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

APDRC receives NOAA Grant

The Asia-Pacific Data-Research Center (APDRC) at the IPRC provides the research community and general public with one-stop shopping for climate data and products. The center received nearly one million dollars from the National Climate Data Center of NOAA's National Environmental Satellite, Data, and Information Service.

The grant is being used to

- expand data sets and products by increasing APDRC archives and access to data sets stored at other institutions,
- serve Global Ocean Data Assimilation Experiment products for research purposes and for practical applications,
- participate in data quality control as a regional Argo application center, and
- implement a high-resolution regional ocean model that downscales operational models for use around Hawai'i and other Pacific Islands.

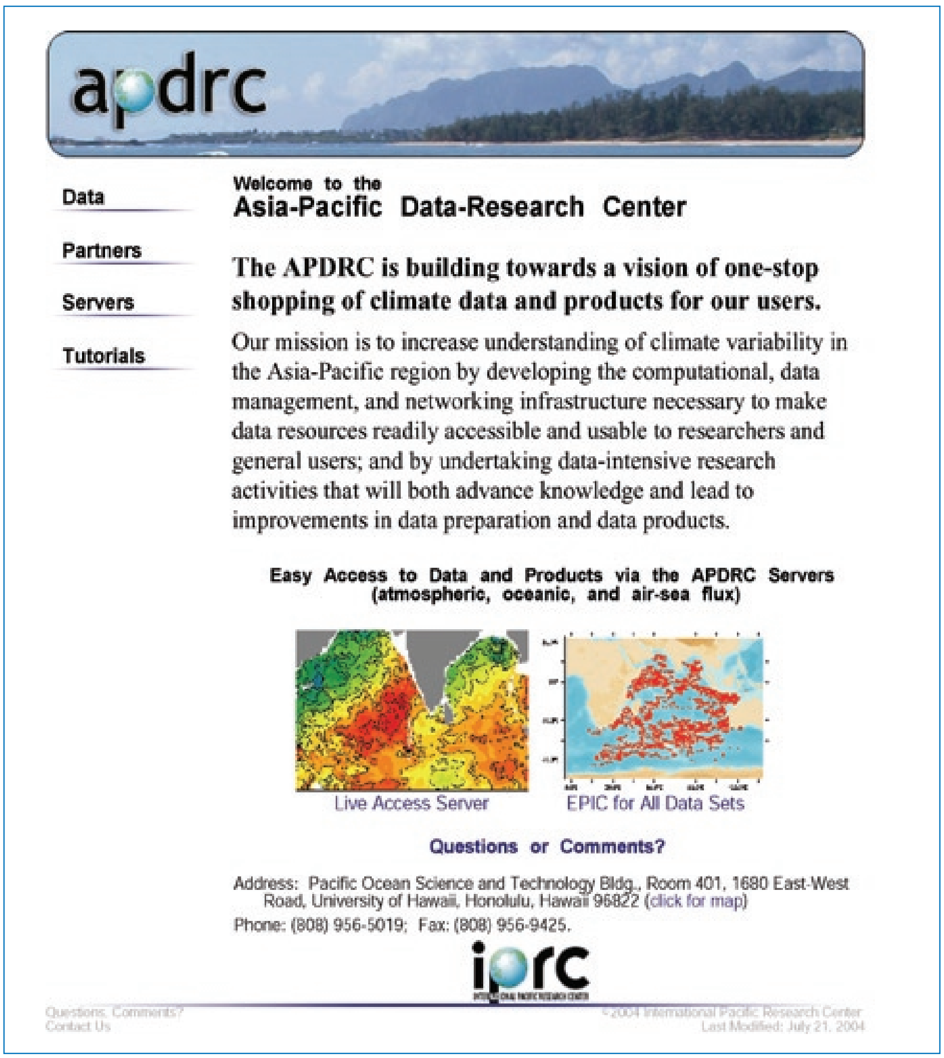
IPRC scientists help build data archives

Several IPRC scientists have been chosen to help with building the APDRC data holdings. **Jim Potemra**, as data manager, heads this activity; he is assisted in acquiring and maintaining oceanographic data by **Gang Yuan**, atmospheric data by **Yongsheng Zhang** and **Xiouhua Fu**, and air-sea flux data by **Zuojun Yu** and **Jan Hafner**. These scientists bring their research expertise to the data-acquisition effort, ensuring that the APDRC serves useful, quality data and flags problematic sets. This combination of research with data acquisition and archiving is unusual and should benefit climate research and improve the quality of the products served by the APDRC.

APDRC website changed

Much has changed and will continue to change at our APDRC website. If you go to our portal, **apdrc.soest.hawaii.edu**, this page (*below*) now welcomes you.

The **Data** link at the top left of the **Welcome** page brings you to the page that provides access to the APDRC datasets in different ways: by data, server, grid, or by variable name. We now also have links to tutorials for the various servers.



Credit for our new APDRC website appearance and structure goes to **Jim Potemra**, assistant researcher with the Regional Ocean Influences team at the IPRC. Potemra is being assisted in maintaining this website by **Sharon DeCarlo**, who recently joined the IPRC (see p. 23).

SODA POP 1.2 now available on APDRC server

***Benjamin Giese**, one of the developers of the new reanalysis of the global ocean SODA POP 1.2 (Simple Ocean Data Assimilation – Parallel Ocean Program) from the University of Maryland/Texas A&M consortium, visited the IPRC from July to December, 2004. During his stay, he worked with our scientists to make this new reanalysis available on the APDRC server, and below he describes the most important changes.*

The ocean model in SODA POP 1.2 has a much higher resolution than the previous SODA analysis. (The upcoming article by Carton and Giese 2004 in the *Bulletin of the Meteorological Society* provides details on the reanalysis). As an intermediate resolution version of the POP (Parallel Ocean Program) code developed at Los Alamos National Laboratories, this global model has 40 vertical levels, varying in depth from 10 m at the surface to 250 m in the deep ocean; a grid resolution of 0.4° longitude and 0.28° latitude; and a "displaced pole" to avoid the singularity that arises from the converging meridians at the North Pole. This change results in a complete Arctic Ocean.

The model is forced with daily averaged reanalysis winds from the European Center for Medium Range Weather Forecasts ERA-40 reanalysis spanning January 1958–2001. Surface freshwater flux for 1979–2001 is provided by a combination of the Global Precipitation Climatology Project monthly merged product and evaporation obtained using bulk formulae, which are also used for surface heat flux. Vertical mixing is parameterized using the KPP mixing formulation and biharmonic horizontal mixing coefficients.

The most important aspect of the reanalysis is the multivariate sequential data assimilation scheme, developed at the University of Maryland (Carton et al., 2000), which updates the ocean model with ocean temperature and salinity observations every 10 days. The subsurface temperature and salinity data sets consist of about 7 x 10^6 profiles. Two-thirds of the profiles have been obtained from the World Ocean Database (WOD) 2001, which has 1.7 million profiles more than the WOD98. (For further changes in WOD2001 see **www.nodc.noaa.gov/OC5/WOD01/ch98to01.html**.) Additional mixed-layer temperature observations are taken from the COADS surface marine observation set.

The SODA reanalysis includes checks for duplicate reports and for errors in the recorded position and time of observations, static stability, deviations from climatology, and checks on the temperature–salinity relationship. In spite of substantial quality control in the WOD2001, the SODA quality control (including buddy-checking, examination of forecast-minus-observation differences, and vertical stability) eliminates an additional 5% of the profiles.

Researchers at the IPRC have been using SODA POP 1.2 to study such climate features as the nonlinear dynamic heating of the El Niño-Southern Oscillation, aspects of the Indonesian Throughflow, and variations in the circulation of the subtropical cells in the Pacific.

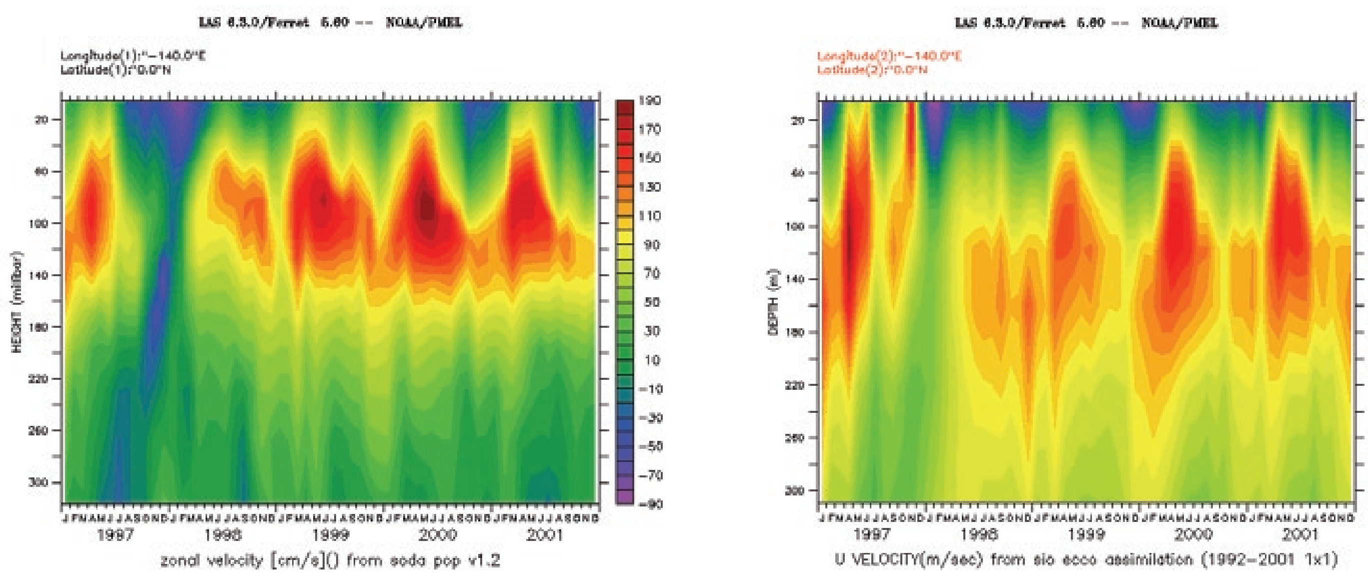


Figure 10. Zonal currents at 140°W on the equator from SODA-POP 1.2 (left panel) and from ECCO (right panel). This figure, which allows comparison of currents as described by two products, was generated using the APDRC LAS.

Interested in this reanalysis? Visit the APDRC and take a test drive of SODA POP 1.2!

APDRC becomes a GODAE product server

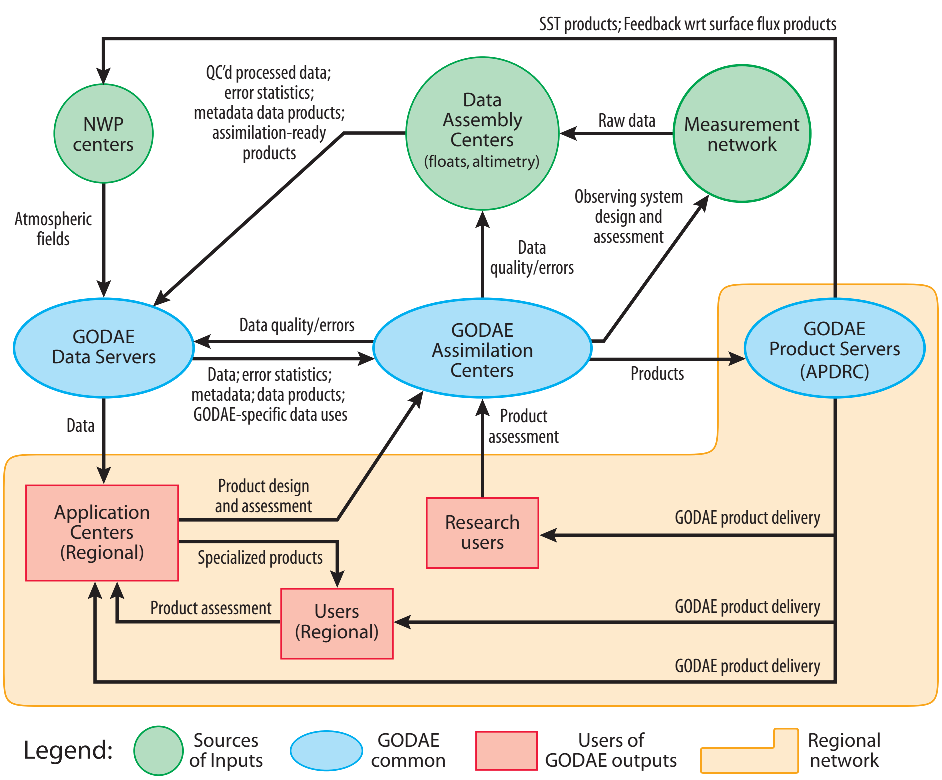
The vision of the Global Ocean Data Assimilation Experiment (GODAE) is to create "a global system of observations, communications, modeling and assimilation that will deliver regular, comprehensive information on the state of the oceans." Involving global telecommunication systems and using the newest technology, GODAE is a huge effort by a great number of international scientific teams to make ocean monitoring and prediction as routine as weather forecasting. This monitoring is to serve interests ranging from climate and climate change to such things as sea level rise, ship routing, and fisheries.

The measurement networks of GODAE include different types of satellites that remotely collect data from *in situ* measurements by Argo floats, moored buoys, tide gauges, and ships, and model-based products from numerical weather prediction centers. Gathered by various national data centers, the data is sent on to the two GODAE Data servers: the US GODAE Real-time Data Server in Monterey (established by the Navy Fleet Numerical Meteorology and Oceanography Center, FNMOC) and the French Coriolis Center (established by the French Research Institute for Exploitation of the Sea, IFREMER). This means massive amounts of information are being collected, ranging from raw instrument data (level 0), to data products that often take the form of a homogeneous gridded field or model assimilation products, to products derived from further processing (level 4).

Having completed the conceptual (1998–99) and development (2000–02) phases, GODAE is now in its operational demonstration phase and making its products available to the public. The APDRC is a designated product server and is already serving several GODAE products.

These products are available on our GDS, the server that combines the Grid Analysis and Display System with the Distributed Ocean Data System for formatting oceanographic data. We are also serving GODAE products on our Live Access Server (LAS), the server that has become the main medium for serving GODAE data because it provides maximum control over data flow. Users can obtain precise subsets of variables, eliminating the transfer of large volumes of superfluous data that is typical of "data push" systems, and users can chose the format in which they get the data, many of the historical format dependency issues having been resolved. LAS users can get an integrated view of real-time, recent-past, and archived data.

Aside from being a GODAE product server, the APDRC is taking part in two other GODAE related activities: application of the HYCOM model to shores surrounding the Pacific Islands, and participation as an Argo regional application center.



The APDRC role as a GODAE product server.

A high-resolution ocean model for the Pacific Islands

The Hybrid Coordinate Ocean Model (HYCOM) fulfills the GODAE objectives of giving users a three-dimensional depiction of the ocean state at fine eddy-resolving resolution in real time and of providing boundary conditions for coastal and regional models so that these models can be used for ocean forecasting as well as research. The improved open-ocean nowcasts and forecasts will be applied, among other things, to search and rescue operations, ship routing, tracking icebergs and major pollutants, and to commercial fisheries. Originally developed at the University of Miami, HYCOM is a model that is isopycnal in the open, stratified ocean, yet reverts smoothly to a terrain-following coordinate model in shallow coastal regions, and to a z-level coordinate model in the mixed layer or unstratified seas.

Yanli Jia (see p. 24) is working with IPRC scientists **Maxim Yaremchuk**, **Jim Potemra**, and **Peter Hacker** and with scientists at the National Research Laboratory Stennis Space Center to implement the HYCOM for the ocean around the Hawaiian Islands. The first test run is being completed just as this issue goes to press. The team will make use of existing ocean measurements to evaluate the model's ability to produce known features of the circulation around the Hawaiian Islands. They expect the complex ocean bathymetry, from deep ocean to shallow shelf, and the open boundaries on all sides to be challenges.

Once the model performs well enough, it will be useful as a research tool to study such physical processes in the region as eddies and wave and topography interactions, biogeochemical processes (by including ecosystem dynamics), and regional influences on climate (by coupling to atmospheric models). Eventually the model will have data-assimilation capability so that it can be used for near real-time regional ocean forecasting and will provide useful information on such things as ocean currents, temperature and sea level variations for fisheries, environmental management, hazard assessment, and search and rescue operations. In the future, the model will be applied to other island settings in the Pacific.

APDRC helps build Argo regional application centers

The international Argo program is filling the global ocean with an array of about 3,000 drifting floats. As the floats rise from a depth of about 2 km, they measure temperature and salinity. When they surface every 10 days or so, they relay these data and location information *via* satellites to national data centers (DACs), where the records are quality checked, coded into NetCDF, a standard file format for internet distribution, and sent on to the two Global Data Acquisition Centers, or GDACs, mentioned above (U.S. GODAE at Monterey and the French IFREMER Center), which make the information available to users within 24 hours. The data are also sent to the principal investigators for delayed-mode quality control. This system will allow continuous monitoring of the ocean, forming the oceanic equivalent of an operational observing system of the atmosphere, and will be invaluable to ocean nowcasting and forecasting as well as weather forecasting and climate change research and detection.

From left (seated) Ruth Curry and Ann Gronell; (standing) Mark Ignaszewski. Charles Sun, Taiyo Kobayashi; Hiroshi Yasunari, Peter Hacker, Shinya Minato, Shiyeki Hosoda, Gang Yuan.

The Argo regional application centers are, among other things, to assist in the scientific quality control of this massive data stream, including checks on internal consistency and systematic errors in the data, and real-time and delayed-mode calibration using, for example, CTD/hydrographic data available from other sources. The centers are to prepare quality-controlled Argo products and distribute these in delayed mode. They also coordinate Argo-float deployment plans for the region and give feedback to principal investigators to improve the real-time data sets.

The APDRC plans to participate with India's DAC (INCOIS) and Australia's DAC (CSIRO) as a regional center for the Indian Ocean, and with JAMSTEC as a center for the Pacific Ocean. To plan for this participation, manager **Peter Hacker** hosted a workshop June 28–30, 2004, sponsored by the IPRC. Joining IPRC scientists for the workshop were **Shinya Minato**, Argo data manager from the JAMSTEC Argo Regional Center, who was accompanied by scientists **Taiyo Kobayashi** and **Shiyeki Hosoda**; **Ruth Curry**, research specialist, Woods Hole Oceanographic Institution; **Ann Gronell** from the Ocean Observing Networks, CSIRO Division of Marine Research; **Mark Ignaszewski**, co-chair of the Argo Data-Management Group and with the Fleet Numerical Meteorology and Oceanography Center (the Department of Defense's main production site for operational meteorological and oceanographic analysis and forecast products worldwide, and the host of the US GODAE server); and **Charles Sun**, deputy chief of the Data Base Management Division of the National Oceanographic Data Center.

At the workshop, Ann Gronell described the CSIRO quality-control system for oceanographic data that she had helped to

Charles Sun presenting to participnts of the workshop on the Argo Regional Application Center.

develop and which we will be applying to upper-ocean thermal data served by the APDRC. Ruth Curry gave a training session on her HydroBase2, a global database of hydrographic profiles and tools for climatological analysis. The database includes the original raw, and quality-controlled data from several sources; the grid-resolution is 0.5–1° and data can be fully interpolated without smoothing; the time record is monthly, topography is included. This database comes with different modules that allow flexible analyses of horizontal or vertical slices, or of different timeseries, and that make it easy to create 5-, 10-, or 15-year climatologies, and study climate change. The software works on all platforms. (For further information on this database visit **www.whoi.edu/science/PO/hydrobase**.) Work is underway to make the HydroBase 2 database and user modules accessible on the APDRC server; the APDRC will use the database for comparison in its quality control of Argo data, and Argo data will be stored in the database.

Kyosei Project

The Japanese national Kyosei Project studies variability and changes in Earth's natural environment. One of its sub-projects, the Kyosei-7 (K7), is taking advantage of the computing power of the Earth Simulator and has developed a coupled ocean-atmosphere data-assimilation system. Until the arrival of the Earth Simulator, data assimilation was carried out mostly in stand-alone ocean or atmospheric models that are forced by surface observations in the other medium. K7's coupled approach should improve the physical consistency and accuracy of data assimilation. As part of the K7 team, IPRC is working with scientists in JAMSTEC to improve coupled model simulation, data assimilation, and product delivery.

Model improvement. Coupled models have long had trouble maintaining the Pacific Intertropical Convergence Zone (ITCZ) north of the equator, in part because of poor representation of the stratus cloud deck in the eastern South Pacific off the coast of South America. The newly developed IPRC regional ocean-atmosphere model (IPRC–ROAM) simulates this climatic asymmetry over the tropical Pacific well and can be used to improve physical parameterizations in global circulation models. In collaboration with **Toru Miyama** and **Takashi Mochizuki** of JAMSTEC, **Yuqing Wang**, **Haiming Xu**, and **Simon de Szoeke** from IPRC are adapting the IPRC–ROAM to run on the Earth Simulator. The first Earth Simulator runs with this regional model will focus on stratus clouds and their interaction with the ITCZ and the ocean.

Product diagnosis. Outputs from multi-decadal simulations with the first version of the K7 coupled global model will soon be available, and IPRC scientists will begin analysis and diagnosis of these outputs and provide feedback to model and assimilation-system developers. The initial focus will be on the assimilated products that deal with the tropical Pacific and the Asian-Australian monsoon.

A K7 workshop on coupled simulation and assimilation is taking place on January 17–18, 2005, in Yokohama. **Shang-Ping Xie**, **Bin Wang**, and **Haiming Xu** from IPRC are participating in this workshop and discussing further collaboration with JAMSTEC scientists.

Server technology upgrade. To enhance data analysis capabilities for the K7 project, our server specialist, **Yingshuo Shen**, has been working with **Kazutoshi Horiuchi** to implement server technology in Japan similar to that at the APDRC. During June 21–25, 2004, they improved and upgraded the LAS and GDS systems for K7, including the system's ability to handle *in situ* data on the LAS and to provide access control for restricted-distribution products. Shen plans to visit Japan again in February 2005 to continue the server collaboration on "sister-server" definition and activities.

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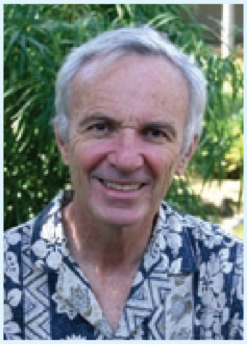
Data Surprises



by Roland Madden

*Senior scientist at the National Center for Atmospheric Research, **Roland Madden** visited the IPRC during October and November 2004. Below he writes about how, with his colleague Paul Julian, he came to discover the atmospheric disturbance that has become known as the Madden-Julian Oscillation. The late 1960s witnessed a flurry of discoveries that revolutionized tropical meteorology, among them the Yanai and Kelvin waves, which Taroh Matsuno's theory predicted, and the Madden-Julian Oscillation, which was not in the theory and still eludes a satisfactory theoretical explanation.*

Several circumstances came together in the late 1960s to facilitate the discoveries in the tropical atmosphere of mixed Rossby-gravity waves (MRGW), Kelvin waves, and the oscillation with a 40–50 day average period. One was the theoretical treatment of wave motions confined to the equatorial region (Matsuno, 1966) describing the first two waves. Another was the growing use of spectrum analysis by tropical meteorologists that allowed a quantitative description of large-scale phenomena with few and far-between observations. Spectrum analysis helped researchers "fill the gaps." With spectrum and cross-spectrum analyses, Yanai and Maruyama (1966 and 1967) examined meridional winds from the western Pacific and identified MRGW, and Wallace and Kousky (1968) studied the zonal winds and identified Kelvin waves. These were among the first demonstrations of zonally propagating, planetary-scale waves in the tropics (other than atmospheric tides). Consisting at times of data from only two locations, or from two vertical levels at one location, or even from just two variables at a single location and vertical level, the studies showed the power of spectrum analysis in interpreting tropical observations.

Technological advances also contributed to increasing knowledge about tropical meteorology. The first geosynchronous satellite making visible observations of clouds was launched over the central Pacific in December 1966. To provide "ground truth" for the satellite, the National Center for Atmospheric Research (NCAR) led its first field program, the Line Islands Experiment (LIE) at Christmas, Fanning, and Palmyra islands during March and April 1967.

I came to NCAR in 1967, and my first responsibility was to compute winds and thermodynamic variables from raw rawinsonde measurements made during the LIE. Paul Julian, a senior member of the group I joined, had just demonstrated with spectrum analysis that there was no quantitative evidence to support a long-held belief in an Index Cycle, and thus had established himself as an expert in applying the new analysis technique to meteorology. Aware of the work of Matsuno, Yanai, Wallace and collaborators, I was happy to learn from Julian how to spectrally analyze my LIE winds. I presented the results at the Symposium on Tropical Meteorology here at the University of Hawai'i in June 1970. Determined from only 60 days of data, the LIE spectra differed from several of Yanai and Maruyama's similarly short records. Someone suggested that longer records must be available and to look at the time variations in these statistical measurements.

Julian and I were in a good position to look at longer records because NCAR's Data Support Section had begun to collect long timeseries of data from tropical stations. One was a 10-year record of daily rawinsonde observations at Canton (now Kanton) Island, longer than any timeseries that earlier investigators had an opportunity to study. NCAR also had the biggest computer available to meteorologists (Control Data Corporation 6600), with a clock speed of 10mHz and a memory of 64kb (compare with 1400mHz and 262, 144kb of a Dell 8600 of today!) Moreover, with the new fast Fourier transform, the spectrum of a 10-year daily observation timeseries needed only about 10 times more computer time than our 60-day LIE timeseries with conventional methods.

Soon we were running newly coded programs on the Canton timeseries to document behavior changes in MRGW and Kelvin waves over time. (Running programs in those days meant submitting decks of hundreds of computer cards to a card reader and waiting hours for results.) To our surprise, the spectral analyses revealed the 40–50 day oscillation that is sometimes now referred to as the Madden-Julian Oscillation (1971, 1972).

In closing, I want to stress the serendipity and "data surprises" in these stories. Yanai and Maruyama, and Wallace and Kousky state in their papers that they had set out to explain the momentum budget of the recently discovered Quasi-biennial Oscillation (QBO). It's hard to imagine they anticipated the MRGW and Kelvin waves they found. Similarily, Reed, Ebdon and others who discovered the QBO, must, too, have been surprised to see the amazing and unmistakable 26-month variation in the winds of the equatorial stratosphere. Julian and I began a study of time variations in the MRGW and Kelvin waves and ended up describing a different, unanticipated but interesting, and as it turned out, important phenomenon.

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When Do the Monsoon Rains Start?

***P.V. Joseph**, retired director of the India Meteorological Department and emeritus professor of Cochin University of Science and Technology, visited the IPRC in Spring 2004 to do modeling research with the monsoon scientists in support of his theory on the onset of the monsoon rains. The onset of the monsoon rains is of great importance to people in Asia. Over India this onset can be anywhere between May 11 and June 18, the long-term average date being June 1. Predicting the actual onset date remains a challenge, and Joseph is a key player in this high-stakes prediction game. Working in weather forecasting for many of his 32 years with the India Meteorological Department, Joseph has been looking at data—data from rain gauges, radiosondes, ship-based measurements, and later from satellite images—and searching for clues to predict monsoon onset. What follows is a story of how he developed this theory.*

The traditional view of the physics of the onset of the monsoon rains is that as the Asian continent heats up with the coming summer, the warm air rises over the land, and the winds start to blow from the cooler ocean to the warmer land bringing the rains. Joseph holds a different view: "These winds are the planetary summer monsoon. They are not very strong and do not bring the rain that has been associated for centuries with the monsoon." According to Joseph, what happens is this: In late May–early June, the warmest ocean waters shift from the western Pacific to the Arabian Sea. Over this 30°C or warmer water, a large amount of moisture converges. As this moist air rises and produces copious rainfall, the latent heat released warms the atmosphere even more; the rising air then sucks in air from as far away as across the equator and turns into a low-level jet stream. This jet carries with it very moist air and forms the monsoon rain band over India. Joseph's proposed sequence of physical processes remains a hypothesis and to test this hypothesis with a model, Joseph visited the IPRC from March to May 2004 to work with our monsoon researchers.

How Joseph has arrived at this controversial but plausible hypothesis is a story spanning nearly 40 years. The first piece to his monsoon onset scenario came when he was assigned to aviation meteorology in 1965. He noted that during the monsoon, the flight paths of airplanes were affected by a low-level jet over peninsular India. This jet, which later came to be called the Findlater Jet after the person who continued further research into it, creates heavy rains on its northern flank.

In 1979 Joseph became director of the Meteorological Training School in Pune. There his attention was drawn to another player in the monsoon, the ocean, for Pune was home to all the archived data collected by ships plying the Indian Ocean. This data he studied with keen interest. He patiently analyzed sea surface temperature (SST) and other variables and related them to rainfall. He discovered a pattern: after dry monsoons (10% below average rain), the northern Indian Ocean would be unusually warm. This would create easterly winds that push the westerlies of the upper troposphere northward and make for a wetter monsoon the following year. Similarly, a wet monsoon would be followed by a colder Indian Ocean and a drier monsoon the next year. These observations formed the beginning of the tropical biennial oscillation concept.

Then there was the 1980 seminal paper by **Sikka** and **Gadgil**, and also **Yasunari** 1979, which described three sets of northward moving rain bands during the summer monsoon, with a 30–50-day interval between the bands. What is the reason for this banding structure? Could not such a band form before the monsoon begins? Analyzing 25 years of rain gauge data and matching it to the monsoon onset, Joseph discovered that about 40 days before onset such a rain band extended from the tip of India eastward. Although this band brought rain to the southern tip of India, it did not move northward, but was a "bogus" monsoon onset. The first appearance of this band, though, was very closely related ($r = .87$) with the real monsoon onset 40 days later. Once several years of satellite images became available, they confirmed for Joseph the picture he had drawn from the rain gauge data. They also pointed to something he hadn't realized from his rainfall plots: the formation of twin cyclones, which are now known to be associated with this pre-monsoon rain band.

A very significant event for Joseph came in 1989. Invited to become a research associate for two years at the Cooperative Institute for Research in Environmental Sciences at the University of Colorado, he retired from the India Meteorological Department and went to Boulder. There he came upon an atlas that showed 80 years of tropical cyclone tracks around Australia. And once again Joseph found a pattern when he put this wealth of information together with the record of monsoon onset dates over India: When the cyclone season in the Southern Hemisphere stops early, say by March, the Indian monsoon comes early; when the cyclones continue into April–May, the Indian monsoon starts late. Regrettably, this information is of limited use for prediction because one can never tell which cyclone will be the last of the season, but the pattern gave Joseph a clue. Relating outgoing longwave radiation (OLR) to SST patterns, he noticed that during years of very delayed and very early monsoons, the date at which the maxi mum equatorial convective cloudiness—which lies over the warmest ocean waters and is called the Intertropical Convergence Zone—shifts to the Northern Hemisphere is closely related to the monsoon onset date. Now Joseph turned his attention to changes in SST in the Indian Ocean and noted the shift of the warm pool from the western Pacific into the Indian Ocean and then into the Arabian Sea just before monsoon onset, accompanied by the rain band formation and the low-level jet that brings the real monsoon rains to India.

Studying the correlation patterns among SST, OLR, and the monsoon onset date, Joseph concluded that delayed northward movement of the equatorial convection maximum, and therefore delayed onset, could result from one or more of the following conditions: from warm anomalies in the central Pacific together with cold anomalies in the western Pacific (usually those associated with El Niño), and from unusually warm water south of the equator in the Indian Ocean, and cold water in the Arabian Sea. Correlations, though, do not mean causation. In the modeling experiments at the IPRC, Joseph could experimentally manipulate the SST in the regions of interest, and see whether these manipulations will have their expected effect on the Arabian warm pool, the convection there, and the onset of the monsoon.

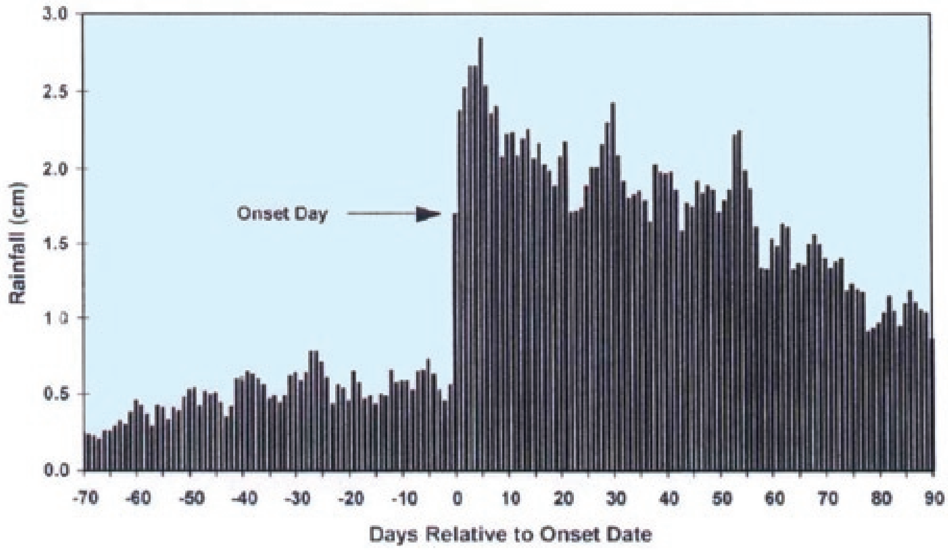

Figure 12. Composite mean daily rainfall in South Kerala from 1901 to 1980 (daily rainfall is the average of 44 well-distributed rain gauge stations) with respect to the date of monsoon onset over Kerala (date-0). Note the abrupt increase in rainfall at monsoon onset. Pre-onset and post-onset rainfall regimes are vastly different (taken from Ananthakrishnan R. and Soman M.K., 1988, *Journal of Climatology*, **8**, 283–296).

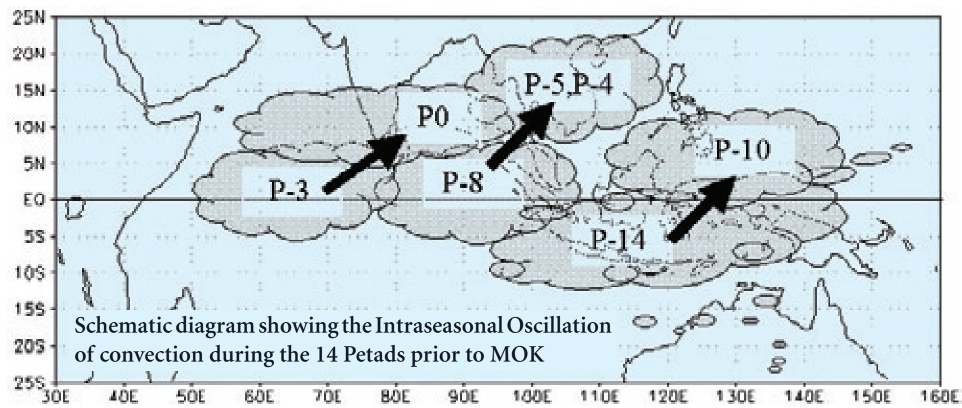

Figure 13. Schematic showing the temporal and spatial evolution of extensive cumulonimbus clouds that pump much moisture and heat into the atmosphere before the monsoon onset over Kerala at day 0 (P-0) and backwards in time to 70 days (P-14), when the convection was still south of the equator. At day 40 (P-8) before onset, the convective clouds form near the equator, just south of the warm pool; at day 15 (P-3) before onset, they form in the Arabian Sea, which now has the large south-north sea surface temperature gradient (from ongoing research work by Joseph, P.V. and Sooraj, K.P.).

The first set of experiments that Joseph conducted together with **H. Annamalai** and **Bin Wang** consisted of placing into the model the SST anomalies that had occurred during the four times when the monsoon was more than 12 days late and comparing their effects on rain-band formation with a simulation under climatological SST conditions. Initial results show that the simulated convective cloud band and the low-level jet over the Arabian Sea and the southern tip of India form about 10 days later than in the climatological SST runs—just as Joseph had predicted.

However controversial his position is, Joseph has started to successfully predict the fickle onset date of the monsoon. In 2002, he had predicted a two-week delayed monsoon onset, but it rained heavily in Kerala on May 29 and the India Meteorological Department declared the monsoon had begun. That rain, though, was followed by two weeks of clear skies and searing heat; the same has happened once again this past summer.

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