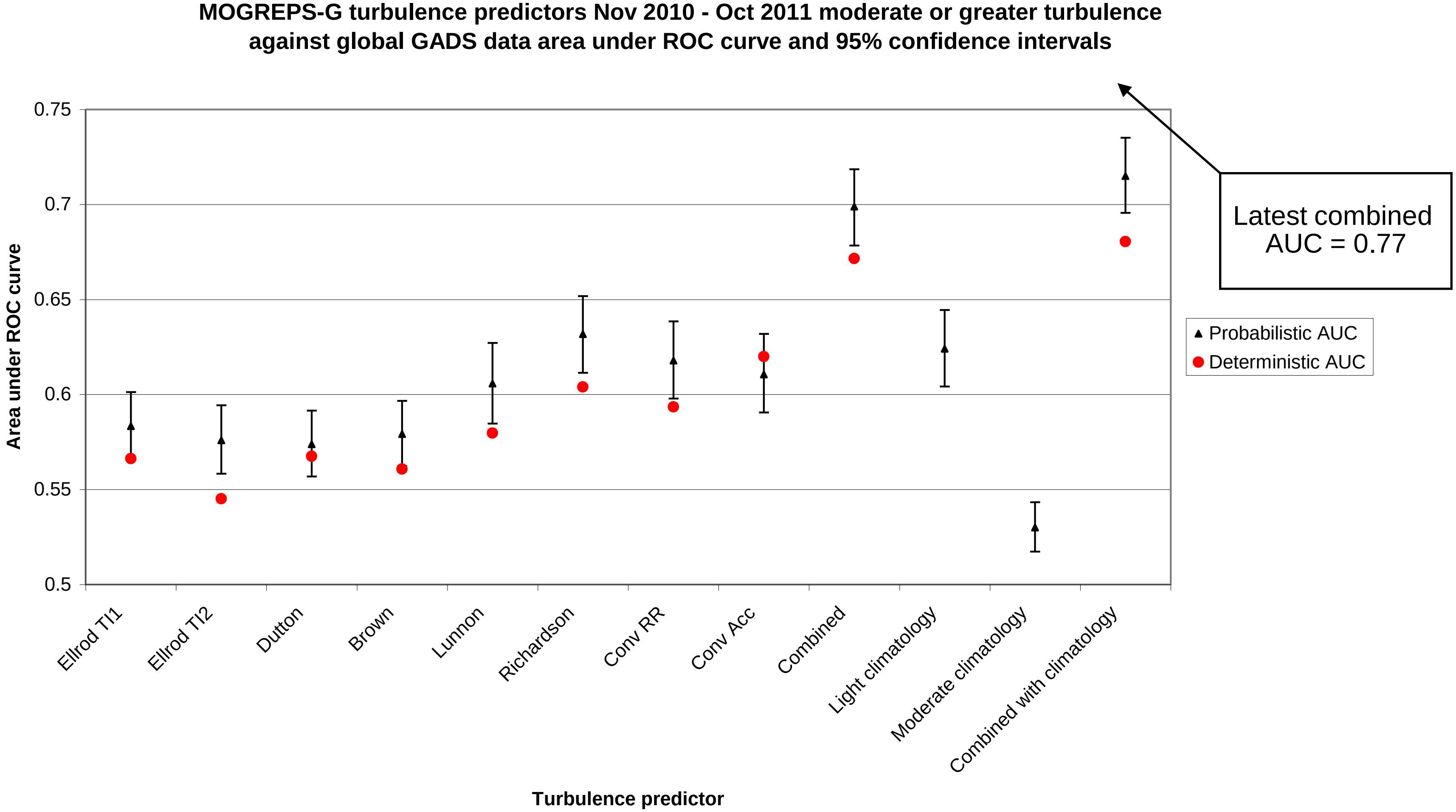


Ellrod TI1

	Turbulence observed	No turbulence observed
Turbulence forecast	Hit	False alarm
No turbulence forecast	Miss	Correct rejection

2x2 contingency table

ROC area for each predictor

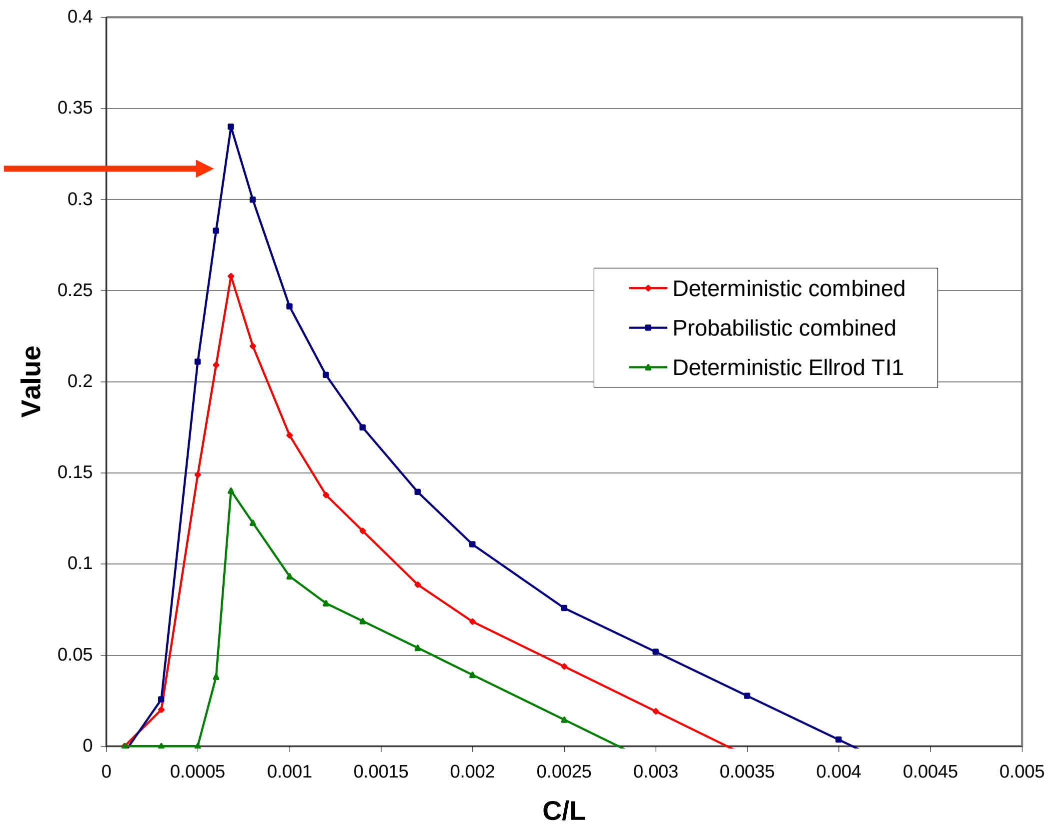


Gill PG, Buchanan P. 2013. “An ensemble based turbulence forecasting system”, *Meteorological Applications*

Ensemble turbulence verification – Relative economic value

Cost-loss relative economic value plot comparing MOGREPS-G probabilistic and deterministic global turbulence forecasts 201011-201110

Greater value combining probabilistic forecasts



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Optimum Routes

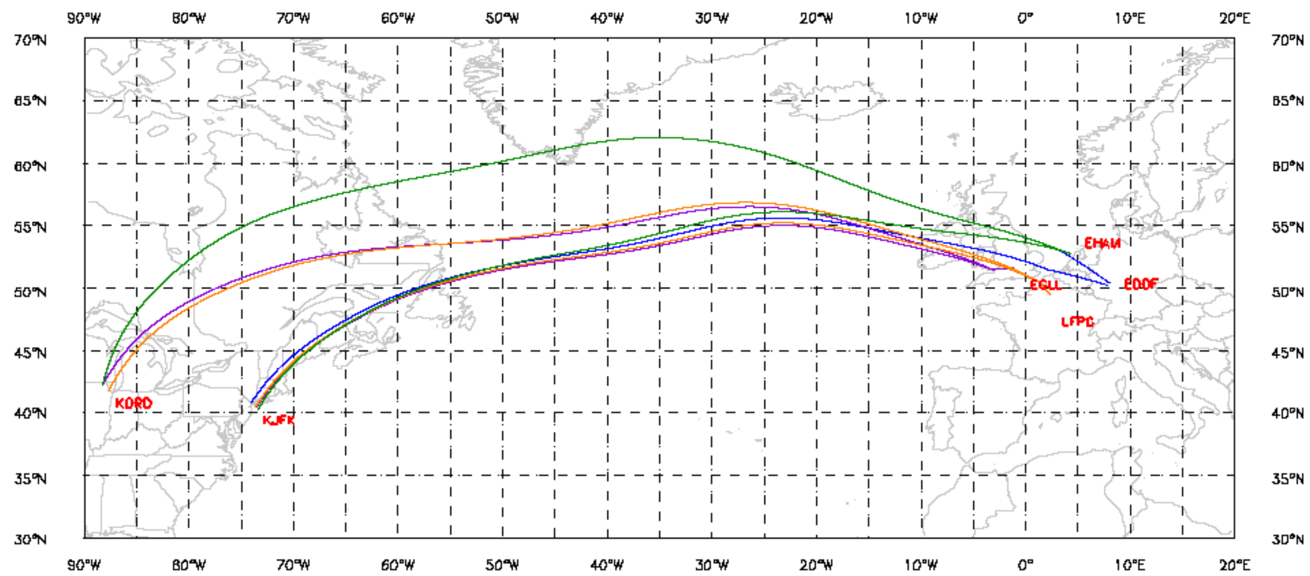
Optimum route service for NATS

Met Office

- **Calculates optimum routes for aircraft between Europe and the US (westbound & eastbound) using forecast winds**
- **Forecasts produced daily, for up to 5 days ahead**
- **Customer uses the information to predict which airspace sectors will be busiest and to plan staffing levels for each sector accordingly**

e.g. Westbound plot

for 17/05/2008



Continuous Descent Approach

Use of Met Office forecasts to aid continuous descent approach

Dr Philip G Gill, Met Office Exeter

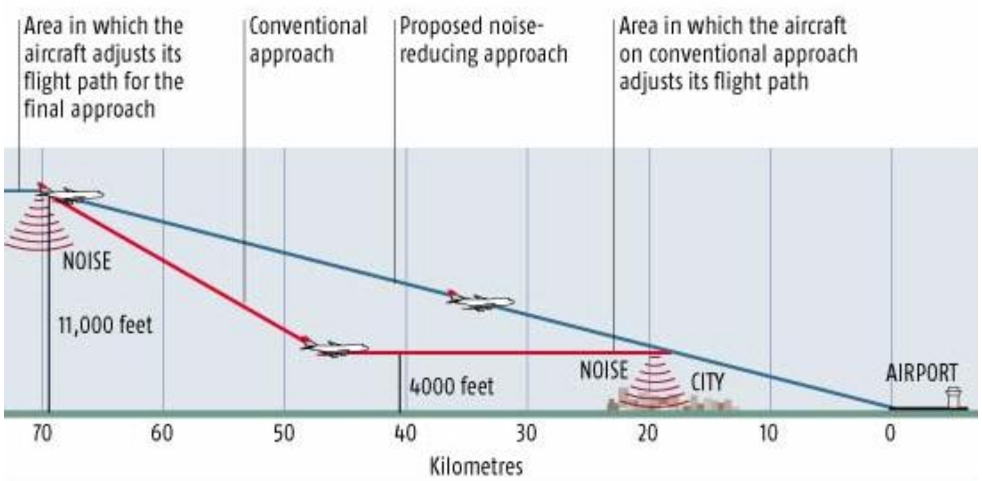
Met Office

Continuous descent approach

• Normally a stepped descent is used into busy airports joining stacks at different levels.

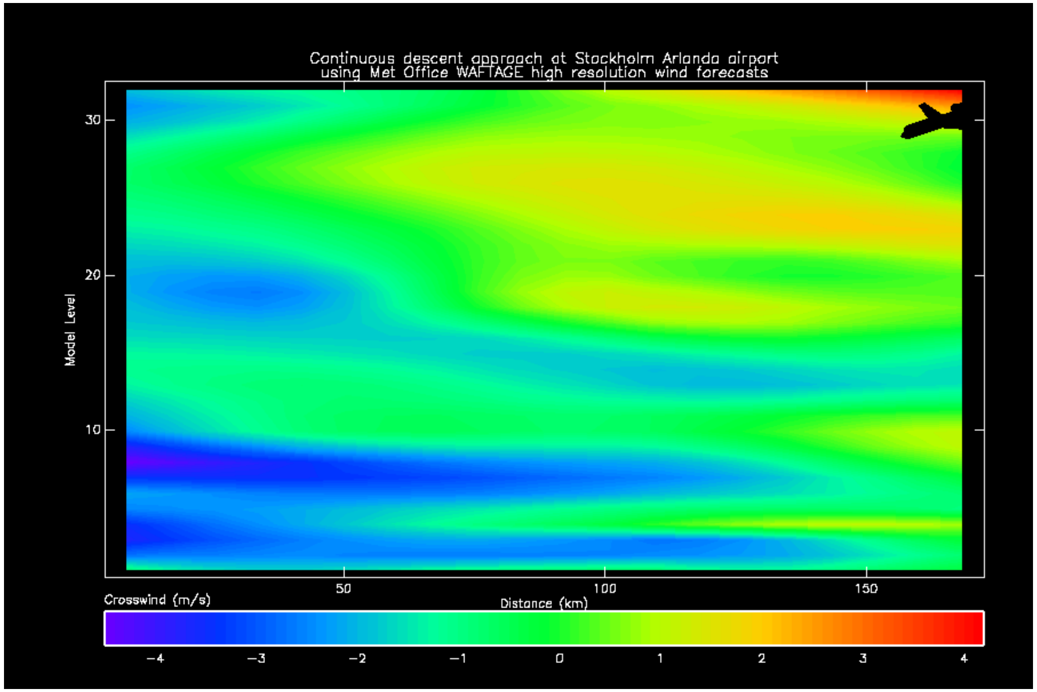
• For CDA manoeuvres are carried out at high altitude and then a steady angle of descent is maintained with minimal corrections.

• For successful CDA accurate forecasts of vector wind are required at all levels of descent.



Benefits of CDA

- **Greener** - Reduction in emissions of CO_2 and other pollutants.
  - Lower noise levels on the ground over a smaller area
- **Safer** - Less chance of encountering wake vortices
- **Cheaper** - Reduced fuel consumption



Benefits from trials

- Trial service since December 2007 at Arlanda airport, Stockholm.
- 240,000kg fuel saved
- 2,300kg NOx reduced
- 756,000kg CO_2 reduced
- Noise reduced by 50% (65db exposure area)
- Arrival time at runway threshold within 15 seconds

SESAR

SESAR

- The Met Office is involved in SESAR (Single European Skies ATM [Air Traffic Management] Research, a major EU project designed to make more efficient use of European airspace while maintaining safety as the priority.
- The aims are to reduce costs (e.g. fuel) and emissions through more efficient flight routing.
- The Met Office is a partner with other NMSs as part of a consortium.
- SESAR will research improvements to all phases of flight, such as the CDA for airport arrivals and en-route flight planning that have been discussed in earlier slides, as well as management of the wider airspace network.

Questions?