Symposium on Advanced Assimilation and Uncertainty Quantification in Big Data Research for Weather, Climate and Earth System Monitoring and Prediction
May 23-24, 2016, State College.

Regional climate change in Tibet: past and future

Deliang Chen
August Röhss Chair
Department of Earth Sciences
University of Gothenburg, Sweden

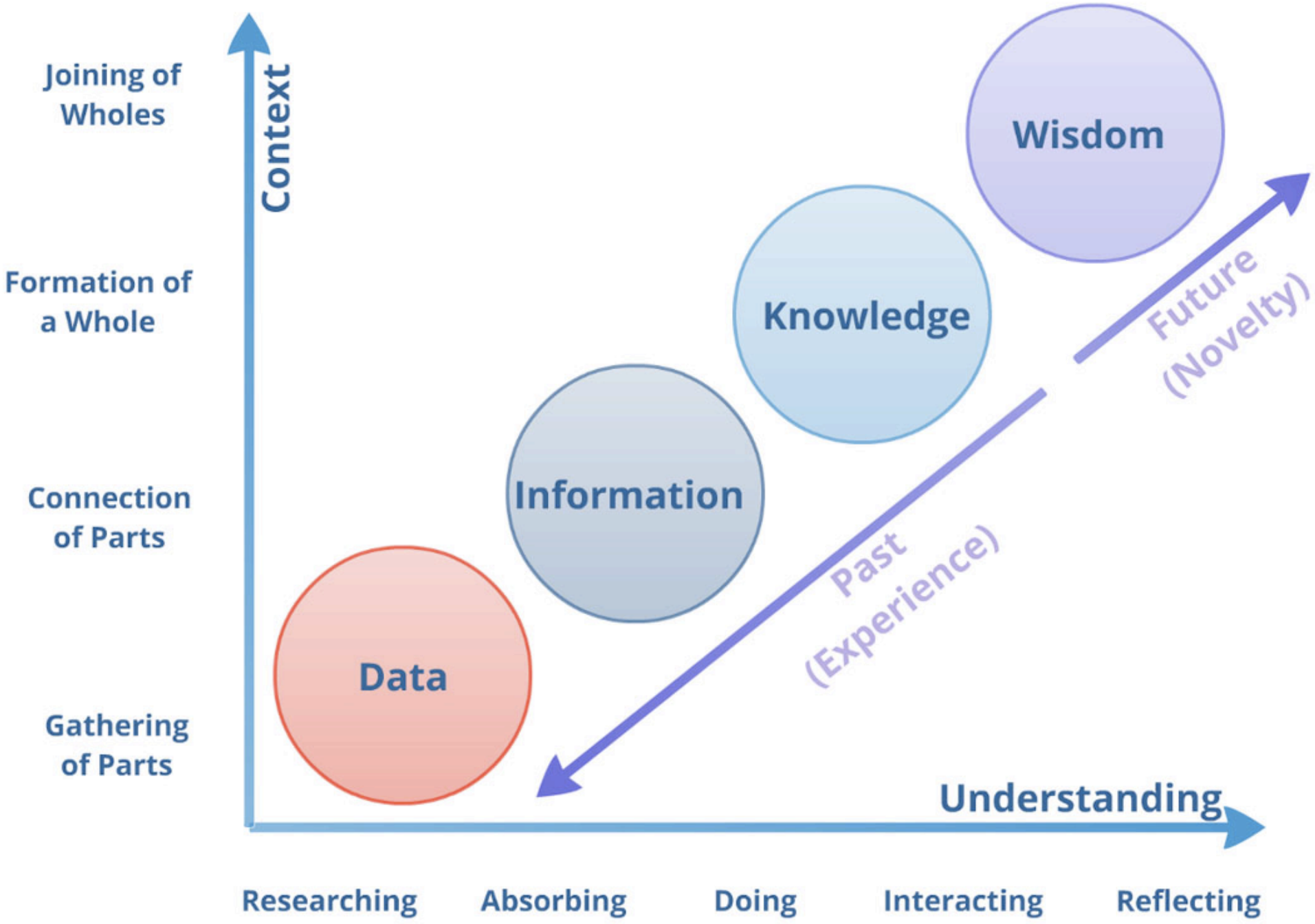
Outline

- Big data in Climate & Earth System Science perspectives
- **Assessment of climate changes over Tibet**

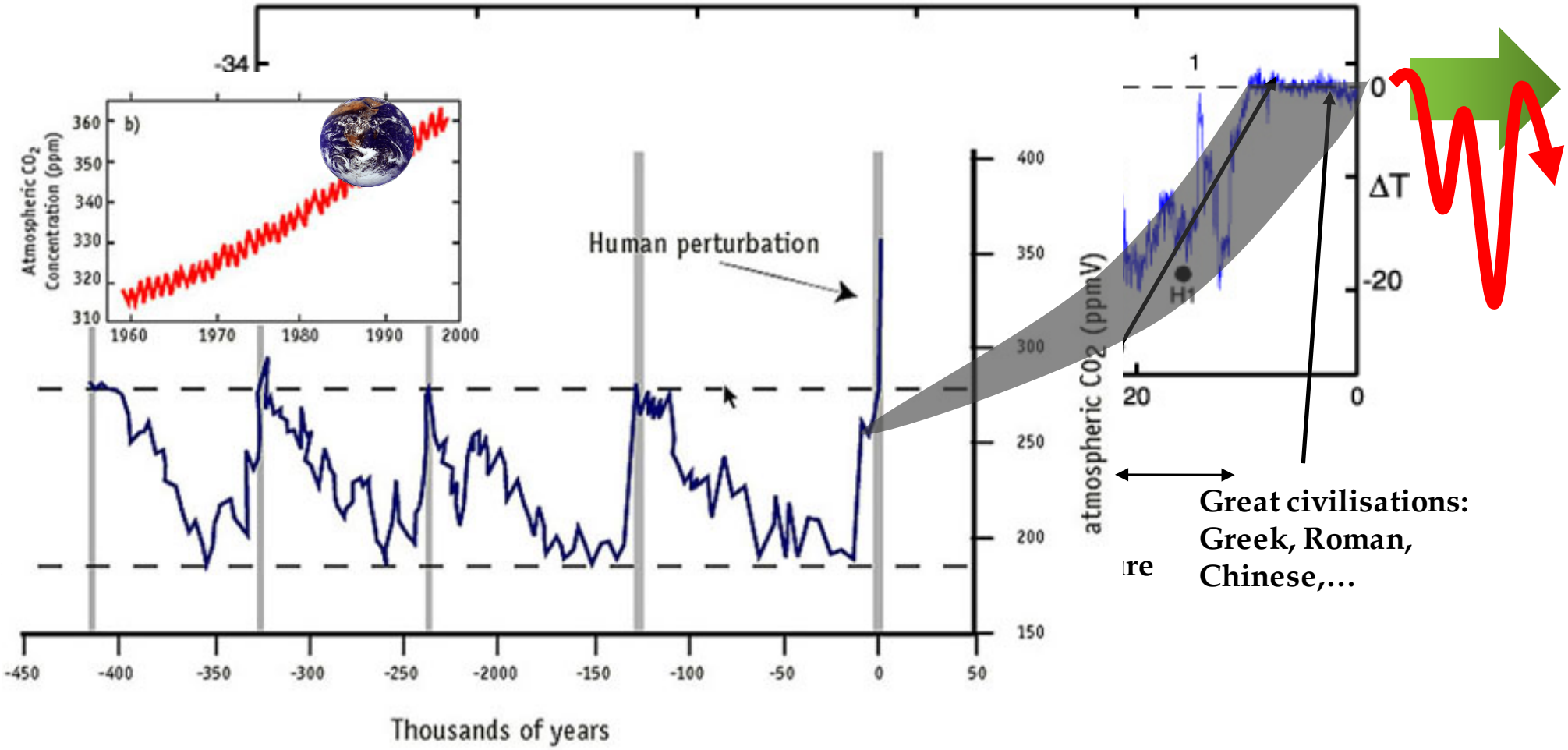
Big data

- **V**olume: big size
- **V**elocity: high speed of data availability & transfer
- **V**ariety: different formats and forms
- **V**eracity: data messiness/trustworthiness
- **V**alue: Data is only useful when we turn it into value.

ACKOFF, 1989


Joining of Wholes
Formation of a Whole
Connection of Parts
Gathering of Parts
Context
Wisdom
Knowledge
Information
Data
Future (Novelty)
Past (Experience)
Understanding
Researching
Absorbing
Doing
Interacting
Reflecting

Humanity's period of grace – the last 10,000 years



Source: GRIP ice core data (Greenland) and S. Oppenheimer, "Out of Eden", 2004

THE GREAT ACCELERATION

SOCIO-ECONOMIC TRENDS

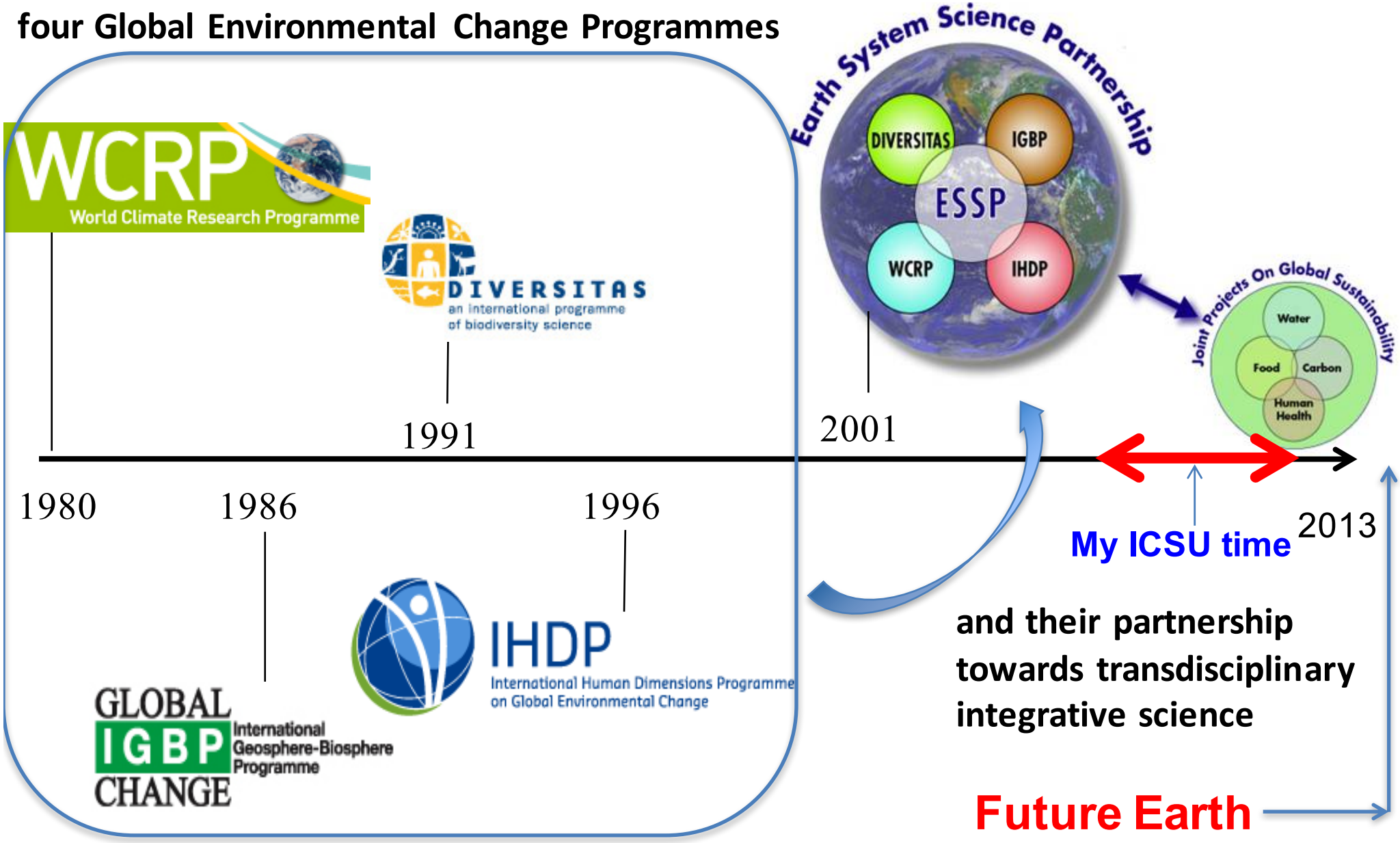
EARTH SYSTEM TRENDS

REFERENCE: Steffen, W., W. Broadgate, L. Deutsch, O. Gaffney and C. Ludwig (2015), The Trajectory of the Anthropocene: the Great Acceleration, Submitted to *The Anthropocene Review.*

MAP & DESIGN: Félix Pharand-Deschênes / Globaïa

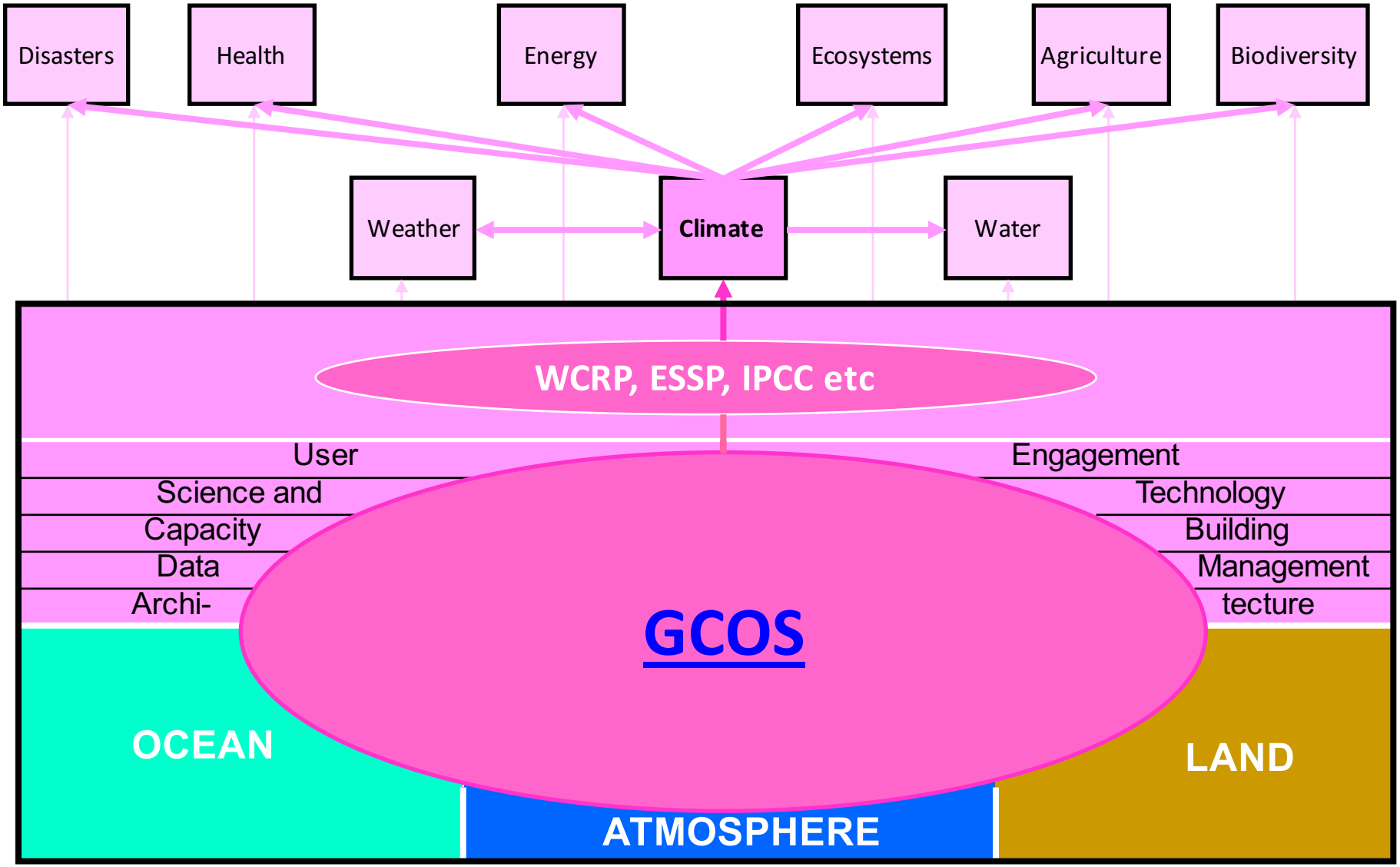
International global change research

four Global Environmental Change Programmes

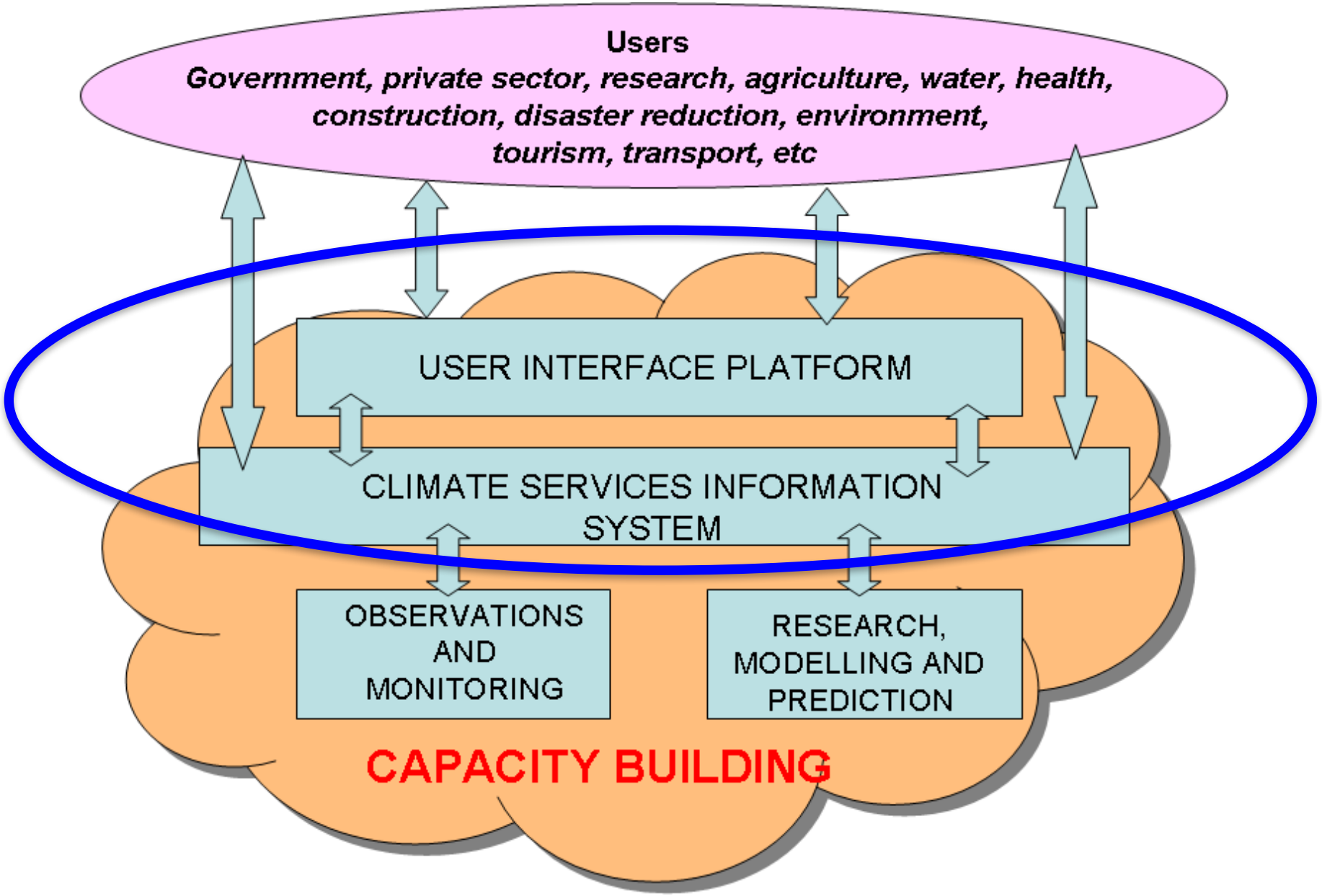


all co-sponsored by ICSU

GCOS as the climate observing component of GEOSS



Global Framework for Climat services



ENVIRONMENT AND DEVELOPMENT

Earth System Science for Global Sustainability: Grand Challenges

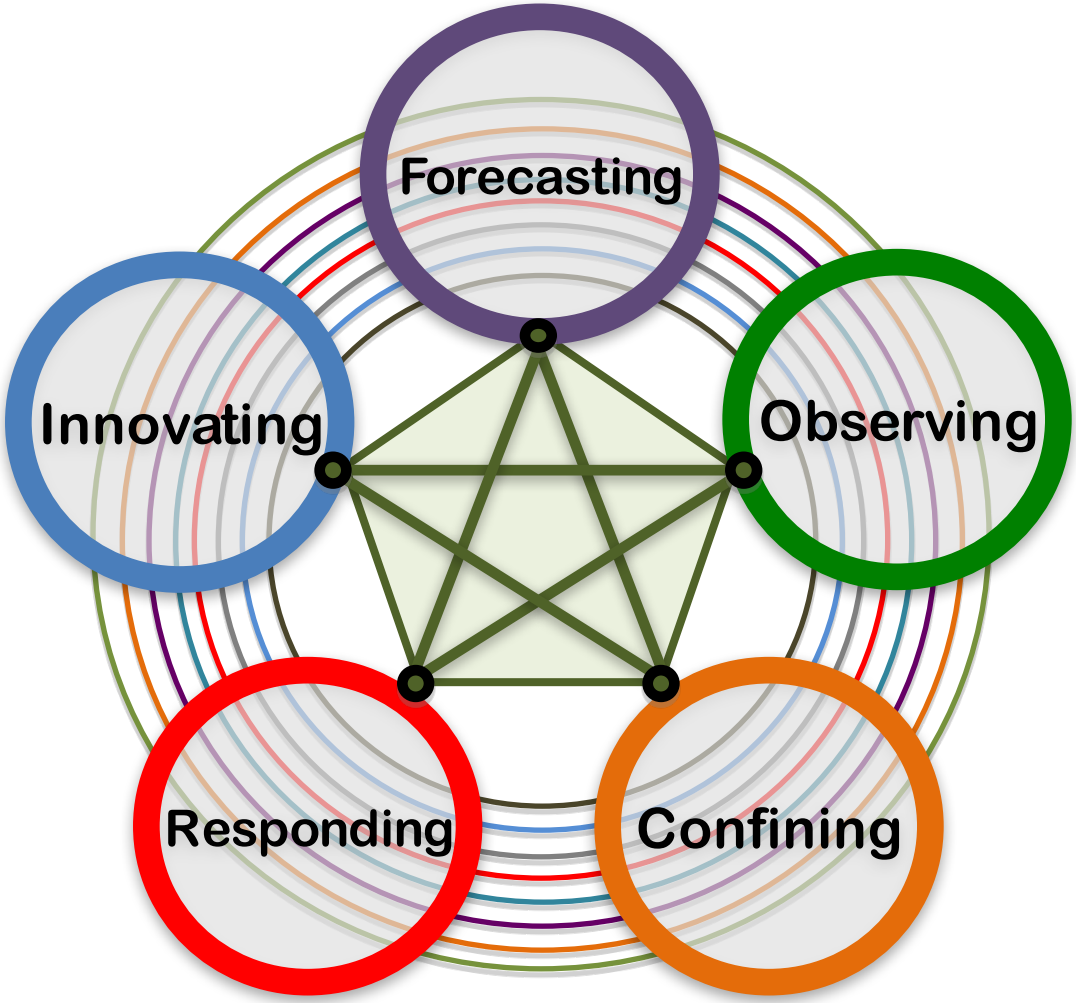
W. V. Reid,[1*] D. Chen,[2] L. Goldfarb,[2] H. Hackmann,[3] Y. T. Lee,[2] K. Mokhele,[4] E. Ostrom,[5] K. Raivio,[2] J. Rockström,[6] H. J. Schellnhuber,[7] A. Whyte[8]

12 NOVEMBER 2010 VOL 330 SCIENCE www.sciencemag.org

Published by AAAS

Earth System Visioning led to Future Earth

A Call to Action



Grand Challenges in Earth System Research for Global Sustainability

The climate reseach community responded promptly to the call….

BAMS: 2010

AN EARTH-SYSTEM PREDICTION INITIATIVE FOR THE TWENTY-FIRST CENTURY

BY MELVYN SHAPIRO, JAGADISH SHUKLA, GILBERT BRUNET, CARLOS NOBRE, MICHEL BÉLAND, RANDALL DOLE, KEVIN TRENBERTH, RICHARD ANTHES, GHASSEM ASRAR, LEONARD BARRIE, PHILIPPE BOUGEAULT, GUY BRASSEUR, DAVID BURRIDGE, ANTONIO BUSALACCHI, JIM CAUGHEY, DELIANG CHEN, JOHN CHURCH, TAKESHI ENOMOTO, BRIAN HOSKINS, ØYSTEIN HOV, ARLENE LAING, HERVÉ LE TREUT, JOCHEM MAROTZKE, GORDON MCBEAN, GERALD MEEHL, MARTIN MILLER, BRIAN MILLS, JOHN MITCHELL, MITCHELL MONCRIEFF, TETSUO NAKAZAWA, HARALDUR OLAFSSON, TIM PALMER, DAVID PARSONS, DAVID ROGERS, ADRIAN SIMMONS, ALBERTO TROCCOLI, ZOLTAN TOTH, LOUIS UCCELLINI, CHRISTOPHER VELDEN, AND JOHN M. WALLACE

An international interdisciplinary initiative to accelerate advances in knowledge, prediction, use, and value of weather, climate, and Earth system information.

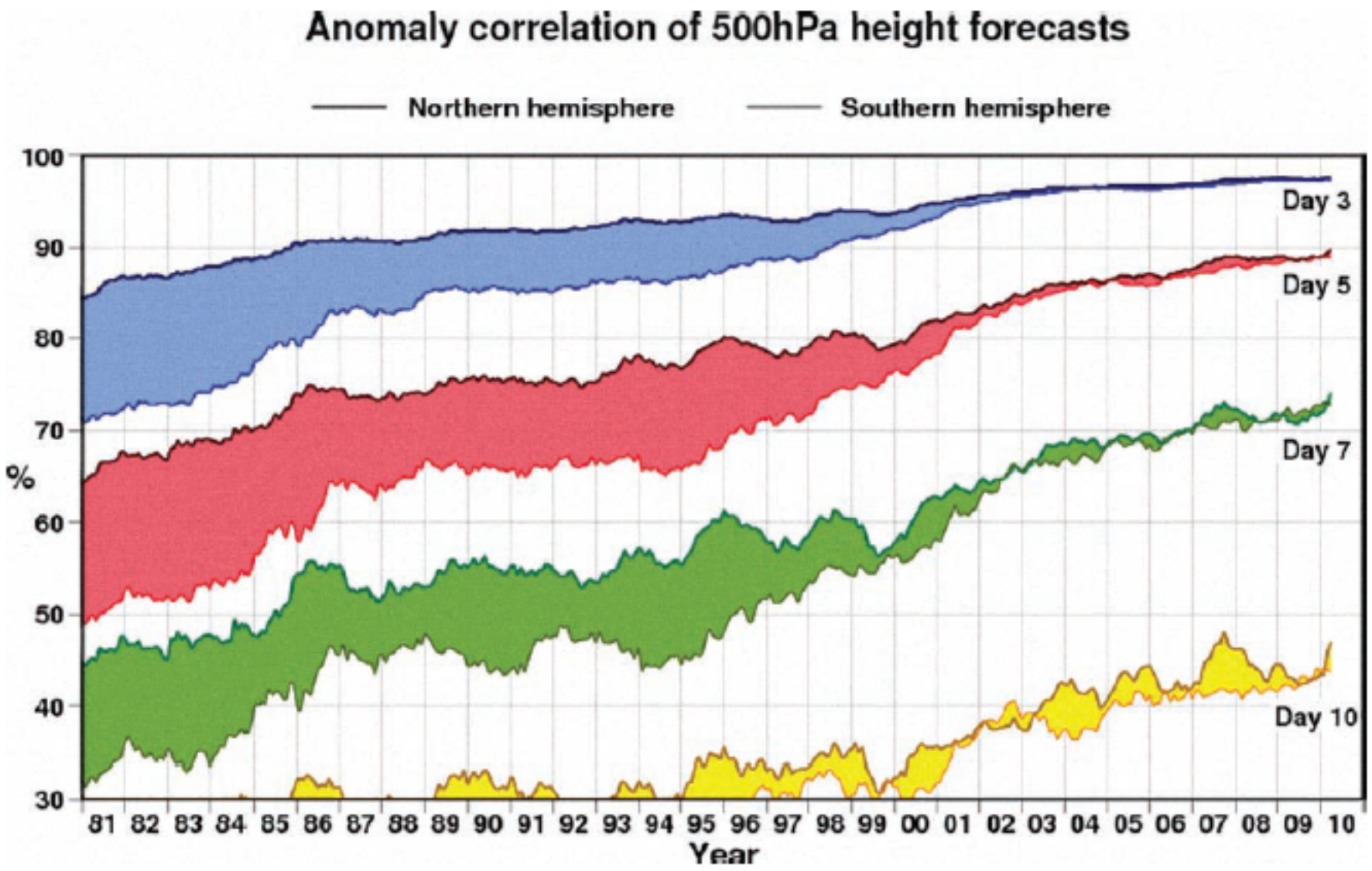
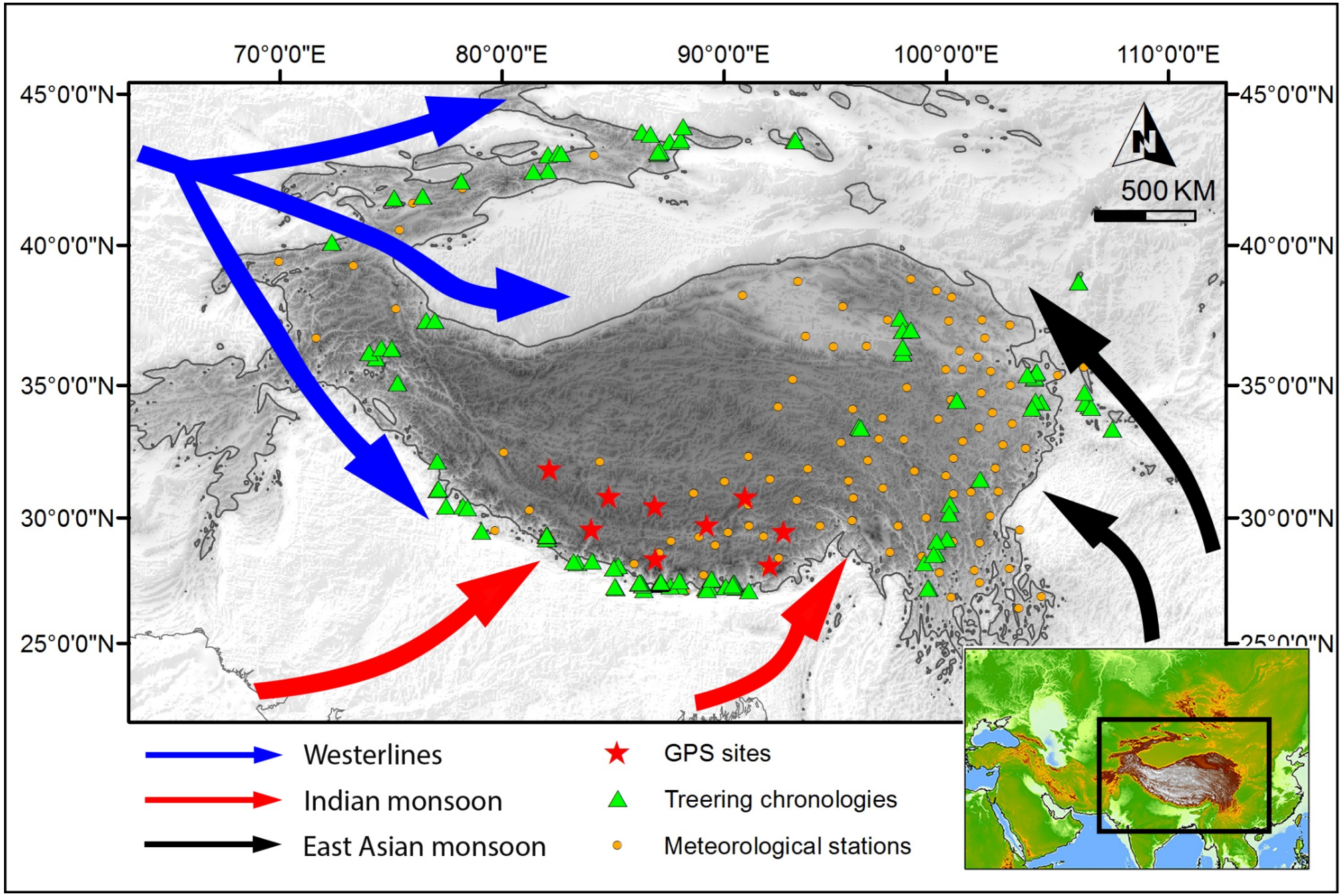
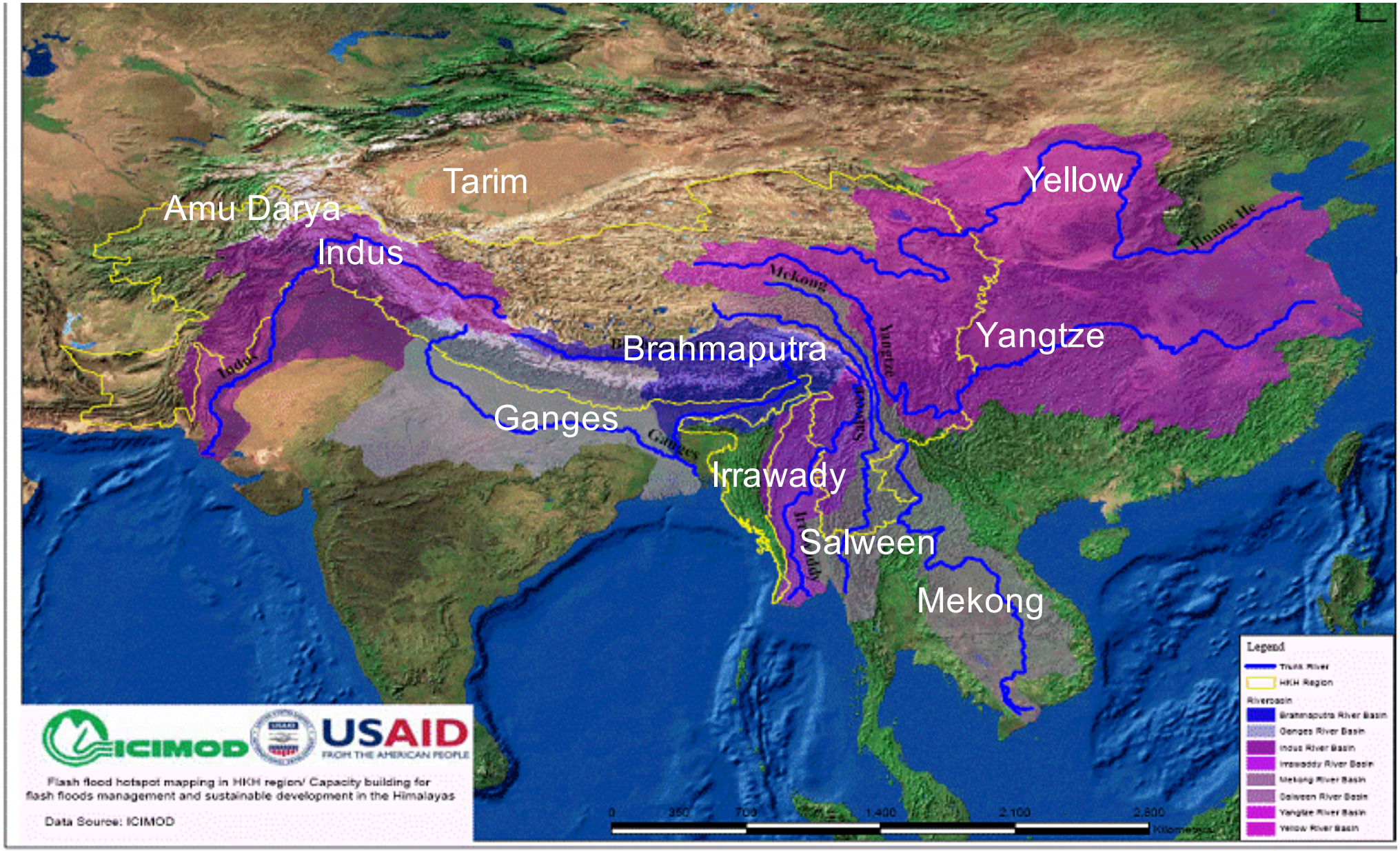


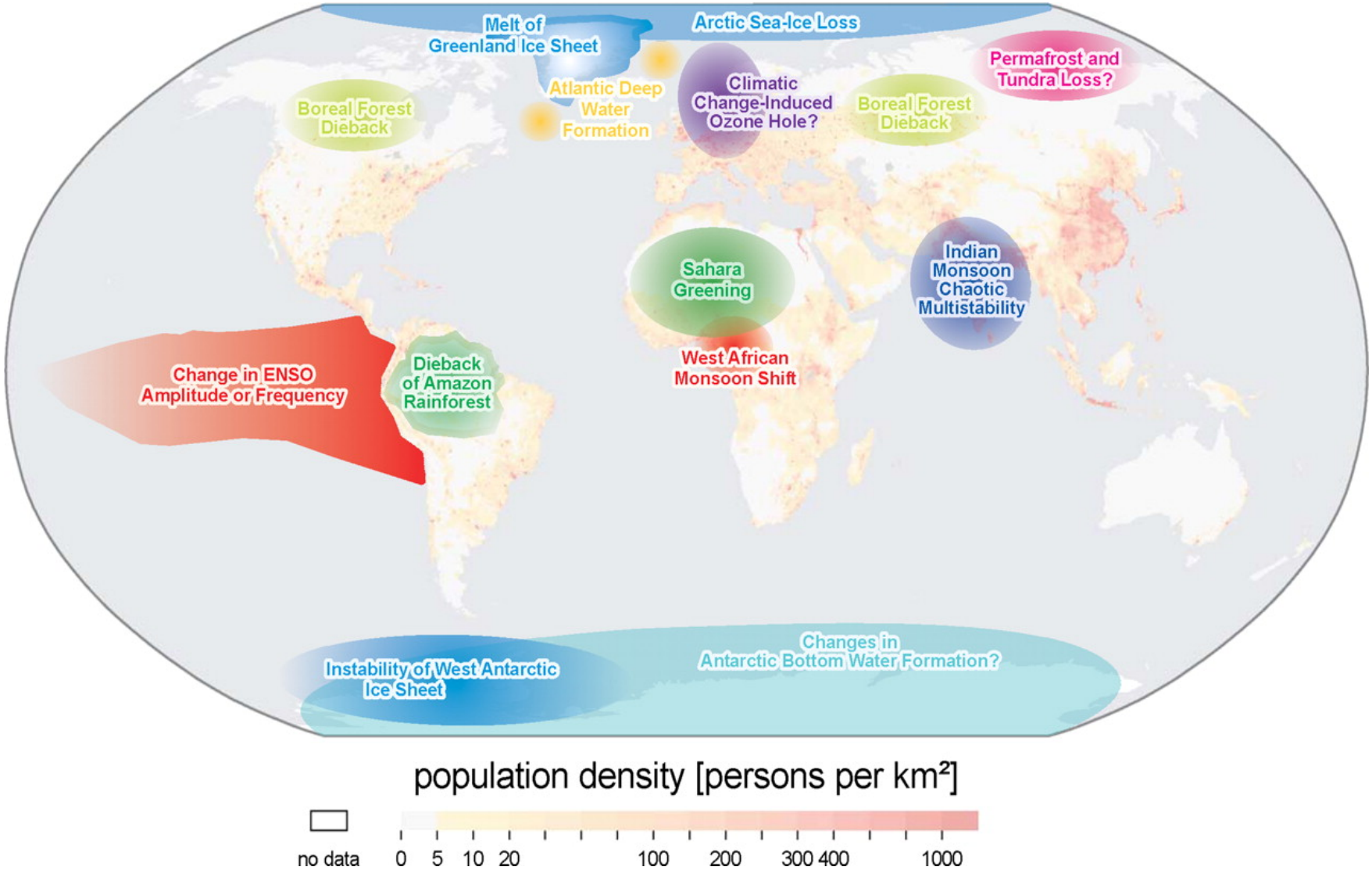
FIG. 1. Evolution of forecast skill for the extratropical Northern and Southern Hemispheres, January 1980–March 2010. Anomaly correlation coefficients of 3-, 5-, 7-, and 10-day ECMWF 500-mb height forecasts plotted as 12-month running means. Shading shows differences in scores between hemispheres at the forecast ranges indicated (adapted and extended from Simmons and Hollingsworth 2002).


70°0'0"E
80°0'0"E
90°0'0"E
100°0'0"E
110°0'0"E
45°0'0"N
40°0'0"N
35°0'0"N
30°0'0"N
25°0'0"N
N
500 KM
Westerlines
Indian monsoon
East Asian monsoon
GPS sites
Treering chronologies
Meteorological stations

10 major rivers in Asia are originated from the Tibet Plateau



Potential policy-relevant tipping elements in the climate system and overlain on global population density

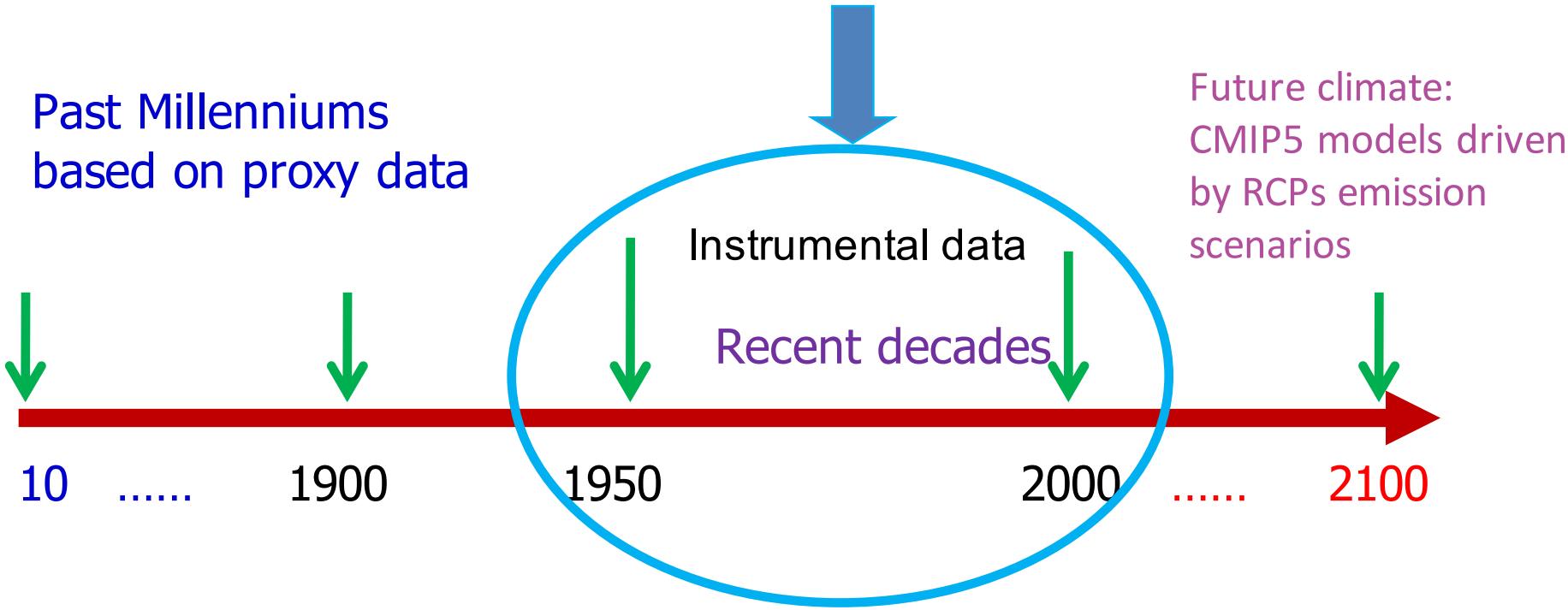


Timothy M. Lenton et al. PNAS 2008;105:1786-1793

Assessment of past, present and future environmental changes on the Tibetan Plateau

Participants & Duration: 80 authors, 24 reviewers, 2012-2015

Environment indices covered: **Climate**, **water, ecosystem**, anthropogenic impact, disaster/risk



科学通报
专题：青藏高原环境变化　评 述　www.scichina.com　csb.scichina.com
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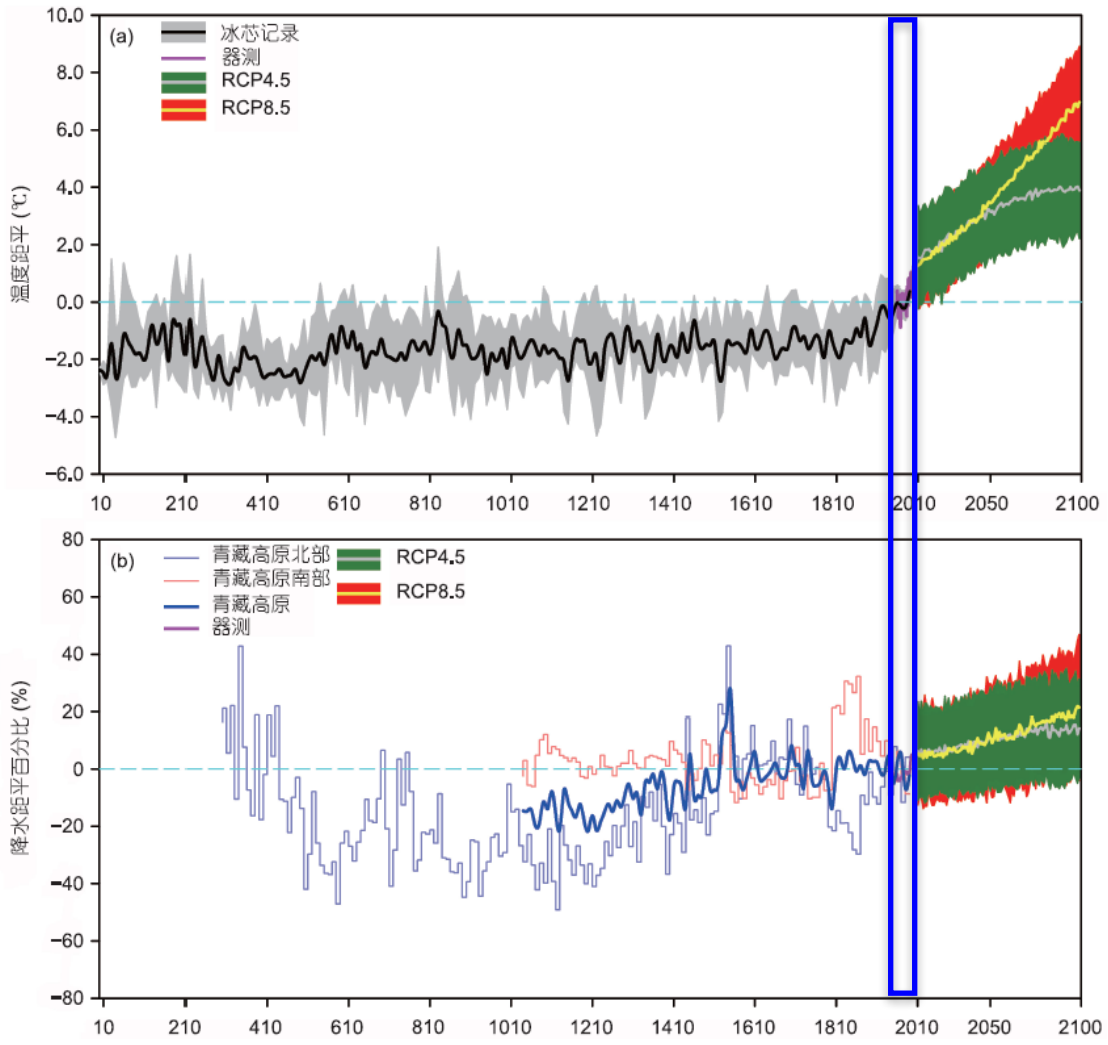
SCIENCE CHINA PRESS

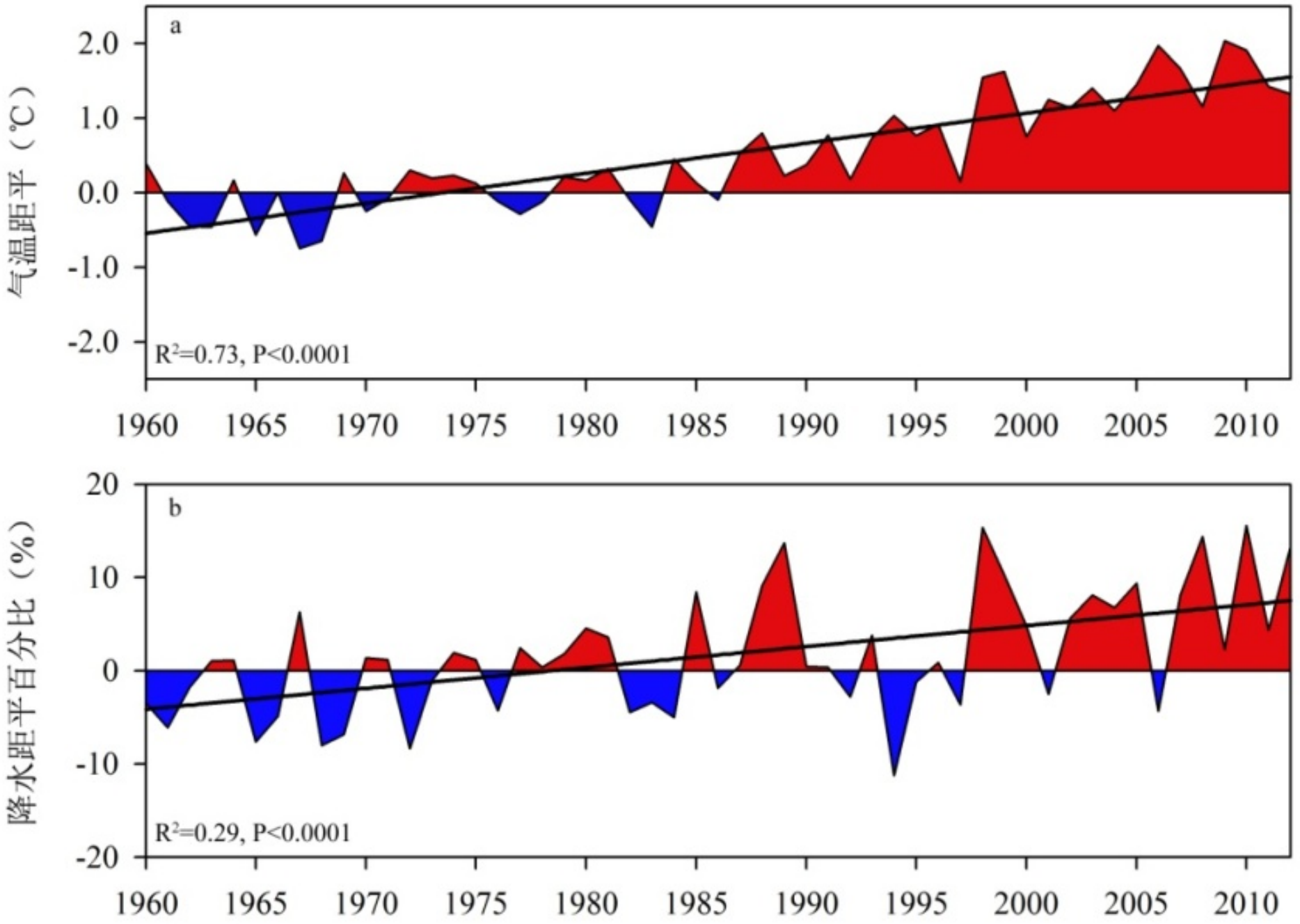
青藏高原环境变化科学评估：过去、现在与未来

陈德亮[①②]，徐柏青[①③]，姚檀栋[①③④*]，郭正堂[③⑤]，崔鹏[③⑥]，陈发虎[⑦]，张人禾[⑧]，
张宪洲[⑨]，张镱锂[⑨]，樊杰[⑨]，侯增谦[⑩]，张天华[⑪]

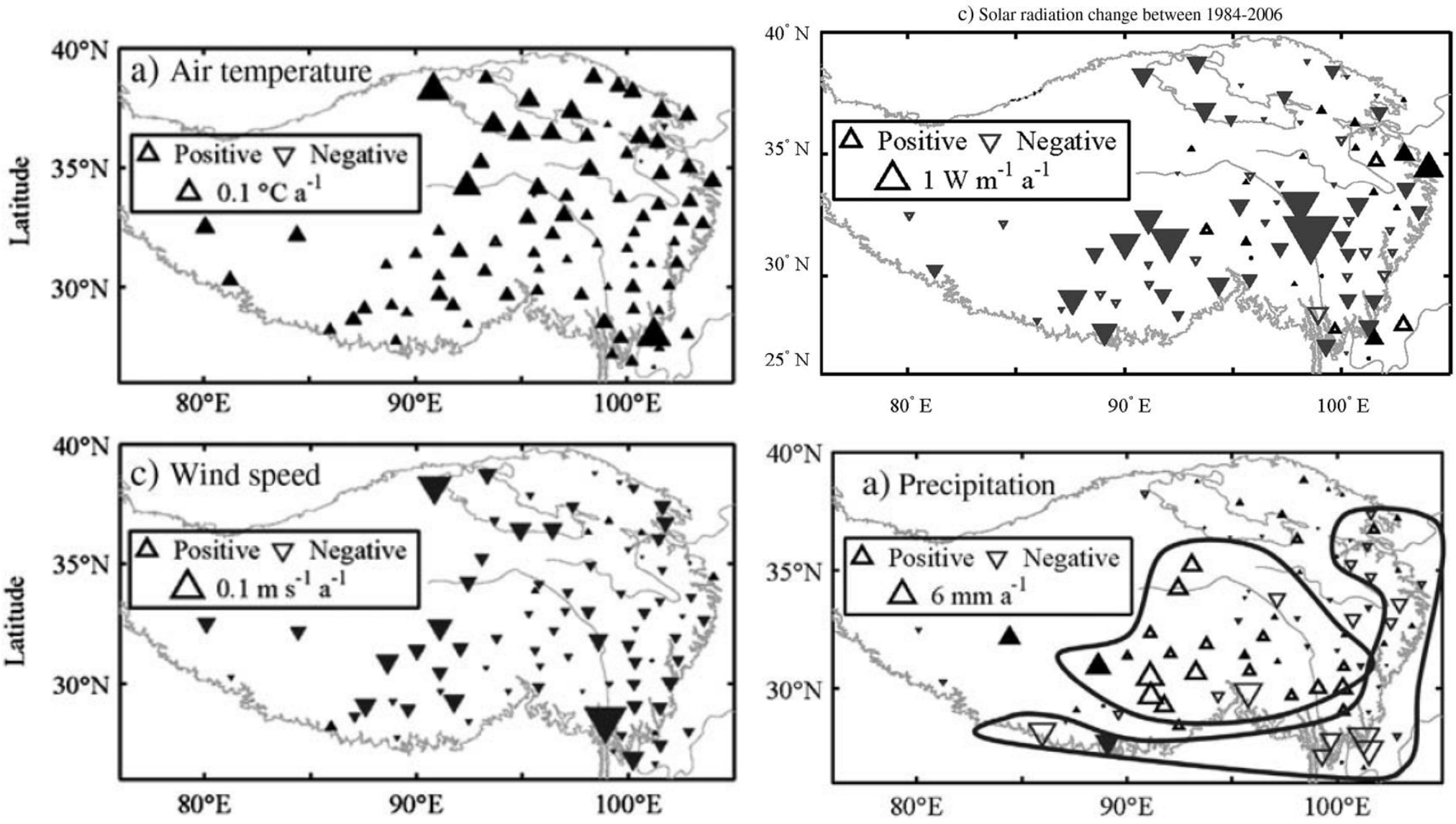
Chen, D., Xu, B., Yao, T., Guo, Z., Cui, P., Chen, F., Zhang, R., Zhang, X., Zhang, Y., Fan, J., Hou, Z., Zhang, T., 2015: Assessment of past, present and future environmental changes on the Tibetan Plateau ***Chinese Science Bulletin***, in Chinese with English abstract, doi: 10.1360/N972014-01370.

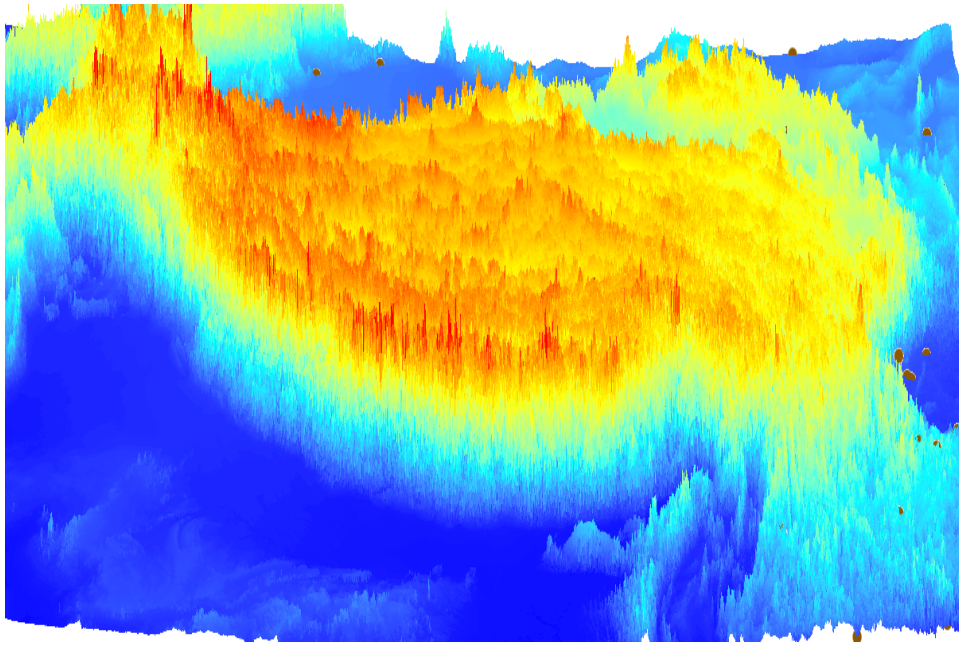


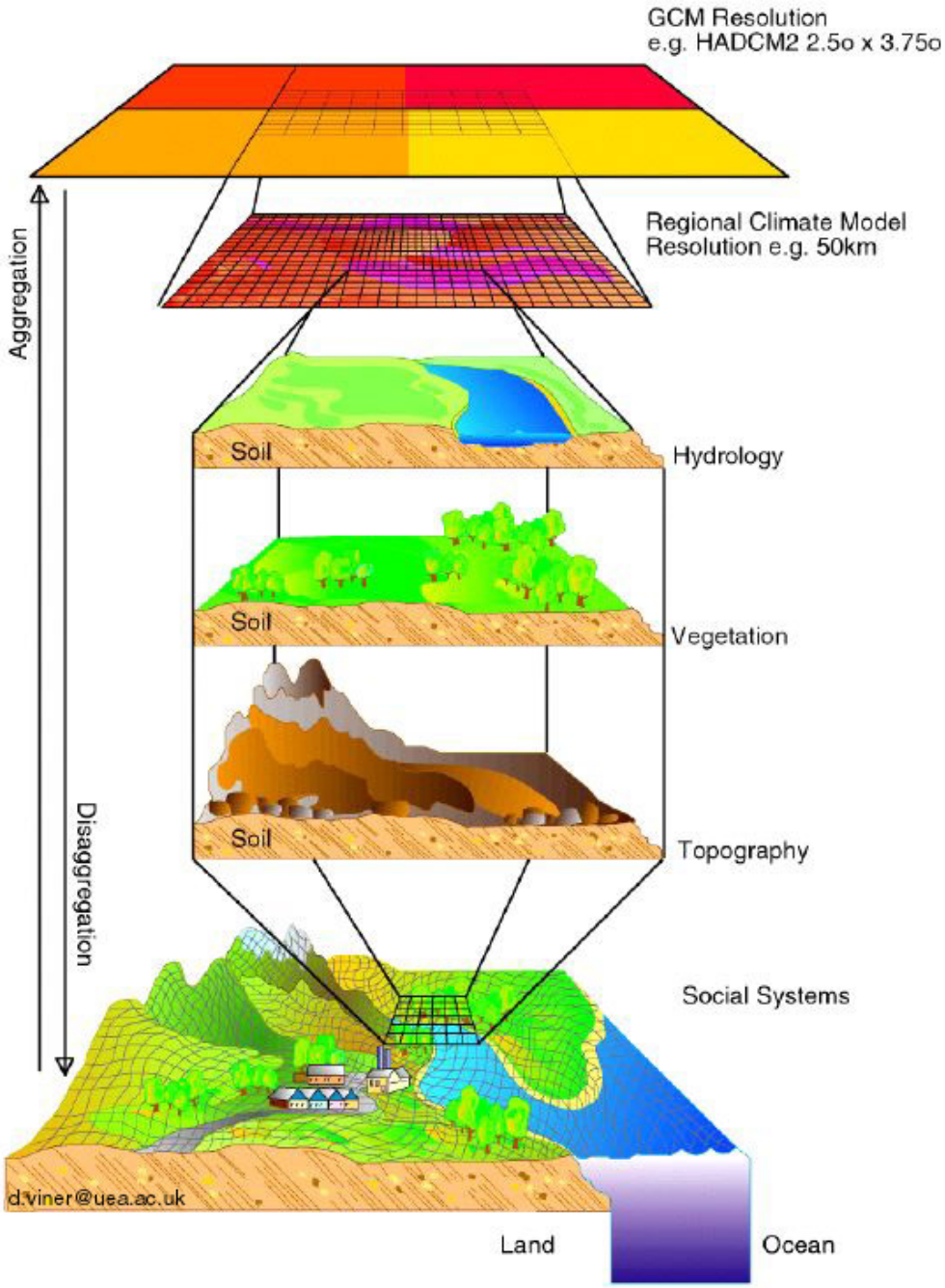
Annual anomalies of temperature (a) and precipitation (b) over Tibet



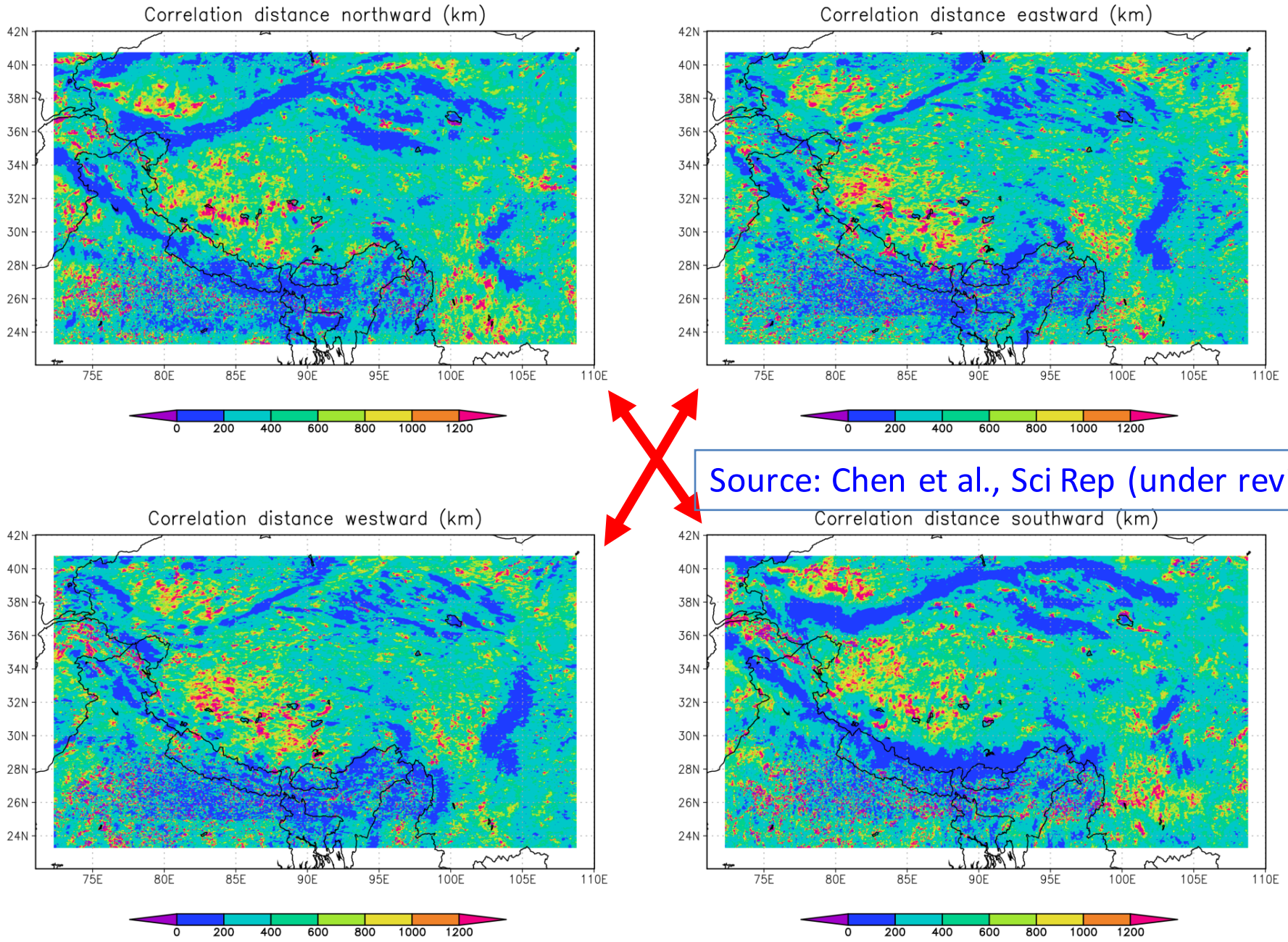
Trends of annual changes over the priod of 1984-2006 (Yang et al., 2014, GPC)





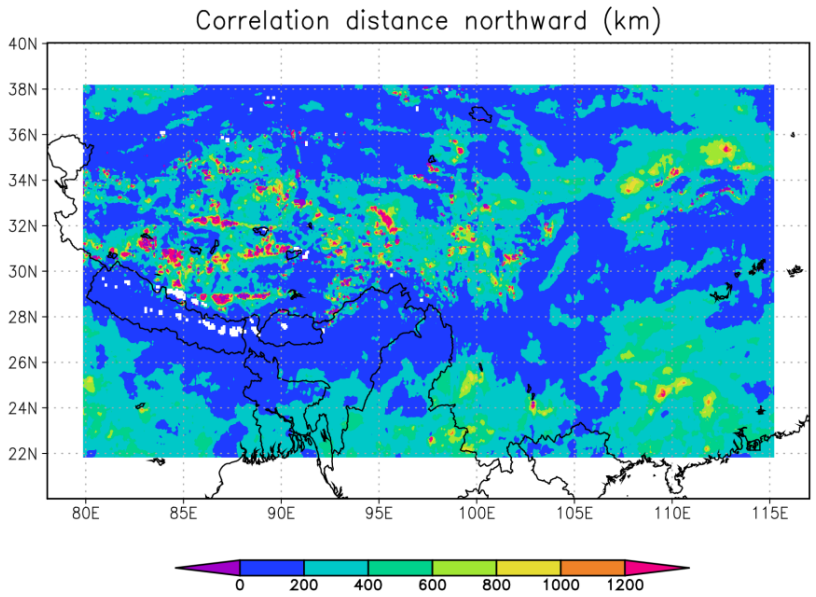

GCM Resolution
e.g. HADCM2 2.5o x 3.75o
Regional Climate Model
Resolution e.g. 50km
Aggregation
Disaggregation
Soil
Hydrology
Soil
Vegetation
Soil
Topography
Social Systems
d.viner@uea.ac.uk
Land
Ocean

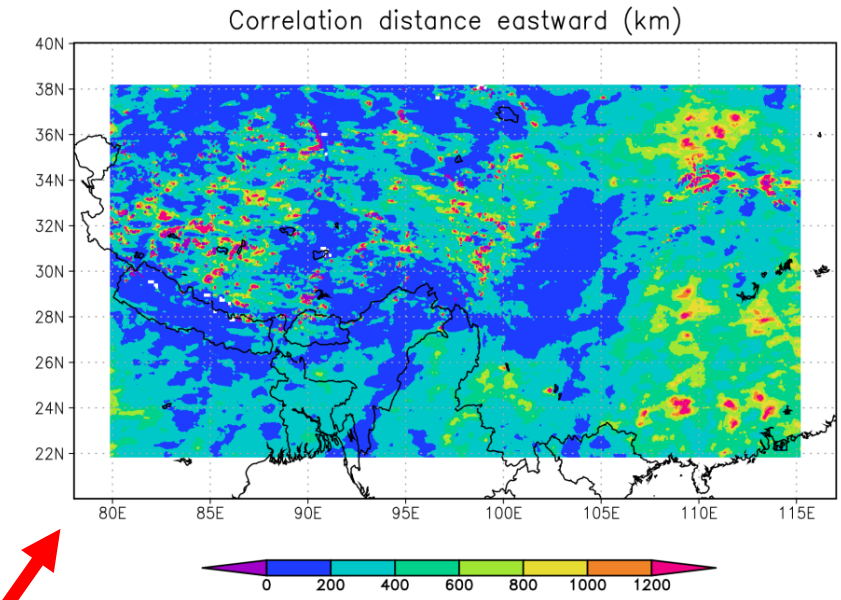
Scale for interannual surface temperature variation



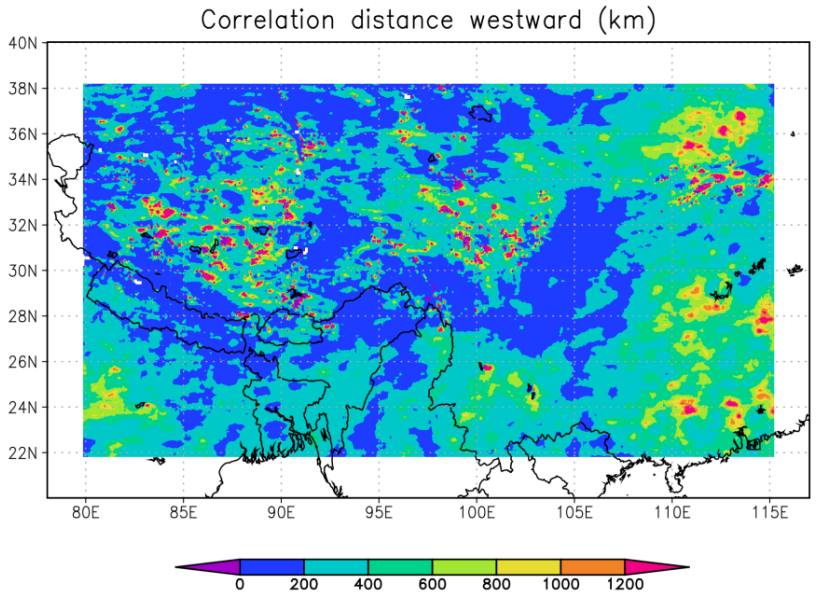
Source: Chen et al., Sci Rep (under revision)

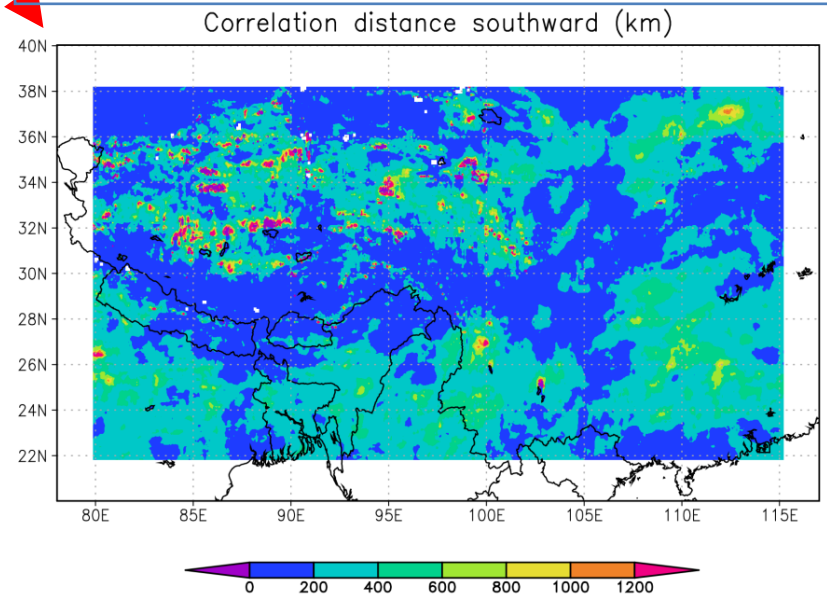
Scale for interannual precipitation variation



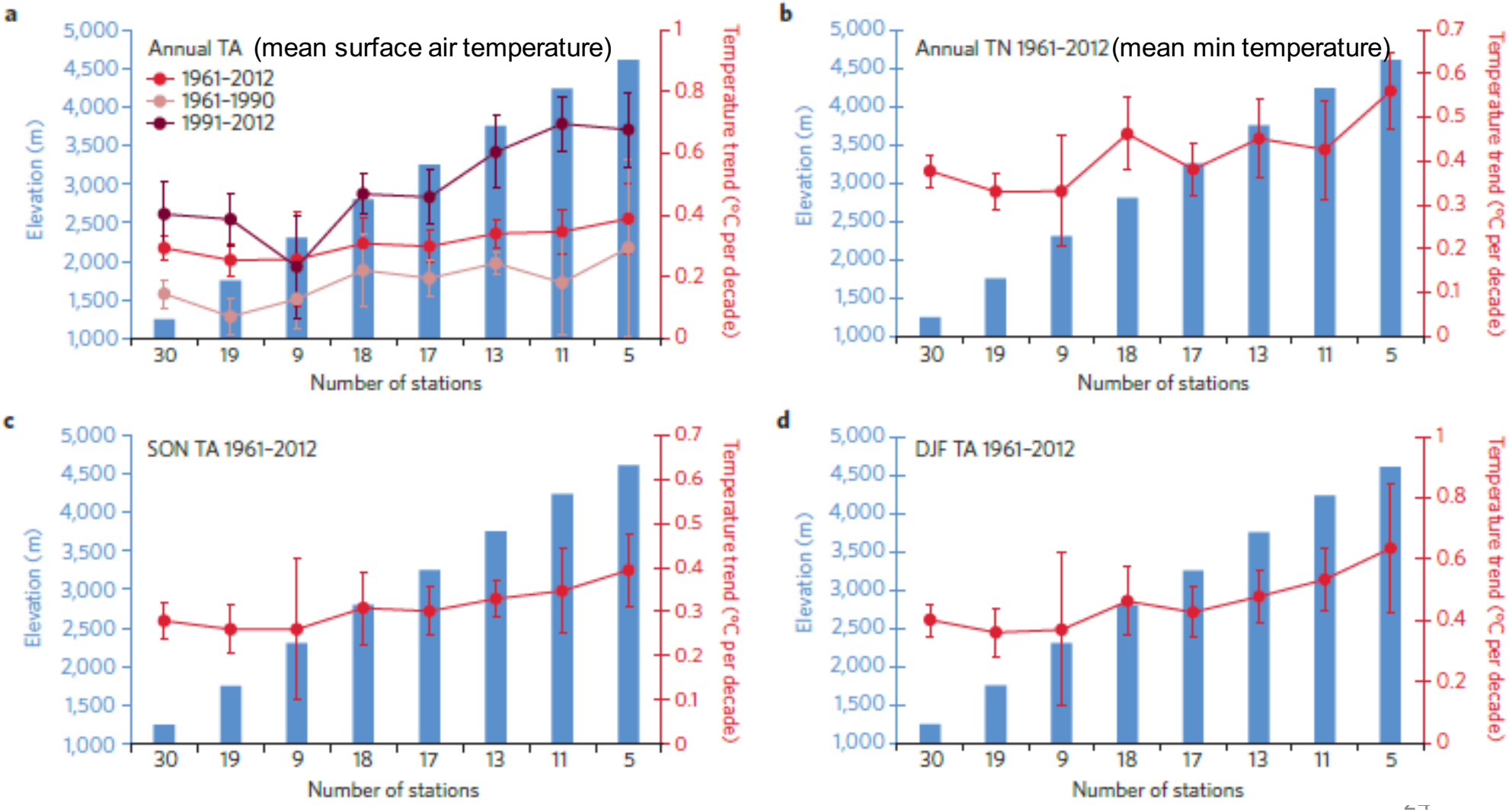


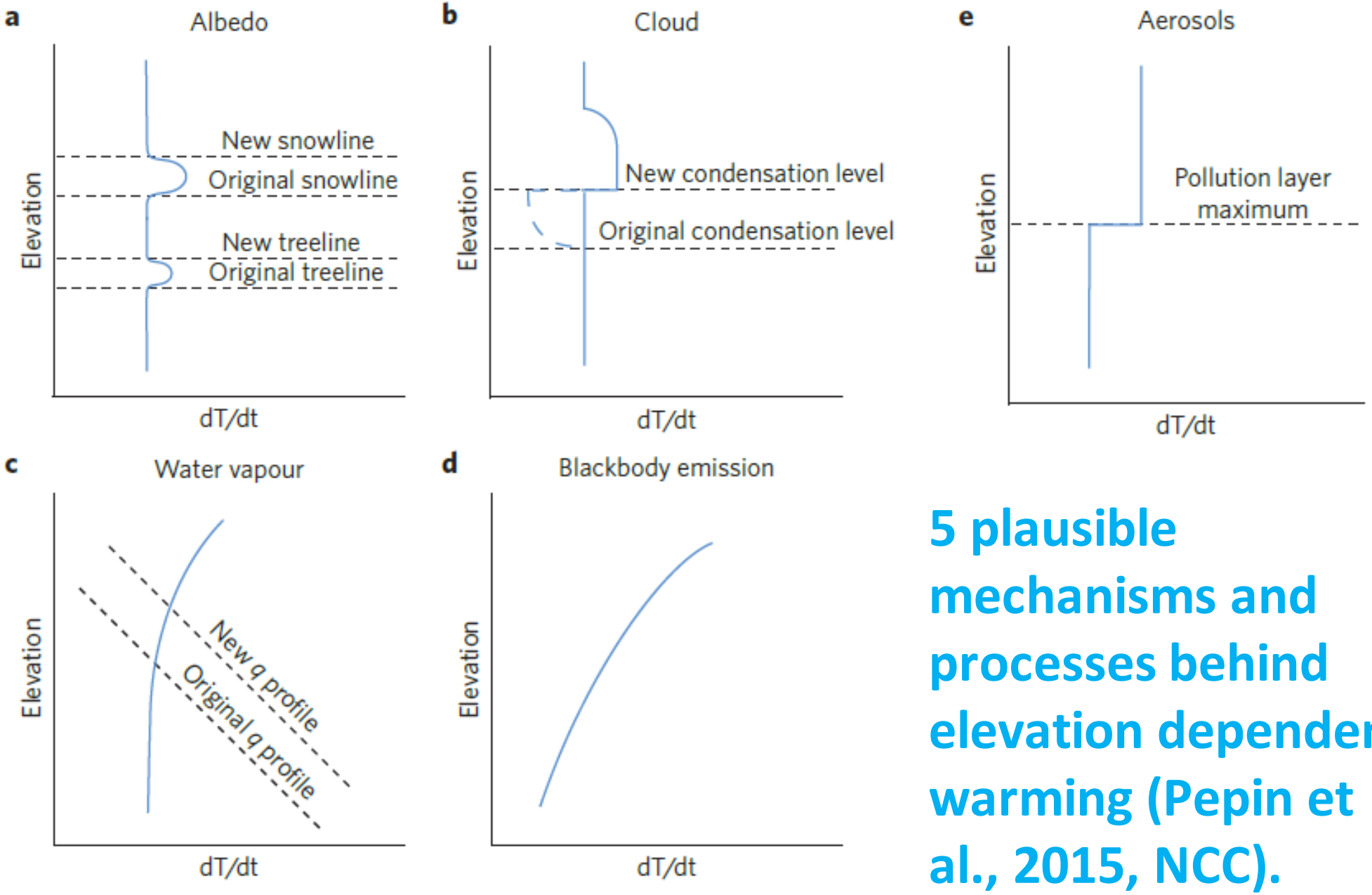
Source: Chen et al., Sci Rep (under revision)





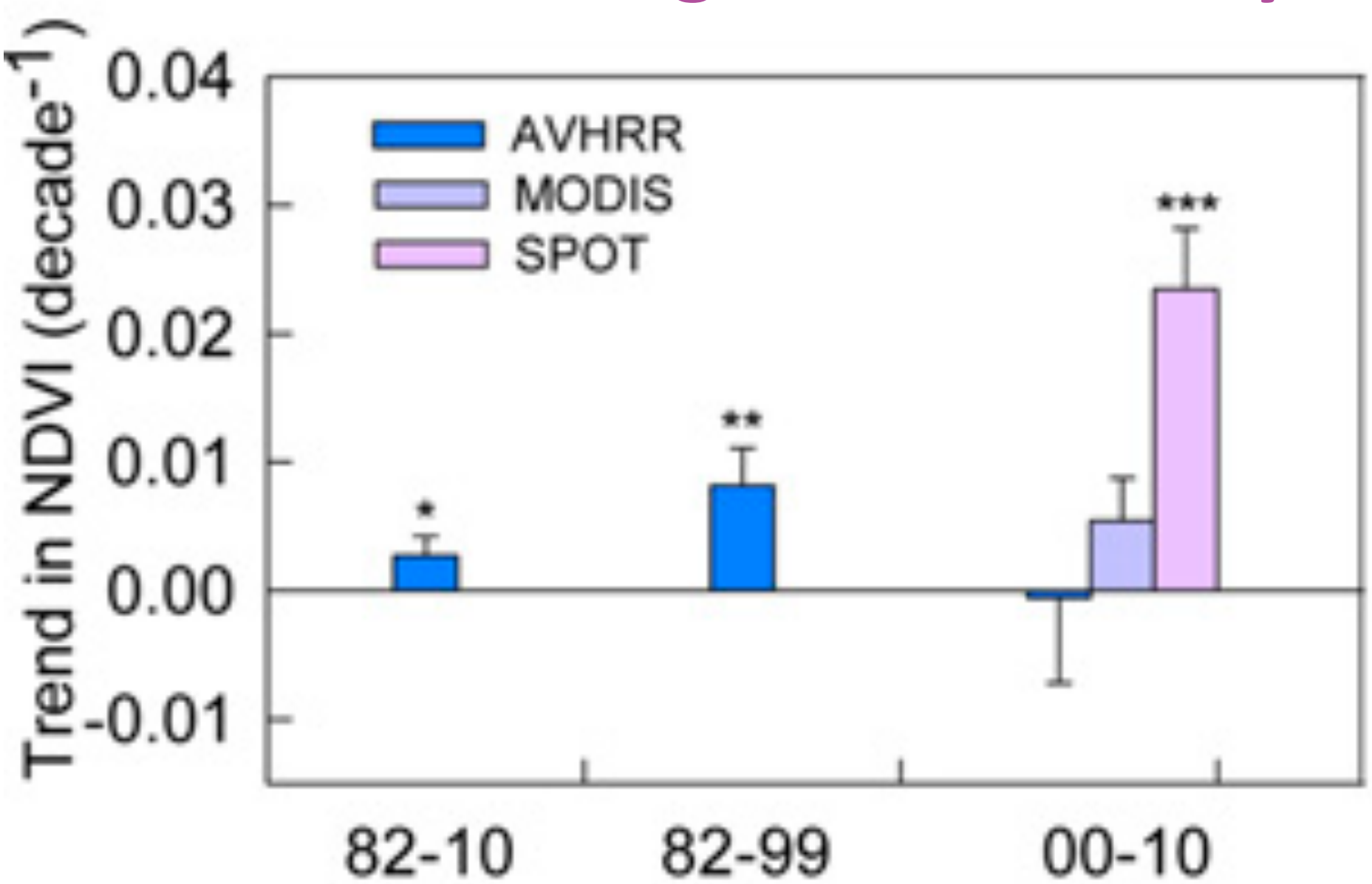
Elevation depedended warming over Tibet (Pepin et al., 2015, NCC)





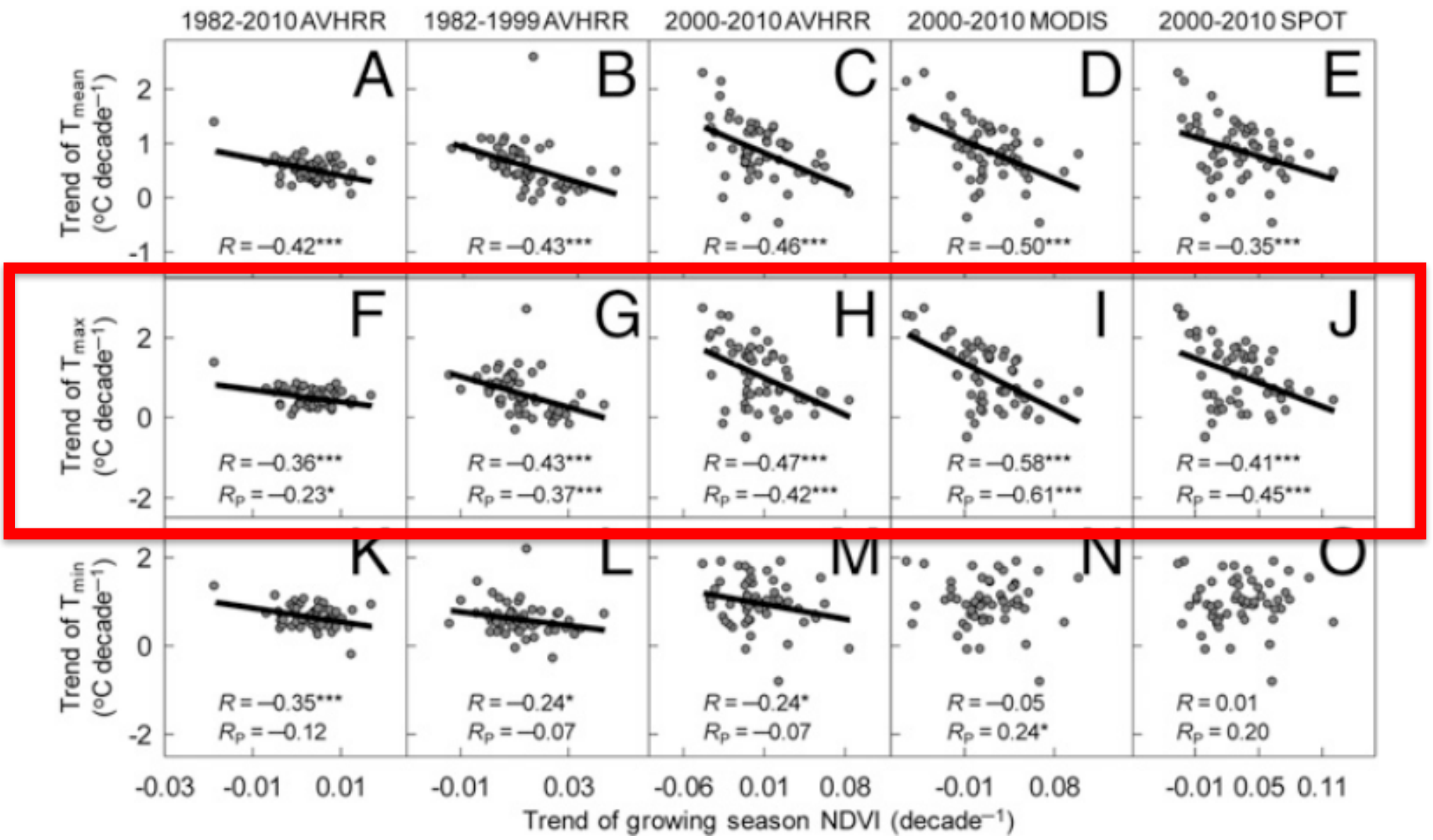
5 plausible mechanisms and processes behind elevation dependent warming (Pepin et al., 2015, NCC).

Increased vegetation activity

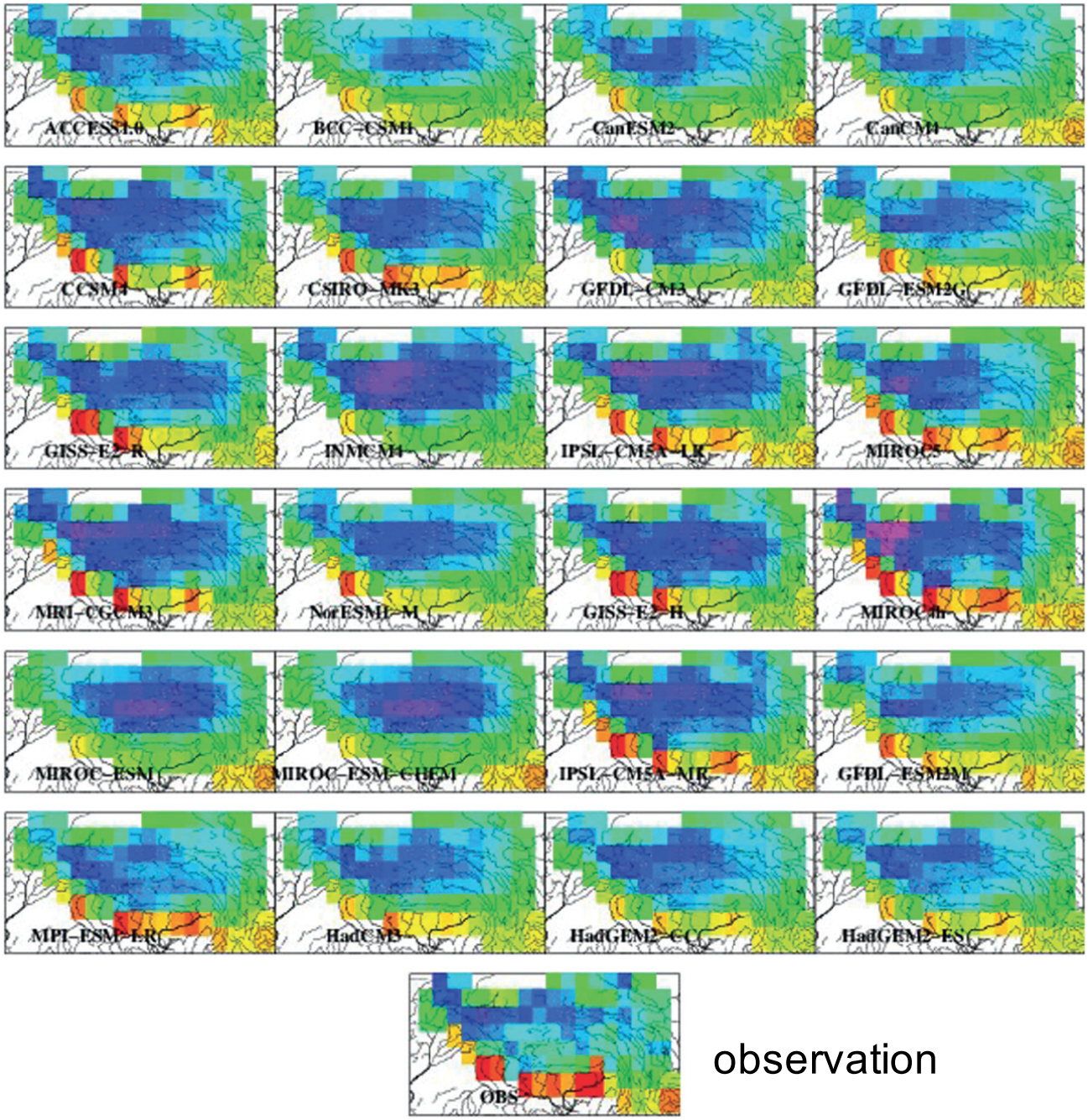


Shen, M., S. Piao, S.-J. Jeong, P. Ciais, D. Chen, C.-S. Jin, L. Z. X. Li, R. Myneni, K. Yang, Z. Zeng, G. Zhang, L. Zhou, T. Yao. 2015: Evaporative cooling over the Tibetan plateau induced by vegetation growth. **PNAS**, doi: 10.1073/pnas.1504418112.

The greening -> evapotranspiration↑ & warming↓

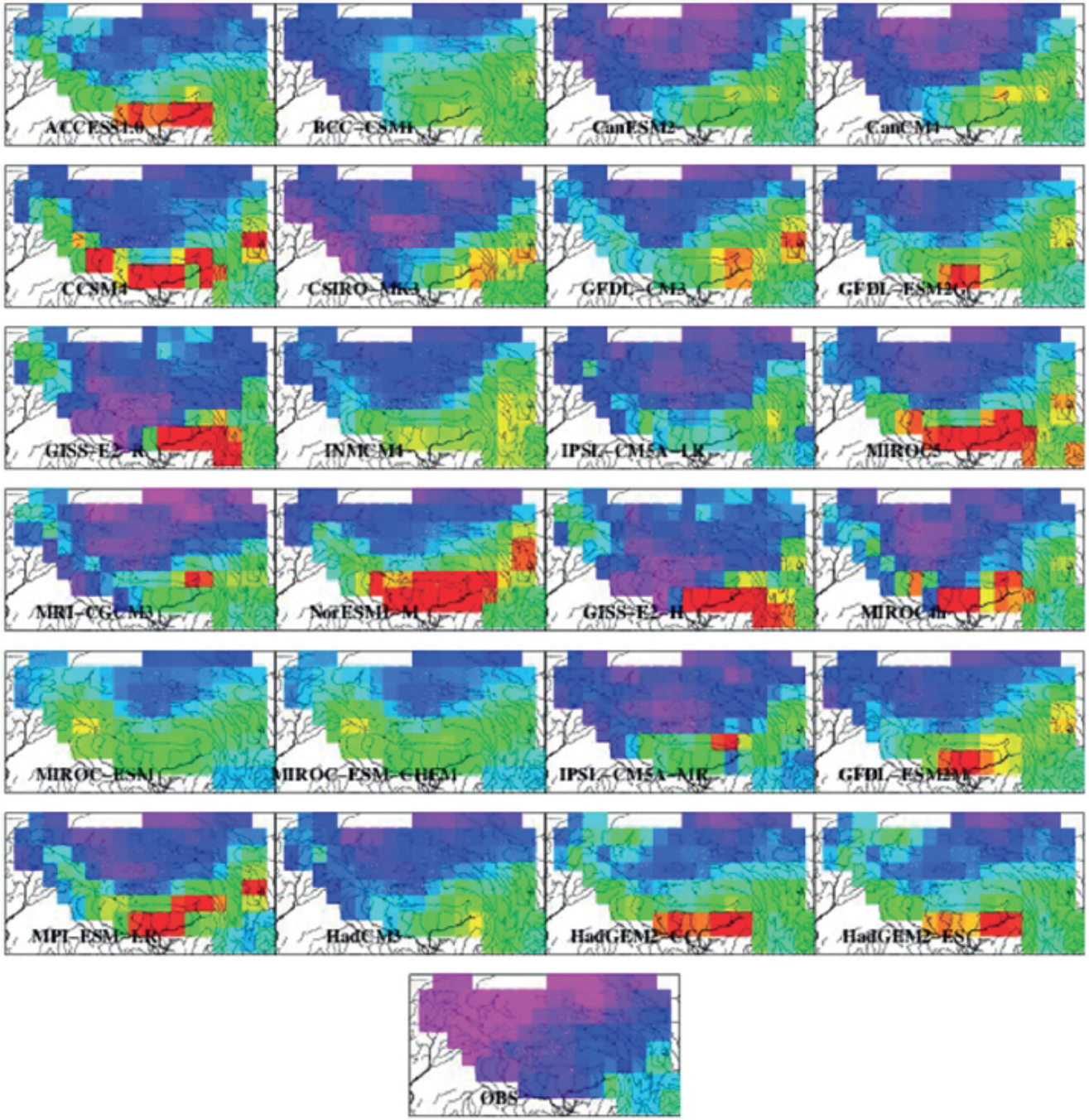


Shen, M., S. Piao, S.-J. Jeong, P. Ciais, D. Chen, C.-S. Jin, L. Z. X. Li, R. Myneni, K. Yang, Z. Zeng, G. Zhang, L. Zhou, T. Yao. 2015: Evaporative cooling over the Tibetan plateau induced by vegetation growth. **PNAS**, doi: 10.1073/pnas.1504418112.



Mean annual temperature from 24 CMIP5 models.

Source:
Su, F., X. Duan, D. Chen, Z. Hao, and C. Lan, 2013: Evaluation of the Global Climate Models in the CMIP5 over the Tibetan Plateau. **J. Climat**e, DOI: 10.1175/JCLI-D-12-00321.1.

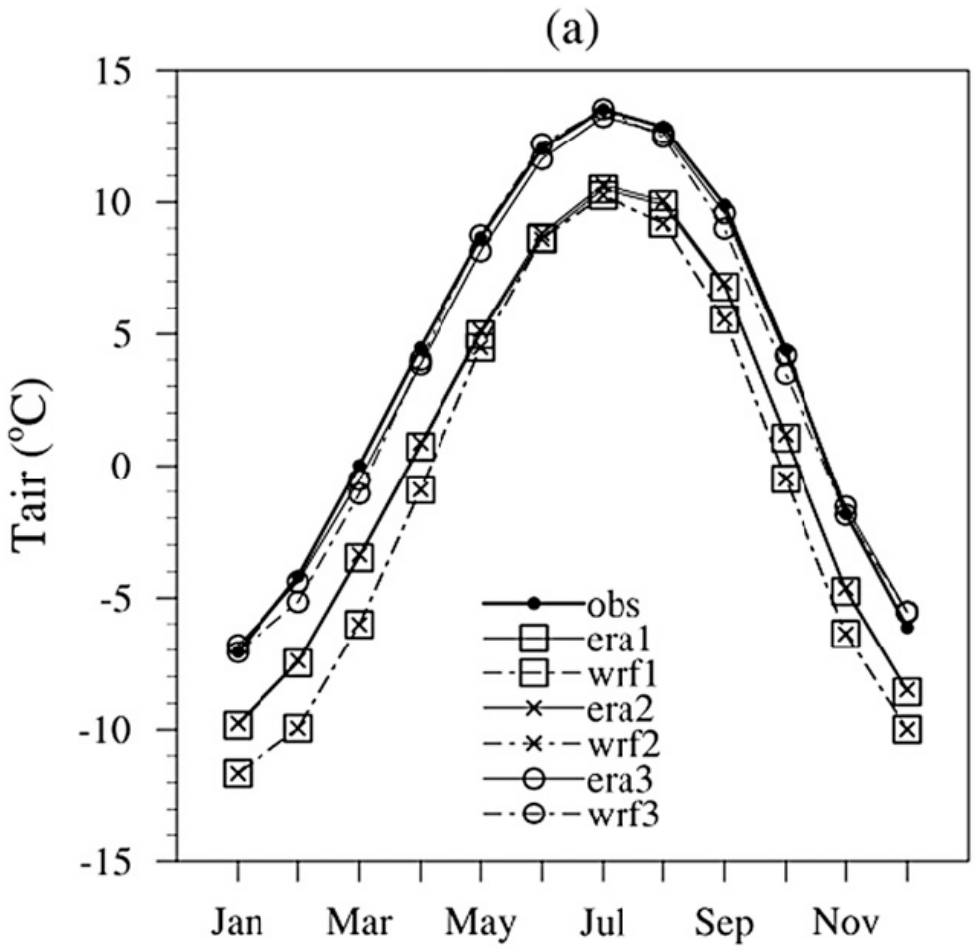


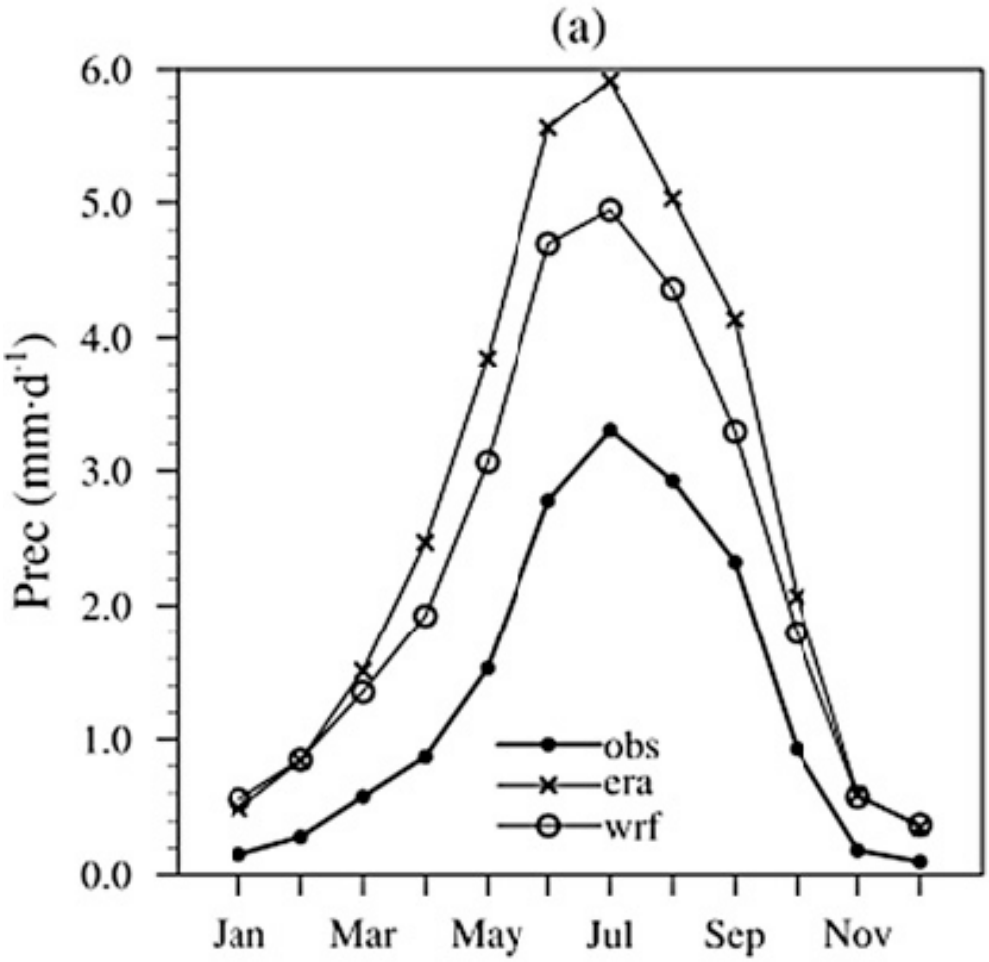
Annual precipitation spatial distribution for 24 GCM,for the TP

Mean annual precipitation from 24 CMIP5 models.

Source:
Su, F., X. Duan, D. Chen, Z. Hao, and C. Lan, 2013: Evaluation of the Global Climate Models in the CMIP5 over the Tibetan Plateau. **J. Climat**e, DOI: 10.1175/JCLI-D-12-00321.1.

Added value by downscaling with WRF (30 km resolution), means for 1979-2011





Source: Gao, Y., J. Xu, D. Chen, 2015: Evaluation of WRF Mesoscale Climate Simulations over the Tibetan Plateau during 1979-2011, **J. Climate,** doi:10.1175/JCLI-D-14-00300.1

Added value by downscaling with WRF (30 km resolution), means for 1979-2011

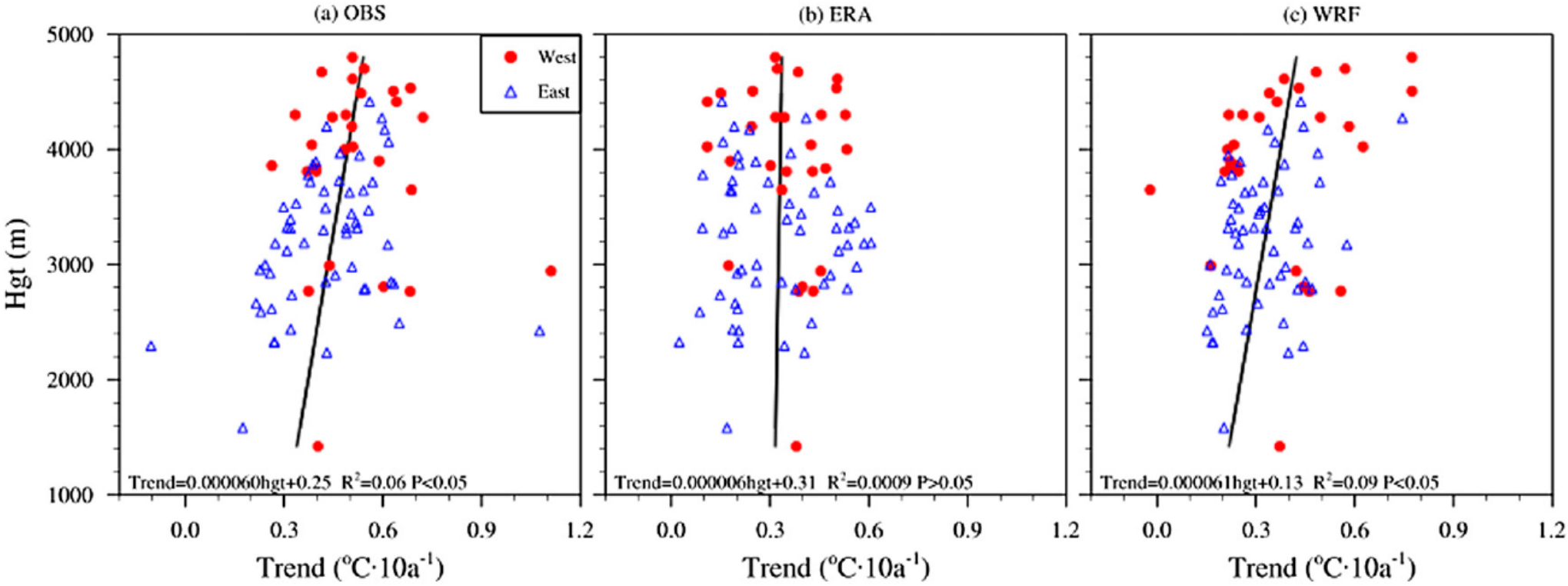
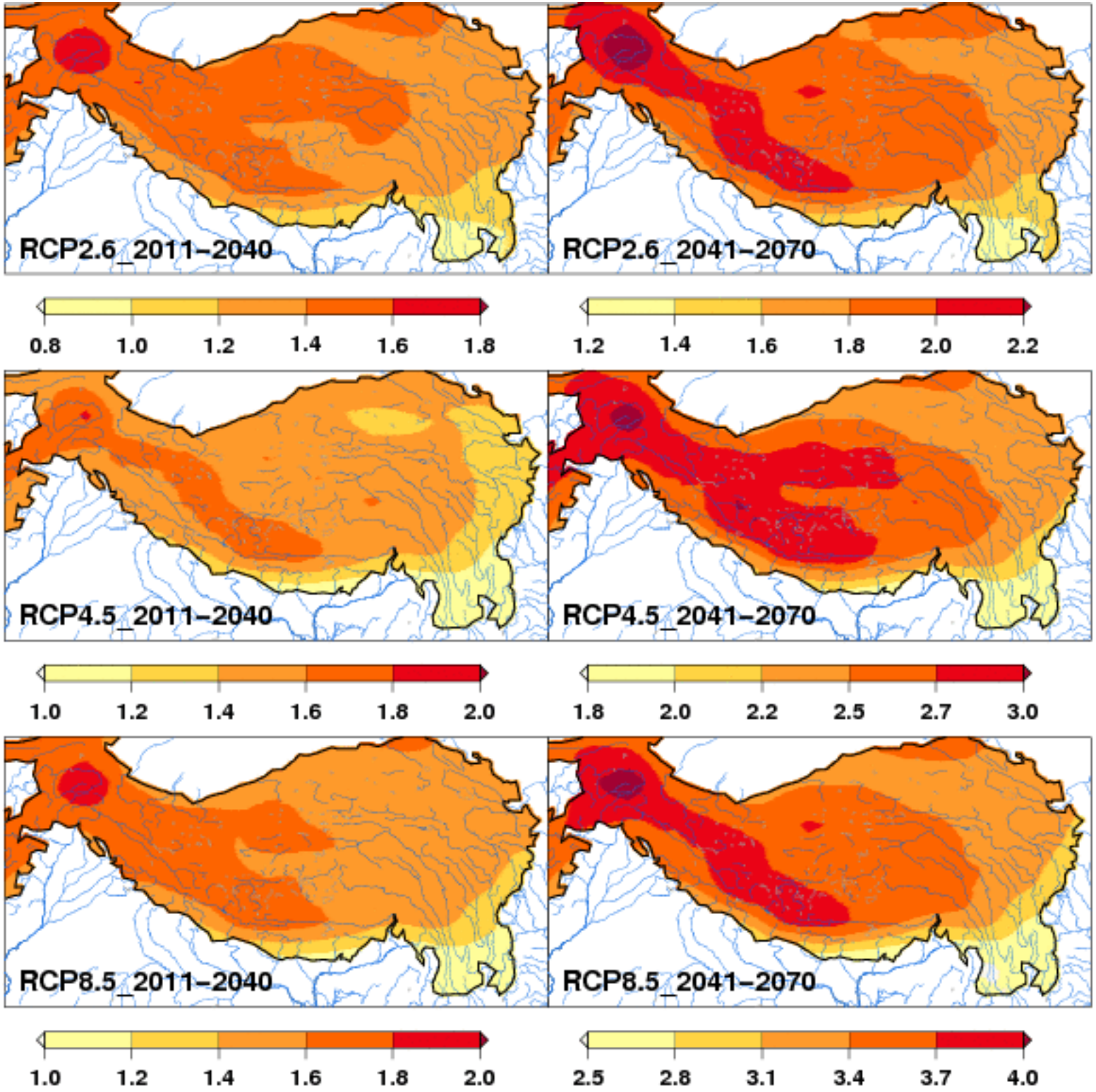


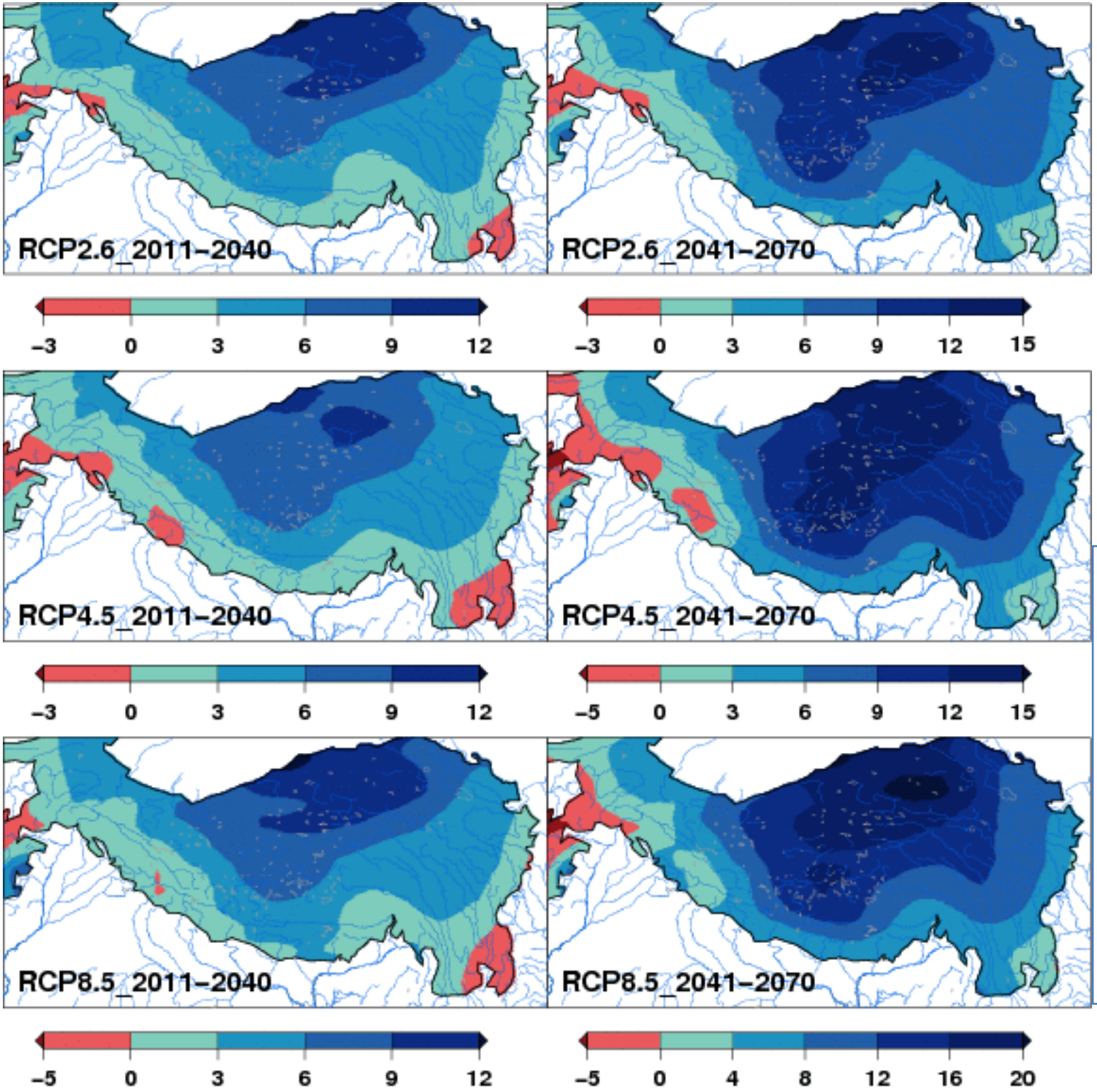
FIG. 6. Scatterplots of Tair at the 83 stations over the TP vs elevation: (a) the station observations, (b) ERA-Int, and (c) the WRF simulation. West is west of 95°E and East is east of 95°E.

Source: Gao, Y., J. Xu, D. Chen, 2015: Evaluation of WRF Mesoscale Climate Simulations over the Tibetan Plateau during 1979-2011, **J. Climate,** doi:10.1175/JCLI-D-14-00300.1



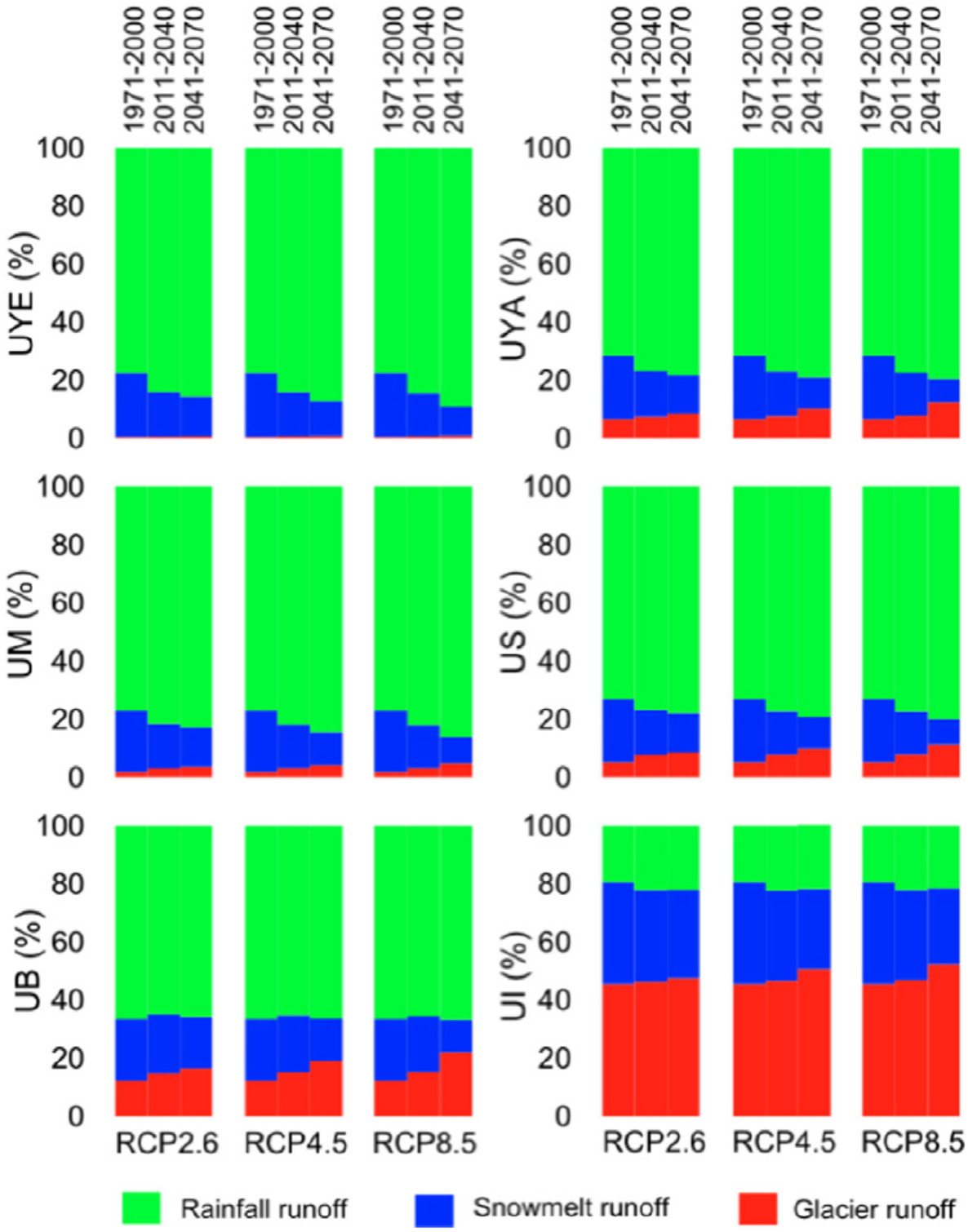
Mean change (ºC) of mean annual temperature from 20 CMIP5 models

Source:
Su, F., L. Zhang, T. Ou, D. Chen, T. Yao, and K. Tong, 2015: Hydrological response to future climate changes for the major upstream river basins in the Tibetan Plateau, Global and Planetary Change, 136, 82-95.



Mean change (%) of annual precipitation from 20 CMIP5 models.

Source:
Su, F., L. Zhang, T. Ou, D. Chen, T. Yao, and K. Tong, 2015: Hydrological response to future climate changes for the major upstream river basins in the Tibetan Plateau, Global and Planetary Change, 136, 82-95.

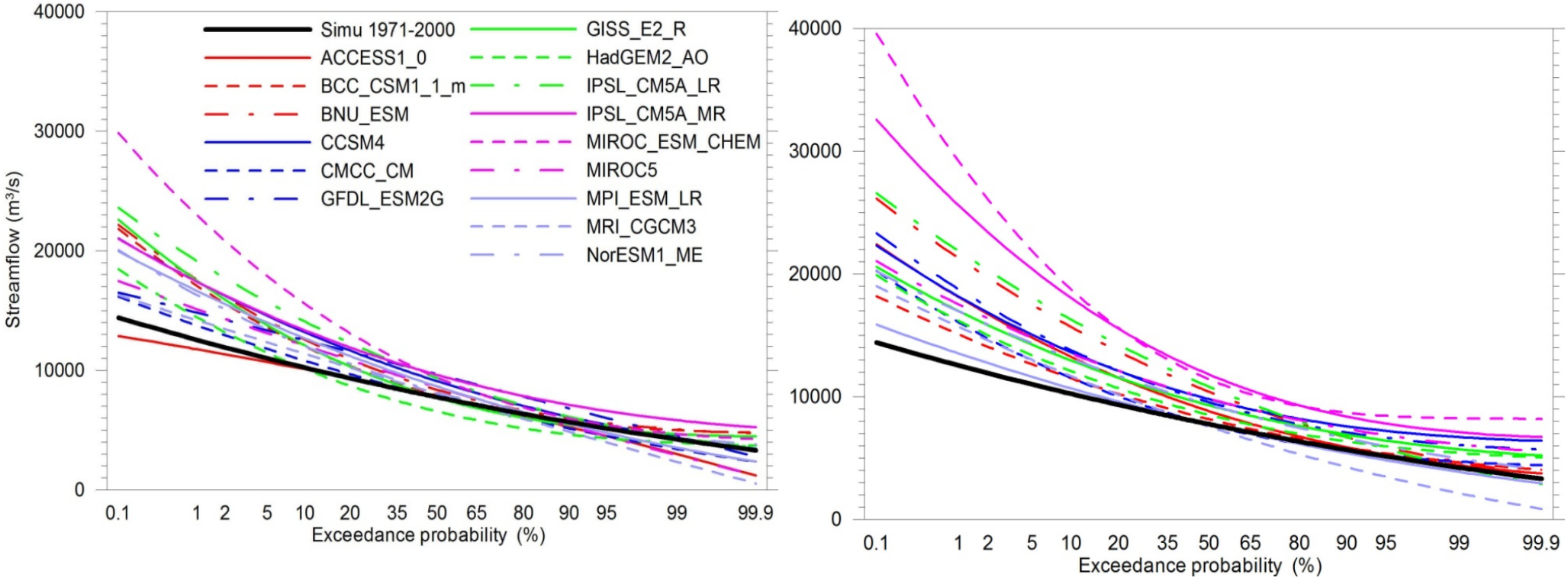


Source:
Su, F., L. Zhang, T. Ou, D. Chen, T. Yao, and K. Tong, 2015: Hydrological response to future climate changes for the major upstream river basins in the Tibetan Plateau, Global and Planetary Change, 136, 82-95.

Exceedance probability curve for the peak flow at the Nuxia in the upper Brahmaputra

a) 2020-2049

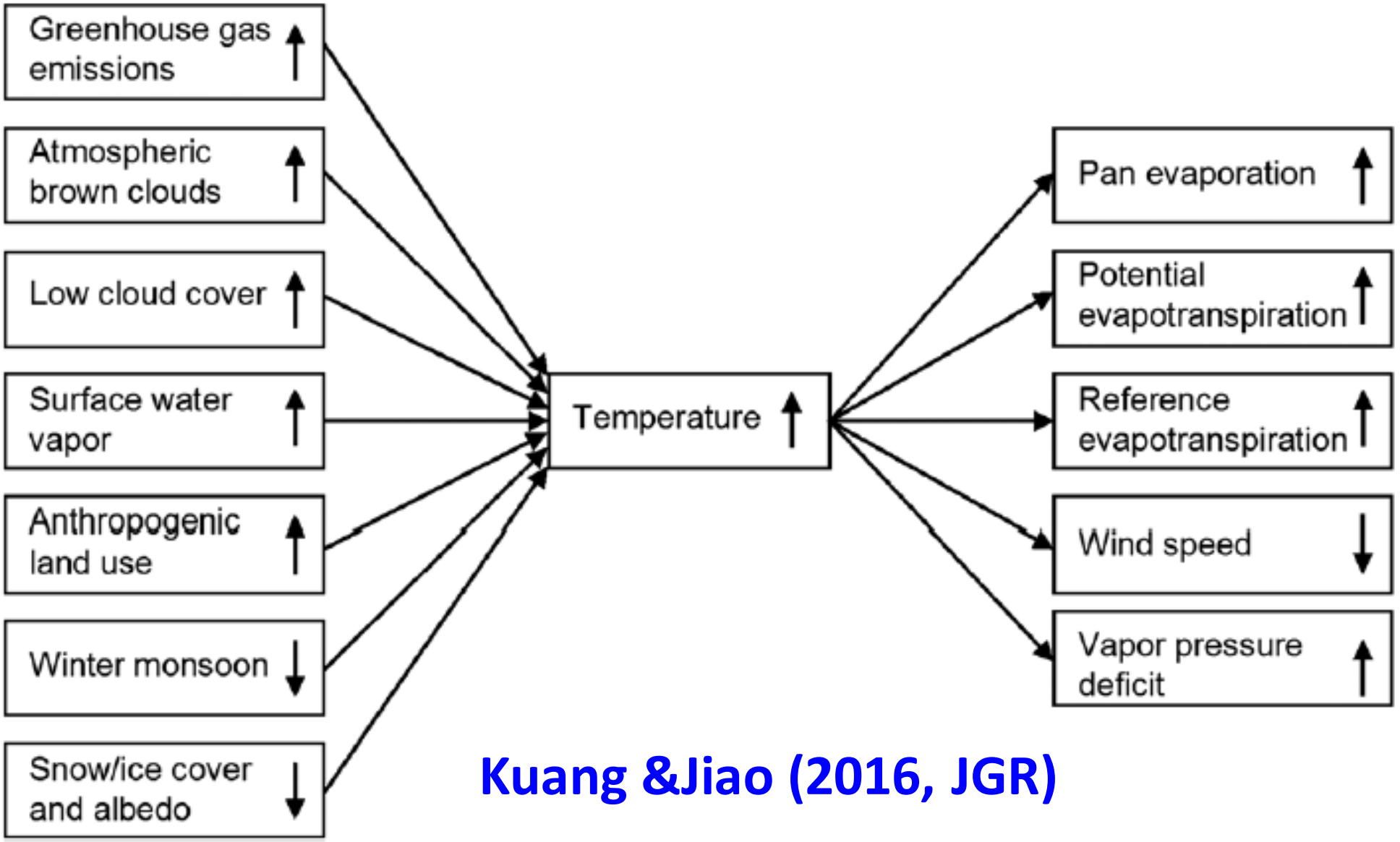
b) 2070-2099



Intensity and frequency of extreme discharges would likely increase in the upper Brahmaputra.

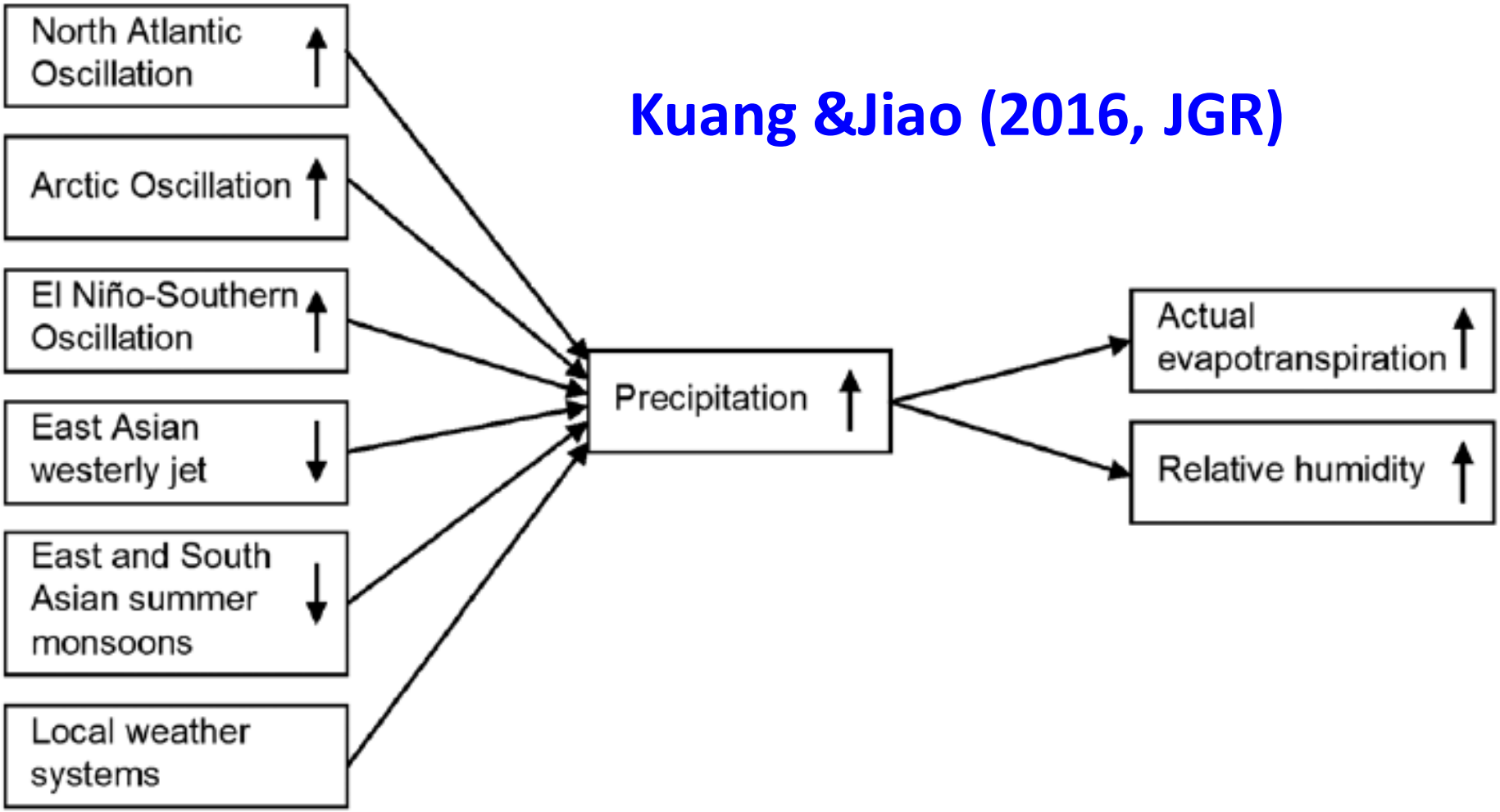
Take home messages

- Climate over Tibet has experienced significant changes in the past, with warming and overall wetting and stilling, along with distinctive regional changes in precipitation and solar radiation over the last decades.
- Big data framework and data assimilation approaches hold great potential to fill the observation gaps and provide more insights into details of and processes behind the climate change in this challenging and important region.



Kuang &Jiao (2016, JGR)

Figure 17. Causes of the temperature increase on the TP and the results of the increasing temperature. The upward arrow means increasing and the downward arrow means decreasing.



Kuang &Jiao (2016, JGR)

Figure 18. Causes of the precipitation increase on the TP and the results of the increasing precipitation. The upward arrow means increasing and the downward arrow means decreasing.