Global Climate Response to Future Arctic Sea Ice

The role of ocean-heat transport

Bob Tomas, Clara Deser & Lantao Sun, NCAR Feb. 2015
Model Experiments (CESM 1°)

Coupled dynamical ocean (POP)
Coupled slab ocean (SOM)

Atmosphere-Land only (AMIP)

Fix GHG at 1990 levels to isolate impact of Arctic sea ice loss

Historical / RCP8.5

CCSM4 Arctic Sea Ice Extent

1990 to 2090

10^6 km^2

1960 1980 2000 2020 2040 2060 2080 2100
Artificially Control Ice

Only ice “sees” the extra long wave

Want to remove some ice cover?

Add long wave radiation into ice model code

1990 Ice

Sea Ice

Arctic Ocean

Ice melted

2090 Ice

Arctic Ocean
Annual Surface Response to Arctic Sea Ice Loss

**Dyn Ocn** (Dynamical Ocean) - more symmetric global response

**SOM** (Slab Ocean Model) - more asymmetric global response

**TS (TS Precip SLP)**:
- Dynamical Ocean -> more symmetric global response
- Slab Ocean-> more asymmetric global response
Annual Surface Response to Arctic Sea Ice Loss

Dynamical Ocean -> more symmetric global response

Slab Ocean-> more asymmetric global response
Annual Surface Response to Arctic Sea Ice Loss

**Dyn Ocn**

- TS
  - Dynamical Ocean -> more symmetric global response

**SOM**

- Slab Ocean -> more asymmetric global response
Northward Energy Transport:
Response to Arctic Sea Ice Loss

Atmosphere brings heat to mid-latitudes
Ocean brings heat into the tropics and SH
Northward Energy Transport: Response to Arctic Sea Ice Loss

Atmosphere brings heat to mid-latitudes
Ocean brings heat into the tropics
Slab ocean: atmosphere has to do all the work
Northward Energy Transport: Response to Arctic Sea Ice Loss

Atmosphere brings heat to mid-latitudes

Ocean brings heat into the tropics

Slab ocean: atmosphere has to do all the work
ΔOHT in fully coupled simulation explains symmetric global response.
SOM Annual Surface Response to Arctic Sea Ice Loss

ΔOHT in fully coupled simulation explains symmetric global response
SOM Annual Surface Response to Arctic Sea Ice Loss

ΔOHT in fully coupled simulation explains symmetric global response
SOM Annual Surface Response to Arctic Sea Ice Loss

Role of ΔOHT

TS

w/ ΔOHT

w/o ΔOHT

Difference

Heat

Precip

Precip

Difference

Mass
SOM Annual Zonal Mean Response to Arctic Sea Ice Loss

Some common features in troposphere response ...

Role of ΔOHT
SOM Annual Zonal Mean Response to Arctic Sea Ice Loss

Temperature

Zonal Wind

w/ ΔOHT

w/o ΔOHT

Differences... also differences

ΔOHT impacts climate response throughout troposphere

Role of ΔOHT

°C

ms⁻¹
SOM Annual Zonal Mean Response to Arctic Sea Ice Loss

**Condensational Heating**

**w/ ΔOHT**
- Precipitation increases slightly equatorward & above clim. maxima

**w/o ΔOHT**
- ITCZ “shifts” into NH - transports energy from NH -> SH

**Precipitation**
- mm day$^{-1}$

**ΔHeating**
- ΔICESOM_FUTQ

**ΔHeating**
- ΔICESOM_PD
SOM & AMIP DJF Mean Surface Response to SST’s

Ice loss -> ΔOHT -> ΔTropical SST’s -> mid-lat. circulation response

Role of Tropical SST’s
Summary and Conclusions (1)

Arctic Sea-Ice Loss (asymmetric forcing)

Dynamical Ocean

Symmetric Response

ΔOHT

Asymmetric Response

SOM QFLUX with ΔOHT

ΔOHT explains symmetric vs. asymmetric global response

AMIP Tropical SST

AMIP Global SST

~SOM/FC response

~mid-lat SOM/FC features

Ice loss -> ΔOHT -> Tropical SST’s -> mid-lat circ. response

Symmetric Response

Glob. SST’s

Trop. SST’s
Are there **broader implications** for other studies that examine the response to asymmetric forcings and use a slab ocean model?
Extra Slides
Model Experiments

Coupled atm-dynamical ocean (CCSM4 1°)
Coupled atm- slab ocean (SOM) (CCSM4 1°)
Atmosphere-only (CAM4 1°)

Fix GHG at 1990 levels to isolate impact of Arctic sea ice loss
Response of surface energy exchange to Arctic sea ice loss

Less sea ice ->
more heat fluxed
into atmosphere

Sea Ice

Arctic Ocean

$Q_{\text{out}}$

GHG

heat

moisture

$Q_{\text{out}}$

$T_s$

albedo, $\varepsilon$
Max. Total MOC at 26° (Sv)

Red - LW Experiment, Blue - Control

![Graph showing Max. MOC at 26° (Sv) over Year]
error = 2%

y-intercept = 35 Wm$^{-2}$

slope = 1.8 Wm$^{-2}$ %$^{-1}$