News Letter

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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.

S2S ICO at NIMS in Jeju

The S2S International Coordination Office (ICO) is located at the National Institute of Meteorological Sciences (NIMS) of the Korea Meteorological Administration (KMA), in Jeju, Republic of Korea.

Group photo of "Sub-seasonal to seasonal regional workshop for Asian countries" in Gyeongju, Republic of Korea

Sub-seasonal to seasonal regional workshop for Asian countries

The S2S regional workshop of "Sub-seasonal to seasonal regional workshop for Asian countries" was held at the Hilton Hotel, Gyeongju, Republic of Korea, on 24-27, June, 2018, hosted by NIMS/KMA. The workshop was an opportunity to discuss S2S national/regional activities in Asia. One of the most important issues were not only inter-disciplinary but also multi-disciplinary cooperation with national/regional projects in Asia. In addition, the cooperation between HIW ICO and S2S ICO was mentioned with emphasis on two-way communication R2O/O2R (research results into operations/operational needs back to research).

A new meeting opportunity for the S2S community at the EGU in Vienna

Francesca Di Giuseppe and Frederic Vitart

S2S oral session and S2S pre-dinner with the conveners and some keynote speakers

At the European Geophysical Union (EGU) General Assembly in 2018 organised in Vienna, took place the first edition of a session on subseasonal to seasonal prediction AS1.6 Subseasonal-to-Seasonal (S2S) Prediction: meteorology and impacts. The idea for this event was to create a community that could meet every year in Vienna and discuss issues related to this scale predictability. The call for abstracts proved popular with 42 abstracts submitted that were allocated in 2 oral slots followed by a lively poster session. During the session, presentations spanned all aspects of S2S meteorological, hydrological and oceanographic prediction, including impacts studies.

Contributions focused on phenomena such as - The Madden Julian Oscillation (MJO)- Tropical/Extra-Tropical waves- Stratospheric variability and stratosphere -troposphere coupling - Predictability and skill of atmospheric or surface variables- Transition of weather regimes. A vast number of contributions regarding impacts studies at the S2S time-range were also discussed including the areas of water management (e.g floods, drought), health (vector-borne diseases, heat waves, air quality) and security (fires), agriculture and energy. A lively discussion followed the talks of the invited speakers. Francisco Doblas-Reyes and Chris White, provided a very good overview of the activities that are ongoing in Europe concerning the applications at the S2S time range.

Given the good reception of this activity we plan to have a second edition of this session at the EGU General Assembly in April 2019, Watch this space!

Sub-seasonal to seasonal models for improving predictions of high impact weather, climate forecasting and advancing operational research across Africa meteorological services, academic and training centres

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S2S Numerical Weather Prediction Models and Sources

The operational science and practice of weather forecasting has greatly advanced with the emergence of numerical weather prediction modelling, data assimilation and automated chart analysis during the recent 3 or so decades. For example, the US National Weather Service Global Forecast System (GFS) released since 1980s and subsequent improved version is run operationally by the US National Oceanic and Atmospheric Administration (NOAA) Environmental modeling Center and output data sets and derived products available freely for international common good, for example, GFS operational and research use (for example GFS real time out data sets are available at (http://nomads.ncep.noaa.gov/). The United Kingdom Met Office Model-UM and its improved versions has been operational since 1980s. The Unified Model is also run operationally by the Korea Meteorological Administration (https://web.kma.go.kr/eng/biz/forecast_02.jsp). European Centre For Medium-Range Weather Forecast (ECMWF) model dates back to about 1985 and subsequent advances leading to the near real-time provision of extended numerical weather prediction products and data sets, courtesy of the WMO S2S project (http://s2sprediction.net/). Access to ECMWF S2S products can be granted, if only users request registration at https://apps.ecmwf.int/registration/. Other global centres running global scale extended numerical weather predictions and contributing to the model output datasets at the WMO lead Centre for Long-Range Forecast Multi-Model Ensemble (https://www.wmolc.org) are global numerical weather prediction models from the Japanese, Canadian, Germany and France centres among others.

Six Sub-projects in S2S

The research topics of the WWRP /WCRP S2S project are organized around a set of six sub-projects, each intersected by the cross-cutting research and modeling issues, and applications and user needs. The science plans of each subproject which can found at the S2S website, include:

1. **Monsoon:** The main goal of this sub-project is to develop a set of societally relevant intra-seasonal forecast products and metrics that are applicable to all the major monsoon systems which can be monitored with operational real-time forecast systems. Case studies of monsoon onset will be investigated.
2. **MJO:** This sub-project will evaluate the state of the art and characterize shortcomings of MJO Maritime Continent interactions. A main goal is to get a better understanding of the roles of multi-scale interactions, topography and land/sea contrasts, and ocean-atmosphere coupling in collaboration with the MJO Task Force of WGNE and Year of the Maritime Continent (YMC).
3. **Africa:** The goal of this sub-project is to develop skillful forecasts on the S2S time scale over Africa and to encourage their and other stakeholder groups.
4. **Extremes:** This sub-project will evaluate the predictive skill and predictability of weather regimes and extreme events (droughts, heat and cold waves), assess the benefit of multi-model forecasting for extreme events and improve our understanding of the modulation of extreme weather events by climate modes. It is also planned to select case studies with strong societal impact.
5. **Products and Verification:** The main goals of this sub-project are to recommend metrics and datasets for assessing the forecast quality of S2S forecasts, provide guidance for a potential centralized effort for comparing forecast quality of different S2S forecast systems, including the comparison of multi-model and individual forecast systems and consider linkages with users and applications.
6. **Teleconnections:** This subproject aims at a better understanding is subseasonal to seasonal forecasts of weather and climate for applications.

S2S database

The S2S Multi-Model database (Data Portals at the European Center for Medium-Range Weather Forecasts (ECMWF), China Meteorological Administration (CMA), and International Research Institute for Climate and Society (IRI)) contains near real-time and re-forecasts up to 60 days from 11 centres:

Australian Bureau of Meteorology (BoM), China Meteorological Administration (CMA), European Centre for Medium-Range Weather Forecasts (ECMWF), Environment and Climate Change Canada (ECCC), The Institute of Atmospheric Sciences and Climate (CNR-ISAC), Hydrometeorological Centre of Russia (HMCR), Japan Meteorological Agency (JMA), Korea Meteorological Administration (KMA), Météo-France/Centre National de Recherche Meteorologiques (CNRM), National Centers for Environmental Prediction (NCEP), and the United Kingdom's Met Office (UKMO). All except CNR-ISAC are WMO Global Producing Centres of Long-Range Forecasts (GPCs). Indian Institute of Tropical Meteorology (IITM) model based on CFSv2 integrations into the S2S database may be added in phase II.

Upcoming Events

- **International Conferences on Sub-seasonal to Decadal Prediction, *17-21 September, 2018, NCAR, Boulder, CO, USA*:** The 2nd International S2S Conference will be held jointly with the S2D Workshop. (https://www.wcrp-climate.org/s2s-s2d-2018-home)
- **Workshop on Subseasonal-to-Seasonal Predictability of the Mid-Summer Drought, *3-7 December, 2018, Antigua, Guatemala*:** It is a one-week hands-on training on mid-summer drought characteristics and prediction. The classes will be given in both English and Spanish. (https://msdworkshop.iri.columbia.edu/)
- **AGU 2018 Fall Meeting: (A097) Sub-seasonal to seasonal prediction of weather and climate, *10-14, December, 2018, Washington DC*:** The meeting will launch AGU's Centennial celebration by observing 100 years of Earth and space science accomplishments. (https://agu.confex.com/agu/fm18/gateway.cgi/)

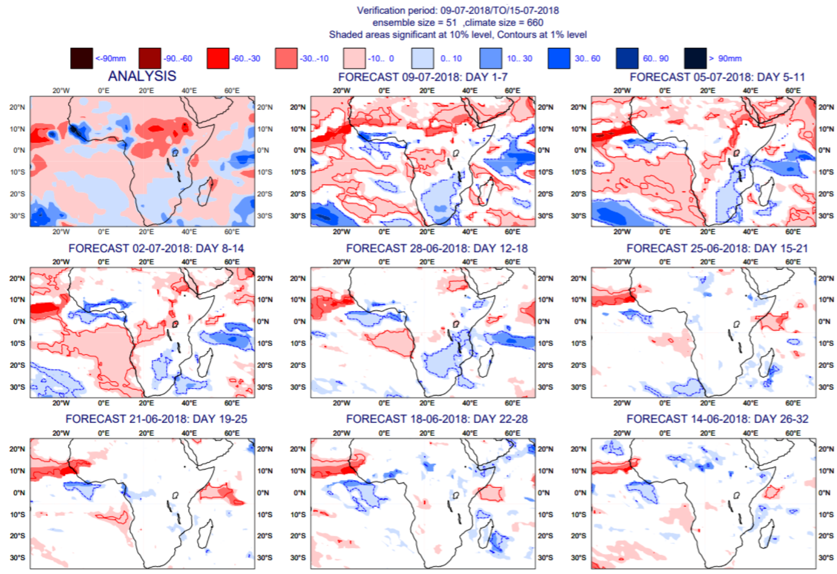

Figure 1. Africa Precipitation anomaly from the near real-time ECMWF Ensemble S2S forecasting system for 02 July 2018 : This graphic displays the weekly mean anomalies relative to the past 20 years climate. The first panel corresponds to the anomalies computed using ECMWF operational analysis and reanalysis for a given week. The other panels correspond to the eight monthly forecasts starting one week apart and verifying on that week. The model anomalies are relative to the model climate computed from the model back-statistics. The areas where the ensemble forecast is not significantly different from the ensemble climatology according to WMW-test are blanked. The time range of the forecasts is day 1-7, day 5-11, day 8-14, day 12-18, day 15-21, day 19-25, day 22-28 and day 26-32. This figure gives an idea of how well the predicted precipitation anomalies verified against the ECMWF analysis and also about the consistency between the monthly forecasts from one week to another.

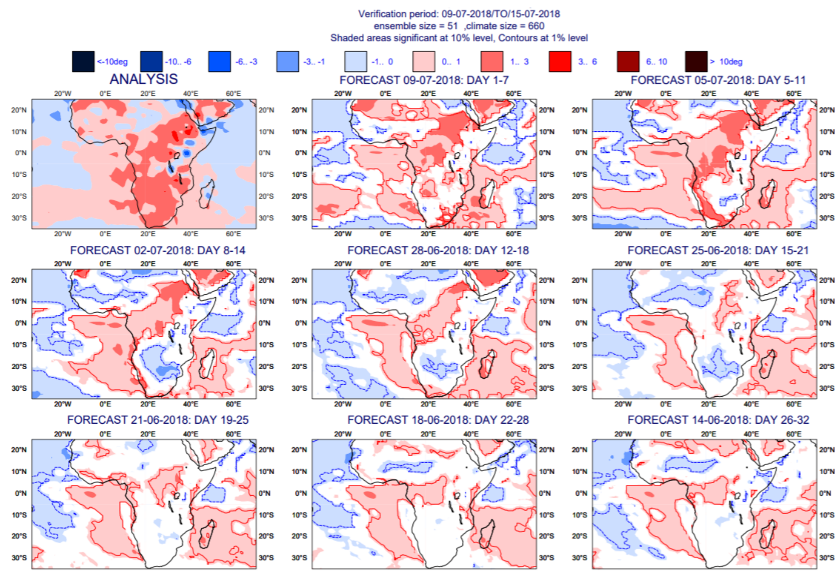

Figure 2. Africa 2-metre Temperature anomaly from the near real-time ECMWF Ensemble S2S forecasting system for 02 July 2018 : Same as above figure 1.

The outputs of the eleven S2S producing centres can be accessed in post-processed formats like charts and maps or downloaded from:

- The WMO LC-LRFMME; (https://www.wmolc.org)
- S2S MUSEUM; (http://gpvjma.ccs.hpcc.jp/S2S/)
- IRI;(http://wiki.iri.columbia.edu/index.php?n=Climate.S2S-IRIDL)
- ECMWF and Chinese Meteorological Administration (CMA)

Role of S2S in Africa: Weather Operations and Science Advancement

Sub-seasonal to seasonal (S2S) weather predictions are basically the bridge between typical weather and climate prediction time scales and it is emerging science of weather services which can fulfill the operational knowledge gap between weather and climate prediction in many countries round the world including those in Africa. Worldwide, it is probably only the UK Met Office which operates a dynamical prediction model for both weather and climate time scales, the Unified Model (UM). Adoption of S2S models and/or use of S2S forecasts products and data sets provides meteorologists in the Africa National Meteorological Services (NMSs), Research and Training Institutions with resources and analysis platforms which can greatly advance the understanding of mechanisms and drivers of high-impact weather; and how transition from weather to climate occurs not only in the tropics, but over the various sub-regions of Africa. There is a need for African NMSs, weather scientists and institutions to upscale the use of S2S Numerical Weather Prediction (NWP) Model products and near real-time data archives to increase the understanding of mechanisms and drivers of predictability of high-impact weather episodes. Herein lies great opportunities for operational meteorologists serving at the Africa NMSs as well as researchers and scholars in training and academic institutions, to ultimately adopt continuous use of S2S products and model output data sets available in various archives to advance understanding of mechanisms of weather and inclusion of these products in routine operations to increase the skill of weather predictions and extended outlooks in various parts of Africa.

Sample S2S Weather Prediction Products for Africa

Over most of Africa, precipitation and temperature are weather elements of greatest socio-economic impacts. The following charts and descriptive texts therein are examples of near real-time S2S Africa precipitation and 2-metre temperature from the ECMWF S2S system.

The availability of these products and corresponding data archives of the various models is an great opportunity for African Meteorological training and research to advance knowledge on the processes of weather across the continent.

S2S in the GCRF African-SWIFT Programme

Advancements and sustainability of Operational Weather Services requires international collaboration. Core attributes of good meteorological services is that weather forecasts are accurate, that the meteorological service institutions have good infrastructure, resources and tools for carrying out their mandate while ensuring continuous scientific advancement and expertize in human resources. We highlight here one research collaboration between African weather centres and research institutions facilitated by a grant from UK Research and Innovation as part of the Global Challenges Research Fund. The programme is called "GCRF African Science for Weather Information and Forecasting Techniques (GCRF African-SWIFT)". The programme will develop capacity and capability of African weather forecasting and research. The focus sub-regions of Africa in the SWIFT programme are East and West Africa including the Sahel. The project is led by the UK National Centre for Atmospheric Science (NCAS) and includes 4 partners from the UK (namely: University of Leeds, Centre for Ecology and Hydrology, University of Reading, UK Met Office). Remarkably, there are 10 Africa partners (namely: ACMAD, ICPAC, ANACIM, UCAD, KMD, University of Nairobi, GMET, KNUST, NiMet, FUTA) along with the World Meteorological Organization. Details of the SWIFT programme are available at https://africanswift.org/partners/.

African Meteorological Services, academic and research institutions and individual scholars have to advance operational usage of S2S models in prediction of extended weather in Africa as well as furthering the scientific understanding. This will provide crucial weather information on the occurence of hazardous weather conditions well in advance. This information is crucial in the hands of policy makers and managers of weather sensitive services in that it can be the basis of triggering strategic decisions which protect lives and property as well as enhancing the weather factor in the livelihood of African communities.

Pathway of developing sub-seasonal to seasonal seamless prediction for disaster risk management over Central Africa

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Introduction

The utmost importance of addressing climate variability for sustainable development in Africa is well known. A major outcome of the Africa Climate Conference 2013 was the recognition of key contribution of improvement of sub-seasonal to seasonal (S2S) prediction for early action to reduce or to cope with impacts of climate variability, through multidisciplinary research. In this regard, strong collaboration needed to be established between National Meteorological, Hydrological Services and Research Institutions. Such collaboration leads to a potential and robust evaluation of the usefulness of S2S forecasts implementation for African countries' adaptation strategies (e.g. farming, water resources, disaster risk management). Previous S2S activities over Central Africa aimed to recommend metrics and datasets for assessing forecast quality of different S2S multi-model ensemble forecast systems, in order to provide guidance for efficient management of sowing periods and cropping seasons. This article provides an overview of S2S activities over Central Africa and presents a way to framework seamless prediction, that will contribute to build a reliable and efficient network of weather monitoring for early warning leading to early action.

S2S Forecasts in the Perspective of Building Climate Information Services for Agriculture in Central Africa

S2S activities over Central Africa started within the framework of a Climate Research for Development in Africa (CR4D) pilot project in 2016. The project was a partnership owned by the United Nations Economic Commission for Africa and operated by the African Climate Policy Centre, along with a regional multi-stakeholder team. The project sought S2S forecasts and hindcasts from the global data archives at multi week lead times (15-90 days) in order to be used more efficiently in agriculture. These forecasts and hindcasts from the global data archives were assessed using specific metrics in the ways that are tailored to the needs of farmers. At the early stage of the project, the strategic plan put in place was intended to fulfil the following objectives: (1) assess the current state of climate services for agriculture over Central Africa; (2) highlight climate information needed by farmers; (3) define meaningful climate index related to information need by farmers; and to (4) assess the skill of climate model predictions at S2S timescales over Central Africa.

With support from the International Research Institute (IRI) of the University of Columbia, a S2S training event was organized in 2016 in Yaoundé (Cameroon) (http://wiki.iri.columbia.edu/index.php?n=Climate.S2S-CentralAfrica), bringing together researchers and experts from international scientific institutions alongside local Universities and NHMSs of Cameroon and Democratic Republic of Congo (DRC). This meeting leads to the selection and the analysis of 5 models from the S2S database (BoM, NCEP, ECMWF, HMCR and CMA), and forecast performance assessed targeting the onset date of growing season, and maximum dry spell duration during the rainy season. Generally, models show better skill to depict dry spell duration during the rainy season. All Models show in general good skill in forecasting the maximum dry spell duration, except some areas like the southern humid forest in Cameroon and the coastal part of DRC, where they tend to show very weak skill. For onset date of the growing season, models show highest skill to capture mean climatological onset date of growing season, and some of them present deficiencies in forecasting earlier and latter onset date events. Broadly, considering particular criteria used in operations, some models present good scores up to lead time 3-4 weeks in Cameroon, while in DRC predictability was of order of 2-3 weeks.

Some extremes events over Central Africa: always MJO footprint?

During 2015 June-September rainy season, several wet episodes occurred at Douala, a city located in coastal region of Cameroon, with the most severe reported on 18-20 June. The accumulated rainfall (Figure 1a, green curve) exhibits an abrupt shift during 18-20 June exceeding 170 mm, with the maximum value (83 mm) recorded on June 19. This maximum is far higher than the climatology. During this extreme event, the MJO was in phase 4 (Fig.1b), which is favorable to suppression of convection, so the related systems would have contributed to suppress precipitation over the region. Thus, the occurrence of this extreme event can be associated either to short range (Kamsu et al., 2014) or longer (Tchakoutio et al., 2012) time scale feature.

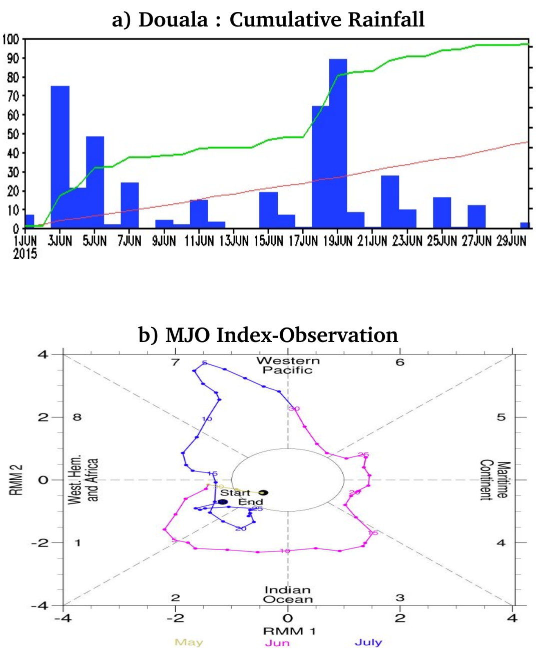
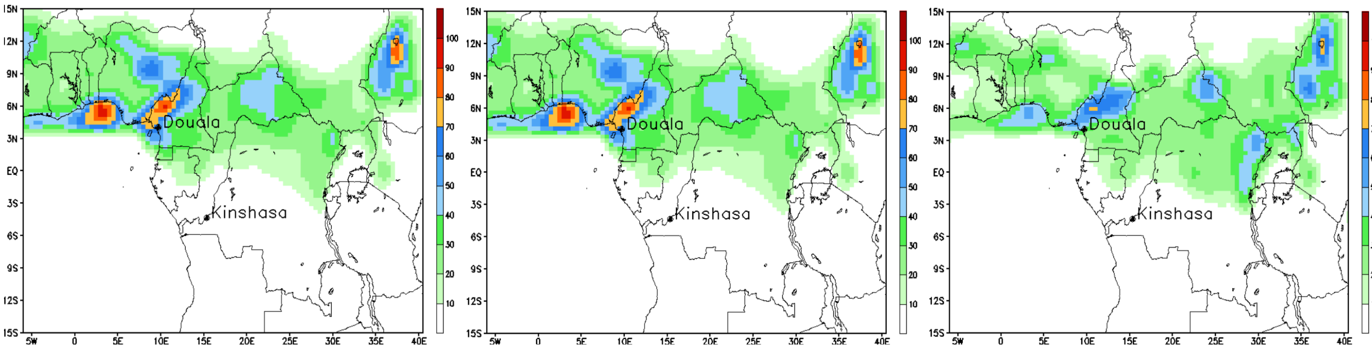


Figure 1. Accumulated rainfall (mm) during June 2015 in Douala and Observed MJO activity from May 29 to July 30, 2015. a) Observed (green) and climatology (red) daily accumulated rainfall (from ARC2) for the month of June. The blue histogram represents the daily value recorded at Douala. b) MJO index (RMM1, RMM2) phase space points from 25 May 2015 to 30 July 2015. Labelled dots represent days; grey line for May, pink line for June and blue line for July.

Soundings from Douala International Airport show that this event was associated with heavy downpours, thunderstorms and high values of Vertical Integral of Water Vapour indicating the intense stormy episode (Tanessong et al., 2017). The intensity and precise extent of this anomaly is relevant for the precise impact of the subseasonal scale events. So more than ever, there is a tough need to improve prediction in order to reduce the impacts of such events.



(a) (b) (c)

Figure 2. CFSv2 ensemble precipitation (mm) forecast for the week June 15-21, 2015. **a)** Week-3 forecast initiated on 31 May 2015; **b)** Week-2 forecast initiated on 07 Jun 2015; **c)** Week-1 forecast initiated on 14 Jun 2015.

Using the S2S databases (Vitart et al. 2017), we intended to analyze the extent to which forecasts were able to predict the occurrence of this extreme event. Figure 2 presents forecasts from the CFSv2 model, for the week 15-21 June 2015 during which the event did occured. Analysis of these forecasts suggests that this event would have been predicted even three weeks before. Is the earliest predictability (up to week-3) of that event related to active MJO at the moment of the initiation of the models? MJO seems not to be the only source of predictability, other sources may have contributed. These are preliminary results, in depth analysis are ongoing.

Pathway of Developing S2S Seamless Prediction over Central Africa

Increasing socioeconomic and environmental damages resulting from extreme events in Central Africa could be reduced through improvement of weather-climate forecasting. Resulting climate information, for efficient management of related climate risk should cover different time scales : medium term (from one week to one month) and long term (more than a month, including the seasonal timescale). Central Africa Regional Forum Climate Outlook (PRESAC) usually deliver mean seasonal forecast during rainy seasons in good time scale for planning, but in a too broad format. During the last PRESAC user's session in August 2017, it was suggested to expand the current seasonal forecasting procedure to subseasonal forecasts in order to produce more tailored forecast products to meet the requirements of practitioners needs. Using ensemble and probabilistic forecasts with the associated uncertainties, weather prediction is produced for 3-10 days with improved output using specific parameterization (Igri et al, 2018). Current satellite imagery products provided through PUMA 2015 and SAWIDRA-AC projects help to follow-up critical parameters like rainfall estimate and ancillaries' products on temperature, pressure and winds which need to be refined gradually at each local level in co-operation with NMHSs through multi-model ensemble systems. Although, this information is detailed enough, lead time is too short for early warning to early action. Proper establishment of an appropriate framework of seamless prediction would help to develop an efficient disaster preparedness system. The seamless prediction concept implies seamlessness across space and time scales, scientific disciplines; across institutions; and across geographical boundaries. Consequently, suggesting research on prediction of weather and climate carried out in a unified framework, is putting together the insights gained from operational weather and seasonal prediction.

Our approach to framework seamless prediction starts with seasonal forecasts that are used as probabilistic trends about the quality of the season over a broad area, with the advantage of providing mean seasonal characteristics 3 months ahead. If the predicted trends are confirmed during the following month over a particular locality, the actual or revised seasonal output will be improved into deterministic tailored forecast based on encoded confidence interval related to the selected metrics and models from S2S database. This is in fact a step further in the design of tailored products, with the aim to satisfy user specific information needs (eg. date of start of growing season for agriculture, wet spells distribution). During the S2S monitoring phase, models with good performance will be retained for nowcasting as the best guesstimates. The prediction of the day-to-day weather will be made dynamically using a dedicated tool such as SYNERGIE or other, with the actual observations over an operating locality. This 1 day NWP is critical in determining the 10 days forecast just as the medium-range weather forecasts progress, based on the improvement of the initial state by using accurate observations and best guesstimates.

Prospects and challenges

- Capacity building : need of funding for PhD students (02)
- Computational-technological capabilities
- Need to coordinate activities in conjunction with S2S WMO project
- Integrate S2S Africa sub-project

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On S2S in South Africa

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Southern Africa is predominantly an austral summer rainfall region, with the southwestern Cape (winter) and southern Cape (all-year) being the exceptions. A significant amount of work has already been done on the description of the climate system over the region (e.g. Mason and Jury 1997, among many others), on the drivers responsible for rainfall and temperature variability (e.g. Reason et al 2000), and especially on the climate forcing related to central Pacific Ocean variability (e.g. Mason and Goddard 2001). A good number of seasonal prediction studies have also been conducted for the region (e.g. Landman et al 2012). However, although S2S work has recently been done for West Africa (Olaniyan et al 2018) investigating predictability on the S2S time scale for the southern African region is still in its infancy. For the most part predictability for individual calendar months is the only recently published work on sub-seasonal time scales over southern Africa (e.g. Phakula et al 2018). Here we will show some of the current work that is being done on this time scale at three institutions in South Africa, namely the University of Pretoria, the Agricultural Research Council and the South African Weather Service.

The North-American Multi-Model Ensemble (NMME; Kirtman et al 2014) hindcast and real-time forecasts are extensively used in South Africa for operational seasonal forecast production (https://tinyurl.com/ybrb3a72). The NMME data are available as monthly values from the data library (http://iridl.ldeo.columbia.edu/) of the International Research Institute for Climate and Society (IRI). As a primary stage in the development of forecasts for periods shorter than the usual 3-month seasonal forecasts, predictability for individual austral summer months is being tested. Figure 1 shows an example of forecast skill over the catchment of the Limpopo River basin that includes parts of Botswana, Mozambique, South Africa and Zimbabwe. The 6 months presented in Figure 1 comprise of the main summer rainfall season over the catchment. The two variables considered here are monthly rainfall totals and maximum temperature monthly averages. Monthly rainfall and maximum temperature hindcasts at a 1-month lead-time of the GFDL Climate Model, version 2.5 (Kirtman et al 2014) are interpolated to Climatic Research Unit (CRU; Harris et al 2014) grids (0.5°x0.5°) by correcting the mean and variance biases of 32 years of NMME hindcasts in a 5-year-outcross-validation process. Area-averaged values over the 32 years of corrected hindcasts are then correlated with area-averaged observations and presented in the figure. Monthly rainfall predictability (correlation significant at least the 95% level) is restricted to December rainfall totals, while monthly maximum temperature averages are predictable for both mid- and late-summer months. Owing to the greater level of skill found for maximum temperatures over the region, a case study for heat wave prediction over Limpopo is presented next.

During the first week of January 2016 it was exceptionally hot over South Africa. Over Limpopo, maximum temperatures were $4-5\,^{\circ}\mathrm{C}$ warmer than normal and most areas over the region experienced about 4 heat wave days during that week. The prediction of the occurrence of the heat wave days during the week of 1-7 January 2016 is explored here for lead times of 1, 2, 3, and 4 weeks by employing ensemble forecasts of maximum temperatures from which heat wave days are derived. The ensemble forecasts, obtained from the S2S database (Vitart et al 2017), of maximum temperature initialized on 27 and 28 December 2015 from the UKMO model are employed for this purpose. A heat wave is defined here as at least three consecutive days when the daily maximum temperature exceeded the climatological 90$^{\text{th}}$ percentile of the January and February maximum temperatures - the latter is determined by using the corresponding reforecasts (1996 to 2009). The ERA-Interim maximum temperature data are used as the observational dataset with which the heat wave day predictions are compared. The comparison of the predicted (ensemble average) and observed number of heat wave days between 1-7 January 2016 for lead times of 1-4 weeks is presented as an area-average (Figure 2). The observed number of heat wave days over Limpopo during the first week of January 2016 are 3.68,whilst the climatological number of heat wave days for the corresponding period is less than 1 day. For all the lead times, the occurrence of some heat wave days are predicted, although the predicted number is less than the observed number, but exceeding the climatological number of heat wave days. As expected, the 1-week lead forecast compares the best.

From the evidence presented here, predictability on S2S time scales is possible for parts of Africa, but may be restricted to certain times of the year (as had been demonstrated for seasonal forecasts). Moreover, benefit in using S2S forecasts may be best utilized if temperature forecasts are also considered and found to be useful by decision-makers. Therefore, the significant amount of model testing and optimization that still needs to be done for Africa may be best achieved when S2S forecasts are integrated with social decision-making.

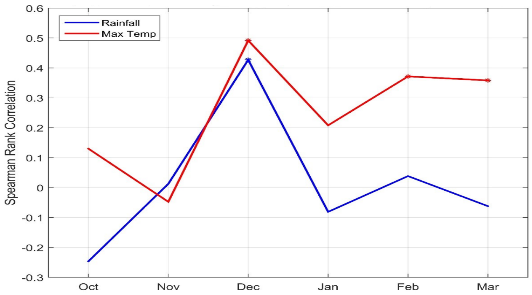

Figure 1. Spearman correlation between area-averaged predicted (1-month lead-time) and observed monthly rainfall totals and monthly averaged maximum temperatures. The area of interest is the Limpopo River Catchment (26 °S to 20 °S , 26 °E to 34 °E). Asterisks represent correlation values significant at the 95% level.

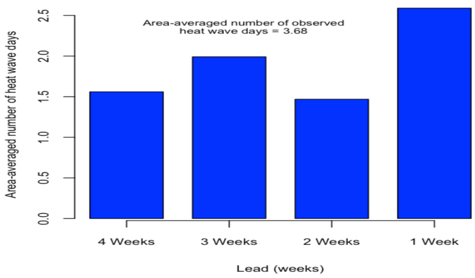

Figure 2. Area-averaged number of heat wave days between 1-7 January 2016 as predicted by the ensemble mean of UKMO forecasts for lead times of 1, 2, 3 and 4 weeks. The observed area-averaged number of heat wave days for the same period is 3.68 days.

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