ISSI-BJ FINAL TEAM REPORT TEMPLATE:

(This report should not exceed 2 pages)

1. Title of your Team project: **Snow reanalyses over the Himalaya-Tibetan Plateau region and the monsoons.** Team leaders: Yvan Orsolini (Norway) and Gianpaolo Balsamo (UK)

2. Objectives: The primary objective was to inter-compare and assess available re-analyses of snow over the Himalaya-Tibetan Plateau region (HTP) in recent years. A secondary objective was to test the impact of improved snow re-analyses upon subseasonal-to-seasonal forecasts, especially in relation to the Asian monsoons.

3. Dates of meetings: February 27- March 3, 2017 & May 14-18, 2018

4. Participants (one meeting[#]): Yvan Orsolini, Gianpaolo Balsamo[#], Martin Wegmann, Emanuel Dutra, Patricia de Rosnay[#], Retish Senan[#], Boqi Liu, Congwen Zhu, Kun Yang, Yongqi Gao[#], Yali Zhu, Jing Ming[#], Wenli Wang[#], Qiong He[#]

5. Assessment of the Team activities; highlights: (figure numbers in red refers to the report attachment)

Often referred to as the Third Pole, the Tibetan Plateau (TP) region is the world highest plateau, with an average elevation of 4000 m above sea level. Due to its spatial extent, elevation and geographical position in the mid-latitudes, it exerts a considerable influence on regional and global climate. Meteorological re-analyses and forecast models commonly produce an extensive snowpack in winter and spring over the entire TP. This is at odds with observational studies revealing that the snowfall events are transient, that the snowpack is distinctly shallow, patchy and short-lived, and that large portions of the TP are snow-free in winter[1]. In fact, the largest relative model bias for precipitation over land, globally, is on the TP.

We compared five recent global snow analyses produced by meteorological prediction centres in Europe, Japan and the USA, to observations from 33 in-situ stations over the TP, obtained through team members affiliated with the Chinese Meteorological Administration. The comparison was carried out over a 5-year period (2009-2013). Satellite snow cover and depth products were also used in the inter-comparison. These comprised (i) the NOAA high-resolution multi-sensor (IMS) snow cover product, combining optical, infrared, microwave and station data, (ii) a dedicated microwave snow depth product developed to account for the specificity of the TP, provided by Chinese team members. The comparison shows a large overestimation of snow depth over the HTP region, but with considerable spread among re-analyses[2]. The Japanese re-analysis is performing best in terms of snow depth since it assimilates some station data over the TP region. The team investigated in closer detail the family of re-analyses from the European Centre for Medium-Range Weather Forecast (ECMWF). We found that the most recent reanalysis (ERA5) is not the one performing best. Rather, ***assimilation of satellite snow cover at high altitudes,*** carried out in the older re-

analysis cycles, proved key to improving the quality of the re-analyses over the TP region in comparison to in-situ data[3].

Chinese team members with field experience in the region suggested that, in the dry, windy conditions of the TP, sublimation of blowing snow was an important missing process. We carried sensitivity experiments with the ECMWF off-line land surface model and found that when introducing a simple parametrisation for the sublimation of blowing snow, the excessive snow bias was significantly reduced[2]. There remains a positive bias likely due to excessive regional precipitation in forecast models.

Given the importance of satellite snow cover assimilation at high altitudes, a new quasi-operational analysis of snow was produced over a one-year period spanning 2011 and 2012. Snow depths in the new analysis remarkably match in-situ observations[4]. New, daily experimental medium-range forecasts have been carried out using this new analysis for snow initialisation. The improved analyses lead to warmer surface temperatures over the TP due to the reduced snow[5]. This surface signal extends vertically into the lower stratosphere and horizontally as a wave train, downstream of the TP region and into the Pacific. Verification of forecast scores indicates improvement against independent observations of surface temperature and pressure over the northern hemispheric extra-tropics over the first five days. The impact of these new, experimental snow re-analyses upon seasonal forecasts have also been investigated using the ECMWF operational coupled ocean-atmosphere seasonal forecasting system.

The team (indeveloped an active project webpage, with some sections being public and other with restricted access.

6. Outcome in relation to the objectives:

The team has embarked on three dedicated publications on the specific theme of this working group. Involvement of Chinese team members with access to local meteorological data or with field experience proved capital. Further parametrisation of missing processes, which are important over the TP such as snow sublimation, should be considered for inclusion in future operational analyses. The major finding is to demonstrate how assimilation of satellite snow cover at high altitudes improves current forecast initialisation over the TP area.

7. Publications resulting from the Team work: (only publications resulting from the team work including acknowledgment to ISSI-BJ)

Orsolini Y., M. Wegmann, E. Dutra, G. Balsamo, P. de Rosnay, R. Senan, B. Liu, C. Zhu, K. Yang, W. Wang: Evaluation of snow depth and snow-cover over the Tibetan Plateau in global reanalyses using in-situ observations and satellite remote sensing products, to be submitted to The Cryosphere, December 2018.

de Rosnay, P., G. Balsamo, E. Dutra, B. Liu, Y Orsolini, R. Senan, M. Wegmann, K. Yang, C. Zhu: Impact of snow cover data assimilation over the Tibetan Plateau on Medium-Range Numerical Weather Prediction, in prep., January 2019

Senan R., Y Orsolini, P. de Rosnay, G. Balsamo, E. Dutra, B. Liu, M. Wegmann, K. Yang, C. Zhu: Impact of snow cover data assimilation over the Tibetan Plateau on seasonal forecasting, in prep., February 2019