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Cover: Flying directly above the top of the nocturnal marine stratus deck near dawn on October 23, 2008 (1800 m above sea level at 20.0S, 80.1W). Local instability in the cloud field possibly due to drizzle. Image courtesy Cameron McNaughton.

Research

University of Hawai'i at Mānoa
School of Ocean and Earth Science and Technology

How Much Will the World Warm?

By Kevin Hamilton

A key challenge for climate science is predicting how the global-mean temperature will respond to anticipated changes in radiative forcing produced by human activities, such as emissions of long-lived greenhouse gases and other pollutants. While the practical effects of climate change will be felt locally and involve other variables besides surface temperature, the overall strength and significance of climate change will be determined by the magnitude of the global-mean warming. Estimating this surface warming in response to projected changes in atmospheric CO_2 concentration was the goal of the early classic studies of climate change – notably the first radiative-convective-equilibrium model studies in the mid-1960s by **Suki Manabe, Fritz Möller** and **Richard Wetherald**, and the first climate change studies with comprehensive general circulation models in the mid-1970s by Manabe and Wetherald. One of the first formal assessments of the problem was by the 1979 US National Academy of Sciences (NAS) panel chaired by **Jule Charney**. The panel concluded that a doubling of atmospheric CO_2 concentration would lead to a global warming of the surface of between 1.5°C and 4.5°C.

The assessments by the Intergovernmental Panel on Climate Change (IPCC) published in 1990, 1995, 2001 and 2007 have all included a review of predictions of the equilibrium warming to a doubling of atmospheric CO_2. The 1990 assessment included results from 22 atmospheric general circulation models (GCMs) that were mainly coupled with simplified representations of the ocean heat storage and transport. These various models predicted a warming of between 1.9°C and 4.8°C. By the Fourth IPCC report in 2007 (AR4) results from 19 fully coupled comprehensive ocean–atmosphere GCMs were available, and they predict equilibrium warming for double CO_2 conditions between 2.1°C and 4.4°C, a range not much narrower than that determined in the NAS study almost 3 decades earlier!

Climate sensitivity is a measure of the strength of the connection between a perturbation to Earth's radiation balance due to greenhouse gases, aerosols, or other natural or anthropogenic forcings, and the resulting change in global-mean surface temperature. High climate sensitivity means the climate system responds strongly to a radiative perturbation and produces a comparatively large temperature change (and correspondingly large changes in other climate variables). As noted above, the present array of state-of-the-art GCMs displays a disconcertingly wide range of sensitivity to the same radiative perturbation. Here I will discuss only what is sometimes called the "Charney sensitivity," which considers just rapid feedbacks such as those from water vapor, clouds, snow or ice cover, etc., but not possible feedbacks that might arise from slower processes in the cryosphere, biosphere, or deep ocean.

It is natural to ask if the real climate sensitivity can be constrained empirically using evidence of past climate behavior. One possibility is to look into the distant past and try to validate comprehensive models by seeing if they can consistently account for proxy reconstructions of such variables as ice cover and temperature during a particular climate period (e.g., Last Glacial Maximum). For the last 150 years, we can use the instrumental record of global-mean temperatures. Two principal approaches have been developed in this latter regard: examining the response of the climate system to transient radiative perturbations caused by volcanic eruptions, and analyzing the overall global warming record of the late-19th through 20th century.

Radiative Perturbations by Volcanic Eruptions

Research on volcanic effects has focused mostly on the aftermath of the 1991 eruption of Mt. Pinatubo in the Philippines, the largest and best observed major eruption of the 20th century. The results claimed in the published literature on this subject are broadly consistent with the wide range of equilibrium sensitivities seen in the IPCC models. Here at the IPRC we examined the issue of how well observations of the climate effects of a Pinatubo-like eruption constrain climate sensitivity. Our conclusions (Boer et al., 2007) suggest that with present-day observational capabilities it may be difficult to use volcanic effects to tightly constrain climate sensitivity. Part of the difficulty is that the climate forcing from a volcano is fairly short-lived and climate feedbacks do not have a chance to be strongly activated. Another problem is the difficulty of accounting for unforced natural variability in the relatively short periods of interest. The situation could be improved if the full global-mean energy budget, including the rate of energy storage in the ocean and cryosphere, could be accurately observed. Despite recent advances in observational capabilities, the required accuracy to close the global-energy budget has still not been achieved (Trenberth and Fasullo, 2010).

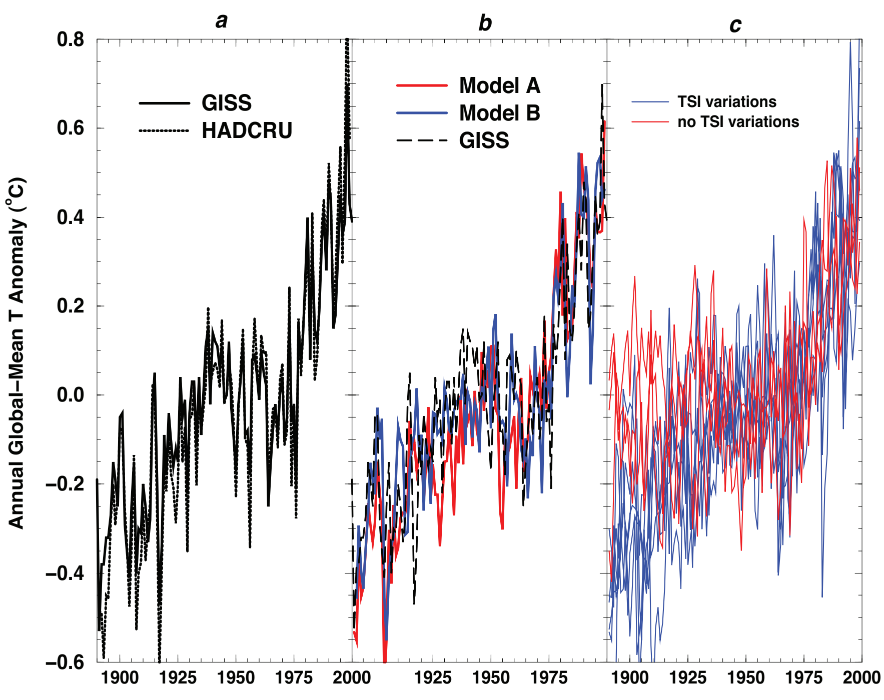

Figure 1. The annual global-mean surface air temperature expressed as a deviation from the 1951-1980 mean. (a) for two observational data sets produced by the Goddard Institute for Space Studies (GISS) and the University of East Anglia Climate Research Unit(HADCRU) (b) results from forced 20th century climate simulations from two different coupled GCMs ("A' and "B") compared with the GISS observations, (c) results from 8 different coupled GCMs. Results from models with no total solar irradiance variation imposed are shown in red.

The 20th Century Global Warming

In order to assess the climate sensitivity to future changes in long-lived greenhouse gas (LLGHG) concentrations, it seems obvious to look at the observed warming of the last 100–150 years, a period that should have been strongly affected by anthropogenic increases in LLGHG. Figure 1a shows the time series of annual-mean surface temperatures from two observational data sets from 1890 to 2000 expressed as deviations from the 1951 – 1980 mean. Taking the difference between the first and last decades of the 20th century in Figure 1 yields a warming of about 0.6°C, sometimes loosely quoted as the observed anthropogenic effect on 20th century global warming.

The figure, however, shows that the observations have a rather complicated structure. The warming appears to have occurred mostly in two spurts: during 1900–1940 and 1970–2000. This complicates the attribution of the warming because both fossil fuel CO_2 emissions and the increase in radiative forcing from LLGHG accelerated sharply in the second half of the century. From the IPCC AR4 (Figure 2.23), it appears the global-mean radiative forcing due to LLGHG increased by about 0.35 W/m^2 between 1900 and 1940, which is much less than the roughly 1.2 W/m^2 increase that occurred between 1960 and 2000. Considering the temperature changes across the entire 20th century, therefore, has the danger of "attributing the warming before 1940 to the CO_2 emitted after 1950"! (I have paraphrased a remark by Massachusetts Institute of Technology professor and prominent critic of the mainstream climate change consensus, **Richard Lindzen**). Our understanding of the multi-decadal details in Figure 1 is hampered by considerable uncertainty about non-LLGHG forcings (e.g., effects of aerosols on clouds, solar irradiance variations, and others) as well as lack of knowledge of the natural unforced variability of the global climate at multi-decadal scales.

The AR4 GCM intercomparison included "climate of the 20th century" (20C3M) runs in which the models had a representation of the changing climate forcings due to LLGHCs, other anthropogenic pollution, solar variations, and volcanic eruptions. As a project in my graduate climate course at the University of Hawai'i last year, the students (**Bob Ballard, Ying Chen, Hiroyuki Ito, Julie Kelly, Thien Van Le, Chase Norton, Kat Scanlon, Chuan-Chi Tu, Baoqiang Xiang**) and I tried to assess how well individual models reproduced the observed temperature time series and whether the results had implications for global-climate sensitivity.

If we define the total 20th century warming as the mean of the 1980–1999 period minus the mean of the 1891–1910 period, the two observational data sets in Figure 1a indicate warmings of 0.6° C (GISS) and 0.7°C (HADCRU). We examined the results for single realizations from 14 of the AR4 GCMs and found this warming ranged from 0.23°C to 0.97°C. Some models do a rather poor job in reproducing the details of the observed warming evolution; others, however, do quite well in reproducing the observed early 20th century as well as the late 20th century warming. Results for two of the GCMs that display particularly realistic-looking simulations are shown in Figure 1b.

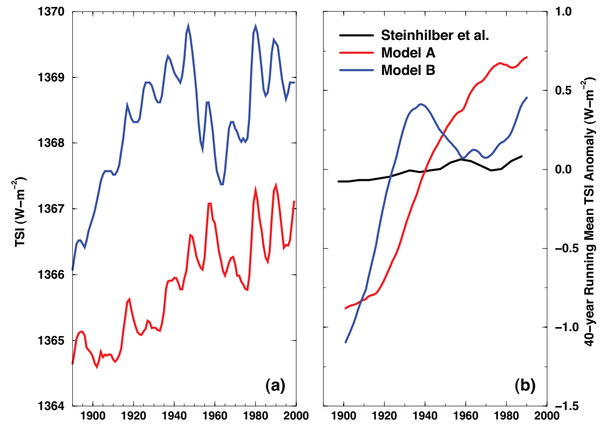

Figure 2. (a) Annual-mean total solar irradiance imposed in the forced 20th century runs for model "A" (red) and model "B" (blue). (b) 40-year running means of the total solar irradiance in models "A" and "B" compared with the recent observational inference from Steinhilber et al.

Figure 1c shows the results for a randomly chosen subset of 8 of the models. The difference between the models that simulate a realistic early 20th century warming (blue curves) versus those that do not (red curves) is quite apparent. The blue curves are for models that included a significant variation in total solar irradiance (TSI) while the red curves are for models with constant TSI throughout the run. This pattern seems to be rather consistent among the models analyzed. Characterizing the early 20th century warming as the 1941–1950 mean minus 1901–1910 mean, the average for the 6 models with TSI variations is 0.26°C, while it is just 0.05°C for the 8 models without significant TSI variations. The observed values for this warming are 0.27°C (GISS) and 0.31°C (HADCRU).

So it is apparent that typical GCMs reproduce the observed early 20th century warming only if a significantly rising solar forcing during that period is included. However, we have accurate direct observations of TSI only after 1978. These have shown a peak-to-peak TSI variation of roughly 1 W/m^2 over the 11-year solar activity cycle, and fairly consistent values from cycle-to-cycle over the last three decades. Figure 2a shows the annual-mean TSI used in the two models whose temperatures are plotted in Figure 1b. Their post-1978 TSI values are similar (except for about a 2.5 W/m^2 mean offset, which is not important for present purposes). The evolution of the pre-1978 TSI values used in these models is based on published studies by solar physicists in the 1990s who had inferred TSI from indirect reconstructions. The recent advances in the field now point to much less multidecadal variability in TSI. The black curve in Figure 2b shows 40-year mean values of TSI from the recent study of Steinhilber et al. (2009), who based their analysis on ice-core observations of the concentration of ^{10}Be, an isotope whose production in the atmosphere by cosmic rays is modulated by the solar magnetic field (which in turn is related to solar luminosity). These inferred results show much less increase in the early 20th century than the TSI values used in the two GCMs.

The role of solar variability in affecting global mean temperatures on decadal-century scales has been investigated in many earlier studies, of course. Also there have been sophisticated studies of the variability of the 20th century temperature record as simulated in different GCMs and the connection of the results with the imposed climate forcings (such studies often focused on identifying an anthropogenic temperature signal). However, as far as I can tell, no earlier reference has highlighted the very elementary point that the biggest differences among 20th century simulations among the AR4 GCMs are due the very different TSI variations imposed, and that perhaps unrealistically large variations in TSI are needed for typical state-of-the-art GCMs to reproduce the basic features of the observed 20th century temperature record.

Mt. St. Helens erupting on May 18, 1980. Photo courtesy USGS

This analysis shows the difficulty in using the 20th century warming as a guide to validating model climate sensitivity. The uncertainties in forcing are large, and it is unclear whether current models can actually account for the observed early 20th century warming if they are forced with realistic solar forcing.

There are perhaps ways to resolve this problem, for example, if the multidecadal fluctuations in the global-mean temperature record are largely driven by internal variations rather than responding to global-climate forcing. However, one hypothesis that cannot be ruled out is that the real climate is actually more sensitive than any of the current GCMs predicts, and that the early 20th century warming was a response to the relatively modest LLGHG forcing increase during that period. Under this hypothesis, the absence of accelerated warming after 1940 could be attributed to the growth of negative forcings (notably from tropospheric aerosol pollution but also from a modest contribution of the stratospheric effects of large volcanic eruptions, which were more prevalent in the last 4 decades of the 20th century than in the first half).

First-Principles Modeling of Climate Feedbacks?

It seems we are some distance from comprehensive climate models that are realistic enough to believe their simulations of the global-mean temperature. Large uncertainties remain in the treatment of the effects of processes with scales that are too small to explicitly resolve in the finite numerical representation of present-day global models. Intercomparisons of state-of-the art GCMs suggest that some key processes determine climate sensitivity, such as water vapor feedback and ice and snow albedo feedback are quite similar among the models. The simulations of how clouds respond in climate change, however, differ greatly and these differences in the cloud feedbacks account for almost all the intermodel spread in simulated global-climate sensitivity. It is this representation of cloud processes that is notoriously challenging for climate modeling and much remains to be done before GCM cloud simulations can be considered successful.

Our work at the IPRC on validating GCM simulations of large-scale cloud fields against satellite observations has demonstrated significant problems. As an example, Figure 3 shows how greatly the annual-mean cloud liquid water

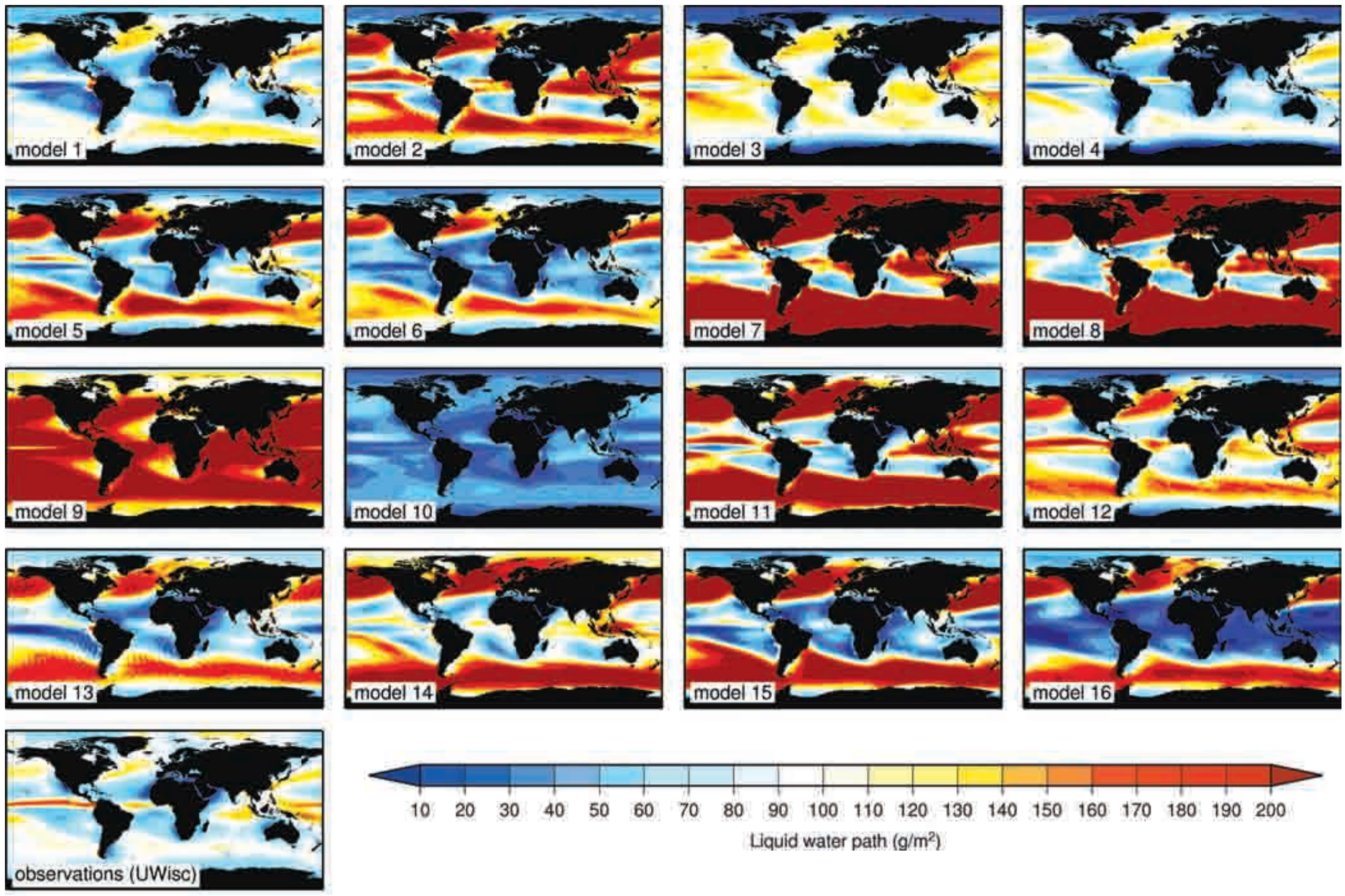

Figure. 3. The annual-mean liquid water path simulated in present-day runs by 16 different coupled GCMs compared with observations (bottom left).

content in 16 present-day GCM simulations differ from microwave satellite observations. Problems are also seen in the GCM simulations of fractional cloud cover and the cloud-climate forcing. Studies here at the IPRC (Stowasser and Hamilton, 2006) and elsewhere (Clement et al., 2009) have also documented the serious difficulty for GCMs in simulating the response of the large-scale cloud fields to interannual climate fluctuations (such as those associated with the El Niño phenomenon). It is difficult to put much credence in the cloud-climate feedbacks from models that do such a poor job of simulating the basic cloud climatology.

Progress in simulating cloud-climate feedbacks in GCMs may be achieved in various ways: improvements in conventional subgrid-scale physics parameterizations; development of models in which conventional parameterizations are replaced with embedded cloud-resolving components, the so-called "super-parameterization" approach; and development of models with very fine, explicit resolution over the whole globe. Unfortunately, it will likely be sometime in the next decade before we have genuinely cloud-resolving global models.

Recently my colleagues and I at the IPRC have taken another approach; we have been evaluating the cloud-climate feedback in a regional atmospheric model with realistic imposed boundary conditions. These new results are discussed in the following story in this issue.

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How Will Low Clouds Respond to Global Warming?

By Axel Lauer & Kevin Hamilton

Persistent low clouds that predominate over the subtropical ocean basins exert a major effect on the global radiation budget by reflecting incoming solar radiation. In collaboration with colleagues at IPRC, the University of Hawai'i meteorology department, and the University of Wisconsin, we have been studying the simulation of the clouds over the eastern Pacific Ocean using the IPRC Regional Atmosphere Model (iRAM). The eastern Pacific region (away from the equator in both hemispheres) is notable for the presence of extensive low cloud decks, and displays interesting transitions from dominant stratus, to stratocumulus, to trade wind cumulus regimes as one moves away from the coast. Our iRAM simulations cover 160°W–50°W, 40°S–40°N and

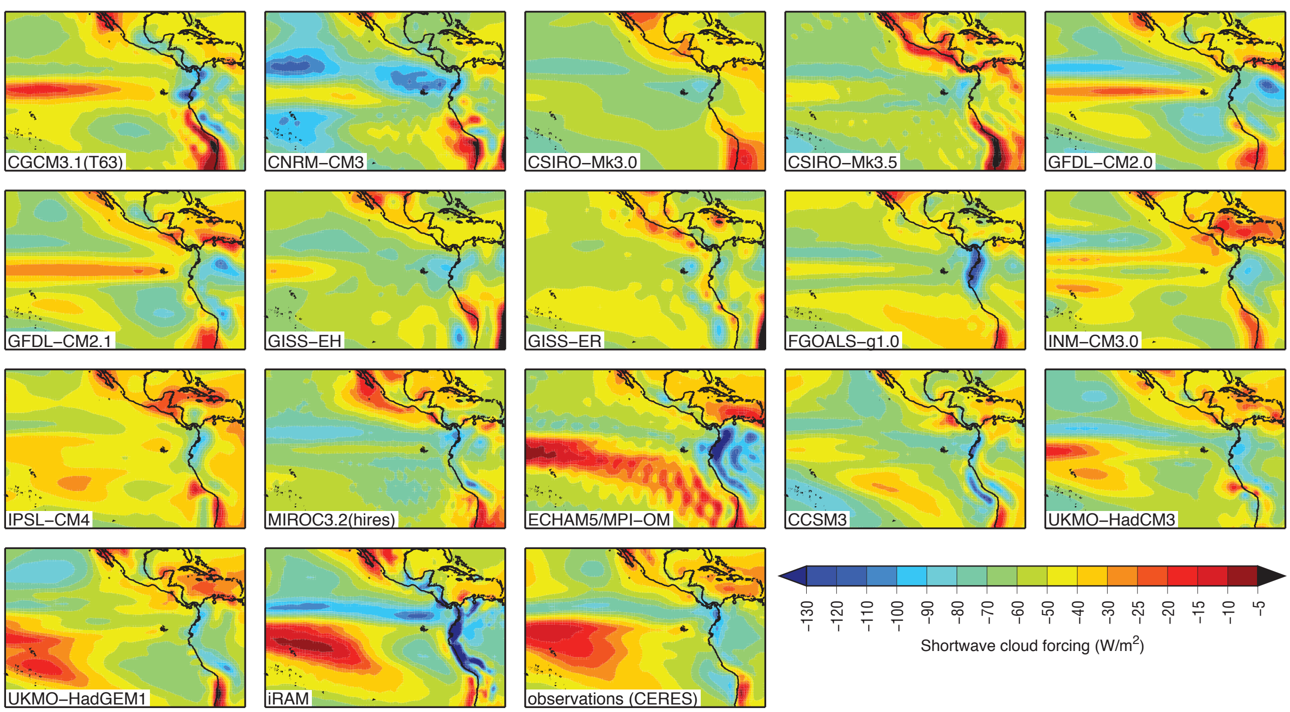


Figure 1. Annual average top-of-the-atmosphere shortwave cloud forcing for present-day conditions from 16 IPCC-AR4 models and iRAM compared with the CERES satellite observations of Loeb et al., 2009. Blue shades represent more reflection (strongly negative shortwave cloud forcing), red shades less reflection (weakly negative shortwave cloud forcing) of solar radiation.

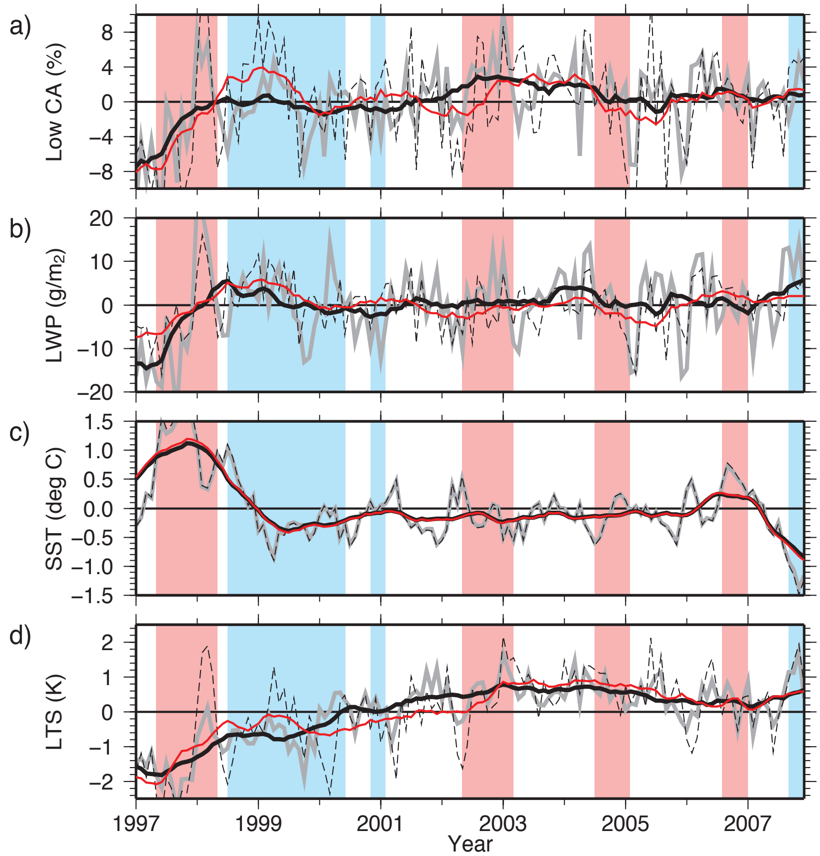


Figure 2. Time series of anomalies of monthly means and 1-year running means averaged over the southeastern Pacific (100°W–75°W, 25°S–5°S) for (a) low-level cloud amount, (b) liquid water path, (c) sea surface temperature, and (d) lower tropospheric stability. Observed values are compared with the resultsfrom the iRAM simulation. Warm (El Niño) and cold (La Niña) episodes are shaded in light red and light blue, respectively.

are forced by horizontal boundary conditions taken from 6-hourly observational analyses and from observed daily sea surface temperatures (SSTs) for the period 1997– 2008. The analysis of results is restricted to the interior region more than 10 degrees away from the boundaries.

As the preceding article "How Much Will the World Warm?" shows, state-of-the-art global climate models (GCMs) do a rather poor job in reproducing the observed long-term mean cloud properties in this region (and in other low-cloud dominated regions). By contrast, we have found that iRAM simulates realistically both the long-term mean cloud properties and the interannual fluctuations in the clouds in this region. Figure 1 presents for the region of interest the shortwave cloud radiative forcing, i.e. the reflected solar radiation at the top of the atmosphere attributable to the presence of clouds, in present-day simulations from iRAM and from 16 coupled GCMs. The results are compared with long-term mean values from satellite observations.

Figure 2 has the time series of monthly means of several quantities in the iRAM simulation averaged over 100°W–75°W and 25°S–5°S, also compared with observations. El Niño and La Niña periods in the equatorial Pacific are denoted by pink and blue shading. The research covers the extremely strong 1997 El Niño. The largest changes in SST and other area-averaged quantities during the 10-years happened during the transition from that El Niño to the extended La Niña starting in 1998. The iRAM successfully simulated the observed increases in low-level cloud amount, cloud-liquid water path and lower tropospheric stability during the 1997–1998 transition, as well as many of the smaller amplitude fluctuations in these quantities seen later in the record.

In order to investigate cloud climate feedbacks in iRAM, several global warming scenarios were run with boundary conditions appropriate for late 21st century conditions. In these

Stratocumulus clouds over the South Pacific. Image courtesy NASA Earth Observatory.

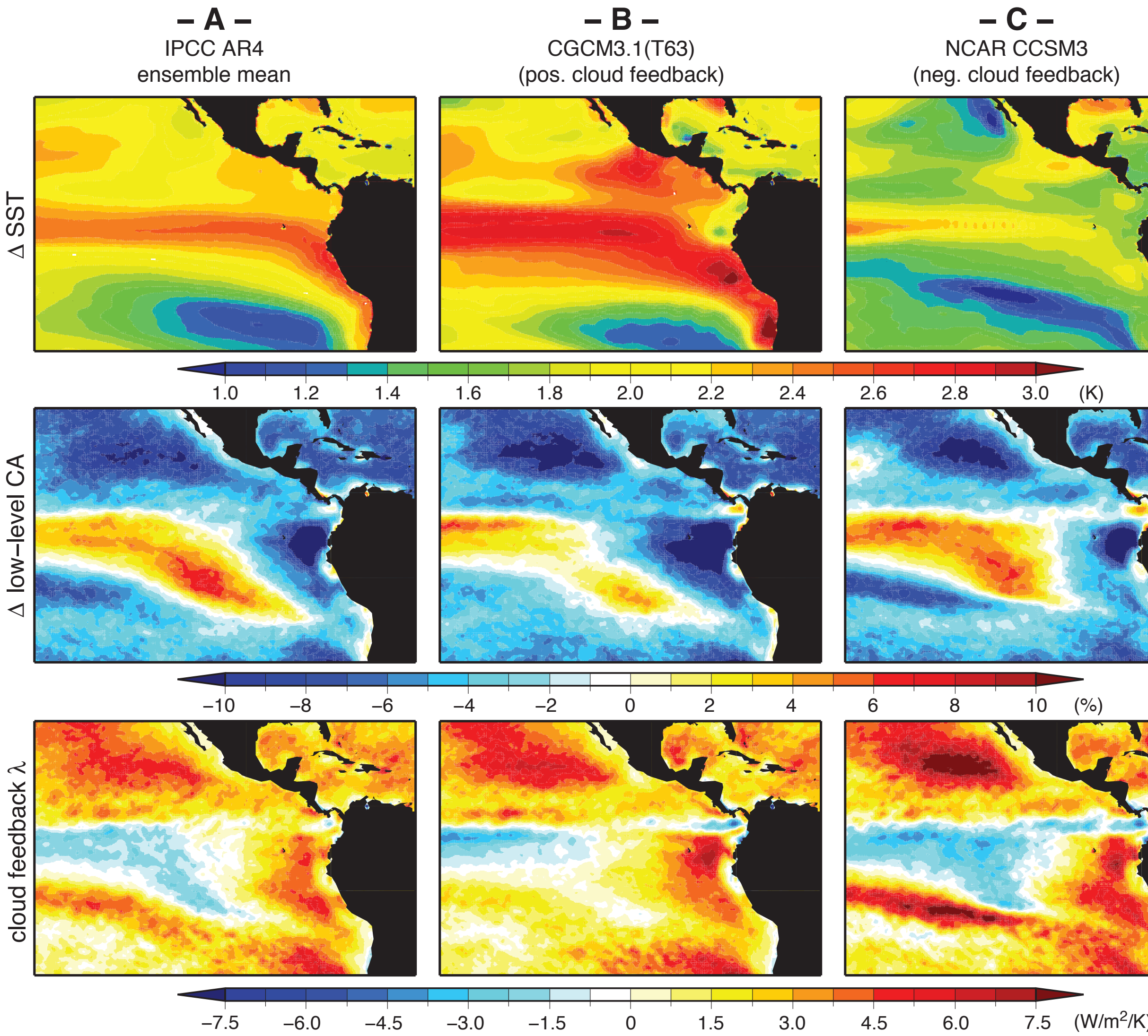
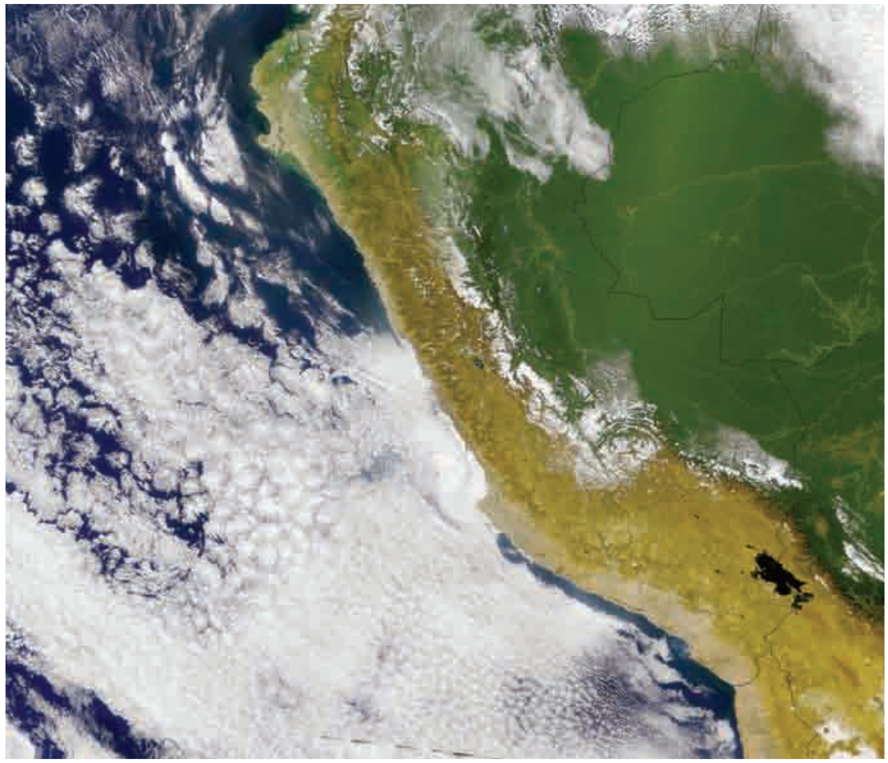


Figure 3. Top: the SST warming increment imposed in each of the three iRAM global warming experiments. Middle: change in the low cloud amount in each of the global warming iRAM simulations relative to the present-day simulation. Bottom: cloud feedback parameter derived from the iRAM global warming simulations.

runs the lateral boundary conditions for the model integration were given by the sum of the 6-hourly reanalysis data used for the present-day experiment plus a climate-change "increment." We based the climate-change increments imposed in these runs on the monthly averaged differences between present-day climate and projections for the end of the 21st century made by coupled GCMs, or ensembles of such models, included in the IPCC Fourth Assessment Report (AR4). Specifically, we adopted a climate-change signal computed as the difference between the 10-year means for each calendar month in the late 20th century [1990–99 in the AR4 20th century forced runs (20C3M)] and in the late 21st century [2090–99 in the Special Report of Emissions Scenarios (SRES) A1B runs].

We performed three experiments, each having a different global-warming increment. In *Case A* the climate change signal is averaged over 19 AR4 models; in *Case B* the signal is taken from version 3 of the Canadian Centre for Climate Modelling and Analysis (CCCma) GCM; and in *Case C* the signal is taken from results of the NCAR Community Climate System Model version 3 (CCSM3). The SST warming patterns in these three cases is shown in the top panels of Figure 3. Among the AR4 GCMs, the NCAR CCSM3 has one



Clouds off the Coast of Peru. Courtesy NASA/Goddard Space Flight Center.

of the lowest global climate sensitivities and also has a negative cloud-climate feedback over the eastern Pacific, while the CCCma model displays a much higher global sensitivity and a positive cloud-climate feedback over the eastern Pacific.

The response of the low-level cloud amounts to the imposed warming is shown for each case in the middle row of Figure 3. All the global warming cases simulated with iRAM show a distinct reduction in low-level cloud amount, particularly in the stratocumulus regime, resulting in positive local cloud-climate feedback in these regions. We defined a local cloud-climate feedback parameter as the change in total (shortwave plus longwave) cloud forcing between the control and the warming case, normalized by the local SST change. The feedback parameter for each of the three warming cases is shown in the bottom row of Figure 3. The magnitude and pattern of the feedback parameter is remarkably similar in the three cases. Domain-averaged (30°S–30°N, 150°–60°W) feedback parameters from iRAM range between +1.8 and +1.9 in $W/m^2/K$ in the 3 cases.

The reduction in low-level cloud amount in the global warming simulations is largely caused by a general thinning of the boundary layer clouds. This thinning reduces their ability to reflect sunlight and consequently amplifies the warming (positive cloud-climate feedback). On average, cloud thickness in the eastern Pacific stratocumulus regions is reduced by 50–100 m by the end of the 21st century. The thinning is thought to result from a reduction in the mean height of the inversion layer that usually caps the marine boundary layer clouds by preventing further vertical growth. This is found to be consistent with the boundary layer becoming shallower as a result of reduced entrainment and weaker turbulence in the global warming simulations.

The cloud-climate feedback parameters averaged over the same eastern Pacific region were also calculated from the SRES A1B simulations for each of the 16 GCMs shown in Figure 1. Averaged over our east Pacific

Photo taken during the 2008 VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Study) field campaign. Image courtesy Cameron McNaughton.

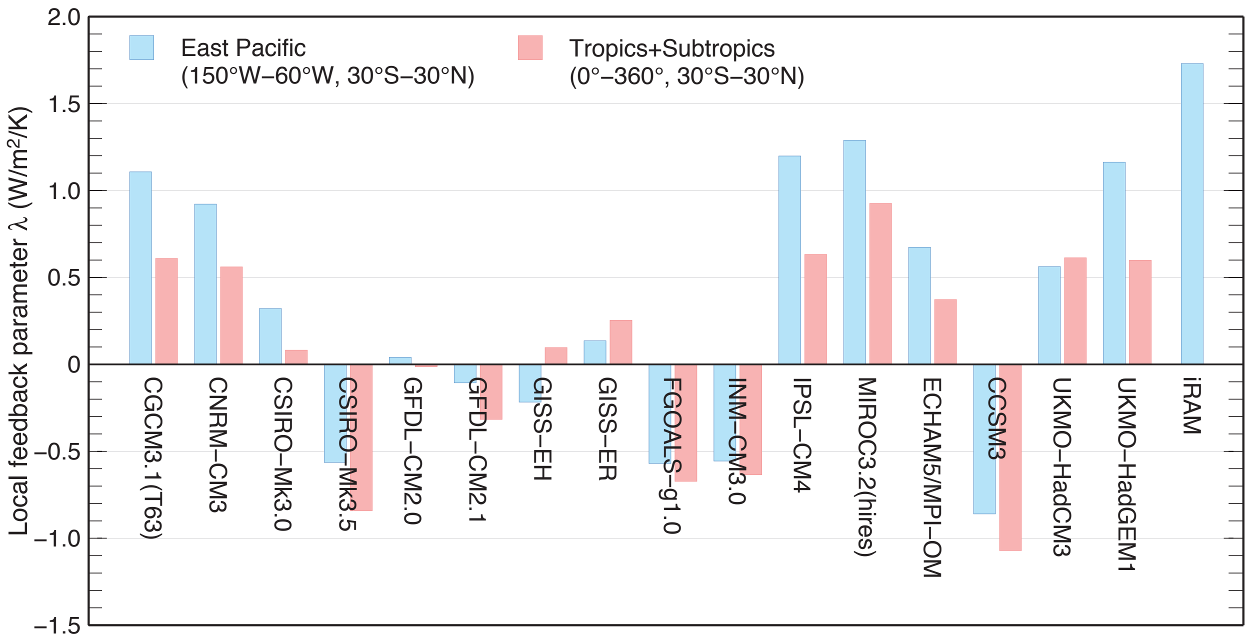


Figure 4. Annual average local feedback parameter λ in W/m²/K for the East Pacific region and the latitude belt 30°S–30°N from 16 IPCC-AR4 models and calculated by iRAM.

region (30°S–30°N, 150°–60°W), the simulated feedbacks varied from –1.0 to +1.3 W/m²/K — all considerably less than the values obtained in the iRAM simulations!

This is seen in the blue bars in Figure 4 that compare the east Pacific average feedback parameters in each of the 16 GCMs and in iRAM (*Case A* simulation result shown). The pink bars show the feedback parameters averaged over the whole 30°S–30°N latitude band for each of the 16 GCMs. The strong correlation between the latitude-band-average feedback (pink bars) and eastern Pacific feedback (blue bars) is apparent.

This work comes with some caveats. Rather than attempting a fully self-consistent calculation of the response of the climate system to external forcing, we have relied on results from another model to provide the surface warming and large-scale changes in wind, stability, and humidity that are then used to force our regional model. This calculation is in the same spirit as numerous earlier calculations of climate feedbacks that have imposed SST changes in an atmospheric GCM that were determined from a separate coupled GCM experiment. Our calculation falls as well into the class of dynamical downscaling simulations of global model climate projections.

The iRAM results by themselves cannot be connected definitively to global climate feedbacks, but the implications for global climate change are likely significant. Cloud feedback largely determines the global climate sensitivity, and among the global GCMs, the cloud feedback in the full tropical-subtropical zone is correlated strongly with eastern Pacific cloud feedback. The iRAM results suggest that all the GCMs underestimate the cloud-climate feedbacks in that region, supporting the high end of current estimates of global climate sensitivity.

This story is based on A. Lauer, K. Hamilton, Y. Wang, V. Phillips and R. Bennartz, 2010: The impact of global warming on marine boundary layer clouds over the eastern Pacific – a regional model study. *J. Climate*, **23**, 5844-5863.

The Asia-Pacific Data Research Center (APDRC) continues to maintain an extensive archive of climate-related data and model outputs that is accessible not only to the international climate science community, but also to the general public. The APDRC data server allows interactive access to these data sets, and the APDRC staff are always working to improve the user-interface in ways that will make the data more useful.

The data sets served include many that are produced elsewhere, but the "Projects" page on the APRDC web site point to many data sets developed by IPRC and our close partners. Most of these IPRC data sets are somewhat specialized products, often involving model simulations. In addition, however, IPRC has recently produced several data sets with our own analyses of long time periods of near-global coverage for standard meteorological and oceanographic variables, and we expect these data sets to have wide application throughout the community. Below we introduce two of these IPRC-developed global data sets, one for surface winds and one for surface ocean currents. We also briefly discuss a recent development that improves user interaction with some historical ocean-current profile data.

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New Marine Wind-product Available for Climate-change Studies

Extensive compilations of sea-surface wind observations taken mainly from ships-of-opportunity have existed for some time. The reported wind values from ships can include direct anemometer observations and also "Beaufort winds," estimated winds from visual observation of the sea state. In addition, determinations of swell and wave amplitudes themselves are often reported, and these values potentially yield information about the near-surface winds. These various raw observations have several error sources that are a concern particularly for determining long-term trends. For example, direct wind observations have a spurious bias towards increasing wind speed due to increasing heights of the anemometers as the reporting "ships-of-opportunity" have become on average taller.

In a project led by IPRC Assistant Researcher **Hiroki Tokinaga**, a new a long-term (1950–2008) data set of monthly mean near-surface winds over the global ocean has been developed that combines ship-based direct observations and estimated winds. The wind product is meant to represent winds 10 m above the sea surface. The raw wind reports are quality-controlled and corrected to minimize spurious trends. This new "Wave and Anemometer Based Sea-surface Wind (WASWind)" data set is notable for its corrections for the anemometer height bias, its use of visually observed wave heights to estimate winds, and omission of the estimated Beaufort winds after 1980 when suspicious trends appear in the raw data.

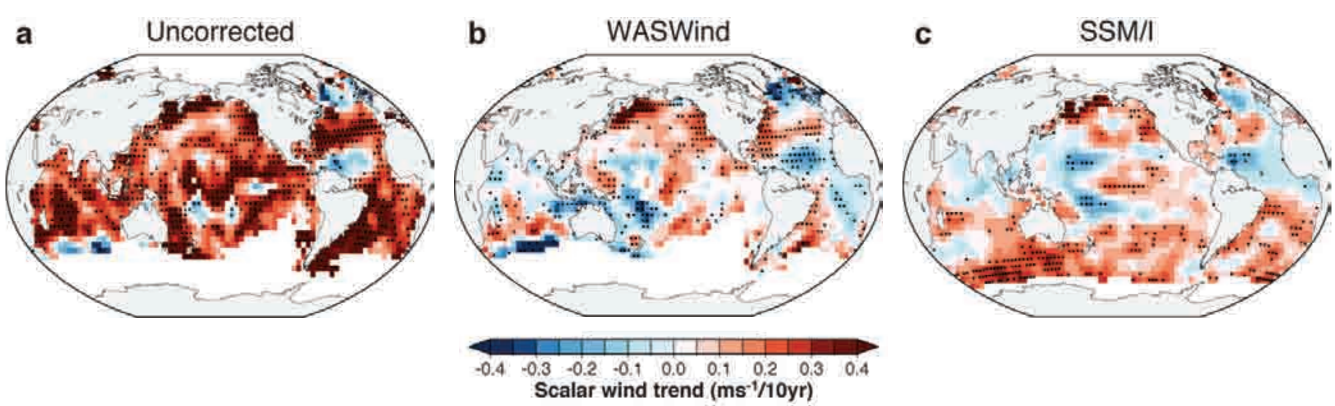


Figure 1. Linear trends in surface scalar-mean wind over 20 years from July 1987 to August 2006 derived from (a) uncorrected ship-observed wind, (b) WASWind, and (c) SSM/I satellite observations. Grid points marked with dots exceed 95% confidence level based on the Mann–Kendall test.

WASWind displays rich spatial structures in trend patterns as shown in the 20-year trend in Figure 1b. The combination of ship-based observations of winds and wind wave-height successfully reproduces not only major modes of seasonal-to-decadal variability, but also trend patterns physically consistent with trends seen over the last two decades in sea level pressure (SLP) and in satellite measurements of the Special Sensor Microwave Imager (SSM/I) (Figure 1c). The agreement in trend patterns with such independent observations illustrates the usefulness of WASWind for climate-trend analyses, especially since it is available from the pre-satellite era starting in 1950 to 2008. The dataset is of sufficiently high resolution to make it valuable for regional climate-change study. [H. Tokinaga and S.-P. Xie: Wave and Anemometer-based Sea-surface Wind (WASWind) for climate change analysis, *J. Climate*, in press]

Ocean Surface Currents from a Diagnostic Model

IPRC's Senior Scientist **Nikolai Maximenko**, with the help of Scientific Computer Programmer **Jan Hafner**, has produced a new surface current data set with high-resolution, daily, near-global coverage. The Surface CUrrents from Diagnostic model (SCUD) data set aims to make the best estimates of an "ocean surface current velocity" that would describe the motion of standard floats drogued at 15-m depth.

The SCUD velocities are derived from AVISO satellite observations of sea-level anomalies, a mean dynamic topography, and QuikSCAT observations of surface winds.

The estimated total surface curent velocity is comprised of a component linearly related to the local horizontal pressure gradient (but not necessarily geostrophic balance) and a component that is a linear function of the local surface wind (but not necessarily assuming Ekman balance). The SCUD velocities are specified daily on a 0.25 degree latitude-longitude grid, but are averaged over the local inertial period for up to three days.

The dataset can be applied to diagnosing trajectories of passive tracers floating at or near the sea surface, such as marine debris, oil spills, etc., but it should be appreciated that movements of a particular tracer may systematically differ from the motion of the standard drifters used to calibrate the SCUD model.

The SCUD data is currently limited to the period of QuikSCAT wind observations from August 1, 1999, through November 19, 2009. The possibility of extending the data set using alternate wind determinations is being investigated.

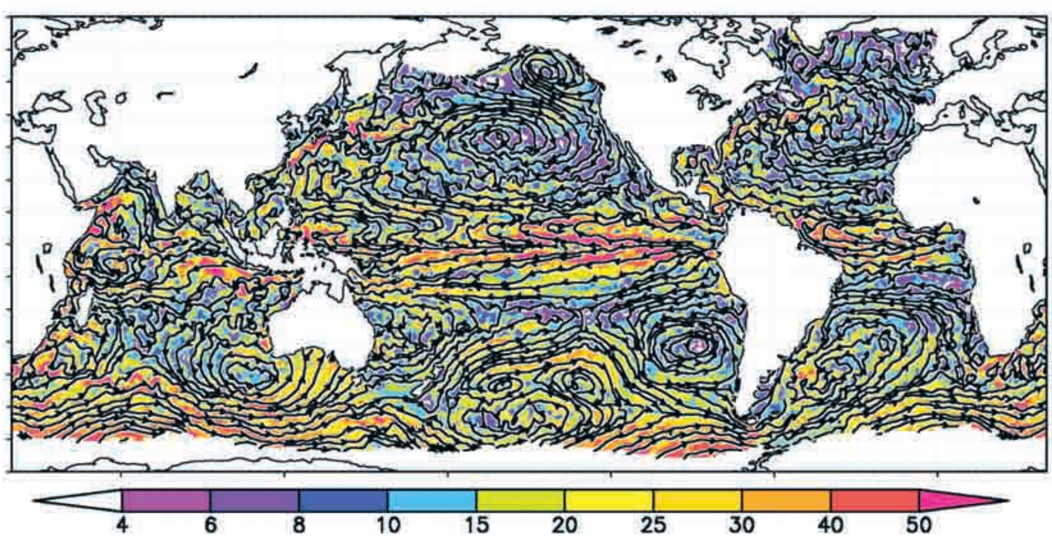
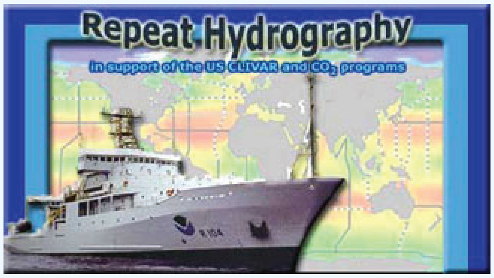


Figure 2. Streamlines of the Surface CUrrent Diagnostic velocity on August 20, 2008. Colors indicate speed and units are cm/s.



On this web page, you will find links to measurements of quasi-instantaneous vertical profiles of horizontal ocean velocities using a Lowered Acoustic Doppler Current Profiler (LADCP) taken as part of the **US component of the CLIVAR/CO2 repeat hydrography program**. Final LADCP processing was performed using the **LDEO processing software** by Andreas Thurnherr (Lamont-Doherty Earth Observatory of Columbia University) through 2008 and by University of Hawaii "currents" group (Firing/Hummon/Ascani) since 2009. This project is supported by NSF grants OCE-0223869 and OCE-0752970. The continous-in-time upper-ocean velocities from Shipboard Acoustic Doppler Current Profiler (SADCP) are available on the **University of Hawaii "currents" group's website**.
Click on the checkboxes to the left of the CLIVAR sections that you would like to see. The station locations will appear on the map below. You may zoom in/out and drag to re-center the *Google* map. Clicking on a station will bring up a popup with a profile plot and links for downloading the data. The third column links (LADCP) provide technical information and access to the entire cruise's data. The fourth column links send you to the CCHDO website with other hydrographic data (CTD etc.)

CLIVAR LADCP Individual sections

☐	A16N 2003	LADCP	CCHDO
☐	A20 2003	LADCP	CCHDO
☐	A22 2003	LADCP	CCHDO
☐	P02W 2004	LADCP	CCHDO
☑	P02E 2004	LADCP	CCHDO
☐	P16S 2005	LADCP	CCHDO
☐	A16S 2005	LADCP	CCHDO
☐	P16C 2006 (P16N leg 1)	LADCP	CCHDO
☑	P16N 2006 (P16N leg2)	LADCP	CCHDO
☐	I08S 2007	LADCP	CCHDO
☐	I09N 2007	LADCP	CCHDO
☐	P18_1 2008	LADCP	CCHDO
☐	P18_2 2008	LADCP	CCHDO
☐	I0 6S 2008	LADCP	CCHDO
☐	I05S 2009	LADCP	CCHDO

Figure 3. Access to shipboard measurements on the APDRC website.

Easy Access to Ship-board Measurements of Currents

In situ measurements of ocean currents are sometimes made with lowered acoustic Doppler current profilers, or L-ADCPs. These instruments are lowered through the water column at measuring stations during oceanographic cruises. Since the measurements are not on a standard horizontal grid but are made along a ship track, they have been difficult to present. To aid in the data search and discovery of these measurements, **Sharon DeCarlo** worked with **François Ascani** to develop a system based on Google Maps to display such ADCP data.

By clicking in Figure 3 on the boxes next to the name of the cruise-data desired, the station locations appears on the map in Figure 4. Clicking on a station will bring up a popup with a profile plot and links for downloading that station's data.

In the third column (LADCP), links provide technical information and access to the entire cruise's data; in the fourth column, links send you to the CLIVAR & Carbon Hydrographic Data Office website with further hydrographic data (CTD etc.) (http://apdrc.soest.hawaii.edu/gg/ladcp.php). Users can select the data by cruise number or geographic location, and then get either quick-look plots or download the data itself.

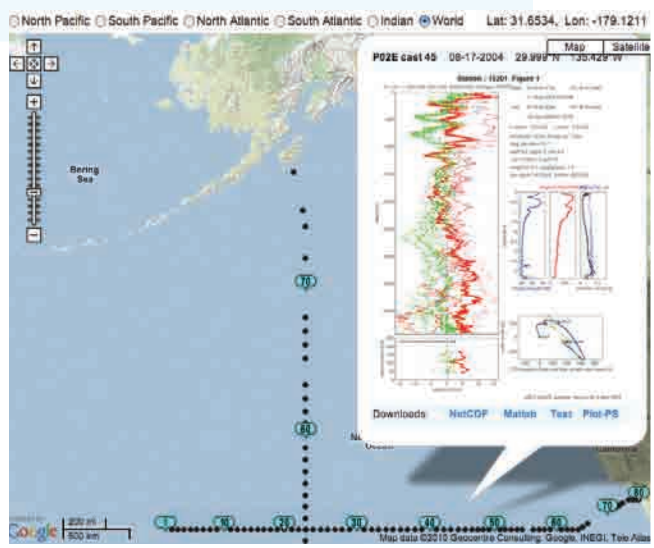


Figure 4. Map of shipboard locations with popup profile for location P02E

The project was done in collaboration with the US component of the CLIVAR/CO2 repeat hydrography program.

IPRC Annual Symposium

IPRC held its 10th Annual Symposium at the East-West Center on May 27. This year's symposium had a novel "all-poster" format, featuring four separate poster sessions extending from morning, through the afternoon, to the evening. Before each poster session, the presenters briefly talked about their poster, giving them a chance to advertise their work and giving the audience an idea of what they were about to see. In addition to the standard posters, the staff of the Asia-Pacific Data-Research Center (APDRC) used IPRC's Magic Planet spherical projection system and a large-screen video display to show off their data server and data products.

Yanping Li, Axel Lauer, Prasanth Appukuttan Pillai, and H. Annamalai during the IPRC Annual Symposium.

Assistant Researcher Kazuyoshi Kikuchi talks about his study with Postdoctoral Fellow Prasanna Venkatraman.

Participants at the 10th IPRC Annual Symposium.

Showing remarkable energy, IPRC scientists still engaged in vigorous scientific discussions at the conclusion of the symposium, at 7:30 pm. Participants agreed the experience was intense, but enjoyable.

All in all there were 42 posters. Organized and chaired this year by IPRC Director **Kevin Hamilton**, the program for the symposium is available at http://iprc.soest.hawaii.edu/meetings/workshops.php.

Tim Li studies poster of Assistant Researcher June-Yi Lee.

Clouds, Chemistry, and Climate

When two valued colleagues – **Hitoshi Irie**, research scientist at JAMSTEC's Research Institute for Global Change, and **Ralf Bennartz**, professor in the Department of Oceanic and Atmospheric Sciences at the University of Wisconsin – visited the IPRC in April, IPRC Director **Kevin Hamilton** took the opportunity to organize the mini-symposium "Clouds, Chemistry and Climate." The symposium featured talks by Irie and Bennartz as well as by IPRC's Assistant Researcher **Axel Lauer** and University of Hawai'i colleagues **Tony Clarke**, **John Porter**, **Cameron McNaughton** and **Vaughan Phillips**.

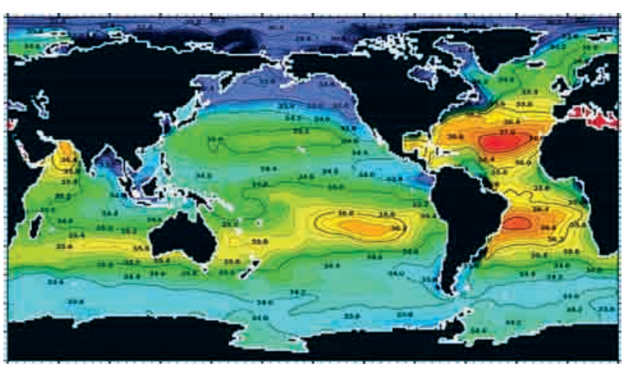
The presentations covered a wide range of topics on the measurements and modeling of aerosols, clouds and climate. They included results from flights of the VAMOS Ocean-Cloud-Atmosphere-Land Study to measure the aerosol entrained from the free troposphere into the marine boundary layer and to study the role of this aerosol as cloud condensation nuclei; results from aerosol measurements taken in the Western Arctic during ARCTAS/ARCPAC in 2008; a proposal for multi-platform measurements in the Hawai'i Region to determine direct and indirect aerosol effects; an overview on the cloud microphysical modeling capabilities at the University of Hawai'i with a case study of the impact of biological aerosols on deep convection; and an overview of current satellite products to evaluate climate model simulations. Discussions on further IPRC–JAMSTEC collaborative research on clouds, aerosols, and atmospheric trace gases rounded out the symposium. The agenda is at http://iprc.soest.hawaii.edu/meetings/workshops/10_04_Clouds,_Chemistry_Climate.html

Participants at the mini-symposium "Clouds, Chemistry, and Climate." Seated around the table from left Tony Clarke, Cameron McNaughton, Axel Lauer, Kevin Hamilton, Barry Huebert, Ralf Bennartz, John Porter, and Hitoshi Irie.

Aquarius Satellite Mission to Boost Climate Research

The Aquarius partnership between NASA and Argentina's Comisión Nacional de Actividades Espaciales is a new satellite mission dedicated to providing weekly global measurements of salinity distribution at the ocean surface. Sea surface salinity (SSS) variations drive the deep ocean conveyor belt, and impact air–sea interactions and the global water cycle, which all affect the ocean's capacity to store and transport heat and regulate Earth's climate. The information from the Aquarius mission will help scientists determine the combined effects of evaporation, precipitation, ice melt, river runoff, advection by currents, and vertical mixing on SSS at seasonal and interannual time scales, and the impact on the global distribution and availability of freshwater.

IPRC scientists are looking forward to this mission as they hope it will provide them with much needed global SSS observations at high temporal resoultion. **Nikolai Maximenko**, **Peter Hacker**, **Jim Potemra**, **Tangdong Qu**, and **Oleg Melnichenko** are members of the NASA Ocean Salinity Science Team. Thus when Principal Investigator of Aquarius, **Gary Lagerloef**, visited the IPRC in August, Maximenko organized the mini-symposium "Ocean Salinity and the Global Water Cycle" during which the scientists talked with Lagerloef about how the Aquarius mission will expand our knowledge of SSS and how the new data might help particular research projects.



Annual mean sea-surface salinity (SSS): red = high salinity, blue = low salinity.

Axel Timmermann, for example, showed the impact of salinity on paleo-ocean circulation and climate. When the Laurentide Ice Sheet melted about 17,000 years ago and sent massive quanities of freshwater into the North Atlantic, it shut down the thermohaline circulation. As the western North Pacific grew saltier, it began to take over partly the driving of the thermohaline circulation.

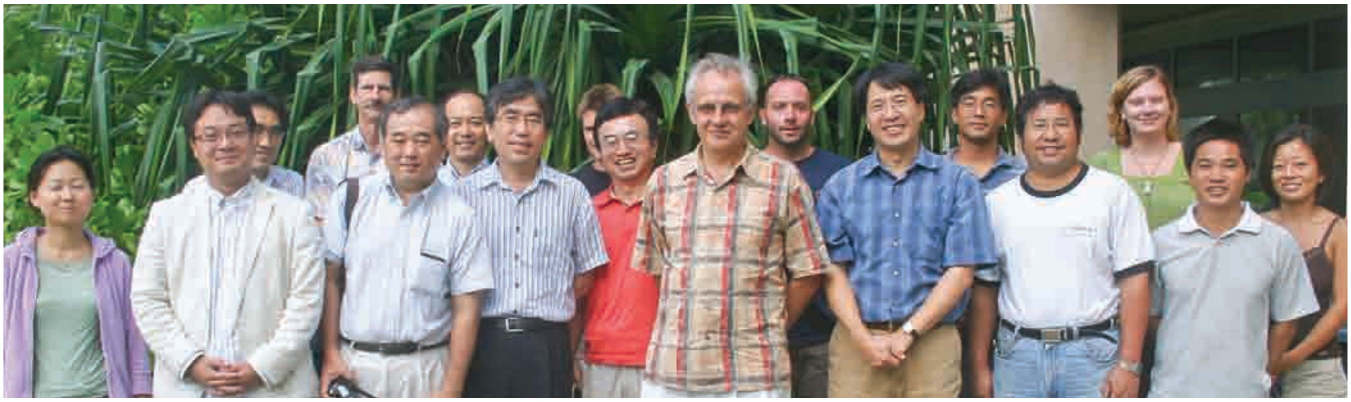
Around the table from left, Guihua Wang, Bo Qiu, Kevin Hamilton, Nikolai Maximenko, Gary Lagerloef, Tangdong Qu, and Axel Timmermann.

Tangdong Qu, who is working on the Salinity Processes in the Upper Ocean Regional Study (SPURS), showed that in the ECCO model the highest ocean salinity is seen in the mid-Atlantic around 24°N, yet the difference between evaporation and precipitation is greatest to the south. Thus SPURS is looking at what maintains the salinity maximum. Where does the excess salt go? In the ECCO model, it appears that a major portion of the salty water is subducted into the thermocline and from there poleward rather than, as has been thought, toward the equator. The Aquarius data will help settle this issue.

Aquarius may also provide data to validate the Wave and Anemometer-based Sea-surface Wind (WASWind) dataset that **Hiroki Tokinaga** has constructed from ship-based observations of wind speed and wind-wave height (see p. 13 this issue). The new data set, which spans 1950 to 2008, suggests that the increasing precipitation trend over the maritime continent in the ERA-40 product is spurious.

Finally, **Oliver Timm**, who is studying rainfall trends in the Hawaiian Islands, thought Aquarius could benefit rainfall prediction in Hawai‘i. Obtaining measurements of surface salinity in the ocean surrounding the Hawaiian Islands could help constrain the variability and trends seen in the rain-gauge-based island rainfall measurements.

For the full workshop program, please visit the IPRC website http://iprc.soest.hawaii.edu/meetings/workshops/2010/2010_Ocean_Salinity.html



Participants at the "Multi-scale Circulation Variability in the Tropical Western Pacific Ocean" meeting. Workshop organizers Kelvin Richards and Bo Qiu center front.

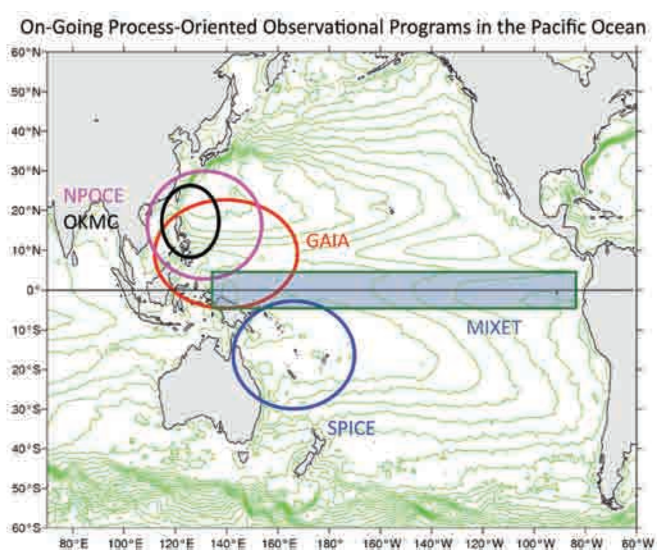
The Western Tropical Pacific under Scrutiny

By Bo Qiu

The tropical western Pacific Ocean has a complicated circulation system with intensive, multi-scale air–sea interactions. It is a crossroad and major pathway where different water masses from mid- and high-latitudes converge, and where waters of Southern and Northern Hemisphere origin interweave. It is also the region where such major oceanic currents as the Kuroshio, the North Equatorial Countercurrent (NECC) and the Indonesian Throughflow (ITF) originate. Oceanic disturbances generated in the region's interior ocean accumulate and amplify in its western basin. These accumulated and amplified oceanic variations can significantly impact conditions in the marginal seas and elsewhere in the ocean.

The IPRC and the UH Oceanography Department hosted in August 2010 the workshop "Multi-scale Circulation Variability in the Tropical Western Pacific Ocean." Scientists from the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Korea Ocean Research and Development Institute (KORDI), the IPRC, and the Oceanography Department reviewed existing, and presented new observational and modeling results on the tropical western Pacific circulation and variability. They discussed the need for scientific and logistical coordination of future observational and modeling activities, and they further explored the designs of experiments and the timing and plans for research cruises. **Kelvin Richards** (IPRC) and **Bo Qiu** (Department of Oceanography, University of Hawai'i Mānoa) organized the workshop. The agenda is at: http://iprc.soest.hawaii.edu/meetings/workshops/10_8_multiscale_circulation.pdf.

It was a timely workshop because several multi-national and multi-institutional observational programs that focus on the tropical western Pacific Ocean circulation and climate are underway or starting up. These programs include the Northwest Pacific Ocean Circulation and Climate Experiment (NPOCE) led by China, the Southwest Pacific Ocean Circulation and Climate Experiment (SPICE) led by France, the Tropical Western Pacific Climate Experiment (GAIA) led by Korea, the Tropical Ocean Climate Study (TOCS) led by Japan, and the two US initiatives: Origin of Kuroshio and Mindanao Currents (OKMC) and Mixing in the Equatorial Thermocline (MIXET) (see figure below). A number of scientists from IPRC and UH Department of Oceanography are investigators in the US programs and are contributors and collaborators to the international programs.



Improving Ocean Models: Update on the NASA Ocean-Mixing Project

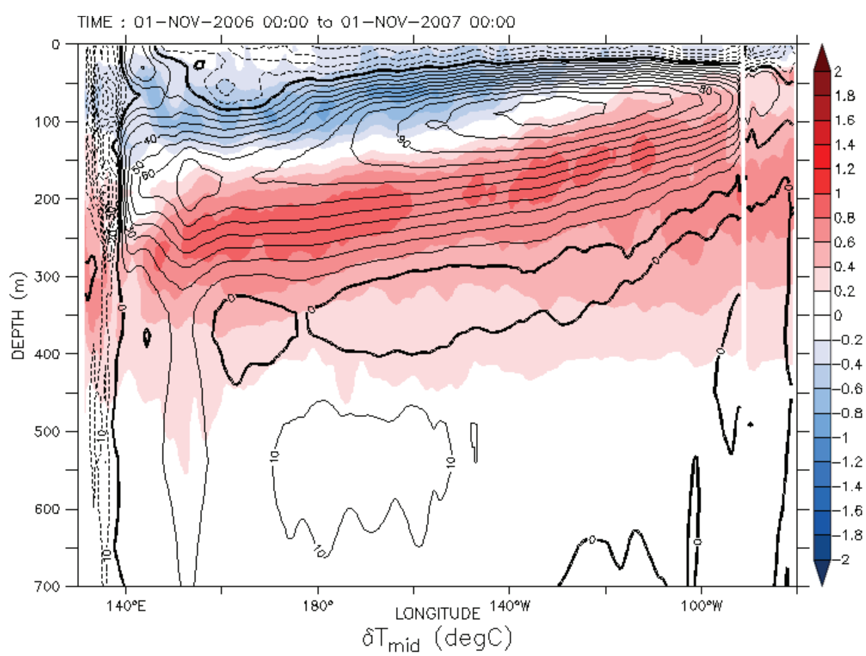
By Ryo Furue

The IPRC has been the meeting place for the NASA-funded project aimed at improving climate models by understanding better the role of ocean mixing and by determining the best estimates of mixing parameters in the large-scale circulation of the tropical Pacific (see *IPRC Climate*, vol. 10, no. 1). Investigators on the project, **Detlef Stammer** and **Chuanyu Liu** (U. Hamburg); **Bruce Cornuelle** and **Nidia Martinez** (Scripps Insitution of Oceanography, SIO); **Jay McCreary**, **Niklas Schneider**, **Yanli Jia**, and **Ryo Furue** (IPRC); and **Peter Müller**, **Roger Lukas**, and **Eric Firing** (UH) met again in October 2010 to discuss their progress and to plan future research steps.

Since the initial planning meeting in March 2010, the Hamburg group has been optimizing its coarse-resolution, global model by adjusting forcing and mixing parameters; the SIO group has configured an eddy-permitting model of the tropical Pacific and has been looking at adjoint sensitivity of selected oceanic variables to various forcing and mixing parameters; and the UH group has been using the SIO model to carry out preliminary, forward sensitivity runs.

Liu presented results from the Hamburg group. On a global scale, the Gent-McWilliams thickness diffusion is found to be the most effective in improving the model field. In the tropical Pacific, however, it is vertical diffusivity that is the most important. Martinez explored the "adjoint sensitivity" of the mean mixed-layer to such parameters as sea-surface height (SSH), wind stress, and vertical diffusivity in the Niño-3 region. These sensitivity fields indicate how changes in the parameters propagate to affect the target variable (in this case, the Niño-3 temperature). Furue described results on the response of the SIO eddy-permitting model to changes in background vertical diffusivity. The off-equatorial vertical diffusivity is found to be most effective in changing the upper-ocean stratification on the equator.

Based on these findings, the group decided the following: the SIO group will use the Hamburg group's distribution of the vertical mixing coefficient in their eddy-permitting model to see if the ocean state improves; the Hamburg group will investigate how and why their vertical mixing field brought about improvements in their model; the UH group will select target variables suitable for exploring their sensitivity to vertical diffusivity; and the SIO group will compute the adjoint sensitivity of those variables to vertical diffusivity, which the UH group, in turn, will use to conduct their forward sensitivity runs.



This plot from the Ocean-Mixing Project shows the sensitivity of the equatorial temperature field in the eddy-permitting, tropical Pacific model. Color: annual-mean temperature difference (°C) between a reference run and one in which background vertical diffusivity is increased poleward of 5° latitude. Contours: zonal velocity (cm/s) along the equator of the reference run (in 10 cm/s intervals). Fields are averages over the final year of four-year integrations. Increased off-equatorial vertical diffusivity lowers (raises) temperature on the equator above (below) the core of the Equatorial Undercurrent (the subsurface core of eastward velocity indicated by the contours). Off-equatorial vertical diffusion is found to impact the equatorial temperature field more than local vertical diffusion.

3rd OFES International Workshop in Japan

By Tangdong Qu

Since the Earth Simulator began operation in Japan in 2002, a series of quasi-global, eddy-resolving ocean simulations using the Ocean General Circulation Model for the Earth Simulator (OFES) have been conducted. Scientists around the world are now analyzing the outputs from these OFES integrations. The research ranges from studies of the behavior of individual meso-scale eddies to global energy analysis of the ocean.

In order to exchange information, generate new research ideas, and encourage further cross-cutting research-partnerships, the 3rd OFES International Workshop was held on 4–5 November 2010 in Yokohama, Japan. Over 50 scientists from seven countries participated. Climate Variation Predictability and Applicability Research Program Director **Yukio Masumoto** opened the workshop and JAMSTEC Executive Director **Shiro Imawaki** gave a welcoming speech. Two keynote presentations provided an overview of the recent progress in numerical modeling. **David Webb**, National Oceanography Centre, Southampton, presented an overview of developments in computational resources, modeling, and analysis techniques over the past two decades. He recounted how high-resolution modeling had revealed the importance of processes previously not realized. He suggested future climate modeling may parallel the developments in ocean modeling. In his keynote address **Lie–Yauw Oey**, Princeton University, presented a historical account of nested-grid ocean modeling and reviewed recent research on uncovering processes in the western North Atlantic and Pacific.

Four sessions followed during which 26 scientists presented their recent analyses of OFES or other model outputs and observations on the following topics: processes of the mid-latitude ocean, the tropical ocean, and the coupled ocean-atmosphere; and ocean dynamics. With IPRC as a co-organizer, IPRC scientists were well represented: **H. Annamalai**, **François Ascani**, **Ali Bel Madani**, **Miho Ishizu**, **Jim Potemra**, **Tangdong Qu**, **Kelvin Richards**, **Yoshinori Sasaki**, and **Niklas Schneider**, most of whom gave presentations.

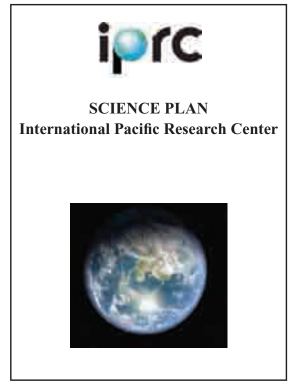
Hideharu Sasaki chaired the final closing discussion. Scientists from the different institutions and different countries agreed to continue collaboration in model development and interpretation and suggested that the 4th OFES International Workshop be hosted by the IPRC next year in Honolulu.

The workshop was organized and sponsored by JAMSTEC's Earth Simulator Center, Research Institute for Global Change, and Application Laboratory on Climate Variation Studies, and the IPRC. The workshop schedule together with PDFs of the talks are available at http://www.jamstec.go.jp/esc/event/ofes-workshop3/schedule.html/.

Participants at the "3rd International OFES Workshop" at the JAMSTEC Yokohama Institute for Earth Sciences. Image courtesy JAMSTEC.

A New Science Plan for the IPRC

The IPRC has a new Science Plan to guide its research. This new plan has been under development for two years and replaces the original plan written in 1999. The IPRC Science Plan presents key scientific questions for the IPRC and describes activities our researchers will conduct to address these questions. The focus is on issues for which substantial effort and progress are anticipated in the next five years, although activities in many areas described in the plan can be expected to continue beyond that time. The Science Plan can be downloaded from the "Research" page of the IPRC website http://iprc.soest.hawaii.edu/research/research.php.



IPRC Scientists Head Meteorology and Oceanography Departments at UH Mānoa

IPRC's **Kelvin Richards** was elected Chair of Oceanography and **Bin Wang** Chair of Meteorology at the University of Hawai'i. They began their 3-year terms on July 1, 2010.

Wang is well known in the monsoon research community through his numerous publications and for his service on international climate research boards and committees, and as editor on climate-related scientific journals. He is currently co-principal investigator of the international project "Climate Prediction and its Societal Application" to improve climate prediction for Asia. As Chair, Wang will work toward integrating climate-science research within the department and facilitating international collaboration to improve scientific understanding and prediction of changing climate in Hawai'i, the Pacific, and the global tropics.

Richards, who joined the IPRC and Department of Oceanography in 2002, is looking forward to the challenge of ensuring the smooth running of this very large department, with a faculty of over 40 and a further staff of over 40 researchers and others. He will also be busy in the next couple years with his growing observational program, participating in research cruises of JAMSTEC and KORDI and leading the new international research program "Mixing in the Equatorial Thermocline" and its partnerships with Woods Hole Oceanographic Institution, JAMSTEC, Korea Ocean Research and Development Institute, Seoul National University, and the University of Tokyo.

IPRC Postdoctoral Fellow Yu Kosaka Awarded Prestigious Prize by the MSJ

IPRC Postdoctoral Fellow **Yu Kosaka** has been awarded the Yamamoto–Shyono Medal by the Meteorological Society of Japan (MSJ) for her work on wave-like teleconnection patterns along the summertime Asian Jet. Each year the society selects two top papers written by young scientists for the award. Kosaka received the medal at the October fall meeting of the MSJ in Kyoto.

Yu Kosaka at the MSJ meeting with the Yamamoto–Shyono Diploma. Photo courtesy MSJ.

IPRC Participates in Annual Symposium of the Research Institute for Global Change

JAMSTEC's Research Institute for Global Change (RIGC) held its first Annual Symposium at Yokosuka Headquarters on April 20, 2010. In recognition of the close partnership between IPRC and RIGC scientists, JAMSTEC invited IPRC to participate in the symposium. IPRC Director **Kevin Hamilton** presented the talk "IPRC Science Highlights" and IPRC Assistant Researcher **Kazuyoshi Kikuchi** presented a poster on his research on tropical cyclone formation.

Kazuyoshi Kikuchi explains his research results to an attentive audience. Image courtesy JAMSTEC.

IPRC Director Visits JAMSTEC Headquarters

IPRC Director **Kevin Hamilton** visited JAMSTEC headquarters in Yokosuka on July 23 to meet with Executive Director **Shiro Imawaki** and **Shiro Matsugaura** of the JAMSTEC International Affairs Division. They discussed such issues as long-term JAMSTEC visitors to the IPRC, IPRC's reports to JAMSTEC, the composition of the IPRC Science Advisory Committee, and future joint JAMSTEC– IPRC science meetings.

NICAM Researchers Discuss New Simulations of Tropical Cyclones

Several participants in the JAMSTEC–IPRC collaborative analysis of results from the cutting-edge Nonhydrostatic ICosahedral Atmospheric Model (NICAM: http://www.ccsr.u-tokyo.ac.jp/~satoh/nicam/index.html) held an informal meeting on April 9, 2010, at the Atmospheric and Oceanic Research Institute (AORI) on the University of Tokyo Kashiwa Campus. Hosted by AORI faculty member **Masaki Satoh**, the meeting included IPRC's **Yuqing Wang**, who was in the middle of his sabbatical visit to AORI, JAMSTEC researchers **Kazuyoshi Oouchi** and **Yohei Yamada**, Yokohama National University faculty member (and recent IPRC postdoctoral fellow) **Hironori Fudeyasu**, and IPRC Director **Kevin Hamilton**.

The group discussed newly available NICAM integrations, including simulations by Yamada designed to study the global warming effects on tropical cyclone climatology. The discussion emphasized the need to optimize the model performance in simulating present-day mean tropical climate and variability.

Seated from left, Masaki Satoh, Kazuyoshi Oouchi, Yuqing Wang, Kevin Hamilton, Hironori Fudeyasu. Standing Yohei Yamada.

Jay McCreary Continues the IPRC - Hokkaido University Partnership

Jay McCreary was invited by **Yasushi Fukamachi**, **Humio Mitsudera,** and **Youichi Tanimoto** to give a mini-course (6 lectures) to graduate students at Hokkaido University from October 20 to 22, 2010, thereby continuing the IPRC–Hokkaido partnership in educating climate scientists. Entitled "Large-scale Coastal Dynamics," the course provided an introduction into large-scale coastal dynamics, including the processes that drive and maintain coastal circulations and cause their variability. McCreary discussed such topics as the forcing mechanisms driving coastal currents, the type of waves generated at coasts, the key differences between two-dimensional and three-dimensional models of coastal circulation, the reason for the existence of eastern-boundary currents. The lectures provided the dynamical groundwork for a seminar given to a general audience on October 22, which summarized research carried out with UH colleagues **Fabian Schloesser**, **Ryo Furue**, and **Axel Timmermann** on the dynamics of the Atlantic meridional overturning circulation.

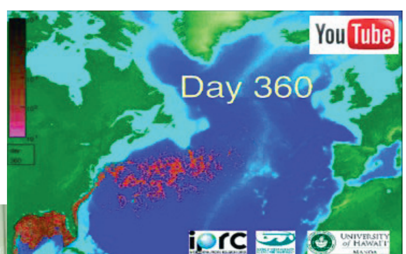
Jay McCreary during his lecture series at Hokkaido University. Image courtesy Yasushi Fukamachi, Hokkaido University

IPRC Scientists in the Media

For most of the news items in this section, there are links on the IPRC "News" page that lead to further information about the stories (http://iprc.soest.hawaii.edu/news/news.php).

Ocean Currents and Early Voyages to the Americas: IPRC Senior Researcher **Nikolai Maximenko** was featured in the History Channel program, "Who really discovered America?" The program explored several possible "discoveries" of the Americas before Christopher Columbus "staked his claim in 1492." Maximenko's work on ocean circulation provided information about ocean currents and whether they could have helped those early seafaring voyagers. The program aired several times internationally from June 2 –28.

Simulating the Spread of the Deepwater Horizon Oil Spill: IPRC's **Axel Timmermann** and **Oliver Elison Timm** together with oceanography Ph.D. student **Fabian Schloesser** studied the possible spread of oil from the Deepwater Horizon rig over the course of one year in a series of computer simulations that were based on typical ocean circulation fields obtained from a high-resolution ocean model hindcast. The scientists placed their findings on YouTube on July 8, while the oil was still flowing. In the simulation, the oil spreads initially in the Gulf of Mexico, then enters the Loop Current and the narrow Florida Current, and finally the Gulf Stream. After one year, about 20% of the particles initially released at the Deepwater Horizon site have been transported through the Straits of Florida and into the open Atlantic. The well was capped one week after the simulation was posted. Nevertheless, the site registered over 100,000 hits. You can watch the animation at http://www.youtube.com/user/SOESThawaii. Discrepancies between the projected and observed spreading of the oil spill were subsequently attributed to the fact that the ocean circulation field of summer 2010 was quite unusual. Furthermore, the posted simulations assumed a longer period of crude oil release. Neither the effects of dispersants on the surface oil concentrations nor the impact of biological weathering were included in the calculations.



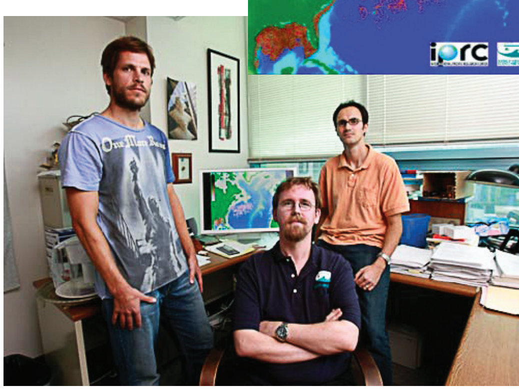


Photo of the team in the StarAdvertiser issue on July 8. From left, Schloesser, Timmermann, and Elison Timm.

Hottest Year Since Record-keeping: **H. Annamalai** was asked to comment for the July 22, 2010, issue of the Canadian *Globe and Mail* newspaper on the revelation by the U.S. National Oceanic and Atmospheric Administration that Earth was on course for the hottest year since record-keeping began in 1880.

A Shift in Pacific Tropical Cyclone Formation with Global Warming? IPRC's **Tim Li** was interviewed by *New Scientist* about his study "Global Warming Shifts Pacific Tropical Cyclone Location" published in *Geophysical Research Letters*. The study predicts that with global warming, the tropical cyclone genesis region will shift from the western towards the central Pacific. The modeling study suggests that more hurricanes could hit Hawai'i in the future. The write-up in *New Scientist* appeared in the October 1, 2010 issue.

Pacific Island Ocean Observing System: IPRC's **Jim Potemra**, acting manger of the APDRC, was a guest on the *Hawai'i Public Radio* technology show "Bytemarks Cafe" on September 8. Potemra was interviewed about his work with the Pacific Island Ocean Observing System (PacIOOS). With him on the show was **Chris Ostrander**, PacIOOS coordinator for the Hawaiian sub-region.

The North Pacific, a Global Backup Generator for Past Climate Change: **Yusuke Okazaki** from JAMSTEC, and **Axel Timmermann** from IPRC together with their international colleagues published "Deep Water Formation in the North Pacific During the Last Glacial Termination" in the July 9 issue of *Science*. The study found evidence that toward the end of the last ice age, a major reorganization took place in the current system of the North Pacific, which may have buffered the global impacts of the collapsed meridional overturning circulation in the Atlantic. The study received wide media attention. In a National Science Foundation interview, Timmermann describes in greater detail the findings (http://www.nsf.gov/news/news_summ.jsp?cntn_id=117283). **Thorsten Kiefer**, director of the international project office of Past Global Changes, wrote a detailed commentary "When Still Waters Ran Deep" on the paper in the July 27 issue of *Science*. Kiefer concludes that the paper clearly shows, "Climate scientists need to abandon their Atlantic centric view and adopt the Pacific Ocean as an active player."

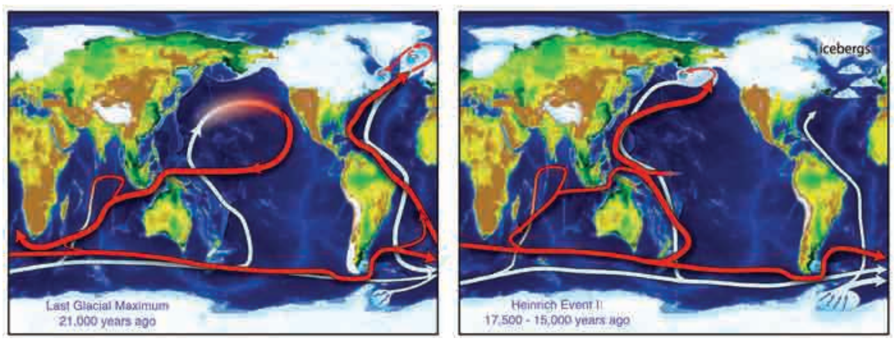
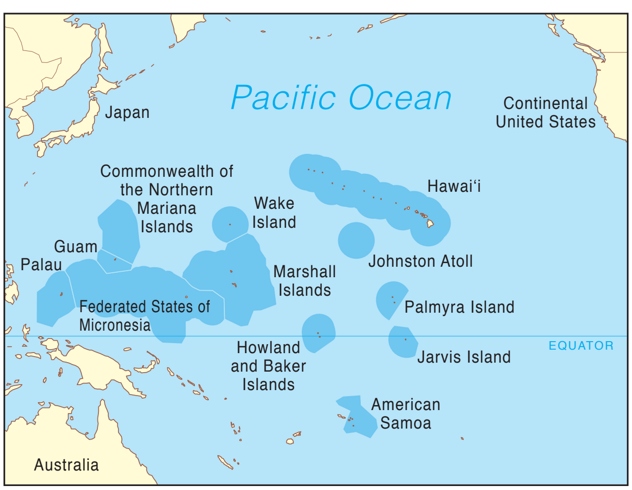


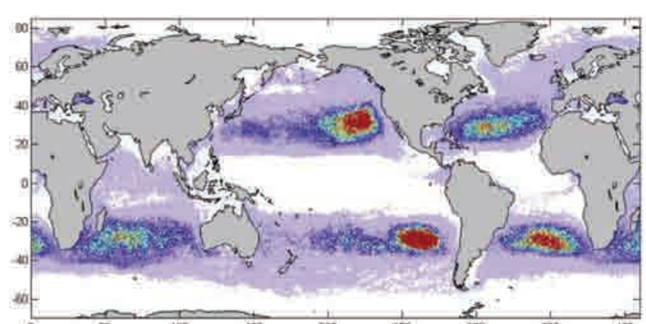
Figure of Back-up Generator. Courtesy Nancy Hulbirt.

Sea-Level Rise Will Be Worse for Some: **Axel Timmermann** was interviewed for a story on *Wired Science* that appeared in the July 16 issue about the impact of winds on sea-level rise, and which islands in the Indo-Pacific region are more threatened by sea-level rise and which less (see also *IPRC Climate*, vol. 10, no. 1). The research was published in the August issue of the *Journal of Climate*.



Map of PacIOOS region. Image courtesy PacIOOS.

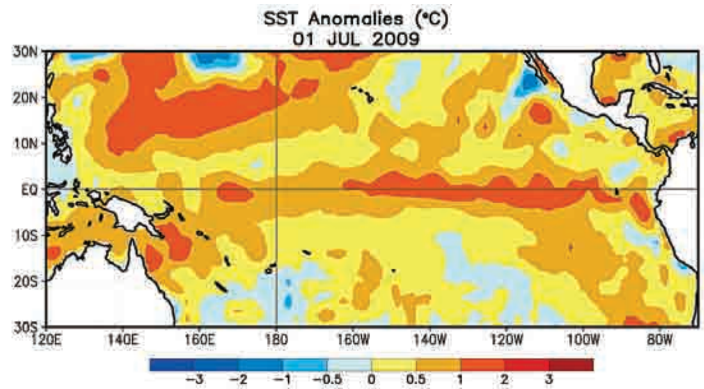
Predicting the North Atlantic Garbage Patch: **Nikolai Maximenko** co-authored the paper "Plastic Accumulation in the North Atlantic Subtropical Gyre," which appeared in the August 19 issue of *Science*. The study presented results from students, who had collected plastic pieces over 22 years at 6100 locations in the North Atlantic as part of their study in the SEA Program, which is associated with Woods Hole Oceanographic Institution. Maximenko contributed to the research through analyses with the drifter-based circulation model that he has developed. The highest concentration of plastic was found in the region predicted by the model, pointing out this model's usefulness in guiding ocean clean-ups. The research received wide media attention.



The garbage patches in Maximenko's model. Image courtesy Nikolai Maximenko.

IPRC Scientists Active in the Climate Research Community

How Will the El Niño-Southern Oscillation Respond to Global Warming?



Sea surface temperatures along the equatorial Eastern Pacific on July 1, 2009, are at least one degree above average — a sign of El Niño. Image courtesy NOAA.

IPRC's **Axel Timmermann** is a member of the Climate Variability and Predictability (CLIVAR) Pacific Panel, which published the review "The impact of global warming on tropical Pacific Climate and El Niño" in the June 2010 issue of *Nature Geoscience* (http://www.nature.com/ngeo/journal/v3/n6/full/ngeo868.html). Combining observations, theories and results from cutting-edge coupled general circulation models, the panel concluded that the tropical-subtropical Pacific climate is likely to change as follows: the easterly tradewinds to weaken further; surface ocean temperatures to warm faster near the equator than in the subtropics; the equatorial thermocline, which marks the transition between the wind-mixed upper ocean and deeper layers, to shoal; and both the north–south and east–west temperature gradients across the thermocline to become steeper. What these changes could mean for the Indo-Pacific region for rainfall patterns has been shown by IPRC's **Shang-Ping Xie** and colleagues (February 2010 issue of *Journal of Climate)*, and for sea-level rise by Axel Timmermann and colleagues (August 2010 issue of *Journal of Climate*).

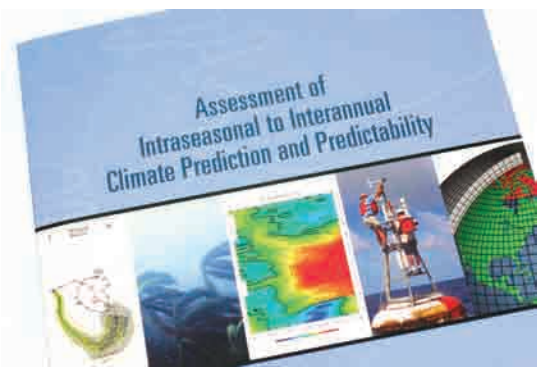
Although the review increases greatly understanding of the feedback processes contributing to the El Niño–Southern Oscillation (ENSO), the panel found no consistent response of ENSO to the projected wind and ocean-temperature changes. Projections based on past climate change are hampered by the fact that the current rapid greenhouse-gas-induced climate change has no past analogue. Ultimately ENSO may be unpredictable, concludes the panel, as these feedback processes are impacted by such (as yet) unpredictable natural events as volcanic eruptions and solar activity.

IPRC Scientists Take Part in IPCC Assessment

IPRC faculty members **Shang-Ping Xie** and **Axel Timmermann** have been appointed as lead authors on the *5th Assessment Report (AR5)* of the Intergovernmental Panel on Climate Change Working Group 1: Xie will be a lead author for the chapter "Climate Phenomena and the Relevance for Future Regional Climate Change" and Timmermann for the chapter "Information from Paleoclimate Archives." The report is scheduled to be completed in 2013.

Improving Climate Forecasts

IPRC's **Bin Wang** served on the National Academy of Sciences Committee on "Assessment of Intraseasonal to Interannual Climate Prediction and Predictability," which produced a report discussing ways to improve climate forecasts in three areas: (1) Make the forecasts more accessible to decision makers and researchers, for example, by greater exchange among operational centers and the research community and by establishing public archives. (2) Improve the tools of forecast systems by using a combination of statistical methods, dynamical models, multi-model ensemble modeling, and state-of-the art data assimilation systems. (3) Investigate further sources of predictability by conducting research on the climate impact of, for instance, the Madden–Julian Oscillation and El Niño, and their interaction; the interaction between the stratosphere and lower layers of the atmosphere; air–sea–land interactions, particularly heat and moisture exchanges; and volcanic eruptions and increasing greenhouse gases. The report was issued in September and can be downloaded from http://dels.nas.edu/Report/Assessment-Intraseasonal-Interannual-Climate/12878.



IPRC Scientists Appointed to Editorships

IPRC faculty member **Yuqing Wang** has been appointed as an editor for the *Journal of the Meteorological Society of Japan*. He will have special responsibility for papers dealing with tropical cyclones. Wang adds this new appointment to his continuing editorial duties as Associate Editor for the American Meteorological Society journal *Weather and Forecasting* and Associate Editor for *Advances in Atmospheric Science*.

IPRC Assistant Researcher **Axel Lauer** has been appointed as an editor for *Geoscientific Model Development* published by the European Geophysical Union. This journal is devoted to articles related to the development and evaluation of numerical models of the Earth System and its components.

IPRC Director **Kevin Hamilton** has been appointed as an associate editor of *Atmosphere–Ocean*, the scientific journal of the Canadian Meteorological and Oceanographic Society. Hamilton adds this appointment to his continuing service as Co-Chief Editor of the *Atmospheric and Oceanic Sciences Library* monograph series published by Springer, and service as a member of the Editorial Advisory Board of the *Journal of Advances in Modeling Earth Systems (JAMES)*. Originally published by the Institute of Global Environment and Society, starting in 2011 *JAMES* will be published by American Geophysical Union (AGU), the first outside journal to be "adopted" by the AGU.

The Future of Oceanography in Space

NASA Program Manager **Eric Lindstrom** and IPRC Senior Resarcher **Nikolai Maximenko** are editors of the December 2010 issue of *Oceanography*. It is a special issue on "The Future of Oceanography from Space," which features an overview of developments in remote sensing over the last decades. The intent of this special issue is to articulate areas of scientific inquiry that are fueling the development of next generation satellite missions and to determine the upcoming challenges in oceanography using satellites.

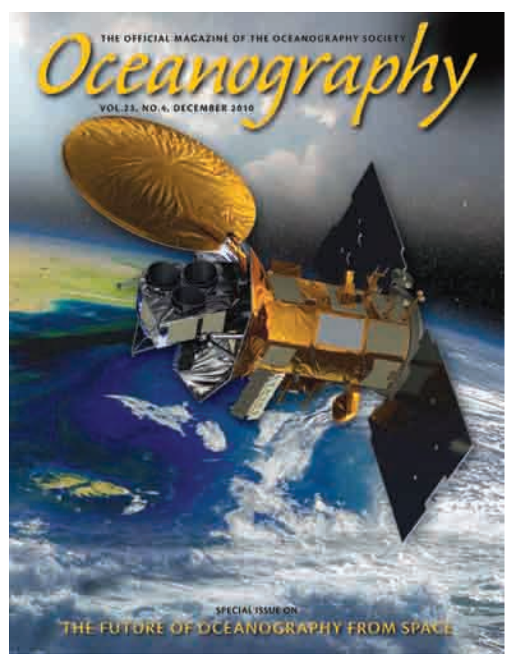


Image courtesy Oceanography Society.

The 2010 IPRC Public Lecture in Climate Science

Every year, the IPRC invites a renowned climate scientist to the University of Hawaiʻi at Mānoa to give a public lecture. This year an audience of about 150 students, faculty, and members of the general public heard the engaging and informative lecture "Changing World, Changing Ocean" presented by Dr. **Susan Avery** on November 9. Dr. Avery has had a distinguished career in atmospheric research and in scientific and educational leadership. She is currently President and Director of the Woods Hole Oceanographic Institution (WHOI) in Massachusetts, the first woman and the first atmospheric scientist to hold this prominent position in the U.S. oceanographic community.

Avery began her lecture by reviewing some basic facts about the world ocean. From a cosmic perspective, the ocean appears as just a thin skin covering parts of the earth; in fact, all the ocean's water could be collected in a sphere smaller than the moon. However, an amazing range of phenomena occurs at and beneath the ocean surface. The ocean covers mountain ranges higher than Everest, canyons deeper and grander than the Grand Canyon. The vastness of the ocean and the difficulty in directly observing below the surface mean that a great deal remains unknown. Avery noted that only two people have reached the deepest part of the ocean at the bottom of the Marianas Trench, a more exclusive "club" than even the 12 men who have walked on the moon!

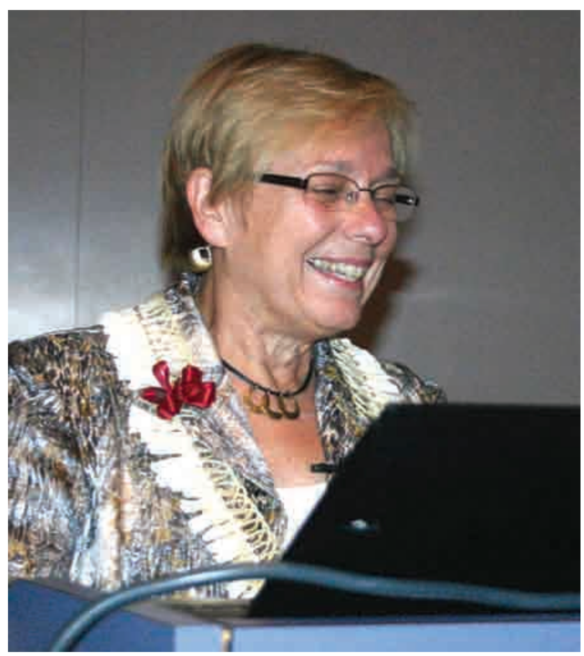
Civilization, indeed human life itself, depends on the ocean. A 1997 study estimated that the ocean and its ecosystems provide services that could conservatively be valued globally at over $20 trillion per year. Unfortunately humankind's exploitation of the ocean is becoming increasingly unsustainable. Energy companies are drilling for fossil fuels ever deeper and farther from the coast with consequent dangers of catastrophic leaks. The world's fishing fleets have expanded the geographical extent and intensity of their fishing even as there is less stock available to catch. Global stocks of high-value fish have dropped by 90 percent over the past 50 years. The ocean is also used as the final repository for much of the waste product of our civilization. A particularly serious problem is runoff of agricultural chemicals causing the formation of as many as 400 low-oxygen "dead zones" throughout the world ocean that may act to further curtail fish populations.

The enhanced greenhouse effect from accumulated air pollution is raising global air temperature. The effects are particularly apparent in the Arctic where the summer melt of sea ice has become more extensive in recent decades. The plight of large mammals such as the polar bears that depend on Arctic ice to survive has received a great deal of attention, but Avery noted that much needs to be learned about the effects on the bottom of the food chain, the algae and other microorganisms that feed the larger animals.

Shrinking sea ice is also a growing flash point for conflict among the countries claiming sovereignty over parts of the Arctic Ocean. At stake are massive reserves of oil, natural gas, and minerals, and access to vastly shortened trade routes. The melting may open a nearly pristine ecosystem to large-scale economic exploitation.

Anthropogenic emissions of CO_2 not only affect Earth's climate (and hence ocean temperature and currents) but directly impact ocean chemistry. As it dissolves in seawater, CO_2 makes the ocean more acidic. If this trend continues, we can anticipate that coral reefs may die and begin to dissolve, shelled animals at the base of the marine food chain will suffer, and marine ecosystems may be wholly reshuffled.

Sea-level changes at any location can have multiple proximate causes, but the overall warming of the ocean water and melting of glaciers and ice sheets on land are producing a global rise in sea level that will significantly impact all coasts



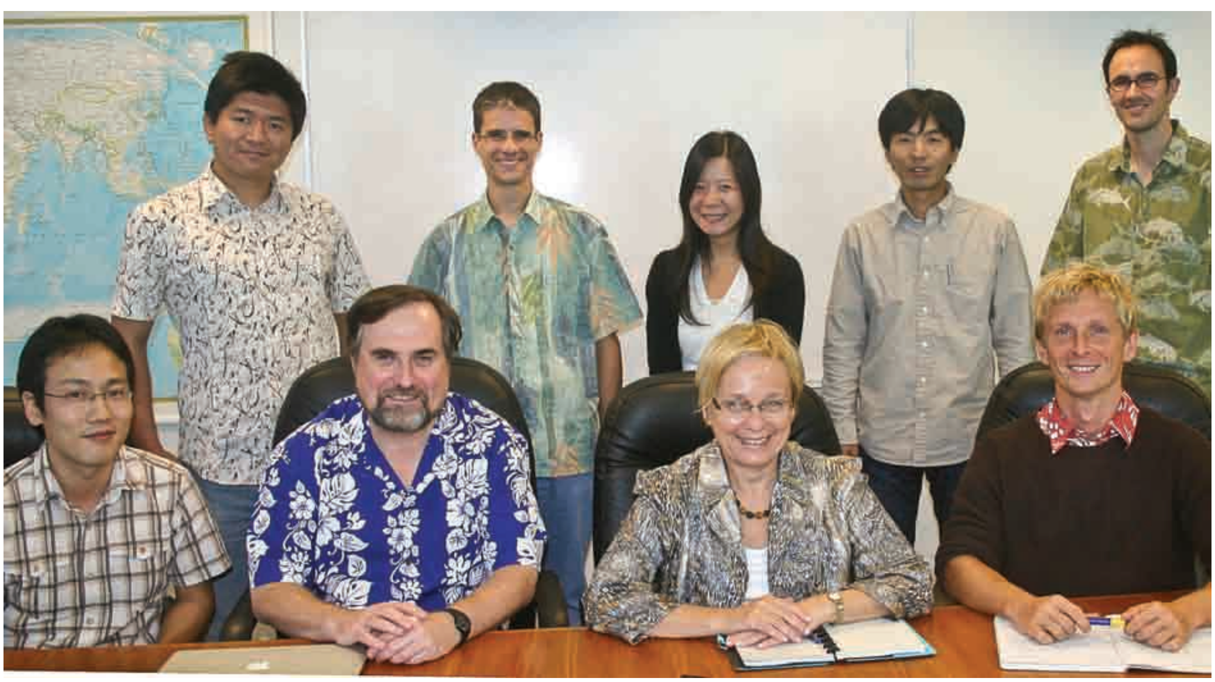
Susan Avery giving the "2010 IPRC Public Lecture." Photo courtesy Jian Ma.

over the next century. Of the world's 25 most populous cities, 22 are coastal. Wealthy countries are constructing, or at least considering, massive engineering projects to keep the waters at bay (such as the Thames Barrier built in 1982). But this is not an option for much of the world. A particularly serious case is presented by the nation of Bangladesh, which has half the population of the U.S. most of whom live near sea level. The US Department of Defense has identified climate change and sea level rise as crucial factors in the global security landscape. Avery noted, "We may be able to wall our cities from the water here in the West, but we can't separate ourselves from the rest of the world."

IPRC Director Kevin Hamilton with Susan Avery and University of Hawai'i at Mānoa Chancellor Virginia Hinshaw. Photo courtesy Jian Ma.

The last part of Avery's lecture focused on the critical role scientific research must play in meeting the many challenges posed by our interactions with the global ocean and the climate system in general. Concentrating on recent advances at WHOI, Avery showed that a new age of ocean exploration and monitoring has been opened by recent developments in autonomous vehicles with new sensors to measure physical, chemical, and biological properties. Avery concluded her lecture by showing how the WHOI expertise obtained in studying the environment around hydrothermal vents in the ocean floor was applied to support the response to last spring's Deepwater Horizon blowout and oil leak in the Gulf of Mexico.

The IPRC looks forward to continuing this high-profile contribution to public outreach efforts in Hawai'i by bringing a world-renowned scientist to the Mānoa campus each year to present the annual "IPRC Public Lecture in Climate Science."



Susan Avery with Kevin Hamilton meet with some of IPRC's younger scientists.

Expedition to Kamilo Beach, the "Dirtiest Beach on Earth"

Five large garbage patches in the world ocean are predicted by **Nikolai Maximenko's** surface current model (*IPRC Climate*, vol. 8, no. 2). The North Atlantic and North Pacific patches have already been found and are making news.

The debris from the North Pacific Patch occasionally escapes and the model shows it floats towards the Hawaiian Islands, making windward shores of the islands trashcans for marine debris. Kamilo Beach near South Point on the Big Island is arguably the most famous beach for the enormous amount of marine debris sweeping up on it. A BBC video labeled it as "The Dirtiest Beach in the World." The beach is unusual, however, in that it lies not on the windward side of the island, but at its southern tip.

Curious about why this beach is so favored by marine garbage and what currents take it to this unusual location, Maximenko put together a team to investigate: Assistant Visiting Researcher **Oleg Melnichenko** took the lead in deploying current meters in the surf to determine the impact of currents, Scientific Computer Progammer **Jan Hafner** took charge of documenting the garbage and collecting samples, and undergraduate marine biology student **Jeremy Soares** was the "above-and-below-water" movie camera man.

The expedition took place in early June 2010. "We had prepared well, but everything turned out differently from what we had pictured in the IPRC conference room," recollects Melnichenko. Already finding the way to Kamilo Beach was an adventure with so many unmarked rough little dirt roads.

"Without **Bill Gilmartin** as our guide, we might still be wandering around the lava," says Maximenko.

Gilmartin, Director of Research from the Hawai'i Wildlife Fund, has been leading clean ups of the beach since 2003, and over 100 tons of marine debris have been removed. Hafner was surprised by how clean the beach looked: "I was maybe a little disappointed, as our mission was to explore the garbage on Kamilo, though of course it is better this way."

The largest piece of debris they saw was a 4-foot long tree trunk. Objects that typically litter the windward Hawai'i beaches were there: Hagfish trap cones from the Pacific Northwest and oyster spacer tubes from East Asia. "The typical size of the debris, however, was 1 inch or smaller," said Hafner.

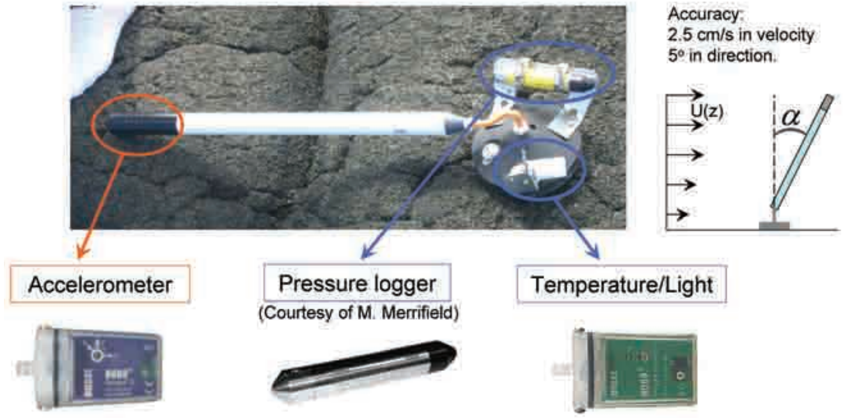
Setting the current meters was a challenge. The surf breaks far out, rolling in over a long rocky distance to shore. So the meters had to be put in place during fairly strong waves. "The meters were too heavy for us to swim with them; so we crawled, pushing them forward and coming up for deep breaths," said Melnichenko.

Kamilo Beach as it was several years ago, before the regular clean-up efforts. Image courtesy Mrs. Soares. Red dot in satellite-picture inset shows location of Kamilo Beach.

The pilot deployment showed the meters were feasible. Although "the environment is hostile" for the meters with waves pounding them ceaselessly, they held. Melnichenko: "Their design is simple and they are inexpensive. We were surprised how well they worked. With an accelerometer and with pressure, temperature and light sensors, they are flexible and can be deployed over uncharted ocean topography. You can move them readily if you want to redesign your experiment, for instance place, them in a line straight out from the beach, or along the beach. No drilling is needed so there is no harm to the environment. And they give instant data. The two days the meters stayed, we collected data that showed the daily cycle, the impact of waves and tides, and lower frequency variations of the currents."

"We are still unclear about the current pattern that brings marine trash to this unusual southwest location. the picture is very complex; the meters are responding to many different things," explained Melnichenko.

"Our exploration brought us no answers but inspired more questions and speculations," said Maximenko. "We confirmed that some debris on Kamilo Beach has travelled in the Pacific subtropical gyre from far away East Asia and from the North American West Coast. The current meters tell us that the waves and the tides provide the energy, pushing the debris to shore like a broom. The rather long shore break may contribute to debris accumulation. But, we still need to understand the interaction between large-scale currents collecting debris from the entire North Pacific and the coastal dynamics that move the debris over the reef."

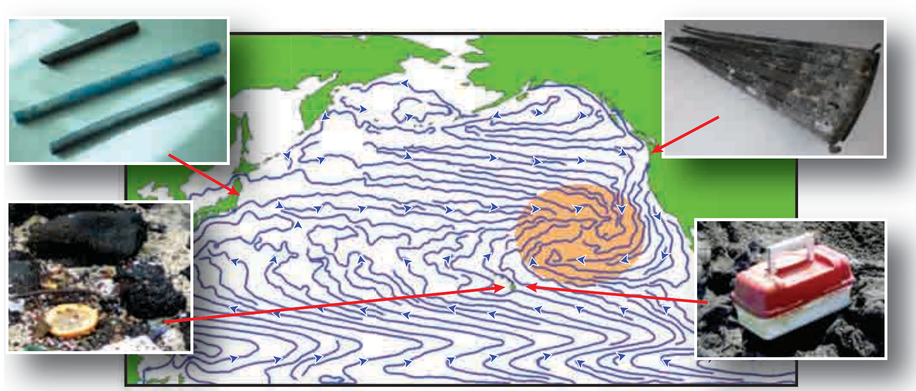


SeaHorse tilt current meter developed by Vitalii Sheremet from the University of Rhode Island. While in the water, a buoyant plastic pipe containing an accelerometer is anchored vertically to the sea floor. Currents cause the pipe to tilt. The angle of the tilt, measured by the accelerometer, is converted into velocity of the current. Additionally, temperature and pressure sensors are attached to the current meter's anchor.

"I'm particularly curious about what happens over time to the plastic, how the small pieces form. The fragments have no sharp edges. Does the plastic dissolve? This could account for the puzzling results of our recent *Science* study with **Kara Lavender Law** on the North Atlantic Patch, which found no increase in plastic density over the decades, even though plastic production increased a lot during that time. If plastic dissolves, does it release CO_2 and contribute to ocean acidity?"

"We need chemists and we need unified global observations to tackle this marine debris problem," Maximenko thinks. "Much is being done, but efforts are so varied that scientifically usable data has not yet been collected."

In conjunction with the "5th International Marine Debris Conference" to be held in Honolulu in March 2011, Maximenko is organizing the "Hydrodynamics of Marine Debris Workshop" to try to generate a more unified and scientific approach to this huge problem facing our oceans and the life in it.



Map showing the actual "mean trajectories of surface drifters" (blue lines with arrows) and the convergence associated with the garbage patch (in orange). The origins of objects found on Kamilo Beach are also shown: oyster spacer tubes from Asia, Hagfish trap cones from the US West Coast, and items from waters around the Big Island.

IPRC Helps Develop a Climate Forecast Tool for Rice Crop Yield

Rice spikelets. Image courtesy TNAU.

IPRC's Senior Researcher **H. Annamalai** continues to work with ClimaRice, the Indian – Norwegian – IPRC project that aims for sustainable rice production amidst changing climate in the Cauvery River basin of Tamil Nadu in India. Annamalai explains, "The project has the ambitious goal of forecasting the impacts of climate change on crop yield and on the economy in the rice bowl region of the Cauvery River Basin. A major stumbling block, however, is that there are no climate projections available yet for the region."

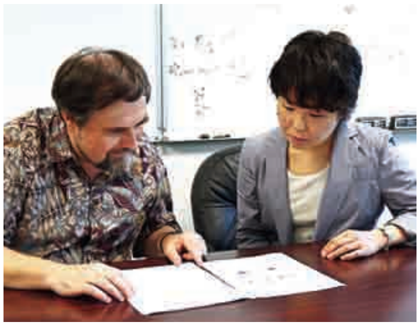
To develop such a forecasting system, the project is sponsoring **Senthilnathan Samiappan**, assistant professor of agricultural economics at Tamil Nadu Agricultural University (TNAU), for a year-long visit to the IPRC that began in August 2010. He is working with Annamalai on downscaling the outputs from the models used in the Fourth Report of the Intergovernmental Panel on Climate Change in order to drive the high-resolution IPRC Regional Atmospheric Model (iRAM), which first needs to be adapted to the Cauvery River Basin. The downscaled climate-warming data will then be fed to the crop model InfoCrop/DSSAT to see the effect of climate change on crop yield.

"Before I can use the models for forecasting, however, I need to validate both iRAM and the crop model for the region," says Samiappan. "I plan to use historical data over the last 40 years to see how well the temperature and rainfall changes in iRAM and the crop-model yields compare with actual climate indicators and crop yields during that time."

Once the 'hindcasts' capture past events, the iRAM and crop model can be run into the future with various IPCC climate-change scenarios to see how the projected climate changes could affect crop yield. "I am especially interested in seeing how years of droughts and floods impact crop yields," notes Samiappan. "The final step is to use the crop yield results from the forecasts to run an agro-economic model to see the socioeconomic impacts of climate change on agriculture. But that is still a long way off."

Samiappan is an excellent choice for this demanding work. His doctoral research dealt with the impact of climate change on crop yields and economics, and he comes from a farming family in Tamil Nadu. His father has noticed the changes in rainfall over the many years he has been farming. Rain comes later in the summer and there is less of it!

Rice transplanting. Image courtesy TNAU.

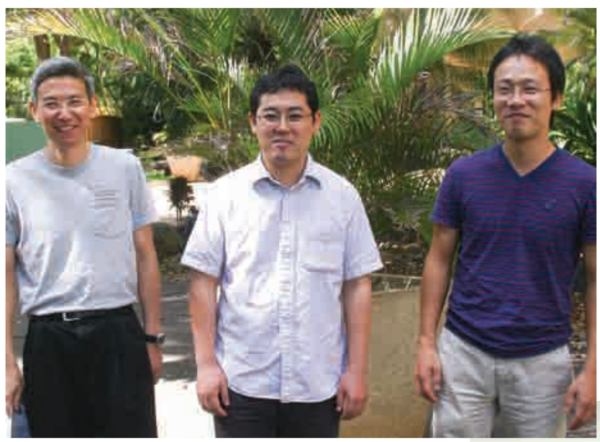


Kevin Hamilton with Ayumi Fujisaki.

A 2009 Ph.D. graduate of the University of Tokyo Department of Environmental and Ocean Engineering, and postdoctoral fellow at Princeton University Atmospheric and Oceanic Sciences Program, Fujisaki visited the IPRC in June. She presented the seminar "Determinative factor of sea ice variability in the Sea of Okhotsk based on a high resolution ice-ocean coupled model." She has now moved on to a research position at the NOAA Great Lakes Environmental Research Laboratory in Michigan.

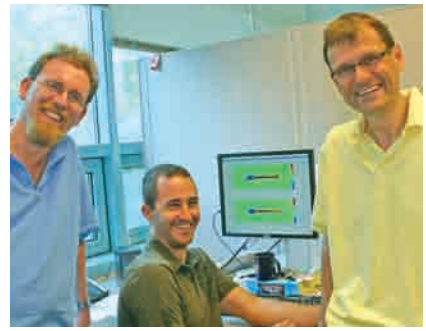
Takatoshi Sakazaki with Kevin Hamilton.

Sakazaki, a Ph.D. student in the Department of Earth Sciences at Hokkaido University, visited in August. He is studying aspects of diurnal variations in wind. Applying observations from the dense network of Japanese automated surface stations and profilers, along with the MU radar at Shigaraki, he determined that the spatial climatalogical daily cycle of the surface wind depends on relatively small scales. He also showed that the standard reanalysis products capture reasonably well the observed diurnal cycle of stratospheric winds. Sakazaki reported on his work in the IPRC seminar "Diurnal variations in the troposphere and stratosphere." During his visit, he discussed with Hamilton ways to determine better the global-scale tidal oscillations of the atmosphere.



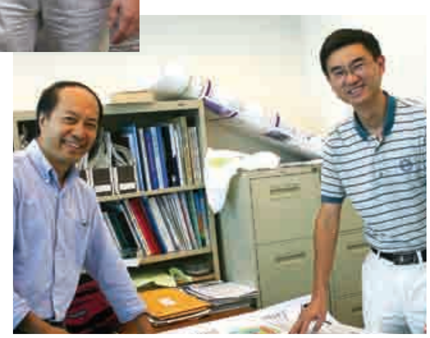
Kazuhiro Oshima (center) with IPRC's Shang-Ping Xie and Hiroki Tokinaga.

Oshima is a postdoctoral fellow at Hokkaido University working with **Youichi Tanimoto**. He is particularly interested in studying how the Pacific Decadal Oscillation responds to global warming. During his visit in October, he gave a joint IPRC–Meteorology seminar, "The response of North Pacific climate to global warming based on CMIP3 multi-model projections."



IPRC's Axel Timmermann and Shayne McGregor with Stephan Lorenz.

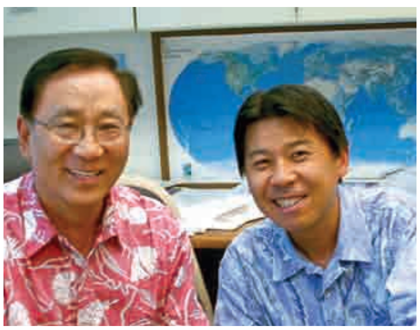
Lorenz from the Max Planck Institute for Meteorology in Hamburg, visited in April 2010 just during the eruption of Eyjafjallajokull in Iceland. Thus the seminar he gave was very timely: "Climate impact of volcanic eruptions in ensemble simulations of the last millennium using the COSMOS model." Lorenz is working with Timmermann and McGregor on modeling the climatic effects of volcanic eruptions.



IPRC's Tangdong Qu with Shan Gao.

Gao, a former IPRC postdoctoral fellow and now associate researcher at the Institute of Oceanology in Qingdao, returned to the IPRC for a two-week visit in September to work with Qu on a project in support of NASA's "Ocean

Salinity Field Campaign and the Salinity Processes in the Upper-Ocean Regional Study" (SPURS). Their work will provide a detailed salinity budget analysis from a global GCM. Results may help to understand processes that maintain and modulate the sea-surface-salinity maximum in the subtropical North Atlantic, and thereby provide useful hints for the design and analysis of observations from SPURS. Preliminary results were presented at the NASA Aquarius/SAC-D Science Team Meeting in July in Seattle and at the IPRC mini-symposium "Ocean Salinity and the Global Water Cycle."



IPRC's Bin Wang with Tomohiko Tomita.

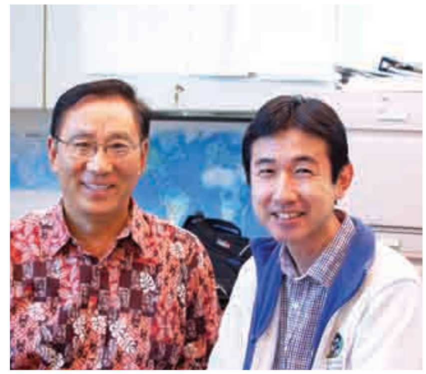
Tomita, one of the very first scientists at the IPRC (1997–2001), returned for a visit in August 2010. Now a professor at Kumamoto University, Tomita and his graduate student **Tsuyoshi Yamaura** stayed for over a month to discuss with Wang and others at the IPRC his work on the interannual variability of the East Asian summer monsoon. Tomita, who gave the joint IPRC–Meteorology Department seminar "Interannual Variability in the Baiu Front," is interested in the multi-scale atmospheric interactions during the Meiu-Baiu rainband and how they contribute to interannual variability and severe rain events. Meiu-Baiu-related rainfall is a major source of freshwater in the warm season.

Hsin-Chien Liang with IPRC's Yuqing Wang.

Hsin-Chien Liang from National Taiwan Normal University visited the IPRC for one month in September to learn about the IPRC Regional Atmospheric Model (iRAM). Liang is working with Professor **Cheng-Da Chen** on developing seasonal tropical cyclone prediction capability for the western North Pacific using a regional climate model. Since iRAM simulates realistically the interannual variability of tropical cyclones in that region, Chen plans to use iRAM for this project.

Carsten Eden and Tanja Mildner flanked by IPRC's Oliver Timm and Axel Timmermann.

Eden, Professor of Theoretical Oceanography at the University of Hamburg, visited the IPRC in November and gave the seminar "A dynamically consistent closure for zonally averaged ocean models." He was accompanied by his Ph.D. student Tanja Mildner, who was here for an extended visit to conduct research on the Last Glacial Maximum with Timmermann and Timm. Mildner presented the discussion "Impact of Last Glacial Maximum sea-level and surface-forcing changes on heat and freshwater transports in the Gulf of Mexico in an eddy-permitting ocean model."



IPRC's Bin Wang with Hisayuki Kubota.

Kubota, a scientist at JAMSTEC's Research Institute for Global Change, visited for 3 months this fall to work with Wang on their project on historical typhoons in the western North Pacific. Three years ago, Kubota had discovered in the University of Hawai'i Hamilton Library the *Monthly Bulletins of the Philippine Weather Bureau from 1901-1940*, which reported the station data in the Philippines and the typhoon tracks over the western North Pacific. Now he is expanding the data base on seasonal typhoon and non-typhoon rainfall climatology and their interannual variability, which he is developing for this region, all the way back to 1900. The *Bulletins* will provide data for this 100-year historical analysis.

IPRC Welcomes New Postdoctoral Fellows

Ali Reda Bel Madani
PhD 2009, Physical Oceanography
LEGOS, Université Paul Sabatier, France
IPRC Mentor: Nikolai Maximenko

Prasamsa Singh
PhD 2009, Environmental Sciences
Nagoya University, Japan
IPRC Mentor: H. Annamalai

Miho Ishizu
PhD 2007, Physical Oceanography
Tokyo University of Fisheries, Japan
IPRC Mentor: Kelvin Richards

Hiroshi Taniguchi
PhD 2004, Meteorology
Hokkaido University, Japan
IPRC Mentor: Bin Wang

Malte Heinemann
PhD 2009, Oceanography
Int'l. Max Planck Research School
on Earth System Modelling, Germany
IPRC Mentor: Axel Timmermann

Yoo-Bin Yhang
PhD 2010, Atmospheric Science
Yonsei University, Korea
IPRC Mentor: Yuqing Wang

Pallav Ray
PhD 2008, Meteorology
Rosenstiel School of
Marine & Atmos. Sciences
University of Miami
IPRC Mentor: Tim Li

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