Impact of initialized land temperature and snowpack on sub-seasonal to seasonal prediction (ILSTSS2S)

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1. Motivation of this project

Intraseasonal to seasonal (S2S) prediction, especially the prediction on extreme climate events such as droughts and floods, is scientifically challenging and has substantial societal impacts and economic consequences. Sub-seasonal to seasonal prediction is the topic of a joint project of the World Weather Research Program (WWRP) & World Climate Research Program (WCRP), which aims to improve understanding and forecast skill on the S2S timescale, between two weeks and a season (WMO, 2013). It is therefore important to understand the sources of such predictability and develop more reliable monitoring and prediction capabilities. Various mechanisms have been attributed to the S2S predictability. The connection between sea surface temperature (SST) [e.g., El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and Atlantic Multidecadal Oscillation (AMO), Madden–Julian oscillation (MJO)] and the associated predictability has been extensively studied for decades. Despite significant correlations and predictive value, numerous studies consistently show that SST is only able to partially explain the phenomena of S2S predictability (e.g., Schubert et al., 2009; Scaife et al., 2009; Pu et al., 2016; Xue et al., 2016a,b). For instance, the 2016-2017 La Niña event has been associated with record rainfall that effectively ended the 5-year Californian drought, contrary to the expected SST-drought/flood relations. While atmospheric internal variability contributes (Hoerling et al., 2014), such exceptions underscore the need to seek explanations beyond SST's influence alone.

The possible remote effects of large-scale spring land surface/subsurface temperature (LST/SUBT) anomalies in geographical areas upstream and closer to the areas of late spring-summer drought/flood have largely been ignored. Preliminary studies have been carried out to explore the relationship between spring LST/SUBT anomalies and summer precipitation anomaly in downstream regions in North America and East Asia (Xue et al., 2012, 2016b, 2018). The analyses based on observed summer precipitation and spring temperature data over these two continents have shown the significant correlation between these two variables, comparable to the well-known SST and precipitation correlations. Meanwhile, the modeling studies using the NCEP Global Forecast System (GFS) and the regional climate model, WRF, have suggested that the long-distance effect of land temperature changes in the West U.S. and Tibetan Plateau (TP) on its respectively downstream region is probably as large as the more familiar effects of SST and atmospheric internal variability. Consideration of LST/SUBT anomalies has the potential to add value to S2S prediction of dry and wet conditions, especially extreme drought/flood events. Although the current studies focus on two continents, it also motivates testing those relationships and general physical principles in other continents with similar geographic settings. This project with multi-model will further examine the potential of the LST/SUBT effect in adding value to S2S prediction, especially extreme drought/flood events in different continents.

Snow is another land factor that contributes to the S2S variability. Snow in the Eurasian continent and TP has been considered as one of the factors affecting the Asian monsoon variability for many decades (e.g., Yasunari et al., 1991). Snow in North America has also shown that it may add value on the intraseasonal to seasonal prediction (e.g., Gutzler and Preston, 1997). A recent study (Broxton et al., 2017) shows that the CFS model produced systematic differences in snow water equivalent (SWE) and surface air temperature, depending on the forecast lead time. Furthermore, SWE differences in earlier versus later forecasts are found to much more strongly affect April–June temperature forecasts than the SST differences over different regions, suggesting the major role of snowpack in seasonal prediction during the spring–summer transition over snowy regions. Furthermore, the aerosols in snow albedo have also shown substantial impact on the seasonal surface temperature simulation (e.g., Oaida et al., 2016; Lau et al., 2018) and will be investigated at the second stage of the project.

2. Project Goals

This project intends to address two questions:

- What is the impact of the initialization of large scale LST/SUBT and snow pack, including the aerosol in snow, in climate models on the S2S prediction over different regions?
- What is the relative role and uncertainties in these land processes versus in SST in S2S prediction? How do they synergistically enhance the S2S predictability?

This project focuses more on the process understanding and predictability rather than the operational S2S prediction.

3. Linkages and Co-Sponsorships

ILSTSS2S is intended to be a joint project between GASS and other international programs. The focus area of its first phase will be the Tibetan Plateau and will be the joint effort with the Third Pole Experiment (TPE) Earth System Model (ESM) inter-comparison project (TPEMIP). The Regional Earth system (multi-sphere) modeling for the Third Pole Region and its impact on the adjacent regions at different scales is one of the TPE's main objectives. The TPE will also provide the data to support this project.

This initiative is relevant to the GEWEX Global Land Atmosphere System Study (GLASS) panel because estimating the contribution of memory in the land to atmospheric predictability from convective to seasonal timescales is one of its main themes. This requires an understanding of the key physical interactions between the land and the atmosphere and how feedbacks can change the subsequent evolution of both the atmosphere and the land state. This initial focus of ILSTSS2S on soil temperature also complements the primary focus on soil moisture of GLASS so far.

The ILSTSS2S activities are closely related to the WWRP/WCRP S2S project, in which land initialization and configuration is one of its major activities (WWRP/WCRP S2S Phase 2 proposal, 2018). The ILSTSS2S will also tackle two challenges: High-Impact Weather and Water, which have been listed in the WWRP Implemental Plan 2016-2023 (WWRP, 2016). The ILSTSS2S research activities to address these scientific challenges will be developed and executed along the line of the WWRP/WCRP S2S project. At the same time, ILSTSS2S model experiments (including model setup) will complement, rather than duplicate, ongoing activities of the WWRP/WCRP S2S project through coordination.

With the co-sponsorship from these programs, the ILSTSS2S will interact with all these project groups and develop the experiments, which will support and complement their planned research sub-projects. We will also coordinate with these projects to develop a skill metrics/predictands to better measure impact against observation. In addition, the ILSTSS2S will also collaborate with the WCRP WGSIP project to exchange the information regarding to activities and discoveries in improving the seasonal prediction.

4. Preliminary timeline for the project

We intend to have several phases in this project and each phase may focus on one continent or one specific issue. We are considering to have East Asia as the focus in the first phase because the high elevation Tibetan Plateau and large scale snow cover there plus more available observational data probably provide an ideal geographical location for initial test. The North America may be the second phase's focus. This issue will be discussed and finalized in the first workshop on this project.

a) We plan to have a kickoff workshop in the 2018 Fall AGU Conference in Washington D.C. on Saturday and Sunday before the AGU meeting. A set of seasonal experiments will be finalized to test LST/SUBT effects on the drought/flood prediction. A dry year with the cold LST/SUBT in the spring and a wet year with warm LST/SUBT in the spring will be selected initially. In addition to the run in which models use their own original initial conditions, we will impose the initial LST/SUBT anomalies (e.g., $T_0 \pm \Delta T$) as the initial condition on May 1st to test its impact on the May, June, and July temperature and precipitation. In addition to the project specified ΔT, each group could select one of their ΔT to produce their model's results that are closer to observed monthly mean surface temperature in TP and monthly mean precipitation downstream. Most modeling groups will use the global earth system models (ESMs); some groups will use regional climate models (RCMs) to downscale the ESM results. Before the availability of the ESM results, some experiments will be designed to test the RCMs' downscaling ability for the TP region. To compare LST/SUBT with the SST effect, an experiment with specified SST will also be conducted. A short training class will be provided during the workshop to help the modeling groups to conduct the LST/SUBT simulations. This will be the basis for the first phase of the experiments.

b). The workshops in 2019 summer in Beijing will be considered to discuss the progress, preliminary results, and problems to be resolved. The ILSTSS2S project will communicate to the WWRP/WCRP S2S project for the snow experiment to make the ILSTSS2S experiment complementary to the WWRP/WCRP S2S project and the WCRP/WGSIP/SNOWGLACE project. The initial snow condition and aerosol in snow will be assigned to test their impact on the summer surface temperature and precipitation.

c). A project session in the 2019 AGU Full Conference will be organized for this project and discussion of further experiments. A possible paper in BAMS and a special issue for the first phase experiment will be discussed.

5. Data

The field data from the Third Pole Environment (TPE) - the Third Atmospheric Scientific Experiment for Understanding the Earth-Atmosphere Coupled System over the Tibetan Plateau, and Zeng et al.'s (2018) snow data, and other available data, such as reanalysis data, will be used for this project. The model output data will be stored in the TPE database.

6. Major Participants

More than 20 institutions from Asia, North America, and Europe have confirmed to participate in this effort. More institutions are in the process of confirmation. Organizers of this project include: Yongkang Xue (UCLA); Tandong Yao (ITPR, CAS); and Aaron Boone (Meteo France). The subgroups for regional climate modeling as well as snow and aerosol modeling will be formed before or at the 2018 AGU Fall Meeting. Additional organizers may be considered, depending on the progress of this project preparation.

7. References

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