Subseasonal-to-Seasonal S2S Prediction Project
WWRP World Weather Research Programme
WCRP World Climate Research Programme

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. The website 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.

The S2S Phase I Final Report and a recent document from the WMO that describes the three WWRP core projects.

WWRP/WCRP Sub-seasonal to Seasonal Prediction Project (S2S) Phase I Final Report

Recently, the WMO published two S2S project related documents, S2S project progress report and a document about WWRP's core projects. The WWRP/WCRP Sub-seasonal to Seasonal Prediction Project (S2S) Phase I Final Report describes the progress and main achievements up to December 2017, and WWRP document "Driving Innovation Together" is describing some of the early successes of the three WWRP projects, High-Impact Weather Project, Polar Prediction Project and Sub-seasonal to Seasonal Prediction Project. The two documents are available from the S2S website at http://s2sprediction.net.

Editor's Note

Won-Tae Yun
S2S International Coordination Office (ICO)

The Sub-seasonal-to-Seasonal prediction project (S2S) started in 2013 as a collaborative structure set up by the World Climate Research Programme (WCRP), the World Weather Research Programme (WWRP) and the Observing system Research and Predictability Experiment (THORPEX) for an initial 5 years, with a possible extension subject to positive review of progress and achievements and a need to fill any important remaining research gaps.

The S2S project aims to improve forecast skill on sub-seasonal to seasonal timescales, and to promote increased use of S2S information in operational centres and the user community. This project is a comprehensive endeavor that brings together research, modeling, information technology, analysis, and information application of worldwide climate and weather specialists to deliver seamless long-term forecast with improved accuracy based on the S2S timescale.

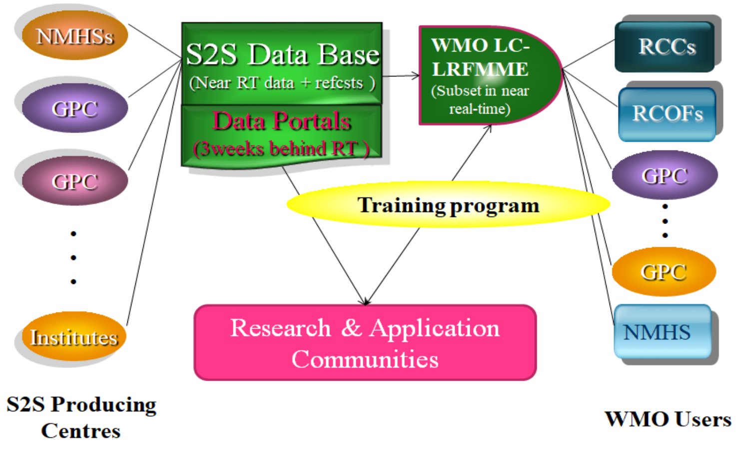

Figure 1. The Sub-seasonal to Seasonal Prediction (S2S) project linkage with WMO operational activities. The S2S project develops, shares and applies scientific knowledge and products that contributes to decision-making in the S2S time scale.

The new paradigm of S2Stime scale prediction will play a vital role in our society and economy, in which policies and decisions on issues regarding agriculture, food, and water security and mitigating natural disaster risks will be made.

The S2S project database is archived at the European Centre for Medium-Range Weather Forecasts (ECMWF) and China Meteorological Administration (CMA) (Fig. 1); in addition, a large fraction of the S2S database is now accessible from the IRI Data Library (see this issue). Currently 11 models are available in the database, which has more than 700 registered users from roughly 60 countries and the numbers are increasing. Using this data, current studies are assessing the skill of the S2S models and identifying their strengths and their weaknesses. This data set provides an ideal testbed for the development of new products, like those that identify signals.

We have assembled a community of scientists from all over the world by hosting workshops and meetings to realize the S2S vision of seamless forecasting both in terms improving the skill of the forecasts and developing the operational infrastructure. To foster enhanced communication, the S2S International Coordination Office (ICO) has established communication environment which provides a forum for S2S communities.

The S2S Project is the new future awaiting our generation and the next generation. The operational centers will be able to generate more accurate and universal information, and the applied research communities will use the data whenever or wherever it is needed in decision-making processes, drafting future policies, and setting industry directions to minimize socioeconomic risks. Adapting to the changing natural environment will not only prepare us for natural disasters but also minimize damage incurred by climate change by helping us draft smarter plans, which will ultimately lead to more economic opportunities.

Many of countries are striving to improve predictability of S2S time scale forecast. The national activities are crucial for the success of S2S project. The countries are conducting research, developing models and producing data. These national efforts require the collaboration of multiple institutions to assess the current capabilities of state-of-the-art operational S2S forecasts and evaluate the potential usefulness of S2S forecasts for various applications. Towards that, some national efforts on S2S time scale over India are introduced in this issue.

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. 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 understanding is subseasonal to seasonal forecasts of weather and climate for applications.

S2S database

The major achievement of S2S project has been the establishment of a database containing near real-time and reforecasts 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). New models may be added in phase II. Work is currently ongoing to add the Indian Institute of Tropical Meteorology (IITM) model which is based on CFSv2 integrations into the S2S database.

Because S2S is a research project, the real-time forecasts are only available with a 3 week delay. The data is archived at ECMWF and CMA, and an increasingly large subset of the S2S data is available from the International Research Institute for Climate and Society (IRI), Columbia University. Users are required to sign the S2S Terms and Conditions which stipulate non-commercial use of the S2S data.

TIGGE Database now accessible through S2S Website

The S2S ICO added a link to the TIGGE Database in the S2S website (http://s2sprediction.net). The TIGGE Database comprises

- TIGGE
- TIGGE-LAM
- CHFP
- NMME
- SubX

Visualizing, Analyzing and Downloading S2S Data with the IRI Data Library: A Swiss-Army-Knife for S2S Data

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The International Research Institute for Climate and Society Data Library (IRIDL) is a powerful and freely accessible online data repository and analysis web-service that allows a user to view, analyze, and download hundreds of terabytes of climate-related data through a standard web browser in a computer or a smartphone. A wide variety of operations, from simple anomaly calculations to more complex EOF or cluster analyses can be performed with just a few clicks.

About 75% of the S2S Database forecasts and reforecasts, including all models' RMM indices for MJO analysis, are presently available in the IRIDL from the ECMWF server and kept up to date as new forecasts & reforecasts are made. It provides a flexible and fully online interface to the S2S database, for easy subsetting, analysis & visualization, and download in a variety of formats, including NetCDF, GoogleEarth's KML and GIS-compatible layers. Furthermore, the IRIDL is an OpenDAP server, which means local client programs –e.g., written in Python, R or Matlab– can read the desired data online, avoiding the need to download it explicitly, saving disk space and increasing efficiency.

These features make the S2S data more accessible to a much broader community of researchers in both climate science, forecasting, and societal applications research & development, including sectors such as agriculture, water resource management, disaster risk reduction, public health and energy.

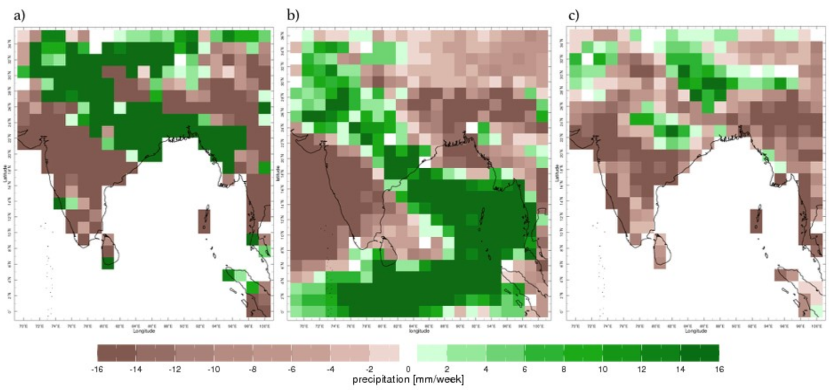

Figure 1. Weekly precipitation anomalies for (a) CHIRPS observed data, Jul 6-12, 2015, (b) ECMWF ensemble mean week-3 forecast from Jun 22, and (c) CHIRPS anomalies composited for July over MJO Phase 8.

The IRIDL contains a large number of observational and reanalysis datasets that can be easily used in conjunction with the S2S model data for forecast verification, calibration and forecast tailoring studies. It also archives the NOAA SubX project data. Having both S2S and SubX in the same platform is a big bonus for researchers.

Downloading S2S Data has never been easier: data can be subsetted and post-processed (such as ensemble or weekly averaging) prior to download, potentially reducing the required bandwidth. A GUI interface provides interactive data selection, filters (e.g. averaging), views and download, while the Ingrid scripting language provides full control. Several examples are shown below. Individual post-processed data can be downloaded interactively through log in to the IRIDL authorization service (and one-time sign-off on the S2S data Terms & Conditions from ECMWF), or from the unix command line via curl (and similar programs) and a security access key. Details on how to use curl directly in the command line, or how to have it working in different coding languages can be found in the IRI Wiki site.

Example: A monsoon break over India during July 2015

Figure 1a shows the weekly rainfall anomaly July 6-12, 2015, constructed from CHIRPS daily 0.25-deg rainfall data. Anomalously dry conditions were present over peninsular India, with anomalously heavy rainfall to the NE over the Indogangetic plain and Himalayan foothills, forming a dipolar pattern characteristic of the Boreal summer intraseasonal oscillation (BSISO), aka the summertime MJO. The Ingrid script used to make this map is shown in Fig. 2a. The **GRID** function regrids the 0.25-deg data to 1.5-deg for comparison with S2S data. Apentad climatology is then loaded, regridded linearly in time to daily and then subtracted from the CHIRPS, before summing over the July 6-12 range; units are converted to mm/week.

The ECMWF ensemble-mean forecast anomaly for July 6-12, initialized on June 22 ("week 3"), is s hown in Fig. 1b. The forecast captures the basic anomaly dipole with anomalously dry conditions over the peninsula and wet anomalies to the Northeast, though with a slight location shift. This plot was made using the script in Fig. 2b, where the start **S** on 22 Jun was selected, and the **difference** of the accumulated precipitation between lead times 21 and 14 days is computed, taking the **[M]average** over all ensemble members. The second part of the script does the same for the reforecasts, and averages over all **hdate** years to subtract the model's lead-dependent climatology.

The model's quite good skill at week 3 suggests that the intraseasonal oscillation is a source of predictability, and indeed the MJO was transitioning from Phase 7 to 8 during the July 6-12 period (details here). This can be approximately assessed by constructing MJO phase composites. Figure 1c shows CHIRPS anomaly rainfall composited for Phase 8, which indeed shows monsoon break conditions over peninsular India and some anomalously high rainfall to the Northeast.

Upcoming Events

- **EGU General Assembly 2018, *8-13 April, 2018, Vienna, Austria*:** The General Assembly 2018 of the European Geosciences Union (EGU) is held at the Austria Center Vienna (ACV) in Vienna, Austria. The EGU General Assembly 2018 will bring together geoscientists from all over the world to one meeting covering all disciplines of the Earth, planetary and space sciences. The EGU aims to provide a forum where scientists, especially early career researchers, can present their work and discuss their ideas with experts in all fields of geoscience. (https://www.egu2018.eu/)
- **AOGS 15th Annual Meeting, *03-08 June, 2018, Honolulu, Hawaii*:** The 15th Annual Meeting for AOGS2018 will be held in Hawaii Convention Centre, Honolulu, Hawaii. The Session AS21 is for Sub-seasonal to Seasonal Forecasting of High-impact Weather and Climate Events. This session focuses on all aspects of the S2S prediction, with emphasis on studies of interactions among various processes, and predictability associated with them. (http://www.asiaoceania.org/aogs2018/)
- **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. This meeting is open to all scientists, producers, and users involved in subseasonal to decadal climate predictions and related topics, including graduate students and early career scientists. (https://www.wcrp-climate.org/s2s-s2d-2018-home)

a)

```
SOURCES .UCSB .CHIRPS .v2p0 .daily-improved
.global .0p25 .prcp
 X 70 1.5 100 GRID
 Y 0 1.5 35 GRID
 T (6 Jul 2015)(12 Jul 2015) RANGE
 home .mbell .UCSB .v2p0 .daily-improved
.global .0p25 .climatology .pc9514 .prcp
  X 70 1.5 100 GRID
  Y 0 1.5 35 GRID
  [T]1.0 regridLinear
  sub
 [T] sum
 /units (mm) def
 prcp_anomaly
 X Y fig: colors thinnish solid coasts_gaz :fig
   /antialias true psdef
   /plotaxislength 700 psdef
   /plotbordertop 40 psdef
   /plotborderbottom 40 psdef
   /XOVY null psdef
```

b)

```
 SOURCES .ECMWF .S2S .ECMF .forecast
.perturbed .sfc_precip .tp
 Y (0N) (35N) RANGE
 X (70E) (100E) RANGE
 S (0000 22 Jun 2015) VALUES
 [M]average
 L (14.0) (21.0) VALUES
 [L]differences
 SOURCES .ECMWF .S2S .ECMF .reforecast
.perturbed .sfc_precip .tp
  Y (0N) (35N) RANGE
  X (70E) (100E) RANGE
  S (0000 22 Jun 2015) VALUES
  [M]average
  L (14.0) (21.0) VALUES
  [L]differences
  [hdate]average
  sub
 c:
  /name /water_density def
  998 (kg/m3) :c
  div
 (mm) unitconvert
 prcp_anomaly
 X Y fig: colors thinnish solid coasts_gaz :fig
   /antialias true psdef
   /plotaxislength 700 psdef
   /plotbordertop 40 psdef
   /plotborderbottom 40 psdef
   /XOVY null psdef
```

c)

```
 SOURCES .UCSB .CHIRPS .v2p0 .daily-improved
.global .0p25 .prcp
 T (1 Jan 1995)(31 Dec 2014) RANGE
 X 70 1.5 100 GRID
 Y 0 1.5 35 GRID
 a: SOURCES .BoM .MJO .RMM .phase
   T (1 Jan 1995)(31 Dec 2014) RANGE
   classifyby
  T (Jul) VALUES
  [T]average
  :a:
   T (Jul) VALUES
   [T]average
   :a
  sub
 7 mul
 /units (mm/week) def
 prcp_anomaly
 X Y fig: colors thinnish solid coasts_gaz :fig
   /antialias true psdef
   /plotaxislength 700 psdef
   /plotbordertop 40 psdef
   /plotborderbottom 40 psdef
   /XOVY null psdef
```

Figure 2. Ingrid code used to create the maps in Fig. 1. Click on the following links to obtain the respective URLs: (a), (b), (c).

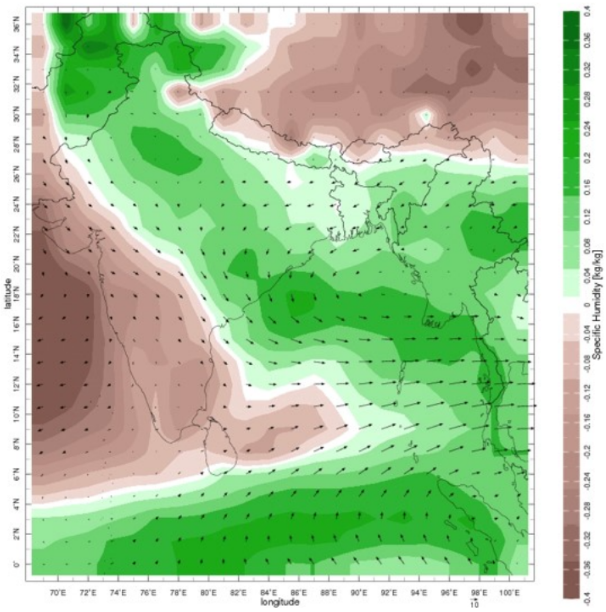

Figure 3. ECMWF week-3 forecast anomalies of vertically integrated moisture flux (vectors) and vertically integrated specific humidity (colors). Details as Fig. 1b. IRIDL link. (Since the calculations in the Data Library are performed in real time, the figure may take some time to appear.)

The Ingrid script (Fig. 2c) first loads and regrids the CHIRPS data. It then loads the RMM index phase time series produced by BoM which it uses to classify the CHIRPS, select all Julys 1995-2005, average for each phase, and lastly subtract the July climatology.

The above example just scratches the surface of the IRIDL's capabilities. Figure 3 shows week-3 ECMWF forecast anomalies of a more complex field computed in IRIDL: the vertically integrated moisture flux (vectors), with the vertically integrated specific humidity anomalies shown in colors. The latter closely mirrors the forecast precipitation anomalies in Fig. 2b, while the moisture flux anomalies show a southeastward flux coincident with the zone of anomalous moisture.

All figures, Ingrid scripts and datasets processed by the user can be easily reproduced online by simply sharing the corresponding URL; and the figures and associated data can be easily downloaded in a variety of formats, or dynamically added as a widget to, for example, a project website. The reader is invited to click on the links in the figure captions, which contains the Ingrid codes used to make the figures, and to visit the IRI Wiki site for further examples. For any inquiries, please send an email to our HelpDesk (help@iri.columbia.edu).

Acknowledgement

Archiving of the S2S Database in the IRI Data Library was made possible through support from NOAA and IRI.

Efforts at NCMRWF (India) to Implement a S2S Seamless Modelling System

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1. Introduction

Indian summer monsoon is well known for its complex coupled interactive components of the Earth System and hence provides a unique set-up to test the skills of the state-of-art numerical models. Realistic representation of Indian monsoon rainfall variability at different time scales is a scientific challenge with great societal consequences. As the computing resources are becoming available to run operationally higher resolution coupled modeling systems in real-time, increasingly progress have been noted in the skill of models. For Indian monsoon, research and investment in Sub-Seasonal to Seasonal (S2S) scale is the most challenging one to bring about new developments in modeling system, which in-turn will produce more skillful models (Mitra et al., 2013). NCMRWF/MoES India is working in close collaboration with the partners of UM consortium to implement and improve upon the seamless modeling system based on the unified modelling concepts.

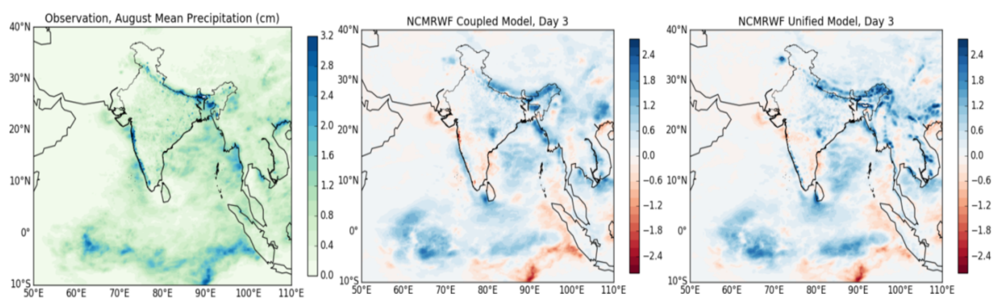

Figure 1. Day-3 Rainfall Forecasts during Monsoon 2017 (JJAS) rainfall from the coupled and atmosphere only systems.

2. Modelling System

A coupled model has been implemented and running in real-time since monsoon season of 2017. The end-to-end assimilation-forecast system is in place. Atmosphere, land, ocean & sea-ice initial conditions are all produced at NCMRWF. The atmospheric model is UM at N216 (65 Km in horizontal) and has 85 layers (up to 80 km) in the vertical. The ocean component is global NEMO3.4 with ORCA tri-polar grid 0.25 degrees horizontal resolution and has 75 layers in the vertical. The land surface component is the JULES and the Sea-Ice component is the CICE4.3 system, all coupled through the OASIS coupler. The ocean component is initialized by a NEMOVar 3-DVar variational ocean data assimilation system on daily basis at the same NEMO global model resolution. The configuration is close to the GC2 system described in William et al. (2015).

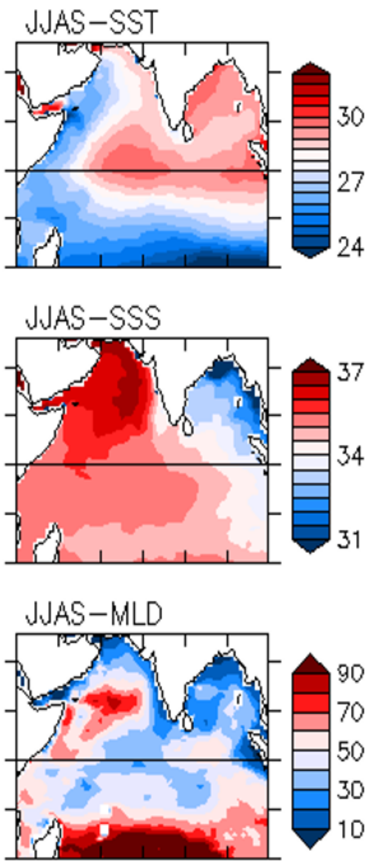

Figure 2. Mean ocean parameters from the NEMOVar system during monsoon 2017(JJAS).

3. Model Simulations

During 2017, due to limited computer resources the coupled model was tested only at N216 resolution up to 15 days runs in real time. Figure 1 shows the summer monsoon 2017 rainfall from N216 coupled and N768 atmospheric only model both in medium range scale. The features of summer monsoon rainfall are captured well in the models. From recent model assessments we know that the models develop errors during first few days in short/medium range itself. However, the monsoon rainfall indicated the nature of rainfall to be close agreement in both atmosphere only and coupled system. Figure 2 shows the seasonal mean ocean features during monsoon 2017 (JJAS) having high SST, low salinity and shallow MLD in Bay of Bengal from the NEMOVar system. These fields are realistically represented in ocean assimilation system. Figure 3 shows that the daily evolution of vertical stratification and is well captured in the NEMOVar system when compared to buoy data. This is crucial for the Interaction of monsoon with Upper Ocean of Bay of Bengal. The CICE component of the coupled model also reproduces reasonably well Sea Ice information for Polar Regions (Figure 4).

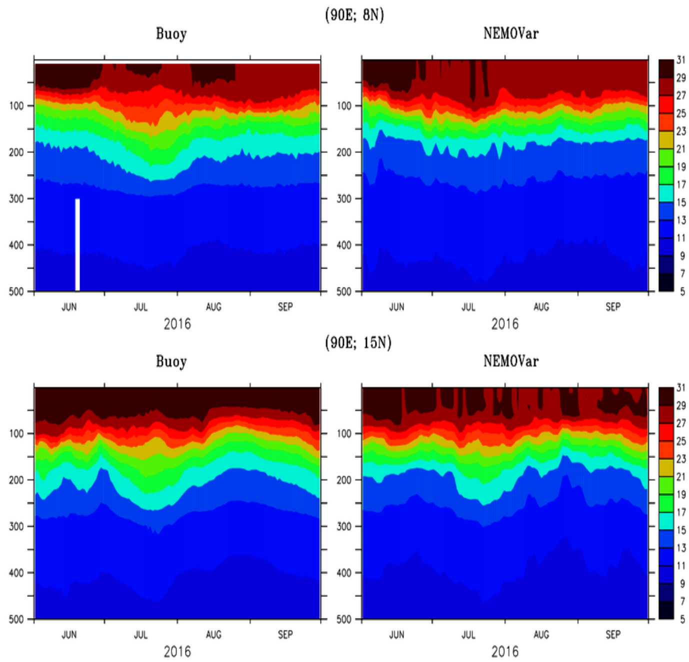

Figure 3. Daily comparison of NEMOVar output with Buoy during Monsoon 2017 (JJAS).

4. Way Ahead

Recently during January 2018, NCMRWF has commissioned a new CRAY-XC40 2.8 Peta Flops HPC system. With this higher resources it is planned that during 2018-19 coupled system will be tested and implemented at all S2S scales with real-time forecasting purpose, namely the NWP at up to 15 days (17 km), sub-seasonal multi-week (at 25 km), and seasonal runs up to 6 months (at 60 km). The multi-week and seasonal runs will have a 20 member ensemble runs. In collaboration with UK Met office there is a plan to implement a weekly coupled data assimilation system during 2019-20. There is a plan to nest a very high resolution meso-scale coupled environmental regional model for India and Bay of Bengal region to the current global coupled system for regional applications in S2S scale.

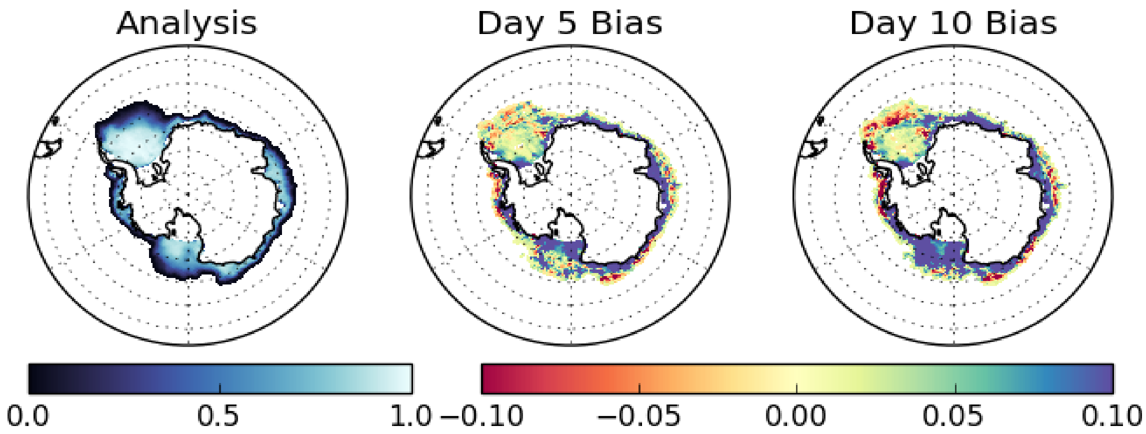

Figure 4. Sea Ice Fraction over Antarctic region during pre-monsoon (northern spring).

Acknowledgement

NCMRWF is thankful to UM consortium partners for useful scientific discussions for model development for Indian monsoon and technical support. Help and discussions with UKMO scientists particularly from Sean Milton and Matthew Martin are of great support. We are grateful to Secretary MoES Dr. M. Rajeevan for his support to NCMRWF coupled modeling programme.

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