13 January 2011

Selection Committee
NOAA Global Change Postdoctoral Fellowship

Dear Selection Committee,

Please find below my application for the 2011 NOAA Global Change Postdoctoral Fellowship. The proposed host is John Marshall at the Massachusetts Institute of Technology. The application package includes the following documents (in this order).

- A Curriculum vitae
- Names and addresses of five (5) references
- Ph.D. dissertation abstract
- A research proposal
- Statement of relevance to the NOAA climate science program

Please don't hesitate to contact me with any questions regarding this application.

Sincerely,

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Education

2004-present **University of Washington, Seattle, WA**

Doctor of Philosophy expected March, 2011, Department of Atmospheric Sciences.

- Doctoral Qualification topic: "Causes of Reduced Storm Activity in a General Circulation Model Simulation of the Last Glacial Maximum"
- Dissertation title: "Radiative and dynamic controls of global scale energy fluxes"
- Committee: David Battisti (Chair), Gerard Roe, Dargan Frierson, Greg Hakim, and Eric Steig

1999-2003 **Bowdoin College, Brunswick, ME**

A.B. in Physics Summa Cum Laude awarded May 2003.

- Honors Topic: "Biases in Inferred Carbon Sources due to Selective Atmospheric Sampling of Carbon Dioxide"
- Advisor: Mark Battle

2001 ` **University of Otago, Dunedin, New Zealand**

One semester as an international student with course work in Geology, Chemistry and Physics.

Peer Reviewed Publications

- 2011 Donohoe, A. and D.S. Battisti: A heuristic model of the seasonal cycle in energy fluxes and climate. In preparation.

- 2011 Donohoe, A. and D.S. Battisti: What controls meridional heat transport in global climate models? Submitted J. Climate.

- 2011 Donohoe, A. and D.S. Battisti: Atmospheric and surface contributions to planetary albedo. Accepted J. Climate.

- 2009 Donohoe, A. and D.S. Battisti: The amplitude asymmetry between synoptic cyclones and anticyclones: implications for filtering methods in feature tracking. Mon. Wea. Rev., 137, 3874-87.

- 2009 Donohoe, A. and D.S. Battisti: Causes of Reduced North Atlantic Storm Activity in a CAM3 Simulation of the Last Glacial Maximum. J. Climate, 32, 4793-4808.

Research Experience

2004-present **University of Washington, Seattle, WA**

Research Assistant in the Department of Atmospheric Sciences. Developed models of linear barotropic and baroclinic stability which were applied to simulations of the glacial mean state and the mid-winter suppression of the Pacific storm track. Assessed the eddy kinetic energy budget for the modern and glacial climate states. Applied Lagrangrian tracking analysis and developed tools to evaluate ensemble eddy growth rates in different climate states, using a Lagrangrian reference frame. Diagnosed biases and aliasing in eddy statistics due to several different commonly used filtering techniques. Compared Lagrangrian eddy statistic resulting from spatially and temporally filtered fields and assessed the validity of each by applying skew-normal statistics. Developed an (untested) theory of abrupt climate change during the glacial based on GCM simulations in which the extratropical jet "jumps" poleward of the Laurentide ice sheet. Developed a simplified energy balance model for the seasonal cycle of energy fluxes. **Field Experience:** Greenland Summit air and snow sampling with the Eric Steig Group (2005), Blue Glacier, Mount Olympus, WA, glacier monitoring (2005-present), Quinalt mixed precipitation monitoring network, Olympic Mountains, WA (2004-present).

2003 **Scripps Institute of Oceanography, San Diego, CA**

Developmental Technician, Bob Guza group, Nearshore Canyon Experiment. Worked as a member of research group responsible for a dense network of *en situ* measurements of pressure and velocity in a surf zone. Developed and fabricated instrument frames and deployment and recovery strategies. Calibrated instrumentation and assessed performance in real time. Mantained suite of instruments during the 3 month observation period and performed public outreach for beach users.

2003 **Bowdoin College. Brunswick, ME**

Undergraduate student, honors work. Assessed impact that baseline selection of atmosspheric carbon dioxide measurements has on inverse calculations of terrestrial and ocean carbon sources.

2002 **Woods Hole Oceanographic Institute, Falmouth, MA**

Summer Student Fellow, Department of Physical Oceanography. Advisor: Al Plueddemann. Performed data analysis to assess the momentum transfer across the air sea interface and the form of bottom drag in a rectilinear tidal flow.

2001 **Frost Gulley Stream Team Freeport, ME**

Hydrological Researcher. Developed and implemented rating curves to monitor watershed discharge as a part of a student research group.

Teaching Experience

2010 University of Washington. Co-directed a graduate level special topics seminar (ATMOS/OCE/ESS 586) on climate feedbacks with Gerard Roe.

2009, 2007 Cornish College. Guest Lecturer: Gave several lectures on climate dynamics for Introduction to Climate Change Class

2007 University of Washington. Teaching Assistant in ATMOS/OCE/ESS 587: Climate Dynamics. Gave several lectures, created and graded homework and projects.
2006 University of Washington. Teaching Assistant, ATMOS 101: Weather. Lead two discussion sections per week, additional review sessions, developed and graded all homeworks and exams.
2003 Bowdoin College. Teaching Assistant in Physics 101. Ran extra help/review sessions and graded homework assignments.

Fellowships and Awards

National Science Foundation Graduate Fellow (2006-2009), Gary Comer Abrupt Climate Change Fellow(2005-2006), Program on Climate Change Fellow (2004), Achievement Award for Colleges Scientists (ARCS) Fellow (2004-2007).
Phi Beta Kappa Alpha of Maine, Bowdoin book prize winner, Sarah and Jamnes Bowdoin scholar, recipient of Edward Acorn Prize (Religion Department) and Bradley Noel Prize in Experimental Physics.

Conferences/Workshops Attended/Talks Given

2010, San Francisco, CA. AGU Fall Meeting. Speaker in Atmospheric Sciences, General Contributions, Climate and Radiation.
2010, Emuclaw WA. 4th Annual Graduate Climate Conference. Speaker in Atmospheric and Ocean Dynamics Session.
2010, Friday Harbor WA. University of Washington Program on Climate Change Summer Institute: Climate Feedbacks.
2009, San Francisco, CA. AGU Fall Meeting. Speaker in high-latitude climate feedback session.
2009, University of Washington. Dynamics Seminar Speaker.
2009, National Academies of Science: BASC Annual Board Meeting, Seattle, WA. Invited Speaker.
2009, Pasadena, CA. Ocean and Atmosphere Energy Transport Conference. Poster presentation.
2009, Emuclaw, WA. 3rd Annual Graduate Climate Conference. Speaker in Atmospheric Dynamics Session.
2008, San Francisco, CA. AGU Fall Meeting. Speaker in mid-latitude cyclone session.
2008, University of Washington. Dynamics Seminar Speaker.
2008, Friday Harbor Labs, WA. University of Washington Program on Climate Change Summer Institute: The ocean circulation and climate change. Attendee.
2007, Enumclaw, WA. 2nd Annual Graduate Climate Conference. Co-organizer, Paleoclimate Session Chair, Speaker.
2007, Friday Harbor Labs, WA. University of Washington Program on Climate Change Summer Institute: Biogeochemical coupling to climate. Attendee.
2007, Valle de Aosta, Italy. Alpine Summer School- Convective Processes in Climate dynamics/ Attendee.
2007, Lamont Doherty Observatory, New York. Gary Comer Abrupt Climate Change Roundtable/ Invited Speaker.
2007, University of Washington. Dynamics Seminar Speaker.

2006, Cambridge University, England. Geophysical Fluid Dynamics Summer School. Attendee.
2006, Enumclaw, WA. 1st Annual Graduate Climate Conference. *Co-founder of Conference,* Dynamics Session Chair, Speaker.
2006, Lamont Doherty Observatory, New York. Gary Comer Abrupt Climate Change Roundtable/ Poster Presentation.
2005, Leavenworth, WA. University of Washington Program on Climate Change Summer Institute: El Nino. Attendee.

Professional Experience (not already listed)

Appalachian Mountain Club/ Maine Woods Initiative **Gorham, NH**
Professional trail crew member/ chain saw operator and grip hoist technician. Cut 15 miles of cross country ski and hiking trails in a newly acquired conservation area in the 100 mile wilderness of Maine. Finished trail work included rock step construction and heavy bridge construction out of locally fabricated materials. Lived in the backcountry and coordinated volunteer trail work. Summer of 2004.

Student Conservation Association/ Baxter State Park **Millinocket, ME**
SCA Resource Assistant/ Summer Trail Crew. Participated in trail maintenance, rock step and water bar construction, bog bridging, and new trail cutting. Learned skills of chain saw, bush saw and grip hoist operation. Summer 2000.

Student Conservation Association/ Payette National Forest **McCall, ID**
High School Trail Crew Member/ Backcountry Rehabilitation Crew. Partook in trail rehabilitation operating sixteen miles into the backcountry of a designated wilderness. Trained in hand tool/cross cut operation and fire suppression. Summer 1998.

Additional Activities

-Graduate Student Representative for the Department of Atmospheric Science (UW, 2008-2009)
-Certifications in Wilderness First Aid, Anaphylaxis response, professional CPR, life guarding, Avalanche Education (I), Glacier Travel and Crevasse Rescue, Chainsaw Operation.
-President of the Bowdoin Society of Physics Students (2002-2003)
-Club Head of the Service and Ecology Club and leader in the Bowdoin Outing Club
-Member of the Bowdoin College Varsity Indoor and Outdoor Track Teams, letter winner (1999-2003)
-Student Mentor and Tutor for local high school students
-Social House leader in charge of organizing campus events for an affiliate of 250 students
-Captain of varsity soccer(1998), alpine skiing(1999), and track and field (1999) teams at Acton-Boxborough Regional High School and Dual County League All Star (track 1997-1999, soccer 1998, skiing 1999)

List of references with addresses

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- Professor Mark Battle
  Department of Physics and Astronomy
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  8800 College Station
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  Department of Earth and Space Sciences
  University of Washington
  Johnson Hall Rm-070, Box 351310
  4000 15th Avenue NE
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- Professor Dargan Frierson
  Dept. of Atmospheric Sciences
  University of Washington
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  Seattle WA 98195-1640
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- Professor John Marshall (proposed host)
  Department of Earth, Atmospheric and Planetary Sciences
  Bldg 54-1526 (The Green Building)
  Massachusetts Institute of Technology
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Aaron Donohoe- Thesis Abstract
University of Washington

Title: Radiative and dynamic controls of global scale energy fluxes

In this thesis I study the processes that control the global scale energy budget of the climate system and the fluxes of energy within the climate system using both models and data. I focus on three primary questions: (1) What determines the Earth's planetary albedo? (2) What determines the meridional heat transport in the climate system? (3) What controls the seasonal amplitude of energy fluxes on the equator-to-pole scale?

(1) Planetary Albedo

The planetary albedo is partitioned into a component due to atmospheric reflection and a component due to surface reflection by using shortwave fluxes at the surface and top of the atmosphere in conjunction with a simple radiation model. The vast majority of the observed global average planetary albedo (88%) is due to atmospheric reflection. Surface reflection makes a relatively small contribution to planetary albedo because the atmosphere attenuates the surface contribution to planetary albedo by a factor of approximately three. The global average planetary albedo in the ensemble average of the CMIP3 pre-industrial simulations is also primarily (87%) due to atmospheric albedo. The inter-model spread in planetary albedo is relatively large and is found to be predominantly a consequence of inter-model differences in atmospheric albedo, with surface processes playing a much smaller role despite significant inter-model differences in surface albedo. The CMIP3 models show a decrease in planetary albedo under a doubling of carbon dioxide -- also primarily due to changes in atmospheric reflection (which explains more than 90% of the inter-model spread). All models show a decrease in planetary albedo due to the lowered surface albedo associated with a contraction of the cryosphere in a warmer world, but this effect is small compared to the spread in planetary albedo due to model differences in the change in clouds.

(2) Meridional Heat Transport

The meridional heat transport (MHT) is expressed as the difference between the equator-to-pole contrast in absorbed solar radiation (ASR*) and outgoing longwave radiation (OLR*). As an example, in the Northern Hemisphere observations, the extratropics receive an 8.1 PW deficit of net solar radiation (ASR*) relative to the global average that is balanced by a 2.4 PW deficit of outgoing longwave radiation (OLR*) and 5.7 PW of energy import via the atmospheric and oceanic circulation (MHT).
The inter-model spread of MHT in the CMIP3 simulations of the pre-industrial climate is primarily ($R^2 = 0.72$) due to differences in ASR* while model differences in OLR* are uncorrelated with the MHT spread. ASR* is partitioned into components due to the incident radiation at the top of the atmosphere and the equator-to-pole contrast of planetary albedo which is further subdivided into components due to atmospheric and surface reflection. In the observations 62% of ASR* is due to the meridional distribution of incident radiation, 33% is due to atmospheric reflection, and 5% is due to surface reflection. The inter-model spread in ASR* is due to model differences in the equator-to-pole gradient in planetary albedo that are primarily a consequence of atmospheric

reflection differences (92% of the spread) and is uncorrelated with differences in surface reflection. As a consequence, MHT in climate models is primarily determined by cloud reflection. These ideas are extended to simulations of anthropogenic global warming and paleoclimate states where it is found that changes in cloud reflection exert as profound an influence on MHT as even zeroeth order changes in surface albedo.

(3) Seasonal energy fluxes

The seasonal amplitude of energy fluxes to the extratropics is driven by large variations in solar radiation that are primarily balanced by ocean heat storage anomalies; changes in meridional heat transport, emitted long wave radiation, and atmospheric heat storage play a decreasingly important role in the seasonal energy balance. We use a simplified coupled (atmosphere-ocean) energy balance model to understand the seasonal amplitude of the various extratropical energy fluxes. The model is found to reproduce the sensitivity of the energy fluxes to the ocean mixed layer depth found in an ensemble of aquaplanet general circulation model simulation with varying mixed layer depths.

Land-ocean contrasts also have a large impact on the seasonal energetics of the extratropical climate system. Over the ocean, zonal heat transport from the land domain is maximized during the summer, and the sum of the insolation and zonal heat transport anomalies is balanced by ocean heat storage. In contrast, over the land, the primary summertime balance is excess solar insolation balanced by an enhanced zonal heat export. The observed seasonal cycle of energy fluxes and the land and ocean temperatures are replicated in a simplified energy balance model that includes land-ocean contrast and the hemispheric differences in fractional land area. The sensitivity of the seasonal cycle in climate (atmosphere and ocean temperatures) – and in the gross partitioning of the mix of energy flux processes that determine the climate – to the fractional land area is further explored in an ensemble of energy balance model integrations. In both the aquaplanet and land-ocean contrast energy balance models, the partitioning of energy fluxes amongst different physical processes can be understood in terms of the sensitivity of those processes to temperature perturbations.

Mechanisms controlling the hemispheric asymmetry in the climate response to global warming

by Aaron Donohoe, University of Washington

1. Background

During my Ph.D. studies with David Battisti at UW, I have been viewing climate dynamics from the perspective of the radiation budget and its interaction with atmospheric dynamics (see, for example, Donohoe and Battisti 2011a). In particular I have been interested in the processes that control global scale energy fluxes into and out of the atmosphere (on both annual and seasonal time scales) including the air-sea flux of energy, the meridional energy flux, the energy flux from the ocean-to-land, and the radiative fluxes (Donohoe and Battisti 2011b). I am applying to join John Marshall and his group at MIT as a NOAA postdoctoral fellow. They have also has been thinking about the same large scale energy fluxes, but from the perspective of the global ocean circulation (Enderton and Marshall 2009, Rose and Marshall 2009) and its coupling to the atmosphere. We believe our individual expertise (including our modeling capabilities and toolboxes of analytical techniques) and differing perspectives, put us in a unique position to make progress in studying mechanisms that control the hemispheric asymmetry in the climate response to global warming. This is a hugely important problem because the response of the climate system to greenhouse forcing is not spatially uniform but exhibits pronounced meridional, and particularly hemispheric, asymmetries.

My proposal is set out as follows. In Section 2 I review the questions I plan to address in my postdoc, including a brief review of prior studies. In section 3 I outline my proposed plan of work.

2. The research problem: Hemispheric Asymmetry in the Climate Response to Global Warming.

The projected climate response to anthropogenic greenhouse gas emissions shows a marked hemispheric asymmetry that is robust across the suite of state of the art coupled climate models (Meehl et al. 2007 -- Figure 1A). The surface temperature increase in the Northern Hemisphere (NH) extra-tropics is projected to exceed the global average temperature increase by a factor of approximately two (IPCC, 2007): a phenomenon know as polar amplification (Holland and Bitz 2003; Serreze and Francis, 2006). In contrast, the surface temperature change in the Southern Hemisphere (SH) extra-tropics is projected to be significantly smaller than the global average temperature change, especially in the vicinity of the Drake passage. The observational record of surface temperature trends over the last century also feature enhanced warming in the NH extratropics (especially over land) and more neutral or even negative trends in the Southern Ocean (Smith and Reynolds 2005).

The cause of the inter-hemispheric asymmetry in the climate response to anthropogenic radiative forcing is an unresolved problem in coupled (atmosphere-ocean-cryosphere) climate dynamics. The inter-hemispheric differences in land area, the geography of the continental boundaries and topography, and the resulting basic state oceanic and atmospheric circulations could all contribute to the asymmetric response. Several mechanisms for the hemispheric asymmetry of the climate response have been discussed in the literature including transient heat storage in the Southern Ocean, changes in the atmospheric energy transport, and hemispheric differences in the cryospheric response imposed by continental geography. We now briefly critically discuss the proposed mechanisms below.

A. Southern ocean heat storage

Stouffer et al. (1989) postulated that ocean heat storage in the region equatorward of the Antarctic Circumpolar Current was responsible for the reduced warming in the southern extratropics as compared to the northern extratropics. The same mechanism is referred to in the IPCC's third report where it is stated that the projected surface temperature change features "a maximum warming in the high latitudes of the Northern Hemisphere and a minimum in the Southern Ocean (due to ocean heat uptake)" (IPCC 2001). The enhanced ocean heat uptake in the Southern Ocean is realized in the simulated response to CO_2 doubling with the CMIP3 ensemble (FIG 1B). However, the magnitude and meridional structure of the ocean heat uptake are highly variable between models, and the hemispheric asymmetry in the ocean heat storage is much less pronounced than the surface temperature response (c.f. FIG 1A and 1B). The lack of correspondence between the inter-hemispheric asymmetry and meridional structures of temperature response and ocean heat storage suggests that additional mechanisms may be important. Even if ocean heat storage in the Southern Ocean is the root cause of the hemispheric asymmetry in the temperature response, the response is highly non-local and is communicated via unresolved changes in atmospheric and/or oceanic dynamics.

Furthermore, the root cause of the hemispheric asymmetry in transient ocean storage is an interesting and unresolved coupled climate dynamics problem in itself. The burying of energy in the Southern Ocean is a twofold process: A.) energy must first be fluxed from the atmosphere to the ocean mixed layer and then B.) removed from the ocean mixed layer into the ocean interior and away from interaction with the atmosphere. Process A occurs preferentially in the Southern Ocean due to the upwelling of cold mid-depth (2-3km) water poleward of the Antarctic Circumpolar current; no where else in the world is water of this depth upwelled directly to the surface (Russell et al. 2006). The cold water extracts energy from the atmosphere as it flows equatorward in the Ekman surface layer. The annual average flux of energy from the atmosphere to the ocean in the SH extratropics (poleward of 40N) has no counterpart in the NH (Czaja and Marshall, 2011) and is thought to be a consequence of coupled ocean-atmosphere dynamics. Process B also occurs preferentially in the Southern Ocean where the outcropping of isopycnal surfaces provides a conduit for energy to flow from the ocean surface to the ocean interior (Sabine et al. 2004). Thus, the basic state oceanic circulation of the Southern Ocean allows energy to be extracted from the atmosphere to the ocean interior.

However, it is unclear if the transient heat storage seen in the simulated response to greenhouse gas emissions is a consequence of the basic state oceanic circulation interacting with a warmer atmosphere or if changes in oceanic and/or atmospheric circulation under global warming also contribute to the energy storage. The storage of heat and carbon in the Southern Ocean is sensitive to the surface winds (*Sallée* et al. 2010 and Mignone et al. 2006) which are projected to change due to both greenhouse and ozone forcing (Thompson and Solomon 2005). Thus, the transient heat storage in the Southern Ocean is a coupled climate dynamics problem that results from both the atmospheric and ocean circulation in the basic state and their changes under global warming.

B. Change in heat transports

Alexeev et al. (2005) found that the climate response to spatially uniform positive radiative forcing exhibits polar amplification due to increased equator-to-pole energy transport associated with the moistening of the atmosphere. Increased energy transport over the observational period has also been linked to polar amplification (Graverson et al. 2008 and Yang et al. 2010). Although enhanced moisture transport should lead to polar amplification in both hemispheres, the land-ocean contrast and topography in the NH could lead to a response that is hemisphericaly asymmetric because the mean atmospheric circulation is very different in the two hemispheres (the NH circulation features stationary waves and zonally localized storm tracks that are largely absent from the SH).

Furthermore, moisture transport also contributes to moderating the land-ocean temperature contrast on both seasonal time scales and in the annual average (Fasullo and Trenberth 2008). The projected and observed spatial pattern of anthropogenic climate change shows the most warming over the NH continents during the winter, suggesting that polar amplification is itself a manifestation of moderated wintertime temperatures over the continents. The seasonal cycle of temperature over the NH continents is driven by the seasonal cycle of solar radiation but is highly damped by the import of moist static energy from the adjacent oceans (Donohoe and Battisti 2011b); winter-time cooling of the atmosphere above the continents is limited by *zonal* energy import (of approximately 6 PW – the same magnitude as *the meridional* heat transport in the climate system) primarily in the form of latent heat fluxes. *Ceteris paribus*, one would expect a warmer and moister climate to lead to an enhanced wintertime ocean-to-land energy flux and thus warmer winter-time continents. During the summer, the reverse flux of energy from the land domain to the ocean domain is impeded by moisture gradients because the ocean domain is moister than the warm land and thus the zonal advection of latent heat opposes the larger zonal advection of sensible heat from the land to the ocean. Thus, in a moister world we would expect the continents to warm more than the global average during the winter and approximately on par with the global average during the summer due to enhanced zonal moisture advection alone. This mechanism of polar amplification is largely absent from the SH due to lack of continents and could explain the inter-hemispheric asymmetry of the temperature response to anthropogenic forcing. This mechanism would be further amplified by reductions in sea ice (independent of the ice-albedo feedback) because a larger area of the ocean mixed layer becomes accessible for seasonal energy storage.

C. Ice albedo feedback

The differing continental geographies of the North and South poles also have large implications for the polar amplification of climate change due to the ice albedo feedback. The Arctic is projected to see large decreases in summertime ice extent due to anthropogenic climate change (IPCC, 2007) because the retreat of the sea ice from the summertime ice edge in the unperturbed climate is unimpeded by coastlines in the Arctic ocean. In contrast, the Antarctic summertime ice extent is projected to undergo half the reduction seen in the Arctic (Eisenman et al. 2011) because the retreat of summer ice is impeded by the coastline (and topography) of the Antarctica continent (Manabe and Stouffer 1980). This causes an enhanced positive radiative feedback in the NH as compared to the SH which could also explain the hemispheric asymmetry of the climate response.

3. Proposed work

The hemispheric asymmetry of the transient climate response to anthropogenic forcing is the consequence of the mechanisms discussed above working in conjunction as well as additional processes. Our future predictions of climate change are contingent on understanding the dominant mechanisms leading to the response and the uncertainties in those processes. Furthermore, the climate change problem is embedded in more fundamental questions of coupled climate dynamics such as: is the climate response to a globally uniform radiative forcing spatially uniform or does it exhibit a meridional structure? Is the meridional structure the same in the transient and equilibrium case? Are these answers contingent on the basic state circulation or are the conclusions applicable on paleoclimate time scales with altered continental geographies and orbital parameters? We propose approaching these problems primarily through the use of idealized models. We will extend our conclusions and analysis to the suite of climate simulations used in the IPCC's fourth assessment and the observational records.

A. Idealized model experiments

We will use a hierarchy of model experiments in both the sense that we will limit the number of radiative/dynamical processes represented in the model and we will change the complexity of the continental/topographical geography. In each experiment we will compare the equilibrium climate state under the pre-industrial CO_2 concentration (the control climate) with a 1% CO_2 ramping to doubling experiment (then run for an additional 150 years) in order to look at both the transient and equilibrium response to doubling CO_2. All simulations will include a seasonal cycle of solar forcing. The series of experiments is listed below.

I. Aquaplanet coupled to a slab ocean – no ice albedo feedback

In this experiment, sea ice will be prohibited from forming even if the temperature drops below freezing. This experiment will exclude the role of ocean circulation, continental geography, and the ice-albedo feedback from the climate response and will be hemispherically symmetric by definition. It will primarily be used as a basis for comparison for later experiments. Alexeev et al. (2005) preformed a similar set of experiments without a seasonal cycle and focused their attention on the equilibrium response only. Our analysis will evaluate the relative importance of heat transport changes, local ocean heat storage, and the spatial structure of shortwave and longwave radiative forcing (see Donohoe 2009 for an analysis of the spatial structure of clear sky shortwave forcing under global warming) for polar amplification.

II. Aquaplanet coupled to a slab ocean – with ice albedo feedback

This experiment will be identical to (I) except it will allow sea-ice formation in both the control (pre-industrial CO_2) and perturbed (ramped CO_2) experiments. It will allow us to assess the role of the ice albedo feedback in polar amplification.

III. Slab ocean with a strip of mid-latitude land in the NH

We will introduce a land mass (no topography) over half the zonal circumference of the NH extra-tropics. This experiment will allow us to explore if the enhanced moisture transport from the ocean domain to the land domain in a warmer planet can explain the magnitude and seasonality of polar amplification in the NH (see section 2B above).

IV. Slab ocean with a south pole island

This experiment will place a disc of land over the south pole, extending to the latitude of the summer ice edge in the control climate. The continental boundary will impede the summer retreat of the ice edge in the perturbed climate (see Section 2C above). We will assess the role of the hemispheric asymmetry in the ice-albedo feedback on the climate response.

v. COUPLED SIMULATION WITH IDEALIZED DRAKE PASSAGE GEOMETRY

This experiment will examine the coupled (atmosphere-ocean) response of the climate system to global warming using an idealized continental configuration. Enderton (2009) has demonstrated that the gross features of the global oceanic circulation, including the hemispheric asymmetry of the deep overturning circulation, can be captured in a coupled aquaplanet model with a thin ocean boundary running from the North Pole to 40S as to mimic the Drake Passage. We will explore the spatial pattern of transient heat storage and its impact on the hemispheric asymmetry of the surface temperature response. We will perform an additional run with the same continental configuration but with the surface wind stress fixed at the climatology of the control run. Analysis of this run will allow us to assess the impact of the surface wind stress change on the transient heat storage by comparison with the fully coupled perturbed run.

B. Additional analysis

The mechanism(s) that were found to contribute most to the hemispheric asymmetry of the climate state will be further analyzed in the CMIP3 suite of simulations. We will compare the pre industrial simulations with the 1%to2X runs (the identical forcing as prescribed in the idealized runs). We will also explore the relevant mechanisms in the observational record.

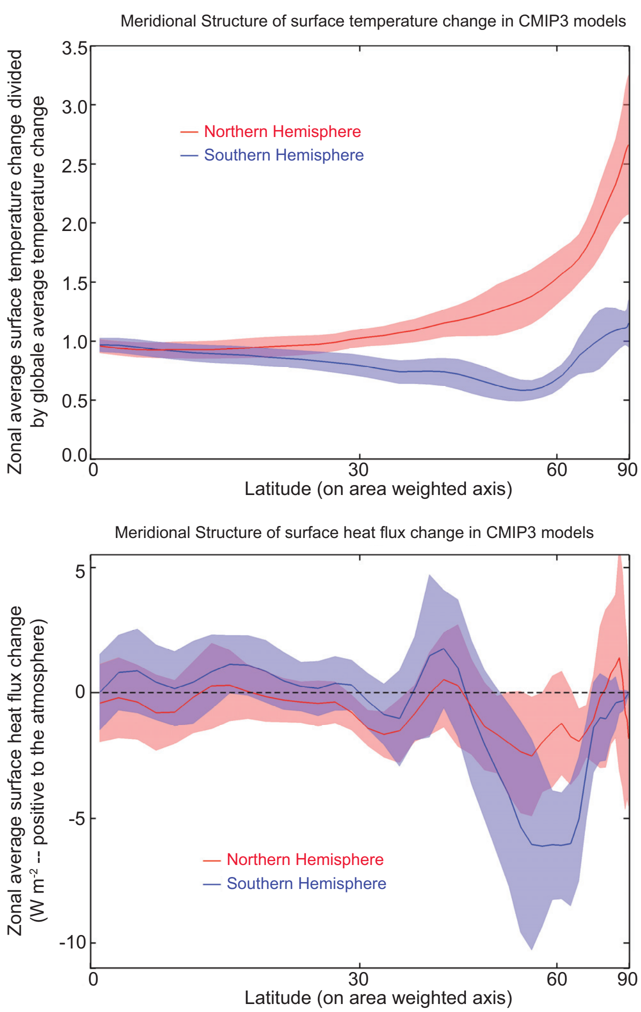

FIG 1. (Top Panel) The CMIP3 ensemble and zonal average surface temperature change due to doubling CO_2 (solid lines). The temperature difference between years 170-220 of the 1% CO_2 and the pre-industrial runs is divided by the global average temperature change and then averaged over the 15 different climate models; the 90% confidence interval is given by the shaded lines. The Southern Hemisphere curve (blue) is mirrored about the equator for ease of comparison with the Northern Hemisphere curve (red). (Bottom panel) As in the top panel except for the net surface energy flux.

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Statement of relevance to the NOAA climate science and services program
Aaron Donohoe

The proposed research project focuses on the underlying and fundamental processes that control the climate system's response to radiative perturbations. We focus on coupled interactions between the atmospheric dynamics, large scale radiation, ocean circulation and the cryosphere recognizing the inherent inter-connectedness of the sub-components of the climate system. We believe this project fits well with NOAA's climate science and services programs, especially with Earth System Science Program's stated 1st major activity: "Elucidating the physical climate mechanisms involving land-atmosphere-ocean-ice interactions responsible for intraseasonal to multi-centennial climate variability, including abrupt climate change."

Our proposed research is global in scale and falls toward the idealized end of the spectrum of climate research. We believe that we are in a unique position to make progress on understanding the fundamental processes in the coupled climate system that control the transient response to climate change. Our proposed research relies heavily on using a hierarchy of models and observational analysis. We will begin by isolating the system behavior given a limited number of physical processes (and idealized boundary conditions). We will then build layers of complexity both in terms of the modeled physics, the coupling between the various subcomponents of the system, and the boundary conditions. Ultimately, we will work toward understanding more realistic simulations of the climate system and the observational record while still keeping site of the lessons learned from the idealized experiments. We believe this approach will allow us to explore the system from a fundamental perspective while maintaining relevance between our experiments and the real climate system and its inherent complexities.

I am a strong believer that climate research needs to be communicated beyond the immediate research community and I believe my service record to the broader community (both the broader science community and the general public) reflects this belief. I founded the Graduate Climate Conference in 2006-- an inter-disciplinary graduate student only conference-- citing a need for inter-disciplinary collaboration and communication amongst young climate scientists. The conference has now been held 4 times and each conference attracts over 80 participants; over 50 different institutions have been represented at the conference. I've also put together and deliver a 3 part lecture series on climate change for the general public at the local libraries and frequently give lectures at Cornish College of the Arts. I believe these priorities are in line with NOAA's Climate and Societal Interactions Program and hope to continue my climate outreach activities during my post-doctoral position.