No.91337106，2014.01-2016.12

青藏高原对热带辐合带影响的耦合模式研究

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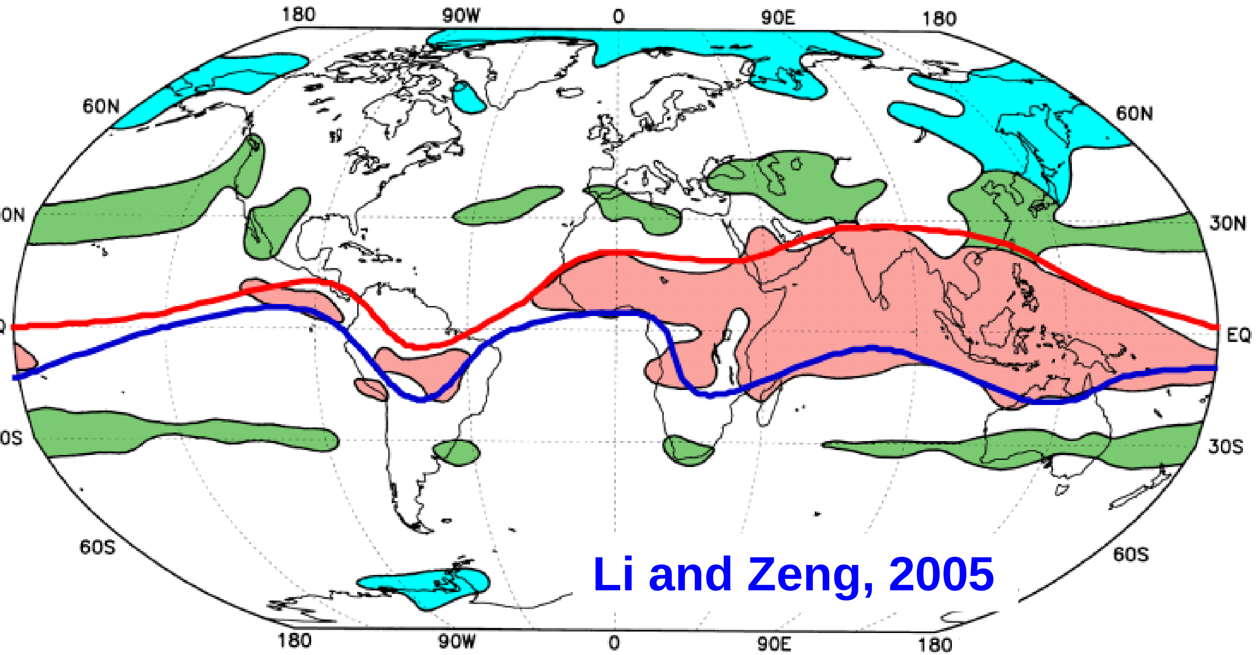
北京大学大气与海洋科学系

论文清单

已发表4篇（其中SCI论文4篇），目前在投1篇

- Shen, X., H. Yang, and Z. Liu, 2018: Effect of Tibetan Plateau on ITCZ climatology. *Tellus A.*, Submitted. 第1资助
- Dai, H., and H. Yang, 2017: Roles of energy conservation and regional climate feedback in Bjerknes compensation: a coupled modeling study. *Climate Dynamics*, 49, 1513-1529, doi: 10.1007/s00382-016-3386-y. 第1资助
- Yang, H., K. Wang, H. Dai, Y, Wang, and Q. Li, 2016: Wind effect on the Atlantic meridional overturning circulation via sea ice and vertical diffusion. *Climate Dynamics*, 46(11), 3387-3403, doi: 10.1007/s00382-015-2774-z. 第1资助
- Zhao, Y., H. Yang, and Z. Liu, 2016: Assessing Bjerknes compensation for climate variability and its timescale dependence. *J. Climate*, 29(15), 5501-5512. 第3资助
- Yang, H., Y. Zhao, and Z. Liu, 2016: Understanding Bjerknes compensation in atmosphere and ocean heat transports using a coupled box model. *J. Climate*, 29(6), 2145-2160, doi: 10.1175/JCLI-D-15-0281.1. 第3资助

ITCZ平均位置

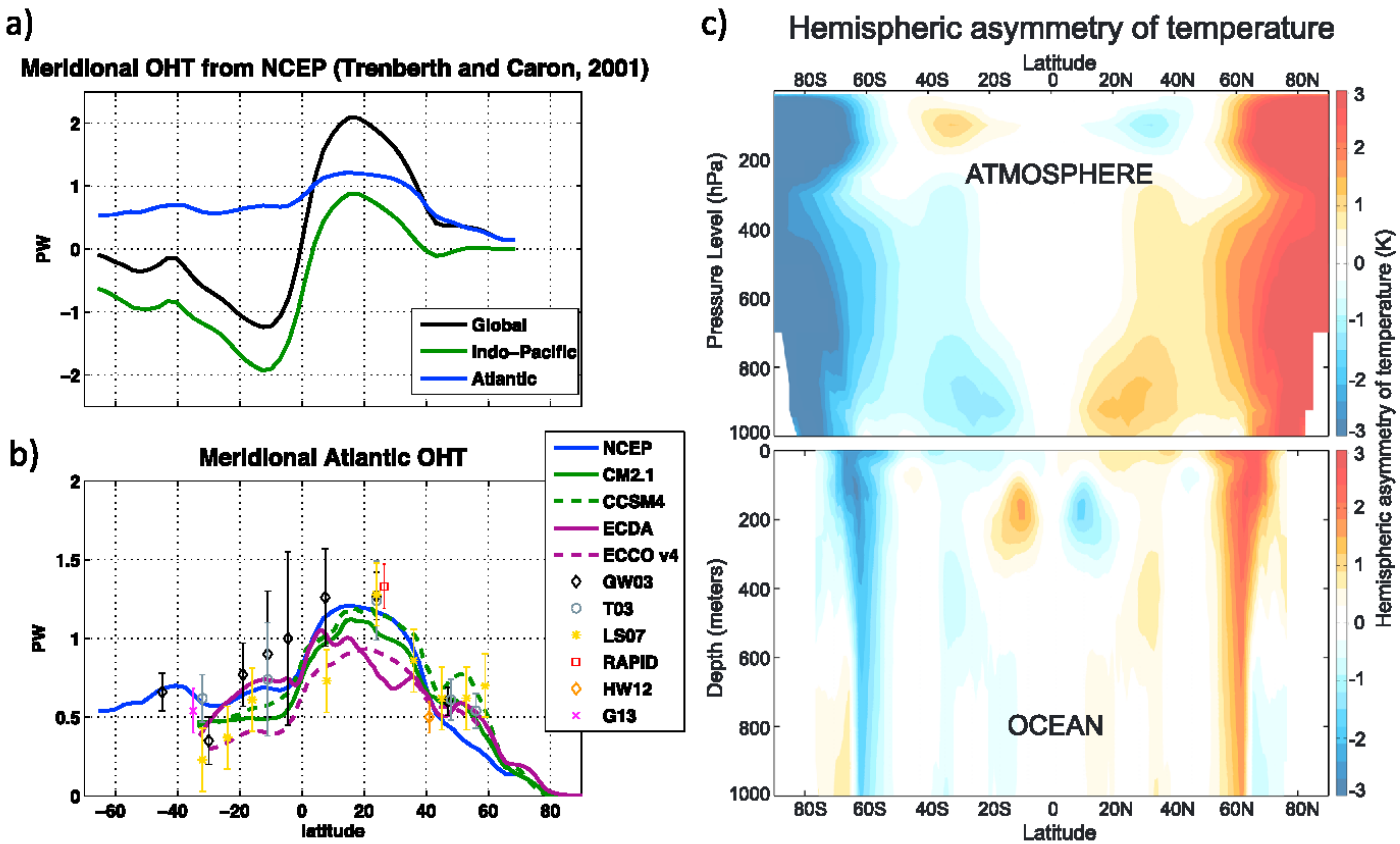


- 海陆分布南北半球不对称 ➔ 年平均位置（Philander et al., 1996)
- 海陆分布 ➔ 季风系统 ➔ 平均位置的季节变化

ITCZ平均位置

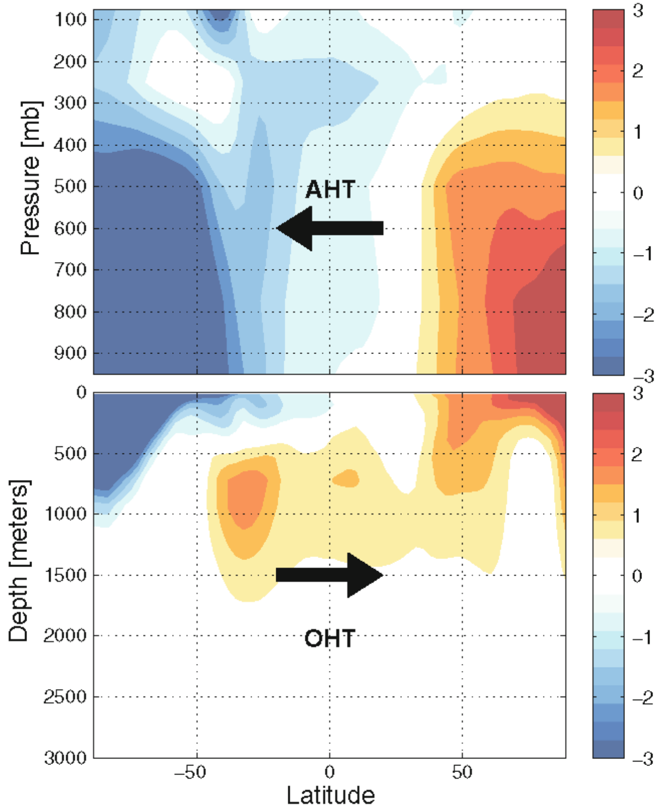
在地球南北半球能量平衡的框架下，ITCZ年平均位置

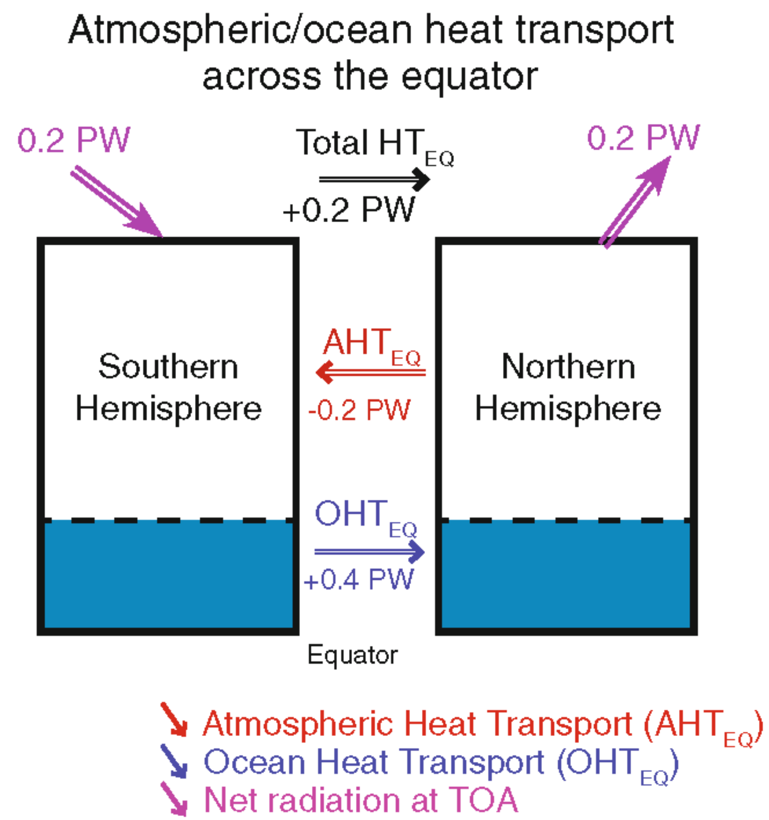
由AMOC的经向热量输送决定（Marshall et al., 2014）



Trenberth and Caron, 2001; Ganachaud and Wunsch, 2003; Talley, 2003; Lumpkin and Speer, 2007; Johns et al., 2011; Hobbs and Willis, 2012; Garzoli et al., 2013; Msadek et al., 2013; Chang et al., 2012; Forget and Ponte, 2015; Forget et al., 2015; Marshall et al., 2014

ITCZ平均位置的变化



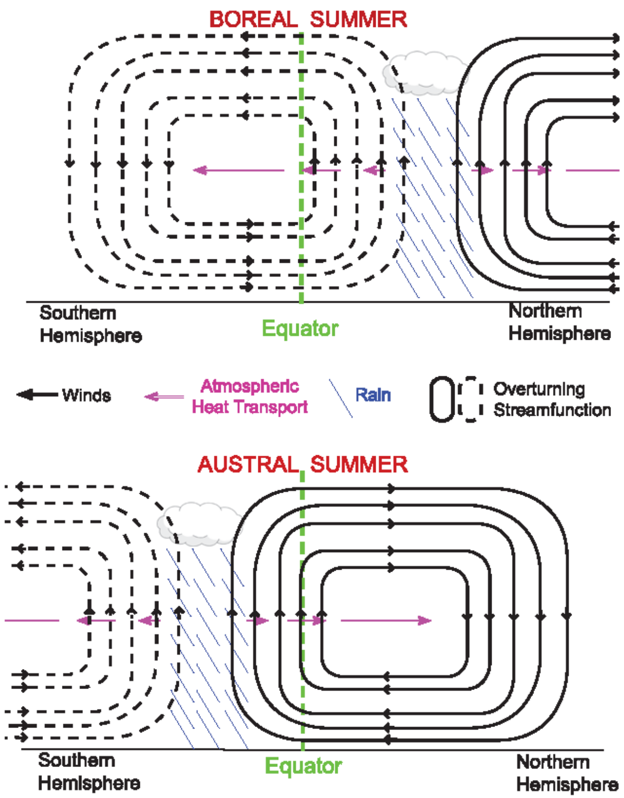


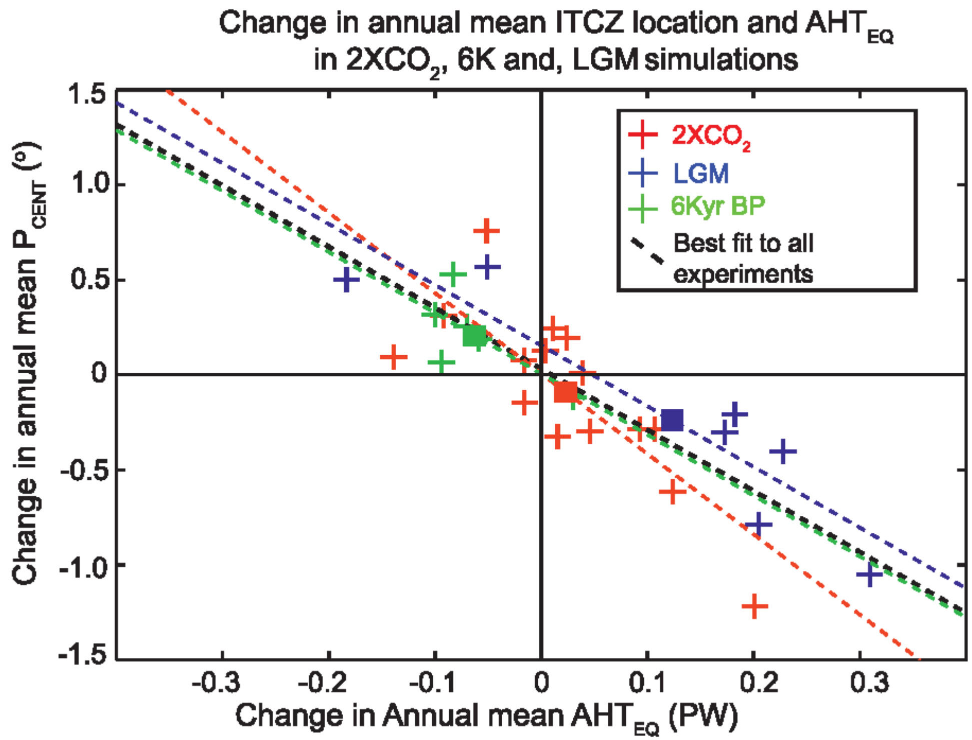
AMOC ⇑ ➔ 向北OHT⇑ ➔ 向南AHT⇑ ➔ ITCZ向北移动

Marshall et al., 2014

Vellinga and Wood, 2002; Chiang and Bitz, 2005; Cheng et al., 2007; Zhang and Delworth, 2005; Stouffer et al., 2006; Kang et al., 2008;

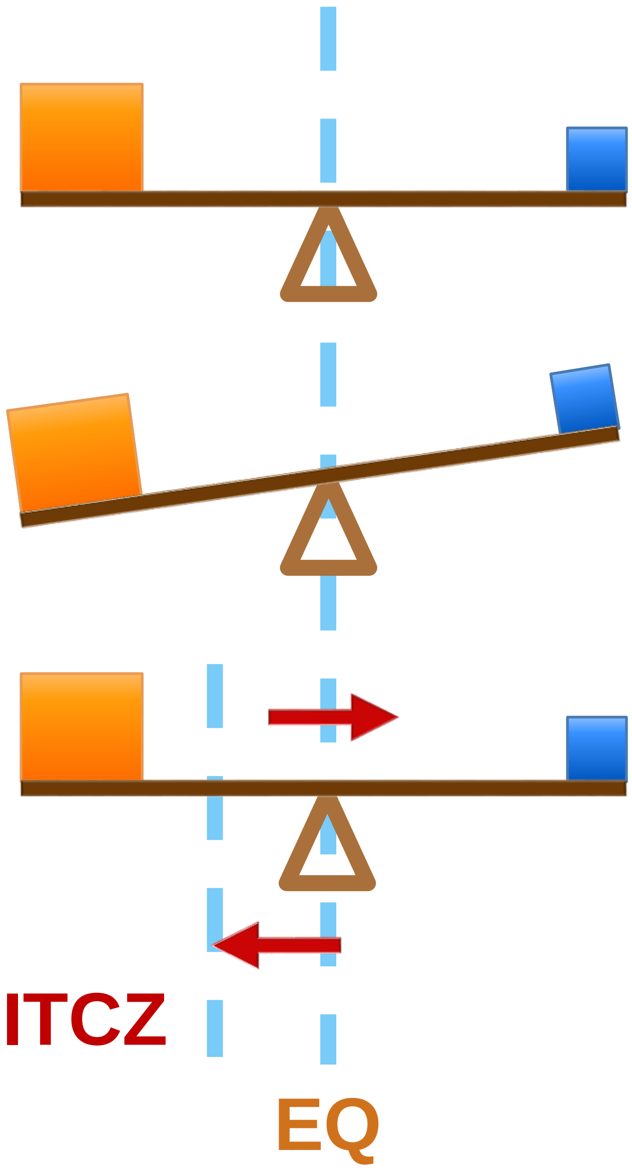
ITCZ位置移动与AHT_{EQ}的关系 3°/PW^{-1}





Donohoe et al., 2013

ITCZ位置是南北半球能量平衡的支点



问 题

1. 青藏高原对南北半球能量平衡有多大影响？

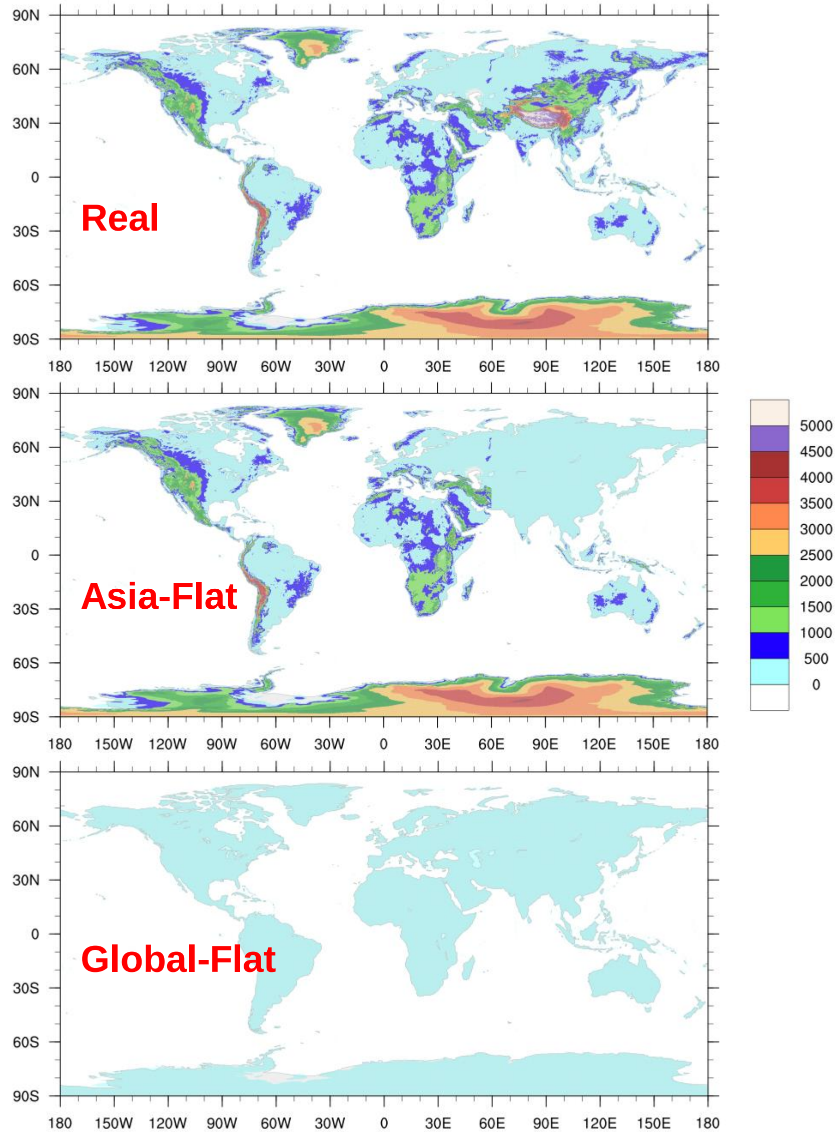
2. 是否能够造成ITCZ位置的显著移动？

耦合模式

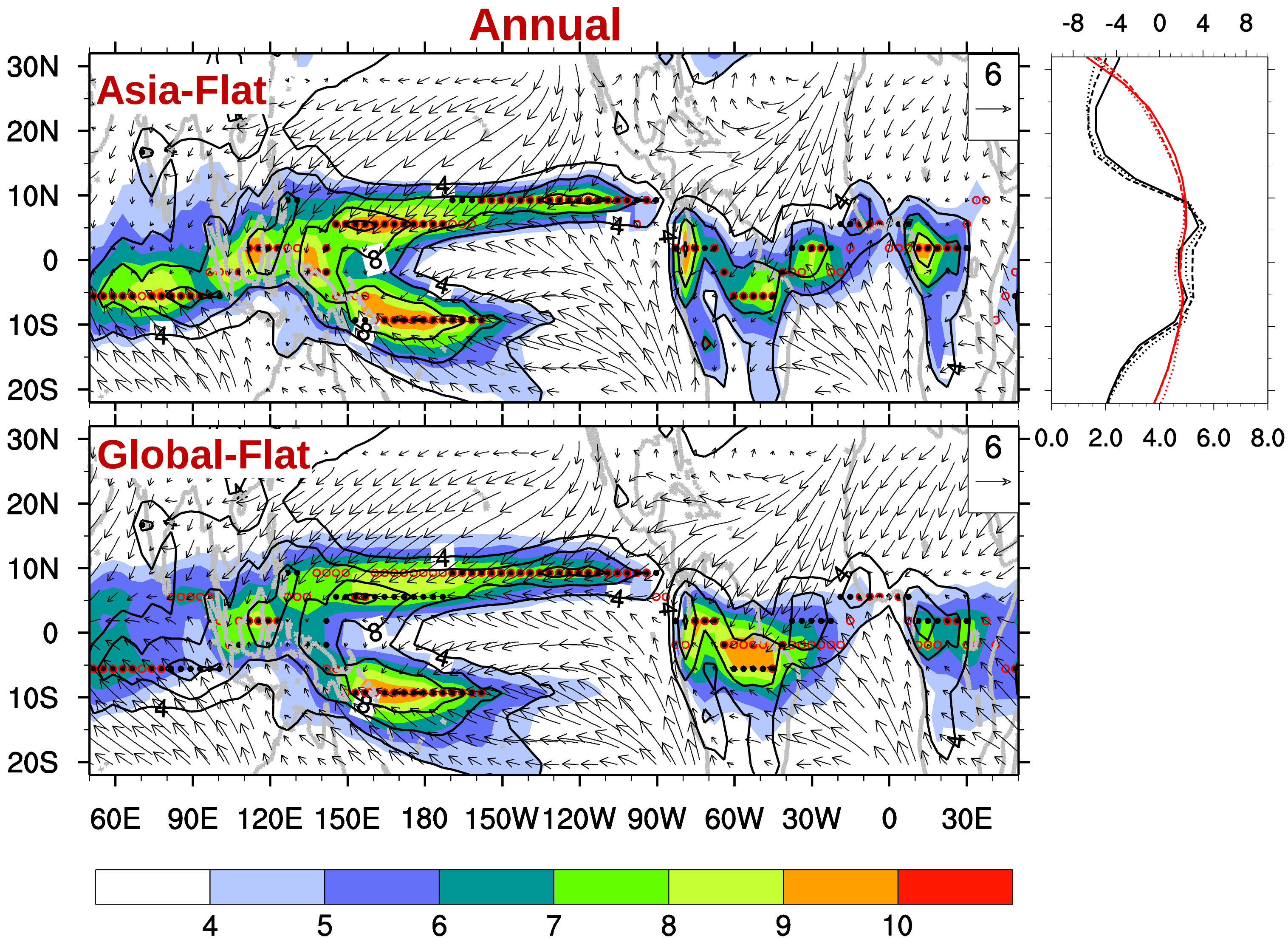
- NCAR Community Earth System Model (CESM1)
  - Atmos. – T31 CAM5 (3.75x3.75x26)
  - Ocean – gx3v7 Los Alamos POP2 (3x3x60)
  - Land – gx3v7 CLM4
  - Ice – gx3v7 Los Alamos CICE4

  - Control Run: 2000 years
  - Global-Flat: 400 years
  - Euro-Asia-Flat: 400 years

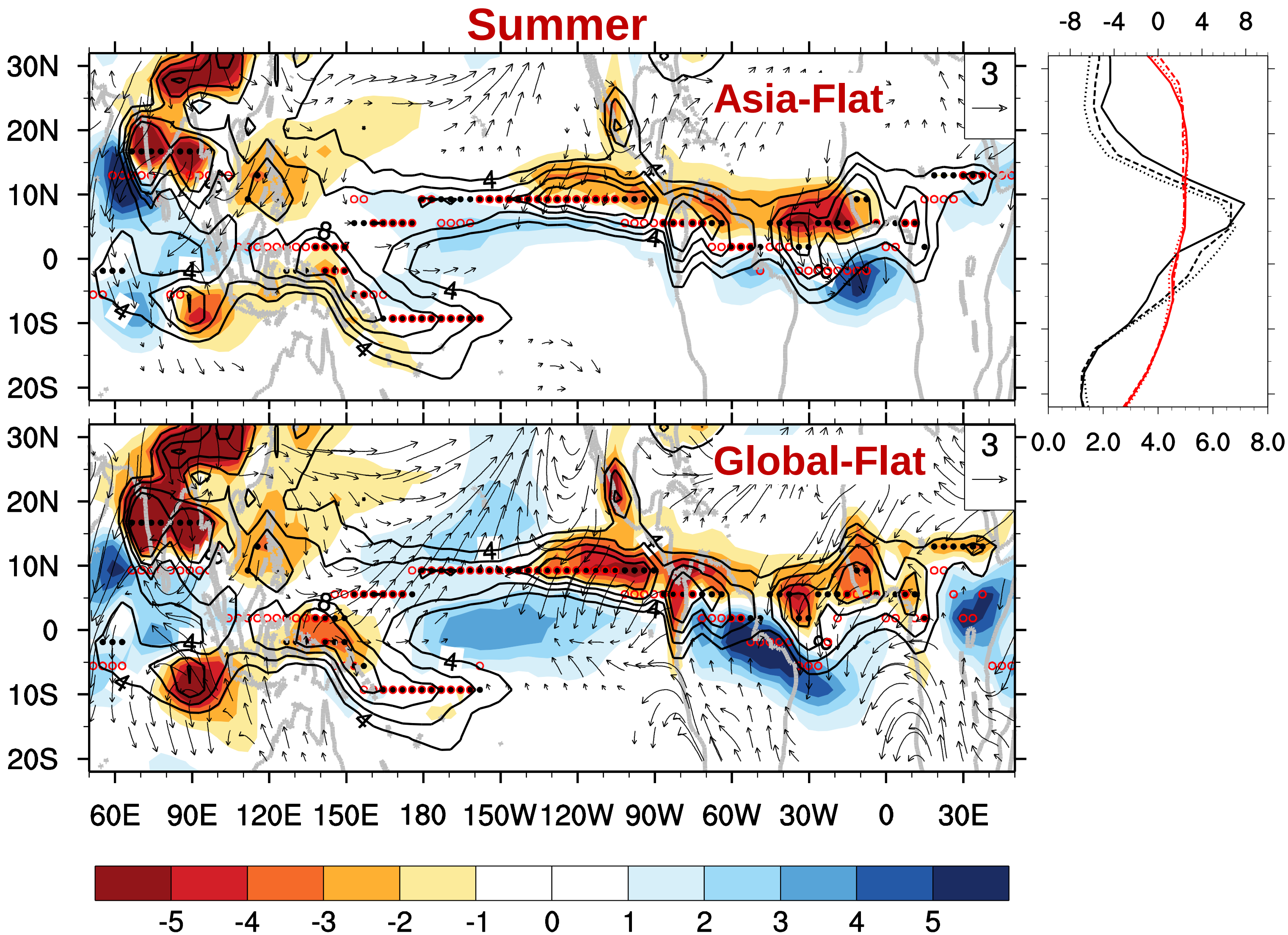
模式地形


Real
Asia-Flat
Global-Flat
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0

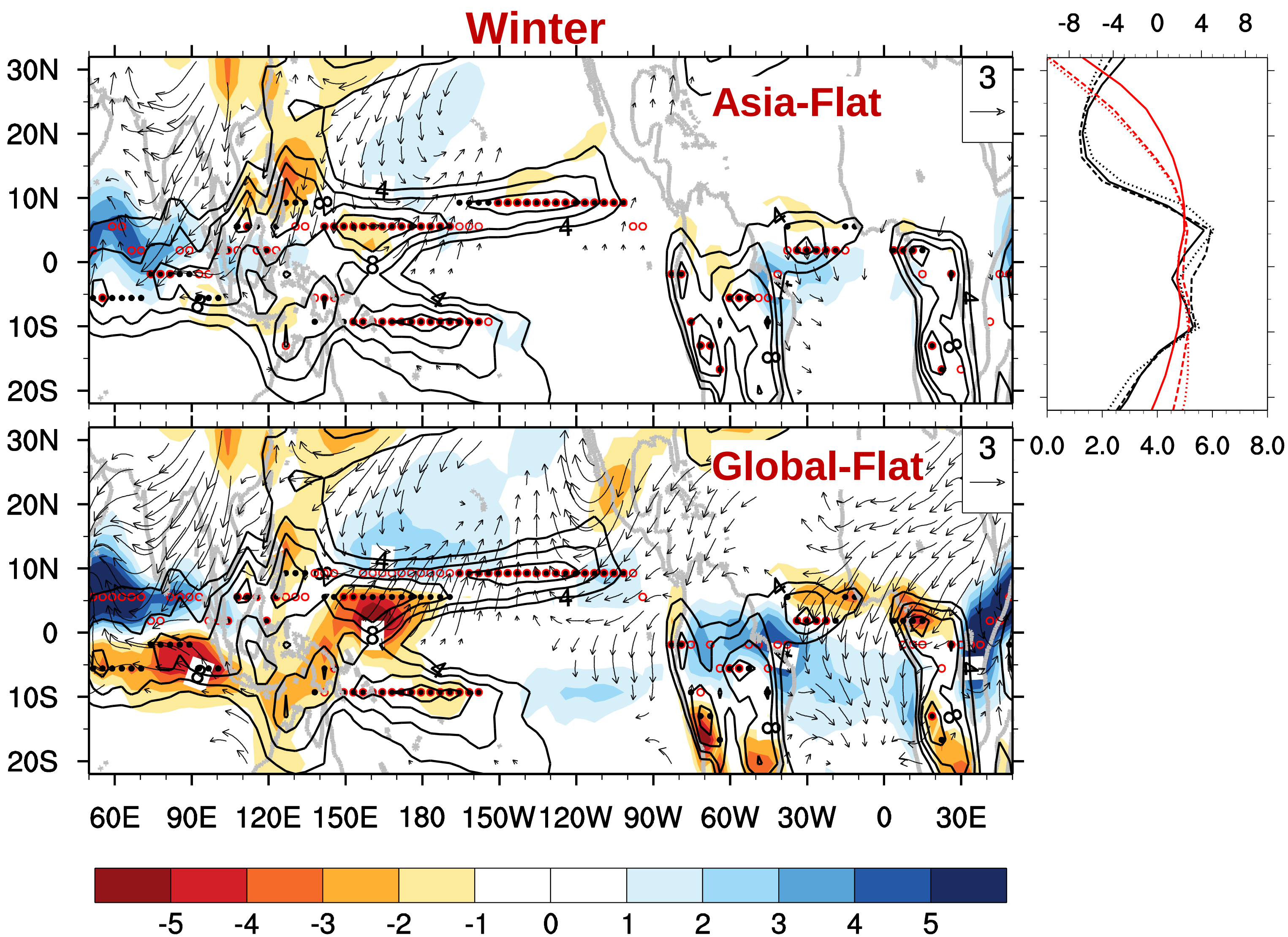
ITCZ定义-降水中心位置



ITCZ的季节平均位置

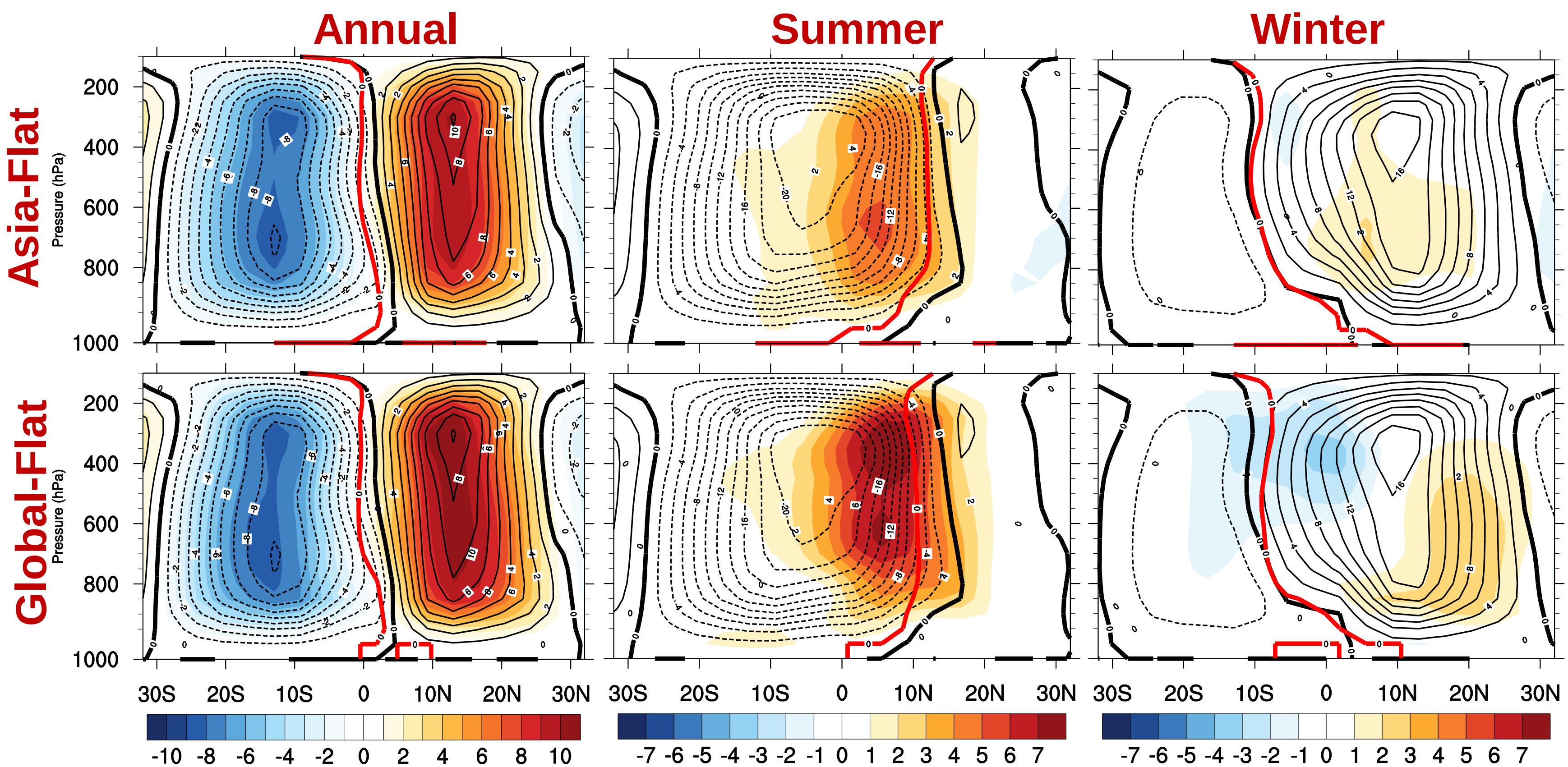


ITCZ的季节平均位置



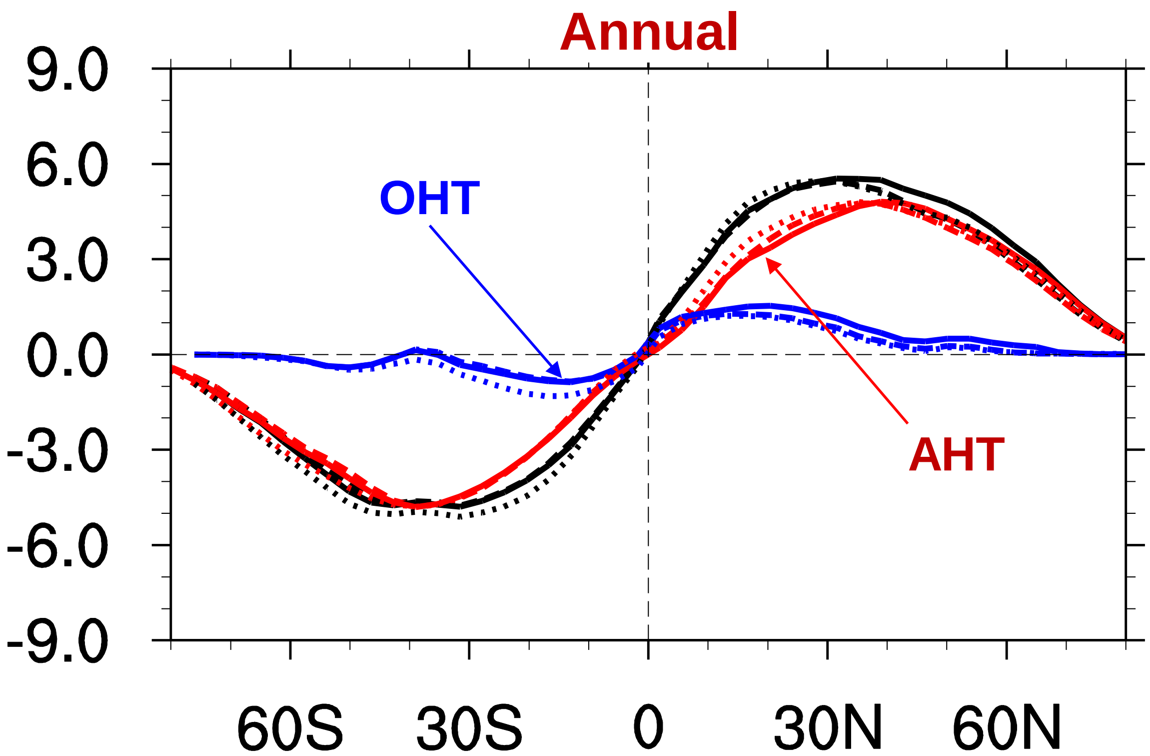
Hadley环流及其变化 $-9°/PW^{-1}$

500hPa ψ=0流线的位置与 ΔAHT_{EQ} 线性相关

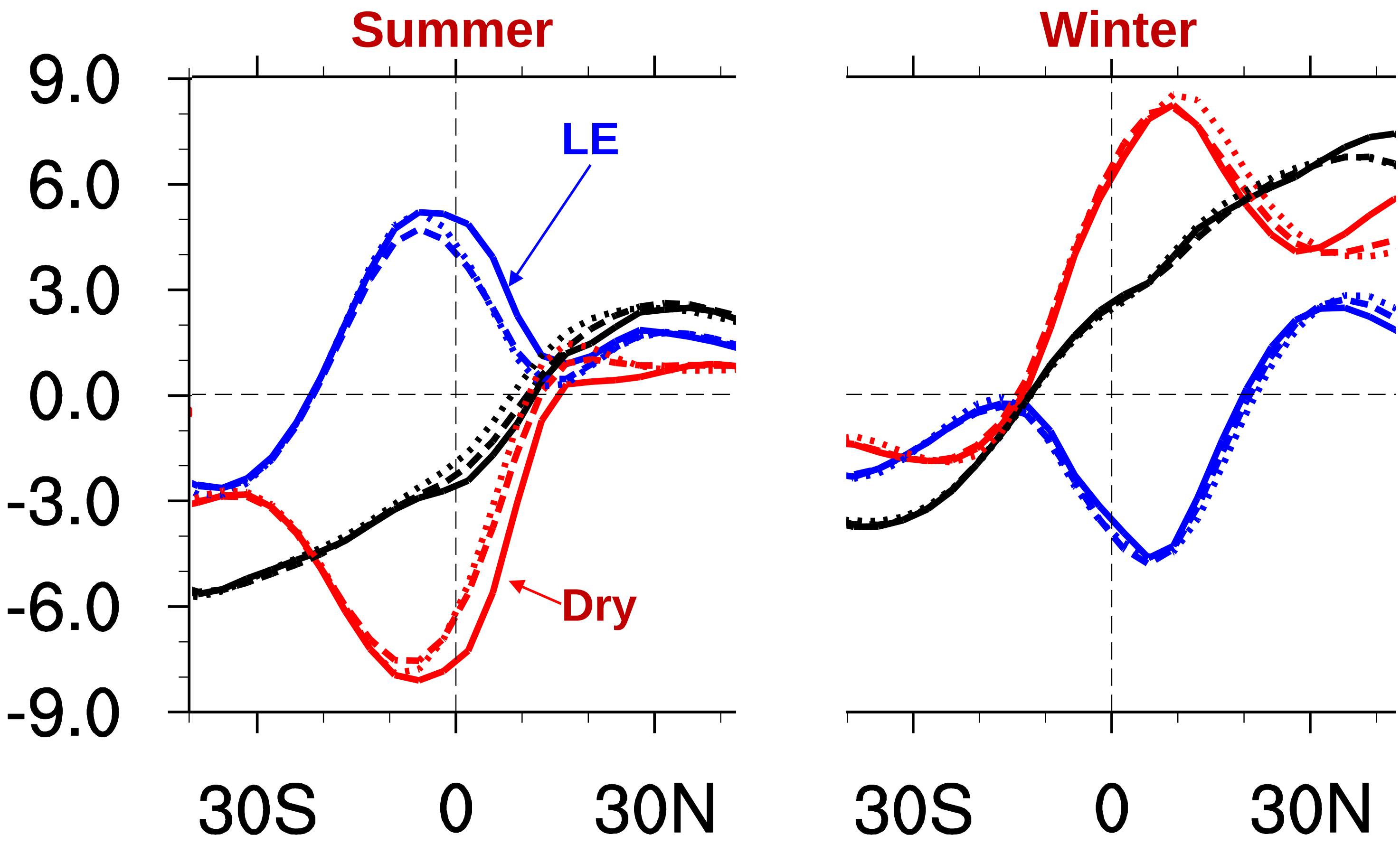


500hPa夏季ψ=0流线的位置~ -3°； 冬季 ~ 0°

气候状态的经向能量输送



大气经向能量输送（AHT）及其分量 3°/PW-1

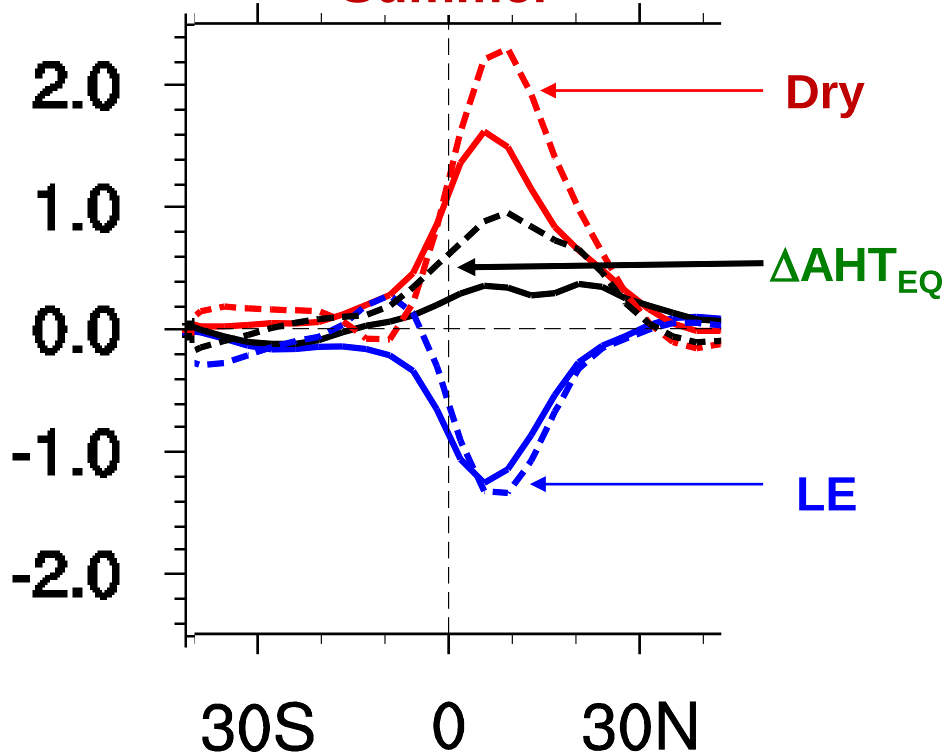


夏季 AHT_{EQ} ~ 2.8 PW, 向南； 冬季 AHT_{EQ} ~ 2.8 PW, 向北

大气经向能量输送（AHT）变化 3°/PW⁻¹

0.6° ITCZ

南移



夏季 ΔAHT_{EQ} ~ 0.3 PW, 向北；　年平均 ΔAHT_{EQ} ~ 0.2~0.3 PW, 向北

总 结

没有青藏高原：

- 年平均ITCZ的位置与强度变化不大；
- 对南北半球能量平衡影响不显著；
- AHT_{EQ}变化可以达到0.3PW

No.91737204，2018.01-2021.12

探究青藏高原在全球海洋经圈环流形成中的角色

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青藏高原重大计划

核心科学问题

- 青藏高原大地形如何调控全球大气环流？
- 青藏高原地-气耦合系统变化如何影响全球能量水分循环？
- 青藏高原地-气耦合系统如何影响我国灾害性天气气候？

科学目标

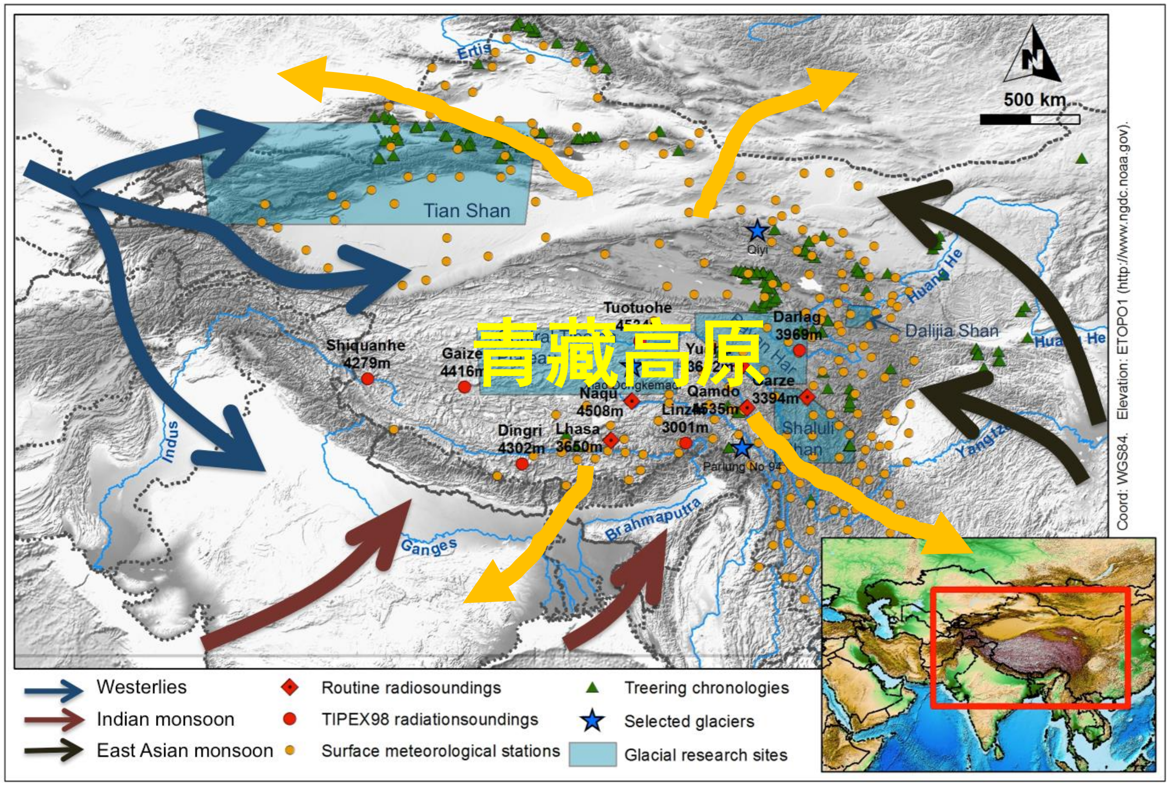
- 揭示青藏高原对全球气候及其变化的影响及机制
- 把我国青藏高原研究进一步推向世界舞台，处于国际的领军地位，为我国可持续发展做出贡献

青藏高原：世界第三极

总面积250万km^2，平均海拔4000m

中国科学家的卓越贡献

青藏高原地-气耦合及其区域环境相互作用



中国科学家的卓越贡献

1950’

Flohn等(1957)热力动力：抬升加热与东亚大气环流和印度季风爆发的关系

季节

1980’

Ye(1981, 1982)，陈隆勋(1985)，黄荣辉(1985)：热力动力更深入，夏季热源与夏季风；李崇银等(1988)：高原与ENSO

季节
年际

1990’

吴国雄等(1997, 1998, 1999)：热力季节变化，对季风爆发时间地点的影响；Li和Yanai(1996)，赵平(1999)：热源年际变率对亚洲环流影响

季节
年际

2000’~

段安民等(2005)北半球年际变率；吴国雄等(2004)，杨修群等(2004)：与ENSO和PDO相互作用；赵平等(2007)，周秀骥(2009)：高原遥相关，亚洲-太平洋涛动(APO)

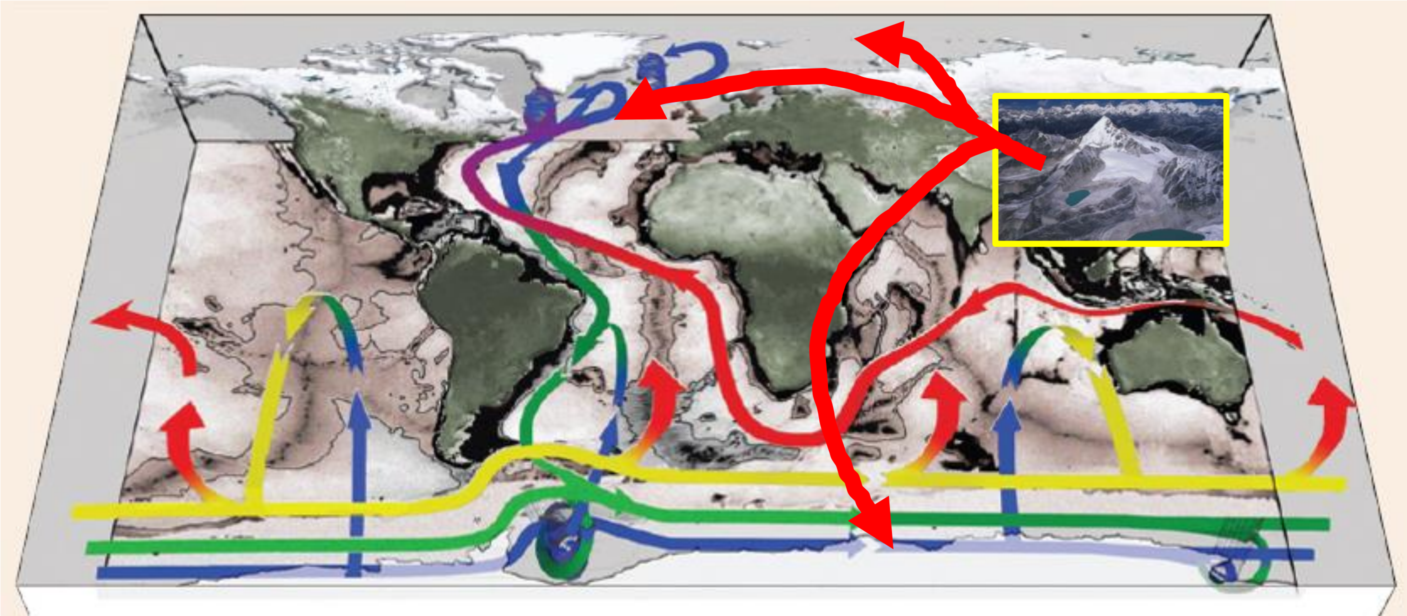
年际
年代际

科学目标之一

- 把青藏高原研究进一步推向世界舞台，达到国际的领军地位，为我国可持续发展做出贡献

青藏高原的全球视角

难点：如何影响？多大影响？



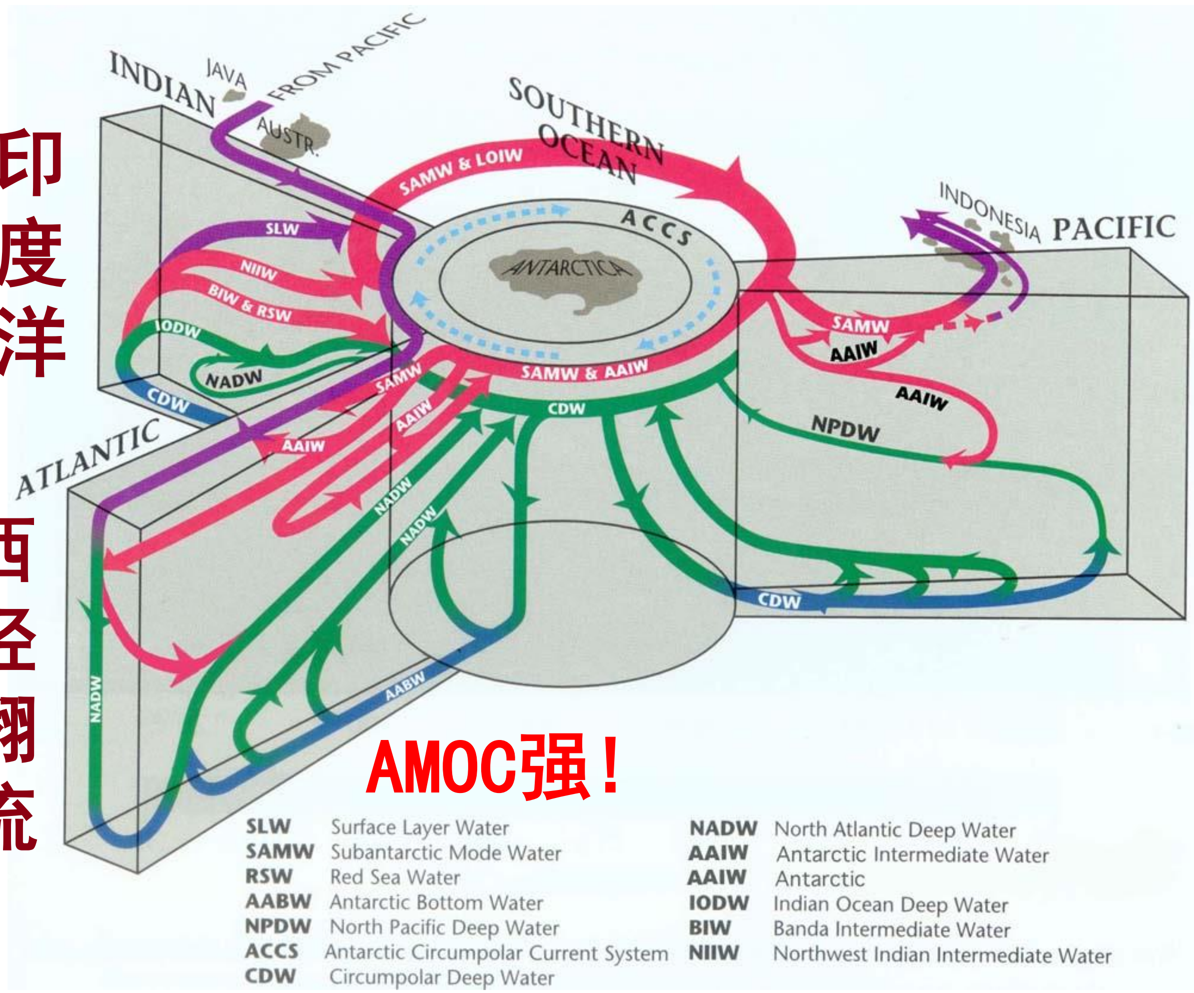
Marshall et al., Nature (2012)

青藏高原 → 南北半球不对称 → 能量与淡水循环 → 海面风场淡水热量 → 全球海洋大输送带

全球海洋经圈环流

维系着整个星球的能量与淡水平衡

弱！印度洋



太平洋经圈翻转流

PMOC非常弱！

大西洋经圈翻转流

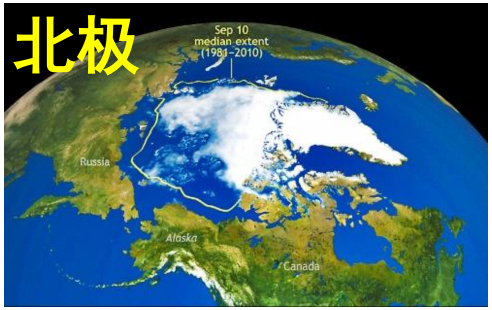
AMOC强！

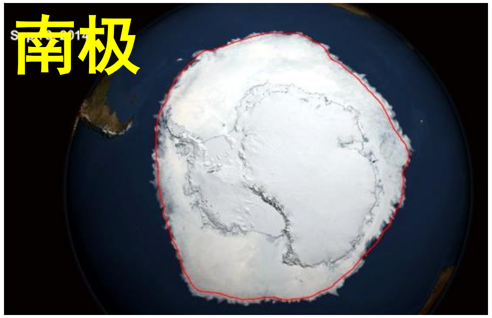
Schmitz (1997) Overturning circulation: Southern Ocean View

科学问题

1. “有/无”青藏高原，地球气候态有什么不同?
2. 如果没有青藏高原，现代全球海洋大输送带还会存在吗?
3. “有/无”青藏高原，气候态的北大西洋深水形成、AMOC有什么不同?
4. 青藏高原、落基山脉、安第斯山脉在全球海洋经圈环流气候态塑造中的相对贡献如何？分别对全球能量-水汽循环有何影响?

“有”或“没有”是个根本问题！

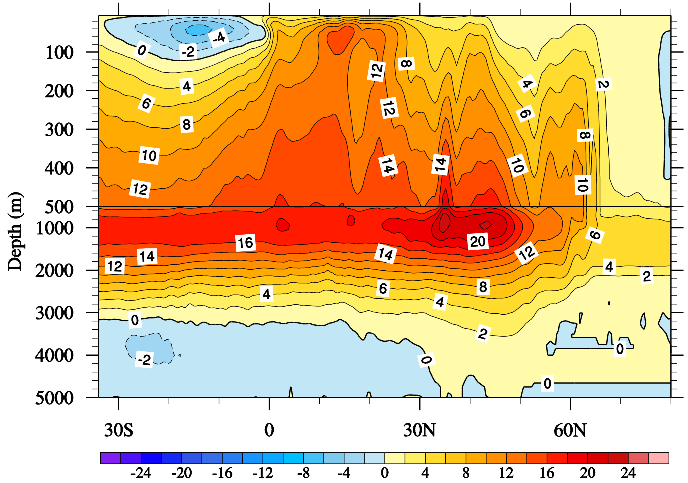




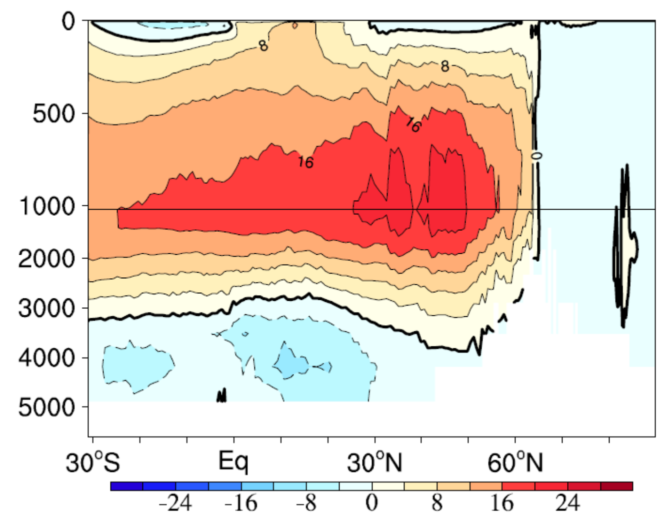
- 格陵兰岛陆冰全部融化将导致海平面升高7米
- 70%的淡水，90%的冰，全部融化将导致海平面升高61米
- “没有”青藏高原，冰川融化将导致海平面升高？地球基本气候态？

耦合气候系统模式

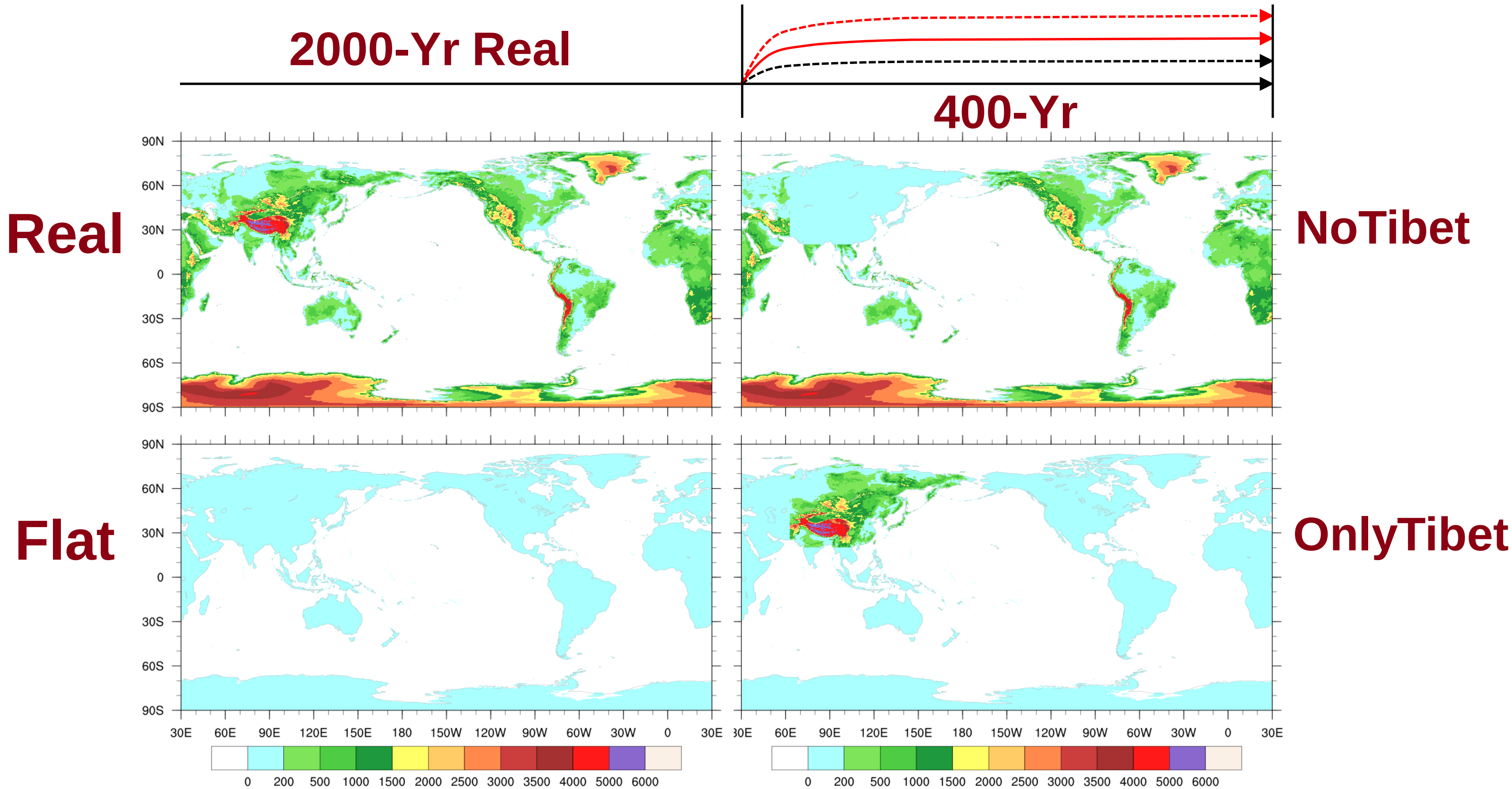
- 美国国家大气研究中心CESM1.0
  - 大气CAM5；海洋POP2
  - 陆面CLM4；海冰CICE4
  - 陆冰Glimmer-CISM



- 中国科学院大气所FGOALS-s2
  - 大气SAMIL2；海洋LICOM2
  - 陆面CLM3；海冰CSIM5

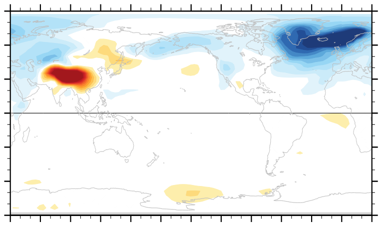


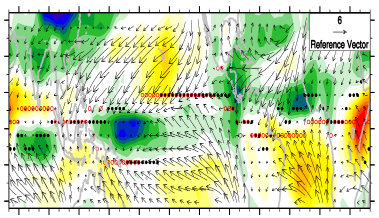
Coupled Earth System Model



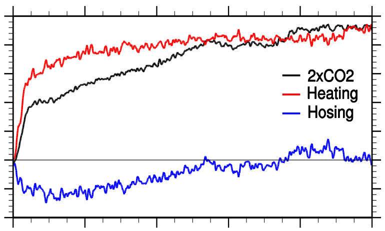
NCAR CESM1.0: CAM5 / POP2 / CLM4 / CICE4 / Glimmer-CISM

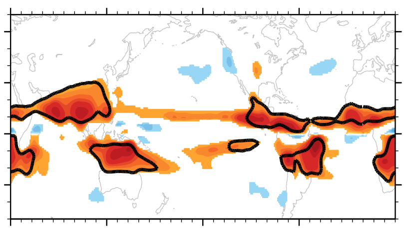
TP in Climate System

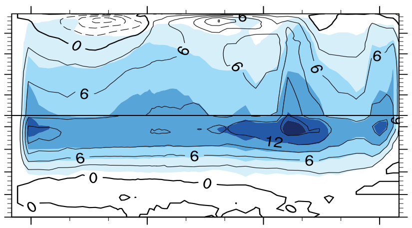


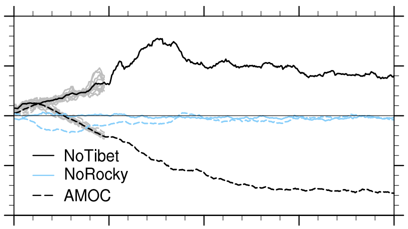


- Yao et al., TP role in global climate: annual mean (*Writing*)
- Yao et al., TP role in global climate: SC and monsoon (*Writing*)
- Wen et al., TP in shaping AMOC (*Writing*)
- Wen et al., TP in see-saw of PMOC and AMOC (*Writing*)
- Shen et al., TP effect on Atlantic ITCZ (*Writing*)

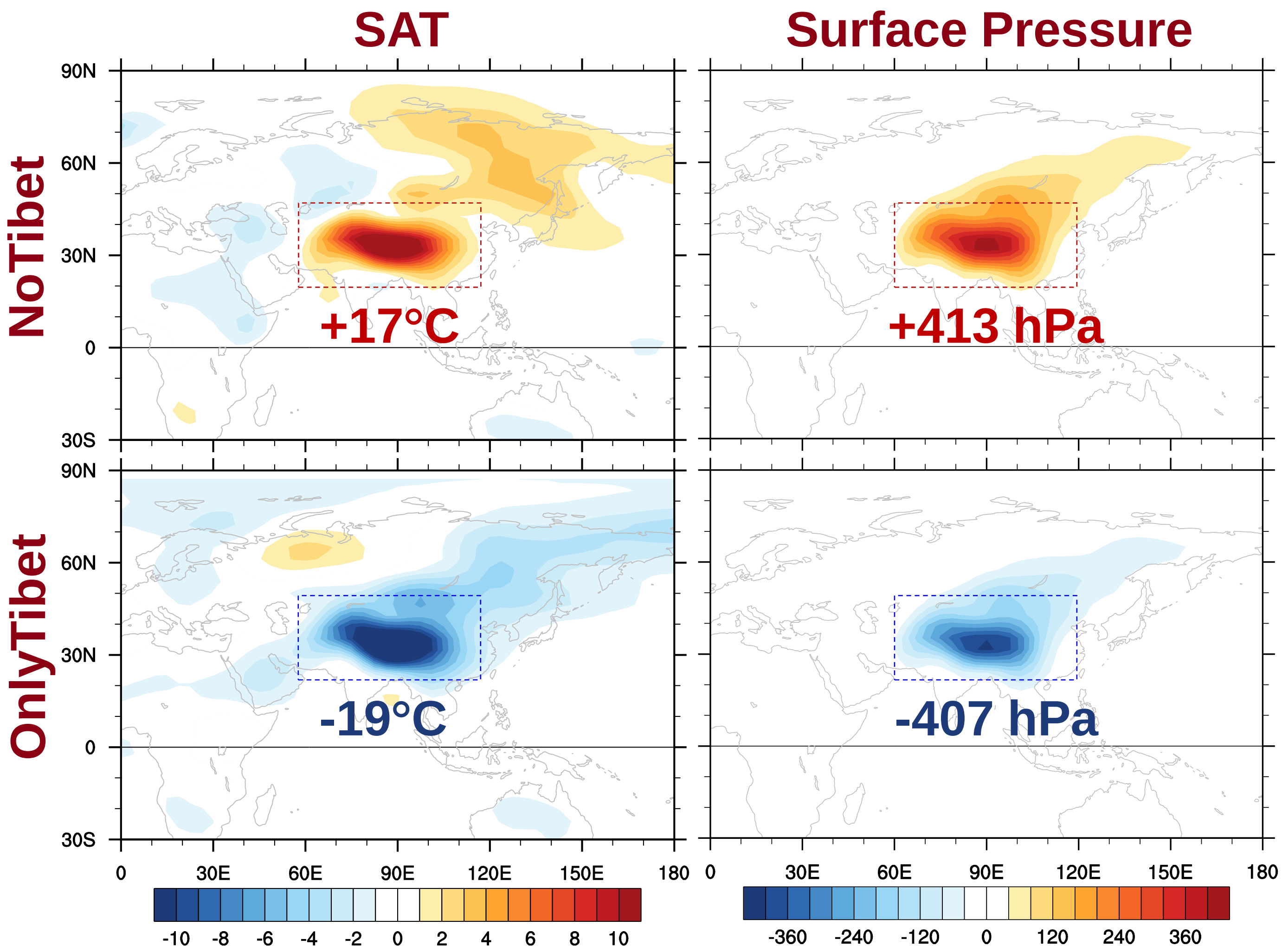






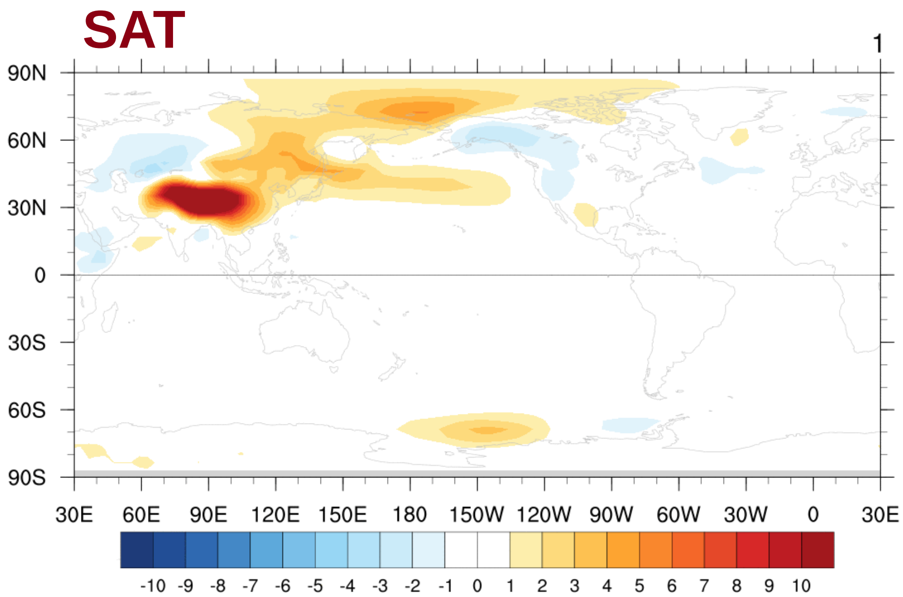


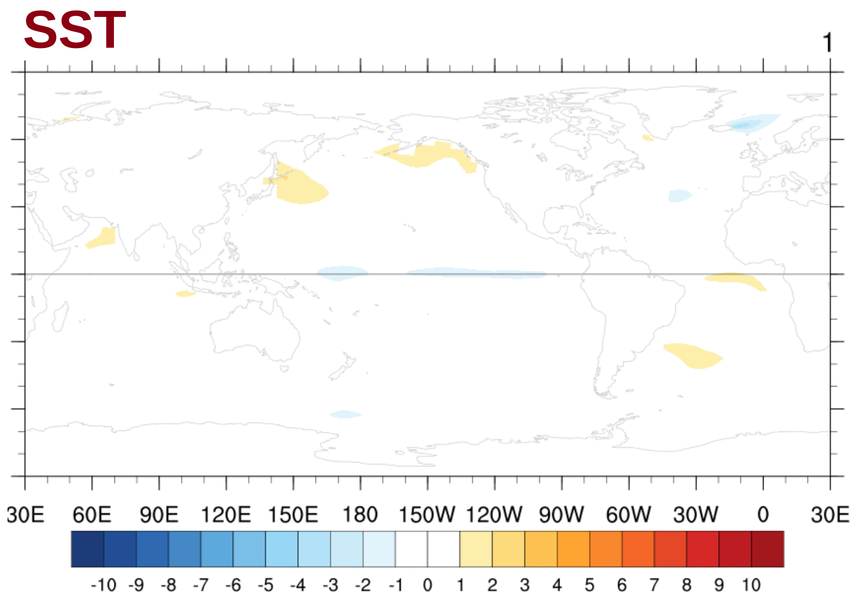
TP Forcing: *Thermal* and *Dynamical*



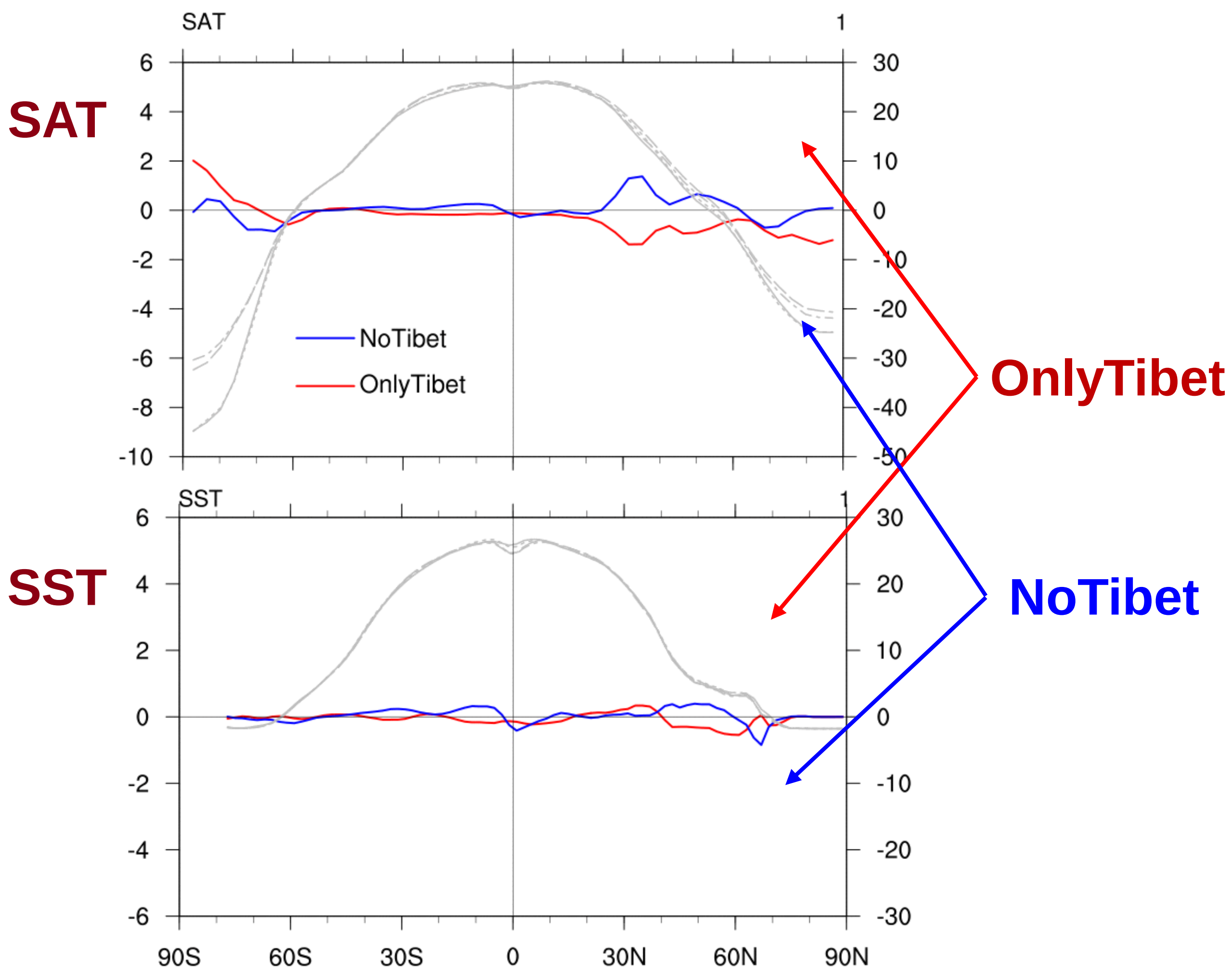
Lapse Rate T **~ 4 km x 7 ~ 28°C**

Surface Temperature w/o TP



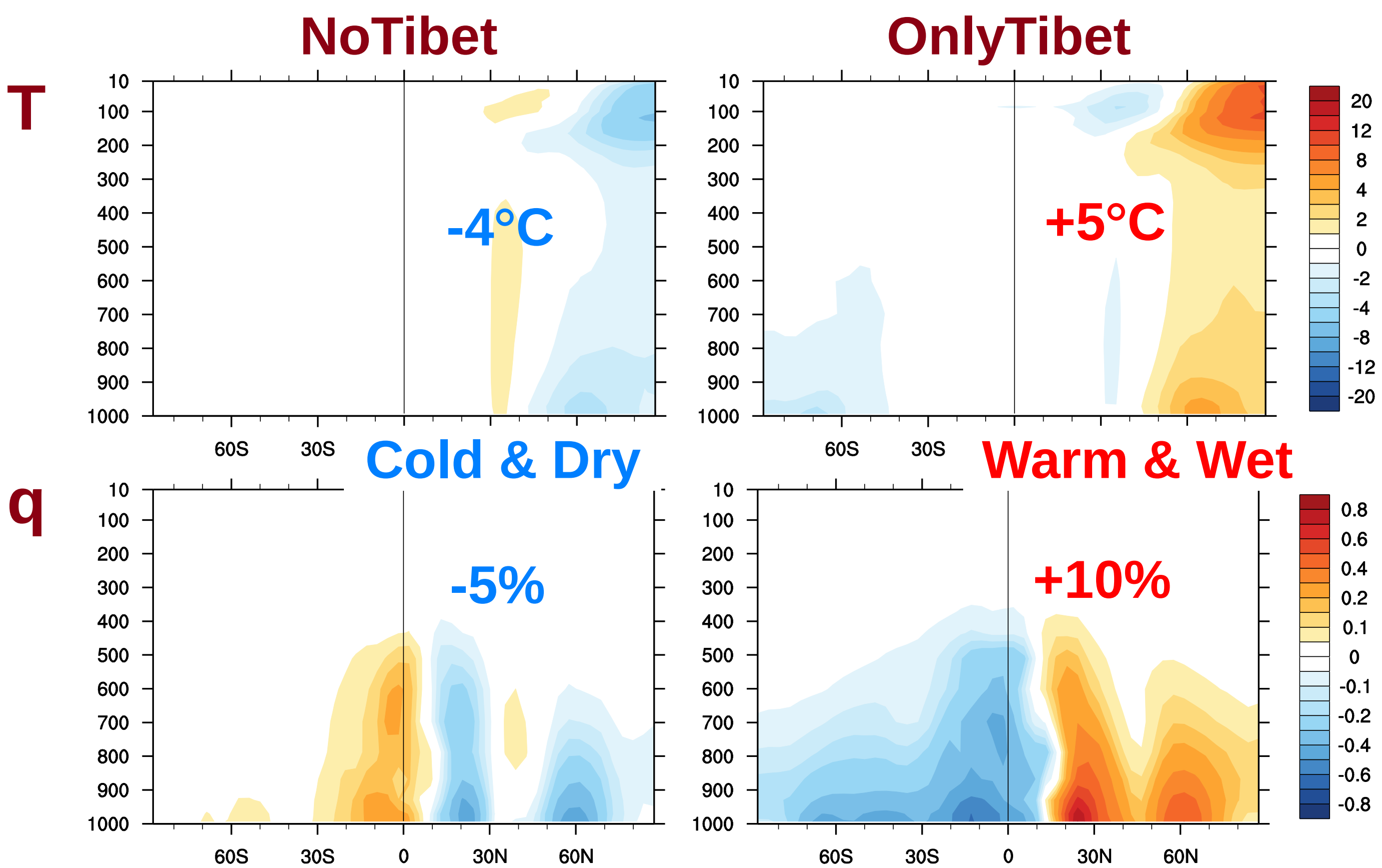


Mean SAT and SST

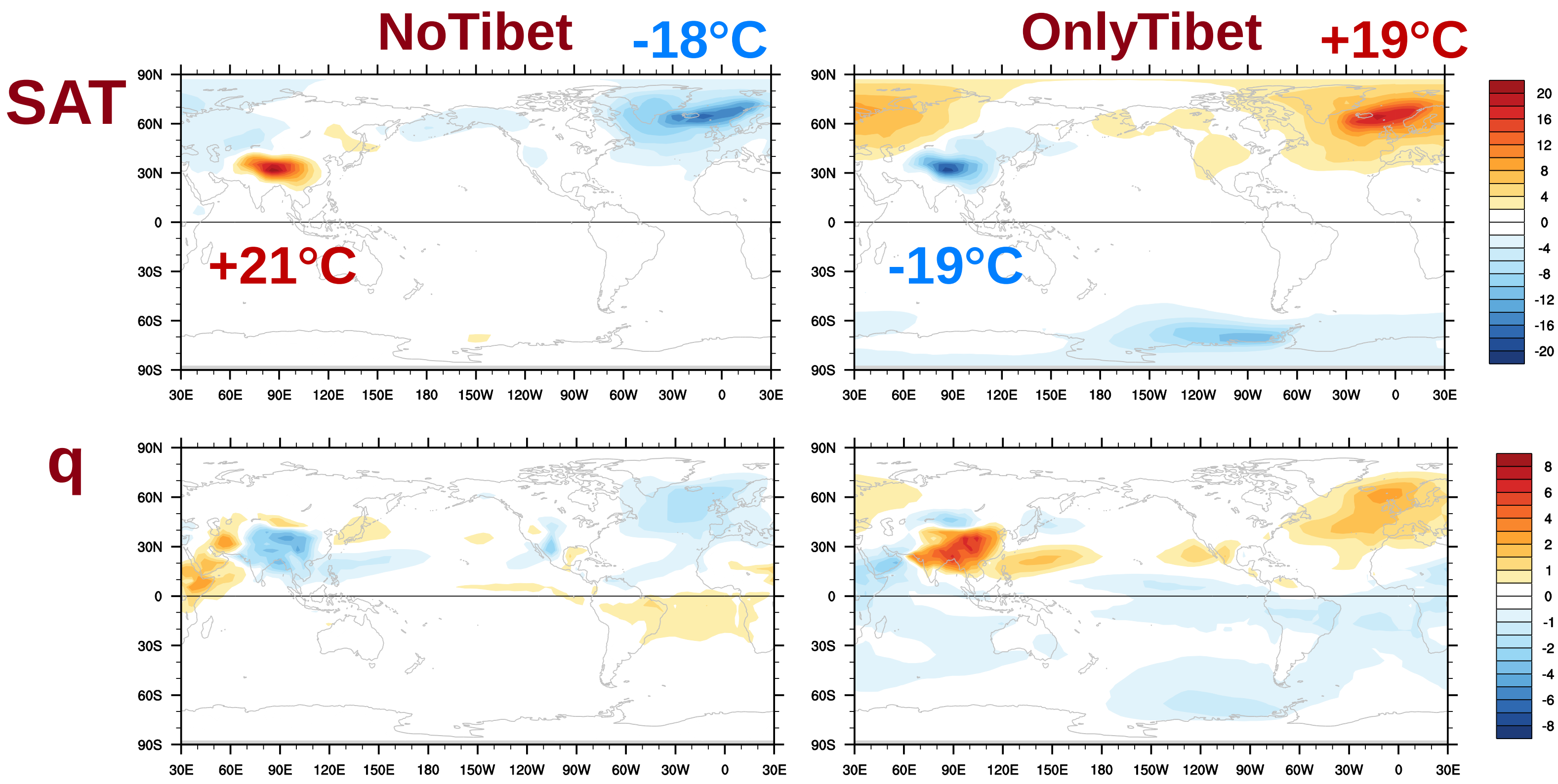


NoTibet: -0.4°C / OnlyTibet: +0.1°C

Atmosphere T and Moisture

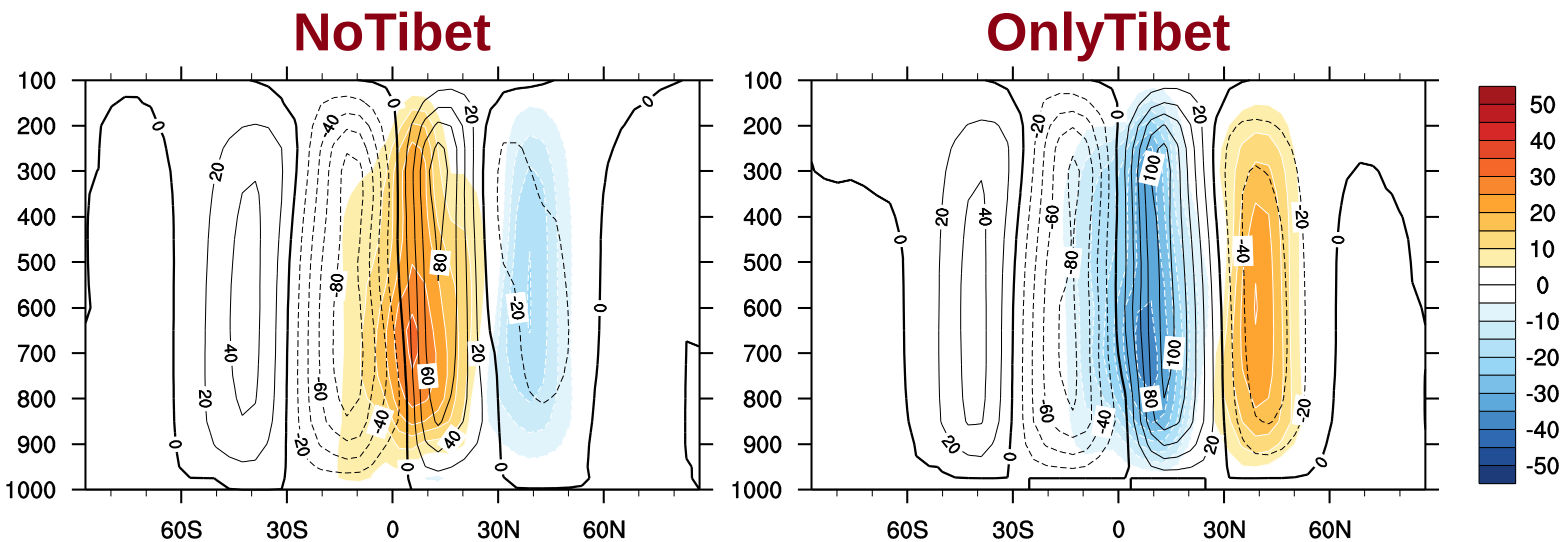


SAT and Specific Humidity



- Local: around Tibetan Plateau
- Remote: Atlantic & Southern Ocean

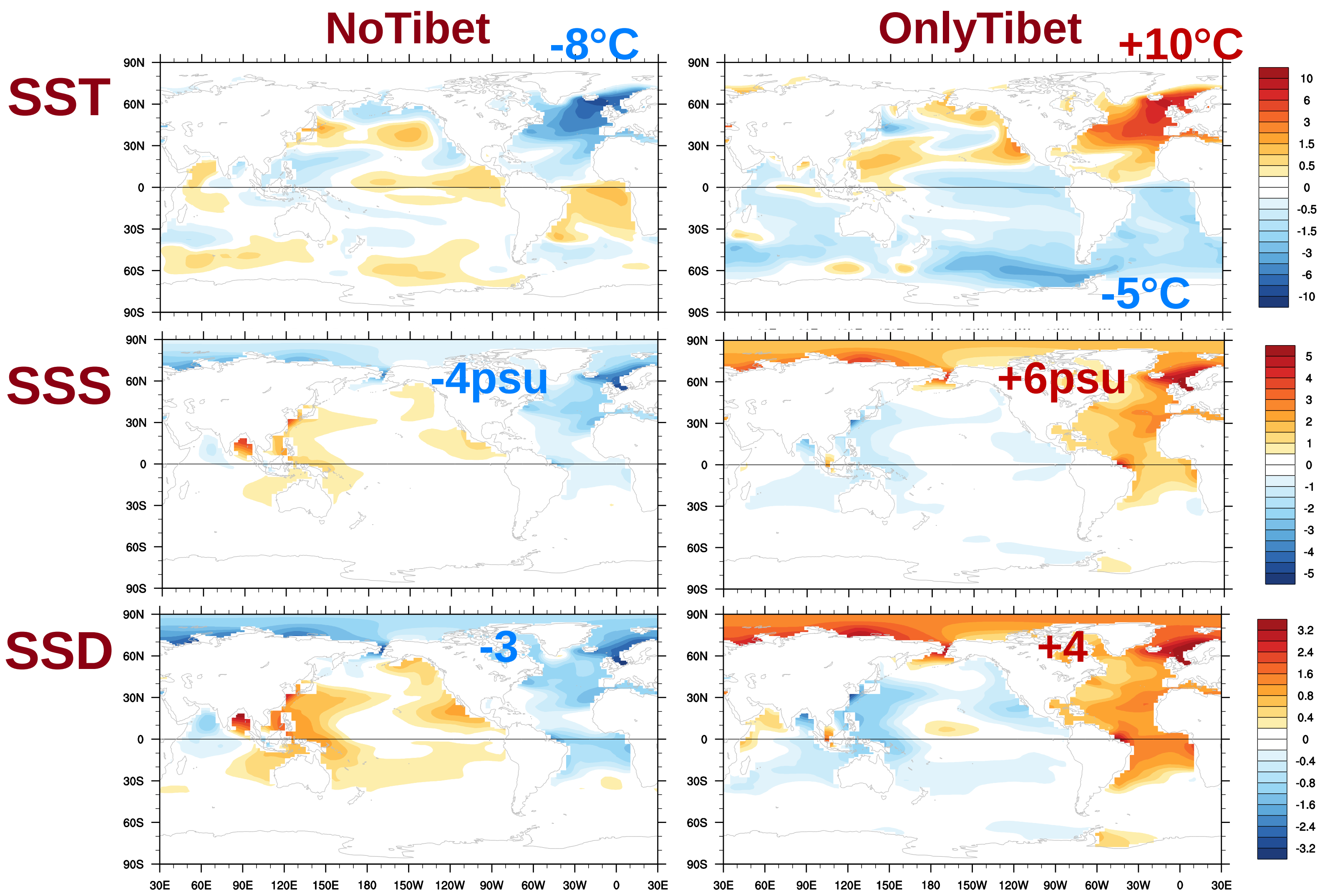
Hadley Cell



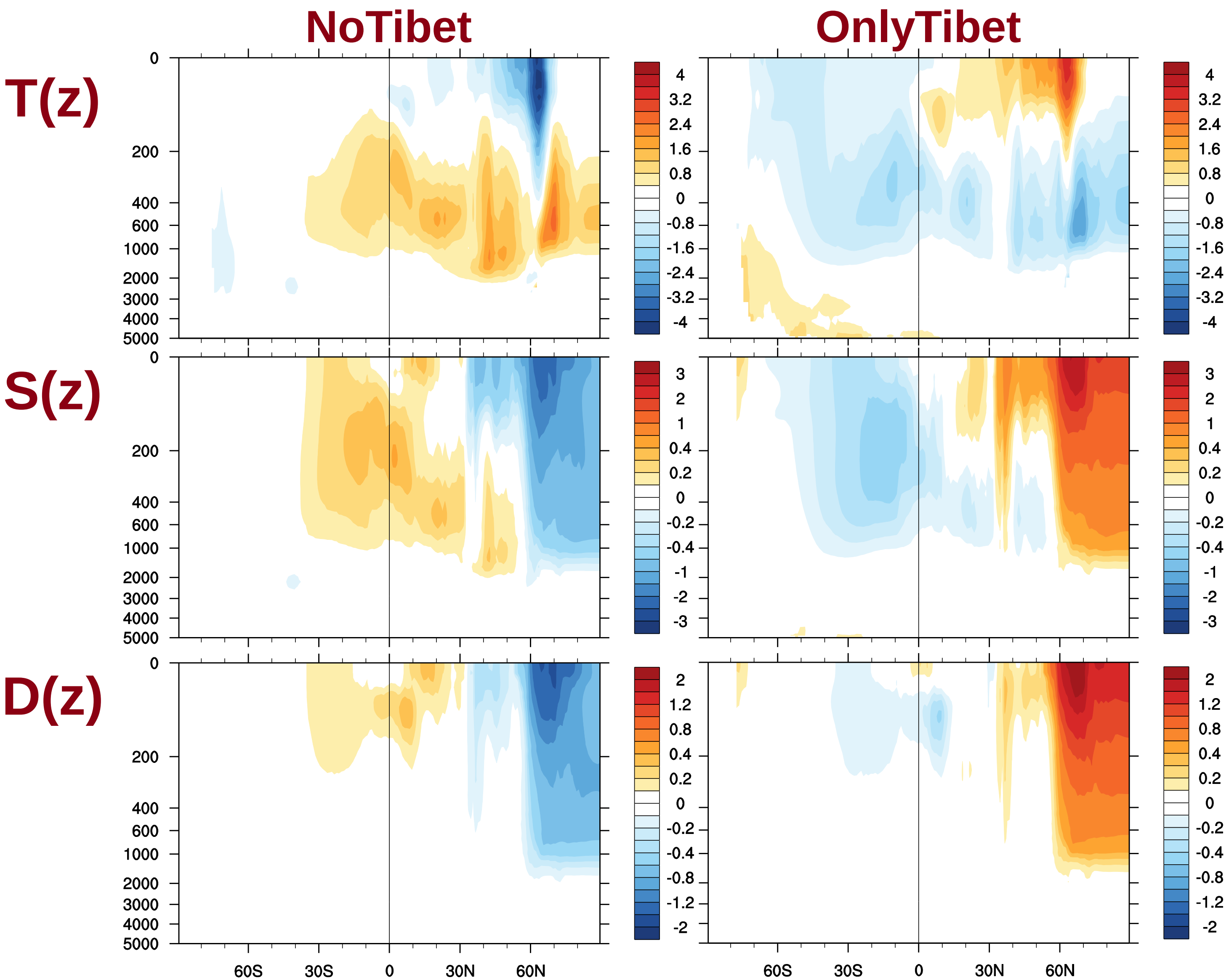
+13% ⇑

-20% ⇓

SST, SSS and SSD

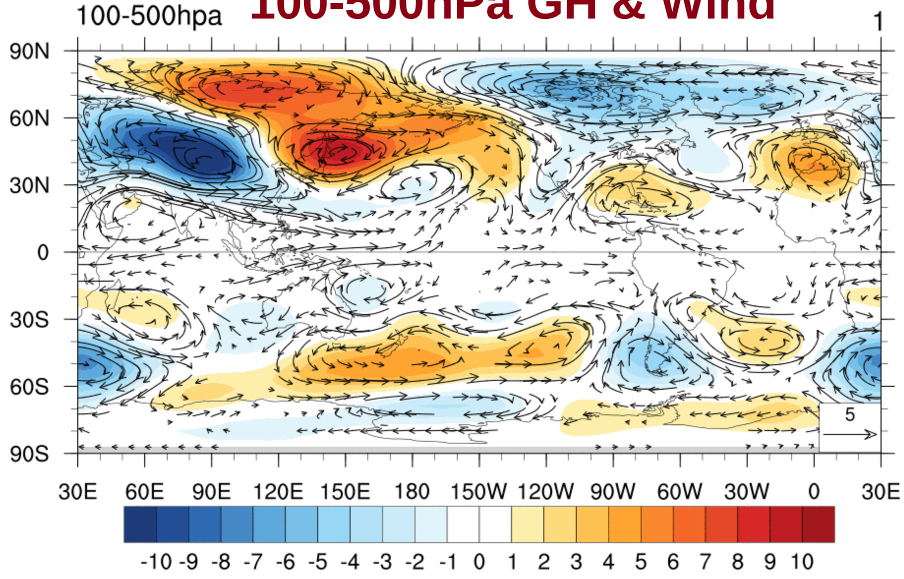


T, S and D

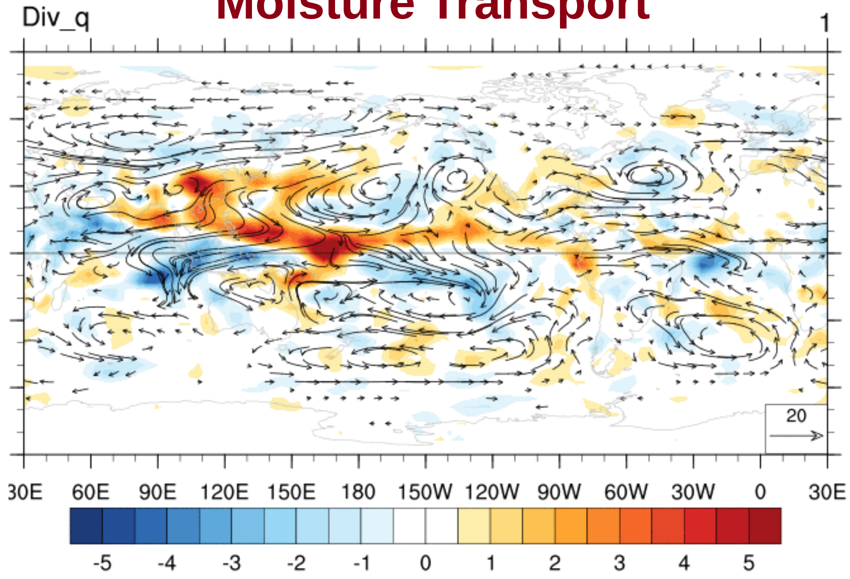

NoTibet
OnlyTibet
T(z)
S(z)
D(z)
0
200
400
600
1000
2000
3000
4000
5000
60S
30S
0
30N
60N
4
3.2
2.4
1.6
0.8
0
-0.8
-1.6
-2.4
-3.2
-4
3
2
1
0.4
0.2
0
-0.2
-0.4
-1
-2
-3
2
1.2
0.8
0.4
0.2
0
-0.2
-0.4
-0.8
-1.2
-2

Planetary Wave and Moisture Transport

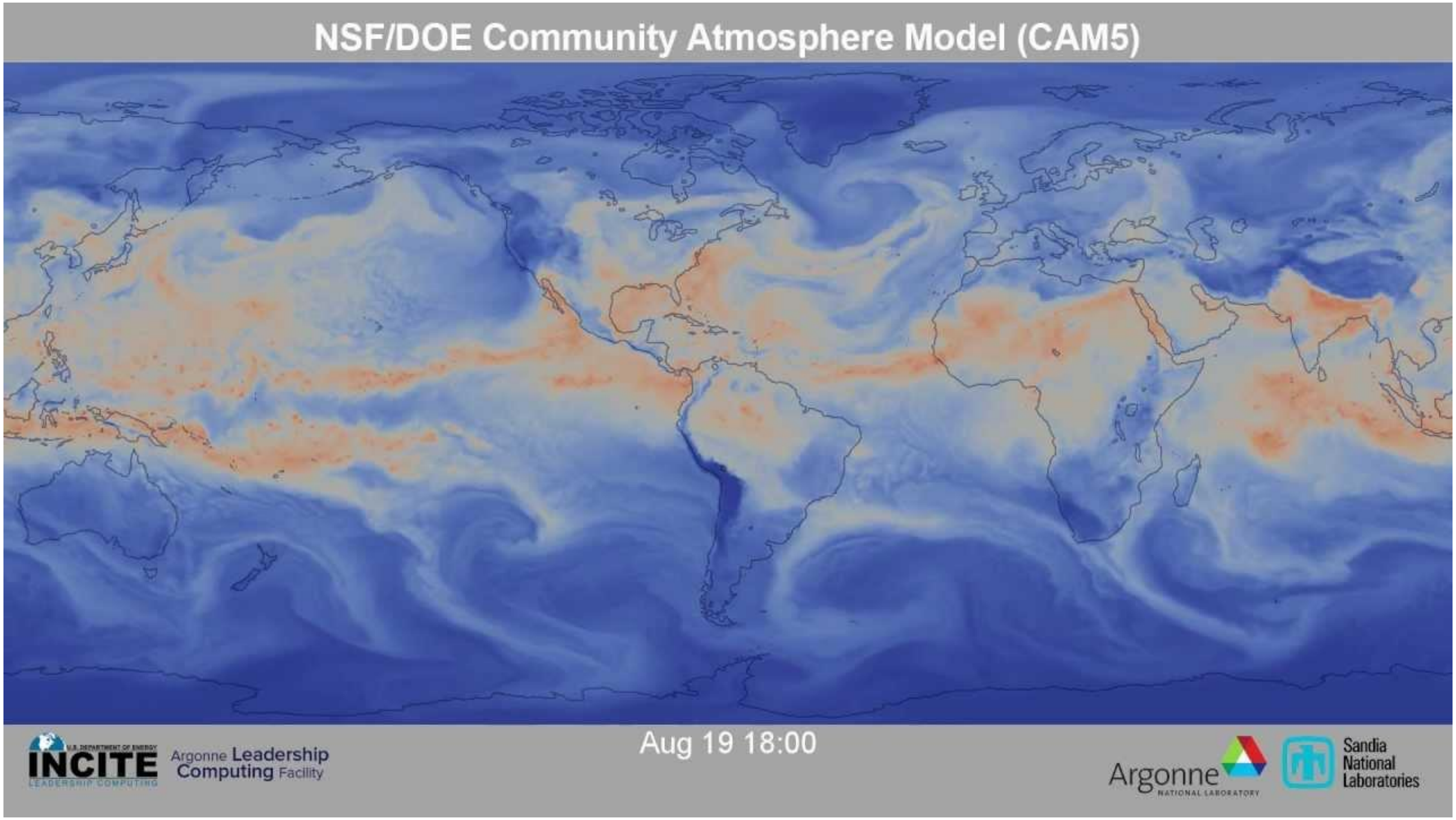
100-500hPa GH & Wind



Moisture Transport



Atmospheric River



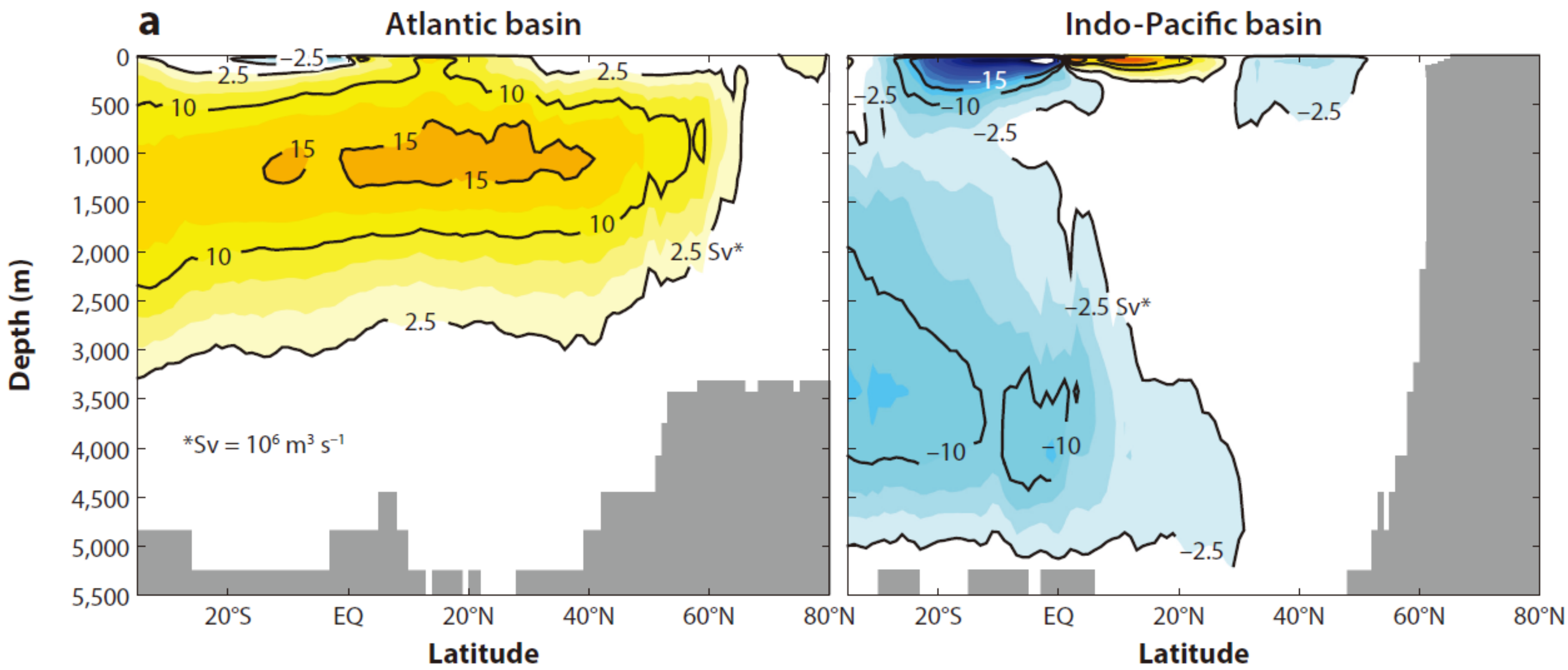
Preliminary Results

		NoTibet	OnlyTibet
Atmos	TOA (PW)	+0.2	-0.04
	Air T (°C)	-4.0	+6.0
	SAT (°C)	-18.0	+19.0
	Air q (%)	-5.0	+10.0
	HC (%)	+13	-20
Ocean	SST (°C)	-8.0	+10.0
	SSS (psu)	-4.0	+6.0
	SSD (kg/m^3)	-3.0	+4.0

0 → 1 : Critical in Shaping Global Climate!

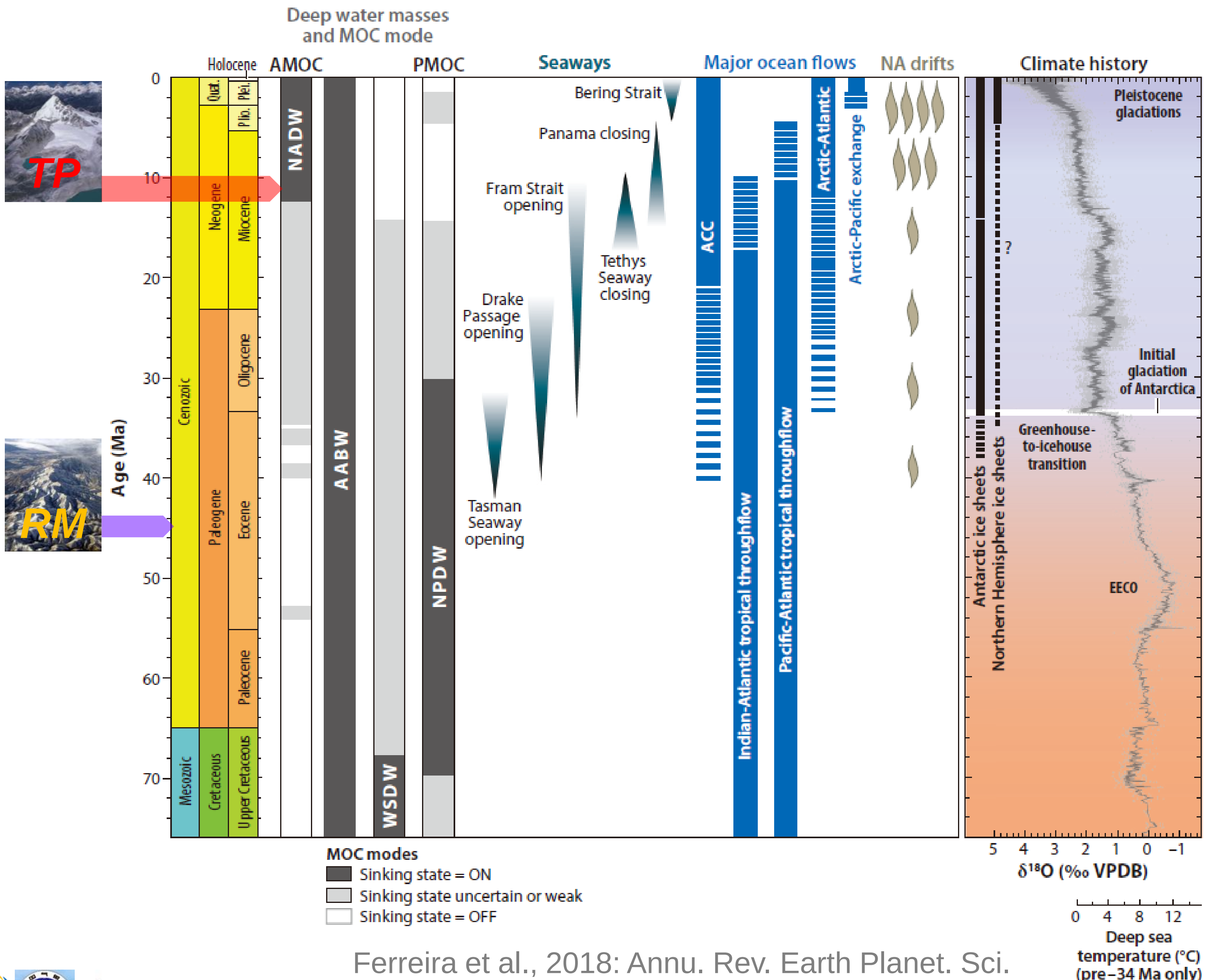
GMOC Now

Strong AMOC | **Weak PMOC**



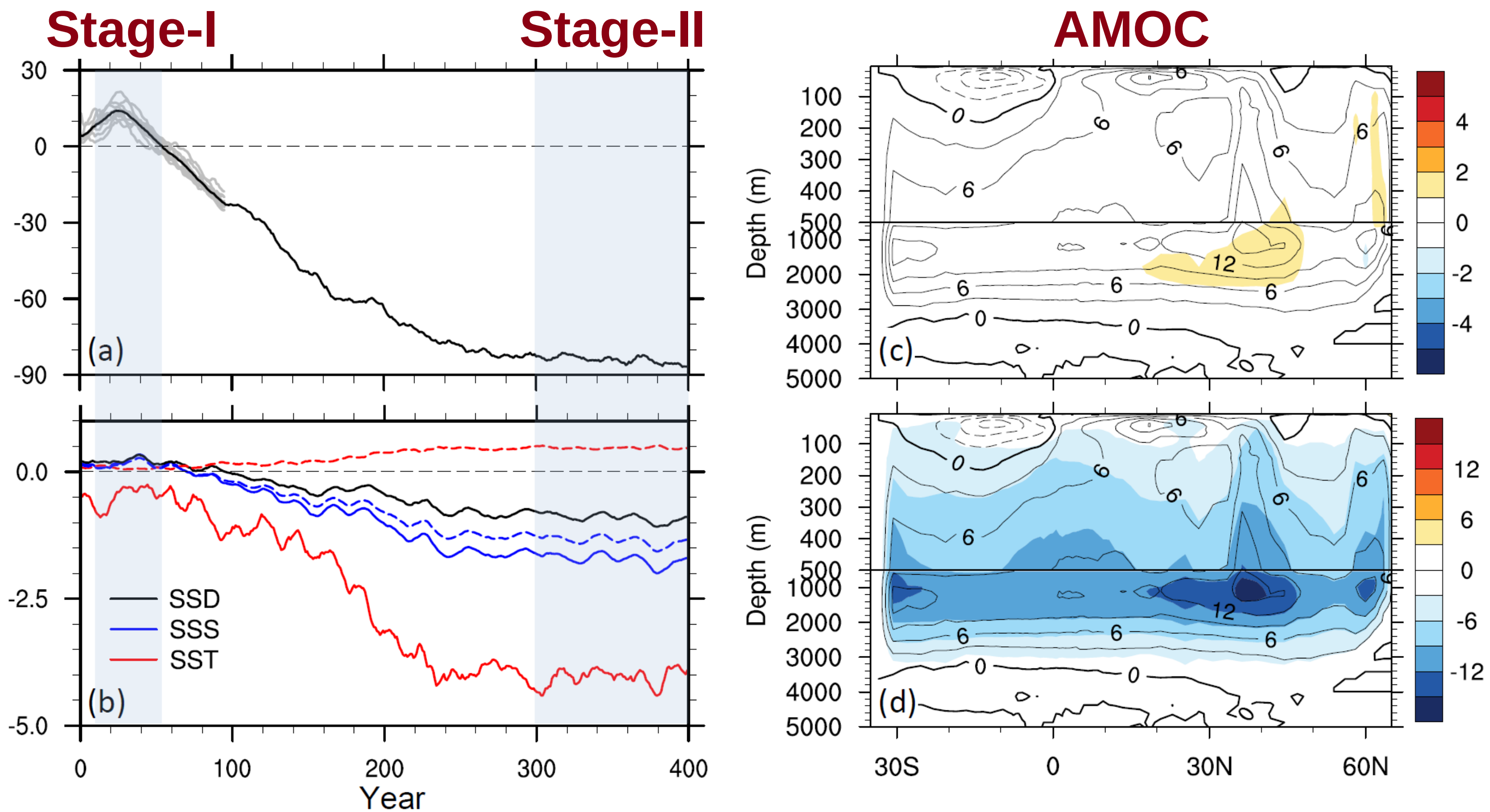
Ferreira et al., 2018: Annu. Rev. Earth Planet. Sci.

Geological History of *GMOC*

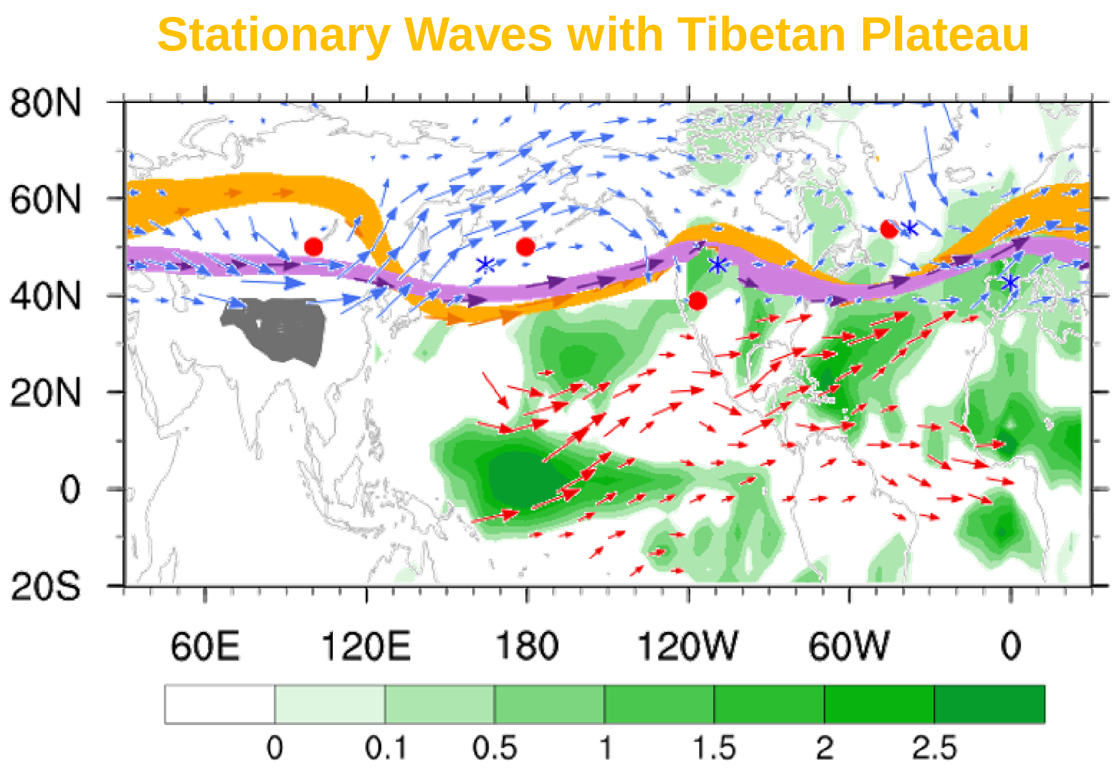


Ferreira et al., 2018: Annu. Rev. Earth Planet. Sci.

AMOC Evolution w/o TP

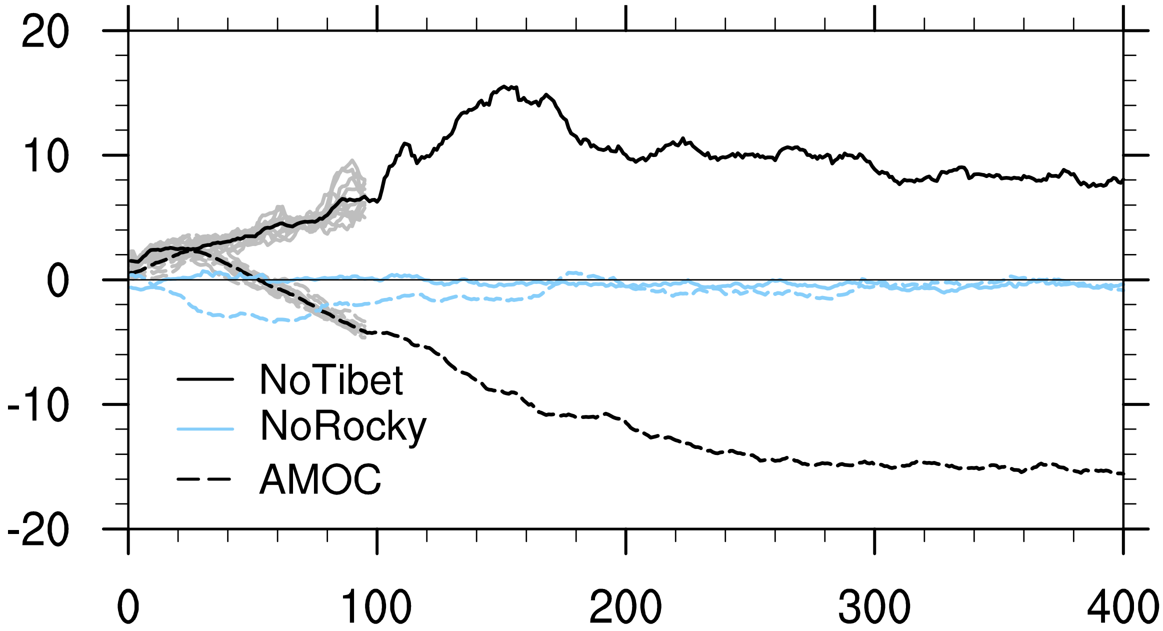


From *TP* to *AMOC: Atmosphere Dynamics*

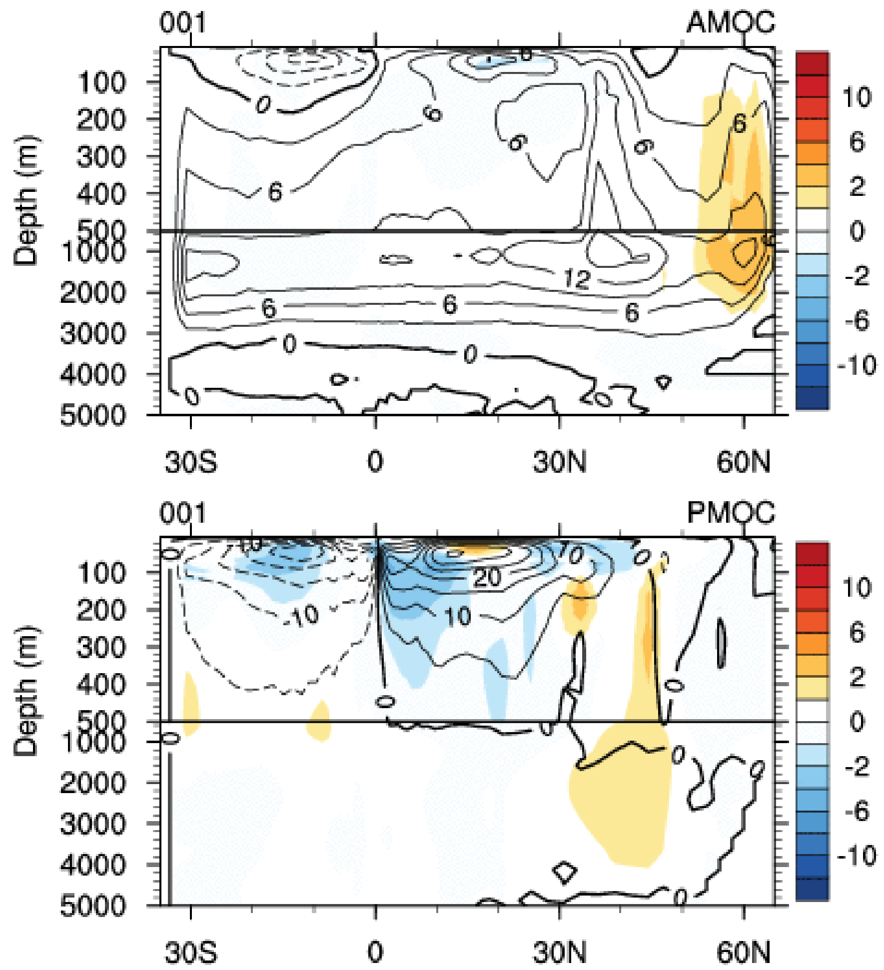


NoTibet ➡ Annular mode ⇑ ➡ Westerlies ⇑ ➡ Moisture transport ⇑

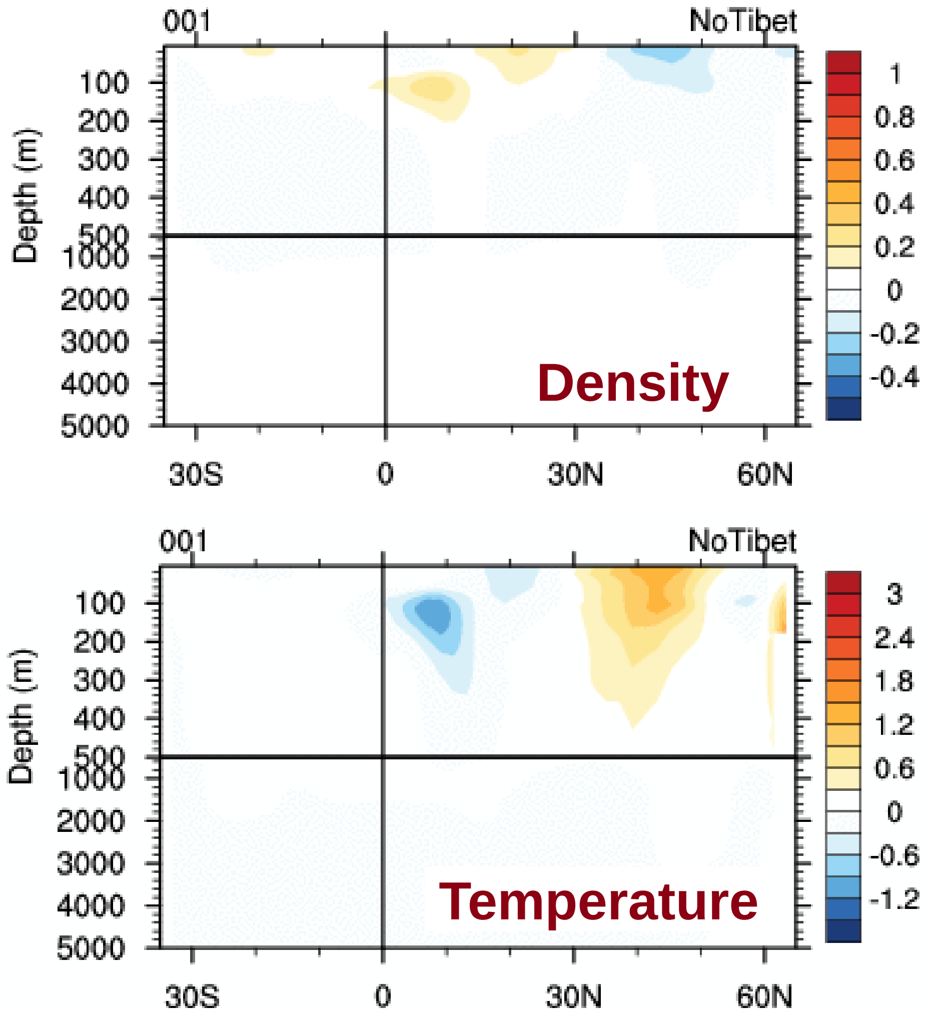
AMOC vs. *PMOC*



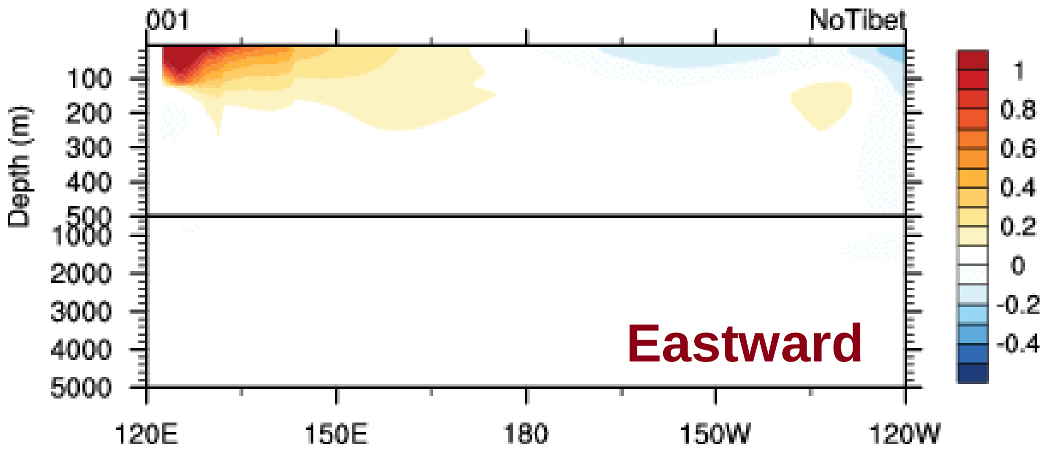
AMOC vs. PMOC: See-Saw?

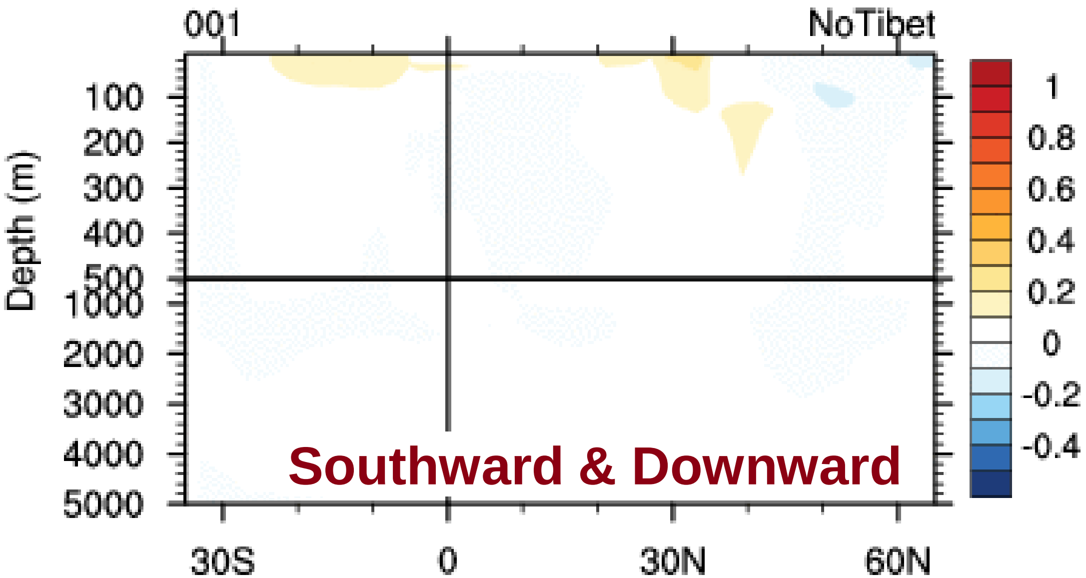


PMOC: Mechanism?

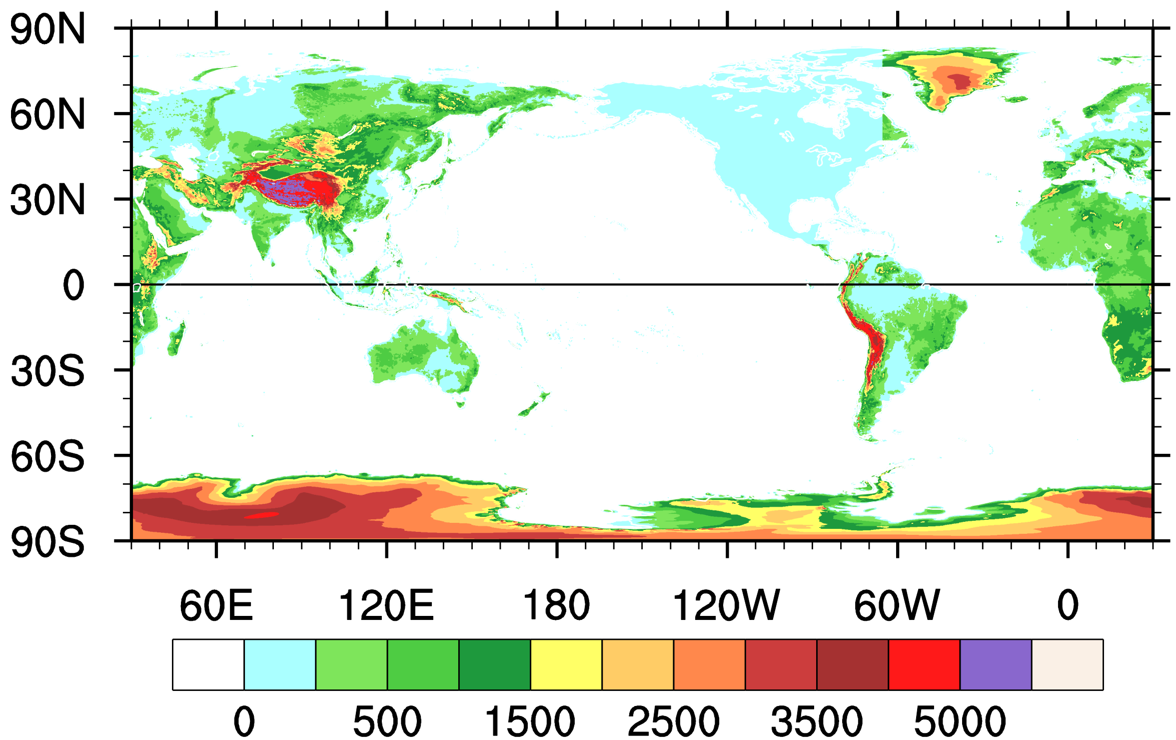


PMOC: *Salinity* Mechanism

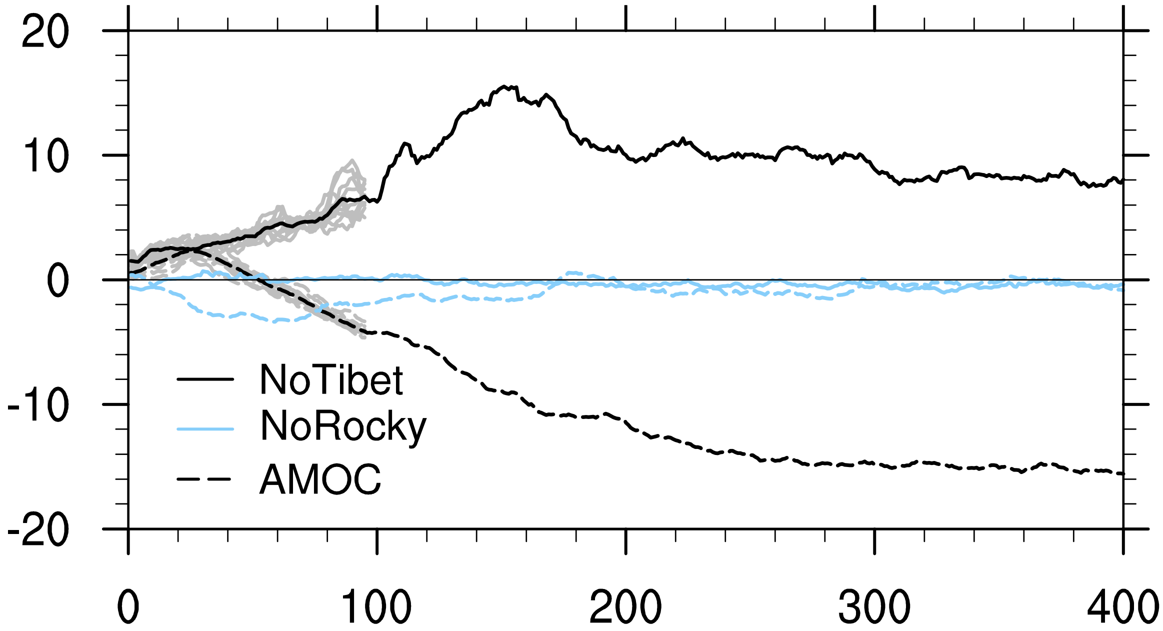




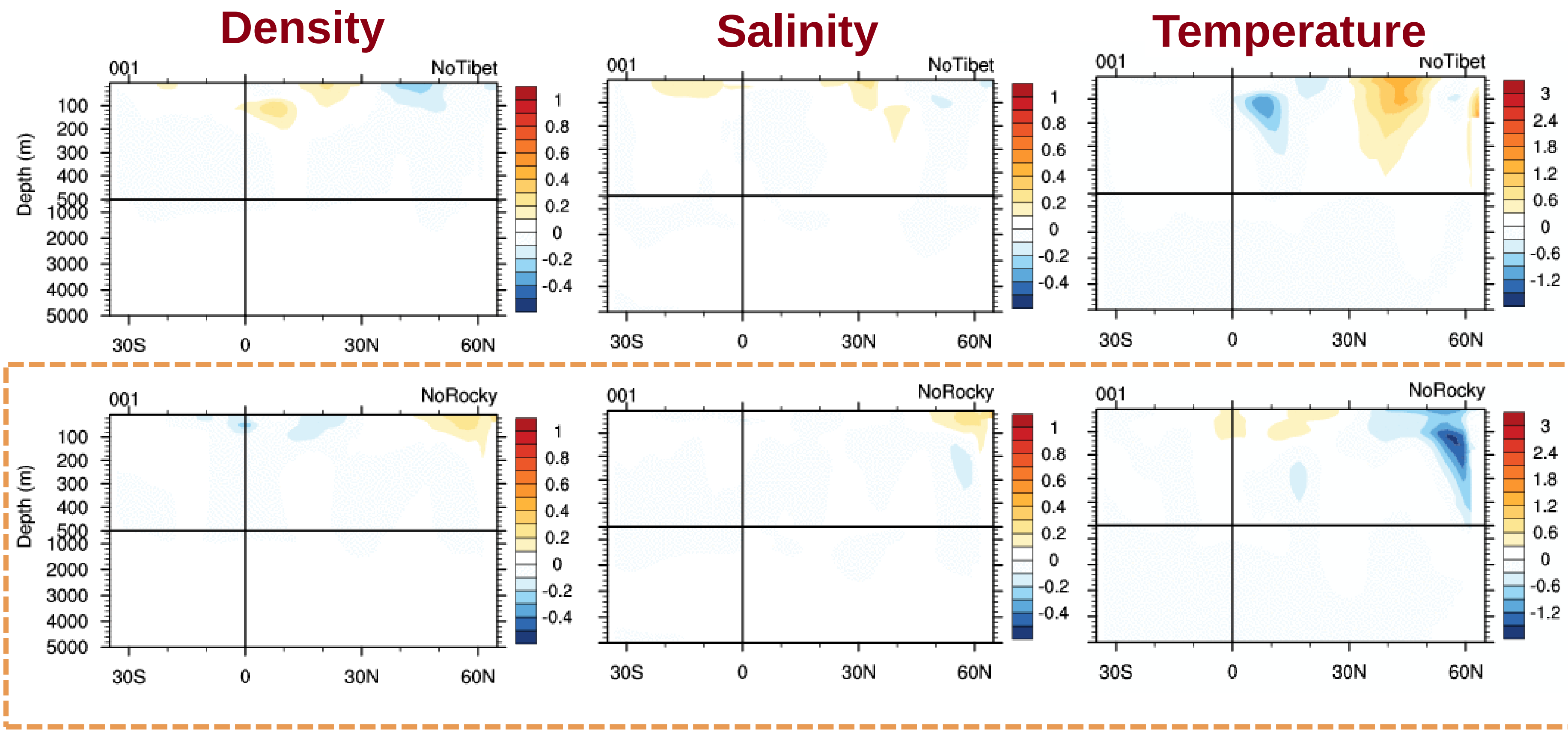
Role of *Rocky* Mountain?



Rocky Mountain: No Role?



Rocky Mountain: No Role in MOC



Preliminary Results

	NoTibet	NoRocky
AMOC	Weak	Unchanged
PMOC	Strong	Unchanged

0 → 1 : Critical in Shaping Global Overturning Circulation!

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Thanks