

Advancing Forecasting Capabilities through Operations-to-Research at the Met Office Space Weather Operations Centre

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Abstract

An effective Operations-to-Research (O2R) process is fundamental to sustaining and enhancing the forecasting capabilities of the Met Office Space Weather Operations Centre (MOSWOC). It enables forecasters to provide structured feedback on the performance of operational models and data, ensuring that challenges and opportunities for improvement are systematically captured, resolved and used to guide research priorities through practical operational insight.

The current O2R framework, centred on the Space Weather Issues and Reviews Log (SWIRL), has been in place since 2020. The SWIRL framework was tailored to meet the needs of space weather operations whilst drawing on best practices from terrestrial weather O2R. It is timely to revisit and improve the O2R process, particularly with the imminent increase in models available to MOSWOC, as systems developed under the SWIMMR programme approach operational readiness.

In the terrestrial context, forecasters submit Daily Forecast Assessments to report model issues. When a bias is identified, a model ticket is raised and logged in a Model Characteristics document to support both forecast interpretation and research planning. MOSWOC maintain similar documents outlining model strengths and limitations, though there is scope to enhance these by integrating with a structured R&D ticketing system and evolving them into living resources.

We explore enhancements to the current framework to better support identifying, tracking, and prioritising model and data improvements - enabling deeper insight into model behaviour and associated space weather impacts, strengthening feedback mechanisms to research, and ultimately improving the resilience and effectiveness of MOSWOC's operational forecasting services.

Space Weather Issues and Reviews Log (SWIRL)

The primary aim of the Space Weather Issues and Reviews Log (SWIRL) process is to establish a centralised repository of model and data issues and queries arising on the MOSWOC bench, along with any model development ideas. The focus is on *scientific* rather than *technical* matters, helping to identify recurring model issues, support capability improvement planning, and to enhance our understanding of model characteristics. SWIRL also captures any potential impacts attributed to space weather (e.g. satellite damage) and borderline Science-IT problems – giving the bigger picture.

MOSWOC use a short Feedback form to record these issues, queries, ideas and impacts - following guidance in the MOSWOC SWIRL Job Instruction. Feedback is reviewed monthly by Science (SWR), Product Managers, and other members of the space weather team, who work together to identify possible solutions. Resulting Reviews are accessible to MOSWOC. Any fixes or ideas for model/data development are prioritised and undertaken. A Model Characteristic Document records the limitations of models, for forecaster reference.

By capturing and reviewing Feedback effectively, SWIRL strengthens communication across the Operations-to-Research (O2R) cycle and enhances space weather forecasting capabilities.

Forecaster Feedback Form: Example Entries

Model issue/query:

- Enlil is over-estimating the solar wind speed by ~100 km/s.
- Enlil at Mars shows a ~1.5 day mismatch between ecliptic view and time series plot.
- Why do Met Office and SWPC D-RAP output differ?

Data issue/query:

- SDO imagery is offline due to problems on the site.

Model/data dev idea:

- Develop Hovmöller views of our model/data to reveal longer-timescale patterns. Leverage MOSWOC's familiarity with this format from terrestrial weather to highlight persistent features that may modulate probability forecasts.

IT issue/query:

- Visualisation of D-RAP crashes when proton level increasing.
- Peak flare of C9.98 was rounded to M0.9 instead of C9.9.

Space weather impact:

- A satellite suffered an SEU over the weekend, leading to degraded service, coinciding with a G3 storm.

Value of a central Feedback and Review Log

Captures Information Effectively - systematically records issues, queries, and impacts, and Reviews

Highlights Recurring Model Issues - helps detect persistent model weaknesses

Supports Capability Improvement Planning - facilitates identification and prioritisation of enhancements to current models and processes

Acknowledges MOSWOC Input - shows 'Feedback' is valued and acted upon through 'Reviews'

Improves Model Understanding - builds shared knowledge of 'Model Characteristics'

Supports Stakeholder Responses - provides a resource for stakeholder enquiries

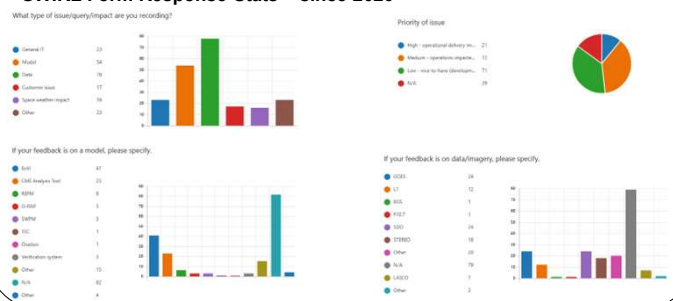
Informs Model Testing - helps select relevant test scenarios for model verification/development

Builds Observation Evidence - a resource to strengthen the case for future observations

Informs Strategy and Collaboration - a resource to inform plans and direct external collaborations

Strengthens R2O2R Process - improves communication between MOSWOC and Science.

SWIRL Form Response Stats – since 2020



Potential Improvements to SWIRL/O2R Process

- Expand to include SWIMMR models nearing operational readiness.
- Extend so MOSWOC conduct "Daily Forecast Assessments (DFAs)" – regular models-observation comparisons, to develop deeper understanding of model biases/issues.
- Extend to log any DFA biases/issues as R&D tickets and record via an expanded, living Model Characteristics Document - to support forecast interpretation and track factors contributing to improved model performance.
- Explore improved ways to share Feedback with community and academia.
- Extend to collect Feedback from end-users.

Summary

The Met Office has an O2R process known as SWIRL. It provides a framework for capturing and reviewing science-related feedback on operational models and data, including any issues, queries and development ideas. It also enables the logging of space weather impacts. Overall, it helps to build a picture of operational challenges.

SWIRL has proven effective in facilitating structured feedback and guiding prioritisation of research. There are opportunities to strengthen the process - by more effectively incorporating model/data issues into prioritisation workflows, and improving feedback mechanisms to the research community.

Looking ahead, expanding SWIRL to incorporate SWIMMR models as they approach operational readiness, will ensure comprehensive coverage across all operational models. Increasing the frequency and depth of forecast assessments, alongside introducing a ticketing system to log and track model enhancements, will support clearer benchmarking and help demonstrate the impact of ongoing improvements.

SWIRL Process (O2R)

