

Decoding **Hosing** and **Heating** Roles in a **Warming** Climate

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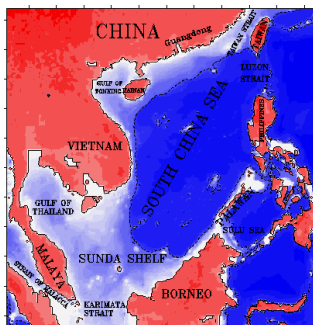
LaCOAS

北京大学气候与海-气实验室

研究历程

1996-2003

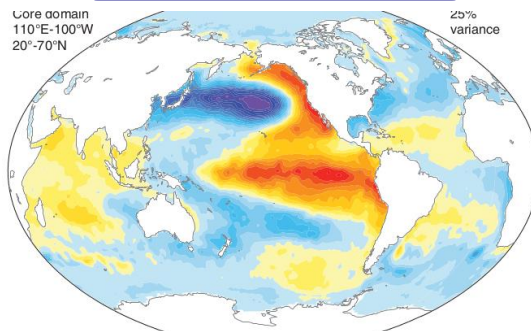
区域海盆



季节

2003-2011

大洋环流



年代际

2008-2017

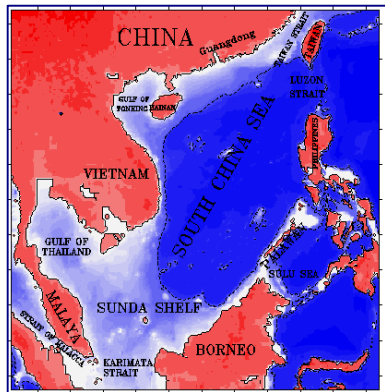
地球海气系统



百年以上

特别关注：海洋在气候系统中的作用

南海海洋环流动力学 (1996-2003)



理论：南海Sverdrup环流理论（2000）

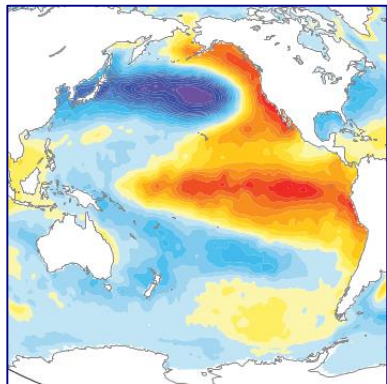
南海环流季节变化动力学（2001）

模拟：南海环流GCM模拟（2002）

南海吕宋冷涡（LCE）及越南冷涡（2003）

南海西边界流系统（SCSWC）（2003）

太平洋环流及年代际振荡 (2003-2011)



理论： 太平洋年代际振荡海盆模理论 (2003)

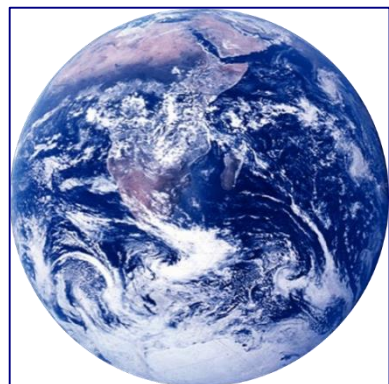
模拟： 太平洋环流76/77位相转换模拟 (2004)

热带-热带外气候相互作用 (2005)

热带外气候对ENSO的影响 (2008)

太平洋-大西洋相互作用 (2011)

地球海气系统能量平衡 (2008-2017)



理论： 海气耦合系统能量输送Bjerknes补偿理论

$$(2016) \quad C_R \equiv \frac{\Delta F_a}{\Delta F_o} = -\frac{1}{1-B} < 0$$

气候变率下的Bjerknes补偿理论解 (2016)

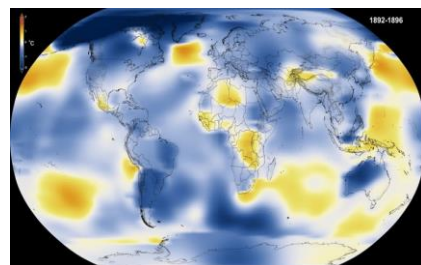
模拟： 定量地球能量输送各个分量 (2015)

气候反馈及能量平衡 (2016)

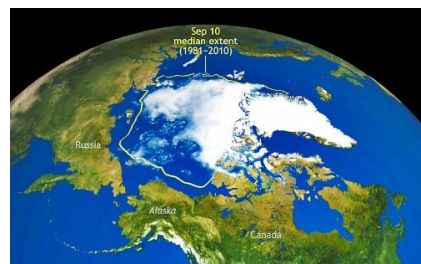
淡水强迫对能量平衡影响 (2017)

全球变暖下的Bjerknes补偿 (2018)

目前研究



- ▣ 变动气候中的海气系统能量平衡研究
(2016 --)

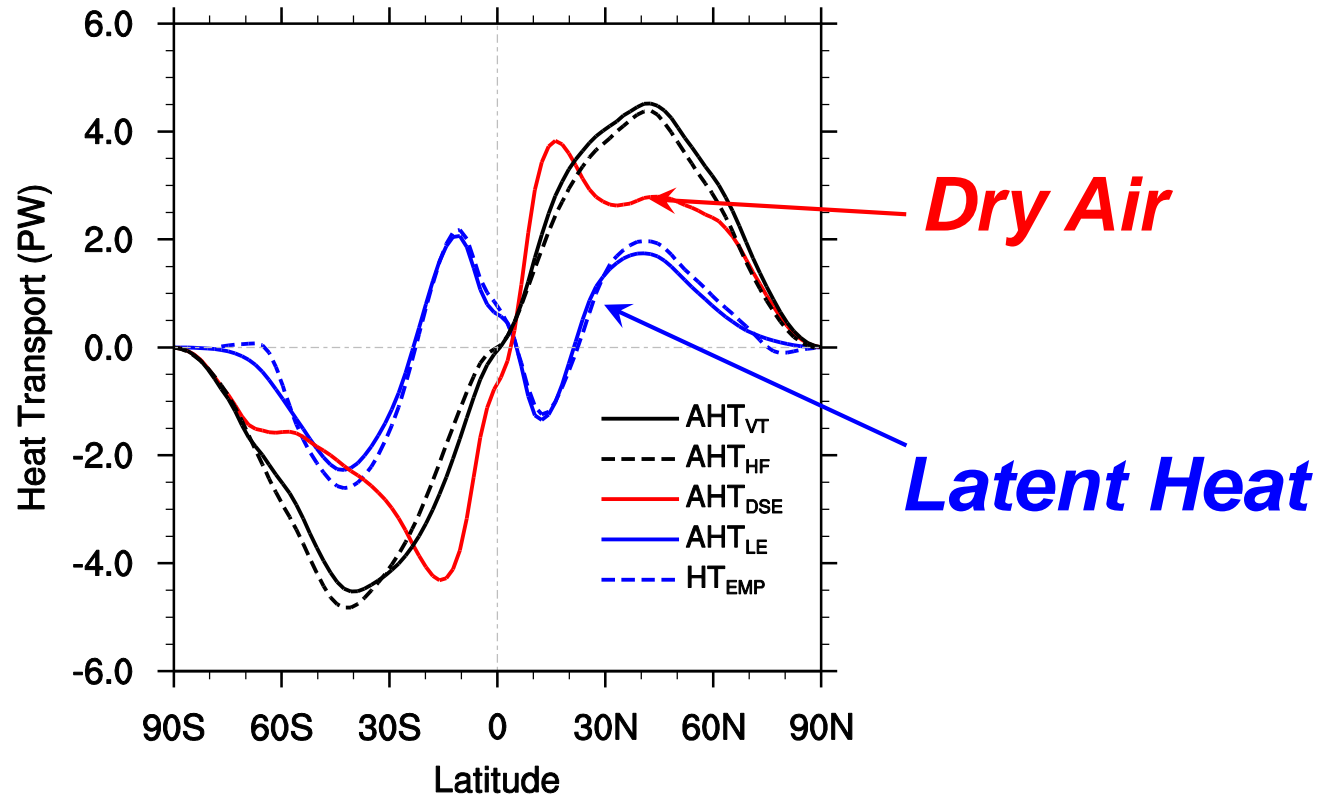


- ▣ 全球变暖背景下的淡水循环 (2015 --)



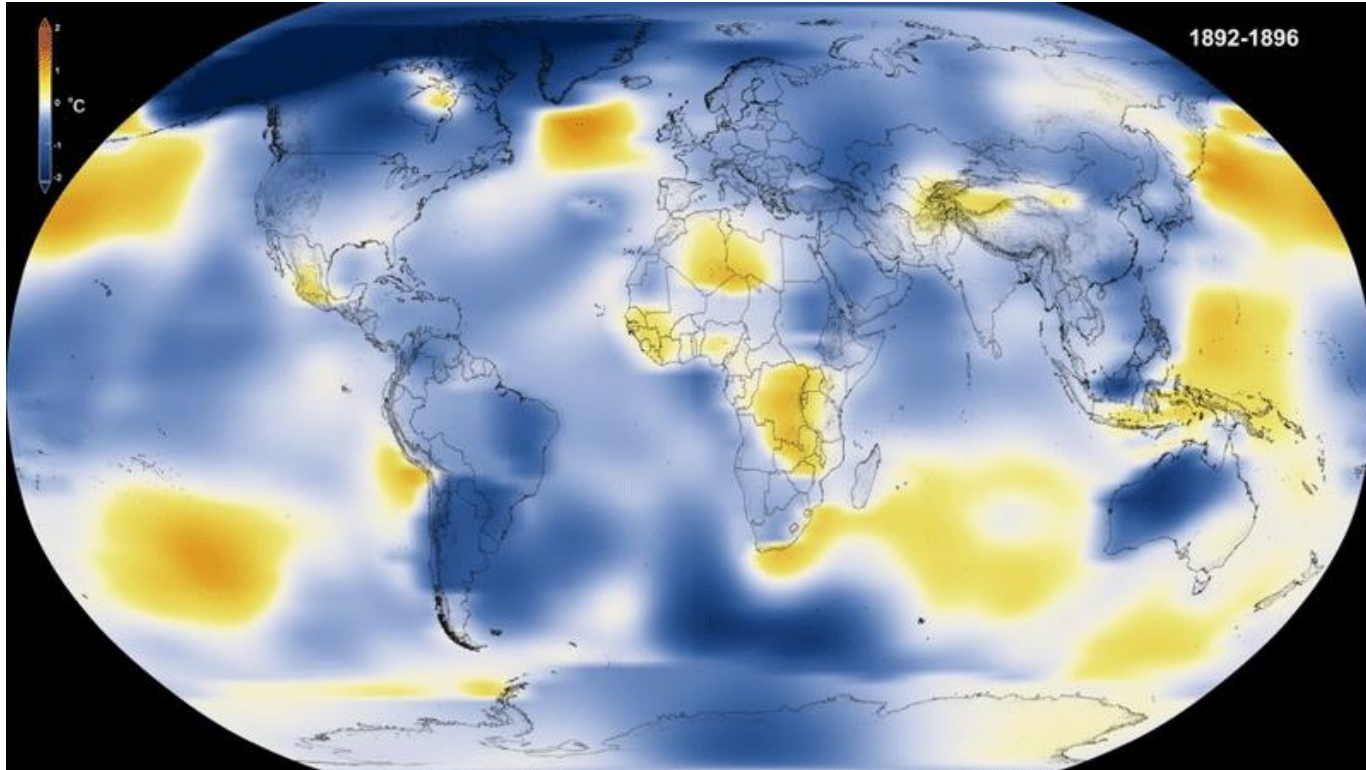
- ▣ 青藏高原在现代全球海洋经圈环流形成中的角色 (2013 --)

Atmosphere *Latent Heat* Transport



Yang et al. 2015: Decomposing the meridional heat transport in the climate system. *Climate Dynamics*.

A Warming Climate



NASA/GSFC/Scientific Visualization Studio

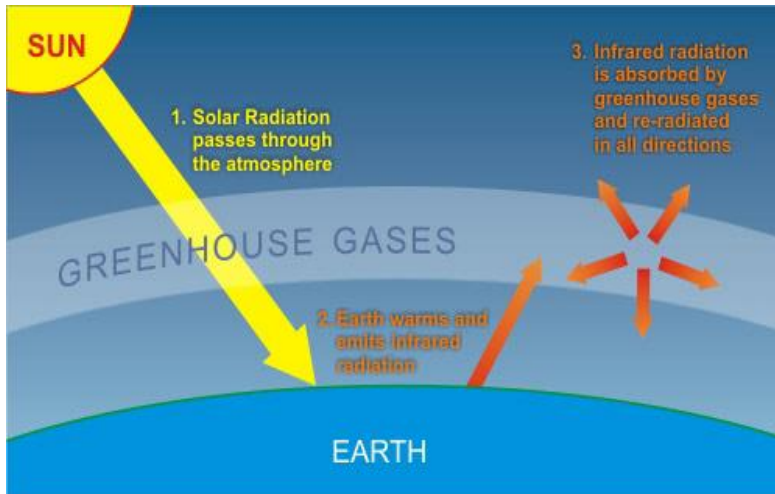
<https://www.giss.nasa.gov/research/news/20170118/2016gistempupdateblack.gif>

A Warming Climate

Resulted from

Heating

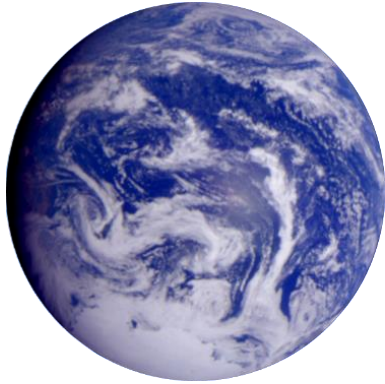
Hosing



Decoding **Hosing** and **Heating** Roles in a **Warming** Climate

Water Role – A Fundamental

Lapse Rate



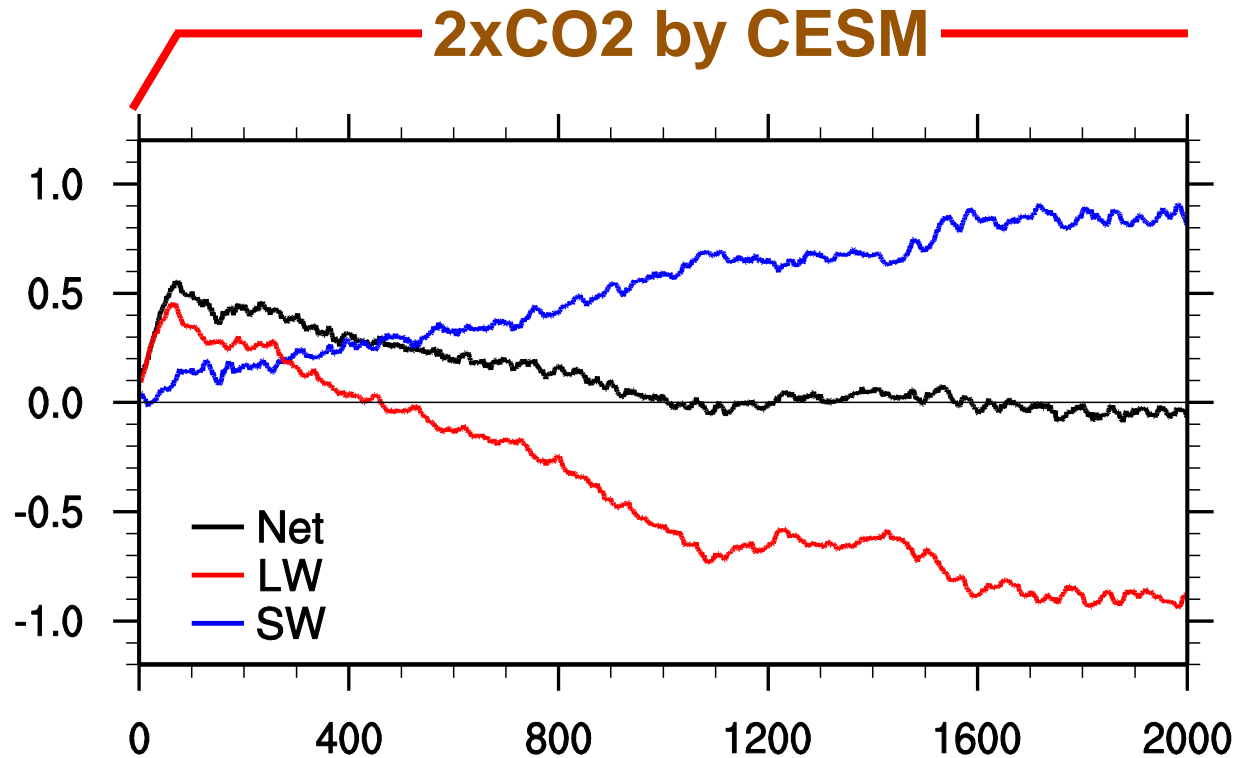
Dry Air: $\Gamma_d = g/c_p = 9.8$ °C/km

Wet Air: $\Gamma_w = \dots\dots = 6-7$ °C/km

30%

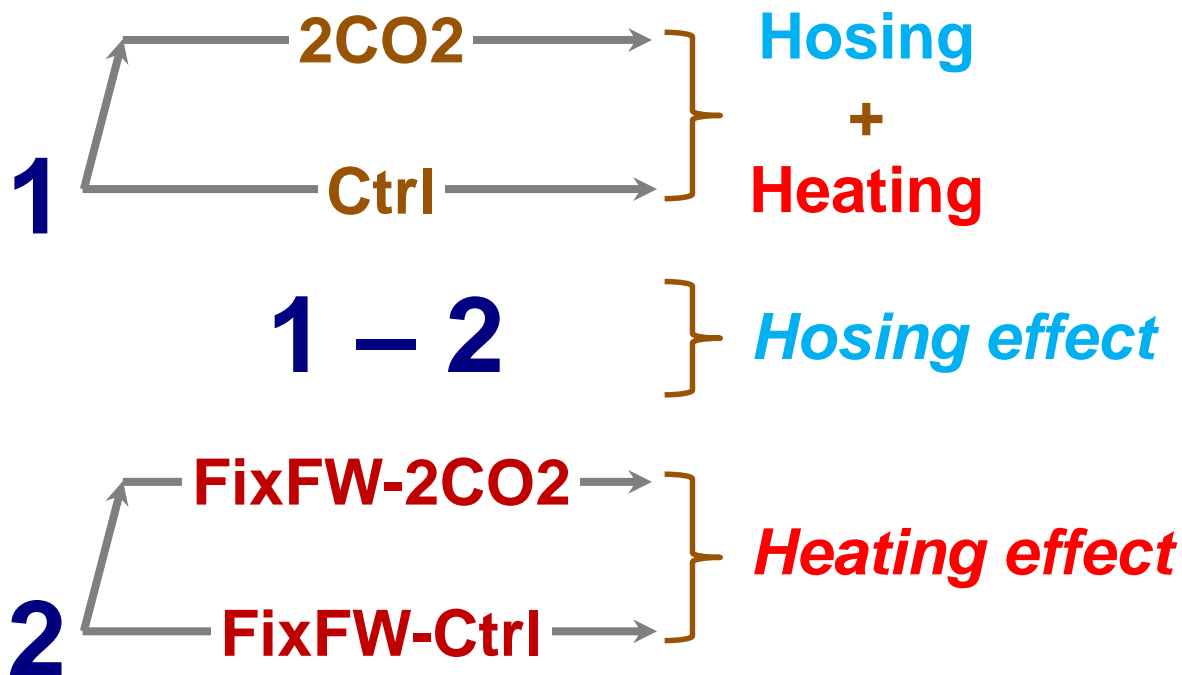
Latent Heat: Solid $\xrightarrow{334\text{J/g}}$ Liquid $\xrightarrow{2260\text{J/g}}$ Gas

TOA Flux Change in a Warming Climate



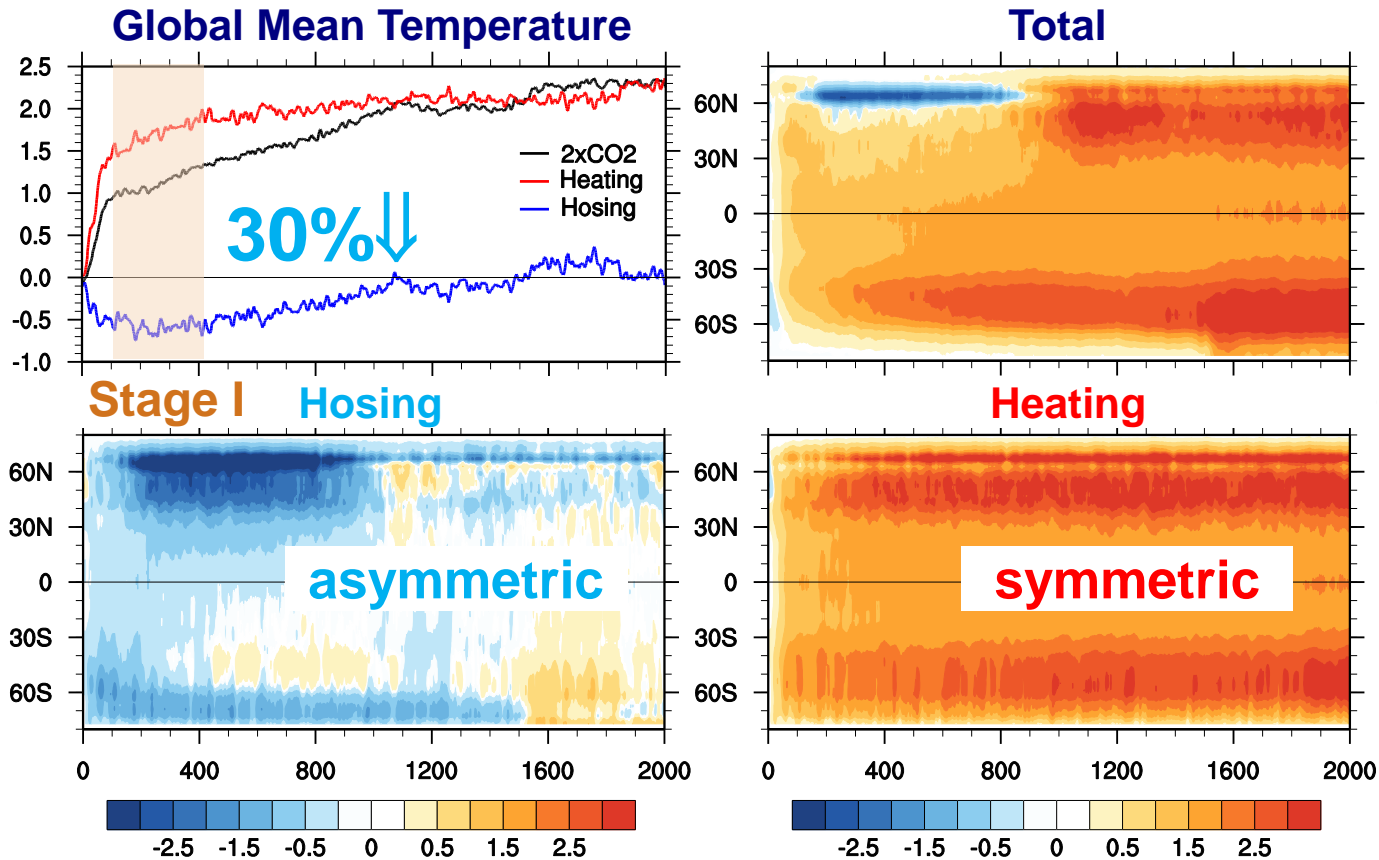
NCAR CESM1.0 global warming experiments

Separate *Hosing* and *Heating*



FixFW: fix net surface ocean flux
precipitation – evaporation
+ sea-ice melting
+ river runoff

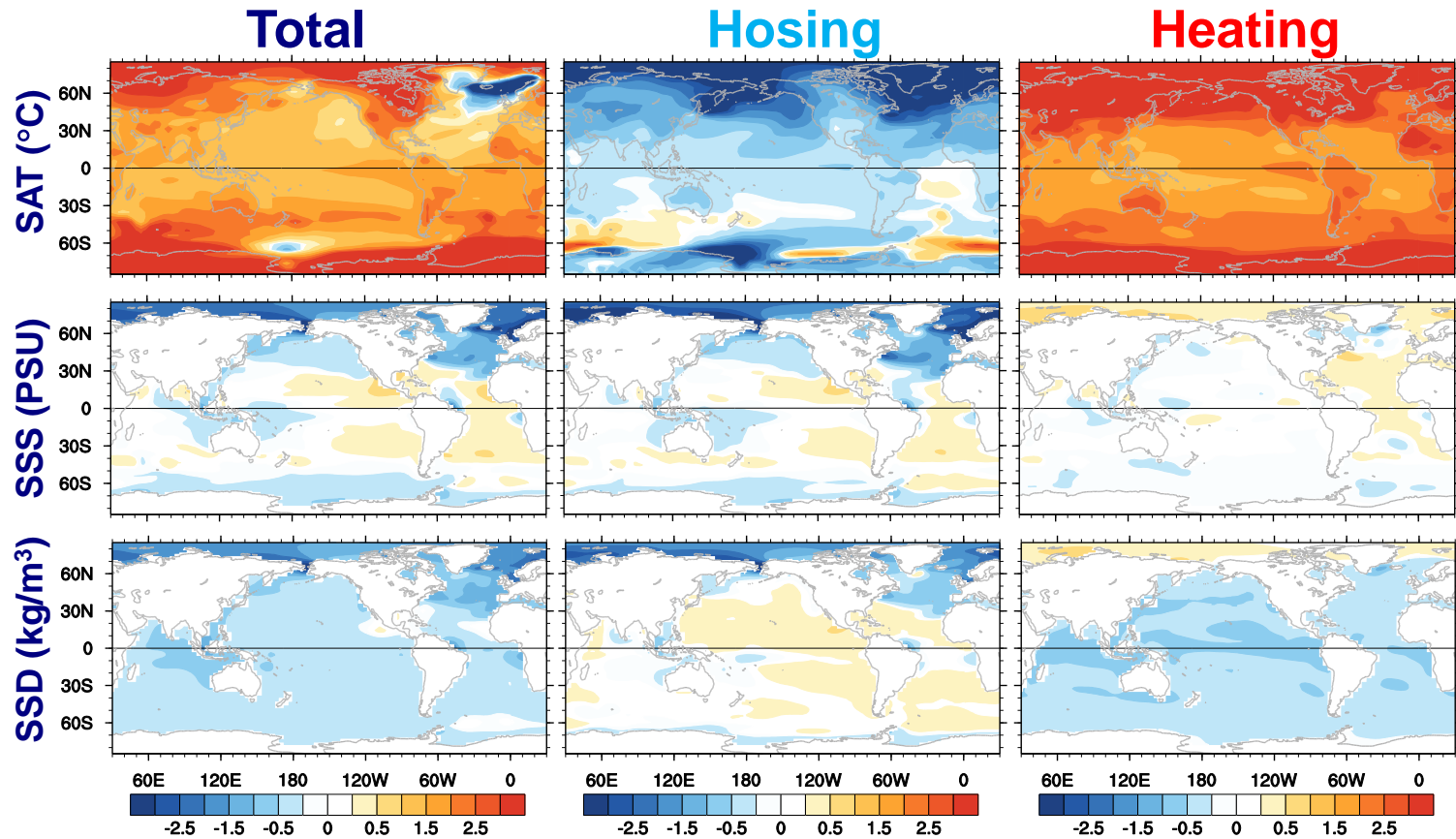
Global *Temperature* Evolution



Stage I in Global Warming

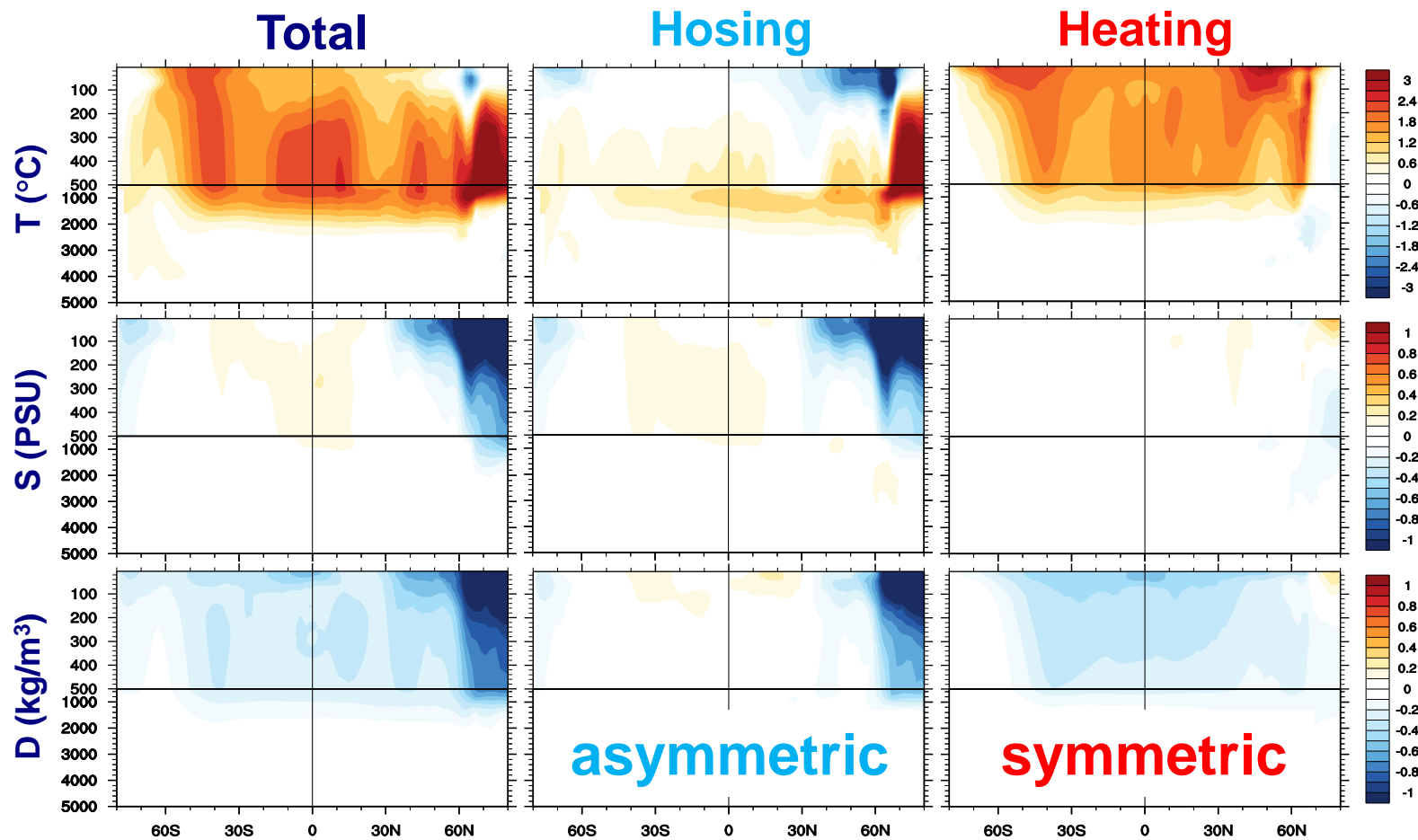
Most relevant to human beings

Surface Changes

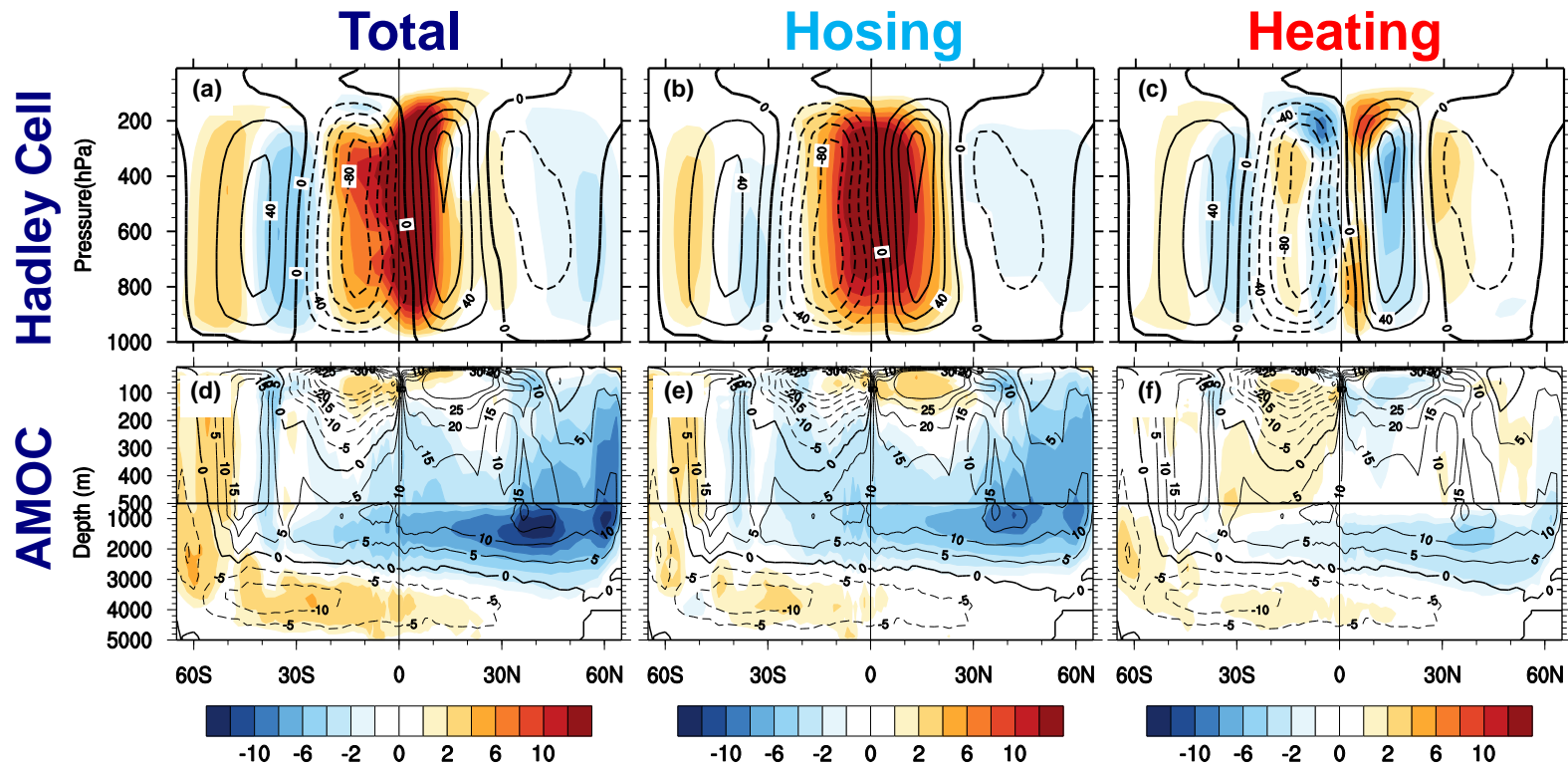


**Freshwater results in cooling and freshening,
asymmetric change**

Ocean Changes



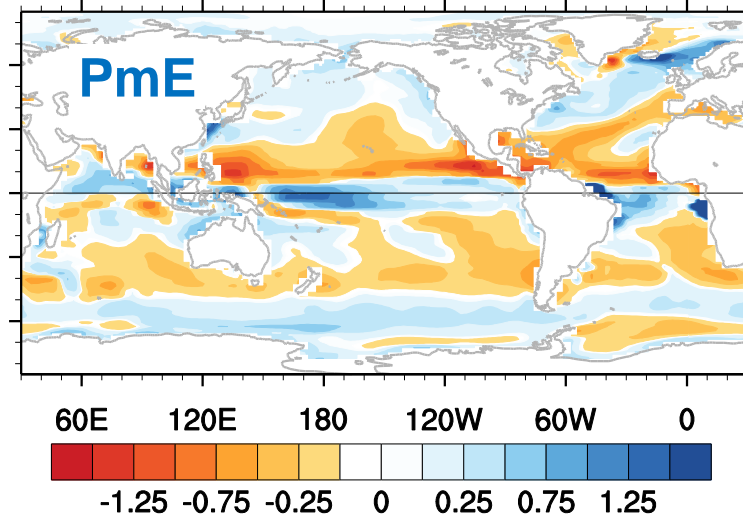
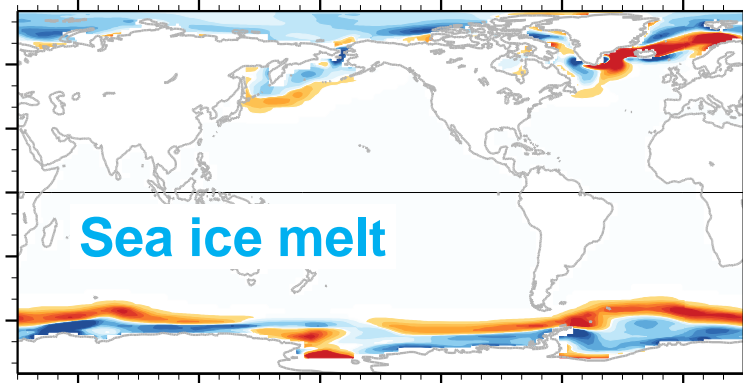
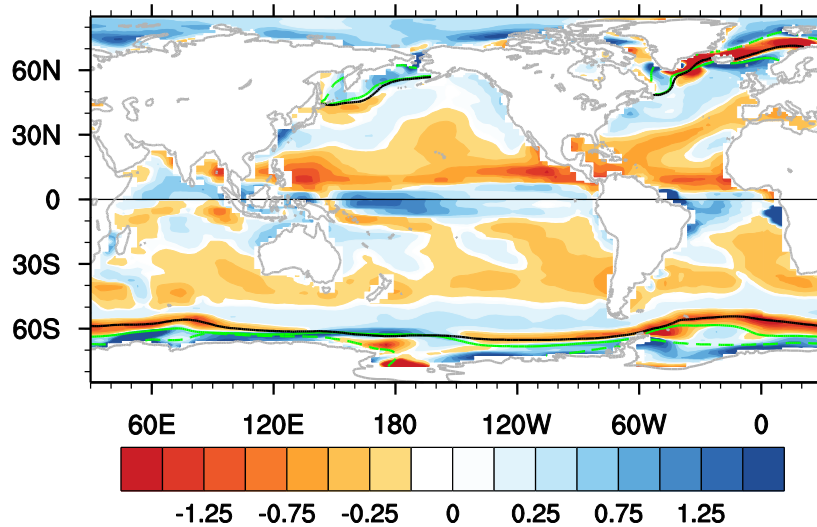
Atmosphere-Ocean *MOCs*



Hosing: HC and AMOC changes;
Heating: nearly unchanged

Global *Freshwater* Change

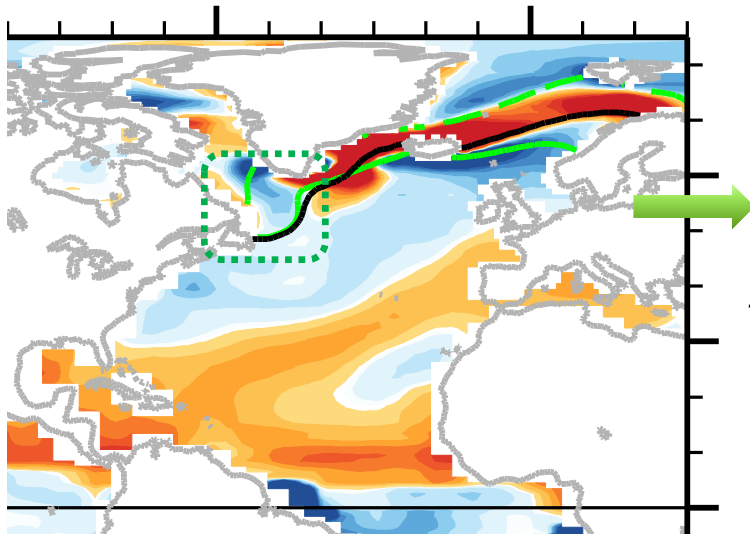
Total



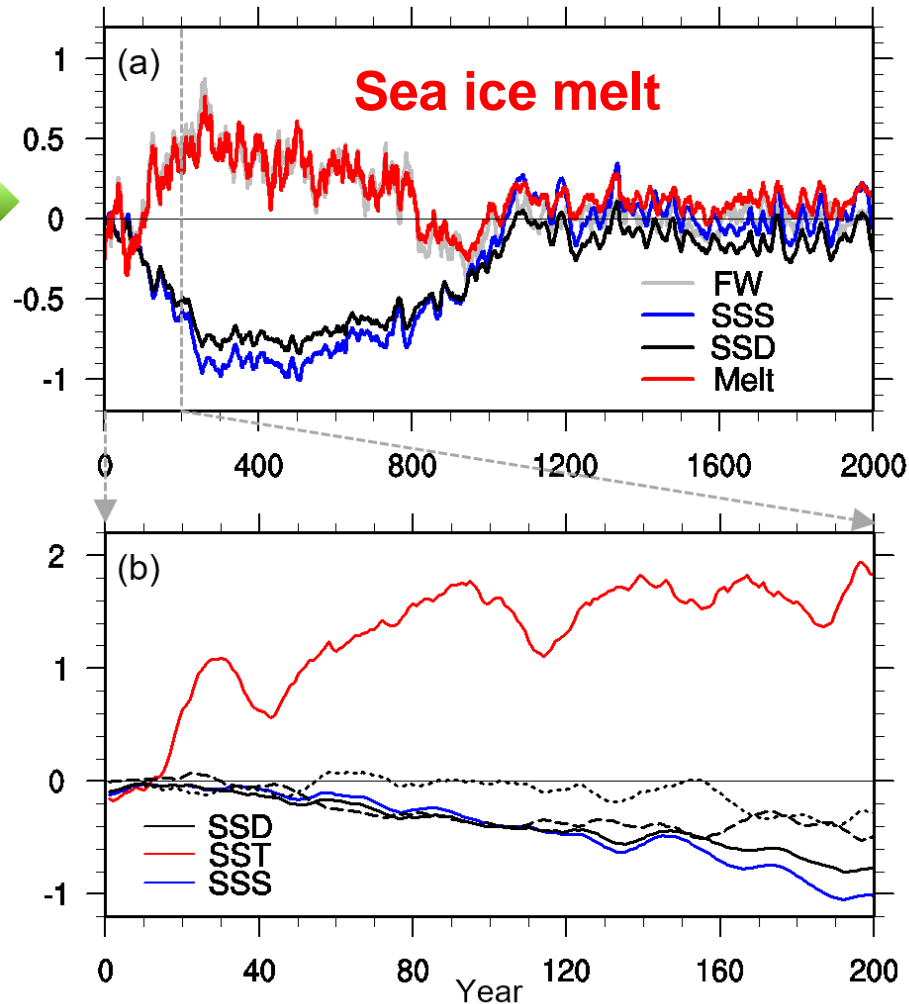
More Freshwater due
to sea-ice melting
and PmE

Freshwater Change in N. Atlantic

Total

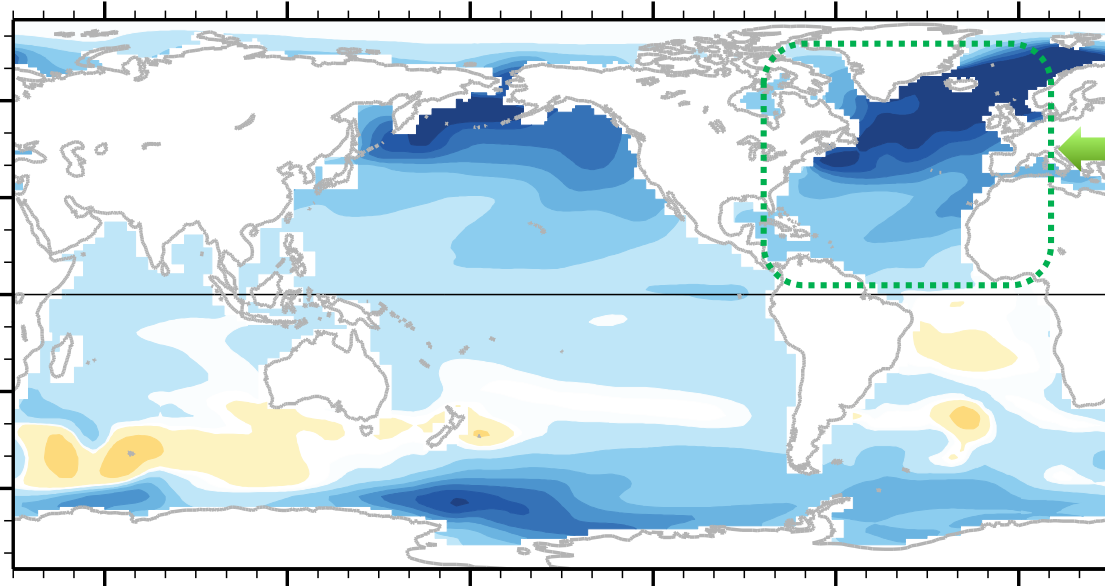


More Freshwater due to **sea-ice melting**



Mechanism of Hosing Cooling

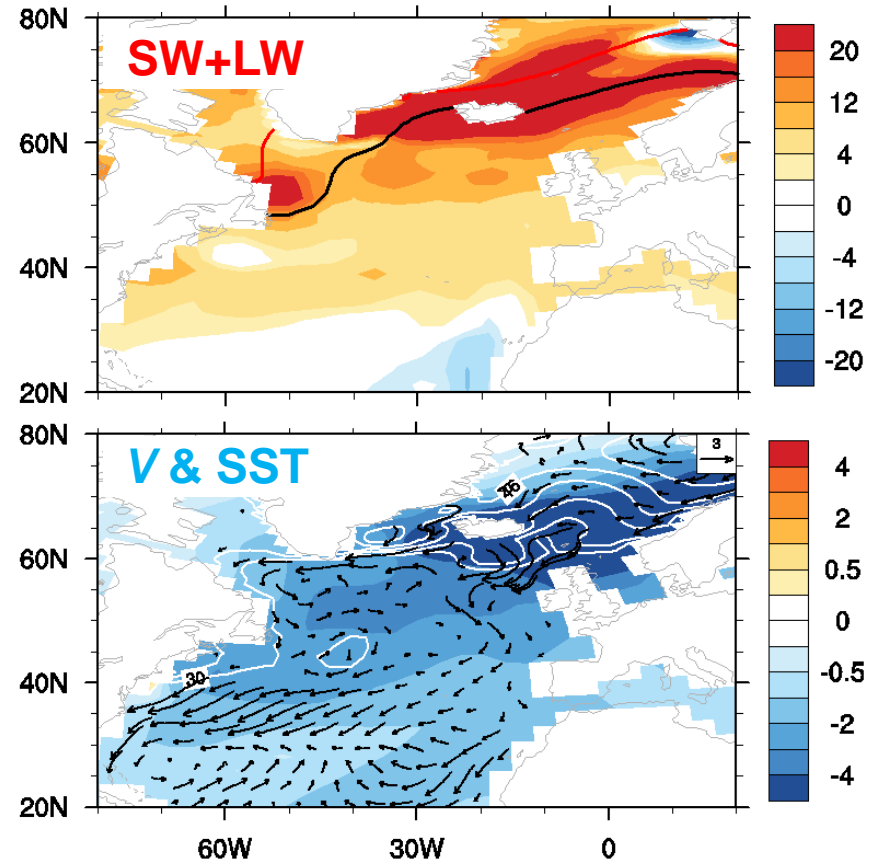
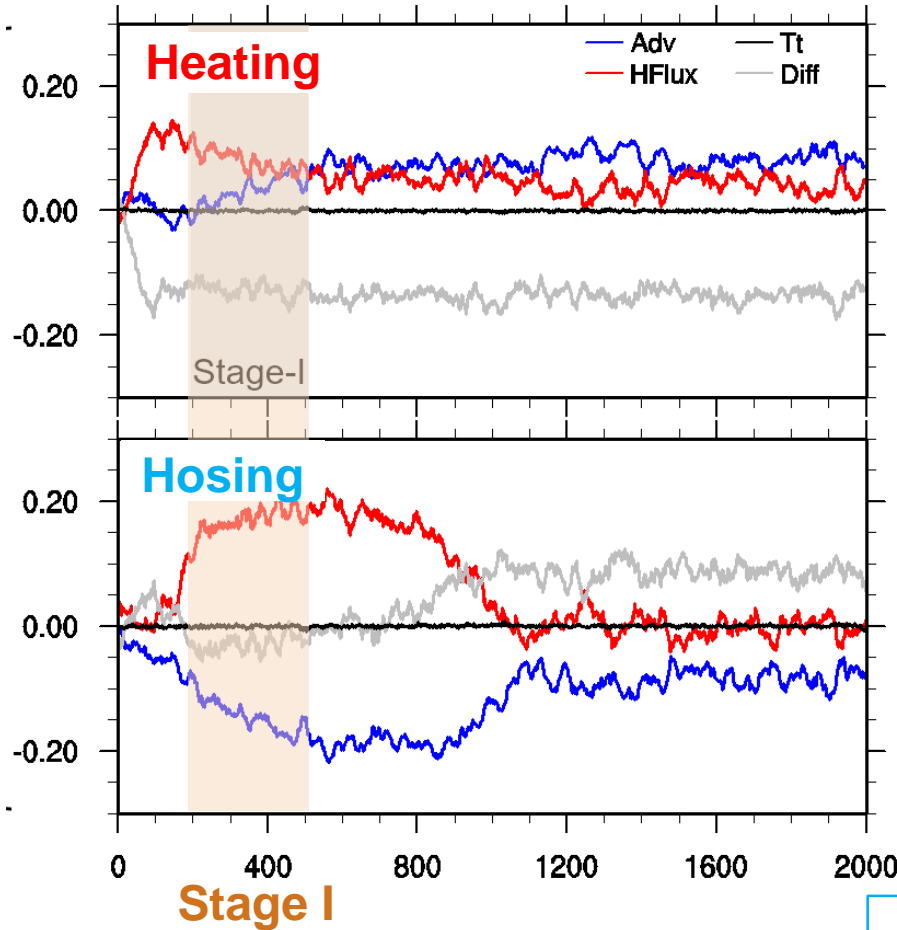
SST



- Freshwater ↑
→ SSS ↓
→ AMOC ↓
- Cold water advection from Arctic ↑

Mechanism of Hosing Cooling

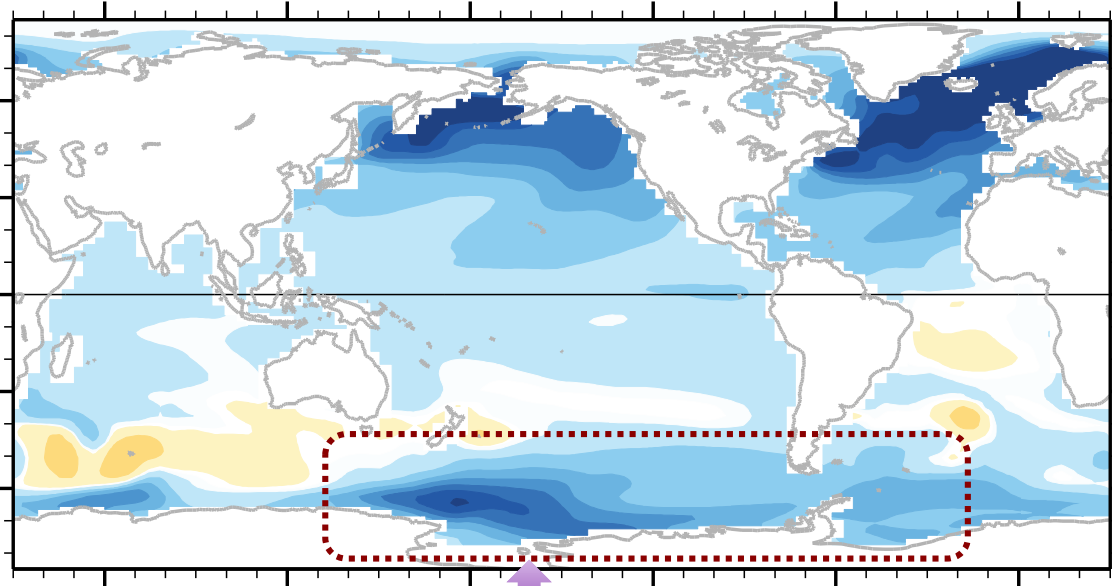
North Atlantic



Cold water advection from Arctic ↑

Mechanism of Hosing Cooling

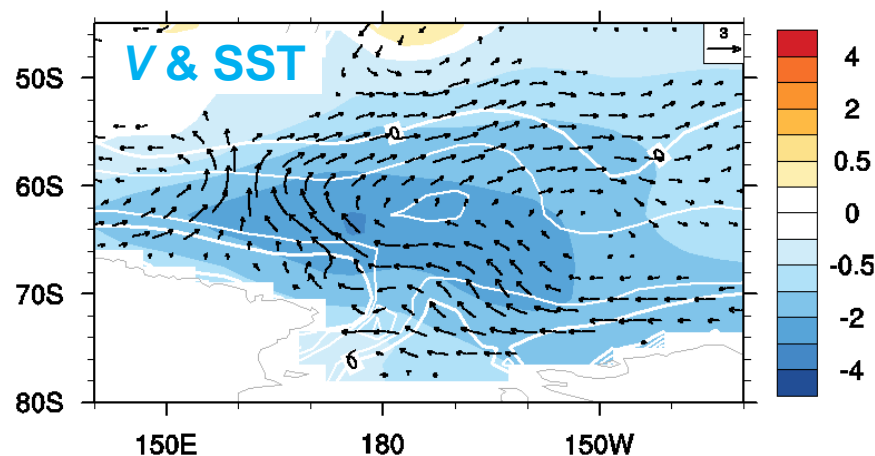
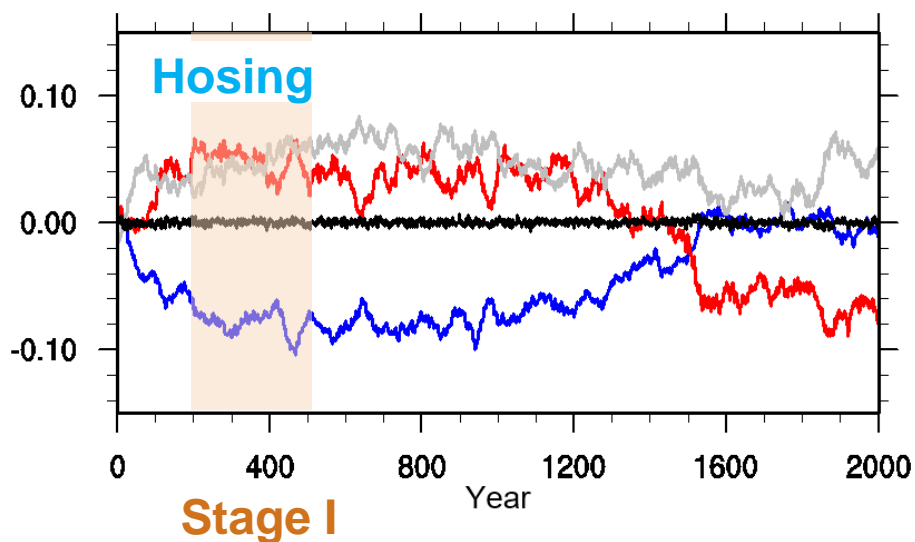
SST



- Sea-ice melting ↑ → Northward Ekman flow ↑
→ Ekman pumping ↑

Mechanism of Hosing Cooling

Southern Ocean

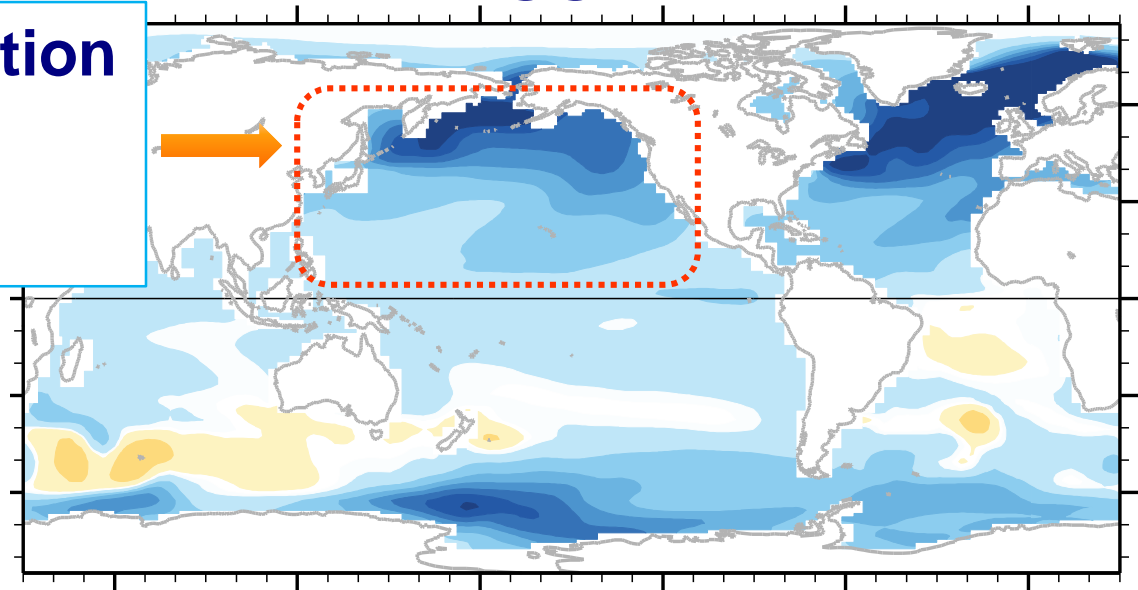


Sea-ice melting \uparrow \rightarrow Northward Ekman flow \uparrow \rightarrow Ekman pumping \uparrow

Mechanism of Hosing Cooling

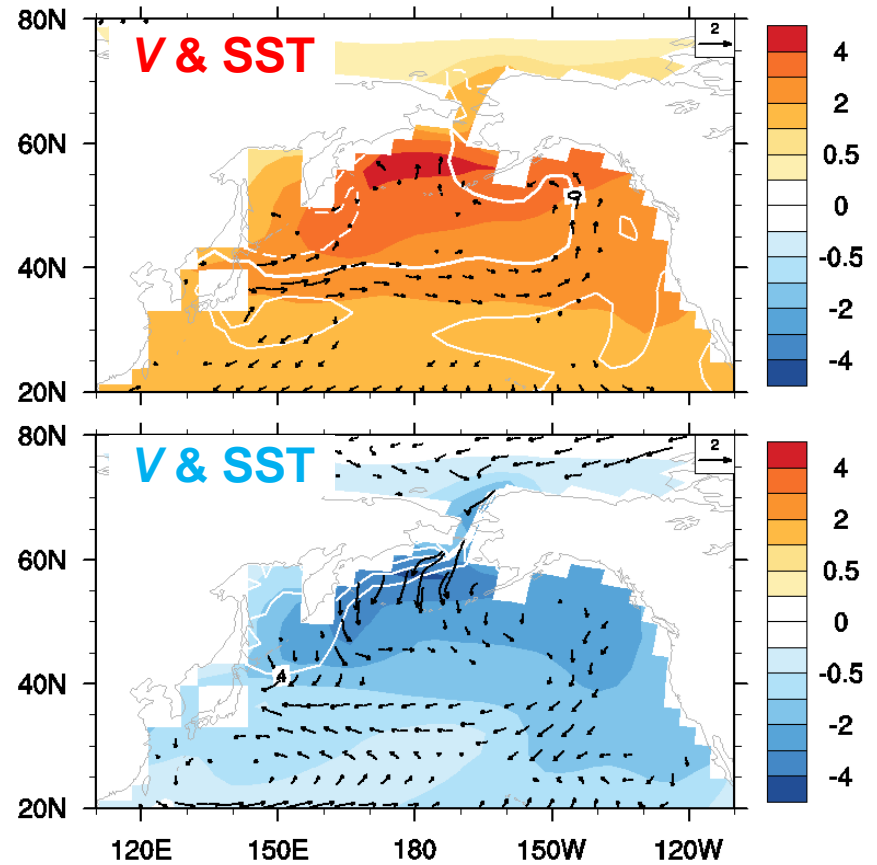
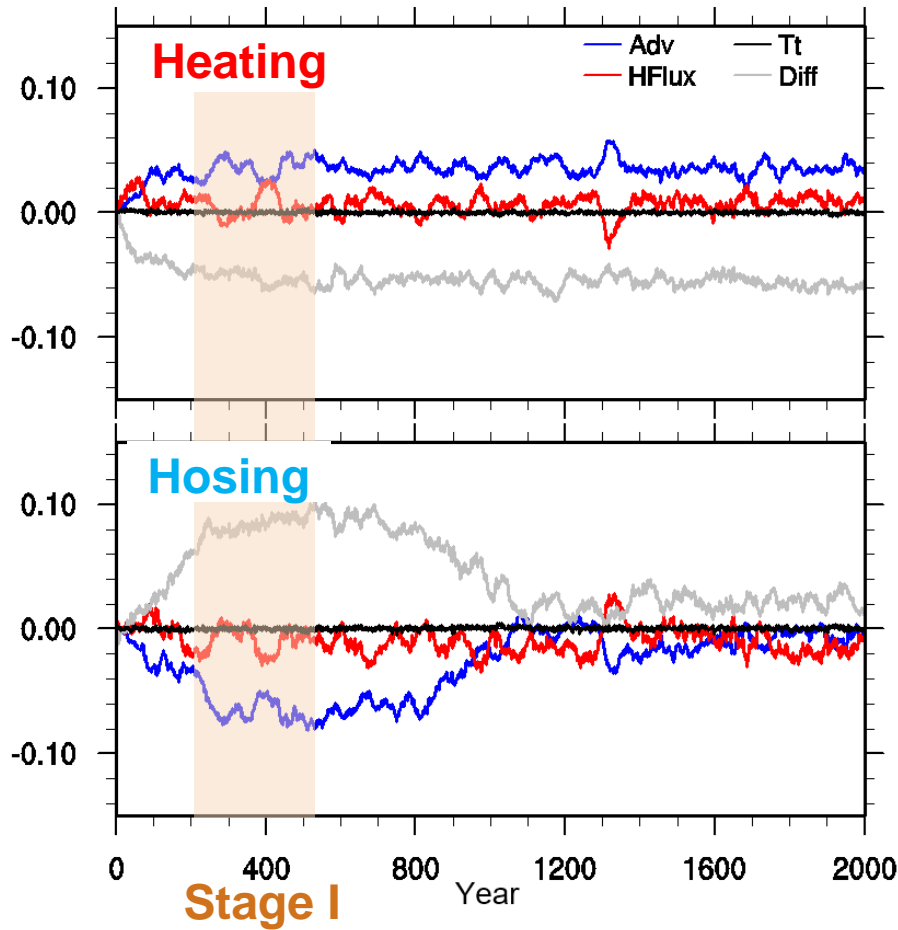
SST

- Cold FW advection from Arctic ↑
- SAT ↓



Mechanism of Hosing Cooling

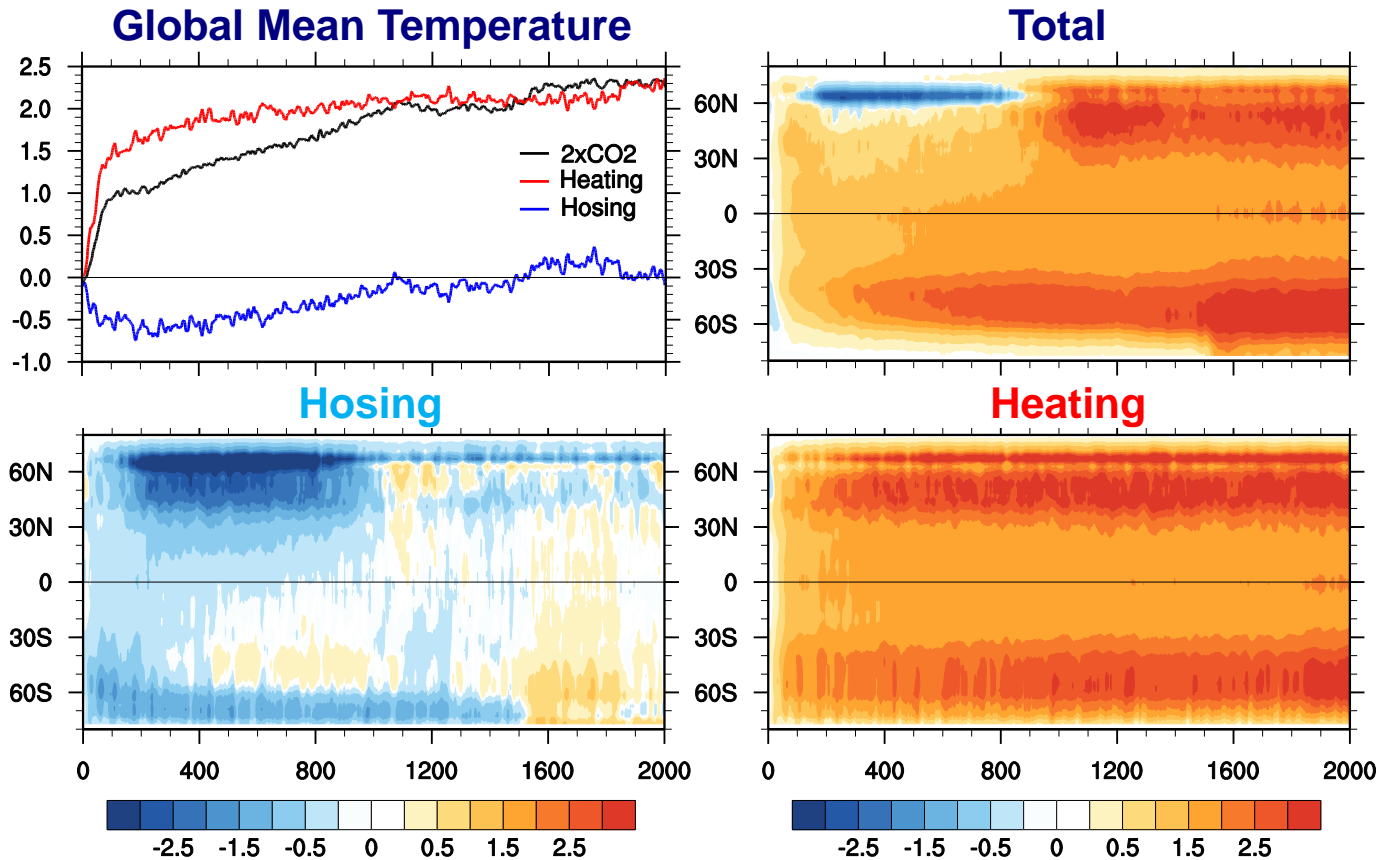
North Pacific



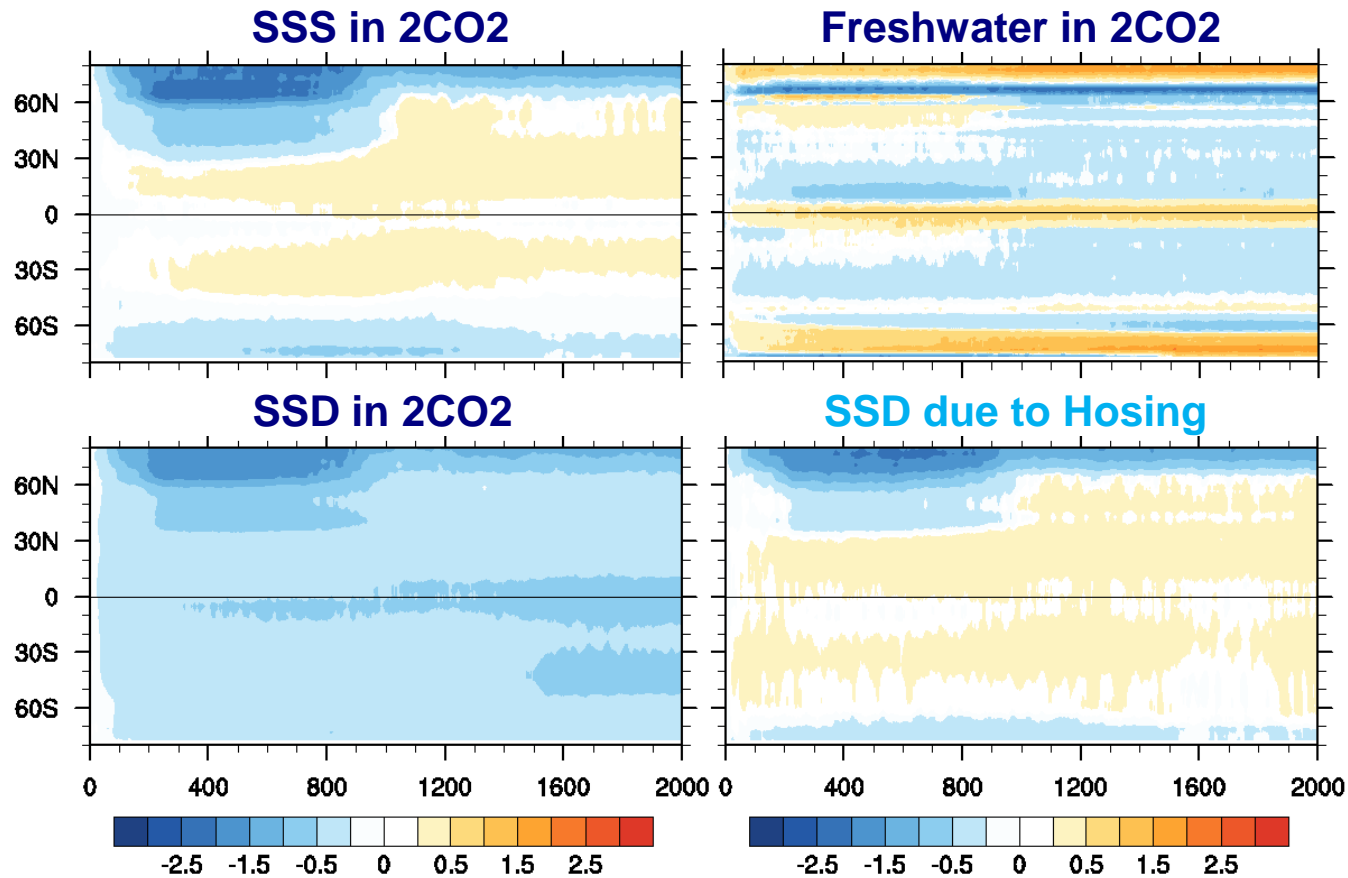
Cold FW advection from Arctic ↑

Later stages in Global Warming ...

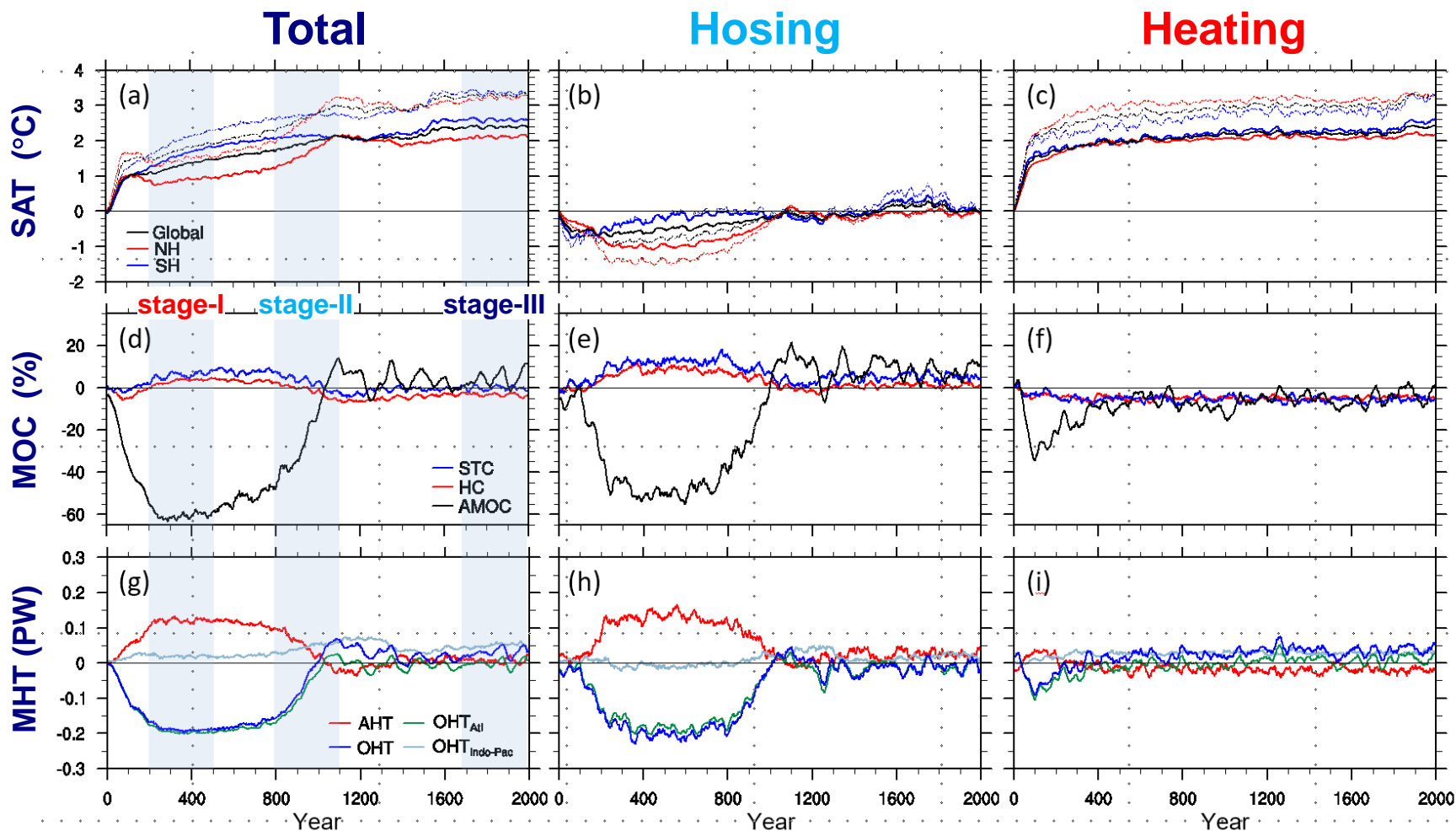
Global *Temperature* Evolution



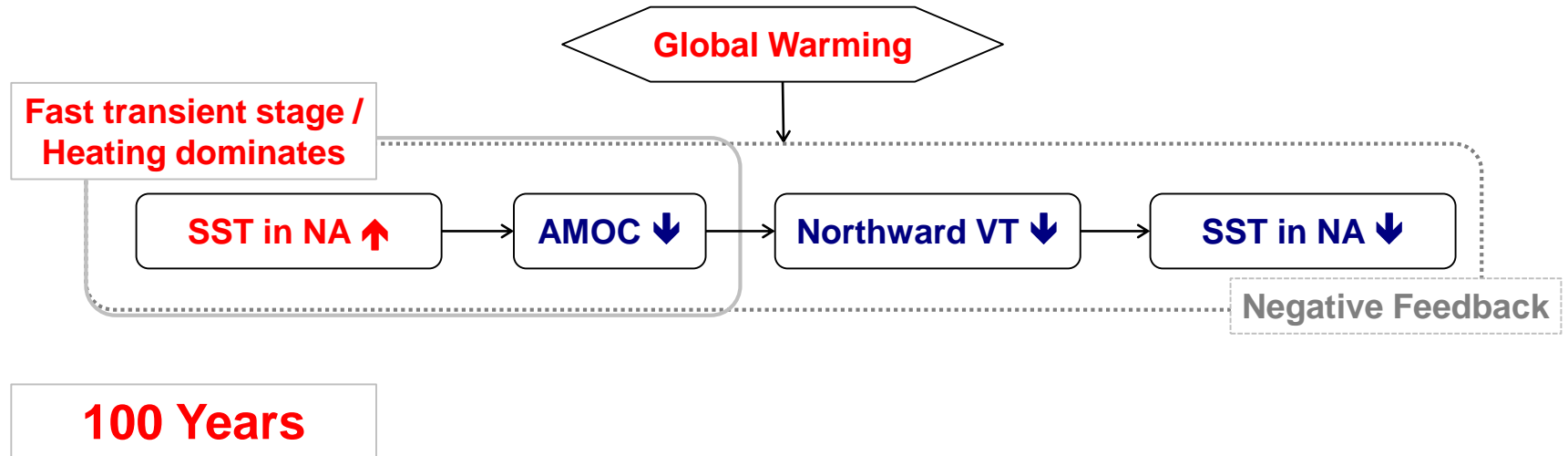
Evolution of *SSS*, *Freshwater*, *SSD*



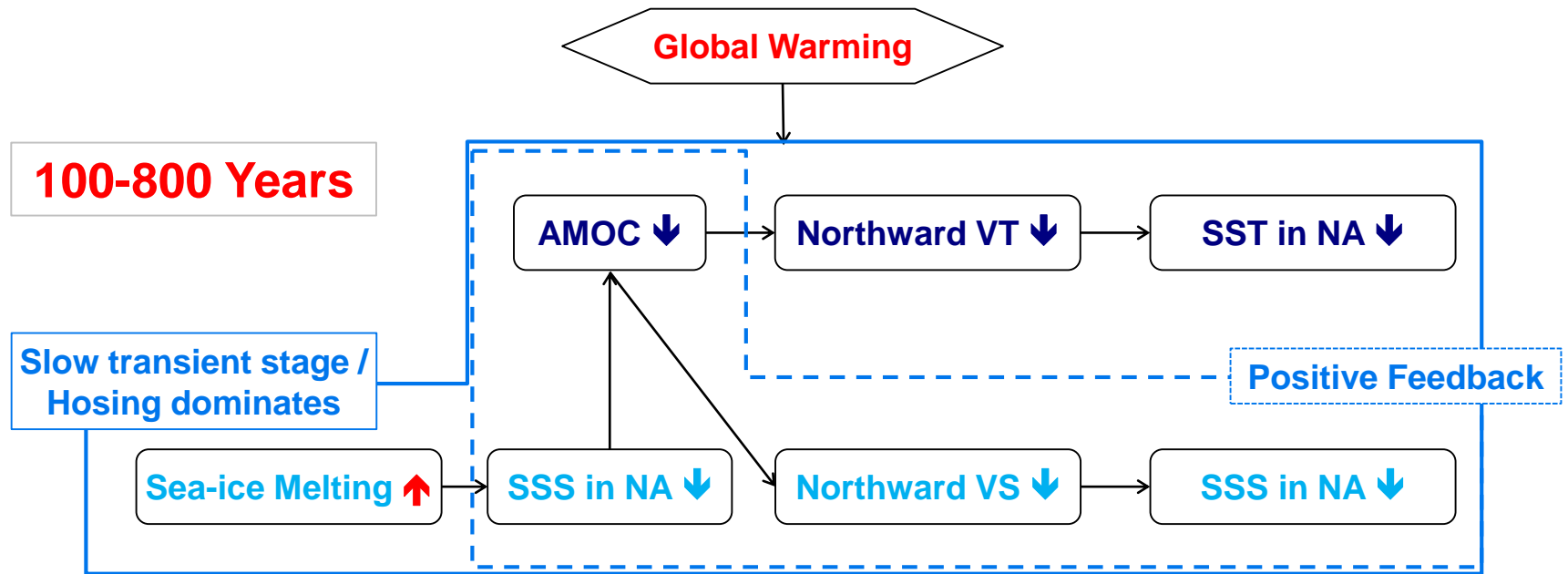
Evolution of *MOCs* and *MHTs*



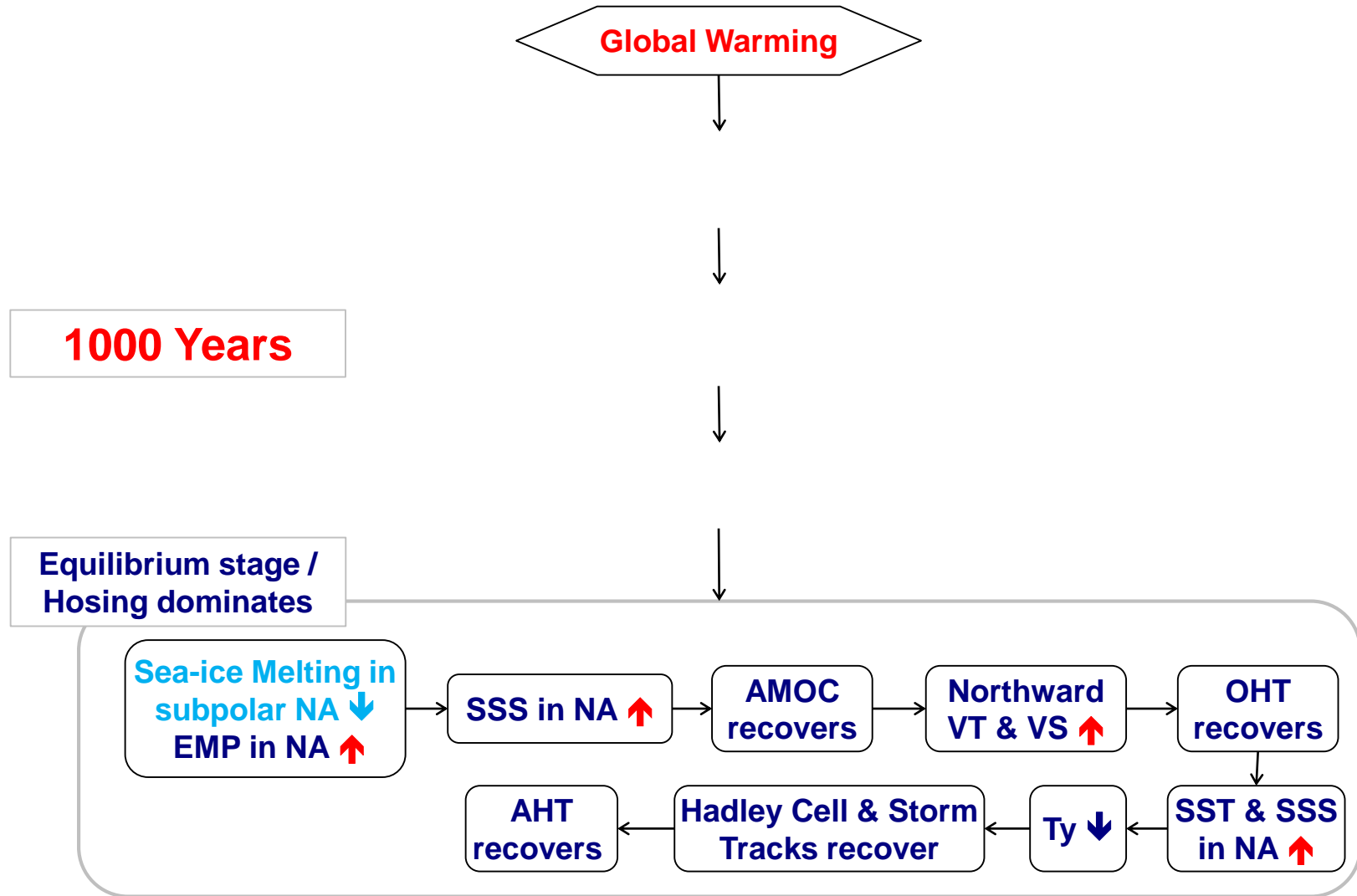
Summary



Summary



Summary



Summary and Discussion

- ◇ **Hosing: 30% cooling**
 - ◇ Asymmetric changes
 - ◇ Arctic sea ice melting
 - ◇ AMOC ↓ and HC ↑
 - ◇ Baroclinic change in ocean T
- ◇ **Heating: symmetric**
 - ◇ Barotropic change in ocean T
 - ◇ Into the deep ocean
- ◇ More studies on different stages



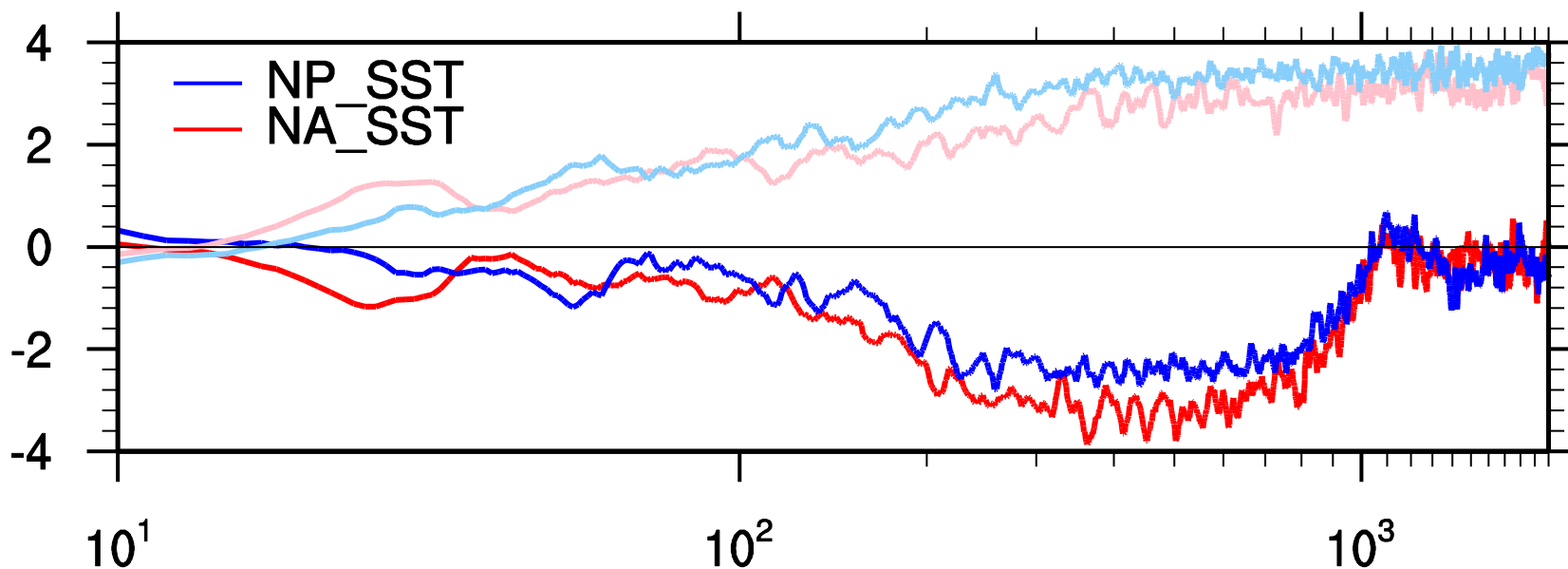
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Thanks

Relationship: N. Pacific and N. Atlantic

N. Pacific *lags* N. Atlantic by 5 years

Lag Corr. (NA, NP)_{max} = 0.85



Summary

