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Arctic Climate (from a newbie and a climate/atmosphere modeler)

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¹PNNL US CLIVAR Summit POS Breakout A new DOE project "High-Latitude Application and Testing of Global and Regional Climate Models" (HiLAT)



- PIs: Jones (LANL) & Rasch (PNNL)
- Team: Burrows, Elliott, Fyke, Hecht, Hunke, Jeffery, Rowland, Urban, Urrego-Blanco, Veneziani, H. Wang, S. Wang, Weijer, Yoon



Global warming strongly affects cryosphere.









- Polar climate change is one of the US CLIVAR Research Challenges.
- Regional sea-level change and Arctic is one of the International CLIVAR Research Foci.
- Link to extreme weather Arctic-Midlatitude interaction working group
- Link to various climatic feedback processes
 - biogeochemistry feedbacks
 - Cloud/aerosol processes
 - Dynamical feedback
 - Troposphere-Stratospheric link

Polar Amplification



- Various climatic feedbacks were suggested as a potential cause.
- What makes difference between Arctic and Antarctic temperature trend?



Biogeochemical feedbacks



 $\mathsf{B}_{\mathrm{ICE}\ \mathrm{trend}}$ А T sfc trend -2.4-1.8-1.2-0.6 0.2 0.3 0.4 0.6 1.2 1.8 2.4 [°C/vr [%/yr] С D_{CHL} trend ICE_free_days trend 6 8 -8 -6-4

[day/yr]

-0.045 - 0.03 - 0.015 0.015 0.03 0.045 [mg m^{-s}/yr]

Park et al. 2015 in PNAS

Warming induced sea ice

shortwave radiation into the

growing season \rightarrow warming

ocean \rightarrow longer phytoplankton

melting and increasing

(positive feedback)

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Cryospheric Impacts on Marine Ecosystems and Clouds



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The sensitivity of high-latitude marine ecosystems to inputs from GrIS, AIS, Arctic deltas is unknown.

- Freshwater inputs tend to reduce biological productivity
 - Stronger stratification reduces upwelling of nutrients
- Nutrient inputs tend to enhance biological productivity
 - Arctic: macronutrient input from deltas
 - Antarctic: micronutrient input from ice shelves

McKenzie River plume





Sediment bearing iceberg

eosnap.com

Raiswell

Greenland ice sheet evolution in a warming climate



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Cold winters in the US in the recent years ~ linked to Hiatus





Polar Control on Midlatitude Weather



- Explore interactions between polar climate and midlatitude weather
 - Does Arctic sea ice retreat alter midlatitude circulation patterns a.k.a. 'Polar Vortex' and cause extreme winter over the U.S. and other?
 - Identify the relative contribution of the Arctic influence vs. the tropics on the past extreme winters in midlatitude (e.g., 2013/14, 14/15).

Approach

- Multi-ensembles of atmosphere-only simulations
- Tag water vapor

Reducing Arctic Sea Ice can change surface energy budget and initiate teleconnection.



Through link to stratospheric circulation

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Kim et al. 2014 in Nature Communications



Traditional view is teleconnection originated from the tropics.

1999–2012 – 1979–1998 300 hPa streamfunction



 Competing with a teleconnection pattern originated from the tropics

> Trenberth et al. 2014 Nature Climate Change

Blob and transient eddy forcing in the atmosphere



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California Drought Linked to Humancaused Global Warming



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Objective

 Identify weather or a climate patterns that link to a recent severe California drought

Approach

- Use Community Earth System Model, a coupled climate model simulation, to identify a potential link to human-caused global warming
- Identify the "Dipole" pattern observed in CA drought
- Vary forcing agents in the Community Earth System Model (CESM) simulations to evaluate the dipole response

Wang S-Y S, L Hipps, RR Gilles, and J Yoon. 2014. "Probable causes of the Abnormal Ridge Accompanying the 2013-14 California Drought: ENSO Precursor and Anthropogenic Warming Footprint." *Geophysical Research Letters*, accepted early online. DOI:10.1002/2014GL059748



Top: The high-low pressure "dipole" pattern that caused drought in California and frigid temperature in the East and Midwest.

Bottom: Change of intensity of the dipole patterns from observation (OBS), climate model simulation forced by greenhouse gases (GHG) and natural forcings (NAT).

Impact

- The persistent dipole and the subsequent California drought is linked to El Niño's initiation phase, rather than El Niño itself
- This link has been strengthening in recent years, likely due to increased greenhouse gases in the atmosphere

A better physics in GCM makes MJO and teleconnection toward high-latitudes more realistic.



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Intensive Observations are on-going by International partners:







Why an atmosphere guy cares about Arctic and Oceanic feedbacks?

In a coupled climate model, what controls the ENSO amplitude?

- A couple of parameters in the atmosphere model, especially in convection...
- An example is here (from Cecile Hannay & Rich Neale @ NCAR).

Dcs = 250 microns

Dcs = 200 microns

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CAM5.4

Why an atmosphere guy cares about Arctic and Oceanic feedbacks?

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In a coupled climate model, what controls the ENSO amplitude?

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Modified CAM5.4



Dcs = 200 microns



Thank you!



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It is all about the coupled climate system.

Extra slides



Antarctic Sea Expansion



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Trend in sea-ice fraction from observations (left) and a CCSM4 ensemble average (right)

Strengthens stratification and reduces upward heat flux

Rainfall extreme



