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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

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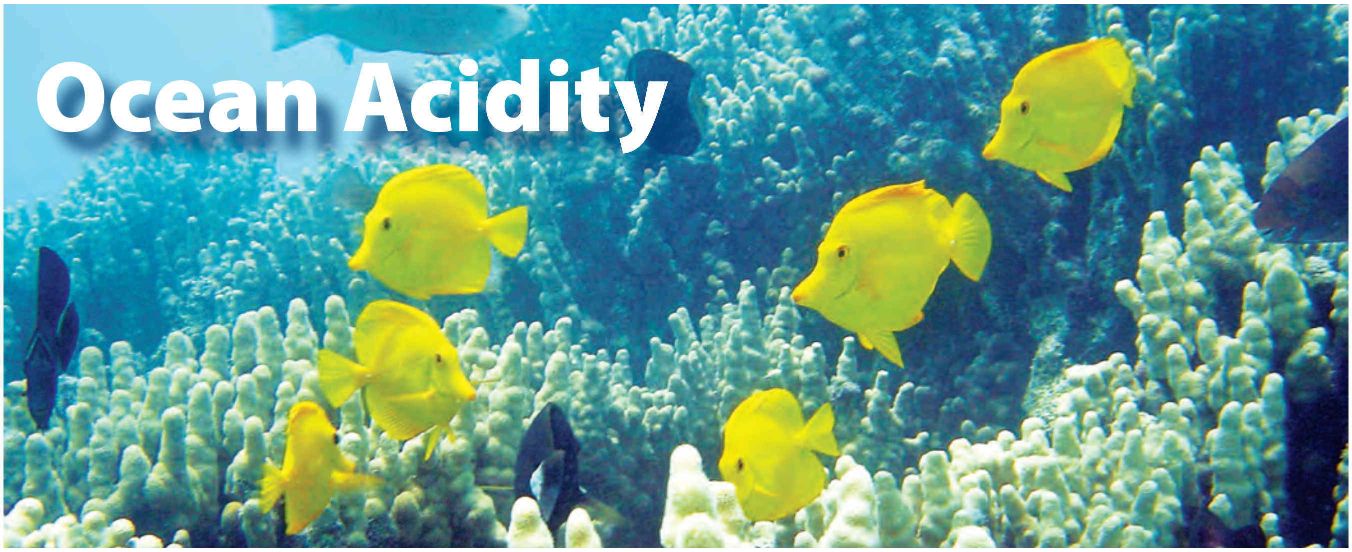
University of Hawai'i at Mānoa
School of Ocean and Earth Science and Technology



Ocean Acidity

Mankind has released around 500 billion metric tons of carbon into the atmosphere since the Industrial Revolution by burning fossil fuels, producing cement, and changing land use. The oceans have soaked up nearly one-third of these emissions, curbing the effects on global warming. The ocean uptake of CO_2, however, threatens the calcifying ability of corals and other calcium carbonate shell-forming organisms. As CO_2 dissolves in seawater it increases seawater acidity, which decreases the carbonate ion concentration needed for shell building.

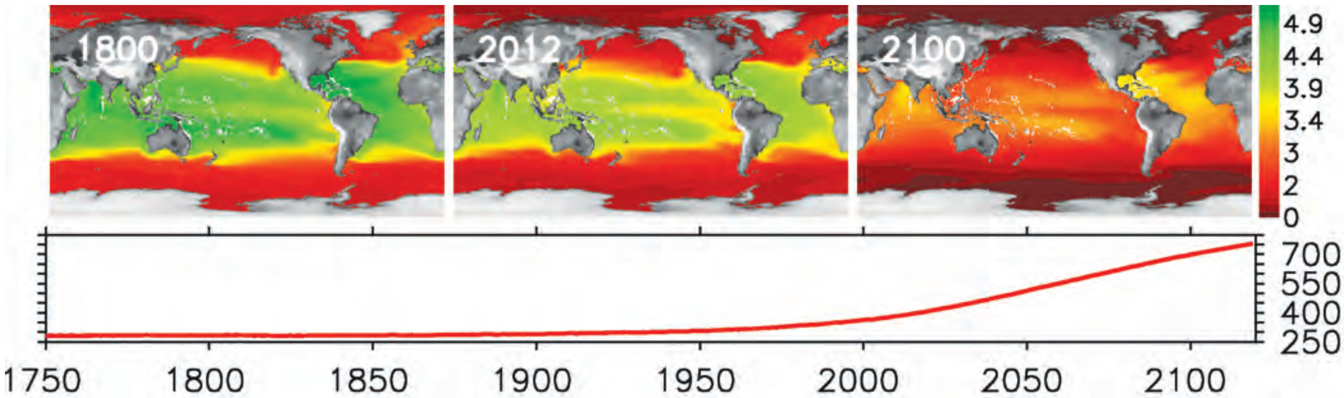
Detecting the man-made CO_2 signal in the ocean has been challenging. Continuous monitoring of ocean chemistry at a few selected stations goes back at most 30 years. The level of seawater pH, furthermore, varies seasonally, annually and regionally, making it difficult to decompose the observed variations into a man-made signal and "natural noise."

IPRC's **Tobias Friedrich** and **Axel Timmermann**, leading a team of climate modelers, marine conservationists, ocean chemists, biologists and ecologists, have developed a method to overcome this difficulty. By using three Earth System models, they have traced the changes in aragonite surface saturation level (a common measure of ocean acidification) 17 thousand years back in time and into the future to the end of this century. They conclude that the surface aragonite saturation levels are currently decreasing at a rate 10–100 times faster than at any time since the Last Glacial Maximum, and that the anthropogenic CO_2 emissions over the last 200 years have pushed ocean acidity far beyond the range that prevailed during those earlier times.

Specifically, their analysis of long-term model simulations conducted with the Max Planck Institute (MPI) Earth System Model yields robust regional signals of decreasing aragonite surface concentrations that compare well with observations over the last 30 years and with proxy indicators going back in time to 800 AD. The carbon-cycle-coupled climate model was driven with the most recent reconstructions of solar and volcanic radiative perturbations, land-use changes, aerosols and orbital variations as well as historical CO_2 and greenhouse gas emissions.

The simulations analyzed by the team showed that for over a thousand years, marine ecosystems have been exposed to aragonite surface saturation levels that varied naturally, like today, on a variety of timescales. Today's observed and modeled levels of surface aragonite saturation, however, have dropped nearly five times below the minimum range existing up until the Industrial Revolution.

For example, if the yearly cycle of aragonite saturation in a region varied between 4.6 and 4.8 units, it varies now between 4.2 and 4.3 units. Based on a recent study by a team of scientists at the Rosenstiel School of Marine and Atmospheric Science in Miami, this drop translates into a 15% decrease in the calcification rates of corals and other aragonite shell-forming organisms. Using this empirical relationship, Friedrich and Timmermann estimate a 60% drop in coral reef calcification by the end of the 21^{st} century; though, to be sure, other factors, such as nutrient and temperature changes, also impact calcification rate.



Upper panel: Simulated surface aragonite saturation. Lower panel: simulated atmospheric CO_2 concentration in parts per million.

"Ecosystems must adapt continually to environmental changes. Adaptation is more likely, though, if the rate of change is slow," explains Friedrich. "The last time that atmospheric temperatures and CO_2 rose rapidly occurred when Earth came out of its last deepfreeze and started to warm 17,000 years ago. Atmospheric CO_2 concentration levels rose from 190 ppmv to 280 ppmv until 11,000 years ago. By simulating this period with two Earth system models, LOVECLIM and MIROC, we could show that aragonite surface saturation had decreased by 0.88 and 0.64 units in LOVECLIM and MIROC respectively during that time. This means that the marine ecosystems had about 6000 years to adjust. Now, for a similar rise in CO_2 to the present level of 392 ppmv and a decrease in aragonite surface saturation of around 0.5 units, ecosystems have had only 100 to 200 years to adapt."

"Any significant drop below the minimum level of aragonite to which the organisms have been exposed to for thousands of years and have successfully adapted will very likely stress them and their associated ecosystems," warns Friedrich.

The study's findings also suggest that ocean acidification will affect calcifying marine ecosystems differently because the variability of aragonite saturation differs by region. This spatial heterogeneity in natural variability together with other local differences, especially in air-sea fluxes, suggests that some regions will be less stressed than others because the greater underlying natural variability of seawater acidity helps to buffer the anthropogenic changes. For example, the Galapagos Islands, located at the center of a strong upwelling region, are exposed to much larger variations in aragonite concentrations than the reefs in the Caribbean and the western Equatorial Pacific, where there is very little natural variability. These two biodiversity hotspots are thus particularly vulnerable to human-induced ocean acidification.

The rate at which aragonite surface concentration decreases in LOVECLIM and MIROC compares well with the rate of decrease recorded over the last 2 to 3 decades at several monitoring sites in the Pacific and the Atlantic. The observed decreases range between 0.09 units per decade for the Canary Islands and the Caribbean to 0.04 for Bermuda. The slowest rate of change in Bermuda already exceeds 32 (56) times the rate estimated in LOVECLIM (MIROC) for the last glacial termination; in the Caribbean, which shows the largest regional trends, the decrease over the last 20 years reaches 78 (138) times the previous rate.

Coral reefs live in places where open-ocean aragonite saturation reaches levels of 3.5 or higher. Such conditions exist today in about 50% of the global ocean – mostly in the tropics. By end of the 21^{st} century, the MPI model simulations project that such levels of aragonite saturation will occur in less than 5% of the ocean. Because aragonite saturation decreases from the equator poleward, the Hawaiian Islands, which sit just on the northern edge of the tropics, could be among the first to feel the impact.

"Our results suggest that severe reductions are likely to occur in coral reef diversity, structural complexity and resilience by the middle of this century," concludes Axel Timmermann.

This story is based on

Friedrich, T., A. Timmermann, A. Abe-Ouchi, N.R. Bates, M.O. Chikamoto, et al., 2012: Detecting regional anthropogenic trends in ocean acidification against natural variability. *Nature Climate Change*, **2**, 167–171.

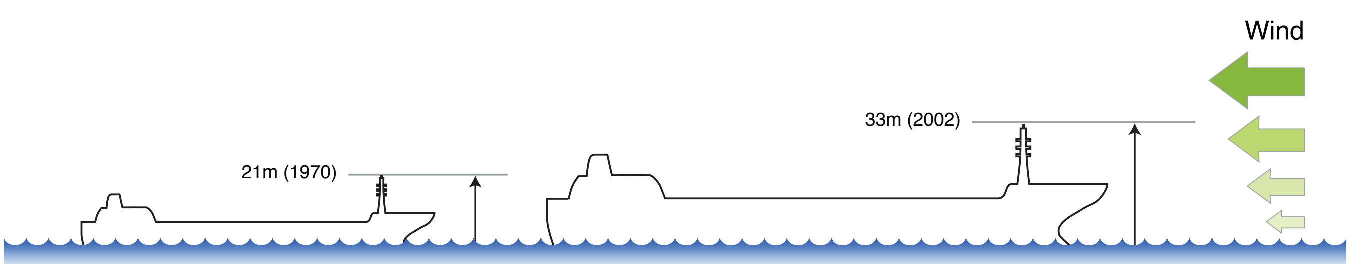
Animation of ocean acidification is at tinyurl.com/IPRCacid.

Walker Circulation Trends

The signal of the surface warming expected to result from increased atmospheric greenhouse gas concentrations has a characteristic pattern with more warming over land than over adjacent oceans and an intensification of warming at high Northern latitudes. This overall pattern is projected by climate models and also appears in the observed record over the last century. When focusing on somewhat finer details the picture is more complicated, however. Notably, the geographical pattern of long-term warming of the surface waters of the tropical Pacific is much less certain, as global climate projections among state-of-the-art models are not consistent, and even the observational record for the last century suffers from ambiguities.

The tropical Pacific is a region of strong coupling of the ocean temperatures to the overlying atmospheric circulation, and the uncertainties in trends and projections for warming are also reflected in uncertainties in the winds and rainfall. The atmospheric circulation in the region includes a component with rising motion over the warm western Pacific region and Maritime Continent, sinking over the cooler eastern equatorial Pacific and surface easterly winds along the equator. This circulation, named for the early 20th century British meteorologist **Sir Gilbert Walker**, has significant interannual variations coupled to the ocean temperatures through the familiar El Niño–La Niña cycle. The long term trends in the Walker circulation have been hard to characterize from existing observations.

Difficulties arise because sampling is limited in space and time, and changes in observational practices over the years have resulted in seriously biased measurements. One of the gravest biases has been in the marine surface wind measurements, which are important in determining sea surface temperature (SST) and regional sea level changes in the tropics. Direct wind measurements are taken mostly



Schematic of changes in anemometer height on ships.

by ships, and their bias comes from the fact that as ships have increased in height over recent decades, so has the height of the wind-measuring anemometers, resulting in spurious intensification of the prevailing winds (Figure 1a). Central to the debate are also the historical SST data sets in the tropical Pacific; but they, too, are inconsistent, some showing a flattening, others a strengthening of the east-west temperature difference.

To provide a clearer picture of the trends in observations, IPRC Assistant Researcher **Hiroki Tokinaga** spearheaded a team of mostly IPRC scientists, who have analyzed in great detail the in situ observational climate data sets in the tropical Indo-Pacific over the last six decades, bias corrected them as necessary, and then synthesized them to see whether a physically consistent pattern emerges among SST, cloudiness, sea level pressure (SLP), surface wind, and subsurface ocean temperature.

The data sets they analyzed consisted of the following: SLP and total marine cloudiness observations (with biases removed) of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS); Tokinaga's bias-corrected Wave- and Anemometer-based Sea Surface Wind (WASWind; *IPRC Climate*, vol. 10, no. 2); subsurface ocean temperatures from bias corrected expendable bathythermographs (XBT) in the Enhanced Ocean Data Assimilation and Climate Prediction of the Hadley Centre, and land precipitation from rain gauge data of the University of Delaware and the Climatic Atlas Project.

Since the SST pattern affects the Walker circulation so much, they cross-checked the SST trends with five different surface temperature reconstructions: Extended Reconstructed Sea Surface Temperature (ERSST), the Hadley Centre Sea Ice and Sea Surface Temperature (HadISST) data sets, bucket-sampled SST from ICOADS, and night-time marine air temperature (NMAT) data sets from ICOADS, and the Met Office Historical Marine Air Temperature (MOHMAT). These observations were compared with the European Centre for Medium Range Weather Forecasting 40-year Reanalysis (ERA40) and the National Centers for Environmental Prediction (NCEP)-National Center for Atmospheric Research (NCAR) reanalysis.

According to the new bias-corrected surface WASWind, the easterly winds over the western tropical Pacific and westerly winds over the tropical Indian Ocean have both weakened (Figure 1b). These changes are consistent with observed changes in SLP, which has been rising over the Maritime Continent and falling over the central equatorial Pacific (Figure 1c). Over the Maritime Continent, the rain gauge data reveal a significant decrease in land precipitation, consistent with ship observations, which show an eastward shift of marine cloudiness from the Maritime Continent to the central equatorial Pacific (Figure 1d). All these changes point to a weakening of the Walker circulation.

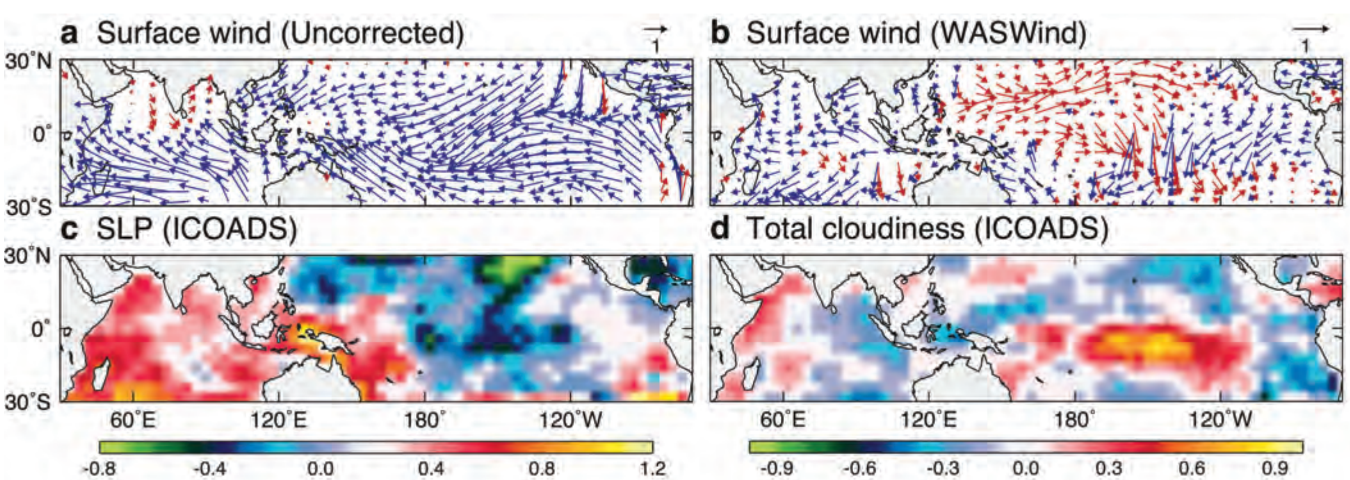


Figure 1. Annual mean trends for 1950–2008. (a) Uncorrected surface wind [m/s over 59 years], (b) bias-corrected surface wind from WASWind [m/s over 59 years], (c) SLP from ICOADS [hPa over 59 years], (d) marine cloudiness from ICOADS [okta over 59 years]. Red (blue) vectors in (a) and (b) indicate westerly (easterly) trends.

Results of changes in the zonal SST gradient, though, are inconclusive in the widely used SST products: one product shows a significant strengthening of the zonal SST gradient in the tropical Indo-Pacific (Figure 2d), while another shows no significant change (Figure 2c). However, the bias corrected XBT observations indicate the ocean mixed layer temperature has warmed more in the eastern than in the western equatorial Pacific Ocean (Figure 2a). The bucket-sampled SST and NMAT are consistent with the XBT pattern (Figure 2b,e,f). In other words, both surface and subsurface observations suggest the zonal thermal contrast across the Indo-Pacific has decreased. These analyses are therefore also consistent with the slowdown of the Walker circulation.

To what degree this long-term weakening trend in the Walker circulation resulted from anthropogenic forcing or natural climate variability is still unknown. In climate model simulations with anthropogenic forcing, the

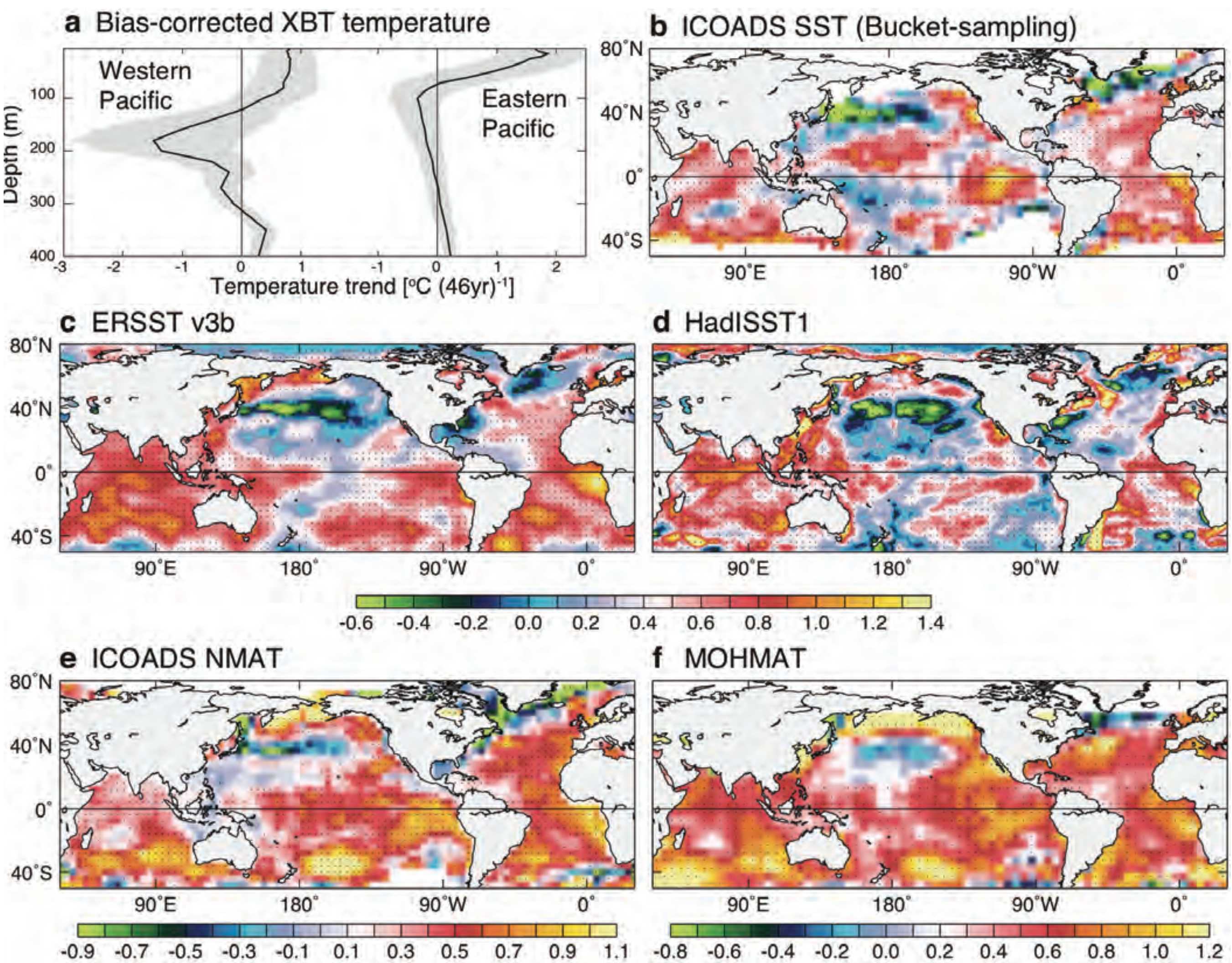


Figure 2. (a) Annual-mean subsurface temperature change [°C over 46 years] averaged in the western and eastern equatorial Pacific for 1963– 2008. (b–f) The surface temperature trends [°C over 59 years] for 1950–2008. (b) Bucket SST from ICOADS, (c) ERSST v3b, (d) HadISST1, and NMAT from (e) ICOADS and (f) MOHMAT.

Sir Gilbert Walker.

Walker circulation also weakened during the twentieth century, but much less than in the above observed changes. Since the mid-1990s, the Walker circulation weakening appears to have been reversing, perhaps due to significant variations on interdecadal timescales. Understanding and projecting the variations in the Walker circulation and its associated ocean temperature and sea level effects thus remain an important challenge for climate science.

The detection of anthropogenic climate change in the midst of natural variability and a conclusive attribution will have to wait for longer observations and a longer response period to a rise in global temperature. Whatever the outcome, the physical consistency among the many different independent ocean-atmosphere observations indicate that ocean-atmosphere coupling is important in the changes that have taken, and are taking place in the Walker circulation.

On a final note, the findings here call for a judicious use of reanalysis products for climate change research. The reanalysis products that show the Walker circulation has strengthened over the last six decades (Figure 3) have often been treated as observations both to drive GCMs and to validate the model simulations. They prove useful for studying weather and even interan-

Anemometer.

nual variability. For long-term trends, however, these products should be used with great care as they can include spurious trends stemming from changes in measurement technique and assimilated data sources. Sustained efforts are needed to develop homogeneous data reconstructions that will yield better descriptions and understanding of regional and global climate changes.

This story is based on

Tokinaga, H., S.-P. Xie, A. Timmermann, S. McGregor, T. Ogata, H. Kubota, and Y.M. Okumura, 2012: Regional patterns of tropical Indo-Pacific climate change: Evidence of the Walker Circulation weakening. *J. Climate*, **25**, 1689–1710. IPRC-814.

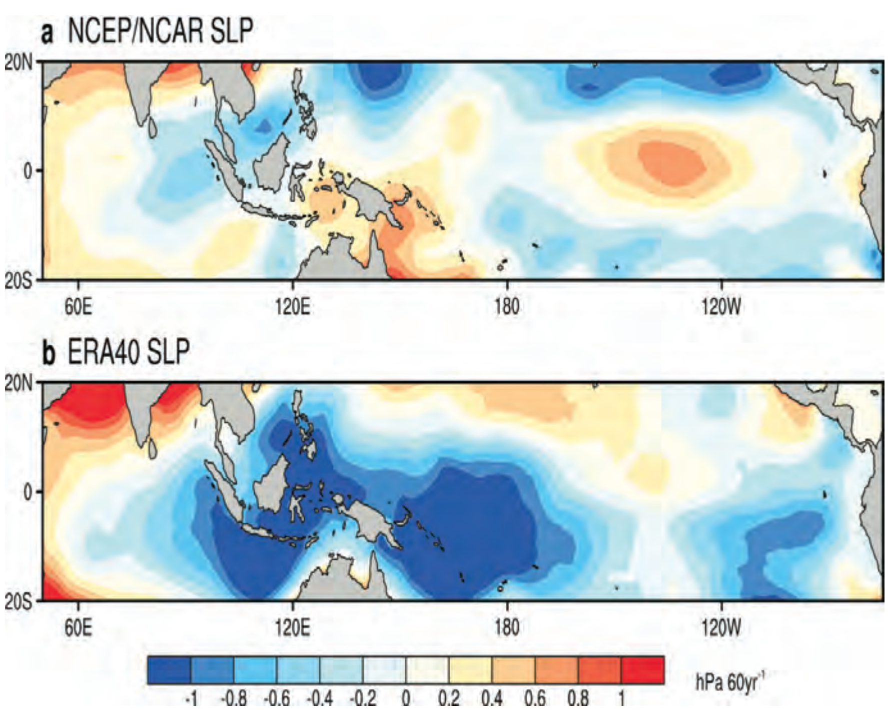


Figure 3. Annual mean SLP trends in reanalysis products [hPa over 60 years]. (a) NCEP/NCAR reanalysis for 1950–2009, and (b) ERA-40 for 1958–2001. ERA40 SLP trends are scaled to the 60-year change.

In the True Spirit of Science

The Second Expedition to Kamilo and Hanalua Beach

Marine Debris is an emerging field of study, charting new territory. We know much about the movement of the large subtropical ocean gyres that collect debris in the garbage patches of the World Ocean, but so little about the transient currents that let masses of man-made debris escape out of the garbage patches and throw it onto such special places as Kamilo Beach, which has been called the "dirtiest beach on Earth."
Nikolai Maximenko

There are no paved roads to Kamilo Beach in the Ka'ū district on the remote southern tip of the Island of Hawai'i. The beach is a sandy crescent that hugs a lava-terraced bay laced with tide pools and deep channels cut by powerful waves. Much of the terrace is above water during low tide and awash during high tide. The beach has made headlines, not for its good swimming or surfing, but for the huge amount of trash that keeps washing up on its narrow strip of white sand.

"A surreal picture…nearly no sand, only debris. You can't walk without treading on some kind of stuff thrown out by the ocean," describes IPRC Assistant Researcher **Axel Lauer** his first visit. "And this only 8 weeks after **Bill Gilmartin**, **Megan Lamson**, and their clean-up team from the Hawai'i Wildlife Fund Debris Project were here."

Nearly no sand, only debris on Kamilo Beach.

Why does Kamilo Beach collect so much debris? The search for answers led Lauer in summer 2011 to accompany Senior Researcher **Nikolai Maximenko**, a physical oceanographer at the IPRC, and his team on their trip to the notorious beach.

Maximenko became interested in marine debris when he realized that the thousands of drifting buoys, which oceanographers have been releasing over the past decades into the ocean to study its characteristics, are a form of marine debris. Studying the drifters' paths and their final demise, he developed a model to understand marine debris behavior and to track it. Since the March 2011 tsunami in Japan, he has adapted the model to study and track the debris swept by the tsunami into the ocean.

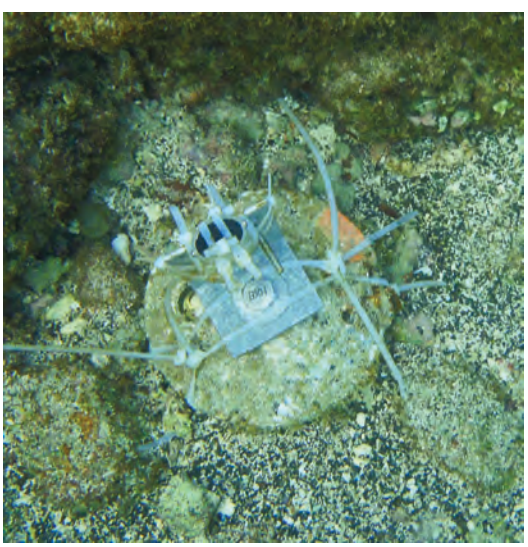
So it is no wonder that the stories of the massive trash collecting on Kamilo sparked Maximenko's interest, and in summer 2010 he took his team on its first exploration there. Now a year later, supported by funding from JIMAR, he is returning with a plan of action: gather more information about the currents inside Kamilo Bay and confirm his hunch that maybe the black lava rocks at nearby Hanalua Beach are sitting on much more plastic than a cursory look suggests.

Painted "bottle-drifters" in bush.

The Currents at Kamilo

On this second visit to Kamilo Beach, the team is hoping to get more clues about the currents in the bay. The summer before, they had installed with great difficulty temperature sensors in the hope that they would reveal something about the daily flow of water in the bay. What disappointment: The sensors are gone, washed away by the power of the ocean. Valuable observations that might have told a story about the currents are lost!

They have to install new sensors, but finding the plates is nearly as hard as mounting them on to the lava the year before, because they have become overgrown with algae and now look just like the rocky bottom (picture). Just when Assistant Researcher **Oleg Melnichenko** finally finds a plate, Maximenko sees a fin and a shadow flitting in the water behind Melnichenko. He yells a warning. But against the wind Melnichenko can't hear him. The fin swims by … and out to sea again! The new sensors get installed. Hopefully they will stay put and record data for a while.



Camouflaged temperature sensor and plate

The "bottle–drifter" experiment is next. Back at the IPRC, the team had brainstormed about how to get more clues to the bay's currents. The usual instruments for studying currents are drifters with heavy, long drogues so that they stick out of the water only a little bit, and their movement reflects mostly the movements of the ocean and not the wind. But the team has no expensive drifters at their disposal. Such drifters would also be too big, too heavy, and their drogues would get entangled in no time in the rough lava-rock bottom of the bay. But what can they use in their place? How about soda bottles?

Now on site, they fill 2-litre coke bottles with sand and test how much sand the bottles need in order to float but not bob out of the water and ride before the wind like sailboats. Trial by error shows that bottles two-thirds full of sand will do it.

On the morning of day 2, the team arrives at Kamilo in eager anticipation: how will the drifter experiment work? Forty-three 2-litre coke bottles, filled two-thirds with sand and painted bright red or pink to see them against the blue ocean are to be dropped into the water far out in the bay. Sounds simple, but proves to be tricky. Melnichenko and UH Hilo Postdoctoral Fellow **Hank Carson** load the rubber dingy with bottles.

Hardly have they climbed in, the wind tips over the dingy and throws them into the shallow water with its sharp lava bottom. A second failed attempt, and they realize, the only way to get the bottles launched from the southern edge of the reef, is to swim them out pulling a net filled with bottles.

Anxiously watching from shore, the others notice a tongue of clear water that extends beyond the reef. It must mean a strong rip current leaving the bay. Warned, Melnichenko and Carson toss out the painted bottles just before reaching the

Swimming the bottles out to the reef.

dangerous rip. Thankfully, the rest of the bottles can be jettisoned from land, from the point projecting out into the bay (see "X" in image below).

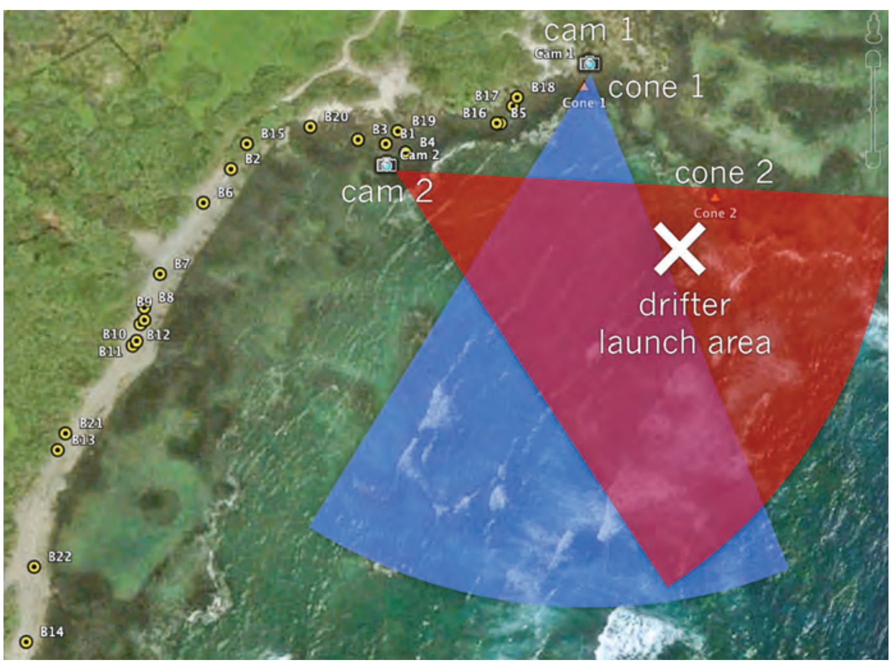
The team had placed two cameras strategically along the shore and now, that the "drifters" are deployed, Scientific Computer Programmer **Jan Hafner** and Lauer take pictures every 10 seconds to see where the bottles go. These pictures are their "data" from which they hope to determine, using the triangulation method, the path taken by the bottles. This will turn out to be a lot more challenging than Lauer had imagined.

The bottles first float parallel to the shoreline far out in the bay. Then many get caught up in the rip current, which is so strong that it pushes the bottles against the wind beyond the reef. Will they drift further out to sea and join the subtropical gyre circulation and the Great Pacific Garbage Patch?

After a while the bottles appear again, riding on waves back across the reef. There must be an eddy that flows out and loops beyond the reef back again into the bay. The bottles eventually escape the eddy and drift toward shore. They land not in one or two spots, as might be expected, but widely dispersed along the whole beach. By the time the team has packed up for the day and is ready to leave, 26 of the 43 bottles have washed up on the beach. The remainder were picked up by **Megan Lamson** the next day. Though many bottles had ventured out beyond the reef, only one of the whole lot never returned.

Back at the IPRC, Lauer has to determine from the pictures the currents in the bay. This requires much ingenuity. He had not anticipated that the bottles would disappear in the waves for minutes at a time and that he wouldn't be able to follow a single bottle from the place it was dropped into the water to shore. By counting the bottles that are visible and graphing their position in each and every of the 1,646 pictures, Lauer is able to develop a chart representing the overall flow pattern (Figure page 12). Violet-blue are the bottle positions at the beginning of the experiment, while red-yellow are the positions during the last half hour. The black lines with arrows show the approximate paths taken by the bottles. The graph shows what the team had suspected: a fair number of bottles circulate for a long time far out, at times floating beyond the reef. Viewing the sequence of pictures from each camera yields a choppy animation of the bottles' travels toward the beach.

Lauer reflects on his results: "I don't think that the incoming tide alone was responsible that most of the bottles washed up on the beach again. When we dropped the bottles into the water, they were quickly taken out to sea in the strong rip current along the reef, but that current also seemed to bring them back in. The mini-gyres we saw within the bay certainly help to bring the junk from outside the bay ashore. The name 'Kamilo' means the twisting or swirling current in Hawaiian,



Schematic view of the setup of the drifter experiment at Kamilo Beach. The camera positions are indicated as "cam 1" and "cam 2", the two reference cones as "cone 1" and "cone 2". The blue and red areas show the fields of view of the two cameras. Also shown is the drifter launch area marked with an "x" as well as the positions of the bottles (B1 to B20) that beached during the first two hours of the experiment.

Bottle-drifters floating in the bay.

suggesting the Hawaiians have been aware for a long time what makes this place so special. And that we retrieved all the bottles except one also suggests that once something enters the bay, it tends not to leave. Although the bottles were dropped into water within 25 meters of each other, their path toward shore varied greatly as shown by how far apart they washed up along the shore."

He adds, "We learned a lot about the technical difficulties in conducting the experiment, and it gives us new ideas about what to try next."

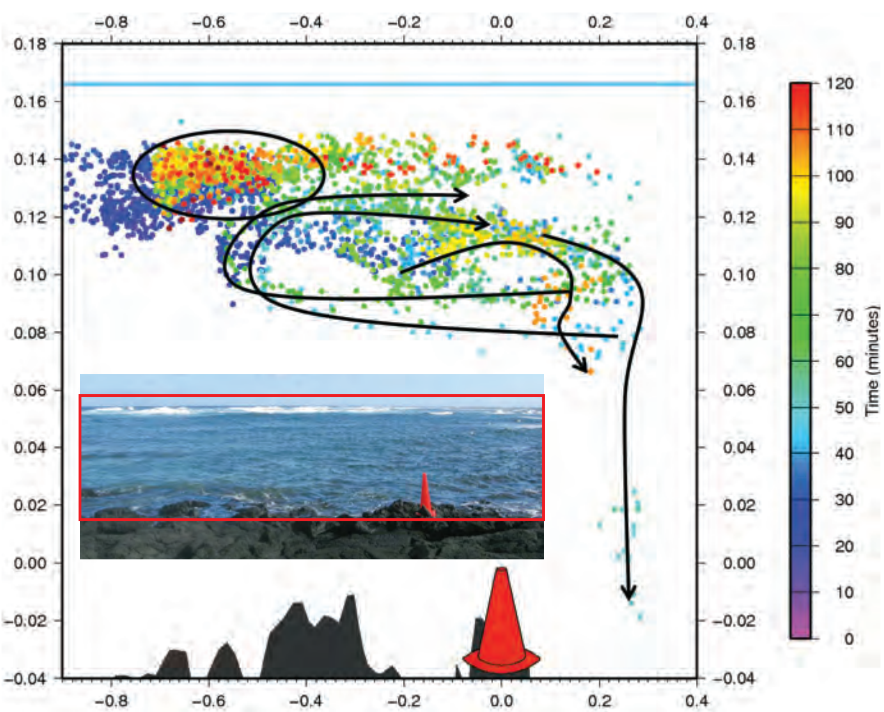
The Hidden Plastic of Hanalua Beach

Driving last summer along the coast between Green Sand Beach and South Point revealed a rocky beach with surprisingly little debris compared to Kamilo Beach just a few miles away. Do the currents and winds keep the stuff away? Or do the retreating tides suck it back out? Melnichenko had noticed some plastic sticking out from under the rocks, and when he removed a few rocks, he saw a pile of plastic hidden underneath. On this trip, therefore, the team wants to find out what is buried below the rocks.

It is a brutally hot, sunny day. Thank goodness for the canopy that shades at least the 3 m x 3 m hole, which they are digging in order to get a rough estimate of the amount of plastic that has piled up on the beach. Their technique: with the top layer, about 30 cm deep, they pick up and get rid of all the rocks first and then collect the plastic found below the rocks. The plastic is stored in a bag and kept to be weighed back at the IPRC. In the next layer, they find the plastic pieces are so tiny, that the only way to collect them efficiently is to shovel the plastic-sand mixture into a bucket of water and then skim the floating plastic off the surface. This second layer reaches a depth of 60 cm. Again they store all the plastic from this layer in a huge plastic bag.

They dig much of the day. The work is grueling! They brainstorm: How about a vacuum cleaner the next time to suck up all the stuff?

Most surprising and frightening, as they dig deeper they are finding that the concentration of plastic increases. With their third layer, at a depth of about 90 cm, they call it quits. They place the plastic bags containing their hard-earned plastic trash into containers to take them back home to weigh. The containers are very, very heavy.



Positions of the bottles (colored dots) as seen from camera 1 during the first two hours of the experiment. The positions are given in coordinates relative to the tip of the red cone on the point of origin (0.0). The color shading of the dots represents the time of sighting in minutes after the bottles were released. The black arrows depict some of the bottle trajectories observed during the experiment. It is remarkable that, although many bottles were still far out after two hours, all bottles save one eventually returned.

The untouched surface.

The layer after removing the rocks.

Back at the IPRC, the carefully labeled bags are weighed and the weight of plastic per square foot at each layer of depth determined (see table). Their impression turns out to be right…the amount of plastic increases with depth. From this sample, they can now calculate how much plastic lies on the whole beach. The result of their calculations? At least 25 tons of plastic lie buried under the black, plastic-free-looking rocks at this beach that is about 200 meters long and 10 meters wide! This impressive figure is clearly an underestimation as the team did not even reach the depth of maximum density of plastic.

Perhaps it is not a difference in currents that makes Kamilo "the dirtiest beach" and Hanalua Beach look so clean by comparison, but rather the difference between a sandy and a rocky beach, where the plastic slips down between the crevices, gets ground up into smaller and smaller bits by the sharp rocks and sinks further and further down into the sand, creating a plastic carpet. As smaller rocks sink further down over time, they continue their plastic grinding.

The plastic collectors, from left Hank Carson, Nikolai Maximenko, Axel Lauer, Oleg Melnichenko, and Jan Hafner.

"This is so different from the science I usually do….sit in front of the computer screen and press keyboard buttons to run my modeling experiments," Lauer recalls. "To go explore in the outdoors, without knowing what we will find or how things will turn out is thrilling. Figuring out how to use the bottles as drifters, the challenge in deploying them, nervously watching how the bottles are swept out beyond the reef, worried that they might add to the plastic in the ocean, the hard work of digging in the sand and the astonishment of finding how much plastic is buried beneath the rocks, all that is energizing, challenging—that's the true spirit of science."

This story is based on an interview with IPRC Assistant Researcher Axel Lauer.

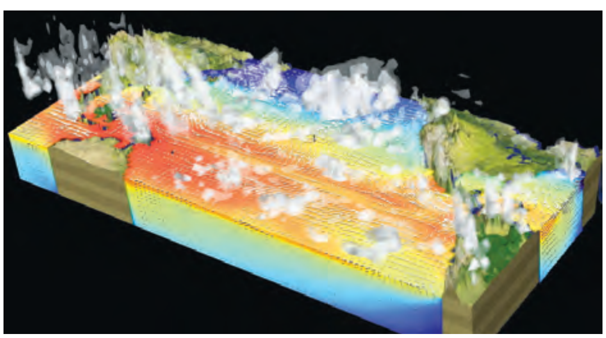
Layer	Plastic density, kg/m^3
0-30 cm	5.9
30-60 cm	14.2
60-90 cm	17.3

The density of plastic in kg per cubic meter in each of the 3 layers.

Modeling the Atmosphere and Ocean

Fine-resolution modeling of the atmosphere and ocean is a major focus for collaboration between IPRC scientists and their JAMSTEC colleagues. With the advent of the Earth Simulator in 2002, JAMSTEC became a world leader in developing and applying very high-resolution models of the atmosphere and ocean. Notable among the global models developed at JAMSTEC 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) and the Multi-Scale Simulator for the Geoenvironment (MSSG) – all projects led by scientists at the Earth Simulator Center (ESC). In addition, University of Tokyo and JAMSTEC scientists have developed the Nonhydrostatic ICosahedral Atmospheric Model (NICAM) for cloud-system-resolving global simulations for application on the Earth Simulator.

For nearly a decade IPRC researchers have joined their Japanese colleagues in analysis of the very high-resolution model simulations conducted at JAMSTEC. The close cooperation in this area was recognized when JAMSTEC invited the IPRC to cosponsor the August 2008 "OFES International



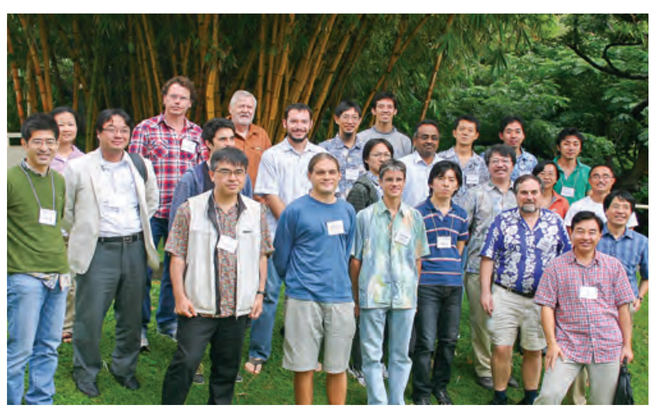
Snapshot from a CFES simulation. Shown are ocean temperatures (colors), ocean currents (vectors) and cloud amounts. Figure courtesy of JAMSTEC ESC Geophysical Fluid Simulation Research Group.

Workshop" in Yokohama (see *IPRC Climate* vol. 8, no. 2). This began a tradition of annual JAMSTEC-IPRC meetings, with the Second OFES International Workshop held in Honolulu in December 2009 (see *IPRC Climate* vol. 9, no. 2) and the Third OFES International Workshop held in Yokohama in November 2010 (see *IPRC Climate* vol. 10, no. 2). Given the breadth of the phenomena being modeled and analyzed by

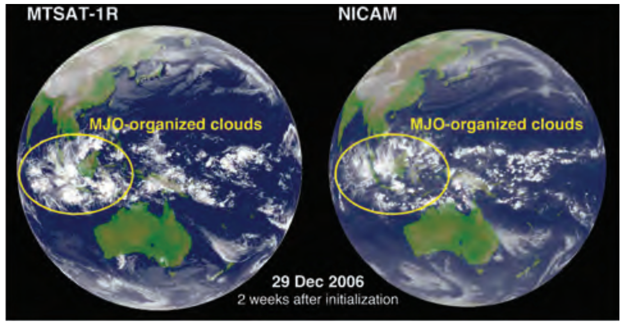
Erik Lindborg presenting keynote lecture at the OFES workshop.

both JAMSTEC and IPRC scientists, the scope of the 2009 Honolulu meeting was expanded to include all areas of computationally intensive climate modeling.

Convened by ESC's **Wataru Ohfuchi** and IPRC's **Kevin Hamilton**, the *Fourth OFES International Workshop and Second ESC-IPRC Joint Workshop on Computationally-Intensive Modeling of the Climate System* was held December 1–2, 2011, in the Keoni Auditorium of the East-West Center. The meeting included presentations by 10 Japanese participants from JAMSTEC and the University of Tokyo. The meeting opened with a keynote address by **Erik Lindborg** of the KTH Royal Institute of Technology in Sweden, who discussed the dynamics controlling the mesoscale energy spectrum in the atmosphere. A total of 19 papers were presented that described results from a wide range of simulation and data assimilation models applied to understand phenomena in the ocean and atmosphere. One interesting development apparent in this year's workshop was that over one-third of the talks referred to global coupled-model results obtained with CFES, an indication of the growing maturity of this important tool developed by ESC scientists. The meeting program and abstracts of the presentations are available at http://www.jamstec.go.jp/esc/event/ofes-workshop4/.



Tropical Dynamics and the Madden-Julian Oscillation



Active phase of MJO as seen in MTSAT IR image (left) and in outgoing IR radiation from a NICAM model simulation (right). Figure adapted from Miura et al., 2007, *Science*, 318, 1763-1765.

The tropical atmosphere is notable for the frequent presence of organized large-scale patterns of intraseasonal variability (ISV) in the circulation. Organized eastward propagating disturbances of 30-60 day period are often referred to as Madden-Julian Oscillation (MJO) events and these are particularly prominent in the Indian Ocean and western Pacific regions. The MJO phenomenon has long been a major field of study for tropical meteorologists. In recent years the possible role of MJO dynamics in extended range weather prediction has attracted increased attention from IPRC researchers (see "NICAM Captures the Leading Weather Disturbance of the Tropics" and "Birth, Growth, & Decay of Tropical Cyclones Simulated by NICAM" in *IPRC Climate* vol. 9, no. 1) as well as from the broader climate research community.

In order to review recent developments in observations and theory of the MJO, IPRC hosted the *Workshop on Tropical Dynamics and the MJO* January 15-17, 2012, at the East-West Center in Honolulu. The workshop was notable as the first major meeting on the subject of tropical ISV to be held since the October 2011 commencement of the joint Japan-US CINDY/DYNAMO field experiment in the tropical Indian Ocean. At the workshop the JAMSTEC leader for CINDY (Cooperative Indian Ocean Experiment on ISV in the Year 2011), **Kunio Yoneyama**, excited the audience with his report of initial results from this major campaign. Other talks covered a wide range of topics from simulation of MJO-like variability in idealized models to evaluation of extended-range weather hindcasts made with sophisticated numerical prediction systems. The IPRC contribution to the workshop was quite prominent as 9 of the oral presentations and 4 of the posters were by IPRC scientists. The organizing committee was led by Colorado State University professor **Eric Maloney**. The workshop was held at the East-West Center in Honolulu and IPRC Director **Kevin Hamilton** acted as local organizer. The meeting was sponsored by the National Science Foundation. The detailed program is available at tinyurl.com/IPRCmjo.

Participants at the Tropical Dynamics Workshop. Organizers David Randall (left) and Eric Maloney (right) with leis.

CMIP5 Climate Model Analysis

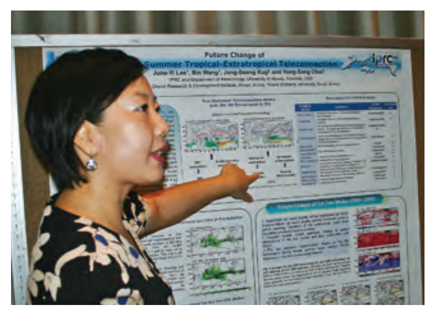
Since its inception in 1995, the Coupled Model Intercomparison Project (CMIP) initiative of the World Climate Research Programme (WCRP) has coordinated international research in numerical modeling of the coupled global climate system. The CMIP Phase 5 (CMIP5) is a current project to distribute and analyze results from a large set of standardized model integrations conducted at many individual centers. The CMIP5 model runs became available starting in Fall 2011 and will provide an important input to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report to be published in 2013.

Thus it was very timely that the IPRC hosted the first meeting devoted to analysis of the WCRP-CMIP5 coupled global climate model simulations. The workshop was held March 5–9 at the East-West Center and attracted very wide international interest. The meeting program was devoted almost exclusively to poster presentations and 231 authors submitted poster abstracts, of which 170 were selected for presentation. With the poster presenters, sponsor representatives and local University of Hawai‘i attendees, the workshop had more than 200 participants, making it the largest meeting ever hosted by the IPRC.

IPRC scientists were well represented in the program with poster presentations by IPRC Senior Researcher **H. Annamalai**, Assistant Researchers **June-Yi Lee**, **Axel Lauer** and **Pedro DiNezio**, and by Postdoctoral Fellows **Pang-Chi Hsu** and **Matthew Widlansky**. In addition, the program was replete with presentations by IPRC alumni and close collaborators, testament to IPRC's considerable influence in the field of climate modeling.

From left: Jerry Meehl (program committee chair), Sandrine Bony (program committee), Kevin Hamilton (local organizer), Karl Taylor (program committee), Thomas Stocker (IPCC Working Group 1 co-chair).

The workshop program committee was chaired by NCAR Senior Scientist **Jerry Meehl** and included **Sandrine Bony** (Laboratoire de Météorologie Dynamique), **Karl Taylor** (Lawrence Livermore National Laboratory) and **Ron Stouffer** (NOAA Geophysical Fluid Dynamics Laboratory). The detailed agenda is available at tinyurl.com/IPRCcmip.



IPRC's June-Yi Lee discussing her poster.

A brief summary of the results from the meeting has been published by WCRP and is available at www.wcrp-climate.org/documents/ezine/WCRPnews_14032012.pdf.

The workshop was sponsored by WCRP, the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), the US Climate Variability and Predictability (CLIVAR) program, the National Science Foundation, the Department of Energy, NASA and NOAA.

Past Climates Guide Projections for a Warmer World

Can information about past climates help to constrain climate projections for a warming Earth? To provide answers, an international group of 50 climate modelers, dynamicists, and paleoclimatologists met at the Bishop Museum in Honolulu for a 3-day workshop at the beginning of March 2012.

A pivotal step missing in climate projections has been the quantitative link between information about past climates and simulations of future climate. The workshop highlighted some important findings contributing to this link. As part of the Paleo-Model Intercomparison Project Phase 3 (PMIP3), a number of climate models were run under Last Glacial Maximum conditions (LGM) 21,000 before present. Researchers found a strong relationship between the responses of these models to the LGM climate and their responses to anthropogenic greenhouse emissions. Thus, by constraining the former with existing paleoclimate reconstructions for surface temperatures obtained from numerous paleoclimate archives (pollen, marine sediment cores, ice-cores), one can derive upper bounds for the future climate sensitivity. Current estimates using this approach suggest that future climate sensitivities higher than 4°C per CO_2 doubling are unlikely to occur.

The workshop continued with discussions on the reliability of paleoproxy reconstructions, reconstruction methods, the physical mechanisms for abrupt climate change, the behavior of El Niño in the past and the response of major ice-sheets and sea level to past and future climate forcings.

The workshop outcome will be a white paper that describes the importance of paleoclimate simulations as part of a suite of criteria that a climate model must meet before its projections are credible.

IPRC's **Axel Timmermann** co-organized the workshop with **Gavin Schmidt** from NASA Goddard Institute for Space Studies.

Paleoclimate workshop participants in front of the Hawaiian Hall Complex at the Bishop Museum.

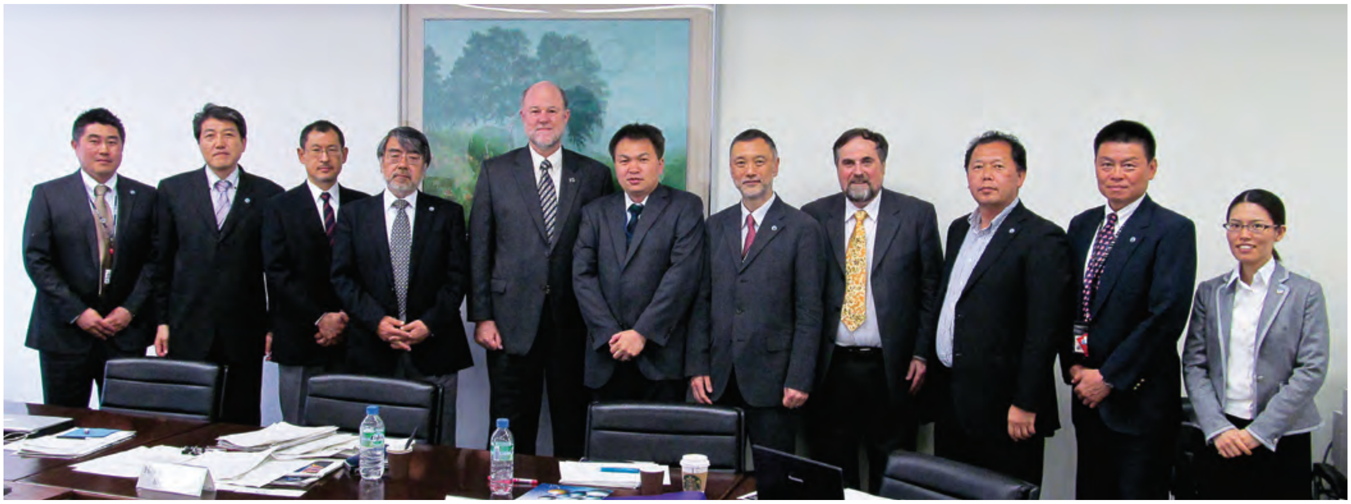
The Uncertainty of Climate Projections

The Japan Uncertainty Modelling Project (JUMP) aims to increase the certainty of climate model projections. With funding from Japan's Ministry of the Environment (MOE) and Ministry of Education, Culture, Sports, Science and Technology (MEXT), and also from JAMSTEC, the project started five years ago. **Julia Hargreaves**, the JUMP coordinator, and **James Annan**, both at JAMSTEC, visited the IPRC in March and met with **Axel Timmermann's** paleoclimate research group to discuss collaborations between JUMP and the IPRC on evaluating the CMIP5 multi-model climate scenarios. For this purpose, IPRC Assistant Researcher **Oliver Elison Timm** organized the *Workshop on Integrating Multi-model Ensembles in Global and Regional Climate Change Studies: Estimating and Understanding Past, Present, and Future Climate Change*.

At the workshop, Hargreaves summarized JUMP's research activities and strategy. Most of the uncertainty in climate model projections is due to the lack of knowledge of the sensitivity of climate to man-made greenhouse-gas and aerosol emissions, and the current coupled general circulation models (GCMs) differ widely in their temperature projections under global warming. Since the abundant paleoclimate records permit model evaluation outside the present-day range of climate variability, Hargreaves and Annan have analyzed how well GCMs capture climate changes in the past. Their comparisons of sea-surface and land-based temperature reconstructions of the Last Glacial Maximum (21,000 years ago) with the mid-Holocene (6,000 years ago) reconstructions in paleoclimate models show that the models capture past climate changes reasonably well. Based on several independent estimates, Hargreaves and Annan have succeeded in fixing the climate sensitivity during past climate changes between 2° to 4°C per CO_2 doubling.

Generalization of this sensitivity to the present situation has been hampered by the fact the coupled GCMs used for current global warming scenarios differ from the paleoclimate models. With the CMIP5 initiative (see page 16), however, Hargreaves and Annan have a new suite of climate simulations ranging from the Last Glacial Maximum to future scenarios based on the same models. The IPRC paleoclimate research group plans to work with Hargreaves and Annan in extending the climate sensitivity analysis, with IPRC research targeting the physical feedback mechanisms that have impacted Earth's climate sensitivity in the distant and recent past.

Discussing how paleoclimate studies can improve current climate models, from left, Oliver Timm, Samantha Stevenson, Matt Widlansky, Axel Timmermann, Yusuke Yokoyama, Malte Heinemann, Julia Hargreaves, and James Annan.



From left: Tetsuro Isono (JAMSTEC), Toru Kimoto (JAMSTEC), Yukio Masumoto (JAMSTEC), Masao Fukasawa (JAMSTEC), Brian Taylor (SOEST), Toshihide Fukui (MEXT), Yoshihisa Shirayama (JAMSTEC), Kevin Hamilton (IPRC), Hisashi Dobashi (JAMSTEC), Katsufumi Akazawa (JAMSTEC), Chihiro Baba (JAMSTEC).

Governing Committee Meets

The IPRC Governing Committee (GC) held its 2012 annual meeting May 10–11 at the JAMSTEC Tokyo Office. The meeting was co-chaired by GC members **Yoshihisa Shirayama** (JAMSTEC Executive Director) and **Brian Taylor** (SOEST Dean, University of Hawai'i). Also participating was GC member **Toshihide Fukui**, Director for Environmental Science and Technology of the Japan Ministry of Education, Culture, Sports, Science and Technology (MEXT). GC members **Eric Lindstrom** (NASA Physical Oceanography Program Scientist) and **Howard Diamond** (NOAA Program Manager for the Global Climate Observing System) joined via telephone from Washington. The meeting participants reviewed overall progress at IPRC and considered IPRC's current and future relationships with its Japanese and US supporting agencies.

IPRC and the APEC Climate Center

The IPRC and the APEC Climate Center (APCC) in Busan, Korea, share a science focus on climate variability in the Asia-Pacific region and have been close partners since the creation of the APCC in 2005. As noted in *IPRC Climate* Vol. 11, no. 2, the IPRC hosted and cosponsored the APCC annual symposium in October 2011, and interactions have continued at a brisk pace in 2012. In February IPRC postdoctoral fellow **Prasanna Venkatraman** took up a position as Researcher at the APCC. In March IPRC faculty member **Bin Wang**, Assistant Researcher **June-Yi Lee** and Postdoctoral Fellow **Baoqiang Xiang** visited APCC. Wang presented the final report of an APCC international research project for the development of an operational extended-range forecast system and for an investigation of high-latitude influences on East Asian climate. During their visit Lee and Xiang worked to transfer to APCC the model codes for two coupled global climate models developed at IPRC. These models will be used for experimental extended-range forecasts at APCC. Wang returned to Busan April 9–10 to participate in a special APCC Science Advisory Committee meeting aimed at helping develop a new APCC strategic plan. IPRC Director **Kevin Hamilton** visited APCC in May and presented a seminar on modeling climate system cloud feedbacks and discussed possible future IPRC–APCC collaborations.

IPRC Director Kevin Hamilton with former IPRC Postdoctoral Fellow Prasanna Venkatraman at the APEC Climate Center.

Pusan University and IPRC Partner on Monsoon Studies

Atmospheric scientists at Pusan National University (PNU) and climate modelers at the IPRC are joining forces to study prediction and predictability of the East Asian and global monsoons. The project sponsor is the Global Research Laboratory (GRL) of Korea's Ministry of Education, Science and Technology, which funds joint projects between Korean and foreign universities, with 1/3 of the funding going as a grant to the foreign partner. The PNU–IPRC project was one of 5 selected from over 100 applications and the only project in environmental sciences. Funding will be for 6 years.

The project goals are as follows: to determine whether variations in the monsoons are predictable given the atmospheric changes expected with global warming; to improve predictions of such monsoon-related disasters as extreme rainfall and extreme droughts; and to develop mitigation and adaptation strategies to deal with the consequences of possible changes in the monsoon.

Kyung-Ja Ha, Professor of Atmospheric Sciences at Pusan National University is the Korean principal investigator. Joining her are 15 Korean graduate students and professors in meteorology. **Bin Wang**, IPRC faculty member and

Unveiling the Project Plaque: IPRC Director Kevin Hamilton, Professor Kyung-Ja Ha, and Professor Bin Wang.

Chair of the University of Hawai'i Meteorology Department, is the US principal investigator, and his scientific team consists of 5 senior researchers and graduate students. The education of young climate scientists, from high school students to PhD candidates, is a significant aim of the project.

To inaugurate this partnership, a two-day workshop was held at the IPRC on January 9 and 10, 2012. Participants came not only from PNU and the IPRC, but also from Seoul National University, the Korea Ocean Research and Development Institute, the First Institute of Oceanography in Qingdao in China, and McGill University in Canada. A joint workshop will be held every year, alternately in Korea and Hawai'i.

Participants of the workshop *Global Monsoon Variability and Change*.

The Japan Taskforce on Tsunami Marine Debris

Concerned about the debris that washed into the ocean with the March 2011 tsunami in Tohoku, the Office of Marine Environment of the Japan Ministry of the Environment organized "The Task Force for Nowcast and Forecast of the 3.11 Tsunami Debris Location." The Task Force coordinates tsunami-debris-related work now underway at JAMSTEC, Kyoto University, the Japan Meteorological Research Institute (MRI), the Japan Atomic Energy Agency, and the Japan Aerospace Exploration Agency (JAXA).

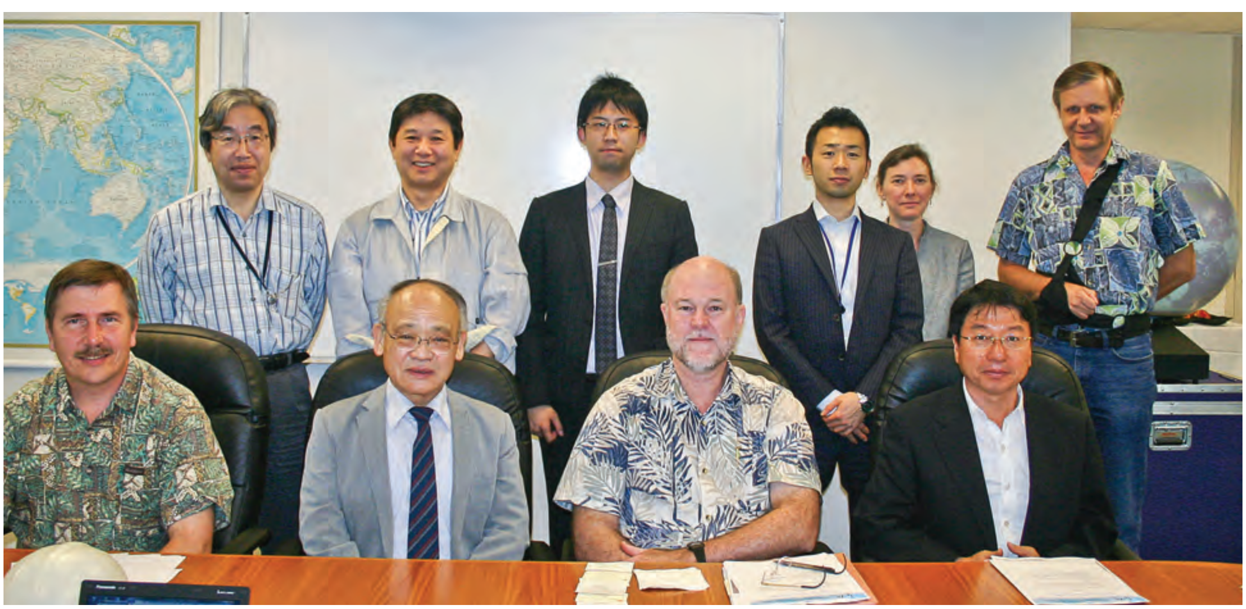
Representatives of this task force, **Toshiyuki Awaji** (Executive Vice President for Education, Kyoto University), **Masafumi Kamachi** (Director, MRI Oceanographic Research Department), and **Hajime Nishimura** (Executive Assistant to the Director-General of the JAMSTEC Data-Research Center for Marine-Earth Sciences) visited the IPRC in February to exchange information with Senior Researcher **Nikolai Maximenko** and Scientific Programmer **Jan Hafner** about efforts to locate the tsunami debris in the ocean.

Accompanying the Japanese scientific team were **Kazuo Tsukada**, Consul of the Consulate-General of Japan in Hawaiʻi, **Yuya Yukishima** of the Ministry of the Environment, and **Fujihiko Hayashi** of the Ministry of Foreign Affairs. Representing NOAA was **Ruth Yender**, coordinator of the efforts by the NOAA Marine Debris Program to respond to the tsunami debris. The meeting opened with a warm welcome to the Task Force by University of Hawaiʻi Mānoa Vice Chancellor **Gary Ostrander** and the Dean of the School of Ocean and Earth Science and Technology (SOEST) **Brian Taylor**.

Professor Awaji, the leader of the visiting team, then described the various ocean, atmospheric, and climate models the Japanese agencies are using in their efforts to locate the debris and to forecast where the debris is headed. Maximenko, Hafner, and **Henrieta Dulaiova** discussed tsunami-related research at the University of Hawaiʻi. Hafner presented the development of the diagnostic model used by the IPRC to describe the distribution and motion of the floating tsunami debris. Maximenko talked about the tsunami debris work at IPRC, including the most recent survey expedition from Honolulu to beyond Midway.

Maximenko showed evidence that if the tsunami had happened on March 11 in another year than in 2011, the debris path and field may have been quite different, since these depend greatly on the prevailing basin-wide ocean-atmosphere conditions.

The scientists hope their partnership will help to locate the debris. The tsunami tragedy may now bring worldwide attention to the long-standing problem of marine debris in the global ocean and help to stimulate rigorous interdisciplinary research on this topic.

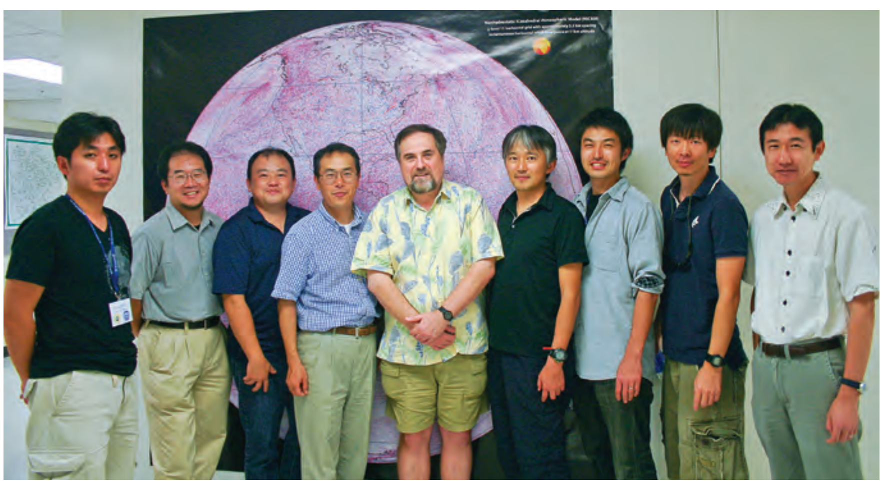


From left front, Nikolai Maximenko, Toshiyuki Awaji, Brian Taylor, Kazuo Tsukada. Back row Hajime Nishimura, Masafumi Kamachi, Yuya Yukishima, Fujihiko Hayashi, Ruth Yender, and Jan Hafner.

JAMSTEC Colleagues Visit IPRC to Discuss Tropical Variability

Six colleagues from the JAMSTEC Research Institute for Global Change (RIGC) and the University of Tokyo visited IPRC in January to discuss recent progress in observations and modeling of tropical intraseasonal variability (ISV), the focus being the recent JAMSTEC-led Cooperative Indian Ocean Experiment on ISV in the Year 2011 (CINDY). The visitors were **Masaki Satoh** (University of Tokyo Professor and Team Leader for Global Cloud-Resolving Modeling Research at RIGC), **Tomoe Nasuno** (Senior Scientist in the Global Cloud-Resolving Modeling Research Team at RIGC), **Kunio Yoneyama** (Team Leader for MJO Research at RIGC), **Kazuaki Yasunaga** (Senior Scientist in the MJO Research Team at RIGC), **Hiroaki Miura** (University of Tokyo Project Assistant Professor and Scientist in the Global Cloud-Resolving Modeling Research Team at RIGC) and **Tomoki Miyakawa** (University of Tokyo Researcher).

The CINDY field observations were coordinated with model simulations and real-time atmospheric forecasts, including forecasts performed with the Nonhydrostatic ICosahedral Atmospheric Model (NICAM) developed at JAMSTEC and the University of Tokyo by Satoh's research group. During the meeting with IPRC scientists, Nasuno reviewed the success of the NICAM forecasts conducted for CINDY, and Satoh described recent developments and plans for NICAM. IPRC Assistant Researcher **Kazuyoshi Kikuchi** organized and chaired the discussion.



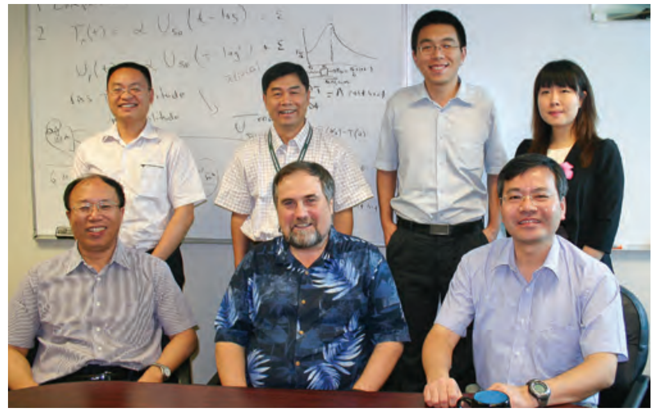
From left: Hiroaki Miura, Kunio Yoneyama, Hiroshi Taniguchi (IPRC), Masaki Satoh, Kevin Hamilton (IPRC), Kazuaki Yasunaga, Tomoki Miyakawa, Kazuyoshi Kikuchi (IPRC), Hisayuki Kubota (JAMSTEC). In the background is a large-format poster prepared by IPRC's Sharon deCarlo showing a snapshot of the horizontal divergence field at 11-km height in an ultrahigh resolution NICAM simulation conducted at JAMSTEC (Miura et al., *Geophys Res. Lett*., 2007).

Bin Wang Named Scientist of the Year

IPRC faculty member **Bin Wang** was named the 2012 Scientist of the Year by the Honolulu Chapter of Achievement Awards for College Scientists (ARCS Foundation, Inc.). He received the award at the foundation's 2012 Scholar Awards Banquet, held on the evening of Monday, May 7, at the Outrigger Canoe Club. The Honolulu Chapter is one of 17 chapters of a national women's organization founded in 1958 to advance science and technology in the United States by providing awards to academically outstanding students in science, engineering, and medicine. Since 1974, the Honolulu Chapter has awarded over $1.7 million to more than 600 scholars at the University of Hawai‘i at Mānoa. Since 1983, the chapter has also made an annual Scientist of the Year award, to a researcher working in Hawai‘i.

First Institute of Oceanography Delegation

In January **Deyi Ma**, Director-General of China's State Oceanic Administration (SOA) First Institute of Oceanography (FIO) in Qingdao, **Bo Lei**, SOA Deputy Director-General of the Department of Science and Technology, and **Weidong Yu**, Director of the FIO Laboratory for Ocean-Atmosphere Interaction and Climate Change, visited IPRC together with several scientists and staff from their institute. In recent years IPRC has hosted a number of scientists from FIO. Discussions focused on ways to enhance the scientific connections between FIO and IPRC.



From left front row: Deyi Ma, Kevin Hamilton, Bo Lei; back row: Honxia Chen, Weidong Yu, Lei Feng, Baonan Sun.

Cutting the ribbon to inaugurate the new expanded office suite.

Renovation Expands Office Space

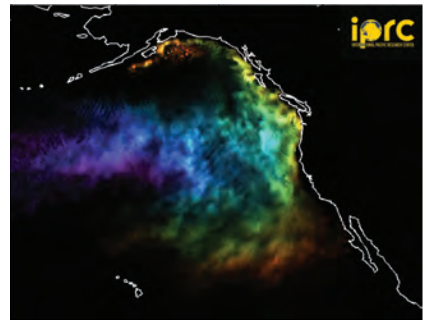
In April the sounds of construction were heard for the first time at the IPRC since the move to the Pacific Ocean Sciences and Technology (POST) Building in the year 2000. The renovations by contractor Kokea Construction connected existing spaces into a large, light-filled office that can accommodate up to 6 scientists. IPRC now occupies almost the whole fourth floor of the POST Building and can accommodate a total of 86 faculty, staff, and visitors at any one time.

IPRC Director Visits JAMSTEC and JAXA

IPRC Director **Kevin Hamilton** was kindly invited by **Masao Fukasawa**, Director-General of JAMSTEC's Research Institute for Global Change (RIGC), to participate in the *RIGC Annual Review Symposium* held on February 9 in Yokosuka. Hamilton presented a talk describing IPRC research highlights that focused on joint projects with JAMSTEC colleagues. The following day Hamilton, along with JAMSTEC International Affairs Division Manager **Katsufumi Akazawa** and International Affairs Coordinator **Toru Kimoto** visited the Japan Aerospace Exploration Agency (JAXA) Tokyo Office. They met with JAXA Associate Executive Director **Toshio Doura** and Director of the JAXA Earth Observation Research Center **Toru Fukuda** and discussed the possibilities for collaboration among JAMSTEC, JAXA and IPRC scientists.

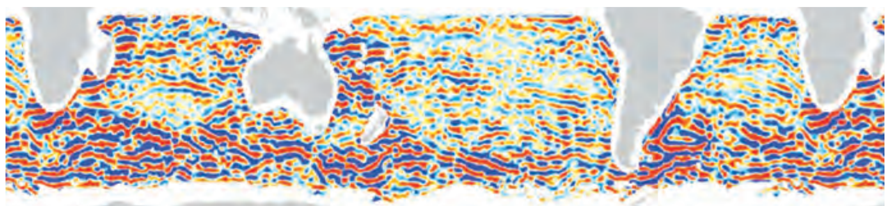
IPRC Model Now Tracks Lighter Tsunami Debris

The IPRC Model for tracking the Japan tsunami debris across the Pacific has been extended to reflect the effects of wind on the movement of debris with varying fractions of surface exposed above water. The original model was based on data from scientific drifting buoys with large drogues extending 18 meters below the surface. Three levels of windage have been added by Senior Scientist **Nikolai Maximenko** and Scientific Computer Programmer **Jan Hafner**, providing a more complete simulation of the debris field and a more accurate estimate of the present location of various types of debris. In the new versions, the greater the fraction of a piece floating above water and exposed to the wind, the faster it travels downwind, and items with high windage started to arrive on the West Coast at the end of 2011.



The new animations generated by the model are available to the public at tinyurl.com/IPRCdebrisnews.

IPRC Scientists Active in the Climate Research Community



Lead Authors Meet for Next IPCC Climate Assessment

As lead authors of Working Group 1 for the upcoming Fifth Assessment Report by the Intergovernmental Panel on Climate Change, IPRC's S**hang-Ping Xie** and **Axel Timmermann** travelled in April to Marrakesh, Morocco, for the Third Lead Author Meeting, where they planned the next draft that addresses the comments of the expert reviewers on the previous draft and incorporates the latest research in the field. Xie's team deals with "Climate Phenomena and their Relevance for Future Regional Climate Change," and Timmermann's with "Information from Paleoclimate Archives." Xie stayed on in Marrakesh to work with the Technical Summary writing team, a subgroup of Working Group 1, to distill the huge report into a short "Summary for Policy Makers." The next lead author meeting will be in January in Australia.

Ocean Striations at AGU 2011 Fall Meeting

Quasi-zonal jet-like features, called also striations, are ubiquitous in observations and eddy-resolving models of the global ocean. As an important part of the large-scale ocean circulation, they impact sea surface temperature and probably also the marine ecosystems. Their dynamics, though, remain unexplained. To review the recent science in this field, which lies at the crossroads of oceanography, geophysical fluid dynamics, and climate science, IPRC Postdoctoral Fellow, **Ali Belmadani**, JAMSTEC Earth Simulator Center Scientist **Bunmei Taguchi**, IPRC Faculty Member **Niklas Schneider** and Senior Researcher **Nikolai Maximenko** convened a special session on "Beta-plane Dynamics: Jets, Eddies, Waves, and Plumes" at the 2011 American Geophysical Union Fall Meeting, in San Francisco. With about 300 attendees, the session was so successful that Belmadani and Maximenko are proposing a session on the broader topic "Mesoscale Ocean Processes" for the 2012 AGU Fall Meeting.

Marine Debris Research

Nikolai Maximenko and **Jan Hafner** are members of the Working Group "Marine Debris: Scale and Impact of Trash in Ocean Ecosystems" of the National Center for Ecological Analysis and Synthesis (http://www.nceas.ucsb.edu/). The group's mission is to (1) construct a theory of marine debris and (2) to determine the type of activities needed to: quantify the extent of the problem, understand what drives the behavior and paths of different types of debris, and develop efficient methods, technology, and policies to cope with and prevent this form of ocean pollution.

IPRC Scientists Active in the Community

IPRC Holds Public Forum at Bishop Museum: Climate Change Past and Future

Over millions of years, Earth has seen dramatic climate changes, which left clues to their causes and their impacts in ice cores, ocean sediments, cave records, and rock formations. Will understanding these events provide clues to how sensitive the climate is to change? Can lessons from the past be applied to current conditions and inform us about how the climate is likely to change in response to the rise in greenhouse gases and global warming? These were among the questions a panel of leading experts on long-term climate change discussed at a free, public forum co-organized by IPRC's **Axel Timmermann** at Honolulu's Bishop Museum on the evening of March 1, 2012. The very animated forum was a standing-room-only success with a spirited exchange between audience and scientists.

Axel Timmermann addresses audience at Bishop Museum Public Forum.

Symposium for Pacific Island High School Students

Every year, the *Pacific Symposium for Science and Sustainability* brings high school students from the far-flung Pacific Islands together at the University of Hawai‘i at Manoa. During this year's symposium in December 2011, 50 students presented their research projects. Topics ranged from studying better ways for controlling mosquitoes in American Samoa, to climate impacts on shoreline erosion in Hawai‘i, to developing better optics with computer artificial-intelligence-routines for image recognition. Manager of IPRC's Asia-Pacific Data-Research Center, **Jim Potemra**, joined six other judges to evaluate the projects. The top ten projects were presented again in a plenary session, with a prize awarded to the most outstanding project.

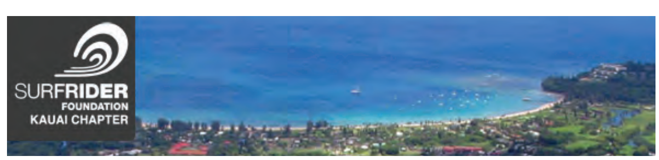
IPRC Scientists Sought as Speakers on Tsunami Debris

Because of their work on tracking the tsunami debris with their Surface Current Diagnostic Model, Senior Scientist **Nikolai Maximenko** and Scientific Computer Programmer **Jan Hafner** have been asked to speak to sundry organizations worried about how much debris is still floating, where it is headed, and how dangerous it is.

Thus, on December 10, 2011 Maximenko spoke at the "Japanese Tsunami Marine Debris Conference" sponsored by the Kaua‘i Community College Marine Option Program and the Surfrider Foundation, a non-profit organization with over 50,000 members worldwide dedicated to the protection and enjoyment of our world's oceans, waves and beaches. He spoke on January 12, 2012, at the Winter Conference of the Association of Pacific Ports, a trade and information association founded to increase efficiency and effectiveness of Pacific ports. On February 7, Maximenko addressed the Hawai‘i and American Samoa Area Maritime Security, Committee General Membership Meeting.

Just before the first anniversary of the Japanese earthquake and tsunami, on February 28, Maximenko participated in *Ocean Conservancy's Japanese Tsunami Debris Webinar*, giving an update on the most recent tsunami debris modeling results. He was joined at the webinar by **Ruth Yender**, NOAA's Japan Tsunami Marine Debris Coordinator, and by Ocean Conservancy's Deputy Director **Leo Viana**, and Conservation Biologist **Nicholas Mallos**.

Jan Hafner was invited to speak at this year's Maui Whale Festival, "Weekend with the Experts," which featured a group of noted researchers, scientists, marine experts and photographers from across the U.S. The three-day event was hosted by the Pacific Whale Foundation, a nonprofit organization founded in 1980 to save whales from extinction. Hafner also spoke about the work of the IPRC marine debris researchers to the Hawaiian Ocean Safety Team (HOST), a non-profit organization that provides a forum for government, industry, and the public to identify problems, propose solutions, and develop safe operating procedures to protect Hawai‘i's marine environment and ensure marine safety. HOST sees itself as the response center for protecting Hawai‘i waters and beaches from possible onslaught of the tsunami debris.



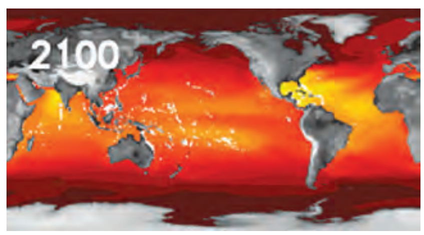
IPRC Scientists in the News

Swampy Tales Give Clues About Hawai'i's Climate Past

The adventures of IPRC's **Axel Timmermann** in extracting soil cores from Hawai'i's mountain swamps in order to draw up a history of Hawai'i's climate reaching thousands of years back in time, was featured in the February *University of Hawai'i System News*. Until about 14,500 years ago, Hawai'i was much cooler than today, with a glacial ice cap of more than 27 square miles sitting on top of Mauna Kea, which is now the home of numerous astronomy observatories. Timmerman's partner in this work is geography department colleague **David Beilman**.

Unprecedented, Man-made Trends in Ocean's Acidity

Recent carbon dioxide emissions have pushed the level of seawater acidity far above the range of the natural variability that existed for thousands of years. This acidification is affecting the calcification rates of shell-forming organism, according to a study of a team of scientists led by IPRC's **Tobias Friedrich** and **Axel Timmermann**. Their findings, published in the January 22 online issue of *Nature Climate Change*, was featured widely in such media as *USA Today; Environmental News Network*; *Honolulu Star-Advertiser*. They have created a striking animation of the increase in the ocean's acidity that can be viewed at tinyurl.com/IPRCacid (see also research story on p. 3 this issue).



IPRC's Marine Debris Scientists Make Headlines Again

Maximenko and Jan Hafner Hold Press Conference

On the upcoming anniversary of the Great Tohoku Earthquake and its tsunami, IPRC's marine debris scientists were once more swamped with requests for interviews. Thus on February 28, 2012, **Nikolai Maximenko** and **Jan Hafner** held a press conference at the IPRC for the local media and updated the press on their most recent activities and findings. Lengthy portions of the interview were broadcast on KHNO2, KITV, Hawai'i News Now, and also featured in Honolulu's daily newspaper.

BBC Features the IPRC Tsunami Debris Modeling Work

At this year's Ocean Sciences Meeting in Salt Lake City, Maximenko and Hafner gave an update of their modeling results on the tsunami debris field. Hafner was interviewed by **Jonathan Amos**, science correspondent for the BBC News. Their work and their Surface Current Diagnostic (SCuD) model animation showing the spread of the Japanese tsunami debris field since March 2011 were featured on BBC News on February 22, 2012.

NASA Archives SCuD Model on Earth Observatory

Permission to use the animations from **Nikolai Maximenko's** and **Jan Hafner's** Surface Currents from Diagnostic (SCuD) model was frequently requested by news agencies, who at times re-colored the animations. The most exciting and impressive request came from NASA's Earth Observatory. The observatory's image version is posted at earthobservatory.nasa.gov/IOTD/view.php?id=77489.

Requests by the media to use Maximenko's and Hafner's Statistical Model, which estimates the tsunami debris dispersion over 15 years based on the average movement of drifters in the North Pacific, were also frequent. For instance, *USA Today* posted it at http://usatoday.tumblr.com/post/25087603926/debris-from-the-2011-earthquake-and-tsunami-in.

Survey for Tsunami Debris Northwest of Midway

By late September 2011, the Surface Current Diagnostic Model showed that the Japan tsunami debris was only about 400 miles northwest of Midway, a location confirmed by observations of STS Pallada. There was concern that dangerous debris might wash up on the Papahānaumokuākea Marine National Monument. Therefore in Fall 2011, IPRC's **Nikolai Maximenko** participated with the Ocean Recovery Alliance and Scripps Institution of Oceanography, in launching a survey into the region. Horizon Lines shipped equipment from California and Nobeltec provided navigational software. This endeavor was featured extensively in University of Hawaii News (tinyurl.com/IPRCuhstory).

About the same time an oceanic front, however, started to develop just northwest of Midway. The current associated with the front has been channeling the tsunami debris toward the northeast, north of the monument. This front has held, and until now has protected the sanctuary. As of yet no confirmed Japan tsunami debris has been reported from the atoll. According to the new model versions, which include different levels of windage (see p. 24), the greatest concentration of tsunami debris has already passed Midway to the north.

Only old debris was spotted during the survey.

Marine Debris from the March 11, 2011, Tsunami: One Year After the Disaster

To accommodate the many media requests for interviews on the eve of the anniversary of the great Tohoku earthquake and tsunami, IPRC's Senior Scientist **Nikolai Maximenko** recorded a presentation reviewing the activities at the IPRC and other agencies. In his talk he discussed the current knowledge of the extent of the debris field and its potential dangers and cleared up some of the exaggerated media reports of the amount of debris floating toward the west coast. He also explained that light objects of the debris could be arriving at the West Coast much earlier than the IPRC SCuD model projections because the basic ScUD model had been developed based on the trajectories of drifters with drogues at 15-m depth. At the time of the talk in March 2011 the model did yet not reflect the effects of the wind on debris. His talk is available at tinyurl.com/IPRCdebrisnews.

Tropical Cyclone Research

At the end of February, IPRC's **Yuqing Wang** hosted several experts on tropical cyclones: **Noel Davidson** from the Centre of Australian Weather and Climate Research (CAWRC), **Peter Black** from the Naval Research Laboratory, and **Pat Harr**, **Michael Bell** and **Robert Atkinson**, all from the Naval Postgraduate School in Monterey, California. In a joint IPRC–UH Department of Meteorology seminar, Davidson described the tropical cyclone research and operational dynamical forecasts at CAWCR, including the newly developed Tropical Cyclone Model for the Australian Community Climate and Earth-System Simulator (ACCESS-TC). Black also gave a seminar titled "Typhoons Fanapi and Megi from ITOP2010: Ocean interaction and extreme-wind boundary layer."

Front row from left: Noel Davidson, Peter Black, Yuqing Wang; back row: Pat Harr, Robert Atkinson, Michael Bell, Gary Barnes.

Alumni Return to IPRC

Three IPRC Alumni, now all working at JAMSTEC, returned to Hawai'i in late fall 2011 to give presentations at the Fourth Annual JAMSTEC-IPRC Workshop on Modeling. (see page 14). **Masami Nonaka**, now Leader of the Mid- and High-latitude Climate Predictability Research Team talked about "Potential predictability of interannual variability in the Kuroshio Extension jet speed in an eddy-resolving OGCM." **Bunmei Taguchi**, scientist with the Geophysical Fluid Simulation Research Group of the Earth Simulator Center, presented on "Propagation features of decadal-scale subsurface signals in the North Pacific Ocean." **Toru Miyama**, with the Ocean Downscaled Prediction Research Team, spoke on "Regional climate modeling study of wind variations over western Pacific warm pool before El Niño onsets." Miyama returned in late winter for an extended visit to

From left: Masami Nonaka, Bunmei Taguchi, and Toru Miyama.

continue work with IPRC's **Yuqing Wang** to apply the IPRC Regional coupled Ocean-Atmosphere Model (iROAM).

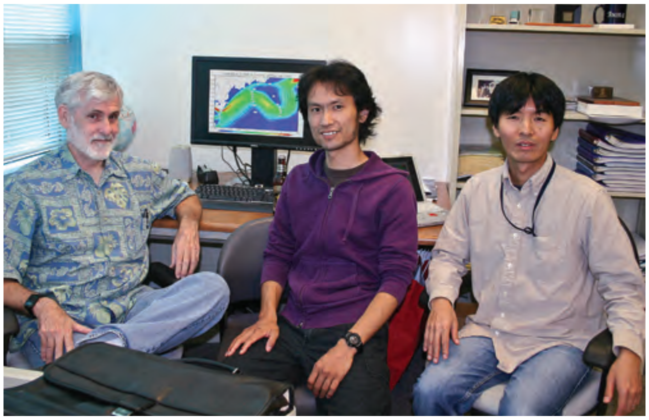
Characterizing Cloud Properties

During February and March **Ralf Bennartz**, Professor of Atmospheric Science at the University of Wisconsin, visited IPRC to work with IPRC Assistant Researcher **Axel Lauer**. Bennartz is a leading authority on satellite observations of clouds and has been collaborating for the last few years with Lauer on ways to characterize the observed small-scale variability of cloud properties and applying the results to inform treatments of clouds in regional atmospheric models. While at the IPRC this winter, Bennartz worked with Lauer on ways to incorporate ground-based cloud and precipitation observations into their approach.

From left: Axel Lauer, Ralf Bennartz, and Kevin Hamilton.

Hokkaido Exchange Continues

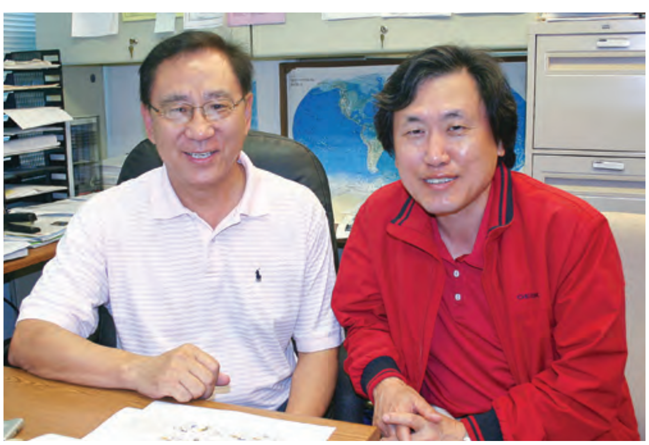
Kunihiro Aoki, a Hokkaido University postdoctoral fellow, visited the IPRC during February and March 2012. Interested in ocean dynamics, he is currently analyzing OFES data to understand the eddy transport of heat, thickness, and momentum in the Kuroshio Extension region. During his stay, he worked closely with IPRC's professor of oceanography **Jay McCreary** and researcher **Ryo Furue**. This was Aoki's second IPRC visit on an overseas-research grant from the President of Hokkaido University. This continues a long-standing exchange program between IPRC and Hokkaido University organized by Hokkaido professor **Youichi Tanimoto**.



From left: Jay McCreary, Kunihiro Aoki, and Ryo Furue.

Predicting the Madden-Julian Oscillation

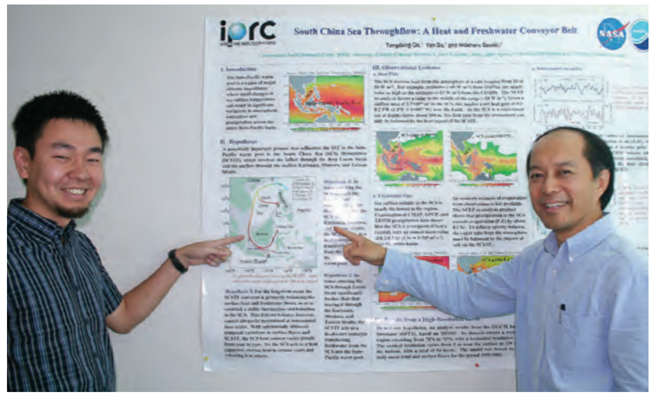
In the early months of 2012, the IPRC welcomed again **In-Sik Kang** from the Climate Environment System Research Center, Seoul National University. A member of the international Multi-model Ensemble Prediction of the Madden-Julian Oscillation (MJO) Project, Kang is working with the project's principal investigator, **Bin Wang**, in assessing the ability of current coupled atmosphere-ocean general circulation models to hindcast the MJO. Kang and Wang are also partnering on determining the essential dynamics of the MJO: Wang, together with long-term visitor **Fei Liu**, is using a theoretical model to analyze the results of Kang's numerical experiments with an atmospheric GCM.



Bin Wang with In-Sik Kang.

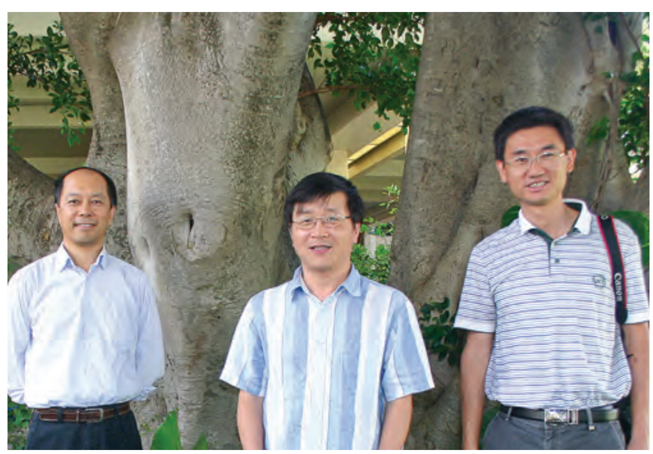
Western Pacific Circulation and Climate

Tomoki Tozuka, associate professor at the University of Tokyo, was an IPRC visitor in early 2012. Among his research interests are the western Pacific circulation, the Indian Ocean dipole, and the South China Sea/Indonesian Throughflow. He discussed with IPRC Senior Researcher **Tangdong Qu** the latest findings on the Indonesian Throughflow and gave a seminar titled "Roles of South China Sea Throughflow in the global climate as revealed by a CGCM."



Tomoki Tozuka (left) and Tangdong Qu.

Jianping Gan, professor at Hong Kong University of Science and Technology, visited the IPRC for three months during winter 2011–2012 to work with Qu on the South China Sea circulation and its interaction with the Pacific western boundary current. Also visiting Qu this winter was former IPRC postdoctoral fellow **Shan Gao**, now an associate researcher at the Institute of Oceanology, Chinese Academy of Sciences in Qingdao. Gao is collaborating with Qu on the analysis of the downstream impact of South Pacific Tropical Water.



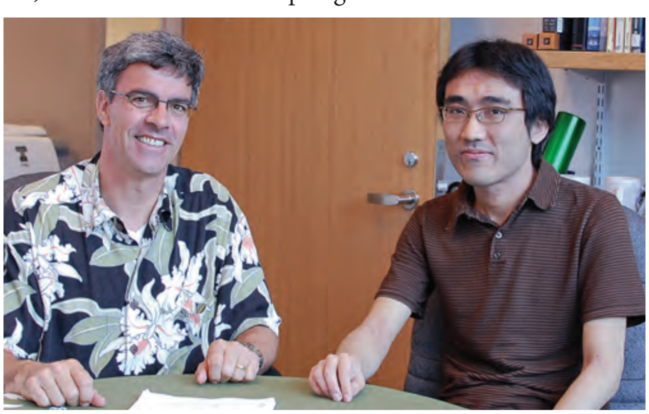
From left: Tangdong Qu, Jianping Gan, and Shan Gao.

Hisayuki Kubota visited the IPRC from mid-January to end of March to work with IPRC's faculty **Bin Wang** and **Shang-Ping Xie**. Kubota has collected a typhoon-track dataset and a surface-weather-station dataset that reach back to the late 19th century for countries in the western North Pacific. This work meant delving into paper records of libraries in the Philippines, Taiwan, Hong Kong, Shanghai, and Hawai'i, to collect the information. Based on this historical station data, he has developed with Xie and **Yu Kosaka** a new Pacific-Japan (PJ) pattern index for the western North Pacific summer monsoon that traces summer monsoon variability back to 1897. This index reveals that the relationship between the PJ index and the preceding winter El Niño-Southern Oscillation has varied, the highest correlation being today and before 1910 and the lowest from the 1910s to 1970s.

Shang-Ping Xie with Hisayuki Kubota.

North Pacific Circulation and Climate

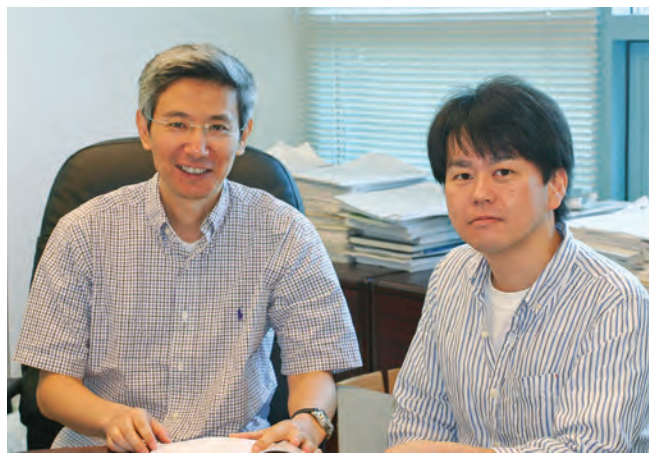
Yoshinori Sasaki, former IPRC Postdoctoral Fellow and now scientist at Hokkaido University, visited his IPRC mentor, **Niklas Schneider** in Spring 2012 to discuss results of a



Niklas Schneider with Yoshinori Sasaki.

just-completed study on the decadal variability of the Kuroshio Extension. The study shows that changes in the wind stress curl in the central North Pacific shifts the axis of the Kuroshio in a north- or southward direction. Surprisingly this shift impacts the speed of the jet after a few months. For example, a weakened wind stress curl shifts the axis of the Kuroshio Extension northward, with the jet strengthening several months later.

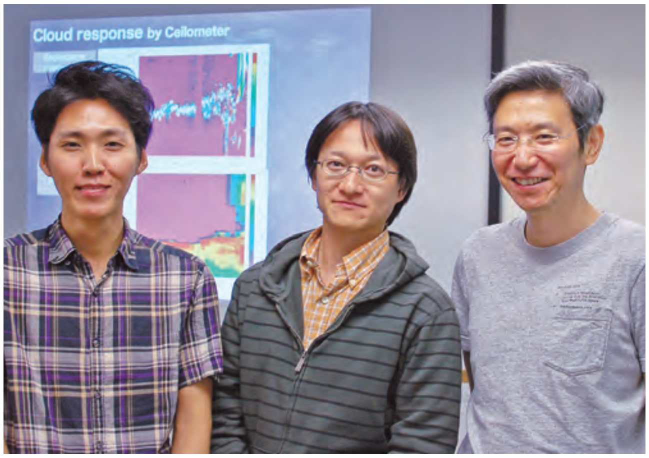
Fumiaki Kobashi, a former IPRC visiting assistant researcher and now associate professor at the Tokyo University of Marine Science and Technology, returned to discuss with his former mentor **Shang-Ping Xie** his latest research on the dynamics of North Pacific mode waters and their representation in climate models and response to global warming. He also reviewed observational plans to study subduction, ventilation and dissipation of North Pacific mode waters.



Shang-Ping Xie with Fumiaki Kobashi.

Xie also hosted **Hiroyuki Tomita**, technical staff member at JAMSTEC's Research Institute for Global Change, who visited from October 2011 to February 2012, and **Akira Kuwano-Yoshida**, scientist with the JAMSTEC Earth Simulator Center's Geophysical Fluid Simulation Research Group. While at the IPRC, Tomita analyzed the atmospheric sounding data from a research cruise that took place during a cold meander of the Kuroshio Extension, thus witnessing the meander's clearing of the low clouds, an effect also seen in satellite images. His visit included work regarding the J-KEO buoy, which his JAMSTEC group deployed north of the Kuroshio Extension.

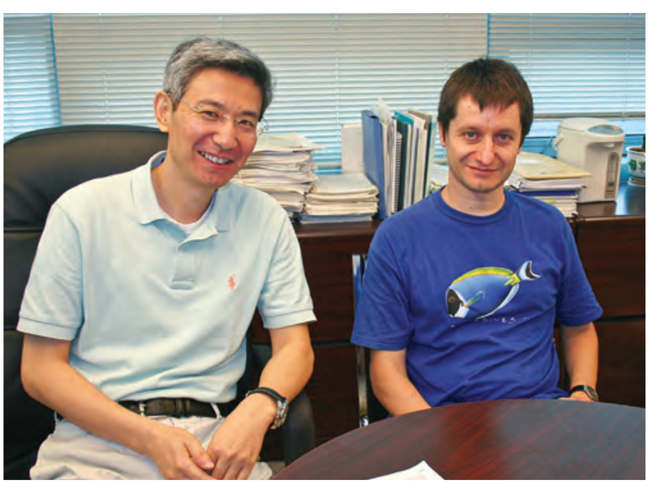
Kuwano-Yoshida studied the differences in the Baiu simulations between the Atmospheric and Coupled GCM for the Earth Simulator (AFES and CFES) during his several month-long IPRC visit in late 2011. In AFES, the Baiu season ends too early, but in CFES it ends too late. His experiments with AFES show that the model differences are due to differences in sea surface temperature, the meridional shifts in the Asian westerly jet being responsible for the Baiu behavior in both models. Specifically, low surface-evaporation north of the Kuroshio Extension brings about the end of the Baiu.



From left: Hiroyuki Tomita, Akira Kuwano-Yoshida, and Shang-Ping Xie.

Atlantic Circulation and Climate

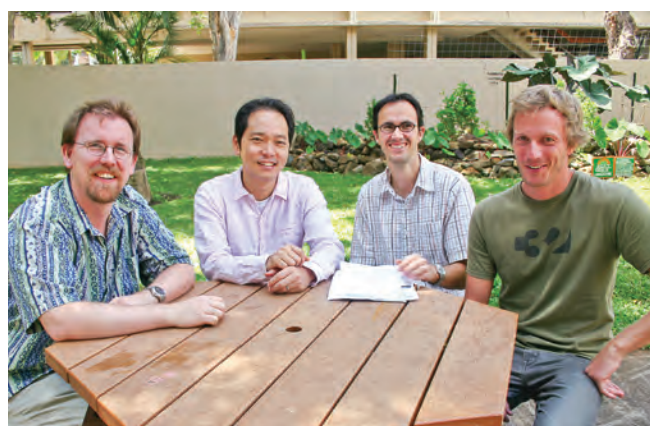
Former IPRC postdoctoral fellow **Ingo Richter**, now scientist with the Low-latitude Climate Prediction Research Team of JAMSTEC's Research Institute for Global Change, visited the IPRC for two months in late winter. He discussed with his former mentor **Shang-Ping Xie** methods for assessing model errors in simulations of the equatorial cold tongue of the Atlantic, and the mechanisms responsible for interannual variability in the equatorial zonal wind and their possible role in triggering the Atlantic Niño. Richter also gave a seminar on errors seen in state-of-the-art climate simulations of the tropical Atlantic.



Shang-Ping Xie with Ingo Richter.

Exploring New Facets of Past Climates

In March 2012, **Yusuke Yokoyama**, a leading authority in paleoclimate research and associate professor at the Atmosphere and Ocean Research Institute, University of Tokyo, met with members of the IPRC paleoclimate modeling group **Axel Timmermann**, **Oliver Elison Timm**, and **Malte Heinemann** to discuss possible collaborative research. Yokoyama is using innovative field and laboratory methods that yield new geobiochemical paleoclimate records, opening new aspects for the study of global climate change during the last glacial cycles. The scientists explored ways that IPRC's new Earth System Model of Intermediate Complexity with its newly coupled 3-D ice sheet model can help decipher information stored in Yokoyama's paleoclimatic archives. By focusing on global sea level changes during the last glacial cycles, they hope to determine the drivers of glacial cycles and the climate response to the dramatic redistribution of water masses between land and ocean. Between 30,000 and 20,000 years before present, the ice-domes in North America, Europe, and Siberia became more massive and sea level dropped 60 m. Yokoyama's geologic archive now reveals that 19,000 years ago, in the early stage of deglaciation, global sea level rose 10–20 m within a few thousand years. The joint proposed research may help answer a crucial question in climate change: How sensitivity is Earth's climate to external forcing?



From left: Axel Timmermann, Yusuke Yokoyama, Oliver Timm, Malte Heinemann.

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