Project 3 (WP4-WP3-TWP3): Assessing the robustness of multi-region and multi-sectoral indicators of climate change impacts

Project lead: Benjamin Sultan
Post-doctoral researcher: Yan Zhao
Project start/end: May 2013 – April 2015

Position offer:

The excellence laboratory L-IPSL of the Institut Pierre-Simon Laplace offers a post-doctoral position of 2 years to assess impacts of climate change in various sectors and regions of the world.

Context: The Fourth Assessment Report of the Intergovernmental Panel on Climate Change has, with greater confidence than previous reports, warned the international community that the increase in anthropogenic greenhouse gases emissions will result in global climate change with potential impacts on natural resources, ecosystems and human's activities. Thus, there is a growing literature on the impacts of climate change, mostly using global climate models (GCM) projections to drive process-based or statistical impact models. However, very large uncertainties remain between impact studies, reflecting the diversity of such studies, which often focus on different locations, and rely on different climate projections (models, scenarios), type of impacts and impacts models, downscaling techniques, time horizons, etc.

Description of work: We therefore propose a coherent multi-region and multi-sectoral approach to examine the robustness of projected impacts driven by IPSL-CMIP5 climate change scenarios. Various downscaling methods (delta method, CDFt, homogenous climatic zones, CORDEX dynamical downscaling, and use of raw GCM outputs) will be used in order to assess knowledge and uncertainty in impacts projections among sectors and regions of the globe. This work is part of the Labex L-IPSL project which aims at improving our knowledge on climate change and to anticipate its impacts on nature and society.

The recruited post-doctorate fellow will participate to the selection of a set of indicators of impacts of climate change on prone sectors and regions. This part of the task implies a very close collaboration with all L-IPSL partners. He/she will be in charge of downscaling IPSL-CMIP5 climate change scenarios with various existing methods (most of them have already been implemented at IPSL). He/she will then use several impacts models developed or used by the l-IPSL teams, including the land surface model ORCHIDEE, to produce maps of relevant indicators of climate change impacts and to analyze the robustness of such impacts projections in regards to the used downscaling method. Experience in biosphere modelling, statistical analysis and linux environment will be greatly appreciated.

Supervision team: The work will be conducted at LOCEAN/IPSL located at University Pierre and Marie Curie (4 place Jussieu, Paris 05), under the main supervision of B. Sultan (LOCEAN) and in close connection with other researchers of LSCE (P. Braconnot, M. Vrac, N. De Noblet, O. Bopp), SISYPHE (A. Ducharne), LATMOS (C. Flamant) and in the L-IPSL project.

Duration and salary: The post-doctorate will be recruited for 24 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.
Contact for applications: Applications should include a vita, a statement of research interests and the names of at least two references including e-mail addresses and telephone numbers. Applications should be submitted by e-mail to Benjamin Sultan (Benjamin.sultan@locean-ipsl.upmc.fr).

Results:

Heat is an environmental and occupational hazard. It can have disastrous consequences, as was illustrated by the hot summer of 2003 in Europe. The risk of heat stress posed by climate change is likely to enhance thus needs to be urgently assessed in order to take corresponding adaption action. With the recruitment of Yan Zhao as a post-doctoral researcher from May 2013 to April 2015 we conducted an analysis of heat stress at the global scale and for a specific country – China – which is particularly vulnerable to heat related risks.

We use three health-related temperature-humidity thermal indicators (Steadman, 1979, 1984; Masterton and Richardson, 1979; ABM), and 21 climate simulations from CMIP5 (historical + RCP8.5) to examine how well climate models simulate present-day heat-stress distribution on global scale, and how the latter may evolve in the future (Zhao et al. 2015a). We also investigate the uncertainty of simulated temperature and humidity attributed to heat-stress estimation. Making use of a bias-corrected database (Hempel et al., 2013) provided by the international project ISI-MIP, the effect of bias-correction technique on heat-stress estimation is explored.

Our results show that humid tropical areas tend to experience frequent heat stress than other regions that is, 250-300 day/year under at least slight stress; the most severe heat stress is found in Sahel and south India during the dry-wet transient period. Generally the severity of heat-stress increases by one category under RCP8.5 by the end of the century (Fig c, d). Heat stress is projected to be significantly enhanced over tropical and subtropical humid areas, although temperature is not projected to increase as much as in mid-latitude (Figure panels a, b). Regions at mid to high latitudes experience rare heat stress today but are vulnerable under climate change. In Western Europe, for instance, the projected frequency of heat-stress increases by about 400% by the end of 21th century.
At present-day GCMs tend to underestimate heat stress over tropics due to dry and cold biases. Over mid to high latitudes, heat stress is only slightly overestimated due to a compensation effect between biases in humidity and temperature (Fischer and Knutti, 2013). As a result there is a risk to underestimate heat stress in tropics while slightly overestimate in mid- and high latitude.

In terms of long-term summertime mean, the bias-correction applied in this study showed little add-value for the climate change signals. For heat-stress estimation which relies on exceedance thresholds, the effect of bias-correction varies geographically. It reduces ca 50% of the biases of simulated heat-stress frequency in tropical humid areas but does not show much advantage, if not worse, in mid to high latitudes. The reason is that the compensation effect between the biases of temperature and humidity does not hold when the current ISI-MIP bias-correction method is applied.

Finally, when estimating the impact of climate change on human health and work productivity, the uncertainty caused by climate models should be taken into account. Here, the spread (STD) of modeled heat-stress frequency is about 2 times larger than the ensemble mean biases, 1-3 times larger than the uncertainty caused by the choice of heat indicators except in extreme severity category. Thus, it is not trivial to disentangle the uncertainty contribution from GCMs and from the imperfection of thermal indicators, as already noticed by d'Ambrosio Alfano et al. (2011).

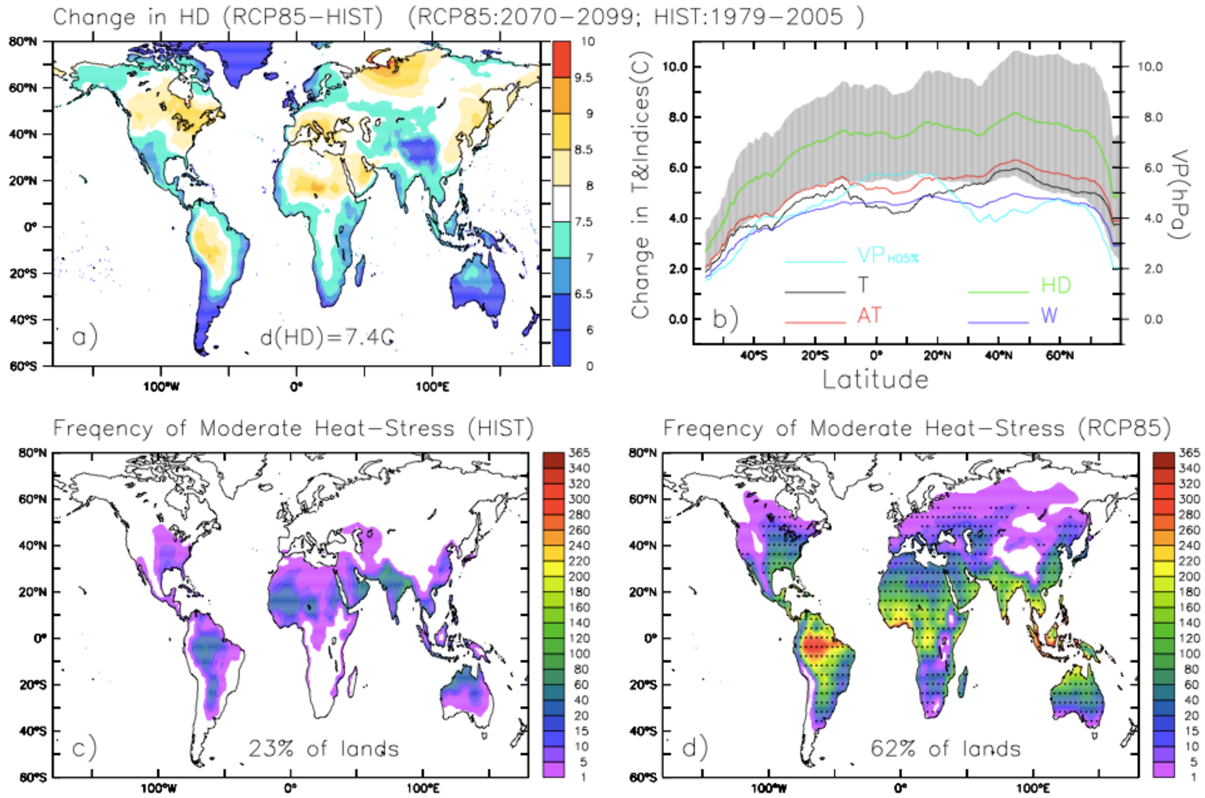

Figure 1: Change in ensemble mean of extreme mean variables (mean of 5% highest values) and heat-stress frequency. (a) Extreme mean Humidex $HD_{5\%}$; (b) Zonal mean extreme mean Humidex (HD), surface air temperature, (T) aparent temperature (AT), simplified WBGT (W) and vapour pressure (VP) corresponding to $HD_{5\%}$. One stand deviation of changes in $HD_{5\%}$ are in shade; (c) Ensemble mean of simulated Moderate heat-stress at present-day (1979-2005); (d) Ensemble mean of projected Moderate heat-stress (2070-2099). The dots in (d) indicate robust change (at least 18 out of 21 models agree in the increasing trend).

A case study was done in China where we found potential escalation of heat-related economic costs with climate and socio-economic changes (Zhao et al. 2015b). China is a country with a large population and is very affected by heat waves which have disastrous consequences on human health and occupational safety. To protect workers from heatstroke at the workplace, governmental high-temperature subsidies (referred to as HTS hereafter) are allocated to workers during hot days but this increases the labour cost. This is the first study to estimate the HTS cost in China from the present day to the end of the 21st century. We identified three main driving factors for HTS, namely population, employment structure, and climate, and estimated the national total cost of HTS to be approximately 38.6 billion yuan per year today. Our results show that this HTS cost is bound to increase during the 21st century, despite substantial uncertainty arising from the evolution scenarios of the driving factors. The evolution of the heat-related labour cost in China may serve as an example for other countries in Southeast Asia, which have a hot climate, low adaptive capacity to climate change and face similar socio-economic change. It is also relevant for developed countries, which may adopt this innovative labour regulation as an adaptation to climate change, with unclear economic impacts.

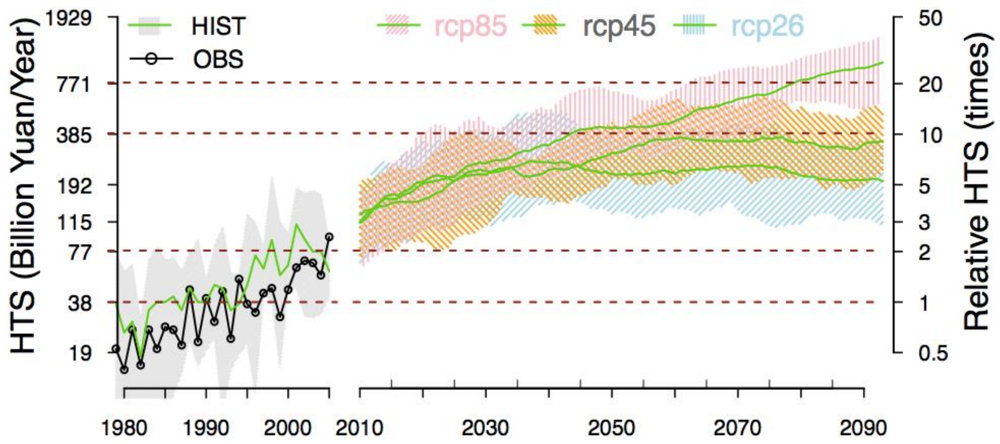

Figure 2: Estimated evolution of Total Chinese HTS (HTSCHN in billion yuan/year) under the medium population projection, and E1 employment scenarios. In all panels, black circles indicate the WFDEI-based reference (OBS), and shaded envelopes show the span of the isiBC ensembles of five GCMs. The ensemble isiBC-based mean is superimposed as solid green lines (using 11-year running means for the period of 2006-2010). The right Y-axis gives the relative change compared to the mean of the 1979-2005 reference period (shown by a horizontal purple dashed line), and is expressed as a multiplicative factor. For ease of presentation, the projected HTS is the change in the modelled HTS plus the mean reference value. The values of HTSPE based on meteorological station data in 2013 and 2014 are shown in black circles. The magenta whisker box gives the statistics for HTS based on the ensemble of the 5 x 3 x 2 isiBC simulations across five models and three RCPs during two years (2013 and 2014): the middle bar is the median value, the bottom and the top of box are the 25% and 75% percentiles respectively, and the short bars outside of the box are the minimum and maximum values.

References:

Zhao Y., Ducharne A , Sultan B , Braconnot P and Vautard R (2015a) Estimating heat stress from climate-based indicators: present-day biases and future spreads in the CMIP5 global climate model ensemble, Environ. Res. Lett. 10 (2015) 084013

Zhao Y, Sultan B , Vautard R, Braconnot P, Wang HJ and Ducharne A (2015b) Potential escalation of heat-related working costs with climate and socio-economic changes in China, PNAS, submitted

ABM: Australian Bureau of Meteorology (http://www.bom.gov.au/info/thermal_stress/)

d' Ambrosio Alfano FR, Palella BI and Riccio G. (2011) : Thermal environment assessment reliability using temperature--humidity indices. Ind Health.;49(1):95-106.

Fischer EM and Knutti R. (2013) : Robust projections of combined humidity and temperature extremes. Nat Clim Change. 3(2):126-130.

Hempel S, Frieler K, Warszawski L, Schewe J, Piontek F (2013). A trend-preserving bias correction – the ISI-MIP approach. Earth Syst Dynam. 4(2):219-36.

Masterton, J.M., and F.A. Richardson. Humidex: A method of quantifying human discomfort due to excessive heat and humidity. (1979) ; Atmospheric Environment Service, Environment Canada, pp45

Steadman RG. (1979) : The Assessment of Sultriness. Part II: Effects of Wind, Extra Radiation and Barometric Pressure on Apparent Temperature. J Appl Meteorol.;18(7):874-885.

Steadman RG. (1984) : A Universal Scale of Apparent Temperature. J Clim Appl Meteorol.; 23(12):1674-1687.