THE PLACE OF USEFUL LEARNING

University of Strathclyde Engineering

Met Office

Subseasonal-to-seasonal prediction: Using the RTP to enhance the user-orientated research and applications of subseasonal-to-seasonal predictions

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S2S RTP Workshop
Day 3, 17 November 2022

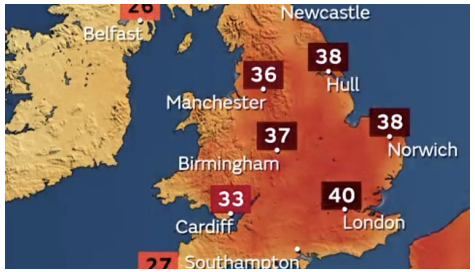
Contents:

01
Introduction

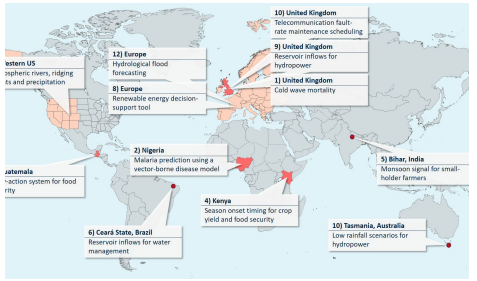
02
Applications of S2S predictions and case studies

Subseasonal-to-Seasonal S2S Prediction Project

03
The European summer heatwave 2022 and the role of seasonal and S2S prediction



04
A global S2S applications community



01

Introduction

02

Applications of S2S predictions and case studies

03

The European summer heatwave 2022 and the role of seasonal and S2S prediction

04

A global S2S applications community

Introduction

Head of the **Centre for Water, Environment, Sustainability and Public Health** in the Department of Civil and Environmental Engineering at the University of Strathclyde. Previously at the Australian Bureau of Meteorology. Chris' research specialisms include the application of hydro-meteorological ensemble predictions, impact-based forecasting of extreme events, multi-hazard / compound natural hazards, and climate change / risk assessment.

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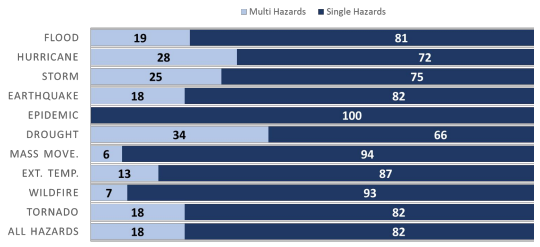
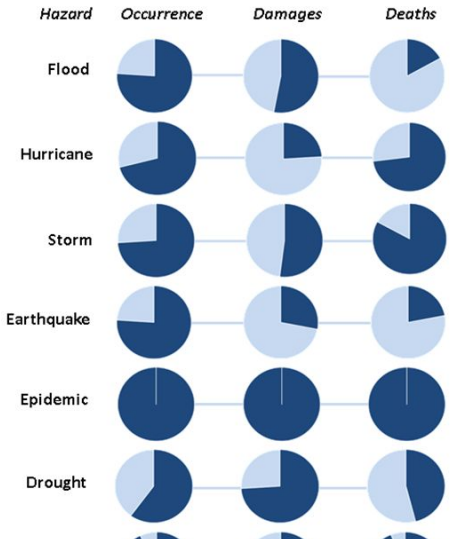
MULTI-HAZARDS & CLIMATE CHANGE

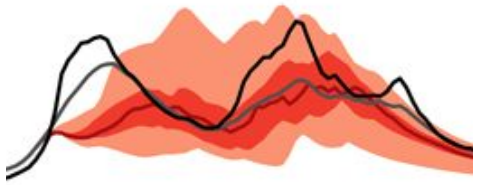
Natural hazards often result from a combination of physical processes referred as **compound events**. Hazard assessments typically only consider one process and/or hazard, leading to an **underestimation of risk**.



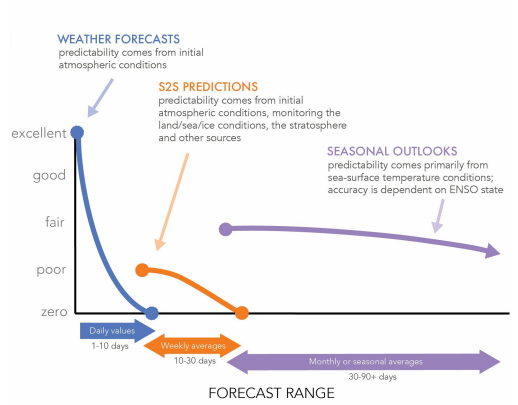


Reclassifying single vs multi-hazards
In draft.

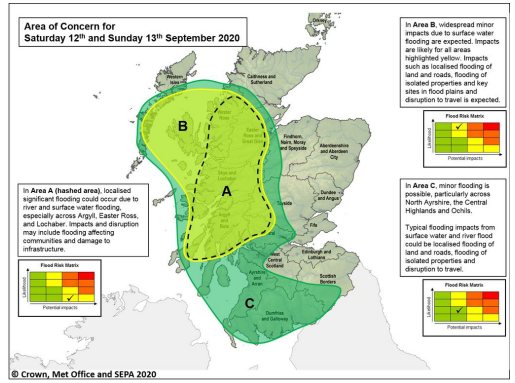
IMPACT-BASED ENSEMBLE PREDICTION



A new generation of **ensemble forecasts** on longer-range timescales are being produced that can be used for **impact-based prediction** for design, operation and logistics and to reduce risk.



Ensemble forecasting timescales
doi:10.1002/met.1654



SEPA pilot impact-based surface water flooding forecasts; read more in doi:10.1002/wat2.1517

01

Introduction

02

Applications of S2S predictions and case studies

Subseasonal-to-Seasonal S2S Prediction Project

03

The European summer heatwave 2022 and the role of seasonal and S2S prediction

04

A global S2S applications community

S2S prediction:
A relatively unexplored forecasting timescale for applications… until the RTP!

- The S2S timescale – 3-4 weeks (10-30 days) extended-range lead time – has, until recently(ish), 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
- Coupled with this, there is a growing requirement for and the exploration of the use 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

Subseasonal-to-Seasonal S2S Prediction Project

WMO

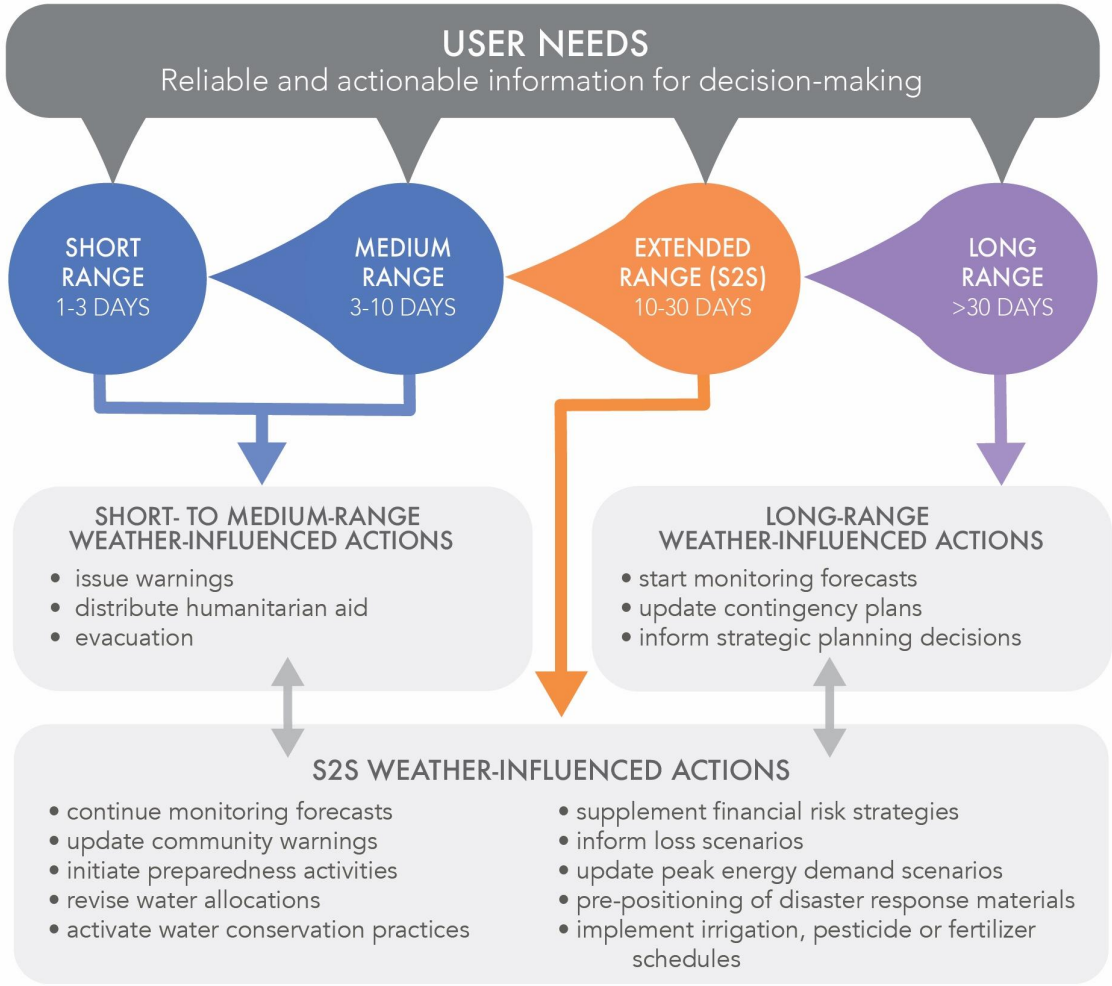
S2S forecasting:
The RTP legacy

The RTP has demonstrated how ***application-focused*** S2S forecast information can be used to produce useful, useable and actionable information, linking extended-range forecasts with decision-making

Using S2S predictions:
RTP has shown the way…

- 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) presents an opportunity for researchers and practitioners to explore the skill and applications of S2S

Sectoral applications of S2S predictions: Putti



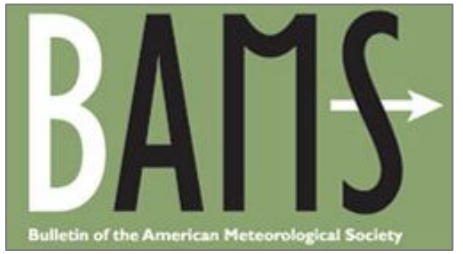
Source: White et al. 2017 https://doi.org/10.1002/met.1654

Using S2S predictions: RTP projects

Project ID No.	Name	Project Focus	Sector	User Partners	Project Contact
1	**Sea Ice Prediction Network Phase 2**	Improve understanding of Arctic sea ice and predictability	Agriculture, Forestry & Fishing Sector	Modelling centres; Shipping industry; Resource management; Defence; Marine mammal subsistence hunting	Cecilia Bitz (University of Washington)
2	**Monthly Climate Outlooks**	To provide sub-seasonal to seasonal forecasts of temperature and precipitation extremes for DFID priority regions in Africa and South Asia (covering about 50 developing countries)	Humanitarian Sector	DFID humanitarian advisors and crisis anticipation advisors in the humanitarian sector (e.g., Start Network).	Nicholas Klingaman (NCAS)
3	**Experimental Subseasonal Forecasting of Atmospheric Rivers along the US West Coast**	Provide probabilistic forecasts of atmospheric river occurrence at week-2 (8-day to 14-day) and week-3 (15-day to 21-day) lead over the Western U.S./North Pacific	Water Sector	California Department of Water Resources	Mike DeFlorio (Jet Propulsion Laboratory)
4	**ForPAc: Towards Forecast-based Preparedness Action**	ForPAc aims towards more anticipatory Early Warning Systems for Flood and Drought Risk in Kenya, through improved S2S hazard forecasts and systematic approaches to the use of forecasts to trigger early actions.	Disaster Risk Management & Humanitarian Sector	Kenya National Drought Management Authority, Kenya Red Cross Society, Kenya Met Dept, ICPAC.	Martin Todd (University of Sussex)
5	**Asia Regional Resilience to a Changing Climate (ARRCC)**	Applied science for end user application. Regional programme recognising the need for trans boundary delivery, with specific focus on 4 countries - Afghanistan, Bangladesh, Pakistan and Nepal.	DRR (Early Warning) & Agriculture, Forestry & Fishing Sector	ARRCC, Met Office Partnership (MOP) programme and RIMES, user partners to be finalised.	Francis Colledge (Met Office)
6	**Navy Earth System Prediction Capability**	Determining how to best utilize S2S model forecasts in a potential future operational Navy subseasonal TC prediction capability.	Defence Sector	Naval Research Laboratory; Joint Typhoon Warning Center	Matthew Janiga (Naval Research Laboratory)
7	**Digiscape**	We are building platform technology that will allow us to take any seasonal climate forecast and use it to force an agricultural model such as for growing grains or pasture to provide real time forecasts.	Agriculture, Forestry & Fishing Sector	CSIRO Agriculture and Food stakeholder network	Jaclyn Brown (CSIRO)
8	**S2S4E Sub-seasonal to seasonal climate forecasting for energy**	S2S4E (H2020 project) offers an innovative service to improve renewable energy (RE) variability management by developing new research methods exploring the frontiers of weather conditions for future weeks and months. The main output of S2S4E is a user co-designed Decision Support Tool (DST) https://s2s4e-dst.bsc.es/#/ that for the first time integrates sub-seasonal to seasonal (S2S) climate predictions with RE production and electricity demand.	Energy Sector	Energy producers: EDP Renovaveis, EnBW Energie Baden- Wurttemberg and Électricité de France.	Andrea Manrique (Barcelona Super Computing Centre)
9	**GCRF-African SWIFT**	Development and provision of improved, reliable, and actionable forecasts and early warning across eastern and western sub-Saharan Africa.	DRR (Early Warning); Agriculture, Energy & Water Sector	Spectrum of African user agencies identified by NMSs in agriculture, water, energy & health	Steven Woolnough (University of Reading)
10	**Intesa Operativa fra DPC e CNR-ISAC (Operational Agreement between Italian Civil Protection Agency and CNR-ISAC)**	Provision of deterministic and probabilistic temperature and precipitation monthly forecasts over the Italian territory using the S2S database.	DRR (Early Warning)	Italian Civil Protection Department (DPC)	Daniele Mastrangelo (Institute of Atmospheric Sciences and Climate (CNR-ISAC))
11	**S2S for Disaster Risk Reduction in Southeast Asia**	Collaboration between ASEAN Specialised Meteorological Centre (ASMC), United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), and Regional Integrated Multi-Hazard Early Warning System for Asia and Africa (RIMES).	DRR & Humanitarian Sector	Selected national and regional DRR agencies in Southeast Asia (to be finalized).	Thea Turkington (Centre for Climate Research, Singapore)
12	**W2SIP (WISER support to ICPAC Project)**	The project aims to strengthen the capacity of ICPAC to deliver wide-reaching, usable, new, improved weather and climate products and services anchored on principles of coproduction and user engagement that cascade down to national and sub-national levels and regional user stakeholders in Africa.	NMHS's; DRR; Agriculture, Forestry & Fishing Sector; Humanitarian Sector (food security); Energy Sector; Health Sector; Media Sector	Resilience Analysis Unit (RAU) multi-stakeholder regional technical hub, IGAD DRM, IGAD and FAO Co-chaired Food Security and Nutrition Working Group.	Zewdu Segele (ICPAC)

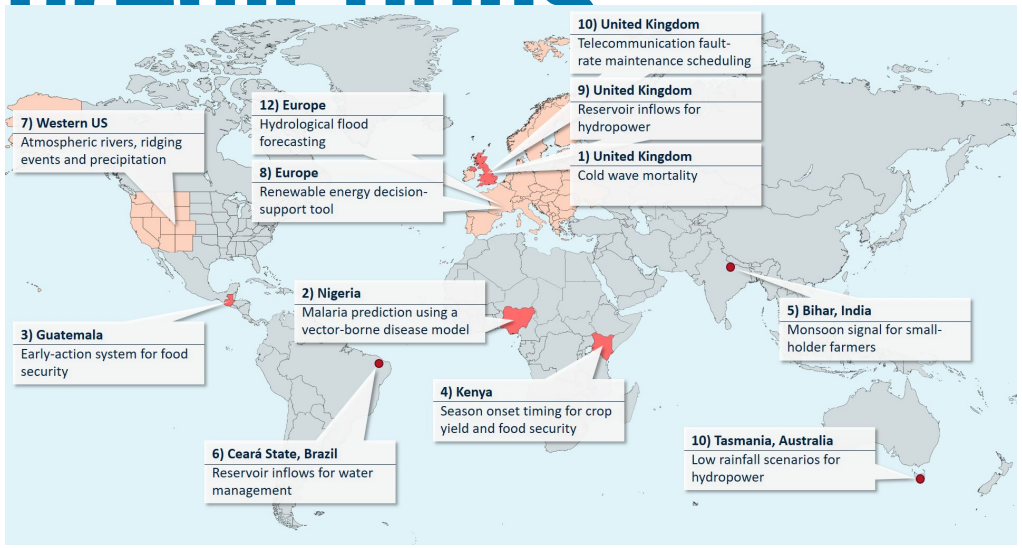
Project ID No.	Name	Project Focus	Sector	User Partners	Project Contact
13	**Multi-scale climate variability in South America and sub-seasonal to seasonal prediction**	Evaluation of the S2S models' skill in reproducing the observed precipitation variability during the rainy season in the Brazil core monsoon region, as well as the MJO contribution to it; Evaluation of S2S forecasts, including prediction of extreme events; tests of S2S forecasting system	Civil Defence; Agriculture, Forestry & Fishing Sector; Energy Sector	ENGIE BRASIL ENERGIA S.A., the largest private energy producer in Brazil.	Alice Grimm (Universidade Federal do Paraná, Brazil)
14	**Tailoring sub-seasonal predictions for Early Warning Systems to support Public Health management - A Case Study in Rio Branco, Acre state, Brazilian Amazon**	Assessing the S2S models' capability to anticipate heat waves; Find the relationship between heat waves and disease statistics; Develop a system to give tailored information about upcoming heat waves.	DRR & Health Sector	Acre's institutions: Environment Secretary of the State, the University of Rio Branco, Acre and Woods Hole Centre and the State Commission for Environmental Risk Management.	Christopher Cunningham (CEMADEN, Brazil)
15	**Understanding the mechanisms and predictability of persistent large-scale circulations patterns over North America leading to extreme fire weather conditions**	Develop benchmark metrics to evaluate the forecast skill of extreme fire weather regimes using dynamical and statistical forecast models.	DRR (Early Warning)	National Interagency Coordination Centre (provides logistical coordination and mobilization to support the wildland fire community) and NWS regional HQ.	Charles Jones (Earth Research Institute)
16	**Adapting Agriculture to Climate Today, for Tomorrow (ACToday) - A Columbia University World Project**	Help end hunger, achieve food security and improved nutrition, and promote sustainable agriculture (Sustained Development Goal 2). More information here: https://iri.columbia.edu/actoday	Agriculture, Forestry & Fishing Sector; Humanitarian Sector	Ministries of agriculture and rural development in 6 developing countries, (Senegal, Ethiopia, Vietnam, Bangladesh, Guatemala and Colombia), FAO, WFP	Angel Munoz (IRI)

Beyond the RTP: Advances in the application and utility of S2S predictions



- A 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
- A global community effort that collates the experiences of application-relevant forecasts on the S2S timescale across sectors and regions
- Involved ~60 authors, focused on 12 sectoral S2S application case studies **–including some in the RTP** – spanning the public health, agriculture, water resource management, energy and utilities, and emergency management
- Available from BAMS as an open access publication: https://doi.org/10.1175/BAMS-D-20-0224.1

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

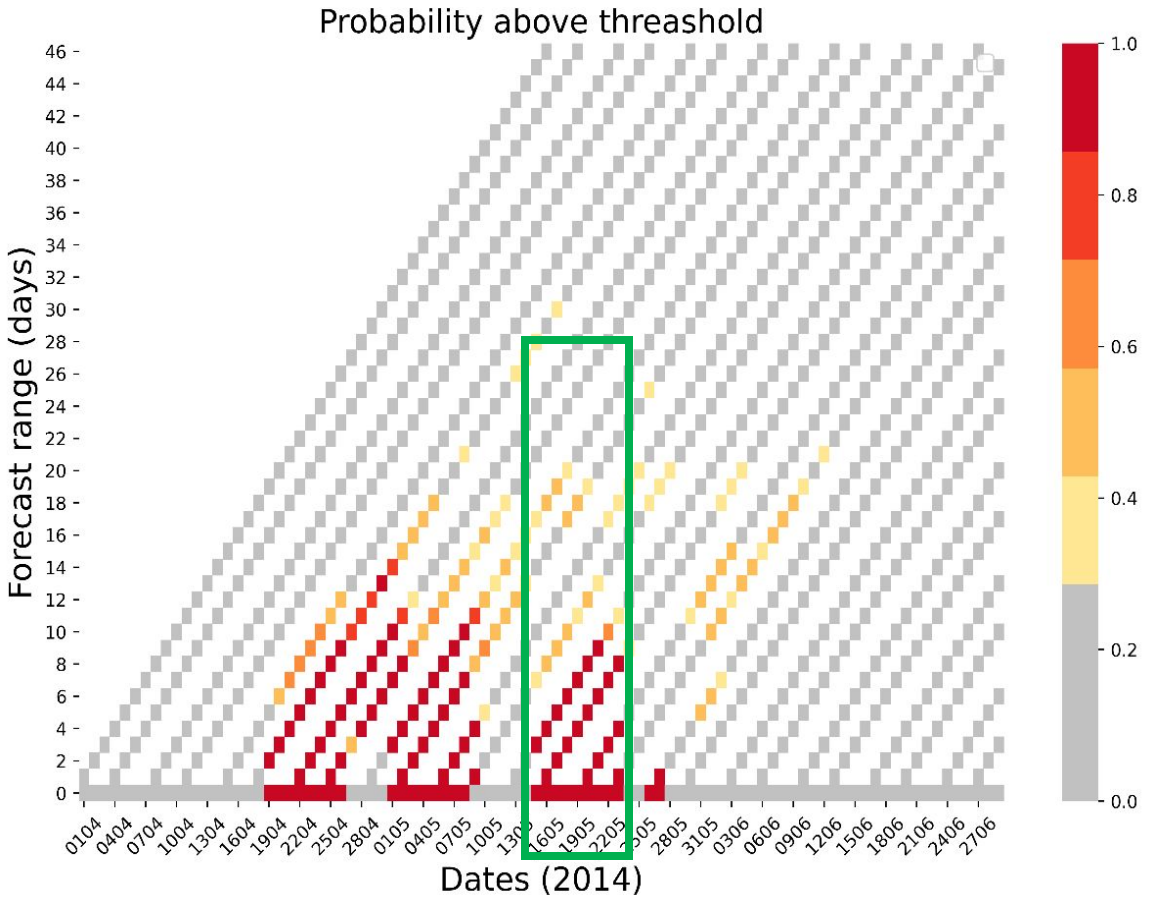


Description	Sector	S2S Application / Product	Prior or Related Studies
1) Mortality predictions during extreme cold weather events in the U.K.	Public health	Cold wave mortality	Charlton-Perez et al. (2019); Huang et al. (2020)
2) Malaria occurrence prediction in Nigeria	Public health	Malaria prediction using a vector-borne disease model	Tompkins and Ermert (2013); Asare et al. (2016) (both related to the VECTRI model)
3) An early-action system for acute undernutrition in Guatemala	Public health	Early-action system for food security	n/a
4) Season onset timing in Kenya	Agriculture	Season onset timing for crop yield and food security	Kilavi et al. (2018); MacLeod et al. (2021a) (both primarily related to heavy rain events in the study region)
5) Agricultural management in Bihar, India	Agriculture	Monsoon signal for small-holder farmers	Robertson et al. (2019); Acharya (2018) (verification of district-level hindcasts and real-time forecasts in 2018)
6) Water management in Ceará State, Brazil	Water resource management	Reservoir inflows for water management	n/a
7) Water management in western U.S.	Water resource management	Atmospheric rivers, ridging events and precipitation	DeFlorio et al. (2019a,b); Gibson et al. (2020a,b)
8) A decision-support tool for the renewable energy sector	Renewable energy and utilities	Renewable energy decision-support tool	Soret et al. (2019)
9) Hydropower inflow predictions in Scotland, U.K.	Renewable energy and utilities	Reservoir inflows for hydropower	Graham et al. (2021)
10) Scenario planning for hydropower operations in Tasmania, Australia	Renewable energy and utilities	Low rainfall scenarios for hydropower	n/a
11) Weather risk management for U.K. fixed-line telecommunications	Renewable energy and utilities	Telecommuni-cation fault-rate maintenance scheduling	Brayshaw et al. (2020)
12) European flood forecasting	Emergency management and response	Hydrological flood forecasting	Wetterhall and Di Giuseppe (2018)

Source: White et al. 2021 https://doi.org/10.1175/BAMS-D-20-0224.1

Case study: #12 European flood forecasting (Di Giuseppe & Wetterhall)

- Morava River in Serbia, 2014
- Catastrophic flooding in May
- Probability of exceeding 98th percentile of discharge
- Maximum notification lead time in EFAS is 7-8 days
- Strong signal 8-10 days ahead, but signs of an event already >3 weeks ahead



Source: White et al. 2021 https://doi.org/10.1175/BAMS-D-20-0224.1

01

Introduction

02

Applications of S2S predictions and case studies

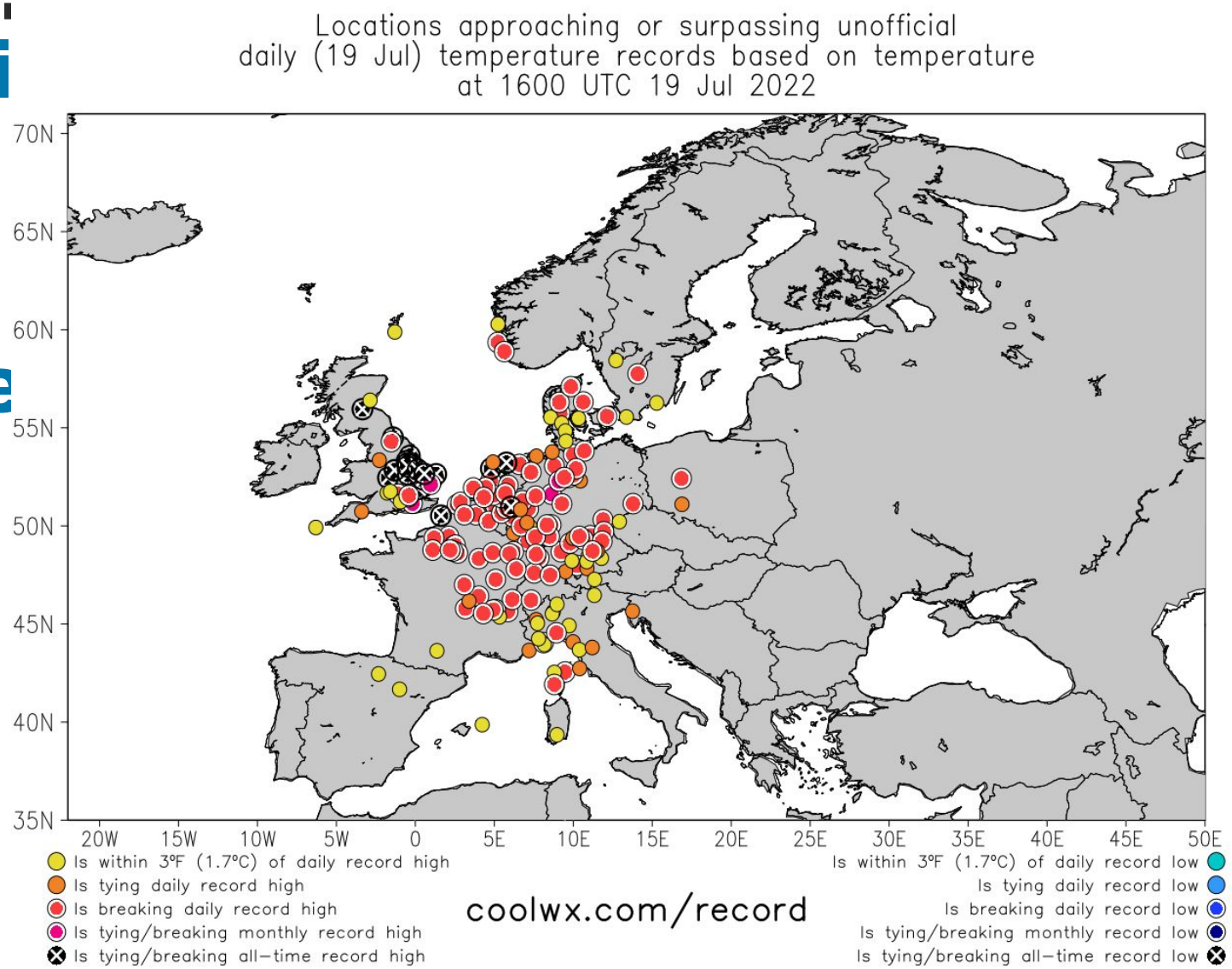
03

The European summer heatwave 2022 and the role of seasonal and S2S prediction

04

A global S2S applications community

Summer 2022: Record-breaking European heatwave: could S2S predictions be used?

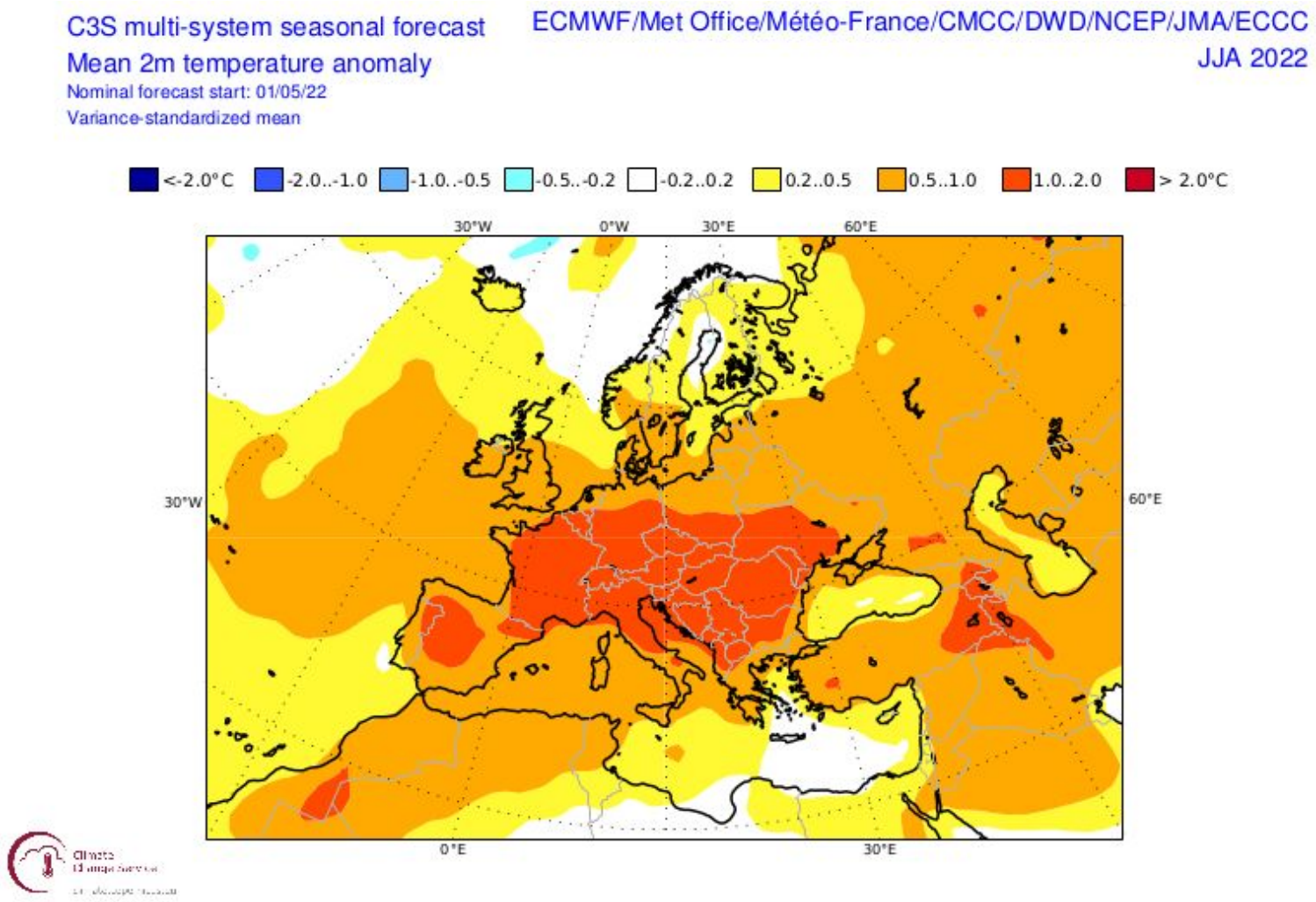


The locations of record-breaking temperatures on 19th July 2022 at 16:00 UTC

Source: coolwx/record

Summer 2022:
Seasonal prediction

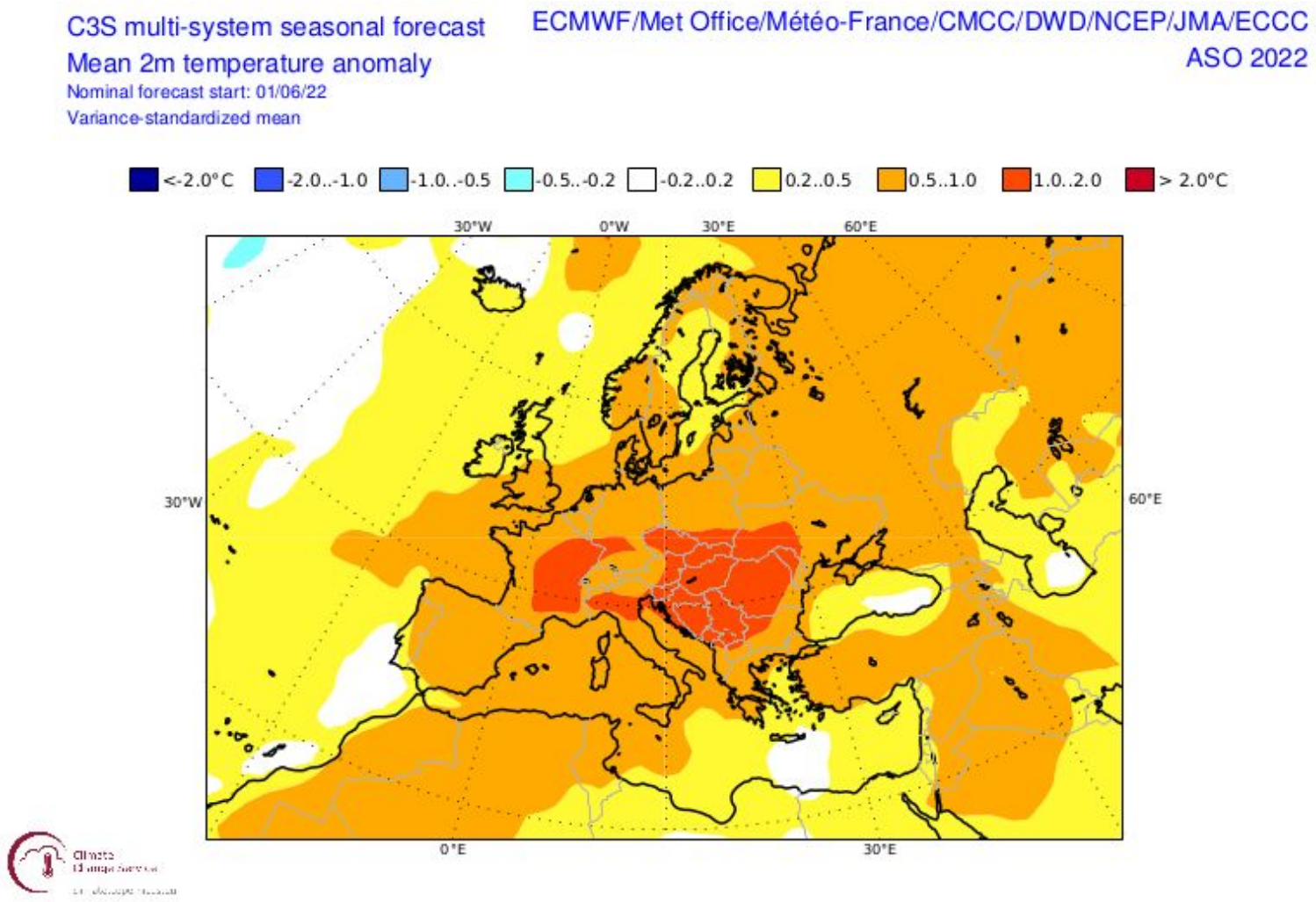
The seasonal forecast (forecast start **01/05/22**) from C3S models for summer predicted a much warmer than average European summer…



Source: https://climate.copernicus.eu/charts/c3s_seasonal/; acknowledgement: Matt Patterson, University of Oxford

Summer 2022:
Seasonal prediction

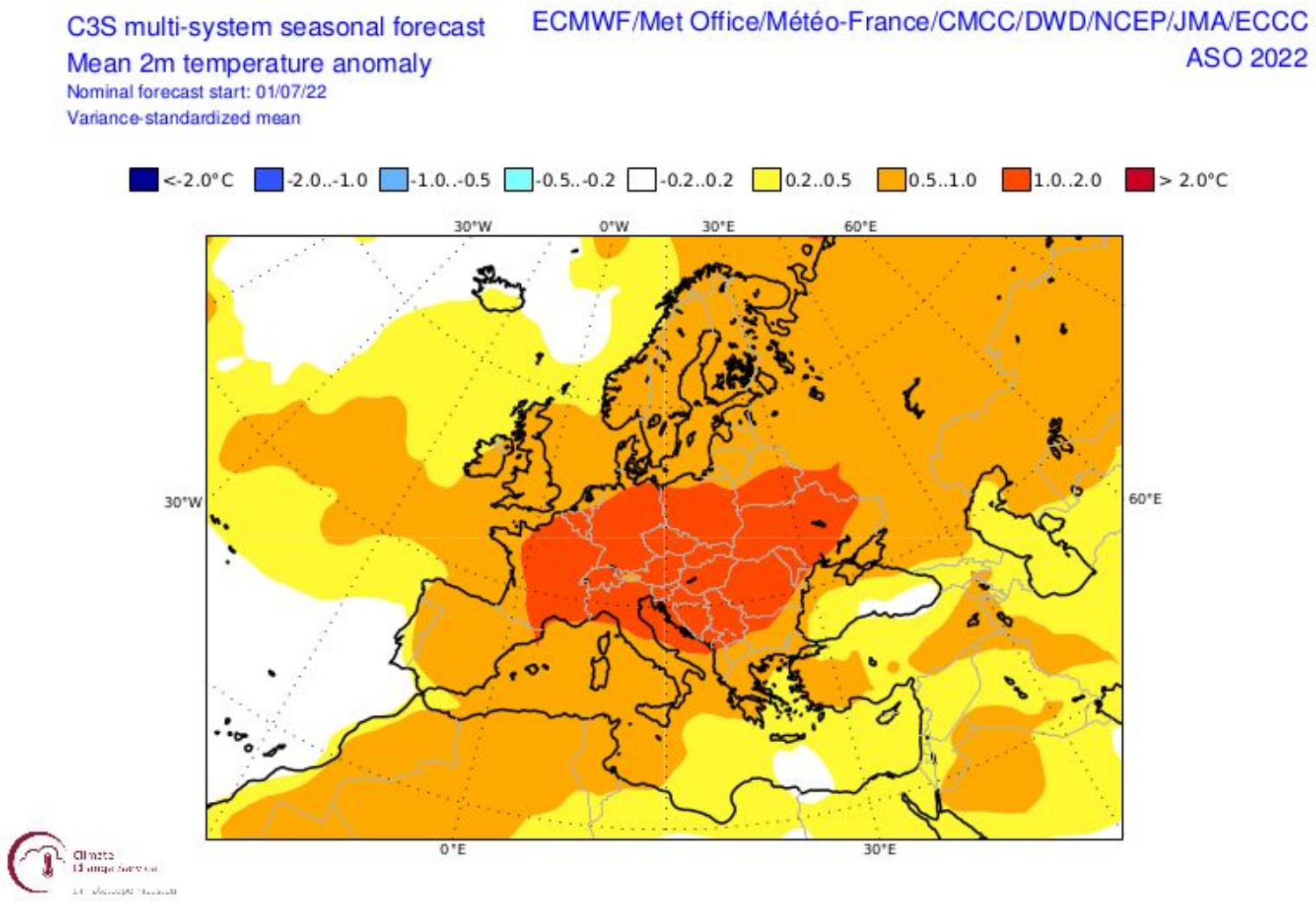
The seasonal forecast (forecast start **01/06/22**) from C3S models for summer predicted a much warmer than average European summer…



Source: https://climate.copernicus.eu/charts/c3s_seasonal/; acknowledgement: Matt Patterson, University of Oxford

Summer 2022:
Seasonal prediction

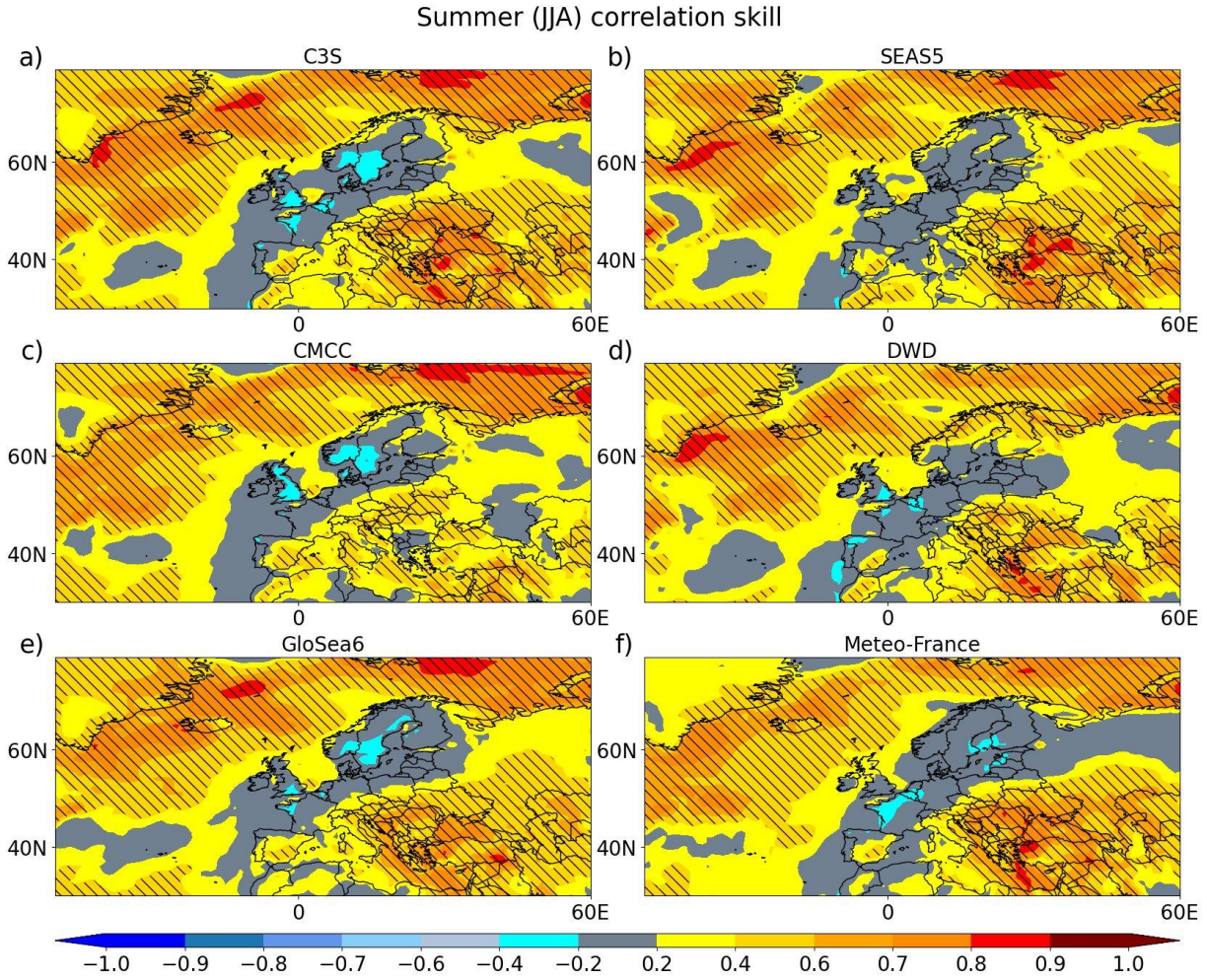
The seasonal forecast (forecast start **01/07/22**) from C3S models for summer predicted a much warmer than average European summer…



Source: https://climate.copernicus.eu/charts/c3s_seasonal/; acknowledgement: Matt Patterson, University of Oxford

Summer 2022:
Seasonal prediction

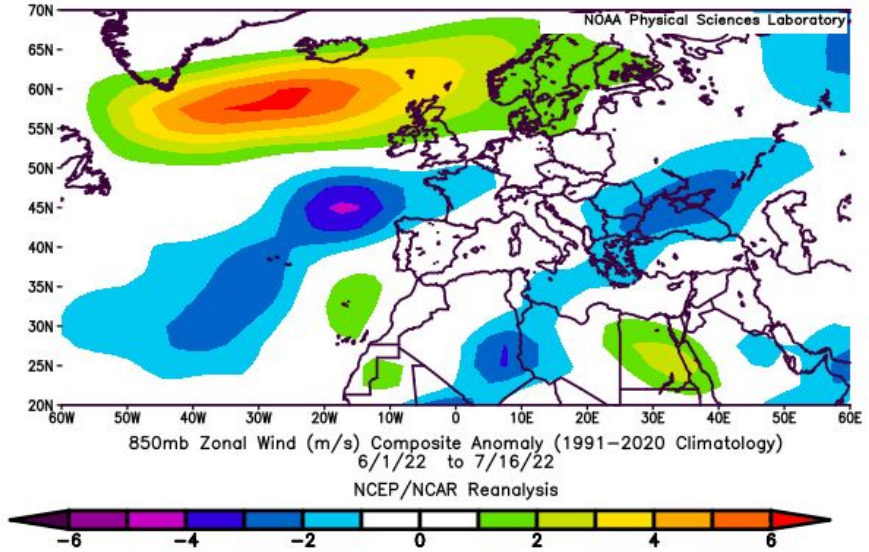
…but while T2m skill in the C3S models is good for southern Europe, it isn't that good over northern Europe, largely due to low skill of the large-scale atmospheric circulations, therefore confidence (for the north) wasn't high.

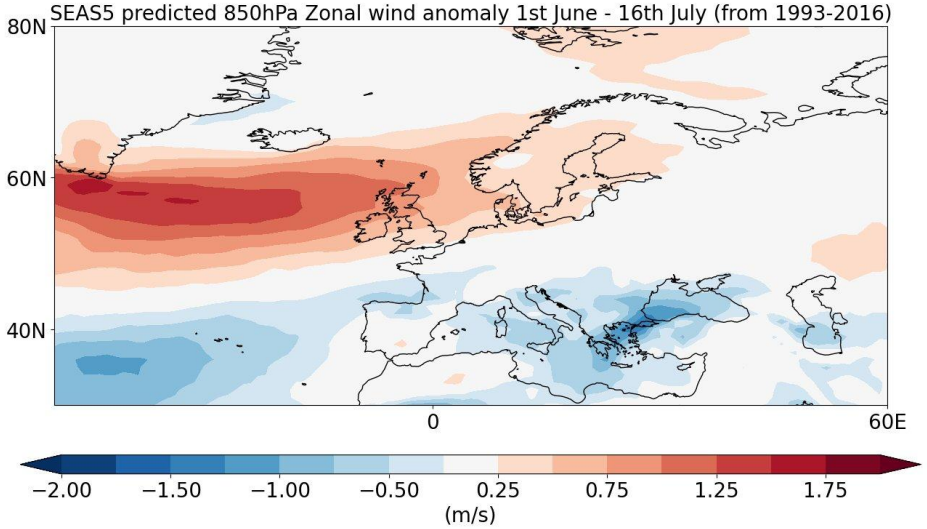


Source: https://climate.copernicus.eu/charts/c3s_seasonal/; acknowledgement: Matt Patterson, University of Oxford

Summer 2022: Seasonal prediction

The seasonal prediction of the hot summer may just have come from the global warming trends (i.e., model forcings), but maybe circulation (e.g. the positive NAO) or the Jetstream played a part?

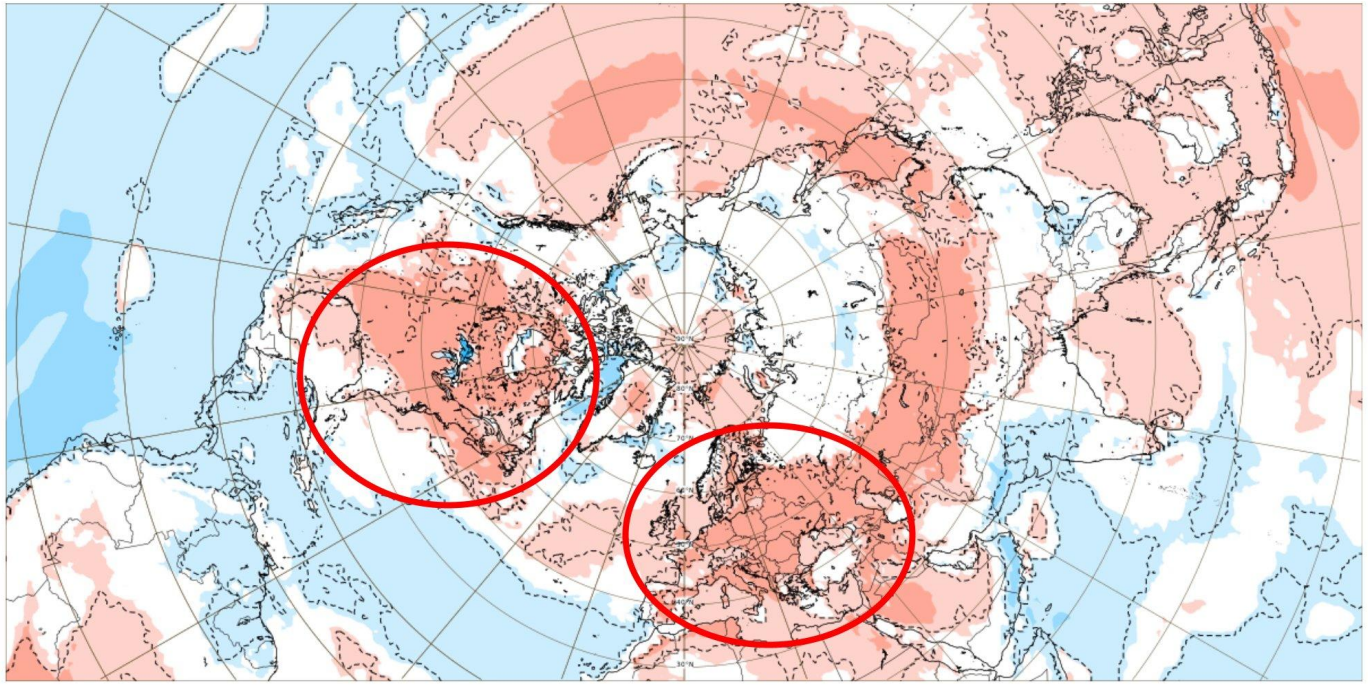




Source: https://climate.copernicus.eu/charts/c3s_seasonal/; acknowledgement: Matt Patterson, University of Oxford

Summer 2022:
Subseasonal prediction

The S2S forecast (forecast issued **23/06/22**) for 32 days ahead (18-25/07/22) from ECMWF showed an unusually warm mid July in Europe (and North America). Ensemble-mean weekly-mean T2m was 1-3 C above model climatology (previous 20 years).

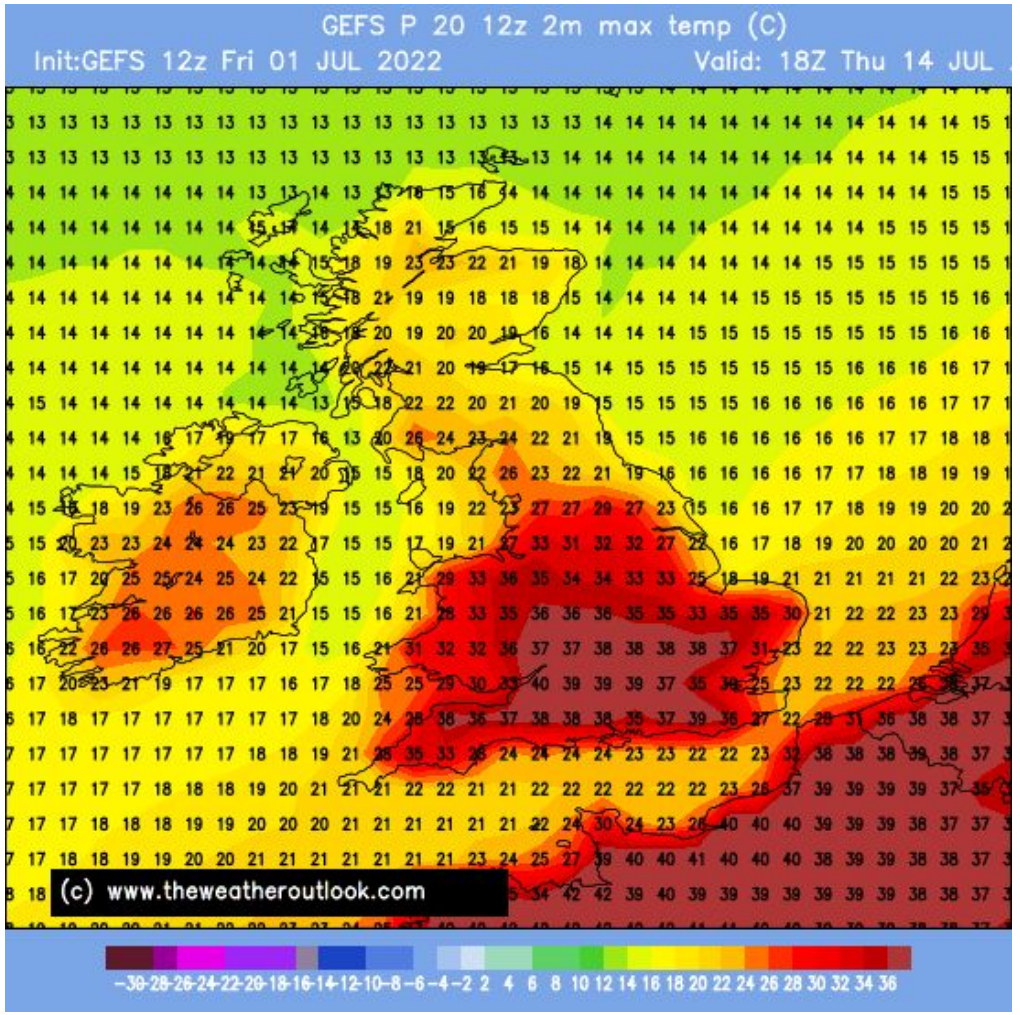


ECMWF

Source: https://twitter.com/SimonLeeWx/status/1540067123631890434 acknowledgement: ECMWF and Simon Lee, Columbia U.

Summer 2022: Subseasonal prediction

On 1 July, one of the 30 model runs produced by GEFS (NCEP) predicted temperatures of 40°C in the UK for 14 July. Not given that much attention, but potentially this was the first time 40°C has appeared in a reliable operational medium-range ensemble forecast for the UK!



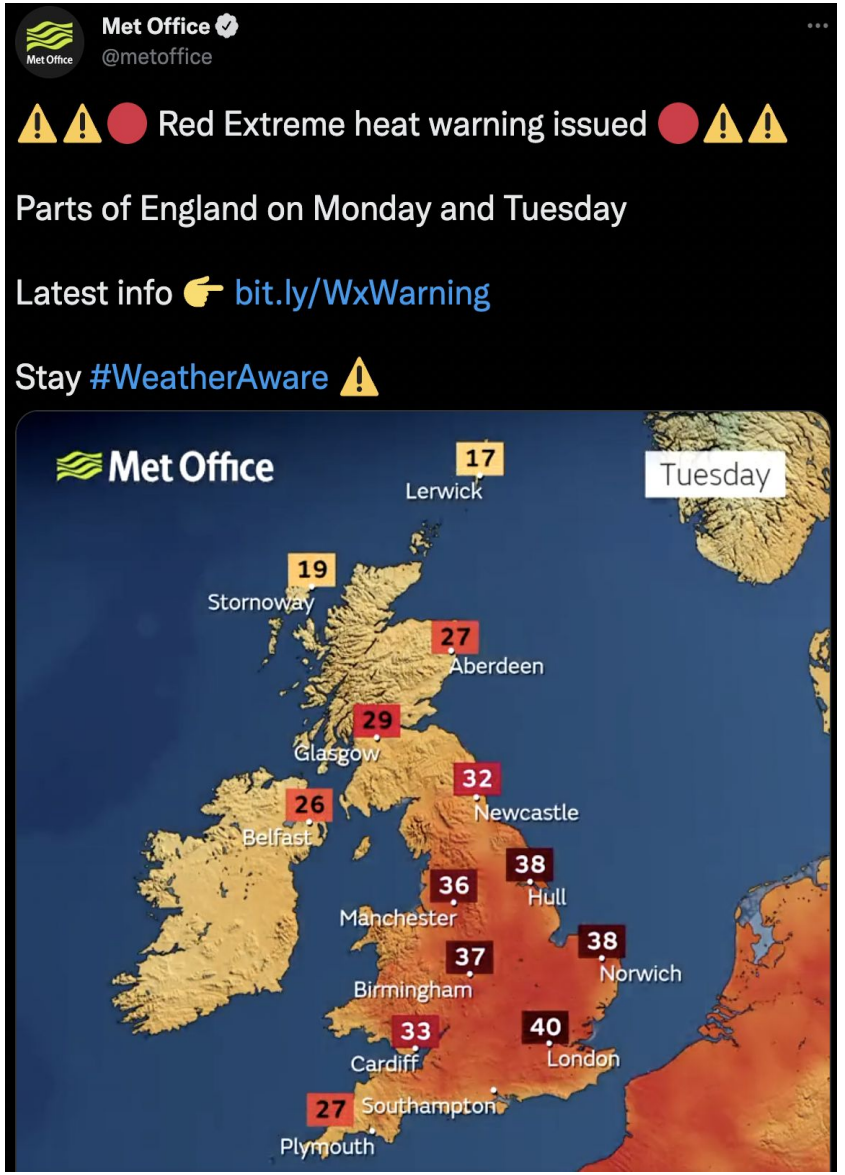
Source: https://www.carbonbrief.org/analysis-how-the-uks-insane-40c-heat-was-forecast-weeks-in-advance/ and TheWeatherOutlook

Summer 2022: Subseasonal prediction

The S2S prediction timescale!

At the start of July, a minority of weather forecast models indicated high temperatures for the middle of the month. But as we moved into July, model runs from a range of institutions suggested exceptionally high temperatures for mid July.

From around 8-9 July, most operational runs and started converging on extreme heat building from southern Europe during 16-17 July and peaking in the high-30°Cs. UK Met Office issued an amber warning on 11 July (for 17 July) and its first ever red warning on 15 July for exceptional heat.



Source: https://www.carbonbrief.org/analysis-how-the-uks-insane-40c-heat-was-forecast-weeks-in-advance/ and the Met Office

Extreme event S2S predictions:
S2S case studies of extreme event prediction

Studies focused on the applications and forecasting of extremes on S2S timescales are lacking. A new study led by Daniela Domeisen provides an overview of subseasonal predictability for case studies of some of the most prominent extreme events across the globe using the ECMWF S2S prediction system: heatwaves, cold spells, heavy precipitation events, and tropical and extratropical cyclones.

Location/target region	Forecast target period
Heatwaves	
Western United States (California) (32°–48°N, 110°–125°W)	23–29 Jul 2018
Central/northeastern Europe (50°–60°N, 10°–20°E)	23–29 Jul 2018
Southeastern United States (25°–45°N, 92°–70°W)	24–30 May 2019
East Asia (eastern China, Korean Peninsula, Japan) (30°–40.5°N, 105°–130.5°E)	5–11 Aug 2013
Cold spells	
Southeastern Europe (37.5°–54°N, 10.5°–30°E)	3–9 Apr 2003
Central/northern Europe (37.5°–65°N, 12.5°W–30°E)	26 Feb–3 Mar 2018
Southwestern Europe (France) (43.5°–49.5°N, 4.5°W–7.5°E)	16–22 Jan 2017
Northern Europe (United Kingdom, Germany, Scandinavia) (45°–65°N, 10°W–30°E)	27 Nov–3 Dec 2010
Precipitation events	
Volcán de Fuego, Guatemala (14.5°N, 91°W)	18–24 Jun 2018
Northwestern Ecuador (0°, 79°W)	21–27 Jan 2016
Northwestern Italy (43.5°–46.5°N, 6.5°–10°E)	21–27 Nov 2016
Northeastern Australia (18°–22°S, 138°–147°E)	31 Jan–6 Feb 2019
Cyclones	
Western Australia: Cyclone Claudia (no landfall)	5 Jan 2020 (formation)/18 Jan 2020 (dissipation)
Mozambique Channel: Cyclone Belna (landfall: Madagascar)	2 Dec 2019 (formation)/9 Dec 2019 (landfall)
Western North Pacific: Typhoon Chan-hom (landfall: China)	29 Jun 2015 (formation)/11 Jul 2015 (landfall)
Mediterranean: Medicane Zorbas (landfall: Peloponnese, Greece)	27 Sep 2018 (formation)/29 Sep 2018 (landfall)

Source: Domeisen et al. 2022 https://doi.org/10.1175/BAMS-D-20-0221.1

01

Introduction

02

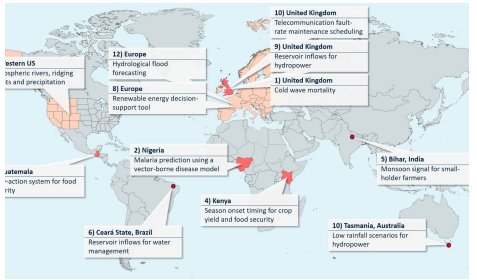
Applications of S2S predictions and case studies

03

The European summer heatwave 2022 and the role of seasonal and S2S prediction

04

A global S2S applications community



WMO S2S prediction project: Science, forecasting and applications

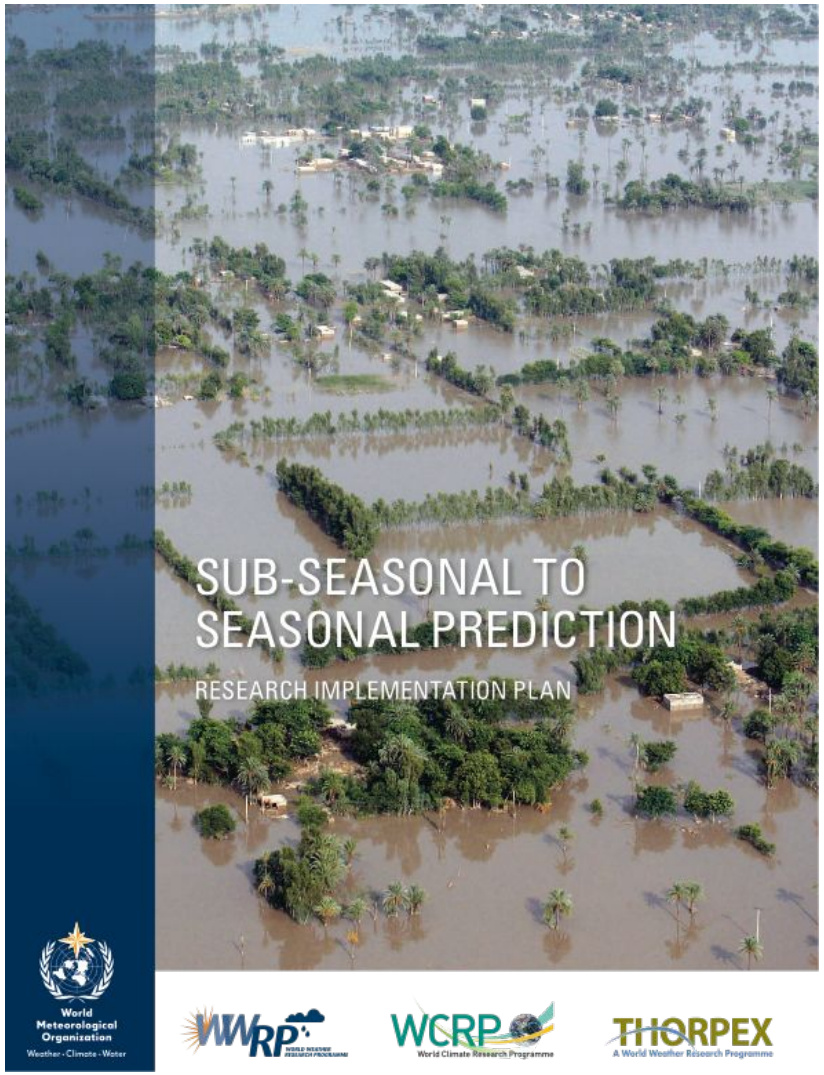
International WWRP-WCRP coordinated research on S2S predictability and modelling. The goal is to improve the accuracy and use of forecasts at lead times from 2 weeks to 2 months.

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

Database of S2S predictions (hosted at ECMWF and CMA) from 11 global producing centers: http://s2sprediction.net/

Subseasonal-to-Seasonal S2S Prediction Project

WMO



WMO S2S prediction project: Science, forecasting and applications

- A new **applications sub-project** aims to support and promote 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
- Co-led by Dr Christopher White (University of Strathclyde) and Dr Joanne Robbins (UKMO): http://s2sprediction.net/xwiki/bin/view/Phase2/AppNet
- Builds on the **real-time pilot** to initiate a network of application-orientated researchers

Applications sub-project: Objectives

- 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, **including the RTP**
- 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

Applications sub-project: … and the home of the RTP

- Led by Dr Joanne Robbins, supported by a Research Assistant from the University of Strathclyde (Rebecca Simmonds), 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 2023!**

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

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Applications sub-project: Current/ongoing activities

- Mission statement, objectives, current activities on the wiki
- This week's real-time pilot (RTP) virtual workshop showcasing and discussing the initiative (15-17 Nov 2022): http://s2sprediction.net/workshop/!
- Exploring promotion and dissemination activities through conferences and workshops, e.g.:

  - EGU 2023 (Vienna, 23-28 Apr 2023): AS1.3 Subseasonal-to-Seasonal Prediction, Processes and Impacts https://meetingorganizer.copernicus.org/EGU23/session/47263

  - IUGG 2023 (Berlin, 11-20 Jul 2023): JM04 Weather and Climate Extremes: Understanding, Modeling, Prediction, and Impacts (IAMAS, IAHS, IACS) https://www.iugg2023berlin.org/922-2/#IAMAS

Summary:

01

Introduction

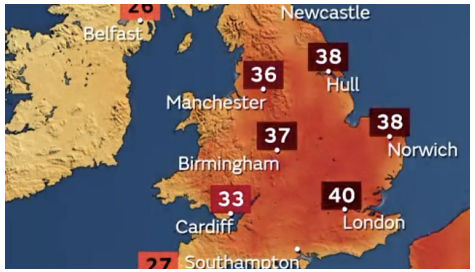
02

Applications of S2S predictions and case studies

Subseasonal-to-Seasonal S2S Prediction Project

03

The European summer heatwave 2022 and the role of seasonal and S2S prediction



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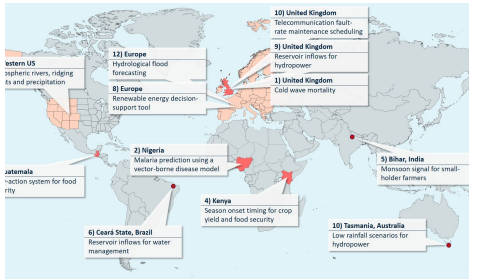
A global S2S applications community



Summary:

- The value of S2S forecasts is increasingly gaining interest among users – the RTP and other activities present a growing body of evidence of S2S forecasts being increasingly used across sectors in developed and emerging economies
- 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, incorporating ensemble S2S forecasts into operations is not trivial
- However, recent initiatives are helping to overcome these challenges and open S2S forecasts up to new users and potential applications, in particular ‘situational awareness’ and increasingly extremes, demonstrating that application-focused S2S forecast information, can produce useful, useable and actionable information
- The RTP with other initiatives like the S2S applications sub-project are helping to create a global applications community and a lasting legacy beyond the S2S prediction project

References:

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