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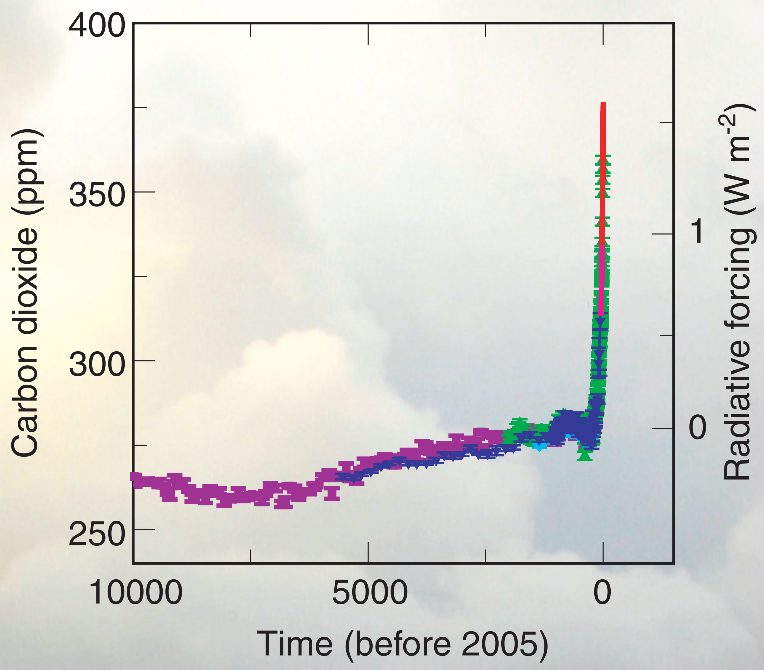
Newsletter of the International Pacific Research Center

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



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Above: The tall mountains of Hawaii are critical for cloud formation and rain over the islands. The coarse global climate models do not see these mountains and project less rains for Hawaii in a warmer Earth (see p. 7).

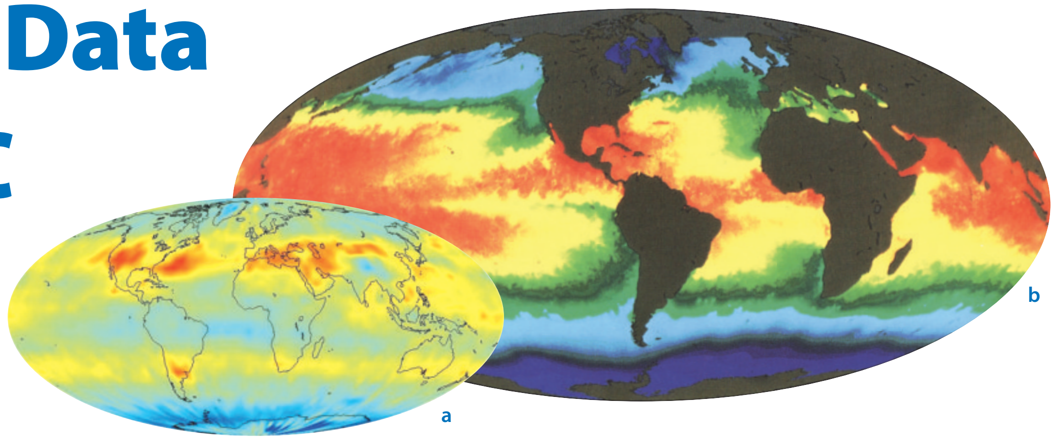
The research section of this *IPRC Climate* issue focuses on analyses by IPRC scientists of model simulations conducted for the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change. The graph on the cover of the atmospheric CO_2 concentration is adapted from the AR4 report.

Research

Meetings

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

Analyses of IPCC Climate Model Data at IPRC



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a) AIRS Global Map of Carbon Dioxide from Space. Credit: NASA/JPL

b) Global Sea Surface Temperature. Credit: MODIS Ocean Group, NASA GSFC, and the University of Miami

by Kevin Hamilton

The Intergovernmental Panel on Climate Change (IPCC) provides authoritative reviews of the state of climate science for national governments throughout the world. A key aspect of its work has been the production of major assessment reports in 1990, 1995, 2001, and now in 2007, the Fourth Assessment Report or AR4. Each of the IPCC reports has included assessment of comprehensive global climate models (GCM) representing the state-of-the-art at the time of the report.

The authors of the latest report developed the GCM-evaluation activity into a more systematic and comprehensive project. Scientists at 17 major climate modeling centers throughout the world ran a series of extensive integrations with their different models under various standard, prescribed climate scenarios. The massive outputs were archived by Lawrence Livermore National Laboratory and made available to the scientific community for analysis beginning December 2004. The expectation was that many resulting studies would be peer-reviewed and published in time for their inclusion in the AR4.

The National Science Foundation, the Department of Energy, and the National Oceanic and Atmospheric Administration (NOAA) jointly created the Climate Model Evaluation Project (CMEP) to fund US investigators to analyze the models in the AR4. IPRC Associate Researcher **H. Annamalai** and I were supported under the CMEP program. CMEP also funded a major workshop for scientists to discuss their preliminary analyses of the AR4 GCM data. The IPRC hosted this workshop, which attracted over 100 submissions from around the world, in March 2005 at the East-West Center (see *IPRC Climate* Vol. 5, No. 1).

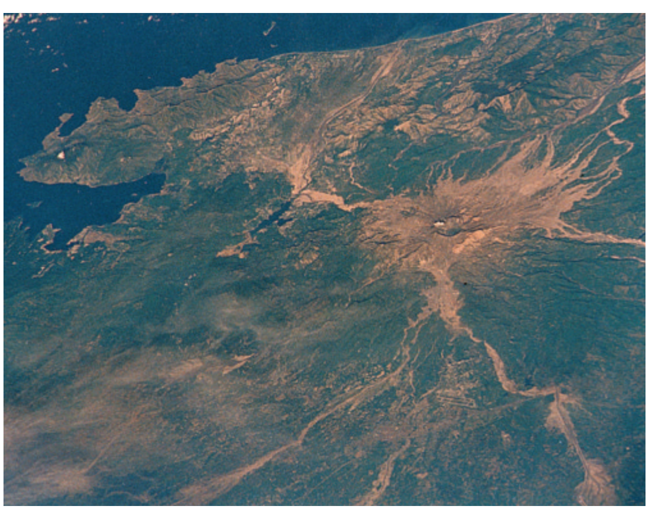
The Lawrence Livermore archive is a remarkable resource for many kinds of climate studies and will remain so long after the publication of the AR4. In fact, the continuation of the data archive is now under the auspices of a new World Climate Research Programme (WCRP) project, the Coupled Model Intercomparison Project-3 (CMIP3; Meehl et al. 2007).

The complete set of AR4 model scenarios are listed at http://www-pcmdi.llnl.gov/ipcc/standard_output.html#Experiments sets of integrations are particularly noteworthy: In the (1) *pre-industrial control* simulations, aspects of the atmospheric composition (long-lived greenhouse gases and tropospheric aerosols) are fixed at values existing in 1850 and are then integrated for several hundred years. The end results are then used as initial conditions for the (2) climate of the *20th century* simulations, in which the evolving natural and anthropogenic variations in atmospheric composition (greenhouse gases and tropospheric and stratospheric aerosols) are imposed. These simulations end with the year 2000, and the end results are then used as initial conditions for various future climate projection runs. One particular scenario is the (3) 1% annual increase to *CO_2 doubling* run, in which long-lived greenhouse gases remain fixed at current values except for the CO_2 concentration, which increases by 1% per year until 2072, when CO_2 values will have doubled. After CO_2 doubling has been reached, the models are then run without further increase for another 150 years to determine the equilibrium response to the doubling. The (4) *SRES A1B* scenario integrations are the same as (3) except that projected changes are imposed throughout the 21st century in concentrations of various forcing agents in addition to CO_2, namely, methane, nitrous oxide and tropospheric aerosols.

IPRC scientists have embraced the opportunities opened up by the AR4 model simulation data. Here I briefly review three different studies I have undertaken with various collaborators using these data. In companion articles, Annamalai discusses several studies using the AR4/CMIP3 data that have focused on monsoon variability, and IPRC Theme Leader **Shang-Ping Xie** and **Simon de Szoeke**, **Ingo Richter**, and **N.H. Saji** describe their analyses of tropical Atlantic, Pacific, and Indian Ocean climates as simulated in the AR4 models.

Climate Response to Volcanic Eruptions

Large explosive volcanic eruptions inject great quantities of sulfur into the stratosphere that rapidly forms sulfuric acid droplets. These aerosol droplets reflect radiation in the visible spectrum and absorb infrared radiation. Such an aerosol has a lifetime of about 2 years, and the direct perturbation to the global-mean radiative balance can be as large as



Mt Pinatubo. Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio

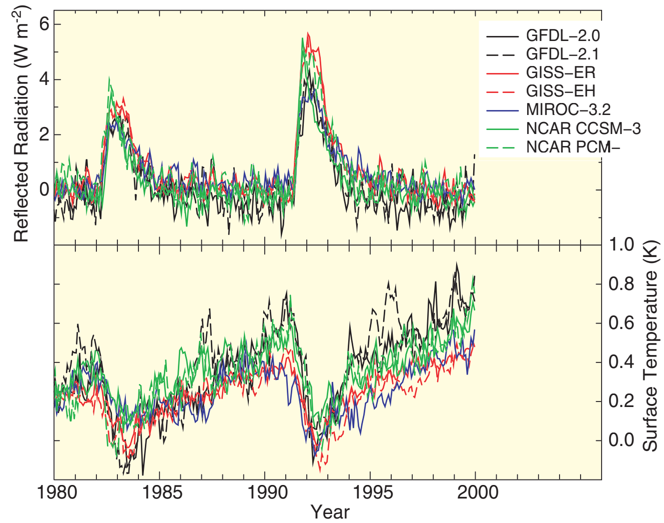


Figure 1. The top panel shows anomalies in the global-mean reflected sunlight at the top-of-atmosphere for seven different models in the 1980–1999 years of their *20th century* integrations. The anomaly is defined as the deviation from the 1880–1999 mean annual cycle. The bottom panel shows the same analysis but for anomalies in global-mean surface air temperature. In both panels each curve represents an average over several realizations for an individual model.

5 W/m^2 (i.e., comparable in magnitude to that expected from a doubling of atmospheric CO_2 content) for large historical eruptions such as Krakatau (1883) and Pinatubo (1991). Volcanic eruptions provide a unique opportunity to observe the response of the climate system to global-scale and fairly long-lived climate forcing.

I collaborated with **Georgiy Stenchikov** (Rutgers University) and other colleagues at Rutgers, the NOAA Geophysical Fluid Dynamics Laboratory, Lawrence Livermore National Laboratory, and Cambridge University Geography Department in a study of the effects of the stratospheric aerosol in the AR4 *20th century* integrations. We identified 7 models that had included a realistic time-varying stratospheric volcanic aerosol field as part of the climate forcing imposed in the *20th century* runs (many of the models in the AR4 unfortunately did not include volcanic aerosol in their historical runs). The time series of simulated global-mean top-of-atmosphere reflected sunlight and global-mean surface-air temperature are displayed in Figure 1 for periods that include the eruptions of El Chichon (1982) and Pinatubo (1991). Each of the models shows increased reflected sunlight and a drop in global-mean surface temperature for roughly 2 years after each eruption. In each model, the post-volcanic surface cooling interrupts an overall warming trend driven by the

increasing greenhouse gas concentrations in the 20th *century* runs.

The focus of our collaborative project was on the geographical distribution of the response to volcanic forcing during Northern Hemisphere winter. Despite the global-mean cooling effect of the aerosol, observations show a tendency for the Arctic Oscillation to be anomalously positive in the first two post-eruption winters, resulting in warmer-than-normal surface temperatures over much of northern Europe and northern Asia. One explanation is that the stratospheric mean flow is significantly affected by the radiative effects of the aerosols (notably the winter stratospheric polar vortex strengthens in the post-volcanic period), and this in turn modifies the structure of large-scale, topographically forced stationary waves in the winter hemisphere. Our earlier studies have shown that this mechanism seems to operate in a realistic manner in the GFDL SKYHI global atmospheric GCM, a model with good resolution in the stratosphere and mesosphere (e.g., Stenchikov and colleagues, 2004).

In the present study we investigated how well the 7 AR4 models that included volcanic aerosol reproduce the observed response in Northern Hemisphere winter. The left panel in Figure 2 shows the anomalies in the surface temperature averaged over a large region of northern Eurasia and over December–February in the two years following the seven strongest low-latitude eruptions during 1880–2000. (Anomaly in this case is defined as the deviation from the decadal mean before the eruption.) These model results are compared with observations during the same period. The right panel shows a measure of the observed strength of the stratospheric polar vortex, namely the 50 hPa geopotential height near the North Pole, averaged over December–February in the two years following the strong low-latitude eruptions (only for the period after 1958 because reliable stratospheric observations were unavailable before 1958).

The results are rather disappointing: none of the models simulates a response in either the polar vortex strength or the Eurasian surface temperatures that is anywhere close to observations. In fact, three of the models actually simulate cooling in the Eurasian region and two simulate a weakening of the polar vortex. It is noteworthy that the model showing the largest stratospheric response (the GFDL version 2.0 model) also shows the most realistic Eurasian warming. However, even in this "best" model, the strength of response to the volcanic forcing is only about 1/3 of that observed. Given the success of the GFDL SKYHI model mentioned earlier, the failure of the AR4 models may be due to inadequate resolution of the stratosphere. If correct, this explanation has far-reaching implications: it suggests that successfully simulating the trend in the Arctic Oscillation in climate-change projections will require models with substantial resolution in the stratosphere.

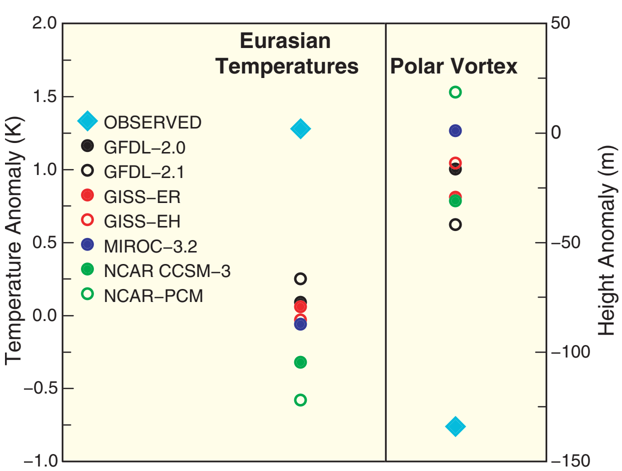


Figure 2. The left panel shows results for the surface air temperature anomaly averaged over 30°E–130°E, 45°N–70°N, and over the two December-February periods following the seven major eruptions observed during 1880–1999. Results are presented for the 20th *century* simulations in seven different AR4 models and for that computed from a global observational analysis. The anomalies are defined as deviations from an average of about 10 years before each eruption. The right panel shows results of a similar analysis, but for the height of the 50 hPa surface averaged over 65°N–90°N. In this case results only after 1958 are used due to limitations in the available observations at this level.

I am continuing analysis of the climate response to the volcanic perturbations in the *20th century* runs, with a focus on the global-mean surface temperature response. The observed change in global-mean surface temperatures following eruptions is often regarded as the strongest available constraint on the actual equilibrium sensitivity of the climate to sustained anthropogenic forcing. The issue of how strongly the volcanic response does actually constrain global climate sensitivity will be addressed by comparing AR4 model results in which the volcanic response simulated in the *20th century* runs with results in which the equilibrium response is simulated in the extended *CO_2 doubling* runs. This new analysis will be conducted in light of results from a more idealized study of the global-mean response to transient "volcano-like" perturbations that I recently completed in collaboration with **George Boer** (Canadian Center for Climate Modelling and Analysis) and IPRC postdoctoral fellow **Markus Stowasser** (Boer et al., 2007).

Cloud Feedback in a Changing Atmosphere

A critical component in determining the response of the climate system to such large-scale perturbations as increasing greenhouse gas concentrations is anticipating the feedbacks in cloud fields. State-of-the-art GCMs differ widely in their global climate sensitivity largely because they differ in the nature of their cloud feedbacks. A study of the response of cloud fields and feedbacks to climate change in the different models should yield insights concerning how realistic the model predictions are. One possible approach is to look at how cloud fields vary as a function of natural variations in the large-scale meteorological fields.

In collaboration with Stowasser, I analyzed the *20th century* runs of 12 of the AR4 models to determine the interannual variability of the monthly means of such meteorological fields as mid-tropospheric vertical velocity and their relationship to local monthly-mean shortwave cloud radiative forcing (i.e., the actual net top-of-atmosphere flux minus the flux computed under cloudless conditions). For each model, we used five years of integration to calculate the climatological mean of the mid-tropospheric vertical velocity at each gridpoint. We then computed the monthly deviations from these means at each gridpoint to determine the monthly vertical velocity anomalies of each model. The top panel of Figure 3 shows the distribution of the climatological mid-tropospheric vertical velocity (omega field at 500 hPa) for all the ocean

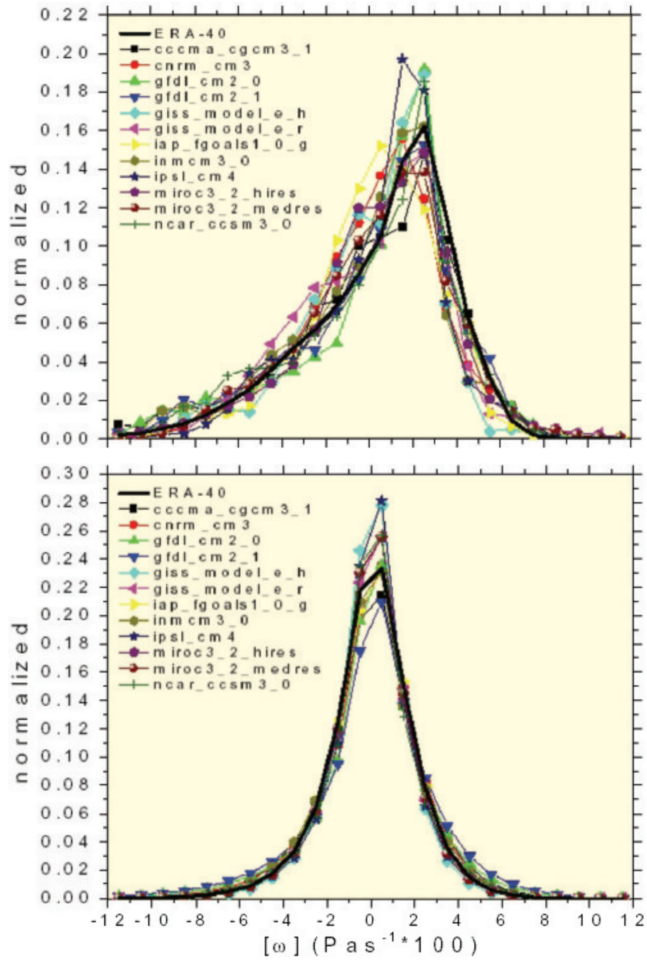


Figure 3. The top panel shows the distribution of individual gridpoint values of the long-term mean 500 hPa omega vertical velocity. Results presented for all ocean gridpoints between 30°S and 30°N. Results for 12 of the AR4 models are compared along with observations based on ERA40 reanalyses. The bottom panel shows the distribution of individual monthly values of the anomaly in the 500 hPa omega vertical velocity for the same collection of gridpoints.

gridpoints between 30°S and 30°N in each of the 12 models and in observations as represented by the ECMWF ERA40 reanalyses. The lower panel shows all the monthly anomalies in the 500 hPa omega field. The models agree reasonably well with the observations on the overall amount of geographical and interannual variability of the monthly mean vertical velocity field for the regions considered here (i.e., tropical and subtropical ocean areas).

The top-of-the-atmosphere mean shortwave cloud forcing for each model was also computed for the 5-year period at each gridpoint, and from these, the monthly deviations from the "climatological" means. The resulting data then represents the monthly deviations in cloud forcing at

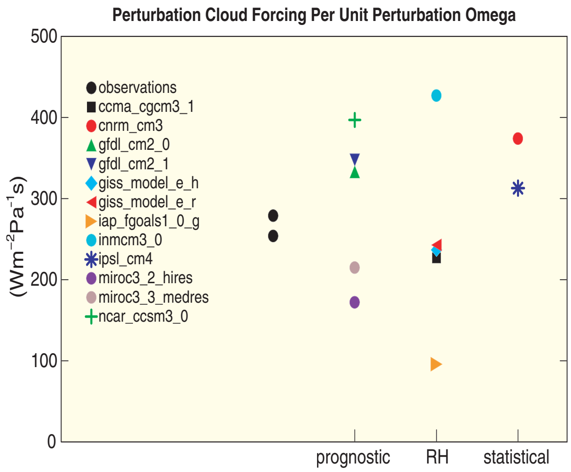


Figure 4. The response of the monthly-mean cloud forcing to interannual fluctuations in grid-scale vertical velocity as simulated in 12 AR4 models, and compared with two observational estimates (one based on ERA40 and one on NCEP reanalyses). The model results are grouped according to the overall nature of the scheme used to compute the cloud amounts. See text for details.

each gridpoint as a function of both the mean vertical velocity and the anomalous vertical velocity. We then fitted a polynomial equation to the data to get a smooth function representing the anomalies in cloud forcing as a function of the mean and the anomaly vertical velocity fields. Figure 4 shows the most revealing aspect of this fit: the rate of change in shortwave cloud radiative forcing as a function of anomalies in the monthly-mean vertical velocity field. Results for all 12 models and 2 observational estimates are presented. In both the observations and all the models, this function is a positive number, indicating that as omega becomes larger (i.e., downward motion increases), the shortwave cloud forcing becomes more positive (i.e., cloud cover shrinks). The models display a four-fold range in the magnitude of this feedback, however, and scatter to both higher and lower values than the observations.

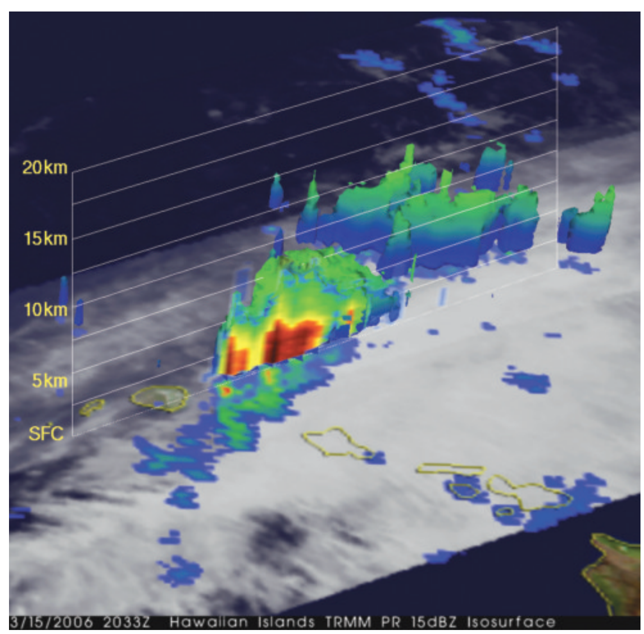
In an attempt to make sense of the scatter among models, we grouped the results by the overall nature of the cloud schemes used in the models. The 5 models that have a simple diagnostic determination of cloud amounts and use the grid-scale relative humidity are grouped as "RH" in Figure 4. The models with a more complicated prognostic scheme for cloud amounts are grouped as *prognostic*, while the two remaining models with other schemes are labeled as *statistical*. The feedback strength, however, seems unsystematically related to the type of cloud scheme used.

We repeated the analysis using the 850 hPa monthly-mean relative humidity as the meteorological variable (not shown). Once again this revealed a wide range among the models in the strength of the cloud feedbacks. Unfortunately some of the models that agree best with observations on the cloud response to vertical velocity do poorly in a similar comparison of the cloud response to relative humidity variations (not shown).

Detailed results of this study can be found in Stowasser and Hamilton (2006).

Climate Change in Hawai'i

A major limitation of the IPCC assessments has been the horizontal resolution of the models. Limitations of computational power have meant that most very long GCM climate forecast integrations have been performed with atmospheric component models that have horizontal grid spacings of ~200 to 500 km. Such low resolution prevents the representation of many aspects of the atmospheric circulation. This problem is particularly acute for Hawai'i. Hawaiian weather is strongly affected by the steep mountains. The typical models in the AR4 might represent all the Hawaiian Islands as a single land grid box or even ignore Hawai'i entirely!



This snapshot of rain rates in one of the disturbances affecting Hawaii in February - March, 2006, was created from instruments on the TRMM satellite. The 3-D perspective helps scientists understand the relationship between the storm structure and the amount of rain unleashed. Towering clouds produce the most rain. Image credit: Hal Pierce (SSAI/NASA GSFC)

The Climate Research Department of the Japan Meteorological Agency's Meteorological Research Institute (MRI) performed the standard set of AR4 runs with a version of their coupled ocean–atmosphere model at spectral horizontal resolution T42 (corresponding to a grid spacing of about 400 km). In addition, the MRI group conducted two special 10-year integrations of their atmospheric model run at much higher resolution (T959, corresponding to grid spacing of about 20 km). The sea surface temperatures (SSTs) used as boundary conditions for this high-resolution run were based on the late 20th century of the *20th century* T42 coupled model run and the late 21st century of the T42 *SRES A1B* run. These two T959 integrations provide, for the first time, a global warming forecast with a model that has a somewhat realistic representation of the coastlines and topography of the main Hawaiian Islands. **Akira Noda** and other scientists at MRI kindly provided a subset of the data for the Hawaiian region from their late 20th and late 21st century T959 experiments. I am now investigating the global warming signal in temperature, rainfall, and wind in these runs.

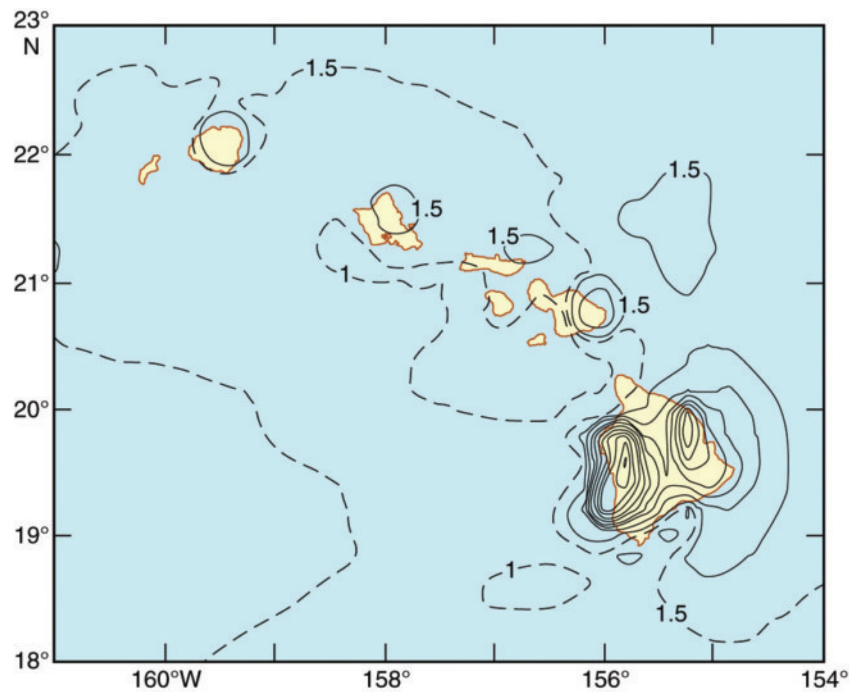


Figure 6. The annual mean rainfall in the Hawaiian region averaged over the 10 years of the late 20th century run of the MRI T959 global model. Contours are labeled in mm/day, and are shown at 1, 1.5, 2, 3, ...12 mm/day.

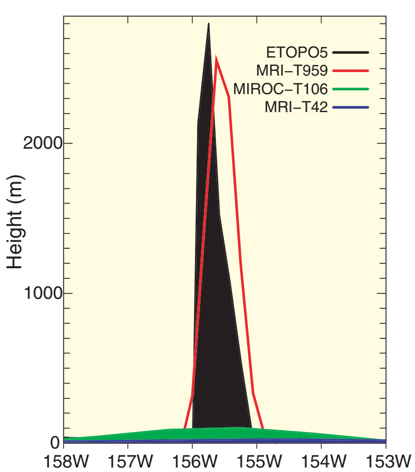


Figure 5. Profile of the topography in an east–west section through the Big Island of Hawai'i at the latitude of the island's highest elevation. Results are shown for the ETOP05 observational data set, for the T959 and T42 versions of the MRI global model, and for the T106 version of the MIROC model.

Figure 5 compares the topography in the high-resolution MRI version with that in the standard version and that in the University of Tokyo/JAMSTEC MIROC T106 model (which was the highest resolution coupled ocean–atmosphere model used in the AR4 runs). Shown is the east-west transect of the topography through the Big Island of Hawai'i at the latitude that passes through the highest elevation for each model, as well as a transect from an observed data set at 5-minute (~6 km) resolution. The T42 and T106 models treat the Big Island as just an extensive, smooth, low bump in Earth's topography, while the high-resolution MRI version comes closer to a realistic representation of the actual topographic profile. Of course, even 20-km grids are too coarse to adequately represent the meteorologically significant details of the topography, a failing that is even more pronounced on Oahu, Maui and Kauai.

The AR4 coupled models all simulate relatively weak rainfall over Hawai'i because the islands are located in what is effectively a desert region dominated by large-scale atmospheric descent. Most of the rainfall over the islands actually results from orographic lifting of warm, moist air that condenses, a process that for Hawai'i is nearly absent from the standard resolution versions of the AR4 models. As Figure 6 shows, the high-resolution *20th century* MRI version run does capture the basic feature of more rainfall over land than

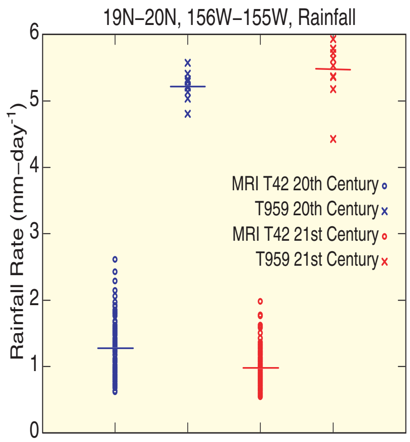


Figure 7. Yearly-mean values of rainfall in the box 19°N–20°N, 155°W-156°W which includes mainly the land areas of the Big Island. Results for 100 years of integration with the T42 MRI model (circles) and for 10 years with the T959 version (crosses), and for the late *20th century* (blue) and for the predicted results for late 21st century assuming the *SRES A1B* scenario of climate forcing (red).

over the ocean and reproduces even such detailed features of the observed rainfall pattern as the two distinct rainfall maxima on the east and west sides of the Big Island. The model also captures the observed seasonal cycle of Big Island rainfall, with a summer maximum on the west side and a winter maximum on the east side.

The left side of Figure 7 shows the annual mean rainfall for a region surrounding the Big Island from 100 individual years in the standard T42 MRI *20th century* run (specifically the years 1980-1999 in 5 different realizations) and from 10 individual years in the high-resolution run. The high-resolution version has a rainfall rate for this region that is almost 5 times that of the coarser version. The right side of Figure 7 shows the yearly rainfall for the end of the 21st century in the T42 MRI model *SRES A1B* runs and for the 10-year high-resolution SRES A1B version run. The T42 model predicts that average rainfall will decrease by 20% in the late 21st century. Such a reduction would seriously hurt water resources in Hawai'i. The high-resolution version, however, predicts a modest increase in rainfall.

The decreased rainfall in the standard version is mainly due to greater stability in the lower atmosphere, which many global warming projections show, and which in this case suppresses the convective rainfall. The high-resolution model also shows greater atmospheric stability and suppressed convective rainfall in the 21st century, but the model also has orographic rainfall. The orographic rainfall can be affected by changes in wind patterns, stability, etc. In this instance, it seems to be mostly affected by increased absolute humidity in the lower troposphere in the late 21st century run, an increase corresponding to the ~2.5°C rise in the model's air temperature. This leads to an increase in orographic rainfall that is somewhat larger than the decrease in the convective rainfall. These results demonstrate that the standard resolution models in the AR4 have little to tell us directly about global warming effects on Hawai'i rainfall. Some kind of downscaling of the coarse-resolution simulations is needed even for a first-order assessment of anticipated climate change on rainfall over the Hawaiian Islands.

I am continuing to use the MRI model results to investigate other interesting aspects of global warming in Hawai'i such as expected changes in extreme rainfall and wind events.

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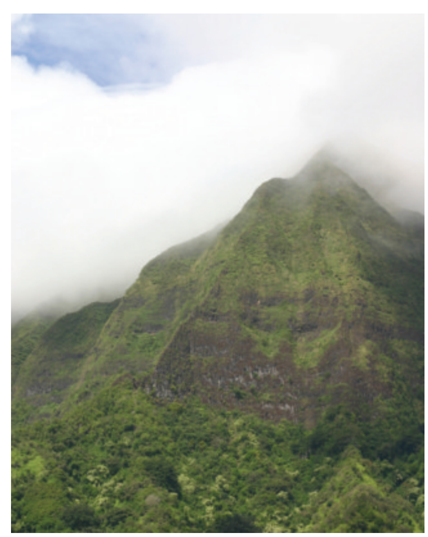


IPCC Climate Models and the Asian Summer Monsoon

by H. Annamalai

This article describes the ability of the coupled models in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change to simulate the mean monsoon rainfall and its variability. The monsoon is a coupled ocean-atmosphere-land phenomenon, and our trust in projections of how the monsoon will respond to overall warming depends on the ability of the coupled models to capture the present-day monsoon climate. The results summarized below stem from a series of collaborative projects I have conducted with IPRC scientists **Markus Stowasser** and **Kevin Hamilton**, and with **Ken Sperber** from the Program of Climate Model Diagnosis and Intercomparison at Lawrence Livermore National Laboratory.

Monsoon climatology and ENSO-monsoon association

Computer simulation of monsoon rainfall climatology has proven difficult and provides a severe test of climate models. A realistic representation of the basic monsoon climate state and its variability in models, however, is a pre-requisite for assessing projections of future monsoon climate in a global warming scenario. In the following project, I examined the success of the AR4 models in capturing the present-day mean monsoon precipitation and the El Niño–Southern Oscillation-monsoon relationship, and then selected those models that best captured present-day climate to study the monsoon response to warming.

For each model, a June–September rainfall climatology of the last 30-years from the *20th century* simulations was constructed and compared with observations. The observations (Figure 1 top panel) show that intense rainfall occurs

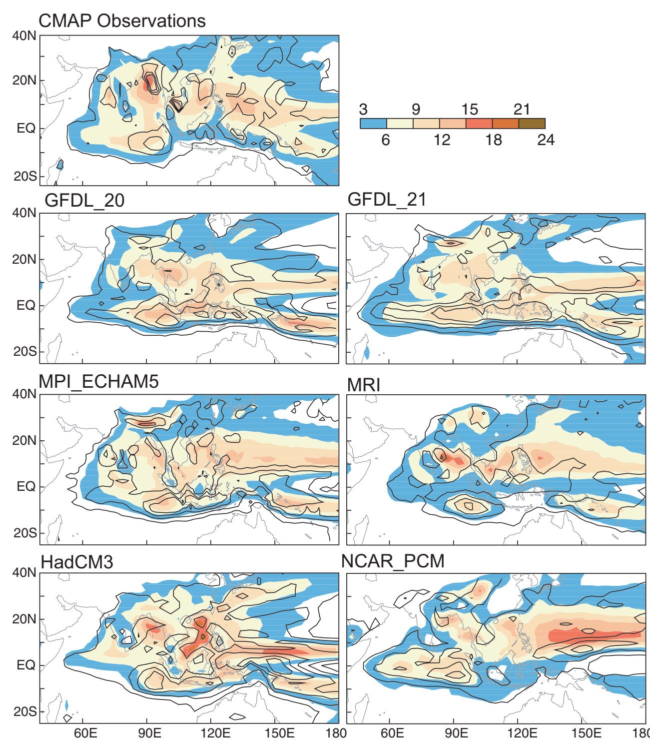


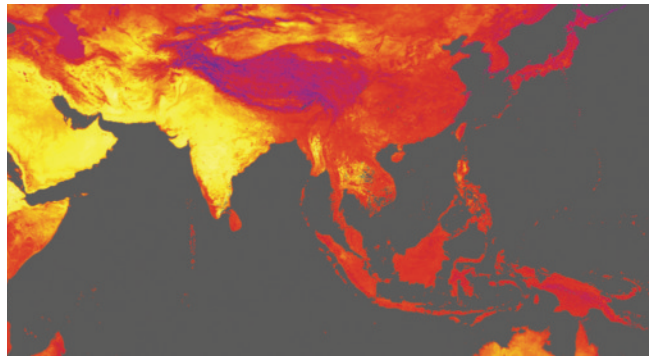
Figure 1: Precipitation climatology (color) and standard deviation (contours in 1.0 mm/day) are shown for CMAP observations and for the *20th century* integrations of the 6 models that have significant pattern correlations with observations.

over three regions in Asia, which represent (1) the Indian Summer Monsoon (ISM: 70°E–100°E, 10°N–25°N,) (2) the Western North Pacific Monsoon (WNPM: 110°E–150°E, 10°N–20°N), and (3) the eastern equatorial Indian Ocean (EEIO: 10°S–0, 90°E–110°E). Because these centers do not respond in unison to El Niño forcing and influence each other, a realistic representation of these three centers is needed if the models are to adequately reproduce the variability of the Indian monsoon.

To see how well the models represent the three major convection centers, we used their simulations of June–September rainfall climatology over both India (the all-India rainfall; 65–95°E, 7°N–30°N) and the larger monsoon domain (40–180°E, 25°S–40°N). Our selection metrics were based on the pattern correlations between simulated and observed rainfall estimates and their root mean square differences (RMSDs) for the period. These are shown in Figure 1, and reflect the “present status” of monsoon precipitation simulation by these state-of-the-art climate models. In only 6 out of the 18 models were the June–September rainfall simulations significantly correlated to observations at the 95% confidence level.

The Indian summer monsoon variability is known to be closely related to central-eastern Pacific sea surface temperature (SST) variations associated with the El Niño-Southern Oscillation (ENSO), with typically less rainfall during El Niño years. This suggests the mean monsoon and its interannual variability are predictable by charting the slowly varying Pacific Ocean conditions. If the relationship remains strong, there is hope that monsoon interannual fluctuations are at least somewhat predictable. The recently observed weakened ENSO-monsoon relationship, however, may be partly due to global warming, and if this relationship fails, then the leading predictor of monsoon variability will be lost. Thus, it becomes important to determine what will happen to the monsoon-ENSO relationship in the future.

For a realistic representation of this relationship, models must capture the ENSO characteristics apart from the mean monsoon precipitation. We examined, therefore, not only the space and time evolution of SST together with the associated precipitation anomalies along the equatorial Pacific, but also the resulting atmospheric circulation anomalies that link the tropical Pacific to the Asian monsoon domain. Out of the 6 models that had shown adequate skill in simulating the mean monsoon (Figure 1), only four were able to represent ENSO characteristics. Figure 2 shows the expected lead–lag relationship between NINO3.4 (120°W–170°W, 5°S–5°N) SST anomalies and all-India rainfall anomalies. We used NINO3.4 SST because the strongest observed negative correlations between all-India rainfall and SST occur over this region (figure not shown). For each of the four models, we first calculated the correlation for each realization, and then computed the ensemble-mean pattern.



Heatwave in Southern India. Credit: Land Surface Temperature data processing by Jesse Allen and provided by Zhengming Wan (UCSB SCF). Purple shades are near 0°C, red between 35°-45°C, yellow up to 50°C.

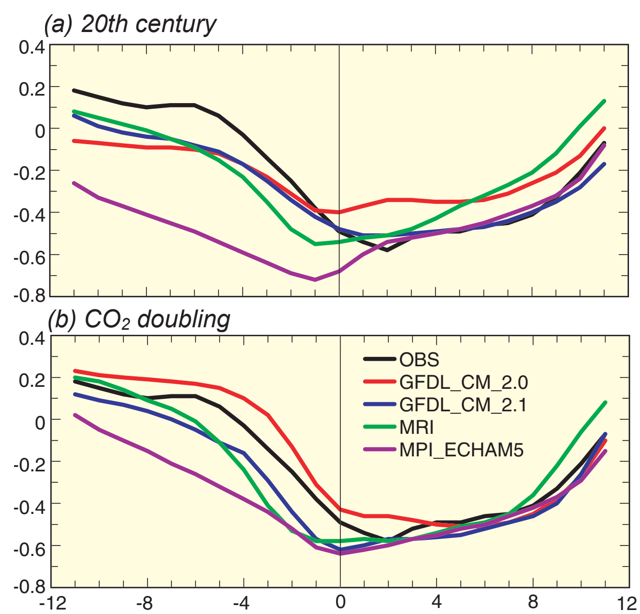


Figure 2: Lag/lead correlations between all-India rainfall anomalies and NINO3.4 SST anomalies, in which 0 on the x axis represents the peak monsoon season: *20th century* (panel a) and *CO_2 doubling* (panel b) simulations. Both panels include the present-day observed relationship. Negative correlations greater than r = –0.24 in magnitude are significant at the 5% level. Lag –12 corresponds to NINO3.4 SST anomalies one year before the monsoon season.

In observations, NINO3.4 SST and the all-India rainfall are negatively correlated (Figure 2a, black curve). In the 20^{th} *century* simulations, all four models capture this inverse relationship during boreal summer, but the maximum negative correlation occurs too early in the GFDL_CM_2.0, MRI, and MPI_ECHAM5 simulations. Three of the models represent reasonably the spring predictability barrier, seen as the near-zero correlations during the preceding winter and spring. Only the GFDL_CM_2.1 model, however, captures the overall timing between El Niño and the all-India rainfall correctly. The model's ability to resolve the timing is possibly related to the model's ability in simulating the space and time evolution of SST and associated diabatic heating anomalies during El Niño events.

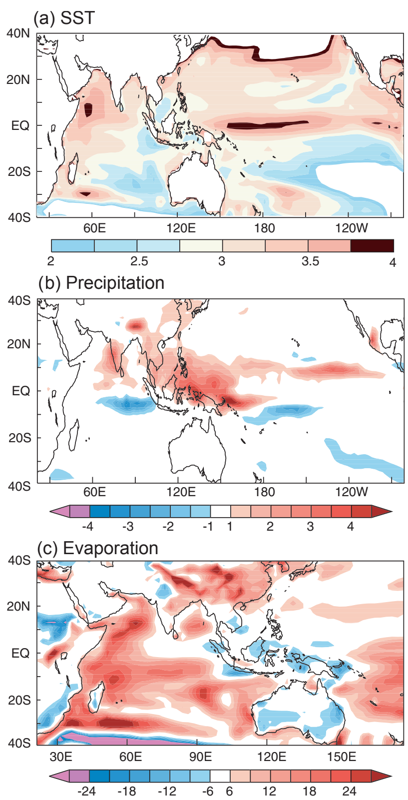


Figure 3: In the GFDL_CM_2.1, the seasonal mean (JJAS) climatology differences between the quadrupled CO_2 and 20^{th} *century* integrations: (a) SST (°C), (b) precipitation (mm/day), and (c) evaporation (in mm). Only statistically significant values for (b) are shown.

Analysis of the warming scenario in which CO_2 was increased from present values by 1% per year and compounded until doubled, the *CO_2 doubling* runs, shows that with warming the lack of predictability in spring becomes even more apparent, and that the negative correlations in GFDL_CM_2.0 and MRI persist for about 3–6 months after the monsoon season (Figure 2b). Overall, our results indicate that the ENSO-monsoon relationship remains strong and stable in a warmer climate, but as in present-day observations, waxes and wanes at decadal time scales.

More detailed results on this project are available in Annamalai et al. (2007).

Monsoon Response to Global Warming

Encouraged by the findings that the GFDL_CM_2.1 represents the mean monsoon and ENSO-monsoon relationship fairly well, Markus Stowasser and I examined in this model the response of the mean monsoon in the simulations with 4 times present-day CO_2 concentrations, the *quadrupled CO_2* runs. We tested the hypothesis that an increase in mid-tropospheric temperature and associated increase in moisture content provide additional potential for latent heat release during the build-up of low-pressure systems, thereby possibly intensifying monsoon depressions, the main rain-bearing systems over central India.

The seasonal-mean differences in precipitation, SST, and evaporation were calculated by subtracting the *quadrupled CO_2* climatology from the corresponding 20^{th} *century* climatology (see Figure 3; the corresponding circulation changes are shown in Figure 4). Notable features in the GFDL_CM_2.1 model during typical El Niño events are anomalous cold SST and less rainfall than usual in the western Pacific, but more rainfall together with low-level anomalous westerlies over central and eastern Pacific (140°W–120°W). With increased SST in the equatorial central Pacific one might expect permanent El Niño-like conditions in a warmer climate. The absence of these signatures in the *quadrupled CO_2* experiment, however, negates the notion of El Niño-like conditions.

Despite a rise of over 2°C in SST everywhere in the tropical Indo-Pacific, the model shows signifi-

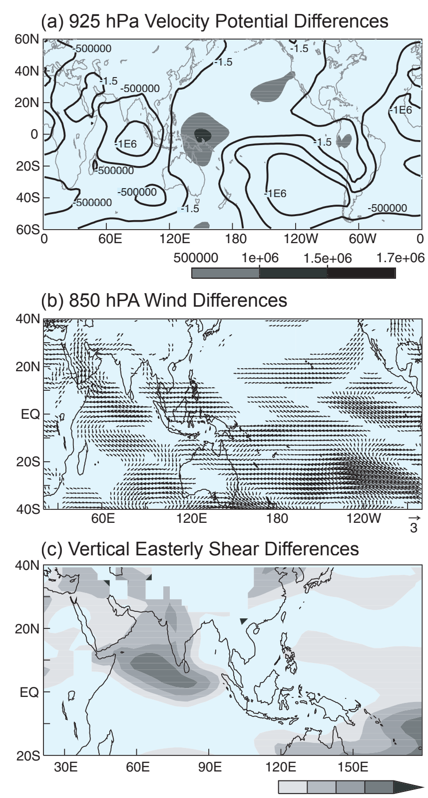


Figure 4: Same as Figure 3 but for: (a) 925 hPa velocity potential (in m²/s, (b) 850hPa wind (in m/s), and (c) vertical easterly shear.

cantly less rainfall over the equatorial Indian Ocean, and more rainfall over the peninsular parts of India, the western North Pacific monsoon region, and the equatorial west Pacific. In sharp contrast, at 850hPa the trades in the southern Indian Ocean and the cross-equatorial monsoon flow are weakened (Figure 4b). This paradox between increased monsoon rainfall and weakened circulation has been noted previously in climate-change experiments, but has not been explained to satisfaction. Here we provide a possible explanation based on (1) the equatorial wave-response to regional heat sources/sinks within the Asian summer monsoon region, and (2) the associated changes in SST that contribute to significantly more evaporation.

Our reasoning goes as follows: The increased precipitation over the equatorial western Pacific forces anomalous descending circulation over the eastern equatorial Indian Ocean, the two regions being connected by an over-turning circulation (Figure 4). The spatially well-organized anomalous precipitation over the eastern equatorial Indian Ocean forces twin anticyclones as a Rossby-wave response (Figure 4b). The southern component of the anticyclones opposes and weakens the climatological cross-equatorial monsoon flow, thereby limiting coastal upwelling along Somalia. As a result, the sea surface warms along the Somalian coast (Figure 3a) and evaporation becomes a local maximum over the southern Arabian Sea. That is, in addition to the increased CO_2-induced rise in temperature, evaporation, and atmospheric moisture, the local air-sea interaction further increases SST, evaporation, and atmospheric moisture (Figure 3c), leading to increased rainfall over India.

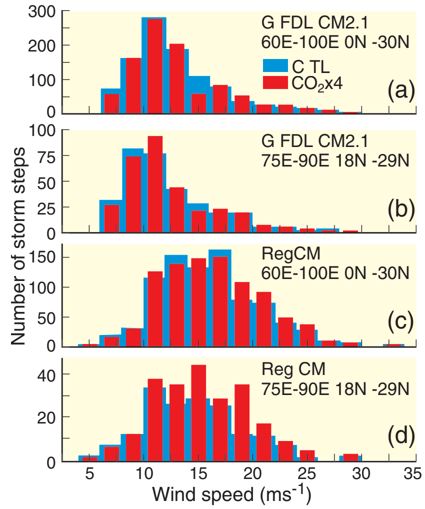


Figure 5: The frequency of the number of 12h-time-steps a system was in the domain is shown as a function of maximum wind speed for the entire northern Indian Ocean in panels (a) and (c), and only over the Bay of Bengal in panels (b) and (d): Results in (a) and (b) are from GFDL_CM_2.1, and (c) and (d) from IPRC–RegCM. Blue bars indicate the control runs and red bars the quadrupled $C0_2$ runs.

To understand the regional features of the rainfall changes, the IPRC Regional Climate Model (IPRC–RegCM) was integrated for 20 years, with lateral boundary conditions taken from the GFDL model *20th century* climate and from the *quadrupled* CO_2 runs. The IPRC–RegCM runs confirm the results obtained from the GFDL model and capture the orographic nature of monsoon precipitation realistically (not shown).

Will intense monsoon depressions become more frequent in a warmer climate? To detect and track synoptic systems in the model, we adapted the method developed by Stowasser et al. (2007) for tropical cyclones. Our criteria for selecting storms to track, however, were more relaxed than theirs because we wanted to track also weaker synoptic systems. Our criteria were as follows: (a) The local vorticity maximum at 850 hPa exceeds 5 x 10^{-5}/s; and (b) a local pressure minimum exists within a radius of 250 km of the vorticity maximum, the pressure minimum defining the center of the storm system. To be included in the storm trajectory, the model storm must last at least 2 days.

The monsoon synoptic systems thus identified were then analyzed as a function of maximum wind speed and as the number of 12-hour time-steps each system was present in the domain (see Figure 5). The results were prepared separately for the main storm genesis location in the Bay of Bengal and for a larger region encompassing both the Bay of Bengal and the Arabian Sea.

The frequency distributions of maximum storm speed for the *20th century* GFDL model runs (blue bars) over the larger domain (Figure 5a) and over only the Bay of Bengal (Figure 5b) are asymmetric. The distributions peak around 12 m/s, after which they fall off rapidly. The model simulates very few intense storms (wind speed > 15m/s). The IPRC–RegCM control runs (blue bars in Figure 5c and d), however, show a more realistic representation of the storm strength probability with a much higher wind-speed maximum and significantly more storms with wind speeds exceeding 15 m/s.

The storm frequency distributions in the GFDL *quadrupled* CO_2 run (red bars in Figure 5a and b) are similar to the *20th century* results, showing only a slight increase in the number of storms with wind speeds greater than 12 m/s. The number of 12-hour storm steps also increases slightly, from 979 in the *20th century* run to 1031 in the *quadrupled* CO_2 run.

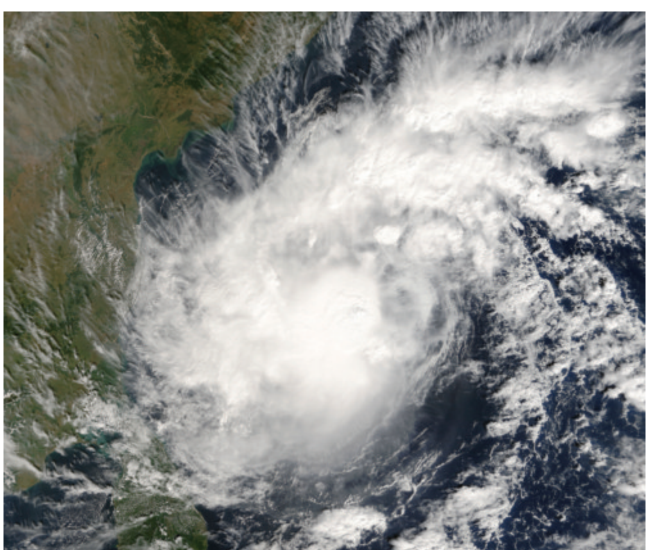
The storm frequency in the IPRC–RegCM *quadrupled CO_2* runs also increases only slightly from that in the control experiment when the Indian Ocean region between 60°E and 100°E and between the equator and 30°N is considered. The storm systems in the Bay of Bengal, however, show a pronounced increase in both frequency and intensity in the *quadrupled CO_2* run.

The results presented here support our hypothesis that in a warmer climate, additional moisture content intensifies monsoon depressions. The present-day coarse resolution climate models, however, are unable to detect such changes in the intensity of synoptic systems over the South Asian monsoon region, and experiments with very high-resolution regional models are needed to make projections of how storms there will change with warming.

More details on this project are available in Stowasser and Annamalai (2007).

Boreal Summer Intraseasonal Variability

The boreal summer intraseasonal variability associated with the 30-to-50-day cycle of wet and dry spells consists of three coexisting components: poleward propagation of convection over (1) India and (2) the tropical western Pacific and (3) eastward propagation along the equator. This complex pattern of convection results in regional heat sources and sinks; in particular, it produces a northwest–southeast tilted rainband thought to arise from a Kelvin–Rossby wave interaction. Thus, this summertime atmospheric circulation has a more complex structure than the wintertime Madden–Julian oscillation (MJO), and its analysis in climate model simulations has received less attention and has met with poorer results than the MJO. Ken Sperber spearheaded this project on diagnosing the ability of the AR4 models to capture this complex convection and rainfall system.



Tropical Cyclone 03B over India. Credit: Jeff Schmaltz, MODIS Rapid Response Team, NASA/GSFC

Recent published research shows there are many conditions that models must represent in order to simulate the summer MJO realistically, the most important being, (1) the three main centers of precipitation in the time-mean state (Figure 1) and their interaction; (2) the climatological easterly wind shear over the Indian Ocean and west Pacific in order to create an environment favorable for the emanation of Rossby waves; and (3) the eastward propagation of equatorial intraseasonal convective anomalies in order to generate the necessary heating for the northward propagation of convective anomalies.

Our results indicate that simulating the life cycle of this summer monsoon phenomenon is still difficult. Though most models exhibit eastward propagation of convective anomalies over the Indian Ocean, few have the eastward propagation extending into the western and central Pacific. Few models show statistically significant rainfall that represents the tilted convection. Our results indicate that correct simulation of the main heat sources and easterly wind shear is a necessary but insufficient condition for simulating the spacing and timing of the summer monsoon dry and wet spells.

Sperber and Annamalai (2007) provide more details on the study.

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IPCC Climate Models and Tropical Climates

by Simon de Szoeke, Ingo Richter, N. H. Saji, and Shang-Ping Xie

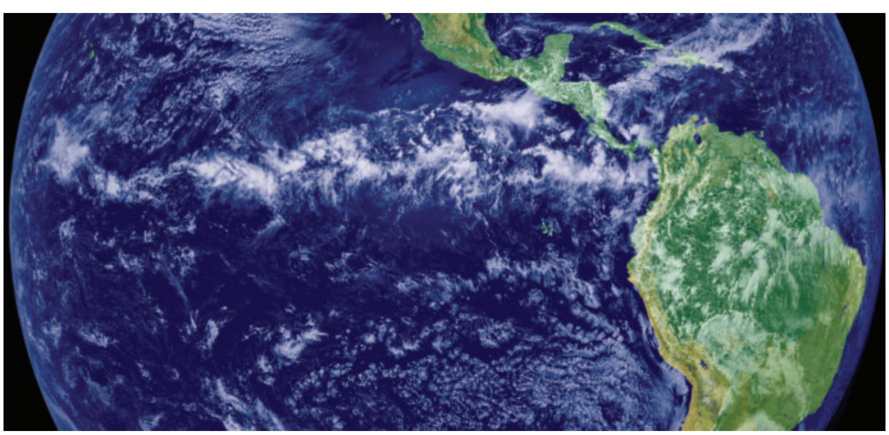
The credibility of global warming projections from numerical models rests on their skillful simulation of current and past climates, and on their seasonal forecasts of climate variability such as the El Niño–Southern Oscillation (ENSO). Deep convection in the tropics is the major driver of global atmospheric circulation, and climate anomalies in the tropics affect climate around the world through so-called atmospheric *teleconnections*. Thus it is important for climate models to simulate accurately the mean state and seasonal cycle of tropical climates.

This article highlights IPRC's effort to assess the simulations of the climate over three tropical oceans by the state-of-the-art coupled ocean–atmosphere general circulation models (GCMs) participating in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). Over the Pacific and Atlantic Oceans, most models fail to maintain the intertropical convergence zone (ITCZ) north of the equator. The ITCZ is the zone of deep convection separating the northeasterly trade winds of the Northern Hemisphere from the southeasterly trade winds of the Southern Hemisphere. A huge amount of condensational heat is released from this zonal band of convective clouds and rainfall that drives the global atmospheric circulation.

Simon de Szoeke's analyses of model simulations of the eastern tropical Pacific climate, a region climatically important for ENSO, show that failure of models' ITCZ to stay north of the equator causes errors in simulation of the Pacific equatorial sea surface cold tongue and its seasonal cycle (see section on Tropical Eastern Pacific).

The model errors in the climate over the equatorial Atlantic are even greater than those over the equatorial Pacific (see section on Tropical Atlantic Climate). While a cold tongue develops in observations in the Gulf of Guinea and extends westward during boreal summer, in the models it is either severely under-developed or completely absent. This error in equatorial Atlantic simulations was identified several years ago but its cause has remained unclear. **Ingo Richter** shows that the error in coupled simulations stems from the models' atmospheric component, which simulates too much rain over equatorial Africa and too little rain over the Amazon. This *zonal dipole* of rainfall weakens the Atlantic equatorial easterly winds, hampering the development of the equatorial cold tongue.

The Indian Ocean differs from the Pacific and the Atlantic in that it lacks the prevailing easterly winds and an equatorial cold tongue. In fact, the Indian Ocean is part of the largest warm pool on Earth, supporting deep atmospheric convection. Only occasionally (every ten years or so), an equatorial cold tongue starts westward from Sumatra during so-called *Indian Ocean dipole* (IOD) events. **N.H. Saji** and colleagues performed the first intercomparison of the AR4 coupled model simulations for the Indian Ocean (see 2006 IPRC Annual Report; Saji et al. 2006). All the models correctly simulate a warm Indian Ocean without a cold tongue on the equator. Many models also capture the major modes of Indian Ocean climate variability: the IOD mode that cools the eastern equatorial Indian Ocean, and the ba-



The Intertropical Convergence Zone. Credit: GOES Project Science Office sin-wide warming shortly after El Niño in the Pacific. The skill in simulating the latter is limited by the simulation of El Niño—many models simulate an El Niño that peaks in boreal summer instead of winter as observed.

Coupled ocean–atmosphere models have demonstrated a degree of skill in reproducing salient features of the observed climates. As detailed below, however, they still suffer from major errors in simulating tropical climate over oceans. Knowing the limits of these models is the first step towards improving them and helps us to apply them judiciously for seasonal predictions and climate projections.

Tropical Eastern Pacific Climate

Typically the seasonal cycle of solar heating is rather symmetric around the equator, with the Northern Hemisphere receiving its strongest solar heating during April–August, and the Southern Hemisphere during October–February. In the eastern tropical Pacific, however, the seasonal cycle is quite asymmetric, with the warmest SST and strongest ITCZ rainfall found from May through February at 8–12°N. Southerly winds blow across the equator and toward the northern ITCZ year-round. Atmospheric heating becomes somewhat more symmetric across the equator during February–April, causing the southerlies to slacken. During this period of weak southerly winds the equatorial SST warms, and briefly during March–April, the season of the double ITCZ, the Southern Hemisphere also has an ITCZ.

Coupled GCMs have long had difficulties correctly simulating this seasonal cycle and north–south asymmetry in the tropical eastern Pacific.

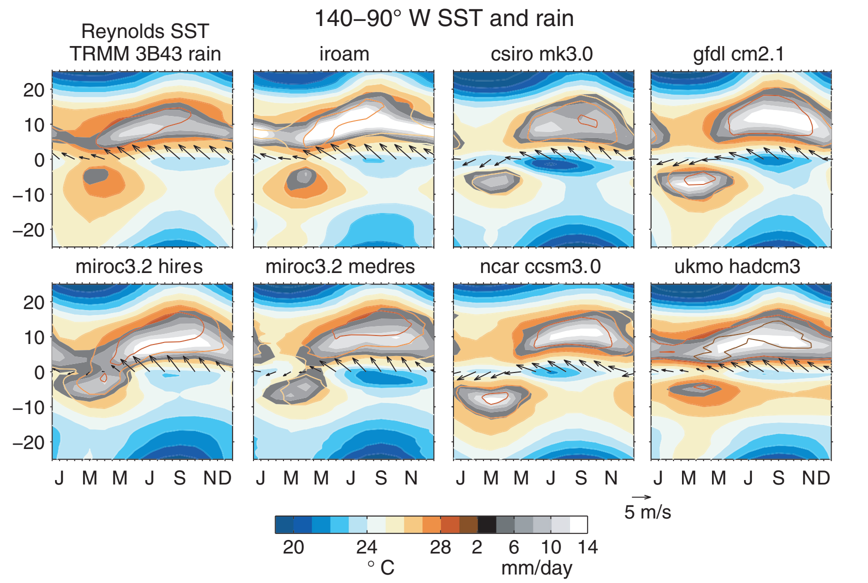


Figure 1. Hovmoeller plots of the seasonal climatology of SST (color shades and contours) and rain (gray) in the tropical eastern Pacific Ocean averaged over 140–90°W. The horizontal axis is month of the year and the vertical axis is latitude. Vectors on the equator denote the seasonal cycle of wind on the equator. Reynolds SST, TRMM 3B43 rain, and QuikSCAT wind analyses are shown in the top left panel. Other panels are climatologies of the *20th century* runs from six of the coupled GCMs used for the IPCC AR4 and from the IROAM regional model.

Models tend to simulate either a double ITCZ that lasts too long (*persistent double ITCZ error*), or an alternating ITCZ with warm SST and rainfall migrating symmetrically between the hemispheres (*alternating ITCZ error*). This latter error is associated with a warm bias in the southeastern tropical Pacific SST off the coast of South America. Other common errors include a warmer-than-usual equatorial cold tongue near the coast and an extension of the cold tongue too far west. Such errors in equatorial SST and seasonal cycle can be expected to affect the strength, frequency, and period of ENSO.

For our paper we assessed errors in coupled model simulations of the seasonal cycle and north–south heating asymmetry in the eastern tropical Pacific. We analyzed the *20th century* climate simulations of 14 models included in the IPCC AR4 and the IPRC Regional Ocean–Atmosphere Model (IROAM).

Differences among the model solutions can arise from random differences in model configuration and are amplified by coupled feedbacks in the models. We analyzed the collection of model solutions as if they were an ensemble of realizations of the climate. We used relationships among the ensemble members to diagnose coupled feedbacks and systematic errors that are similar among models.

We noted considerable improvement in coupled models since Mechoso's last comprehensive multimodel assessment of the seasonal cycle over the tropical Pacific in 1995. Figure 1 shows the north–south seasonal cycle of SST in color shades, and of rain in gray, for observations and 6 of the 15 models. Rain follows the warmest SST. Observations (top left panel) show rainfall exceeding 4 mm/day year-round in the Northern Hemisphere, and the brief double ITCZ in March–April. Models such as the IPRC Regional Ocean–Atmosphere Model (IROAM) and the UKMO HadCM3 have north–south seasonal SST and rain patterns that resemble observations. Most of the models analyzed, however, still have errors. Three of the 15 models have a persistent double ITCZ: that is, they have a perennial northern ITCZ and a southern ITCZ that lasts longer than two months. Eight models have a seasonally alternating ITCZ. The seasonally alternating but north–south symmetric rainfall associated with this error appears in the annual mean as a double ITCZ error, but its seasonal cycle is very different.

The alternating ITCZ error results in a wrong seasonal cycle for the winds, which in turn affects equatorial SST. Figure 1 shows the wind vectors on the equator. In the observed climate, southeasterlies blow across the equator towards the Northern Hemisphere ITCZ year-round. Southerly winds cool the sea surface around the equator by evaporation, by turbulent entrainment of cold sub-thermocline water into the mixed layer, and by a north–south circulation in which wind stress drags surface water across the equator and cold water upwells south of the equator. The brief slackening of the southerlies in March–April allows equatorial water to warm up. In models with an alternating ITCZ, however, winds reverse toward the Southern Hemisphere ITCZ during this time rather than weaken. This erroneous second maximum in meridional wind speed causes a cooling, resulting in a spurious second cold season on the equator in spring in some models. The wind effect on the spring equatorial cold error is confirmed by the correlation (r=-0.61) across models between March SST and cross-equatorial wind speed. Thus, in addition to easterly wind-driven equatorial Ekman divergence—the canonical explanation of the equatorial cold SST error—our study shows that the alternating ITCZ error contributes to the cold bias on the equator by simulating the wrong seasonal cycle of wind.

Models that simulate a more symmetric north–south climate than observed tend to have southerlies that are too weak within 1000 km of the South American coast. The mechanisms for equatorial cooling are weaker (less evaporation, less entrainment of cold sub-thermocline water, and less upwelling on the equator) than in alternating ITCZ models, and weaker southeasterly winds are related to the warm bias of the sea surface around the equator near the coast (r =-0.66; Figure 2a).

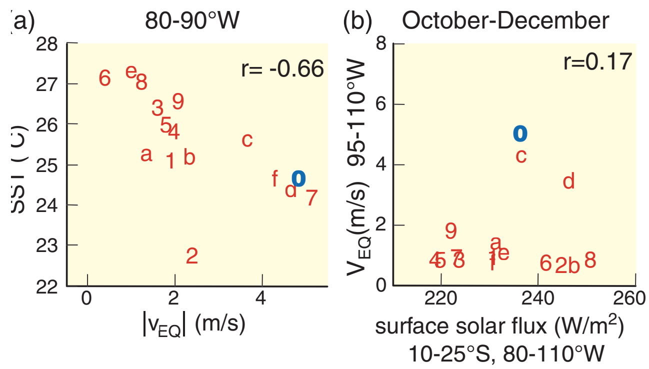


Figure 2. (a) Southerly wind speed and SST near the South American coast: models with higher wind speed have cooler SST; **O** refers to observations, the other numbers and letters refer to the results for each of the 15 models assessed (models not identified). (b) Surface solar radiation and meridional equatorial wind. Though the model spread in the surface solar flux in the southern stratocumulus region (mostly due to clouds) includes the observed surface solar flux, no model is as asymmetric (measured by east-Pacific equatorial southerly wind) as observed.

Studies that others have conducted to determine the reasons for difficulties in simulating eastern tropical Pacific have focused on representations of the southeastern tropical stratocumulus cloud deck. Our analysis of AR4 models shows that in the stratoculumus region the models have downward solar radiation at the surface that scatters around the observed values, but in no model is the equatorial southerly wind as strong as in the observations (Figure 2b, observations indicated by **O**, and each model is indicated by another character). Although clouds are important in maintaining the north-south asymmetry of the climate by cooling southeastern tropical Pacific Ocean, our study suggests that their realistic representation in models is necessary but insufficient to eliminate the tropical eastern Pacific errors in coupled GCMs. Few models simulate the correct seasonal cycle of north–south climate asymmetry and year-round southerly wind on the equator. The wind error is reflected in well-known SST errors on the equator.

Tropical Atlantic Climate

Of the three major ocean basins, the tropical Atlantic may be the most difficult one to simulate in coupled GCMs. A study conducted in 2002 showed that all the models examined (except one) reversed the SST gradient along the equator compared with observations. This was largely due to the fact that the models did not capture the development of the eastern equatorial cold tongue during June–August. Other errors commonly encountered in the tropical Atlantic include a southward shift of the ITCZ and too few marine stratocumulus clouds in the subtropical southeast Atlantic. These model shortcomings seriously affect seasonal-to-interannual climate predictions, and model predictions are matched or even outperformed by statistical and persistence forecasts. This lack of skill undermines the results from climate warming scenarios for the region, such as the *CO_2 doubling* experiments. To get a better understanding of the errors related to Atlantic climate simulations, we have examined the tropical Atlantic climate in the *20^{th} century* experiments.

Figure 3 depicts the annual mean SST across the equatorial Atlantic. The models' SST shows a wide spread, the coldest (CNRM CM3) being about 3°C colder than the warmest (UKMO HadCM3). Clearly, the SST representation has not improved much since the 2002 IPCC Third Assessment Report. All the models feature a warming from the central Atlantic eastward, whereas observations show a cooling.

As in the 2002 assessment, the models fail to simulate the seasonal development of the equatorial cold tongue. This is illustrated in Figure 4, which shows the equatorial winds

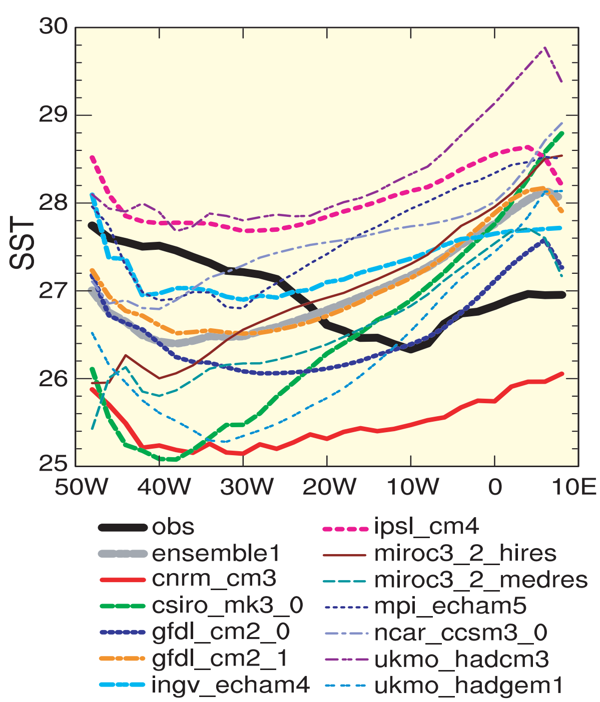
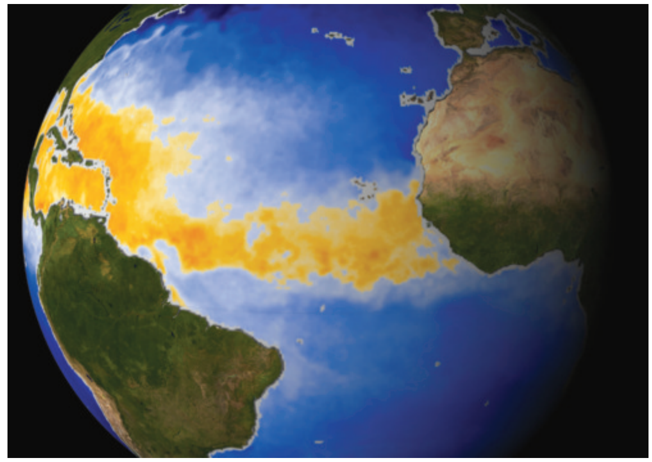


Figure 3: Annual mean of SST (°C) along the equator, averaged between 2°S and 2°N. The thick black and grey lines denote COADS SST and the ensemble mean, respectively. None of the models is able to capture the eastward decrease of SST in the observations between 50°W and 10°W.



Sea Surface Temperature. Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio

and SST across the Atlantic over the year of the ensemble mean from several IPCC coupled GCMs. The greatest warm SST bias occurs during June–August and is most pronounced off the African coast.

Compared to observations, the models' equatorial easterly winds are too weak and sometimes even reversed (Figure 4), especially during March–May. This bias leads to a deepening of the thermocline in the eastern basin, the 20°C isotherm depth increasing eastwards (not shown). In summertime, the equatorial wind errors become small and winds

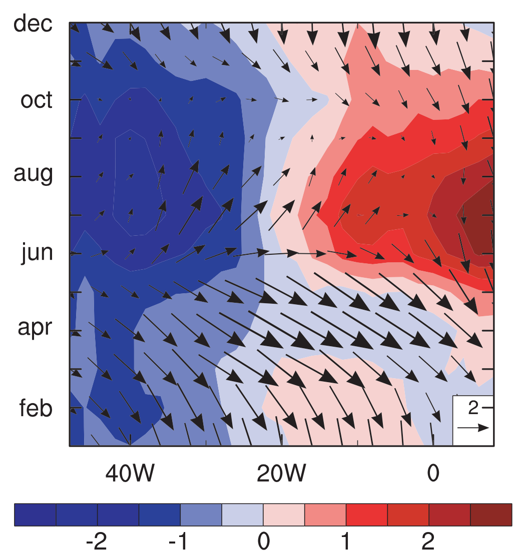


Figure 4: Equatorial longitude-time section of SST (K) and surface wind (m/s) biases for the ensemble mean of IPCC AR4 models. The reference dataset is ICOADS. Fields are averaged between 2°S and 2°N. A strong westerly wind bias during boreal spring precedes the maximum SST bias in boreal summer.

are more favorable to upwelling (Figure 4). Because the model thermocline is too deep, however, a cold tongue cannot form in the east. Our results thus show that the warm SST bias in June–August is due to westerly winds that are too strong during the preceding season.

For some of the models in the IPCC database, atmosphere-only simulations with prescribed climatological SSTs are available. Analyses of these simulations provide an opportunity to determine whether model errors are due to the atmospheric components or due to unrealistic SST patterns. Studying the same models as above, we analyzed these atmosphere-only experiments. Figure 5 shows that even when forced with "perfect" SSTs, the models have surface westerly winds along the Atlantic equator that are too strong, simulating too little rain over the western Atlantic and South America and too much rain over the eastern Atlantic and Africa. Further analysis showed that these rainfall errors are linked to an erroneous sea-level pressure gradient that maintains the westerly wind bias in the models. All these model errors are associated with a weaker Atlantic Walker cell than observed.

Comparison of the atmosphere-only with their coupled model runs shows that coupling amplifies the surface-wind and rainfall errors. The westerly wind bias, for example, doubles in the ensemble mean, indicating amplification by the Bjerknes feedback.

Apart from the zonal biases along the equator, both coupled and uncoupled models suffer from an erroneous southward shift of the ITCZ. This shift is accompanied by an anomalous southerly wind at the equator, which can be seen in Figures 4 and 5. These errors, too, are amplified by coupled feedbacks, namely the windstress–evaporation–SST feedback.

In summary, our results show that tropical Atlantic biases remain a serious problem in the AR4 models. To a large extent these biases originate in the atmospheric components of the models and are amplified by SST feedbacks in the coupled simulations. Analyses not presented here suggest, furthermore, that rainfall errors over equatorial South America and Africa increase the westerly wind biases. Improving simulation of rainfall over land may, thus, hold the key to a realistic simulation of the tropical Atlantic climate in general circulation models.

Our results are described in more detail in Richter and Xie, 2007.

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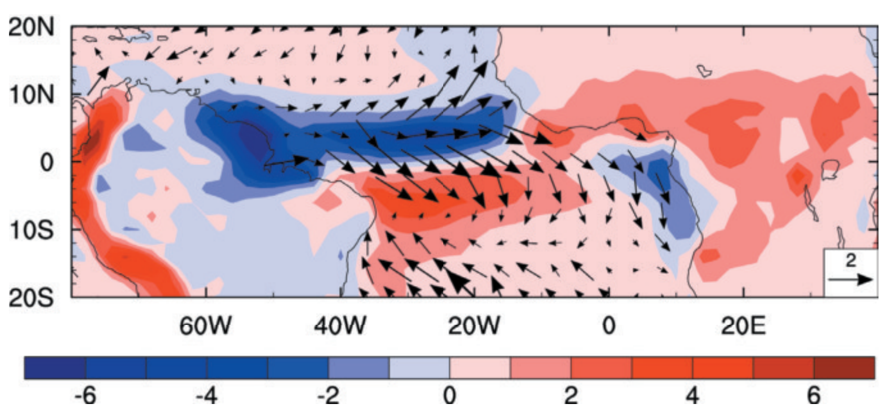


Figure 5: March–May precipitation (mm/day) and surface wind (m/s) biases for the uncoupled atmospheric model ensemble. The reference datasets are CMAP (precipitation) and ICOADS (surface winds). The westerly wind bias along the equator is similar to the one seen in the coupled models. Precipitation errors over the ocean indicate a southward shift of the ITCZ. Furthermore, precipitation is too low over tropical South America and too high over tropical Africa.

Global Energy and Water Cycle Experiment

Participants of the GEWEX 19th Scientific Steering Group meeting.

The IPRC hosted the 19th Scientific Steering Group (SSG) meeting of the Global Energy and Water Cycle Experiment (GEWEX) at the East-West Center in Honolulu on January 22–26, 2007. Chaired by **Soroosh Sorooshian**, University of California at Irvine, the meeting focused on how to fulfill the requirements of the GEWEX Phase II Roadmap of the World Climate Research Programme (WCRP) strategic plan and the goals of climate research.

A major GEWEX reorganization taking place is the merging of the Coordinated Enhanced Observing Period and the Hydrometeorology Panel into the Coordinated Energy and Water Cycle Observations Project (http://www.gewex.org/projects-CEOP.htm).

Of great interest for IPRC scientists is GEWEX's plan for a 5-year monsoon research strategy. An overarching issue for monsoon prediction is the need to improve representation of tropical convection. GEWEX, therefore, has decided to participate in the upcoming WCRP project "The Year of Tropical Convection" which will focus on understanding, computer modeling, and forecasting tropical convection. See also Asian-Australian Monsoon Panel.

GEWEX will also participate with the Climate Variability and Predictability Program (CLIVAR) in the Asian Monsoon Year (AMY), which is geared toward improving observations, analyses, and computer modeling of climate in the Asian monsoon regions. This project will contribute to the Year of Tropical Convection. AMY is to bring together the monsoon efforts of GEWEX, CLIVAR, and the Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction Initiative (MAHASRI; http://mahasri.cr.chiba-u.ac.jp/index_e.html).

For a detailed meeting report by **Rick Lawford** and **Dawn Erlich**, see *GEWEX News* http://www.gewex.org/Feb2007.pdf.

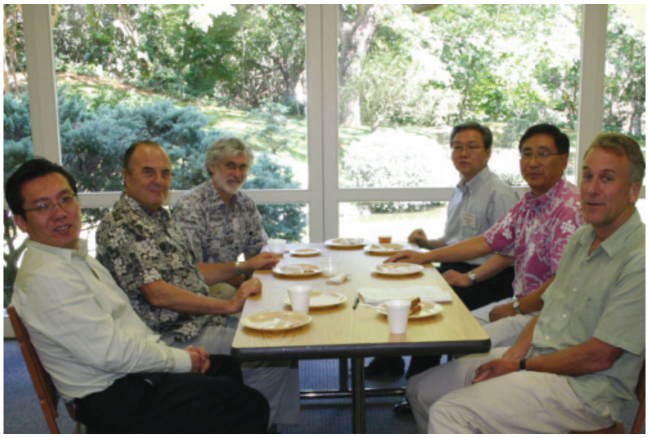
Asian–Australian Monsoon Panel

As a part of CLIVAR, the Asian–Australian Monsoon Panel (A–AMP) deals with research on the Asian–Australian monsoon, its variability and predictability, and coordinates monsoon-related activities of the WCRP. The IPRC hosted the A–AMP 8th Steering Committee Meeting on February 19–21, 2007, at the East-West Center. Co-chairs of the meeting were **Bin Wang** from the IPRC and **Harry Hendon** from the Australian Bureau of Meteorology.

Meeting topics included developments and challenges in monsoon modeling and prediction, the monsoon-ocean observing system, and ways to coordinate with, and contribute to, other CLIVAR monsoon-related activities. The agenda and the presentations are at http://www.clivar.org/organization/aamp/8thmeeting.htm/.

Of IPRC scientists, Bin Wang spoke about the status and challenges of dynamic seasonal prediction of the Asian–Australian monsoon and strategies for improving these predictions; **H. Annamalai** discussed his analysis of the monsoon circulation and depressions simulated by the IPCC AR4 models (see p. 10); **Tim Li** talked about processes responsible for restarting the intraseasonal oscillation; and **Axel Timmermann**, co-chair of the CLIVAR Pacific Panel, discussed the possibility that North Atlantic climate sets the pace for the Asian–Australian monsoon and the El Niño–Southern Oscillation (ENSO).

Timmermann noted that CLIVAR's Asian–Australian Monsoon, Indian



Gathering together at the Asian-Australian Monsoon Panel Meeting are from left Jianping Li, Carlos Ereno, Jay McCreary, Chung-Kyu Park, Bin Wang, and Harry Hendon.

Ocean, and Pacific Ocean Panels are all interested in better understanding the Madden–Julian Oscillation (MJO); westerly windbursts and their modulation of, and by, ENSO; northwestern tropical Pacific climate and its influence on the monsoons; and the impact of the North Atlantic Oscillation on the Pacific. As cross-cutting issues, he identified warm pool dynamics, the South Pacific Convergence Zone, and interactions among ENSO, the Indonesian Throughflow, the monsoon, and the Indian Ocean Dipole.

A major initiative that was discussed is the project "The Year of Tropical Convection." The A–AMP is to develop a proposal for the project together with other WCRP groups under the guidance of The Observing-System Research and Predictability Experiment (http://www.wmo.ch/pages/prog/arep/thorpex/index_en.html/). The project is to leverage the vast new observational datasets and computational resources together with new, high-resolution modeling frameworks to better understand, represent, simulate, and forecast multi-scale convective processes and their dynamical interactions.

Regarding other decisions, the panel will work with the CLIVAR Working Group on Seasonal to Interannual Prediction, the WCRP Task Force on Seasonal Prediction, and the CLIVAR Pacific and Indian Ocean Panels on the following: hindcast experiments aimed at studying how land–surface initialization and land–atmosphere interaction affect monsoon predictability; analysis of the MJO during the onset of the 1997 El Niño; and analysis of hindcasts of Indian Ocean Dipole predictability.

The panel will participate in the Asian Monsoon Year and proposed expanding the effort to an International Monsoon Year with broader objectives of interest to all the monsoon panels. The Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction Initiative (MAHASRI: http://mahasri.cr.chiba-u.ac.jp/index_e.html/) and its plans to establish a hydrometeorological prediction system were discussed. Topics under this initiative of interest to the A–AMP are the role of hydrometeorological variables in changing environments, the effect of the diurnal cycle, the interactions of small-scale and large-scale climate processes, and the impact of aerosols on the monsoon. The panel is also interested in working with the Asia Integrated Regional Studies (MAIRS: http://www.mairs-essp.org/), a project dealing with environmental change and research challenges in the Asian monsoon region.

Satellite Data Analysis

In February 2007, the IPRC invited **Dudley Chelton** for a mini-workshop on satellite data analysis. Chelton, a distinguished professor of physical oceanography at Oregon State University in Corvallis and a member of several NASA science teams, has had many years of experience in using satellite scatterometer, altimeter, and microwave data to study the ocean circulation and processes of the coupled ocean–atmosphere interaction.

The aim of the workshop was to discuss the broad range of IPRC research that uses satellite data and to learn from Chelton's views and comments. IPRC scientists presented their research using satellite data to document such diverse phenomena as the Kuroshio Extension variability, the South China Sea Throughflow, decadal variability in the large-scale sea surface height field of the South Pacific Ocean, surface

Chatting with Dudley Chelton during a break at the Mini-workshop on Satellite Data Analysis.

currents in Tropical Instability Waves, cloud mapping over the Hawaiian Islands, global mapping of high sea winds, and sea surface salinity to constrain estimates of precipitation over the ocean.

Discussing his own research, Chelton reported that, like IPRC researchers, he had found across sea surface temperature (SST) fronts stronger winds over warmer water and weaker winds over colder water. Moreover, QuikSCAT sea winds reveal small-scale features in SST gradients that are not detectable in the NCEP or ECWMF reanalyses. Generally, he has noted that the atmospheric circulation in satellite data is more energetic than in models. This is probably because in models mixing is too strong and the effects of the diurnal cycle and SST fronts on winds are too weak.

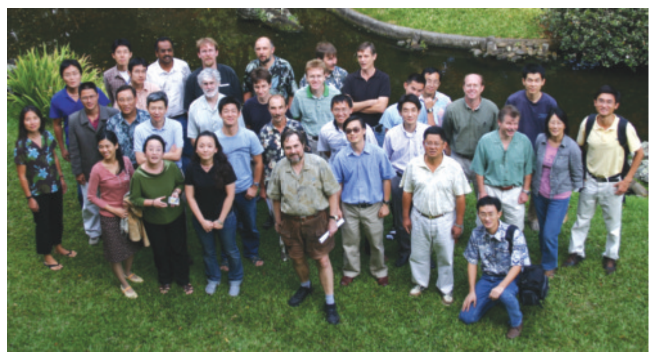
The IPRC – Kyousei 7 Partnership

Over the past 5 years, the Frontier Research Center for Global Change (FRCGC) and the IPRC have collaborated under Kyousei 7 (K-7) Project funding on assimilation of data into ocean models and model development, climate predictability, and data management. At the ending of the K-7 funding in March 2007, the achievements and future research collaboration were discussed during a workshop at the IPRC. The K-7 project has developed techniques for data assimilation into ocean and coupled atmosphere–ocean computer models and has created data assimilation products for climate predictions with such models. These activities will continue to be an important research area for the partnership. Another major accomplishment under the Kyousei funding was the construction of the K-7 data website (http://www.jamstec.go.jp/frcgc/k7-dbase2/), which the APDRC helped to build. The K-7 legacy of the FRCGC and the IPRC partnership will be passed on to the new project Data Integration and Analysis System (DIAS).

Professor Toshiyuki Awaji is addressing the Kyousei-7 Partnership. Around table from left: Junko Kubota, Shuhei Masuda, Toru Miyama, Nozomi Sugiura, Peter Hacker, Max Yaremchuk, Shang-Ping Xie, Yuji Sasaki. Window: Hiromichi Igarashi, Takahiro Toyoda, Takashi Mochizuki.

Seventh Annual IPRC Symposium

The Seventh Annual IPRC Symposium was held April 17 and 18, 2007, at the East-West Center in Honolulu. This yearly event is designed for IPRC scientists to share with each other the highlights of their research over the year. The symposium is a time to reflect upon the progress made in understanding climate processes, especially as they relate to the IPRC Science Plan. The meeting also serves to detect common research interests and to solicit comments and suggestions from colleagues.



IPRC Symposium participants in the Japanese Gardens of the East-West Center. *(Photo: Courtesy Lori Wakumoto)*

This year's symposium co-chairs were **Kelvin Richards**, leader of IPRC research on Regional Ocean Influences, and **Tim Li**, co-leader of research on the Asian-Australian Monsoon System. The symposium session topics were Ocean Dynamics, Ocean Circulation and Variability, Ocean–Atmosphere Coupling, Monsoons, Atmospheric Processes, Predictability and the Stratosphere–Troposphere Connection. The individual talks are listed at http://iprc.soest.hawaii.edu/meetings/workshops/07_04_7th_IPRC_annual_symposium.htm.

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New JAMSTEC–IPRC Research Initiative

Front from left: Dr. Brian Taylor (Dean, School of Ocean and Earth Science and Technology), Dr. Kiyoshi Suyehiro (Executive Director, JAMSTEC), Mr. Saichiro Yoshimura (Principal Administration Specialist, FRCGC/JAMSTEC). Back: Dr. Lorenz Magaard (Executive Associate Director, IPRC), Mr. Howard Diamond (Program Manager, US Global Climate Observing System, NOAA/National Climatic Data Center), Dr. Eric Lindstrom (GC Co-Chair; NASA Physical Oceanography Program Scientist), Dr. Julian McCreary (Director, IPRC), Dr. Tatsushi Tokioka (Acting GC Co-Chair; Director General, FRCGC/JAMSTEC), Mr. Katsuhiko Masuda (Director, Research Promotion Office, FRCGC/JAMSTEC). Ms. Yoko Watanabe (Administrative Officer, International Affairs Division, Planning Department, JAMSTEC), Mr. Tetsuro Isono (Chief Administrative Officer, Research Promotion Office, FRCGC/JAMSTEC).

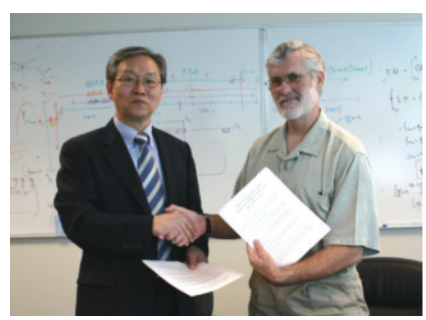
The Governing Committee of the IPRC met at the IPRC on March 8 and 9, 2007. Dr. **Tatsushi Tokioka**, Director General, Frontier Research Center for Global, served as acting Japanese Co-Chair for Dr. **Shuichi Sakamoto**, and NASA Physical Oceanography Program Scientist Dr. **Eric Lindstrom** took part as the US Co-Chair. JAMSTEC Executive Director Dr. **Kiyoshi Suyehiro** also participated. For all the meeting participants, see photo caption.

A major topic at the meeting was the new JAMSTEC–IPRC research initiative. Discussion of this initiative had already begun in December 2006 at a Yokohama meeting between JAMSTEC and IPRC scientists. The initiative will help to coordinate the research activities of JAMSTEC and the IPRC.

IPRC Expands Research Partnerships

The IPRC is expanding its climate research partnerships in Asia. In February 2007, IPRC Director **Julian McCreary** signed a memorandum of understanding with Executive Associate Director of the APEC Climate Center **Chung-Kyu Park**. The two institutions agreed to partner on research related to the scientific and technical aspects of climate prediction in the Asia–Pacific region. The APEC Climate Center offers real-time climate predictions for APEC member economies, shares costly climate data and information, and builds capacity in climate prediction and its application. The center aims to be a major catalyst towards social and economic prosperity among member economies by developing and applying innovative climate prediction techniques to mitigate climate-related damages and by developing methods to adapt to climate fluctuations and change.

In April 2007, the IPRC signed a memorandum of understanding with the Institute of Tropical and Marine Meteorology of the China Meteorology Administration. Under this agreement, a Cooperative Tropical Climate Research Laboratory will be set up with a focus on the tropical atmospheric and oceanic circulation and on climate of the Indo-Pacific warm pool. The research partnership will include the following: assessment of the impact of ocean–atmosphere interactions on the intraseasonal and interannual variability of the East Asian monsoon, development of an effective seasonal climate prediction strategy, determination of changes in tropical cyclone tracks and intensity, and study of the impact of global warming on regional climate and weather. Two 3-year research grants have already been secured from the Chinese National Science Foundation for the partners to jointly study the East Asian monsoon intraseasonal and interannual variabilities.



Executive Associate Director of the APEC Climate Center Chung-Kyu Park signs memorandum of understanding with IPRC Director Julian McCreary to partner on climate prediction research.

The IPRC, furthermore, has signed an agreement with the College of Earth Sciences at the National Central University in Taiwan to promote scientific collaboration in research related to regional climate and the water cycle.

Then in July 2007, IPRC's **Yuqing Wang** was appointed overseas director of the newly founded Pacific Typhoon Research Center at the Nanjing University of Information Science and Technology (NUIST) in Nanjing, China. The new center conducts research on tropical cyclones and regional climate, and fosters international coordination in these areas. As overseas director, Yuqing Wang is helping to develop the research directions and international collaborations of the center. NUIST, formerly known as Nanjing Institute of Meteorology, is a major training ground for meteorologists in China. The institute has graduates all over the world.

IPRC's Axel Timmermann Receives Rosenstiel Award

Axel Timmermann receives Rosenstiel Award; he is flanked by Professor Amy Clement, Dean of the Rosenstiel School of Marine & Atmospheric Science Otis Brown, and Professor William Johns.

Axel Timmermann, co-leader of IPRC research on Impacts of Global Environmental Change and associate professor of oceanography, received the Rosenstiel Award for Outstanding Achievement and Distinction in Oceanographic Science. The award ceremony took place on April 24, 2007, at the University of Miami Rosenstiel School of Marine & Atmospheric Science.

The Rosenstiel Award honors scientists who have made significant and growing impacts in their field over the past decade. It is targeted to researchers who, in their early to mid-career stages, are making outstanding scientific contributions. Timmermann was awarded the prize "for his seminal modeling study predicting increased El Niño frequency in response to future greenhouse warming (which) is widely cited and is part of his large collection of papers that seek to understand the fundamental mechanisms of ENSO operating in the past, present and future. His more recent work has revealed mechanisms that link climate variability in the Pacific with the Atlantic on decadal and longer timescales, and his ideas have contributed to a new integrated view of the global climate system. Timmermann is known not only for his innovative ideas and methodologies, but also for the curiosity and enthusiasm that he brings to scientific discussions. (excerpt from Rosenstiel School news release, April 5, 2007).

Published!

The special *Journal of Climate* issue "Indian Ocean Climate" was released in July 2007. IPRC Associate Researcher **Tommy Jensen** is the editor. The special issue grew out of papers and discussions at the Indian Ocean Modeling Workshop, hosted by the IPRC in December 2004 (*IPRC Climate*, vol. 5, no. 1). The special issue includes 24 papers written by foremost atmospheric scientists and oceanographers with expertise in the Indian Ocean region. The papers discuss, among other issues, how best to monitor the Indian Ocean conditions, how Indian and Pacific Ocean conditions impact each other, and how the Indian Ocean affects the Asian monsoon and, through teleconnections, far-away midlatitude climate.

The paper entitled "South China Sea Throughflow: A heat and freshwater conveyor" by IPRC researchers **Tangdong Qu** and **Yan Du**, and JAMSTEC Earth Simulator Center research scientist **H. Sasaki**, was published in *Geophysical Research Letters* in late 2006 and selected by the American Geophysical Union for its January 2007 *Journal Highlights*: Based on their study, the authors hypothesize that the South China Sea acts as a heat capacitor, storing heat in certain years and releasing it in others. Results from a high-resolution general circulation model support this hypothesis and the possibility that the South China Sea plays a key role in regulating sea surface temperature patterns in the region"(excerpt from www.agu.org/journals/gl/gl0623/2006GL028350).

IPRC Scientists Active in the Community

IPRC co-leader of research on Impacts of Global Environmental Change **Kevin Hamilton** served as a consultant for the 2006–2007 "US Academic Decathlon," a nationwide competition, in which American high school students take written and oral examinations on 10 subjects, including a special topic chosen each year. The special topic for 2006–2007 was "Climatology." Hamilton reviewed over 800 questions for the climatology exams.

"MELTDOWN! Understanding Abrupt Climate Changes in the Last Ice Age" was the title of the talk given by **Axel Timmermann**, co-leader of research on Impacts of Global Environmental Change, on June 19, 2007, at the Science Café of Honolulu's Bishop Museum. For his talk, Timmermann had created animations of climate change for the NOAA *Science on a Sphere*, the sphere on to which satellite images and numerical model simulations of Earth's climate can be projected. Over 100 people attended the event. The talk generated many questions and much discussion. Sphere images of the talk can be seen at http://apdrc.soest.hawaii.edu/projects/iprc_photos/subalbum_1_slideshow.html. Timmermann also gave talks to the Honolulu Adventurer's Club in January 2007 and the Wahiawa Rotary Club in February 2007.

Kevin Hamilton and Axel Timmermann were interviewed by the *Honolulu Advertiser* for the front page article that appeared on February 25, 2007, and dealt with climate changes associated with rising levels of atmospheric carbon dioxide concentrations. Topics included such dangers threatening Hawai'i as global warming, sea level rise, eroding shorelines, and increasing acidity of the ocean.

At the Bishop Museum Science Café, the opening of A. Timmermann's talk "Meltdown!"

From left, H. Annamalai, Kevin Hamilton, Jay Fidell, and Shang-Ping Xie during the Hawai'i Public Radio show ThinkTech.

On the whole, the weather in the Hawaiian Island chain has been anomalously dry this year: in most places, the January-May rainfall was 40-60% of the long-term average. IPRC's Associate Researcher **H. Annamalai** was interviewed for the *Honolulu Advertiser* article, "We're in a Drought!" Annamalai explained how this drought could be linked to the 2006–2007 El Niño.

Shang-Ping Xie, Kevin Hamilton, and H. Annamalai took part in the Hawai'i Public Radio weekly show *ThinkTech*, which aired August 15, 2007. Host **Jay Fidell** interviewed them extensively about "Current discoveries on the science of global climate change and how it is now affecting Hawai'i and the Pacific." The scientists talked about the findings of the recent *Fourth Assessment Report* by the Intergovernmental Panel on Climate Change, what climate change means for Hawai'i and Asia, and what it is like to be a climate scientist at the IPRC. For podcasts of the show and the aftershow please visit http://iprc.soest.hawaii.edu/news/news.html.

IPRC Scientists Active in the Climate Research Community

Kevin Hamilton, co-leader of IPRC Impacts of Global Environmental Change research, was lead convener for a four-day symposium *Middle Atmosphere Science* at the 24th General Assembly of the International Union of Geodesy and Geophysics (IUGG) held in Perugia, Italy, in July 2007. At the IUGG meeting Hamilton also completed his service (1999–2007) as President of the International Commission on the Middle Atmosphere (ICMA). ICMA is the body within the IUGG hierarchy that fosters international research in the physics and chemistry of the atmosphere from the tropopause to the lower thermosphere. Hamilton has written an article describing the activities of the ICMA Commission. The article will appear soon in a forthcoming edition of *The International Association of Meteorology and Atmospheric Sciences Newsletter* (http://www.iamas.org). Hamilton has accepted, furthermore, a four-year term on the Executive Bureau of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). SCOSTEP is an interdisciplinary committee of IUGG, the International Astronomical Union and the International Union of Pure and Applied Physics. SCOSTEP fosters research to understand the effects of solar variability on the terrestrial environment (www.scostep.ucar.edu).

Shang-Ping Xie, co-leader of IPRC research on Indo-Pacific Climate, gave the keynote address at the 22nd International Conference on Computers and Their Applications, held at the Sheraton Princess Kaiulani Hotel, in Honolulu, March 28–30, 2007. His talk "Global Environmental Modeling and Its Applications to Climate Change Research," was geared to a general audience and outlined the scientific basis for computer model projections of climate. Xie also gave the keynote speech "Foretelling Future Climate Change: The Scientific Basis" at the opening of a meeting on the environment, hosted by the Environment Program Office of the Asia Foundation on August 12, 2007, in Honolulu.

H. Annamalai, IPRC researcher, gave an invited address at the February 2007 meeting of the World Climate Research Programme's Working Group on Numerical Experimentation in San Francisco. His talk was entitled "Systematic Errors in the Simulation of the Mean and Variability of the Asian Summer Monsoon in Climate Models."

Yuqing Wang, associate professor of meteorology and IPRC scientist, has been asked to serve on the Tropical Meteorology and Hurricane Committee of the American Meteorological Society (AMS) for a four-year term. The committee is seen as the authority on tropical meteorology and tropical cyclones within the AMS and serves as the communication channel with the national and international organizations on tropical meteorological and related activities. The committee stimulates research, encourages exchange of ideas and information on the tropical atmosphere, and promotes the application of acquired knowledge to operational problems in the tropics. Specific committee tasks include sponsoring and coordinating national and international scientific sessions on tropical meteorology, http://www.ametsoc.org/stacpges/tmtc/. Yuqing Wang was also co-chair of the organizing committee for the Second International Workshop on Tropical Cyclones held July 7–10, 2007, at Nanjing University of Information Science and Technology in Nanjing, China.

Educating a Climate Scientist

Ahira Sanchez-Lugo, an employee at the NOAA National Climatic Data Center (NCDC), completed the requirements for her master's degree in the Meteorology Department at the University of Hawai'i this past March. Her thesis supervisor was **Kevin Hamilton**, co-leader of IPRC research on Impacts of Global Environmental Change.

For her thesis "An Index to Measure the Influences of Climate on Residential Natural Gas Demand," Sanchez-Lugo investigated the relationship between daily temperature fluctuations and residential natural gas usage during winter months. She applied these results to make projections of future natural gas demands given the atmospheric warming expected to result from anthropogenic forcing.

Ahira Sanchez-Lugo with adviser Kevin Hamilton.

Sanchez-Lugo was a participant in the NOAA Educational Partnership Program, which is aimed at increasing the number of minority students trained in sciences directly related to NOAA's mission. The program allowed her to pursue her graduate studies at the University of Hawai'i while being employed at NCDC.

Visiting the IPRC

The IPRC has been host to several Japanese scientists who are taking advantage of an initiative at universities in Japan—sabbatical leaves. This initiative is fortunate for the IPRC because it allows Japan's mid-career scientists to come for protracted stays and conduct research at the IPRC. Thus, from September 2006 until early March 2007, **Hiroaki Ueda**, assistant professor in the Graduate School of Life and Environmental Sciences at Tsukuba University, visited the IPRC. He gave a joint Meteorology–IPRC seminar, "Formation, Fluctuation and Projected Future Change of the Asian Monsoon." While at the IPRC, Ueda and IPRC's **Shang-Ping Xie** conducted a study

Hiroaki Ueda (center) with Klaus Wyrtki, emeritus oceanography professor at the University of Hawai'i, and Niklas Schneider, co-leader of IPRC research on Indo-Pacific Ocean Climate.

on how air–sea interaction shapes the Asian monsoon.

Also on sabbatical leave at the IPRC was **Youichi Tanimoto**, associate professor in the Faculty of Environmental Earth Science at Hokkaido University. He spent his 5-month leave at the IPRC to further analyze data that he collected with Shang-Ping Xie during two scientific cruises in 2005 and 2006. On the cruises, atmospheric soundings were conducted across the steep sea surface temperature gradient of the Kuroshio Extension during the Meiyu–Baiu-front season. This monsoon front brings much moisture to the Kurshio Extension region. The study, among other things, shows under which conditions sea fog forms that

Youichi Tanimoto and Shang-Ping Xie enjoy time together.

is dangerous to navigation. Tanimoto held a luncheon discussion for IPRC scientists, entitled "Modifications of the Marine Boundary Layer over the Kuroshio Extension."

The IPRC is fortunate to have had many other visitors these past months, both short- and long-term and for various meetings. For seminars or luncheon discussions they have given, visit the IPRC website: http://iprc.soest.hawaii.edu/.

Among our visitors was Professor **Michael McIntyre**, FRS, of the University of Cambridge Department of Applied Mathematics and Theoretical

Michael McIntyre with IPRC's Nikolai Maximenko (left), Kevin Hamilton, and Jay McCreary

Physics. In January 2007, he gave a special lecture, "Multiple Jets, Beta Turbulence and the Phillips Effect," which was sponsored jointly by the IPRC and the Departments of Meteorology and Oceanography at the University of Hawai'i. McIntyre, acknowledged as a world leader in the field of geophysical fluid dynamics, has been responsible for many of the key innovations in this field over the last four decades. IPRC scientists greatly appreciated the opportunity to discuss their current research with this renowned scholar.

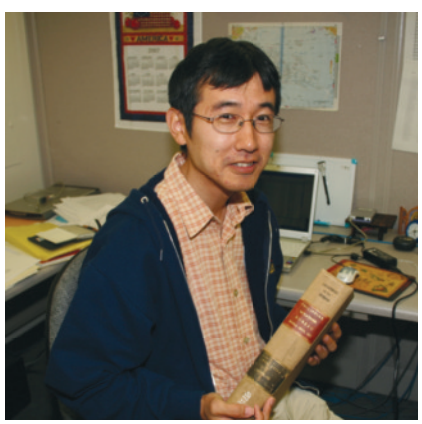
In February, **Shoshiro Minobe** from Hokkaido University visited the IPRC to work with **Shang-Ping Xie** and **Niklas Schneider** and to give a talk on climatic effects of the Gulf Stream "Deep penetration of Gulf Stream influence into the troposphere: A synthesis of satellite observation, operational analysis and AGCM. During Minobe's visit, **Yoshinori Sasaki** was at the IPRC for two weeks as part of the Hokkaido's Center of Excellence program, a program funded by Ministry of Education, Culture, Sports,

A fortunate get together: from left Yoshinori Sasaki, Kazuyoshi Kikuchi, Shang-Ping Xie, Niklas Schneider, Shoshiro Minobe, Seita Emori, and Takeaki Sampe.

Science and Technology to promote internationally competitive graduate schools in Japan. Sasaki is working with Schneider on a study of South Pacific decadal variability. **Seita Emori**, Chief of the Climate Risk Assessment Research Section of the National Institute for Environmental Studies in Tsukuba, Japan, happened to be visiting at the same time. The IPRC had invited Emori to present Japanese activities in climate-change research and to discuss possible collaborations with the IPRC in this area. He gave a seminar, "Dynamic and Thermodynamic Changes in Mean and Extreme Precipitation under Changed Climate."

Climate modeler **Markus Jochum** from the National Center for Atmospheric Research (NCAR) spent three months in 2007 at the IPRC. He and IPRC's **James Potemra** took a close look at how the NCAR Community Climate System Model portrays the vast and complex Asian–Australian monsoon. Arguably the representation of this monsoon system is the biggest shortcoming in the latest version of the model, according to Jochum. Together with Potemra, he improved the model's depiction of freshwater mixing in Indonesia's Banda Sea, a process that strongly affects sea surface temperature and rainfall in the surrounding area.

Hisayuki Kubota, JAMSTEC Institute of Observational Research for Global Change, visited the Meteorology Department at the University of Hawai'i from October 2006 until Fall 2007. Working with IPRC's **Bin Wang**, he has been analyzing meteorological station data he brought with him to Honolulu. While browsing in the University of Hawai'i library, Kubota discovered the *Bulletins of the US Department of the Interior Philippine Weather Bureau from 1901–1940*. The bulletins reported on typhoons and their tracks. Wishing to extend backward in time the Best Track Typhoon data that began in 1945, Kubota has been analyzing the typhoon data in the Bulletins.

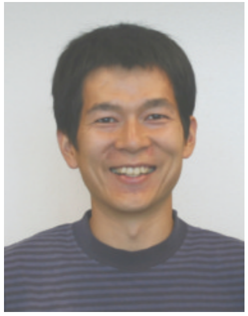


Hisayuki Kubota with one of the *Bulletins of the US Department of the Interior Philippine Weather Bureau* that he discovered in Hamilton Library at the University of Hawai'i.

Kazuhisa Tsuboki, associate professor at the Hydrospheric Atmospheric Research Center at Nagoya University, visited in July and August. In a luncheon discussion, he presented results from his "Cloud Resolving Storm Simulator" (CReSS). The model has simulated typhoons, heavy rainfall, snowstorms, and even tornadoes. For instance, in a recent typhoon over Japan, dramatic supercells formed and spawned a tornado. In a 500-m resolution version, the model was able to capture the tornado and the spiral rainbands over eastern Kyushu.

Soon-Il An, who had worked at the IPRC for 7 years before returning to Korea as an associate professor in the Department of Atmospheric Science at Yonsei University, this summer came "home" to the IPRC to study with **Axel Timmermann's** group the impact of pan-oceanic connections, such as the Panama sea gateway, on tropical climate during the Tertiary period when the super continent Gondwana began to break up. Results should throw light on the emergence of warm pools and the effects of continental configurations and oceanic pathways on climate and its variability.

NEW IPRC STAFF

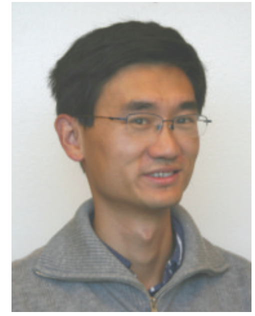


Hidenori Aiki

Hidenori Aiki joined the IPRC in January 2007 as a visiting research scholar from JAMSTEC on a two-year Postdoctoral Fellowship for Research Abroad from the Japan Society for the Promotion of Science. Supervised by **Toshio Yamagata** at the University of Tokyo, Aiki received his PhD in 2003 for his numerical study on the successive formation of *Meddies* (Mediterranean Sea eddies). Meddies are the anticyclonically rotating disks of salty water (about 50–100 km in diameter) drifting at 1000-m depth in the eastern North Atlantic Ocean. A Meddy is formed each month, and Aiki's numerical study identified the conditions that sustain the continued birth of new eddies. His modeling results also revealed that a Meddy is formed as the anticyclonic lower part of a vertically-tilted dipolar vortex with a cyclonic upper part.

As postdoctoral work at JAMSTEC, Aiki developed a locally high-resolution, yet global ocean GCM to investigate the outflow of Red Sea Water to the Indian Ocean. The outflow is puzzling in that it stops in late summer. The reason for the stoppage, he found, was the seasonal coastal upwelling in the Indian Ocean associated with the monsoon. More recently, Aiki has been analyzing energy conversion by mesoscale eddies in the global ocean, the residual effect of hydrostatic pressure perturbations, the so-called eddy form drag. Classical energy theory has difficulty explaining the energy conversion due to this drag. Aiki developed a theory of oceanic energy to account for such energy conversion. Understanding this drag will help to develop appropriate mixing parameterizations for GCMs. He is working on this project with **Kelvin Richards**, leader of IPRC Regional Ocean Influences research.

Asked about how he got interested in oceanography, Aiki laughs: "I grew up in Nagano, where the 1998 winter Olympics were held, and often climbed mountains to see beautiful scenery of clouds spreading below my eyes. I also enjoyed and practiced rowing every morning when I was studying mathematics as an undergraduate at Nagoya University. It was a practical exercise of fluid dynamics and oceanography to keep thinking about an effective way to push water with an oar and feeling the breath of ocean tides on a boat in a river mouth."



Shan Gao

Shan Gao joined the IPRC as a postdoctoral fellow in Spring 2007. He studied physical oceanography for 10 years at the Ocean University of China, obtaining his PhD in 2003. "When I was a child," Gao recalls, "I was told the ocean was full of treasures and mysteries, mermaids and pirates. I think that's why I went into ocean research when I grew up. From the start, I was attracted to ocean waves, and after several years study, I learned to forecast offshore waves accurately with different wave models. In fact, I like to learn everything about the ocean. Whenever I face the immense water, I feel tiny."

For his dissertation, Gao used the boundary-element and mixed Euler-Langrange methods to develop a two-dimensional numerical wave tank. The tank has perfect wave generation and absorption functions, and it is stable and accurate enough to simulate all kinds of fully nonlinear surface waves.

Using this tank, he documented the role of the Coriolis-induced lateral body-force in wave–current interactions and showed that the effect of this force on the sea is of the same order as that of wind turbulence under normal conditions. These findings indicate that lateral body-force must be taken into account in wind-driven currents.

Gao is working with **Tangdong Qu** at the IPRC on analyzing the origin, pathway, and fate of the Equatorial 13°C Water using a tracer and adjoint tracer technique. This water mass contributes to the temporal evolution of the eastern Pacific "cold tongue" and to eastern-boundary sea surface temperature, which are related to ENSO and Pacific decadal variability.

June-Yi Lee

June-Yi Lee came to the IPRC in May 2006 as a postdoctoral fellow with the project "Climate Prediction and Its Application to Society" (CliPAS; http://iprc.soest.hawaii.edu/~jylee/clipas/). Lee was interested mainly in astronomy when she started college. Then in her last year at Ewha Womans University in Korea, she became fascinated by the monsoon and by climate studies, and she decided on graduate studies in the Department of Atmospheric Sciences at Seoul National University. In 2003 she received her PhD from that department.

For her dissertation, Lee studied monsoon predictability in dynamical models. She assessed the skill of a multi-model ensemble system to predict seasonal precipitation using the CLIVAR Seasonal Prediction Model Intercomparison Project design. To improve seasonal prediction, she developed a statistical model based on the Singular Value Decomposition method to correct a bias stemming from anomalous rainfall and a statistical downscaling method based on the Coupled Pattern Projection Method. She also developed a global SST prediction model for two-tier prediction using this projection method and a dynamical El Niño model.

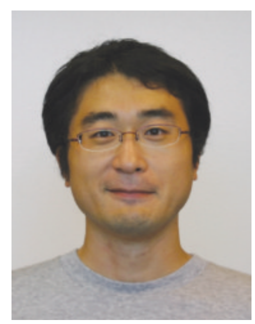
Since August 2005, Lee has been a coordinating program scientist for CliPAS, working with the project head **Bin Wang**, co-leader of IPRC Asian-Australian Monsoon System research. Partly supported by the APEC Climate Center in Busan, Korea, the project's aim is to assess how well current climate models predict one month ahead the El Niño –Southern Oscillation (ENSO), the monsoon, the ENSO–monsoon teleconnection, and the intraseasonal oscillation. Lee is especially interested in the impact of systematic model climate-mean-state errors on the accuracy of the seasonal prediction, and in the ENSO–monsoon teleconnection characteristics as a source of errors in predicting monsoon precipitation.


Oleg Melnichenko

Oleg Melnichenko joined the IPRC as a postdoctoral fellow in January 2007. He recalls, "When I was a high school student I dreamed about becoming a sailor. So, when I went to university, I chose to study physical oceanography at the Leningrad Hydrometeorological Institute, Russia, so that I could combine my education with going to sea. The Institute had promised an extensive field program, which I really enjoyed." After obtaining his master's degree in physical oceanography, he had to serve a time in the Soviet Union Air Force as an operational meteorologist.

Melnichenko returned to physical oceanography when he started work at the Ukraine Marine Hydrophysical Institute, from which he received his PhD in 2005. For his dissertation, he focused on the problem of reconstructing oceanic currents from irregularly spaced and noisy observations. The work involved analysis of such data as drifter- and current-mooring observations on the Texas–Louisiana continental shelf, subsurface isobaric float trajectories in the California Current System, high-frequency radar velocity measurements in Monterey Bay and, close to his home, measurements of currents in the Black Sea. He then studied the subsurface velocity data from Argo profiling floats to reconstruct mid-depth circulation in the tropical off-equatorial North Atlantic, with particular emphasis on deep flows related to westward propagating long Rossby waves.

At the IPRC, Melnichenko is working with associate researcher **Nikolai Maximenko** on the different types of alternating zonal jets recently found in satellite altimeter and drifter data. The goal of this project is to validate these jets through comprehensive analysis of *in situ* observations collected in different parts of the World Ocean. Output from the JAMTEC Ocean Model for the Earth Simulator (OFES) will also be used to understand the dynamics of these jets better.

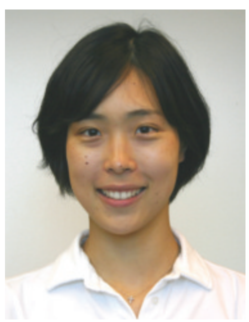

Kazuyoshi Soma

Kazuyoshi Soma came to the IPRC as a postdoctoral fellow this August after he received his PhD from the Department of Urban and Environmental Engineering at Kyoto University. Wanting to learn a useful profession, Soma recalls, he had started out with courses in the Faculty of Engineering at Kyoto University. Attending a meteorology lecture, however, he heard about extratropical cyclones and how they form and found himself interested in meteorology. Luckily, there were professors studying land–atmosphere interactions and meso-scale meteorology in the Department of Urban and Environmental Engineering at Kyoto University.

For his dissertation, Soma developed a scheme for estimating the spatial distribution of land surface to initialize short-term numerical weather prediction models. Using a cloud-resolving, coupled atmosphere–land-surface model, he investigated the effects of soil moisture distribution on heat thunderstorms, the type of thunderstorms that develops towards the end of a hot, humid summer day. The simulated rainfall over a plain with evenly wet soil, he found, was less than with the same overall, but realistically distributed, moisture. Thus, at least for Japan, realistic initial soil moisture distribution results in more accurate rainfall predictions for heat thunderstorms than parameterized wet soil. Moreover, studying the impact of urban environment (artificial land cover, anthropogenic heat, and building distribution and density) on heavy rainfall over Tokyo, he found that the urban environment affected the location and amount of rainfall.

These studies at Kyoto University made Soma realize that, in order to predict and mitigate water-related problems, a better understanding of long-term and large-scale climate change was needed. Wishing to expand his knowledge of modeling climate change, he decided to come to the IPRC.

Soma is now working with IPRC's **Yuqing Wang**. Using the IPRC atmospheric regional climate model (IPRC–RegCM), he is studying the impact of land–atmosphere interactions on climate. His particular interests are extreme climate events in East Asia.


Sachiko Yoshida

Sachiko Yoshida joined the IPRC as a postdoctoral fellow in July 2007 after receiving her PhD from the Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Japan.

Studying atmospheric physics as an undergraduate, she heard by chance a lecture on coastal oceanography. Yoshida recalls, "The professor talked about simple physical processes of the small bay in my hometown, and he told us what our generation could do for this field in the future. Until then, I didn't know anything about physical oceanography. That lecture made a great impression. It was then that I decided to study physical oceanography."

For her dissertation, Yoshida investigated with a global barotropic model, high-frequency sea-surface height variations that are induced by atmospheric disturbances but cannot be resolved spatially or temporally by satellite measurements. Focusing on the ocean's dynamic response to surface pressure changes, she found that in most regions, but especially in the Arctic Ocean, high-frequency sea level changes are mainly induced by surface pressure rather than wind forcing. A complex empirical orthogonal function showed that energy leaks from the Arctic Ocean to the North Atlantic Ocean along the North American continent as a Kelvin wave. This result suggests that the energy propagation from the Arctic to the tropical Atlantic is a major reason why the sea surface height variations due to surface pressure signals become stronger in the Atlantic. The results also indicate that the uniform signal to surface pressure is relatively small at mid- or high-latitudes compared to strong meteorological disturbances, but can be relatively large at the equatorial band under rather small surface pressure forcings.

At the IPRC, Yoshida is working with APDRC manager **Peter Hacker** on conducting intercomparisons of Global Ocean Data Assimilation Experiment (GODAE) model outputs for the North Pacific Ocean.


Rieko Armstrong

Rieko Armstrong joined the IPRC as an administrative assistant in July 2007. Her primary responsibility is to act as a liaison between IPRC and JAMSTEC. She has extensive public administration experience and is a skilled Japanese–English interpreter and translator. Before coming to the IPRC, Rieko served as a research associate and recruiter for a medical research company in Hawai'i. As the primary recruiter of Japanese volunteers, she frequently acted as an interpreter and translator for the organization. In addition to her administrative and linguistic duties, she was responsible for maintaining Japanese corporate and customer relations.

Before coming to Hawai'i in 2001, Rieko was a government official for the prefecture of Kagawa, Japan, where she held positions with the International Affairs and Tourism Promotion divisions. Rieko's responsibilities were varied and ranged from accounting to interpreting, from event management to publicity.

Rieko holds a bachelor degree from the University of Hawai'i in Gerontology through the Interdisciplinary Studies Program, and is a member of the academic honor society Phi Beta Kappa. As an avid outdoor person, Rieko enjoys stroller jogging with her 1-year-old daughter and days at the beach with her family.

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