Subseasonal-to-Seasonal S2S Prediction Project

WWRP World Weather Research Programme

WCRP World Climate Research Programme

Newsletter

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1. What is S2S ?

To bridge the gap between medium-range weather forecasts and seasonal forecasts, the World Weather Research Programme (WWRP) and World Climate Research Programme (WCRP) launched a joint research initiative in 2013, the Subseasonal to Seasonal Prediction Project (S2S). The main goal of this project is to improve forecast skill and understanding of the subseasonal to seasonal timescale, and to promote its uptake by operational centres and exploitation by the applications communities.

Phase II of the S2S project began in January 2019 and will continue until 2023. A new set of scientific sub-projects has been developed, as outlined in the sidebar in next pages. Enhancements to the database will be made including access to the S2S ocean and additional models. The second phase will also include new research-to-operations activities and a real-time supplications initiative introduced in this edition of the newsletter.

The S2S Phase II Proposal is available online at this link.

The contribution of S2S forecasts to the activities of the Italian Civil Protection Department

Daniele Mastrangelo[1], Luca Delli Passeri[2], Emanuela Campione[2], Piero Malguzzi[1]

[1]CNR-ISAC, Bologna, Italy

[2]Department of Civil Protection, Presidency of the Council of Ministers, Rome, Italy

Autumn 2006 and the following winter months featured a warm and dry period in South-Eastern Europe and in Italy, where the strongest anomalies were recorded in the regions surrounding the Po Valley. Low precipitation accumulations and persisting warm anomalies contributed to a reduced snowpack over the Alps, making clear, since the beginning of 2007, that a water resources shortage would have occurred in the following months. To tackle the upcoming emergency, in January 2007, the Italian National Civil Protection Department (DPC) set up an expert panel with the aim of providing meteorological forecasting information on both the monthly and seasonal scales. This long-lead meteorological information extended the normal forecasting and monitoring activity already carried out by the meteorological and hydrological office of the Department. Indeed, since 2004, DPC had been designated by the central government as the main entity coordinating a national alert system for the short-term (up to 48 hours) hydrogeological risk. The expert panel gathered the main Italian institutions and research centers able to provide forecasts on the subseasonal/seasonal scale or climatological monitoring based on observational data. The Institute of Atmospheric Sciences and Climate of the National Research Council of Italy (CNR-ISAC) was among the research centers convened in the expert panel. Within this framework, CNR-ISAC started to produce experimental subseasonal ensemble forecasts using the atmospheric general circulation model GLOBO, which had recently been developed in the institute.

The 2007 water emergency fostered the cooperation between CNR-ISAC and DPC on subseasonal forecasting. Forecasts were initially run occasionally, as part of the meetings of the expert panel, and, together with outputs from other monthly prediction systems, contributed to the generation of a consensus forecast for the next month. After many years, the activity of the expert panel is still ongoing: a forecast report is independently shared by each participating institution at the beginning of each month; meetings of the panel are now organized every 3 months, more frequently in case of issues affecting a large part of the population and territory. In all cases, the forecast is summarized through monthly-averaged tercile probabilities of 2 m tem-

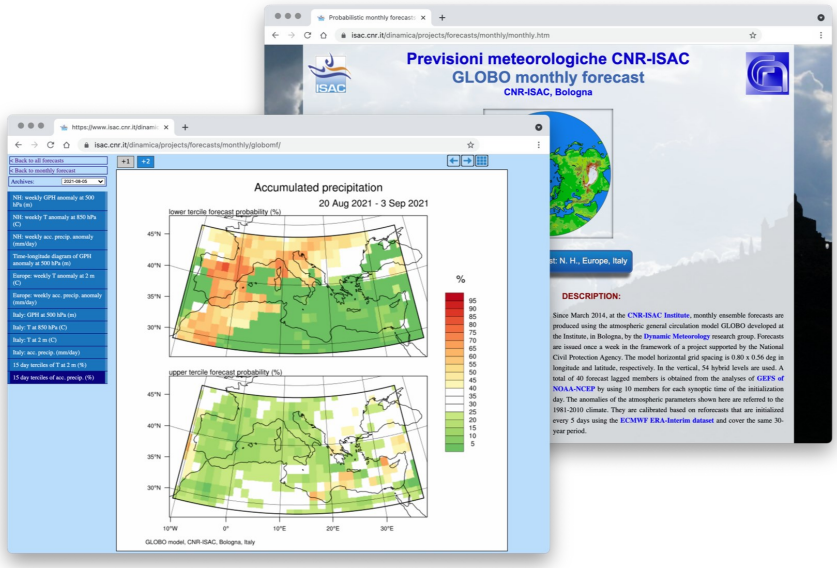


Fig. 1: The website showing graphical outputs of the CNR-ISAC subseasonal forecasting system (https://www.isac.cnr.it/dinamica/projects/forecasts/monthly/monthly.htm)

perature (T2m) and total precipitation for Italy, with a focus on shorter periods and smaller areas. Especially during emergency periods, the forecast is released by the DPC press office to get to different potential stakeholders.

Since 2014, the CNR-ISAC subseasonal forecasting system is systematically operated on a weekly basis—after some upgrade it entered the S2S project in the following year. Graphical outputs are made available to DPC on a freely accessible website (Fig. 1): in addition to total precipitation and T2m, anomaly maps and time series of temperature at 850 hPa and geopotential height at 500 hPa are also shown. Precipitation and T2m are the two primary variables used at DPC. The probabilistic prediction of these variables (the consensus forecast if present) is elaborated by DPC from the available forecasting sources and used for different tasks of the Department, or provided to external users.

The aforementioned hydrogeological-risk alert system is based on and triggered by short-term meteorological forecasts: subseasonal predictions are used as an assist information to timely highlight the possibility of an incoming critical period. This activity is routinely accomplished by DPC along the whole year and the availability of subseasonal forecasts on a weekly basis has been a major advantage. The same consideration applies to one of the prime DPC internal activities: the wildfire risk prevention and management on the national territory. This activity schedules a field campaign formally starting in May and is performed by a dedicated office of DPC. This office collects several monitoring data including soil humidity, different parameters of the vegetation, water availability, and the subseasonal/seasonal forecasts. The evaluation of these data produces an estimate of the fire risk that is disseminated to all the involved local authorities and is continuously updated during the campaign. Also, in this context, interest has been

2. Six sub-projects in S2S Phase II

The new research Phase II sub-projects will address issues related to sources of predictability, forecast system configuration, and model development. These sub-projects are more oriented towards model experimentation than the Phase I sub-projects which were more about model assessment. Some of the new sub-project research plans will include coordinated experiments and also process studies in coordination with the Working Group on Numerical Experimentation (WGNE).

1. **MJO and teleconnections**: This sub-project focuses on the representation of teleconnections and their modulation in S2S models. Metrics for assessing model teleconnections and diagnosing sources of errors in teleconnections will be applied.

2. **Land**: This sub-project investigates the impact of the observing system on land initialization and S2S forecasts, the representation of the coupled land/ atmosphere processes in S2S models, and contribution of anomalies in land surface states to extremes. It will work in concert with other relevant programs to pool resources and coordinate scientific studies (e.g. GEWEX/GLASS).

3. **Ocean**: This sub-project aims to evaluate the ocean feedbacks which directly influence sub-seasonal variability and prediction skill, the predictability influenced by pre-existing ocean state, the effect of low-frequency variability on S2S predictability, the impact of ocean mean state drift on S2S predictability, mechanisms which affect extreme ocean weather (heat waves) and their predictability.

4. **Aerosol**: This sub-project is a collaboration between S2S, WGNE and GAW. It aims to evaluate the benefit of interactive instead of climatological aerosols on sub-seasonal forecasts through a series of coordinated reforecast experiment with and without

interactive aerosols. The sub-seasonal predictability of aerosols will be assessed as well as their impact on sub-seasonal forecast skill scores.

5. **Ensembles**: This sub-project will study the influence of burst vs lagged ensemble initialization on the forecast spread using S2S database. It will also investigate the impacts of stochastic parameterizations and coupled initial perturbations on the sub-seasonal prediction, review the techniques for coupled initial perturbations which are under development in a few centers (ECMWF, NCEP, BoM, and JMA).
6. **Stratosphere**: This is a joint sub-project between S2S and WCRP/SPARC/SNAP. Its main goals include: developing additional stratospheric diagnostics and investigating the use of DynVarMIP additional diagnostics to S2S models; Coordinating damping experiments to examine the dynamics of downward coupling; Studying the link to tropospheric dynamics.

3. Upcoming events

- **Atmospheric blocking virtual workshop,** *27-29 Sep 2021, online.*
  - *Abstract Submission: 1 June 2021*
  - *Registration: 1 Sep 2021.*
  - *https://blocking-workshop-2021.wavestoweather.de/*
- **WCRP Workshop on Extremes in Climate Prediction Ensembles (ExCPEns),** *25-27 Oct 2021, online.*
  - *Abstract Submission: 30 Jun 2021*
  - *Registration: 20 Oct 2021*
  - *https://www.wcrp-climate.org/news/wcrp-news/1702-excpens-workshop*
- **AGU Fall Meeting 2021***, 13-17 Dec 2021, New Orleans, hybrid.*
  - *Abstract Submission: Closed*
  - *Early Registration: 3 Nov 2021*
  - *https://www.agu.org/Fall-Meeting*

growing on the 10 m wind subseasonal forecasts, an important factor for wildfire propagation.

Two main external sectors benefit from a cooperation implemented with DPC at national level: the water resources management and the public health sectors. The first activity is carried out separately for each of the seven main river basin districts of the country (e.g., Po Valley, Southern Apennines). The involved agencies monitor the available water resources on and below the ground. This diagnostic activity is periodically supported by the prognostic meteo-climatological information provided by DPC to get an evaluation of the possible water shortage risk.

The Ministry of Health coordinates a national plan with the aim of reducing mortality associated with extreme heat. From the beginning of June to September, a short-term (up to 72 h) daily bulletin is issued for about 30 main cities on the health-risk level caused by high temperatures. Similarly to the hydrological-risk prevention activity, the long-term forecast provided by DPC is used to draw attention in advance on a period of possible increased risk.

Finally, besides these systematic activities, subseasonal forecasts have been occasionally (in winter) supplied to the road transportation sector and are included in the set of meteorological information adopted in the management of all the emergencies DPC has to cope with (e.g., humanitarian sector, natural and man-made disasters).

The activities of DPC are a natural testbed for subseasonal forecasts: although most of the tasks and alert procedures rely on short-term prediction, a meteorological information beyond 2 weeks can give room to plan and manage the possible actions to implement. For instance, the starting date of the wildfire campaign can be anticipated or delayed also according to the indications obtained by subseasonal predictions.

The long-lasting partnership with DPC has promoted the development and application of the CNR-ISAC subseasonal forecasting system, resulting in a virtuous example of cooperation between national entities. With the same cooperation, CNR-ISAC is currently participating in the S2S Real-Time Pilot Initiative providing experimental multi-model subseasonal predictions to DPC.

Sub-seasonal case study:
Late July 2021 anomalous extreme heat in northern Australia

Catherine Ganter, Avijeet Ramchurn, Robert Smalley, and Andrew Watkins (Australian Bureau of Meteorology)

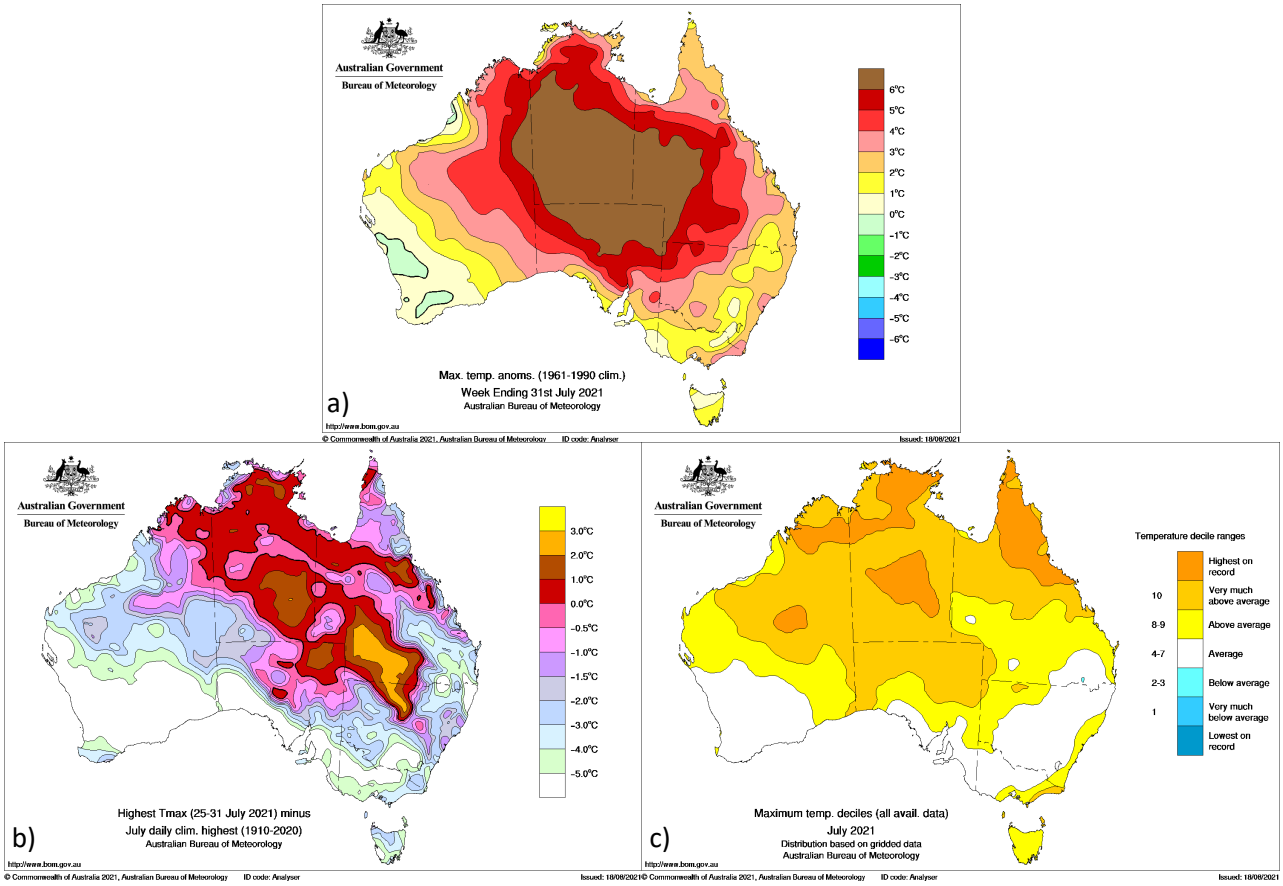


Figure 1. a) Maximum temperature anomalies for the week of 25 to 31 July 2021 with respect to 1961-1990 base period b) Highest daily temperature during 25 to 31 July compared to highest July daily temperature in the 1910-2020 record; positive values indicate where the July record was broken on at least one day during that week, and c) Maximum temperature deciles for July 2021, distribution based on 1910 -2021.

The Bureau of Meteorology has used ACCESS-S1 (Hudson et al. 2017) as its operational sub-seasonal to seasonal (S2S) model since August 2018. It will soon include S2S outlooks of potentially hazardous conditions (forecasts for rainfall and temperatures falling in the top 20% of historical observations). Case studies of extreme events are useful to see how well sub-seasonal forecasts would have performed, and hence help to build confidence for users. This article looks at the recent anomalous heat in late July 2021 over northern Australia, and the degree to which the Bureau of Meteorology's ACCESS-S1 model captured this heat.

During the last week of July 2021, heat built up across much of central and northern Australia. This build-up of heat was due to a lack of south-easterly trade winds, which typically act to cool north-western Australia, which is typically the warmest part of the country at this time of year. The final week of the month, 25 to 31 July, saw maximum temperatures in the tropical north-west 3 to 6 degrees above average across a broad region, with areas further inland more than 6 degrees above average for the week (Figure 1a). The heat built across the week, peaking on 31 July, with cooler conditions in the following days as cooler southerly air arrived. Many stations set records for their warmest July temperature on 30 and 31 July (Figure 1b). The event contributed to Australia's equal 5th highest July maximum temperature in 112 years of records (Figure 1c). This is a prime example to look at weekly outlook capability given the broad area of records and the extended time period.

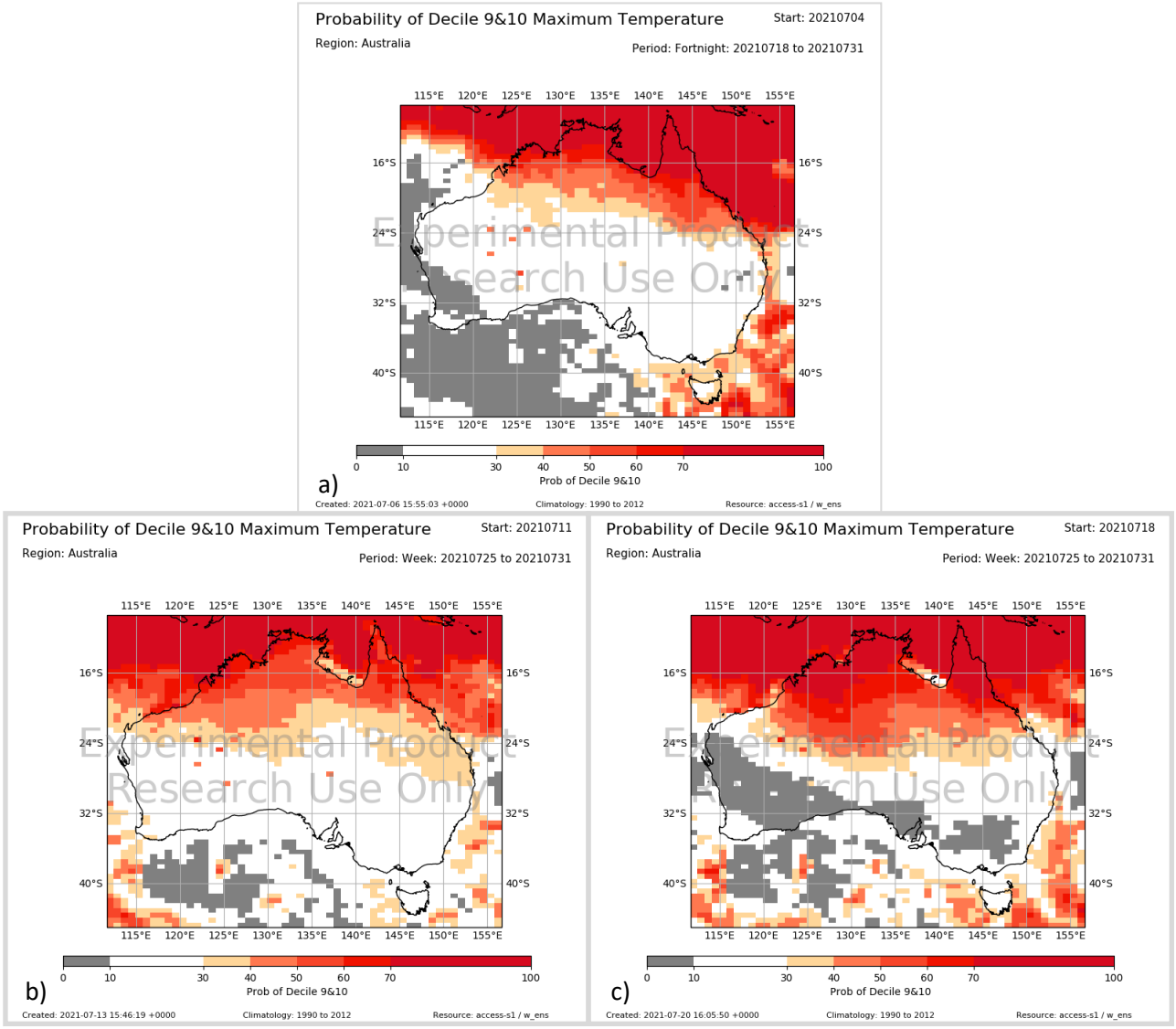


Figure 2. Experimental ACCESS-S1 outlooks of probability of decile nine and ten maximum temperature for a) the fortnight of 18 to 31 July (forecast date 4 July 2021), b) the week of 25 to 31 July (forecast date 11 July 2021), and c) the week of 25 to 31 July (forecast date 18 July 2021). ACCESS-S1 base period 1990-2012.

Forecasts in early July gave signs of upcoming warmer weather. Forecasts for the fortnight of 18-31 July made on 4 July indicated some chance of extreme maximum temperatures (in the historical top 20%) across the northern tropics (Figure 2a). By 11 July, forecasts for the week of 25-31 July were available, with the extent of the likely extreme conditions extending further south to cover most areas of Australia north of 24°S latitude (Figure 2b). On the 18th of July, a week prior to the heat event, the chance of extreme temperatures (Figure 2c) had increased in magnitude and further extended south to around 26°S latitude (the SA-NT border). The 850hPa wind vector forecast for the week (not shown) provides some insight into the change between the forecasts from the 11th and 18th of July, with the later outlook showing a broad area of northern and central Australia with north-westerly wind anomalies likely for the week. The earlier forecast also showed north-westerly wind anomalies were likely, but to a much weaker and less broad extent.

ACCESS-S1 forecasts captured the northern extent of the extreme heat early, with later forecasts extending the likely warmth area further south down to the NT-SA border. Some of the southern extent of the anomalous warmth was missed, but overall the extreme tropical heat was well forecast.

References:

- Hudson, D., Alves, O., Hendon, H.H., Lim, E., Liu, G., Luo J.-J., MacLachlan, C., Marshall, A.G., Shi, L., Wang, G., Wedd, R., Young, G., Zhao, M., Zhou X., 2017: ACCESS-S1: The new Bureau of Meteorology multi-week to seasonal prediction system. Journal of Southern Hemisphere Earth Systems Science, 67:3 132-159 doi: 10.22499/3.6703.001.

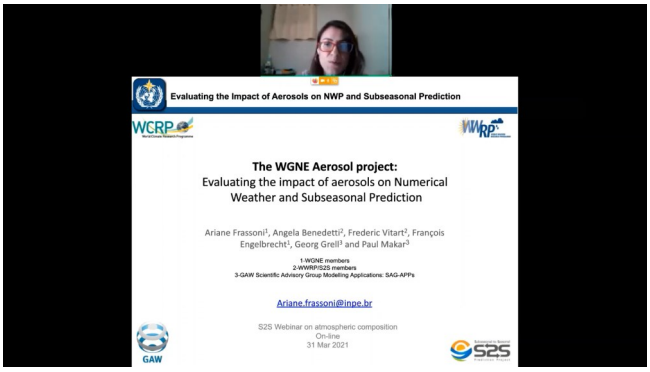
S2S Webinar Series

WMO S2S Prediction Project

Sharing knowledge with our peers helps get feedback and is essential for the S2S sub-projects to achieve success. With the uncertainties associated with COVID-19, we have started a new tradition of sharing research and knowledge online through the WMO S2S Prediction Project monthly S2S webinar series. This series highlights various aspects of the project and promotes engagement from the broader community, cycling through the various S2S sub-projects/activities. The first S2S webinar was launched in May 2020. The webinars are generally one-hour, with a few short presentations. The S2S webinar recording and presentation files are available on the S2S homepage (s2sprediction.net).

Aerosols in S2S (Andrea Molod, NASA)

The webinar focused on Phase II of the Working Group on Numerical Experimentation (WGNE) Aerosols project, expanded from Phase I to include experiments on the subseasonal time scale. The webinar was held on 30 March 2021 and was attended by a total of 66 participants. The recording of the webinar is available at: https://www.youtube.com/watch?v=2g8vaqma8Ew



Dr. Ariane Frassoni from the Brazil National Institute for Space Research gave a talk entitled: The WGNE Aerosol project: Evaluating the impact of aerosols on Numerical Weather and Subseasonal Prediction. The talk detailed the configuration of Phase II of the WGNE Aerosol Intercomparison project, designed to identify and quantify the importance of aerosols for the predictability of the atmosphere at short, medium-range and subseasonal time scales.

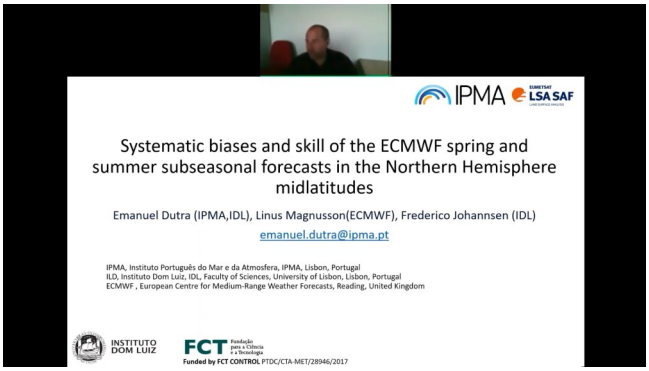
Dr. Angela Benedetti from the ECMWF gave a talk entitled: Aerosol impacts at the S2S scale in the ECMWF model. The talk included some results from the ECMWF experiments, showing that the interactive aerosol experiment increased the skill in predicting aerosol, showed a degraded meteorological forecast skill in the dust-related experiments and an increased skill in the biomass burning experiments. Both sets of results point to the importance of interactive aerosol in subseasonal forecast skill.

Dr. Donifan Barahona from NASA presented a talk entitled: Aerosol-cloud interactions in the NASA GEOS S2S prediction system. The talk described results from experiments conducted by NASA/GMAO, which included a suite with the aerosol-radiation interaction (ARI) and aerosol-cloud interaction (ACI) included. The talk focused on the impact of ACI, and reported that there is a clear positive impact from including ACI on the predicted 2-meter temperature in some locations and on the precipitation.

Dr. Georg Grell from NOAA gave a talk entitled: Aerosol Impacts on Regional and Sub-seasonal Forecasting: Plans and Initial Results. The talk included a description of the clear and significant impact on skill of using complex physics and chemistry in the WGNE Phase I experiments, and reported that the WGNE Phase II experiments will be conducted with and without aerosol-cloud interaction. NOAA is also interested in an additional regional experiment to capture the California wildfires in September 2020.

S2S Land sub-project (Paul Dirmeyer)

The webinar was held on 26 May 2021 and was attended by a total of 85 participants. The recording of the webinar is available at: https://youtu.be/gydzwiIER-A



Dr. Emanuel Dutra (IPMA) showed systematic temperature biases in S2S forecasts in the ECMWF model can only be understood by examining the diurnal cycle. Coupled land-atmosphere processes affecting biases are different between night and day. Precipitation and radiation biases affect the evolution of forecast biases and duration of skill over land, but biases and forecast skill are not strongly related. However, techniques of

soil moisture initialization and representation of vegetation may improve maximum temperature forecasts.

Dr. Joshua Roundy (U. Kansas) demonstrated the role of land-atmosphere interactions on drought prediction in both global and regional models, exploring how models run at convection-permitting scales affect drought prediction. Sensitivity studies with WRF over the US Great Plains suggest cumulus parameterizations can affect coupling processes degrading drought prediction. Hybrid statistical-dynamical forecasts show promise to overcome model biases in drought forecasting.

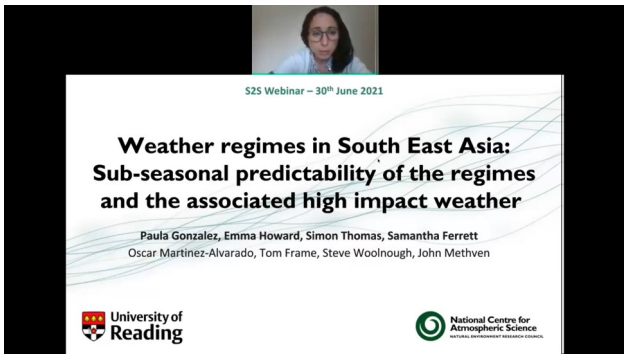
Dr. Gabriëlle de Lannoy (U. Leuven) discussed land data assimilation, which can be used for initializing soil moisture, snow and vegetation for S2S forecasts using satellite information. Microwave data from SMOS, SMAP and Sentinel-1 platforms. Satellites can detect areas of irrigation, shallow groundwater percolation (e.g., in peat soils) and frozen versus unfrozen soils. Techniques of data assimilation were described, and applications ranging from agriculture monitoring to landslide prediction. Snow depth, a crucial initial condition for forecast initialization, can be estimated using Sentinel data.

Dr. Andy Wood (NCAR) reviewed the value of S2S forecasts for water management over the western US. S2S timescales are crucial for hydrologic prediction. S2S forecasts have useable skill; temperature forecasts are especially valuable for snowmelt prediction. Research is showing patterns of relative sensitivities to uncertainties in S2S forecasts versus hydrologic model initialization, informing interpretation. Tailoring S2S products can improve applicability for sectoral users.

European Geophysical Union 2021 (Daniela Domeisen)

A webinar highlighting contributions from the European Geophysical Union (EGU) 2021 virtual session "Subseasonal-to-Seasonal Prediction: Processes and Impacts" (convened by Daniela Domeisen, Francesca Di Giuseppe, Angel Muñoz, Frédéric Vitart, and Christopher White) was held on June 30, 2021. More than 90 people attended the webinar to learn about the newest research on sub-seasonal predictability using weather regimes and statistical / data science methods. The video is available at https://youtu.be/ZCoMwkJsNxU.

Dominik Büeler (KIT, Germany) presented European weather regimes (WRs) and their potential for subseasonal prediction. Seven WRs are defined in the ECMWF S2S ensemble forecasts. The duration and frequency of the WRs, as well as differences in their forecast skill is investigated. The zonal regime and Greenland blocking are best predicted, while European blocking tends to have the lowest skill in all seasons. Winter shows the highest skill, partly arising from stratospheric forcing, while MJO phases 4 + 7 induce an enhancement of skill. The related paper is under review. More information can be found here.



Paula Gonzalez (U. Reading, UK) identified WRs for southeast Asia using different clustering methods, finding connections of the WRs to ENSO, the MJO, tropical cyclones, and anomalous precipitation. These WRs are tested in GloSea5 S2S hindcasts, where skill is found out to lead day 12. Regime - conditioned forecasts allow for the prediction of extreme precipitation out to lead week 3 in a case study for Jakarta. The related paper is under review. More information can be found here.

Kirsten Mayer (Colorado State University, USA) introduced an explainable neural network (NN) for determining subseasonal forecasts of opportunity. The NN uses tropical outgoing longwave radiation (OLR) as input and two hidden layers to predict the sign of 500hPa geopotential height anomalies over the North Atlantic 3 weeks later. Periods of enhanced predictability are identified using model confidence. Enhanced predictability is identified using layerwise relevance propagation, finding OLR structures resembling MJO phases 6-8 (3-4) as precursors of a negative (positive) NAO. The related publication can be found here.

Matthew Newman (CIRES/NOAA, USA) investigated how to identify skill a priori for forecasts of the NAO using a linear inverse model (LIM), yielding skill comparable to the ECMWF system beyond lead week 3 for high skill cases. High skill forecasts are related to two dynamical subspaces: (1) precursors in the stratosphere and from sea surface temperatures (SST), and (2) internal variability. Predictability beyond lead week 2 stems entirely from the stratosphere / SST subspace. The related papers can be found here and here.

S2S Forecast and its Applications in South Asia (Susmitha Joseph, IITM Pune, India)

A webinar on "S2S Forecast and its Applications in South Asia" was held online on 28 July 2021. There were four talks (each of 20-minute duration) by Prof Subimal Ghosh (IIT Bombay, India), Dr Giriraj Amarnath (IWMI, Srilanka), Dr Nachiketa Acharya (Pennsylvania State University, USA) and Dr Susmitha Joseph (IITM, India). The webinar was chaired and moderated by Dr AK Sahai, SSC member, WWRP. More than 75 participants attended the event worldwide. The webinar recording is available at https://youtu.be/-A15D1pl0BY

Prof Subimal discussed the development of an irrigation optimization tool for irrigation water management in grape farms in the state of Maharashtra in India. The framework was extended for extended range forecasts from IITM using the hidden Markov model. He demonstrated that it is possible to make early water arrangements for farm irrigation without wasting water and losing yield.

In his talk, Dr Giriraj briefed on the applications of extended range forecasts from IITM in managing floods and droughts over South Asian countries, and in the agricultural sector. He also highlighted the use of machine learning methods in improving precipitation forecasting on the subseasonal to seasonal scales.

"Research to Operation" aspect of the southwest monsoon on the sub-seasonal to seasonal scale was presented by Dr Nachiketa. This he demonstrated using the subseasonal experimental system that was developed for the state of Bihar (in India) and the recently developed "NextGen" forecast system that follows the WMO's recent seasonal forecast guidance on objective-based methods for Bangladesh.

Dr Susmitha talked about the development of an efficient extended range prediction system for societal applications over South Asia by IITM under the "National Monsoon Mission" project of the Government of India. This system has remarkable skill up to 2-3 weeks and is being utilised by several stakeholders for sector-specific applications.

The webinar instigated a lot of fruitful discussions.

Upcoming Webinars

There will be a webinar on September 29. The topic and speakers are yet to be determined.

The webinar schedule is delivered via emails to people who are enrolled in the S2S mailing list. The webinar schedule varies from month to month based on the speakers' locations. We look forward to seeing you online!

Welcome to our New S2S SG/LG Members!

Claire Spillman

Dr. Claire Spillman is a Senior Research Scientist and team leader of the Seasonal and Marine Applications team in Research at the Bureau of Meteorology, Australia. Dr Spillman's current research is primarily focused on dynamical forecasting on sub-seasonal to seasonal timescales for marine applications. Applications include marine heatwave prediction, coral bleaching risk forecasts for Australian reefs, and decision support tools for commercial fisheries and aquaculture management.

Call for articles for the S2S Newsletter

S2S ICO welcomes the submission of articles to the S2S Newsletter related to the research in a diverse range of S2S subprojects (http://s2sprediction.net). The S2S Newsletter is published every four months.

Please contact Ms. Bo Ra Kim, S2S ICO, at bkim@apcc21.org with any submissions to the S2S newsletter.

S2S ICO based in APCC in Busan, Republic of Korea

The S2S International Coordination Office (ICO) is located at the **APEC Climate Center (APCC)** in Busan, Republic of Korea.