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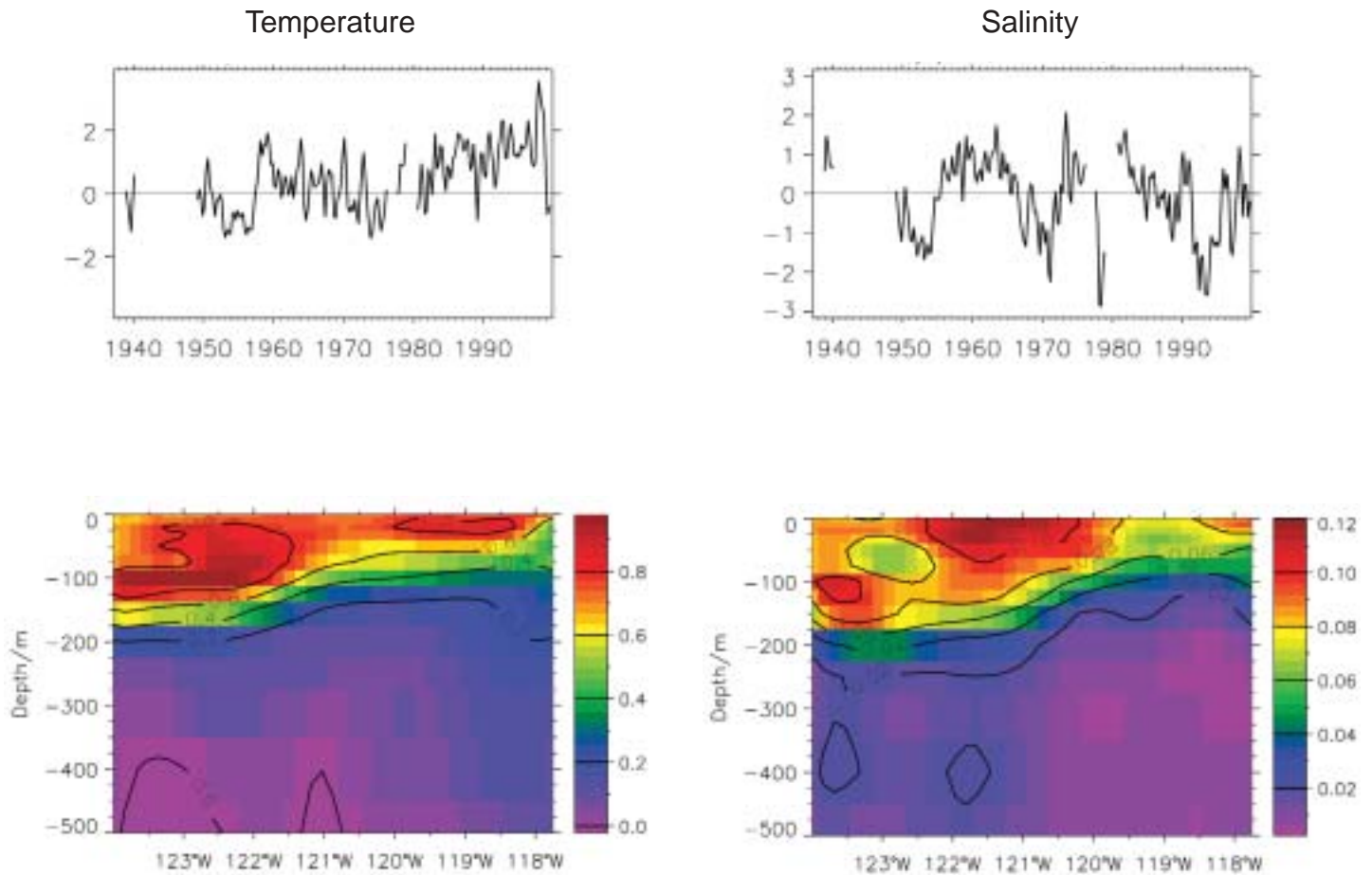


Figure 1. (Left) Leading EOF (empirical orthogonal function) of temperature at CalCOFI line-90. Top panel shows the principal component as a thick black line over time in years. The bottom panel shows the spatial loading pattern (in $^{\circ}\text{K}$) as a function of depth (in m) and longitude. Contour interval (color) is 0.02°K . This EOF accounts for 47% of the variance of the seasonally averaged temperature anomalies. (Right) Leading EOF of salinity. Contour interval in the bottom panel is 0.02 psu. The EOF accounts for 38% of the variance in the seasonal salinity anomalies. This salinity signal is independent of the leading EOF and does not correlate with El Niño-Southern Oscillation and Pacific Decadal Oscillation indices. Rather, the salinity anomalies, which are largest in the California Current, are consistent with changes of along-shore advection due to fluctuations in the current. Line-90 extends from Long Beach, California, about 600 km offshore, approximately perpendicular to the coast. The coast is on the right with the southern California Bight located east of 119°W ; the California Current flows equatorward west of 119°W .

Variations in the California Current

Upwelling and southward flow in the California Current supply cool and nutrient-rich waters to a highly productive ecosystem that once supported a major sardine fishery. This fishery collapsed mysteriously in the 1940s, leading to the establishment of the California Cooperative Oceanic Fisheries Investigation in 1949. Since then the physical and biological characteristics of the California waters have been monitored. Today more than 50 years of these ocean observations provide a unique opportunity to investigate long-term changes and variations in this eastern boundary current, which displays energetic variations in temperature, salinity, and biology. El Niño, for example, warms the water, depresses the thermocline, and is associated with a decline in zooplankton stock.

Taking advantage of these existing observations, **Niklas Schneider** (IPRC) and his collaborators **Emanuele Di Lorenzo** and **Peter Niiler** at Scripps Institution of Oceanography looked at decadal changes in salinity and temperature along the best observed section, which extends from Long Beach in California to over 600 km offshore. They included data from cruises conducted by the US Coast Guard and Harald Sverdrup in the 1930s, extending the data coverage further back in time.

Salinity measurements, in addition to being of scientific interest as one of the main ocean properties, are a useful way in the California Current to distinguish between fluctuations due to changes in upwelling and fluctuations due to changes in advection from the north. Upwelling brings saltier and cooler water to the surface from the halocline - the layer in the ocean that shows a sharp gradient in salt concentration - whereas transport of water from the north brings fresher and cooler water to the region. Moreover, unlike temperature, salinity variations do not affect the fresh-water flux between the atmosphere and ocean and therefore do not result in a feedback that affects the ocean over longer periods of time. Thus, any imbalance in the ocean's salt budget that is, for example, traceable to changes in advection will lead to a salinity trend and cause

the largest salinity variations on time scales of several years to a decade.

The team's analyses of the above data sets show that in the California Current surface temperature varies differently from salinity. Temperature varies mostly in association with the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation and shows a warming since the 1980s, which has already been noted by others. Salinity, in contrast, varies mostly over decades, with variations that are in the order of 0.2 parts per thousand and that are independent of both ENSO and the Pacific Decadal Oscillation. The California Current was fresher during the early 1950s, around 1970, and since the mid-1980s; it was saltier in the late 1950s, the early 1960s, the mid-1970s, and the early 1980s.

In searching for the cause of these differences in variability between salinity and temperature, Schneider and his colleagues distinguished between variations that may result from vertical undulations of the ocean's stratification and variations that are independent of these undulations. They found that in the halocline, salinity varies mostly with vertical undulations, which are highly correlated inshore with ENSO: El Niño conditions in the tropical Pacific usually deepen the halocline, while La Niña conditions occasionally raise the halocline. On the other hand, the prominent salinity variations described above are found mainly in the surface layer and are little affected by variations in the halocline.

A comparison with the along-shore geostrophic current estimated from the observations indicates that the changes in salinity are roughly consistent with changes in the along-shore transport of water from the north. This suggests that an intensified California Current increases the transport of fresher water to the south, displacing the climatological along-shore salinity gradient southward; a weakened current, on the other hand, would have the opposite effect. In the 1990s, however, short salty bursts occurred, yet the current was flowing toward the equator and was fresher overall, indicating a new advective equilibrium with conditions upstream in the North Pacific.

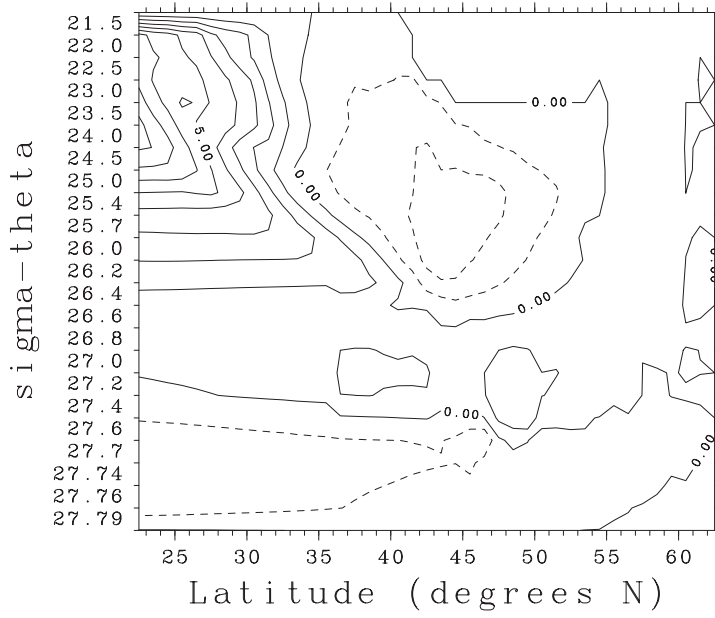


Figure 2. The annually averaged meridional overturning streamfunction. Contour interval is 1 Sv ($1 \text{ Sv} = 10^6 \text{ m}^3\text{s}^{-1}$). Dashed contours are negative.

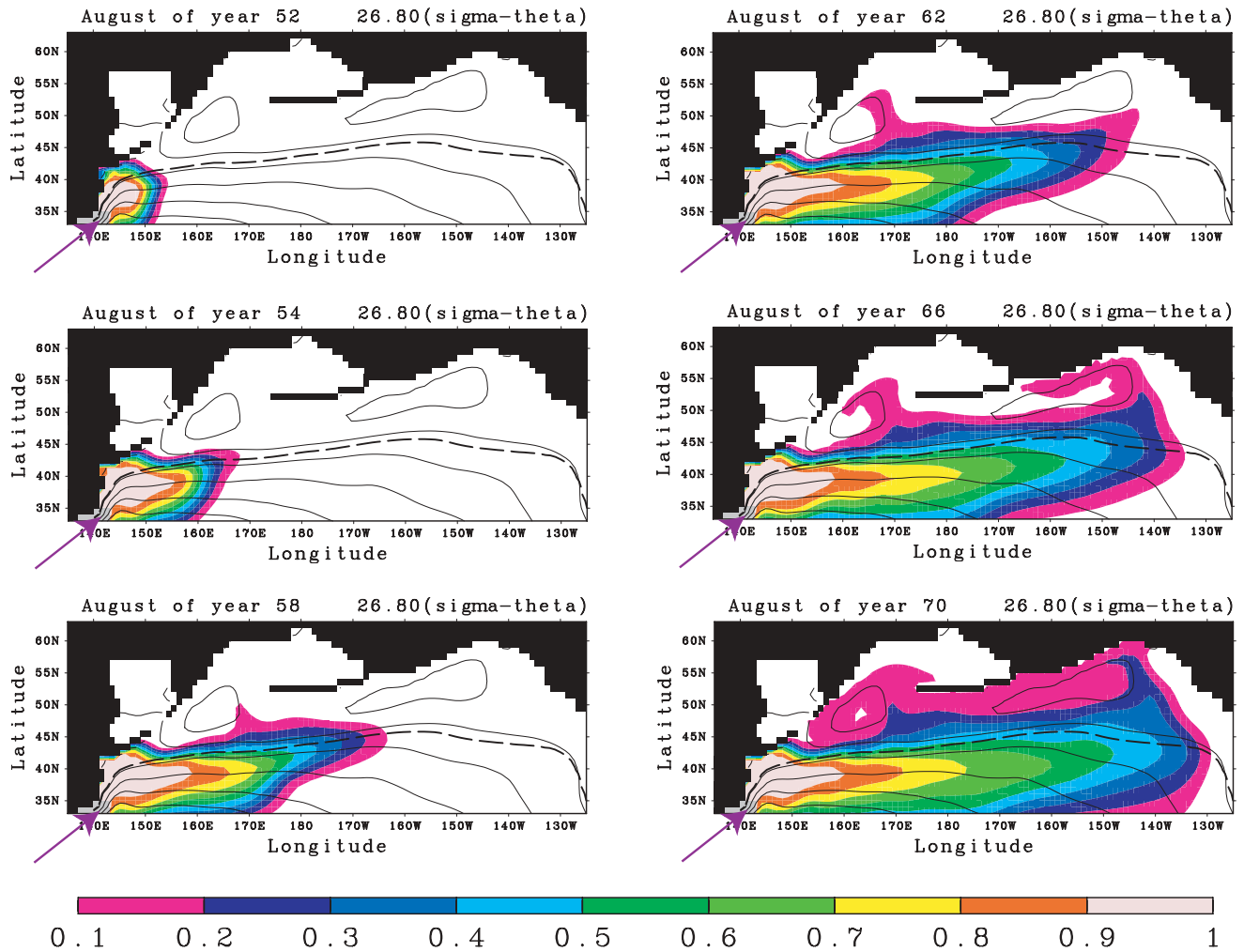


Figure 3. Horizontal distribution of the passive tracer injected into the layer of $26.8 \sigma_\theta$, which is maintained at saturation in the gray shaded region (indicated by arrows) after year 50. Superimposed are the annually averaged barotropic streamfunction (solid contours; contour interval = 5 Sv) and the gyre boundary (dashed lines) derived by subtracting the annual mean Ekman transport from the annually averaged volume transport.

Tracing the Subarctic Circulation in the North Pacific

Given the role of atmospheric carbon dioxide (CO_2) in regulating global climate, recent observations on CO_2 exchange in the subarctic North Pacific are of significance. This region has areas where large quantities of CO_2 enter the atmosphere and other areas where large quantities of CO_2 enter the ocean. The exchange of CO_2 is regulated by the concentration of dissolved and suspended materials and is a function of the extent to which the mixed-layer mixes with the ocean interior. Little is known, however, about the subarctic North Pacific circulation, which affects this mixing.

A feature of the subarctic North Pacific is a shallow layer of cold water lying over a warm-water layer rather than the usual warmer water over colder water. This oceanic temperature inversion is called “mesothermal structure.” Numerical experiments to investigate the ocean circulation in the North Pacific so far have not examined how the mesothermal structure forms because models fail to simulate a surface mixed layer that is deep enough to reproduce the structure.

IPRC researchers **Takahiro Endoh**, **Humio Mitsudera**, **Shang-Ping Xie**, and **Bo Qiu** (UH) have successfully reproduced the mesothermal structure using the Miami Isopycnic Coordinate Ocean Model (MICOM) that combines a bulk mixed-layer model and a 3-dimensional, primitive, isopycnic coordinate model of the oceanic interior. The most significant difference compared to previous numerical studies is that the model simulates in winter a surface mixed-layer deeper than 100 m in the western subarctic and the Alaskan gyres, leading to a more realistic simulation of the thermohaline structure in the subarctic North Pacific.

In the model, the cold-water layer originates from cold and low-salinity water formed locally in winter when strong cooling and wind-mixing deepen the surface mixed layer. During spring and summer, the seasonal thermocline develops over this cold water. In contrast, the warm-water layer, also called “mesothermal” water, originates as sub-

tropical water that enters the North Pacific subarctic region. Figure 2 shows the annually averaged north-south overturning streamfunction. Analyzing the model output, Endoh and his colleagues found water in the density range of $26.8\text{--}27.0\ \sigma_\theta$ flowing from the subtropics into the subarctic region and forming the mesothermal water. In winter, the mesothermal water enters the surface mixed-layer by upward Ekman suction – weakened somewhat by water intruding sideways. Entrained into the surface mixed layer, the mesothermal water then flows out to the subtropics as low-density water by southward Ekman drift. The mesothermal water is thus a part of the shallow north-south overturning cell, the subpolar cell (SPC).

To show the pathway of this warm water in more detail, a passive tracer was continually injected, after a 50-year spin-up, into the $26.8\ \sigma_\theta$ layer of the model south of Japan in the gray region indicated by the arrows in Figure 3. This figure shows the annually averaged barotropic streamfunction in solid contours and the gyre boundary in dashed lines. The tracer path shows clearly that the source of the mesothermal water is the warm and saline water from the Kuroshio south of Japan. Kuroshio water that crosses the gyre boundary near the western boundary flows eastward along the gyre boundary in the Kuroshio-Oyashio Extension and, after 6 years, it has spread into the western subarctic gyre. The water then travels in the northern part of the North Pacific Current and after six more years, is found in the Alaskan gyre. Some Kuroshio water south of the gyre boundary enters the Alaskan gyre west of 150°W after 18 years.

This numerical study is the first to show clearly the mesothermal structure in the subarctic North Pacific. Endoh and his colleagues are now planning to use MICOM to investigate the interannual-to-decadal variation of the water-mass exchange between the surface mixed layer and the oceanic interior in the subarctic North Pacific. Results from these studies are an important step toward understanding the pattern of CO_2 fluxes in this region.

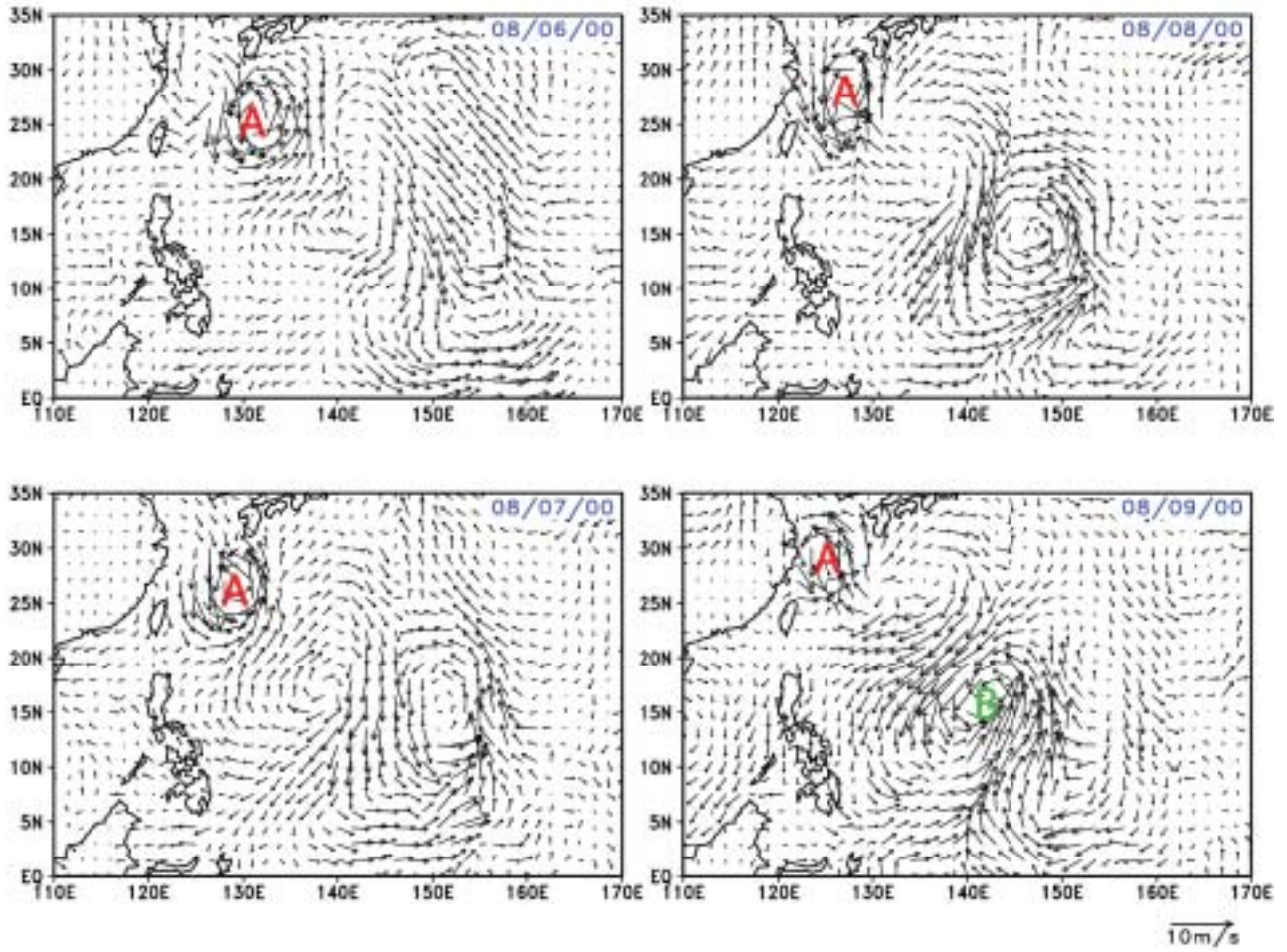


Figure 4. Time sequence of the synoptic-scale wave train associated with tropical cyclone Jelawat, which formed 1 August 2000. “A” shows Jelawat’s center. A new cyclone, Ewiniar, with “B” denoting its center, formed on 9 August 2000 in the wake of the Rossby wave train of Jelawat. A 3-8 day filter has been applied to the QuikSCAT surface-wind data to isolate synoptic-scale signals.

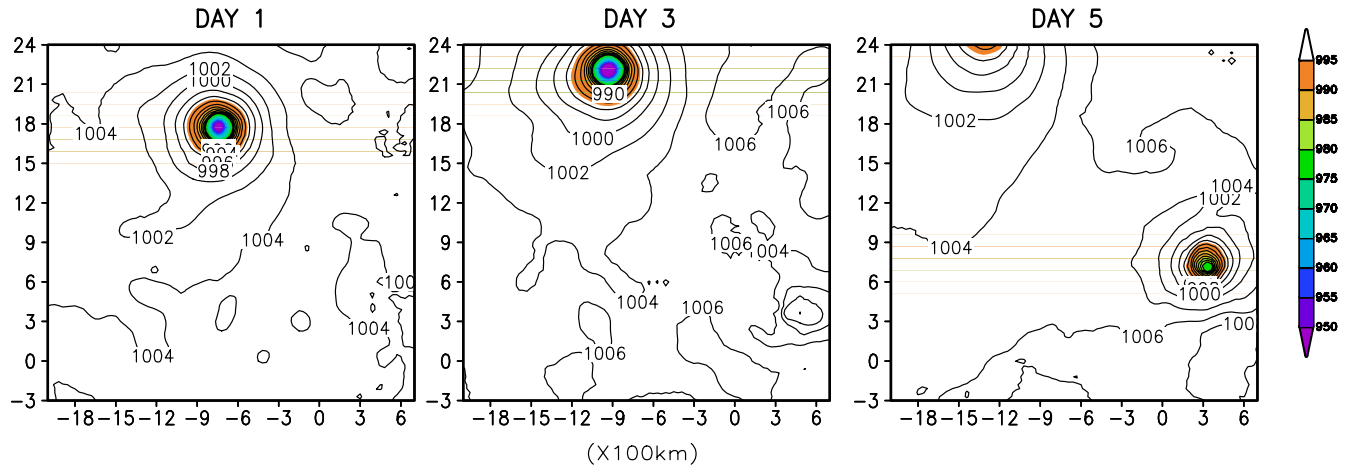


Figure 5. Time sequence of the surface pressure field obtained from a numerical experiment. A mature tropical cyclone with its Rossby wave train is specified at the outset in an environmental flow similar to the western North Pacific summer monsoon. Five days later a new cyclone with realistic dynamic and thermodynamic structures forms in its wake. The minimum pressure at the center of the new cyclone is about 970 mb.

The Birth of Tropical Storms

Forecasting the formation of tropical cyclones has been a challenge in part because of a lack of reliable observations over the ocean. Modern satellite products are now providing a great opportunity for studying and predicting this important meteorological phenomenon. Using QuikSCAT surface-wind and Tropical Rainfall Measurement Mission (TRMM) Microwave Image (TMI) data, **Tim Li** (IPRC) and **Bing Fu** (UH) looked at the formation of tropical cyclones in the western North Pacific during the summers 2000 and 2001. In their analysis, they identified two formation processes: the dispersion of energy of a mature tropical cyclone in the form of Rossby waves, and the energy accumulation of easterly waves in the monsoon confluence region. Of the 34 cyclones studied, 7 were associated with easterly wave propagation and 6 with energy dispersion of a mature cyclone.

An example of the birth of a storm in the wake of Rossby waves of an existing cyclone is seen in Figure 4. On August 1, Tropical Cyclone Jelawat forms, then moves northwest and intensifies. The four panels show the surface wind patterns from August 6 to 9, 2000, associated with Jelawat. (The QuikSCAT daily wind data were subjected to a 3-8 day filter to isolate synoptic-scale signals.) A Rossby wave train forms on August 6 in the wake of Jelawat, a process that continues until August 9 and can be clearly seen in the figure. As the scale of the Rossby wave train contracts, a new tropical cyclone, Ewiniar, forms on August 9.

Motivated by these satellite analyses, **Tim Li**, **Yongti Zhu** (IPRC visitor from the Shanghai Typhoon Institute), **Yuqing Wang** (IPRC), and **Bin Wang** (IPRC) conducted a simulation of tropical cyclone formation associated with the dispersion of energy through Rossby waves. They used the 3-dimensional tropical cyclone model developed by Yuqing Wang, modifying it to allow the cyclone to evolve in a specified summer-mean flow that does not change with time; they initialized the model with a mature tropical cyclone that has developed its Rossby wave train. Two different convective heating schemes (explicit heating

scheme and mass-flux scheme) are applied in the model. Their experiment shows that, in the presence of the mean summer monsoon circulation, a new cyclone with realistic dynamic and thermodynamic structures forms in the wake of an existing cyclone (Figure 5). When the model is run again without the summer-mean flow, no tropical cyclone forms, suggesting that the monsoon flow is necessary for the Rossby wave scale contraction.

Tim Li has analyzed also the tropical cyclone formation associated with energy accumulation of easterly waves in the confluence region where the monsoon westerly winds meet the easterly trade winds. He has found, for instance, that four days before Jelawat formed, a kinetic energy perturbation and precipitation signal appeared in the western Pacific around 175°W to 172°E. This disturbance continued to move westward and then gave birth to Jelawat at 152°E. Using the same tropical cyclone model as in the other cyclogenesis simulation, Li and his collaborators were able to also simulate this second tropical cyclone formation process.

The observational and modeling results above have important implications for operational forecasts of tropical cyclones. In a newly funded project supported by the Department of Defense, Li and his colleagues propose to extend the current scope by taking advantage of modern satellite products (such as the Advanced Microwave Sounding Units A and B), which provide in 3-dimensions the spatial-structure and time evolution of temperature and moisture fields of synoptic-scale perturbations over the tropical oceans. These products together with other available datasets, such as QuikSCAT surface winds, are expected to provide detailed tropical wave structures and wave propagation characteristics. By injecting these characteristics into the model's initial fields, the group plans to develop a dynamic approach in order to simulate and predict the birth of tropical storms in the western North Pacific. The findings of this research project should lead to improvements in forecasting the formation of tropical cyclones.

El Niño: Exploring its Background State

Introduction

The eastern equatorial Pacific is the epicenter of the El Niño-Southern Oscillation. Within the tropics, this region has the largest year-to-year climate variability and is marked by large sea surface temperature (SST) gradients in both north-south and east-west directions. During *normal* periods, a cold tongue extends from the South American coast along the equator, the core temperature increasing gradually toward the west. From the cool water at the equator, sea surface temperatures increase both northward and southward, but more so to the north, where during much of the year a band of warm water is found along 7°N-10°N with surface temperatures at or above 27°C, about 5°C higher than those at the equator and 1 to 2°C higher than those at the same latitudes in the southeastern Pacific. This band of warm water — which lies in the region where the Northern and Southern Hemisphere trade winds converge, the Intertropical Convergence Zone (ITCZ) — gives rise to deep convection and heavy rainfall. Studies over the past two decades have revealed that the El Niño-Southern Oscillation (ENSO) originates from an ocean-atmosphere interaction that is sensitive to this background climate state. To predict successfully the swings of ENSO and their global impacts, accurate simulation and understanding of the eastern Pacific climate are therefore needed.

An important feature off the South American coast is the extensive stratocumulus cloud deck in the first kilometer or so above Earth's surface — the boundary layer. This cloud deck shields the surface from incoming solar radiation, keeping the sea surface underneath it cool and affecting the global heat budget. Despite its importance for climate, this cloud deck is poorly simulated in global atmospheric general circulation models (GCMs): the models do not resolve the clouds adequately in either the horizontal or the vertical. The poor simulation of the clouds appears to be the reason why many atmospheric GCMs coupled to ocean models fail to keep the Pacific ITCZ north of the equator for most of the year and fail to keep a strong equatorial cold tongue in the eastern Pacific.

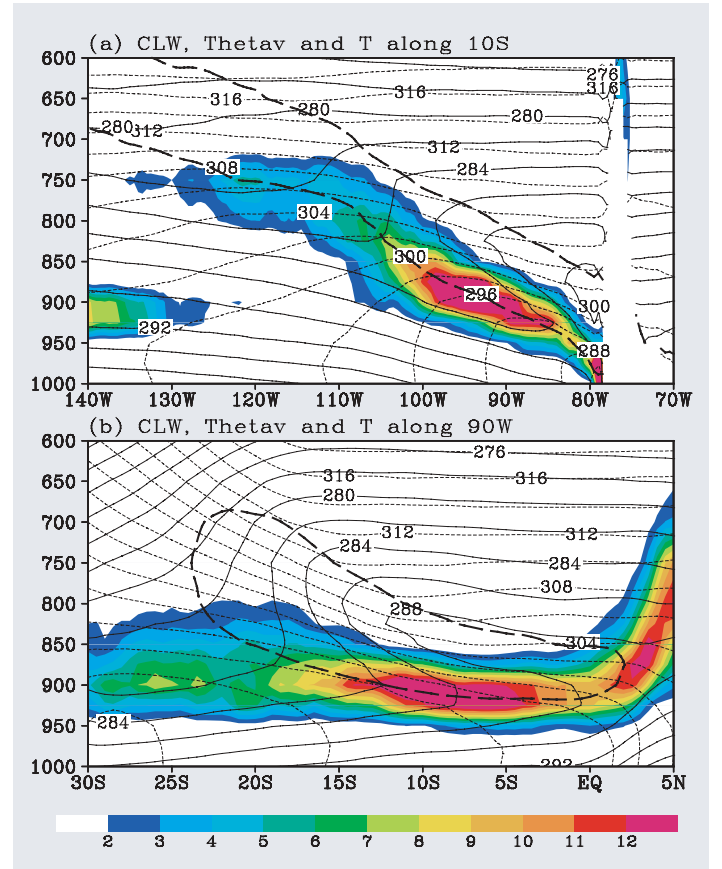
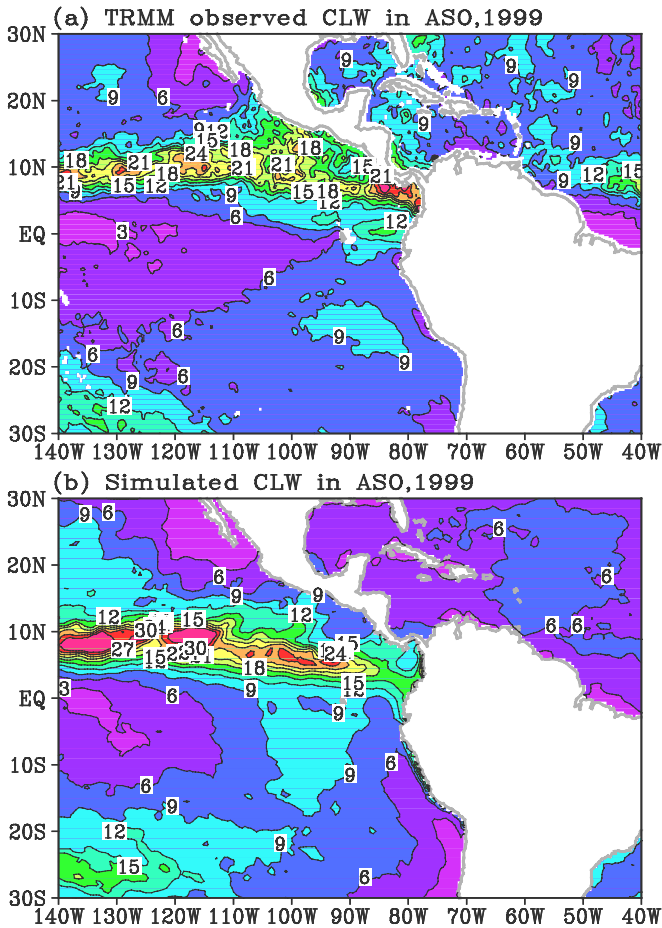
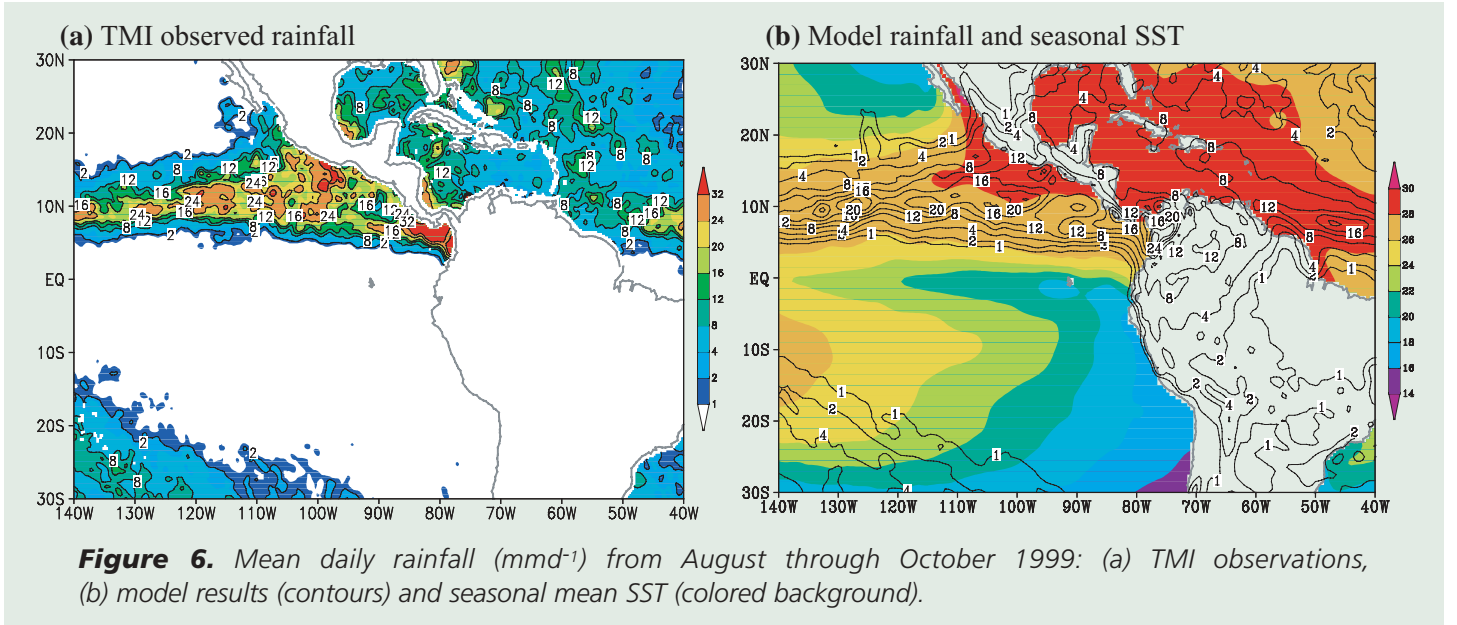
By improving their cloud parameterization schemes, some GCMs have improved their simulation of the cloud deck, yet the clouds are still very different from those

observed. Perhaps the reason is that the steep Andes, which rise from sea level to more than 3 km in just 100 km, remain poorly represented in the GCMs, their realistic representation being very costly in computing time. How and to what extent the Andes affect the clouds in the boundary layer and rainfall over the eastern Pacific is yet unknown.

To understand eastern Pacific climate better and especially the role of the Andes, IPRC scientists **Yuqing Wang**, **Shang-Ping Xie**, and **Haiming Xu** are conducting experiments on the region with the IPRC regional climate model (IPRC-RegCM), which has a high resolution and state-of-the-art physics (IPRC *Climate*, 1, Fall; 2, No. 2). Below are some preliminary findings of this research on the background climate state in the equatorial eastern Pacific.

Realistic Simulation of the Cloud Deck

Applying the IPRC-RegCM, with 28 vertical levels and fine horizontal resolution (0.5°), to a region in the eastern Pacific large enough for the model physics to develop (150°W-30°W, 35°S-35°N), resulted in a simulation that reproduced the stratocumulus cloud deck over the Southeast Pacific off South America during austral spring (August, September, and October 1999), the season of the cloud deck's greatest extent. This success now allowed Yuqing Wang and his colleagues to study the dynamical, radiative, and microphysical properties of clouds in the model, and also their interaction with the large-scale circulation. The model simulations of surface winds, precipitation and cloud water path compare favorably with satellite observations (Figure 6). The model captures the major features of the region's boundary layer: the surface mixed layer, the capping temperature inversion (air temperature rising instead of falling with height, capping the height at which clouds can form), and the stratocumulus clouds with their drizzle (Figures 7 and 8). The clouds develop in the lower half of the temperature inversion layer and below, the inversion layer rising toward the west. The strength of the inversion is determined not only by the large-scale subsidence — sinking air — and the local cool sea surface temperature, but also by feedback between the clouds and radiation. A heat budget analysis indicates that the outgoing longwave radiation cools the upper cloud layer at the inversion base, thereby strengthening the tem-



perature inversion. This cloud-top cooling, in turn, increases local subsidence in and above the inversion layer, which results in greater temperature stratification above the clouds. While of secondary importance, in the model, solar radiation drives a pronounced diurnal cycle in the boundary layer, a cycle that is consistent with observations: the clouds become more dense after sunset and their liquid water content reaches a maximum just before sunrise.

Far-Reaching Effects of the Cloud Deck

Since clouds in the boundary layer greatly reduce the absorbed solar radiation both at the top of the atmosphere and at the underlying ocean surface, they have a general cooling effect and are important modulators of Earth's climate. To understand how the large stratocumulus cloud deck takes part in driving the atmospheric circulation over the eastern Pacific, Yuqing Wang carried out a sensitivity experiment with the IPRC-RegCM, in which he removed the effect of liquid clouds on the radiation budget over the eastern Pacific south of the equator. When the absorption of solar radiation is experimentally removed, the clouds in the boundary layer south of the equator almost disappear and precipitation to the north in the ITCZ decreases by 10-15%, indicating that the stratocumulus clouds over the Southeast Pacific have both local and cross-equatorial effects.

The schematic in Figure 9 shows how the cloud deck affects the north-south circulation over the tropical eastern Pacific at the surface. The clouds impose a net cooling at the cloud top that brings about an anomalous high-pressure system, which, in turn, strengthens the high-to-low pressure gradient and air flow across the equator at the surface and enhances convection in the ITCZ north of the equator. This low-level north-south circulation that develops in response to the low-level atmospheric cooling, strengthens the local Hadley circulation, increasing the surface southeasterly cross-equatorial flow, the mass and moisture convergence and convection in the ITCZ north of the equator, and the large-scale subsidence and cloud deck off the Peruvian Coast. This positive feedback sequence, thus, helps to keep the ITCZ in the tropical eastern Pacific north of the equator.

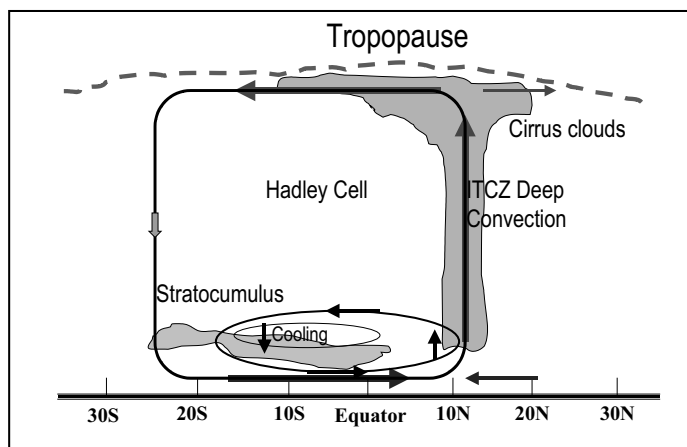


Figure 9. Schematic showing how the large cloud deck over the Pacific off South America shapes eastern Pacific climate.

Effects of the Andes

What effects do the narrow and steep Andes have on the stratocumulus cloud deck and on eastern Pacific climate in general? Conducting an experiment with the IPR-RegCM, Xu and Xie removed the Andes. Removal of the Andes produced a very different climate picture from that described above: during Southern Hemisphere spring (August-October 1999) the warm air from the South American Continent flows westward unhindered, lowering the off-shore temperature inversion height and reducing the low-level wind divergence. Both changes greatly decrease cloudiness, allowing more solar radiation to reach the sea surface (Figure 10). Thus, by blocking the warm easterly winds from eastern South America, the Andes help to maintain the wind divergence, the temperature inversion, and hence the stratocumulus cloud deck.

Moreover, a simulation of the Southern Hemisphere fall season (March and early April 1999) with realistic Andes present shows a double ITCZ — that is two bands of deep convection — one north of the equator and one south. The southern ITCZ is in response to the seasonal warming on and south of the equator, and is also seen in observations. Removal of the Andes in a further experiment allows the warm easterlies from South America to converge in the lower atmosphere over the ocean and tran-

sient disturbances to travel unhindered westward from the continent. Both effects favor deep convection south of the equator (Figure 11) and prolong the southern ITCZ for three weeks.

These sensitivity experiments were repeated with the orography used in T42 global models (equivalent to a grid spacing of about 2.8°). The results confirm that the overly smooth representation of the Andes in atmospheric GCMs shrinks the stratocumulus cloud cover in austral spring and prolongs the southern ITCZ in austral fall, resulting in a false picture of greater climate symmetry across the equator in the eastern Pacific.

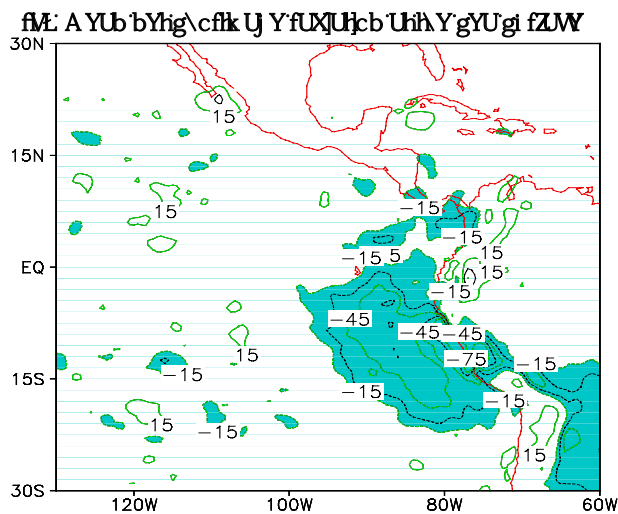
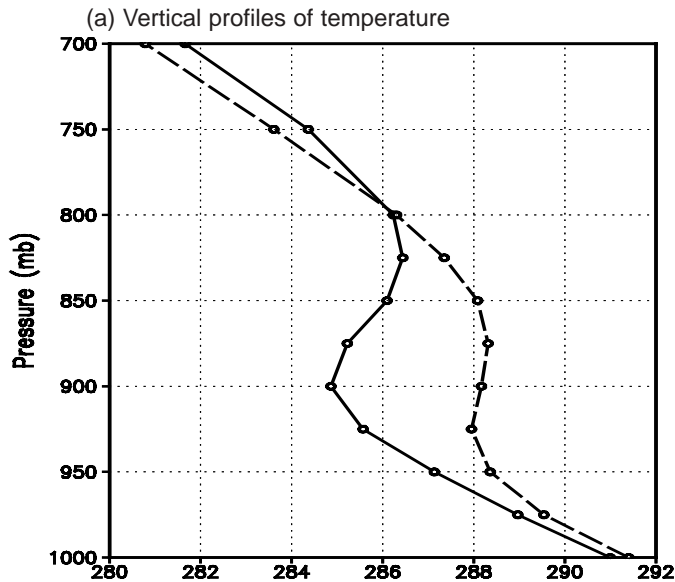


Figure 10a. Model results of vertical temperature (in K) profiles averaged over 83°W – 95°W , 5°S – 20°S for the simulations with realistic Andes (solid line) and without the Andes (dashed line). **10b.** Differences in the mean net shortwave radiation flux at the sea surface (averaged over August–October, 1999) between the realistic Andes simulation and the simulation without the Andes. Contour interval is 15 Wm^{-2} ; values less than -15 Wm^{-2} are colored.

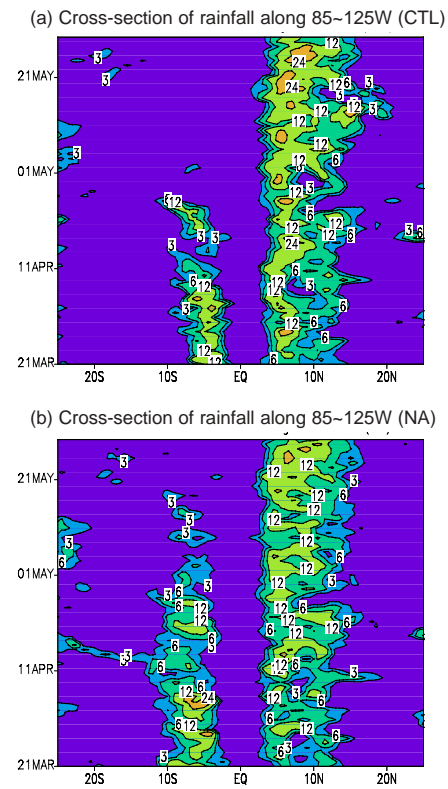


Figure 11. Cross-sections (averaged between 85°W – 125°W) of daily rainfall (in mm) over time and latitude: (a) model results with realistic Andes, and (b) model results without the Andes.

Conclusion

The ability of the IPRC-RegCM to reproduce the complicated formation of the cloud deck off the Peruvian coast is a significant advance in climate modeling. This rather permanent, low, and unbroken cloud deck acts like a huge white sheet, reflecting sunlight back to space and cooling the atmosphere and the ocean below. The cooling helps to prevent the formation of cumulus clouds that occur elsewhere in warm equatorial regions and helps to keep deep convection and the ITCZ north of the equator in the eastern tropical Pacific except for March and April. In the IPRC model, the sinking air on the leeward side of the Andes contributes to formation and maintenance of the cloud deck and to the northward-displaced ITCZ. The strong interaction among the clouds, the ocean, and the atmosphere reinforces the existing Hadley Circulation. To further understand this interaction between the boundary layer clouds and the ocean, and the influence of the Andes on this interaction, a group of IPRC researchers is now coupling the IPRC-RegCM to a mixed-layer ocean model. In the meantime, the findings so far contribute much to understanding the background state on which the El Niño–Southern Oscillation develops.

Field Experiment Examines Effects of Deep Tropical Convection

A key issue for modeling atmospheric climate and chemistry is the parameterization of the unresolved effects of gravity waves on the explicitly resolved flow. This has been difficult to achieve due to a lack of empirical data on the details of the wave spectrum and its relation to sources such as moist convection, flow over topography, and jet stream instabilities. IPRC Theme-4 leader, **Kevin Hamilton**, helped to organize the Darwin Area Wave Experiment (DAWEX), a field experiment in northern Australia to study the gravity waves excited by deep convection in the pre-monsoon period. During the Southern Hemisphere winter, there is little convection over northern Australia. This changes in the late pre-monsoon period, typically from November to mid-December, when intense convection over the Tiwi Islands develops virtually every afternoon. Known locally as “Hector,” this convection results from an interaction of convectively driven cold pools and sea breeze fronts. It builds into a bundle of intense thunderstorms over the western portions of the islands, reaching up to the tropopause by mid-afternoon. Hector thunderstorms are among the most intense and penetrative convection observed on earth, with updrafts as strong as 40 m/s and cloud tops sometimes reaching above 20 km.

Scientists from 10 institutions in Australia, Japan, and the USA took part in the DAWEX field campaign, which was organized around three intensive observing periods in 2001: October 13-18, November 15-20, and December 11-16. Convection over the Tiwi Islands and in the Darwin area was observed by the Australian Bureau of Meteorology Research Centre C-band polarized Doppler radar located near Darwin. Five airglow imagers recorded wave responses in the vicinity of the mesopause. A boundary-layer radar on the Tiwi Islands profiled low-level winds. At Katherine, about 400 km southeast of the Tiwi Islands, a medium-frequency radar measured horizontal winds near the mesopause. Three-hourly balloon soundings of the wind and temperature were made on the Tiwi Islands, at Darwin, and at Katherine.

At the “Analysis of DAWEX Results” workshop, held at the IPRC December 3-5, 2002, experiment participants reviewed preliminary observations and developed strategies for integrating the findings from the different types of observational systems. Analysis showed that convection differed from one observing period to the next as the prevailing circulation changed from pre-monsoonal to mon-

soonal. October had three days with modest Hectors and two days with only disorganized convection. November had three consecutive days with very strong Hectors and more extensive areas of convection. December showed a more monsoonal pattern with widespread convection over the mainland.

The airglow imagers, which yielded rich data on the horizontal wavelengths and phase velocities, all recorded a southward propagation tendency. This suggests their dominant source in this season is convective activity in northern Australia or the Maritime Continent region. Detailed analyses are now being performed on the behavior of the waves at each station and their relation to the weather each day.

The radiosonde observations revealed systematic wavelike variations at both shorter and longer time scales. One prominent component near the tropopause in the October and December observations is a large-scale wave (coherent at Darwin and Katherine) with a period near 84 hours. Small vertical-scale variations tend to be stronger near the tropopause and also above 25 km, but suppressed in the 20 to 25 km height range, an unexpected finding awaiting explanation. The workshop also reviewed current efforts at the detailed numerical modeling of the Hector convection and of the gravity wave field excited by isolated deep convection.

Plans for a follow-up experiment to study also the chemical and microphysical effects of the Hector convection are summarized in a draft White Paper posted at <http://www.soest.hawaii.edu/~kph/EXP2>.



Workshop participants, front row: Shin Suzuki, Alan Liu, Toshitaka Tsuda, Kevin Hamilton, and Joan Alexander. Back row: Kazuo Shiokawa, Mike Taylor, Peter May, Andrew McKinnon, Bob Vincent, Jim Hecht, Richard Walterscheid, and Gera Stenchikov.

Capturing the Daily Cycle in Global Atmospheric Models

The daily cycle of solar radiation has a number of important signatures in the climate system. On a local scale, differences in surface heating over land and ocean produce the familiar land-sea breezes; over topographic slopes it produces mountain-valley breezes. Restricted mostly to the lowest 2 to 3 km of the atmosphere, these local diurnal circulations typically involve a rough balance between the radiatively driven horizontal pressure gradients and small-scale turbulent “friction.” On a larger horizontal scale, the Coriolis force and acceleration terms balance the atmospheric pressure gradients caused by diurnal heating variations, resulting in large-scale inertia-gravity waves. On the global scale, this yields a large sun-following wave that can propagate vertically upward and downward from its forcing altitudes.

Atmospheric scientists have resolved this sun-following wave into diurnal (24 hour), semidiurnal (12 hour), terdiurnal (8 hour), and shorter components that are called the sun-synchronous or “migrating” atmospheric tides. These waves have fairly modest amplitudes: near the ground, generally less than 3 hPa peak-to-peak surface pressure. At low latitudes, however, this pressure variation exceeds typical day-to-day synoptic changes. This was first noticed by the famous 18th century explorer Alexander von Humboldt, who wrote that at low latitudes, the daily cycle of air pressure is so regular that a barometer can serve as a clock!

Regional modulation of the diurnal heating amplitudes and local-time phase yields other diurnal and semidiurnal tide components, the so-called non-sun-synchronous tides. These are caused by regional variations in the diurnal cycle of latent heat released in moist convection, which involves many aspects of tropospheric meteorology.

Global climate models cannot adequately represent the small-scale land-sea breeze circulations, but they simulate both the migrating and non-sun-synchronous tides. Simulation of the tides is of particular interest as it is one of the best tests of how numerical models respond to a well-defined forcing.

To review current understanding and identify uncertainties in the numerical simulation of atmospheric tides, the Working Group on Numerical Modelling of the International Commission for the Middle Atmosphere held the “Modelling of Atmospheric Tides” workshop at the IPRC March 3-7, 2003. **Kevin Hamilton**, chairman of the working group, organized and chaired the workshop.



Workshop participants. Seated, from left: William Ward (University of New Brunswick), Robert Vincent (University of Adelaide), Rashid Akmaev (University of Colorado), and Xun Zhu (Johns Hopkins University). Standing, from left: Rolando Garcia (NCAR), Ruth Liebermann (Northwest Research Associates), Francois Vial (Ecole Polytechnique), Kevin Hamilton (IPRC), Anne Smith (NCAR), Charles McLandress (University of Toronto), Dan Marsh (NCAR), and David Ortland (Northwest Research Associates).

Twelve scientists from Canada, Australia, France, and the USA participated. They brought to the workshop expertise in lower atmospheric meteorology and in upper atmospheric dynamics and chemistry. Perhaps no other phenomenon in atmospheric science requires such a wide range of expertise.

The workshop presentations revealed some successes in simulating the diurnal cycle in state-of-the-art global models. In particular, such models appear to reproduce reasonably well the overall amplitude and phase of the migrating tides. The models, however, perform less well on reproducing the observed geographical and intraseasonal variability of the non-sun-synchronous tides. The problem seems to lie mainly in poorly simulating the daily moist convection cycle in the troposphere. Another issue identified at the workshop, but left unresolved, is how the interannual variability in mean wind distributions affects seasonal and year-to-year variations in the tides.

Hamilton is now coordinating a review article on atmospheric tides based on the presentations and discussions at the workshop. The preparation for the meeting has also inspired IPRC Researcher **Yuqing Wang** to draft another review paper focused specifically on simulating diurnal cloudiness and rainfall variations in global and regional atmospheric models.

The Hadley Circulation: Present, Past, and Future

The Hadley Circulation is Earth's main distributor of heat. The very warm, moist air near the equator rises high into the atmosphere. As it moves poleward, it loses much heat and sinks again, according to the textbook definition around 30 degrees latitude; there the cooler air then travels as trade winds toward the equator. Letting off the equator's "steam," and warming the mid-latitudes, the Hadley Cell is thought to have a major role in climate variations. Climate researchers, therefore, want to know how global warming will affect this circulation. Will the circulation strengthen or weaken? How will it affect precipitation? As yet, there is no agreement as to what will happen. One approach to understanding more about how global warming might affect the Hadley Circulation is to see how it has changed in the past. Extensive instrumental records go back less than two centuries, but there are proxy records of ancient climates.

November 12-15, 2002, the IPRC hosted "The Hadley Circulation: Present, Past, and Future" workshop at the East-West Center, bringing together over 50 climate dynamics scientists and paleoclimate researchers from 10 countries. The workshop covered two main areas: proxy records and what they can tell us about past climates, and recent numerical modeling research on the Hadley Circulation.

The reports on paleoclimates included records of ocean corals and fossilized corals now on land; speleothems, such as stalagmites or stalagmites; lake, riverbed, and deep-sea sediments; ice cores; tree rings, planktonic foraminifera, and other plant biomarkers. These records, which span the globe and cover the last 130,000 years, are being used to reconstruct such past climate conditions as air and sea surface temperatures, precipitation, winds, storm activity, ocean currents, and the chemical composition of the atmosphere. For example, the oldest records presented at the workshop are from fossilized corals in New Guinea and suggest that the El Niño-Southern Oscillation has existed for at least 130,000 years, through warming and glacial cycles (Tudhope).

Several reports showed that past climate changes in the high latitudes of the Northern Hemisphere are also seen in paleo records from the tropics and even the Southern Hemisphere (Hughen; Cobb). The rapid warming periods occurring within decades, as recorded in the Greenland Ice Cores, are found in stalagmite records in the tropics (Burns; Fleitmann). The mechanisms that can lead



Workshop organizers Raymond Bradley and Henry Diaz with IPRC Director Julian McCreary.

to such a rapid, large rise in temperature are not known. A change in the distribution of solar irradiation does not seem to account for their large amplitudes, but natural fluctuations in CO₂ and other greenhouse gases are suspects.

Not all proxy data, though, are so consistent across the globe. For example, in many parts of the tropics and subtropics, glacier formation and starvation are more in line with wetter and drier conditions than with surface temperatures (Thompson), although oxygen isotope changes that record prevailing air temperature do reflect the cooling and warming cycles of the last glacial-interglacial cycle. The highest mountains in the Southern Hemisphere were ice-free during a time when Earth was in the grip of a global glaciation. Moreover, subtropical ice-core records from glaciers in the Himalayas show that they were formed during the Early Holocene warm period.

By the end of the workshop, the accumulated reports made it clear that once the diverse proxy records are pieced together into a cohesive global picture of past climates, they will be a most useful data source for testing general circulation models (GCMs). At present, the main tools for climate change predictions are the comprehensive GCMs, which do fairly well in simulating the current climate and the current Hadley Cell. GCM simulations of past climates are an active area of research, and improvements in the detailed reconstructions of past climates from proxy data would enhance our confidence in their predictions of how climate may change in response to increasing concentrations of greenhouse gases.

The reports on experiments with atmospheric and coupled ocean-atmosphere circulation models ranged from simulating climate conditions 58 million years ago to future global warming scenarios. The findings on how different forcings affect the Hadley Circulation, particularly the intensity of the winds and the circulation's poleward reach, presented a complex picture. For example, a comparison of GCM simulations using surface temperatures existing in the Paleocene, the Last Glacial Maximum, the present, and a doubled CO₂ scenario found that the intensity and the poleward extent of the Hadley Cell are not related in a straightforward way to global or equatorial temperatures; intensity of the circulation correlated the most with differences in sea surface temperature between the tropics and subtropics (Rind). A study of changes in conditions over the last 50 years suggested that the changes in the Hadley Circulation depend on season: the Hadley Cell has intensified during the northern winter, but has changed little during northern summer (Quan). A modeling study covering the period from the Last Glacial Maximum to the present also suggests that any changes in the Hadley Cell intensity arising from global-mean surface temperature changes depend upon the season (Valdes).

Effects of incoming solar-radiation changes on the Hadley Cell depend upon the nature of the change: obliquity variation seems to affect the circulation, but not precession (Clement). A modeling study comparing the effects of increased solar irradiance and increased CO₂ in the 20th century, suggests that they have different effects: increases in solar irradiance strengthened the Hadley Cell, exacerbating local droughts and floods, while the effects of increased CO₂ are distributed more evenly (Meehl).

On the whole, the presentations showed that the textbook definition of the Hadley Circulation, in which air rises at the equator and symmetrically moves toward both poles, is a drastic oversimplification. The circulation varies in complex ways across the globe: the location and strength of the ascending and descending branches are affected greatly by geographic features and seasons, and sometimes behave as a single cell with strong flow across the equator. The general thinking at the workshop was that the symmetrical circulation with its averaged yearly east-west characteristics was still a useful concept when combined with local and seasonal variations in its expression. An unresolved debate is whether the Hadley Cell is driven mostly from the tropics or the subtropics.

The workshop abstracts are posted at <http://www.geo.umass.edu/climate/hadley/abstracts/abstracts.html>. A book on the workshop presentations is in

preparation. Moreover, workshop participants thought the dialog between researchers from paleoclimatology and modern climate dynamics, including observationalists and modelers, was most helpful. To continue this cross-discipline dialog, the group decided to suggest to the National Science Foundation that it should develop a programmatic theme and a call for proposals on projects in which scientists from different climate-related disciplines could study the variation of the intertropical circulation over the last 1,000 years.

Raymond Bradley (Climate System Research Center, University of Massachusetts) and **Henry Diaz** (NOAA Climate Diagnostics Center) organized the workshop. Sponsors were NOAA Office of Global Programs and NOAA Climate Diagnostics Center, NSF, the Climate System Research Center, Past Global Changes (PAGES), and the IPRC.

Stewards of the World Oceans

The IPRC hosted the spring meeting of the **Ocean Studies Board** of the National Academies March 5-7, 2003. The board provides the US federal government with balanced, unbiased scientific and technical advice on ocean issues. Among other things, presentations on two recently completed reports were given: *The Decline of the Steller Sea Lion in Alaskan Waters* concluded that the main suspects in the present decline of the endangered Steller sea lions are killer whales. Their former food source dwindling, killer whales go for smaller catch: one beached whale had 14 sea lion tags in his stomach. The report recommends an adaptive management program with numerous areas of "take" and "no-take" or sanctuaries in the region. Complicating matters is that killer whales are also endangered. The *Ocean Noise and Marine Mammals* report concluded that we know little about the noise budget in the ocean. The report recommends establishing a long-term ocean-noise monitoring program in marine habitats and studying how marine animals react to different aspects of noise. NOAA needs standards to guide its approval process for ocean noise-producing projects; yet, lawsuits brought to protect the marine environment are hindering research to develop such standards.

How Sensitive is Climate to Greenhouse Gases?

George Boer is on the forefront of research into climate's "sensitivity" to greenhouse gases. He is a lead author of the chapter "Projections of Future Climate Change" and a contributing author to three other chapters in *Climate Change 2001: The Scientific Basis*, the latest report of the Intergovernmental Panel for Climate Change (IPCC). A senior research scientist and former Chief of the Canadian Centre for Climate Modelling and Analysis, Boer has worked with his colleague **Norman McFarlane** and others since the early 1980s on developing and applying the Canadian Climate Model, which was one of the models used for the global warming studies in the IPCC report.

Boer's visit to the IPRC during February and March 2003 gave us the opportunity to ask him what he considers to be the leading issue in climate modeling research. "The focus should be on climate as a system and how sensitive the climate is to perturbations," was his reply. "By climate sensitivity I mean the magnitude and pattern of the temperature increase in response to the radiative forcing resulting from a perturbation such as an increase in CO₂."

"If a relatively small perturbation results in a large temperature increase, then the climate system is 'sensitive,' and we need to worry; if a large perturbation results in little temperature change, we can say, 'So what!' But we don't know how sensitive the climate system is. The models used for predicting climate change vary quite a bit in sensitivity, and this is the basis for much of the argument on whether we should do something about global warming."

"For instance, there is a lot of scatter in the climate response to a doubling of CO₂ in the models, with results differing by a factor 2 or more." He points to a graph in the IPCC Report (p. 560), in which, depending on the model, the predicted increase in global surface temperature ranges from 2° to 5°C, and the global precipitation increase ranges from less than 2% to 15%. The Canadian Model is in the middle range of the temperature increase predictions.

The difference of 3°C in mean-temperature increase among models is significant since the change plays out

very differently in different parts of the world. In simulations with versions of the Canadian model (for a description of these models see <http://www.cccma.bc.ec.gc.ca/models/models.shtml>) from 1900 to 2100, some regions warm dramatically, others actually cool. Generally, there is greater warming in the higher latitudes of both hemispheres, though this is slowed somewhat in the Southern Hemisphere due to mixing of the surface ocean with the deep ocean. In the tropical ocean, there is a mean warming rather similar to an El Niño state. Not all models, though, produce this mid-Pacific warming.

"It is very important for us to understand why models differ and what determines their climate sensitivity," Boer believes, "and the key to determining the climate's sensitivity to greenhouse gases lies in the feedback processes operating in the climate system." An example of a positive-negative feedback system is the following sequence: as the atmosphere warms, it holds more water vapor, but water vapor is a greenhouse gas (the most prevalent one) and heats up the atmosphere even further (positive feedback); Earth's surface, on the other hand, as it warms further, radiates more heat back into space (negative feedback).

One hint of the critical role of feedbacks is that the nature and pattern of radiative forcing does not strongly determine the resulting temperature pattern: whether, for instance, solar radiation or greenhouse gases are changed in the model experiments, the results show similar overall sensitivity and patterns of temperature increase. "This tells us that the patterns in temperature change depend in the first order on the feedback processes and not on the nature of the forcing."

To understand these patterns, Boer has separated feedback processes into those associated with clouds and those associated with the cloud-free atmosphere and surface. He is examining each of these feedback's regional contributions to changes in longwave, shortwave, and total radiation. His analyses show that depending upon the region, the feedback processes have different effects on long- and shortwave radiation. For example, in higher latitudes



George Boer and Kevin Hamilton studying results of model simulations.

clouds decrease net shortwave heating, but the surface-atmosphere feedback overrides their cooling effect. This positive feedback comes mainly from the melting of snow and sea-ice, resulting in more absorption of incoming shortwave radiation.

Of great interest to Boer is an area of overall positive feedback in the mid-Pacific surrounded by negative feedback in much of the rest of the tropical band. This positive feedback supports a mean El Niño-like response due to positive radiative forcing, which is absent in simpler climate models without a dynamic ocean.

While at the IPRC, Boer has begun to compare simulations from the Canadian model with those made at the IPRC by **Kevin Hamilton** and **Weijun Zhu** using the numerical model from the National Center for Atmospheric Research (NCAR). The NCAR simulations show a generally similar positive feedback distribution, for example, over the higher latitudes and in the mid-Pacific, but negative feedbacks are generally stronger and positive feedbacks weaker, indicating that the model is less sensitive than the Canadian model (indeed, the NCAR model is one of the least sensitive of current climate models). Preliminary analyses suggest that the positive water vapor feedback is weaker in the NCAR model. Boer speculates that this may have to do with differences in moisture distribution.

Boer can well have some confidence in the validity of the Canadian Climate Model and in its sensitivity to green-

house gas and other forcings. Colleagues at his centre have simulated conditions during the Last Glacial Maximum. The model was initialized with CO₂ levels and increased glacial topography existing during the Last Glacial Maximum. As the model approached a new equilibrium, a La Niña pattern with cool sea surface temperatures had developed in the mid-Pacific and the thermohaline circulation in the North Atlantic had slowed. The sea surface temperature and thermohaline findings corresponded to those reconstructed independently by paleoclimatologists with paleo data from the Last Glacial Maximum. The fact that the feedbacks are robust when the climate system is cooled provides convincing evidence of the importance of the geographical feedback patterns in determining the pattern of temperature change.

The next version of the Canadian model is already on the production line and is expected to be released within a year. This model will have more sophisticated cloud parameterization and radiation and convection schemes, and it will include treatments of the sulfur and carbon cycles. With this new model, George Boer will continue to look further into how our climate responds to radiative forcing arising naturally and from human activities.

Publication available

The lectures from the School on the Physics of the Equatorial Atmosphere, directed by Kevin Hamilton at the International Centre for Theoretical Physics in Trieste (*IPRC Climate, 2, Fall*), have been published. *Physics of the Equatorial Atmosphere*, edited by **L. Gray** and **K. Hamilton**, is aimed at an advanced graduate student audience. Copies are available on request from Library and Information Services, Rutherford-Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX, United Kingdom.

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

<http://apdrc.soest.hawaii.edu>

As you read this article, a huge amount of climate information is being generated. This information exists in many formats and at many locations, making it arduous to use. The APDRC is there to help scientists access such information quickly. Since first featured in the *IPRC Climate* (2, No.1), the APDRC, under the leadership of Peter Hacker, has been actively developing and widening the scope of its servers, has made new products such as those from WOCE and Argo available, and has begun exciting collaborations with GODAE, Frontier, and the Earth Simulator activities.

The most challenging task we have taken on at the APDRC is to make the massive model products now being generated by supercomputers, such as the Earth Simulator in Japan, accessible to researchers in an easy and manageable fashion. Data Server Manager **Yingshuo Shen** has been grappling with how to make servers provide efficient access to both local and remote products. The side-panel (p. 20) details some of the technical issues and current solutions. The vision is to develop a system whereby users can select, with only a few clicks on the monitor screen, those specific data products from the vast global data sets that they need for their research. Toward this end, we are greatly increasing the storage capacity of the servers so that a portion of the Earth Simulator and other model products can be stored at the APDRC. Moreover, Shen and his colleagues are working on the concept of "sister servers", in which servers at other institutions store parts of the data sets, yet users will be able to access the diverse data sets seamlessly at the APDRC site without noticing that the data resides on different servers around the world. This past November, for instance, visitors **Kazutoshi Horiuchi** and **Yutaka Oyatsu** from IPRC's Japanese sister institutions worked with Shen to prepare the transfer of the IPRC server systems (LAS, EPIC, and CAS) to Japan as a first step in setting up such connections between the computers.

We have begun at the APDRC to make plans on how to best help in the delivery and evaluation of products associated with the Global Ocean Data Assimilation Experiment (GODAE), which has started its demonstration phase. GODAE will usher in a new era of oceanography — an era of now-casting and forecasting of the ocean state, much like weather forecasting. Specifically, GODAE is

working to provide, with the help of ocean data-assimilation models, real-time and forecast products for temperature, salinity, sea level, and currents frequently and at high spatial resolution. This information will be of great importance for a wide range of research activities and applications, such as fisheries, public safety, resource management, and adaptation to climate change. Our servers can facilitate the use and evaluation of the GODAE products and are already serving the following assimilation-based products: JPL-ECCO products, NOAA-GFDL products, and the Naval Research Laboratory (NRL) Layered Ocean Model (NLOM) products (Figures 12 and 14). The Live Access Server (LAS, version 6.0) allows comparison between two different products from two remote sites. The NLOM product is a real-time research product that has been created operationally by NAVOCEANO. Convenient premade output is available at the NRL website (http://www7320.nrlssc.navy.mil/global_nlom/index.html). The output files of this model, however, are huge and the task of downloading and filtering through the data for individual use is difficult. Thus, we are currently downloading the real-time surface layer products globally and serving them on the public LAS (6.0), allowing any user — climate, or reef-coral researcher, or fisherman — to easily prepare custom plots of real-time information for their region of interest.

Our server homepage, <http://apdrc.soest.hawaii.edu>, has been updated, and **Gang Yuan** has provided easy access to several in-situ data sets served on the local EPIC servers. The servers provide web-based access to thousands of WOCE CTD stations, Upper Ocean Thermal profiles, and current-meter records. Argo profiles from the Global Data Assembly Centers at US GODAE, Monterey, and IFREMER, France, are also available on a test server. These records will be updated regularly. The EPIC server provides easy sampling of information by region, time, and float, and creates graphic representations of the sampled data (Figure 13). Try the Argo server and tell the APDRC about your experience.

The Integrated Modeling Research Program (under Professor **Toshiyuki Awaji**) at Frontier is developing a cutting-edge 4-dimensional atmosphere-ocean-land coupled data-assimilation system on the Earth Simulator computer for a reanalysis of data from the 1990s. The IPRC, led by **Takuji Waseda**, is assisting with the establishment of an international data network for the project by identifying

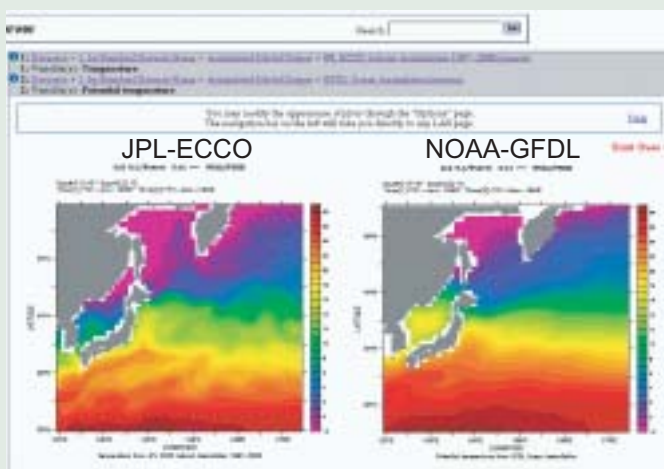


Figure 12. The Live Access Server (LAS) version 6.0 at the APDRC serves QuikSCAT level 3 wind velocity data from JPL (left) and allows model product comparison from two different sites, JPL/ECCO adjoint output and NOAA/GFDL output (right) for fields such as ocean surface temperature.

Figure 13. The EPIC server for in situ ocean data now serves WOCE data, as well as Argo float data (on a “test” site). If you pick “Pacific Ocean Argo Float Data” from the APDRC’s EPIC server, you will get the left panel (11,120 profiles). Select a drag-and-drop subregion in the North Pacific and you get the upper right panel. You can view individual profiles, or select a specific float and see the temperature (shown) or salinity data from a sequence of profiles as on the lower right panel.

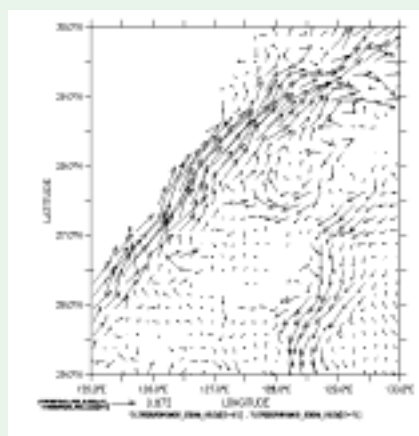
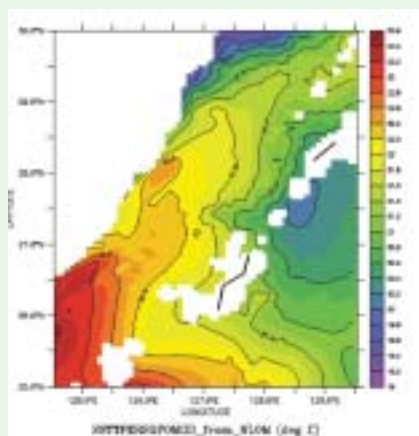
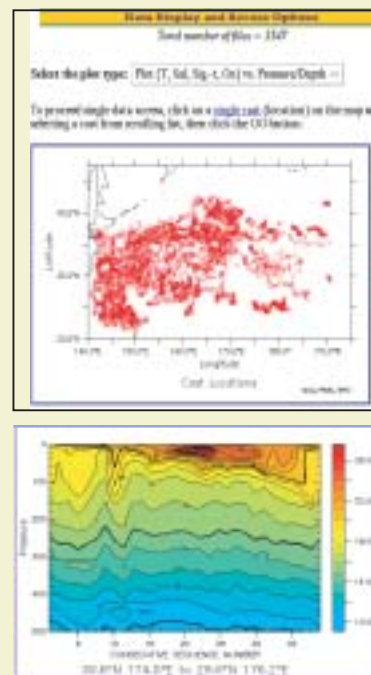


Figure 14. We recently began serving the NRL NL0M, 1/16°, global surface layer product. The figure shows sea surface temperature (SST) on the left and surface layer velocity vectors on the right associated with the Kuroshio for 8 March 2003 near Okinawa, Japan.

and collecting global ocean, atmosphere, and land-surface data, by providing quality control and value-added information, and by conducting data analyses. The IPRC, moreover, will participate in Earth Simulator experiments conducted with an advanced ocean model (OIFES) and a coupled ocean-atmosphere model (CFES) specifically developed for the large capacity of the Earth Simulator. The coupled model is the same as that for the data-assimilation project described above. For both the Integrated Modeling Research Program and the Earth Simulator Center collaboration, the APDRC's data serving capacity based on the LAS, CAS, and GDS infrastructure (see side panel) should become invaluable for serving the large model output (many tera-bytes) efficiently.

Finally, **Humio Mitsudera** has moved to the University of Hokkaido. We wish him all the best in his new position, though his active role is much missed. We would like to thank **Klaus Wyrski** for his comments on model-based products (below). As more of these products become available and used, it is essential that their error fields are readily available and that the actual data or observation content of the products can be tracked.

Letter to the editor:

Data have always been of great interest to me. So when I saw an article "Go Data Shopping" (*IPRC Climate*, 2, No. 1), I became very excited. My eyes immediately focused on the map of the eastern Pacific and the adjoining diagram of temperatures to the west of the Galapagos Islands (Figure 8). The diagram shows temperatures from the surface to 400 m and from 1950 to 2000. I am sure there are almost no temperature measurements in this location between 1950 and 1960, and very few in the following decade; thus these data must have been synthetically generated.

When I hear "data," I think of course of observations, measurements. But today the term "data" is too often used for information generated from model outputs. Scientists should, of course, know the difference and make a proper distinction between different kinds of data: observed, interpolated, model output, and simulated — or what I call "invented data." As long as that is done, it is not a problem; but it becomes scary if outsiders, like environmentalists, use these data in place of observations to draw conclusions. It might, therefore, be useful to warn "shoppers of data" that these are synthetic data and not observations.

Klaus Wyrski
Professor Emeritus

APDRC Server Infrastructure

This note focuses on the OpeNDAP (formerly DODS) infrastructure at the APDRC. Three types of OpeNDAP servers are running; each has specific capabilities and potential.

First, the cgi (common gateway interface) on an Apache server is used to obtain in-situ data with the EPIC "Pointer File" option. The cgi also translates HDF files (a common format for satellite products) into OpeNDAP to support other client applications, such as APDRC's serving of JPL's SeaWinds data (QuikSCAT satellite level 3 data), shown in Figure 12. Technology from Unidata called NcML will enhance this service.

Second, the servlet type server running on a Tomcat server has the capability of an aggregation server (AS) to configure OpeNDAP products stored locally, remotely, or both. As more products become available on OpeNDAP (e.g., NCEP daily reanalysis data from <http://www.cdc.noaa.gov/>, GFDL assimilation model output from <http://nomads.gfdl.noaa.gov/>, and ECCO's assimilation model output from <http://ecco.jpl.nasa.gov/>), the AS at the APDRC makes their access easier and user friendly. The AS can also combine remote and local data into a dynamic distributed-data storage system (an intelligent distributed-data system): client access feedback adjusts data configuration, increasing access speed while keeping local storage at a minimum. The APDRC and Frontier in Japan are working on this capability and doing benchmark testing in order to manage and serve large sets of model- and satellite-derived products emerging from the Earth Simulator activities.

Third, the GrADS DODS (a.k.a. GDS) server, also a servlet type OpeNDAP server, allows different file types to be configured on the server. Any file that GrADS can access may be configured into OpeNDAP, avoiding the conversion of other formats to netCDF (binary to netCDF, GRIB to netCDF, as examples). Another advantage of GDS is its ability to serve large products, such as those from the Earth Simulator. Current GDS model output files are 13 Gb.

The Live Access Server, LAS, at the APDRC is a flexible interface between user and data servers; all datasets on the OpeNDAP server can be accessed with LAS. Our server also supports Ferret and GrADS (two common applications), as well as IDL, Matlab, Fortran, C, Java, and others.

New International Center for Climate and Society

Lorenz Magaard, Executive Associate Director of the IPRC, has received approval for his proposed International Center for Climate and Society within the School of Ocean and Earth Science Technology (SOEST) at the University of Hawai'i at Mānoa, and has been appointed the center's director. The mission of this sister center of the IPRC is to develop improved methods of utilizing economic innovation to mitigate and adapt to climate fluctuations and climate change. The idea of the center grew out of a project of **Lorenz Magaard, Wolf Dieter Grossmann,** and **Hans v. Storch,** described in *IPRC Climate*, 2, No. 1, p.12. The premise for the center is that the New Information and Communication Technologies are turning our society into an "information society" with a "new economy" characterized by "globalization." These technologies are eliminating ever more jobs in the mature industry, which uses energy and materials as its main resources. At the same time, across the globe, new companies are being founded that use information as their prime resource. The mature industry is thus being transformed by advanced information and communication technologies for gathering information, producing and distributing parts, products, and services. Examples of new information-based industries are seen in multimedia industries, cellular phone networks, genomics, and the health-products industry.

The transformation of mature industries and the rapid emergence of a new, information-based economy provide a unique opportunity for dealing with environmental problems arising from climate change. The challenge is to learn what societal adjustments to make based on this new economy in order to decrease present and future environmental problems. Making such adjustments while the economic restructuring and new developments are underway may allow certain environmental problems to be solved at little additional cost, and sometimes with gain.

Magaard and his group have completed a study in which they used a systems model to test policies that capitalize on the new economy in order to help mitigate and adapt to climate fluctuations and climate change. They found several instances in which such policies enhanced economic growth and at the same time solved problems of climate change. The outcome of this study is promising. It will be much more difficult, however, to make societal

adjustments once this economic metamorphosis has been completed. In other words, there is a rather small window of opportunity and that window is *now*.

During his recent visit to the IPRC, Grossmann (UFZ Center for Environmental Research, Leipzig/Halle, Germany) gave examples of how such restructuring can be made cost effectively in industries that are most related to greenhouse gas emissions, namely, power plants, housing, transportation, and forestry. Speaking on "Using Economic Innovation for Mitigation of Global Climate Change," Grossmann presented ways to reduce greenhouse gases in a cost effective manner by replacing the existing infrastructure with new technologies at the most strategic time in the life cycle of each industry. The group now plans to calculate both the cost effectiveness and the reduction in greenhouse gas emissions expected from present large-scale economic restructuring.

The center will conduct basic research to study the options and the costs and benefits associated with certain societal adjustments that make use of the information-based economy. A dynamical systems approach (e.g., Katok and Hasselblatt, 1995) will be used in this research to model interactions among the economy, environment, human knowledge, human attitude, and climate parameters. Moreover, the center will conduct applied research on a) managing natural resources such as energy, fisheries, coral reefs, and tropical forests; b) managing environmental risks; and c) developing policies for decision makers in government and in the private sector. The center will also take part in graduate education programs within SOEST.



Core members of the center, from left: Wolf Dieter Grossmann, James Marsh, and Lorenz Magaard.



IPRC Director **Julian McCreary** was selected a Fellow of the American Meteorological Society (AMS) at the society's last annual meeting, held February 9-13, 2003, in Long Beach, California. The AMS bestows this prestigious, life-long title on only a small number of its approximately 11,000 members worldwide.

McCreary received the honor for his outstanding research contributions toward understanding the dynamics of the upper ocean and its influence on atmospheric circulation and climate. Active in the AMS for many years, McCreary was awarded the Sverdrup Medal by the AMS in 1996 for his research on the ocean dynamics of El Niño, the Equatorial Undercurrent, and the eastern boundary currents. He received the Editor's Award in 1981 for "providing observative, constructive, and thought-provoking reviews on numerous manuscripts submitted to the *Journal of Physical Oceanography*." He served as an editor and then senior editor of this journal from 1996 to 1999.



Tommy Jensen, oceanographer and associate researcher at IPRC, has recently been appointed editor of the *Journal of Climate*. He is replacing Mojib Latif in this capacity. Jensen has been an associate editor of the journal since February 2001. His editorial assistant will be Summer Silva. For more information see

<http://www.ametsoc.org/AMS/pubs/jnl/index.html>.



Takuji Waseda, Frontier researcher at the IPRC, received the Outstanding Research Scientists Award of the Frontier Research System for Global Change during Frontier's symposium in Tokyo, March 2003. He received the award for his research on Kuroshio meander formation arising from eddy-Kuroshio interaction.

IPRC bids Sayonara

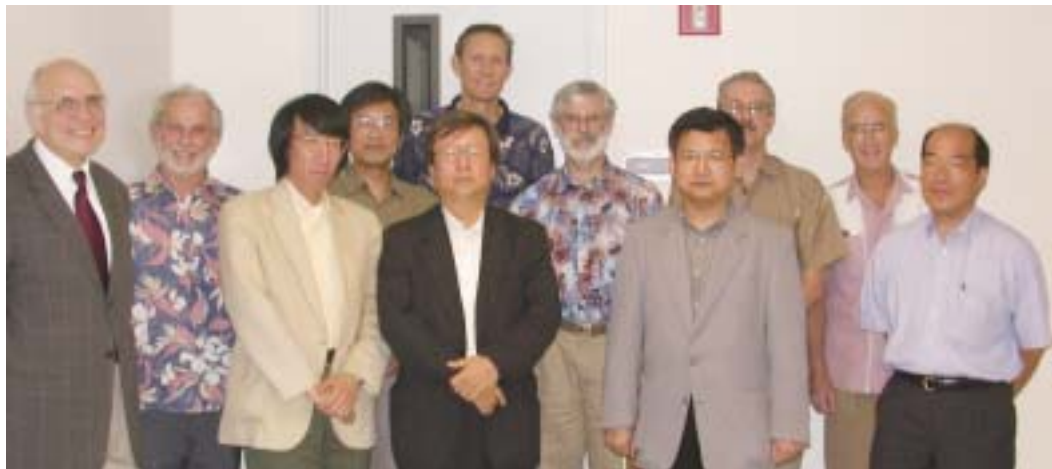
Humio Mitsudera, IPRC Theme 2 Leader, has taken a professorship at the Institute of Low Temperature Science at Hokkaido University. He joined the IPRC as a Frontier scientist in December 1997, shortly after the founding of the IPRC. During those early days, he recalls, the most exciting work was the discovery, with Takuji Waseda, of a new mechanism by which a Kuroshio meander can form. His recent work has been on the dynamics of the Kuroshio-Oyashio confluence, which shows that the water from the Sea of Okhotsk is very important for Oyashio's southward intrusion and for the formation of the Mixed Water Region. Mitsudera was also a driving force behind the establishment of the Asia-Pacific Data-Research Center, serving as chair of its data committee (p. 18). At Hokkaido University, Mitsudera will focus on numerical modeling of the subarctic ocean including the Okhotsk Sea and the North Pacific. He is also keen to study the Antarctic Circumpolar Current, the largest current in the world.

Masami Nonaka, a Frontier researcher at the IPRC since 1999, has transferred back to Japan, to Frontier headquarters at Yokohama. While at the IPRC, he conducted research on the role of the subtropical cells, the shallow north-south overturning circulation connecting the midlatitudes and the equatorial Pacific Ocean (*IPRC Climate*, 1, Spring). Recently, he studied the effects of the Kuroshio and the Kuroshio Extension on winds (*IPRC Climate*, 2, No. 2). At Yokohama, he will continue to investigate these effects, using the solutions of a high-resolution ocean GCM that is being run on the Earth Simulator.

Hyoun-Woo Kang, who worked as a postdoctoral fellow with Tangdong Qu and Humio Mitsudera on the "Low Latitude Western Boundary Currents in the Pacific" project, has taken a research position at the Korea Ocean Research and Development Institute (KORDI). He will be studying long-term changes in the Japan Sea circulation using the Indo-Pacific ocean model that he developed at the IPRC based on the Princeton Ocean Model. He will also take part in KORDI studies on coastal processes and the Indo-Pacific Ocean.

Scientific Advisory Committee Meeting

Honolulu, December 11-12, 2002



From left to right: Roberto Mechoso (M), Gary Meyers (M), Atsushi Kubokawa (M), Akio Kitoh (M), Yong-Hwan Yoon (Co-Chair), Gerry Meehl (M), Julian McCreary, Eiichi Muto, Antonio Busalacchi (Co-Chair), Lorenz Magaard, and Saichiro Yoshimura. (M = committee member)

Implementation Committee Meeting

Honolulu, February 18, 2003

From left to right, back row: Julian McCreary, Eric Lindstrom (Co-Chair), Chigusa Hanaoka, (Co-Chair), Toshiyuki Awaji, Eiichi Muto, Lorenz Magaard, and Barry Raleigh. Front row : Takafumi Shimizu (M), Tetsuya Sato, Maiko Taniguchi (M), Sonomi Sato, Hitoshi Hotta (M), and Saichiro Yoshimura. (M = committee member)



IPRC in the News

Kevin Hamilton and colleagues at Rutgers University and the NOAA Geophysical Fluid Dynamics Laboratory have been studying the effects of explosive volcanic eruptions on Earth's surface climate (*IPRC Climate*, 1, Fall). The first paper of this collaboration was recently published (G. Stenchikov et al., 2003: Arctic Oscillation Response to the 1991 Mount Pinatubo Eruption: Effects of Volcanic Aerosols and Ozone Depletion, *J. Geophys. Res.*, **107**, 4803-4818) and was the subject of a NASA press release: <http://earthobservatory.nasa.gov/Newsroom/NasaNews/2003/2003031211342.html>.

Kuroshio's surprising effect on winds, discovered by IPRC scientists **Shang-Ping Xie** and **Masami Nonaka** when they analyzed recent satellite data (*IPRC Climate*, 2, No. 2), was featured in a Frontier press conference held at MEXT on December 26, 2002. Articles appeared in several newspapers following the press conference, among them Japan's *Mainichi Shimbun* and *Science News* and China's *Science and Technology Daily*.

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