

iprc climate

Vol. 10, No. 1, 2010

Newsletter of the International Pacific Research Center

*The center for the study of climate in Asia and the Pacific
at the University of Hawai'i*





Cover: Pacific Surf

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School of Ocean and Earth Science and Technology

Patterns of Regional Climate Change



Comprehensive global climate models predict that global average surface temperature will rise by about 1°C over the first 50 years of the present century if the global emissions of pollutants continue to grow in a "business as usual" economic and regulatory environment. Any practical effects of the anticipated climate change, however, will depend on the geographical distribution of the warming and other associated changes, particularly changes in precipitation.

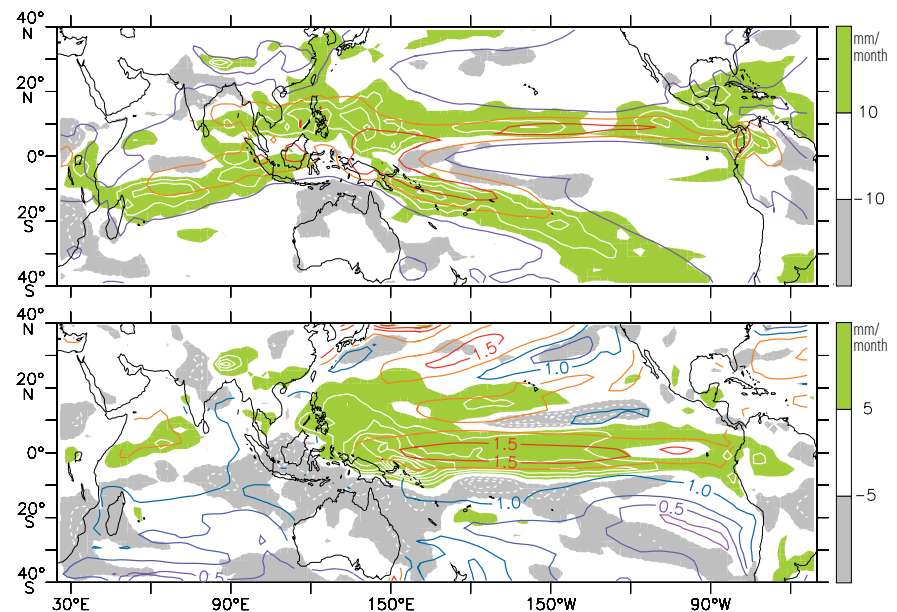
A group of researchers, led by IPRC meteorology professor **Shang-Ping Xie** and including collaborators at NOAA's

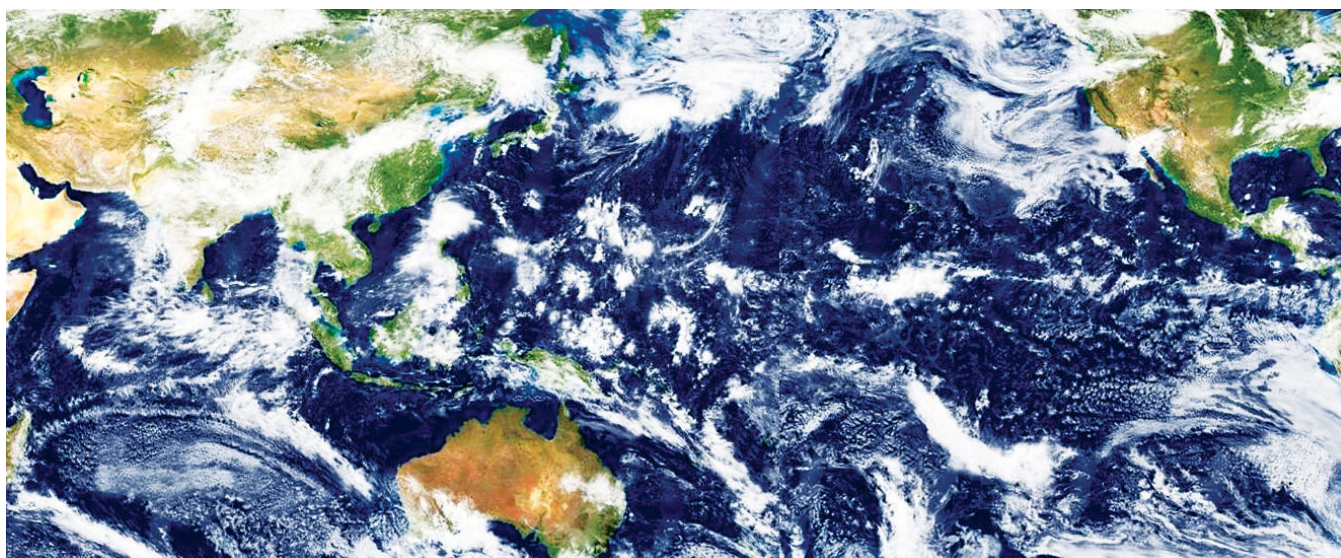
Geophysical Fluid Dynamics Laboratory (GFDL) and the National Center for Atmospheric Research (NCAR), has made important progress in identifying and explaining the robust large-scale regional patterns of climate change seen in global model projections.

For their study, they performed ensemble simulations with both the GFDL CM2.1 and NCAR CCSM3 global climate models. The runs covered roughly the first half of the 21st century and assumed a moderate-growth scenario for greenhouse gas emissions. The 50-year changes in the simulations were analyzed.

Some of the team's key findings relate to regional changes in rainfall in response to the warming. A popular interpretation of such rainfall changes assumes spatially uniform warming and no circulation changes. This assumption results in a zero-order effect of just increasing atmospheric absolute humidity in accordance with the warming, magnifying present-day values of atmospheric moisture convergence and divergence. This leads to a tendency for present-day wet regions to get wetter and dry regions to get drier (Figure 1, top panel).

Figure 1. Annual-mean projected precipitation change (in mm/month: green/gray shade and white contours. Note different contour intervals in the two panels). Top: AM2.1 simulation run with a uniform 2°C sea surface temperature (SST) increase; color contours represent present-day climatological rainfall [100 (purple), 200 (orange), and 300 (red) mm/month]. Bottom: CM2.1 A1B ensemble mean, featuring spatial patterns of SST (color contour interval = 0.25°C). Top panel shows greatest projected rainfall increase (green areas) for currently the wettest regions; bottom panel shows greatest projected increase in rainfall for regions with the largest projected mean increase in SST.





Cloud patterns over the Indo-Pacific region. Source: a rearranged image of “blue marble” stitched together from months of satellite observations by NASA Goddard Space Flight Center.

Xie and his colleagues show that this view has to be significantly modified in order to explain the actual changes seen for low-latitude regions in the warming simulations. In particular the geographical patterns of rainfall changes in the tropics and subtropics are strongly affected by modification in the low-level winds, which themselves are strongly linked to the gradients in the surface warming.

Xie found that the predicted geographical variations in surface warming are large. In fact, the difference between surface-temperature rise in locations with the least and the greatest warming in the tropics exceeds the magnitude of the mean tropical warming. Broadly speaking, Xie noted that regions with the greatest warming would become wetter, while those with little surface warming would become drier.

The influence of the spatial patterns of warming is evident in Figure 1, which compares the annual-mean rainfall change simulated in response

to a uniform 2°C increase in sea surface temperature (top), and the change in the GFDL coupled model run that includes the spatial pattern in ocean warming (bottom).

Xie and his colleagues identified several characteristic regional patterns of warming and rainfall change in the simulations. First, the maximum sea surface temperature (SST) rise in the Pacific is along a broad band at the equator. This broad band of peak warming alters the atmospheric heating in the models significantly and anchors a rainband analogous to that occurring during an El Niño. The reasons for the broad band of maximum surface warming along the equatorial Pacific are present-day weaker winds, lower SST, and higher humidity along the equator, which render evaporation less efficient there than in the subtropics. Since evaporation is the major means by which the ocean balances heating due to greenhouse gases, the ocean surface in the equatorial region

will warm more than in the subtropics.

The subtropical oceans in the Northern and the Southern Hemisphere warm asymmetrically in response to the climate forcing. The north warms on average by 0.5°C more than the south. This asymmetry seems to be mostly the result of changes in the winds (Figure 2). The northeast trades weaken, leading to a warming of over 1°C in the Northern Hemisphere. The southeast trades in all three ocean basins, on the other hand, intensify, leading to cooling by evaporation and by mixing of cooler water from below, which keeps the warming below 1°C.

The stronger South Pacific trades create a cool patch in the southeastern corner that stretches westward and equatorward. The annual rainfall over the cool patch is projected to decrease compared to present-day rainfall. This means that Tahiti could get less rain in the future even though it lies beneath the South Pacific convergence zone. On the other side of the equator, the

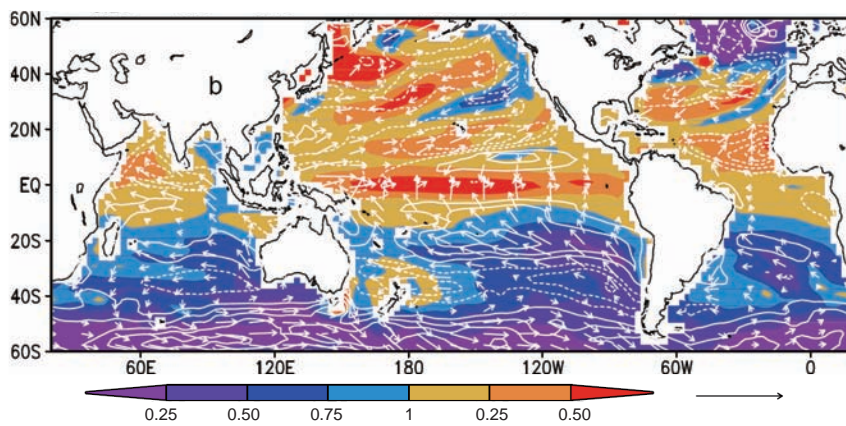


Figure 2. Annual-mean changes in CM2.1 A1B: SST (color; °C) and surface wind velocity (m/s), along with scalar wind speed (contour interval=0.1 m/s). Zero contour is omitted for clarity.

warmer tropical-subtropical North Pacific could get more rain than today (Figure 1, bottom panel).

A third ocean warming pattern noted by Xie and his colleagues results in rainfall changes in the Indian Ocean and would affect the lives of billions of people. The tropical Indian Ocean generally becomes warmer, the warming in the models reaching 1.25°C from December to June. Overlaid on this average warming, is a yearly pattern during July–November that is similar

to the present-day, rather infrequent Indian Ocean Dipole pattern. That is, model warming in the western Indian Ocean is amplified, reaching 1.5°C, while in the eastern Indian Ocean it reaches only around 0.5°C. This pattern emerges because strong easterly winds bring cold thermocline water to the surface off the Indonesian coast and pushes the warm equatorial water westward (Figure 3).

The projected Indian Ocean Dipole pattern can be expected to dramati-

cally shift rainfall over eastern Africa, India, and Southeast Asia. Indonesia and Australia could be more prone to drought, whereas parts of India and regions of Africa bordering the Arabian Sea could get more rain than today.

After publication in the *Journal of Climate*, this work attracted a commentary in the News and Views section of *Nature Geoscience* by University of Miami climate scientist **Amy Clement** and her colleagues: "The study by Xie and his colleagues lays the groundwork for increasing confidence in the pattern of projected tropical and subtropical ocean warming over the twenty-first century... Warming can have an immediate impact on local ecosystems, and coral reef ecosystems provide a poignant example of this."

This story is based on:

S.-P. Xie, C. Deser, G.A. Vecchi, J. Ma, H. Teng, and A.T. Wittenberg, 2010: Global warming pattern formation: Sea surface temperature and rainfall. *J. Climate*, **23**, 966–986. IPRC-632.

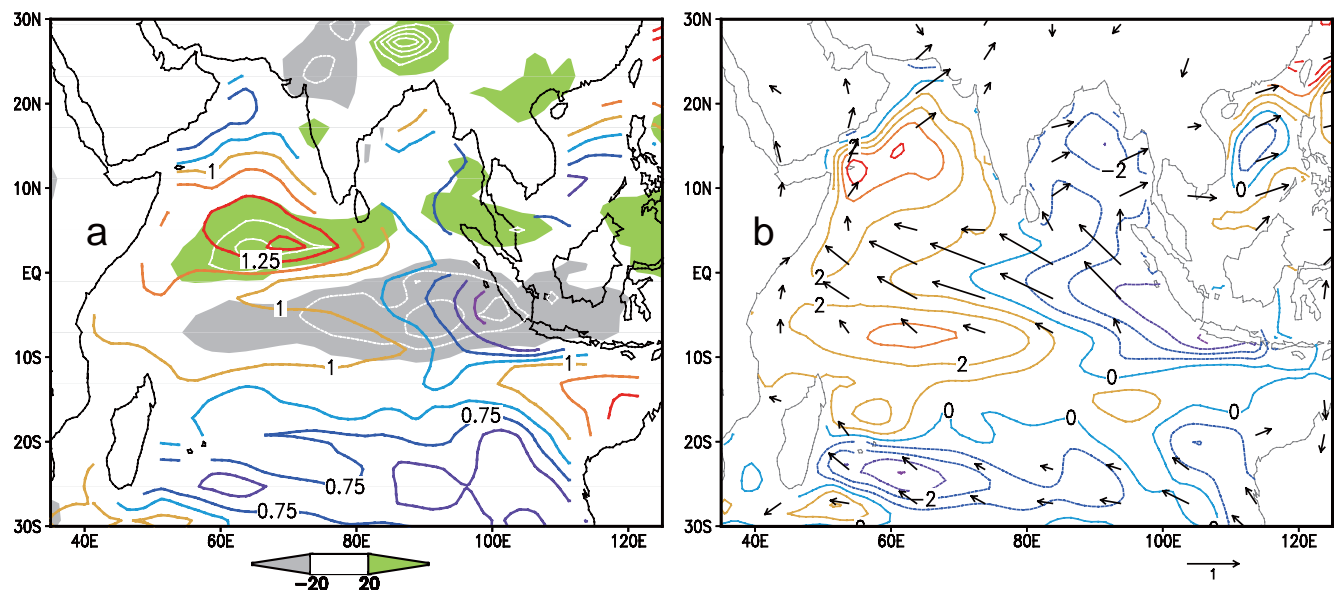


Figure 3. August–October changes in CM2.1 A1B: (a) SST (color contour interval=0.125°C) and precipitation (green/gray shade and white contours at intervals of 20 mm/month) and (b) sea surface height (contour interval=1 cm) and surface wind velocity (m/s).

Rising Seas and the Winds

If sea-level trends continue, low-lying coastal areas and low islands are seriously threatened with flooding. Sea level has been rising at a rate of over 3 mm per year and, disturbingly, most recent observations suggest the rate is accelerating. The trend, however, has not been uniform across the world ocean, and some areas in the western tropical Pacific have already seen the sea rising by about 10 mm per year.

According to recent work by Axel Timmermann and Shayne McGregor at the IPRC and Fei-Fei Jin at the University of Hawai'i, the sea-level trends seen over the last 40 years in the tropical Indo-Pacific are due not only to the expansion of warming oceans and freshwater input from melting glaciers and ice sheets but also to changes in the prevailing winds. Indeed, they found that the winds play a key role in establishing the spatial characteristic of regional sea-level rise in the Pacific. In some regions the changing winds partly offset, in others they amplify the rise projected with further warming.

The team started their investigation of sea-level trends with a 1½-layer shallow water model of the Indo-Pacific Ocean. The top layer in the model responds to wind stress, while the bottom layer is assumed to be motionless and deep. With this model, they carried out two hindcast experiments of sea-level rise: in one, the shallow water model was driven with wind stress for the 1958–2001 period from the ERA-40 Re-analysis (European Centre for Medium-Range Weather Forecasts 40-Year Re-analysis) Data Archive; in the other, the model was driven with an operational wind product (also from the European Centre for Medium-Range Weather Forecasts) for the 1993–2008 period.

Both hindcasts captured the yearly variations and the decadal trends in sea level seen in actual sea-level satellite altimetry observations from AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic Data) as shown



in Figure 1a–d. The hindcasts also captured the redistribution of water mass in the equatorial band: over the last 40 years, sea level fell in the western and rose in the eastern equatorial Pacific as a result of a slow-down of the Walker Circulation, the atmospheric east-west circulation in the tropics. The slow-down is presumably a response to global warming.

Having confidence in the performance of their shallow water model, the team then looked at how their model responded to projections in wind stress due to global warming. They drove their model with the wind stress projections from 14 global climate models that had been run for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. These models had been driven with two increasing greenhouse gas emission scenarios from 2001 to 2100: the A1B scenario, that is, a world of rapid economic growth with a balanced emphasis on all energy sources; and the B1 scenario, which assumes a world with some regulation to reduce manmade greenhouse gas emissions. In these climate model simulations, the southeasterly trades intensify over the 100 years of the study. Further experimentation showed that the strengthening of the trades in the South Pacific results from the geographic pattern of sea-surface warming, the strongest warming being simulated along the equator (see *Regional Climate Patterns*, p. 3).

Driven with these stronger winds, the shallow water model reveals that sea-level rise due to global warming is

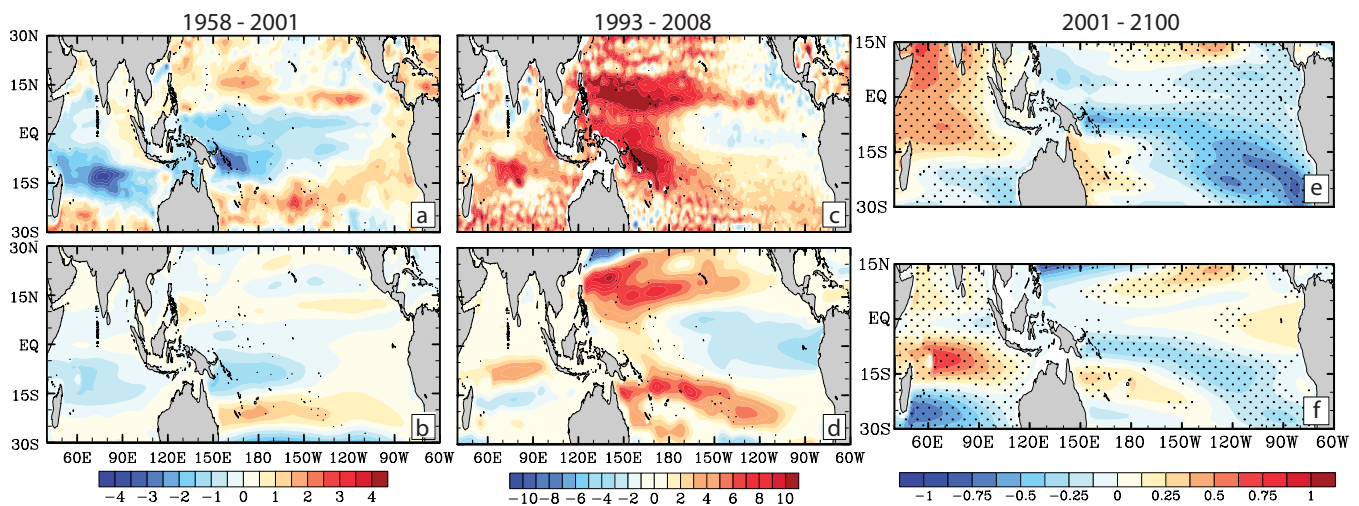


Figure 1. Linear sea-surface height trends in mm/year: for 1958–2001 (a) in ocean re-analysis data and (b) as simulated by the shallow water model forced by ERA40 winds; for 1993–2008 (c) in satellite altimeter-data and (d) as simulated by the shallow water model forced by ECMWF operational winds; for 2001–2100 (e) as derived from a 14-member ensemble of coupled GCM simulations forced with greenhouse gas concentrations following the A1B emission scenario (where the Indo-Pacific spatial average between 30°S–30°N has been subtracted and stippled areas indicate high agreement among models); and (f) as simulated by the shallow water model forced by wind from the A1B multi-model coupled GCM ensemble (again, stippled areas indicate high agreement among models).

offset by about 0.5 mm per year in large areas of the tropical South Pacific, including the tropical Islands of Tuvalu, parts of French Polynesia, Kiribati, the Cook Islands and the Solomon Islands. But in other regions, the stronger trades amplify sea-level rise. Thus south of the Solomon Islands, in Vanuatu, Fiji and the Indian Ocean between 5°S and 15°S, the shallow water model projects sea level will rise even more than the global sea-level rise due to warming. The model shows similar trends for the two greenhouse gas emission scenarios, but effects are stronger for the A1B scenario, than for the B1 scenario.

The large-scale features of the sea-level trends seen in the shallow water model are in agreement with projections of sea level from 10 of the century-long climate simulations (Figure 1e and f; not all 14 climate models had archived sea-

level data that could be analyzed).

Thus for the Solomon Islands, the threat of being flooded may not be quite as serious as has been thought. For Tuvalu, already being inundated often, the findings hold only little hope as the offset in sea-level rise by wind-stress changes is only 10 – 30% of the projected global-mean sea-level rise.

Timmermann and his team caution, “The models may not have simulated exactly right the spatial characteristics of warming signal. Much more work needs to be done before we can be fully confident in local projections due to global warming.”

This story is based on

A. Timmermann, S. McGregor, and F.-F. Jin: Wind effects on past and future regional sea-level trends in the southern Indo-Pacific. *J. Climate*, in press.



Funafuti Atoll, Tuvalu. Photo credit Bruce Richmond, USGS

Kuroshio's Impact on Fog, Clouds, and Storms

Satellite monitoring of weather systems over the vast oceans has greatly changed scientists' view of the ocean's impact on weather and climate in the extratropics. Rather than passively reacting to winds, major ocean currents are now thought to be anchors of extratropical storm tracks. Thus the 2008 study, published in *Nature* and spearheaded by IPRC's Japanese colleague **Shoshiro Minobe** at Hokkaido University, found that the sharp temperature front created by the warm Gulf Stream as it flows northward in the cold North Atlantic leads to winds converging and a vertical pathway by which the warm, moist air over the Gulf Stream rises into the free troposphere. There, in the free troposphere, the strong heating gives rise to storms and generates planetary waves that can impact climate over Europe.

Similar to the Gulf Stream, the Kuroshio, flowing northeast past Japan, and its eastward Extension transport huge amounts of tropical warm water northeastward. And, similar to the Gulf Stream, warm, moist air rises high into the mid- to upper-troposphere, leading to deep clouds over the course of the Kuroshio and the Kuroshio Extension. But the winds over the Kuroshio blow very differently in summer than in winter (Figure 1), giving rise to very different cloud formations in summer and winter, according to a recent observational study headed by Visiting Assistant Researcher **Hiroki Tokinaga** at the IPRC.

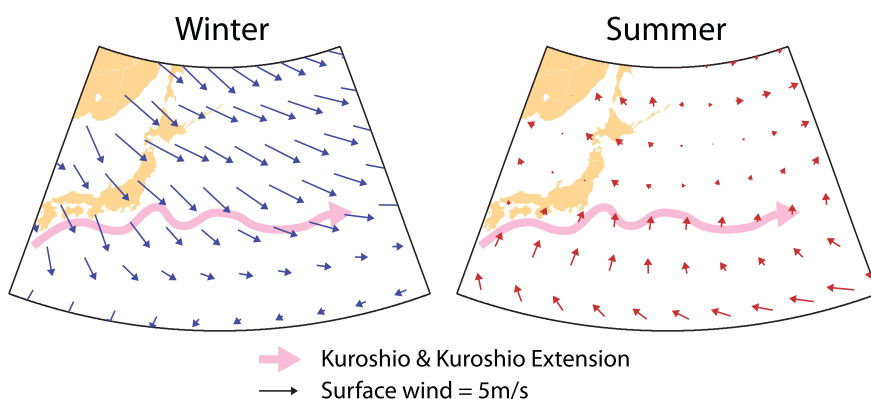
Tokinaga and his colleagues analyzed extensive observational data bases. Measurements taken from the JAMSTEC Research Vessel *Mirai* included sea surface temperature, sur-



face air temperature, the height of the cloud base, and ocean current velocity. A total of 561 radiosonde soundings over the northwest Pacific taken from several research vessels provided information for the structure of the marine atmospheric boundary layer, the lowest 1-1.5 km layer of the atmosphere over the ocean. The International Comprehensive Ocean-Atmosphere Data Set yielded long-term surface meteorological measurements and weather information. Furthermore, from instruments on different satellites came measures of sea surface temperature, sea surface wind, cloud liquid water, cloud-top pressure, lightning flash frequency, as well as air temperature and humidity. These and more measures were synthesized into three-dimensional pictures of cloud structures and the influences from sea surface temperature fronts over the western North Pacific.

During both winter and summer, the ship observations show sharp differences in sea surface temperature and the marine atmospheric boundary

Figure 1. Climatological surface winds (left) in winter and (right) in summer. Block arrows represent the Kuroshio and its Extension.



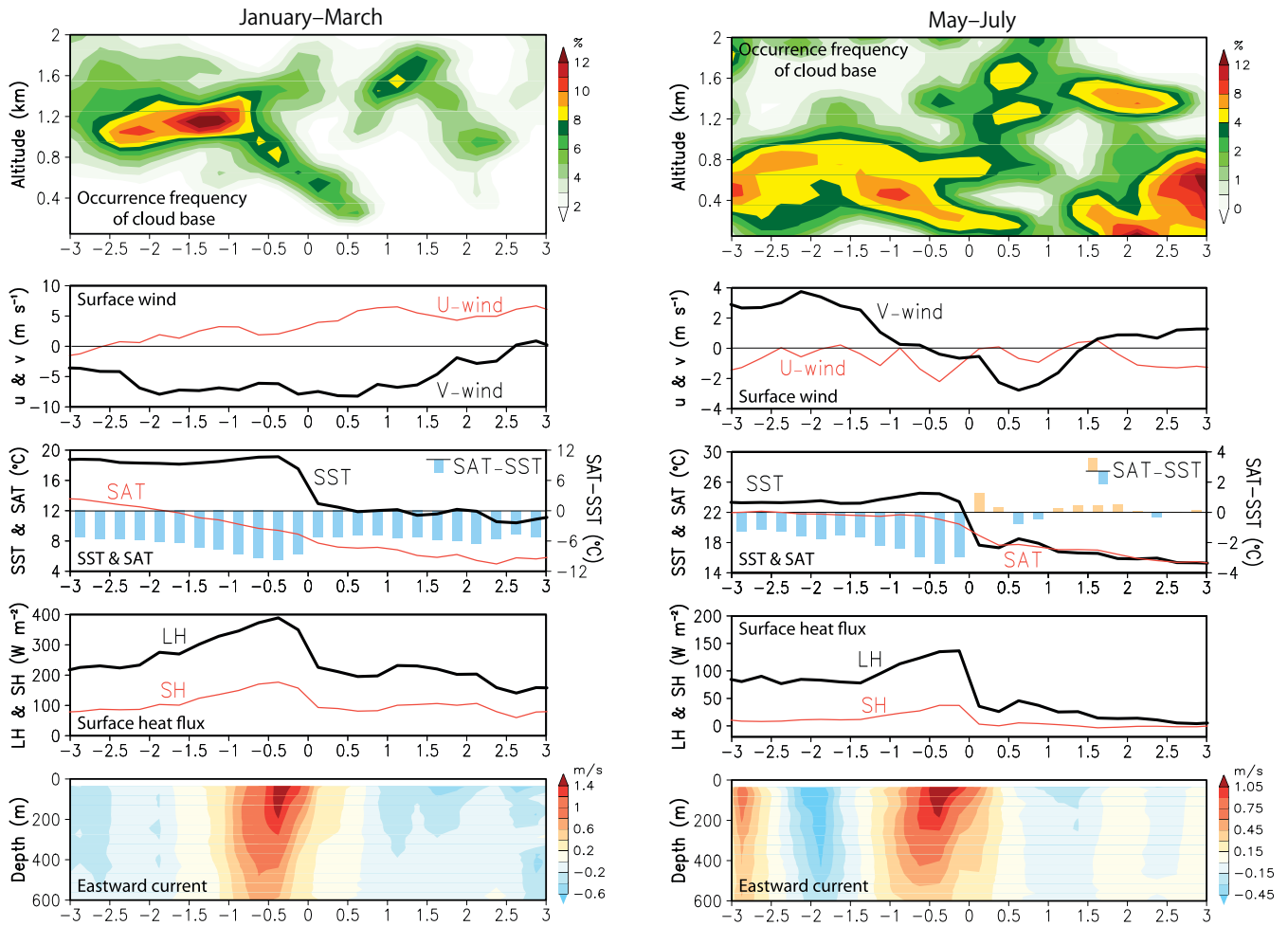


Figure 2. Cross-frontal observations from the R/V *Mirai* (left panels) during January–March: (a) frequency of cloud-base occurrence as a function of latitude and height observed by a laser ceilometer; (b) surface zonal (red) and meridional (black) winds; (c) surface air temperature (red), sea surface temperature (SST; black), and their difference (bar); (d) upward surface latent (black) and sensible (red) heat fluxes; and (e) eastward ocean current speed observed by ship-mounted ADCP. All variables are composited referenced to the maximum SST gradient of the Kuroshio Extension front ($y=0$); distance to the center of the SST front (y) is in degrees latitude; (right panels) observations for May–July.

layer at the northwestern front of the Kuroshio and its extension. Satellite observations reveal conditions across the front that generate deep clouds rising into the mid-to-upper troposphere, where they affect weather systems.

During winter, sea surface temperature rises 7°C in less than 100 km across the southern flank of the Kuroshio Extension (Figure 2, left panel). The prevailing winds are cold, dry northwesterlies from Siberia (Figure 1, left panel), and the surface air arriving at the Kuroshio is significantly colder than the sea surface and warms only gradually as it blows across the current. The largest difference in temperature and moisture between the air and the sea surface occurs right over the strong current and on the warmer flank of

the front where the air is more than 8°C colder than the sea surface. This huge difference between the warm ocean and the cold, dry air produces turbulent heat fluxes that release huge amounts of heat and moisture into the atmosphere. The cloud bases and cloud tops are much higher on the southern than the northern flank of the current. The cloud bases are often more than 1 km high and cloud tops can tower as high as 5 km, with frequent lightening along this southern flank of the Kuroshio and its Extension (Figure 3).

In summer, due to the prevailing southerly winds that bring warm, moist air, the temperature over the southern flank is only slightly cooler than the Kuroshio (Figure 2, right panel). As a result, surface heat fluxes and atmospheric

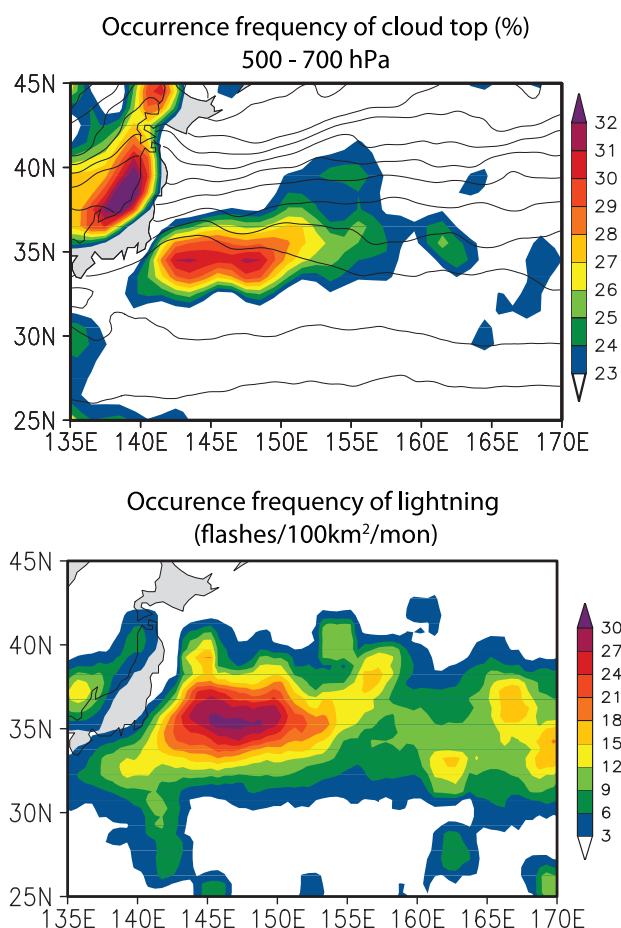


Figure 3. December to February climatology: (top) horizontal pattern of cloud-top occurrence in the 500–700-hPa layer (color in %) with superimposed climatological SST derived from AVHRR (contours at 2°C intervals); (bottom) lightning observed by LIS/OTD (color in units of flashes per 100 km²/month).

vertical mixing are strongly suppressed, and the cloud bases are typically lower than in winter, around 0.4–0.8 km. But on the northern flank, sea surface temperature drops nearly as sharply as it does in winter, leading to a drastic vertical gradient in temperature and moisture. The icy subarctic water cools and saturates the warm, moist air north of the Kuroshio, and the water vapor condenses. Thus sea fog occurs over 40% of the time on the northern flank of the Kuroshio, southeast of Hokkaido, and northeastward (Figure 4). Over the Kuroshio and the Extension itself, sea fog occurs rarely during summer because the warm ocean current destabilizes the lower atmosphere and promotes vertical mixing.

In June–July, the narrow band of surface wind convergence over the Kuroshio Extension (KE) supports a broad

spectra of upward motion that is associated with the eastward extension of the Baiu rainband, and the air warmed by the current rises up high through the entire troposphere. This particular oceanic influence of the KE on the Baiu rainband, however, needs further investigation according to Tokinaga and his colleagues.

This careful, detailed study of the impact of ocean temperature fronts on cloud patterns in the western North Pacific will help to understand better how these fronts anchor storm tracks and how their effects on the atmosphere can lead to the growth of cyclones in the extratropics.

This story is based on:

Tokinaga, H., Y. Tanimoto, S.-P. Xie, T. Sampe, H. Tomita, H. Ichikawa, 2009: Ocean frontal effects on the vertical development of clouds over the western North Pacific: In situ and satellite observations. *J. Climate*, **22** (16), 4241–4260.

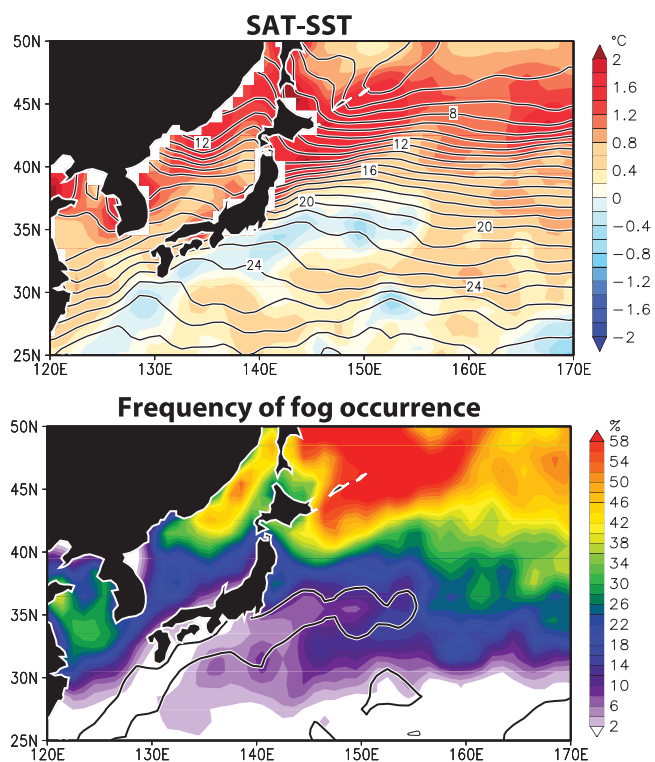
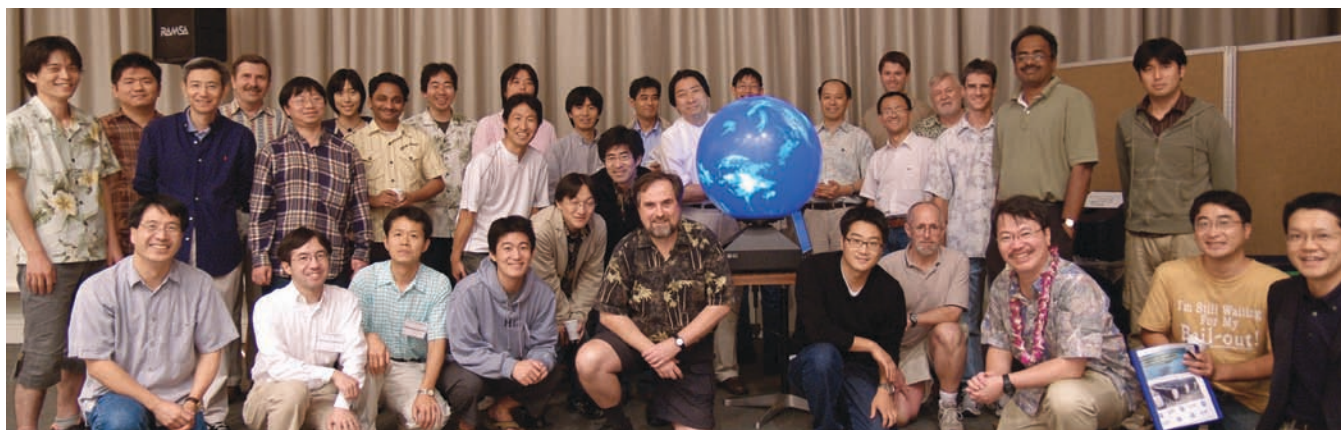


Figure 4. Southerly composite of (top) the difference in surface air temperature and sea surface temperature (SAT–SST; color in °C) and SST (contours at 1°C intervals); (bottom) frequency of fog occurrence (color in %) and the zero contour of SAT–SST. This difference measure is an indicator of stability in the lower atmosphere. (ICOADS, June 1982 to 2006 average)

MEETINGS



Participants at the workshop on computationally intensive modeling gather around IPRC's Magic Planet. Photo credit: Jian Ma.

Computationally Intensive Modeling of the Climate System

The advent of the JAMSTEC Earth Simulator in 2002 represented a major leap in computational power available for environmental research, and it inspired important developments in climate modeling and related areas. At JAMSTEC itself, an array of models has been developed for climate simulation. Notable among these models are the Ocean General Circulation Model for the Earth Simulator (OFES), the Atmospheric General Circulation Model for the Earth Simulator (AFES), the Coupled General Circulation Model for the Earth Simulator (CFES), the Multi-Scale Simulator for the Geoenvironment (MSSG), and the Nonhydrostatic ICosahedral Atmospheric Model (NICAM) for cloud system resolving global simulations. Published results obtained with these models have helped inspire interest in the area of high-resolution atmosphere and ocean simulation. In the US and elsewhere, the success of the Earth Simulator has

helped to motivate development of major supercomputers intended, at least in part, for climate research applications.

From the early days of the Earth Simulator Center (ESC), IPRC scientists have been privileged to collaborate with their JAMSTEC colleagues on computationally intensive research using the results from the Earth Simulator. Perhaps the most significant contributions from IPRC have been in the analysis of very high-resolution global ocean and atmosphere model simulations conducted at JAMSTEC.

The close cooperation in this area was recognized when IPRC was invited by JAMSTEC to co-sponsor the August 2008 "OFES International Workshop" in Yokohama (see *IPRC Climate*, vol. 8, no. 2). After the very successful OFES workshop, and with the strong support of ESC Director-General **Kunihiko Watanabe**, plans were made to hold a 2009 sequel in Honolulu. Given the breadth of the phenomena being modeled by both JAMSTEC and IPRC scientists, the scope of this second meeting was expanded. Convened by ESC's **Wataru Ohfuchi** and IPRC's **Kevin Hamilton**, the "Second OFES Interna-

tional Workshop and ESC-IPRC Joint Workshop on Computationally-Intensive Modeling of the Climate System" was held December 9–10, 2009, at the East-West Center.

The meeting attracted over 70 participants from the University of Hawai'i and elsewhere, including 15 JAMSTEC researchers, and colleagues from the University of Tokyo, Kobe University, the University of Alaska, and the Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER). Presentations discussed results from a wide range of simulation and data assimilation models applied to understand various phenomena in the ocean and atmosphere. Abstracts of the presentations are at <http://www.jamstec.go.jp/esc/event/ofes-workshop2/>.

In connection with the workshop **Jan TenBruggencate** of the *Honolulu Advertiser* interviewed Hamilton about the IPRC collaboration with the ESC. This interview appeared in the *Advertiser's* science and environment blog *Raising Islands* on December 15, 2009 (<http://raisingislands.blogspot.com/2009/12/uh-climate-collaboration-uses-raw.html>).



Participants at the “Face-to-Face” meeting of the JAMSTEC-IPRC Initiative in Yokohama. Photo credit: Shiro Matsugaura, JAMSTEC

IPRC – JAMSTEC Science Partnership Meeting

The IPRC theme leaders of the JAMSTEC-IPRC Initiative (JII) travelled to Yokohama for a “Face-to-Face” meeting with their JAMSTEC JII partners and other researchers on November 2, 2009. This second JII Face-to-Face meeting, which was held almost exactly 3 years after the 2006 meeting

that established the partnership, provided an excellent opportunity to review progress and to plan future research directions. The opening plenary session consisted of presentations of research highlights by IPRC theme leaders and a subsequent general discussion. Several parallel breakout sessions on the individual research themes followed. At the closing plenary session, the scientists summarized the outcomes of the indi-

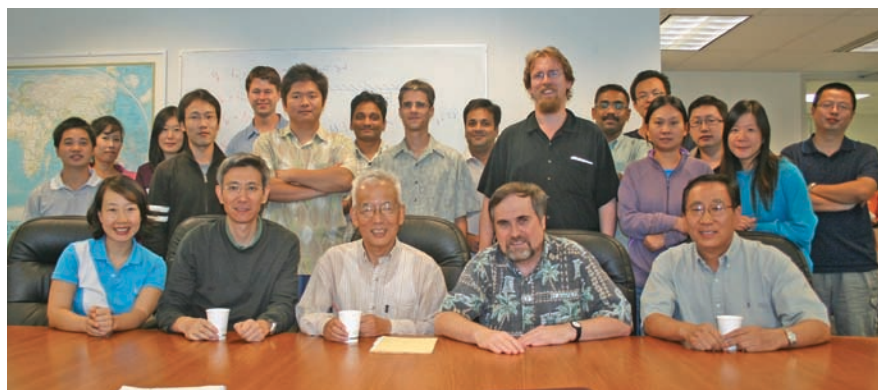
vidual sessions. The meeting attracted almost 50 JAMSTEC scientists. It is gratifying to find that many younger JAMSTEC researchers are interested in participating in JII activities. After the meeting, the theme leaders began work on revising the original JII document to reflect the new directions explored during the meeting.

Miniworkshop on Climate Change: Modeling and Analysis

Syukuro (“Suki”) Manabe, currently senior meteorologist in the Atmospheric and Oceanic Sciences Program at Princeton University, visited IPRC on February 26. Manabe, whom many regard as the “Father of Global Climate Modeling,” was on his way back to Princeton from a trip to Japan, where he had been honored by being among the first three people to

be inducted into the new Kyoto Earth Hall of Fame. IPRC scientists took the opportunity of Manabe’s visit to discuss the latest research in atmospheric modeling with him and held a meeting,

“Climate Change: Modeling and Analysis.” Organized by IPRC faculty member **Shang-Ping Xie**, the miniworkshop featured presentations from IPRC faculty, researchers, and students.



Suki Manabe (center front) with participants at the Climate Change Miniworkshop.

Improving Ocean Models: The NASA Project on Ocean Mixing

For over a decade now, oceanographers have been trying to develop models that realistically capture such essential large-scale ocean features as surface and subsurface currents and temperature patterns. They have had success, but they have struck a wall—ocean mixing. “Although ocean mixing significantly impacts the large-scale ocean circulation and surface fluxes, it is among the least well understood phenomena in climate modeling. The processes directly responsible for mixing occur at such small spatial and temporal scales that they must be parameterized by representing small-scale effects on large scales *in terms of large-scale variables*,” wrote **Ryo Furue** after an IPRC mini-workshop on ocean mixing in March 2009 (*IPRC Climate*, vol. 9, no. 1). From that meeting emerged a proposal for a project to investigate ocean mixing processes more closely.

Recognizing the importance of ocean mixing, NASA funded the project, which may serve as a model for future ocean-mixing studies. During a second meeting at the IPRC, in March 2010, a research plan was developed and a list of products to emerge from the project was drawn up. IPRC members of the team are **Jay McCreary**, **Kelvin Richards**, **Niklas Schneider**, and **Ryo Furue**. Joining them are **Bruce Cornuelle** and **Nidia Martinez** from Scripps Institution of Oceanography, **Detlef Stammer** and **Armin Köhl** from the University of Hamburg, **Peter Müller** and **Eric Firing** from the University of Hawai‘i, and **Ren-Chieh Lien** from the University of Washington.

The plan is to use two versions of the ocean MITgcm to test the sensitivity of the ocean state to various mixing parameters. The first version is a global ocean model version adapted by the Hamburg scientists, who will continue to work on their model version to gain further insight into how data assimilation works in estimating mixing parameters. The second version is the high-resolution version adapted at Scripps to a limited Pacific Ocean domain. The Scripps group will continue to develop their eddy-permitting assimilation model.

The scientists at the University of Hawai‘i will first test the initial results on flow fields from the Scripps model and improve them in discussion with the whole team as needed. The UH group will then explore the sensitivity of the tropical Pacific Ocean state in some 10 to 20 experiments. Sensitivity parameters to be explored include vertical diffusivity, fresh water flux, wind stress, and viscosity impact on SST, surface and subsurface currents, and mixed layer heat budget. The parameter changes are to be introduced singly and at a single region so that the physics causing the change can be pinpointed and the “best parameterization” for a particular region can be estimated. The idea behind this approach is that some of the small-scale changes in ocean mixing introduced in the experiments will bring large-scale features in the model closer to observations.

To Bruce Cornuelle falls the final major task of using the many results from the separate experiments to develop an assimilation procedure that yields a model producing flow fields and other large-scale ocean features that best fit observations.



Wrestling with ocean-mixing processes, around the table from the left: Ryo Furue, Jay McCreary, Niklas Schneider, Bruce Cornuelle, Peter Müller, Yoshinori Sasaki, Armin Köhl, Detlef Stammer, and Eric Firing.



Members of the JAMSTEC “DrC” and of IPRC’s Asia-Pacific Data-Research Center gather in IPRC’s conference room to discuss how to best serve climate data.

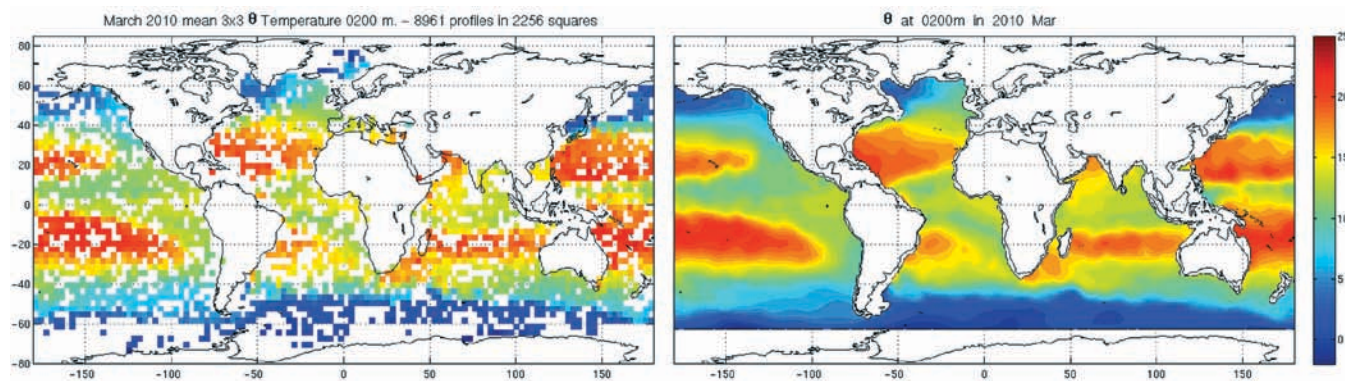
JAMSTEC Data Research Center Staff Meets with IPRC

A team from JAMSTEC’s new Data Research Center for Marine-Earth Sciences (“DrC”), headed by Director-General **Toshiyuki Awaji**, met on March 10 with IPRC colleagues to share and discuss their work on analyzing and serving the huge and diverse climate data available to scientists.

JAMSTEC scientists talked about their important work on data assimilation in the coupled atmosphere-ocean system, as well as about application of data and models to such issues as temperature trends in the abyssal ocean and inter-annual rainfall variability in East Africa.

IPRC scientists presented results on Hawai‘i regional ocean modeling and Argo data analysis, and they gave a description of the new Surface Current from Diagnostic model (SCUD) data set recently released to the public. The meeting concluded with a detailed discussion of technical issues related to data management and data serving at JAMSTEC and at IPRC. Visiting with Awaji from JAMSTEC were **Yasunori Hanafusa**, **Nozomi Sugiura**, **Shuhei Masuda**, **Hideaki Hase**, **Hiromichi Igarashi**, **Yoshihisa Hiyoshi**, and **Takahiro Toyoda**.

Held in the IPRC Conference Room, the meeting was organized and chaired by IPRC’s **Jim Potemra**, acting manager of the Asia-Pacific Data-Research Center (APDRC).



An example of Argo plots that can be created at the APDRC project website (<http://apdrc.soest.hawaii.edu/>). This sample shows potential temperature at a depth of 200 m for March 2010: (left) as observed by Argo floats averaged over 3-degree bins and (right) the interpolated IPRC product (unit is °C).



Governing Committee participants from left, front: Kevin Hamilton, Brian Taylor, Eric Lindstrom, Howard Diamond; back: Rio Tanabe, Yukio Masumoto, Hirota Tani, Shiro Imawaki, Masao Fukasawa, Mototaka Nakamura, and Katsufumi Akazawa. Photo credit: Shiro Matsugaura, JAMSTEC

IPRC Governing Committee Meets

The IPRC Governing Committee held its 2010 annual meeting on April 7 and 8 at the Tokyo Office of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). JAMSTEC Executive Director **Shiro Imawaki** served as Japanese co-chair and NASA Program Scientist **Eric Lindstrom** served as US co-chair. This year, **Hirota Tani**, Director for Environmental Science and Technology of Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT), participated in the meeting. The meeting reviewed governance issues and the overall progress of the IPRC.

IPRC Leadership

Kevin Hamilton has been appointed IPRC Director. Hamilton, who had served as Interim Director from April 2008, has been a faculty member at the IPRC since October 2000 and served as Meteorology Department Chair from 2004 to 2007. Before joining the IPRC, Hamilton was for twelve years a research meteorologist at the NOAA Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey, and a visiting professor at Princeton University. He has been honored for his research achievements by the award of the Canadian Meteorological and Oceanographic Society *President's Prize* and the American Meteorological Society (AMS) *Meisinger Award*. He was the 2000 American Geophysical Union *Jule Charney Lecturer*, and has been a *Fellow of the AMS* since 2001.

IPRC Takes Part in Aerospace in Hawai'i Week

Established by the United Nations in 1999, *World Space Week* celebrates the contributions of space science and technology to improving the human condition. Hawai'i participated during this year's week in October by hosting statewide a series of public events that highlight Hawai'i's achievements, current activities, and future possibilities. Among happenings at the Hawai'i State Capitol was a panel "Mission to Planet Earth." Members of the panel included IPRC Director **Kevin Hamilton**, who spoke on satellite observations and global climate change, and Senior Researcher **Nikolai Maximenko**, who spoke about the synthesis of satellite and in situ observations to study ocean currents.



At the Hawai'i State Capitol during *Aerospace in Hawai'i Week*, from left Jim Crisafulli, Director of the Hawai'i State Office of Aerospace Development; Kevin Hamilton; Peter Mouginis-Mark, Director of the Hawai'i Institute of Geophysics and Planetology at the University of Hawai'i; and Nikolai Maximenko.

Monsoon Modeling for Sustainable Rice Production

IPRC Senior Researcher **H. Annamalai** travelled to Hyderabad and Coimbatore, India, in November 2009 for the second meeting of the ClimaRice project (see *IPRC Climate*, vol. 8, no. 2). The project aims to assess effects of climate change on agriculture and water availability and to make recommendations to farmers, local government, and other stakeholders on how to mitigate consequences of future climate change. It is a partnership among the Norwegian Institute for Agricultural and Environmental Research (Bioforsk), the Tamil Nadu Agricultural University in Coimbatore, and the IPRC. The Norwegian Ministry of Foreign Affairs is funding the project through the Royal Norwegian Embassy in New Delhi.

“The most interesting part for me on this trip was that I got to talk with the farmers and the water resource engineers and heard first-hand from them about their experiences with climate change over the last 30 to 40 years,” says Annamalai. “The farmers are very sensitive to the changes that have happened to agriculture and have already seen the effects of warming. They have to use more chemicals because insect pests have increased. The failing monsoons are bringing less water, and so they have turned to rice varieties that need less water, take shorter time to ripen, and can resist the higher temperatures better. The chief



The farming community at Bhavanisagar discusses with the ClimaRice scientific team how to adapt to such extreme conditions of drought, unusually heavy rainfall, temperature changes, and what climate scenarios can be expected in the future. Photo credit: Nils Otto Kitteroed, Bioforsk



Canal from the Bhavanisagar Dam brings water to the rice fields. Photo credit: Hanne Sørli, Bioforsk

water engineer for the Cauvery Basin has seen the groundwater table fall. He says the intrusion of saline water is reducing the amount of land suitable for farming. Because of the uncertainty of viable farming in the future, the number of young people going into farming is plummeting, and a shortage of farmers is looming.”

Annamalai’s contribution to the project is his expertise in numerical modeling of climate, especially of the monsoon. He has adapted the IPRC Regional Climate Model to the region and is driving the model with warming signals from those IPCC AR4 models that are able to simulate the monsoon well, such as the GFDL model. “Based upon these simulations, I will make projections about regional temperature rise and changes in rainfall patterns, especially the frequency of extreme droughts and flooding over this century. An important part will be to assess the level of uncertainty of my projections,” explains Annamalai.

Phase 1 of the project is coming to a close. The Norwegian Ministry of Foreign Affairs has already funded three more years for a second project phase. Project members are writing a book intended for policymakers, non-governmental offices, agriculture and water managers, as well as scientists. The book hopes to contribute to the development of adaptation measures and to recommend management strategies and policies that are based on input from both stakeholders and scientists.

For details of the project and the meeting, please visit <http://www.tnau.ac.in/climarice/>

Will Ancient Trees in Hawai'i Tell Stories of Past Climates?

"It all began with an analysis of climate model simulations that showed over decades a strong connection between the concentration of an oxygen isotope in precipitation over Hawai'i and the El Niño-Southern Oscillation," says IPRC oceanography professor **Axel Timmermann**. Would anything on the Hawaiian Islands store this information on a yearly basis, he wondered, and thereby help to reconstruct past El Niño occurrences? Trees probably would, but an accurate dating of oxygen isotope variations in tree cellulose requires the trees to have annual bandings. Because the annual cycle in the tropics is weak, tropical trees usually don't have clearly marked tree rings.

But Timmermann thought, "Hawai'i has tall mountains, and maybe trees higher up might supply the key." He decided to explore this with a team of scientists.

He first turned to **Patrick Hart**, a biology professor at the University of Hawai'i at Hilo. Hart is an expert on trees that grow at high elevations in Hawai'i because they are an important habitat for native birds. Hart came up with two candidate trees, the mamane and the ōhi'a. These trees can reach an age of 600 years and may have tree rings or store isotope information that reflects the oscillation between wet La Niña and dry El Niño periods. Since their wood is so hard and nearly indestructible, ancient dead trees might be used to splice together information extending back even further than live trees.

Timmermann also asked **Edward R. Cook**, senior scholar at the Tree-Ring Laboratory, Lamont-Doherty Earth Obser-



Section of a mamane branch from the western slopes of Mauna Kea reveals clear tree rings. Photo credits: Niklas Schneider

vatory, and **Lowell Stott**, professor of earth sciences at the University of Southern California, to join the team. Cook is an expert in tree-ring analyses and Stott, an expert in isotope analyses. On the team are also IPRC oceanography professor **Niklas Schneider**, **Jinbao Li**, an IPRC postdoctoral fellow, and two students of Patrick Hart.

Equipped with tree-coring equipment, the team headed out towards the upper slopes of Mauna Kea and Mauna Loa. On a vague dirt road leading up the western slope of Mauna Kea, they drove to an elevation of about 3,000 m. Timmermann was amazed by what he saw, "gnarled trees that really looked ancient." The next day, the team drove to an ancient *kipuka*, a place that survived the many lava flows, on the east facing slope of Mauna Loa. There they collected more tree-core samples from ōhi'a trees, many of which may have been around years before Captain Cook visited the Hawaiian Islands.

The first results of the tree-core analyses conducted at the Tree-Ring Laboratory at Lamont are already in. The exciting news is that mamane trees do have clear rings that probably form annually. Ōhi'a trees, however, do not have a pronounced annual banding, which prevents the cross-validation efforts needed to interpret oxygen isotope signals in the cellulose and thus makes these trees useless for the project.

What will the mamane trees reveal about the history of past climate in the Hawaiian Islands? Have their tree rings and isotopes kept a memory of the droughts and rainy periods that accompany the cycles of El Niño and La Niña in the Pacific? If yes, they will be an extremely valuable new archive of Pacific climate.



Edward Cook takes core samples from a mamane tree.

Climate Research, Environmental Sustainability, and Finance

“In Nature’s casino the insurance companies had set themselves up as the house, and yet they didn’t know the odds.....potential losses from various catastrophes are too great and too complicated to be judged by human intuition.”

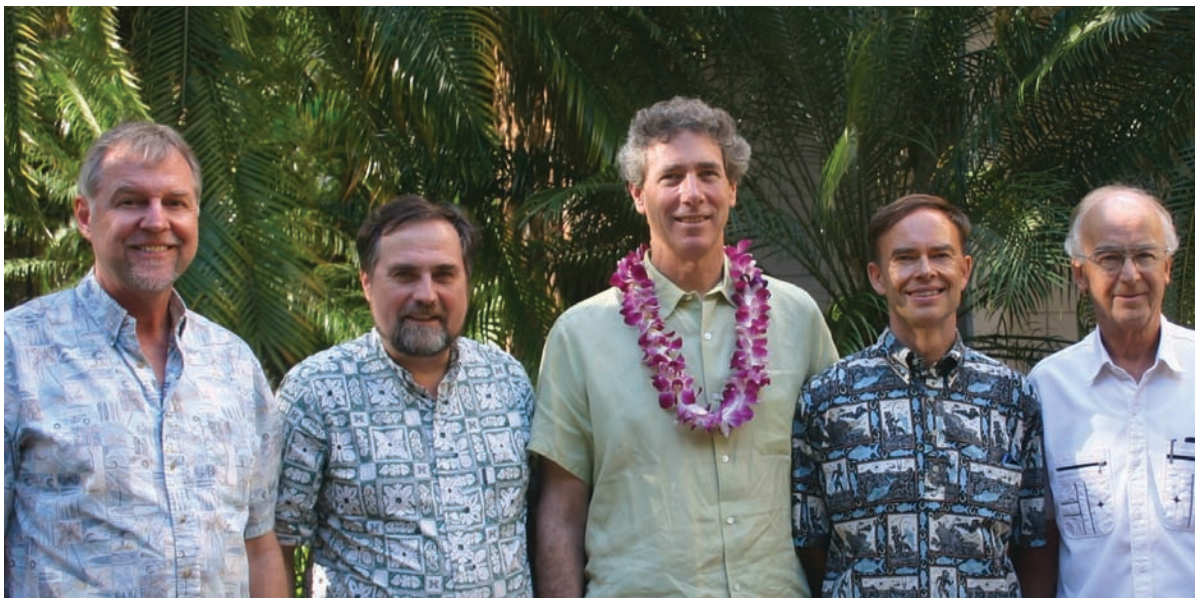
Michael Lewis, *In Nature’s Casino*

Research in the science of climate variability and change ultimately is driven by a desire to inform practical decisions that impact society. One increasingly important connection between climate science and real-world decision-making is provided by financial markets. Such recent innovations as weather derivatives and catastrophe bonds, together with conventional insurance and reinsurance markets, provide ways to manage the financial component of the risks associated with climate variability and change. The emergence of markets for carbon emission credits is also beginning to impact business decisions that may affect the long-term sustainability of our society. Optimal pricing of environmentally related market securities depends on having the best possible understanding of, and projections for, climate trends and variability. More generally, climate information is needed to inform both regulatory and market decisions related to financing mitigation and adaptation efforts.



Kevin Hamilton lecturing in the new MFE program at the Shidler College of Business.

In Fall 2009 the Shidler College of Business of the University of Hawai‘i Mānoa, with the generous support of Hawai‘i businessman **Jay Shidler**, started a new program, a Master’s of Science in Financial Engineering (MFE). This is an ambitious effort to teach state-of-the-art quantitative finance at the graduate level. The importance of environmental finance was recognized by having one of the eight new courses in the program devoted to this topic.



From left, Steven Businger, Kevin Hamilton, Richard Murnane, Gunter Meissner, and Lorenz Magaard.



The floor of the Chicago Mercantile Exchange, where weather derivative contracts and carbon emission credits are traded. Photo source: Wikimedia.

Spurred in part by the developments at the Shidler College, the IPRC has become increasingly interested in contributing in the area of environmental finance. IPRC Director and Meteorology Professor **Kevin Hamilton** taught part of the course on environmental finance in this inaugural year of the MFE program, together with Business Professor and MFE Program Director **Gunter Meissner** and Meteorology Professor **Steven Businger**. In his lectures Hamilton explained the nature of weather observations, described available climate data bases, introduced the principles of climate modeling and discussed the basis for climate prediction on various timescales.

This spring the IPRC hosted an international leader in the field of climate change and finance, **Richard Murnane**, Program Director for the Risk Prevention Initiative at the Bermuda Institute of Ocean Sciences. Murnane's seminar, co-sponsored by the IPRC, the Shidler College of Business, the International Center for Climate and Society (ICCS), and the Meteorology Department, was titled "Natural Hazards and the Catastrophe Reinsurance Industry." In conjunction with Murnane's visit, the IPRC organized a panel discussion on "Some Issues Related to Weather Risk Mitigation," which included Meteorology Professor **Thomas Schroeder** and **Brendan Larson**, a Honolulu-based entrepreneur in weather information services.

Given its focus on Asia-Pacific issues and strong connections with Japan, the IPRC is naturally interested in exploring common interests with relevant Japanese businesses. In April Hamilton visited the Tokyo headquarters of Tokio Marine Nichido, the oldest casualty insurance company in Japan and



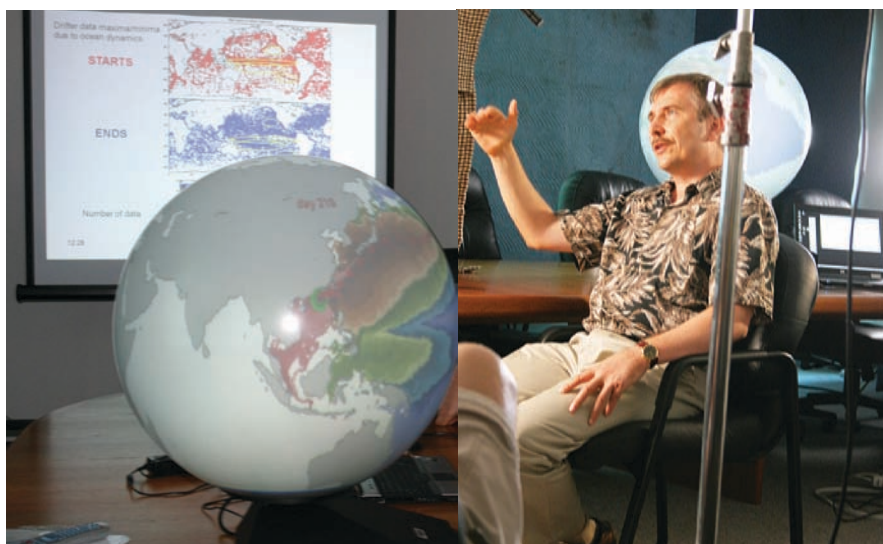
NASA Image of Hurricane Isabel. Isabel made landfall in North Carolina in September 2003 and caused over 3 billion dollars damage in several states in the US.

one that is developing a progressive approach to incorporating climate information in its business operations. Hamilton enjoyed discussions with members of the Tokio Marine Research Institute (the company's "think tank"), including Managing Director **Terumasa Miyoshi**, and researchers **Hiroo Shimada**, **Kei Masuyama** and **Akira Juri**. The Tokio Marine researchers have a particular interest in projections of how global warming will affect western Pacific tropical cyclones, an issue that is also a focus of IPRC research (e.g., *IPRC Climate*, vol. 5, no. 2), and the IPRC is looking ahead to sharing results in this area.

IPRC's developing interest in environmental finance is a step towards applying basic climate science to pressing, real-world issues of managing the risk of climate change to society and enhancing sustainability. IPRC scientists look forward to bolstering their capabilities in this area through further connections within the University of Hawai'i and beyond.

"The risks surrounding our customers have become increasingly complex and diversified due to issues such as the escalation of global environmental problems and rapid changes in the social structure.... Tokio Marine Nichido established ...a comprehensive program concerning global warming in November 2007, which holds up our policy of a comprehensive and aggressive commitment to the global warming issue through risk research...."

Shuzo Sumi, President, Tokio Marine Nichido Group



Left: Magic Planet animation of tracer paths from Japan to the West Coast of North America. Right: Nikolai Maximenko explaining drifters and ocean currents during filming.

Can Ocean Drifters Help Solve Historical Puzzles?

“America Before Christopher Columbus: Who really discovered the New World?” is the title of a two-hour special program aired on the History Channel (<http://www.history.com/>) as this issue of the IPRC Climate is going to press. In a 5-hour interview, IPRC Senior Researcher **Nikolai Maximenko** talked about ocean circulation to **Maria Awes** of Committee Films. The company is

producing a video that explores possible ocean voyages to the New World before Christopher Columbus.

The program features, among other stories, that of Japanese fishermen from Kyushu sailing in Jomon fishing boats to coastal Ecuador and Chile as early as 3044 BC; a Chinese explorer reaching Southern California around 458 AD on a Chinese junk; and ancient Hebrews from the Mediterranean reaching between the 1st and 8th century AD the east coast of America, where some members

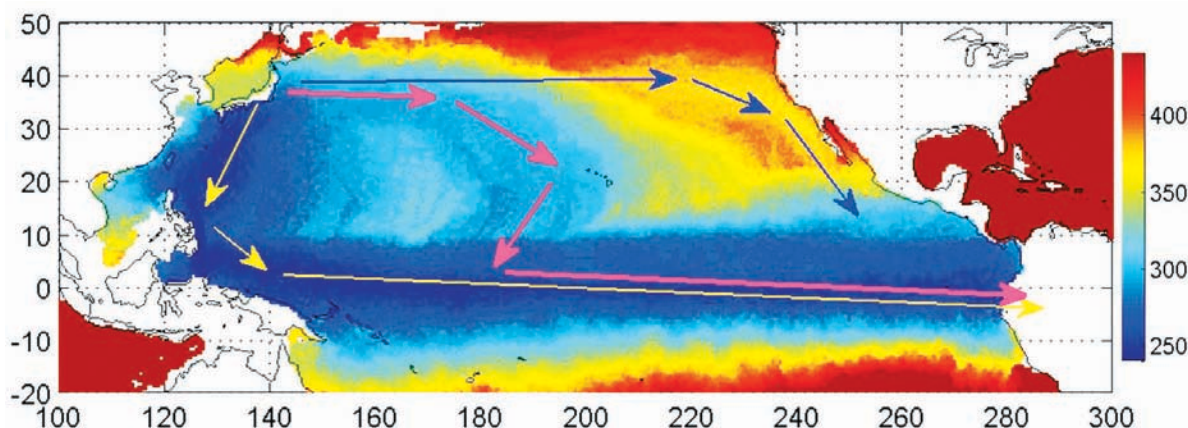
of the Cherokee tribe today believe they are descendants.

Committee Films had heard about Maximenko and his work on charting ocean currents using drifters. Awes interviewed him for the film to see whether ocean currents and winds would help to support or to disprove the stories of these early voyages.

Maximenko made calculations for 7 of the possible ancient travels the program is exploring. For the Jomon story, for instance, he calculated that the fastest path for a passively floating object from Kyushu to Ecuador is 240 days (figure below).

“While the suggested ‘fastest’ path is not impossible for one-time travel, it is largely provided by anomalous currents and the winds that drive the currents but that cannot be relied upon for regular navigation,” Maximenko cautions.

With the help of **Jan Hafner** at the IPRC, Maximenko generated animations of the possible drifter paths on IPRC’s Magic Planet. “These animations give a colorful, visual demonstration of how things move and drift in the ocean from one continent to the next,” says Maximenko.



Current-favored pathways from Kyushu to Ecuador of 240, 290, and 320 days duration are represented by yellow, purple, and blue arrows respectively. Ocean colors (in days) represent the fastest drift between Kyushu and Ecuador through the particular locations.

Plastic Oceans

The plastic garbage dumped directly or swept by rivers into the ocean is accumulating in huge “garbage patches.” IPRC Senior Researcher **Nikolai Maximenko** has developed a statistical model of ocean currents, based on actual drifter observations, that is applicable to tracking ocean plastic pollution.

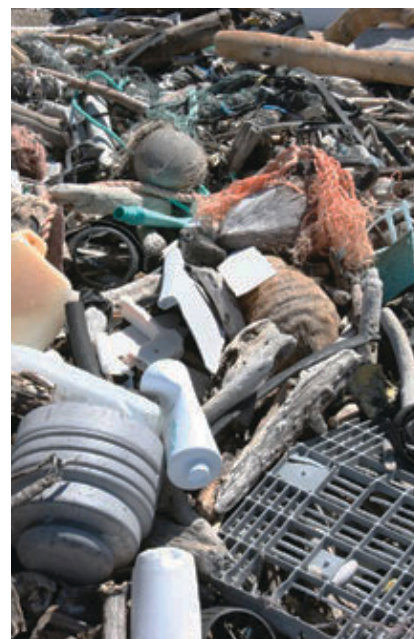
At the 2010 AGU Ocean Sciences meeting in February in Portland, Oregon, Maximenko gave a talk on his work and also participated in the press conference “Plastic Oceans” with **Kara Lavender Law** and **Giora Proskurowski**, oceanographers with the Sea Education Association of Woods Hole Oceanographic Institution. During the press conference, Maximenko explained how his research on surface currents and ocean mixing helps to understand where the plastic debris comes from and where it goes once it enters the oceans.

The press conference led to internet media coverage, including Science

News, National Geographic Daily News and BBC News <http://iprc.soest.hawaii.edu/news/news.php>

Maximenko’s modeling work on ocean currents is featured extensively in **Edwin Schiele’s** article describing how atmospheric and oceanographic processes lead to the accumulation of plastic in certain regions of the ocean. Schiele’s article is found on the Ocean Motion NASA-funded website produced by **Eric Lindstrom**. The website covers everything a layperson might want to know about ocean currents (<http://www.oceanmotion.org>).

Maximenko’s work is also contributing to a story about plastics in the ocean by **Amanda Martinez**, a student in the MIT Graduate Program in Science Writing. She interviewed Maximenko in January about his research on currents and the convergence regions where garbage collects. The description of Maximenko’s research is a crucial installment of a larger article that is to be her master’s thesis.



This plastic trash has been carried on ocean currents from far away to be washed ashore at Kamilo Beach. Photo credit: Beach Environmental Awareness Campaign Hawai‘i

Maximenko is at present investigating why so much debris washes up on certain beaches in Hawai‘i and not others. One beach that collects a particularly large amount of marine debris is Kamilo Beach on the Island of Hawai‘i.

Climate and Mode Water

As part of the Spring Meeting of the Oceanographic Society of Japan in Tokyo, **Shang-Ping Xie** organized the “Symposium on New Developments in Mode-Water Research: Dynamics and Climate Effects” with **Atsushi Kubokawa** (Hokkaido University) and **Fumiaki Kobashi** (Tokyo University of Marine Science and Technology). Mode waters are thick layers of water mass with rather uniform temperature,

density, and potential vorticity. In the North Pacific, such a mass anchors the eastward subtropical countercurrent (STCC), flowing near the sea surface, to the westward flow in the lower thermocline. The symposium presentations and discussions dealt with new developments in mode-water research, mostly in relation to the North Pacific.

“Argo observations, for instance, show that interannual Rossby waves, meanders, and eddies modulate mode-water formation in the Kuroshio Ex-

tension,” explains Xie. “Through subsurface stratification and advection, the STCC impacts sea surface temperature and thereby affects precipitation and wind stress curl.”

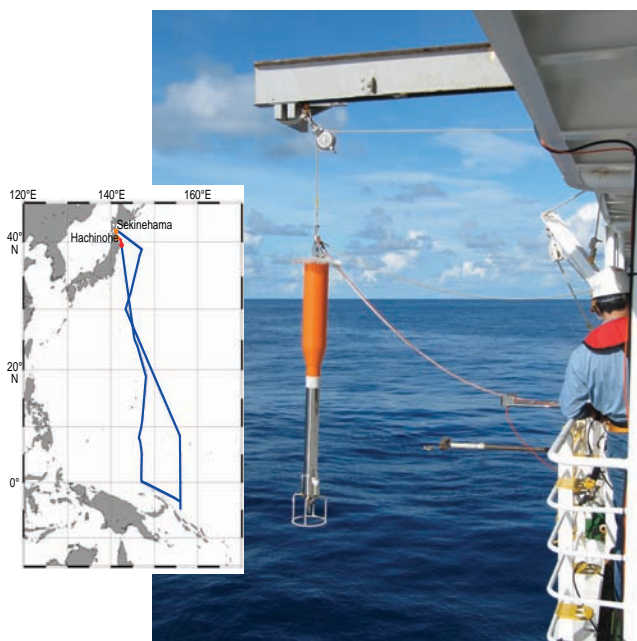
The symposium participants plan to summarize the recent studies in a special journal issue and to pursue funding toward multi-disciplinary research in this new area. Among the presenters from Hawai‘i were, in addition to Xie, **Bo Qiu** (University of Hawai‘i) and **Ryo Furue** (IPRC).

In Search of Small-Scale Ocean Features

Oceanographer **Kelvin Richards** went data gathering on a 37-day-long cruise of JAMSTEC's Research Vessel *Mirai* in November–December 2009. It was his third trip on the ship, which was on a Triton mooring-maintenance cruise this time. Richards and his colleague **Yuji Kashino** (RIGC, JAMSTEC) are interested in ocean turbulence measurements taken near the equator with a microstructure profiler (MSP) and a high-frequency Acoustic Doppler Current Profiler (LADCP). Sampling at high vertical resolution, the LADCP shows that features with a vertical scale of a few tens of meters dominate the vertical shear of the currents in the thermocline. The combined LADCP and MSP measures reveal that these features, though small in scale, control much of the mixing in the equatorial thermocline.

“Since ocean mixing is known to greatly influence the state of the equatorial ocean and ocean-atmosphere interactions,” says Richards, “these small-scale features may well impact such climate phenomena as the El Niño–Southern Oscillation.”

Richards is now using the data sets to study the dynamics of the small-scale features in numerical experiments with **Andrei Natarov** (IPRC) and **Hidenori Aiki** (RIGC), and their impact in a coupled ocean-atmosphere model with **Jing-Jia Luo** and **Wataru Sasaki** (RIGC).



Left, cruise track of the *Mirai*, right, deployment of the microstructure profiler.

The Story of Chlorofluorocarbons: A Possible Disaster Averted

Kevin Hamilton was invited by **Leticia Colmenares**, Professor of Chemistry at Windward Community College in Kaneohe, to talk at the American Chemical Society *Community Forum in Chemistry*. The Forum builds bridges between the classroom and real-world applications for students and the community. Hamilton reviewed the powerful effects of man-made chlorofluorocarbon compounds (CFCs) on the atmosphere and the climate system. Calculations suggest that the introduction of CFCs into the atmosphere since about 1960 has resulted in a significant forcing of anthropogenic global warming. Some CFC molecules are 10,000 times more effective in trapping heat than a CO₂ molecule and can survive in the atmosphere for over a century.

“Had it not been for the Montreal Protocol in 1987, which restricted the use of CFCs, the annual growth rate of CFCs could have been 7%,” says Hamilton, “and this could have led to dangerous levels of global warming.”

Some Coolness on a Weather Modification Scheme

IPRC's **Kevin Hamilton** was interviewed for a story in the October 19, 2009, *Honolulu Advertiser* that discussed a patent application for a hurricane suppression method filed recently by a group of businessmen and scientists including Microsoft's **Bill Gates**: “Billionaire's plan strikes familiar chord” <http://the.honoluluadvertiser.com/article/2009/Oct/19/hn/hawai'i910190329.html>. The idea is to pump cold water from the ocean depth to the surface in a region over which the hurricane is projected to pass.

Hamilton dumped some “cold water” on the proposal, noting the difficulty in creating a practical demonstration-scale project: “If you only make the ocean surface a little colder, it won't weaken the hurricane enough to make much of a difference. Even as an experiment, you have to go the whole way, and that's a pretty big investment.” Hamilton also warned of the legal, philosophical, and ethical issues, for example, “What happens if you divert a hurricane away from Florida, and it hits Cuba?”

Mid-Pacific Islands and the Copenhagen Climate Change Conference

Kevin Hamilton participated in a discussion on the relevance of the Copenhagen Climate Change Conference for mid-Pacific Islands on Hawai'i Public Radio's *Energy Futures* program with host **Doug Carlson** on December 7, 2009, the opening day of the Copenhagen Conference. In addition to providing a general background, Hamilton talked about IPRC's climate modeling work. "Simulations with our regional climate model," he noted, "suggest that the overall intensity of cyclones and hurricanes is likely to increase in response to the warming of the ocean and atmosphere as greenhouse gases accumulate. Combined with sea level rise, future storms could be all the more destructive when they crash into our islands and coastal regions." Joining the conversation by phone was **John Barnes**, principal investigator of the Mauna Loa Observatory. Hamilton and Barnes also answered phone-in questions from the public during the show.



Kevin Hamilton and Doug Carlson moments before going on air at the Hawai'i Public Radio studio.



IPRC Director Gives TV Interview on Global Warming

On February 24, IPRC Director **Kevin Hamilton** was interviewed about global warming by **Justin Fujioka**, the broadcast meteorologist for Honolulu's KITV television station. The interview was aired in two stories the next day on KITV evening news.

High School Students Film at IPRC

A group of students from Waipahu High School on O'ahu descended on **Kevin Hamilton's** office with TV camera and microphone in November. The students are in a high school career path for humanities, performing, visual, literary, and the media arts, and interns at 'Olelo Hawai'i Community television network. They were making a video for a symposium on climate change held at their school. Student **Sharmaine Tiburcio** reported, "Our symposium went very well. Our advisor commented on how excellent the video was and how well we used our interviewee, Dr. Hamilton."

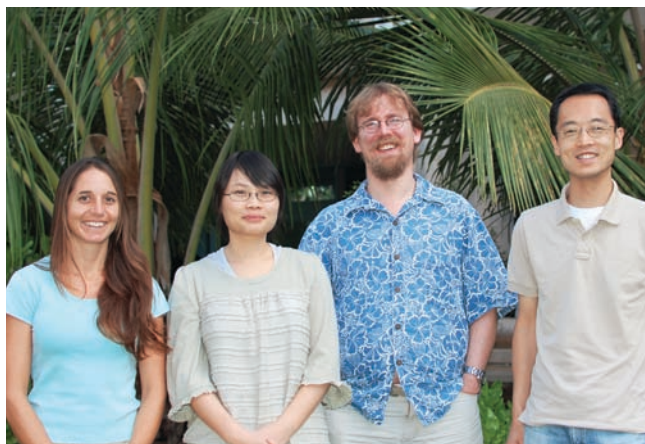


From left: Jenalyn Ramos, Sharmaine Tiburcio, Kevin Hamilton, Kenneth Tenoso, and Domingo Beltran.

Pacific Climate Change during the “Mystery Interval”

During the “Mystery Interval” from 18,000 to 10,000 years ago, melting ice-sheets dumped freshwater into the North Atlantic, triggering a collapse of the Atlantic Meridional Overturning Circulation. This brought on a major climatic reorganization. As part of the JAMSTEC–IPRC partnership, a team of researchers from JAMSTEC (**Yusuke Okazaki**, **Megumi Chikamoto**, **Naomi Harada**, **Ayako Abe-Ouchi**) and the IPRC (**Laurie Menviel** and **Axel Timmermann**) is trying to uncover how these massive changes in North Atlantic climate affected the North Pacific Ocean circulation, the climate over Japan, and also the global carbon cycle. Using latest results from a combination of deep-sea sediment core and climate model simulations, the team has found striking evidence that from about 17,500 to 15,000 years ago, a deep Pacific overturning circulation formed, as if it were replacing the collapsed North Atlantic overturning circulation.

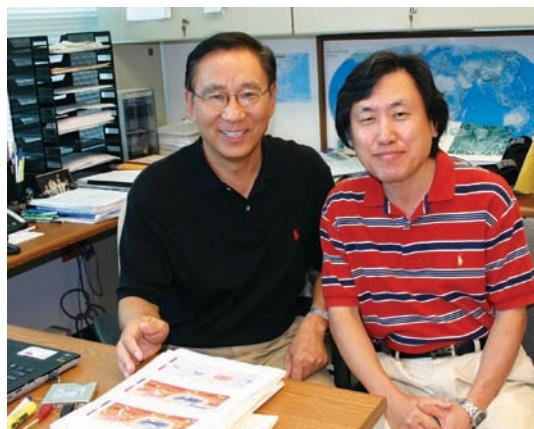
To throw more light on the mechanisms that led to the climate shift in the North Pacific, Chikamoto and Okazaki visited the IPRC this winter. Chikamoto is comparing the Pacific Meridional Overturning Circulation in MIROC with LOVECLIM, the model that Timmermann’s team is using at the IPRC. Okazaki is analyzing patterns of deep-sea ventilation during the Mystery Interval in his paleo sediment data of the Pacific and comparing it with climate model simulations.



Studying the “Mystery Climate Interval” from left, Laurie Menviel, Megumi Chikamoto, Axel Timmermann, and Yusuke Okazaki.

An MJO Prediction System

In-Sik Kang, professor at the School of Earth Environmental Sciences at Seoul National University, visited the IPRC in January–February 2010 to work with IPRC’s **Bin Wang** on the predictability of the seasonal and intraseasonal forecasting of major weather and climate disturbances, such as the Madden-Julian Oscillation (MJO), the El Niño–Southern Oscillation, and the Asian monsoon. The prediction tools they are assessing are ensemble forecasts of major climate models such as those from National Centers for Environmental Prediction, NASA, Geophysical Fluid Dynamics Laboratory, and other institutions.



Bin Wang and In-Sik Kang studying the predictability of seasonal climate.

“Of major interest,” says Kang, “is the development of an MJO prediction system using an improved version of the Seoul National University coupled general circulation model and better initialization methods.”

A Unique Regional Atmospheric Model

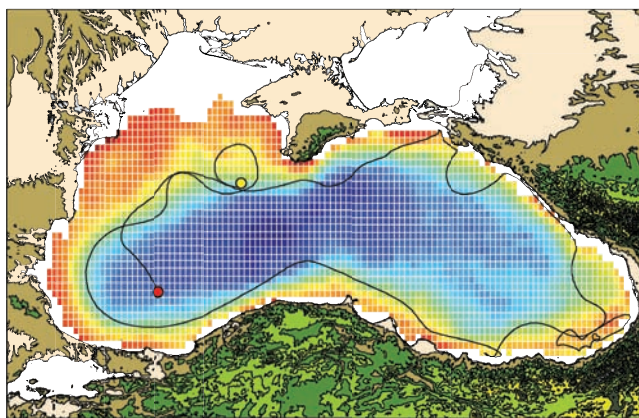
Masaru Inatsu, associate professor at the Department of Natural History Sciences, Hokkaido University, visited the IPRC in March 2010. He gave a seminar on a two-way regional–global atmospheric general circulation, which is nested within the MIROC coupled general circulation model and which he developed with scientists at the University of Tokyo. Inatsu is looking into working with IPRC scientists on research projects that would tap into the strengths of his unique model.

Probing Small-Scale Coastal Processes in the Black Sea

Viacheslav Kremenetskiy, senior researcher at the P.P. Shirshov Institute of Oceanology in Moscow, visited the IPRC from December 2009 to February 2010. On a joint grant from the US Civil Research and Development Foundation and the Russian Foundation for Basic Research, he came to the IPRC to work on the dynamics of the Black Sea with senior researcher **Nikolai Maximenko**. The Black Sea is of special interest to oceanographers because the coastal processes in that inland sea are of unusual complexity, taking place on small space- and time-scales over intricate shoreline topography.

Kremenetskiy described the Black Sea at an IPRC Luncheon Discussion. Fed by rivers and draining through the Bosphorous, the sea is very deep. Below 150 m it is anoxic and virtually dead aside from a few bacteria. The mean current flows clockwise around its rim. Currents near the coast swiftly react to varying winds blowing over coastal terraces. Eddies form frequently along the irregular shorelines and then move offshore, where they fall apart within a few weeks.

"A better grasp of these complicated processes will greatly advance the knowledge of eddy formation, coastal currents, and shelf sea processes. The Black Sea is a gem for such study," says Maximenko, "because of the dense coverage by drifting buoys that furnish data."



Kremenetskiy calculated this Black Sea mean dynamic topography (superimposed on a coastal relief map) from drifter, altimetry and wind data. Red indicates high, blue low sea surface height (SSH); the difference in SSH between the Rim Current coastal zone and the sea's interior reaches 0.5 m. Black line shows trajectory of a real drifting buoy, driven by mesoscale eddies, Rim Current meanders, and wind-induced flows; red and yellow dots show trajectory start and end points.

While at the IPRC, Kremenetskiy finished his calculations of the mean dynamic topography of the Black Sea. "These calculations," Kremenetskiy says, "can be used to produce weekly maps of absolute geostrophic currents required for many applications. The product will be available on the server of the Asia-Pacific Data-Research Center."

Modeling the Quasibiennial Oscillation

The Quasibiennial Oscillation (QBO) of the tropical stratosphere is a dominant component of variability in the stratosphere, and may play a role in the interannual fluctuations of tropospheric circulation. JAMSTEC researcher **Yoshio Kawatani** visited the IPRC from December to March to work with **Kevin Hamilton** on analysis of simulations of the QBO in a high-resolution general circulation model. The project emphasizes the application of the model to study possible changes in the QBO behavior in response to anticipated global warming.



Taking a break from their QBO research, Yoshio Kawatani and Kevin Hamilton visit the John Young Art Museum of the University of Hawai'i.



IPRC alumni from top to bottom: Bunmei Taguchi, Ingo Richter, Masami Nonaka, and Shin Kida

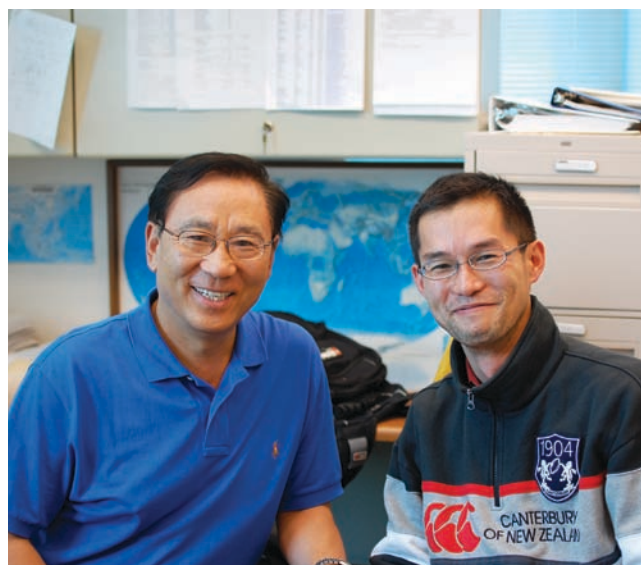
Alumni Come Home to the IPRC

Four IPRC alumni now at JAMSTEC—**Masami Nonaka**, **Ingo Richter**, **Shin Kida** and **Bunmei Taguchi**—came back to Hawai'i and the beautiful University of Hawai'i Mānoa campus in early December 2009. They each gave a talk at the Second OFES International Workshop (p. 11). They had fun climbing the monkey pod tree, which they used to rush past to attend Oceanography and Meteorology Seminars. And here is what they are doing at JAMSTEC: Masami Nonaka is senior scientist and team leader of the Mid- and High-latitude Climate Predictability Research Team of the Research Institute for Global Change (RIGC); Shin Kida is scientist with the Multiscale Simulation & Modeling Research Group of the Earth Simulator Center (ESC); Bunmei Taguchi is scientist with the Geophysical Fluid Simulation Research Group of ESC; and Ingo Richter is scientist with the Low-latitude Climate Prediction Research Team of RIGC.

Changes in Asian Monsoon Rainfall

Former postdoctoral fellow **Yoshiyuki Kajikawa** returned to the IPRC for a week in March. During his visit he gave a luncheon discussion about his present work with Professor **Tetsuzo Yasunari** at the Hydrospheric Atmospheric Research Center, Nagoya University. Yasunari's group is conducting an all-encompassing study named "Impact of Integrated Effect of Land Cover/Use Change and Aerosol Forcings on Climate Change in Asia."

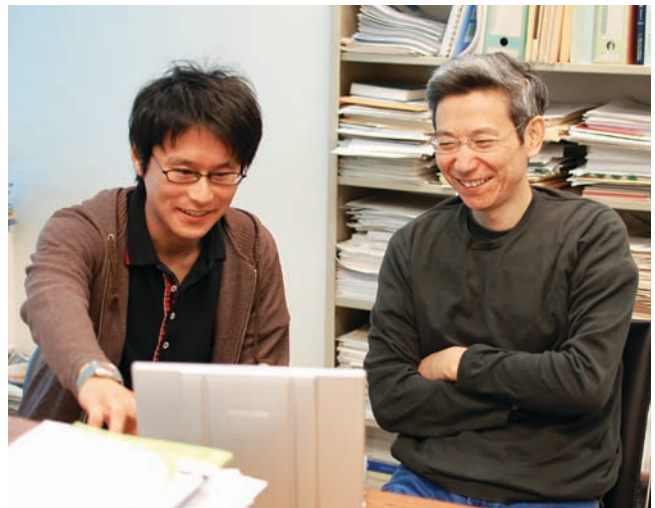
Agriculture-induced nitrate aerosols and secondary organic aerosols can impact the formation of clouds and precipitation and therefore the Asian monsoon. The study intends to unravel such processes using a full-aerosol process model coupled with CHASER, an atmospheric chemistry climate model. Kajikawa is part of the team that is analyzing the observational data on the effects of aerosols and land-surface changes on Asian monsoon rainfall and its seasonality from 1950 to 2000. The observational analysis will then be used to validate the model's results. The project is funded by Japan's Global Environmental Research Fund.



Yoshiyuki Kajikawa discusses Asian monsoon rainfall with Bin Wang.

Hokkaido-IPRC Exchange Program Continues

Yusuke Udagawa visited the IPRC on a Hokkaido University fellowship for 3 weeks in March. He is continuing the exchange program between the IPRC and Hokkaido University Graduate School of Environmental Science, the initiative begun by Hokkaido University's **Youichi Tanimoto** (*IPRC Climate*, vol. 8, nos. 1 and 2). Udagawa had just defended his PhD thesis at Hokkaido University, and during his visit he discussed with IPRC scientists the idea that the Southern Annular Mode might impact the westerly waveguide and thus the tropical forcing of the Pacific–South American teleconnection pattern. In November 2009, **Axel Timmermann** gave a lecture series on El Niño to graduate students at Hokkaido University.



Yusuke Udagawa with Shang-Ping Xie: “What about the Southern Annular Mode?”

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A publication of the
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Printer Hagadone Printing Company, Honolulu, Hawai'i

June 2010

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The IPRC is a climate research program funded by agencies in Japan and the United States and by the University of Hawai'i.

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