主办单位：中国科学院青藏高原研究所

中国青藏高原研究会

青藏高原科学大讲堂

Tibetan Plateau Science Forum

第一讲

2011 年 6 月 9 日

中国科学院青藏高原研究所（北京市海淀区双清路 18 号）

http://www.itpcas.cas.cn/

目 录

青藏高原科学大讲堂

Tibetan Plateau Science Forum

“青藏高原科学大讲堂”是由中国科学院青藏高原研究所、中国青藏高原研究会共同主办的青藏高原科学问题的学术论坛。

该论坛的主要目的在于体现青藏高原研究的高水平、国际化、学科交叉融合等特点,。

论坛将聘请国内外知名科学家针对青藏高原科学的热点和前沿科学问题和研究进展做讲座和交流。

主讲人刘征宇教授介绍

刘征宇教授现任北京大学物理学院大气和海洋科学系“千人计划”讲座教授、教育部长江学者、美国威斯康星一麦迪逊大学 Nelson 环境研究所气候研究中心主任及大气和海洋科学系教授。主要的研究兴趣是：海洋-大气-陆地相互作用与气候动力学；大洋环流动力学；古气候模拟；地球系统模拟。目前已经在 J.Phy. Oceanography, Bulletion of the AMS, Nature,Science，Geophysical Res.Letter 等期刊公开发表学术论文 180 多篇。

刘教授在科学研究中做出的根本贡献在于加深了人类对于海-气相互作用过程、年代际海洋与气候变化的理解，以及对过去与未来的气候变化过程的认识。他的研究广泛涉及多个领域，在多种学科与交叉学科中做出了非常大的贡献。他对科学所做出的最重要的贡献在于：1）海洋上层和海气耦合系统的年代际变化； 2）重建了冰期/间冰期的气候变化与气候突变过程。在其他方面，特别是在气候和下垫面生态植被的相互作用与热带气候动力学耦合模式的研究也颇有造诣。

讲 座 主 要 内 容

题 目： Transient Climate Evolution of Last 21000 years:Modeling,Model-Data Comparison and Mechanism

过去 21000（TRACE-21）年的气候演变过程：模拟对比与机理

主讲人： 刘征宇教授

主持人： 姚檀栋院士

时　间： 2011 年 6 月 9 日 14:30-16:00

地　点： 中国科学院青藏高原研究所二层会议室

讲座主要内容：

刘征宇教授的报告首次使用 CCSM3 模型对过去 21000 年的环境演变过程进行了模拟，重建了如 H1 事件与 YD 等古气候特征事件以及全新世时期的气候演变过程。研究重建了 BA 变暖时期的气候变化过程，显示 BA 时期的气候变暖主要由 CO2 的温室效应、AMOC 的恢复与 AMOC 的过度恢复等三个因素所导致。研究表明 CCSM3 模型具备良好的气候敏感性，与代用数据一样具有重建冰消期气候演化特征事件的能力。

姚檀栋院士主持

主讲人刘征宇教授

刘征宇教授与参会的科研人员和研究生进行深入讨论和广泛交流

附件 1：刘征宇教授简历

北京大学物理学院大气和海洋科学系
北京市海淀区成府路 209 号，100871
Phone: 86-10-62767436(o)
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Email: zliu3@wisc.edu

工作经历	2010.06 – 现在	北京大学物理学院大气和海洋科学系“千人计划”讲座教授
	2002.08 – 现在	美国威斯康星－麦迪逊大学 Nelson 环境研究所气候研究中心主任
	2002.08 – 现在	美国威斯康星－麦迪逊大学大气和海洋科学系教授
	2000.08 – 2002.08	美国威斯康星－麦迪逊大学 Nelson 环境研究所气候研究中心副主任
	1998.08 – 2002.08	美国威斯康星－麦迪逊大学大气和海洋科学系副教授
	1993.08 – 1998.08	美国威斯康星－麦迪逊大学大气和海洋科学系助理教授
教育经历	1987.07 – 1991.10	美国麻省理工学院物理海洋学博士
	1982.02 – 1985.09	中国科学院大气物理研究所气象学硕士
	1978.02 – 1982.02	中国南京气象学院应用数学学士
研究兴趣	海洋-大气-陆地相互作用与气候动力学	
	大洋环流动力学；古气候模拟；地球系统模拟	
主要荣誉	2010	美国地球物理学会会士
	2009	普林斯顿大学高级会员
	2008, 2002, 1995	美国大气研究中心职业学术奖
	2008	德国麦克斯－普朗克研究所/汉堡大学高级研究会员
	2002	日本教育文化运动科技部高级访问教授
	2001	中国教育部长江教授
	1999	威斯康星－麦迪逊大学 Vilas 副教授
	1995	美国海军研究办公室青年研究员奖
	1991	美国国家海洋大气局博士后奖

Personal CV of Prof. Liu
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NO. 209 Chengfu Road, Haidian District, Beijing, China 100871
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Occupa-tional history	2010.08 - present "The one-thousand-talents scheme " Professor in Department of Atmospheric and Oceanic Sciences of Peking University 2002.08 - present Director, Climate Research Centre, Nelson Institute for Environmental Studies, Wisconsin - Madison University 2002.08 - present Professor, Department of Atmospheric and Oceanic Sciences, Wisconsin - Madison University 2000.08 - 2002.08 Deputy director, Climate Research Centre, Nelson Institute for Environmental Studies, Wisconsin - Madison University 1998.08 - 2002.08 Associate Professor, Department of Atmospheric and Oceanic Sciences, Wisconsin - Madison University 1993.08 - 1998.08 Assistant Professor, Department of Atmospheric and Oceanic Sciences, Wisconsin - Madison University
Education	1987.07-1991.10 Doctor. of physical oceanography in MIT, 1982.02-1985.09 Master of meteorology in Institute of Atmospheric Physics, Chinese Academy Of Sciences 1978.02-1982.02 Bachelor of applied mathematics, Nanjing meteorological institute, China
Research Topics	Atmosphere-ocean-earth interactions, and climate dynamics; Ocean circulation dynamics; Paleoclimate simulation; The earth system simulation
Honors	2010 Fellow of the American Geophysical Union 2009 Senior fellow of Princeton University 2008, 2002, 1995 Faculty fellowship award, National Center for Atmospheric Research 2008 Senior research fellow, Max Planck Institute/Hamburg University, Germany 2002 Senior Visiting Professor Award, Japan Ministry of Education, Culture, Sports, Science and Technology 2001 The Yangtze River professor of Ministry of Education, China 1999 Vilas Associate Professor, Univ. Wisconsin-Madison 1995 Young Investigator Award, Office of Naval Research 1991 NOAA Global Change Postdoctoral Fellow Award

附件 2：刘征宇教授最重要的 10 篇文献目录

1.Liu, Z., S.G.H.Philander and R. Pacanowski, 1994: A GCM study of tropical -subtropical upper ocean mass exchange. *J. Phys. Oceanogr*., 24, 2606-2623.

2.Sun, D. and Z. Liu, 1996: Dynamic ocean-atmosphere coupling: a thermostat for the tropics. *Science*, 272, 1148-1150.

3.Kutzbach J. and Z. Liu, 1997: Response of the African Monsoon to Orbital Forcing and Ocean Feedbacks in the Middle Holocene. *Science*, 278, 440-443.

4.Liu, Z., 1999: Forced planetary wave response in a thermocline gyre. *J. Phys. Oceanogr*., 29, 1036-1055

5.Wu. L, Z. Liu, R. Gallimore, R. Jacob, D. Lee, and Y. Zhong, 2003: Pacific Decadal Variability: The Tropical Pacific Mode and the North Pacific Mode. *J. Climate*, 16, 1101-1120

6.Liu, Z., S. Vavrus. F. He, N. Wen and Y. Zhong, 2005: Rethinking tropical ocean response to global warming: the enhanced equatorial warming. *J. Clim*., 18, 4684-4700

7.Liu, Z., M. Notaro, J. Kutzbach and N. Liu, 2006: Assessing global vegetation-climate feedbacks from the observation. *J. Clim*., 19, 787–814.

8.Liu, Z., Y. Wang, R. Gallimore, M. Notaro, C. I. Prentice, 2006: On the cause of abrupt vegetation collapse in North Africa during the Holocene: Climate variability vs. vegetation feedback. *Geophys. Res. Lett.*, 33, L22709, doi:10.1.29/2006GL028062

9.Liu, Z., Y. Liu, L. Wu and R. Jacob, 2007: Seasonal and Long-Term Atmospheric Responses to Reemerging North Pacific Ocean Variability: A Combined Dynamical and Statistical Assessment. *J. Climate*, 20, 955–980.

10.Liu, Z., B. Otto-Bliesner, F. He, E. Brady, P. Clark, J. Lynch-Steiglitz, A. Carlson, W. Curry, E. Brook, R. Jacob, D. Erickson, J. Kutzbach, J. Cheng, 2009: Transient Simulation of Last Deglaciation with a New Mechanism for Bølling-Allerød Warming. *Science*, *Science*, 325, 310-314.

附件 3：刘征宇教授讲座 ppt

Simulating Deglacial Climate Evolution towards Bølling-Allerød Warming

Zhengyu Liu
Center for Climatic Research &
Dept. Atmos. and Oceanic Sci.
University of Wisconsin-Madison

Collaborators
B. Otto-Bliesner, F. He,
E. Brady, R. Tomas, S. Levis,
P. Clark, A. Carlson, J. Lynch-Steglitz,
W. Curry, E. Brook,
D. Erickson, R. Jacob, J. Chen

Simulating Deglacial Climate Evolution towards Bølling-Allerød Warming

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Collaborators
B. Otto-Bliesner, F. He,
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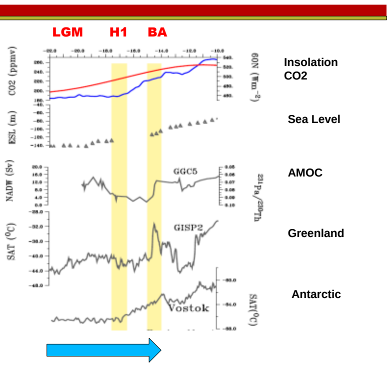
P. Clark, A. Carlson, J. Lynch-Steglitz,
W. Curry, E. Brook,
D. Erickson, R. Jacob, J. Chen



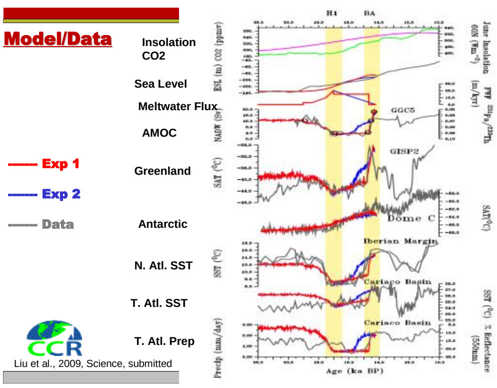
Model Setup

CCSM3 (T31_gx3v5) + Dyn Veg

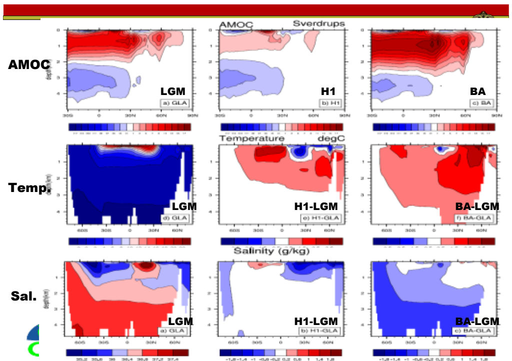
- Atmosphere (CAMT31): ~ 3.75° (long) x 3.75° (lat) x 26 level
- Ocean (POP+Sea Ice): 100 (long) x 116 (lat) x 25 level
- Land (CLM+LPJ):
- Forcing: Realistic Orbital, GHGs, Continental Ice Sheet

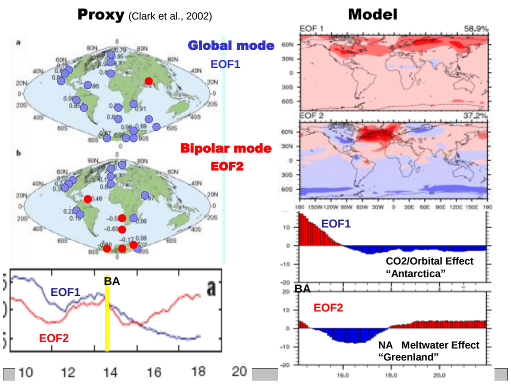
Meltwater ???

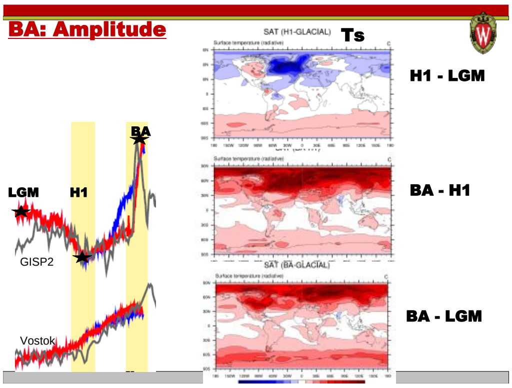
Model/Data

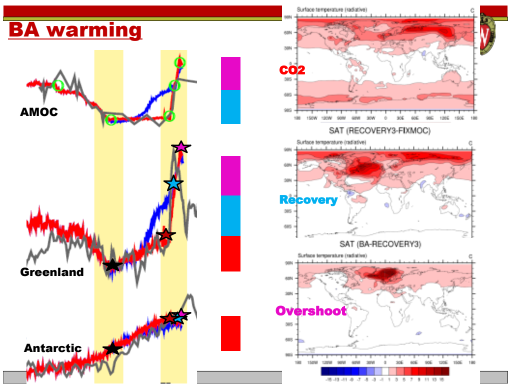


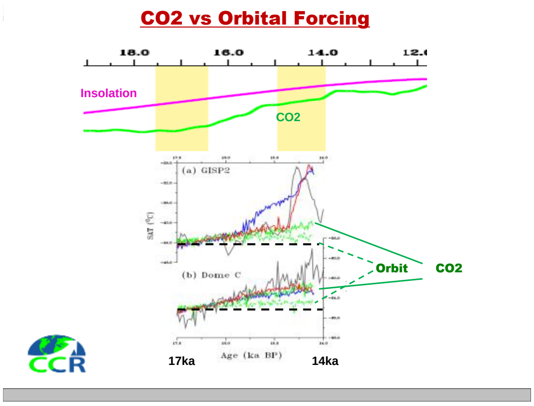
Liu et al., 2009, Science, submitted

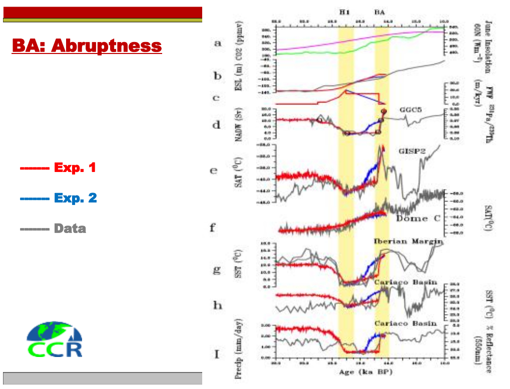


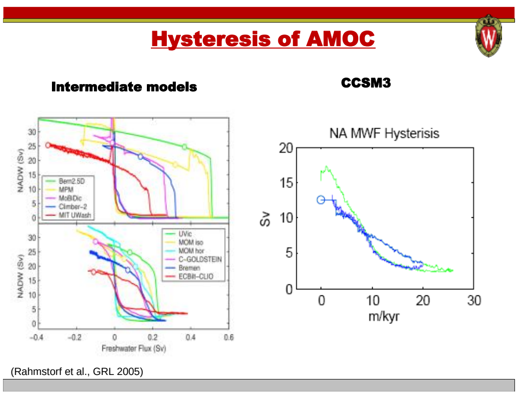

Proxy (Clark et al., 2002)
Model
Global mode
EOF1
Bipolar mode
EOF2
EOF1
EOF2
BA
CO2/Orbital Effect
"Antarctica"
NA Meltwater Effect
"Greenland"
10 12 14 16 18 20


BA: Amplitude
Ts
H1 - LGM
BA - H1
BA - LGM
LGM
H1
BA
GISP2
Vostok

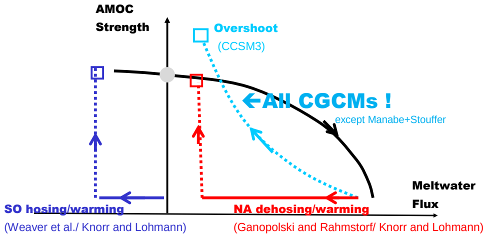

BA warming
AMOC
Greenland
Antarctic
CO2
Recovery
Overshoot


CO2 vs Orbital Forcing
18.0
16.0
14.0
Insolation
CO2
Orbit
CO2
17ka
14ka


BA: Abruptness
Exp. 1
Exp. 2
Data


Hysteresis of AMOC
Intermediate models
CCSM3
NA MWF Hysterisis
Sv
m/kyr
Freshwater Flux (Sv)
(Rahmstorf et al., GRL 2005)

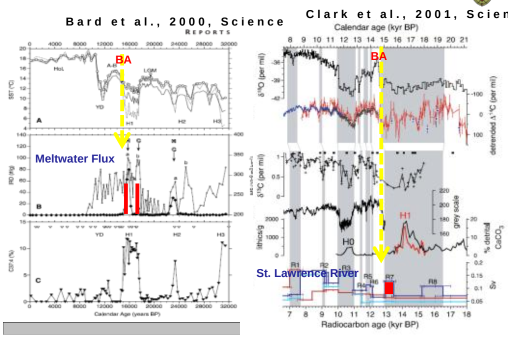
THC recovery and BA -- An unified view



Questions

- Why intermediate models tend to have A hysteresis while CGCMs not?
- Which is more correct, intemediate models or CGCMs?
- Does the real world AMOC has hysteresis?
  Need the reconstructioin of meltwater history prior to BA
- Is the NA abrupt change originated from the AO system, or ice sheet dynamics?

Meltwater History?



Summary

- **Deglaciation Climate Evolution**
  CCSM3 is able to simulate major features of deglaciation climate evolution as in proxy records, under realistic CO2, orbital forcings, and reasonable meltwater forcings. Global temperature evolution is dominated by the CO2/orbital forcing for the global mode, and meltwater forcing for the bipolar seesaw mode.
- **BA warming magnitude!!**
  CCSM3 reproduces the magnitude of the BA warming, suggesting good climate sensitivity of CCSM3. The BA warming is found to be caused by: the CO2 warming effect, the AMOC recovery and the AMOC overshoot.
- **BA warming abruptness??**
  It remains uncertain if CCSM3, and, more generally, current generation of GCMs, are able to simulate the abruptness of the BA warming. The key observation reqruied is the detailed meltwater history prior to BA.

AMOC recovery in CMIP

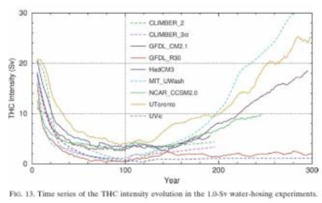


FIG. 13. Time series of the THC intensity evolution in the 1.0-Sv water-hosing experiments.

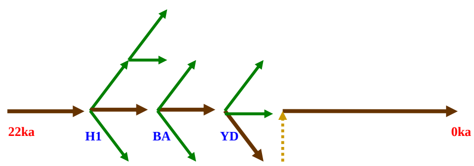
Intermediate model

CGCM

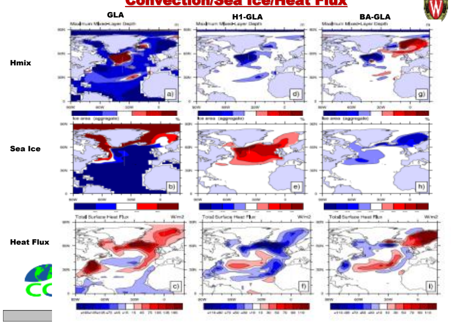
Stouffer et al., 2006, JC

Meltwater Forcing Strategy

------A "Pine Tree"



Convection/Sea Ice/Heat Flux



附件 4：刘征宇教授最重要的 10 篇文献摘要

1.Liu, Z., S.G.H.Philander and R. Pacanowski, 1994: A GCM study of tropical -subtropical upper ocean mass exchange. *J. Phys. Oceanogr.*, 24, 2606-2623

ABSTRACT

Experiments with an oceanic general circulation model indicate that the tropical and subtropical oceanic circulations are linked in three ways. Far from coast in the oceanic interior, equatorial surface waters flow poleward to the southern part of the subtropical gyre, and then are subducted and returned in the thermocline to the upper part of the core of the Equatorial Undercurrent. There is, in addition, a surface western boundary current that carries waters from the equatorial region to the northern part of the subtropical gyre. After subduction, that water reaches the equator by means of a subsurface western boundary current and provides a substantial part (2/3 approximately) of the initial transport of the Equatorial Undercurrent. The eastward flow in the Equatorial Undercurrent is part of an intense equatorial cell in which water rises to the surface at the equator, drifts westward and poleward, then sinks near 3°latitude to flow equatorward where it rejoins the undercurrent.

2. Sun, D. and Z. Liu, 1996: Dynamic ocean-atmosphere coupling: a thermostat for the tropics. *Science*, 272, 1148-1150.

ABSTRACT

The ocean currents connecting the western tropical Pacific Ocean with the eastern tropical Pacific Ocean are driven by surface winds. The surface winds are in turn driven by the sea-surface temperature (SST) differences between these two regions. This dynamic coupling between the atmosphere and ocean may limit the SST in the tropical Pacific Ocean to below 305 kelvin even in the absence of cloud feedbacks.

3. Kutzbach J. and Z. Liu, 1997: Response of the African Monsoon to Orbital Forcing and Ocean Feedbacks in the Middle Holocene. *Science*, 278, 440-443.

ABSTRACT

Simulations with a climate model that asynchronously couples the atmosphere and the ocean showed that the increased amplitude of the seasonal cycle of insolation in the Northern Hemisphere 6000 years ago could have increased tropical Atlantic sea surface temperatures in late summer. The simulated increase in sea surface temperature and associated changes in atmospheric circulation enhanced the summer monsoon precipitation of northern Africa by more than 25 percent, compared with the middle Holocene simulation with prescribed modern sea surface temperatures, and provided better agreement with paleorecords of enhanced monsoons.

4. Liu, Z., 1999: Forced planetary wave response in a thermocline gyre. *J. Phys. Oceanogr.*, 29,1036-1055

ABSTRACT

The response of a thermocline gyre to anomalies in surface wind stress forcing and surface buoyancy forcing is investigated in light of planetary wave dynamics, both analytically and numerically. The author’s theory suggests that anomalous Ekman pumping most efficiently generates the non-Doppler-shift mode, which resembles the first baroclinic mode and has the

clearest signal in the sea surface height field and the lower thermocline temperature field. The non-Doppler-shift mode propagates westward rapidly regardless of the mean circulation.In contrast, anomalous surface buoyancy forcing, which can be simulated by an entrainment velocity, produces the strongest response in the advective mode, which resembles the second baroclinic mode and has the largest signature in the upper thermocline temperature field. The advective mode tends to propagate in the direction of the subsurface flow, but its propagation speed may differ substantially from that of the mean flow. The theory is further substantiated by numerical experiments in three ocean models: a 3-layer eddy-resolving quasigeostrophic model, a 2.5-layer primitive equation model, and an oceanic general circulation model. Finally, relevance of the theory to recent observations of decadal variability in the upper ocean and the climate system is also discussed.

5. Wu. L, Z. Liu, R. Gallimore, R. Jacob, D. Lee, and Y. Zhong, 2003: Pacific Decadal Variability: The Tropical Pacific Mode and the North Pacific Mode. *J. Climate*, 16, 1101-1120

ABSTRACT

Pacific decadal variability is studied in a series of coupled global ocean–atmosphere simulations aided by two “modeling surgery” strategies: partial coupling (PC) and partial blocking (PB). The PC experiments retain full ocean–atmosphere coupling in selected regions, but constrain ocean–atmosphere coupling elsewhere by prescribing the model climatological SST to force the atmospheric component of the coupled system. In PB experiments, sponge walls are inserted into the ocean component of the coupled model at specified latitudinal bands to block the extratropical–tropical oceanic teleconnection.Both modeling and observational studies suggest that Pacific decadal variability is composed of two distinct modes: a decadal to bidecadal tropical Pacific mode (TPM) and a multidecadal North Pacific mode (NPM). The PC and PB experiments showed that the tropical Pacific mode originates predominantly from local coupled ocean–atmosphere interaction within the tropical Pacific. Extratropical–tropical teleconnections, although not a necessary precondition for the genesis of the tropical decadal variability, can enhance SST variations in the Tropics. The decadal memory in the Tropics seems to be associated with tropical higher baroclinic modes. The North Pacific mode originates from local atmospheric stochastic processes and coupled ocean–atmosphere interaction. Atmospheric stochastic forcing can generate a weaker NPM-like pattern in both the atmosphere and ocean, but with no preferred timescales. In contrast, coupled ocean–atmosphere feedback can enhance the variability substantially and generate a basin-scale multidecadal mode in the North Pacific. The multidecadal memory in the midlatitudes seems to be associated with the delayed response of the subtropical/subpolar gyre to wind stress variation in the central North Pacific and the slow growing/decaying of SST anomalies that propagate eastward in the Kuroshio Extension region. Oceanic dynamics, particularly the advection of the mean temperature by anomalous meridional surface Ekman flow and western boundary currents, plays an important role in generating the North Pacific mode.

6. Liu, Z., S. Vavrus. F. He, N. Wen and Y. Zhong, 2005: Rethinking tropical ocean response to global warming: the enhanced equatorial warming. J. Clim., 18, 4684-4700

ABSTRACT

The response of tropical Pacific SST to increased atmospheric CO_2 concentration is reexamined with a new focus on the latitudinal SST gradient. Available evidence, mainly from climate models, suggests that an important tropical SST fingerprint to global warming is an enhanced equatorial warming relative to the subtropics. This enhanced equatorial warming provides a fingerprint of SST response more robust than the traditionally studied El Niño–like response, which is characterized by the zonal SST gradient. Most importantly, the mechanism of the enhanced equatorial warming differs fundamentally from the El Niño–like response; the former is associated with surface latent heat flux, shortwave cloud forcing, and surface ocean mixing, while the latter is associated with equatorial ocean upwelling and wind-upwelling dynamic ocean–atmosphere feedback.

7. Liu, Z., M. Notaro, J. Kutzbach and N. Liu, 2006: Assessing global vegetation-climate feedbacks from the observation. *J. Clim*., 19, 787–814.

ABSTRACT

The feedback between global vegetation greenness and surface air temperature and precipitation is assessed using remote sensing observations of monthly fraction of photosynthetically active radiation (FPAR) for 1982 to 2000 with a 2.5° grid resolution. Lead/lag correlations are used to infer vegetation–climate interactions. Furthermore, a statistical method is used to quantify the efficiency of vegetation feedback on climate in the observations. This feedback analysis provides a first quantitative assessment of global vegetation feedback on climate. In northern mid- and high latitudes, vegetation variability is found to be driven predominantly by temperature; in the meantime, vegetation also exerts a strong positive feedback on temperature with the feedback accounting for over 10%–25% of the total monthly temperature variance. The strongest positive feedback occurs in the boreal regions of southern Canada/northern United States, northern Europe, and southern Siberia, where the feedback efficiency exceeds 1 ℃ (0.1 FPAR)$^{-1}$. Over most of the Tropics and subtropics (outside the equatorial rain belt), vegetation is driven primarily by precipitation. However, little vegetation feedback is found on local precipitation when averaged year-round, with the feedback explained variance usually accounting for less than 5% of the total precipitation variance. Nevertheless, in a few isolated small regions such as Northeast Brazil, East Africa, East Asia, and northern Australia, there appears to be some positive vegetation feedback on local precipitation, with the feedback efficiency over 1 cm month^{-1} (0.1 FPAR)$^{-1}$. Further studies suggest a significant seasonal variation of the vegetation feedback in some regions. A preliminary analysis also seems to suggest an enhanced intensity of the vegetation feedback, especially on precipitation, at longer time scales and over a larger grid box area. Limitations and implications of the assessment of vegetation feedback are also discussed. The assessed vegetation feedback is shown to be valuable for the evaluation of vegetation–climate feedback in coupled climate–vegetation models.

8. Liu, Z., Y. Wang, R. Gallimore, M. Notaro, C. I. Prentice, 2006: On the cause of abrupt vegetation collapse in North Africa during the Holocene: Climate variability vs. vegetation feedback. *Geophys. Res. Lett.*, 33, L22709, doi:10.1.29/2006GL028062

ABSTRACT

The abrupt desertification over the northern Africa in the mid-Holocene is studied in both a complex and a simple coupled climate-vegetation model. In contrast to the previous mechanism that relies on strong positive vegetation-climate feedback and the resulted multiple equilibria, we propose a new mechanism in which the abrupt desertification is caused by low frequency climate variability, rather than a positive vegetation-climate feedback. The implication of this new mechanism to modelling and observation is also discussed.Citation: Liu, Z., Y. Wang, R. Gallimore, M. Notaro, and I. C.Prentice (2006), On the cause of abrupt vegetation collapse in North Africa during the Holocene: Climate variability vs. vegetation feedback.

9. Liu, Z., Y. Liu, L. Wu and R. Jacob, 2007: Seasonal and Long-Term Atmospheric Responses to Reemerging North Pacific Ocean Variability: A Combined Dynamical and Statistical Assessment. J. Climate, 20, 955–980.

ABSTRACT

The atmospheric response to a North Pacific subsurface oceanic temperature anomaly is studied in a coupled ocean–atmosphere general circulation model using a combined dynamical and statistical approach, with the focus on the evolution at seasonal and longer time scales. The atmospheric response is first assessed dynamically with an ensemble coupled experiment. The atmospheric response is found to exhibit a distinct seasonal evolution and a significant long-term response. The oceanic temperature anomaly reemerges each winter to force the atmosphere through an upward heat flux, forcing a clear seasonal atmospheric response locally over the Aleutian low and downstream over the North America/North Atlantic Ocean and the Arctic regions. The atmospheric response is dominated by the early winter response with a warm SST-equivalent barotropic ridge and a wave train downstream. Starting in later winter, the atmospheric response weakens significantly and remains weak throughout the summer. The seasonal response of the atmosphere is then assessed statistically from the control simulation. It is found that the major features of the seasonal response, especially the strong warm SST–ridge response in early winter, are crudely consistent between the dynamical and statistical assessments. The statistical assessment is finally applied to the observation, which also suggests a strong seasonal atmospheric response locally over the North Pacific dominated by a warm SST–ridge response in early winter.

One important conclusion is that the atmospheric response becomes more significant at annual and longer time scales, with the signal/noise ratio increasing up to 4 times from the monthly to the 4-yr mean response. This increased signal/noise ratio is caused by a much faster reduction of the atmospheric internal variability toward longer time scales than that of the response signal. The slow decrease of the response signal is due to the long persistence associated with the subsurface ocean. This suggests that the subsurface extratropical oceanic variability could have a much stronger impact on the extratropical atmosphere (and climate variability) at interannual–interdecadal time scales than at monthly–seasonal time scales.

10. Liu, Z., B. Otto-Bliesner, F. He, E. Brady, P. Clark, J. Lynch-Steiglitz, A. Carlson, W. Curry, E. Brook, R. Jacob, D. Erickson, J. Kutzbach, J. Cheng, 2009: Transient Simulation of Last Deglaciation with a New Mechanism for Bølling-Allerød Warming. Science, Science, 325, 310-314.

ABSTRACT

We conducted the first synchronously coupled atmosphere-ocean general circulation model simulation from the Last Glacial Maximum to the Bølling-Allerød (BA) warming. Our model reproduces several major features of the deglacial climate evolution, suggesting a good agreement in climate sensitivity between the model and observations. In particular, our model simulates the abrupt BA warming as a transient response of the Atlantic meridional overturning circulation (AMOC) to a sudden termination of freshwater discharge to the North Atlantic before the BA. In contrast to previous mechanisms that invoke AMOC multiple equilibrium and Southern Hemisphere climate forcing, we propose that the BA transition is caused by the superposition of climatic responses to the transient CO2 forcing, the AMOC recovery from Heinrich Event 1, and an AMOC overshoot.