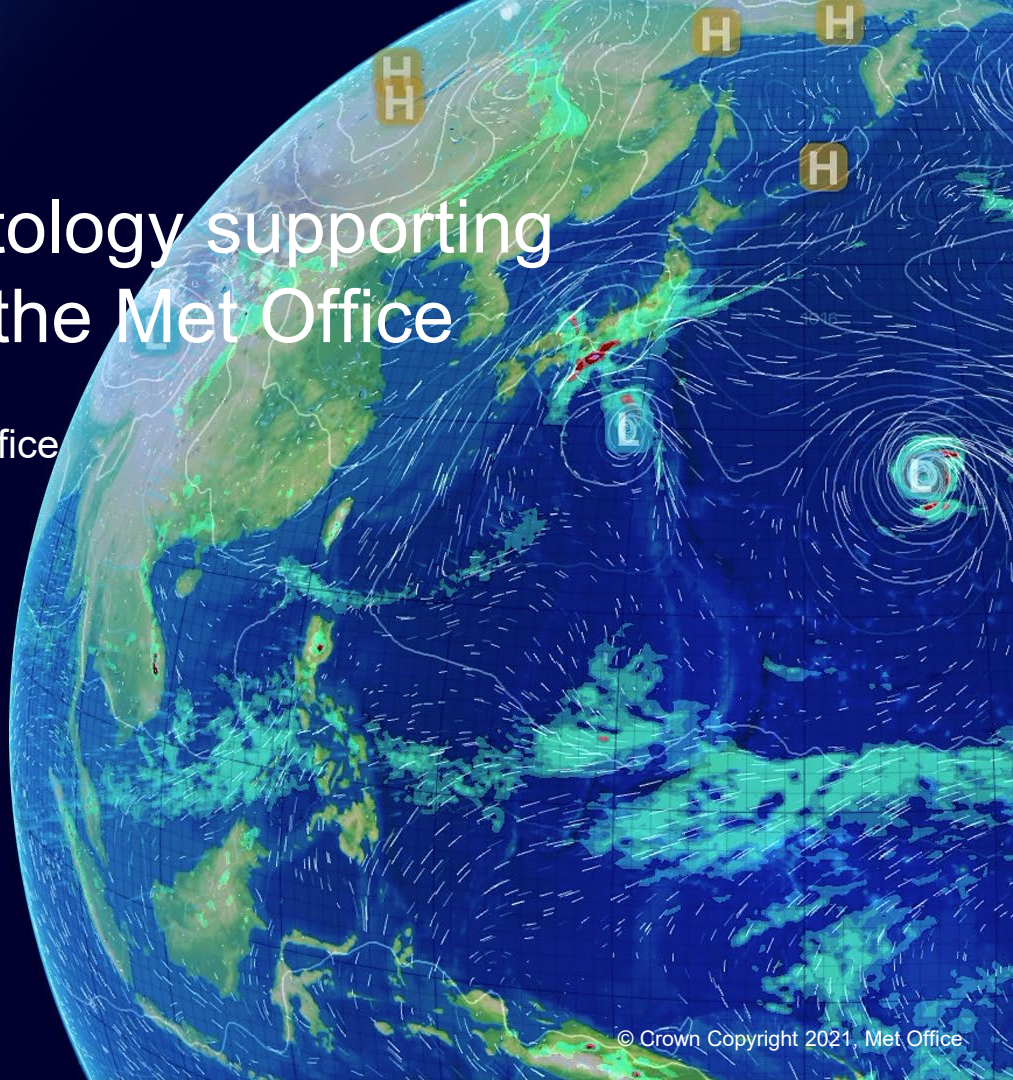


# A global turbulence climatology supporting turbulence forecasting at the Met Office

Debi Turp, Phil Gill and Piers Buchanan, Met Office



# Global aviation turbulence at the Met Office

Piers Buchanan



# Background

The World Area Forecast System (WAFS) provides seamless global forecasting of upper air winds, temperatures and significant weather hazards to enhance safety and identify potential for delays.

Provided by WAFC London (Met Office) and WAFC Washington (NOAA)

Forecasts currently produced both by forecasters – Significant Weather Chart (SIGWX) and from gridded model output.

In the period from 2020 to 2026 there are several stages of major upgrades to the service to make sure it's ready for the next generation of aviation.

# Hazards Improvements Timeline

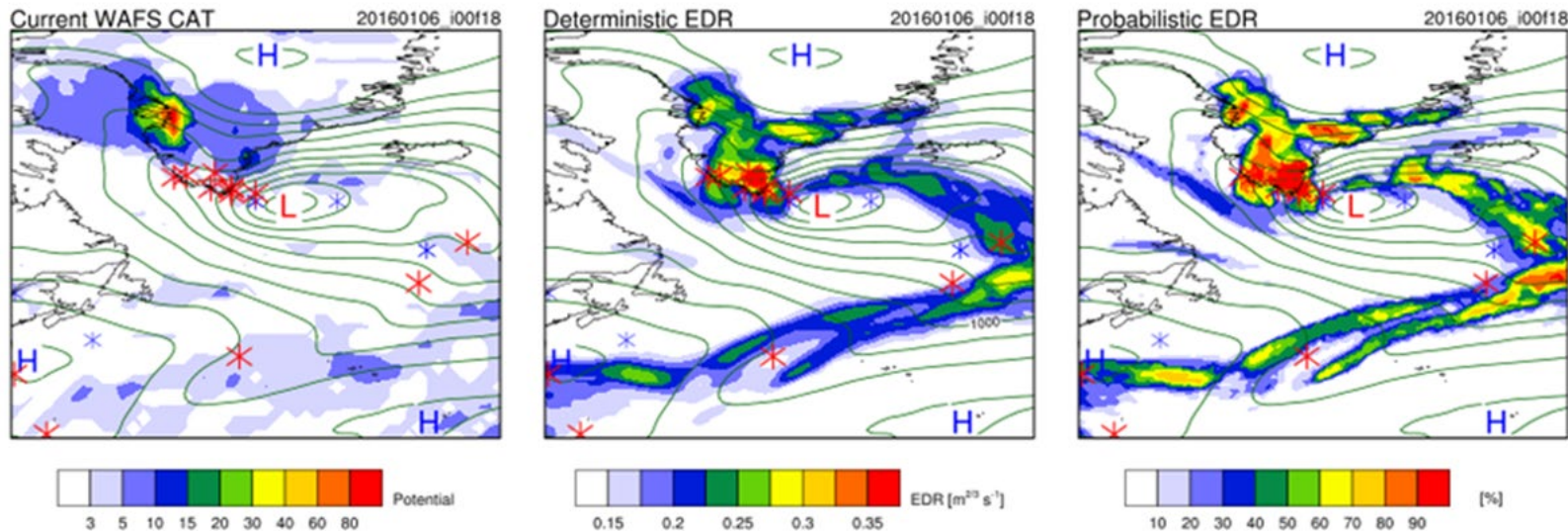
~~2020: 0.25 degrees high res hazard files available in real time to customers.~~

2023 Extra timesteps and levels available to customers in realtime

2026 Prototype probabilistic WAFS hazard output available in realtime.



# Turbulence past, present and future



Kim, Sharman, Strahan, Scheck, Bartholomew, Cheung, Buchanan and Gait: 'Improvements in Non-Convective Aviation Turbulence Prediction for the World Area Forecast System (WAFS)', BAMS, 2018.

# Towards Probabilistic WAFS

- **Useful**

- It presents something the user understands *and wants*\*.

\*or at least wants when they become aware of the product's existence and how they might use it.

- **Usable**

- Does it integrate with the decision making process the user is following?
  - Does it integrate with other products / data (possibly non weather) that the user is using?

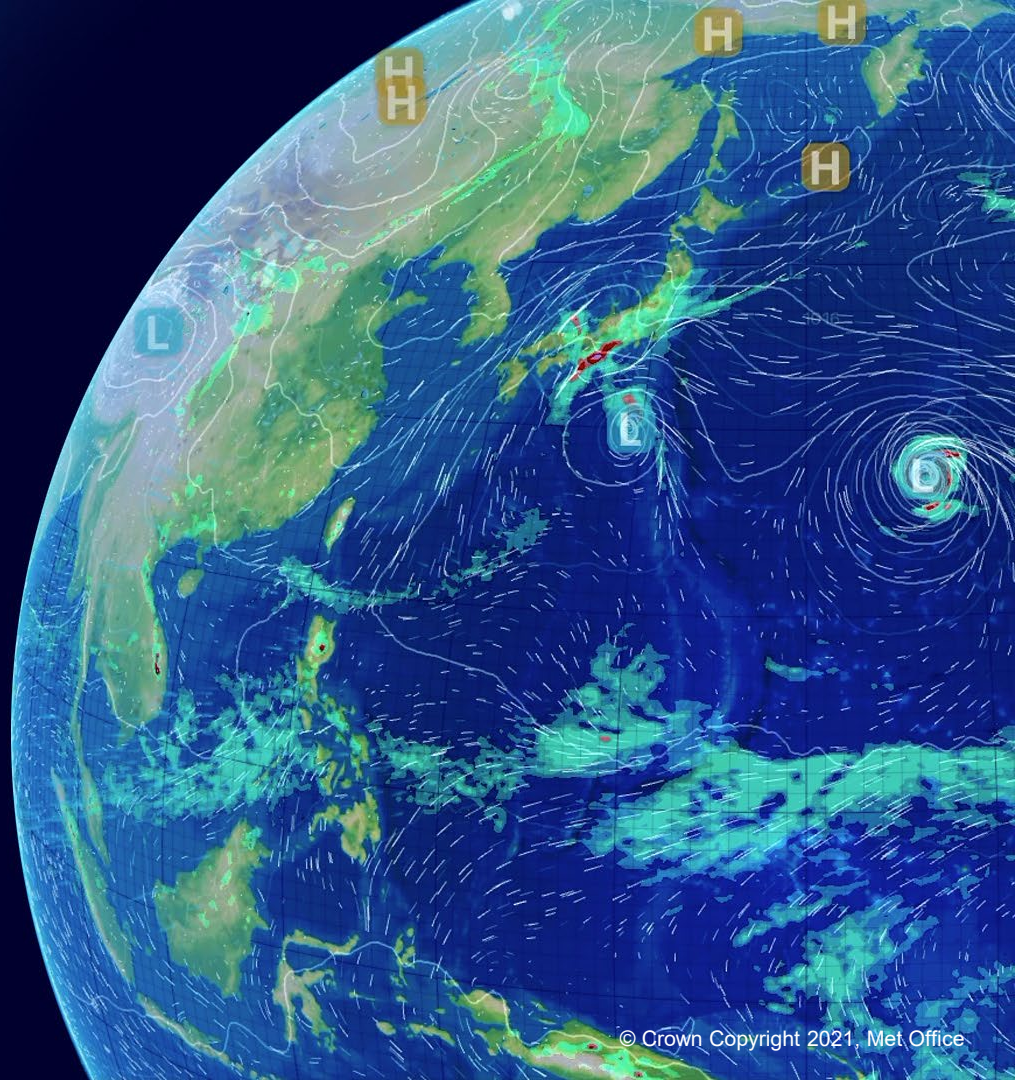
- **Used**

- Does it run reliably from a technical point of view (hopefully yes but this issue applies to a lot of trial products)
  - Does it produce a product available at an appropriate time?
  - Does it give the user a better outcome than with what they currently already use?
    - For example, when the user looks back over say a year of using it has it been more 'reliable' than their current set up.

# Turbulence climatology

Debi Turp, Met Office

8<sup>th</sup> November 2021



## Global Aircraft Data Set (GADS):

Vertical acceleration measurements

January 2008 - March 2020

## Delta Airways dataset:

Eddy Dissipation Rate measurements

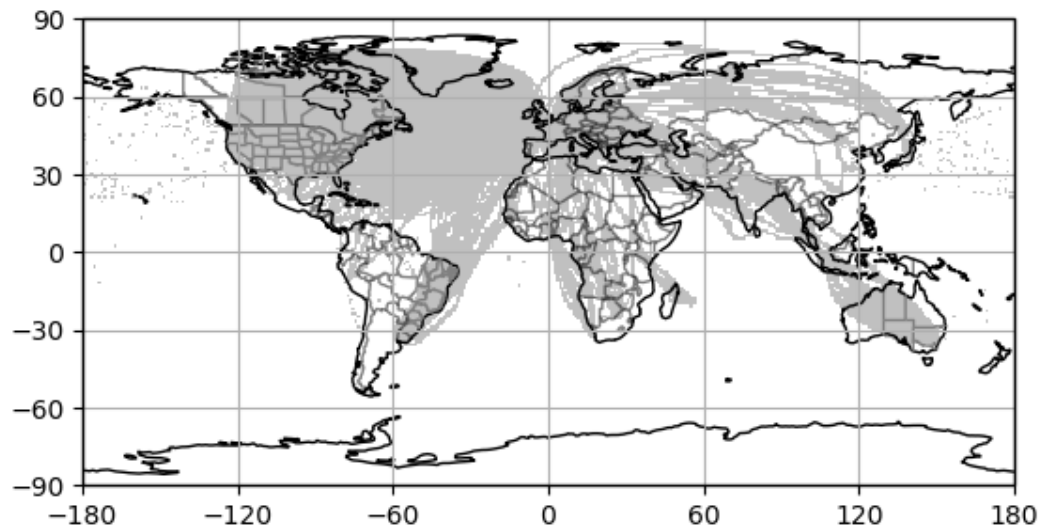
January 2009 - March 2020

Available from MADIS website:

<https://madis-data.blr.ncep.noaa.gov/>

## Cruise level data (>28,000ft)

## Observations of moderate or greater (MOG) turbulence

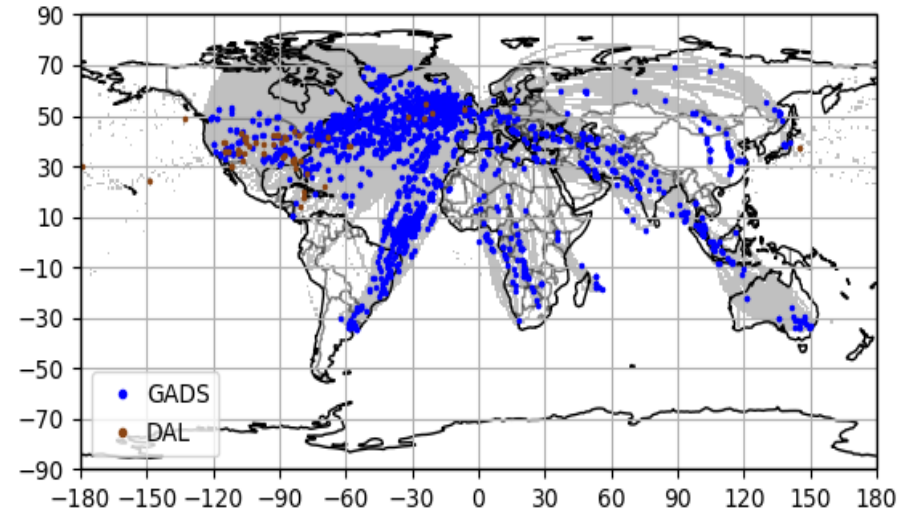


 Data coverage

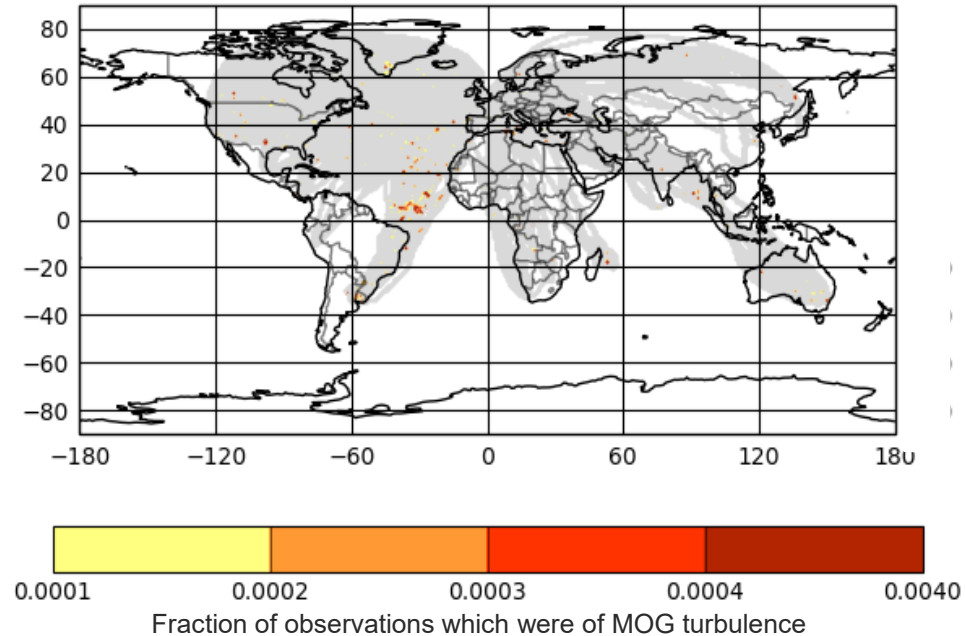


# Met Office Turbulence climatology: December

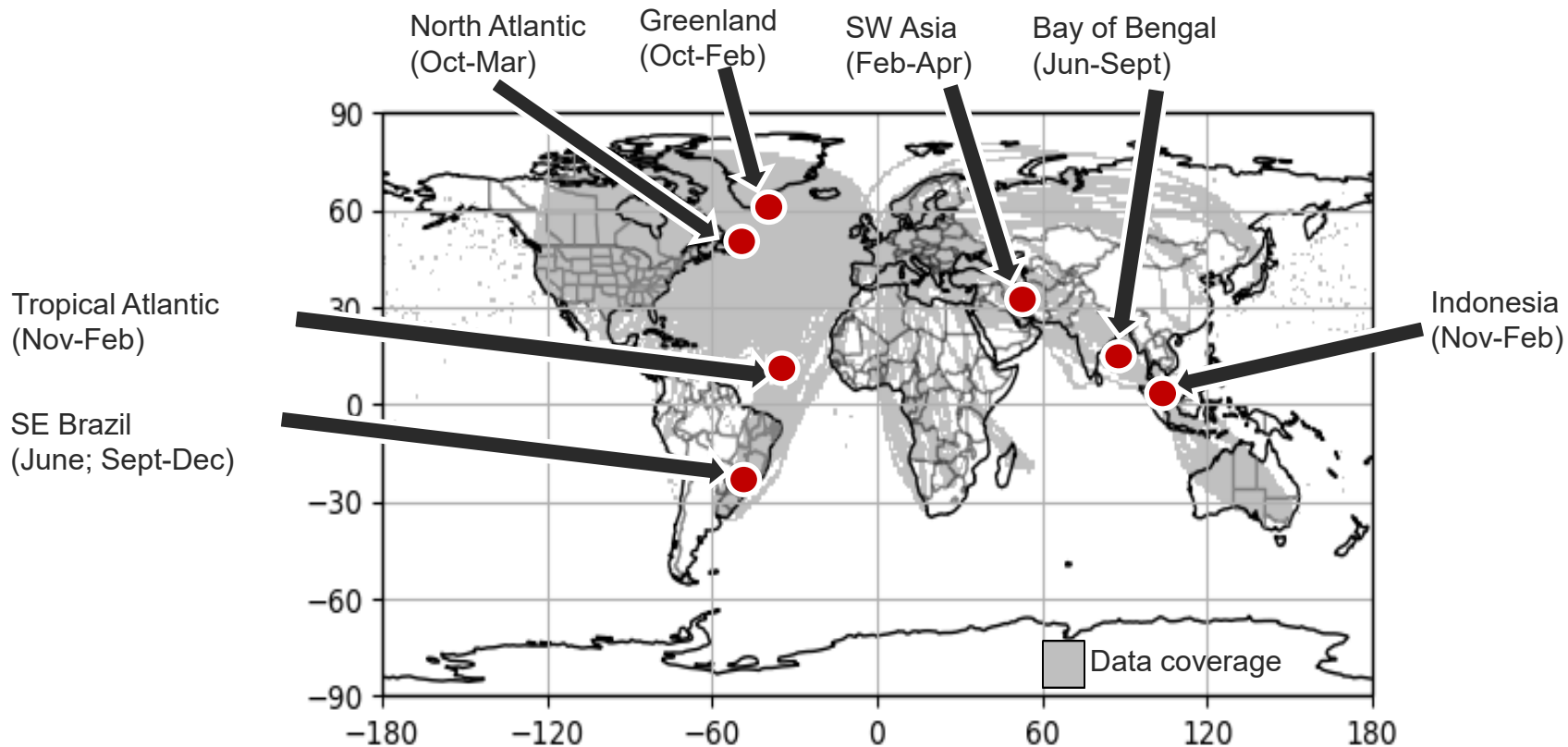
Climatological MOG turbulence observations, December



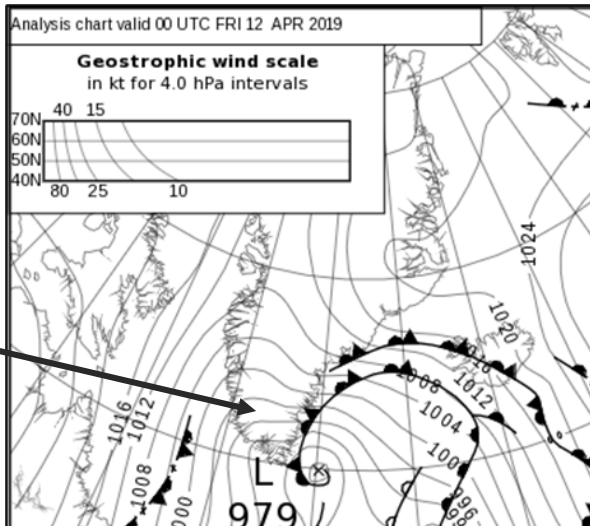
Climatic frequency of MOG turbulence, December



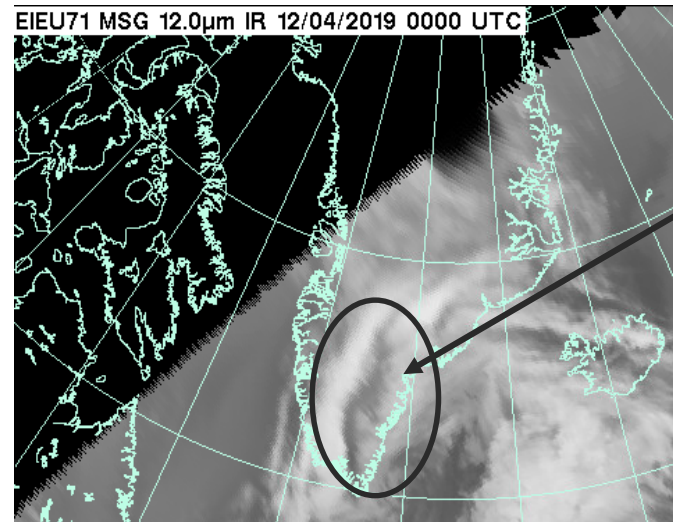
## Features of the climatology: Regions with significant turbulence



# Met Office Turbulence climatology over Greenland

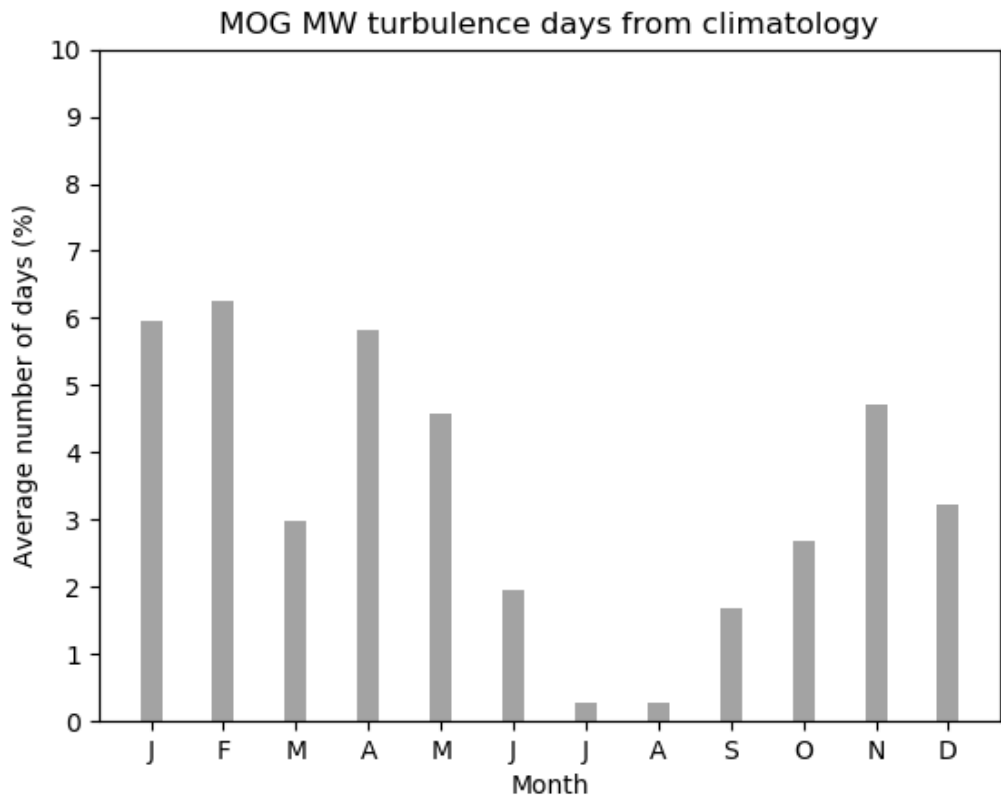


Easterly low level flow favourable for mountain wave activity (following Lane et al, 2009)



Tear in cloud cover indicating mountain wave activity

Lane et al. 2009: Statistics and dynamics of aircraft encounters of turbulence over Greenland. Mon. Wea. Rev. 137, 2687-2702





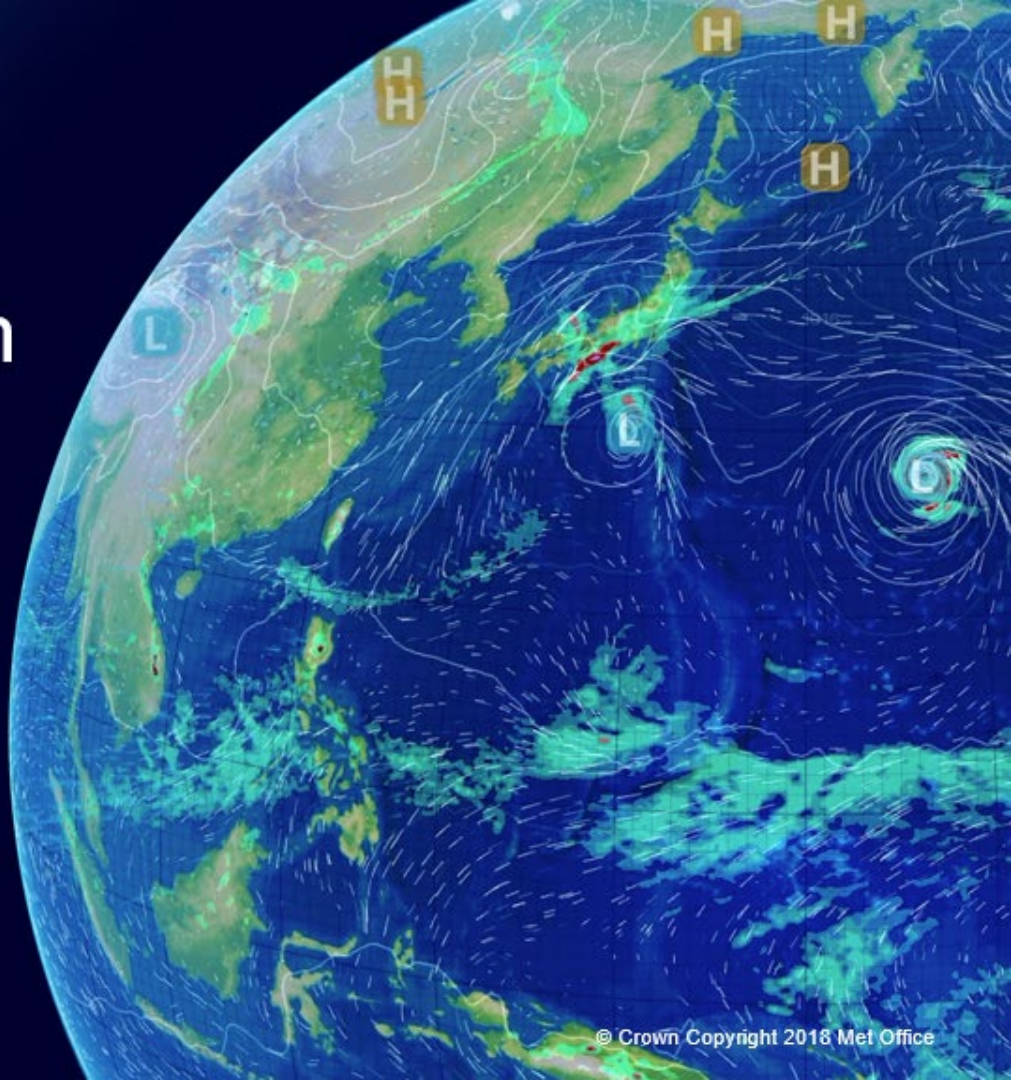
- Global turbulence climatology constructed from over 10 years of aircraft obs
- Highlights areas with significant turbulence
- Shows turbulence pattern around globe
- Useful for verification and further research
- New source(s) of observations required to extend climatology

# Turbulence verification

Philip Gill, Robert Coulson, Graeme  
Anderson

Met Office

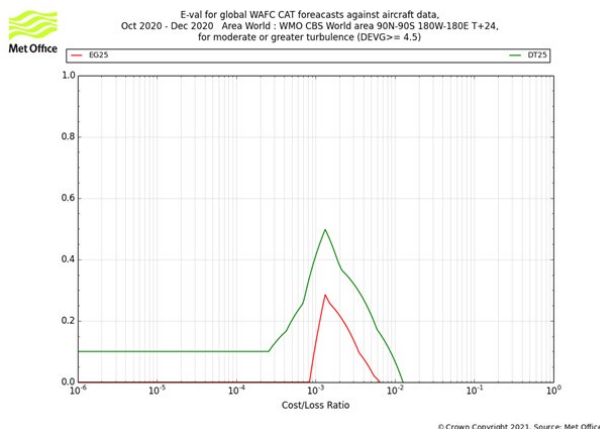
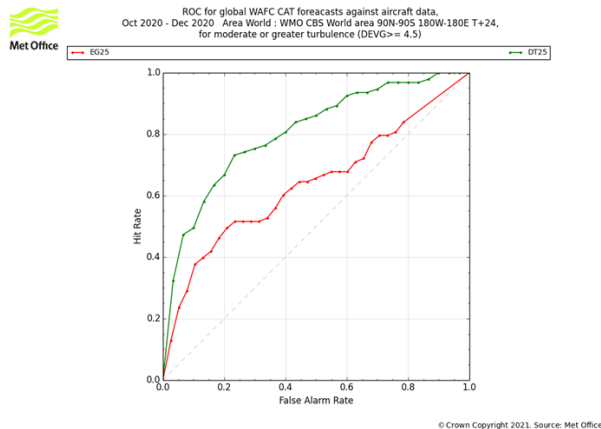
8<sup>th</sup> November 2021



# Introduction

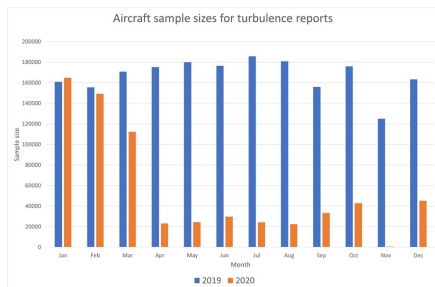
Comparison of the operational 1.25 deg and new 0.25 deg WAFS  
turbulence forecasts

Verification of automated SigWx guidance products



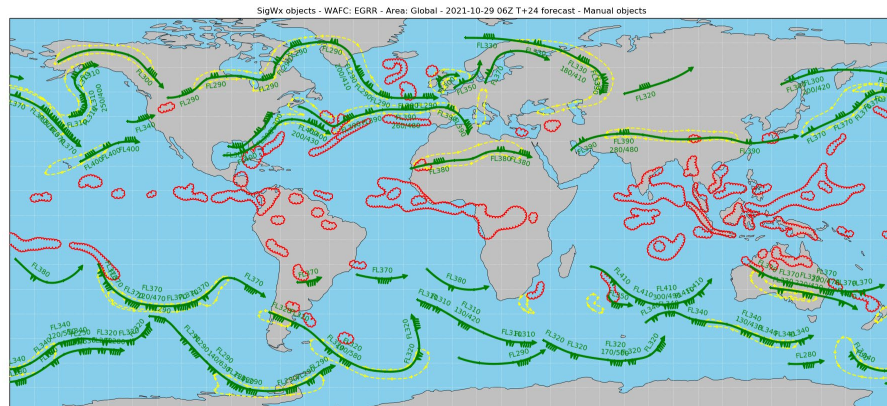
Verification of moderate or greater turbulence events using aircraft observations for Global area from Oct 2020 to Dec 2020

Significant improvements to skill and value from the 0.25 deg GTG turbulence forecasts (green) compared to the operational WAFc London forecast at 1.25 deg (red). However:



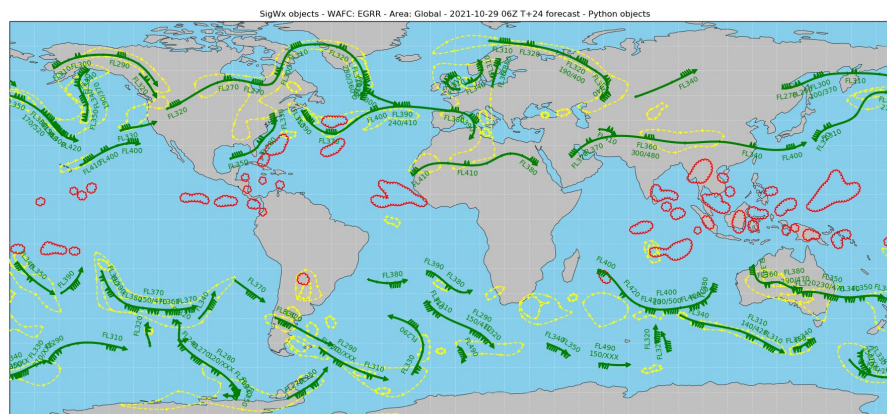
- 2020 saw a dramatic reduction in aircraft turbulence observations making turbulence verification less robust
- Likely GTG brings most of the benefit
- Further studies changing resolution alone required to determine resolution benefit





## Manual SigWx objects

- Based on forecaster produced charts
- Charts produced by both WAFCs

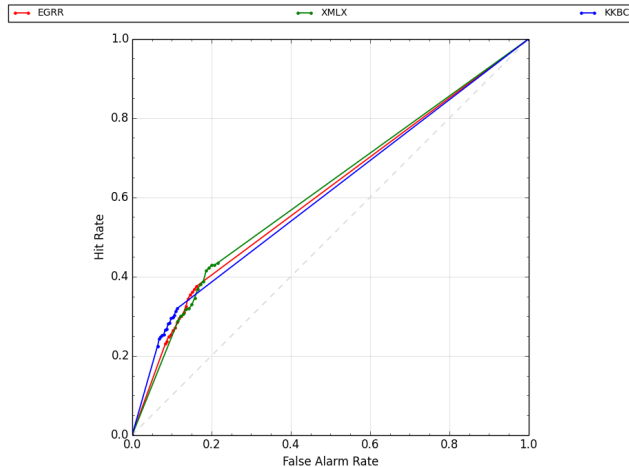


## Automated SigWx objects

- Automated object to assist with SigWx production
- Turbulence areas in yellow (Cb, Icing, jets and tropopause also produced)
- Based on WAFS gridded forecasts



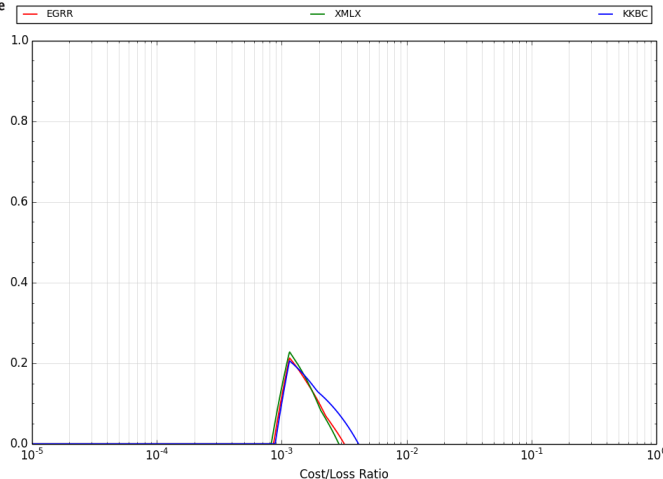
ROC for global WAFC CAT forecasts against aircraft data,  
Mar 2020 - Feb 2021 Area World : WMO CBS World area 90N-90S 180W-180E T+24,  
for moderate or greater turbulence (DEVG  $\geq$  4.5)



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E-val for global WAFC CAT forecasts against aircraft data,  
Mar 2020 - Feb 2021 Area World : WMO CBS World area 90N-90S 180W-180E T+24,  
for moderate or greater turbulence (DEVG  $\geq$  4.5)



© Crown Copyright 2021. Source: Met Office

- Guidance is reasonable although varies by area
- On the whole tends to slightly higher false alarm rates



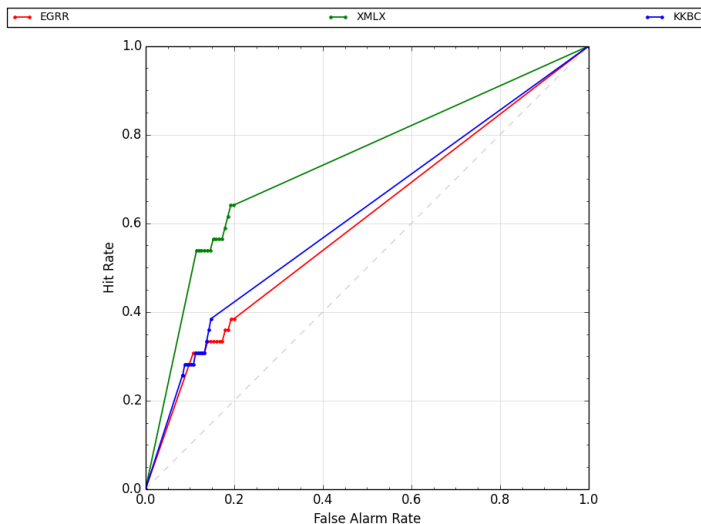
Met Office

# SigWx guidance products – New version



Met Office

ROC for global WAFC CAT forecasts against aircraft data,  
Jan 2021 - Feb 2021 Area World : WMO CBS World area 90N-90S 180W-180E T+24,  
for moderate or greater turbulence (DEVG  $\geq 4.5$ )

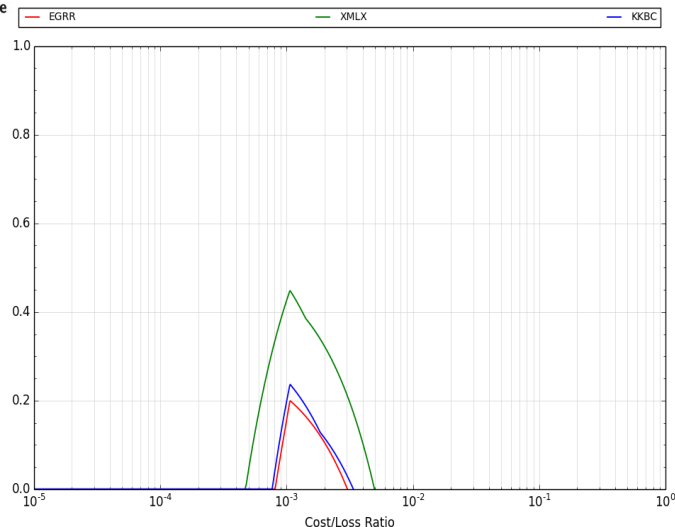


© Crown Copyright 2021. Source: Met Office



Met Office

E-val for global WAFC CAT forecasts against aircraft data,  
Jan 2021 - Feb 2021 Area World : WMO CBS World area 90N-90S 180W-180E T+24,  
for moderate or greater turbulence (DEVG  $\geq 4.5$ )



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- SigWx performs well and overall has greater skill and value than UK and US forecasters
- SigWx does tend to have slightly higher false alarm rates but hit rates also substantially higher
- May benefit from a moderate calibration to reduce forecasting areas
- **Should be cautious as only two months but definitely promising**

# Summary and further work

WAFS Turbulence at 0.25 deg with GTG shows significant improvements

Assessment at 0.25 deg may not be the most appropriate way – how are users likely to use the gridded data?

- Interpolation from 0.25 deg grid to aircraft flight paths – may not realise benefits due to increased displacement errors at high resolution
- Further post processing before use to make the most of the increased resolution – worth investigating and possibly implementing by WAFS?

The observations for turbulence stopped at the end of Feb 2021, alternatives need to be sourced to continue verifying WAFS turbulence forecasts