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

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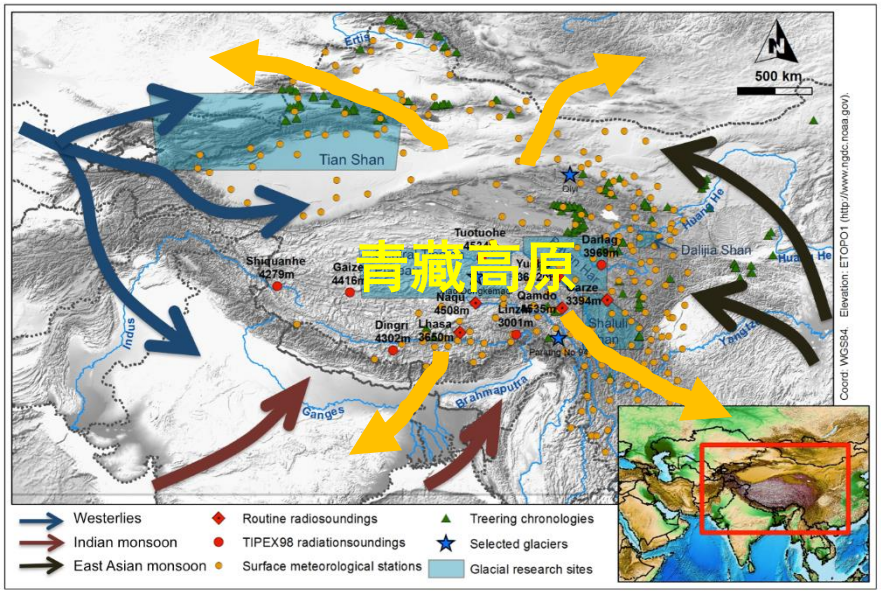
国家自然科学基金委员会 National Natural Science Foundation of China

青藏高原：世界第三极

总面积250万km^2，平均海拔4000m

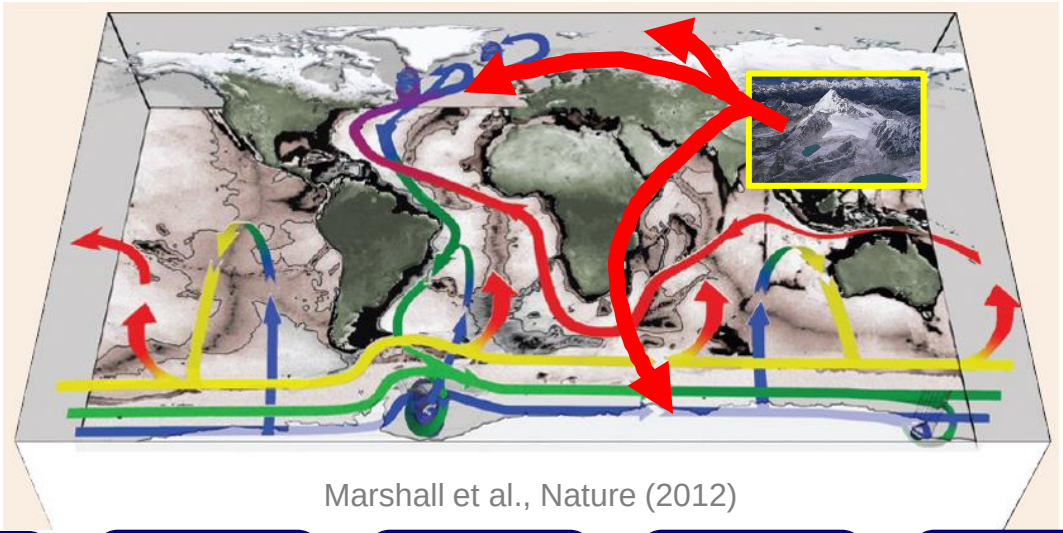
中国科学家的卓越贡献

青藏高原地-气耦合及其区域环境相互作用



青藏高原的全球视角

难点：如何影响？多大影响？



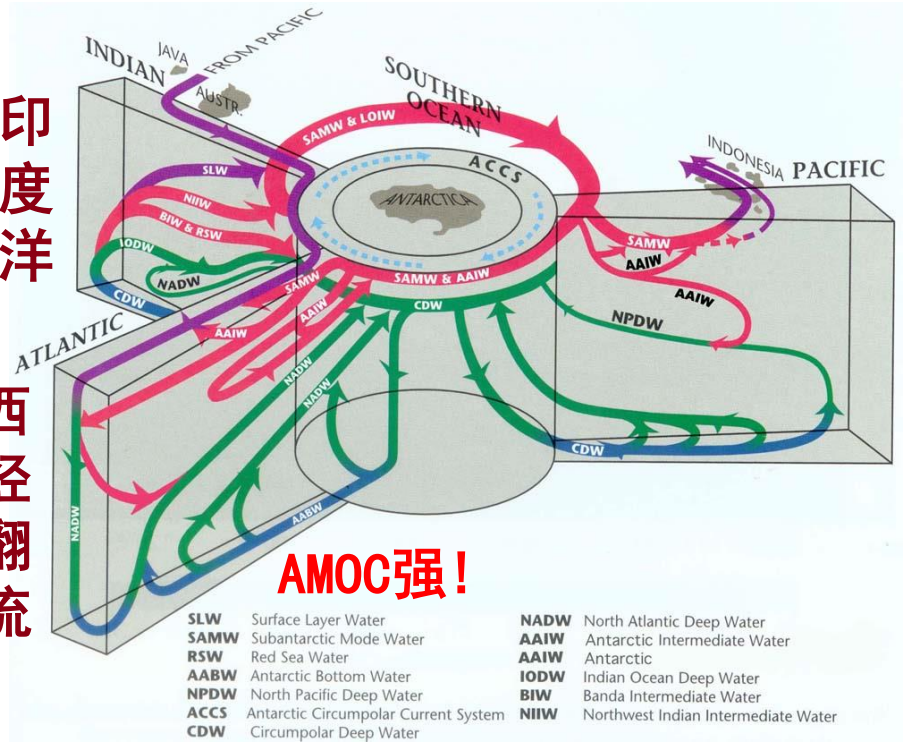
Marshall et al., Nature (2012)

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

印度洋弱！



大西洋经圈翻转流

AMOC强！

太平洋经圈翻转流

PMOC非常弱！

Schmitz (1997) Overturning circulation: Southern Ocean View

科学问题

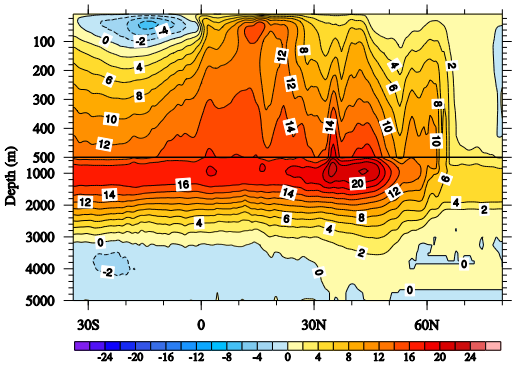
1. “有/无”青藏高原，地球气候态有什么不同？
2. 如果没有青藏高原，现代全球海洋大输送带还会存在吗？
3. “有/无”青藏高原，气候态的北大西洋深水形成、AMOC有什么不同？
4. 青藏高原、落基山脉、安第斯山脉在全球海洋经圈环流气候态塑造中的相对贡献如何？分别对全球能量-水汽循环有何影响？

耦合气候系统模式

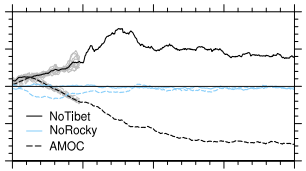
- 美国国家大气研究中心

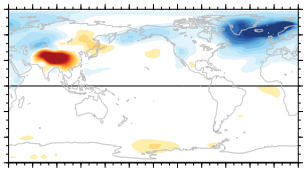
  CESM1.0

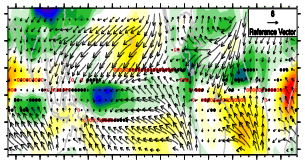
  - 大气CAM5；海洋POP2
  - 陆面CLM4；海冰CICE4
  - 陆冰Glimmer-CISM

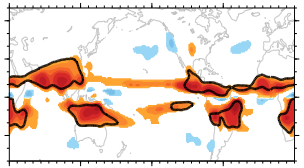


TP in Climate System









- **Yang et al., TP role in global climate: annual mean (*Published*)**
- **Yang et al., TP in shaping AMOC (*Published*)**
- **Wen et al., TP in see-saw of PMOC and AMOC (*Published*)**
- **Wen et al., TP effect on ENSO variability (*Published*)**
- **Wen et al., TP effect on the AABW (*Published*)**
- Chen et al., TP effect on the North African precipitation (*Accepted*)
- Jiang et al., Rocky Mountain effect on GMOC (*Accepted*)
- Yao et al., TP role in global climate: SC and monsoon (*Submitted*)
- Wang et al., TP connecting to Arctic and Antarctic (*Writing*)
- Jiang et al., TP determining the AMOC (*Writing*)

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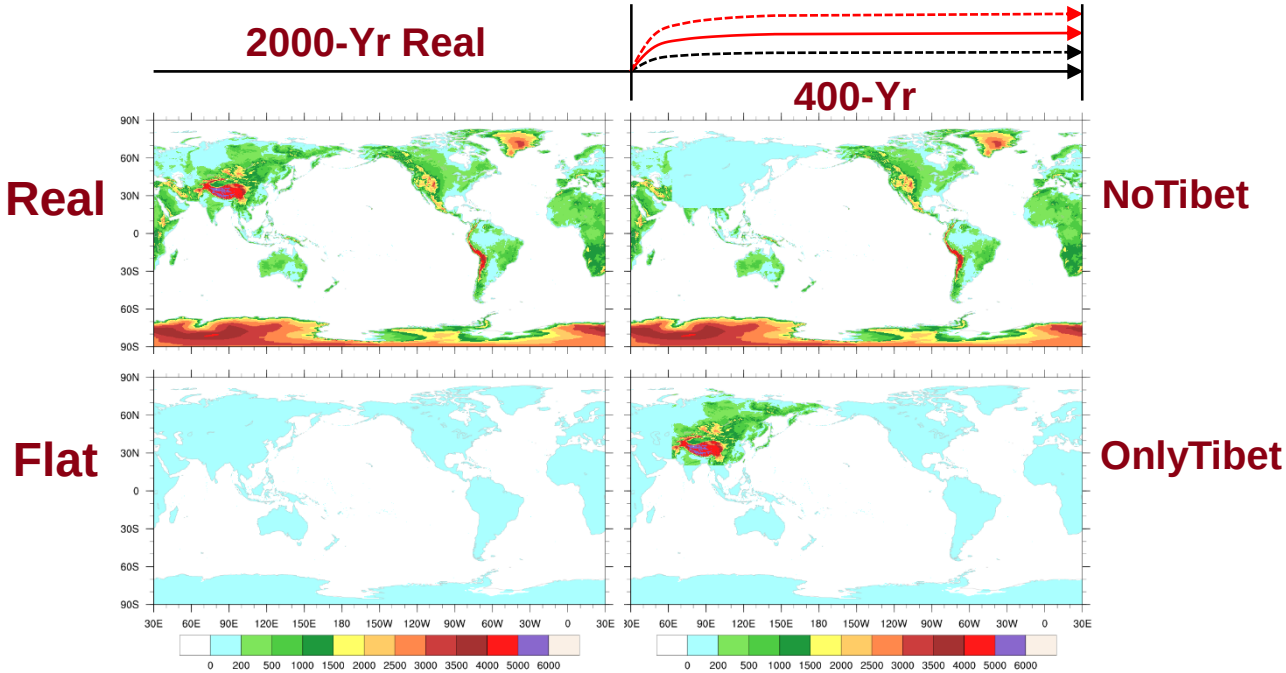
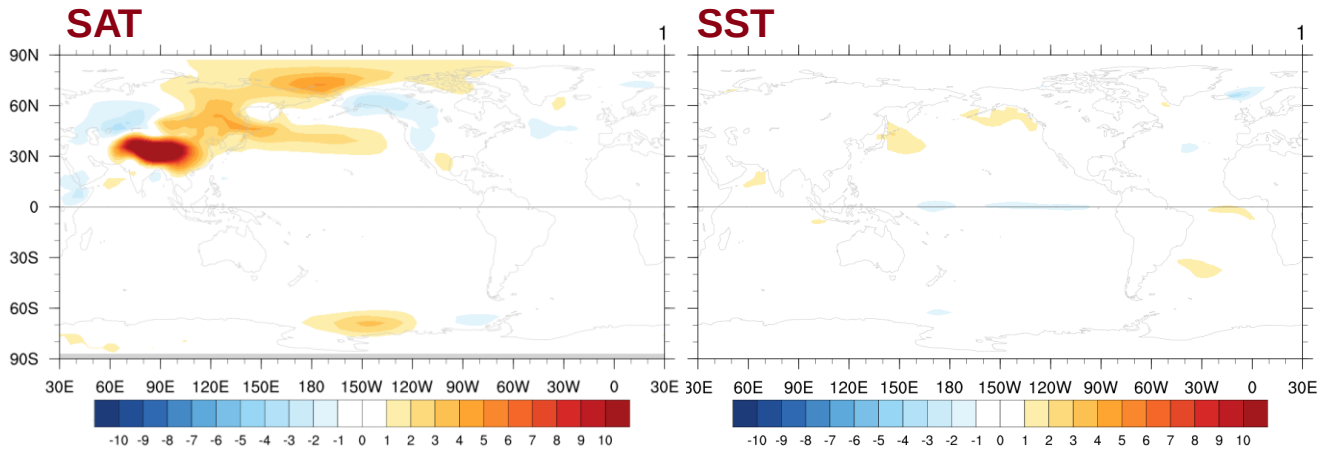
Coupled Earth System Model



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

1. TP's Global Impact



Yang, H., X. Shen, J. Yao and Q. Wen, 2019: Portraying the impact of the Tibetan Plateau on global climate. *J. Climate*, 32, doi:10.1175/JCLI-D-18-0734.1

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!

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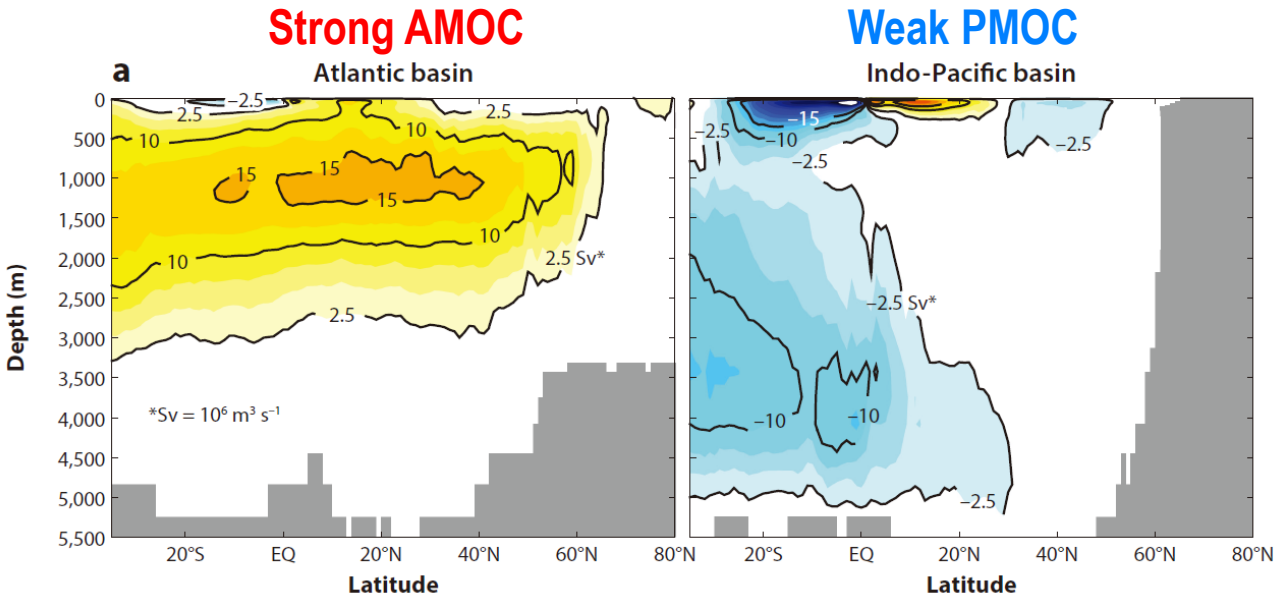
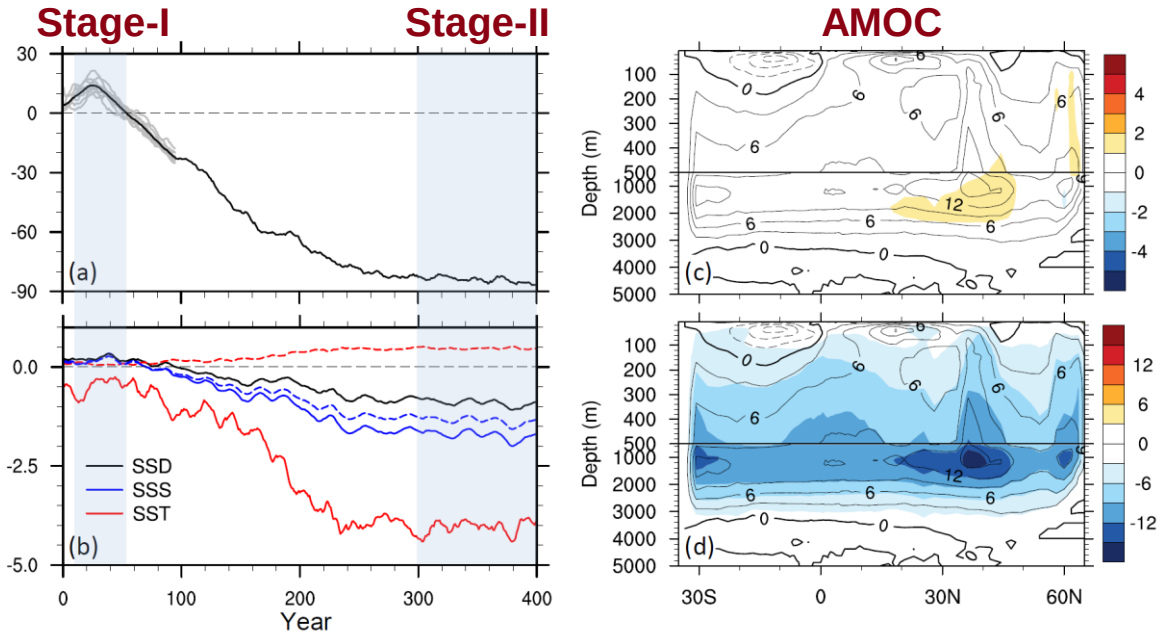
2. TP's Impact on GMOC

Present GMOC



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

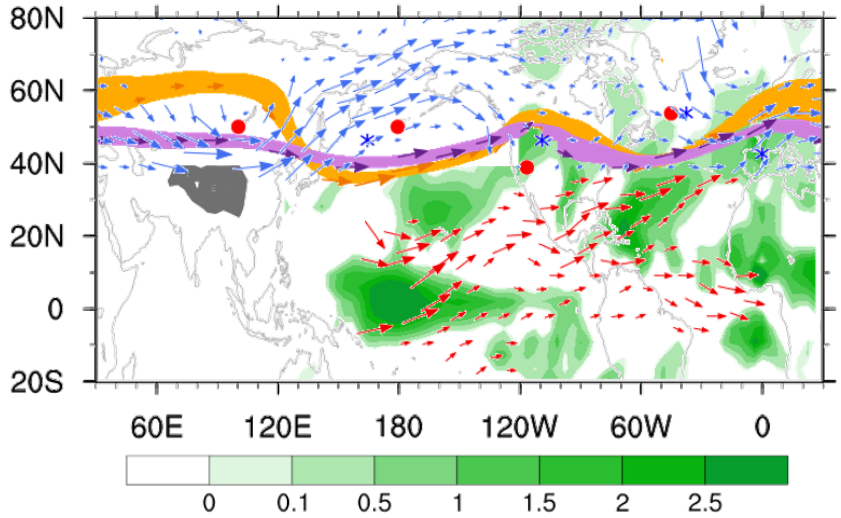
2.1. AMOC Evolution w/o TP



Yang, H., and Q. Wen, 2019: Investigating the role of the Tibetan Plateau in the formation of Atlantic meridional overturning circulation. *J. Climate*, 32, doi: 10.1175/JCLI-D-19-0205.1.

From *TP* to *AMOC: Atmosphere Dynamics*

Stationary Waves with Tibetan Plateau



NoTibet → Annular mode ⇑ → Westerlies ⇑ → Moisture transport ⇑

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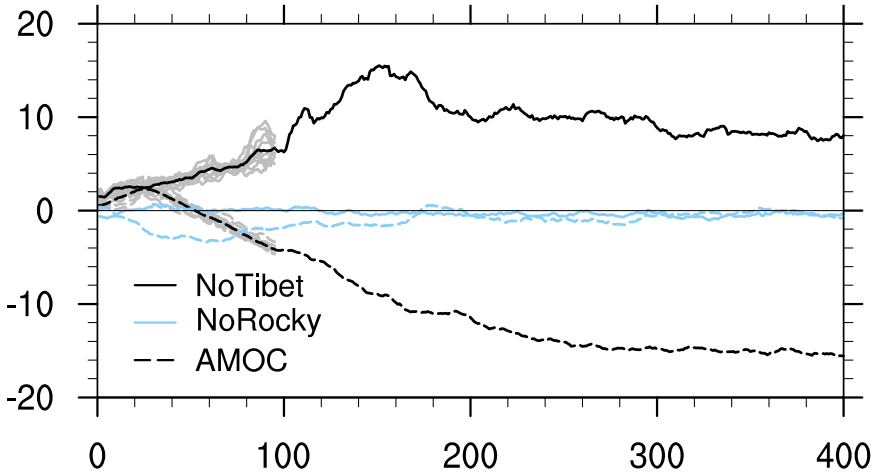
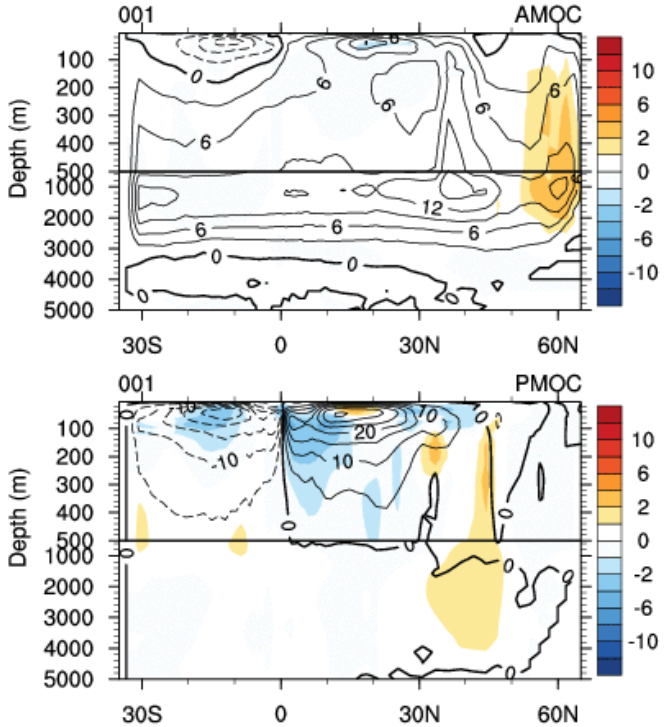
2.2. PMOC Evolution w/o TP

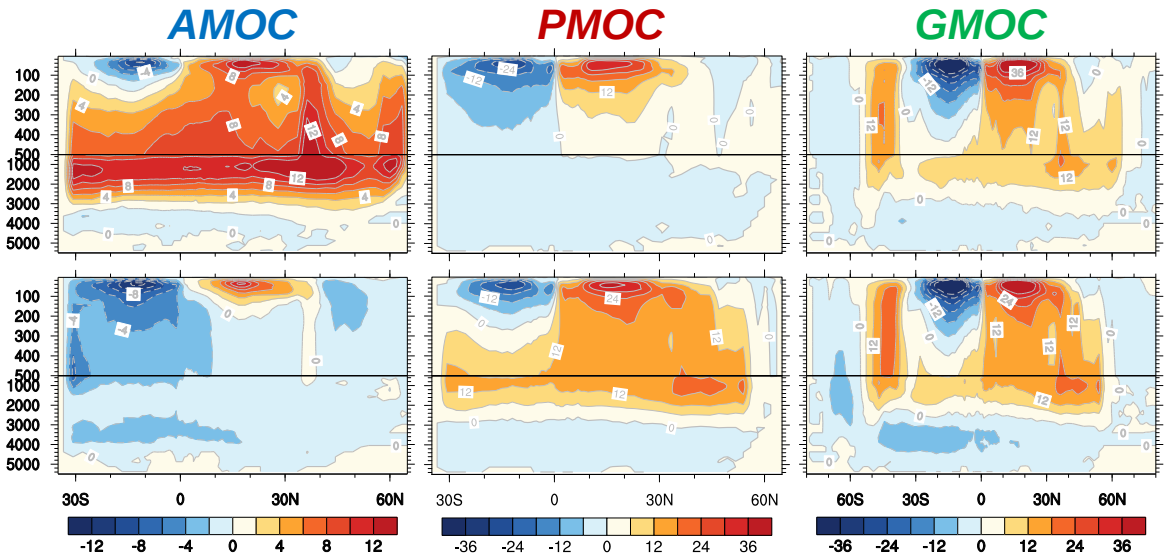


Wen, Q., and **H. Yang**, 2019: Investigating the role of the Tibetan Plateau in the formation of Pacific meridional overturning circulation. *J. Climate*, 32, doi: 10.1175/JCLI-D-19-0206.1

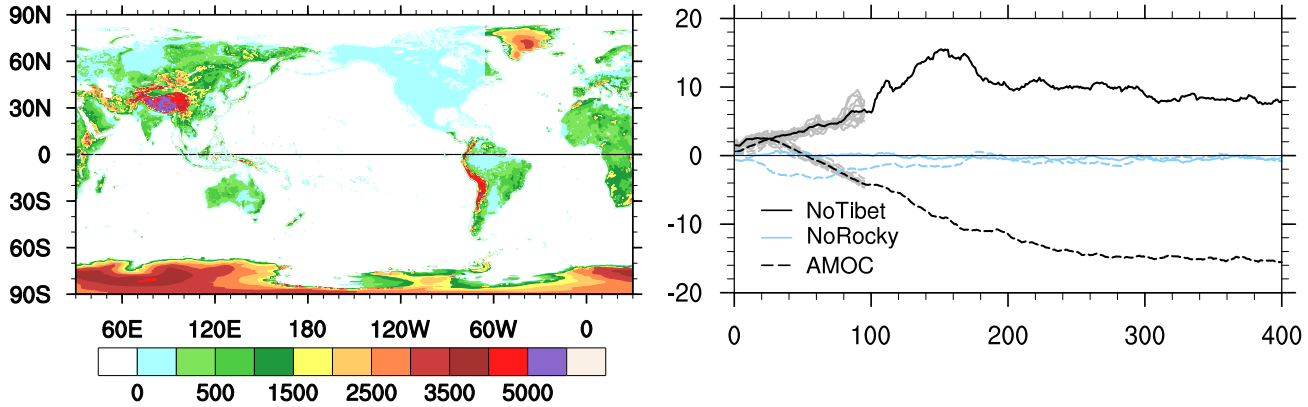
AMOC vs. *PMOC*: See-Saw



Global MOC


AMOC
PMOC
GMOC
Real
NoTibet
100
200
300
400
500
1000
2000
3000
4000
5000
30S
0
30N
60N
60S
-12 -8 -4 0 4 8 12
-36 -24 -12 0 12 24 36

3. Rocky Mountain Impact on GMOC



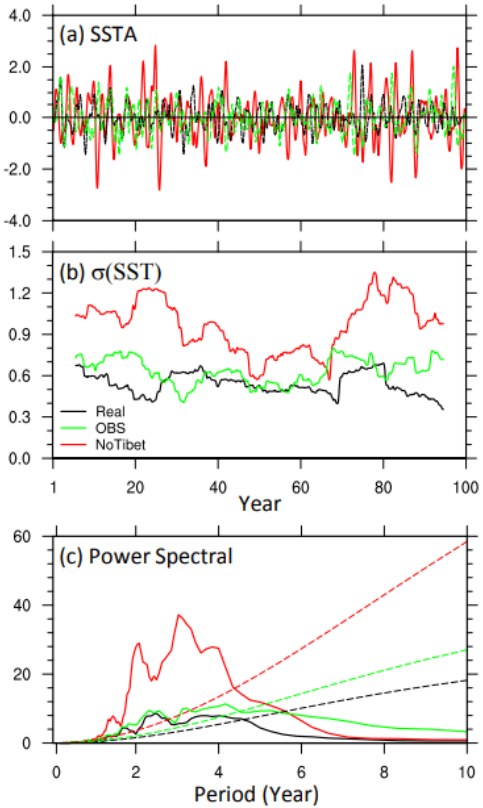
Yang, H., R. Jiang, and Q. Wen, 2021: Investigating the role of the Rocky Mountain in the formation of global meridional overturning circulation. *J. Climate*, 32, accepted.

Preliminary Results

	NoTibet	NoRocky
AMOC	Weak	Unchanged
PMOC	Strong	Unchanged

0 → 1 : Critical in Shaping GMOC!

4. TP's Impact on ENSO



Amplitude: 80%⇑

Period: unchanged

Wen, Q., K. Doos, Z. Lu, Z. Han, and **H. Yang**, 2019: Investigating the role of the Tibetan Plateau in ENSO variability. *J. Climate*, doi: 10.1175/JCLI-D-19-0422

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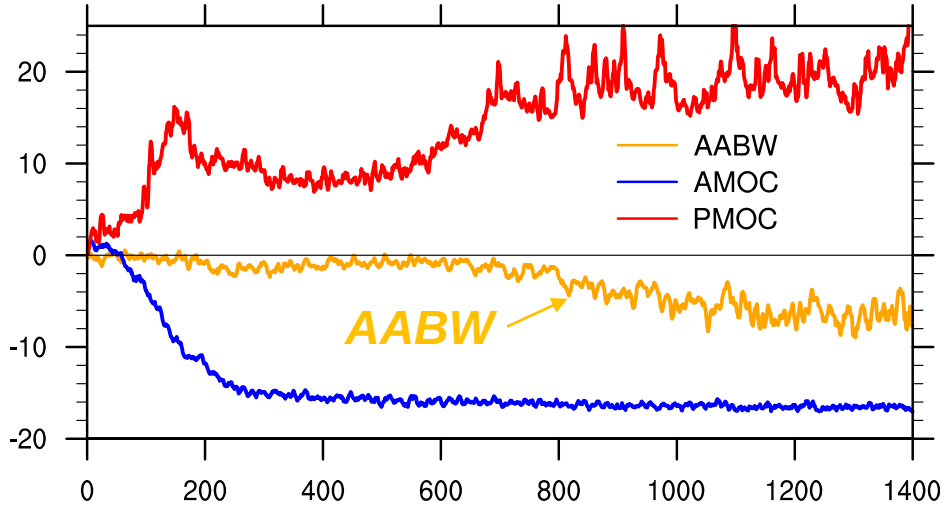
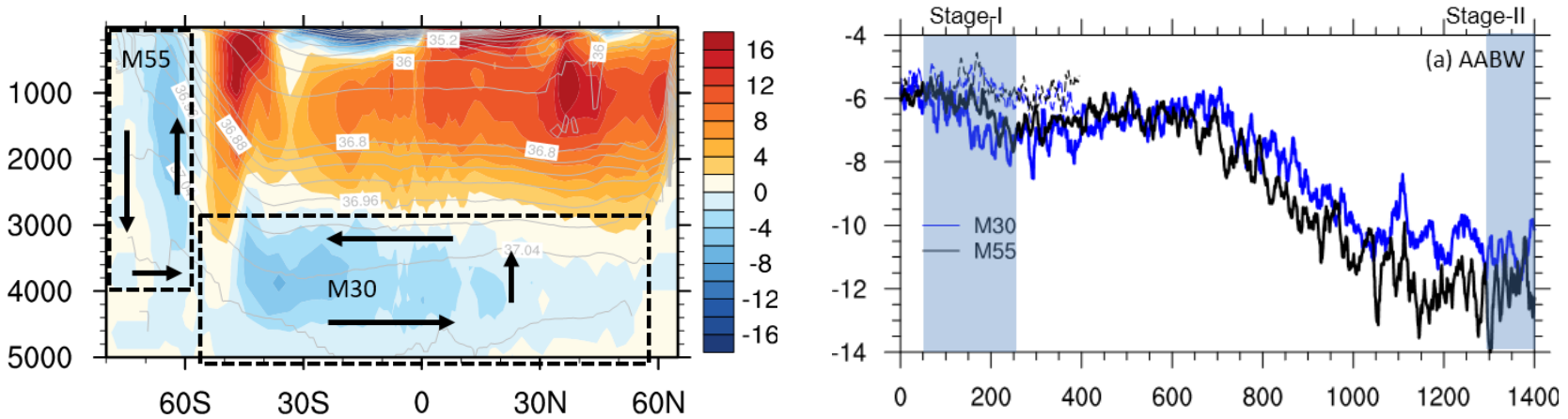
5. TP's Impact on AABW



TP's Impact on AABW

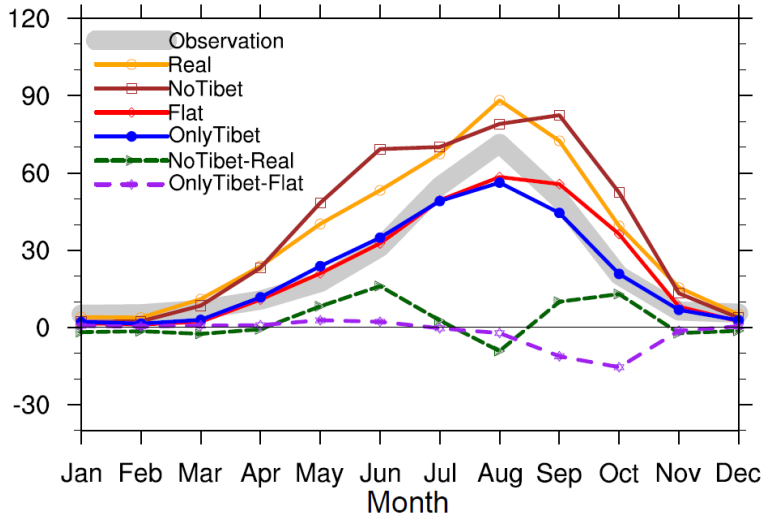
NoTibet → AABW ⇑



Wen, Q. et al., 2021: Can the Tibetan Plateau affect the Antarctic Bottom Water. *Geophys. Res. Lett.* doi: 10.1029/2021GL092448.

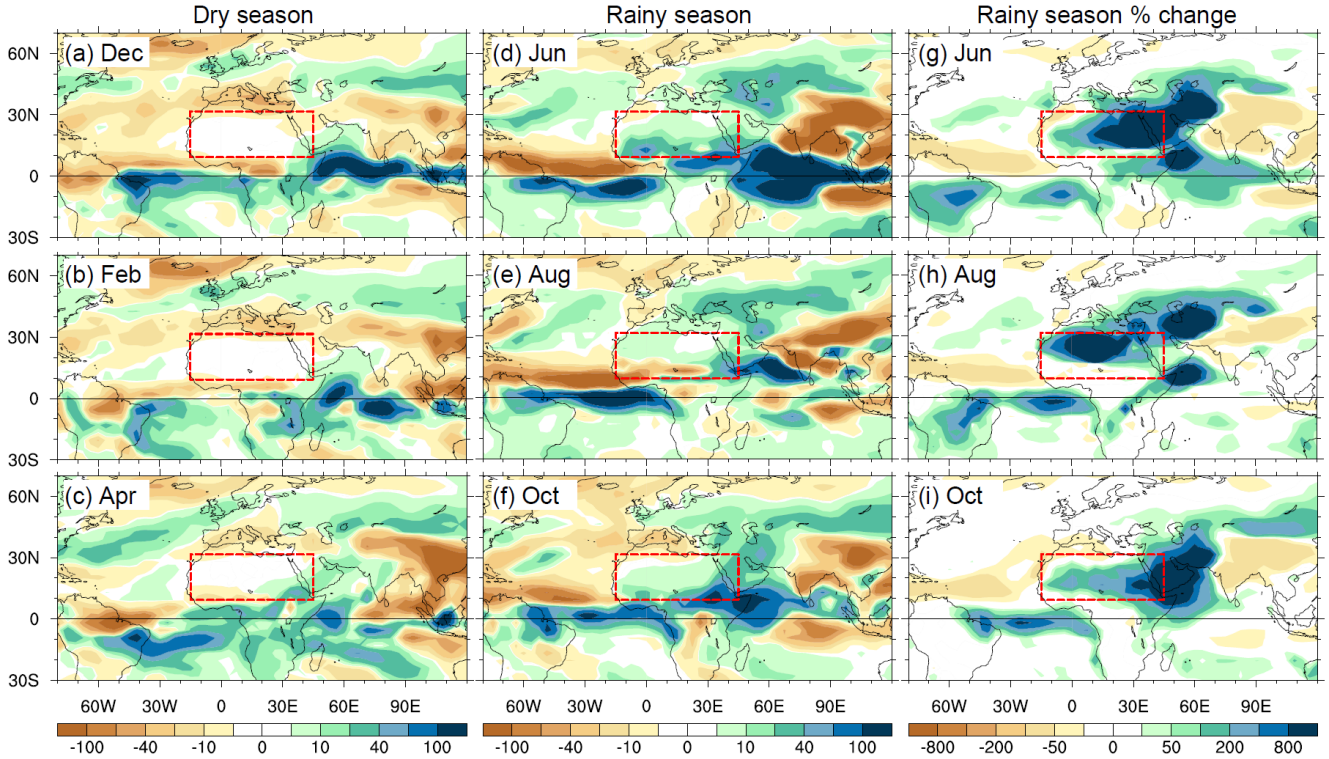
6. TP's Impact on North Africa Precipitation

NoTibet → North Africa Precipitation ⇑



Chen Z. and **H. Yang**, 2021: Impact of Tibetan Plateau on North African Precipitation. *Climate Dynamics*. Accepted.

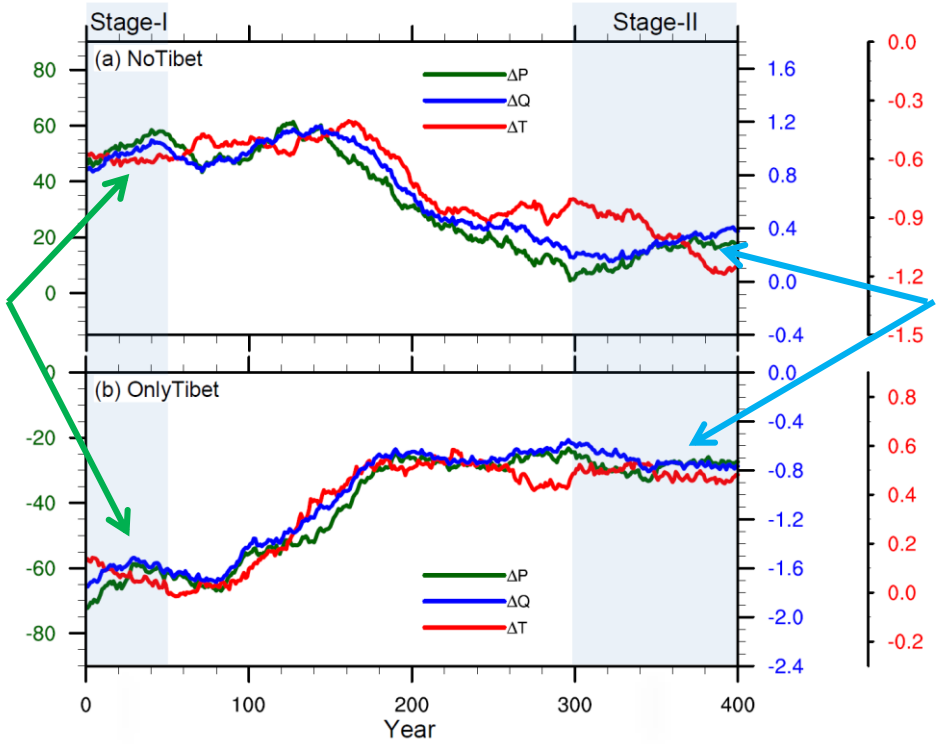
TP affect Rainy Season of North Africa Precipitation



TP affect Rainy Season

Fast Stage:

Atmos. Dynamics



Equilibrium Stage:

AMOC Dynamics

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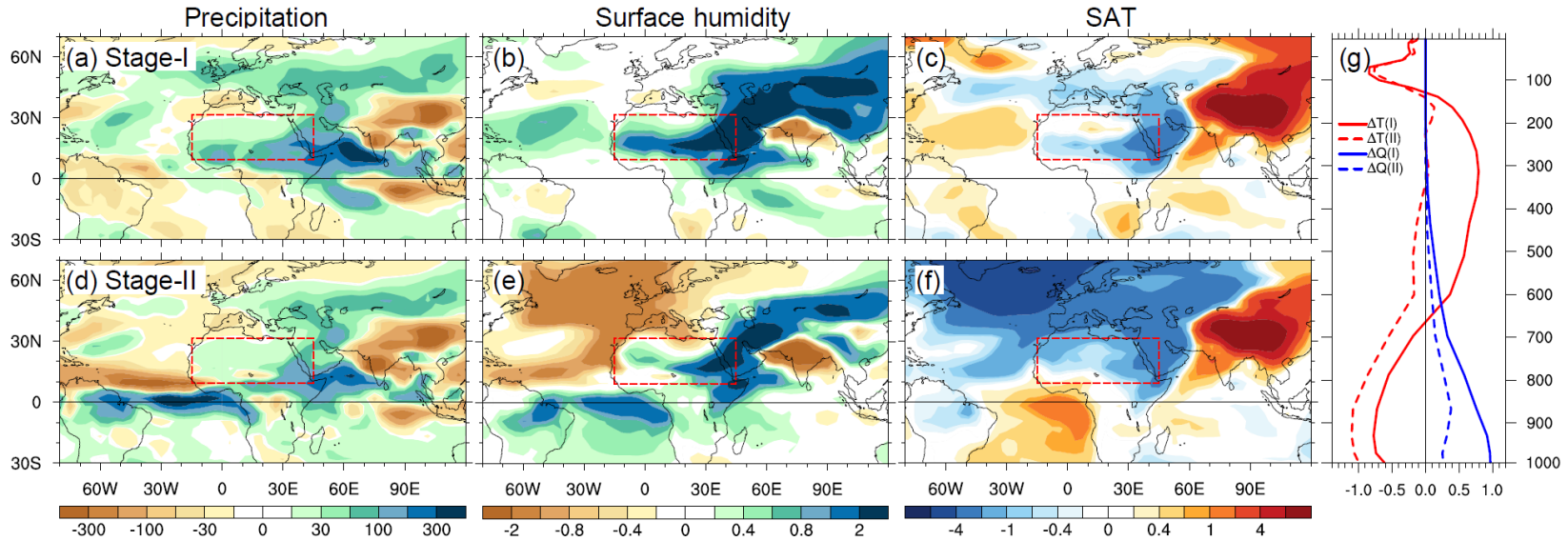
Precipitation Change in Different Stage

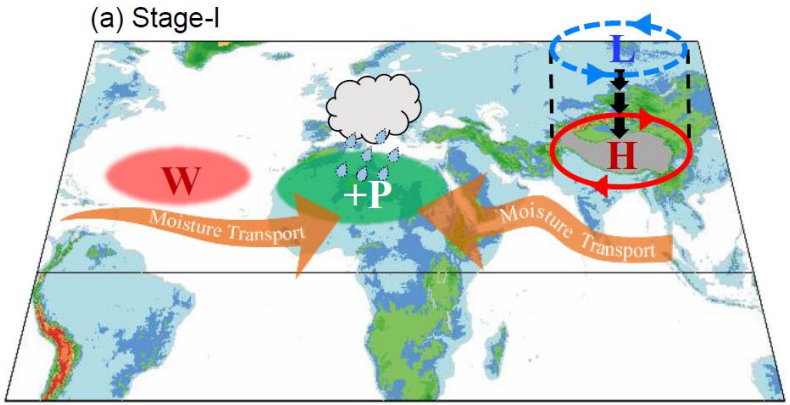
NoTibet ➡ Precipitation ⇑ ➡ AMOC ⇓ ➡ Precipitation ⇓



Mechanism for Precipitation Change

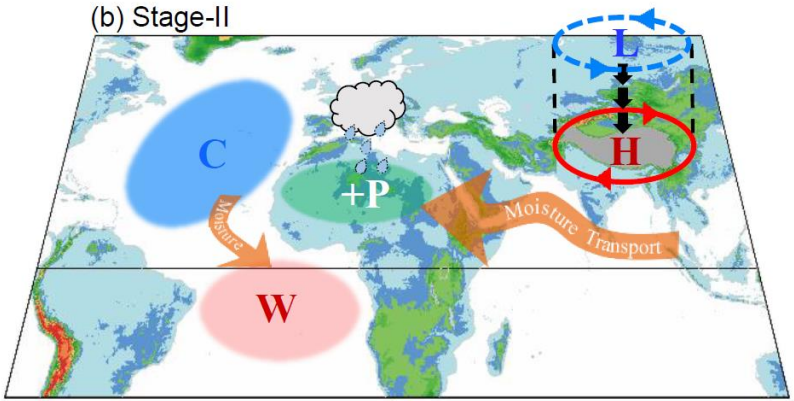
Fast Stage

Atmos. Dynamics



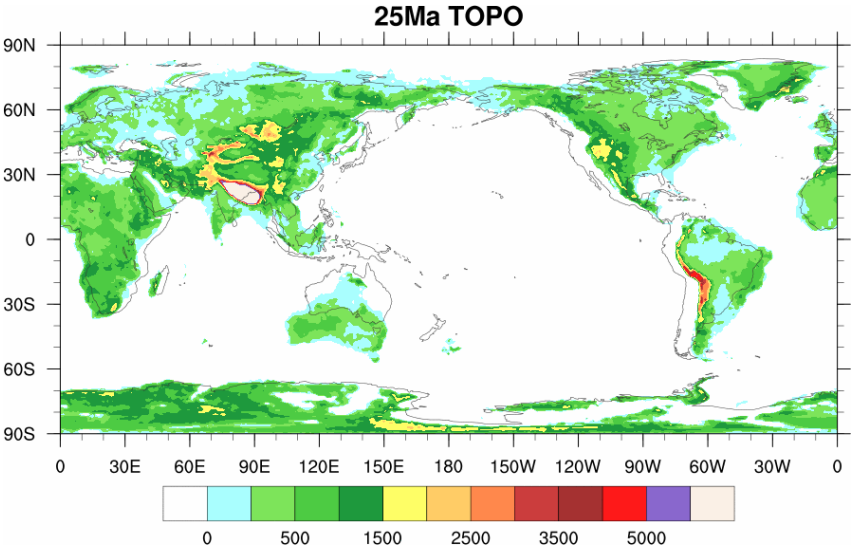
Equilibrium Stage

AMOC Dynamics



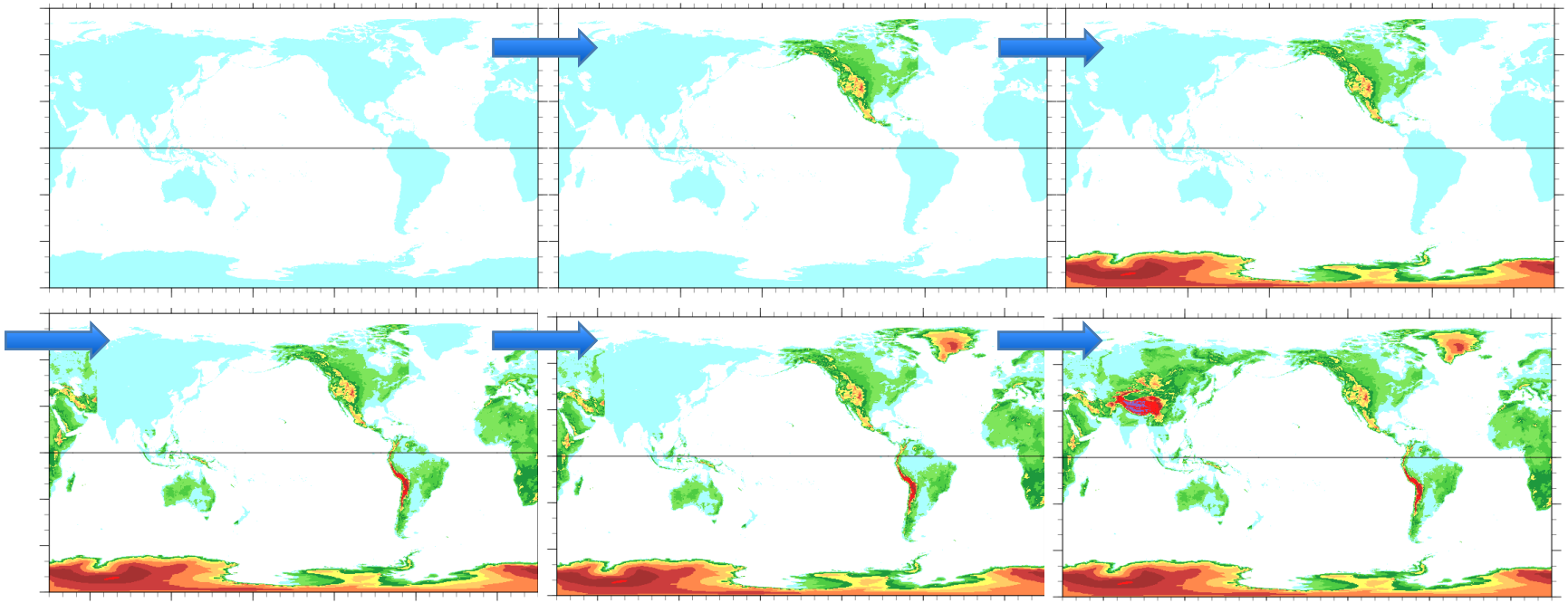
7. TP: *determining* the *Modern GMOC*

Tibetan Plateau → **Necessary to Modern AMOC**

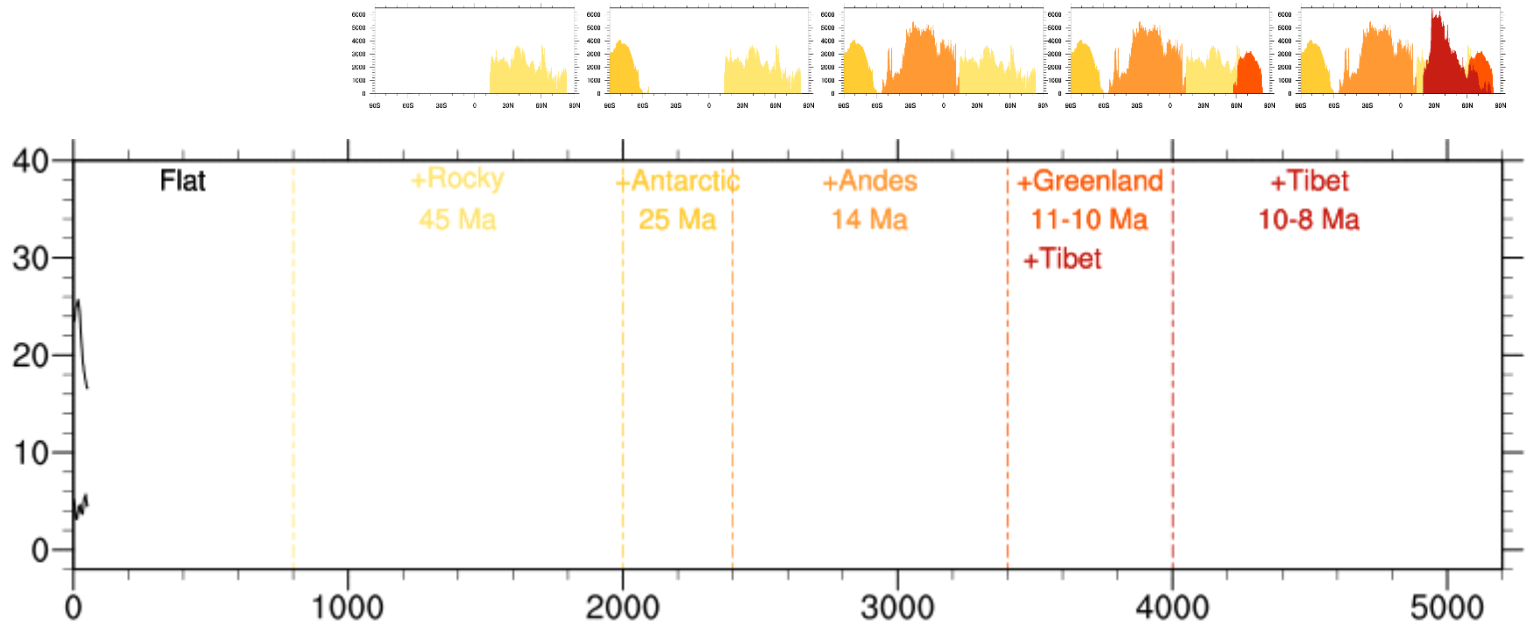


Jiang R. and **H. Yang**, 2021: Tibetan Plateau: A necessary for the modern AMOC. In *Writing*.

From *Flat* to *Real*

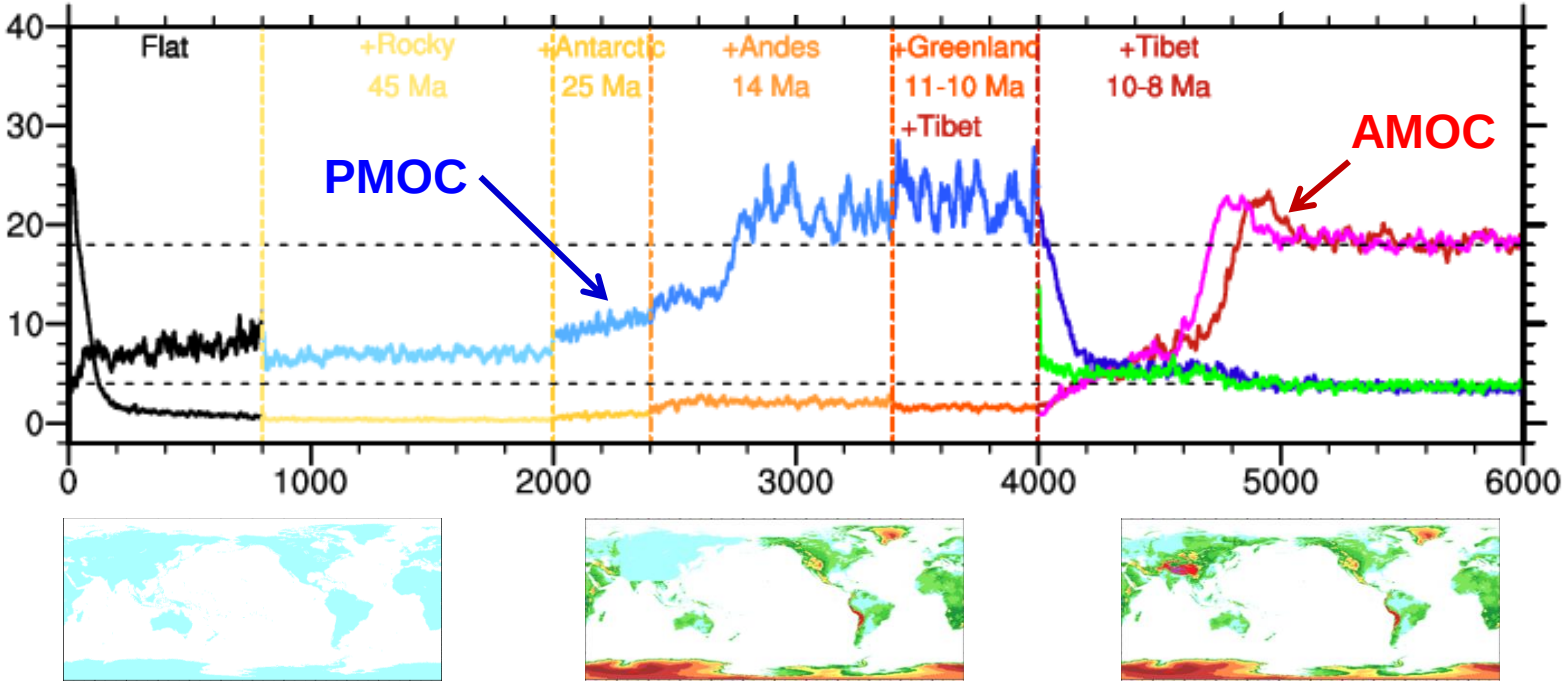


From *Flat* to *Real*



TP: *determining* the *Modern GMOC*

Total 6000 Years Simulations



Experiments: *Topography Combination*

单个地形	试验时间	
Flat	1-1600	平板
Only _Rocky	801-2000	45Ma
Only _Ant	801-1600	25Ma
Only _Andes	801-1600	14Ma
Only _Greenland	801-1600	11-10Ma
Only _Tibet	801-4700	10-8Ma
Only _All	801-3200	全地形

组合地形试验	试验时间
Only _Tibet _Rocky	801-1400
Only_Tibet _Rocky _Ant	801-3400
Rocky-Ant	2001-2400
Rocky-Ant-Andes	2401-3400
Rocky-Ant-Andes-Green	3401-4000
Rocky-Ant-Andes-TP	3401-5000
Rocky-Ant-Andes-Gn-TP	4001-6000

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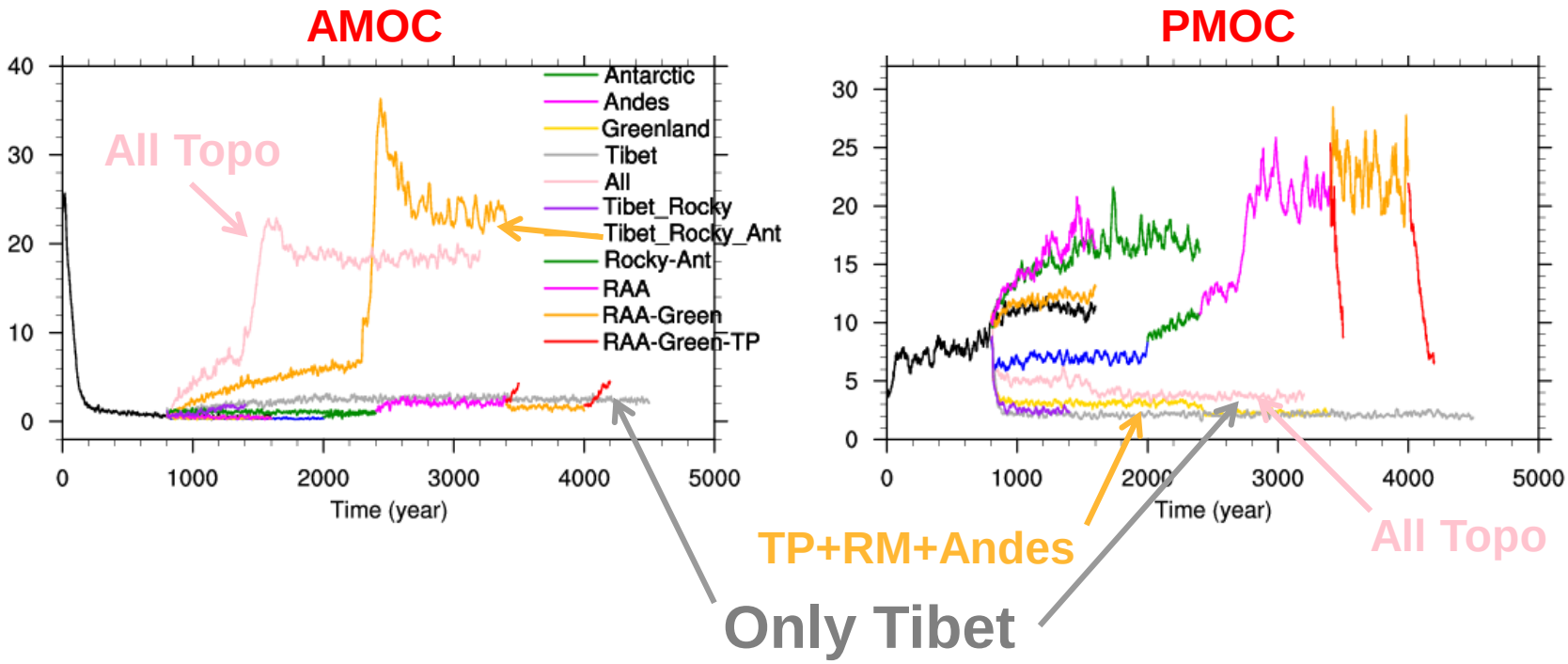
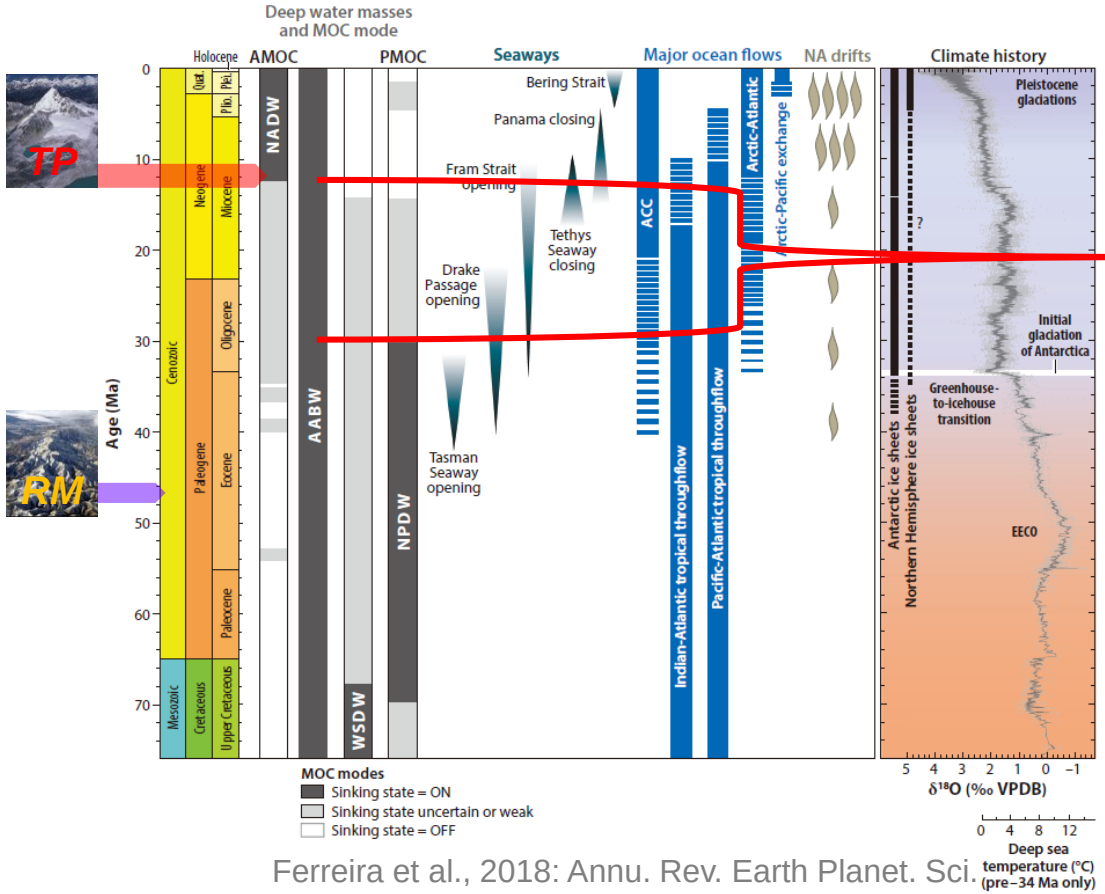
Experiments: *Topography Combination*



没有青藏高原就没有AMOC；有青藏高原就没有PMOC

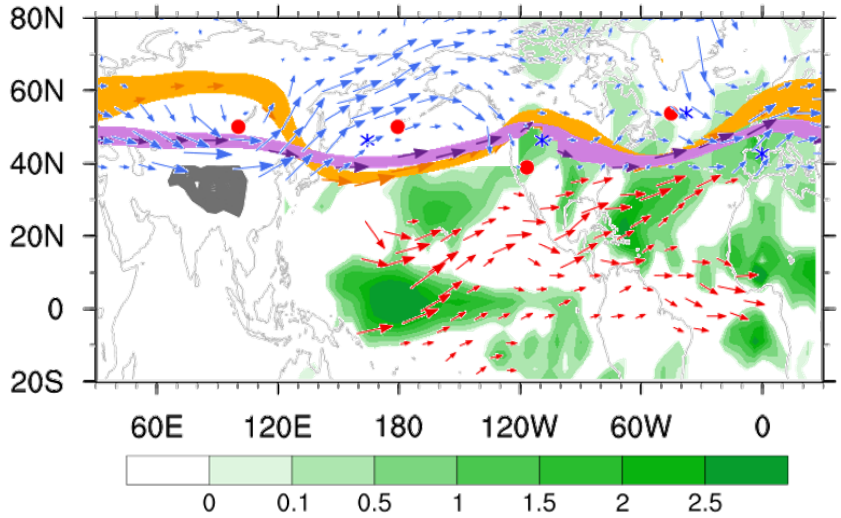
Geological History of GMOC



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

From *TP* to *AMOC: Atmospheric Moisture Balance*

Stationary Waves with Tibetan Plateau



On Working !

Tibetan Plateau → **Atmospheric Moisture transport**

Most Critical

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Conclusion

无 Tibetan Plateau

↓

无 AMOC

有 Tibetan Plateau

↓

无 PMOC

青藏高原的存在是*AMOC*建立的*必要条件*，是*PMOC*消失的充分条件

LaCOAS
北京大学气候与海-气实验室

Thanks

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国家自然科学基金委员会 National Natural Science Foundation of China