Publishable Summary for 17SIP02 SimpleMeteoU
Simple Expression of Uncertainty for Meteorological Observations

Overview

For users of weather and climate information, confidence in the observational data is key. Many factors, however, can affect meteorological observations, from weather station location to the type of measurement equipment used. This project addressed a widely recognised need for a simple way to attribute uncertainty in these meteorological observations. The project's primary supporter, the UK Met Office (MO), sought an approach to doing this by refining existing metrology knowledge, including that from EMRP JRP ENV58 MeteoMet2, to form a simplified system of expressing measurement uncertainty.

This project developed proposals for rule-based systems that could be applied to meteorological data, to give simplified expression of uncertainty based on influences such as siting location and current weather conditions. It offered recommendations on how best to present this uncertainty information. The resulting approach to expressing uncertainty could in future be used to improve numerical weather prediction leading to more accurate weather forecasts.

Need

Weather affects a vast range of human endeavours, and its importance ranges from convenience and comfort to matters of safety, environmental and economic impact. Despite ever-improving techniques, there is always some uncertainty in weather forecasts. Users at all levels (such as meteorologists, infrastructure operators, businesses, and individuals) needed uncertainty information, so that they could assess weather-related risks. In addition, the large class of users of commercially supplied weather services needed uncertainty as a differentiator of quality in order to select between sources. However, this uncertainty information was generally not available, or was not provided in an easy-to use format.

In addition, MO itself had particular needs for simplified expression of uncertainty for observations. MO needed to use more widely sourced data in order to meet its ambition of improving the resolution of numerical weather prediction from 500 m, previously, towards 100 m, with a rapid turnaround of 2 hours from data to forecast. In order to achieve a higher resolution, a wider source of data was required, including data from third parties such as public or private organisations. Such data would be of mixed quality and could not have uncertainty evaluation case by case: a simple and fast system was needed. In order to provide this, a simplified system to express the uncertainty of meteorological data in an easily understandable form was required.

Objectives

The overall aim of the project was to demonstrate a system of expressing uncertainty in a simplified way, for meteorological observations. The specific objectives of this work were:

1. To develop a system (methodology and visual representation) for simplified expression of uncertainty for meteorological data, suitable for observations of varying sources and quality from both MO and third parties, and for use by non-experts, demonstrated in a worked example for air temperature.

2. To communicate, consult and agree the approach for the simplified expression of uncertainty with the World Meteorological Organisation (WMO) Commission for Instruments and Methods of Observation (CIMO) Expert Teams on Operational In Situ Technologies and Operational Metrology and with other selected stakeholders, and propose how this could be implemented across a range of variables and for a range of audiences including non-experts.

Results

Development of simple expression of uncertainty for meteorological observations

Available information was selected and used to develop simple expression of uncertainty for meteorological observations. This involved summarising the outputs of EMRP project ENV58 MeteoMet2 *Metrology for Essential Climate Variables* which quantified the influences of aspects of siting and conditions on meteorological observations of temperature. A worked example was produced showing a detailed evaluation of uncertainty for a temperature observation. This provided a valuable illustration not widely available for uncertainty of an entire observation, as well as providing a necessary baseline for a simplified approach.

This methodology considered the main influence factors for a given measurement, in order to establish approximate uncertainty. The documentation also included examples of displaying information in a simple form, such as tables or graphical visualisations, designed to support less-expert users to recognise and attribute measurement uncertainty in a simplified but appropriate way. This resulted in a discussion document describing a draft simplified system for expressing uncertainty of meteorological observations, including a worked example for air temperature.

Overall, creation of the draft document achieved the objective of development of simple expression of uncertainty for meteorological observations. The Met Office (primary supporter) was actively involved in the development of this document. They gave input and feedback at many stages, including contributions to the text.

Stakeholder engagement concerning simple expression of uncertainty for meteorological observations

The developed discussion document was shared for review and feedback from specialists within WMO CIMO, and other selected experts in the field of meteorology. This included the Chairs of three WMO Expert teams on Measurement Uncertainty, Surface and Sub-surface Measurement, and Quality Traceability and Calibration. The reviewers were consulted on the approach to uncertainty evaluation and presentation, and on its correct applicability to the meteorology context. Feedback from this stage was used to refine the approach and document. Based on the agreed approach, recommendations were prepared in an open-access report (publication due end of 2021). The approach was outlined in general terms with detailed illustration for meteorological temperature observation. Considerations were also outlined for application to other variables, with details for relative humidity, for wind speed and direction, and for marine observations.

Awareness and uptake of the approach were promoted through presentation at events such as WMO CIMO TECO 2018 and through involvement of stakeholders in commenting on the draft stage of the report. These stakeholders represented national metrology organisations, national metrology institutes, academia as well as WMO.

Overall, these actions achieved the objective of stakeholder engagement concerning simple expression of uncertainty for meteorological observations.

Impact

Details of the project been disseminated through a number of events and personal interactions from 2018 to 2021. These engagements spanned subject areas of meteorology and climate, temperature and humidity, and engagements with more general audiences.

Meteorology- and climate-specific engagements included an NPL seminar on H2020 GaiaClim/Fiduceo project work; a seminar meeting on awareness of uncertainty treatment in the Copernicus Climate Change Service; presentations to WMO CIMO TECO 2018 International conference, a site visit to Teddington Bushy Park weather station; and participation in the kick-off meeting of the European Metrology Network on Climate and Ocean.

Engagement with the metrology community included meetings of EURAMET Technical Committee on Thermometry (2019 and 2021) and BIPM CCT Working Group for Humidity (2019, 2020), and presentations at TEMPMEKO and TEMPBEIJING with MMC 2019 international conference.

Engagement with wider audiences included presentations to NPL Programme (External) Expert Groups, and participation in “Improving reproducibility in research” public technical meeting on uses of machine-actionable data and metadata.

Early impact

The project has been of early benefit to MO at several levels. It was useful to them that the project initially collected the findings of research literature on effects of siting and conditions on metrological temperature observations, including those from work in EMRP ENV58 MeteoMet2 whose quantitative results had not previously been summarised. MO also benefited from the production of a worked example of a full evaluation of uncertainty for a temperature observation, to reinforce understanding of conventional uncertainty evaluation. The project identified, for this application, the key sources of uncertainty and outlined how to take a simplified approach by focusing on these main sources. For the simplified approach, the project report documented a number assumptions and qualifications of the approach, at the request of the MO in order for them to take into account any limitations of the approach. The project report also provided several visualisations of the analysis of uncertainty which are available to MO to support communication of the ideas in the report, and for communication about uncertainty analysis generally. In addition, the identification of next steps in developing and making use of the simplified approach provided MO with indications for possible future work.

A wider immediate benefit of the work was to promote discussion of uncertainty evaluation in meteorology, among experts in the target readership (such as specialist in meteorology and in measurement uncertainty). Awareness has been raised of approaches to reporting meteorological uncertainty, both rigorously and by approximation, as an improvement to the current state of the art. The process of sharing the project document for comment with a number of influential readers (such as individuals with leading roles in WMO activities) has also increased awareness of the earlier MeteoMet2 work.

This work has brought together and applied some outputs of EMRP ENV58 MeteoMet2. That project had delivered several studies of the effects of siting and conditions on meteorological observations of temperature. Within 17SIP02 SimpleMeteoU, the quantitative findings of the MeteoMet2 studies have been collected, together along with those of some other relevant studies in the field. For the collected findings, the magnitude of the influence on temperature observations has been examined to consider how such effects can be taken into account individually or in combination, to evaluate uncertainty. This has been analysed in the project alongside the system of siting classifications previously established on a consensus basis by the World Meteorological Organization Commission on Instruments and Methods of Observation (WMO CIMO). The quantitative summary of MeteoMet2 outputs provides material to support possible future review of the CIMO attributed uncertainties associated with siting.

The project was publicised at CIMO TECO conference in 2018 and also by networking and short presentations at meetings on low-cost sensor networks, reproducibility in research, and others.

Following on from joint working in the project, MO nominated NPL to the expert list for selection for the newly re-formed committee structure of WMO CIMO. Consequently, NPL accepted an invitation to join the Expert Team on Quality, Traceability and Calibration within the WMO Standing Committee on Measurements, Instrumentation and Traceability. In addition, NPL was invited to Join a newly-formed Task Group on Air Temperature, within the BIPM CCT WG-Env, as well as participating in a research intercomparison of air temperature calibrations among members of EURAMET TC-T.

Longer term impact and wider benefits

The processes developed in this project, of assimilating uncertainty in observations from different sources into a simplified expression of uncertainty, will support MO towards using weather observations from an increased range of widespread sources of differing quality - sources including infrastructure (roads, airports), industrial premises and amateur observations. This will support attribution of uncertainty to observations in cases where uncertainty was not previously reported. This can ultimately contribute to the use of more third-party observations in numerical weather models, using weightings according to quality (uncertainty). Such third-party data can ultimately contribute to forecasts with finer resolution than at present. Using available metadata, as illustrated in the project, there is potential for this type of approach to be made machine-actionable to be applied on the rapid timescale needed for timely forecasting.

The simple approach to expressing uncertainty, once implemented by MO, can improve user understanding and confidence in weather information. The illustrations and visualisations available from the project will support understanding by non-experts in uncertainty, including meteorology specialists and consumers of meteorology services.

For users purchasing commercial meteorological services, improved expression of uncertainty will ultimately provide a basis for selecting according to the quality (uncertainty) of weather data. Clearly expressed uncertainty can increase user understanding and trust of weather forecasts and can enable decisions based on awareness of risk. In the longer term, the developments in the project, for simplified calculation and for communication of uncertainty, will allow MO's customers (including transport sector, utilities, agriculture, large-scale construction, defence and management of civil emergencies) to better consider weather risks and to improve their risk mitigation strategies associated with weather. Overall, weather risk management can have benefits such as: optimised safe running of transport infrastructure; energy-efficient operation of building management systems and of utility networks; and protection of citizens across spheres of business, health, and leisure.

In addition, the engagement of WMO CIMO Expert Teams, which establish best practice in meteorology worldwide, will provide a route for further exploitation of the project outputs to influence practices globally.

<table>
<tr><td colspan="3">Project start date and duration:</td><td colspan="3">01 May 2018, 33 Months</td></tr>
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1. NPL, UK</td><td colspan="2">External Funded Partners:</td><td colspan="2">Unfunded Partners:
2. MO, UK</td></tr>
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