Photo 2 - In 2007, this area of Bryggen was inundated for 12 days due to a storm surge. There are ongoing projects to address measures to protect this beautiful heritage site.

climate-change questions at a regional scale. The orography of Norway is rather complex with a number of deep fjords and high mountains - which represent challenges when it comes to estimating changes in precipitation and runoff. Snowpack is an important source of drinking water to cities like Bergen, but also for the different hydropower stations throughout the country. Existing climate modeling projects have been conducted using a limited-area atmospheric model, followed by an offline hydrological assessment. An optimal solution would be the coupling of both models in order to improve the simulations.

The Hydrometeorological Applications Prediction group, led by Dr. Roy Rasmussen at the National Center for Atmospheric Research (NCAR), has worked on such a coupling of an atmospheric model to a hydrological model. Their framework is called NDHMS, which stands for "NCAR Distributed Hydrological Modeling System". NDHMS is a modeling system which facilitates the coupling of multiple land and hydrological process models with weather and climate models using the NDHMS coupler. The philosophy of NDHMS is to provide a framework for hypothesis testing as well as operational forecasting and the system adopts a 'multi-physics' or 'plug-compatible' approach to model development, similar to the Weather Research and Forecasting model (WRF). Currently, NDHMS is coupled with the WRF and work is nearly complete on coupling NDHMS with the CESM (Community Earth System Model) and NASA/LIS (Land Information System) models.

When officially released with the 2013 version of WRF, WRF-Hydro will come as a new 'extension' to the WRF model, such as the existing WRF-Chem extension package. Even though WRF-Hydro has not been officially released yet, its "beta" version and associated documentation and test cases is available. The Bjerknes Centre for Climate Research has recently adopted it for its hydrological-related projects, such as a new project called NORINDIA - which addresses future hydrological impacts in India. WRF-Hydro will also be useful to address hydrological changes in Norway. Although it is still uncertain as to how much precipitation will change in the future, it is hoped the new modeling tools like WRF-Hydro can provide new insights to the future climate of the beautiful city of Bergen!

References: Bader, J., Mesquita, M.d.S., Hodges, K.I., Miles, M., Østerhus, S. and Keenlyside, N. (2011) A Review on Northern Hemisphere Sea-ice, Storminess and Teleconnection patterns: Observations and Projected Changes. Atmos. res., doi:10.1016/j.atmosres.2011.04.007.

Interview with Christopher Castro

Hans von Storch

Dr. Christopher L. Castro is an Adjunct Professor in the Department of Atmospheric Sciences at the University of Arizona. His doctoral and postdoctoral work at the Department of Atmospheric Science at Colorado State University applied a regional atmospheric model to the investigation of North American summer climate. Current research within his group at the University of Arizona focuses principally on physical understanding and prediction of climate in North America through regional atmospheric modeling and analysis of observations. His main research emphasis is the North American Monsoon. As the Chair of the Geophysics Commission of the U.S. National Section of the Pan American Institute for Geography and History, Dr. Castro also helps facilitate joint research in this area between investigators in the United States and throughout Latin America.

Your research field is the analysis of North American climate, in particular the monsoon. For doing so, you employ regional climate models. What do you think is the significance of these tools? What is the added value over global models and global re-analyses?

Use of regional atmospheric modeling, or equivalently high resolution global atmospheric modeling, is important to reasonably represent the physical processes on the mesoscale that drive convective precipitation in the warm season. These include the diurnal cycle of convection and transport of low level moisture. We have found that the difference in the ability of coarse resolution global models versus regional models (at a grid spacing of 35 km) to represent the warm season climate of the Southwest U.S. is quite dramatic. For example, use of a regional model is necessary to simulate a salient monsoon in Arizona where none exists in the driving global model or global atmospheric reanalysis. The value added by the regional model is a result mainly of the enhanced resolution of the terrain and the differences in parameterizing convection and cloud microphysical processes. We have also found that simulations of the monsoon at a convective resolving scale (2 km grid spacing) can further improve on the representation of organized convection, such as mesoscale convective systems, that account for the heaviest monsoon precipitation events in urban areas, like Tucson and Phoenix.

Dr. Christopher L. Castro

Regional climate is changing, and will continue to do so. To what extent to you think ongoing man-made climate change is manifesting itself in "your" regional climate?

The data from the recent observational record strongly suggests that anthropogenic climate change is already affecting the climate of the western United States, entirely consistent with the conclusion of the IPCC Fourth Assessment Report that the anthropogenic signal in climate becomes statistically discernible after about 1980 or so. Some of these effects include: 1) a long-term warming trend, that is most pronounced during the hottest and driest part of the year before the onset of the monsoon; 2) an earlier occurrence of snowmelt in the spring; 3) increases in the incidence and intensity of forest fire; 4) more intense drought; 5) an increase in extreme precipitation; and 6) rapid alteration of natural ecosystems. Many of these changes are occurring here in the Southwest more dramatically than any other region in the United States. While any one weather or climate event cannot be conclusively linked to climate change, of course, the summer of 2011 was generally reflective of these documented long-term changes in our climate. Arizona

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experienced its worst wildfire season in history. This was followed by a strong monsoon onset with severe thunderstorms that caused a massive dust storm in Phoenix. Texas also experienced its worst one year drought ever that, as their state climatologist John Nielson Gammon noted, was likely due to a combination of natural variability and climate change.

Are you engaged in the science/policy interface, dealing with stakeholder exchange and planning/omplementation of adapation measures?

Yes, I have been involved in stakeholder outreach on the climate change issue in Arizona, primarily to water resource providers, like the Bureau of Reclamation and the Salt River Project, and the Department of Defense. We are currently developing methodologies through which regional climate model projection data can be used to drive hydrologic models for future water resource projection. We are also assessing how severe weather during the monsoon will change in the future, as this will potentially adversely affect the operational capabilities and infrastructure at military facilities in the Southwest.

You are involved in the Pan American Institute for Geography and History. Can you say a bit about this institute?

The Pan American Institute of Geography and History (PAIGH) helps facilitate research activities between members of the Organization for American States in the areas of Cartography, Geography, History, and Geophysics. I currently serve as the Chair of the Geophysics Commission for the U.S. National Section. PAIGH support is in the form of funded collaborative projects between its member states, for example short courses and workshops or student training. Such projects, while small, are very effective for technology transfer and outreach, and are typically the seeds for much larger, more sustained research efforts. For example, I am involved in a PAIGH project that will expand the use of global positioning satellite (GPS) technology for monitoring of atmospheric water vapor in Mexico. PAIGH also regularly hosts international meetings that are a means of scientific exchange on project outcomes.

You are Hispanic American, i.e., a person with a partially non-English cultural background – to what extent is this an advantage or disadvantage for your scientific endeavor?

I actually think it is an advantage. As a person of Hispanic origin, I have been able to leverage my cultural background and ability to speak Spanish to help advance research in atmospheric science within Latin America. My involvement in PAIGH is a good example. It is also crucial that more people of Hispanic background, that are native born American citizens, pursue careers in science. Hispanics are the most rapidly growing demographic within the United States, but have traditionally been one of the most socioeconomically disadvantaged groups. So I take my responsibility as a mentor and educator in that regard very seriously. A failure to educate this population with the skills necessary to confront the complex challenges that we face will ultimately endanger our ability as a country to prosper in the future.

What would you consider the most two significant achievements in your career?

Much of my research work has focused on the North American monsoon. My most significant achievement in that regard was to help establish the relationship between Pacific-SST associated atmospheric teleconnections and the timing of monsoon onset. Late (early) monsoons in Arizona tend to occur in association with El-Nino like (La Nina like) conditions in the tropical and North Pacific. Thus, given a global climate model that can reasonably simulate Pacific SST variability and summer atmospheric teleconnections over North America, there may be some skill in seasonally forecasting the timing and strength of the monsoon. We are currently investigating this possibility by dynamically downscaling retrospective forecasts from the operational global seasonal forecast model (the Climate Forecast System Model) used by the National Center for Environmental Prediction.

My other significant achievement has been my contribution to the question of the value added of regional climate models. In this regard, my work has help to provoke some discussion about the use of interior nudging to maintain the variability of the large-scale circulation within the regional model domain. The question is very important to resolve, as how the regional model represents the large-scale atmospheric circulation affects how it represents surface temperature and precipitation—the variables that are probably most important for climate impacts assessment.

You work in the area of atmospheric modeling. Do you think typical users of these models have an adequate background to understand how they work and their limitations?

Atmospheric science, as a discipline, is a relatively young field. From my research perspective, one of the most significant developments, among many others, was the advent of numerical weather prediction back in the 1950s. I think it's quite astounding to consider how these models have advanced from the simple vorticity-conserving barotropic models, simulated on giant computers with vacuum tubes that filled entire rooms, to the vast array of sophisticated global and regional atmospheric models that we have today.

The increasing level of complexity of these models, however, necessitates high levels of specialization to understand how their various components work. In the one semester regional atmospheric modeling course I teach here at the University of Arizona, I am really only able to scratch the surface of how model parameterization schemes work. My concern as an atmospheric scientist, as we use these models in applications like weather prediction and climate change impacts assessment, is that users of this information will not really understand the complexities of how atmospheric models work, and therefore not be able to intelligently question their results.

Is there a politicization of atmospheric science?

MOST DEFINITELY! Please note that I write my response in all caps, which means I'm shouting here! Nowhere is this more apparent than in the area of climate science. Within the United States, the climate change issue in media and among the general public is perceived as somehow scientifically controversial. There are two reasons for the wide disparity in public versus scientific opinion. First, the policy changes required to address climate change will necessitate an alteration of our current American way of life, with dramatic changes in the way we produce and use energy. Second, most Americans don't have a basic level of scientific knowledge necessary to understand how climate change actually works, from a physically-based perspective. This reflects the poor quality of public education in math and science in the United States, in comparison to other developed countries. I say that very honestly, and with great regret, from the perspective as an American educator of first-year college students in an introductory weather and climate course. It is common, for instance, that college students confuse the greenhouse effect or the ozone hole, with the concept of global warming. Many of our elected officials don't fare much better, and it's frankly shocking to see how ignorant some of them are when they interact with climate scientists, for example, in the context of U.S. congressional hearings. I try to illustrate this point when I teach undergraduates, without appearing to be politically biased.

So in the absence of accurate scientific information on which to base a rational, informed public policy, misinformation and fear fills the void. In recent years, some American politicians have actually touted their distrust of science and educators to gain political favor, calling global warming "junk science" or university professors as "liberal snobs." I frankly find it disgusting and appalling. The respect of scientific knowledge, as a source of betterment for the human condition, is now being openly questioned in

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Dr. Christopher L. Castro

our political process within the United States. Maybe it's because now we just don't want to hear what the science, at least on climate change, is telling us. It's a very dangerous turn than will threaten our future prosperity as a country if it continues. Political parties can convey their contrasting messages on climate change through the well-funded think tanks and media outlets they control—fostering the false perception of scientific controversy. A viewer can choose basically whatever version of "truth" that conforms to their views. If you're conservative, for example, you'll watch only Fox News and believe global warming is a hoax and Climategate was some giant scientific conspiracy. If you're liberal, you'll watch MSNBC and believe that all Republicans want to dismantle the Environmental Protection Agency and will oppose all efforts to transition to alternative forms of energy. Climate change becomes one of the plethora issues that fall into the "us versus them" mentality that now permeates our politics, and there's no room for rational and informed discussion lest your side appears weak and compromising. The political polarization on this issue within the United States has really prevented any meaningful legislative action to address it. That situation is, unfortunately, singularly unique to the United States among developed countries. I hope in earnest that this situation may change in the near future. As an American citizen, who cares for the future of my country and the world, I am ashamed and embarrassed for it.

What constitutes "good" science?

"Good" science should 1) pose specific, testable hypotheses that are suggested by available empirical evidence, 2) explore those hypotheses using experimental methodologies that are robust and reproducible, 3) honestly report all relevant findings that validate or refute the hypotheses, without prejudice to the final result, and, finally 4) document the research in peer-reviewed literature, ideally those publications that represent the reputable professional societies in a given field. In that respect, the recent explosion in non-peer reviewed scientific information available on the internet—which can circumvent this rigorous process of "good science" that I just outlined—has been quite unfortunate and has contributed to climate science misinformation, in my opinion.

What is the subjective element in scientific practice? Does culture matter? What is the role of instinct?

Ideally, culture and instinct should not matter in scientific practice, but my life experience tells me otherwise. A good example, and one that strongly contrasts with the traditional practices of Western culture, is Native American traditions. Western culture has traditionally viewed science as a means to master the natural environment and subdue nature for the benefit of human beings. Native Americans, by contrast, tend to have a much more holistic perspective that considers man to be part of the natural world. When man is out of balance with the natural world, it will respond in kind to restore the balance. Is the Native American philosophy inferior, because it was Western culture that "won" as a result of the European conquest of the Americas? Or is actually the better one, since how that Western culture ultimately evolved in the five hundred or so years since has now created an unsustainable, polluted world that threatens the entire planet and the survival of our human species?

Dr. Christopher L. Castro web page: www.atmo.arizona.edu/personalpages/castro/castro.htm

The opinions expressed in this interview do not necessarily represents those of the reviewer or the AGU.

Towards an integrated observing system for South America: Air Quality Assessment and Forecasting in Megacities

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As rural populations have migrated to urban areas there are many benefits in terms of efficiency in distribution of goods and wealth. However concentrated populations generally increase emissions. In South America many megacities have emerged each with their problems. Also increased economic activity has led to larger industrial emissions such as in smelters, coal fired power plants, and biomass burning for agricultural and biofuel purposes.

The purpose of the workshop (http://ossaf.cmm.uchile.cl/) was to write a white paper on the current status of air quality management and science capabilities in South America, which would also explore applications in inverse modeling to improve chemical weather forecasting, optimal network design, etc. Also the workshop serves as an excellent platform to engage scientists and policy makers in lieu of establishing more integrated observing systems, and air quality management strategies. The workshop was organized locally by Universidad de Chile, with a steering committee with researchers

Figure 1. Launching of the ozone sonde.

from Universidad de Sao Paulo, the Argentinian Commission for Atomic Energy, World Meteorological Organization, the University of Iowa, and Universidad Andrés Bello.

The workshop was attended by over 50 professionals (scientists and policy makers), and more than 40 students (undegraduate and graduate) from Brazil, Argentina, Colombia, Bolivia, Perú, Chile, Ecuador, United States, France, Switzerland, and Greece. The students followed brief courses on optimal network design, in situ and sounding observation techniques, and emission inventories. All courses had presentations and hands-on training including the launching of an ozone sonde!

More than 16 presentations were given by experts from university researchers, international agencies, and policy makers from. The science based presentations focused on comparing South American megacities photochemical patterns, comparing satellite measurements with in situ measurements, aerosol processes, recent advances in chemical

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