Systematic Observations Financing Facility

Sixth Steering Committee
27 November 2023

SOFF Impact Reports

Decision 6.8

Systematic Observations
Financing Facility

Weather and climate data for resilience

Decision 6.8: Approval of the SOFF Impact Reports

The Steering Committee

Endorses the initial two-year plan to produce SOFF Impact Reports based on scenarios of GBON implementation.

Approves the funding for the initial two-year plan to produce SOFF Impact Reports for an amount of USD 300,000.

Requests

- The UNMPTF Office to disburse the above stated amount to WMO.
- WMO to put in place an agreement with ECMWF to execute this plan and to coordinate the production of the Impact Reports

This document requests approval of USD 300,000 to produce the initial SOFF Impact Reports as adopted in the SOFF work programme 2025-2027 (Decision 1.6). It proposes a study of the impact of multiple GBON observation scenarios on weather forecasting skill to inform SOFF decisions. The study will be undertaken by the European Centre for Medium-Range Weather Forecasts and coordinated by WMO.

SOFF Impact Reports
Project Document

<table>
<tr><td>Project Title:
SOFF Impact Reports</td><td>Recipient UN Organization:
World Meteorological Organization</td></tr>
<tr><td>Project Contact:
Markus Repnik
SOFF Secretariat
7bis Avenue de la Paix
Case postale 2300
Nations, 1211 Genève
Telephone:
+41797901882
E-mail:
mrepnik@wmo.int</td><td>Project Location:

WMO Secretariat Geneva
7bis Avenue de la Paix Case postale 2300
Nations, 1211 Genève</td></tr>
<tr><td rowspan="2">Project Description:
A study of the impact of multiple GBON observation scenarios on weather forecasting skill to inform SOFF decisions.</td><td>Total Project Cost for June 2024 – January 2025
USD 300,000 including 7% WMO indirect costs</td></tr>
<tr><td>Project Start Date: 1 December 2023
Proposed Project End Date: 30 June 2025
Project Duration: 19 months</td></tr>
<tr><td>Recipient UN Organization and signatory:

Petteri Taalas
Secretary-General, World Meteorological Organization
Signature:

Date:</td><td>Chair of the SOFF Steering Committee:

Jørgensen Aage
Co-Chair of the SOFF Steering Committee
Signature:

Date:</td></tr>
</table>

Table of contents

SOFF Impact Reports:

An initial two-year plan to inform WMO and SOFF decisions with a study of the impact of multiple GBON observation scenarios on weather forecasting skill

1. Motivation

A key SOFF output for the compliance phase defined in the SOFF Terms of Reference[1] are annual reports of the Global Basic Observing Network (GBON) compliance and *impact*. Impact is defined as the "impact of improved observations in forecast skill in SOFF supported countries and globally," produced in collaboration with the WMO Technical Authority and available WMO World Meteorological Centres[2]. In Decision 1.6, the SOFF Steering Committee adopted a preliminary work programme that included an allocation in the amount of USD 300,000 to produce the SOFF Impact Reports.

As SOFF beneficiary countries are just now starting to move to the investment phase and new SOFF-funded GBON observations are not yet in place, this paper presents a plan to work in an initial two-year phase with WMO Technical Authority and the European Centre for Medium-Range Weather Forecasts (ECMWF), one of the World Meteorological Centres and a member of the SOFF Advisory Board, to evaluate *scenarios* of GBON implementation and their impact on weather forecasting skill, in order to inform the SOFF Steering Committee and WMO Technical Authority in their decision-making, and provide SOFF funders and potential funders with information on the potential impact of their investment on weather forecasts and early warnings.

2. Measuring an observation's impact in forecast skill

The measurement of the **impact** of an observation in a numerical weather prediction (NWP) system is critical part of defining observational requirements and strategies, where feasibility and impact are balanced (analogous to studying cost and benefit). Estimates of the improvement of forecast skill for global NWP were a central part of the motivation for the design of GBON and SOFF[3]. There are several ways to undertake these studies.

Observing System Experiments (OSE)

Described as the "gold standard" to measure impact, in an Observing System Experiment (OSE) meteorologists remove one observation or type at a time and run the NWP model

[1] https://www.un-soff.org/document/terms-of-reference/

[2] The ten centers that have been designated as World Meteorological Centres by the WMO Integrated Processing and Prediction System (WIPPS), run by WMO Members as providing global numerical weather prediction products for all Members.

[3] Kull et al., The Value of Surface-based Meteorological Observation Data, World Bank Study report, 2021. https://alliancehydromet.org/wp-content/uploads/2021/07/The-Value-of-Surface-based-Meteorological-Observation-Data.pdf

without it. They compare this "data-denied" forecast with the full forecast to see the difference.

If taking out an observation makes the forecast less accurate, it means that observation had a significant impact. If not, it might not be as critical.

OSEs are easy to interpret but have some disadvantages. They are computationally intense and therefore expensive to run since the forecast needs to be run multiple times. They do not quantify an observation's impact, and do not capture the interactions between observation types.

Forecast Sensitivity-based Observation Impact (FSOI)

Another common method used is Forecast Sensitivity-based Observation Impact (FSOI) studies. In these, meteorologists use the assimilation of observational data into the forecast to identify the relationship between short-range forecast error and the observations. This can be incorporated into routine operations and provide a quantitative link between an observation and its impact.

The disadvantage of FSOI methods is an assumption that the impact of an observation on a forecast is linear - but atmospheric processes are nonlinear, limiting interpretation of the results.

Impact assessed using Ensemble of Data Assimilations (EDA)

NWP centres now routinely run ensembles of data assimilations and forecasts, each with slightly different initial conditions based on the observations. Each member of the ensemble (somewhere between 10 and 50) provides a different forecast, and comparison across the forecasts for their spread identifies the confidence of the overall forecast, its uncertainty.

Significantly, the perturbations in the initial conditions of the data assimilations can use both real and simulated observations, and by comparing the members in the ensemble, meteorologists can see which observations had the most consistent impact on the short-term forecast. If a particular observation consistent leads to better forecasts in different members of the ensemble, it is considered highly valuable.

Past experience in simulating the impact of future satellite observing missions was confirmed with actual improvements in forecast skill once the satellite was operational, building confidence in this method developed at ECMWF.

WMO impacts workshops

WMO has organized a series of workshops on the impacts of various observing systems on numerical weather prediction, taking place roughly every four years since 1997. Results from a multitude of observing system experiments, with both global and regional aspects, were presented each time and conclusions were drawn concerning the

contributions of the various components of the observing systems to forecast skill at short and medium range.

The eighth in this series will be held 27-30 May 2024[4], expanding from numerical weather prediction to other areas of Earth System prediction for key weather, climate, and water applications. Amongst its aims will be to evaluate the impact of GBON implementation. The outcomes of the workshop will inform both WMO and SOFF, as well as orient the analysis of the scenarios developed in this study.

3. Proposed study plan

For the SOFF work programme 2022-2025, it is proposed that WMO works directly with one of the WMO World Meteorological Centres, ECMWF, in two phases.

3.1. Phase 1 (Dec 2023 – June 2024)

This phase would focus on:

- A summary of the outcomes of past studies,
- Review of the status of existing metrics available at ECMWF to build understanding of the confidence and limitations of the approach to looking at different scenarios,
- The definition of the possible scenarios (up to 5), including prioritization, from the list in Section 4, and
- Initial report provided for consideration of the 8th SOFF Steering Committee in June 2024.

3.2. Phase 2 (July 2024 – June 2025)

This phase would focus on:

- Preparation for testing the scenarios, including an Observing System Experiment to calibrate the confidence in the Ensemble of Data Assimilations method,
- Creating simulated data for each scenario,
- Running the scenarios using the high-performance computing facility,
- Analysis of the scenarios and developing recommendations to WMO and SOFF,
- Report provided for consideration of SOFF Steering Committee in June 2025.

At the conclusion of these two phases, the SOFF Steering Committee, with advice from the WMO Technical authority, will consider whether to extend these scenario studies with ECMWF to a third phase, to include further interested WMO World Meteorological Centres, or to change the orientation of this impacts work.

[4] https://community.wmo.int/en/meetings/8th-wmo-impact-workshop-home

4. Scenarios

These potential scenarios in the study plan would explore:

- **The impact of meeting GBON targets in Least Developed Countries (LDCs) and Small Island Developing States (SIDS)**

  This will confirm previous estimates of the impact of SOFF investments with more numerical precision.

- **Additionally meeting GBON targets in Middle-Income Countries**

  This scenario would help SOFF as it monitors the proposed phased expansion of support to Middle-Income Countries (MICs). The scenarios would differentiate between lower and upper MICs.

- **Identifying the relative impact of surface vs. upper-air stations**

- **Identifying the relative impact of mandatory GBON standard and recommended high horizontal resolution implementation**

- **Identifying geographic areas that would have the greatest impact in improving forecasts**

  These scenarios would help in a resource-constrained environment to inform SOFF investment decisions based on its first programming criteria, to "close the most significant data gaps: …where strengthening the observing network would yield the largest results regarding the quality of the numerical weather prediction products."

- **Meeting GBON marine observation targets**

  GBON technical regulations already include a country's responsibility to take basic meteorological measurements over its Exclusive Economic Zone (EEZ) area. The ocean covers 70% of the surface of the Earth, and EEZs comprise one third of that. SOFF is not presently funding this existing GBON target as WMO finalizes guidance material for GBON marine implementation, including compliance monitoring. This scenario would inform a potential medium-term SOFF expansion of GBON implementation.

- **Expansion of GBON to different domains:** hydrological observations, high-seas ocean observations, cryospheric observations

  These are unlikely to figure as selected scenarios for the initial study period, but could be considered for further work to inform the evolution of GBON and therefore potential long-term evolutions of SOFF support, as identified in SOFF Decision 5.5.

5. Choice of partner

The ECMWF is both a research institute and a 24/7 operational service producing and disseminating numerical weather prediction products. Its core mission includes both the production of numerical weather forecasts and monitoring of the Earth System, and the carrying out of scientific and technical research to improve forecast skill.

It is one of the ten WMO World Meteorological Centres (WMC), the top level in the WMO Integrated Processing and Prediction System, with responsibility to produce global weather forecasts for all WMO Members.

The work in this study could be done with a number of the WMCs. However, ECMWF has a comparative advantage since it is a member of the SOFF Advisory Board and has been a close partner in the development of SOFF. ECMWF has committed to provide significant in-kind support to the proposed study, including computing infrastructure and time, and expert guidance to the funded work and experts in the study. These experts are available and committed in the time frame envisioned.

It is therefore recommended that SOFF proceed with ECMWF in this first phase, and consider potential expansion to work with other WMCs in future phases.