Subseasonal-to-Seasonal S2S Prediction Project

News Letter

"Verification" Subproject under S2S

The S2S subproject on verification was established with the objective of recommending verification metrics and datasets for assessing forecast quality of S2S forecasts, and also providing 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 considering linkages with users and applications. In order to achieve these objectives a number of issues to be addressed were spotted including the identification of current practises in sub-seasonal to seasonal forecasts, the identification of user-relevant variables and quantities to be verified, the provision of guidance on minimum hindcast standards (length and ensemble size), the promotion of subseasonal forecasting intercomparison efforts and evaluation of benefit of the multi-model approach.

This sub-project has links with the WMO Joint Working Group on Forecast Verification Research (JWGFVR), the WMO CBS/CCl Expert Team on Operational Predictions from Sub-seasonal to Longer time scales (ET-OPSLS), the WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME) and other S2S sub-projects. A science plan was developed with inputs from JWGFVR, the WMO Working Group on Societal and Economic Research Applications (SERA) and S2S. The S2S verification science plan is envisaged as a guidance document to stimulate scientific community to address S2S verification problems. The science plan is available at http://www.s2sprediction.net/resources/documents/sub-projects/Verification.pdf and contains the following key science questions:

- What forecast quality attributes are important when verifying S2S forecasts and how they should be assessed?
- How should issues of short hindcast period availability and reduced number of ensemble members in hindcasts compared to real-time forecasts be dealt with when constructing probabilistic skill measures?
- How can the contributions of the MJO and ENSO to S2S forecast skill be assessed (e.g. consider skill assessment conditioned on ENSO phases and try to identify opportunities for improved skill when MJO and ENSO are acting simultaneously)?
- How well do current S2S forecast systems predict active and break rainfall phases and wet/dry spells?

A dedicated Wiki page was implemented as the main channel for the subproject activities dissemination and is accessible at http://s2sprediction.net/xwiki/bin/view/Main/Verification.

Originally the subproject was focused solely on forecast verification aspects, but it was later decided by the S2S Steering and Liaison Group to also consider forecast products aspects, and therefore the subproject was re-labeled to verification and

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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. The web-site is at **http://s2sprediction.net**.

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. The primary function of the ICO is to provide support to planning and implementation of S2S priorities.

Six Sub-projects in S2S

The research topics of the WWRP/WCRP Sub-seasonal to Seasonal Predict ion project (S2S) are organized around a set of six subprojects, each intersected by the cross-cutting research and modeling issues, and applications and user needs. The science plans of each subproject which can be found at the S2S webpage, include:

1. Monsoons: 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 onsets 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 landsea 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 subproject is to develop skilful forecasts on the S2S time scale over Africa and to encourage their uptake by national meteorological services and other stakeholder groups. This sub-project is more application oriented than the other sub-projects.

4. Extremes: This sub-project will evaluate the predictive skill and predictability of weather regimes and extreme events (droughts, floodings, 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 under-standing of sub-seasonal tropical-extratropical interaction pathways and identifying periods and regions of increased predictability (" forecasts of pportunity"). This would help improve sub-seasonal to seasonal forecasts of weather and climate for applications.

products. A number of subproject activities have been performed and are disseminated via the wiki including:

- A list of published literature on verification methods relevant to S2S verification, including books, technical reports and scientific papers.
- A literature survey on S2S verification, including a list of publications on S2S verification addressing the following topics: Assessment of S2S systems forecast skill, assessment of MJO/ISO forecast skill, assessment of monsoon systems forecast skill and associated characteristics, S2S applications, and seamless verification.
- The collaboration between S2S and WMO: A questionnaire on subseasonal verification practices in operational centers (GPC) was prepared, with the purpose of sharing current practices used to verify subseasonal forecasts (both for operations and research) and also to help identify gaps and guide novel developments. The summary of responses was discussed with WMO CBS/CCl ET-OPSLS and is available at the wiki. A key result emerging was that very few centres conduct verification of extremes predictions or of "tailored" forecasts such as rain day frequency or frequency/timing of in-season dry spells.
- The development of pilot real-time sub-seasonal multi-model ensemble (MME) predictions: The WMO LCLRFMME developed a pilot system for real-time multi-model subseasonal forecasts using real-time forecasts (and hindcasts) from a subset of models contributing to the S2S project accessible via ECMWF data archive. The S2S wiki page provides a link for the S2S research community to see the initial developments and provide feedback for future developments and improvements in this pilot under development system. The S2S community is kindly invited to provide feedback on this pilot development.
- The coordination of input for the WMO ET-OPSLS on S2S application areas under development and operational needs. Such input is also available via the wiki.
- The provision of a comprehensive collection of links to available datasets for S2S verification following suggestion of S2S Steering and Liaison Group meeting in Jeju in 2015. Links to reference datasets (both reanalysis and gridded products) for assessing S2S forecast quality, including links for data access via the IRI data library and the KNMI Climate Explorer, for the atmospheric, oceanic and surface parameters are available at the wiki.
- The provision of links and instructions on the subproject wiki on how to access S2S project model datasets. This includes a summary table of S2S project models, links for accessing S2S models data at ECMWF and CMA data portals, links to instructions on how to extract S2S models data from ECMWF S2S portal, and links to the IRI Data Library for accessing a subset of these data (from ECMWF, NCEP and CMA models) in various file formats, including OpenDAP access. A link to an introduction to the IRI Data Library is also provided on the wiki.
- The provision of a link to JWGFVR user-oriented verification challenge created in support of the WWRP projects on High Impact Weather (HIWeather), Subseasonal to Seasonal Prediction (S2S), and Polar Prediction (PPP).

https://www.wmo.int/pages/prog/arep/wwrp/new/FcstVerChallenge.html

Finally, we would like to draw the attention of the S2S community to the 7th International Verification Methods Workshop (7IVMW), which will be held in Berlin, Germany, 8-11 May 2017, preceded by a tutorial on forecast verification methods, 3-6 May 2017. This workshop is being organized by the WWRP/WGNE JWGFVR and will have a dedicated session on S2S verification, with a keynote talk by the S2S co-chair (Frederic Vitart) on verification methods and procedures used in sub-seasonal verification. The S2S community is cordially invited to submit abstracts on S2S verification methodologies to the workshop. Abstract submission is open until February 27, 2017, at http://www. 7thverificationworkshop.de/. The deadline for registration is March 31.

ESCAPE

(European Commission funded initiative for high-resolution weather forecasting using emerging HPC architectures.)

ESCAPE stands for **Energy-efficient Scalable Algorithms for Weather Prediction at Exascale**. The project will develop world-class, extreme-scale computing capabilities for European operational numerical weather prediction (NWP) and future climate models. The biggest challenge for state-of-the-art NWP arises from the need to simulate complex physical phenomena within tight production schedules. Existing extreme-scale application software of weather and climate services is ill-equipped to adapt to the rapidly evolving hardware. This is exacerbated by other drivers for hardware development, with processor arrangements not necessarily optimal for weather and climate simulations. ESCAPE will redress this imbalance through innovation actions that fundamentally reform Earth system modelling. ESCAPE addresses, among others, the ETP4HPC (http://www.etp4hpc.eu/) Strategic Research Agenda 'Energy and resiliency' priority topic, developing a holistic understanding of energy-efficiency for extreme-scale applications using heterogeneous architectures, accelerators and special compute units. The three key reasons why this project will provide the necessary means to take a huge step forward in weather and climate modelling as well as interdisciplinary research on energy-efficient high-performance computing are:

* Defining and encapsulating the fundamental algorithmic building blocks ('Weather & Climate Dwarfs') underlying weather and climate models. This is the prerequisite for any subsequent co-design, optimization, and adaptation efforts.

* Combining ground-breaking frontier research on algorithm development for use in extreme-scale, high-performance computing applications, minimizing time- and cost-to-solution.

* Synthesizing the complementary skills of all project partners. ECMWF and leading European regional forecasting consortia are teaming up with excellent university research and experienced high-performance computing centres, two world-leading hardware companies, and one European start-up SME, providing entirely new knowledge and technology to the field.

ECMWF's partners in the project are Danmarks Meteorologiske Institut; Deutscher Wetterdienst; l'Institut Royal Météorologique

S2S database new variables

The current list of variables in the S2S database includes standard variables at 10 pressure levels (between 1000 and 10 hpa), together with a large number of single-level level variables including thermodynamic, hydrological, and surface flux fields. However, some models are providing just a subset of the requested variables. The list of variables provided by each model can be found here: https://software.ecmwf.int/wiki/display/S2S/Provided+parameters. Each data provider has been encouraged to provide all the S2S database variables, but this is often possible only when a new model version is introduced, which may take a few years for the models with fixed re-forecasts (model version is frozen for several years).

In order to make the S2S database more useful to some applications, it was decided to extend the list of currently available variables to include:

1) Vertical velocity at all pressure levels (originally this variable was available at 500 hPa only). This was requested by the S2S teleconnections sub-project to allow the computation of teleconnection diagnostics. An email has been sent last October to all the S2S partners to provide vertical velocity at all levels. Some operational centres (e.g. ECMWF) are already providing vertical velocity at all levels.

2) New ocean and sea-ice variables

Currently only sea-surface temperature and sea-ice cover are available in the S2S database. It is planned to add the following variables:

Sea surface salinity

Depth of 20 deg isoth

Mixed layer depth

Heat content at top 300m

Salinity in top 300m

U surface current /V surface current

Sea surface height /Sea ice thickness

These new variables will be archived in netcdf instead of GRIB2 as for the other variables. This is due to the fact that ocean model outputs are mostly available in netcdf rather than GRIB2 which does not contain definitions for all of the new variables yet. Work is currently ongoing to make it possible to archive these new variables in the ECMWF archiving system, but it will take at least several months before this will be achieved.

These new variables will not be ready for all the S2S models straight away. As discussed earlier, the inclusion of the new variables will often happen only when a new version of a model is introduced.

At the last S2S steering group meeting (8-9 December 2016), it was decided to send a survey to all the S2S database users. This questionnaire will ask if other important variables should be included in the S2S database.

Upcoming Events

7th International Verification Methods Workshop

3-11, May, 2017, Berlin

The Seventh International Verification Methods Workshop is being organized by the WMO Joint Working Group on forecast Verification Research and will be hosted in Berlin, Germany, jointly by the Free University

The goal of the workshop is to discuss and promote all aspects of verification methodology research and practice, as applied to weather forecasts and warnings, climate predictions, and their applications. Special sessions are planned on verification methods for sub-seasonal and longer range forecasts. Participants and welcome from operational, research and forecast communities.

More information on the workshop is available at http://www.7thverificationworkshop.de/.

5th WGNE workshop on systematic errors in weather and climate models

19-23, June, 2017, Montreal

The WCRP-JSC/CAS Working Group on Numerical Experimentation(WGNE) is organizing a workshop on systematic errors in weather and climate models, to be hosted by Environment and Climate Change Canada(ECCC) in Montreal during 19-23 2017.

The principal goal of the workshop is to increase understanding of the nature and cause of errors in models used for weather and climate prediction, including intra-seasonal to inter-annual scales. Of special interest will be studied that consider errors found in multiple models and errors currently fail to represent accurately.

More information on the workshop is available at http://collaboration.cmc.ec.gc.ca/science/rpn/wgne_wse/index-en.html.

de Belgique; Météo-France; MeteoSchweiz; Instytut Chemii Bioorganicznej Polskiej Akademii Nauk; Loughborough University; National University of Ireland, Galway; Bull SAS; NVIDIA Corporation; and Optalysys Ltd.

ESCAPE is an integral part of the ECMWF Scalability Programme and supports in particular the Polymitos and PantaRhei projects in view of the future dynamical core developments at ECMWF. ESCAPE will also produce benefit for ESiWACE (http://esiwace.eu), the Centre of Excellence in Simulation of Weather and Climate in Europe, as code developments will be made available to the wider community via OpenIFS.

ESCAPE is funded by the European Commission under the Future and Emerging Technologies - High-Performance Computing call for research and innovation actions, grant agreement No. 671627 (http://www.hpc-escape.eu/).

Dr Peter Bauer, Coordinator of the ESCAPE points out : "The enhancement of spatial resolution and complexity of forecast models makes the models physically more realistic and thus will improve forecast skill. We assume that the dimension of the models will increase by a factor of 100-1000 in the next 10 years because of that. Obviously, the acquisition and power supply for 100-1000 times larger high-performance computer (HPC) facilities will be extremely expensive. ESCAPE aims at identifying and reformulating the key model components (called 'weather and climate dwarfs' inspired by the Berkeley computational dwarfs) that drive this cost."

For more information, please visit the ESCAPE website at www.hpc-escape.eu.

5th S2S Steering group meeting

The S2S steering group meeting took place at Earth Institute, Columbia University on 8-9 December 2016, just after the S2S Extremes workshop at IRI, which was also the opportunity for a meeting between the S2S project and the NOAA MAPP S2S Task Force. The outcomes of the workshop and the meetings with the NOAA MAPP S2S Task Force were discussed, and it was agreed to include a dedicated liaison from the NOAA MAPP S2S Task Force in the S2S Steering Group. This steering group meeting was also an opportunity to discuss a proposal for a possible 5-year renewal of the project (2018-2023) called Phase 2.

Paolo Ruti (WMO/WWRP) gave a presentation on the WWRP implementation plan which is divided into 4 sections (High Impact Weather, Water, Urbanization and Evolving technologies). S2S is cited in several tasks in the 4 sections. Michel Rixen (WMO/WCRP) presented the current structure of WCRP, which includes working groups (WGSIP, SPARC, GEWEX...) and the recent addition of Grand Challenges.

These two presentations were followed by a discussion on the current status and future plans of the S2S database. Frederic Vitart presented the latest status of the S2S archiving at ECMWF. Currently, 10 models over 11 are available from the ECMWF data portal. The number of active users (about 80 per month so far) is increasing steadily. Work is ongoing to make it possible to archive ocean data in the S2S database. The ocean data will be archived in netcdf. Tongwen Wu (CMA) presented the latest status of the CMA database. Most of the data archived at ECMWF is now available at CMA (data is transferred automatically from ECMWF to CMA). About 160 users have registered to the CMA data portal. Andrew Robertson (IRI) mentioned that the S2S data in IRI DL has been used extensively in trainings in Africa, as well as for in-class use at Columbia. More data is expected to be added as part of a NOAA-funded S2S project at Columbia. There have been 600 unique visitors to the S2S data at IRI.

Frederic Vitart mentioned that the MJO RMMS have been computed for all the 10 currently available real-time forecasts and re-forecasts. These MJO RMMS will be made available to the research community in an agreed format in a few months. The presentations of the sub-projects are available here:

http://s2sprediction.net/static/meetings#2016

During the second day of the meeting, Yuhei Takaya presented on the activities of the WMO Lead Centre for sub-seasonal prediction (KMA). The Lead Centre is developing a prototype of multi-model real-time sub-seasonal forecasts from 5 S2S centres (ECMWF, UKMO, JMA, KMA and NCEP) which have agreed to participate. It was argued that the WMO LC should make past forecasts publicly accessible to S2S researchers. It was also agreed that the Verification sub-project should recirculate the LC's report on its pilot S2S activities to the S2S SG mailing list, and request input by Jan 2017.

The main topic of discussion at this S2S meeting was the 5-year renewal of S2S. It was agreed that the second phase of the S2S project should be more dedicated to forecast improvement and also user applications. It was agreed to set up surveys to potential donors, other working groups to get feedbacks on what type of research/applications studies could be included in Phase 2.

The last afternoon of the meeting, Aneesh Subramanian (Oxford University) showed that super-parameterization (embedding cloud resolving models within the GCM grid) or stochastic-parameterization implemented in the ECMWF climate model has improve the model's representation of the climate and weather systems. He showed that the combination of the two approaches helps improve reliability of forecasts of certain tropical phenomena such as MJO precipitation and probabilistic tropical cyclone forecast for lead time of week 2 and 3. Angel Muňoz (GFDL) first presented the efforts of the Latin American Observatory to provide S2S information for decision makers in Latin America and the Caribbean; The S2S products are freely available at Latin American Observatory Datoteca's Situation Room (in Spanish). Then Muñoz reported advances on the use of IRI's Climate Predictability Tool ("CPT") to validate and perform Model Output Statistics (MOS) of raw models available at the S2S Database. Finally, he discussed a new cross-timescale diagnostic framework for coupled circulation models based on the evaluation of simulated weather regimes' statistics and physical links to climate drivers at multiple timescales; he illustrated the approach using GFDL model's LOAR and FLOR.

Willem Landman (University of Pretoria) discussed sub-seasonal and seasonal prediction in South Africa. Various sources of S2S predictability have been identified over southern Africa, but most prediction models provide skillful forecasts mostly during ENSO events. The presentation was concluded by presenting examples where seasonal forecasts have been applied to crop yield and river flows, claiming that similar applications models can be developed for S2S.

The time and location of the next S2S SG meeting and S2S workshop were discussed. The preferred venue for the next S2S steering group meeting is the WCRP working groups meeting which will take place in Exeter Oct 9-13, 2017. The working groups participating will include WGSIP, WGNE, WMAC, WGCM and CORDEX. More details, along with the full list of actions, are available from the Minutes in www.s2sprediction.net.

Participants at the Workshop on Sub-Seasonal to Seasonal Predictability of Extreme Weather and Climate, held at IRI, Dec. 6-7, 2016. Details and video recording of the workshop presentations can be found at http://iri.columbia.edu/s2s-extremes-workshop-2016/.

The Science for Citizens Project:

Tailoring Sub-seasonal Predictions for Early Warning Systems – A Case Study in Southwestern Amazon

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1. Introduction

The subseasonal to seasonal (S2S) Prediction Project was created to bridge the gap between weather and climate predictions (Brunet et al., 2010; Robertson et al., 2015). Among many challenges S2S is facing is the demand for developing and demonstrating the potential value of applications-relevant information. In order to be successful into developing relevant applications that could aid decision making process at several key social and economic sectors it is key to involve the end-user from the beginning of the process (Morse et al., 2005; Coelho and Costa, 2010; National Academies of Sciences, Engineering, and Medicine, 2016).

One of the key communities that can benefit from the scientific advances of subseasonal to seasonal predictions is the Disaster Risk Reduction (DRR) community. Disasters are inherently multi-disciplinary and pose new challenges to governments, scientific community, policymakers and the various stakeholders that suffer recurrent damages and losses. Early Warning System (EWS) can provide information, knowledge and tools to reduce the disaster risk. Still, effective EWS must be people-centered (Basher, 2006; Baudoin et al, 2016; Villagrán de León, 2012) and consider scientific knowledge in the realms of (i) risk knowledge; (ii) monitoring and warning service; (iii) dissemination and communication; and (iv) response capacity, hence the importance of interdisciplinary research.

2. The State of Acre

During the last three decades, the State of Acre (Figure 1), in southwestern Amazon, demonstrated to be particularly susceptible to climatic extremes (floods and droughts). Four major drought events affected the region in 1997–1998, 2004–2005, 2009–2010 and very recently in 2015-16, with the 2005 and 2010 events considered one-in-a-century drought events in terms of intensity (Marengo et al., 2011; Coelho et al., 2012). There are indications that during such droughts, sub-seasonal events (heat waves, dry spells and wind bursts) might have contributed to enhance the local impacts.

3. Project objective

The present project was structured to incorporate and conciliate guidance from three international programs: the Global Framework for Climate Services, the Sendai Framework for Disaster Risk Reduction and the Subseasonal to Seasonal Project.

In this context, the objective of the project is to assess the potential utility of sub-seasonal predictions as part of an Early Warning System and a Climate Services exercise for Disaster Risk Reduction, developed as a case study in southwestern Amazon (Acre State - Brazil). This will be achieved by strengthening communication among the sub-seasonal forecast producers, forecast products developers, interpreters,

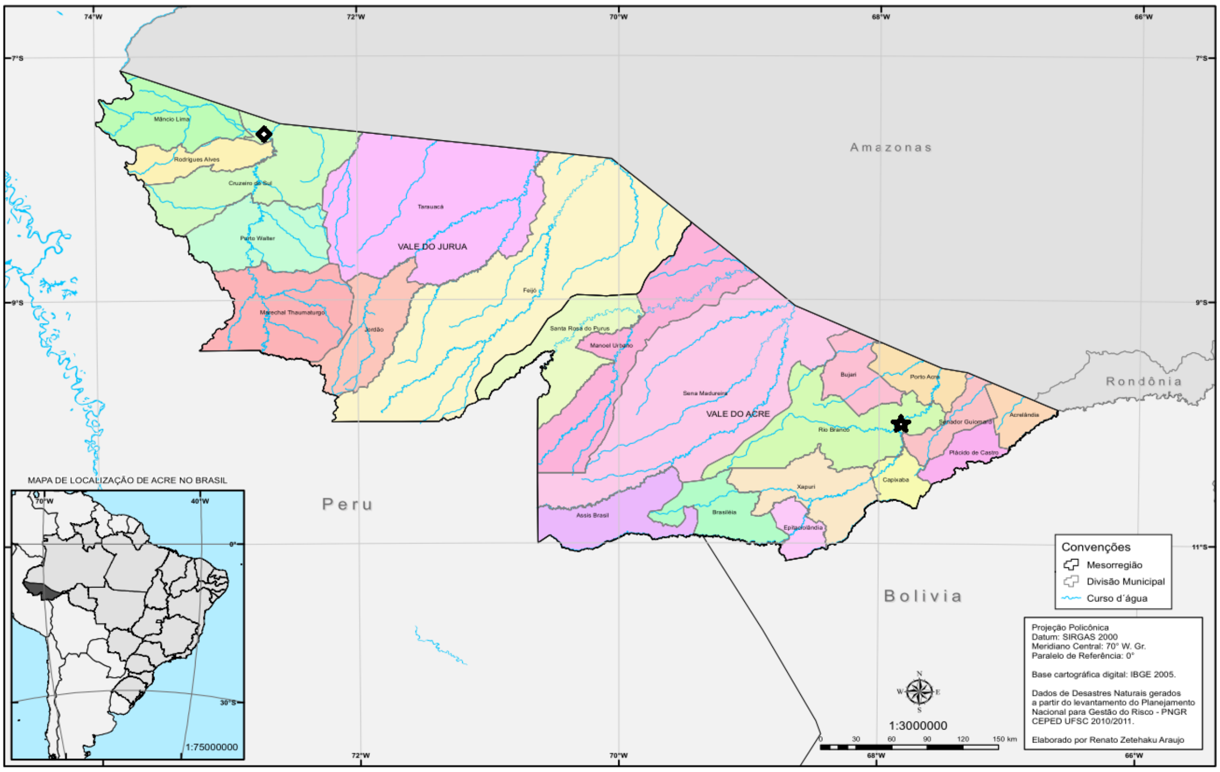

Figure 1. Map of the Acre state, in southwestern Amazon, and its 22 municipalities. The star indicates the location of State of Acre capital (Rio Branco) and the diamond indicates the municipality of Cruzeiro do Sul, on the northwest portion. *Source*: Universidade Federal de Santa Catarina (UFSC-CEPED). Brazilian Atlas of Natural Disasters: volume Acre, 2012.

and the decision-make community. It is envisaged that this will constitute a productive chain of scientific and traditional knowledge exchange for an effective collaboration towards Disaster Risk Reduction.

The project goals were defined as: (i) To promote use of the S2S forecasts and their uncertainty estimates by the applications community; (ii) To unveil the role of subseasonal forecasts to promote preparation and/or preparedness for disasters; (iii) To assess the quality of pilot tailored forecast products for aiding decision in a strategic economic sector.

Important questions that the project seeks to address are:

- What is the skill of heat waves and dry spells S2S predictions in Southwestern Amazonia?
- What are the details of the production cycle in a key socioeconomic sector and which steps within this cycle are sensitive to climate variability at the subseasonal scale?
- How to improve communication between stakeholders with different backgrounds in order to produce useful information to mitigate losses due to natural hazards?

4. The application: fish production

The present project will explore fish production as the target socioeconomic sector to benefit from an S2S climate service. Fish production is one of the main sustainable economic activities in Acre State. It has been established as an economic sector since 1985. In 2011 this sector started to reach a new production level. The Acre state government decided then to create a socio-economic policy focused on the sector, aiming to generate income and improve the well-being of the state population. One of the main actions was the construction of two Production Centres, one in the Juruá Valley (western Acre) and other in Senator Guiomard (eastern Acre). Those Centres were conceived to provide high-quality fingerlings for small producers, encouraging fish farming growth throughout Acre. Nowadays fish production is spread across the Acre state, with several small fish producers that possess this activity as their major income source, depending on fingerlings production by those two Centres.

5. Research strategy

The project has been divided into two pillars (Figure 2). The first pillar refers to the evaluation of the model skill at a grid point level, according to the standard procedures currently used to assess the skill of earth systems predictions and will be conducted by project partners CPTEC/INPE and CCST/INPE. The second pillar aims the assessment of the S2S predictions from the perspective of a key socioeconomic sector in Acre State in order to support decision-making and will be conducted by CEMADEN, Acre's Institutions and the Federal University of ABC. The latter has been dived in two phases; phase 1 is already in progress. A 2-days meeting in September 2016, in Acre, carried out a stakeholder consultation where several representatives of key socioeconomic sectors were present. The outcomes of this phase were: (i) the identification of fish producers as a key user of this applied proposal, and (ii) the identification of the need in normalizing the concepts and the understanding risks, probabilities among the actors involved in all steps of the products construction. In phase 2, the aim is to achieve a matrix of event impact per likelihood of occurrence. The development of such tool will enable that key forecast and fish production information to be compiled into a matrix that will subsidize actions by the situation room and local actors.

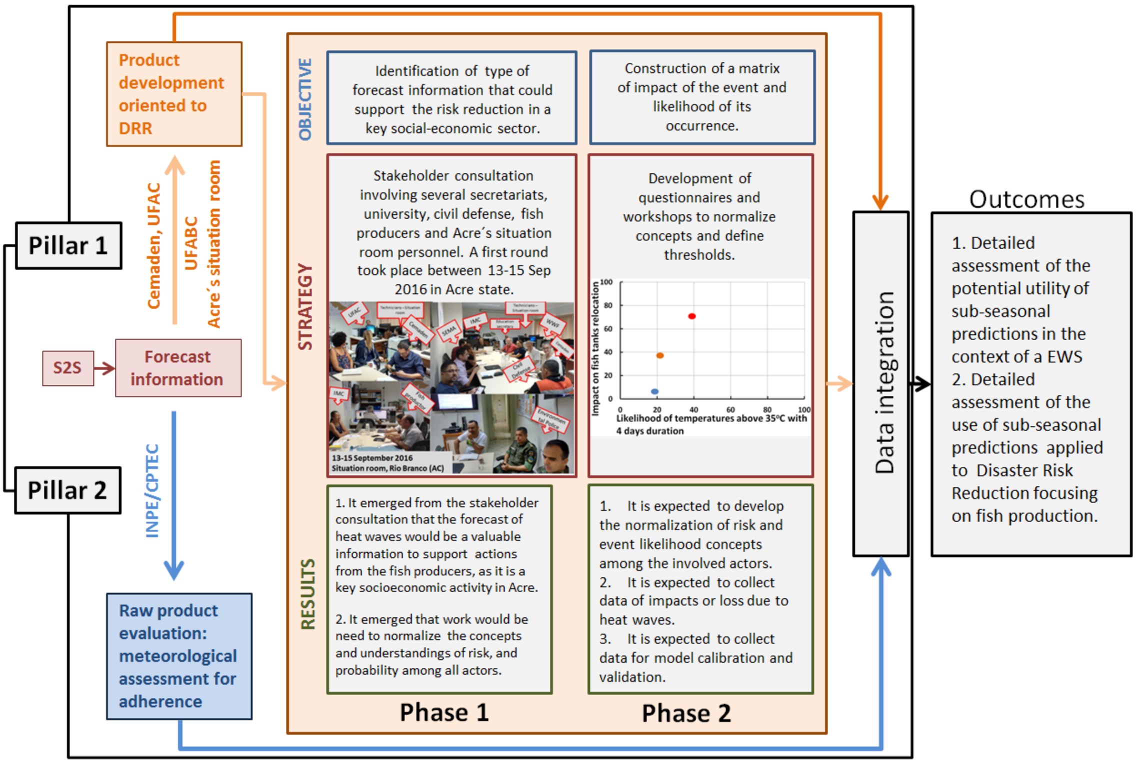

Figure 2. Diagram illustrating the general strategy adopted to accomplish the objective of the project.

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Simulations of Boreal Summer Intraseasonal Oscillation in the Sub-seasonal to Seasonal Prediction Project (S2S) database

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The Sub-seasonal to Seasonal (S2S) prediction project database has been used to assess the S2S simulations of Boreal Summer Intraseasonal Oscillation (BSISO) in multiple operational models including 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), Météo-France/Centre National de Recherche Meteorologiques (CNRM), National Centers for Environmental Prediction (NCEP) and the United Kingdom's Met Office (UKMO) by using BSISO index during May to October for 1999–2010 in our recent work. This index suggested by Lee et al. (2013) is based on multivariate empirical orthogonal function (MV-EOF) analysis of daily anomalies of OLR and zonal wind at 850-hPa (U850) in the region 10°S–40°N, 40°–160°E during the period 1st May to 31st October. While BSISO1 defined by the first two principal components (PCs) of the MV-EOF is often associated with the eastward propagating Madden-Julian Oscillation (MJO), BSISO2 characterized by the second two PCs is related to the northward/northwestward propagating BSISO, which occurs in conjunction with the evolution of Asian Summer Monsoon (ASM).

Figure 1 shows Bivariate Anomaly Correlation (BAC) and Root Mean Squared Error (RMSE) between ECMWF-interim reanalysis and forecasts as a function of lead time for BSISO1 and BSISO2. The BACs for BSISO1 (Figure 1a) indicate that Control Forecasts (CF; dashed lines) from 10 models can predict the summer MJO more than 6 to 17.5 days in advance as the corresponding correlations exceed 0.5 which is taken as the threshold of useful skill (black dashed horizontal line). The ensemble mean skill scores (ENS; solid lines) show an obvious enhancement in the ECMWF, UKMO, BoM, CNRM and ECCC models compared to the CF, whereas only slight improvements are displayed in the NCEP, CMA and JMA models. This improvement is possibly related to the perturbation methods and the ensemble size for different models. These skillful ensemble forecasts display skill between 10 and 24.5 days. In particular, the ECMWF ensemble forecast can increase the MJO predictability by nearly one week compared to CF. Similarly, the summer Asian monsoon can be predicted by the CFs 6.5 to 12 days in advance, depending on the model, and by the ENS between 7 to 14 days in advance (Figure 1b). Particularly, the ASM prediction skill of ECMWF, UKMO and CNRM models increases by up to 2 days when using ENS rather than CF. These results are confirmed by the RMSE (Figure 1c and d) of CF and ENS for BSISO1 and BSISO2 as the RMSE values exceed 1.414 (black dashed horizontal lines) between 6 and 24.5 days and between 6.5 and 14 days, respectively.

To further evaluate the skills of strong BSISO events (i.e., the amplitude is greater than 1.5) in eight phases for all of the 10 models, BACs between the observed strong events and forecasts have been calculated as a function of lead time and target phase (not shown). The results indicate that the low skills for BSISO1 (BSISO2) happen mostly in phase 3 to 5 for all the models, suggesting that the MJO (monsoon) is not easy to be predicted when it is located over the India and Maritime Continent (India, south of China Sea and Bay of Bengal), although the higher skills appear in different phases for different models. In particular, the predictability of strong MJO and monsoon events in phase 6–7 for the ECMWF ensemble forecast could exceed 30 days and 28 days, respectively.

Reference:

Lee JY, Wang B, Wheeler MC, Fu X, Waliser DE, Kang IS. 2013. Real-time multivariate indices for the boreal summer intraseasonal oscillation over the Asian summer monsoon region. *Clim. Dyn.* 40: 493–509.

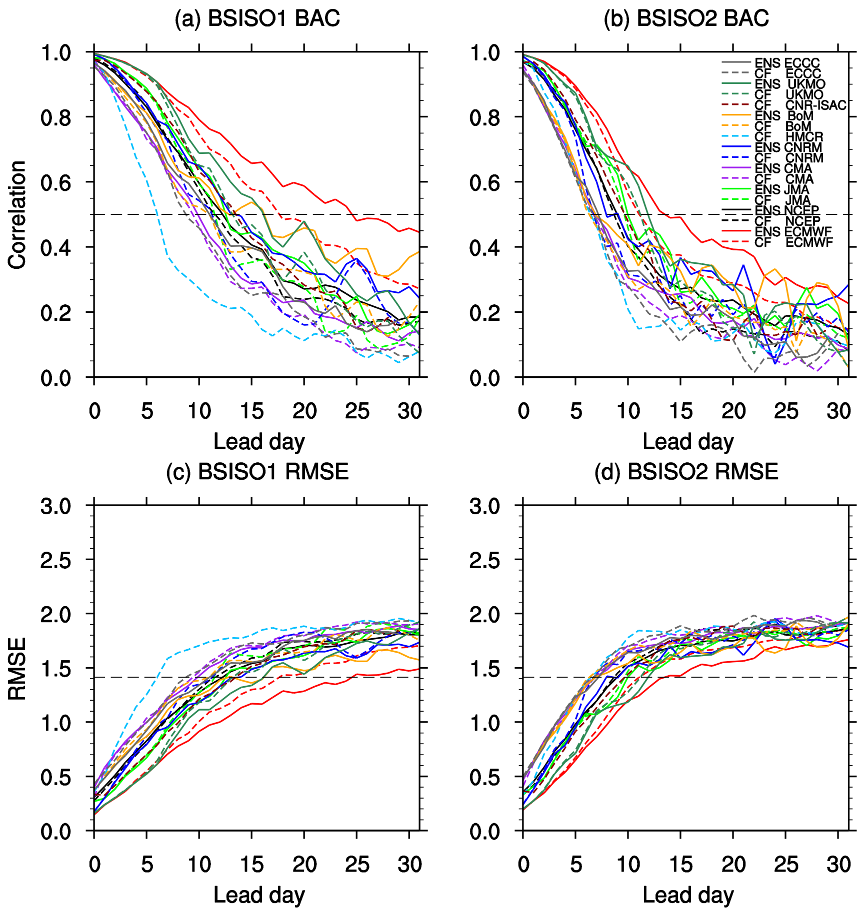

Figure 1. Bivariate Anomaly Correlation (a-b) and Root Mean Squared Error (c-d) as a function of lead time for BSISO1 and BSISO2 between ECMWF-interim and forecasts from S2S models during MJJASO for the 12 years of 1999–2010. The dashed lines denote the control forecasts (CF) and the solid lines are the ensemble means (ENS). Due to the uncompleted upload of the KMA data and a possible problem of the HMCR perturbed re-forecasts, the forecasts of the KMA model and the ensemble mean of HMCR model are not shown here.