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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

Fine-Grained Ocean Mixing Vital for Modeling Global Climate

o map out the processes responsible for vertical mixing in the equatorial ocean, IPRC scientists **Kelvin Richards** and **Andrei Natarov** and their JAMSTEC colleagues, headed by **Yuji Kashino**, have taken advantage of the cruises of the Research Vessel *Mirai* servicing the TRITON buoys in the western equatorial Pacific. (The TRITON buoys are part of an array that monitors the state of the ocean for ENSO research and prediction.)

Why are these scientists interested in such vertical mixing? Studies have shown that the magnitude and time evolution of El Niño and La Niña depend on the mean state of the tropical Pacific Ocean. The mean state of the tropical ocean and its interaction with the atmosphere, in turn, depend strongly on the vertical mixing of water properties and momentum in the equatorial thermocline. The team's measurements suggest, however, that currently available climate models are missing important physics regarding ocean mixing in, and above, the equatorial thermocline.

Direct measurements of ocean currents are typically made with an Acoustic Doppler Current Profiler (ADCP). *Mirai* has such a device (SADCP), which is attached to the ship's hull and operates at 75kHz. The relative low frequency allows the sound signal to penetrate a few 100 m into the water column but the vertical resolution is relatively coarse (~10 m). To increase the vertical resolution, the team has been making use of a 600kHz ADCP, which has a vertical resolution of ~1 m. The higher frequency, however, means the depth penetration of the sound signal is much reduced. To obtain deep measurements, this higher frequency ADCP is mounted on a CTD frame and lowered through the water column (LADCP).

Figure 1 shows the eastward component of velocity measured by the two types of instruments along 156°E in



Figure 1. Left: eastward component of velocity measured by the SADCP along 156°E in August 2008 (units: m/s). Right: as for left panel, but measured by the higher frequency LADCP.



Figure 2. Location of the meridional sections taken on the 3 cruises by the RV Mirai.

August 2008. The major eastward flowing currents are the Equatorial Under Current (EUC), seen in the left panel centered around 200-m depth at 0.5°S, and the North Equatorial Counter Current (NECC) centered at 100-m depth at 3°N. The high-resolution measurements with the LADCP in the right panel show a great deal more vertical structure than those with the SADCP and reveal the existence of small vertical scale structures (SVSs) superimposed on the broader scale currents. The strength of the SVSs splits the core of the EUC into several distinct maxima and minima.

To date the team has conducted three surveys along the lines 156°E and 147°E and one along 138°E (Figure 2). The latter line is being surveyed a second time in late summer 2011, at the time of this writing. In all surveys, the vertical shear of the currents is dominated by SVS features, which have a vertical scale of O (10 m). This is illustrated in Figure 3, which shows the mean-squared shear, S², observed at the equator, 156°E, averaged over a 24hour period in December 2010, based on both the SADCP and the higher resolution LADCP current measurements. The blue curve shows the characteristic small vertical scale and high valued peaks measured by the LADCP, whereas the cyan curve reflects the shear measured by the lower frequency SADCP. Both the magnitude and depth of the maximum flows differ greatly.

Figure 3 also shows the timeaveraged turbulent kinetic dissipation rate, ε , which is estimated from measurements taken with a microstructure probe (MSP) that was deployed after each CTD/LADCP cast. Above 300-m depth, the peaks in S² and ε coincide remarkably, implying that the SVSs are responsible for a significant fraction of the mixing. The average LADCP and MSP measurements taken reveals that high values of ε tend to occur mostly when the Richardson number is around ¼ or less.

These measurements highlight the importance of resolving the structures that cause the mixing. The patch of high ε between 320- and 370-m depth seen in Figure 3b is in a region of weak stratification that requires much weaker vertical shears to promote turbulent mixing. Patches of elevated shear



Figure 3. Left panel: time-averaged vertical shear squared, S², at the equator, 156°E, as measured by the LADCP (blue curve) and SADCP (cyan curve). Right panel: time-averaged turbulent dissipation rate, ε.



Microstructure profiler before deployment. The shear probes are at the tip of the instrument (protected by a cage). The instrument free-falls through the water and data is transmitted to the ship by a conducting cable. Photo courtesy Kevin Richards.

persist over the 24-hour period but much less than those in and above the thermocline, indicating that a different flow regime causes the mixing there.

Why do these small-scale vertical features exist? Theory and models point to a combination of instabilities in the current system (inertial and parametric subharmonic instabilities) and high vertical-mode, wind-generated, inertia-gravity waves, both of which have scales similar to those observed. Moreover, observations during different states of the El Niño – Southern Oscillation show a large modulation of mixing and of the effective vertical diffusion coefficient: the level of mixing induced by small vertical structures in December 2011 during La Niña conditions was considerably greater than in December 2009 during El Niño conditions.

Conventional climate models do not have sufficient resolution to resolve the small-scale vertical structures and are thus missing an important source of mixing in the equatorial ocean. Initial tests performed by **Wataru Sasaki**, JAMSTEC, using the climate model SINTEX-F2 run on the Earth Simulator, suggest the impact of the small-scale vertical-induced mixing is large. Parameterizing their impact will require taking their generation mechanisms into account. To gain a better understanding of the generation of small-scale vertical structures and their impact on mixing, more observations are needed. In 2012 an experiment, funded by the National Science Foundation and called MIXing in the Equatorial Thermocline (MIXET), will take place. A collaborative effort among the IPRC, the Department of Oceanography at the University of Hawai'i at Mānoa, JAMSTEC, Woods Hole Oceanographic Institute, and Seoul National University, the experiment calls for observations that include long-term moorings and intensive sampling using the LAD-CP and a microstructure probe. The effort should yield more information on the controls of the formation of small-scale vertical structures and their impact on mixing. Such information is vital for improving the representation of mixing processes in climate models.

This story is based on: Richards K.J., Y. Kashino, A. Natarov and E. Firing (in press): Mixing in the western equatorial Pacific and its modulation by ENSO. *Geophys. Res. Lett.*



Recovery of the CTD/LADCP after deployment. The LADCP is the orange instrument attached to the frame. The transducer heads point downwards. Photo courtesy Kevin Richards.

Modeling the Stratosphere's "Heartbeat"



Far above the equator, where the density of air is only about 1-10% of that at the ground, the circulation takes the form of intense zonal jets that display one of the most remarkable cyclical phenomena in the climate system. Figure 1 shows the monthly mean zonal wind determined from daily balloon observations at Singapore (1.3°N) from near the tropopause (100 hPa or ~17 km) up to 10 hPa or ~30 km. At any level, the winds are observed to change

from strong easterlies to strong westerlies roughly every other year in a quasiregular cycle. In the observed record since 1953, the period from cycle-tocycle has varied between about 22 and 36 months and seems to average about 27 to 28 months. The phenomenon has become known as the Quasibiennial Oscillation (QBO).

Notable features of the QBO include the downward propagation of the wind reversals and the formation of thin layers of strong mean wind shear. The QBO is believed to be forced internally in the tropics by the interaction between the zonal-mean flow with vertically propagating waves. Although primarily a low-latitude phenomenon, this nearly regular "heartbeat" in the tropical stratosphere impacts the circulation and chemistry throughout the global atmosphere, affecting seasonal-mean conditions even at Earth's surface.



Figure 1. Time-height section of monthly mean zonal wind near the equator based on balloon-borne radiosonde observations. The contour interval is 10 m/s and westerly winds are denoted by shading. Plot courtesy of the Institute for Meteorology of the Free University of Berlin.



Figure 2. Time-height sections of the monthly mean, zonal-mean, zonal wind at the equator as simulated by 23 individual GCMs. Each panel displays 10 years from "20th century" simulations. The vertical domain shown is from near the tropopause (100 hPa) to about 30 km (10 hPa). Plot courtesy of Yoshio Kawatani, JAMSTEC.

Although the QBO is a very prominent feature of the real atmosphere, it has been a remarkably elusive target for comprehensive global numerical models. JAMSTEC's **Yoshio Kawatani** has analyzed the simulated equatorial zonal wind over 10 years of present-day-simulations by 23 individual Global Climate Models (GCMs) in the model intercomparison conducted for the 2007 Assessment Report of the Intergovernmental Panel on Climate Change (Figure 2). Almost all the models simulate rather steady, weak easterly mean winds in the equatorial lower stratosphere and none displays anything resembling the observed QBO.

A few atmospheric GCMs have spontaneously simulated a mean-flow oscillation in the equatorial stratosphere that

resembles to some degree the QBO in the real atmosphere. Such models typically have high vertical and horizontal resolutions and employ convection parameterizations that excite a spectrum of strong vertically propagating waves at low latitudes. Perhaps the most successful GCM in this regard has been the Model for Interdisciplinary Research on Climate (MIROC) developed at the University of Tokyo, JAMSTEC, and the National Institute for Environmental Studies.

A frequent visitor to the IPRC, Kawatani has been partnering with IPRC Director **Kevin Hamilton** in analyzing the detailed mechanisms that maintain the QBO in the MIROC model and in assessing the expected response of the QBO to global warming.



corresponding to heights of about 17 to 35 km. The color bar is labeled in m/s and the contour interval is 10 m/s. Adapted from Kawatani et al. (2011).

Figure 3a shows the simulated equatorial wind oscillation in a MIROC run using late 20th century climatological sea surface temperatures (SSTs) and CO_2 concentrations. The simulated wind oscillation has the observed downward propagation, roughly the right amplitude, and a mean period only somewhat shorter than observed (24 months vs the observed 27 – 28 months). The simulated oscillation, however, is more regular than that observed, the period of almost every cycle locking on to exactly two years.

The MIROC was then run with SSTs and CO₂ values expected for the late 21st century (Figure 3b). The rise in SST was taken from a multimodel ensemble of coupled global coupled models that were run under a moderate economic growth scenario for future atmospheric composition. The simulated QBO appears as well in the global warming simulation (Figure 3b), but its properties are significantly changed. The period increases to a mean value of about 26 months and is freed from the apparent locking with the annual cycle that dominates the present-day simulation. Even more striking is the change in the vertical amplitude structure, with the oscillation nearly disappearing around 70 hPa and below.

Further diagnosis and experimentation suggest that the alteration in the QBO in the MIROC global-warming-case is caused mainly by a change in mean upwelling in the tropical stratosphere. In the real world, the QBO zonal wind reversals descend through a region characterized by mean upwelling with magnitude roughly 1 km/month, and the mean upwelling is believed to play a key role in determining the period and vertical structure of the QBO. The situation is depicted schematically in Figure 4. The mean meridional overturning

circulation in the stratosphere intensifies, and in the equatorial lower stratosphere, the mean upwelling increases by as much as 40% (largest increase near 70 hPa). Almost all GCM simulations reported in the literature show increased mean upwelling in the lower stratosphere in response to increased greenhouse gas concentrations; so the MIROC results, in this regard, may be quite robust.

Taken at face value, the MIROC results predict that the QBO should eventually disappear at the lower stratospheric levels, while retaining its present amplitude at higher altitudes. Analysis of the monthly mean zonal-wind station-observations (not shown) reveals evidence for a decline in recent decades in the QBO amplitude at 70 hPa, while at 50 hPa and higher altitude, there seems to be no significant trend. This observation may represent an early detection of the expected greenhouse-gas-driven change in the mean meridional stratospheric circulation and a harbinger of quite

large circulation changes over the next century, which may have important effects on the chemistry of the middle and upper atmosphere.

This story is based on:

Kawatani, Y., K. Hamilton and S. Watanabe, 2011: The quasibiennial oscillation in a double CO₂ climate. J. Atmos. Sci., 68, 265–283.

Figure 4. Schematic shows stacked easterly and westerly QBO phases (ovals) descending through the lower stratosphere, which has a mean meridional circulation (black arrows) with significant upwelling.

Delving Into the History -A Hawai'i Connection

espite the prominence of the QBO over a wide geographical area and through a deep layer of the atmosphere, it was "discovered" only in 1960 fol-

lowing the establishment of regular daily balloon observations of the upper air at a number of tropical Pacific islands during the 1950s. IPRC Director **Kevin Hamilton** has had a longstanding interest in the history of the exploration of the tropical stratosphere and had previously reviewed the scattered pilot balloon observations taken in the first half of the 20th century [1].

The first balloon observations had taken place against the background of the earliest determination of the equatorial stratospheric circulation,

which was obtained from observations of the geographical spread of the twilight phenomena occurring after the August 1883 eruption of the Indonesian island of Krakatoa. The eruption had injected enormous amounts of material into the stratosphere and produced colorful sunsets and extended twilight periods that were eventually observed globally. As summarized in a famous 1888 Royal Society report [2], during the 2 weeks after the eruption the optical effects near the equator were observed further west each day, consistent with a jet of strong and steady easterlies exceeding 30 m/s (Figure 1).

By 1888 the existence of these "Krakatoa easterlies" was generally accepted, but, according to Hamilton, the question of who first discovered this phenomenon was not so clear: "I had long known that a certain **Sereno Bishop** in Hawai'i was among the first who published on the volcanic aftermath, but only recently was I able to pin down his important contribution." Bishop, who was born on the Big Island of Hawai'i in 1827, had a long and colorful career in Hawai'i as a clergyman, educator, public servant and journalist. In 1883 he was living in Honolulu in what was then the Kingdom of Hawai'i. He first observed the unusual twilight phenomena on September 5, 1883, and began to investigate their possible connection to the great volcanic eruption that had occurred thousands



Sereno Bishop in 1888.

of km away over a week earlier. By April 1884 Bishop was able to express what seems to be the first modern concept of the global transport circulation in the stratosphere, one that recognized the relatively slow meridional dispersal of air but that included the existence of a remarkably strong equatorial zonal jet.

Specifically Bishop noted "one phenomenon of unique and colossal character, which not coming under the personal observation of European and American savants, seems to have attracted

little attention. It is the ... strong fling from the eruptive column of Krakatoa of a vast stream of smoke due west with great precision along a narrow equatorial belt with an enormous velocity, nearly around the globe. It thus appears that while the general diffusion of the bulk of the Krakatoa vapors was tardy, reaching New York in twelve weeks, there was ... a special and exceptional stream ... due west along the equator striking our Honolulu skies only 10 days from its source." Hamilton's historical research on this topic is reported in [3].

- K. Hamilton. Observations of tropical stratospheric winds before World War II. Bull. Amer. Met. Soc, 79, 1367-1371. (1998).
- [2] The Eruption of Krakatoa and Subsequent Phenomena, Report of the Royal Society of London, 494 pp. (1888).
- [3] K. Hamilton (in press). Sereno Bishop, Rollo Russell, "Bishop's Ring" and the discovery of the "Krakatoa easterlies." *Atmosphere-Ocean*. iprc.soest.hawaii.edu/users/kph/K.pdf

Figure 1. Map showing the observed spread of the twilight phenomena in the two weeks following the Krakatau eruption. The black lines show the westward extent of the phenomena each day from August 26 through September 9.



Swampy Tales Give Clues about Hawaii's Climate Past



Bushwacking along the summit trail. Image courtesy Axel Timmerman.

This about 14,500 years ago, Hawai'i was much cooler than today, with a glacial ice cap of over 27-square miles sitting on top of Mauna Kea, and very likely an ice cap also on Mauna Loa. What happened to Hawai'i's climate when Earth warmed and the ice sheets in the Northern Hemisphere started to retreat?

IPRC's **Axel Timmermann** and his colleague **David Beilman**, professor of Geography at the University of Hawai'i, are finding out. Two years ago, they hiked into Ka'au Crater in the back of Palolo Valley on O'ahu, to take a sediment core from the swamp within the crater walls. The expedition was a success. They extracted sediment core samples 5½-m deep. Radiocarbon dating revealed that this core was



Invaluable core sample. Image courtesy Kimber Nelon.

going about 14,000 years back in time and that its history overlaps the end stages of the last glacial period. Further analyses in Beilman's lab showed highly unusual dense organic matter and nitrogen isotope values in a layer of the core dating back 5,200 years. Other sections of the core are now being analyzed by specialized labs on the Mainland. Whether the 5200-year anomaly is the local manifestation of a massive tropical drought that occurred at the same time in many different places around the world is a question the researchers plan to tackle by extracting sediment cores from other swamps and lakes in Hawai'i.

One such other possibility is a bog near the Poamoho section of the Koʻolau summit trail. Reaching this swamp is a challenge, even without carrying all the heavy equipment needed to take core samples. Timmermann and Beilman had tried several times in vain to get to the swamp. Then a graduate student from Beilman's lab found a way down. On a Sunday last August, Timmermann, IPRC postdoctoral fellow **Malte Heinemann**, Beilman and a group of Beilman's students made another attempt. After a two-hour hike, they arrived at the Koʻolau summit trail, which they had to follow for another hour. That was when the real adventure began. Fighting vertigo, they crept along the slippery, muddy, narrow trail, no more than a foot wide in places, and powerful wind gusts threatening to blow them off the ridge.

When they were finally above the swamp, Heinemann said: "We saw the swamp; it looked so close, only a few

hundred feet below us. But it took us nearly two hours to reach it. Each step, I thought might lead to nothingness, so I always held onto some kind of vegetation."

Timmermann: "Once my hiking pole suddenly hit no ground. I looked and saw I was walking on a moss-overgrown tree, next to a 100-foot-deep pit."

Bushwhacking through thick vegetation, they came to a place where they attached a rope ladder for the final descent. By the time they had found a good place to core into the sediment, it was early afternoon.

Taking core samples is tricky: An augur attached to the coring instrument cuts into the swamp's surface, then the handle is twisted into the earth for a depth of about 2 feet. The section is pulled out, cut with a knife and gently wrapped into a foil. They only had time for two whole core sections, for a total of about 5 feet.

"The top layer was wet," said Heinemann. "Then came a good firm core and then came a layer that was contaminated with little pebbles...a sign of a disturbance, a landslide. So we were a bit disappointed that we couldn't get deeper."

Before leaving, they installed a water logger to keep track of the water level in the swamp and a box to house instruments for collecting climate data. Climbing back up the swinging rope ladder with heavy equipment to the summit trail was harder than climbing down, especially for Beilman who was carrying the core sections, which needed to remain horizontal in their foil wrappings. They reached the trailhead just in time—by dusk.

"We are planning more trips to this unique place in the hope that we can take longer cores," said Timmermann. "We will send the samples to highly specialized labs in Ireland and at the University of California in Santa Cruz to measure radiocarbon and hydrogen isotopes. We're also thinking of collaborating with paleopollen experts from the University of Wisconsin. These sediments could be a useful addition to the sparse proxy data archive for Pacific climate in the distant past."



Poamoho Swamp: hardly accessible. Image courtesy Axel Timmermann.

IPRC NEWS

IPRC Plays Key Role in Climate Science Center

On October 7, Secretary of the Interior Ken Salazar announced the establishment of the Pacific Islands Climate Science Center, a consortium of the University of Hawai'i at Mānoa and Hilo, and the University of Guam. "The nationwide network of Climate Science Centers will provide the scientific talent and commitment necessary for understanding how climate change and other landscape stressors will change the face of the United States, and how the Department of the Interior, as our nation's chief steward of natural and cultural resources, can prepare and respond," said Salazar.

The Pacific Islands Climate Center will be led at UH Mānoa by IPRC

Director Kevin Hamilton; at UH Hilo by Donald Price, Director of the Tropical Conservation Biology and Environmental Science (TCBES) graduate program; and at the University of Guam by Frank Camacho, Executive Director of the Center for Island Sustainability. Key contributions to the development of the successful proposal were provided by Charles "Chip" Fletcher, Associate Dean of UH Mānoa's School of Ocean and Earth Science and Tech-



nology (SOEST), UH Mānoa Professor of Geography **Thomas Giambelluca**, and **Samuel Walker**, Institutional Researcher for Renewable/Alternative Energy Management at the University of Guam.

"The University of Hawai'i is conducting groundbreaking research in the area of climate change, and we're excited to be recognized for our expertise in this area with the establishment of this climate science center," said UH President **M.R.C. Greenwood**. "Together with the University of Guam and other government and institutional partners, we will continue our efforts to understand the nature of climate systems and improve the predictability of climate change and variations, particularly as it affects the Asia Pacific region."

Koji Omi Visits IPRC

Koji Omi, founder and chairman of the Science and Technology in Society (STS) Forum, visited the IPRC on September 2. Until his recent retirement from politics, Omi was a prominent figure in the Japanese government, elected to the House of Representatives for a total of 26 years. He served in the cabinet in several portfolios including Minister of State for Science and Technology Policy and Minister of Finance. Omi founded the STS Forum with the aim of building a worldwide network among scientists, policymakers, and business people. The Forum considers the implications of the "lights and shadows" of science for humankind, and seeks ways to ensure further progress of science and technology while keeping inherent risks under proper control. Climate science and its role in public policy is an important component of the Forum's deliberations. During his visit, Omi invited IPRC participation in the Forum's annual meeting in Kyoto.

Koji Omi was accompanied by **Asako Omi**, Executive Secretary to the *STS* Chairman, and by **Yuko Miyabe**, Vice Consul at the Consulate General of Japan in Honolulu.



Asako Omi, Koji Omi, and Kevin Hamilton studying display on IPRC's Magic Planet.

IPRC and the 2011 APEC Leaders' Meeting

Hawai'i was on the world stage when Honolulu hosted the annual Leaders' Meeting of the Asia Pacific Economic Cooperation (APEC) November 12–13. This was the finale and the centerpiece of a series of major APEC-related events in Hawai'i, attracting President Obama and many national leaders and top-level officials from the Pacific region and over two thousand reporters.

The University of Hawai'i was asked by the Hawai'i Host Committee to play a key role in making the APEC events productive and memorable for the participants. One of the goals of the Host Committee was highlighting Hawai'i's scientific accomplishments related to "Sea and Sky." IPRC, with its expertise in environmental science and its international focus on the Pacific region, played a major role in this. IPRC hosted the annual symposium of the APEC Climate Center (see page 24), one of the biggest APEC thematic meetings preceding the Leaders' Meeting.

The IPRC was also chosen to be highlighted in "familiarization tours" organized for Chinese media by the Host Committee. In July, eight Beijing-based journalists from such news organizations as the *China Daily*, the *Economic Daily*, the *People's Daily* and the *Economic Observer* visited Honolulu. As part of their visit, a tour of the University of Hawai'i's research vessel *Kilo Moana* was arranged along with a briefing for the reporters in the ship's conference room. IPRC Director **Kevin Hamilton**, who introduced the IPRC and described some recent noteworthy studies, was one of the two scientists presenting.

Two further tours were arranged: One on September 14 for ten Shanghai journalists from the *Shanghai Morning Post*, *Jiefang Daily*, *Wenhui Daily*, and the *Shanghai Daily*; and on September 21 for Guangzhou journalists from the *Southern Daily/Nanfang Daily*, *Guangzhou Daily*, *Yangcheng Evening News*, and *Guangzhou TV*. Each group visited C-MORE Hale on the UH Mānoa Campus, where the journalists heard presentations about UH research relating to China. Among the scientists presenting was IPRC's **Shang-Ping Xie**, who spoke in Chinese about IPRC's research on climate change in East Asia and on developing a better understanding of how global warming will affect rainfall and severe weather.

The Host Committee also created videos about Hawai'i that were shown on hotel TV channels during the meeting (see www.apec2011hawaii.com/stay-connected/videos). The video



IPRC's Professor Shang-Ping Xie at familiarization session for Guangzhou journalists.

"From Deep Space to Deep Ocean" describes IPRC's role as a Japan – US collaboration and features animations showing several recent IPRC research results. Finally IPRC was featured in a special booklet, *Inspiration to Inovation*, prepared for the APEC meeting that highlighted accomplishments of UH Mānoa scientists.

IPRC Director Visits JAMSTEC and MEXT Officials

IPRC Director Kevin Hamilton visited the Headquarters of the Japan Ministry of Education, Culture, Sports, Science and Technology (MEXT) on October 11 to review IPRC's achievements and its close ties with Japanese climate science. He met individually with Kanji Fujiki, Director-General of the MEXT Research and Development Bureau; Toshihide Fukui, Director for Environmental Science and Technology; and Yuichi Inoue, Director of the Ocean and Earth Division. On October 12 the JAMSTEC Tokyo Office hosted a meeting between Hamilton and Executive Directors Yoshihisa Shirayama and Hitoshi Hotta, together with Katsufumi Akazawa, Manager of International Affairs Division; Yukio Masumoto, RIGC Program Director; Tsuneyoshi Yamanishi, Director of the Advanced Research and Technology Promotion Department (ARTPD); Toru Kimoto, International Affairs coordinator for the ARTPD; and Tetsuro Isono and Chihiro Baba of the International Affairs Division. The participants discussed the current status of operations at IPRC and possible long-term plans for IPRC and JAMSTEC.

Recent IPRC Postdoc Receives Major Award

Takeaki Sampe, former IPRC postdoctoral fellow and now assistant professor at the University of Aizu, received the 2011 Yamamoto-Syono Award for Outstanding Papers at the annual fall meeting of the Meteorological Society of Japan (MSJ) in Nagoya. Each year the MSJ gives this award to a scientist under the age of 35 for outstanding papers in meteorology. Sampe received the award for his paper on the Meiyu-baiu formation (Sampe and Xie 2010, Journal of Climate), titled "Large-scale dynamics of the Meiyu-baiu rainband: Environmental forcing by the westerly jet." The work, which was done while Sampe was at the IPRC, addresses the mechanisms forming the Meiyu-baiu rainband, which lingers over East Asia in early summer. The paper pointed out that conventional analyses could not separate cause and effect of the rainband. By focusing on the mid-tropospheric circulation the authors disentangled the causality, showing the role of advection of warm air and transient eddies along the jet stream in the rainband's formation.



Intergovernmental Oceanographic Commission Official Visits

Wenxi Zhu, head of the UNESCO Intergovernmental Oceanographic Commission Regional Secretariat for WEST-PAC, visited the IPRC in September as part of his three-week trip across the US under the auspices of the US Department of State "International Visitor Leadership Program." Zhu is involved in coordinating marine policy, ocean research and capacity building in the Western Pacific. Zhu was interested in learning about IPRC's research related to the climate of the Western Pacific and about the excellent community resource provided by IPRC's Asia-Pacific Data-Research Center. IPRC Senior Researcher **Nikolai Maximenko** also gave a briefing on his efforts to study surface ocean currents and the transport of floating marine debris. Zhu was accompanied on his visit by State Department official **Linda Harris**.



From left: IPRC Director Kevin Hamilton, Linda Harris and Wenxi Zhu.

Russian Ship Encounters Tsunami Debris

Ever since the March 11 Japan tsunami washed millions of tons of debris into the Pacific Ocean, IPRC's Senior Researcher **Nikolai Maximenko** and Scientific Programmer **Jan Hafner** have been trying to track the trajectory of this debris, which is a threat to marine life, small ships and coastlines. For nearly half a year they had only their state-of-theart — but still untested — computer models of ocean currents to speculate where the debris might be traveling.

Then on September 11 a surprising event came to their aid when the Russian ship *Pallada* docked in Honolulu Harbor. *Pallada* is a "tall ship," i.e., a traditionally rigged threemasted sailing vessel used for training Russian cadet seamen. The 354-foot-long *Pallada* had arrived in Honolulu on its homeward journey to Vladivostok at the end of a 3½-month training voyage. **Chris Woolaway** (Hawaiian Ocean Safety Team) arranged an interview on board the ship between Maximenko and Captain **Vasily Sviridenko** and Information and Education Mate **Natalia V. Borodina**.

Maximenko, a native of Russia, described in fluent Russian where the tsunami debris might be found, pointing to the September 11 computer-model plot of the debris field.



The STS Pallada. Images courtesy STS Pallada.

"The captain is seriously concerned about the debris," translated Borodina. "The reason the huge commercial vessels travelling the North Pacific have not reported anything is because they cut through such stuff like a knife through butter. Although *Pallada* is one of the largest tall ships plying the seas, it is still by comparison a small ship and the debris is very dangerous for *Pallada's* thin hull."

When asked whether he would help in the search for the debris, the captain replied, "Sure! I will have our eager young cadets be on the lookout for debris 24 hours a day."

After nearly two weeks, exciting email messages started coming from *Pallada*. Soon after passing Midway Islands (see plot below): "Yesterday, i.e. on September 22, in position 31°042,21'N and 174°045,21'E, we picked up on board the Japanese fishing boat. Radioactivity level – normal, we've measured it with the Geiger counter," writes Borodina. "At the approaches to the mentioned position (maybe 10 – 15 minutes before) we also sighted a TV set, fridge and a couple of other home appliances." Later, on September 27: "We keep sighting every day things like wooden boards, plastic bottles,



The fishing boat from Fukushima is being lifted aboard the Pallada.

buoys from fishing nets (small and big ones), an object resembling wash basin, drums, boots, other wastes. All these objects are floating by the ship."

On October 8, *Pallada* entered the port of Vladivostok, and Borodina was able to send pictures. The most remarkable one was of a small fishing vessel about 20 feet long, which they were able to hoist up onto *Pallada*. The markings on the wheel house of the boat show its home port to be in the Fukushima Prefecture, the area hardest hit by the tsunami.

With the exact locations of some of the by now widely scattered debris, the scientists can make more accurate projections about when the debris might arrive at the Papahānaumokuākea Marine National Monument. The first landfall on Midway Islands is anticipated this winter. What misses Midway will continue towards the main Hawaiian Islands and the North American West Coast.

The IPRC has created a series of web pages dedicated to marine and tsunami debris information. The address is soest.hawaii.edu/iprc/news/marine_and_tsunami_debris/debris_news.php



Plot shows the stretch of *Pallada's* route where debris was sighted between September 21 and 28, 2011. The red rhombus marks the location where the Japanese boat was found, and the red circle denotes maximum debris density experienced. Purple color shows the distribution of the tsunami debris in the Surface Current Diagnostic (SCUD) model on September 25.

IPRC Scientists in the Community

Hawai'i Climate Change Stakeholders Meet

IPRC Director **Kevin Hamilton** was a speaker at two daylong workshops titled "Climate Change Impacts on Fresh Water Resources in Hawai'i" held at the East-West Center in Honolulu on July 8 and July 15. The very interactive workshops were designed to inform officials who make decisions that impact, or are impacted by, the availability of fresh water in Hawai'i. The following Hawai'i State offices were represent-



Participants at the Hawai'i Climate Change Stakeholders Meeting.

ed: Commission on Water Resource Management; Civil Defence; Department of Agriculture; Department of Business, Economic Development and Tourism; and Department of Health. Also present were representatives of the US Army Corps of Engineers and the Honolulu Board of Water Supply, and representatives of several nonprofit community organizations.

IPRC Takes Part in the Hawai'i Conservation Alliance Annual Conference

This yearly conference of the Conservation Alliance gathers hundreds of people to discuss strategies for managing and protecting Hawai'i ecosystems and to share information and practical experiences among the various organizations dealing with land management, legislature, and government. This year's meeting on August 2–4 focused on "Island Ecosystems: The Year of the Forest." Standing questions for the Alliance are: How will global warming impact rainfall in Hawai'i? Will heavy rain events become more frequent, droughts become more severe? Will windward and leeward regions face the same threats?

Oliver Elison Timm, Assistant Researcher at the IPRC, hopes to find answers by looking at the historical rainfall data and by downscaling computer-simulations of future climate change scenarios. Regarding historical records, Elison Timm and his colleagues in Geography at UH Mānoa and at the Cooperative Institute for Research in Environmental Sciences, University of Colorado, have expanded their rainfall stations from 150 to more than 1000 stations, covering the seven major Hawaiian Islands. This large data set allowed them for the first time to zoom in on the spatial details of the projected rainfall changes. Using the 40-member ensemble simulation from NCAR's CCSM3 (medium-range emissions scenario

A1B), the statistical downscaling revealed for the 2040–2060 period a general increase in precipitation by 10–30% along the already wet mountain ranges of Kauai, Oahu, Maui and the Big Island. Leeward and central regions of Oahu, Kauai, and the northeast part of the Big Island appear to suffer from a 10–30% loss in the wet-season rainfall under this scenario. Overall, the findings suggest that with further global warming, the Hawaiian Islands are in for less winter rainfall.

The plot shows changes in rainfall that could be expected under future global warming according to projections in a downscaled global climate model.





Jan Hafner with Nikolai Maximenko wearing hard hat found at Barking Sands Beach.

Inspecting Marine Debris at the Pacific Missile Range Facility

IPRC's marine debris specialists **Nikolai Maximenko** and **Jan Hafner** were invited in July to inspect unusual pieces of marine debris that had just been found at the Pacific Missile Range Facility on Barking Sands Beach, on the west side of the island of Kaua'i. The beach is patrolled daily for security purposes. Since **Dennis Rowley**, Environmental Manager and Range Complex Sustainment Coordinator, took up his post 6 years ago, he had never seen such a large amount of marine debris on the beach! Maximenko thinks that this debris is from the March 11 tsunami — probably not from Japan but from some other Hawaiian island that was inundated by the tsunami.

IPRC Scientist Gives Keynote at Laulima Conference

Nikolai Maximenko was invited to speak at the 2011 Laulima Conference, a statewide meeting about litter control, greening initiatives and other ways to keep Hawai'i beautiful. Held on August 27, 2011, at the Maui Arts & Cultural Center, the meeting was sponsored by the "Keep the Hawaiian Islands Beautiful" organization. During the opening ceremonies, the mayor of each of Hawai'i's four counties presented awards for environmental achievements in business, community and government in his county. In the aftermath of the March tsunami in Japan, marine debris was a major topic at the conference. Maximenko presented his modeling results showing that the Hawaiian Islands could see some tsunami debris on their west-facing beaches in Spring 2012 and eastfacing beaches in 3 to 5 years.

IPRC Participates in SOEST Open House

The School of Ocean and Earth Science and Technology (SOEST) at UH Mānoa opened its doors October 21-22 to the public. Over 6000 public and private school students, children, parents, and other interested people came to the two-day event to learn about earth science. IPRC scientists put on several events featuring slide shows and the Magic Planet spherical projection system for the occasion: Jim Potemra described how the tall and powerful surfing waves are generated by winds far away from Hawai'i; Jan Hafner told about the tsunami debris and where it was headed, showing the animation of the debris field expansion and pictures of the Fukushima boat picked up by Pallada (see p. 14); Malte Heinemann and Michelle Tigchelaar demonstrated with a video they had created, how car exhaust makes water more acidic and how a more acidic ocean dissolves corals. Pedro DiNezio, Matt Widlansky, Ryo Furue, and Michael Mehari showed various climate and earth-science animations on the Magic Planet, taking requests from the audience. Miho Ishizu, Pang-chi Hsu, Jinbao Li, and Prasamsa Singh insured that everything ran smoothly. François Ascani did a great job as IPRC's "salesman" attracting the crowds to our events.



Demonstrating how CO_2 from car exhaust enters water, making the water more acidic; this happens also in the ocean, dissolving corals.

IPRC Scientists In the Media

Tree Rings Tell 1,100-year History of El Niño

IPRC's **Jinbao Li** and **Shang-Ping Xie**, and their international colleagues published a study in the May issue of *Nature Climate Change* titled "Interdecadal modulation of El Niño amplitude during the past millennium." Their analyses show that the annually resolved tree-ring records from North America correlate closely with 150 years of ocean surface temperature records and various coral isotope records in the tropical Pacific, giving an account of the intensity of El Niño events over the past 1,100 years and offering key observational benchmarks for evaluating and perfecting climate models. Their study was picked up by a wide range of media, including the *Honolulu Star-Advertiser*, *Discovery-News*, *Tuscon Citizen*, *PlanetSave*, and *MSNBC.com*.



Bristlecone Pine



East Africa's Climate under the Spell of El Niño since the Last Ice Age

IPRC's **Axel Timmermann** coauthored the August *Science* article "Reduced inter-annual rainfall variability in East Africa during the last ice age," which shows that the waxing and waning of rainfall in eastern tropical Africa in unison with the El Niño– Southern Oscillation existed already 20,000 years ago. The region's last 3,000 years have seen a less stable climate. The study was featured in such online media as *ScienceDaily*, *ScienceNewsline*, and *Red Orbit*.

\$3 Billion "Big Wind" Project and Climate Change

In an August 24 *Honolulu Weekly* article about controversial plans to build a wind farm on the islands of Lanai and Molokai to generate electricity for Oahu, **Kevin Hamilton** was quoted: "In response to anticipated global warming, we have a fairly robust expectation of weaker tradewinds in the

Pacific, nearer the equator. What will happen around Hawai'i, up here at 20 degrees North, is less certain, however, and we can't be sure that the long-term trend will be for weaker trades here, or how big the trend could be. As research at my center, led by Dr. **Hiroki Tokinaga**, has shown that since wind speed generally increases with height, the trend to larger ships has introduced a



spurious increase in the 'observed surface' winds over the ocean."

El Niño and the Tropical Eastern Pacific Annual Cycle Run to the Same Beat

Like waves on an ocean, different climate cycles will occasionally synchronize—but two Pacific cycles not only briefly synchronize but then "lock" into phase. This locking synchronization occurs between El Niño events and the seasonal cycle of sea surface temperatures in the eastern equatorial Pacific according to research by UH Mānoa PhD candidate **Karl Stein** and IPRC's **Axel Timmermann** and **Niklas Schneider**, Their study titled "Phase Synchronization of the El NiñoSouthern Oscillation with the Annual Cycle" appeared in the September issue of *Physical Review Letters*. The findings are expected to improve prediction of El Niño events. Their study was featured by many online science news media: *ScienceDaily, Physorg, ScienceNewsline*, and *Raising Islands*.



The 2011 IPRC Public Lecture in Climate Science

The 2011 *IPRC Public Lecture in Climate Science* was held on the evening of October 19 on the Mānoa campus of the University of Hawai'i. Over 150 students, faculty, and members of the general public listened to the talk entitled "Climate Change and Development: Avoiding the Unmanageable and Managing the Unavoidable" by **Rosina Bierbaum** of the University of Michigan's School of Natural Resources and Environment. A former Acting Director of the White House Office of Science and Technology Policy, Bierbaum is a distinguished expert in the interface of environmental science with national and inter-

national policy and was appointed by President Obama in 2009 as one of the 20 members of the President's Council of Advisors on Science and Technology.

Bierbaum began by noting the idea that human-induced increases in atmospheric concentrations of CO_2 could lead to higher global temperatures dates back to the 19th century. Recent decades have seen rapidly rising atmospheric concentrations of CO_2 and other greenhouse gases and accumulating evidence of a warmer climate. Bierbaum referred to ten

well-established observed trends in recent decades consistent with a warming world. Air temperatures through the troposphere, surface air temperature over land and over oceans, sea surface temperature, atmospheric humidity, ocean heat content and global sea level are all increasing, while sea-ice cover, snow cover and glacier mass are decreasing.

Other observed indicators of a warming world include plants that are shifting upward on moun-



Rosina Bierbaum. Image courtesy Jian Ma.

tain slopes and toward the poles and that flower earlier in the year. Projections suggest that a mean global warming of at least 2°C above the preindustrial baseline is nearly inevitable, but if we continue "business as usual," future generations could see global temperatures rise by 6°C or even more.

Worrying trends that may be related to global climate change are already impacting societies worldwide. Global precipitation has increased along with the num-

ber of severe storms and major flooding events. At the same time drying trends in the interior of some continents have been observed and crop losses due to drought now average about \$5 billion/year. With fewer cold days such pests as red ants and kudzu are not kept at bay and are presenting increasing problems for agriculture.

Bierbaum stated that, left unmanaged, climate change will reverse development progress and compromise the wellbeing of current and future generations. Impacts will be felt



Listening to Rosina Bierbaum's lecture. Image courtesy Jian Ma.

everywhere, but much of the damage will be felt by citizens of developing countries. The world's poorest people will suffer the most, especially through losses in agricultural land and food production.

Co-author of the World Bank's 2010 World Development Report, Bierbaum discussed the report's approach to creating a climate-smart world for managing climate change. Human activities must change. The report's mantra is *act now, act to*gether, act very differently before it's too late.

We must act now, or staying near the 2°C global mean warming will be out of reach. Retrofitting our infrastructure, changing our institutions and our behaviors to become climate smart will take decades. The Rio Accord was nearly 20 years ago, but the global community still has not acted effectively on controlling greenhouse gas emissions.

We must act together as a global community. Highincome countries must take the lead in creating a climatesmart world, building more efficient electricity generation systems and providing for more efficient energy use in buildings, vehicles and other machines. For example, switching the US SUV fleet to cars meeting current European Union fuel economy standards would offset the emissions needed to provide basic electric power service to the world's 1.6 billion people who now lack electricity. Since developed countries have caused much of the greenhouse emissions to date, they may reasonably be expected to help offset costs for curbing emissions in developing countries. But developing countries, too, must help to mitigate greenhouse gas emissions by controlling deforestation, more planting of forests, and implementing sustainable grassland management, soil restoration, and improvements in farming practices.

We must act differently. Bierbaum pointed out that worldwide public funding for alternate and more efficient

energy research & development stands currently at \$13 billion/year, the amount Americans spend on pet food or the French on cheese. World subsidies for petroleum products, in contrast, are over \$150 billion/year. Stabilizing the global temperature rise near 2°C, will require a dramatic decrease in energy demand and a radical transformation of our energy infrastructure by expanding renewable energy sources and developing carbon sequestration technology. It will also be necessary to increase global biosphere carbon sinks by



Rosina Bierbaum with Kevin Hamilton. Image courtesy Jian Ma.

planning and managing our soils and forests sustainably. As substantial climate change seems inevitable we also need to plan for a broad program to adapt our infrastructure and economic practices to the expected warmer world.

This was the third IPRC Public Lecture presented by distinguished colleagues. The IPRC looks forward to continuing this series of annual lectures for the community.

IPRC Public Lectures

2009 A Tale of Environmental Change

By Dr. Susan Solomon, Senior Scientist, National Oceanic and Atmospheric Administration

2010 Changing World, Changing Ocean

By Dr. Susan Avery, President and Director of Woods Hole Oceanographic Institution 2011 Climate Change and Development: Avoiding the Unmanageable and Managing the Unavoidable By Dr. Rosina Bierbaum, Professor, University of Michigan

MEETINGS

Minisymposium on Regional Climate

In July three esteemed colleagues from the University of Alaska visited the IPRC: John Walsh, Chief Scientist for the International Arctic Research Center (IARC), Sarah Trainor, Coordinator for the Arctic Center for Climate Assessment and Policy (ACCAP), and Scott Rupp, Director of the Scenarios Network for Alaska and Arctic Planning (SNAP). A minisymposium was arranged on the topic of "Regional Climate Change." Three IPRC assistant researchers — Hiroki Tokinaga, Axel Lauer and Oliver Elison Timm — and longterm IPRC visitor from India Senthilnathan Samiappan presented. Tokinaga described his work on diagnosing long-term climate changes in the equatorial Atlantic (*IPRC Climate*, Vol. 11, No. 1); Lauer presented his results on modeling projected long-term climate changes over the eastern Pacific Ocean (*IPRC Climate*, Vol. 10, No. 2). Elison Timm discussed statistical approaches to downscaling climate change projections from global models for the Hawaiian Islands. Senthilnathan described his work on modeling climate change and its impacts on agriculture in the Tamil Nadu region of India (*IPRC Climate*, Vol. 10, No. 2).

Walsh ended the seminar with his discussion of the statistical downscaling approaches for Alaska being developed for application by ACCAP and SNAP. Although the IPRC presentations dealt with low-latitude regions, the discussion revealed that our high-latitude colleagues share with us many of the same challenges in their efforts to understand and predict the regional climate changes and their effects in Alaska.



Around the table from left: Hiroki Tokinaga, Senthilnathan Samiappan, Axel Lauer, Kevin Hamilton, John Walsh, Sarah Trainor, Scott Rupp, Ali Bel Madani, Nat Johnson, Oliver Elison Timm.

The IPRC Annual Symposium

The IPRC held its 11th Annual Symposium at the East-West Center on September 7. The very lively "all poster" format – so successful the previous year – was organized and chaired this year by a committee of the eight IPRC assistant researchers. At the beginning of each poster session, the scientists advertised their poster in 2-minute summaries, giving the audience an idea about what they were about to see. In addition to the posters, the staff of the Asia-Pacific Data-Research Center showed off their data server and products on a large-screen video display. The symposium format made for energetic discourse and animated exchange of research ideas among the IPRC and other UH Mānoa scientists who attended. The stimulating discussion concluded after 6:00 pm, with pupus and refreshments.



At the IPRC Symposium. Program organizers are wearing leis.



From left front: Bin Wang, Jagadish Shukla, Rosina Bierbaum, Chin-Seung Chung, Soon-Chang Yoon, In-Sik Kang. Back row: Neil Plummer, Brian Taylor, Kevin Hamilton.

IPRC Hosts 2011 APEC Climate Symposium

The Asia-Pacific Economic Cooperation (APEC) Climate Center (APCC) held its 2011 Annual Symposium in Honolulu. IPRC hosted the meeting at the East-West Center from October 19 to 22.

APCC Director **Chin-Seung Chung** opened the meeting, stressing that this year's symposium theme, *Harnessing and Using Climate Information for Decision Making*, represents a new direction for the APCC, which will now include more research directly applicable to climate change adaptation efforts in the APEC economies.

IPRC Director **Kevin Hamilton** then welcomed participants on behalf of the IPRC, noting the close connections between the APCC and the IPRC since APCC's founding tific Advisory Committee **Jagadish Shukla** made congratulatory remarks on behalf of the APCC SAC.

Rosina Bierbaum (University of Michigan), **In-Sik Kang** (Seoul National University), **Neil Plummer** (Australian Bureau of Meteorology), IPRC faculty member **Bin Wang**, and Jagadish Shukla gave keynote lectures. Oral and poster sessions followed, covering topics that ranged from a review of extended-range and seasonal climate prediction systems now operational in various APEC economies to workshops on climate effects related to agriculture, freshwater and energy resources in the Asia-Pacific region. Incorporated within the symposium was the *US–Korea Workshop on Use of High-Resolution Models for Prediction of Extreme Events* organized by **Emilia Jin** (NGMDC, Korea) and **Siegfried Schubert** (NASA Goddard Space Flight Center).

in 2005. IPRC scientists serve on the APCC Science Advisory Committee (SAC) and as APCC affiliate members. Moreover, the two centers share a common focus on climate change and variability in the Asia-Pacific region as well a broad international orientation in their operations.

The Honorable **Brian Schatz**, Lieutenant-Governor of the State of Hawai'i, welcomed attendees to Hawai'i and commended both the APCC and the IPRC on their important work on climate change. SOEST Dean **Brian Taylor** welcomed participants on behalf of the University of Hawai'i. Chair of the APCC Scien-



versity of Hawai'i. Chair of the APCC Scien- At the APCC reception from left: UH President M.R.C. Greenwood, Kevin Hamilton, Chin-Seung Chung, and Jagadish Shukla.



Symposium participants.

The meeting attracted over 100 registered participants, including representatives of each of the 21 APEC economies. Many students and researchers from the IPRC and other departments in the University also attended.

A highlight for the participants was a reception hosted by University of Hawai'i President **M.R.C. Greenwood** at the University's College Hill estate.

The symposium attracted considerable media attention with an extended TV news report broadcast in Chinese on

The Hot Spot Project in the Western North Pacific

By Yu Kosaka

Recent studies show that the warm Kuroshio and Gulf Stream release strong fluxes of heat and moisture that penetrate deeply into the troposphere. Such strong and deep thermal forcing of the atmosphere may drive significant circulation changes, contradicting the conventional notion that for large-scale climate only the midlatitude ocean's passive response to atmospheric forcing needs to be considered. In fact, through such "hot spots" midlatitude air–sea interaction may well influence features of regional and global-scale climate such as the wintertime North Pacific storm track and the summertime Meiyu-Baiu rainband.

A nation-wide Japanese project on this "Hot Spot" in the climate system aims to understand the multi-scale air–sea interaction over the western North Pacific and its impact on large-scale climate and its variability. On September 15–16,

the *New Tang Dynasty* cable network as well as coverage in local TV news reports and in an *Associated Press* story. The *Honolulu Star-Advertiser* included both an October 19 news article and an October 21 editorial ("Don't Wait to Adapt to Global Warming") inspired by the symposium.

IPRC Assistant Researcher June-Yi Lee dealt with the many practical details of hosting the symposium. The full agenda for the meeting is available on the IPRC web page: http://iprc.soest.hawaii.edu/meetings/meetings.php

the IPRC held the workshop "Air-sea Interaction over the Northwest Pacific: Research Progress and Observation Campaigns" to exchange views with visiting Japanese colleagues and plan further work on this project.

Chief principal investigator of the "Hot Spot" project, Hisashi Nakamura (University of Tokyo and JAMSTEC), summarized the project and its current status. Yoshimi Kawai (JAMSTEC) reported a preliminary analysis of ship observations over the Kuroshio extension and the Subarctic Ocean. He had detected surface pressure minima over high sea surfaces temperature (SST) along the Kuroshio in a scale of ~100 km. Ryuichiro Inoue (JAMSTEC) introduced the Integrated Physical-Biogeochemical Observation Experiment (INBOX) led by Toshio Suga (Tohoku University and JAMSTEC), who joined the discussion via Skype. INBOX aims to examine effects of atmospheric and oceanic fronts on ocean ventilation and biogeochemical processes by observing subtropical mode water in the Northwest Pacific. Meghan Cronin (NOAA Pacific Marine Environmental Laboratory) described activities of the Kuroshio Extension



Hotspot Workshop participants.

Observatory (KEO), and **Nicholas Bond** (University of Washington) presented plans for aircraft observations of aerosol and cloud cover over the western North Pacific.

To plan fruitful observations, understanding of the dynamics and predictions of midlatitude air-sea interactions was shared. Shoshiro Minobe (Hokkaido University) discussed dynamics of atmospheric surface divergence/convergence along the oceanic frontal zone and indicated that pressure adjustment predominated over vertical momentum mixing. Thomas Kilpatrick (Department of Oceanography, UH Mānoa) described his study with IPRC's Niklas Schneider that shows changes in surface-pressure gradient and vertical-momentum mixing over the Gulf Stream SST front impact the atmospheric Ekman layer. Bo Qiu (Department of Oceanography, UH Mānoa) discussed decadal prediction of the dynamical state of the Kuroshio extension, which switches between a stable and tight SST gradient and an unstable front with enhanced eddy activity. Qiu predicts, the stable state will continue until 2014 (after completion of intensive observation) and then shift to the unstable state.

IPRC's **Shang-Ping Xie** talked about dynamics of modewater ventilation and the Subtropical Countercurrent in the North Pacific. A coupled GCM study suggests the Subtropical Countercurrent will weaken under global warming. **Hiroki Tokinaga** (IPRC) presented his analysis showing that the western North Pacific CO₂ partial pressure varies interannually as a function of ENSO and Indian Ocean warming.

The observation plan was discussed on the second day. In addition to KEO and JKEO buoys administered by PMEL and Japan, a buoy is to be moored on the Kuroshio extension axis. With these three buoys, the pressure minimum and pressure-adjustment mechanism will be examined. Possible doppler-radar observations for ship cruises were discussed. Aircraft observations are planned for cloud sampling over the East China Sea in winter and the Kuroshio extension in the summer Baiu season. Xie described a Chinese research project to be launched on subtropical-mode-water formation and air-sea interaction over the western North Pacific that could be coordinated with the Hot Spot Project.

Mitigating the Impact of Tsunami Debris on Coastlines

The March 11 tsunami in Japan swept millions of tons of debris into the ocean. Visible from airplanes during the first weeks as distinct mats of complex composition, the debris drifted offshore, dispersed and became effectively invisible to observing systems. The model debris-path predictions made by IPRC's **Nikolai Maximenko** and **Jan Hafner** have recently been confirmed by ship observations that showed end of September the leading edge of the debris only about 400 km northwest of Midway and the Papahānaumokuākea Marine Monument (see p. 14). The workshop was convened at the IPRC on November 14 by Maximenko to discuss the necessity and feasibility of mitigating the tsunami debris impact and to propose a science-based plan for effective use of available limited resources to explore, monitor, and handle tsunami debris drifting toward Midway, the Hawaiian Islands, and the US/Canada West Coast. The workshop was accessible live by WebEx, set up and monitored by Postdoctoral Fellow **Ali Bel Madani**, Assistant Researcher **Oleg Melnichenko**, and Computer Systems Manager **Ron Merrill**. Scientific Computer Programmer **Jan Hafner** ran demonstrations of computer movies on the Magic Planet and explained debris samples collected on Hawaiian beaches.

Robin Bond (Hawai'i Ocean Safety Team) opened the meeting with a first-hand account of the tsunami aftermath in Japan. Bond, who had been invited by the famous Hawai'iborn sumo wrestler **Konishiki Yasokichi** to visit the Sendai region 100 days after the tsunami to document in pictures the destruction and the cleanup, showed photos of once beautiful coastal towns from Fukushima to Hokkaido now as flat cement foundations. Other pictures showed huge mats of floating wood.

Rick Lumpkin (NOAA Atlantic Oceanographic and Meteorological Laboratory), presenting over WebEx, explained how drifter trajectories can be used to predict the paths of floating marine debris, a method used by Maximenko and Hafner to develop their models of the debris trajectory.

Maximenko reviewed the ten-year projection of the tsunami-debris field in his statistical model (see below) and then the results from the real-time diagnostic model called Surface Currents Diagnostic or SCUD model. Driven by satellite-measured winds and sea-level height, this latter model yields daily updates of the estimated location of the debris field. On its Honolulu-to-Vladivostok journey end of Sep-



The ten-year projection of the tsunamis-debris field in the statistical model. Image courtesy Maximenko and Hafner.



Observed drifter (red) and tracer paths in model run by Yi Chao. Image courtesy Yi Chao.

tember, the Russian Sail Training Ship *Pallada* encountered flotsam that was identifiable as tsunami debris in regions predicted by the model.

Using a different approach to projecting the debris path, Yi Chao (NASA Jet Propulsion Laboratory) over WebEx described a two tier system, in which nine-month forecasts of global atmosphere and ocean models are assimilated into the JPL Regional Ocean Modeling System to predict how the debris will spread. "Drifters" introduced into this model-system in April 2011 have a similar trajectory as in Maximenko's diagnostic model, some of which have already crossed the Date Line.

Henrieta Dulaiova (SOEST, University of Hawai'i) reviewed the likelihood of the debris being radioactive. Radioactive fumes from one of the Fukushima plants first escaped into the atmosphere the day after the tsunami and was blown northwest over Japan. Release of radioactive water into the ocean was the largest in history, but the earliest release occurred on March 28, i.e., 17 days *after* the tsunami. Given this sequence of events, radioactivity of the debris should pose no health threat.

Samuel Pooley (Director of the NOAA Pacific Islands Fisheries Science Center) described how existing marine debris has been harming the endangered monk seal, sea turtle, and albatross at the Papahānaumokuākea Marine National Monument through entanglement, ingestion of microplastics and larger objects (such as cigarette lighters), modification of habitat, and introduction of invasive species. The arrival of the tsunami debris, together with its possible toxins and invasives, will further endanger these animals. NOAA has been talking with EPA about the tsunami debris. The foremost issue is to gain more knowledge of the debris composition and whereabouts.



Nikolai Maximenko with NHK Los Angeles Bureau Chief Noboru Nakashima at the workshop.

Chris Woolaway (Hawai'i Ocean Safety Team) reviewed work on various marine-debris cleanup projects, the most ambitions being the Ocean Conservancy's International Coastal Cleanup Project: over 25 years, nearly 9 million volunteers in 152 countries removed over 144 million pounds of trash along 291,514 miles of coastlines and waterways.

The present Midway Atoll–Marine Debris Coastal Monitoring Pilot Project has developed a marine debris monitoring protocol for Midway and Papahānaumokuākea. People on Midway, already trained to sort and clean up marine debris using a standardized format, now need to know what to expect with the tsunami debris and how it will be dealt with. Currently much of the debris is shipped back to Honolulu after removal from shores.

Mary Crowley, Director of Project Kaisei of the Ocean Voyages Institute, and her "Marine Debris Think Tank" are bringing together "new technologies, innovations, and capabilities" to help clean debris from our oceans. Based on the debris encountered during her ocean voyages, she has developed categories and technologies for removal. The tsunami debris forms a new category of large debris, such as telephone poles, and requires further research into the appropriate technology for cleanup.

In the final presentation, Maximenko talked about ways to mitigate the impact. Only a fraction of the tsunami debris, he says, will threaten Mainland coastlines since much will travel into the North Pacific Garbage Patch. After 5 years, 95–99% of the debris will probably still be in the water, either having sunk or still floating.

For mitigation at sea, he recommends the following: explore the debris composition along the pathways predicted by SCUD; monitor the pathways continually with drifting buoys that relay their position via satellite; use available resources to clean and block passages. For mitigation at coastlines, he suggests using various observations along the pathways in order to project landfall for different types of debris.

Maximenko closed by broaching the larger issue: "We should use this tragic experiment of nature to understand the general dynamics of marine debris in the North Pacific and to develop the modeling tools for tracking. Sooner or later we will need to solve the overall debris problem. Marine Debris is an emerging science with specific tasks to develop prognostic models for debris circulation: tracking debris pathways; quantifying the dynamics and describing the characteristic of different kinds of debris; and determining the processes defining different trajectories for different types of debris in different years."

The final discussion focused on practical solutions for the immediate threat to Midway and the Marine Sanctuary. Strong winter storms make monitoring and cleanup efforts in the region very dangerous, and the high seas make spotting the debris difficult even from airplanes.



From left, front row: Nikolai Maximenko, Mary Crowley, Chris Woolaway, John Bond; back row: Oleg Melnichenko, Ali Bel Madani, Ray Born, J.C. Hutchinson, and Jan Hafner.

VISITING SCHOLARS

IPRC Alumni Return

"IPRC has grown so much! Scientists have to share offices now," exclaimed IPRC founding scientist **Takuji Waseda** when he returned to the IPRC in June. "I was one of the five scientists that JAMSTEC sent in 1997 to the University of Hawai'i at Mānoa, and **Leland Jameson** and I were the first to arrive in Honolulu to 'launch' the IPRC."

Since those early IPRC days, Waseda has accomplished much. He returned to Japan in 2004 to take a teaching position at the University of Tokyo. Now as associate professor in the Department of Ocean Technology, Policy, and Environment at the University of Tokyo, he mentors eight graduate students and studies the mysterious and feared "freak waves" with experiments in his wave tank as well as in direct reports of their occurrence.

During an IPRC lunchtime discussion, Waseda and two of his graduate students presented their latest research findings. How the strong Kuroshio generates a vortex in the ocean after flowing around Miyake Island was the topic of Tsubasa Kodaira's talk; how cargo ships could be wind powered in the future by routing ships to take advantage of the most favorable winds was Tomoya Nishida's topic. Waseda described his innovative GPS-based system that can record the actual conditions in the ocean under which freak wind-driven waves arise. This system is a huge step forward since direct observations of such waves are sparse and the conditions under which they arise



From left, Hiroki Tokinaga, Ryo Furue, Tsubasa Kodaira, Tomoya Nishida, Takuji Waseda, Nikolai Maximenko, and Bo Oiu.

difficult to measure accurately. These GPS-based observations show that freak waves tend to form when there is a strong atmospheric pressure gradient. Ocean currents and wind gusts probably contribute to their formation.

Yuko Okumura former IPRCsponsored student from Japan and now postdoctoral fellow at NCAR wants to research why some observations in the tropical Pacific show no clear-cut weakening of the Walker Circulation over the 20th century while most climate models do show such a weakening. In May she returned to the IPRC to discuss with her PhD mentor, Shang-Ping Xie, the kind of experiments she might run with the NCAR atmospheric model. She wants to also explore whether millennium simulations with the NCAR climate model can help answer another long-standing conundrum: what causes the swings in El Niño amplitude and its other properties over decades? While at the IPRC, Okumura gave a seminar on her analyses of recent high-resolution icecore records in Antarctica. These show that sea surface temperature variations in the tropics, particularly the tropical Pacific, impact Antarctic climate,

a finding with serious implication for stability of the Antarctic ice sheets and associated change in global sea level.



Yuko Okumura with Shang-Ping Xie.

Hyoun-Woo Kang, who worked with Jay McCreary and Tangdong Qu as a postdoctoral fellow from 2001 to 2003 and is now at the Korea Ocean Research and Development Institute (KORDI), visited the IPRC from July 20 to 27. He came to discuss collaborations in oceanography and climaterelated research between the U.S. and Korea in general, and between IPRC and KORDI, specifically. A partnership with Qu and Ryo Furue on the western Pacific circulation and climate already exists under a Joint Project Agreement among NOAA and the Ministry of Land, Transport and Maritime Affairs

(MLTM), and the Ministry for Food, Agriculture, Forestry and Fisheries (MIFAFF) of the Republic of Korea with funding from the KORDI. The project called "Modeling study on ocean dynamics and its role in climate in the Pacific," has Kang and **Young-Ho Kim** (KORDI) as the Korean principal investigators and Furue and Qu as the US investigators. The project is twopronged: Qu and Kang are studying the western Pacific current variability and climate dynamics, while Kim and Furue are focusing on the sensitivity of climate model performance to the oceanmixing parameterization employed.

Tommy Jensen was also one of the first scientists at the IPRC, coming in May 1998. He is now at the Naval Research Laboratory, Stennis Space Center, Mississippi. He visited the IPRC in September to give several talks: "Wavecurrent Interaction in the Florida Current in a Coupled Atmosphere–Oceanwave Model" and "Coupled Modeling of Air-sea Interaction in the Indian Ocean during an MJO."



IPRC Researcher Zuojun Yu with Tommy Jensen.

Other Visitors

South Pacific Rainband and Global Warming

The South Pacific Convergence Zone (SPCZ) is the rainband that is so important for agriculture in northern Australia and in the South Pacific Islands, making that region one of the wettest on Earth. What will happen with global warming to this rainband? This is question a team of scientists from University of New South Wales (NSW) and the IPRC is looking into. Matthew England, co-director, Climate Change Research Centre at UNSW, visited the IPRC during part of his sabbatical in July - August 2011 to work with IPRC's Axel Timmermann and Postdoctoral Fellow Matt Widlansky. Shayne McGregor, a former IPRC postdoctoral fellow and now at UNSW, joined them for a week in August.

Current climate models used in the IPCC projections of the later 21st century suggest that the SPCZ will become stronger, which would mean more rainfall for Northern Australia and such South Pacific Islands as Fiji. Timmermann and his colleagues, however, are finding that current climate models do not produce a realistic SPCZ, and actually simulate presentday temperatures that are up to 5°C higher than those measured in the eastern South Pacific. Once the bias is corrected, the present-day SPCZ becomes more realistic. When this correction, however, is used in model simulations for climate projections, it appears that the SPCZ will get weaker with warming, and these regions will become drier than today. The reason, the scientists say, is that the South Pacific will warm less than equatorial regions, weakening convection and thus rainfall. Should this come to pass, it would mean less rain for northern Australia.



From left, Matt Widlansky, Shayne McGregor, Axel Timmermann, and Matthew England.

Partnerships in Global Atmospheric Modeling

Two of IPRC's longstanding partners and frequent visitors came for extended stays to the IPRC during August in order to continue their collaborations on comprehensive global modeling of atmospheric circulation.

Masaki Satoh of the University of Tokyo and JAMSTEC worked with IPRC faculty member Yuqing Wang and IPRC postdoctoral fellows Chunxi Zhang and Hiroshi Taniguchi on the analysis of ultrahigh-resolution global atmospheric simulations. The work with Wang and Zhang focuses on improving aspects of the subgrid-scale parameterizations in Satoh's global nonhydrostatic atmospheric model. Satoh's collaboration with Taniguchi involves diagnosing tropical intraseasonal variability in his high-resolution model simulations.

On August 26, Satoh presented some of his group's exciting recent results in a seminar titled "Global Nonhydrostatic Simulations by a Nonhydrostratic Icosahedral Atmospheric Model, NICAM: Intraseasonal Oscillations and Tropical Cyclones."

During his month-long visit, **Yoshio Kawatani** from JAMSTEC's Research Institute for Global Change continued his work with IPRC Director **Kevin Hamilton** on simulation of the tropical middle atmosphere (see story on page 6 in this issue). New directions that were discussed during Kawatani's visit included further diagnosis of the mechanisms involved in climate change influence on the tropical middle atmo-



From left, Yuqing Wang, Masaki Satoh, Yoshio Kawatani, and Kevin Hamilton.

sphere, analysis of the effects of the quasibiennial oscillation on atmospheric thermal tides, and simulation of the largescale flow in the equatorial mesosphere and lower thermosphere.

The Latest on Bomb Cyclones

Koki Iwao is on a year-long visit to the IPRC on a "studyabroad-year" from Kumamoto National College of Technology, where he is associate professor in the Faculty of Liberal Studies. A 2004 doctoral graduate of Kyushu University, Iwao worked as a postdoctoral researcher at the University of Tokyo with **Masahide Kimoto** before beginning his current faculty position in 2007.

Iwao's sabbatical visit to IPRC has allowed him to focus on his research and to take up again his collaboration with Kimoto on the subject of explosive cyclogenesis. In a typical year, the western North Pacific sees the formation of 7 or 8 rapidly developing "bomb" cyclones (i.e., storms with central pressures falling by more than 1 hPa/hour for at least 24 hours). In his research, Iwao has found the frequency of bomb cyclones increased over the western North Pacific from the winter periods 1979/80 – 94/95 to the winter periods 95/96 – 2010/11. Dynamical analysis suggested that the increase was probably due to an increase in humidity associated with rising sea surface temperature, which results in more condensational heating and thus in more disturbances that develop very rapidly into cyclones.



Koki Iwao and Kevin Hamilton.

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