International Civil Aviation Organization

METPWGMOG/7/SN/22-rev
22/03/18

STUDY NOTE

MEETING OF THE METEOROLOGY PANEL (METP) WORKING GROUP MOG (WAFS)

SEVENTH MEETING

Offenbach, Germany, 11 to 13 April 2018

Agenda Item 3.3: Work required in support of WAFS Developments
3.3.2 Matters relating to the Significant Weather Provision

NEXT GENERATION WAFS SIGWX PRODUCTION

(Presented by the WAFC Provider States)

SUMMARY

The WAFCs have developed plans on how to deliver SIGWX forecasts fit for the next 10+ years through the introduction of multiple time-step SIGWX forecasts in November 2022.

This paper describes the provision of SIGWX object data sets and proposes an implementation timeline and discusses changes in the data sets.

Action by the METP-WG/MOG is in paragraph 4.

1. INTRODUCTION

1.1 METP-WG/MOG/7 SN/21 describes the 10 year plan for the next generation of SIGWX forecasts. Feedback received from SIGWX users has highlighted how the existing provision of T+24 hour SIGWX objects (data) and charts does not meet the needs of the aviation industry for several reasons, namely in providing fully harmonised, multiple time-step SIGWX data.

1.2 The WAFCs have been formulating plans for how multiple time-step SIGWX forecasts can be delivered, and have concluded that direct use of the gridded hazard data sets is now possible, however some changes will need to be made to the structure of data made available to users. This paper presents a discussion of each issue, and proposes a series of changes that require the groups approval.

2. **DISCUSSION**

2.1 Over the past 10 years, feedback has been provided to the WAFCs by States, IFALPA and IATA about SIGWX forecasts not fully meeting the needs of the aviation industry. Three main issues were identified:

- The SIGWX Charts issued by WAFC Washington and WAFC London are not harmonised
- The WAFC Gridded data sets are not harmonised with the SIGWX forecasts
- SIGWX forecasts are only produced for a single timeframe and are therefore do not adequately meet the needs of long or short haul flight planning.

2.2 The group may recall that at METP-WG/MOG/4 the WAFC Provider States presented some preliminary ideas of the improvements that could be made (METP-WG/MOG/4-SN/26 refers). This paper provides more detailed information on the changes that are required.

TIMESTEPS

2.3 A key requirement for the next generation SIGWX provision is the requirement to provide data for more than just the T+24 hour time-step. Short haul flight planning would typically require data for the T+6 to T+18 timeframe, whilst ultra-long haul flight planning requires data beyond T+24.

2.4 Scientific developments made by both WAFCs over the past few years is now enabling the direct use of the underlying forecast data sets in SIGWX production. WAFC London has been trialling the production of T+24 SIGWX objects in a non-operational environment for the past few years. Verification has been carried out which shows that the T+24 SIGWX Object data has a higher quality than objects drawn manually by a meteorologist. This evidence is presented in Appendix A.

2.5 For the reasons presented in paragraphs 2.1 and 2.2, both WAFCS now believe that the oversight of meteorologists in SIGWX production can be reduced, which enables an increase in the number of time-steps of SIGWX data that is provided.

2.6 SIGWX data for many time-steps can be created with a minimal additional overhead. Therefore the WAFCs are proposing that the following time-steps are provided:

T+6, T+9, T+12, T+15, T+18, T+21, T+24, T+27, T+30, T+33, T+36, T+39, T+42, T+45 and T+48

HARMONISATION

2.7 Both WAFCs currently blend gridded hazard datasets. This will continue, and blended WAFC 0.25° gridded data sets will be used in the production of cumulonimbus cloud, turbulence and icing SIGWX objects. Identical algorithms will be used to create the objects.

2.8 An evaluation will be carried out to determine the best approach for creating jet stream objects, in order to ensure that peak jet information is not smoothed out by blending WAFC Washington and WAFC London wind fields together.

DATA

2.9 The group should note that in delivering multiple time-step SIGWX objects it will not be possible to produce exactly the same data sets as are produced now. Each element is discussed in the table below

Existing Parameters (2018)	Next-generation SIGWX objects (from Nov 2022)
CB Extent Criteria: ● affecting an area with a maximum spatial coverage of 50 per cent or more of the area concerned; ● along a line with little or no space between individual clouds; or ● embedded in cloud layers or concealed by haze;	Discussion: Current global numerical prediction models used by the WAFCs can not forecast with any skill whether CBs are embedded in nature, or are closely spaced along a line. By November 2022 the underlying gridded data set will be based on probabilistic information therefore criteria relating to "spatial coverage" will need to be adjusted slightly. CB objects will be created using a probability that closely matches the "50 per cent or more" spatial coverage. **Action:** **Only the following criteria will be used:** ● **CB forecasts will be based on probabilistic information, and areas will be depicted using a probability that closely matches 50 per cent or more spatial coverage**
CB Base and Top	Discussion: SIGWX data will be provided in the range FL100-FL530 so CB top information will have a maximum altitude of FL530. Even with a CB base of FL100, most of the time CB bases will lie beneath the base of the SIGWX data set. Even if the base is above FL100 users should not be using CB base information to fly underneath a CB, therefore this information will not be provided. **Action:** ● **CB top information will be provided up to FL530.** ● **CB base information will be omitted.**
Clear Air Turbulence	Discussion: The new Graphical Turbulence Guidance system will produce an Eddy Dissipation Rate (EDR) for both Clear Air Turbulence and Mountain Wave Turbulence. This will enable objects to be drawn for both types of turbulence. Areas of moderate and severe turbulence will be drawn using the EDR thresholds, but the specific type of turbulence will not be designated.

	Action: ● **Turbulence objects will be included (which incorporate turbulence due to both Clear Air and Mountain Wave turbulence) within the range FL100 to FL530.**
Flight Level of Tropopause	Discussion: It is difficult to provide selected tropopause height information in a way that will suit SIGWX data sets. Traditionally, tropopause height information has been used as a "filler" on the SIGWX charts. In other words, tropopause heights were placed on SIGWX forecasts in areas void of jet streams, turbulence or cumulonimbus clouds. The largest changes in tropopause height are coincident with jet streams and it will be difficult to clearly depict this information on a SIGWX chart. Instead users will be encouraged to use the high resolution tropopause height gridded data set. **Action:** ● **Tropopause height information will not be provided**
Jet streams ● Jet position, speed, flight level of the jet core, and jet depth	Discussion: The WAFCs will harmonise jet stream information to ensure that peak speed information is not averaged out. Jet depth information will not be provided, and instead users will be encouraged to use the high resolution gridded data sets. **Action:** ● **Jet position, speed and height of the jet core will be provided**
In Cloud turbulence	Discussion: The WAFCs have determined that "in-cloud" gridded turbulence product has little or no skill. From November 2020 the WAFCs will begin producing turbulence output using the Graphical Turbulence Guidance system, however this does not specifically differentiate in cloud turbulence, and therefore this field will be discontinued. **Action:** ● **This parameter will be retired.**
In Cloud Icing	Discussion: The WAFC gridded data icing algorithm will be updated in November 2020. It does not discriminate between cloud types, and will therefore capture icing associated with CB's. This will be used to create icing areas, and icing base/top information. **Action:** ● **Icing areas information will be provided.**

Tropical Cyclones	Discussion: Tropical cyclones move with time, and at present the information contained in a Tropical Cyclone Advisory only contains information for T+0, T+6, T+12, T+18 and T+24. Therefore it is not possible to mark the position at other times aligned with the SIGWX forecasts. This issue is discussed in METP-WG/MOG/7 SN/24. **Action:** ● **To be consistent with the decision arising from METP-WG/MOG/7 SN/24**
Volcanic Eruptions **Radioactive Incidents**	**Action:** ● **Information on volcanic eruptions and radioactive incidents will be included, derived from the appropriate advisories.**
Sandstorms/Dust Storms	Discussion: Global forecast information on sand and dust storms is not available and has not been included on WAFS SIGWX forecasts as far back as 2005. **Action:** ● **Sand and Dust storm information will not be included.**

2.10 Changes will be required for Amendment 80 to Annex 3 and these are described in METP-WG/MOG7 SN26.

DATA FORMAT

2.11 At present SIGWX forecast data is provided in BUFR Edition 3 format. BUFR Edition 3 has not been supported by WMO since 2012. The WAFCs chose not to transition to Edition 4 and instead await the implementation of XML/GML for the SIGWX, so that States and vendors would not need to make costly changes for Edition 4 and then make more changes for XML/GML.

2.11.1 In addition, the planned 2018 GANP ASBU AMET description states the following:

AMET-B1/4: Dissemination of Meteorological Information

This element represents the dissemination of meteorological products using a variety of formats, including:

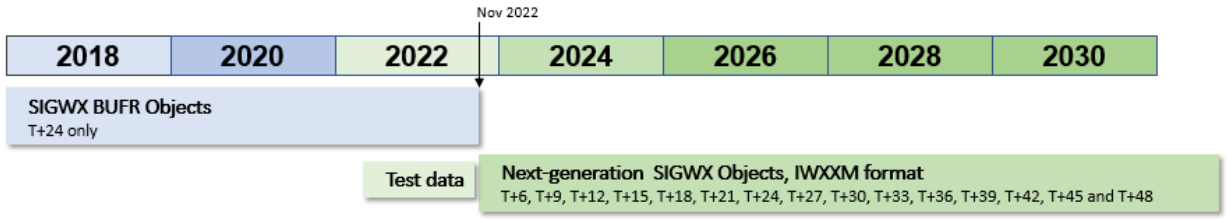
- *ICAO Meteorological Information Exchange Model (IWXXM) format*
- *Graphical (PNG and BUFR to be phased out)*

2.12 The WAFCs will develop the next-generation, multi time-step SIGWX object data sets using the latest IWXXM standard formats. Test data sets will be made available to users for at least 1 year prior to the operational implementation of the products in November 2022.

2.13 The production of T+24 SIGWX data in BUFR format will cease in November 2022.

TIMELINE

2.14 The timeline of proposed changes is shown below:



2.15 Next-generation SIGWX data sets will be provided on the next-generation SWIM compliant data delivery system by November 2022.

2.16 Test IWXXM format data sets will be made available to users and software providers by November 2021 at the latest.

2.17 From November 2022 to November 2028 T+24 IWXXM format data will be available on SADIS FTP and WIFS.

DOCUMENTATION CHANGES

2.18 Some minor adjustments to Annex 3 are required for Amendment 79, and these are proposed in METP-WG/MOG7 SN25

2.19 Larger changes are required for Amendment 80 to Annex 3 (including the expected transfer of technical specifications for SIGWX information to the new PANS-MET). These are proposed in METP-WG/MOG/7 SN/26.

3. CONCLUSION

3.1 In order for the WAFCs to deliver the next generation of SIGWX forecasts in IWXXM format that the aviation industry requires, some compromises will need to be made. It is not possible to simply replicate what we do now for lots of additional time-steps.

3.2 The group is invited to consider the evidence presented in paragraphs 2.2 through to 2.13 and formulate the following draft actions:

Agreed Action 7/xx – Next Generation SIGWX forecast data

That the METP-WG/MOG prepares a working paper for METP/4 on the planned improvements to the provision of WAFS information, and that this paper includes the WAFC's plans to enable the production of SIGWX forecasts in IWXXM format for 3 hourly time-steps (between T+6 and T+48) from November 2022. The following items are to be included in the data set and are as follows:

a) Jet stream position, speed and flight level of the jet core;

b) Cumulonimbus extent, and top (in the range FL100-FL530)

c) Turbulence areas due to CAT and MTW (in the range FL100-FL530)

d) Icing areas associated with cloud (in the range FL100-FL300)

e) Information on the position of tropical cyclones, volcanic eruptions and radioactive release, in accordance with the relevant advisories

Agreed Action 7/xx – BUFR Format SIGWX data

That the METP-WG/MOG include in their working paper to METP/4 on the planned improvements to the provision of WAFS information, that the production of SIGWX forecasts in BUFR format to cease in November 2022.

4. ACTION BY THE METP-WG/MOG

4.1 The METP-WG/MOG is invited to:

a) note the information contained in this paper

b) formulate agreed actions to take to METP/4 regarding the future provision of the next generation of SIGWX forecasts from November 2022.

APPENDIX A

VERIFICATION OF SIGNIFICANT WEATHER OBJECTS

Significant Weather Object forecasts for jets, turbulence and cumulonimbus cloud (CB) for T+24 are being created using the blended, gridded WAFC Hazard data. These objects are produced as a first guess product for the WAFC London forecasts, but are not used operationally.

Verification

Turbulence forecasts are verified against automated aircraft reports provided by a fleet of B747 and B777 aircraft. Although the flights are global they are heavily based towards the Northern Hemisphere, and in particular the Europe, North America and North Atlantic Areas.

Cumulonimbus horizontal extent forecasts are verified against a severe convection satellite product using data from the Meteosat Second Generation (MSG) and Himawari-8 satellites. The coverage is good for Europe, parts of Asia, Australia, North Atlantic, Africa but poor for North America at present.

Explanation of the verification techniques used:

Both turbulence and CB horizontal extent forecasts are verified in a categorical manner using 2x2 contingency tables to store the information as counts of hits, false alarms, misses and correct rejections.

The Relative Operating Characteristic (ROC) plots are useful for visualising the discriminatory skill of the forecast by plotting the hit rate against the false alarm rate. This shows the trade-off between increasing the hit rate at the expense of increasing the false alarm rate by changing the threshold at which a forecast is converted into a binary yes/no forecast. The diagonal can be considered as a line of no skill with points closer to the top left representing more skilful forecasts with higher hit rates and lower false alarm rates. This is shown in figure 1.

The relative economic value plots are a good way to show how useful a forecast would be in decision making. The relative value is shown on the y-axis with a value of 0 representing what could be achieved through knowledge of the observational climatology alone and a value of 1 representing the perfect value that could be attained by a forecast where events are observed every time they are forecast and no events occurring without a forecast. This is shown in figure 2.

These relative values depend on the user and what cost they would have in taking mitigating action compared to the loss associated with an event occurring having taken no action. Clearly these costs and losses will be different for any user, however by plotting the ratio of the cost to the loss on the x-axis the actual values are not needed to visualise the potential value of a forecast to the whole range of users. It is likely that the cost/loss ratio will be a low value due to the potential loss through injury, aircraft damage or even loss of life would be far greater than the cost involved in a small alteration to the flight plan or in the case of turbulence this could just be through more careful planning in the use of the seatbelt sign and timings of meal service to minimise the amount of time passengers and crew are not securely belted into their seats.

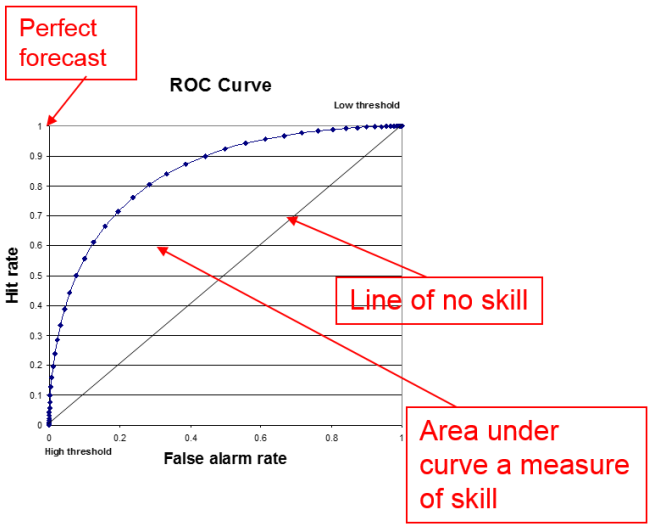


Figure 1 – Example ROC plot

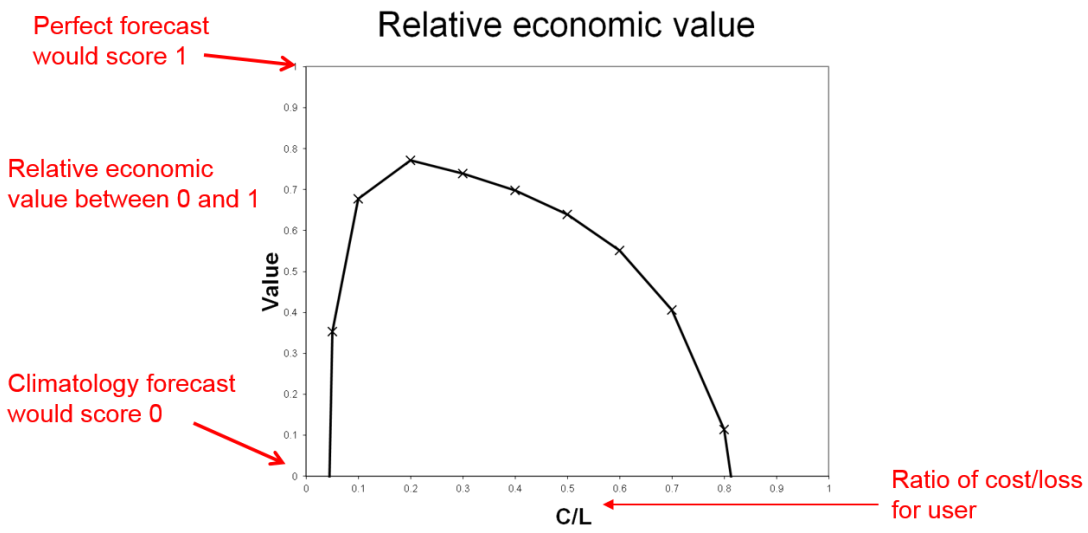


Figure 2 – Example Relative Economic Value plot

Results

Cumulonimbus Cloud Horizontal Extent

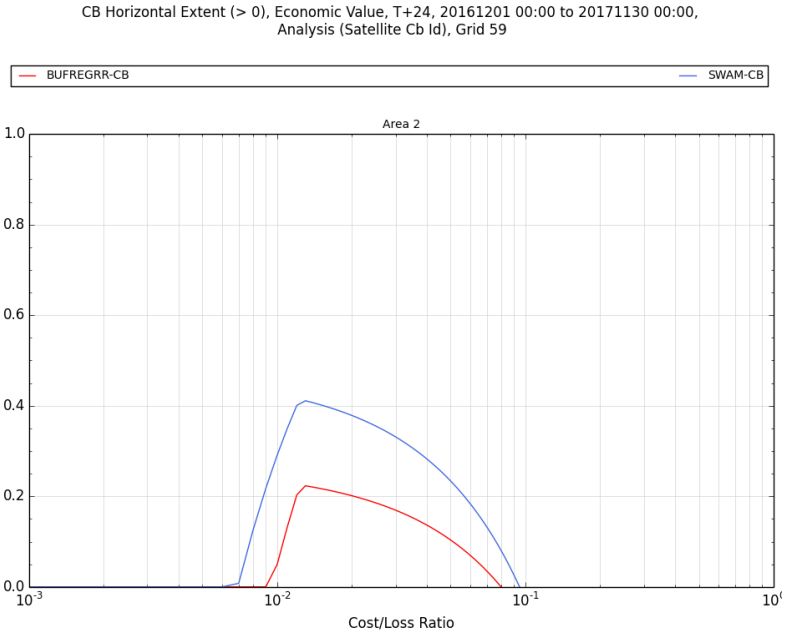


Figure 3, Relative economic value plot for the North Atlantic Region

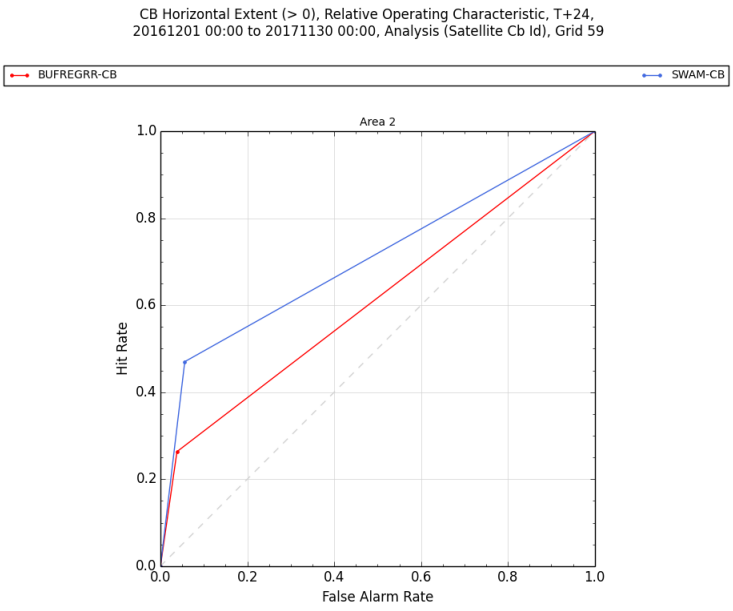


Figure 4, ROC plot for the North Atlantic region

"SIGWX Object" data is shown in blue, whilst T+24 "SIGWX BUFR" (meteorologist drawn) data is shown in red.

The relative economic value plots created when verifying the CB horizontal extent forecasts (figure 3) show that at the T+24 forecast range there is substantially more value across the user cost-loss ratios with the SIGWX object forecasts than from the BUFR data sets for the North Atlantic (Area 2) region. The value of the SIGWX Objects and BUFR data for the Asia and Australian regions (not shown) are very similar to each other.

The corresponding ROC plot for the North Atlantic region (figure 4) shows that the SIGWX Objects all have a much higher hit rate than the BUFR forecasts but do have a slightly higher false alarm rate too. The increased areas under the SIGWX Object ROC curves indicate the greater skill of these forecasts at discriminating between events and non-events. The ROC plots for the Asia and Australian regions (not shown) show similar skill between the SIGWX Objects and BUFR forecasts, with the SIGWX Objects having a slightly higher hit rate but also a slightly higher false alarm rate than the BUFR data.

Turbulence

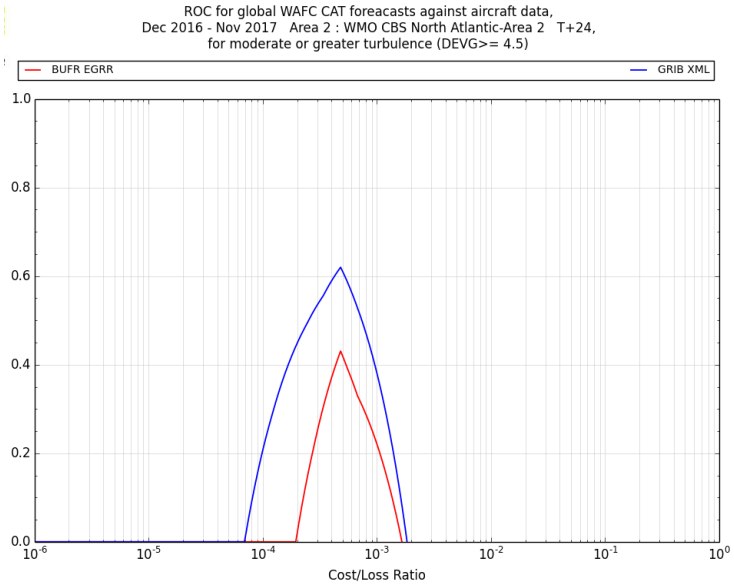


Figure 5, Relative economic value plot for the North Atlantic Region

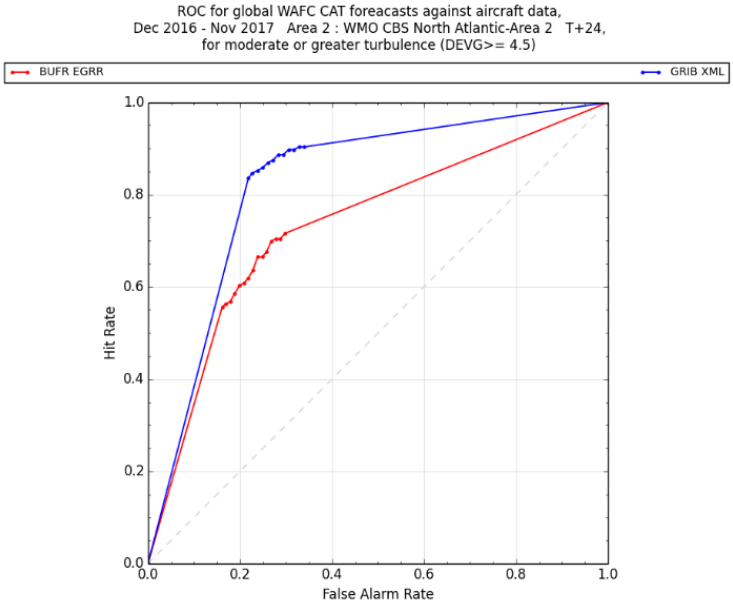


Figure 6, ROC plot for the North Atlantic region

"SIGWX Object" data is shown in blue, whilst "SIGWX BUFR" is shown in red

The turbulence verification ROC (figure 6) plots show that the SIGWX Objects have a much higher hit rate than the BUFR data, although they do generally have a slightly greater false alarm rate too depending on the area. The increased area under the SIGWX Object ROC curves indicates the greater skill of this technique in discriminating turbulent events from non-turbulent events compared to the BUFR forecasts.

Comparing the relative economic value plots, the SIGWX Object shows that at all cost/loss ratios there is higher value from using this over the BUFR data.

The relative economic value plots for turbulence in other areas of the World vary in the amount of value but are consistent in showing that there is generally considerably more value from the SIGWX Object turbulence forecasts, across all user cost/loss ratios than the SIGWX BUFR forecasts.

Conclusion

Preliminary analysis shows that SWAM forecasts clearly give an increase in value across the different regions, whilst for cumulonimbus the increase in value is greatest for the North Atlantic region. It is worth noting that this study used the existing 1.25° resolution data.

Development work is planned to upgrade the algorithms to use 0.25° resolution data, and to use the new turbulence predictor (Graphical Turbulence Guidance) and probabilistic cumulonimbus information. All measures are expected to increase the value of the SWAM objects further.

For these reasons it is believed that the amount of meteorologist oversight when using these SIGWX Objects in the production of WAFC SIGWX forecasts can be reduced.