METEOROLOGY PANEL

Improvements to the World Area Forecast System (WAFS) – Nov 2020

Presented by Karen Shorey – SADIS and WAFS manager, UK Met Office.

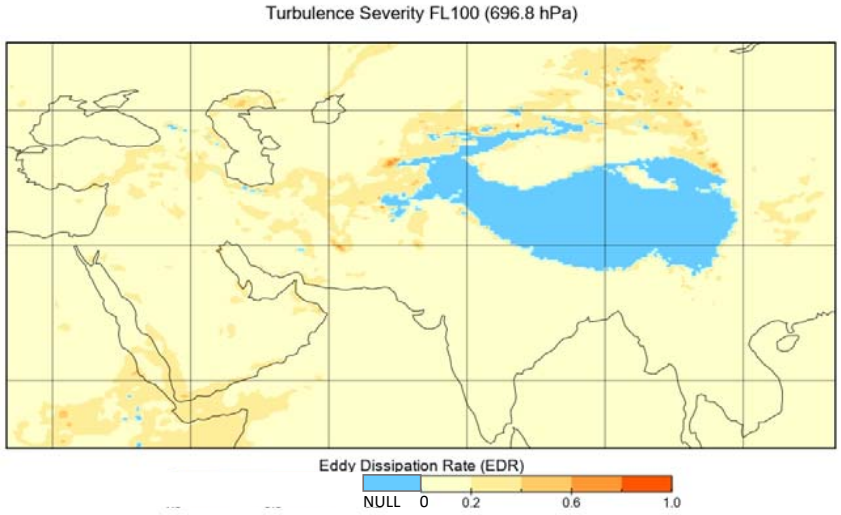
- The World Area Forecast System (WAFS) provides global gridded model forecasts of wind, temperature, relative humidity, turbulence, icing and cumulonimbus cloud.
- In November 2020 the turbulence, icing and cumulonimbus fields was upgraded as part of Amendment 79 to ICAO Annex 3 – *Meteorological Service for International Air Navigation*

OLD	NEW
1.25 degree Turbulence Potential (CAT) – mean and max	**0.25 degree Turbulence Severity**
1.25 degree Icing Potential – mean and max	**0.25 degree Icing Severity**
1.25 degree Cumulonimbus extent, base and top	**0.25 degree Cumulonimbus extent, base and top**
~~1.25 degree in-cloud-turbulence – mean and max~~	

Note: In-cloud turbulence was retired in March 2021.

CHANGES TO THE DATA

- Both icing severity, and turbulence severity data are be produced using exact pressure levels
- For example FL100 is calculated using data for 696.8hPa and not 700hPa. This is in preparation for future changes where icing data will be provided at 1000ft intervals.
- Where the flight level is below the ground surface, a “null” value will be given. In the raw data this will be a negative value.



In this example the Himalayas are higher than FL100, and are shown in blue. No turbulence severity value is forecast

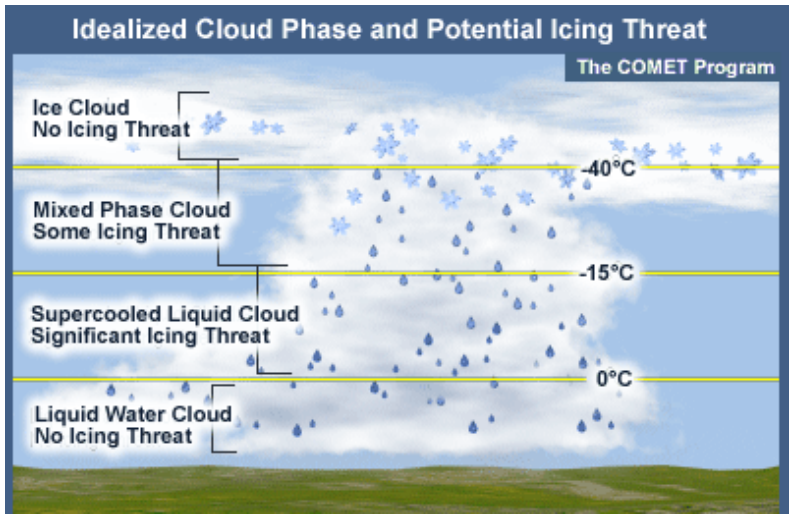
OTHER CHANGES TO THE DATA

- The Old 1.25 Icing and Clear Air Turbulence Potential fields were provided as an icing mean (average) and icing maximum field.
- Information on how these were calculated can be found here: https://www.icao.int/airnavigation/METP/Pages/Public-Documents.aspx in the “Training on WAFS grid point forecasts for CB, icing and turbulence

- The new 0.25 degree data is much closer to the underlying model resolution used by WAFC London and WAFC Washington, therefore a single deterministic field is provided.

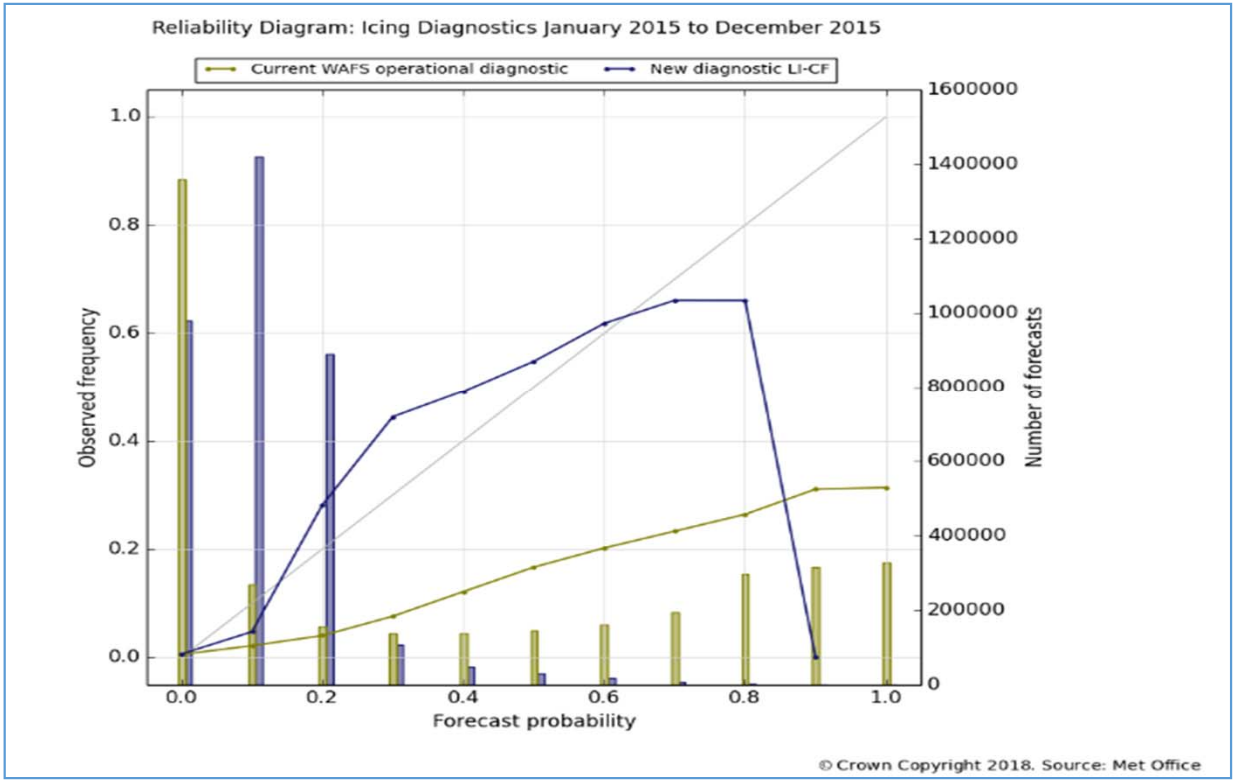
ICING SEVERITY

- Severity of airframe icing is dependent on temperature, liquid water content, droplet size, and vertical motion
- WAFC London has improved the algorithms used in the calculation of icing in order to produce more realistic forecasts, and a wider range of meteorological parameters are now used in its calculation.
- Icing severity is calibrated through verification using various aircraft observations (including PIREPS) to create a statistically weighted combination of meteorological variables.



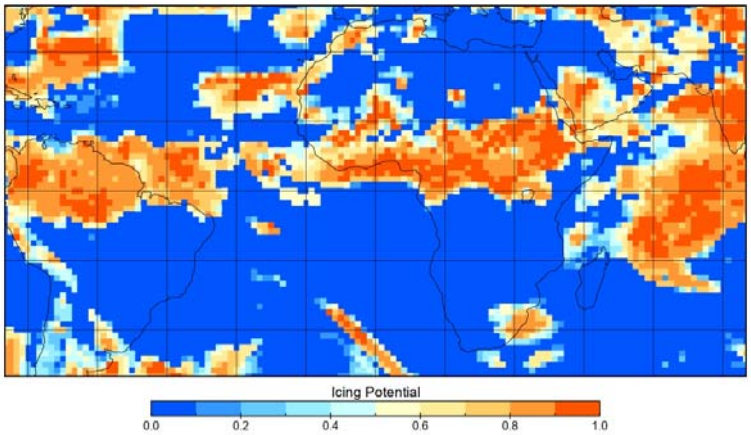
IMPORTANT NOTE: Within the GRIB 2 coding, a new parameter number "37" is used. This is was added to the WMO No. 306 FM-92 GRIB code form in May 2020 into code table 4.2-0-19

ICING SEVERITY DATA

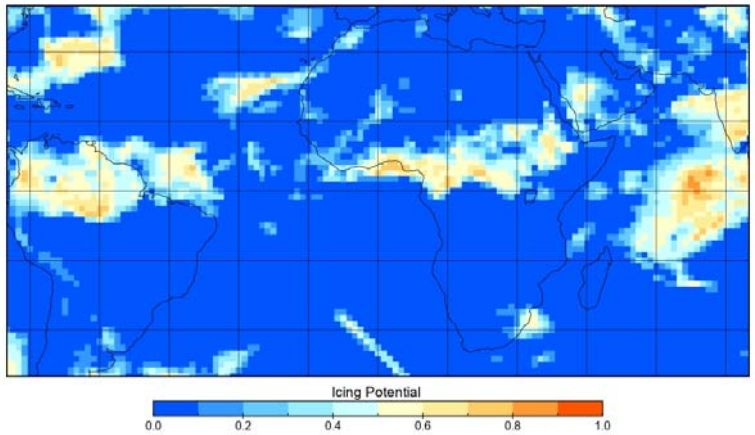


The reliability diagram assesses how well the predicted icing potentials correspond to their observed potential frequencies.
Perfect reliability is line along the grey diagonal line.
The new diagnostic (blue line) shows an improvement in the reliability of the icing forecasts with more correct forecasts of low icing potential and fewer incorrect forecasts of high icing potential.

MAX

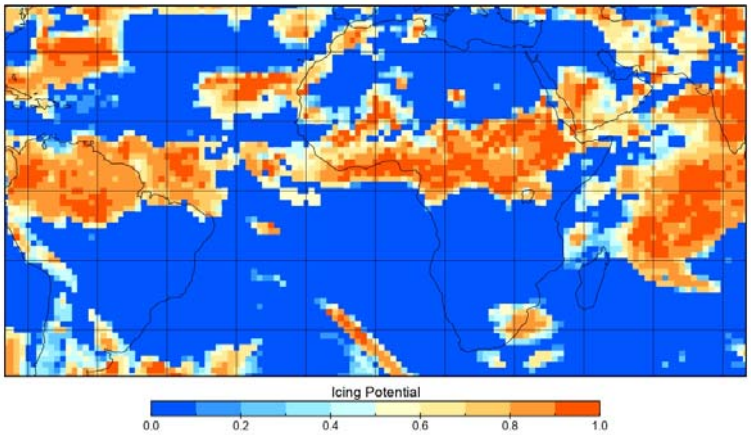


MEAN

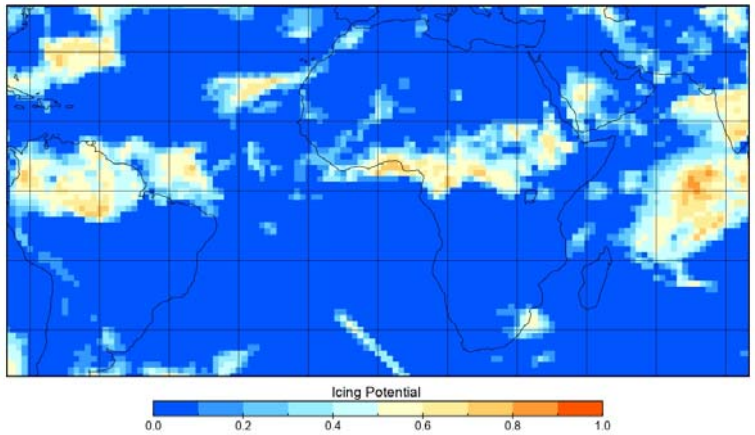


← Old 1.25 Icing Potential fields

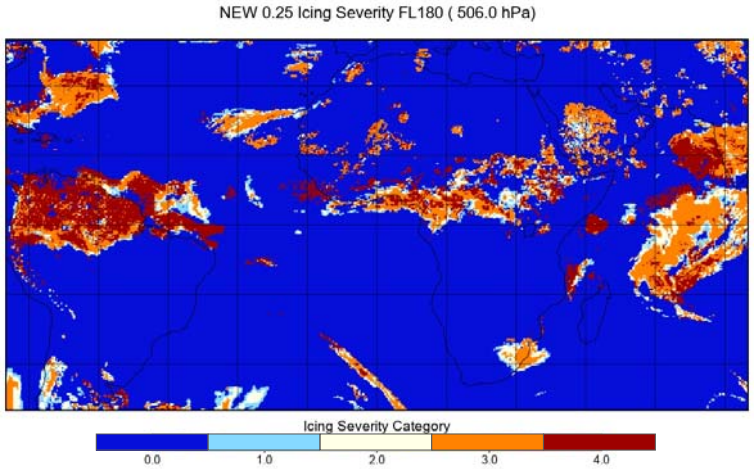
MAX



MEAN



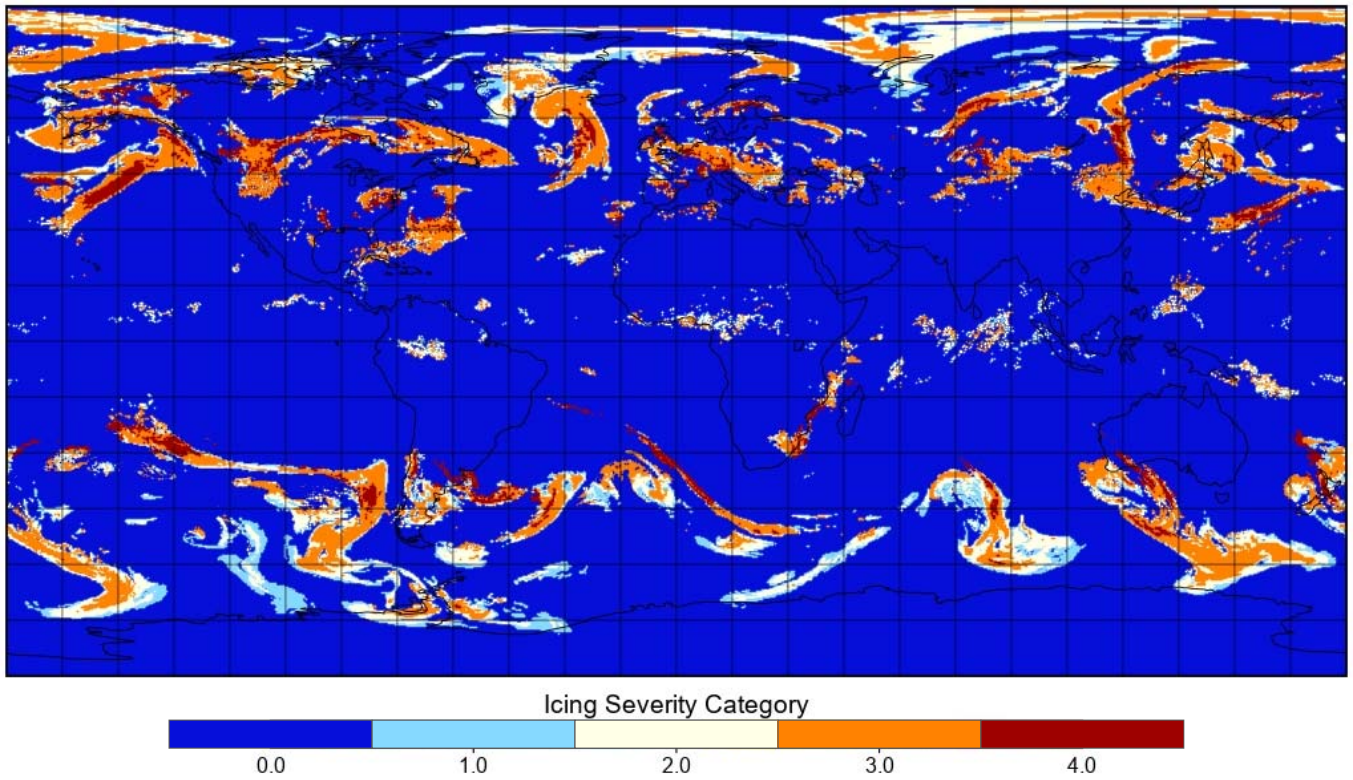
← Old 1.25 Icing Potential fields



← NEW 0.25 Icing Severity

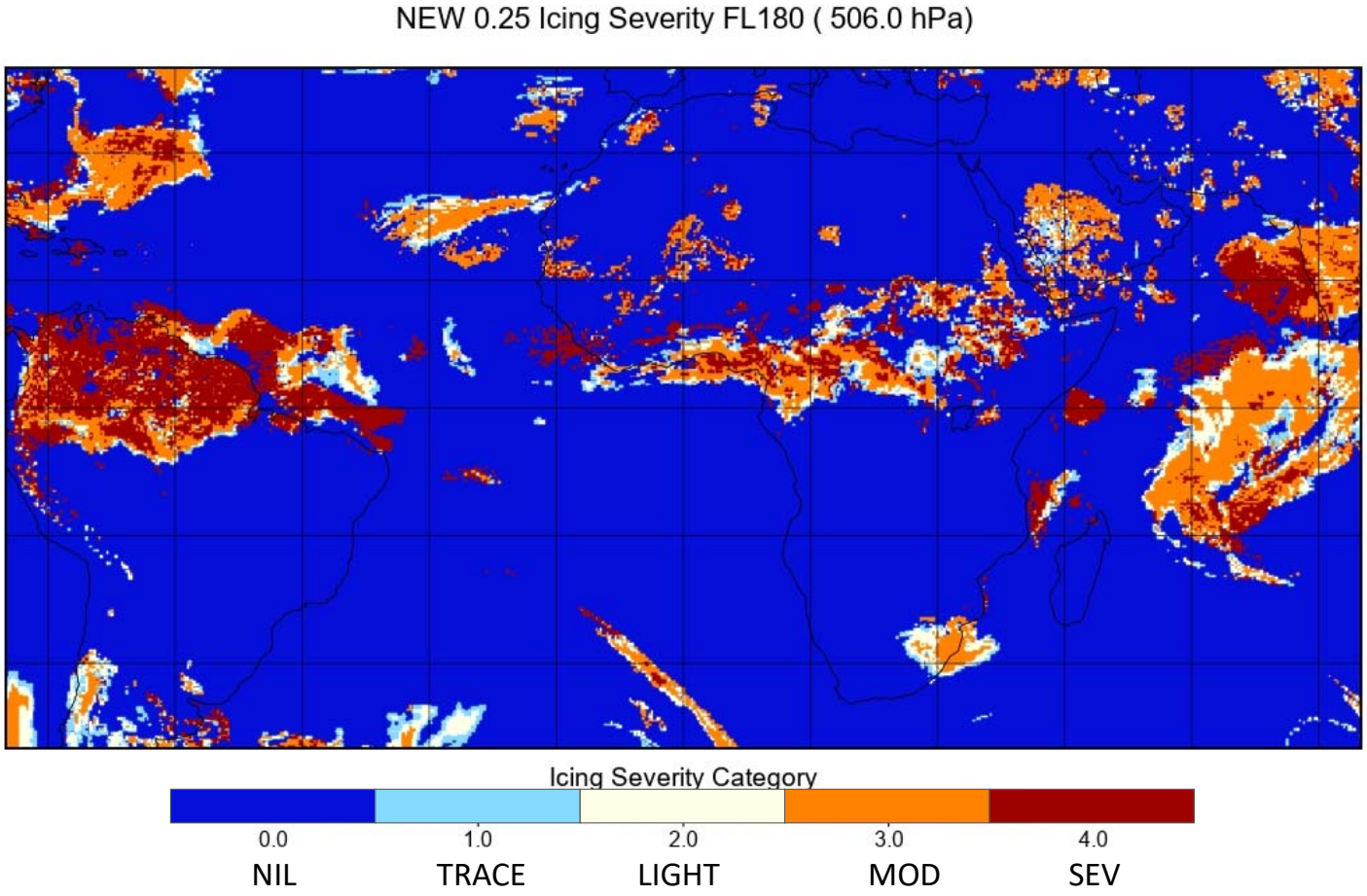
A single deterministic model field is provided.

NEW 0.25 Icing Severity FL140 (595.2 hPa)



- Icing Severity data is provided for the following levels:
  - FL060 (812.0 hPa)
  - FL100 (696.8 hPa)
  - FL140 (595.2 hPa)
  - FL180 (506.0 hPa)
  - FL240 (392.7 hPa)
  - FL300 (300.9 hPa)

Each of these is calculated over a 100hPa deep layer centred on that flight level. For example this FL140 chart is calculated using data from 645.2hPa to 545.2 hPa.



- Closer examination shows the improvement in detail that can be seen in the icing field.
- Icing occurring in frontal systems and icing from convection are both captured.
- The categories relate to an icing intensity

  0 = NIL

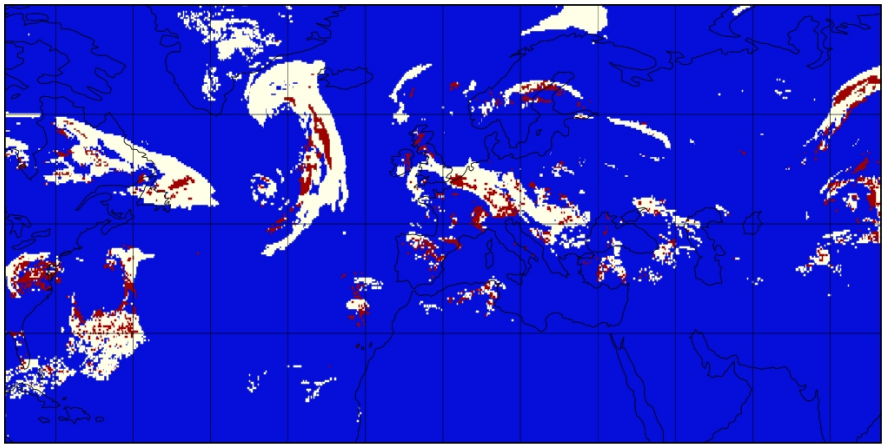
  1 = TRACE

  2 = LIGHT

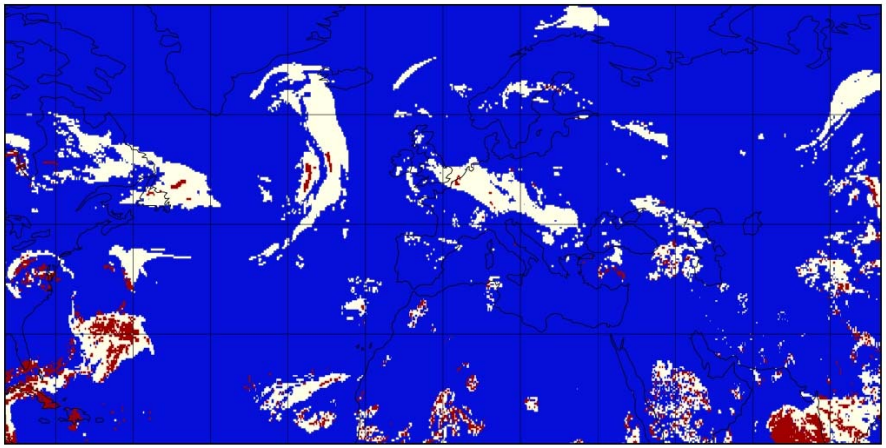
  3 = MODERATE

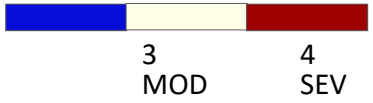
  4 = SEVERE

NEW 0.25 Icing Severity FL140 (595.2 hPa)



NEW 0.25 Icing Severity FL180 (506.0 hPa)

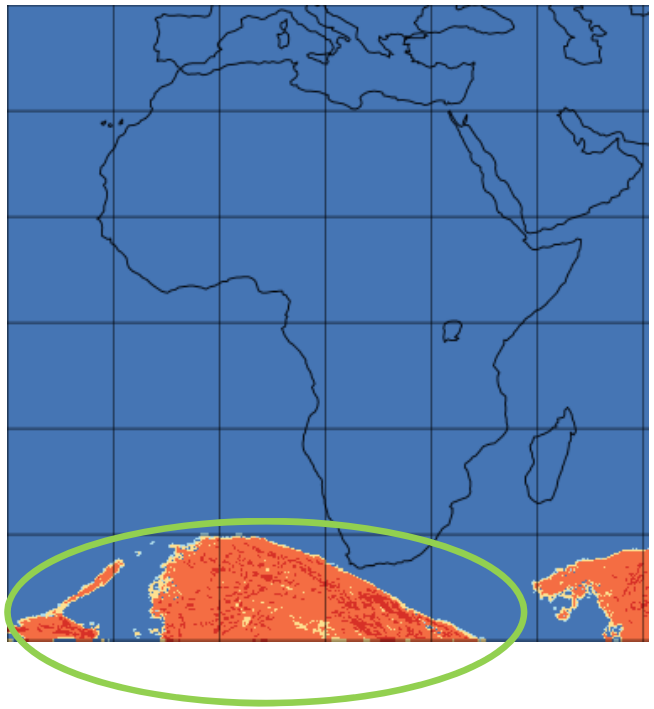




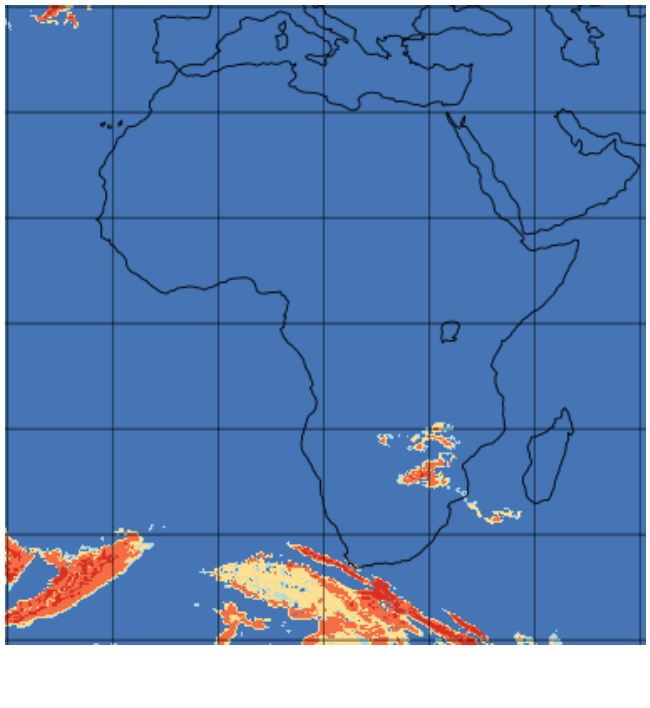
- Of course, a threshold could be applied to icing severity data.
- In these example only MOD and SEV icing intensities are shown.

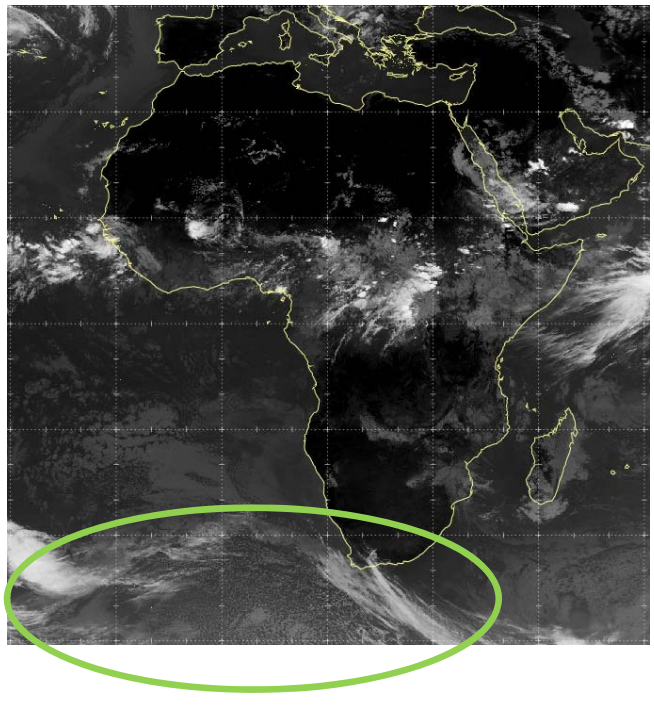
Case Study: 19 July 2021 – Forecast data valid at 12 UTC.

FL060 (812.0 hPa)



FL100 (696.8 hPa)

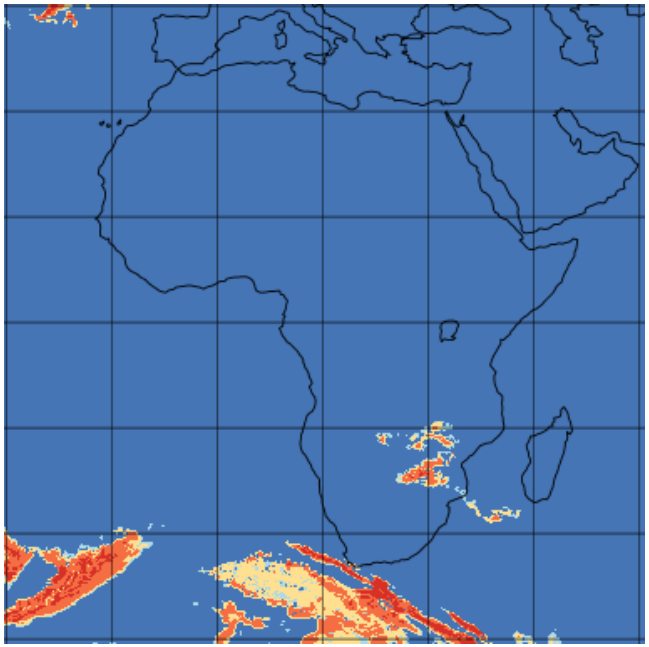




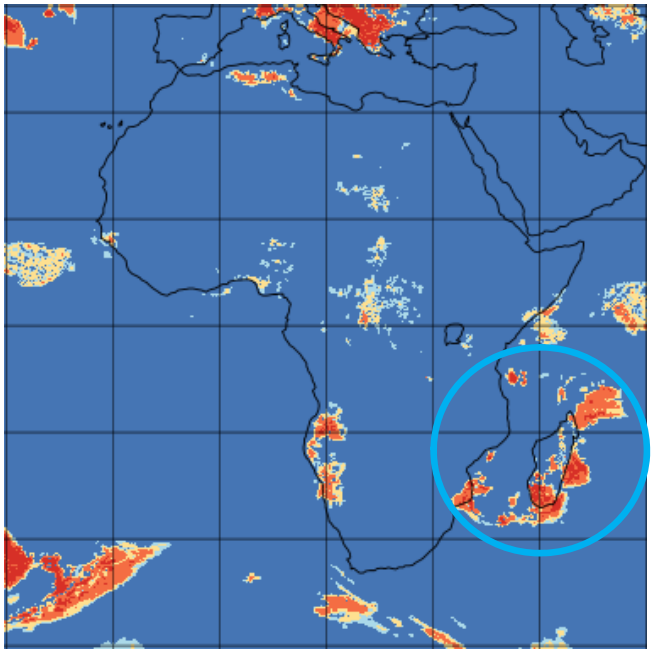
Low level moisture – frontal cloud and stratocumulus sheet with MOD-SEV icing between <FL050 and ~FL140

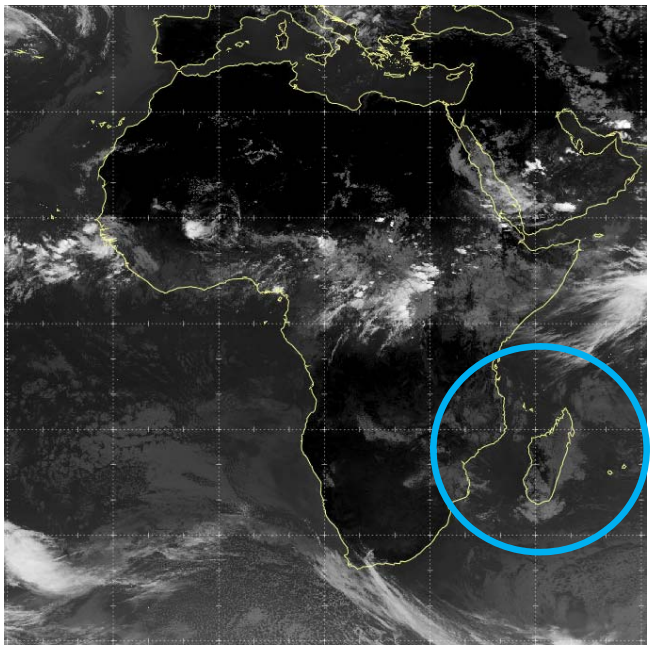
Case Study: 19 July 2021 – Forecast data valid at 12 UTC.

FL100 (696.8 hPa)



FL140 (595.2 hPa)



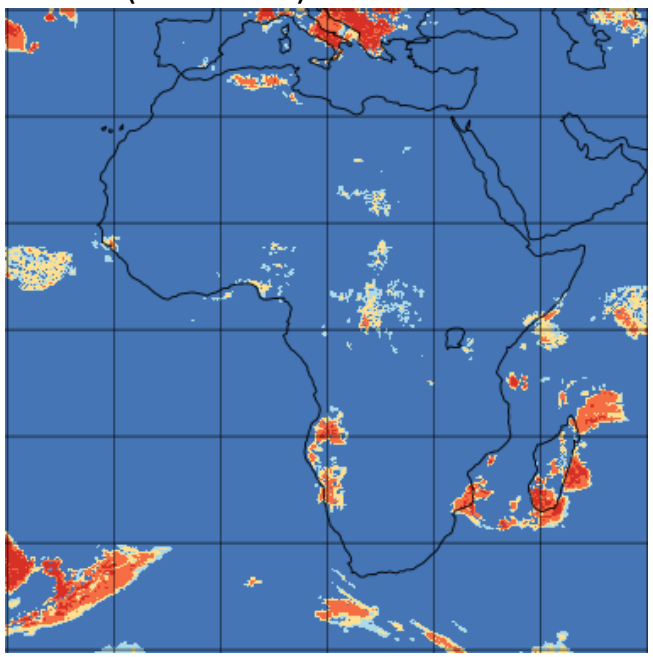


Cu/Sc with MOD-Severe icing between ~FL140 and ~FL180

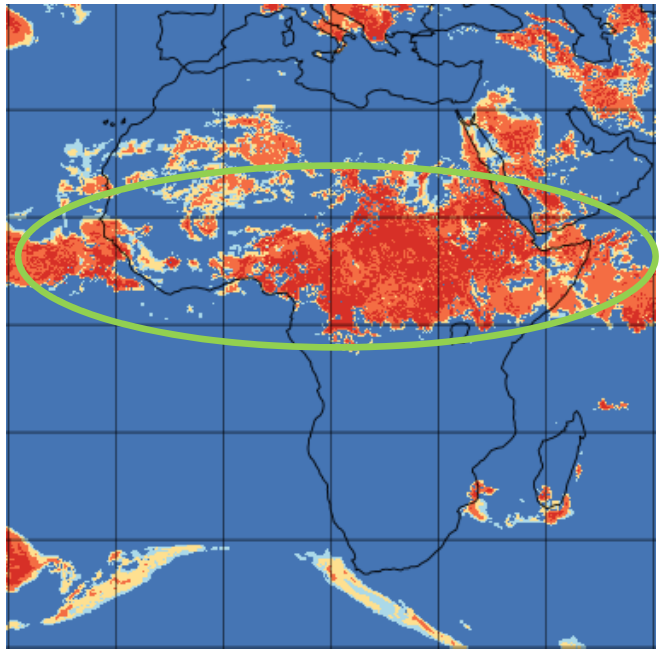
METEOROLOGY PANEL

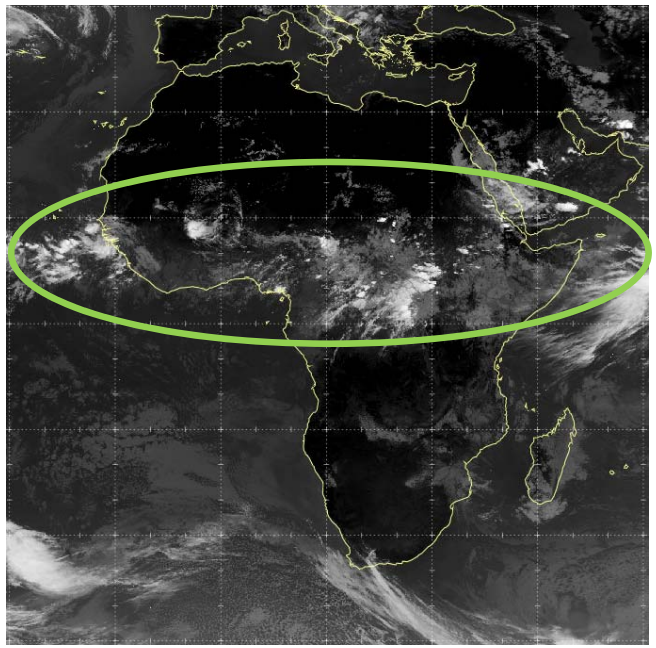
Case Study: 19 July 2021 – Forecast data valid at 12 UTC.

FL140 (595.2 hPa)



FL180 (506.0 hPa)



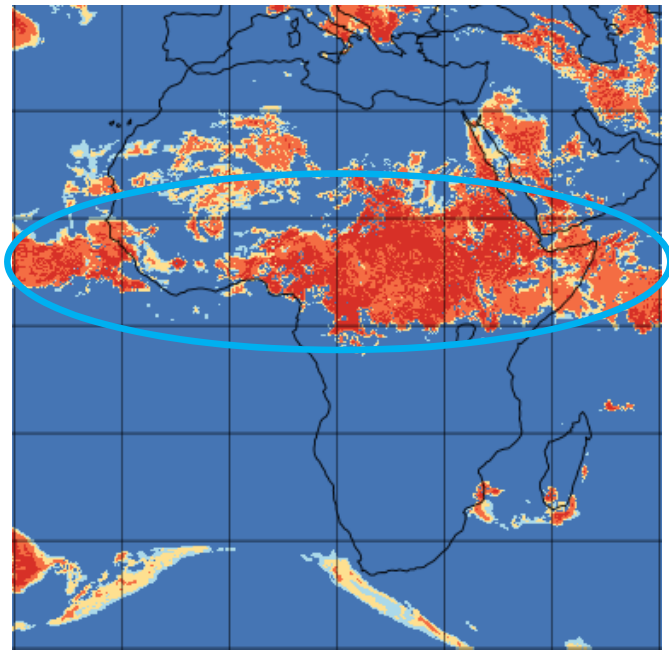


Convective cloud. SEV icing from around FL160 upwards.

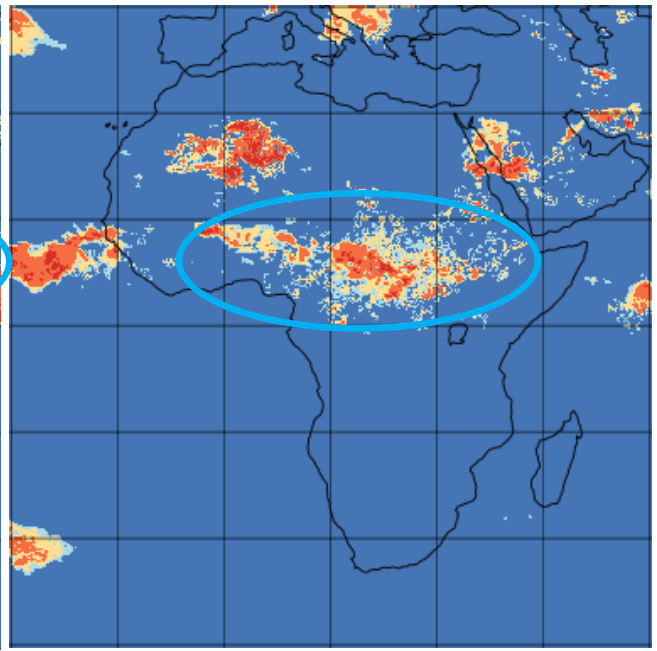
Of course this will only be expected where the convective cloud occurs

Case Study: 19 July 2021 – Forecast data valid at 12 UTC.

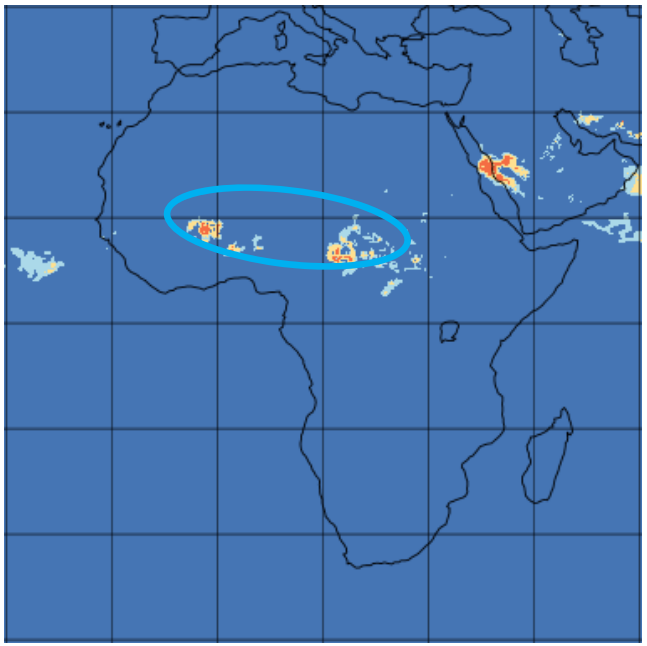
FL180 (506.0 hPa)



FL240 (392.7 hPa)



FL300 (300.9 hPa)



Convective cloud. SEV icing from around FL160 upwards up to around FL240, and in the largest Cumulonimbus up to FL300.

TURBULENCE SEVERITY DATA

- The new Turbulence Severity data uses a multi-diagnostic algorithm, Graphical Turbulence Guidance (GTG) developed by the National Center for Atmospheric Research (NCAR)
- Both WAFC London and WAFC Washington are using the same algorithm in the creation of their data sets, which are then blended together to create the final published WAFS data set.
- GTG forecasts **both clear air and orographic turbulence** and will provide output in terms of Eddy Dissipation Rate (EDR). EDR is the official ICAO and WMO atmospheric turbulence intensity metric.
- Eddy Dissipation rate is measured by many aircraft.

https://aviationweather.gov/turbulence/help?page=tutorial contains further information on the GTG algorithms used. Note that GTG3 is being used for WAFS.

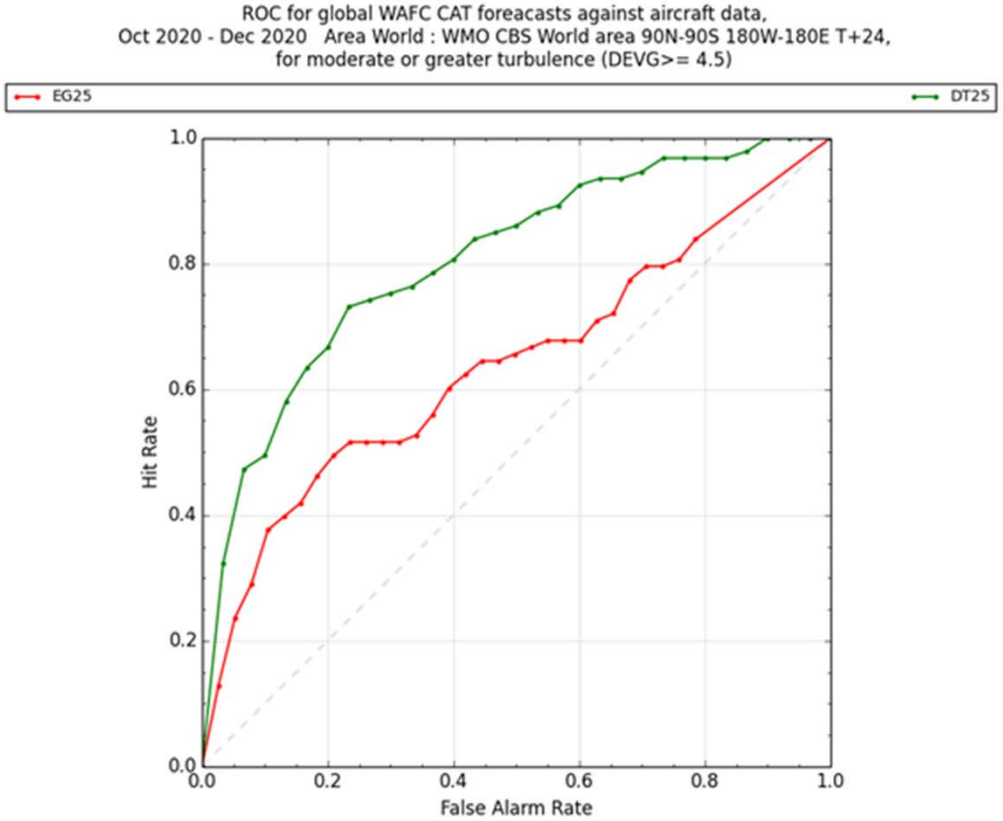
WHAT IS EDDY DISSIPATION RATE (EDR)

- Eddy Dissipation Rate is an objective, aircraft-independent, universal measure of turbulence based on the rate at which energy dissipates in the atmosphere. EDR is the official ICAO and WMO atmospheric turbulence intensity metric and will have values that range between 0 and 1.
- When the atmosphere is dissipating energy quickly (i.e the EDR is large), atmospheric turbulence levels are high."
- The effect of a particular EDR value on an aircraft will depend on the size (weight) of the aircraft.

For example: an EDR of 0.24 might be moderate turbulence for an A320 but light turbulence for a B777.

TURBULENCE SEVERITY DATA

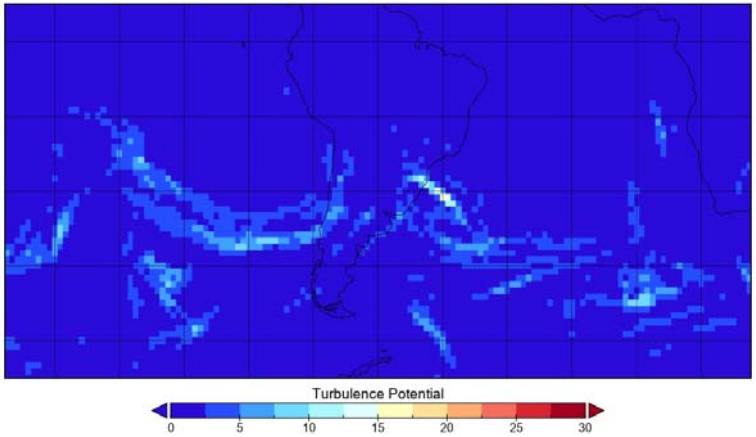
Met Office



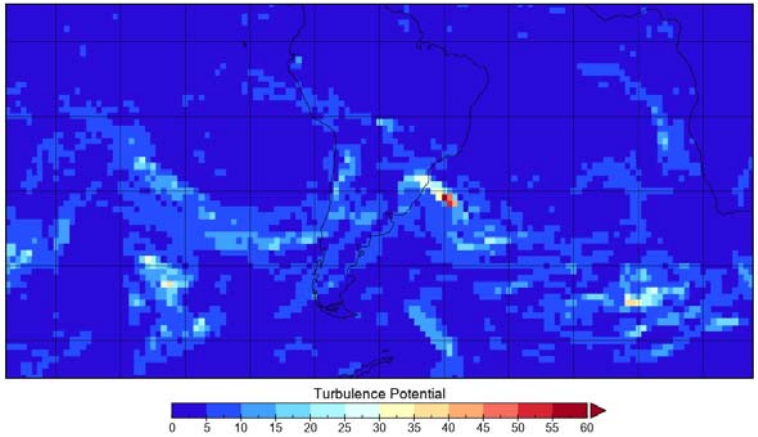
This ROC plot shows how the new Turbulence Severity forecasts at 0.25° resolution (green line) outperform the old WAFS turbulence forecasts (red line) at 1.25°

Note: the number of aircraft observations available for verification purposes was greatly reduced due to COVID.

MAX 1.25 degree Clear air turbulence (CAT) Potential Average at 400hPa (FL240)

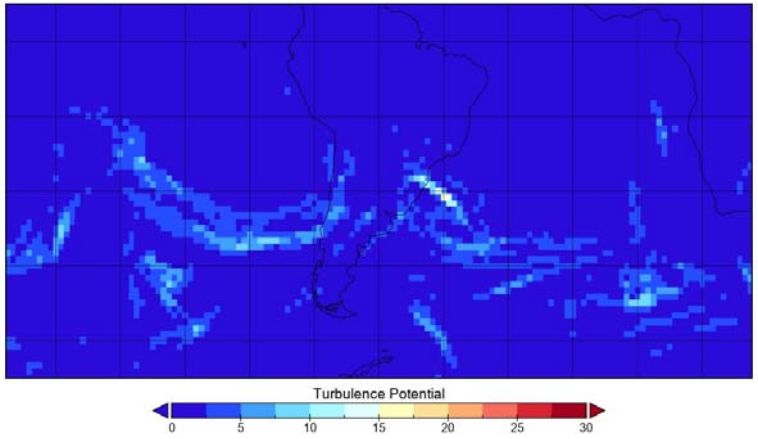


MEAN 1.25 degree Clear air turbulence (CAT) Potential (Max) at 400hPa (FL240)

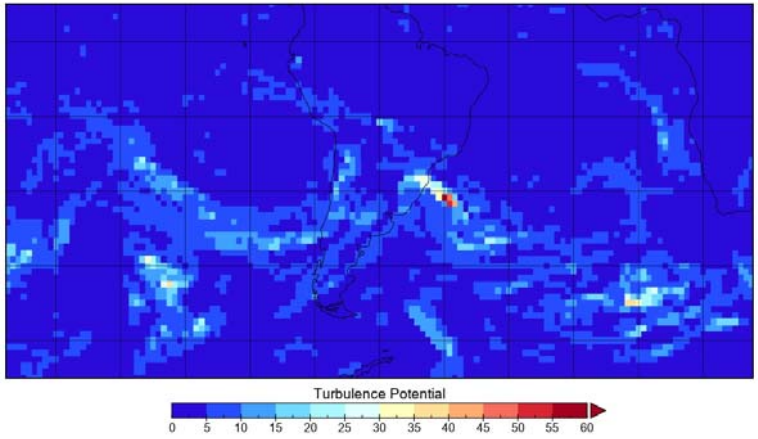


Old 1.25 Clear Air Turbulence Potential fields

MAX 1.25 degree Clear air turbulence (CAT) Potential Average at 400hPa (FL240)

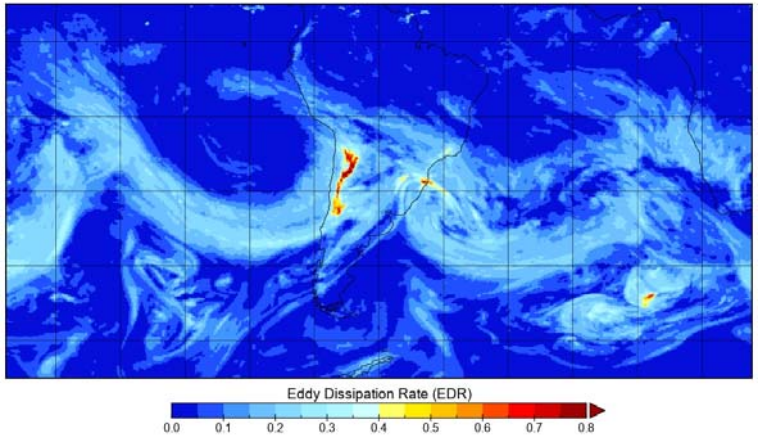


MEAN 1.25 degree Clear air turbulence (CAT) Potential (Max) at 400hPa (FL240)



← Old 1.25 Clear Air Turbulence Potential fields

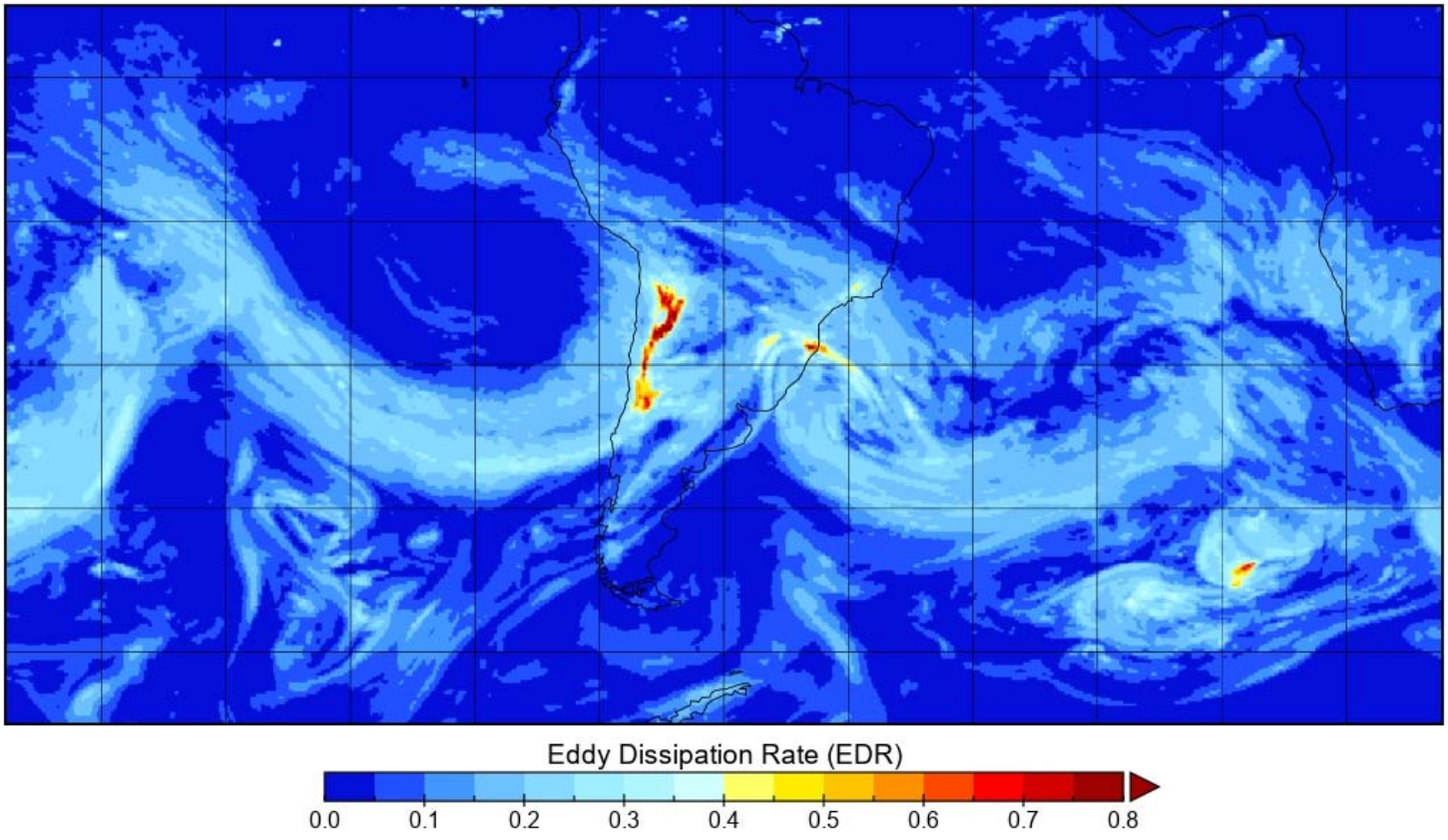
0.25 degree Turbulence Severity (GTG) at FL240 (392.7hPa)



← NEW 0.25 Turbulence Severity

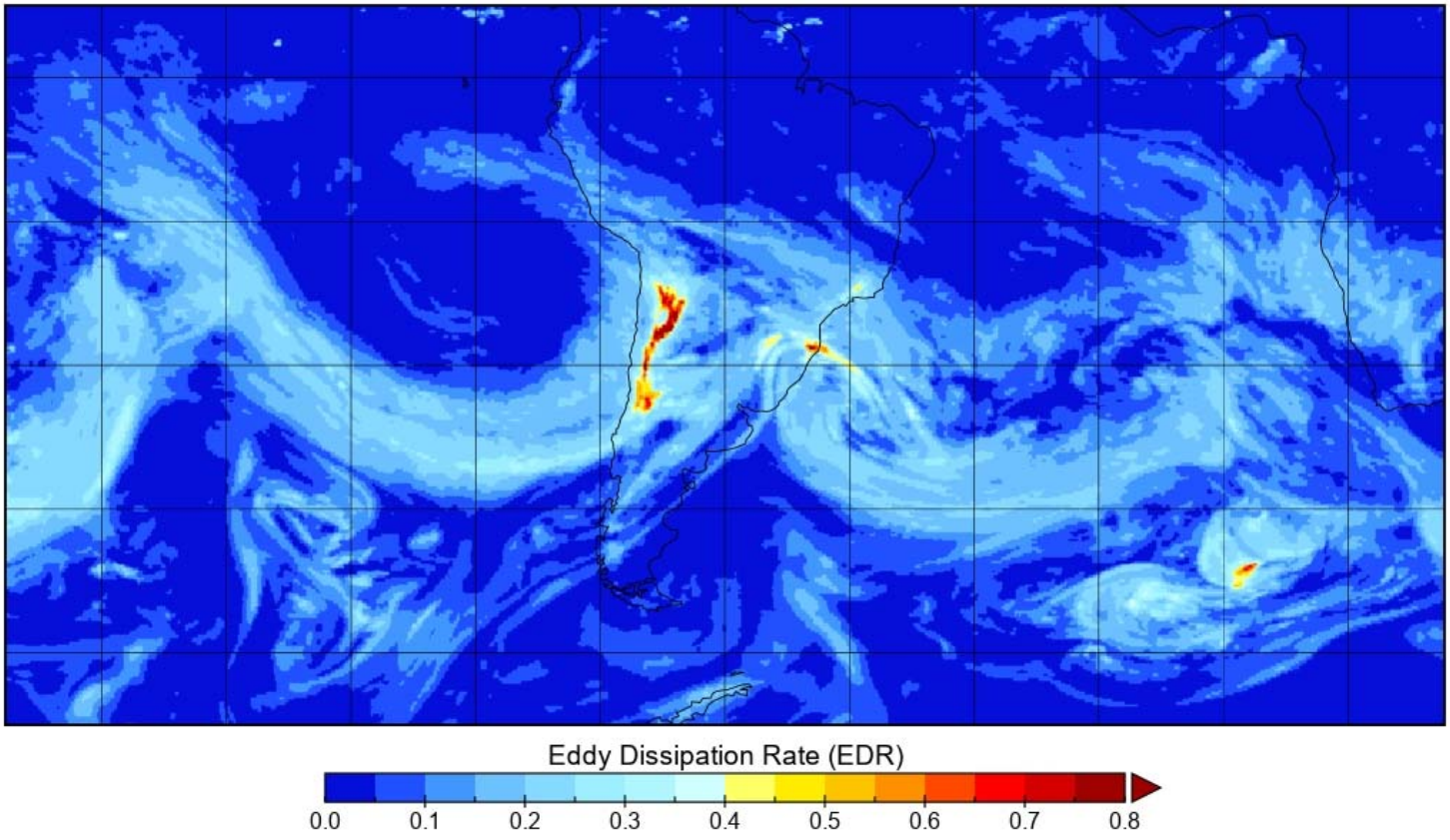
A single deterministic model field is provided.

0.25 degree Turbulence Severity (GTG) at FL240 (392.7hPa)



- Turbulence Severity data is provided for the following levels:
  - FL100 (696.8 hPa)
  - FL140 (595.2 hPa)
  - FL180 (506.0 hPa)
  - FL240 (392.7 hPa)
  - FL270 (344.3 hPa)
  - FL300 (300.9 hPa)
  - FL340 (250.0 hPa)
  - FL390 (196.8 hPa)
  - FL450 (147.5 hPa)
- Below FL240 each level is calculated over a 100hPa deep layer centred on that flight level, while for FL240 and higher a 50hPa deep layer is used.

0.25 degree Turbulence Severity (GTG) at FL240 (392.7hPa)



- The new turbulence severity field is able to forecast orographic turbulence and CAT.

- ICAO Annex 3 - *Meteorological Service for International Air Navigation*, Appendix 4 (from Amendment 79) has the following information:

  Turbulence shall be considered:

  a) Severe when the peak value of EDR equals or exceeds 0.45;

  b) moderate when the peak value is equal to or above 0.20 and below 0.45;

  c) Light when the peak value is above 0.10 and below 0.20; and

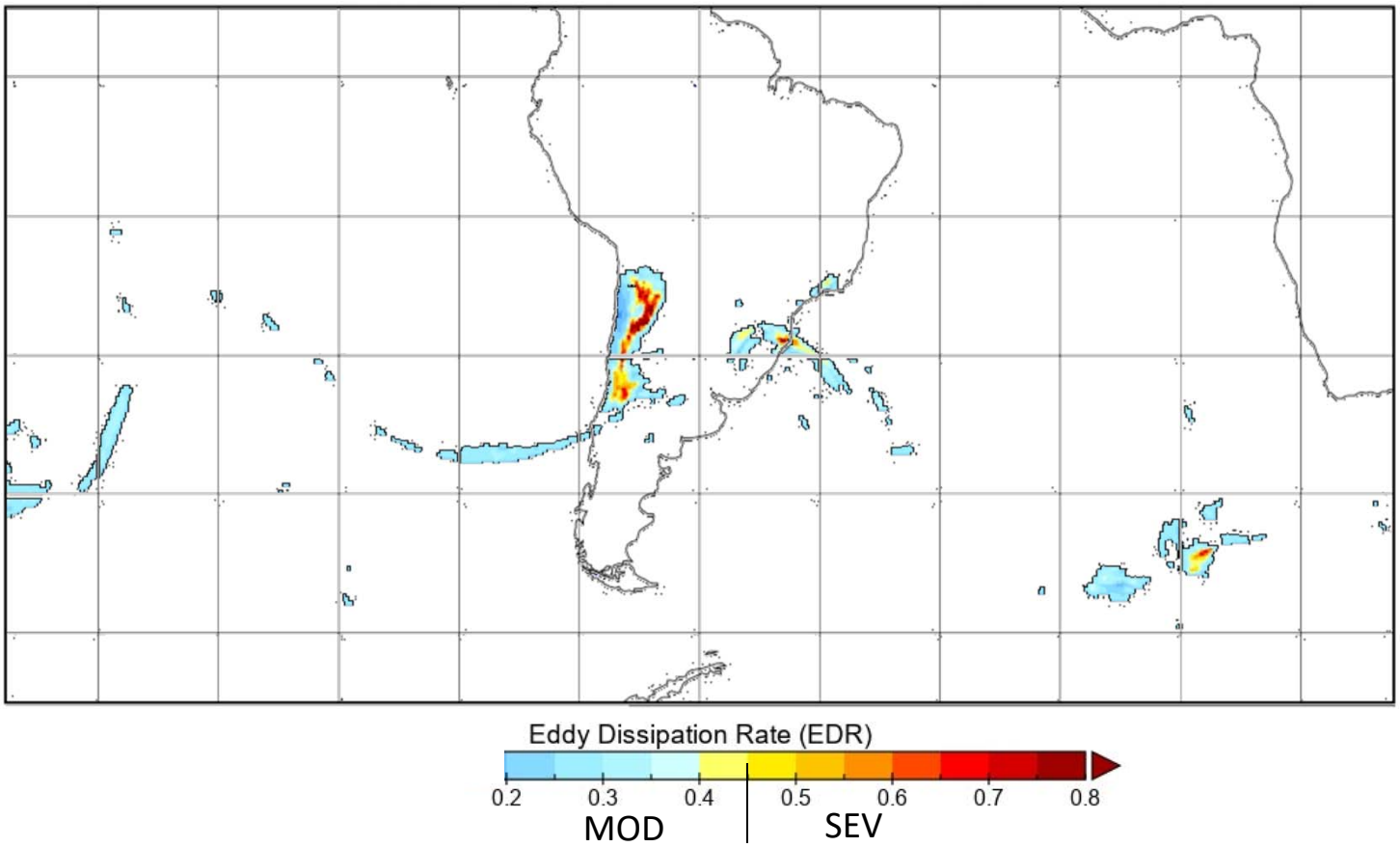
  d) nil when the peak value is below or equal to 0.10.

  Note: The EDR values given in Annex 3 describe the severity levels for a medium-sized transport aircraft under typical en-route conditions (i.e. altitude, airspeed and weight).

- Whilst EDR forecasts for the other size classes of aircraft have not been defined in the ICAO Annex 3 for a "heavy" classification of aircraft a higher EDR value would be necessary for it to experience severe turbulence, whilst a lower value would be required for an aircraft in the "light" category. The EDR threshold values for a specific aircraft type should be defined in the aircraft technical documentation.

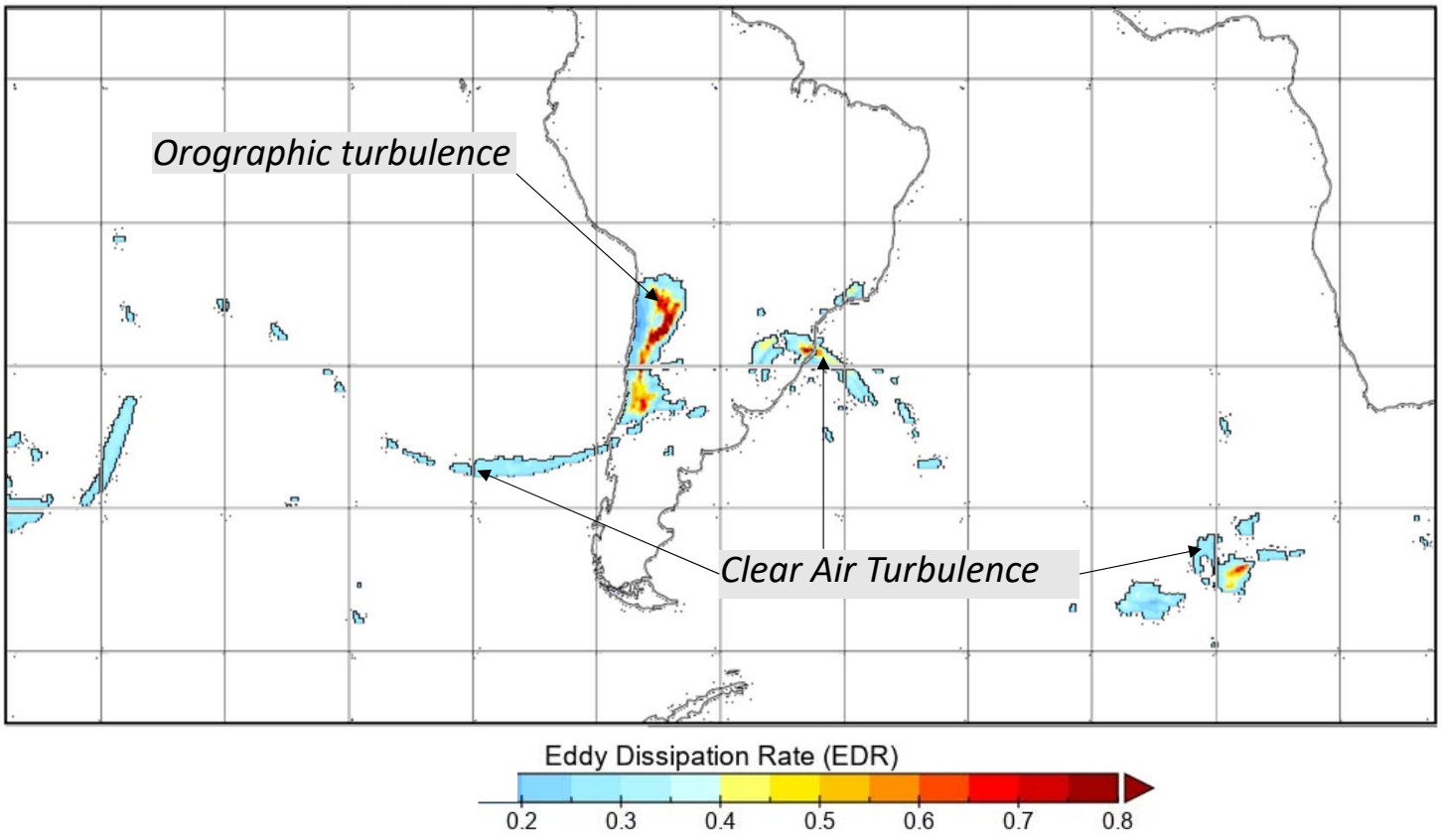
[1] https://www.skybrary.aero/index.php/ICAO_Wake_Turbulence_Category#

0.25 degree Turbulence Severity (GTG) at FL240 (392.7hPa)



- On this example only EDR values greater than 0.20 are shown, which would equate to moderate or greater turbulence for a medium[1] sized aircraft
- If the threshold EDR threshold for a particular aircraft is known, then the scale used to visualize EDR data can be set accordingly.

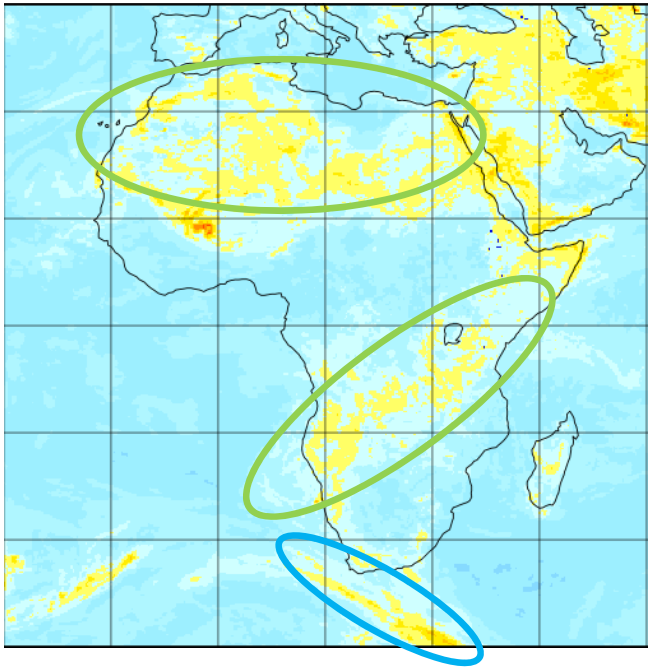
0.25 degree Turbulence Severity (GTG) at FL240 (392.7hPa)



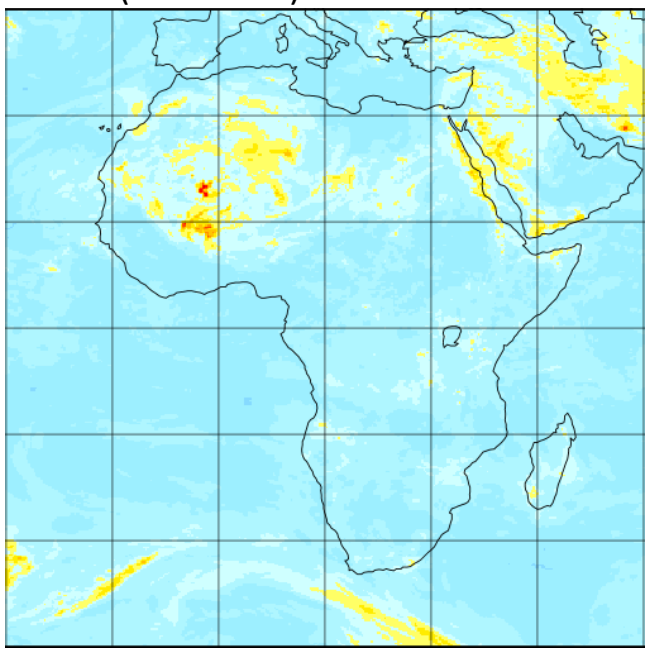
- Whilst the Turbulence Severity field forecasts both Clear Air and Orographic turbulence it isn't possible to differentiate them using just one plot.
- Examination of data at multiple levels and time steps, as well as applying meteorological principles will assist in the identification of the different types of turbulence.

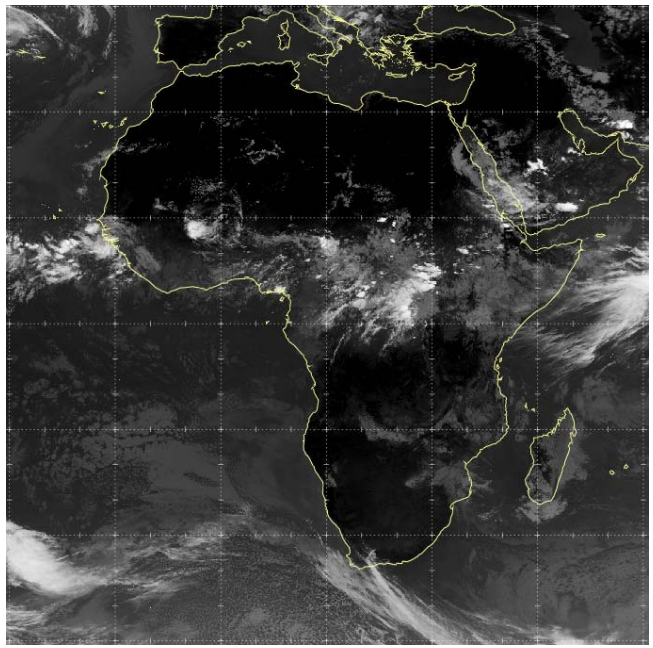
Case Study: 19 July 2021 – Forecast data valid at 12 UTC.

FL100 (696.8 hPa)



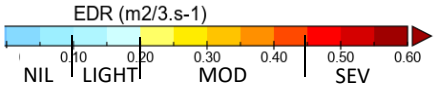
FL140 (595.2 hPa)





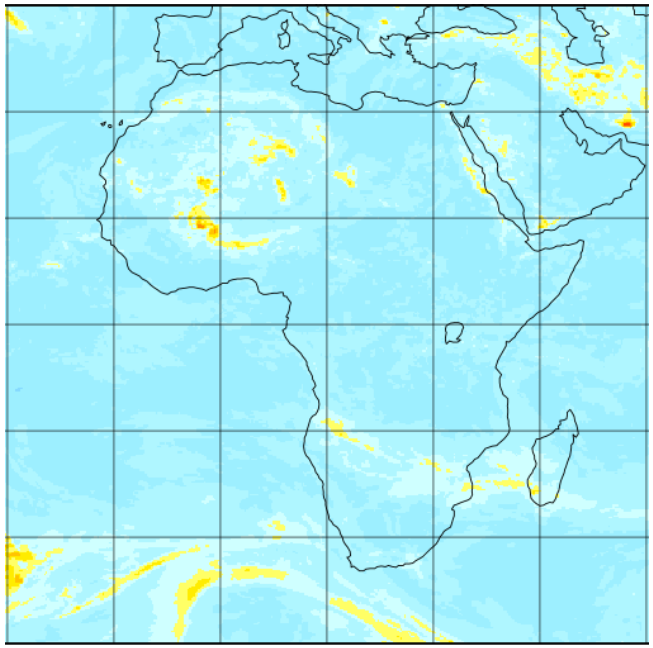
MOD Turbulence FL100-FL140 due to wind shear at that level.

MOD Turbulence FL100-FL140 along frontal boundary.

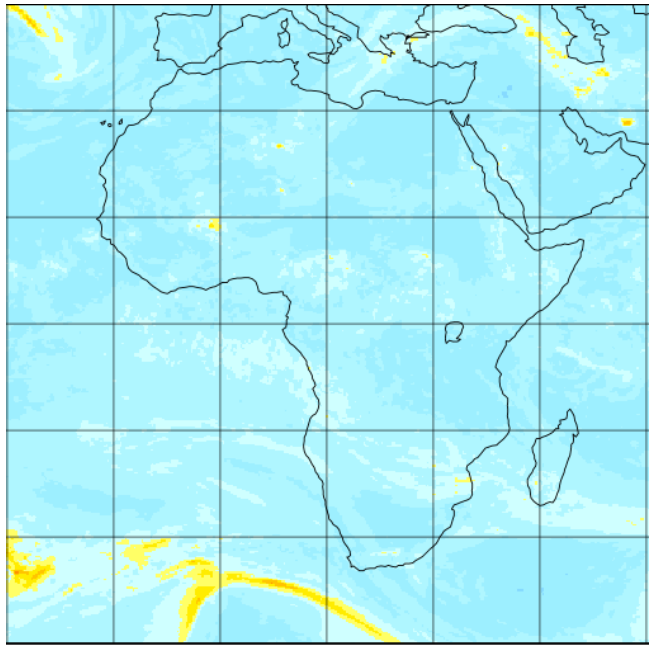


Case Study: 19 July 2021 – Forecast data valid at 12 UTC.

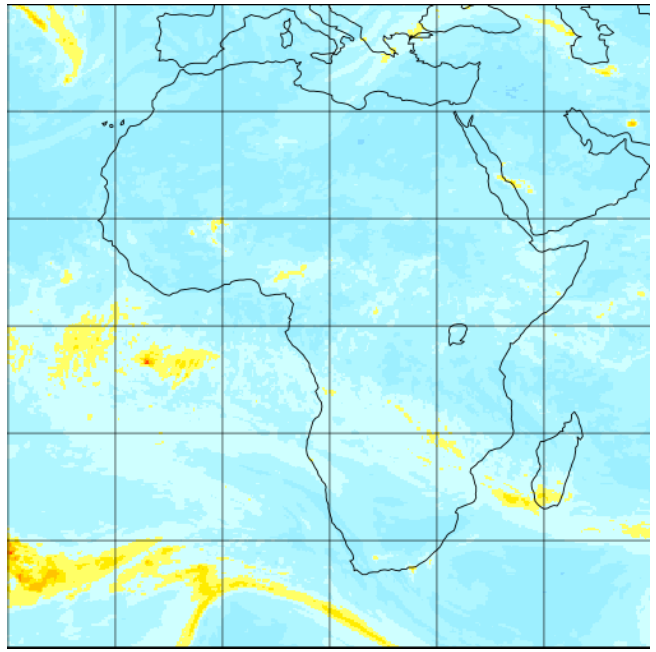
FL180 (506.0 hPa)

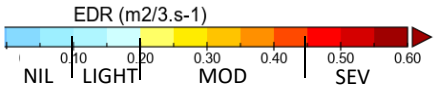


FL240 (392.7 hPa)



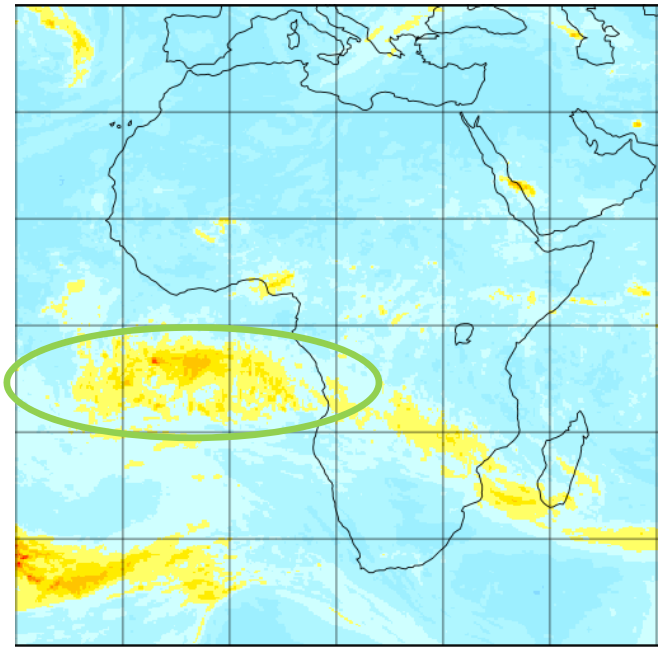
FL270 (344.3 hPa)



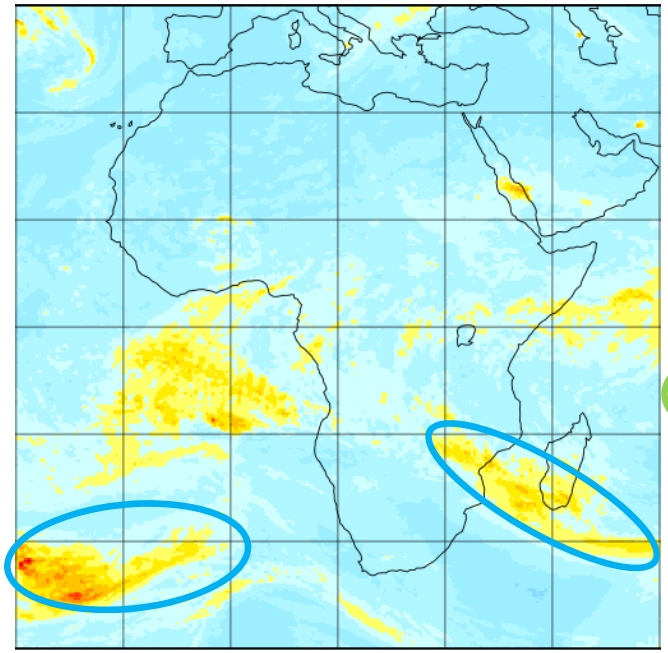


Case Study: 19 July 2021 – Forecast data valid at 12 UTC.

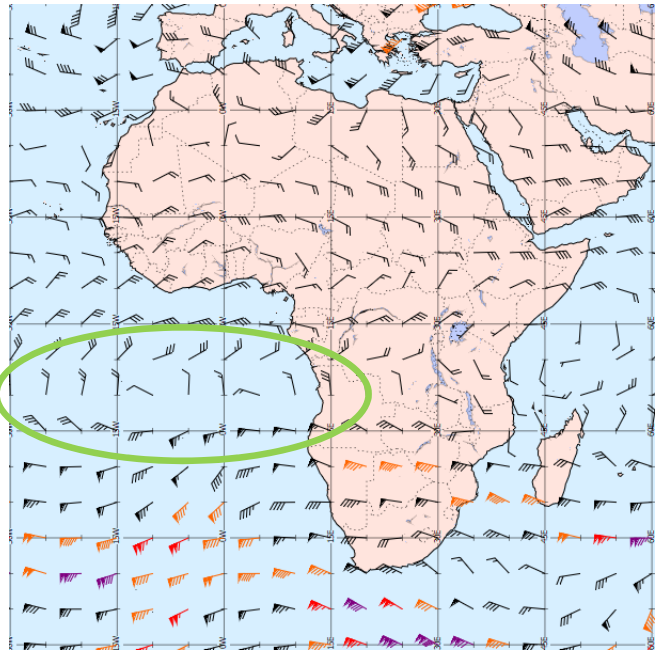
FL300 (300.9 hPa)



FL340 (250.0 hPa)

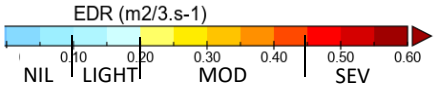


FL300



MOD Turbulence FL300+ due to large directional wind shear.

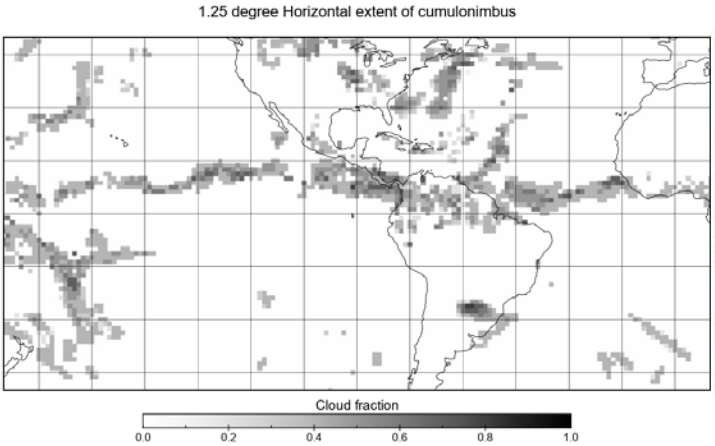
MOD LOC SEV Turbulence FL300-FL390 associated with the strong jet stream

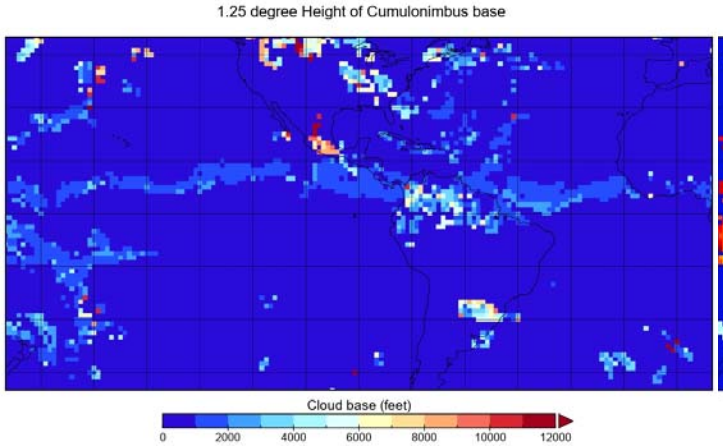


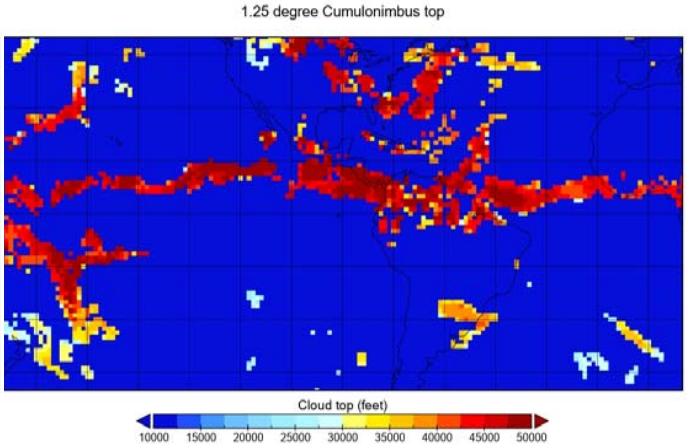
CUMULONIMBUS DATA – EXTENT BASE AND TOP

The Old 1.25 Cumulonimbus fields are provided as three separate data sets:

- Cumulonimbus Extent – which shows where CB are expected to occur
- Cumulonimbus Base – which showed the forecast CB base (in feet or metres) using ICAO standard Atmosphere
- Cumulonimbus Top – which shows the forecast CB top (in feet or metres) using ICAO standard Atmosphere

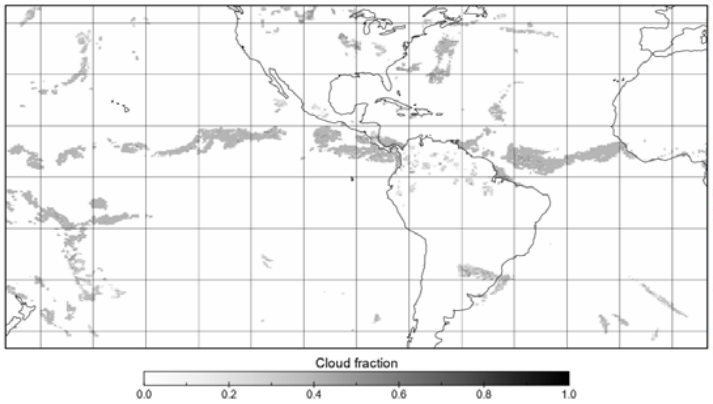




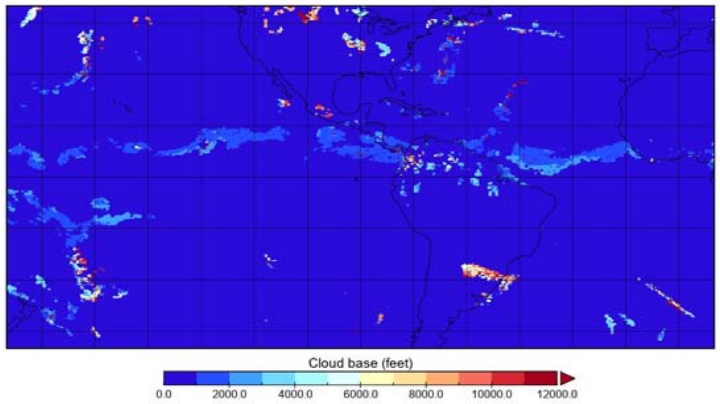


- The New 0.25 data set uses the same cumulonimbus algorithms, and keeps the same three data sets. The higher model resolution means that cumulonimbus should be more realistically captured.

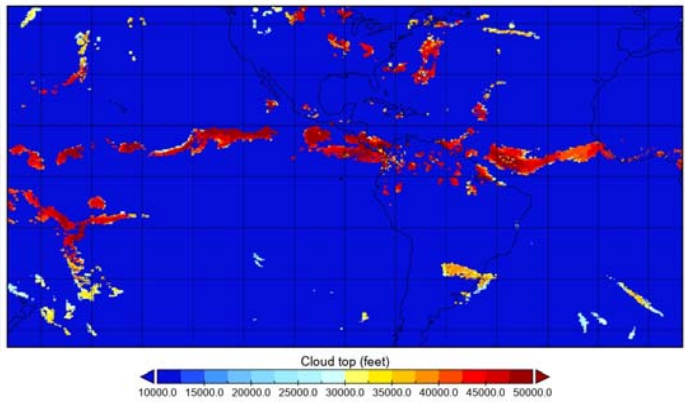
NEW 0.25 Horizontal extent of cumulonimbus



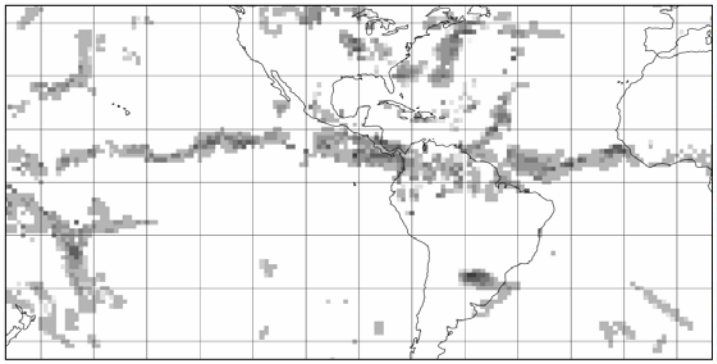
NEW 0.25 Height of Cumulonimbus base



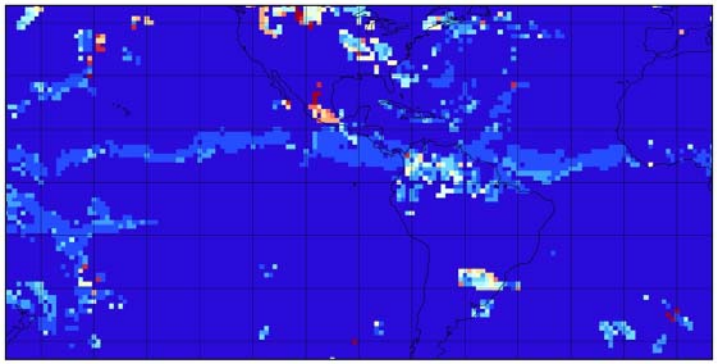
New 0.25 Cumulonimbus top



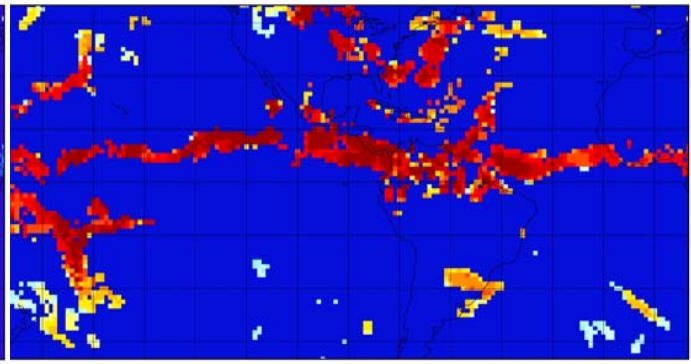
1.25 degree Horizontal extent of cumulonimbus



1.25 degree Height of Cumulonimbus base

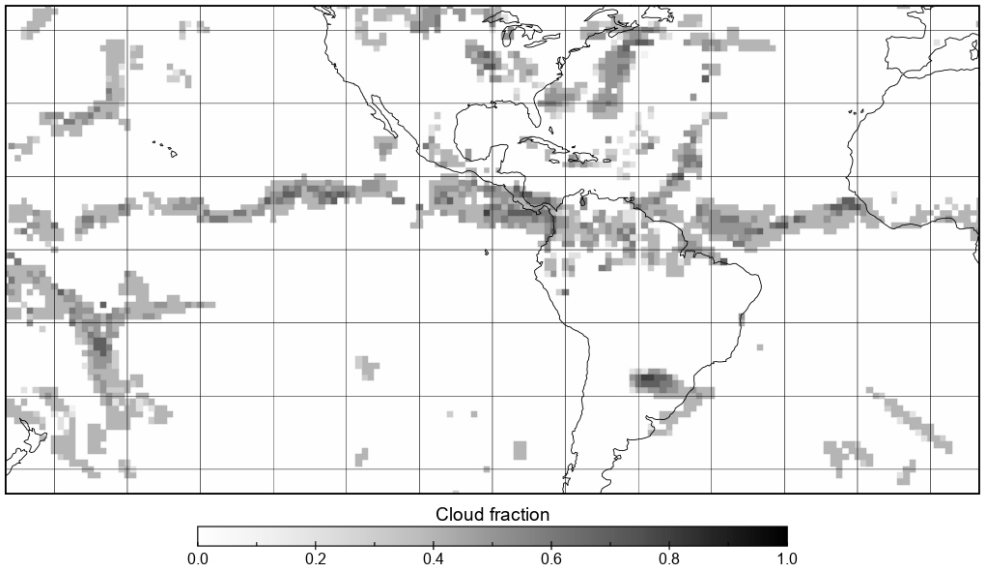


1.25 degree Cumulonimbus top

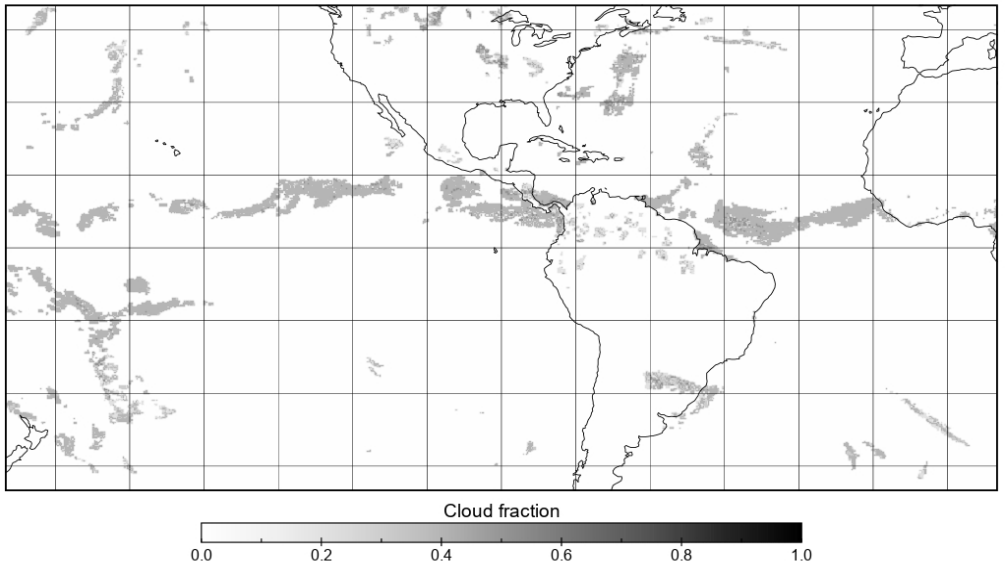


- Closer examination of the cumulonimbus extent field, seems to suggest that the new 0.25 degree resolution data has lower values overall.
- This is because at 1.25 degree resolution all of the model points that lie within this grid box (at the underlying model resolution) are sampled, and the highest value is used. This process is not applied to the 0.25 degree data.

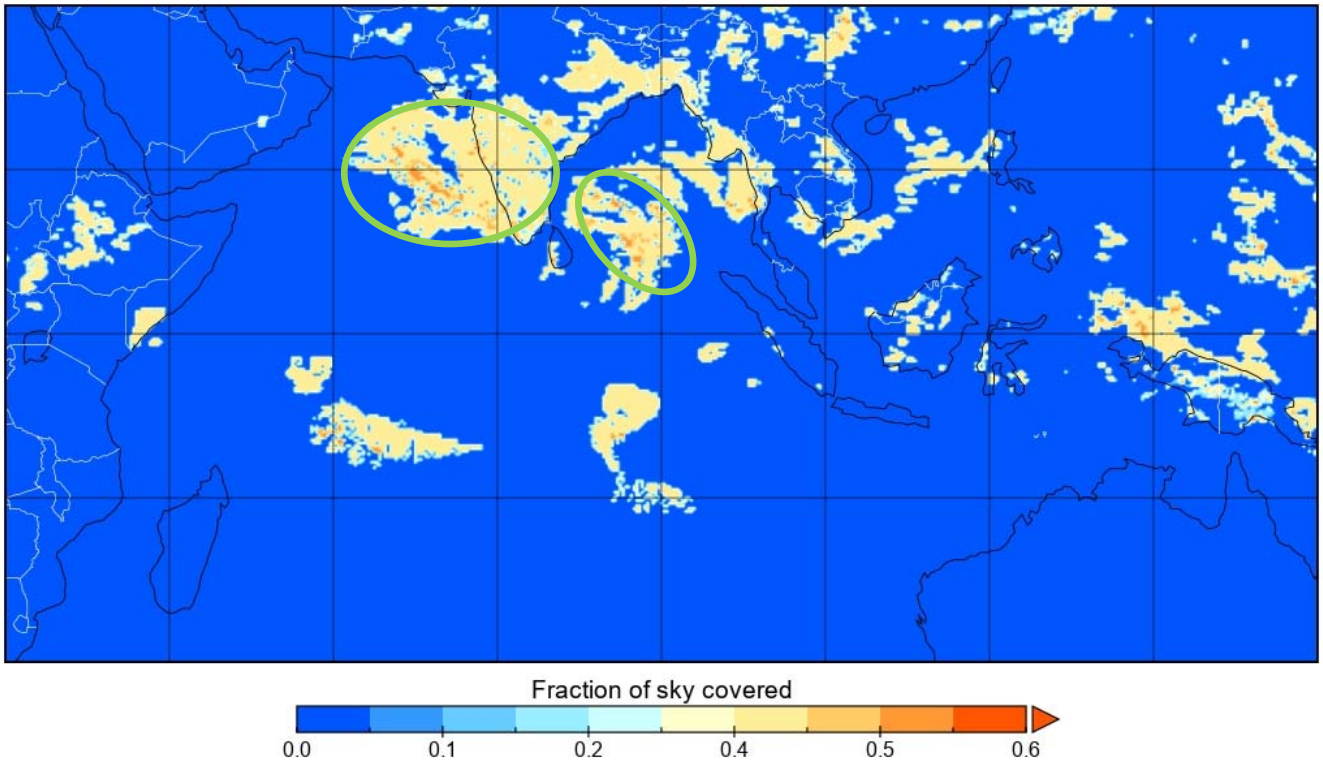
1.25 degree Horizontal extent of cumulonimbus



NEW 0.25 Horizontal extent of cumulonimbus



Horizontal extent of cumulonimbus



The cumulonimbus (CB) extent field is provided as the “fraction of sky covered”. Values of 0.3 or higher generally indicate where CBs are forecast.

It is rare to see a fraction of sky covered value greater than 0.5, therefore this field cannot be used to determine whether the CB’s will be SCT, BKN or OVC in amount.

If a large area indicates that CB are forecast then multiple CBs are likely to be occurring in that area

SUMMARY

- On 5th November 2020 the turbulence, icing and cumulonimbus fields were upgraded as part of Amendment 79 to ICAO Annex 3 – *Meteorological Service for International Air Navigation*

NEW	
0.25 degree Turbulence Severity	Output in Eddy Dissipation Rate (EDR) Forecasts CAT and Orographic Turbulence 9 levels
0.25 degree Icing Severity	Categorical forecast of icing 6 levels
0.25 degree Cumulonimbus extent, base and top	

PROVISION OF DATA

- The new data sets are be published on SADIS (and WIFS) and can be downloaded in exactly the same way that the old data sets are accessed.
- The new data sets are usually available around 4-hours 40 minutes after the model data time. For example for 1200UTC model data will be available by 17:00UTC at the latest.
- Harmonized data is provided – this means that WAFC London and WAFC Washington data is blended together to make the final data set. If it is not possible for one of the WAFCs to harmonize data then unblended data will be issued at the cut off time of 4-hours 55 minutes.

File location on SADIS:
/GRIB2/COMPRESSED/EGRR/CB_0.25
/GRIB2/COMPRESSED/EGRR/ICE_0.25
/GRIB2/COMPRESSED/EGRR/TURB_0.25

RETIREMENT OF OLD DATA

- The old turbulence, icing, and cumulonimbus fields will be retired.

OLD	Retirement Date
1.25 degree Turbulence Potential (CAT) – mean and max	Nov 2023
1.25 degree Icing Potential – mean and max	Nov 2023
1.25 degree Cumulonimbus extent, base and top	Nov 2023
1.25 degree in-cloud-turbulence – mean and max	Already retired

Thank you for listening.

- Please e-mail me on SADISmanager@metoffice.gov.uk if you have any questions.