

# Near real-time verification of operational solar flare forecasts

Suzy Bingham<sup>1</sup>, David Jackson<sup>1</sup>, Michael Sharpe<sup>1</sup>, Sophie Murray<sup>2</sup>, Jesse Andries<sup>3</sup> and Catherine Burnett<sup>1</sup>

## 1. Abstract

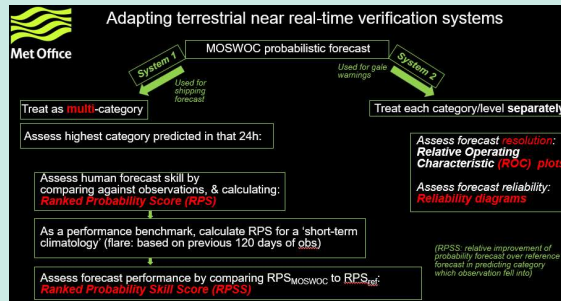
Verification of operational space weather forecasts is in its infancy. However, progress in this area has advanced considerably over the past few years with increasing awareness of its importance. Development has benefited from adaptation of existing, suitable, terrestrial weather forecast verification methods. Presented here are results from near real-time verification systems used to verify the UK Met Office Space Weather Operations Centre's (MOSWOC's) 4-day flare forecasts. Flare forecast verification efforts within the International Space Environment Service (ISES) are described; recommendations are presented on which metrics to apply to verify ISES's operational probabilistic flare forecasts.

## 2. Met Office near real-time forecast verification systems

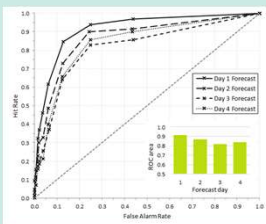
Example MOSWOC flare forecast

X Ray Flare Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active M-Class	N	20	20	15	10	
Active M-Class	N	2	2	1	1	

- MOSWOC 4-day probabilistic flare forecasts are verified using two verification systems
- Systems' output includes: ROC plots, Reliability diagrams, RPSS plots

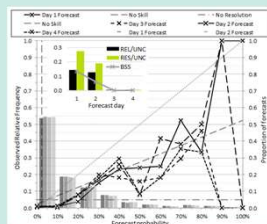


## 3. MOSWOC flare forecast verification results

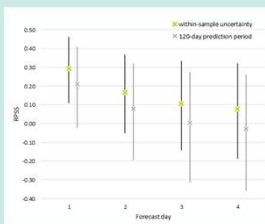


ROC & Reliability for M-class flare exceedance forecasts, 1<sup>st</sup> Apr '15 – 31<sup>st</sup> Dec '18

Left ROC plot & area. Days 1-4 forecasts lie above the diagonal no-skill line. Day 1 most skillful.



Middle Reliability diagram (forecast is skillful if lies between the no-skill dashed lines) suggests MOSWOC generally over-forecast. Histograms show greater proportion of low probability forecasts. Brier type scores. Only positive on days 1 & 2. Reliability is similar on days 1 & 2, but resolution is lower on day 2.



RPSS, Jan '16 – Dec '18

Right RPSS for days 1-4 forecasts calculated using frequency of occurrence as reference (rolling 120 day, & 3 years). Statistically significant evidence of MOSWOC day 1 forecast skill at predicting M-class, compared to 3 year reference.

## 4. International Space Environment Service

- ISES - primary organisation engaged in international coordination of space weather services since 1962
- Mission: deliver, coordinate & improve operational space weather services through rapid exchange of space environment information; share best practices for data analysis & product development; open dissemination of products & services
- Organised & operated for the benefit of the international user community
- Includes 20 centres. Collaborates with international organisations, e.g. WMO
- <http://www.spaceweather.org/>



## 5. Recommendations for verification of ISES members' probabilistic forecasts

- Why verify? To ensure individual centres improve, & to understand how well different forecasting approaches perform
- Initial standard set of metrics to verify probabilistic M-class flare forecasts: ROC plot, Reliability diagram, area under ROC plot. Potentially: Brier Skill Score (BSS) calculated with reference to a short-term climatology. Consider using RPSS by comparing to a rolling short-term climatology.
- Involve expert group in ISES discussions, e.g. from terrestrial verification community
- Encourage members to send forecasts to NASA's Community Coordinated Modelling Center (CCMC) Flare Scoreboard – potential to use this infrastructure to verify forecasts
- Consider using National Center for Atmospheric Research's (NCAR's) Model Evaluation Tools (MET): [https://dtcenter.org/met/users/support/online\\_tutorial/METv6.1/index.php](https://dtcenter.org/met/users/support/online_tutorial/METv6.1/index.php)
- Next step: apply same set of metrics to geomagnetic storm forecasts. Use rare event metrics for X-class flare forecasts.

## 6. Summary

- MOSWOC 4-day probabilistic flare forecasts are verified in near real-time using two adapted terrestrial weather verification systems
- MOSWOC forecast verification methods: ROC, Reliability, Ranked Probability Skill Score (compared to short-term climatologies), suggest MOSWOC over-forecast M-class flares & that shorter lead-time forecasts are more skillful
- ISES is engaged in coordinating verification of forecasts produced by a network of space weather service-providing organisations around the globe
- Recommendations for verification of ISES Centres' flare forecasts include: calculating ROC plot, Reliability diagram, ROC plot area
- Future: operational ensemble flare forecast using ISES members' forecasts and verified in near real-time through Met Office verification systems