Recent advances in the application and utility of subseasonal-to-seasonal (S2S) predictions

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Acknowledgements: Daniela Domeisen (ETH Zürich), Joanne Robbins (Met Office), Ángel G. Muñoz and Andrew Robertson (IRI), Frederic Vitart (ECMWF), Jethro Browell (University of Glasgow), Doug Bertram and Robert Graham (University of Strathclyde)

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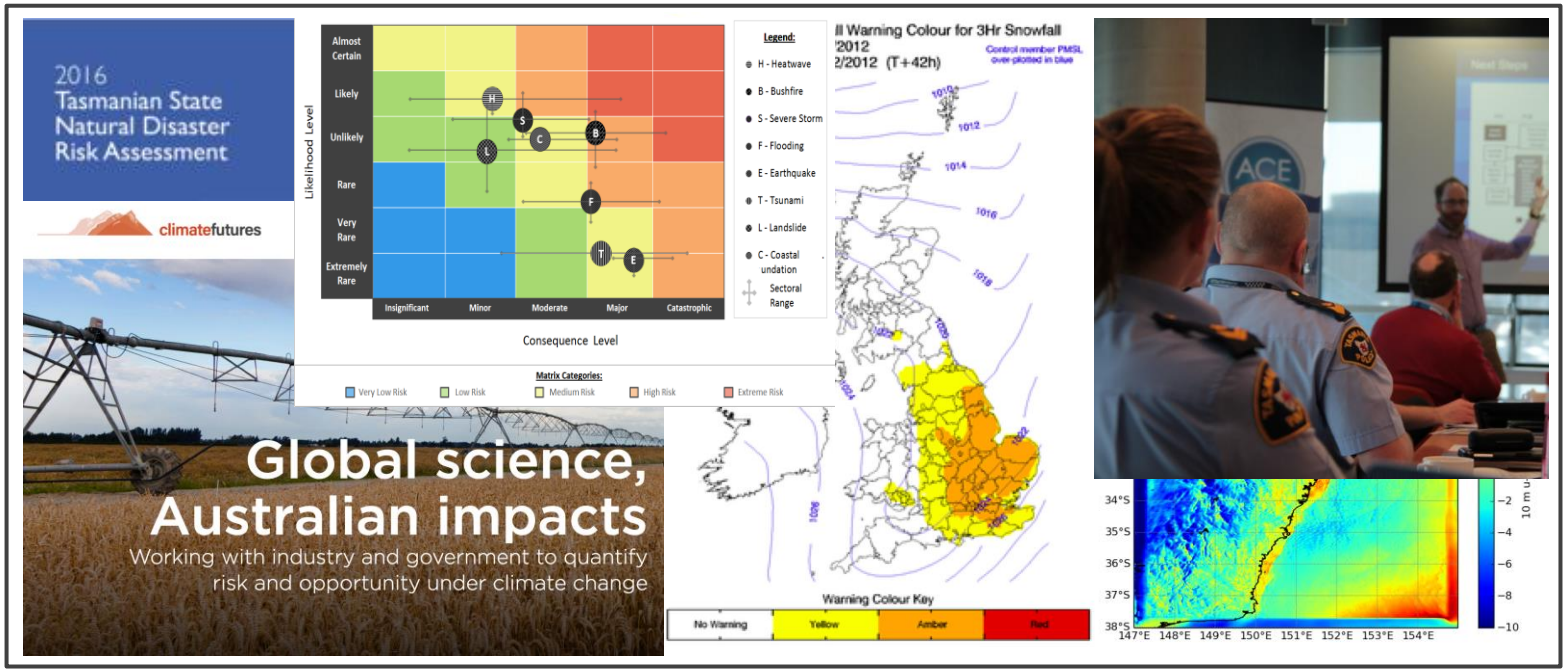
Introduction

Introduction

– A hydro-meteorologist in the Department of Civil and Environmental Engineering at the University of Strathclyde, specialising in understanding and forecasting natural hazards and extreme weather event impacts.



Introduction

- Head of the **Centre for Water, Environment, Sustainability & Public Health**, which undertakes fundamental and applied research, including net zero, water and waste, environmental health, and **climate resilience**.
- I lead the **Engineering for Extremes** research group that focuses on understanding extreme weather events and hydro-meteorological hazards such as floods and droughts, their impact on the built and natural environments in a changing climate, and the development and application of climate forecasts and services for improved decision-making and climate resilience.

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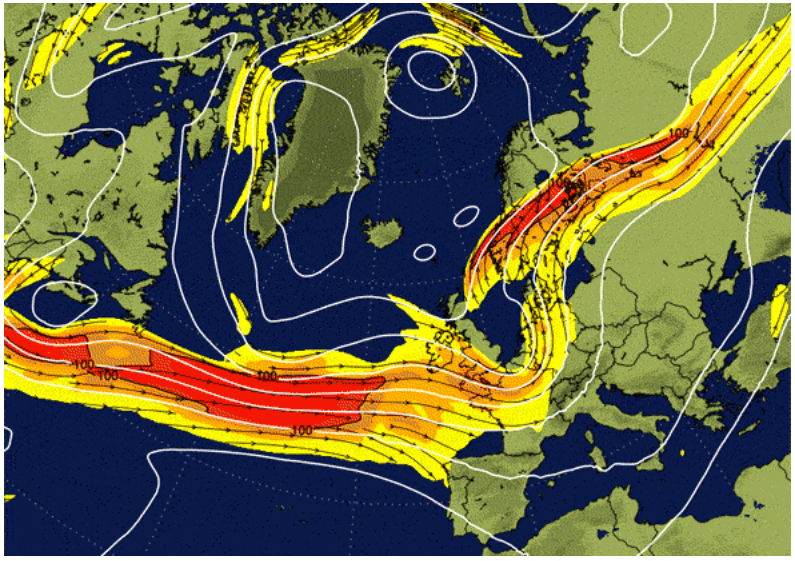
Longer-range weather forecasting

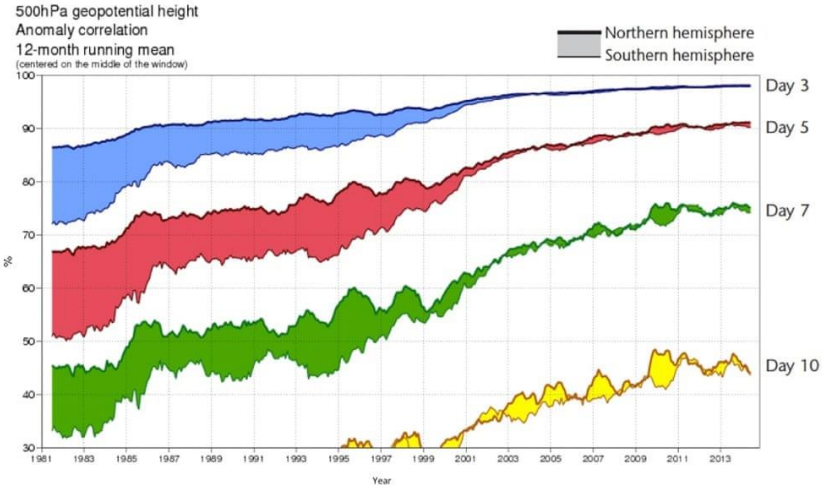
What is ‘longer-range’ forecasting?



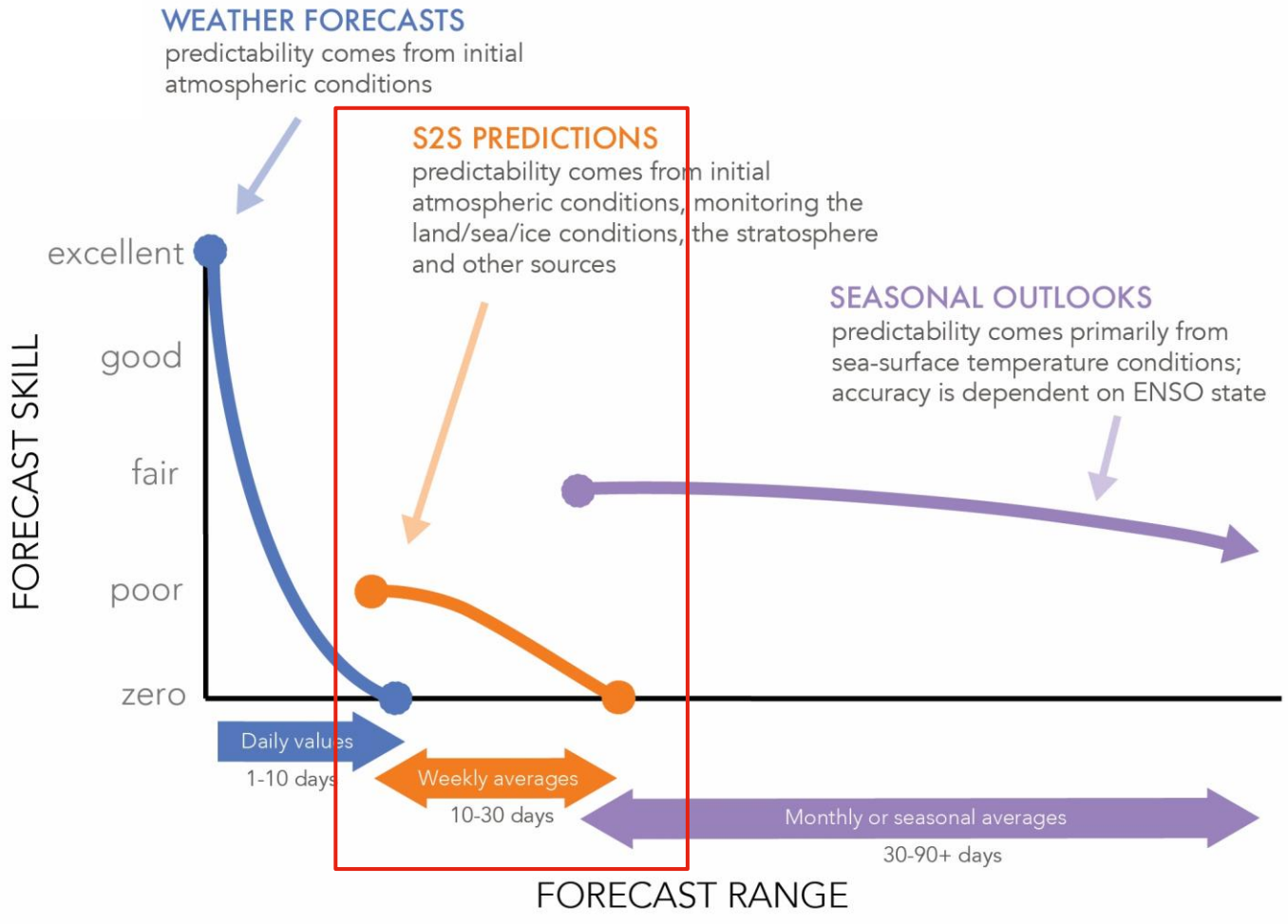
We intuitively know that a forecast for several days from now will change before it arrives – this makes weather-dependant decision-making uncertain.

Because of the chaotic nature of the atmosphere, even small developments can have a significant impact on the position and strength (and therefore impact) of a weather system.

However, the accuracy of the weather forecasts has increased significantly over time. For example, a 7 day forecast made today is as good as a 5 day forecast made 20 years ago, and a 4 day forecast is now as accurate as a 1 day forecast was 30 years ago.

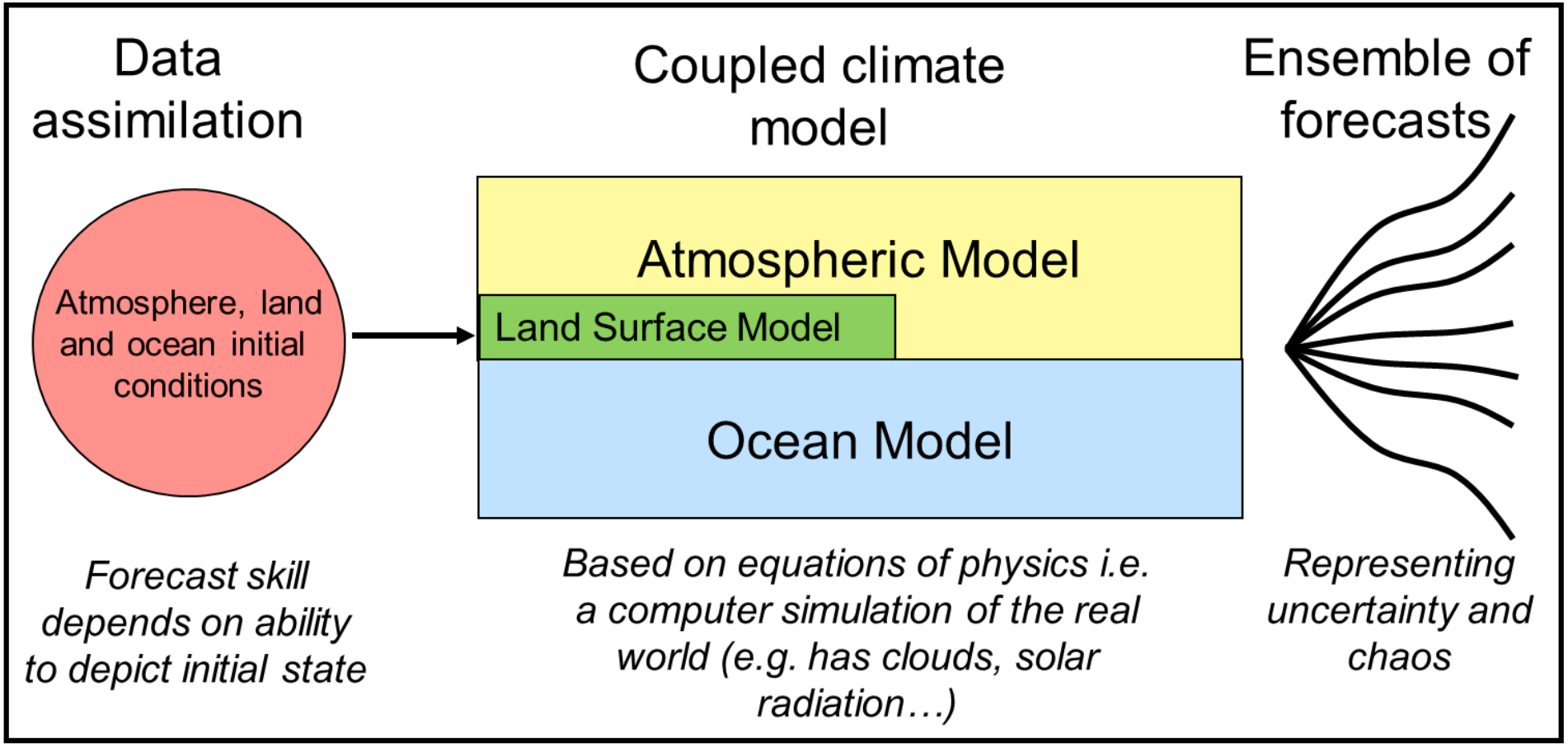


What is 'longer-range' forecasting?

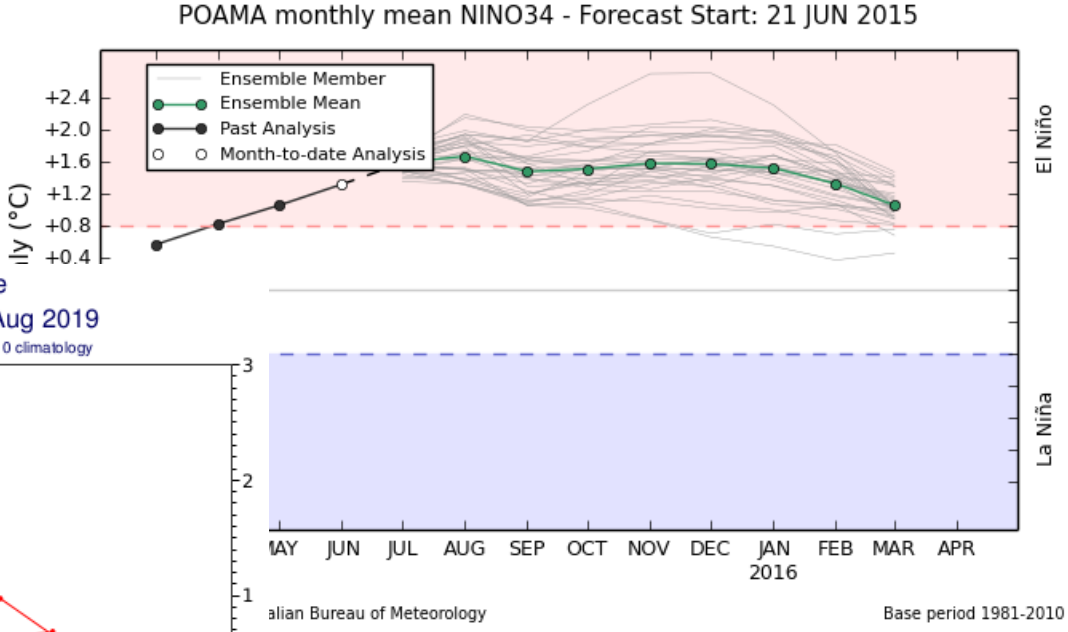


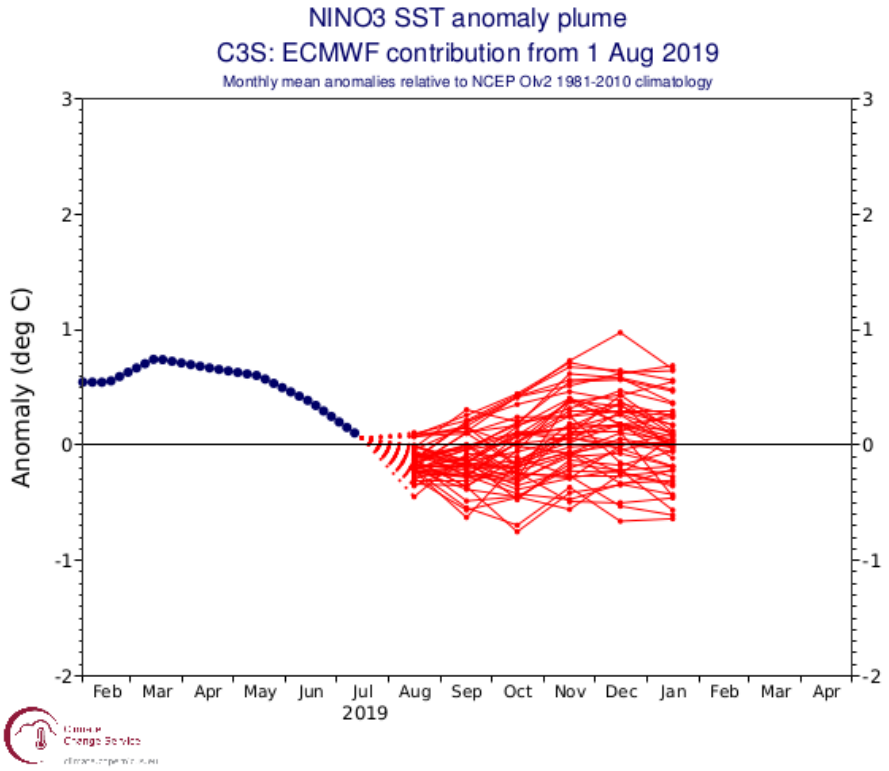
White, C.J. *et al.* (2017) Potential applications of subseasonal-to-seasonal (S2S) predictions, *Meteorological Applications*

Longer-range forecasting:
Ensemble modelling

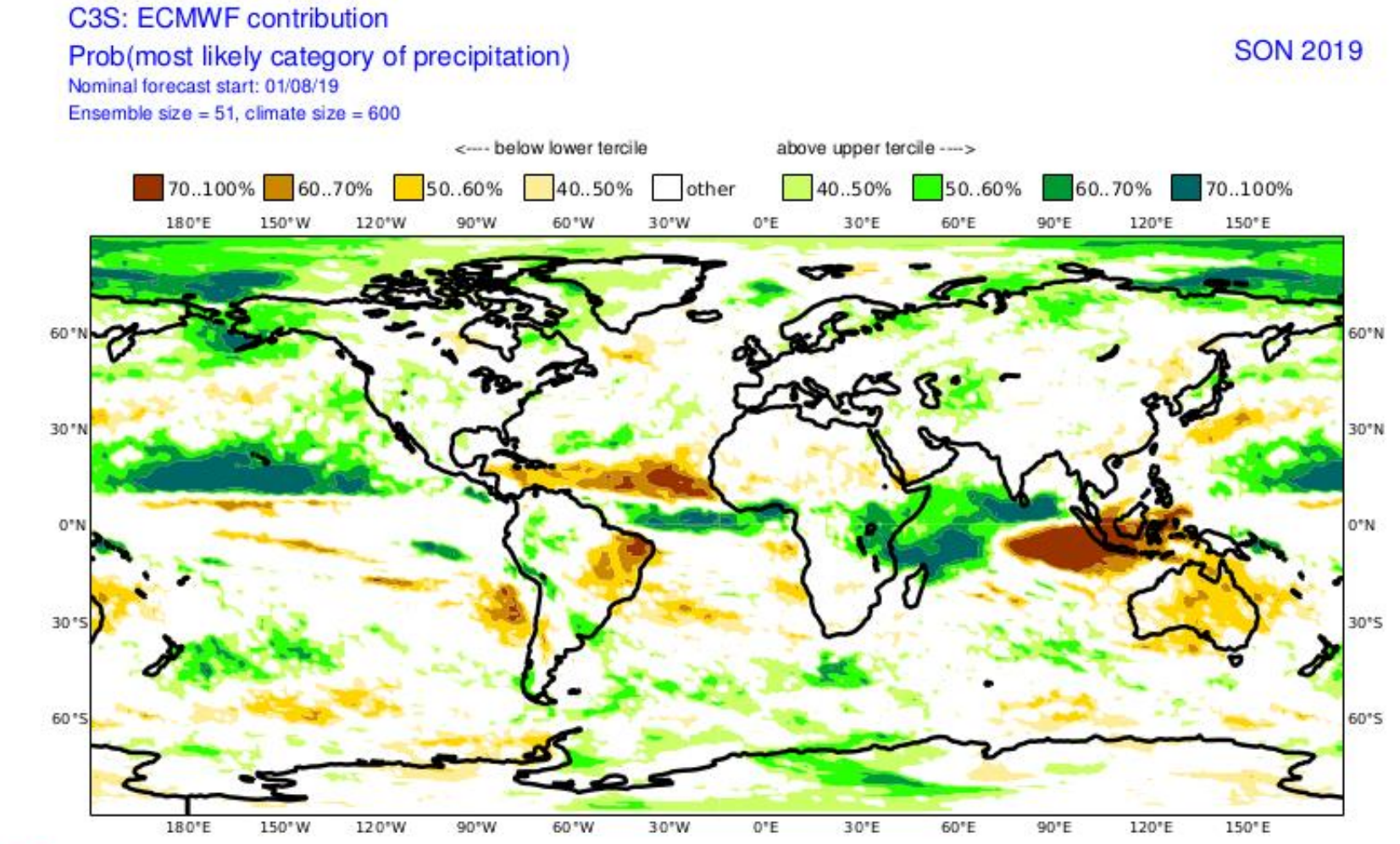


Operational / public products:
Climate driver outlooks and model summaries





Operational / public products:
Climate anomalies



Longer-range forecasting:
What is missing?

Application-focused forecast information, producing useful, useable and actionable sectoral information, with the overarching goal of seamlessly linking longer-range forecasts with risk management to support decision-making

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Subseasonal-to-seasonal forecasting: applications for decision-making

Acknowledgements: Daniela I. V. Domeisen, Nachiketa Acharya, Elijah A. Adefisan, Michael L. Anderson, Stella Aura, Ahmed A. Balogun, Douglas Bertram, Sonia Bluhm, David J. Brayshaw, Jethro Browell, Dominik Büeler, Andrew Charlton-Perez, Xandre Chourio, Isadora Christel, Caio A. S. Coelho, Michael J. DeFlorio, Luca Delle Monache, Francesca Di Giuseppe, Ana María García-Solórzano, Peter B. Gibson, Lisa Goddard, Carmen González Romero, Richard J. Graham, Robert M. Graham, Christian M. Grams, Alan Halford, W. T. Katty Huang, Kjeld Jensen, Mary Kilavi, Kamoru A. Lawal, Robert W. Lee, David MacLeod, Andrea Manrique-Suñén, Eduardo S. P. R. Martins, Carolyn J. Maxwell, William J. Merryfield, Ángel G. Muñoz, Eniola Olaniyan, George Otieno, John A. Oyedepo, Lluís Palma, Ilias G. Pechlivanidis, Diego Pons, F. Martin Ralph, Dirceu S. Reis Jr., Tomas A. Remenyi, James S. Risbey, Donald J. C. Robertson, Andrew W. Robertson, Stefan Smith, Albert Soret, Ting Sun, Martin C. Todd, Carly R. Tozer, Francisco C. Vasconcelos Jr., Ilaria Vigo, Duane E. Waliser, Fredrik Wetterhall and Robert G. Wilson

Subseasonal-to-seasonal (S2S) forecasting: A relatively unexplored predictive timescale

- The S2S timescale – **3-4 weeks (10-30 days) extended-range lead time** – has, until recently, been viewed as a predictive 'desert'
- Research is now looking for 'windows of forecast opportunity' on the S2S timescale using teleconnections to known large-scale climate drivers
- However, there is a growing requirement for the employment of S2S predictions for a wide range of societal and economic applications including forecasts of high-impact events such as flooding and heatwaves, streamflow forecasting, and humanitarian planning and response to disasters

WMO S2S prediction project: Science, forecasting *and* applications

International WWRP-WCRP coordinated research on S2S predictability and modelling

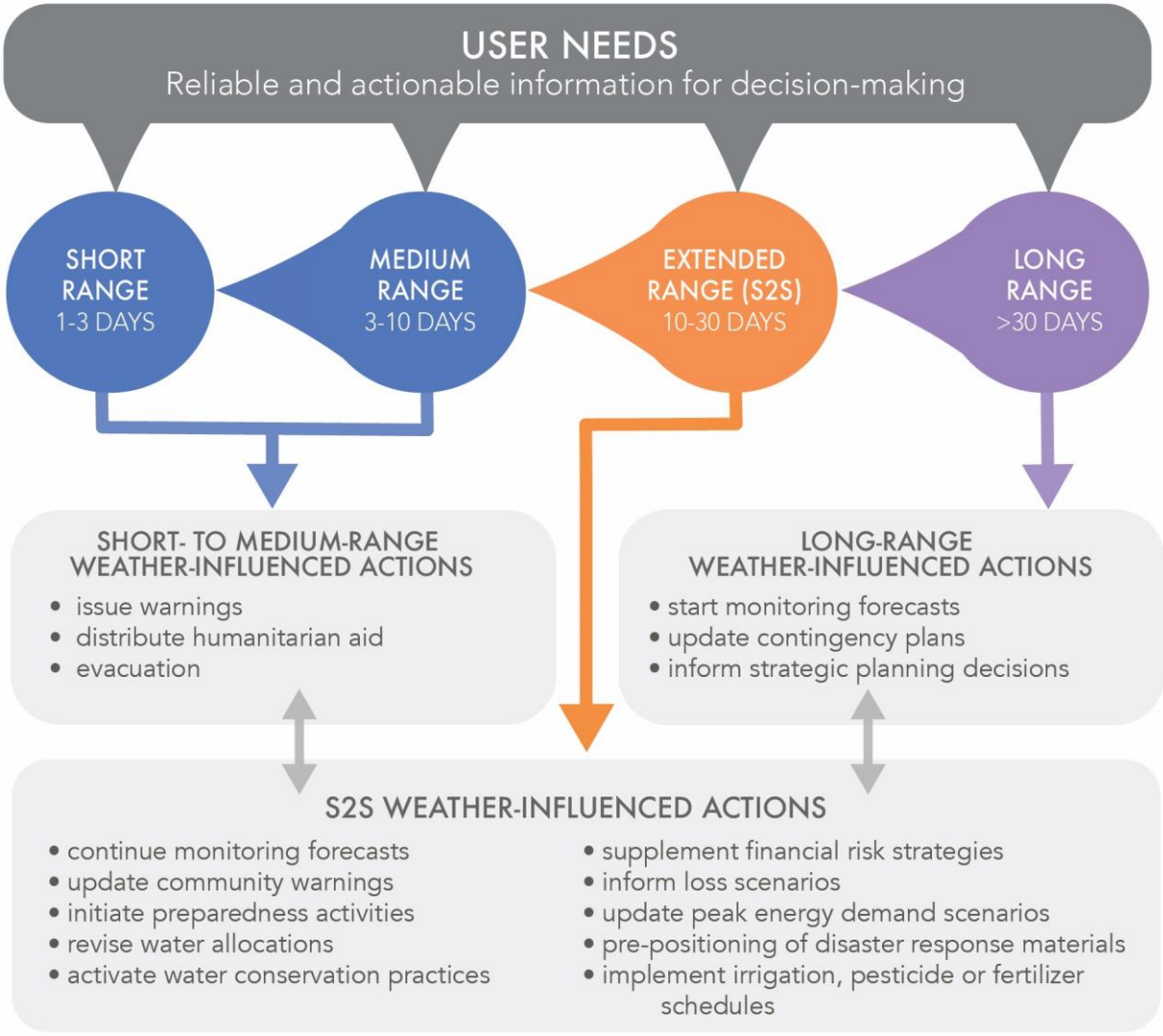
Goal is to improve the accuracy and use of forecasts at lead times from 2 weeks to 2 months

Focus is on science, forecasting ***and* applications**

Database of S2S predictions (hosted at ECMWF and CMA) from 11 global producing centers:

http://s2sprediction.net/

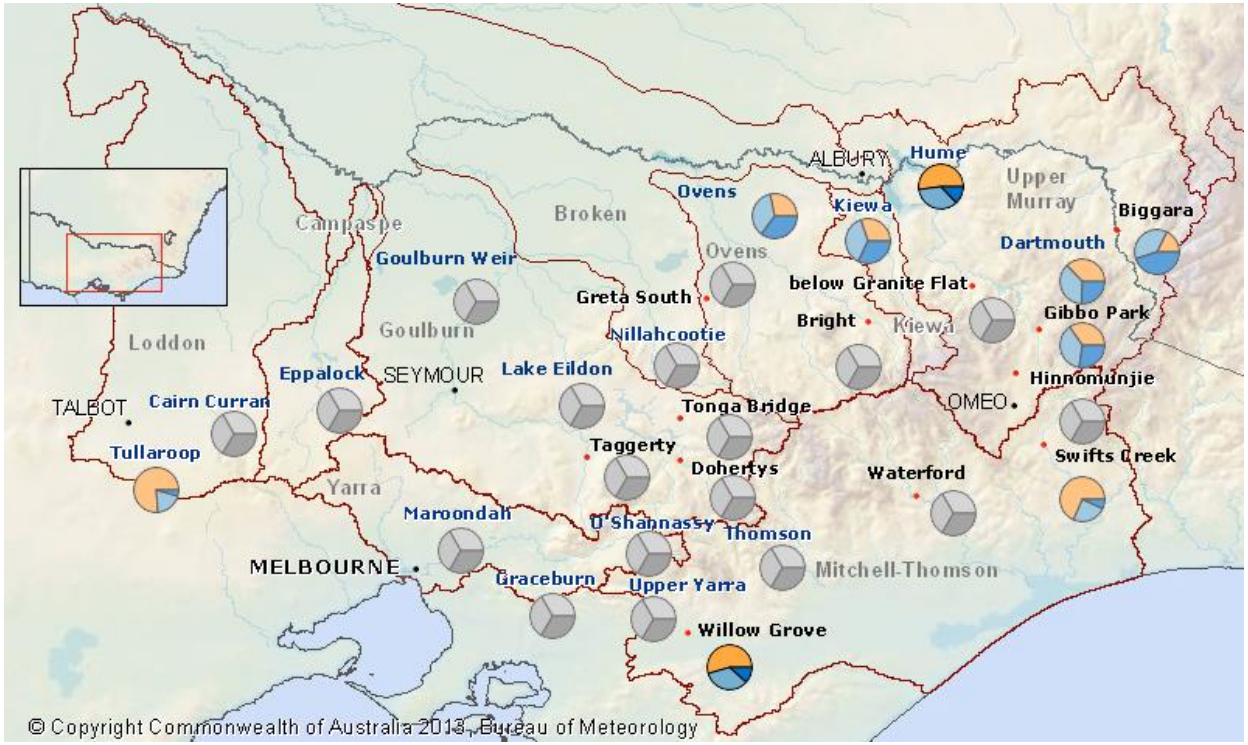
Sectoral applications of S2S predictions: Putting the user first



White, C.J. *et al.* (2017) Potential applications of subseasonal-to-seasonal (S2S) predictions, *Meteorological Applications*

Sectoral applications of S2S predictions: Water management

S2S lead times cannot be used to make specific flood predictions but S2S could bridge the flood and streamflow forecasting communities to provide seamless flood forecasting with longer lead times, with benefits for sub-seasonal water resource management decision-making.



Moderate to high skill

Low skill or missing climate data

Very low skill or missing antecedent condition data

Pie chart legend

- Likelihood of high flow (%)
- Likelihood of near median flow (%)
- Likelihood of low flow (%)

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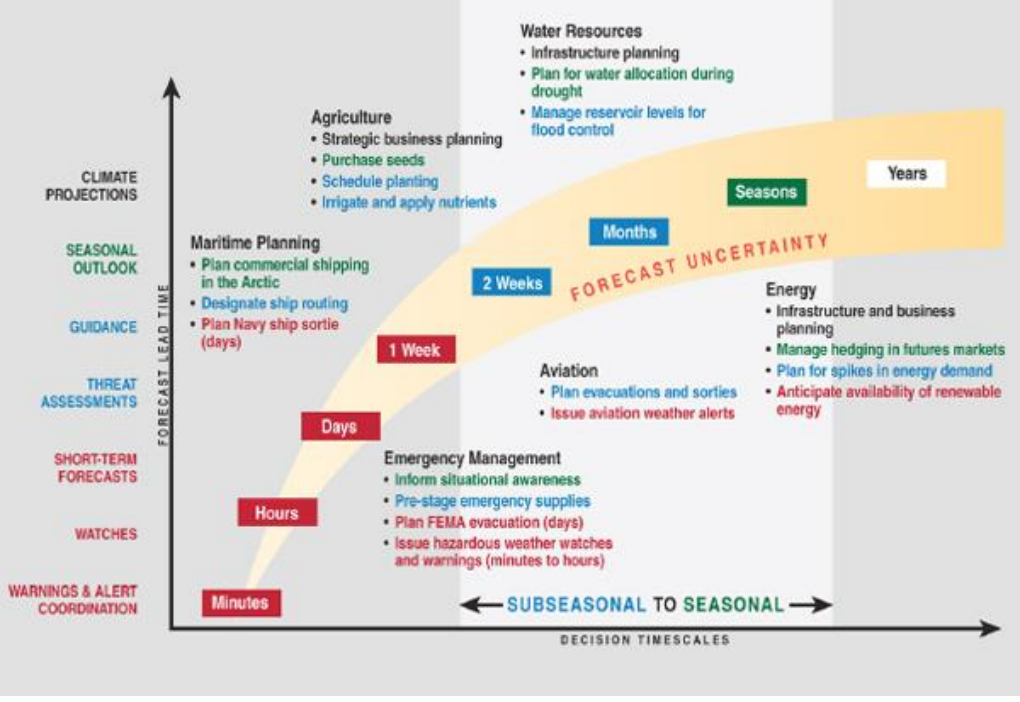
Sectoral applications of S2S predictions: Humanitarian and development sectors

S2S could support early warning and disaster risk reduction activities by tracking the progress of evolving (and potentially threatening) climate modes throughout the transition from seasonal outlooks to weather forecasts, i.e. shift the conversation from **response** to **resilience**.



National Academies of Sciences, Engineering, and Medicine. 2016. *Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts*. https://doi.org/10.17226/21873

Sectoral applications of S2S predictions: Agriculture

S2S predictions could supplement the current use of forecasts through supporting early action in the face of weather extremes, for example scheduling irrigation and pesticide application around heavy rainfall events or heat waves. Forecasts on the S2S timescale could also be used to support dynamic updates of crop yield estimates, which could support early planning to alleviate food security issues.

Sectoral applications of S2S predictions:
Energy

Energy pricing, production and usage is intricately tied to weather-related risk. Weather forecasting is already routinely used in many areas of the energy sector, so the development of successful relationships and the integration of S2S forecasting may be easier to achieve compared to other sectors. S2S forecasts could also be used to manage infrastructure and schedule maintenance, e.g. offshore wind farms where work can be stopped (and money lost) during storms.

Opportunities:
Using S2S predictions

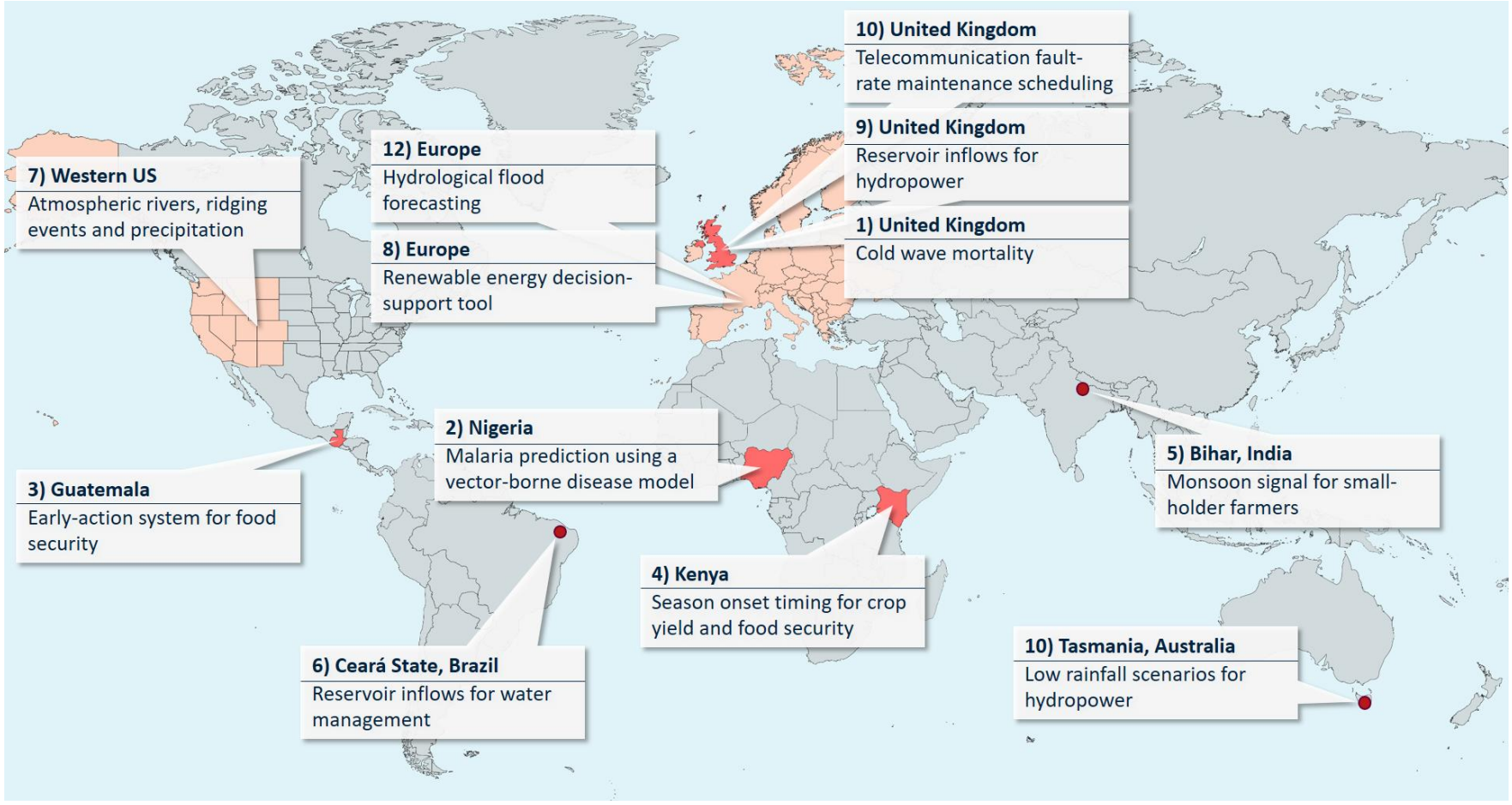
Opportunities

- There is a growing requirement for the use of S2S predictions for a wide range of societal and economic applications **= opportunity**
- Research is currently exploring ‘windows of forecast opportunity’ on the S2S timescale where the skill in predicting in temperature and rainfall in certain regions is likely to be increased using teleconnections to known large-scale climate drivers (e.g. ENSO), but there is much work to be done to link this to applications and products that can support user decision-making
- The WMO WWRP-WCRP open source near real-time S2S project database (hosted by ECMWF and CMA), for the first time, presents an opportunity for researchers and practitioners to explore the skill and applications of S2S

New community-led paper in BAMS: Advances in the application and utility of S2S predictions

- Led a coordinated global community effort over the last couple of years, aimed at collating and summarizing the experiences of application-relevant forecasts on the S2S timescale across sectors and regions.
- New paper in BAMS draws on recent advancements from across the S2S community to explore the use and utility of S2S predictions and demonstrate how they can be employed to maximize societal benefit.
- Involves ~60 authors and focusing on 12 sectoral S2S application case studies spanning the public health, agriculture, water resource management, energy and utilities, and emergency management and response domains.
- The paper presents a growing body of evidence of S2S forecasts being increasingly used across sectors in developed and emerging economies.
- Accepted for publication in BAMS – for publication soon!

New community-led paper in BAMS: Advances in the application and utility of S2S predictions



New community-led paper in BAMS: Summary outcomes

- The S2S forecasting timescale is a new concept for many users. While the additional value of S2S forecasts for decision-making is increasingly gaining interest among users, incorporating probabilistic ensemble S2S forecasts into existing operations is not trivial.
- S2S forecasts do not produce a “go/no go” answer of what a user should do; instead they provide additional, supplementary ‘situational awareness’ information that can be used to drive decision-making.
- A lack of ‘in house’ expertise in how to effectively apply S2S forecasts, combined with a lack of access to S2S forecasts, have also been barriers to widespread adoption of S2S forecasts – a ‘knowledge-value’ gap.
- The paper marks a significant step forward in moving from *potential* to *actual* S2S forecasting applications – demonstrating both skill and utility across sectors, and placing user needs and applications at the forefront of S2S forecast development.

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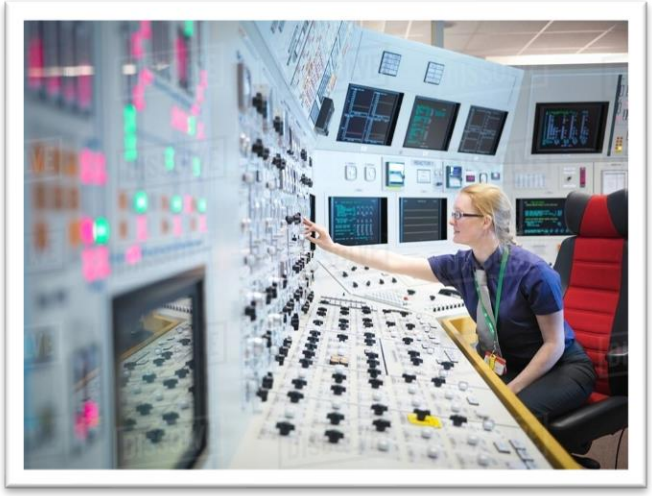
S2S case study: hydropower resource pilot study with SSE

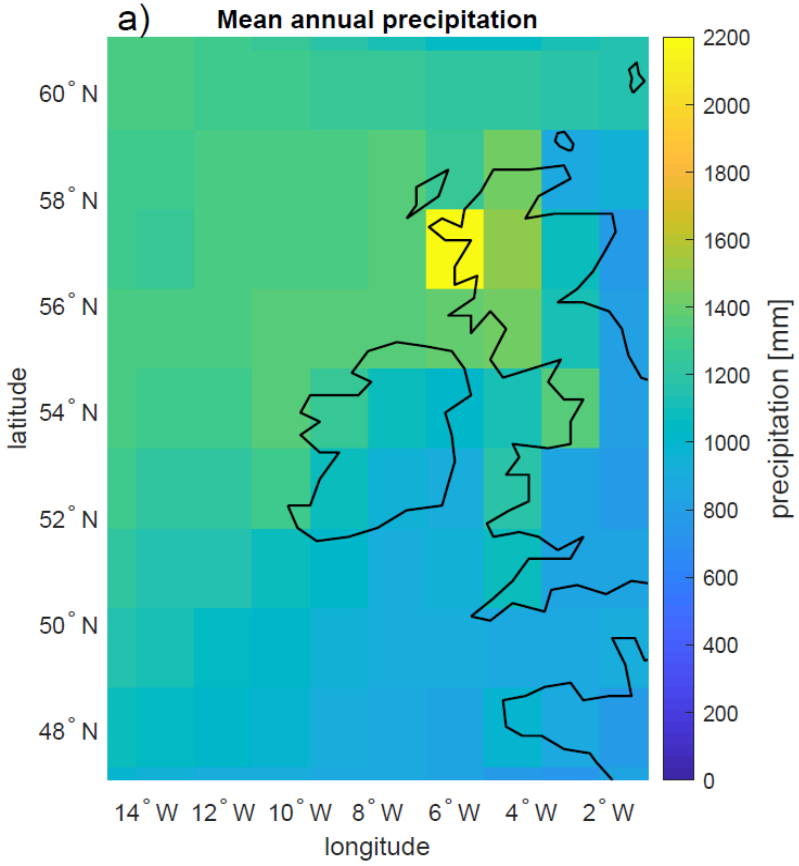
Acknowledgements: Jethro Browell (University of Glasgow), Doug Bertram and Robert Graham (University of Strathclyde)

Case study:
S2S hydropower resource pilot study with SSE

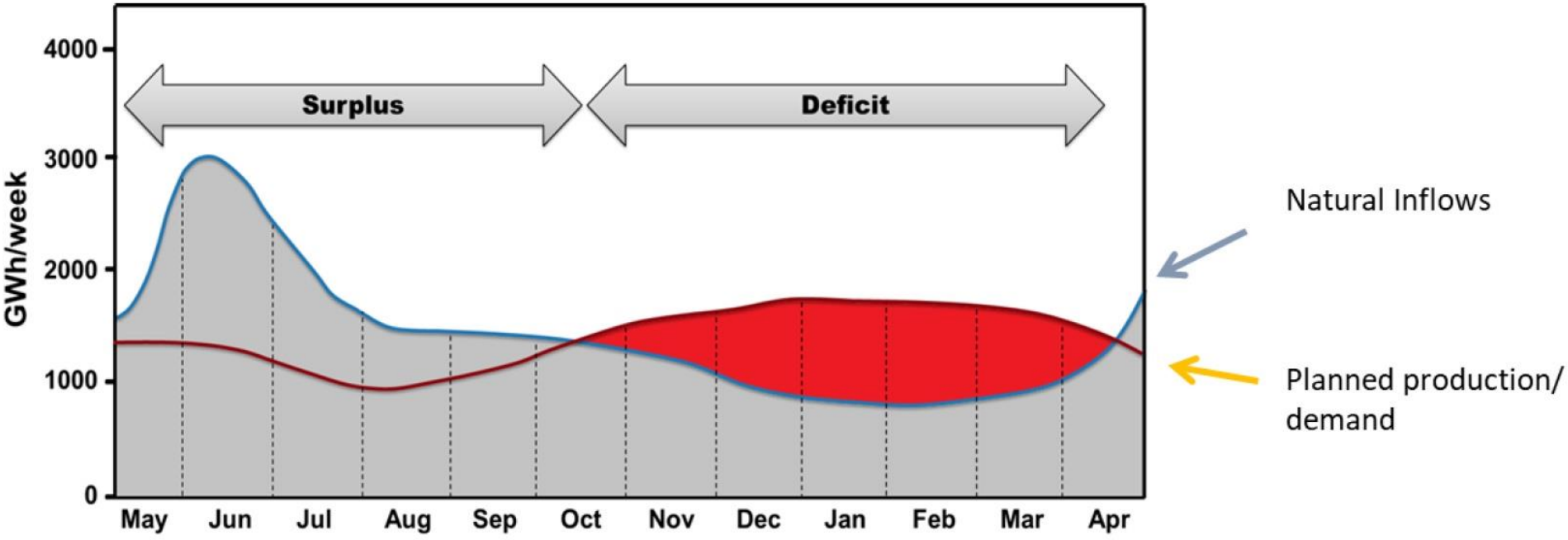
8 month pilot study with SSE pls

- Evaluation of S2S forecasts hydro resource on various timescales
- Economic / operational assessment (reservoir inflows and outflows)





Case study:
S2S hydropower resource pilot study with SSE



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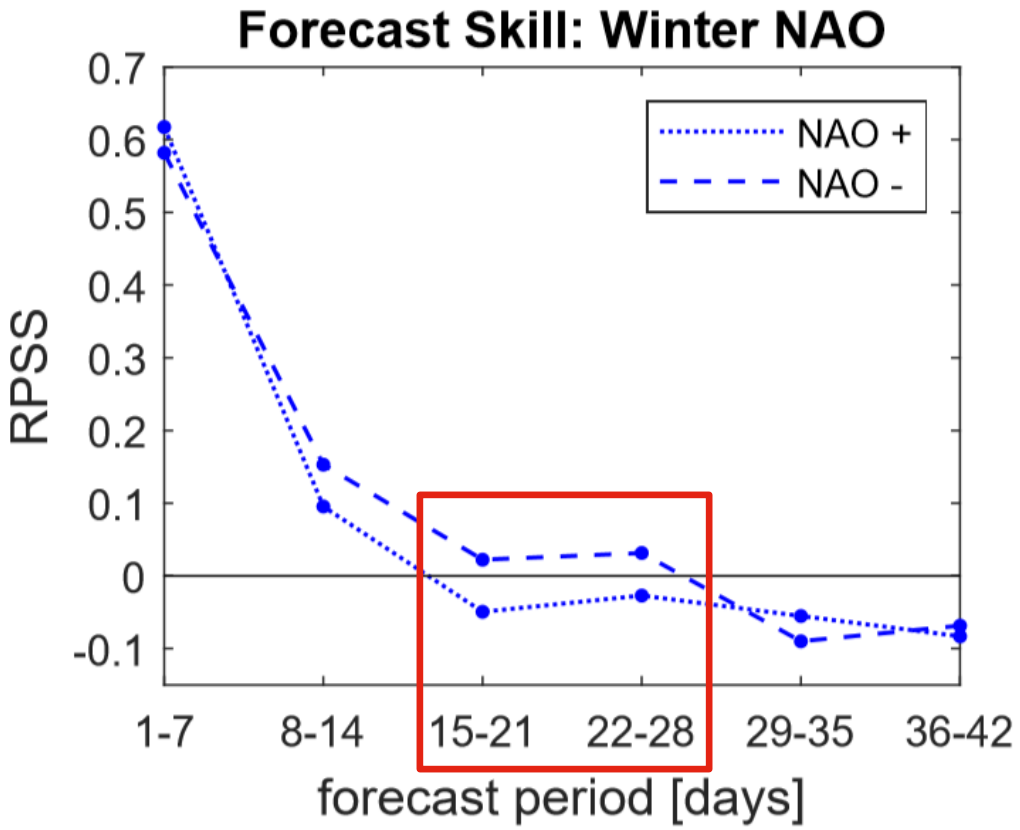
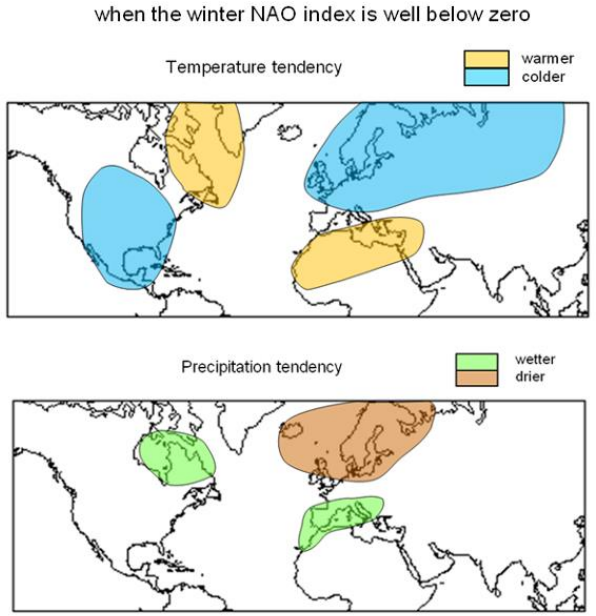




Precipitation forecasts provide skill **up to 28 days ahead** across Scotland in winters with negative NAO*. Highest forecast skill found during conditions that are likely to have significant implications for hydro water management, i.e. winter drought.

*The NAO is the 'North Atlantic Oscillation'. It is used by meteorologists to refer to variations in the large-scale surface pressure gradient in the North Atlantic region: https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/ens-mean/nao-description

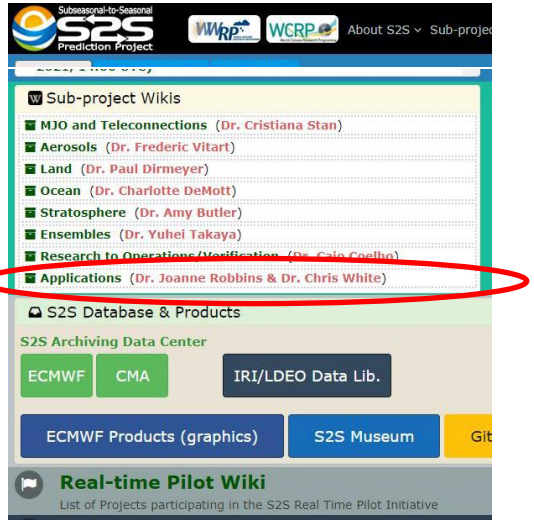
05

Building a S2S applications community

Acknowledgements: Joanne Robbins (Met Office), Daniela Domeisen (ETH Zürich), Ángel G. Muñoz and Andrew Robertson (IRI), Frederic Vitart (ECMWF)

WMO S2S applications sub-project: Mission statement

*The **Applications sub-project** aims to support the uptake and use of S2S predictions by providing a resource for the global community of researchers, modellers and practitioners who are exploring and promoting cross-sectoral services and applications of S2S predictions*



WMO S2S applications sub-project: Objectives

- New applications sub-project co-led by Dr Christopher White (University of Strathclyde) and Dr Joanne Robbins (UKMO): http://s2sprediction.net/xwiki/bin/view/Phase2/AppNet
- Support the uptake and use of S2S predictions through a resources for the global community of researchers, modellers and practitioners
- Promote the S2S timescale to the wider user community through workshops/meetings and coordinated papers
- Encourage co-production of S2S applications and services
- Explore cross-sectoral users and decision-makers needs and wants
- Understand what decisions are made on S2S timescales
- Identify what applications and methods of communication are appropriate for various sectors
- Build on the real-time pilot to provide a more cohesive network of application-orientated researchers

WMO S2S applications sub-project: Real-time pilot

- Led by Dr Joanne Robbins, supported by a researcher from the University of Strathclyde, the S2S real-time pilot initiative is making real-time S2S forecasts available to select projects that are trying to address user needs from November 2019 through to November 2022.
- The initiative hopes to draw on the experiences of the projects (15 in total) and develop best practice guidelines for producing useful and useable, application-orientated forecasts and tools.
- Paper to follow in 2022.

Sectors:
- Water
- Energy
- Health
- Agriculture/food security
- Disaster risk reduction

Countries/regions:
- Senegal
- Ethiopia
- Bangladesh
- Guatemala
- Columbia
- Ghana
- Kenya
- Nigeria
- Singapore
- USA
- Europe
- Asia & Pacific
- Global

Summary

- The additional value of S2S forecasts for decision-making is increasingly gaining interest among users
- Application-focused S2S forecast information, can produce useful, useable and actionable sectoral information, in particular ‘situational awareness’, but incorporating probabilistic ensemble S2S forecasts into existing operations is not trivial
- Recent papers, including the forthcoming applications case study paper in BAMS*, are helping to open S2S forecasts up to new users and potential applications [*part of a two paper ‘series’ in BAMS – the other is being led by Daniela Domeisen at ETH Zürich which is collating recent advances in S2S forecasting of extreme events. This is currently in review.]
- This with other initiatives like the WMO WWRP-WCRP S2S applications sub-project are creating a global applications community

Thank you

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Papers:

White, C.J. *et al.* (2017) Potential applications of subseasonal-to-seasonal (S2S) predictions, *Meteorological Applications*, 24:3, 315-325 doi:10.1002/met.1654 https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/met.1654

Merryfield, W.J. *et al.* (2020) Current and emerging developments in subseasonal to decadal prediction, *Bulletin of the American Meteorological Society*, doi:10.1175/BAMS-D-19-0037.1 https://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-19-0037.1

White, C.J. *et al.* (2021) Advances in the application and utility of subseasonal-to-seasonal predictions, *Bulletin of the American Meteorological Society*, accepted