Fast response of the Tropics to an Abrupt Loss of Arctic Sea Ice via Ocean Dynamics

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Follow-up to Deser et al. (2015) and Tomas et al. (2016) who examined the *equilibrium* coupled ocean-atmosphere response to Arctic sea ice loss.

Here we examine the *transient* response using the same experimental design.
Equilibrium SST Responses

Full ocean model

Slab ocean model

After Tomas et al. (2016)
Sea Ice Nudging in CCSM4-1° via LW flux to sea ice model (GHG fixed at year 2000)

- 20 pairs of simulations with fully-coupled version
- 10 pairs of simulations with slab-ocean version
- Each simulation is 100 years long

Control simulation: 1980-1999 sea ice (historical)
Perturbation simulation: 2080-2099 sea ice (RCP8.5)
1) How long does it take for ocean dynamics to influence the Tropical response to Arctic sea ice loss?

2) What processes are involved?
Zonal-mean Tropical SST and Surface Wind Responses

~ 20 years

Equatorial maximum  Hemispheric asymmetry
Zonal-mean Tropical SST and Surface Wind Responses

Minus Tropical Mean

Full ocean model

Slab ocean model

~ 20 years

Equatorial maximum

Hemispheric asymmetry
Tropical precipitation (color) & surface wind divg (contours)

Full ocean model

Slab ocean model

P climatology

Equatorial maximum

Hemispheric asymmetry

mm/day
Initial Response (years 6-25)

Full ocean model

Slab ocean model

SST

°C

-2 -0.5 -0.25 -0.2 -0.15 -0.1 0 0.1 0.15 0.2 0.25 0.5 2
Initial Response (years 6-25)

Full ocean model

Slab ocean model

SST

Precipitation

°C

mm/day
Equilibrium Response (years 81-100)

Full ocean model

Slab ocean model

SST

Precipitation

°C

mm/day
Meridional Heat Transport: Full Ocean Model

![Graph showing meridional heat transport with labels for Atmosphere and Ocean, indicating initial and equilibrium states.](image)
Meridional Heat Transport: Full Ocean Model
Equatorial Pacific Mixed Layer Heat Budget
Equatorial Pacific Mixed Layer Heat Budget

Full ocean model

SST

$T'(z) > 20$ years

$Q_{net}$ and horizontal advection damp
Equatorial Pacific Mixed Layer Heat Budget

> 20 years $\bar{W} \; dT'/dz$

Qnet and horizontal advection are damping terms

$T'(z)$

$\bar{W} dT'/dz$
Initial Response in Fully-Coupled Model
1) How long does it take for ocean dynamics to influence the Tropical Pacific response to Arctic sea ice loss? ~ 20 years

2) What processes are involved?

\[ \bar{W} \frac{dT'}{dz} \]

but origin of subsurface warming remains to be understood
Summary

1) How long does it take for ocean dynamics to influence the Tropical Pacific response to Arctic sea ice loss? ~ 20 years

2) What processes are involved?

\[ \bar{\nabla} \cdot \frac{dT'}{dz} \]

but origin of subsurface warming remains to be understood

See Zhang and Delworth (2005) for related freshwater hosing experiments
Tropical Pacific precipitation (color) & sfc wind divg (contours)
Response of AMOC
Response of the 26.5 kg/m$^3$ isopyncal surface

Located at 300-400m depth in the Eastern Equatorial Pacific

Global adjustment to a weakening of AMOC (Timmermann et al., 2005)
Meridional Heat Transport

Full ocean model

![Graph showing meridional heat transport in full ocean model with initial and equilibrated states for atmosphere (Atm) and ocean.](image)

Slab

![Graph showing meridional heat transport in slab model with initial and equilibrated states for full ocean.](image)
Meridional Streamfunction

Initial Equilibrium

Full ocean model

Slab ocean model