

**STATEMENT OF RESEARCH ACCOMPLISHMENTS**

My research interests and experience span a wide range of topics from physical oceanography to ocean climate and marine ecosystems dynamics. More specifically there are four focus areas of my work: **(1)** dynamics of coastal ocean circulation and climate, **(2)** regional ocean predictability and inverse dynamics, **(3)** ocean decadal variability and climate change from coastal to global-scales and **(4)** impacts of large-scale climate forcing on regional ecosystem dynamics. My work strongly relies on combining advanced numerical, statistical and inverse models of the ocean circulation (and ecosystems) with observations. Because of the strong interdisciplinary nature of my research I have developed a rich network of collaborations with scientists in major oceanographic institutions in the US (e.g. Scripps UCSD; UCLA; UCSC; University of Washington; NCAR; IPRC - University of Hawaii; OSU and others) and abroad (Institute of Ocean Science, BC, Canada; Japan Agency for Marine-Earth Sciences, JAMSTEC-ESC, Japan; University of Concepcion, Chile; University of Bologna, Italy). Below is a summary and overview of my research initiatives.

**Ocean Climate and Ecosystem Dynamics from coastal to basin scales**

Climate change has become a topic of widespread interest both scientifically and economically. However, the impacts of climate change on the coastal ocean and regional marine ecosystems are highly uncertain. Yet these coastal and regional scales are most relevant to humans. These uncertainties stem from the fact that the dynamics controlling low-frequency variations in coastal ocean and regional ecosystems are not well understood and poorly modeled.

My early work focused on understanding the coastal dynamics of the California Current System (CCS). While a graduate student at Scripps I developed one of the first high-resolution physical-biological modeling applications for the CCS. I used the Regional Ocean Modeling System (ROMS) and implemented a biogeochemical component with a simple 7-component ecosystem model that included nitrogen, phytoplankton, zooplankton and detritus pools with the addition of carbon cycle chemistry and oxygen. By combining this modeling platform with a reanalysis of the 50 year hydrographic data from the California Cooperative Oceanic Fisheries Investigations (CalCOFI), I was able to explain the dynamics of the CCS on seasonal timescales [*Di Lorenzo, 2003; Di Lorenzo et al., 2004*].

While at Georgia Tech I have expanded my studies of the California Current to include all the Northeast Pacific eastern boundary. With new computational resources at my disposal I began using the regional ocean models I had developed to explore the interannual and decadal scale regional dynamics of the Northeast Pacific and its connection to basin-scale climate variability [*Di Lorenzo, 2005a; Di Lorenzo et al. 2005b; Schneider, Di Lorenzo et al, 2005*]. For example, I was able to explain for the first time the low-frequency fluctuations of salinity, nutrients and Chl-a observed off the California coast and show how they are connected to a large-scale climate pattern of the North Pacific that I termed the North Pacific Gyre Oscillation (NPGO; *Di Lorenzo et al. 2008*). Subsequently we found that the NPGO also explains long-term observations (1948-present) of salinity and nutrients in the Gulf of Alaska, which have also been unexplained until now [*Di Lorenzo et al., in prep., GRL*]. This discovery has received much attention

in the coastal oceanography community as well as in external press ([www.ocean3d.org/npgo](http://www.ocean3d.org/npgo)) for its potential to change our understanding of Pacific regional climate variability.

To further quantify the dynamics of the NPGO and of the Pacific Decadal Oscillation (PDO), the other dominant mode of climate variability in the North Pacific, we performed a rigorous budget analysis of upper ocean variations in temperature and salinity between 1950-present using the regional model outputs. We found that the PDO and NPGO oceanic footprints are driven by the first two dominant modes of North Pacific large-scale wind variability [*Chhak, Di Lorenzo et al., submitted, JC*] and that these two separate components of the wind variability drive different decadal changes in coastal upwelling along the North Pacific eastern boundary [*Chhak and Di Lorenzo, 2007*]. The large-scale nature of the NPGO atmospheric forcing led us to explore the large-scale ocean-atmosphere connections of the NPGO. Specifically we found that the NPGO is a global-scale mode that provides a direct link between decadal variability in the North Pacific eastern and western boundaries [*Ceballos, Di Lorenzo et al., submitted, JC*]. More recently we found a relationship between the NPGO and the El Niño-Southern Oscillation (ENSO), where the NPGO mode leads the ENSO mode by 10 months. This result may have important implications in studies of ENSO predictability, and it provides a new conceptual framework for Pacific climate variability. My lab is currently focused on further isolating the dynamics that link ENSO and NPGO in coupled climate models and their role in regional ocean dynamics and ecosystems variability across the Pacific. For example, by comparing the ability of the IPCC models to capture the observed ENSO/NPGO relationship, we are diagnosing the coupled dynamics that underly the models' different expressions of ENSO [*Furtado and Di Lorenzo, in prep*]. This type of comparison also provides a screening method to isolate those IPCC models that have more realistic simulations of Pacific climate.

As my research focus area expands to include larger-scale dynamics and the tropics, I have begun expanding the tools I use for my investigations. I have been working on developing a coupled-ocean-atmosphere climate model that uses ROMS as the ocean component and SPEEDY [*Molteni et al., 2003*] for the atmosphere. I plan to use this modeling framework to investigate Indo-Pacific decadal variability, as there is growing evidence that Pacific variability cannot be fully understood without considering the Indian Ocean. The novelty of this framework is that the ROMS ocean model will be able to properly resolve the dynamics of the coastal upwelling systems, which play a fundamental role in triggering large-scale modes of variability such as the Indian Ocean dipole. Furthermore, this regional ocean modeling framework will better resolve the oceanic connections between the Pacific and Indian Ocean through the Indonesian throughflow and hopefully lead to improved simulations of ENSO and of decadal adjustments of the Indo-Pacific thermocline.

While I am eager to explore the mechanics of large-scale climate variability, I still retain a strong interest in regional ocean and ecosystem dynamics. In particular I would like to understand how regional/coastal dynamics will respond to climate change (e.g. global warming) and isolate coastal processes that can lead to upscale effects on the basin scale. An example comes from research I conduct in the Gulf of Alaska, where large-scale ocean eddies that form along the eastern boundary are the primary means by which coastal waters are mixed into the North Pacific subpolar gyre. Because the open ocean ecosystem productivity of the subpolar gyre is limited by the iron supply from the coastal waters, changes in eddy transport statistics directly modulate the open ocean ecosystems. Using high-resolution ocean model experiments I was able to diagnose the dynamics of generation of these large-scale eddies [*Di Lorenzo et*

*al. 2005c*] and diagnosed how interannual changes in the atmospheric forcing affect their generation [*Combes and Di Lorenzo, 2007*] and transport statistics [*Combes, Di Lorenzo et al, in press*]. I will apply this line of research to the entire Northeast Pacific in my role as the physical-biological modeler for the NSF Long-Term-Ecological-Research site at Scripps, which is devoted to understanding Ecosystem climate transitions in the California Current.

Recently I have expanded my regional ecosystem studies to the Southeast Pacific (South America) and North Pacific western boundary, Kuroshio region (Japan). I am currently leading an international project that investigates the mechanisms of climate-related variability of ecosystems along three major boundary current systems of the Pacific Ocean, and attempts to estimate their response to different climate change scenarios. This project ([www.Pacific-Ecosystems-Climate.org](http://www.Pacific-Ecosystems-Climate.org)) was recently funded by NSF GLOBEC and includes over 25 interdisciplinary Co-PIs (e.g. climate dynamics, biological and physical oceanography) from both national and international institutions in the US, Japan, South America and Canada. As the most important climate-related questions require an interdisciplinary approach, I am excited about the opportunity to develop and coordinate networks of scientists that can exchange ideas and observations towards a common research goal. I am also trying to take an active role in coordinating coastal oceanographers of the Pacific Ocean to contribute to future IPCC assessments, which have been deficient in terms of coastal ocean circulation and ecosystem change.

### **Ocean Predictability, Inverse Methods and Data Assimilation**

Terabytes of new coastal ocean observations are becoming available under various coastal ocean observing system initiatives, fueling the development of advanced data assimilation tools that combine these observations with coastal models in a dynamically consistent framework to provide real time estimate of the coastal ocean circulation.

Over the last 8 years, I have been part of a team that developed the tangent and adjoint models of the Regional Ocean Modeling System (ROMS), one of the most widely-used and advanced coastal ocean modeling platforms [*Moore, Arango, Di Lorenzo et al. 2004*]. These sub-models allow us to perform inverse calculations and stability analyses of coastal flows, which are essential in diagnosing complex coastal dynamics. It is important to note that this is the first time these modeling tools have been implemented for a coastal ocean model. Following this effort, I took the lead in implementing one of the first 4-dimensional variational data assimilation system for high-resolution coastal model applications with ROMS [*Di Lorenzo, Moore, Arango et al. 2007c*] and continue to be actively involved in further developments and applications (e.g. the Intra Americas Seas [www.myroms.org/applications/ias](http://www.myroms.org/applications/ias) and the Mediterranean Sea [www.Med-ROMS.org](http://www.Med-ROMS.org)) [*Powell et al., 2008; Powell et al. submitted*]. These tools not only enable us to monitor and forecast the coastal ocean circulation, but they also allow us to understand the dynamics controlling the predictability of coastal ocean circulation on timescales of weeks to months.

My interest in inverse modeling also extends to other ocean-climate applications. For example, we have used inverse ocean models to track decadal changes in the 3-dimensional upwelling cell in the California Current [*Chhak and Di Lorenzo, 2007*] and in the Humboldt Current off South America [*Combes and Di Lorenzo in prep., JPO*]. In a paleoclimate application, I have used inverse techniques to assess and quantify the skill of tropical SST reconstructions using multi-proxy records [*Furtado, Di Lorenzo et al., in press, JC*]. More recently I have been involved with other Georgia Tech scientist in a

project that aims to combine multi-proxy records with a coupled ocean-atmospheric modeling platform to reconstruct changes in the mean sea surface temperatures of the tropical Pacific.

## STATEMENT OF TEACHING INTERESTS AND OUTREACH

I have developed three new courses during my four years at Georgia Tech: an undergraduate introductory class in *Oceanography* (<http://ocean3d.org/eas-4300>), a graduate class in *Environmental Data Analysis* (<http://ocean3d.org/eas8803>), and an *Ocean Modeling* course (<http://ocean3d.org/eas8803b>). In the preparation of these courses I try to introduce new teaching tools. For example, while teaching the ocean modeling class I provided the students with real hands-on experience in the use of ocean models on supercomputers. Because of the complexity involved in using state of the art ocean models I developed a set of over 40 video tutorials that show step by step the methods involved in configuring, running and diagnosing the output of ocean models of a particular class. These videos are now freely available on the the web [www.o3d.org/ROMS-Tutorial/tutorials.html](http://www.o3d.org/ROMS-Tutorial/tutorials.html) and have served other young scientists around the world with over 1000 downloads of the web tutorials. In many cases I also provided computer accounts to both foreign and national graduate students to facilitate and advice them while conducting ocean modeling research. I also maintain a MATLAB toolbox for the Regional Ocean Modeling System (ROMS) called the ROMS Numerical Toolbox ([www.o3d.org/RNT/](http://www.o3d.org/RNT/)).

As part of my outreach and scientific dissemination efforts I maintain an OpenDAP web data-server that provides access to every model simulation ever performed in my lab as well as access to reanalysis of observational datasets ([www.imanu.org/datatools.html](http://www.imanu.org/datatools.html)). I also post scientific presentations in forms of videos that summarize my findings ([www.o3d.org/nngo/videos-images.html](http://www.o3d.org/nngo/videos-images.html)). Through these efforts I not only maintain an active network of scientific collaborations, but have also supported training and exchanges with graduate students at other institutions.

I enjoy my role as advisor to 5-6 graduate students, and am passionate about their education. Most of my students are not assigned to a specific project based on grant money availability, but rather are encouraged to find their own research topics. I encourage students to use graduate school as an opportunity to widen the breath of their knowledge by taking classes that are not always directly connected to their research projects. This fosters an appreciation for interdisciplinary science – a critical component of modern oceanography. I strive to maintain an informal environment in my lab in order to facilitate the exchange of ideas and information among lab members – a process which is critical not only to the success of my students, but to their happiness as budding scientists.