

Understanding Stratospheric Processes and their Role in Climate

The Ninth Annual Meeting of the SPARC Scientific Steering Group

Kevin Hamilton

The IPRC played host to the 9th annual meeting of the Scientific Steering Group (SSG) of the SPARC (Stratospheric Processes and their Role in Climate) program last December. SPARC is one of the six main initiatives of the World Climate Research Programme and focuses on understanding and modeling the circulation and chemistry of the stratosphere, and how these influence and are influenced by tropospheric climate and climate change.

The meeting participants discussed a range of current issues relating to stratospheric circulation and climate. In the 1990s, SPARC undertook major assessments of trends observed in stratospheric temperature, ozone, and water vapor over the last few decades. The SSG considered how to update these assessments and formulated plans for assessing the observed trends in stratospheric aerosol concentration. Preliminary plans were discussed for a more integrative assessment of the consistency of the observed temperature trends and the coincident changes in atmospheric composition.

In addition to these assessment efforts, the SSG reviewed some other activities SPARC has undertaken in order to advance understanding of certain key physical processes. A notable example among these is the effort to apply routinely collected, operational upper-air weather data to the study of the gravity-wave field in the upper troposphere and lower stratosphere. Modern radiosonde systems actually record data at quite fine vertical resolution (~100 m, or better). Unfortunately, the standard practice has been to archive only the data at the levels mandated by the World Meteorological Organization (WMO). By saving only the WMO-mandated data, the national meteorological services are discarding potentially important information about the atmosphere. For some years now, **Kevin Hamilton** (IPRC) with his colleague **Robert Vincent** (Adelaide University) have led a SPARC-sponsored working group to “rescue,” archive, and analyze the very fine vertical resolution wind and temperature data from operational balloon-borne radiosondes. They have coordinated the accumulation and analysis of the raw data, and through their effort, suitable data have been obtained from



From left to right: Kevin Hamilton, Roger Newson (WMO), SPARC Co-chair Alan O'Neill, head of the SPARC Office Marie-Lise Chanin, and SPARC Co-chair Marvin Geller

over 190 stations provided by the national meteorological services of 12 countries. The SSG reviewed these achievements along with preliminary scientific analyses that have examined the geographical and seasonal variability in the wave-like fluctuations seen in these data. The activities of other SPARC working groups were reviewed, including one devoted to understanding the dynamical and chemical structure of the tropopause region, and another that is conducting a series of intercomparisons of results from several global simulation models with substantial resolution of the stratospheric circulation.

The participants concluded the meeting with a discussion of how SPARC should react to the recent surge of interest in the relationship between large-scale stratospheric and tropospheric circulations (see Hamilton's review article in this issue). This is a particularly challenging issue and will require substantial efforts in both modeling and observation to reach clear conclusions.

Kevin Hamilton, IPRC Theme-4 leader and SPARC SSG member, acted as local host for this SSG meeting, which was held December 3–6, 2001, at the Tokai University Honolulu campus. **Marvin Geller** (Stony Brook University) and **Alan O'Neill** (University of Reading) were co-chairs. The 26 participants included the members of the SSG, the SPARC working group leaders, some personnel from the SPARC Office in Paris, and representatives of other international organizations and national funding agencies.

Linking Pacific Climate and Fisheries

The Pacific Climate and Fisheries Workshop

Fish make up over 15 percent of the animal protein in the world's food supply, and in many countries, fisheries are a major part of the economy. Fish populations have large swings, however, as witnessed by the Peruvian anchovy fishery in the early part of the 1970s, when the annual yield fell from about 13 to less than 2 million metric tons within 3 years. This collapse was devastating to Peru's economy and dealt a blow to the worldwide food supply.

Overfishing is one obvious cause of a shrinking fish population. Another candidate is variation or change in ocean climate. This latter link, though, is not well understood yet, and to shed more light on the climate–fish ecosystem question, the IPRC hosted the Pacific Climate and Fisheries Workshop at the East-West Center, November 14–17, 2001. Climate scientists, social scientists, ecologists, fish biologists, and fisheries managers worked together at the workshop to lay the foundations for new research approaches that integrate climate knowledge and marine ecology with sustainable fishery management and social and political concerns.

“The time is now ripe for such an interaction, as physical oceanographers and climate researchers are making great strides in describing and understanding ocean climate variations using numerical models,” according to **Claude Roy** (IRD, French–South African IDYLE Project).

Coming from very diverse backgrounds, a challenge for these experts is to learn to talk to each other, develop common terminologies, common goals, and common frameworks. The workshop was therefore unusual in that it had no pre-set presentations. Rather, all the available time was reserved for discussion and communication among the scientists, and the program alternated between plenary discussions of central questions and smaller focus groups. **Jürgen Alheit** (Baltic Sea Research Institute) as the plenary discussion leader created an environment that stimulated lively, all-around participation. A synopsis of the most important discussion points follows below.

The question *what climate information is useful to fisheries management* yielded wide-ranging answers. Some participants thought that climate forecasts are not yet good enough to provide fisheries with useful forecasts, and that too little is known about how climate variations affect different species; others pointed out that enough is known on

how El Niño affects certain fishes, and this information has already provided helpful forecasts.

The complexity of applying climate information to fisheries was further mirrored in the following concerns: forecasts are given with too short notice; some climate variations, themselves, are too brief for meaningful adjustments; forecast information may be misused by banks; and recommendations for adjusting to climate change may result in oversupply. For example, when governments in South America, noting an impending El Niño, recommended that fisheries shift attention to dolphin fish, the result was an oversupply of dolphin fish and very low prices.

Defining marine ecoshifts and determining indices of regime shifts received intense discussion. Basic indices were debated: some argued against using primary productivity saying there is little relationship between primary productivity and number of fish; others were against using chlorophyll, since areas of strong upwelling with lots of nutrients sometimes have few fish (for example, the Benguela Current); still others saw a problem with using zooplankton biomass as an index.

On what spatial scales do shifts occur—local, regional, basinwide, or global? On what timescales do they occur—biennial or decadal, sudden or gradual? Regime shifts in the physical ocean may have different timescales from biological ones. A small shift in the seasonal cycle can sometimes have a significant impact, as for example, the early blooming of zooplankton, on which Cassin's auklets feed while hatching their eggs, may result in abandonment of the nests.

A further question pertaining to the regime shift definition is whether comprehensive or separate indices should be developed for shifts in ocean climate, marine ecosystems, and various fish populations. **Arthur Miller** (Scripps Institution of Oceanography) suggested that an analysis of the last three Pacific Ocean climate shifts might reveal patterns of the similarities and differences accompanying these shifts and could help in developing appropriate indices.

The *mechanisms that drive regime shifts* are also not well understood yet. **Andrew Bakun** (IRI) described a fascinating, rapidly evolving (about 10 – 50 years) adaptive mechanism, the school-mix feedback hypothesis, whereby cli-

mate change may trigger a biological change, namely, a change in reproductive habitat selection. If there is such a mechanism, then Bakun believes that we might learn how to take actions to effect the operation of the mechanism in order to avoid the collapse of a fish population, such as the one off the coast of Namibia several decades ago. When large industrial fisheries began to fish in the spawning grounds there, it appears that the sardines shifted their primary spawning site to the adult feeding grounds. It has not been possible to bring the sardine population back to its original abundance. Understanding the mechanisms by which fish may move away from their most favorable spawning habitats because of local overfishing could help to prevent or rectify such happenings.

Participants agreed that much more needs to be learned about the typical migration, feeding, and spawning behaviors of different fish species and how these behaviors are affected by climate variations. The climate–spawning relationship, for instance, may be quite different for different species. Thus, anchovies have a short life-span making them sensitive to high frequency climate events, and they do well in cold water; sardines have a 5 – 10 year life-span, and they do alright in warmer waters.

A major goal of the workshop was to plan an interdisciplinary climate–fisheries project. Three possible topics for such a project emerged by workshop’s end:

- 1) **Andrew Bakun’s** school-mix feedback adaptive mechanism in fish populations under strong selective pressures mentioned above. This mechanism may allow a schooling fish population to effectively track longer-period environmental (climatic) variability and so maintain correct adaptation to longer-term variability.
- 2) **Patrick Lehodey’s** approach to researching the interaction between climate and tuna by using different modeling approaches, for example, individual energetics models (IPM), mass-balance models (ECOPATH-ECOSIM), and spatial ecosystem models (SEPODYM), to explore the underlying mechanism by which climate-induced environmental variability affects the pelagic ecosystem and tuna populations.
- 3) **Alec MacCall’s** Flow Hypothesis, which suggests that decadal variations in flow speed (strength) of the three major Pacific boundary currents systems (South America, North America, and Japan) affect the mesoscale structure of the flow patterns and the associated frontal zones, as well as the marine



From left to right: Jay McCreary, Lorenz Magaard, Andrew Bakun, Kenneth Broad, and Jürgen Alheit

habitat, including nutrient supply and conditions for fish survival and growth. Thus, when the flow of the Kuroshio Current is weaker and slower, it tends to meander, and cooler, nutrient-rich Oyashio water intrudes, providing favorable conditions for sardine spawning and larval retention.

This third project already reflects the desired fruitful interaction among workshop participants: Fishery biologist MacCall developed this hypothesis in discussion with biological oceanographer **Takashige Sugimoto**, physical oceanographer **Don Olson**, and fishery oceanographer Andrew Bakun.

Scientists from the workshop are meeting again at the PICES North Pacific Transitional Areas Symposium held April 2002 in La Paz, Mexico, where they have planned to develop further the framework for this interdisciplinary climate–fisheries research project.

The workshop concept was suggested by Lorenz Magaard (IPRC), who also organized the workshop logistics. The International Research Institute for Climate Prediction (IRI) strongly supported Magaard’s suggestion and asked Andrew Bakun (IRI senior research scientist) and Kenneth Broad (University of Miami) to develop and organize the workshop program. The IRI and the IPRC were the primary sponsors of the workshop; co-sponsors included the North Pacific Marine Science Organization (PICES), the Center for Sustainable Fisheries of the University of Miami, the International GLOBEC Project Office and the IDYLE Project of the French Institut de Recherche pour le Developpement (IRD). Moreover, a number of additional organizations and institutions (e.g., the NOAA Office of Global Programs, NASA, IOC, FAO, and others) contributed

Indian Ocean Dipole Takes Center Stage

Symposium on the Ocean–Atmosphere Coupled Dynamics in the Indian Ocean

Shang-Ping Xie

The Symposium on the Ocean–Atmosphere Coupled Dynamics in the Indian Ocean, jointly organized by the Frontier Research System for Global Change and the IPRC (co-conveners: **T. Yamagata** and **J.P. McCreary**), took place December 17–18, 2001, in Tokyo. Scientists from 5 continents presented 49 papers. Compared to the first International Symposium on Indian Ocean and Monsoon Variability in March 2000, held also in Tokyo, the number of papers on Indian Ocean climate variability increased dramatically, a reflection of the explosion of interest and progress in this topic.

The Indian Dipole Mode (IDM), a contrasting sea surface temperature (SST) pattern in the tropical eastern and western Indian Ocean (see Figure 7), was the central theme of the symposium. There is consensus among scientists that cooling in the eastern equatorial Indian Ocean SST is associated with a major shift in atmospheric convection and ocean circulation; under debate is the significant link between this cooling and western equatorial Indian Ocean SST variability and the mechanism that might be responsible.

Empirical analyses of observations show a significant correlation between the IDM and ENSO in boreal fall, but not during other seasons. The physical explanation for this seasonal correlation is now being debated. One school argues that the IDM variance explained by ENSO is small and hence the IDM is largely an independent mode intrinsic to the Indian Ocean. The other holds that this seasonal correlation is evidence for an ENSO-forced scenario.

While only one coupled general circulation model (GCM) group reported success in reproducing the IDM at the first Tokyo Symposium, five coupled GCM groups presented successful simulations this time. Carefully designed coupled GCM experiments will shed light on the coupled dynamics in the Indian Ocean in general, and on the relation between IDM and ENSO in particular. For example, the GFDL atmospheric GCM, forced by observed history of SST variations in the equatorial Pacific east of the dateline and coupled with a slab-ocean mixed-layer elsewhere, yields an ENSO composite (the average of many ENSO events) resembling the IDM.

The rather short instrumental measurement record during which only a few strong IDM events have occurred limits empirical studies on this topic. **N. Abram** analyzed isotope compositions of modern and Holocene corals off Sumatra, Indonesia, at a subseasonal resolution. Her analysis of fossil corals indicates that the IDM existed at least as early as the mid-Holocene period and that many paleo-IDM events occurred independent of the Pacific ENSO.

The synthesis of such high-resolution coral analysis with Pacific paleo-coral records appears promising, and together with coupled GCM experiments, offers hopes of resolving the issues that cannot be answered by the short instrumental records.

There appears to be a consensus that the IDM involves a positive air-sea interaction but that it is a damped mode, requiring external forcing to be excited. Several papers investigated the triggers for a strong IDM, and several papers dealt with the IDM influence on rainfall anomalies over the surrounding continents, on marine biological activity, and on tropospheric ozone.

Besides air–sea interactions and Indo–Pacific Ocean interactions along the equator, papers also dealt with off-equatorial variability. Evidence for links between the IDM and the South Asian summer monsoon was presented. Furthermore, off-equatorial Rossby waves in the tropical South Indian Ocean have large amplitudes, and several observational and modeling studies suggest that these waves induce significant SST anomalies in the west where the mean thermocline is shallow, a unique Indian Ocean feature. These Rossby waves, according to some studies, appear to affect tropical cyclone formation through their effects on SST.

Papers were also presented on oceanic processes causing Indian Ocean climate variability, including cross-equatorial flow, the Indonesian Throughflow, and waves. Given the small horizontal gradient in climatological SST in the Indian Ocean, salinity may have significant effects on ocean dynamics and on SST variability. High-frequency disturbances like the atmospheric Madden-Julian Oscillation may also lead to adjustments in the Indian Ocean climate and affect its variability.

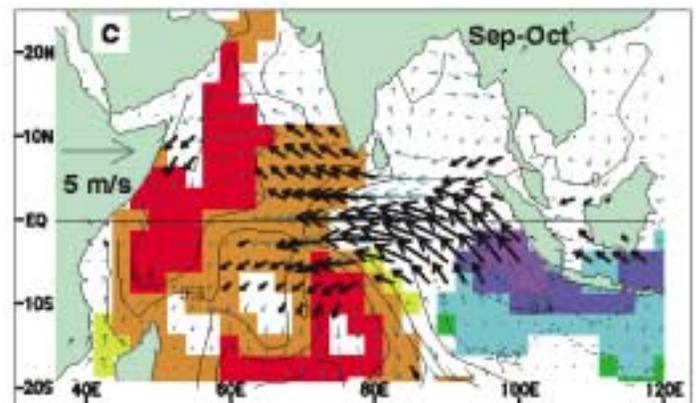


Figure 7. Evolution of composite SST and surface wind anomalies during the peak of an IDM event (Sep-Oct)

CLIVAR's Pacific Focus

CLIVAR Pacific Implementation Panel

CLIVAR Pacific Implementation Panel's first meeting was hosted by the IPRC at the East-West Center, February 7–9, 2002. Chair, **Kelvin Richards**, School of Ocean and Earth Sciences, University of Southampton, described the Panel's functions, which are to provide an overview of Pacific climate events and projects, spot gaps and weaknesses, convene scientists for discussions on key issues, and provide the community with information on Pacific climate. **John Gould**, International CLIVAR Director, reviewed the panel's charge to understand natural climate variability and human-induced changes, and to study the long-term predictability of climate in order to improve predictions. A better observing system in the Pacific is essential, given the region's influence on global climate.

Panel members reported on CLIVAR-Pacific-related projects in their respective countries. Simulation of climatology with the Australian Commonwealth Scientific & Industrial Research Organization's new coupled model agrees well with observations; the Bureau of Meteorology Research Centre's ENSO prediction model suggests that with global warming, Australia will have less rain. Canada is working with the Japan Marine Science and Technology Center on a system of weather buoys strung across the North Pacific. Chile and Peru are joining forces in the Chili-Peru Oxygen Minimum Circulation Experiment, a study of dynamic and biochemical processes affecting the oxygen minimum content. China is studying causes of variability in the Indo-Pacific warm pool, where huge amounts of water vapor enter the atmosphere, and the movement of SST anomalies from the Indian to the Pacific Ocean. The supply ship for China's two Antarctic stations, traveling once a year to and from Antarctica, can take ocean measurements. France is studying ENSO predictability using an ENSO-observing system that includes data from coral drilling, tide gauges, and timeseries stations. Japan has an extensive CO₂ mapping study; climate modeling research on Japan's supercomputer, the Earth Simulator, starts April 2002.

Details on the "Launching of the Argo Armada" were given by **Howard Freeland**. The data collected by the free-drifting profiling Argo floats (measuring ocean temperature and salinity of the upper 2000 m) are made publicly available within hours after collection and allow continuous monitoring of the ocean state. At present 708 floats have been set adrift; over the next three years, 2,373 more are planned for a total of 3,000 floats. By the end of 2002, we can expect good coverage except for the East Pacific from the equator southward. The Argo system is a truly international endeavor. Built by the individual nations, the floats relay data to their national centers. Standardized calibration and quality control are a problem. Also, countries



must be willing to deploy floats far away from home for global coverage and to continue funding replacements, the floats having only a 4-year life span.

The new Global Ocean Timeseries Observing System—a mooring system collecting data for marine ecologists, oceanographers, meteorologists and solid earth geophysicist—was presented by **Robert Weller**. A complement to Argo, the moorings are to be long-term and placed at sites with the greatest overlapping scientific interests. Support and funding for this system is now being sought among the scientific community. Weller also reported on the East Pacific Investigation of Climate, which is producing interesting data on the interaction between the ocean-atmosphere boundary layer. A southward extension of buoys is planned and will form the Ocean South East Pacific Array.

The Panel was briefed on several studies being planned, including the Kuroshio Extension System Study and The Hemispheric Observing System Research and Predictability Experiment. **Roger Lukas** described the Pacific Basin Extended Climate Study (PBECS), a long-term experiment to test and improve dynamical models of ocean processes causing climate variability. PBECS is based on the belief that the best hope for climate prediction and assessment lies in models that have sound approximations of important physics and are initialized with accurate observations. The international panel has adopted an implementation and planning strategy closely aligned to PBECS in order to provide a framework for national contributions to CLIVAR Pacific.

Peter Hacker, manager of the APDRC (see p. 19), described the activities of the APDRC, which the Panel strongly endorsed. **Daniela Turk** (CLIVAR office) presented the CLIVAR links with biogeochemical/carbon programs. The Panel recognized the benefits for collaboration with these programs, particularly in view of the ENSO impacts on biogeochemical processes in the Pacific Ocean.

For further information on CLIVAR Pacific visit www.usclivar.org.

Closer Japan - US Partnership in Climate Research

The Japan–US partnership in climate research received a boost at the Climate Modeling and Applications Science Meeting in Tokyo, February 25, 2002. This meeting between high-level Frontier Research System for Global Change (FRSGC) scientists and scientists from NOAA Office of Oceanic and Atmospheric Research (OAR) and collaborating programs resulted from President Bush’s wish for closer climate research collaboration with Japan. The meeting’s aim was to explore specific partnership possibilities. Described below are the participating programs and the projects proposed for collaboration.

Research at Japan’s FRSGC focuses on prediction of global environmental change by conducting process studies and developing models to be run on the Earth Simulator. **Taroh Matsuno** (Director-General, FRSGC) described research and the main models being developed at the FRSGC: a coupled atmosphere–ocean GCM for modeling the Baiu front, typhoons, and baroclinic eddies; a very high-resolution (5 km) atmospheric GCM; and an integrated global environment model. Tests on the Earth Simulator supercomputer using the first two models with several horizontal resolutions are underway. **Hirofumi Sakuma** (Group Leader, FRSGC) expects that the very high-resolution models will be able to simulate precipitation patterns, storm tracks, Kuroshio meanders, the Indian Ocean Dipole, and more. **Toshio Yamagata** (Director of the FRSGC’s Climate Variability Project and of the Japanese portion of the IPRC) expanded on the FRSGC research on the Indian Ocean Dipole, which appears to have a global effect on midlatitude temperature variability. Discussions are underway with African countries and India to take more measurements in the area. (NOAA is also exploring the extension of moored buoys into the Indian Ocean.)

NOAA’s plans for climate services, described by **Ken Mooney** (Deputy Director, Office of Global Programs), are to provide on-demand climate assessments, produce maps of US carbon sources and sinks, develop options for managing greenhouse gases and aerosols, and produce routine state-of-the-atmosphere reports. Earth system models are being developed at the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) to provide knowledge on natural climate variability and man’s effects on climate. According to **Ants Leetma** (Director, GFDL), plans include production of forecast products (from future climatologies to seasonal and weather forecasts), development of an

ocean model with a $1/10^\circ$ resolution and a chemical transport model, and an assessment of the Pacific Ocean impact on the Indian Ocean. A major project is the Earth System Modeling Framework, a \$10 million NASA-funded, 5-year project to produce a general modeling framework among US climate modeling efforts. The main US climate modeling institutes have agreed to use the framework.

The current status and plans for IPRC’s Asia–Pacific Data–Research Center (APDRC, p. 19) were presented by **Julian McCreary** (Director, IPRC). The APDRC currently receives funds from NASA and NOAA in order to link US data centers to the APDRC, allowing easier access to high-quality data sets and products from many centers. Concerning ocean data assimilation, **Toshiyuki Awaji** reported FRSGC’s plans, and **Ming Ji** described GFDL efforts and ECCO (Estimating Circulation and Climate of the Ocean), a joint project between Scripps, JPL, and MIT. The International Research Institute (IRI) focuses on societal applications of climate research. **Antonio Moura** (Director, IRI) gave examples of the institute’s worldwide projects: El Niño forecasts to advise agriculture in Argentina and fisheries management in Peru; a global mosquito population study to predict outbreaks of Dengue; a 10-member ensemble run on 16 PCs in Brazil to predict rainfall. Stephen Zebiak described the IRI applied modeling efforts, which include study of seasonal and longer timescale climate variation, the role of land surface, regional model development, and the Indian Ocean influence on global climate.

As a result of the meeting, the following projects for US–Japan research partnerships are being proposed (institutional programs are listed in parenthesis): 1) study of the Indian Ocean Dipole by application of coupled ocean–atmosphere GCMs, investigating (a) the teleconnections between the Pacific and Indian Oceans, (b) the links between annual and interannual cycles, and (c) the predictive ability of models (FRSGC, IRI, GFDL, and IPRC); 2) ocean data assimilations with the Earth Simulator (FRSGC, NOAA, and GFDL); 3) development of ocean and atmosphere models with a focus on testing parameterizations, reducing biases, and common diagnostics (FRSGC, IRI, IPRC, and GFDL); 4) development of data centers and data sets to improve data coverage and coordination (YIES; FRSGC; APDRC; IPRC; IRI; NOAA-OGP); the IPRC is to hold a workshop on this topic.