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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

Vol. 7, No. 1, 2007 **Newsletter of the International Pacific Research Center**

Above: Research station at Dome Concordia erected as part of the European Project for Ice Coring in Antarctica (EPICA). Read more on p.13. **Cover:** Mountain view from Terra Nova Bay, Antartica. (*Both photos courtesy of J. Flückiger, Switzerland*.)

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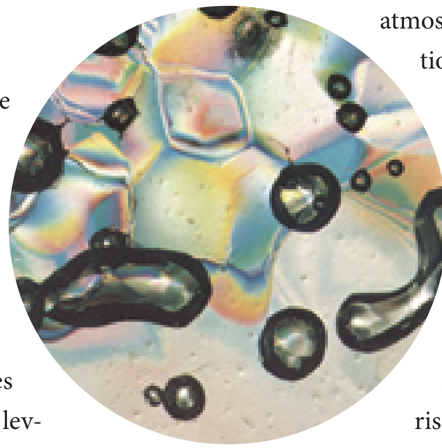
School of Ocean and Earth Science and Technology

Why Did Antarctica Warm?



Antarctica is covered by a massive blanket of glaciers. It is difficult to believe that the continent is now quite a bit warmer than it was 20,000 years ago—according to gas bubbles trapped in Antarctic ice. Those bubbles reveal that 20,000 to 17,000 years before present, surface-air temperatures started to rise about 5 to 8°C until they leveled off around 10,000 years ago. About the same time, the Southern Ocean warmed, sea-ice retreated, and CO_2 concentrations in the atmosphere rose.

A prevalent view of this "end of the last Ice Age" in Antarctica holds that it was indirectly triggered by more solar radiation striking the Northern Hemisphere in summer. The amount of solar radiation reaching the Northern and Southern Hemispheres varies over the millennia with cycles of Earth's path around the Sun: precession, obliquity, and eccentricity. Around 20,000 years ago, the higher northern latitudes started to receive increasingly more solar radiation during June–August. This increase is thought to have triggered glacial melt, pouring fresh water into the North Atlantic. In numerical model simulations, such freshwater flushing abruptly changes the North Atlantic thermohaline circulation and shifts heat to the Southern Hemisphere, with the result that Antarctica warms up.

Another scenario, however, is possible. About 20,000 to 17,000 years ago, the Southern Hemisphere began to receive more solar radiation during its springtime, September–November. Springtime insolation reached a maximum around 10,000 to 8,000 years ago, and then decreased. Today it is about the same as it was 20,000 years ago. Perhaps this change in solar forcing directly triggered the warming in Antarctica.

Axel Timmermann, IPRC co-team leader for research on Impacts of Global Environmental Change, IPRC postdoctoral fellow **Oliver Timm**, and their colleagues **Lowell Stott** at the University of Southern California and **Laurie Menviel-Hessler** at the University of Hawai'i explored this possibility. Their strategy was to simulate the temperature changes over the past 21,000 years in an accelerated global climate model of intermediate complexity called ECBilt-CLIO. They varied over the 21,000 years the ice-sheet cover and atmospheric greenhouse gas (GHG) concentrations in accordance with values estimated by the proxy records, and the solar radiation in accordance with orbital changes computed from astronomical theory.

Figure 1 shows the simulated Antarctic temperature evolution from glacial to interglacial times for the four seasons. There are clear seasonal differences. During December–February, temperatures rise until about 5,000 years ago and then plateau; during March–August temperatures continue to rise from 18,000 years ago to the present. Only for September–November do the changes in the model's mean air-temperatures map well onto the magnitude and phases of the reconstructed isotope-based temperatures from the Antarctic Vostok ice cores. Figure 1 (lower right) and Figure 2a show that the temperature in the model rose from below −34°C to −28°C from 17,000 years to 10,000 years ago (black curve) and then leveled off. The Vostok ice core records show a similar rise of about 6°C above the average long-term record.

To separate the effects of solar radiation, sea-ice albedo feedback, and greenhouse gases on Antarctic temperature evolution, the team ran several simulations in addition to

Above. Thin slice of a polar ice sample illuminated through two polarizing filters. Grain boundaries appear in rainbow colors, the gas bubbles enclosed in the ice are dark. The bubbles range from 1 to 3 mm in diameter. Analysis of the gas composition in these bubbles permits reconstruction of greenhouse gas concentrations (CO_2, CH_4, and N_2O) over the past 650,000 years (*Copyright: W. Berner, 1978, PhD Thesis, University of Bern*).

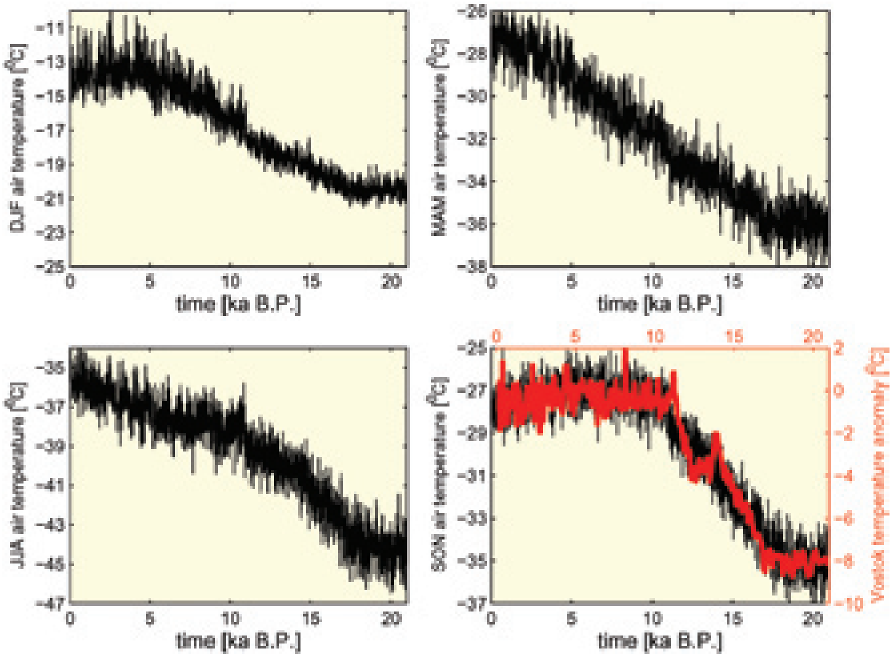


Figure 1. Simulated and observed evolution of Antarctic temperature: (**upper left**) simulated surface air temperature for austral summer (December–February) averaged for latitudes 65°S–90°S; (**upper right**) same as upper left but for austral autumn (March–May); (**lower left**) same as upper left but for austral winter (June–August); (**lower right**) same as upper left but for austral spring (September–November). In red, the reconstructed surface air temperature anomalies relative to present-day values for the Vostok ice core (latitude 78°28′S, longitude 106°48′E). The temperature anomalies are reconstructed from the δ-deuterium concentration and are plotted on the GT4 timescale.

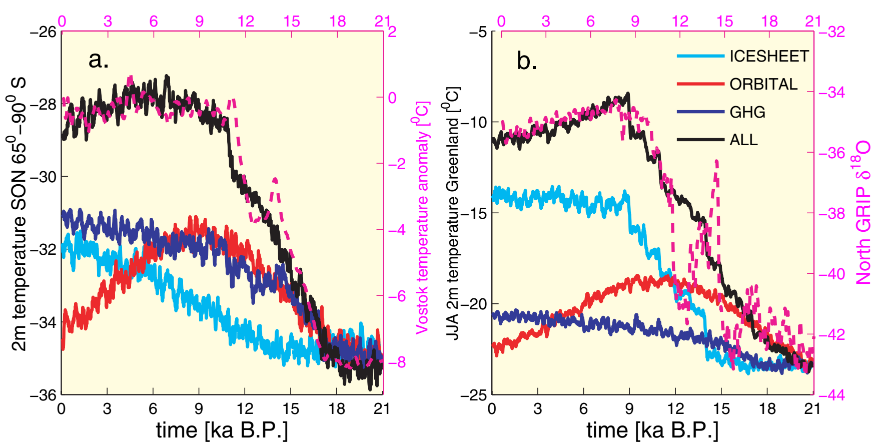


Figure 2. Simulated evolution of Antarctic and Greenland temperatures and sensitivity to different forcings. (**left**) Simulated smoothed austral spring surface air temperatures averaged over latitudes 65–90°S for the transient simulation that includes orbital, greenhouse gas, and ice sheet changes (black) and the simulations that capture only the time-evolution of the orbital forcing (red), the greenhouse gases (blue), and the ice-sheet orography and sea-ice albedo (cyan). Reconstructed temperatures at Vostok are represented in magenta. (**right**) Simulated smoothed boreal summer temperatures over Greenland obtained for four forcing integrations and the temperature reconstruction (magenta) from the oxygen isotope ratio $\delta^{18}O$ recorded in the Greenland North Greenland Ice Core Project.

the control that had included all three forcings (ALL experiment). The ORBITAL experiment varied insolation in accordance with orbital changes, while the other variables were kept at values existing around 21,000 years ago. Temperatures first rose and then after 10,000 years before present fell again as springtime solar radiation waned (Figure 2, left panel) red curve). The GHG experiment varied atmospheric greenhouse gas concentrations as indicated in the ice core records, while keeping everything else at the original values (dark blue curve). The temperature changes again did not follow those captured in the ice core. Finally, the ICESHEET experiment included only changes in orography and albedo arising from ice and sea-ice coverage, but again the effect on temperature did not match the ice records (cyan). Only the ALL condition (black curve) matched the temperature reconstructions from the Vostok ice core (magenta curve).

Driving the model with conditions as they had evolved in Greenland, Timmermann and his colleagues studied the Greenland temperature evolution (Figure 2, right panel). When all three variables—orbital changes, greenhouse gases, and sea ice coverage—were included, the model captured the overall evolution of temperature recorded in the Greenland ice core. The phases and the contribution of the three variables, however, differed from those seen in the Antarctic simulation and in the Antarctic records.

The end of the last Ice Age in Antarctica, therefore, does really seem to have been triggered by local changes in the Southern Hemisphere.

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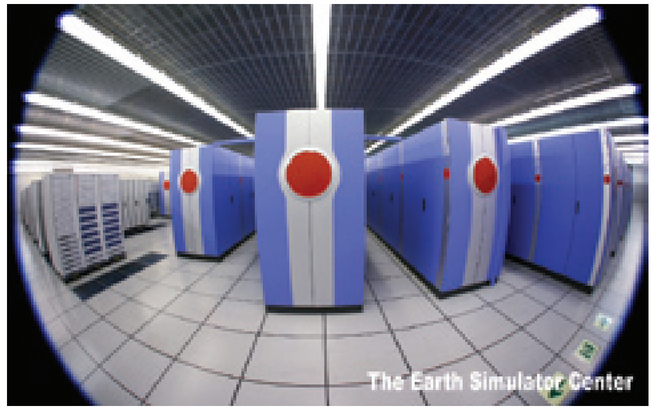
Earth Simulator's Virtual Ocean Brings New Insights



In March 2002, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) began operations of its high-speed supercomputer, the Earth Simulator. Scientists at the JAMSTEC Earth Simulator Center developed three general circulation models (GCMs) to study the climate system at unprecedented fine resolution: The Atmosphere, the Ocean, and the coupled Atmosphere-Ocean GCMs for the Earth Simulator, or AFES, OFES, and CFES. "We can now build the virtual atmosphere and ocean on the Earth Simulator. Information exchange between observations and simulations shall lead to better understandings of the weather and climate systems," writes **Wataru Ohfuchi**, Group Leader for Atmospheric and Ocean Modeling, on the Earth Simulator website.

IPRC scientists have been participating with their partners at the Earth Simulator Center in the analysis of outputs from these high-resolution models. The following describes several findings from OFES, the ocean model.

Because of the Earth Simulator's ability to perform a nominal 40 trillion floating-point operations per second (Tflops), fewer ocean processes need to be parameterized in OFES than in existing global circulation models. The model's high resolution with a grid-spacing on the order of 0.1° and 54 vertical levels allows good representation of the western boundary currents and mesoscale eddies. The codes, based on the GFDL Modular Ocean Model 3, are optimized for massively parallel computations on the Earth Simulator. The model, driven with observed atmospheric fields, provides a comprehensive three-dimensional view of the ocean that aids scientists in interpreting the extensive observations made during the last decades.

Alternating Zonal Jets

At the IPRC, associate researcher **Nikolai Maximenko** was among the first to use OFES output. He had noticed in satellite altimetry data unusual east-west jets that alternated their direction with latitude. Together with **Bohyun Bang**, now a research scientist at the University of Washington, and **Hideharu Sasaki**, a research scientist at the Earth Simulator Center, he decided to look at the climatological run of OFES, and, indeed, found these jets occurred in OFES, too. The finding was consistent with the earlier result by Nakano and Hasumi, who demonstrated the formation of zonally elongated structures in their model of the North Pacific. Furthermore, **Kelvin Richards**, team leader for IPRC Regional-Ocean Influences Research saw these jets also in the high-resolution POP model run on the Earth Simulator and in the OFES hindcast run forced by NCEP reanalysis winds. The presence of these time-varying alternating zonal jets is changing the long-held view of world ocean circulation (see *IPRC Climate*, Vol. 5, No. 1).

OFES, with its high horizontal resolution and many vertical levels, turned out to be ideal for analyzing these jets further, particularly their vertical structure. The model revealed that the jets extend deep into the ocean, although they are significantly more energetic at the surface than at one-km depth. The jets populate virtually every part of the world ocean and the marginal seas. Moreover, the jets are closely related to ocean eddies, and not just at the surface but also at depth.

Maximenko has continued to study these jets. He has found that, although alternating zonal jets are predicted by the theory of geophysical turbulence, the two most distinct classes of jets—seen in both observational and model data—seem to be of different origin.

The first class of jets is amazingly steady over a 10-year and longer period. Such jets all seem to be controlled by local processes at their eastern origins. Most of the jets are located in the eastern parts of oceans with unknown forcing mechanisms. Their kinematical structure reveals a new, interesting interaction between zonal jets and the surrounding large-scale flow. They are not advected by the geostrophic current, according to Maximenko, because they take the form of Rossby wake waves standing in the surrounding flow. He believes this is the mechanism that sets the orientation of such currents as the Azores Current and the Hawaiian Lee Countercurrent (HLCC). The warm eastward-flowing HLCC, for example, results from the blocking of the tradewinds by the tall mountains of the Hawaiian Islands and is associated with positive and negative wind stress curl, according to an OFES simmulation by **Hideharu Sasaki**, and **Masami Nonaka**. This air-sea interaction sustains the HLCC along its 4000-km path from west to east. The current, however, is oriented slightly northward, and Maximenko could demonstrate that the path's orientation is inconsistent with that expected from the prevailing wind direction. He suggests that the orientation results from the northward propagation of the HLCC as a Rossby wave that opposes its southward advection by the geostrophic flow. This is illustrated in Figure 1.

The second class of jets is found at mid-latitudes. This class appears as alternating jets only on snapshot maps of altimetry or model data. The jets behave like sets of linear Rossby waves with a nearly meridional wave vector and north-south wavelengths of about 500 km, propagating toward the equator at 0.45 cm/s phase speed with a 3.5-year local period. The origin of these jet-waves remains unknown and is under active investigation.

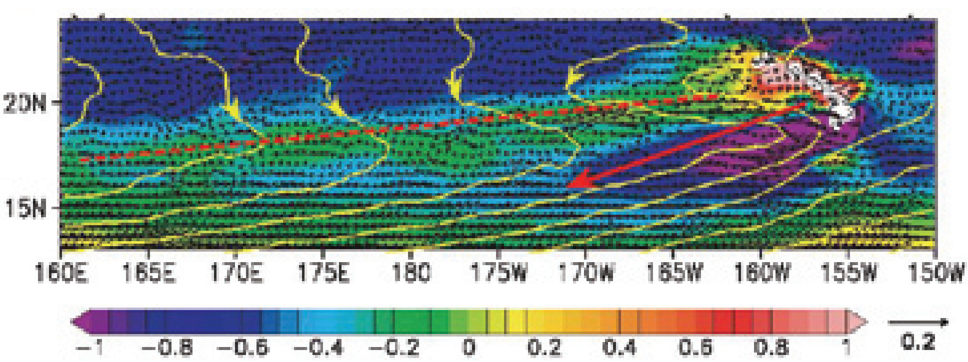


Figure 1. The Hawaiian Lee Counter Current (HLCC)—the dashed red line—is induced by the wind stress curl in the lee of the tall islands and sustained by strong air-sea interaction along its entire 4000-km path. The figure, adapted from Sasaki and Nonaka (2006), shows the eastward OFES surface velocity vectors (black) in the area of larger QuikSCAT wind stress curl (colors). The yellow lines, representing the contours of mean surface dynamic topography plotted at 5 dyn. cm intervals, show the mean southward geostrophic flow. The northward tilt of the HLCC differs from the mean wind direction and suggests that the current system behaves like the crest of a Rossby wave standing in the geostrophic flow.

The Shifting Kuroshio Extension

The Kuroshio Extension (KE) is the swift, warm, eastward current formed when the Kuroshio separates from the Japanese coast. The jet impacts North Pacific climate considerably, carrying nearly 140 million cubic meters of warm water per second (140 Sv) eastward into the North Pacific. Above the jet lies the Pacific storm track. The KE is also a large carbon sink and a busy fishing region.

Satellite altimetry measurements have shown that the sea surface height (SSH) in the Kuroshio region has varied greatly over the last 10 years, indicative of both a shift in the current's latitude and strength. The mechanism that causes the KE to slowly shift in this manner is being debated. There are two views. One holds that the shift is due to a change in winds over the region, the other that it is due to internal ocean dynamics. Until OFES, the resolution of the ocean circulation models was too coarse to answer this question. But OFES now resolves the 100-km-wide KE front.

"The combination of high-resolution modeling that matches satellite observation resolutions allows new science to be done. Now the slow changes in the jets' intensity and the position of its front over time can be studied," according to IPRC research team leader **Shang-Ping Xie**.

To resolve the debate, **Bunmei Taguchi**, an IPRC-sponsored University of Hawai'i graduate student until Spring 2006 and now scientist at the Earth Simulator Center (see p. 29), Xie, and **Niklas Schneider** at the IPRC partnered with Hideharu Sasaki and Masami Nonaka and **Yoshikazu Sasai** at the JAMSTEC Frontier Research Center for Global Change. To determine whether OFES captures past changes in this region, they studied an OFES hindcast of ocean conditions for the period of 1950 to 2003. The hindcast, conducted by Earth Simulator Center scientists, was driven with NCEP reanalysis daily mean winds for the 54-year period. This is the first multi-decadal hindast that resolved fronts and eddies in the world ocean from the tropics to midlatitudes.

The OFES simulation matches remarkably well the 10 years of SSH anomaly maps compiled from TOPEX/Poseidon, JASON, and ERS-1/2 satellites (referred to as T/P in the figures). OFES, like the satellite data, shows the interannual variability of the jet concentrated in a narrow latitudinal band that broadens as it approaches the dateline (Figure 2). The meandering of the KE also stands out distinctly.

Figure 3 shows fluctuations in the jet's latitude position and strength over time as reflected in an index. The model tracks the altimetry data very closely, with the initial south-

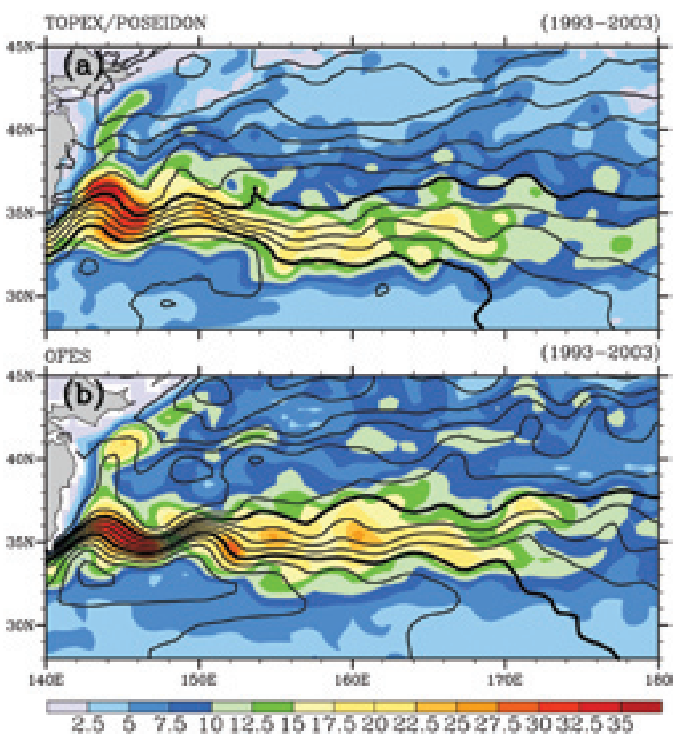


Figure 2. (**a**) Standard deviation of 12-month low-pass filtered SSH observed by satellite altimeters (shade) and the mean absolute sea level (contours at 10-cm intervals; the 60- and 100-cm contours thickened to delineate the KE frontal zone. (**b**) Same as (a) but for the OFES hindcast (the 30- and 70-cm contours for the mean SSH are thickened). Adapted from Taguchi et al., *J. Climate*, in press.

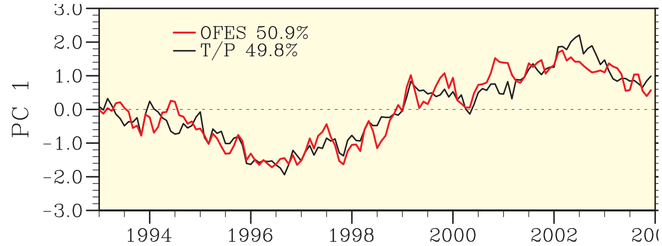


Figure 3. The first principal component of the zonal and monthly mean SSH anomalies (cm) for the period 1993 to 2003: the OFES hindcast (red) and satellite altimeter observations (black). Adapted from Taguchi et al., *J. Climate*, in press.

ward excursion of the KE during the early 90s and then the subsequent northward shift. To validate the OFES hindcast before the satellite altimeter era, the team compared monthly ocean temperature data from OFES with data compiled from expendable bathythermograph measurements gathered by Scripps Institution of Oceanography. Again, the temperature patterns follow each other fairly closely. In short, the OFES hindcast is realistic enough to explore what causes the KE to shift in latitude.

Taguchi and colleagues went on to compare the evolution of the KE latitude–strength index derived in OFES with projections made by the theory that holds the KE variations are due to changing winds (the linear Rossby wave theory). The comparison supports the view that the KE position-shift is due to a change in the wind—the northward shift of the current in the early 1980s follows four years on the heels of a wind shift associated with changes in the Aleutian Low (Figure 4). The north–south structure of the KE, however, is

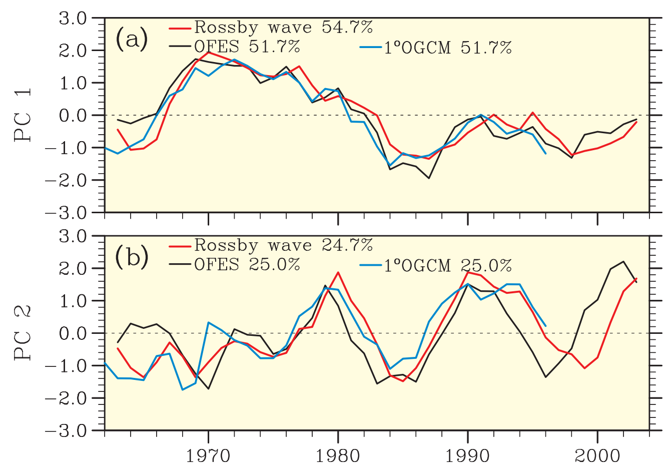
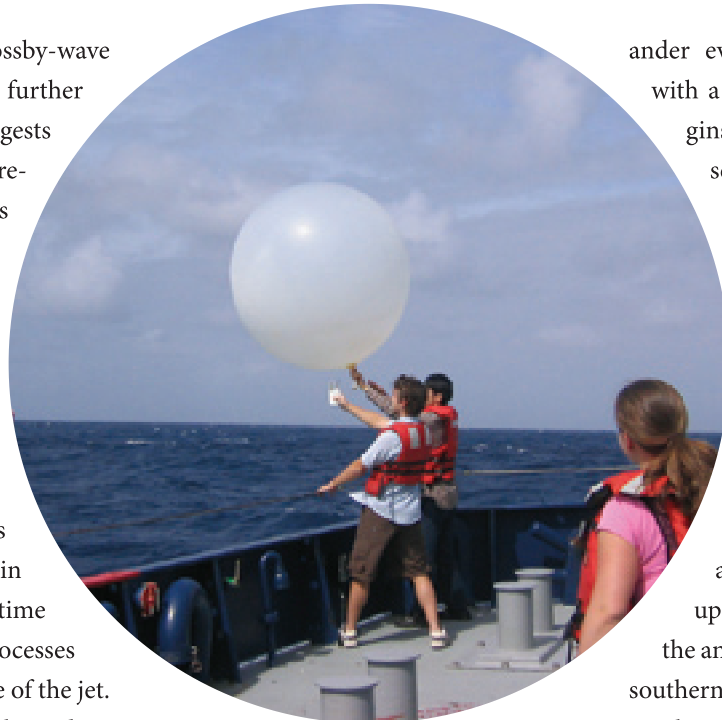


Figure 4. Meridional EOF modes of annual and zonal mean OFES SSH (black), SSH hindcasted with a linear Rossby wave model (red) and the 400-m-temperature simulated with an Ocean GCM (blue): (**a**) PC-1, and (**b**) PC-2. Adapted from Taguchi et al., *J. Climate*, in press.

much narrower than the Rossby-wave theory would predict. A further analysis of OFES output suggests that this narrow structure results from internal dynamics of the KE, with subsurface variations exerting a strong influence. The wind-forced Rossby waves appear to act as pacemaker regulating the intrinsic variability of the jet.

In sum, the analyses show that wind shifts explain the variations in the jet over time and that nonlinear ocean processes organize the spatial structure of the jet. The next question now is, how does this oceanic front (as well as others) affect the atmosphere that lies above it and the storm track? Experiments at the Earth Simulator Center with the high-resolution AFES are already looking into this significant question.



Releasing a GPS sonde from the RV *Melville*, see p. 27 (*photo courtesy Kohei Kai*).

Kuroshio's Shifting Pathways

The Kuroshio flows along the coast of Japan in one of three paths: a large meander, which moves offshore near Shikoku for up to 300 km and returns to the coast west of Izu ridge; a rather straight path along the shore past Kii peninsula and north to Miyake-Jima; and a small offshore excursion south of Hachijo-Jima. The location of the Kuroshio impacts Japan's coastal ocean and fishing industry.

Several theories have been put forward to explain the sudden switches in Kuroshio paths: lee Rossby waves, multiple steady states selected by upstream variations in the Kuroshio, and accumulation of potential vorticity in the recirculation of the Kuroshio. OFES with its near-global domain, eddy-resolving grid, and multi-year hindcast provides a unique opportunity to investigate the dynamics of the Kuroshio paths.

IPRC research team leader **Niklas Schneider**, **Bo Qiu** (University of Hawai'i) and **Hideharu Sasaki** (Earth Simulator Center) found that the 1950–2003 OFES hindcast produces variations in sea level, thermocline temperature, and ocean pressure that indicate vigorous variations in the Kuroshio path. They used a Complex Empirical Orthogonal Function to decompose sea level or geostrophic stream function anomalies; the leading mode accounts for 63% of the variance in this area and yields an index for the Kuroshio path. The index suggests the systematic evolution of two preferred paths, similar to the large observed meander and the straight path (Figure 5).

Using the evolution of the leading principal component, the team obtained a composite of the large meander evolution (Figure 6). Starting with a straight path, a meander begins to form near Izu ridge. Over several years, this meander grows and moves upstream until the large meander is established. After a period of several years to a decade, the system collapses in a few months into a straight path again. This evolution is independent of upstream anomalies in the Kuroshio, and is associated with a build-up of low potential vorticity in the anticyclonic recirculation on the southern side of the Kuroshio. On the northern side, high potential vorticity is generated at small topographic features, a process that can only be simulated because of the high resolution of OFES. Lateral mixing in the OFES due to friction along the coast appears to

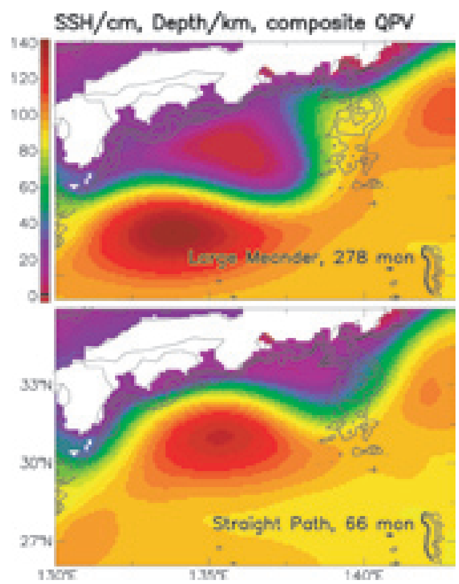


Figure 5. Sea level (in cm) composites for OFES's large meander and straight path, the preferred states in the principal component of the CEOF. Out of 648 months, the large meander occurs 278 months and the straight path only 66 months.

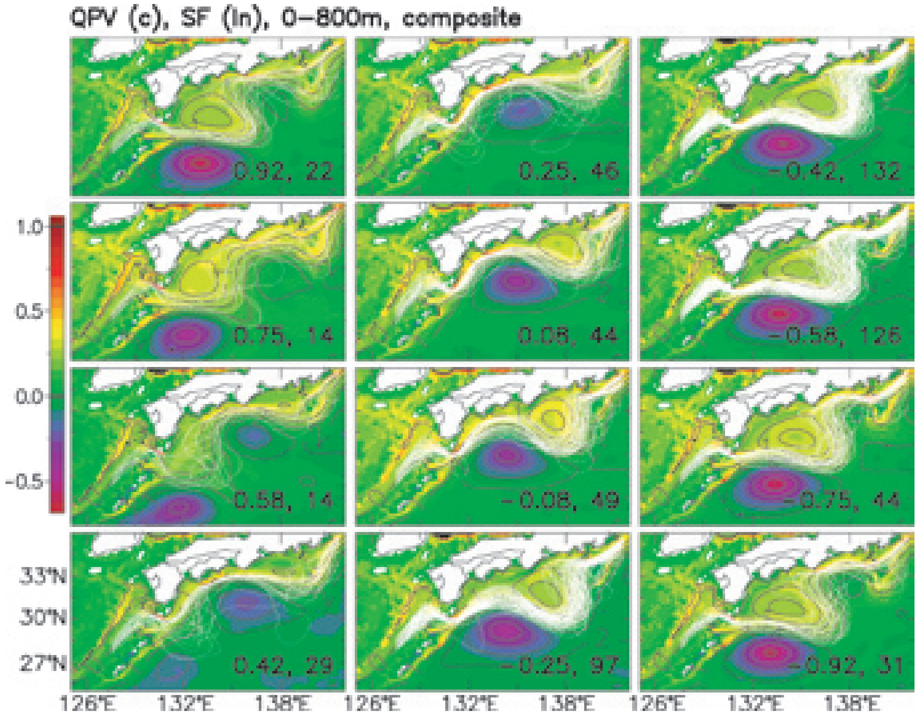


Figure 6. Composite evolution of the large meander based on the phase of the CEOF of quasi-geostrophic potential vorticity south of Japan. Contours denote stream function, colors denote quasi-geostrophic potential vorticity, and white lines the Kuroshio path for the months within the phase. The first number in the bottom right corner of each panel denotes the phase in units of π and decreases as time progresses; the second number denotes the number of months in the phase. Note the continuous buildup of the large meander and very fast collapse to a straight path.

be insufficient to mix these waters and to convert low potential vorticity water into the high potential vorticity water known to leave the coast of Japan in the Kuroshio Extension. Thus, in OFES, the low potential vorticity water accumulates until the system becomes unstable and forms the straight path again.

In these OFES simulations, a few features differ from observations. The large meander, for instance, detaches from the Japan coast already near Tokara Strait and returns to the coast just west of Izu Ridge. During its straight path, the Kuroshio departs at Kii peninsula to loop around the northern part of Izu Ridge. Furthermore, the preferred state in OFES is a large meander, the straight path occurring for only a fraction of the cycle.

These differences pose an exciting challenge to understand the model's physics and improve the simulation. Previous studies, which have used simplified, idealized models of the Kuroshio, detail many features that can affect the behavior of the Kuroshio. Schneider and his colleagues now intend to combine the insights gained from the OFES simulations with those from the simpler models to further investigate the observed evolutions of the different Kuroshio paths.

South China Sea May Impact Indo-Pacific Warm Pool

The Indonesian Throughflow transports water between the Pacific Ocean and the Indian Ocean through the Indonesian Archipelago. The region has unusually high sea surface temperature (SST). The interaction between atmosphere and ocean in the region significantly impacts climate, particularly the El Niño–Southern Oscillation. Research has shown that small changes in SST there may significantly change atmospheric convection and rainfall across the Indo–Pacific basin. The adjacent South China Sea, though, has been seen as a passive body of water and has received little attention in climate research.

IPRC Associate Researcher **Tangdong Qu** has been studying this region for some time and believes the South China Sea heat content and freshwater concentration vary in ways that very likely influence the climate not only of the Indonesian Seas but also the tropical Indian and Pacific oceans. Existing models, however, have not resolved the region well enough to explore this idea.

Analysis of the climatological run from OFES by **Yan Du** (IPRC postdoctoral fellow), Qu, **Hideharu Sasaki** (JAMSTEC Earth Simulator Center) and **Gary Meyers** (Australia's CSIRO) demonstrated that the high-resolution OFES represents the complex topography of the passages through the islands and the region's ocean bottom much more realistically than previous models. Qu, Du, and Sasaki, therefore, decided to examine the region's circulation, heat content, and freshwater flux in the 1950–2003 OFES hindcast.

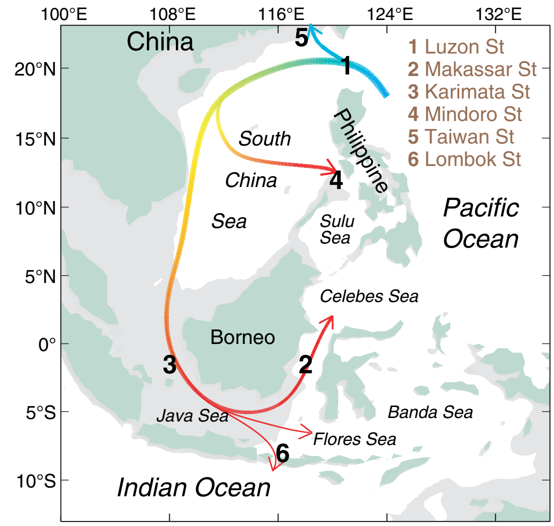


Figure 7. A schematic diagram showing the South China Sea throughflow adapted from Qu *et al.*, *GRL* 2006. Water entering the South China Sea through Luzon Strait is lower in temperature (blue) than water leaving it through Karimata, Mindoro, and Taiwan Strait (red).

OFES results show Pacific water entering the South China Sea through Luzon Strait. This water leaves the South China Sea through three straits: Karimata, Mindoro, and Taiwan, each transporting on average approximately 1.3 million cubic meters of water per second (Figure 7). Comparing the mean heat transported through Luzon Strait and the three exit straits, the team determined that the water in the exit straits is 1.8°C warmer than in the inflow through Luzon Strait. That means strong heat flux from the atmosphere warms the water while in the South China Sea.

The team estimated that between 0.1 to 0.2 Petawatts (the total heat flux transported by Earth's atmosphere and oceans away from the equator towards the poles is estimated at 4 Petawatts) leaves the South China Sea through Karimata and Mindoro straits. This large amount of heat transfer can be expected to have considerable effect on the heat and freshwater distributions in the Indonesian Seas, as well as the Indian and Pacific oceans. Even more important for long-term climate fluctuations is the finding that in OFES the outflow through Karimata and Mindoro straits varies greatly from year to year. In most years, the flow through the Karimata and Mindoro straits is stronger during El Niño years and weaker during La Niña years. Because volume and heat transport are nearly perfectly correlated ($r = 0.98$), the maximum heat transported out of the South China Sea through Karimata and Mindoro straits tends to occur during El Niño years—around four months before the mature phase of El Niño.

During El Niño years, the South China Sea receives more heat from the atmosphere than during La Niña years, according to the surface-heat-flux data from the NCEP reanalysis. This increase usually has less impact on the upper heat content of the SCS than the variations in the transport through Karimata and Mindoro. Since this transport is stronger during El Niño years, the South China Sea actually tends to lose more heat during El Niño years than in other years (Figure 8).

There are intriguing exceptions to this trend, though. During the two super El Niños of the last century, the 1982–83 and the 1997–98 El Niño, the surface heat flux into the South China Sea was stronger than the transport out of the sea, increasing the heat content of the South China Sea.

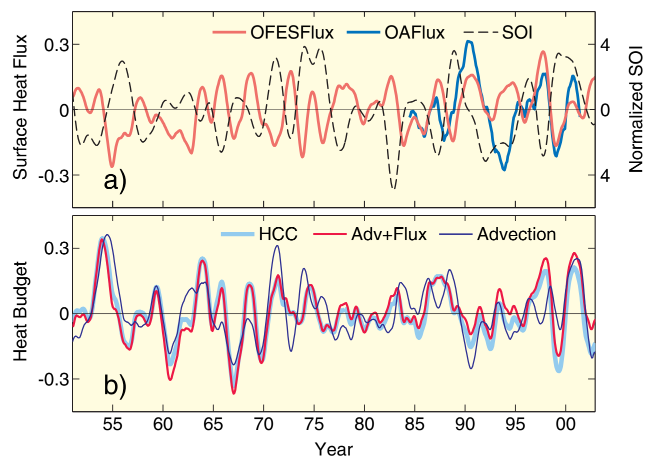


Figure 8. (**a**) OFES surface heat flux compared with the OAFlux surface heat flux and the Southern Oscillation Index (SOI), and (**b**) upper layer (0–432 m) heat content change (HCC) compared with heat advection and the sum of surface heat flux and heat advection averaged over the South China Sea. The 13-month mean filter has been applied twice to remove the mean seasonal cycle. Unit is 1014 W. Adapted from Qu *et al.*, *GRL* 2006.

What does all this mean? The year-to-year fluctuations in the South China Sea heat content should impact long-term climate variability. Based on the OFES results, Qu believes that the South China Sea is acting as a heat capacitor, storing and releasing heat and modulating conditions in the Indo-Pacific warm pool region. The sea should, therefore, impact the southeast Asian monsoon and El Niño and La Niña. He hopes that this OFES research with his partners at the Earth Simulator Center is putting the South China Sea on the map as worthy of attention from climate scientists.

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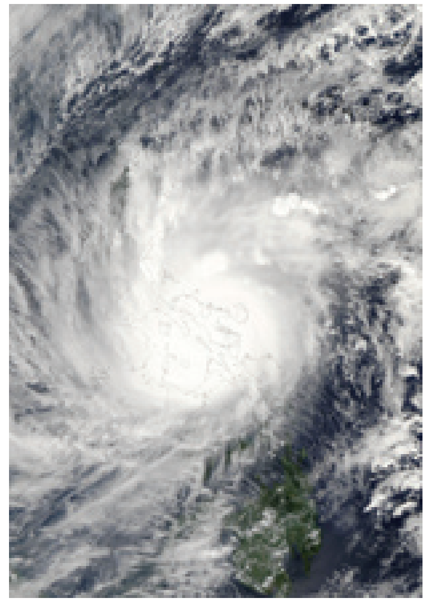
Forecasting the Intensity of Tropical Cyclones



Super Typhoon Durian (*courtesy NASA Earth Observatory*).

Forecasting the intensity of tropical cyclones remains a serious challenge for meteorologists. Track forecasts are much more likely to be accurate than intensity forecasts. A source of guidance for calculating the intensity that a tropical cyclone can reach is the theoretical concept of maximum potential intensity. This is an estimate of the highest intensity (typically characterized by the strongest surface wind) a storm can have and still fall within the constraints of thermodynamics. The maximum potential intensity is a function of such factors as atmospheric temperature structure and the temperature of the ocean surface layer. A simulated cyclone might reach theoretical maximum potential intensity in a geographically uniform environment and weak vertical shear. Few real storms, though, ever reach the theoretical maximum. The strength of real storms is capped by dynamical factors such as the environmental vertical wind shear and the movement of the storm.

IPRC scientist **Yuqing Wang**, together with his visitor **Zhihua Zeng** from the Shanghai Typhoon Institute and **Chun-Chieh Wu** from the National Taiwan University, analyzed data on western North Pacific tropical cyclones in order to get a better grasp of the relationship between the maximum intensity each storm actually reaches and environmental factors. They analyzed the "best track" data for tropical cyclones produced by the Joint Typhoon Warning Center from 1981 to 2003, together with Reynolds sea surface temperature (SST) and NCEP-NCAR reanalysis data. In addition to the usual measures for calculating maximum potential intensity—temperature of the ocean surface and of the outflow of air at the top of the storm—they looked at the impact of environmental vertical shear and storm translational speed (the speed at which a storm moves) on intensity.

Figure 1 shows the scatter diagram for intensity (the maximum surface winds), observed every six hours, plotted against the SST at the storm center for storms that packed at least 17 m/s wind. Higher SST is associated with increasing intensity, at least up to 27°C. The scatter is large, however, with weak storms found fairly often over high SST

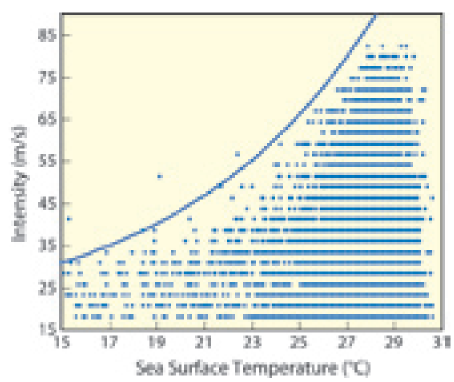


Figure 1. Scatter plot of tropical cyclone intensity (maximum surface sustained wind in m/sec) as a function of SST (°C) over the western North Pacific during 1981 to 2003. The intensity was corrected by subtracting the storm translational speed. The solid curve represents the empirical maximum potential intensity (m/s) derived for the western North Pacific. Adapted from Zeng, Wang, and Wu, *Mon. Wea. Rev.*, 2007.

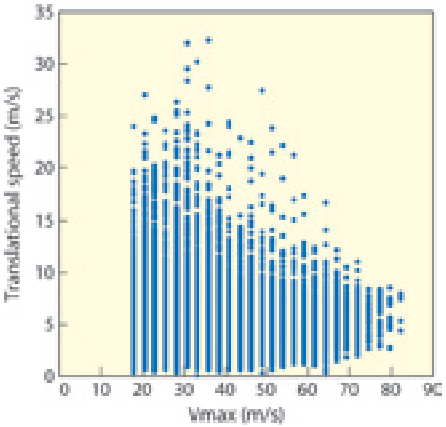


Figure 2. Scatter plot of tropical cyclone intensity (m/s) as a function of translational speed in m/s from the best track intensity data over the western North Pacific during 1981 to 2003. The most intense storms occur within a narrow range (between about 3–8 m/s). Adapted from Zeng, Wang, and Wu, *Mon. Wea. Rev.*, 2007.

during the early stages of formation, while very intense storms often have moved poleward away from the very warm ocean surfaces over which they first formed. Wang and his colleagues fitted an exponential function to the most intense storms at each SST value, shown as the solid curve in Figure 1. This represents a simple empirical determination of a maximum realizable intensity, which turns out to be considerably less than the theoretical maximum potential intensity.

The scientists analyzed in a similar way the storm intensity as a function of translational speed, the speed at which storms move (Figure 2). The most intense storms occur within a narrow range, between about 3 and 8 m/s. The overall dependence of intensity on storm speed can be readily understood. When a storm moves slowly, the winds will have time to stir up the ocean and bring cool water to the sea surface, preventing strong intensification. When a storm moves quickly, its structure typically becomes asymmetric, again limiting its ability to intensify.

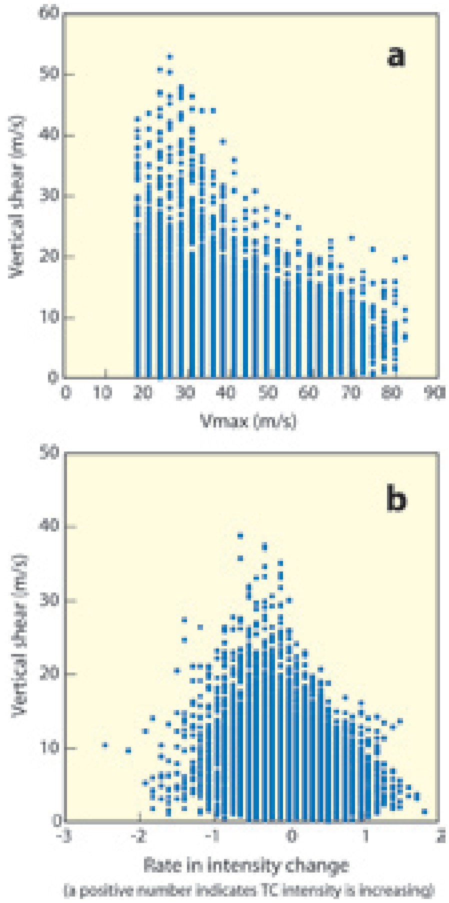


Figure 3. (**a**) Scatter plot of tropical cyclone intensity (m/s) against vertical shear (m/s) from the best track data over the western North Pacific during 1981–2003. (**b**) Scatter plot of intensity-change rate (m/s/hour) and vertical wind shear (m/s). The most intense storms are found in weaker vertical shear (20 m/s or less). Few storms intensified in shear greater than 20 m/s. Adapted from Zeng, Wang, and Wu, *Mon. Wea. Rev.*, 2007.

Wang and his colleagues also plotted storm intensity against the environmental vertical wind shear, which was taken to be the difference in area-averaged winds between the 200 and 850 hPa levels (Figure 3a). They furthermore plotted the rate of change in storm intensity (computed from the 6-hour data) as a function of the environmental wind shear (Figure 3b). The plot shows that generally the most intense storms are found in weaker vertical shear. There is a fairly well-defined critical point: hardly any storms intensified when the environmental shear was greater than 20 m/s.

On the basis of these analyses, Wang and his colleagues developed a new empirically based maximum intensity formula. The formula includes, in addition to SST and the temperature of the air flowing out the top of the tropical cyclone, the effects of translational speed and vertical wind shear. This provides an explicit representation of the thermodynamic and environmental dynamic factors that determine a storm's maximum realizable intensity.

Of course, most storms still do not reach this new maximum, and other factors must be limiting the intensity of tropical cyclones. A particularly important factor is the response of the inner core of the tropical cyclone to environmental conditions and the underlying ocean cooling. With help of the numerical hurricane model he has developed, Wang is now investigating how the internal structure of a tropical cyclone interacts with environmental factors to affect the ultimate storm strength.

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From Polar Ice Cores to Better Climate Models?

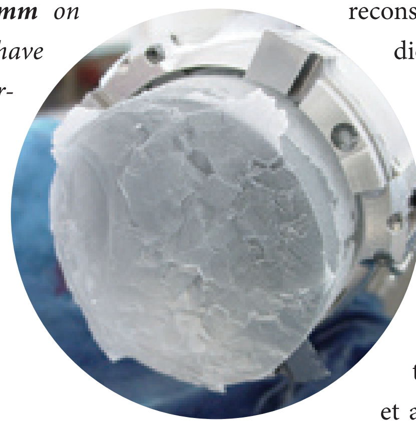
*Thomas Stocker, Professor of Climate and Environmental Physics and Co-Director of the Physics Institute at the University of Bern in Switzerland, spent his 2006 sabbatical at the IPRC. He worked with IPRC research team leader **Axel Timmermann** and postdoctoral fellow **Oliver Timm** on modeling the abrupt climate changes in the past that have resulted from changes in the Atlantic meridional overturning circulation. Understanding processes that have shaped past climates is central to determining what lies ahead for climate change. We asked Professor Stocker to write for the* IPRC Climate *about this work and how it advances our knowledge of Earth's climate system.*

Climate models require accurate forcing data

Numerical models are used to simulate and understand past climate conditions. The forcing conditions in the distant past, such as the concentration of the greenhouse gases or the extent of ice areas, however, were very different from today and must be quantified before experiments with climate models can be performed.

Knowledge of past greenhouse gas composition in the atmosphere is necessary to drive climate models that are to simulate past conditions. This composition can be obtained from polar ice cores. When snow falls on polar ice sheets, it soon forms a porous material, firn, in which air can circulate. The air in the firn becomes trapped under the slow compaction of snowfall, year after year. These bubbles contain tiny samples of ancient air that can be analyzed, and the physical and chemical composition of the atmosphere can be reconstructed by applying various analytical techniques to the ice core samples. Currently, more than 50 components in the ice and in the enclosed gas of a polar ice core are measured (photo below). Such analyses have enabled us at the University of Bern, in partnership with many European colleagues, to trace back climate change in Antarctica to at least 740,000 years ago (EPICA Community Members, *Nature* 2004) and reconstruct the concentrations of carbon dioxide and methane, the two most important greenhouse gases after water vapor.

Within the resolution of the current measurements, our results show that today's levels of CO_2 in the atmosphere are 27% higher than any time during the last 650,000 years (Siegenthaler et al., *Science* 2005). Today's concentrations of CO_2 (annual average in 2006: 382 ppm, as measured on Mauna Loa, Hawai'i, **www.cmdl.noaa.gov/ccgg/trends**) are clearly outside the range of natural fluctuations over the past several 100,000 years (Figure 1). These data provide an indispensable forcing boundary condition for climate models that are used to simulate ice ages and dynamical processes in the distant past.



Above. Drill head with ice core drilled on November 30, 2002, from a depth of 2,874 m at Dome Concordia Station. The ice is about 491,000 years old. The drilling is part of the European Project for Ice Coring in Antarctica (EPICA). This ice core contains a continuous time series of greenhouse gases over the last 650,000 years. The drill head and cutters were designed and constructed by Henry Rufli (University of Bern, Switzerland; *photo courtesy of L. Augustin, LGGE, Grenoble, France*).

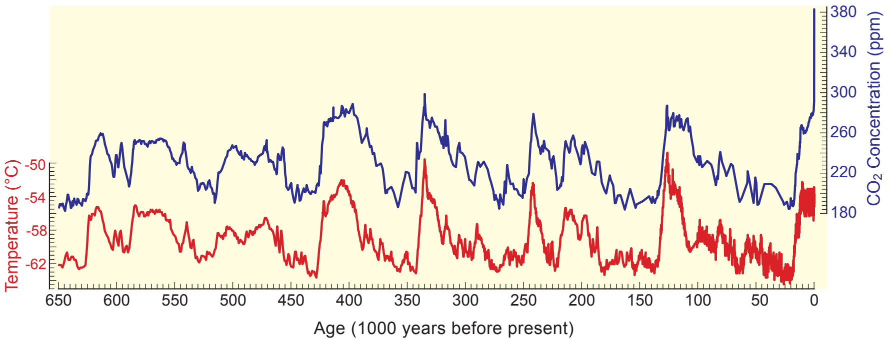


Figure 1. Reconstruction of the atmospheric CO_2 concentration of the last 650,000 years (blue curve) based on data from several Antarctic ice cores, combined with the observed increase measured since 1958 on Mauna Loa (Hawai'i). The estimate of temperature in Antarctica (red curve) is derived from measurements of the stable isotopes of the water molecule.

Signals of abrupt climate change

Ice cores from Greenland and Antarctica have radically changed the way we look at climate as a dynamical system on many time scales. More than 10 years ago, two independent international projects, one in the U.S. (GISP2) and one in Europe (GRIP), confirmed earlier reports that a series of abrupt warmings characterized the last ice age. These abrupt swings of climate in Greenland are now commonly known as *Dansgaard/Oeschger* events, and are thought to cause climate change worldwide. A recent, more detailed ice core from North GRIP (NorthGRIP Members, *Nature* 2004) shows 25 of these events during the last ice age. During Dansgaard/Oeschger events temperature in Greenland rises over a few decades by as much as 16°C and then falls over the following millennia (Huber et al., *Earth Plan. Sci. Lett.* 2006). (These short-term events are different from the gradual deglaciation described in the work by Timmermann and his team on p. 3.)

The synchronization of ice core records from Greenland with those from Antarctica by using global time markers, shows that the strong Dansgaard/Oeschger events in the north have a counterpart in Antarctica (Blunier and Brook, *Science* 2001). When Antarctica is warming, Greenland ice cores register very cold temperatures. However, when an abrupt warming occurs in Greenland, the warming in Antarctica stops, and a cooling trend starts. The pattern is very consistent during the entire ice age and is referred to as the bipolar seesaw (Broecker, *Paleoceanogr.* 1998; Stocker, *Science* 1998). This is illustrated in Figure 2, which shows temperature reconstructions from ice cores from Greenland and Antarctica in a typical time window during the last ice age.

Two questions arise from these ice core records: (i) What is the physics behind this north-south connection, and (ii) can current coupled climate models simulate the time and space signature of such dramatic climate events? This is a hard but crucial test for models that are used to assess the likelihood of low-probability but high-impact climate events in response to global warming.

The combination of numerous paleoclimatic reconstructions, climate model simulations, and theory suggests that the Atlantic meridional overturning circulation is a key component in the physics of these abrupt changes (Clark et al., *Nature* 2002; Alley, *Science* 2003). When freshwater is discharged into the North Atlantic Ocean from unstable ice sheets, the meridional overturning circulation is reduced or even stopped. This leads to a decreased meridonal heat flux in the Atlantic Ocean and an associated hemispheric cooling owing to response of the atmospheric circulation.

In fact, climate models are able to capture many aspects of these abrupt changes, such as the rapidity of the events, the amplitude of the cooling in the Northern Hemisphere (Knutti et al., *Nature* 2004), and various other changes reconstructed by paleoclimate archives (LeGrande et al., *Proc. Natl. Acad. Sci.* 2006). They make specific pre-dictions as to what one may find in the paleoclimatic record of variability in the tropical Pacific (Timmermann

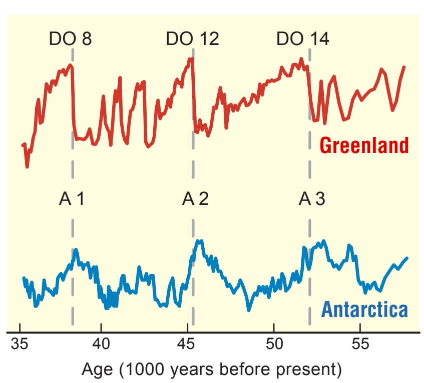


Figure 2. Reconstructions of temperature changes in Greenland (red curve) and Antarctica (blue curve) during a sequence of six Dansgaard/Oeschger events during the last ice age. The curves are put on a common time scale obtained by synchronizing the two ice cores using measured methane variations in both cores. Time is running from right to left (1000 years before present).

et al., *J. Clim.* 2005). While the response of climate models is consistent in the Northern Hemisphere, their signals in the high latitudes of the Southern Hemisphere are ambiguous: one comprehensive model shows cooling, another warming (Stocker, *Science* 2002).

In the current partnership between IPRC (**Axel Timmermann** and **Oliver Timm**) and the University of Bern (**Thomas Stocker** and **Manuel Renold**), established during my sabbatical visit to the IPRC, we set out to better understand this ambiguity. We are analyzing results from a comprehensive coupled climate model that has no flux corrections (NCAR CCSM3-T31). The climate model is perturbed with a strong freshwater flux delivered to the North Atlantic Ocean. Freshwater is injected into the North Atlantic, increasing linearly from 0 Sv (1 Sv = 10^6 m^3/s) to 2 Sv over 100 years, and decreasing to 0 Sv again over the following 100 years. We are considering two cases. In the first case, we applied a globally uniform negative freshwater flux (*i.e.*, saltier water) of the same total magnitude to ensure conservation of mean salinity in the simulation. In the second case, we applied no compensating flux. The model response in the Northern Hemisphere is very similar. The reduction in the meridonal overturning circulation in the Atlantic causes a strong cooling (Figure 3), which is rather uniform but strongest in the northern North Atlantic except for a warm spot in the northwestern part of the subtropical gyre. This is caused by the displacement of this gyre due to changes in the wind stress curl.

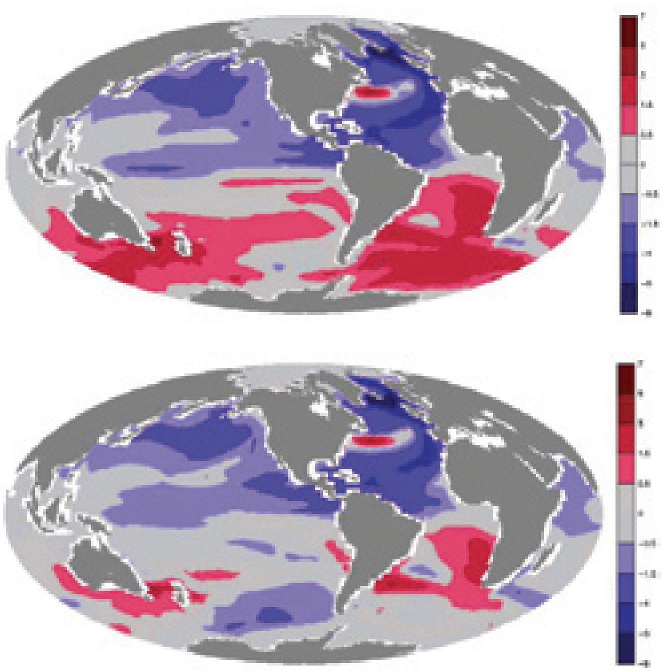


Figure 3. Anomalies of sea surface temperature (°C) in a freshwater experiment using the NCAR CCSM3 model. Freshwater is delivered to the northern North Atlantic increasing to 2 Sv over 100 years and then decreasing again, and globally compensated to ensure salt balance (top panel), or not compensated (bottom panel). Shown are the changes with respect to a control simulation.

The model response in the Southern Hemisphere differs markedly in the two cases. In the experiment with global compensation fluxes, the warming is widespread throughout the entire Southern Hemisphere (top panel); in the uncompensated case, the warming is limited to the South Atlantic and regions south of Australia (bottom panel). Although the compensating freshwater fluxes are comparatively small and uniform, they strongly modify the response beyond the Atlantic Ocean. Particularly in the South Pacific, large spatial differences are found. Thus, while the simulations produce robust results for the Northern Hemisphere (Stouffer, *et al. J. Clim.* 2006), the response of the tropics and the Southern Hemisphere is inconclusive and appears to depend on small changes in how these models are forced. We are now focusing on the dynamical processes responsible for the different response.

Towards models for climate-change impact

Paleoclimate models are indispensable tools to understand the full dynamics of the coupled atmosphere–ocean–land–surface-ice system under altered boundary and forcing conditions. They are also useful for better quantifying changes measured in various paleoclimatic archives such as polar and mid-latitude ice cores, marine sediments, tree rings and speleothems. As models are being improved and their capability is being demonstrated in combination with high-resolution paleoclimate records, future research with these models will be aimed at assessing impacts of climate change on regional scale to continental scale. Of particular interest are extreme weather and climate events and how they might respond to the warming.

As a visitor to the IPRC, I experienced the 46-day rain in February and March 2006, which caused widespread damage in the Hawaiian Islands. What are the odds that such an extreme event occurs again in the next five years, and how will those odds be in the year 2020? Although just one particular example, it stands for the type of questions our science will have to answer in the near future.

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Climate Effects of a Regional Nuclear Conflict

The climate effects of the regional nuclear conflict simulated in this study would last much longer and be much larger than those of the June 15, 1991 Mt. Pinatubo eruption, which followed the smaller June 12 eruption pictured here.

***Alan Robock**, Professor in the Department of Environmental Sciences at Rutgers University, New Jersey, visited the IPRC in August 2006. He gave two seminars, "Climatic Response to High-Latitude Volcanic Eruptions" and "Climatic Effects of Regional Nuclear Conflict." The effects of nuclear explosions described in the second seminar have very grave implications for climate and societies, and we asked Professor Robock to contribute this article based on the seminar.*

The first nuclear war, in which the United States dropped two atomic bombs on Hiroshima and Nagasaki, Japan, in 1945, so shocked the world that in spite of the massive build-up of these weapons since then, they have never been used in war again. In the mid-1980s, research conducted jointly by Western and Soviet scientists discovered that if a third of the then existing nuclear arsenal were exploded, a nuclear winter would result. The climatic consequences and indirect effects of the collapse of society would produce famine for billions of people far from the target zones. This realization helped end the arms race between the United States and the Soviet Union, reducing their arsenals by about two-thirds, but each still retains many thousands of deployed nuclear weapons. In the meantime, the number of nuclear weapon states has grown to nine (Table 1), with 40 more countries possessing enough enriched uranium and/or plutonium to quickly assemble nuclear weapons.

In this context, I have been working with **Brian Toon** and **Charles Bardeen** (University of Colorado), **Richard Turco** (UCLA), **Georgiy Stenchikov** (Rutgers University), and **Luke Oman** (Johns Hopkins University) to examine the effects of a regional nuclear war between new nuclear weap-

Country	No. of Weapons
Russia	10,000
United States	10,000
France	350
China	200
Britain	200
Israel	75–200
India	40–50
Pakistan	<50
North Korea	<15

Table 1. Approximate number of nuclear weapons in the arsenals of different countries. (From Table 2.1 from **International Panel on Fissile Materials**, 2006, with original data from Norris and Kristensen, 2006). The totals for the United States and Russia do not include warheads awaiting dismantlement.

ons states. (Turco, Toon, Stenchikov, and I had been deeply involved in nuclear winter research 20 years ago.)

With support from the National Science Foundation, we studied the following scenario: A nuclear war between two countries in which each country is using 50 Hiroshima-size (15 kilotons) weapons to attack the other's most populated urban areas with populations that could exceed 10 million. These 100 bombs represent less than 0.03% of the explosive power of the current nuclear arsenal worldwide. In our 100-weapon scenario, we estimate that five megatons of smoke would result from urban firestorms rising into the upper troposphere due to pyro-convection. Direct fatalities due to fire and smoke would be comparable to those worldwide in World War II. Furthermore, the megacities exposed to atmospheric fallout of long-lived radionuclides would likely have to be abandoned indefinitely, with severe national and international implications. We also anticipate substantial perturbations of global ozone.

To investigate the climate response to this massive smoke injection, we conducted simulations with a state-of-the-art general circulation model, ModelE from the NASA Goddard Institute for Space Studies, which includes a module to calculate the transport and removal of aerosol particles. Our experience with this model shows it simulates realistically the climate response to large volcanic eruptions.

The atmospheric model is coupled to a full ocean general circulation model that allows the surface-ocean to respond quickly and the deeper ocean on yearly time scales. We ran both models at 4°×5° latitude–longitude resolution, the atmospheric model with 23 vertical layers extending to a height of 80 km, and the ocean model with 13 layers.

We conducted a 30-year control run with no smoke aerosols and three 10-year simulations in which we injected five megatons of black carbon on May 15 into a column of grid boxes at 30°N, 70°E, and placed the black carbon in the model-layers that correspond to the upper troposphere (300–150 mb). Compared to the control run, the three ensemble members differed little in their response to the smoke injection, ensuring us that natural, chaotic weather variability is not responsible for the effects we see.

In the model, the black carbon particles in the aerosol layer are heated by absorption of shortwave radiation. This heating induces vertical motions and the aerosols are lofted close to the top of the stratosphere, much higher than is typical of weakly absorbing volcanic sulfate aerosols. As a result, the carbon aerosols have a very long residence time and continue to affect surface climate for more than a decade. The mass e-folding time for the smoke is six years; for typical volcanic eruptions, one year; and for tropospheric aerosols, one week.

The global-average surface shortwave radiation in response to the aerosols decreases by up to 15 W/m^2 (Figure 1). Five years after the initial smoke injection, the global-average perturbation is still at –7 W/m^2. This exceeds the maximum global-average surface cooling of –4 W/m^2 following the 1991 Mt. Pinatubo volcanic eruption, the largest of the 20th century. The cooling is also greater than the global average increase of 1.5 W/m^2 at the surface or 4 W/m^2 at the tropopause for a doubling of atmospheric CO_2.

The smoke cloud lowers surface temperature significantly (Figure 1). (Stratospheric temperatures are also severely perturbed.) A global average surface cooling of –1.25°C persists for years. After a decade, the cooling is still –0.5°C (Figure 1). The temperature changes are largest over land. A map of the temperature change for the Northern Hemisphere summer one year after the smoke injection is shown in Figure 3. Large areas of North America and Eurasia, including

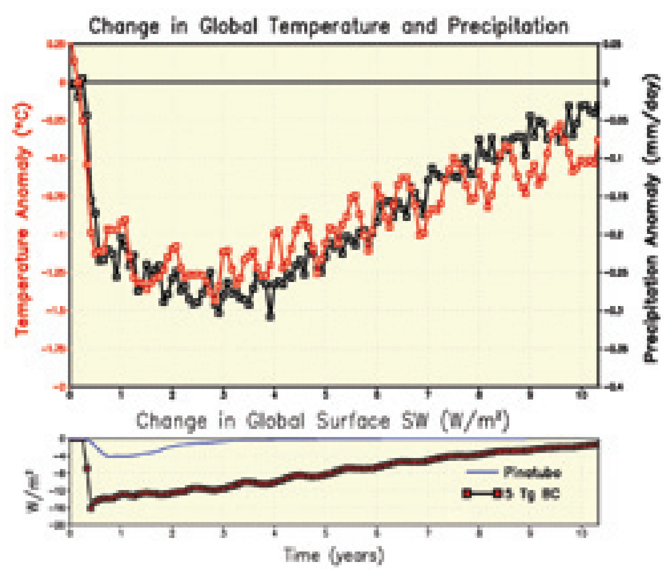

Figure 1. Time variation of global average net surface shortwave radiation, surface air temperature, and precipitation changes for the five megaton standard case. The global average precipitation in the control case is 3.0 mm/day, so the changes in years 2 to 4 represent a 9% global average reduction in precipitation. Precipitation recovers faster than temperature, but both lag the forcing. For comparison, the global average net surface-shortwave forcing from a model simulation of the 1991 Mt. Pinatubo eruption is shown.

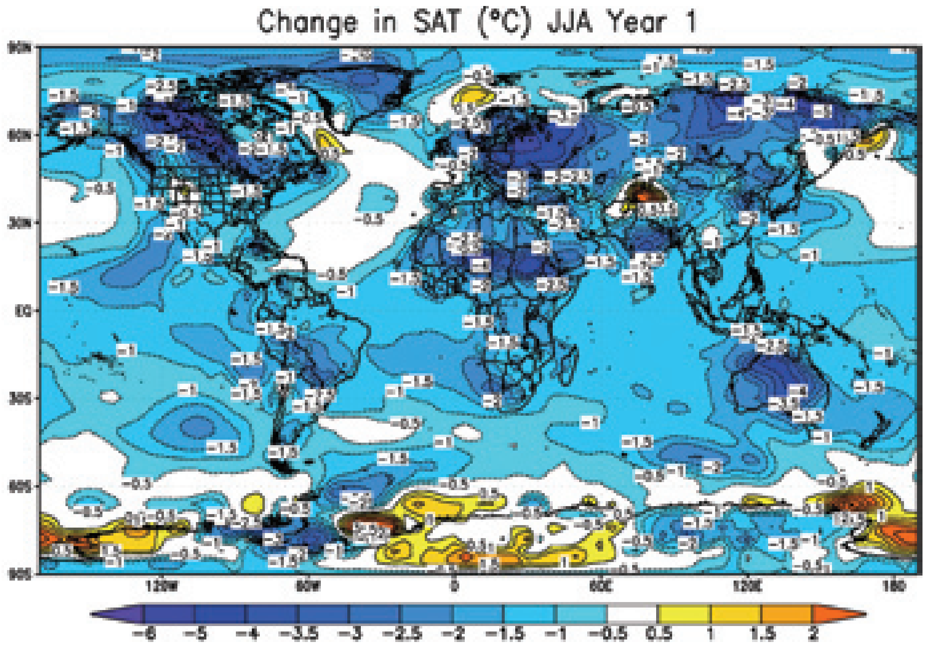

Figure 2. Surface air temperature changes for the five-megaton standard case averaged for June–August of the first year following the smoke injection. Effects are largest over land, but there is substantial cooling over tropical oceans, too. The warming over a small area of Antarctica is part of normal winter interannual variability and is not significant.

most of the grain-growing regions, are several degrees cooler. As in the case with the earlier nuclear winter calculations, large climatic effects are felt in regions far removed from the countries involved in the conflict.

As a result of Earth's surface cooling, evapotranspiration slows and the global hydrological cycle is weakened, with global precipitation reduced by about 10% (Figure 1). Although rainfall decreases mostly in the Intertropical Convergence Zone, as observed after the 1991 Pinatubo eruption, large areas on the continents are also affected, including the Asian summer monsoon.

The temperature, precipitation, and insolation changes would affect agriculture greatly. For example, the growing season in some regions of North America and Europe are shortened by 10 to 20 days. Such a reduction in growing season may completely eliminate crops that have insufficient time to reach maturity. And these reductions continue for several years.

To put the results in a larger historical context, the greatest volcanic eruption of the past 500 years, the 1815 Tambora eruption in Indonesia, resulted in a "Year Without a Summer" in 1816 in the Northern Hemisphere. Killing frosts disrupted agriculture throughout the summer in New England and led to significant emigration. In Europe, the wet cold summer caused a widespread harvest failure, resulting in famines and economic collapse. That climatic disruption only lasted one year. Because the black carbon aerosols in the current nuclear simulation are lofted into the upper stratosphere where their residence time is close to a decade, the climatic effects of the five-megaton case are significantly greater and more persistent than those following the Tambora eruption. Moreover, the cooling in the decade following our five-megaton injection is almost twice as large as the global warming of the past century (about 0.7°C) and would lead to temperatures cooler than the pre-industrial Little Ice Age.

The calculations presented here are the first ever of the effects of black carbon from nuclear conflicts as simulated in a coupled air–sea general circulation model, presumably the most complete and accurate representation of our understanding of the climate system. (Detailed results are found in Toon et al., *Atm. Chem. Phys. Disc.*, 2006, and Robock et al., *Atm. Chem. Phys. Disc.*, 2006.) The results may differ with finer model resolution and models that include smoke other than black carbon rising from burning cities, coagulation of black carbon particles, and photochemical processing in the stratosphere.

In our scenario, the estimated quantities of smoke generated by the detonation of one megaton of nuclear explosives could lead to global climate anomalies exceeding any changes experienced in recorded history. The current global arsenal is about 5,000 megatons!

The results in this paper need to be tested with other climate models, and the detailed consequences on agriculture, water supply, global trade, communications, travel, air pollution, and many more potential human impacts need further study. Each of these potential hazards, however, already now deserves careful analysis by governments, advised by a broad section of the scientific community.

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What's New at the Asia-Pacific Data-Research Center?

The Asia-Pacific Data-Research Center (APDRC) at the IPRC provides the research community and the general public with one-stop shopping for climate data and products. Besides developing server technology and building a climate-relevant database, it has expanded its services to generating data products and assisting other centers with establishing their own data centers. For example, APDRC's procedure for integrating different types of servers is becoming a model for other data centers. Some of the recent outreach activities by the APDRC are described below.

Participation in the Pacific Argo Regional Center

The autonomous Argo floats are a key component of the Ocean Observing System. Almost 3000 floats are now reporting ocean conditions (temperature and salinity) in near-real time. These data are transmitted to two global data assembly centers and nine national centers. The Argo program is setting up procedures to combine, compare, and create products from Argo-float data for specific ocean regions. The APRDC has been active in setting up the Pacific Argo Regional Center (PARC) (see *IPRC Climate*, Vol. 4. No. 2).

This fall has seen several Argo-related meetings. The Fourth PARC meeting was held on October 16 at the Korean Oceanographic Research and Development Institute (KORDI) in Ansan, Republic of Korea. The APDRC, along with JAMSTEC, JMA, KORDI and other oceanographic institutes in the Pacific, used the meeting to determine the needs for Argo data, products, and applications for the Pacific region.

The PARC meeting was followed by the Argo Trajectory Meeting, in Incheon, Korea. Former IPRC postdoctoral fellow **Hiroshi Yoshinari** presented his work on the YoMaHa05 data product (*IPRC Climate*, Vol. 6, No. 1), which he developed with **Nikolai Maximenko** and **Peter Hacker**. The Sixth Argo Data Management meeting, held in Tianjin, China, followed from November 1 to 3. As part of APDRC's continued commitment to the Argo program, **Jim Potemra** represented the APDRC at the three meetings.

SOPAC Partnership

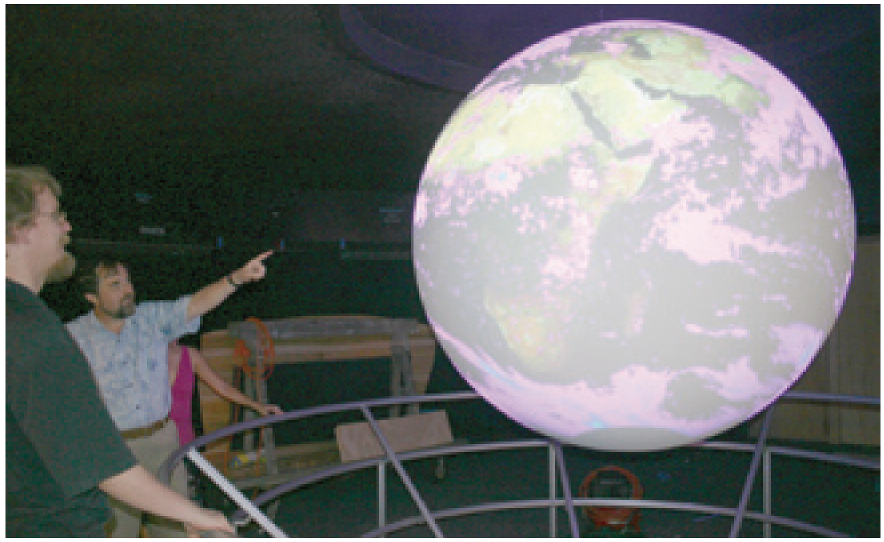
Arriving by propeller plane in Suva, Fuji, where Jim Potemra installed an APDRC server for the Pacific Islands Applied Geoscience Commission (*photo courtesy James T. Potemra*).

As part of its work with NOAA, the APDRC has been providing data to countries in the South Pacific through the Pacific Islands Applied Geoscience Commission (SOPAC). The commission is an inter-governmental, regional organization dedicated to promoting sustainable development in its member countries, which include nearly all the South Pacific Island nations: American Samoa, Australia, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, New Zealand, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu. SOPAC's work is carried out through its Secretariat based in Suva, Fiji.

SOPAC had shown interest in becoming a sister-server with the APDRC, but bandwidth limitations restricted serving many of the larger data sets. The APDRC, therefore, decided to set-up a stand-alone server for SOPAC, essentially a personal computer having all the functions of the APDRC machines but serving only a subset of the available data. To install the server, IPRC Assistant Researcher **Jim Potemra** visited the SOPAC Secretariat in Fiji in September. The APDRC is now working with SOPAC members to determine which data sets and products are most useful to these island nations, and it will then help to keep these data sets up-to-date. This is also an opportunity for the APDRC to obtain feedback about the servers and user interfaces and about the ease of applying the data to practical uses.

SCSIO Partnership

As part of IPRC's new partnership with the South China Sea Institute of Oceanology (SCSIO) in Guangzhuo, China (see p. 26), **Yingshuo Shen** visited the institute in November to help set up data servers on the local SCSIO machines. As an *in situ* data server, Shen installed dapper/dchart (a new server of the Pacific Marine Environmental Laboratory) and trained SCSIO staff on its various functions. This server gives SCSIO a platform by which it can integrate its own datasets into publicly available datasets (such as the World Ocean Database and Argo). Shen also set up an OPeNDAP server for gridded products, which will be used to serve SCSIO model outputs. **Dongxiao Wang**, director of the Laboratory of Tropical Marine Environment Dynamics, a frequent visitor to the IPRC, said of this effort, "Our dream of such a server finally comes true; it will greatly support our ongoing research. One of the goals in the IPRC-SCSIO MOU now has seen great progress."



Axel Timmerman (left) and Kevin Hamilton studying the display of hourly precipitation rates from a high-resolution global model on the Bishop Museum *Science on a Sphere.*

Collaboration with Bishop Museum's *Science on a Sphere*

The Bishop Museum in Honolulu has installed one of a handful of NOAA *Science on a Sphere* exhibits that have been established throughout the United States. When visitors enter the darkened exhibit room, they have the illusion of looking from outer space at beautiful Earth. The illusion is created with a series of projectors displaying global satellite images or computer simulations of earth-system data onto a six-foot diameter sphere (**sos.noaa.gov**). Animated images of atmospheric and oceanic data can be projected on the sphere to show complex environmental processes. *TIME* magazine selected the *Science on a Sphere* system as one of the best inventions of 2006.

The Bishop Museum exhibit opened on November 17, 2006. IPRC's Assistant Researcher **Jim Potemra** has been working with **Leon Geschwind** at the museum to generate animations from APDRC's large holding of global climate data for the sphere-display. For the exhibit opening, Potemra had made animations of global mean surface temperatures, precipitation, and ice-cover from four different model runs for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Team leaders of IPRC Impacts of Global Environmental Research **Axel Timmermann** and **Kevin Hamilton** are working to produce climate and weather "exhibits" for the sphere.

Participation in the Ocean Observing System

A huge international effort is underway to monitor and understand the global climate system. The ocean component of this effort is the Global Ocean Observing System (GOOS) and the U.S. is contributing to this effort through the Integrated Ocean Observing System (IOOS). Both GOOS and

IOOS have regional associations, with PI-GOOS and PacIOOS representing the Pacific region for the international and the U.S. efforts, respectively.

The APDRC participates in PI-GOOS mainly by supporting SOPAC (see above), with **Jim Potemra** serving on the PI-GOOS Steering Committee. In October, Potemra attended in this capacity the latest PI-GOOS Steering Committee Meeting that took place in Honiara on the Solomon Islands. Regarding participation in PacIOOS, the APDRC contributes to the newly formed NOAA Integrated Data and Environmental Applications (IDEA) Center. The PacIOOS effort consists largely of serving integrated climate data for the Pacific region, and the APDRC is at the forefront of this activity.

APDRC Demonstrates New Uses of Unidata Technology

Unidata at UCAR is a key developer of data-archiving and data-serving technologies. Unidata, for example, developed the widely used netcdf format. The APDRC relies on Unidata's THREDDS server to aggregate data housed at remote locations. In other words, the data physically reside at other sites, for example at the Jet Propulsion Laboratory, but they are aggregated and served by the APDRC through THREDDS. This new technology gives users a more friendly, logical, and complete pathway to such aggregated data than before.

This use of THREDDS servers is still rare, and **Jim Potemra** was invited to attend the recent annual Unidata meeting to demonstrate how the APDRC uses Unidata products. The meeting was held in September and hosted by the IPRC. The Unidata newsletter featured APDRC's novel use of this Unidata product (**www.unidata.ucar.edu/newsletter/2006oct/index.html**).

A concern for users when data are archived in different locations is access speed because two servers are needed. To give users an indication of the access time, **Sherwin Gao** worked with **Yingshuo Shen** this summer to develop an automated method for determining remote access rates. These rates are now displayed for all data that the APDRC servers access on other (non-APDRC) servers.

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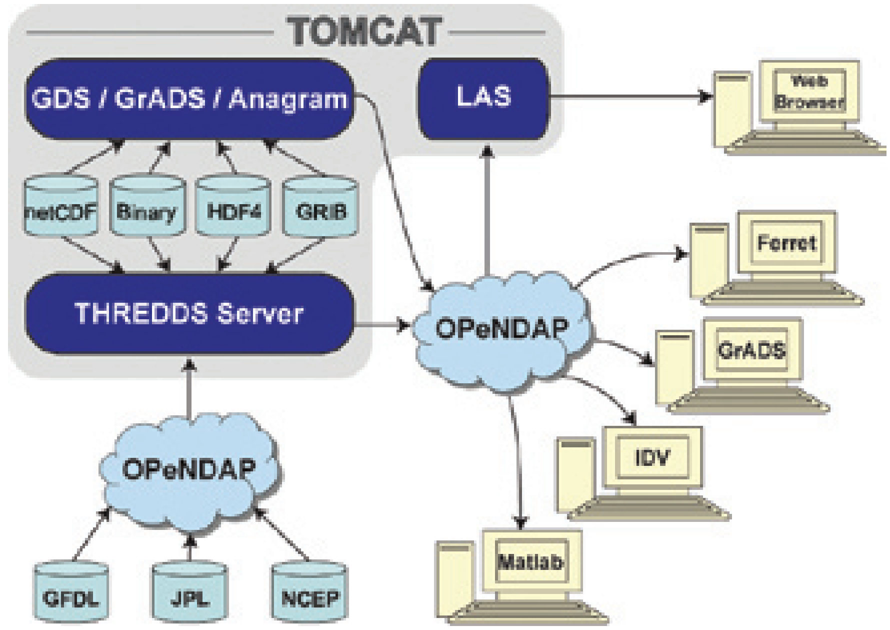


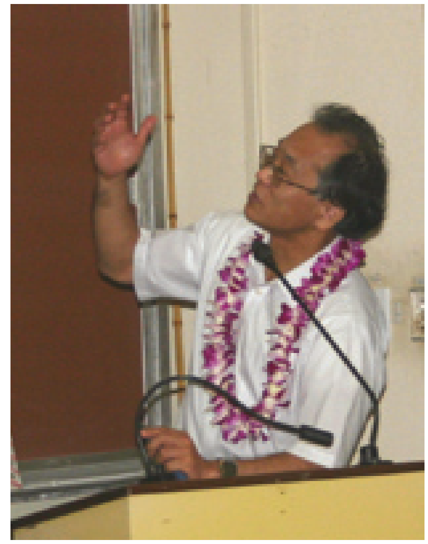
Illustration of THREDDS Server function: for example, NCEP runs a numerical model of the atmosphere every day, and places the output files on its OPeNDAP server. These files typically have the date as part of the file name, and the files might exist in separate directories for different years, or model runs. If a researcher wanted to make a timeseries of the model results, he would typically have to load each file for each day of interest. Using THREDDS, the APDRC can merge these files in a virtual sense, and the user then needs to only processes a single file to get a timeseries. The APDRC can also use THREDDS to present the data in a more meaningful way, for example through our data search tool, or pass it directly to the LAS server for web-based plotting.

Informal Workshop on Climate Feedbacks

IPRC scientists took the opportunity of the visit of Professor **Teruyuki Nakajima**, Director of the University of Tokyo Center for Climate System Research, to hold an informal workshop that dealt with research efforts in climate modeling on the accurate determination of climate system feedbacks to large-scale radiative forcings.

In his opening remarks, IPRC's **Kevin Hamilton** noted that the most important question related to anthropogenic impact on climate remains unanswered: scientists still do not know how much global surface temperature will rise in response to a given perturbation (such as doubling atmospheric carbon dioxide concentration). Current state-of-the-art climate models differ by more than a factor of two in their global-mean response to specified perturbations.

Hamilton then reviewed his research with **Markus Stowasser** (IPRC) and **George Boer** (Canadian Centre for Climate Modelling and Analysis, CCCMA) using the concepts of local and global climate feedbacks to diagnose the responses of the NCAR Community Climate Model and the CCCMA model to climate perturbations in order to understand the very different global climate sensitivities of these two models. Hamilton also talked of the role of feedbacks in determining the response of the models to transient forcing perturbations, similar to those occurring in the real world after large volcanic eruptions.



Teruyuki Nakajima during his Aug. 9, 2006, IPRC seminar, "A study of the effects of air pollution on the earth's climate using climate modeling and satellite remote sensing."

Axel Timmermann discussed the climate feedbacks during the last glacial termination in Antarctica (see p. 3 for details) and reviewed his research on what may happen to eastern Pacific climate and El Niño when the Atlantic Meridional Overturning Circulation (AMOC) collapses as a result of fresh water infusion into the North Atlantic. The collapse appears to have two quite different consequences: In the ocean, an oceanic wave is generated that moves southward along the Atlantic coast, across the equator, southward along the South African coast and into the Indian, and then the Pacific Ocean. This deepens the Pacific Ocean thermocline and essentially collapses El Niño variability (*IPRC Climate,* Vol. 5, No. 2). In the atmosphere, the cooler SST in the Caribbean generates stronger trade winds, setting up a wind-evaporation-cooling feedback loop in the eastern Pacific. This raises the thermocline and increases El Niño variability, overriding effects of the oceanic wave.

Sixth IPRC Annual Symposium

Sixth IPRC Symposium.

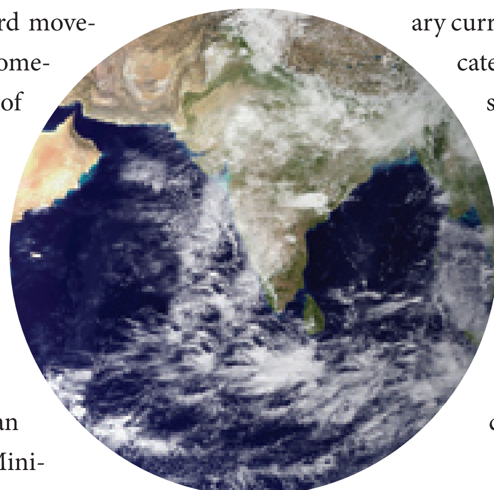
The Sixth Annual IPRC Symposium was held May 8 and 9, 2006, at the East-West Center in Honolulu. At this yearly event, IPRC scientists present the highlights of their research over the year. **Yuqing Wang**, associate professor of meteorology and IPRC scientist, organized and chaired the symposium.

This annual sharing is a time to pause and reflect upon the progress that has been made in understanding climate phenomena, particularly those affecting the Asia-Pacific region. It is an occasion to solicit comments and suggestions from peers and to detect common research threads. The agenda is found at **iprc.soest.hawaii.edu/meetings/workshops/06-05_6th_iprc_annual_symposium.htm**.

Focus: The Tropical Indian Ocean

"The North Indian Ocean is a very special ocean. It is not connected to the poles, it is tropical, and it has very strong seasonal forcing, with a total reversal of winds and dramatic ocean current reversal. The time-dependence of flows from a week to months makes their monitoring a challenge." With these words IPRC distinguished guest **Satish Shetye**, director of the National Institute of Oceanography in Goa, India, and expert on the physical oceanography of the Indian Ocean, introduced this past September his talk, *Local and Remote Wind-forcing of the West India Coastal Current*.

Shetye spoke about short-term variations seen in the currents along the Indian coastline. Recent observations of the West India Coastal Current off the coast of Goa, for example, show northward and southward movements with periods of a few days and somewhat longer periods. Using an analysis of observed currents, local winds, and sea-level fluctuations in two nearby estuaries, Shetye concluded that over shorter time periods (less than about 10 days) this coastal current is driven by local winds, and over longer time periods, mainly by remote winds.



Shetye's talk on the complex Indian Ocean currents set the stage for the "Mini-Workshop on Indian Ocean Research at IPRC." The workshop covered strategies for obtaining more accurate estimates of salinity, the challenge of modeling water exchange between the Arabian Sea and the Bay of Bengal, finding the source waters of the Leeuwin Current, and the impact of Indian Ocean sea surface temperature (SST) anomalies on the large-scale atmospheric circulation and climate.

The sharp contrast between the salty Arabian Sea, with its high evaporation rate, and the rather fresh Bay of Bengal, with its many river runoffs, is thought to impact climate. Direct rainfall measurements over the open ocean hardly exist and satellite-derived precipitation products have broad error ranges. IPRC researcher **Zuojun Yu** described the technique she and IPRC Director **Jay McCreary** developed to evaluate precipitation products used in climate studies. **Max Yaremchuk** showed how assimilation of sea surface salinity into a model can improve estimates of river discharge and rainfall over the Bay of Bengal.

The current reversal between the Arabian Sea and the Bay of Bengal due to the seasonal monsoon changes has been difficult to model. **Tommy Jensen** at IPRC has been using tracers and floats to study this reversal in a 4½-layer model: Arabian Sea water reaches the Bay of Bengal by flowing around Sri Lanka, but Bay of Bengal water tends to stay in the bay; no floats move around Sri Lanka and then north along the western coast of India as observed. Why is this? Perhaps the model does not capture the ocean's response to the monsoon well enough for the wind-driven circulation to act on the flow?

Another puzzle tackled in the workshop was the source of the water in the Leeuwin Current off the west Australian coast. This remarkable current flows into the face of winds and is the only permanent poleward flowing eastern boundary current. **Jim Potemra** described the complicated current system in the equatorial and southern Indian Ocean from which the Leeuwin Current might draw its water: the Indonesian Throughflow, the tropical Indian Ocean water in the Eastern Gyral Current, or a spin-off from the South Equatorial Current. Altimeter data suggest that during part of the year the supply may even come from Madagascar.

H. Annamalai reviewed his numerical modeling research on the unusually high SST in the Southwest Indian Ocean during an El Niño and its persistence into the following summer. Teasing apart the effects of unusual SST patterns in the tropical Pacific and Indian Ocean, he showed that the unusually high SST in the Indian Ocean shifts the model's Walker Circulation westward over the Indian Ocean. This causes subsidence and decreased rainfall in the tropical western Pacific. In the model, the anomalously warm SST in the southwestern Indian Ocean contributes to the Philippine anticyclone during and after an El Niño and to late onset of the monsoon rains over India; it may even alter atmospheric disturbances over Pacific North America triggered by El Niño.

Parts of Asia regularly experience anomalous weather during the summer after an El Niño. This is puzzling because the SST anomalies in the equatorial Pacific have disappeared. **Shang-Ping Xie** and his collaborators at the Ocean University of China show that this lingering influence of El Niño

Satish Shetye (left) with IPRC Director Jay McCreary.

is a manifestation of Indian Ocean warming that is due to the unusual El Niño conditions and persists through the next summer. Xie views the Indian Ocean as a “capacitor”. Once charged by El Niño, it feeds the anomalous summer circulation and precipitation patterns in the tropical Indo–western Pacific Ocean and East Asia.

In a final session, Shetye, presented an analysis of recently available high-resolution precipitation and SST products that points to the development of a north–south SST gradient in the Bay of Bengal just before a low-pressure system forms. When SST is 0.75°C or higher in the northern than the southern bay, the chance of rainfall and a low-pressure system developing in the northern part of the bay within one week is 78% during May–September. Shetye felt that here was a challenging problem for IPRC climate modelers: “Can this sequence of events be modeled to understand the processes that link these events?”

Meteorology at the University of Hawai‘i Celebrates Its 50th Anniversary

The Meteorology Department chairs (from left): Gary Barnes (1996–1999), Kevin Hamilton (2004–present), Colin Ramage (1956–1988), Thomas Schroeder (1988–1989, 1993–1996, 1999–2004, and Duane Stevens (1989–1993).

On August 19, 1956, the U.S. Air Force signed a contract with the University of Hawai‘i to study “the formation, intensification and movement of typhoons” in the Pacific. **Colin Ramage** was then recruited from the Royal Observatory in Hong Kong to lead this effort, and meteorology as a discipline began at the University of Hawai‘i (UH). Four years later, the Department of Meteorology and Oceanography was created.

To celebrate the 50th anniversary of meteorology at UH, the Meteorology Department hosted the symposium “Tropical Meteorology and Climatology in the 20th and 21st Centuries — The View from Hawai‘i” on September 11, 2006, at the East-West Center. The symposium attracted well over a hundred participants, including current and retired faculty, current and alumni undergraduate and graduate students, colleagues in other UH departments, and professional meteorologists with the National Weather Service in Hawaii. The celebration was an important day for IPRC scientists, five of whom are part of the Meteorology Department faculty.

Kevin Hamilton, Meteorology Department chair and an IPRC research team leader, organized and chaired the symposium. He opened the symposium with a speech that emphasized the key role for meteorological research in global warming and climate change. UH Manoa Interim Chancellor **Denise Konan**, School of Ocean and Earth Science and Technology Dean **Brian Taylor**, and Chief of the National Weather Service Honolulu Forecast Office **James Weyman** gave speeches, congratulating the department on this memorable occasion. Professor of Meteorology **Tom Schroeder** recounted the history of meteorology at the University of Hawai‘i.

The symposium was particularly fortunate that Professor Ramage returned to Hawai‘i for the celebration and spoke on “Hot Towers and Tropical Cyclones” and “Remembering Research.” **Richard Johnson** of Colorado State University, in his keynote address, “Fifty Years of Progress in Meteorology: A Personal View," gave a perspective on the field of tropical meteorology over the last 50 years with a focus on contributions by meteorologists at UH. The talks on present and future key research areas in the Meteorology Department were given by current faculty **Steven Businger**, **Gary Barnes**, **Kevin Hamilton**, and **Tim Li**.

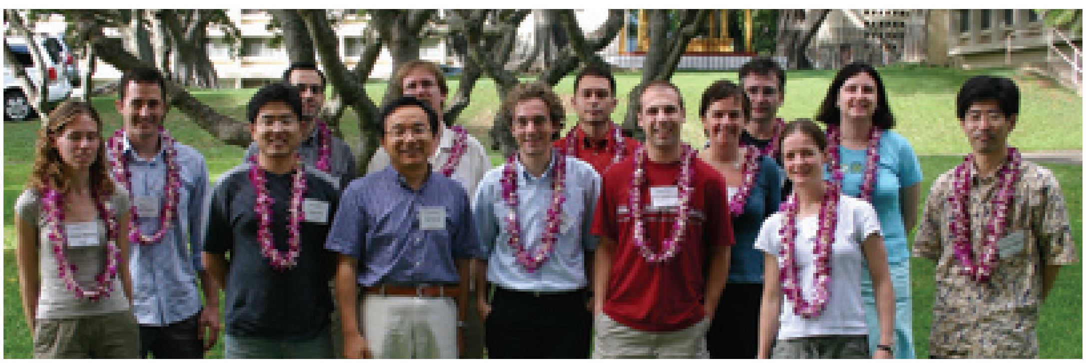
A collection of documents including texts and figures from many of the talks, photos from the meeting, and a detailed narrative history of meteorology at UH are available at **iprc.soest.hawaii.edu/~kph/50th**.

Report on Weather and Climate Extremes in a Changing Climate

The US Climate Change Science Program (CCSP) provides the overall management direction for integrated U.S. government-supported research on climate and global change. The CCSP Strategic Plan calls for more than 20 synthesis and assessment reports over the next several years.

The IPRC hosted from October 30 to November 2 the workshop for drafting the assessment report that deals with the climate extremes. The information will be based partly on findings from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change and will include chapters on the following topics: why weather and climate extremes matter, observed changes in weather and climate extremes, attributing causes to changes in extremes, forecasts of future weather and climate extremes, and recommendations for improving the forecasts.

Grappling with Global Climate Variability



Young scientists with the workshop organizers at the Multidecadal to Centennial Global Climate Variability Workshop.

To make predictions about future climate change, scientists must determine mankind's impact on climate superimposed on the natural swings of climate in the past. This is not an easy thing to do because instrumental records are at the most 100 years old. To grapple with this issue, the IPRC co-sponsored with US-CLIVAR and the World Climate Research Program of the World Meteorological Organization the workshop Multidecadal to Centennial Global Climate Variability from 15 to 17 November at the East-West Center.

Axel Timmermann (IPRC) **Henk Dijkstra** (IMAU, Utrecht, the Netherlands), and **Fei-Fei Jin** (University of Hawai'i) organized the workshop.

At the workshop, over 50 scientists from 10 different countries exchanged ideas and presented new results on physical mechanisms that underlie the natural climate variability over periods of decades to centuries and that establish pan-oceanic climate connections. Scientists can extend the climate record backward in time through reconstructions of temperature and moisture in such environmental records as sediments, ice cores, and tree rings. Using such proxy data in their research, the presenters could identify a long-term climate variability in the North Atlantic called the Atlantic Multidecadal Oscillation (AMO) that acts as a pacemaker for global climate, the El Niño–Southern Oscillation, the Asian summer monsoon, and possibly even for variations in Caribbean hurricane activity, and Sahel droughts.

The workshop had another mission: to provide a platform for 10 young scientists—graduate students and postdoctoral fellows from around the world—to present their latest work on global multidecadal variability issues and to discuss their findings with established experts in the field.

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JAMSTEC Executive Director Visits IPRC

Meeting between JAMSTEC Executive Director and IPRC scientists: (seated from left) Yukihisa Washio, Kiyoshi Suyehiro, Brian Taylor, Axel Timmermann, Shang-Ping Xie, Kevin Hamilton, Jay McCreary, Niklas Schneider, Kelvin Richards, Peter Hacker (standing).

To strengthen IPRC–JAMSTEC (Japan Agency for Marine-Earth Science and Technology) partnership in climate research, JAMSTEC Executive Director **Kiyoshi Suyehiro** and Manager of the International Affairs Division, Planning Department, **Yukihisa Washio** visited the IPRC and the University of Hawai'i on October 10 and 11, 2006. They met with Vice President for Research **James Gaines**, Vice Chancellor for Research and Graduate Education **Gary Ostrander**, Dean of SOEST **Brian Taylor**, and IPRC Director **Jay McCreary**. The visitors also attended overviews of IPRC research activities and met with team leaders of IPRC's five research areas.

IPRC Expands Research Partnerships

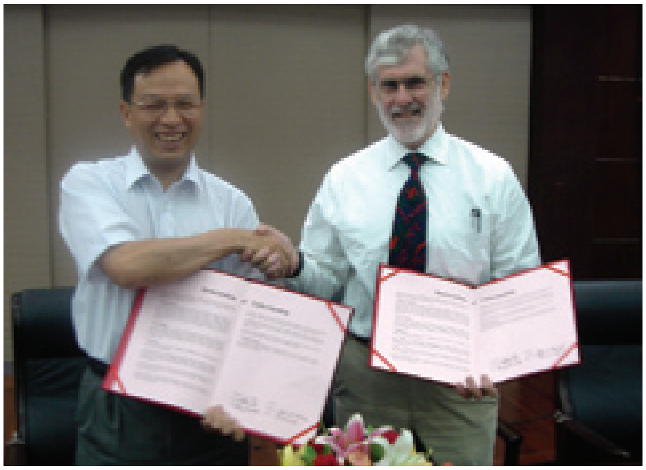
IPRC Director **Jay McCreary** and South China Sea Institute of Oceanology (SCSIO) Director **Ping Shi** signed a memorandum of understanding on July 18, 2006, in Guangzhou, China. Under the agreement, a Joint Laboratory for South China Sea Research will be set up to promote research by the two institutions on the ocean circulation and climate of the South China Sea and the Indo-Pacific warm-pool region.

The South China Sea is not only a very important economic region, but it also has strong impact on regional climate, affecting close to one billion people; scientific evidence suggests it may even impact the large-scale Pacific climate. Topics for research under this partnership include the impact of South China Sea surface temperatures on tropical cyclone tracks and on locally generated tropical cyclones: measurement and description of the South China Sea Throughflow; the development of a regional East Asia climate model based on the IPRC model iROAM, and establishment at the SCSIO a data-center that mirrors IPRC's Asia-Pacific Data-Research Center and serves climate data to both scientists and the general public.

Following the signing of the memorandum, Inspector **Anshuo Gen** of the Chinese Academy of Sciences gave his congratulations, and Jay McCreary and **Dongxiao Wang**, Director of the Chinese Academy of Sciences Laboratory for Tropical Marine Environmental Dynamics, gave presentations on ongoing research activities at their two institutions.

The IPRC and SCSIO already have a history of successful partnership leading to joint publications in well-known climate journals. The development of the memorandum for more systematic joint research began when Director Ping Shi visited IPRC in February 2006. The China News Agency published a report on the signing ceremony.

The IPRC also signed in December a memorandum of understanding with the Institute of Tropical and Marine Meteorology (ITMM) of the China Meteorology Administration. Under the agreement, a Cooperative Tropical Climate Research Laboratory (CTCRL) will be set up that has as its research focus the tropical atmospheric and oceanic circulations and the climate of the Indo-Pacific warm-pool region. The research partnership will include the following activities: assessing the impact of ocean–atmosphere interactions on the intraseasonal and interannual variability of the East Asian monsoon, developing an effective approach for seasonal climate prediction, determining changes in tropical cyclone tracks and intensity, and studying the impact of global warming on regional climate and weather. The agreement will



SCSIO Director Ping Shi (left) and IPRC Director Julian McCreary (right) celebrate signing of the Memorandum of Understanding between the SCSIO and the IPRC (*photo courtesy of Dongxiao Wang*).

cover observational data collection and application of climate models to diagnose the underlying climate processes. Each institution already has secured two three-year research grants from the Chinese National Science Foundation to jointly study the subseasonal and year-to-year fluctuations of the East Asian monsoon.

In addition to the above partnerships, the IPRC has signed in November an agreement with the College of Earth Sciences at the National Central University in Taiwan to cooperate on research related to regional climate and the water cycle.

IPRC–Earth Simulator Collaboration Attracts Attention

Publication of work by the JAMSTEC – IPRC – Hokkaido University collaboration on high-resolution atmospheric modeling attracted favorable attention in the scientific community. As described in *IPRC Climate* Vol 3, No 2, **Kevin Hamilton**, IPRC Team Leader for Research on Impacts of Global Environmental Change, **Wataru Ohfuchi**, Leader of the Atmosphere and Ocean Simulation Research Group at the JAMSTEC Earth Simulator Center, and **Yoshiyuki Takahashi**, now at Hokkaido University, have been analyzing output from very fine-resolution global atmospheric models run on the Earth Simulator.

The American Geophysical Union featured as a Journal Highlight the first publication by the group, "Explicit Global Simulation of the Mesoscale Spectrum of Atmospheric Motions," which appeared in the June 2006 *Geophys. Res. Lett.* issue (**www.agu.org/sci_soc/prrl/jh060724.html#1**).

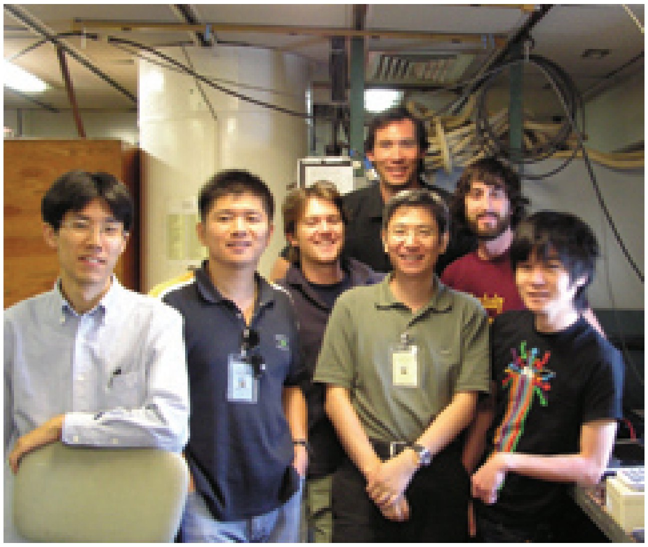
Kevin Hamilton downloads AFES data onto a portable hard disk at the JAMSTEC Earth Simulator Center for transportation back to Hawaii.

This publicity led to an interview with Hamilton and a news story on high-resolution atmospheric modeling in *Science* ("Sharpening Up Models for a Better View of the Atmosphere" by R. Kerr, in the August 25, 2006, issue). The article emphasized the crucial role of the JAMSTEC Earth Simulator in sparking a surge in climate research.

IPRC and Japanese Scientists Conduct Atmospheric Soundings in the Northwest Pacific

IPRC team leader of Indo-Pacific Climate Research **Shang-Ping Xie** organized an atmospheric sounding survey in the Kuroshio Extension (KE) region east of Japan with **Youichi Tanimoto** of Hokkaido University and other scientists in Japan. For this survey, IPRC postdoctoral fellow **Takeaki Sampe**, **Jian Ma** (UH Meteorology Department), **Karl Stein** (UH Oceanography Department), and **Kohei Kai** (Hokkaido University) were aboard the National Science Foundation Research Vessel *Melville* from June 1 to July 5, 2006. They launched 140 GPS sondes to measure temperature, humidity, pressure, and wind velocity from the sea surface to a height of 24 km. Continuous observations of surface meteorological variables and observations with a lidar ceilometer, an instrument for detecting the presence of clouds overhead and measuring the height of their bases, were also made from the ship during this period.

The research cruise was part of the Kuroshio Extension System Study (KESS) field experiment funded by the U.S. National Science Foundation. Xie, Tanimoto, and their col-



Aboard the RV *Melville* (front, from left) Takeaki Sampe, Tony Ma, Shang-Ping Xie, Kohei Kai; (middle) Karl Stein, Jason, (back) Timothy Lim.

leagues have already conducted three such cruise surveys in the region in which otherwise few atmospheric soundings are being made. The data are now being studied to determine how the ocean affects the atmospheric boundary layer, the clouds, and the Meiyu–Baiu front, the northeastward tilted rain band that stretches from eastern China through Japan to the Northwest Pacific.

IPRC Scientists in the Media and Public

IPRC Director **Julian McCreary** and IPRC Research Team Leader **Kevin Hamilton** took part in the Hawai'i Public Radio show "Beyond the Reef" with host **Alvin Adams** on October 17, 2006. They were joined by **Andy Nash**, director of operations at the National Weather Service Honolulu Forecast Office, and **Gerard Fryer**, seismologist at the NOAA Pacific Tsunami Warning Center. The topic of the show was Mother Nature: Climate Change, Hurricanes, and Earthquakes. McCreary and Hamilton were interviewed about climate change. A podcast of the interview is available at **iprc.soest.hawaii.edu/news/news.html**.

Following the FRCGC's successful prediction of the 2006 Indian Ocean dipole, **Shang-Ping Xie** and **H. Annamalai** sent out a news release predicting that the unusual cool sea surface temperatures off the Sumatra Coast in the Indian Ocean could affect the ongoing El Niño this fall and winter. Their release resulted in a flurry of interviews by various media sources. Links to the news release and to some of the news coverage are found at **iprc.soest.hawaii.edu/news/news.html**.

At the Hawaii Public Radio Show "Mother Nature: Climate Change, Hurricanes, and Earthquakes," (from left) Julian McCreary, Kevin Hamilton, host Alvin Adams, Andy Nash, and Gerard Freyer.

IPRC research team leaders **Kevin Hamilton**, **Shang-Ping Xie**, and **Axel Timmermann** participated in discussion panels following showings of the climate-change movie, "An Inconvenient Truth." The movie, which was shown several times by the University of Hawai'i Sustainability Group, was open to the public and attracted several hundred viewers.

IPRC Scientists Active in the Climate Research Community

IPRC Director **Julian McCreary** was appointed in Spring 2006 to serve on the Earth Science Subcommittee of the NASA Advisory Council (NAC). The subcommittee provides recommendations and advice to NASA on Earth science through the NAC Science Committee. NASA Earth Science deals with the scientific exploration of the Earth system, particularly with issues critical to the future of humankind. This includes understanding variability and change of the Earth system, which requires maintaining long-term continuity of highly accurate measurements.

Yuqing Wang, IPRC Scientist and Associate Professor of Meteorology, has accepted the invitation to serve as an Associate Editor of *Weather and Forecasting* for the term beginning in January 2007. This journal of the American Meteorological Society publishes research on techniques for weather forecasting and analysis, forecast verification studies, and case studies useful to forecasters. Included in the journal

Shang-Ping Xie answering questions after the showing of "An Inconvenient Truth."

are studies that show the transfer of research results to the forecast community, or illustrate the societal use and value of forecasts.

Bin Wang, co-leader of Asian-Australian Monsoon System Research at the IPRC and professor of Meteorology, co-chaired the workshop on "Decadal-Centennial Variability of the East Asian Monsoon" from July 7 to 9, 2006, and co-charied the organizing committee for the meeting Winter MONEX: A Quarter Century and Beyond, April 4 to 7, 2006, Kuala Lumpur.

Jim Potemra, assistant researcher at the IPRC, chaired the Fourth Meeting of the Pacific Argo Regional Center (PARC), which was hosted by the Korean Oceanographic and Research Development Institute (KORDI) in Ansan, Republic of Korea, on October 26, 2006.

Shang-Ping Xie, co-leader of Indo-Pacific Climate research at the IPRC and professor of Meteorology, has been elected to the Council of the Oceanographic Society of Japan (OSJ) for a two-year term beginning in 2007. The OSJ has about 2700 members, organizes two scientific conferences each year, and publishes two journals: *Oceanography in Japan* (*Umi-no-Kenkyu*) in Japanese, which contains original papers, contributions, and communication articles for the members; and *Journal of Oceanography* in English, which is devoted to the publication of original articles, short contributions, reviews, and correspondence in oceanography and related fields.

Axel Timmermann, co-leader of Impacts of Global Change Research at the IPRC and associate professor of Oceanography, co-chaired the workshop on Multidecadal to Centennial Global Climate Variability, held November 15 to 17, 2006, in Honolulu.

Becoming a Climate Researcher at the IPRC

Four years ago, the *IPRC Climate* featured **Bunmei Taguchi** in "The Makings of a Climate Researcher." Taguchi had joined the IPRC under a contract from a Japanese company to study the Kuroshio with **Humio Mitsudera**. When Taguchi's company wanted him to return to Japan, Taguchi decided to forgo the security of a good job and to follow his research interests. He enrolled in the UH Meteorology graduate program with IPRC's **Shang-Ping Xie** as his dissertation advisor. The IPRC gave financial support.

This spring Taguchi completed his dissertation, which dealt, not surprisingly, with the Kuroshio Extension (see p. 6 this issue). Upon submitting to the *Journal of Climate* the manuscript based on this research, Taguchi received this note from Chief Editor **Andrew Weaver**: "I wanted to personally congratulate you on this fine manuscript and thank you for submitting it to the *Journal of Climate*. You will see that you received four sets of reviewer comments. In my years as an editor, I have rarely (if ever) seen four sets of reviewers comments unanimously describe a manuscript as excellent with such minor suggested revisions."

Bunmei Taguchi (right) and his dissertation adviser Shang-Ping Xie at Taguchi's graduation in 2006.

Before even the graduation festivities, Taguchi had secured a position as a scientist at the JAMSTEC Earth Simulator Center and returned to Japan. Now at the Earth Simulator Center, he is working on the ocean component of the Coupled GCM for the Earth Simulator (CFES), and continuing research with OFES.

Congratulations, Bunmei!!

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Shinichiro Kida

Shinichiro Kida joined the IPRC as a postdoctoral fellow in September 2006 after receiving his PhD from the Massachusetts Institute of Technology/Woods Hole Oceanographic Institution Joint Program in Oceanography/Applied Ocean Science and Engineering.

A friend at the University of Tokyo had introduced Kida to the field of oceanography. He recalls, "I was fascinated by the beautiful pictures from satellites and numerical models. Turns out, learning the underlying physics that result in these beautiful pictures is even more exciting. Ever since then, I have been trying to learn and understand how the complex ocean and climate system works."

Kida's dissertation deals with the interaction between the Mediterranean Overflow and the upper ocean. Marginal sea overflows are an important source of dense water in the deep open ocean. But as overflows descend the continental slope, they take along a substantial amount of upper-ocean water. The upper ocean balances this loss of mass and the associated vortex stretching by establishing a horizontal circulation along the continental slope. Known as a *beta-plume,* this circulation transports more water than required to balance the mass loss, and its strength is largely controlled by the background topography. The study showed that along a steep slope, such as Cape St. Vincent for the Mediterranean Overflow, the beta-plume can escape from the continental slope and form a basin-scale circulation. This may be the mechanism that forms the Azores Current, a current whose origin is intriguing oceanographers.

At the IPRC, Kida is working with team leader for Regional Ocean Influences Research **Kelvin Richards** on the interaction among the Indonesian Throughflow, the surrounding marginal seas, the Pacific and Indian oceans and the atmosphere.


Elodie Martinez

Elodie Martinez joined the IPRC as a postdoctoral fellow in summer 2006. She recalls, "I have always been fascinated by the ocean. So I studied physical oceanography at the Université de la Mediterranée in Marseille and ocean engineering at the Ecole Supérieure d'Ingénieurs de Marseille. As part of my training, I spent half a year at the University of French Polynesia." Martinez returned to Marseille in 2002 to receive her master's degree in both physical oceanography and in engineering.

"For a short while, I worked for an oil company, designing risers for pumping oil from the bottom of the ocean to the surface. This work was not for me, though, and I returned to physical oceanography and to the University of French Polynesia, from where I obtained my PhD in April 2006."

For her dissertation, Martinez used satellite wind and sea surface anomaly data to determine the surface currents in the South Pacific Ocean basin and then used these results to study the floating debris drift in the Economic Exclusive Zone of French Polynesia. With this approach, she could show the extent to which invasive brown algae had dispersed among the French Polynesian archipelagoes and how the input of nutrients around islands increased the phytoplankton in Marquesan waters. Using a regional ocean circulation model, she extended her work to below the ocean surface and studied the seasonal and annual temperature and current variability of the region's thermocline.

Martinez is now working with **Kelvin Richards**, IPRC team leader for Regional Ocean Influences Research. They are examining the impact of mixing and stirring on the interactions among populations in the "twilight zone," the ocean depth that still receives a little a bit of sunlight, but not enough for photosynthesis to take place.


Ingo Richter

Ingo Richter joined the IPRC as a postdoctoral fellow this past September. His path to climate science was rather indirect, starting with linguistics classes at university. He soon switched to study fluid dynamics and physics at the University of Göttingen. During his studies there, he worked at the Institute for Bioclimatology, an interdisciplinary research center devoted to the study of ecosystems from physical, biological, and chemical perspectives. His research there included measuring turbulent fluxes of CO_2 and water vapor in a nearby forest.
"My work," he recalls, "required climbing up and down a 52-m-high tower to collect data and maintain the equipment.

In winter it could get pretty uncomfortable on the top platform with the ice-cold wind blowing in your face."

"While at Göttingen, I got to know Americans on exchange programs from University of California campuses. After finishing my Diplom, I took advantage of this exchange program and went to UCLA because it is famous for general circulation modeling. Although I had planned just a one-year exchange, I stayed, working in the GCM group led by Professor Mechoso."

For his dissertation, Richter focused on subtropical stratocumulus clouds and the large-scale factors controlling them. The work involved AGCM experiments with idealized SST distributions and no-mountain experiments. After receiving his PhD in 2005, he stayed on as a postdoctoral fellow.

At the IPRC Richter is working with **Shang-Ping Xie**, team leader for Indo-Pacific Ocean Climate Research. Using the IPRC Ocean–Atmosphere Coupled Model, iROAM, they are studying the ITCZ-cold tongue complex in the eastern tropical Atlantic in order to understand better the processes responsible for region's climate. The goal is to get information that can be applied to reduce model biases and improve prediction.


Takeaki Sampe

Takeaki Sampe joined the IPRC as a postdoctoral fellow this past summer after obtaining his PhD from the Department of Earth and Planetary Science, University of Tokyo.

"I became interested in weather forecasting when I was 10 or 11 years old," Sampe recalls. "It was exciting that the weather chart I drew from the weather report on radio gave me a prediction of the future. I wanted to become a weather forecaster. Unfortunately, before I entered university, numerical models on high-speed computers came to do a much better job in forecasting than human insight and experience. But the dynamics of the atmosphere are so complex and many things are not yet elucidated that I find research in climate dynamics fascinating."

Sampe's research for his master's degree at the University of Tokyo focused on the dynamics and variations of storm tracks. In contrast to the North Atlantic, storm activity over the northwestern Pacific tends to be weaker in midwinter than in late fall and early spring. His research with Professor **Hisashi Nakamura** showed that during the northwestern Pacific midwinter, the upper-level core of the storm track tends to shift southward and upward, away from the oceanic front. This results in more uniform air temperatures over the ocean in the storm-track region and in weaker storms.

For his dissertation, Sampe studied the impact of oceanic fronts on storm tracks and on the general circulation of the atmosphere. In simulations from AFES (Atmospheric GCM for Earth Simulator), he determined that oceanic fronts enhance and anchor storm tracks. The storms help to maintain midlatitude westerly surface winds, which in turn drive oceanic currents. In other words, storms and storm tracks are a matter of atmosphere-ocean interaction, and oceanic fronts significantly affect the atmospheric variability at mid- to high-latitudes.

Working with **Shang-Ping Xie** at the IPRC, Sampe is examining storm-track data in satellite observations of surface winds affected by sea surface temperature (SST). Storm tracks in these surface wind fields differ from traditional ones: wind intensity correlates remarkably well with SST around the fronts. The initial research will study the dynamics of Meiyu–Baiu front. This front is important for southern China and Japan because it brings about their rainy season.

IPRC Bids Sayonara

N.H. Saji has taken a position as Senior Research Scientist with the APEC Climate Center in Busan, Korea, where he manages the center's Climate Information Services. **Chi-Yung Francis Tam** has also joined the APEC Climate Center as a research scientist for climate prediction and model development. **Hongwei Yang** has become an associate researcher at the Institute of Atmospheric Physics, Chinese Academy of Sciences. **Hiroshi Yoshinari** is now working for the National Research Institute of Fisheries Science, Fisheries Research Agency. He is developing methods to predict the tuna population around Japan by using ocean condition prediction system: FRA-JCOPE System. **Simon de Szoeke** has been awarded a National Research Council Research Associateship and has chosen to work at NOAA's Earth System Research Laboratory in Boulder.

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