Assimilation, Analysis and Dissemination of Pacific Rain Gauge Data: PACRAIN

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1. PROJECT SUMMARY

Tropical rainfall data taken over both land and ocean is particularly important to the understanding of our climate system. Not only is it a tracer of latent heat, it is vital to the understanding of ocean properties as well, such as latent and sensible heat flux, salinity changes and attendant local ocean circulation changes. In addition, rain gauge observations from low-lying atolls are required to conduct verification exercises of nearby buoy-mounted rain gauges, most of which are funded by NOAA's Office of Climate Observations' (CPO) program.

This project supports the effort to "build and sustain the global climate observing system that is needed to satisfy the long-term observational requirements of the operational forecast centers, international research programs, and major scientific assessments". We also are continuing in our role as the Surface Reference Data Center (SRDC), a core program that supports the Global Precipitation Climatology Project (GPCP) and the Global Energy and Water Cycle Experiment (GEWEX). Our current and future efforts include expanding our mission to collect, analyze, verify and disseminate global rainfall data sets and products deemed useful for Operational Forecast Centers, International Research Programs and individual researchers in their scientific endeavors. Housed in the Environmental Verification and Analysis Center (EVAC) at the University of Oklahoma, the EVAC/SRDC has built upon work from past NOAA-supported projects to become a unique location for scientists to obtain scarce rain gauge data and to conduct research into verification activities. These data are continually analyzed to produce error-assessed rainfall products and are easily assessable via our web page (http://pacrain.evac.ou.edu/). We're also actively involved in research of the tropical rainfall process using data obtained from this project.

Scientists need only to access the PACRAIN web site <http://pacrain.evac.ou.edu> to obtain the most comprehensive Pacific rainfall data set anywhere in the world. The Surface Reference Data Center web site <http://srdc.evac.ou.edu> contains validation data for various regions. Many of these regional data sets are impossible or impractical to obtain elsewhere. The EVAC/SRDC serves the research community by actively working with individual countries in environmentally important locations to help provide them with infrastructure, education and other short and long-term support. The return on this investment by NOAA has been significant in terms of enabling EVAC/SRDC to provide the scientific community with critical, one-of-a-kind rain gauge data sets and to have established ongoing mutually beneficial relationships that should lead to future collaborations. Past successes with this strategy have proven very worthwhile on a cost-benefit basis.

Due to the importance of tropical Pacific rainfall data to climate research and operational and climate forecasting we work collaboratively with the Pacific Island Global Climate Observing System (PI-GCOS) program to effectively and efficiently match the areas of commonality among both CPO's and PI-GCOS's objectives. One of these common areas is the strengthening of the existing Pacific observation climate network for both atmosphere and ocean.

Specifically, we seek to collect all available rain gauge data 1) in environmentally critical locations (e.g. tropical Pacific), 2) where dense rain gauge networks exist and 3) where agreements can be made to help construct rain gauge networks in these critical locations. These data are

assimilated, homogenized, and error-checked and then made available to the general research community.

To create the most comprehensive Pacific raingauge database possible it is necessary to continue to work closely with the Pacific meteorological services to help them sustain high their quality gauge networks. One of our most successful efforts during the last few years was (and is) the implementation of a large network of new manual-read rain gauges and automatic data-logger equipped tipping bucket rain gauges located on various atolls and islands managed by the local Pacific meteorological services. A total of approximately 60 automatic, high quality tipping bucket gauges are being operated by various Pacific Island meteorological services. We currently are collecting the data in tip format and converting it to 1 minute resolution. One of new efforts this year has been to conduct research using the tipping bucket data. The research this year has one of the first articles on stochastic modeling tropical rain rates. His paper was published in the International Journal of Climatology.

Our Pacific educational program, SPaRCE (http://sparce.evac.ou.edu/) contributes in a direct way to the PACRAIN database through the contribution of Pacific schools taking manual read daily rain gauge measurements while learning about the importance of weather and climate. Underlying these projects is the long-term effort to help build the capacity of the all the PNMS to better serve their constituents. This will ultimately result in the PNMS being able to self-sustain their data networks. We continue to contribute to this effort by providing what we can in terms of needed supplies, education and communication infrastructure (e.g. involvement in the Radio/Internet; i.e. RANET project) until the PNMS become completely self-sustainable. We also work collaboratively with the Secretariat for Pacific Regional Environmental Programme (SPREP) which is located in Apia Samoa. SPREP acts as a communication conduit through which we communicate and collaborate with the different PNMS. This project is continually in the process of implementation with a portion of the total number of gauges on operational status, some currently being shipped to the Pacific and some needing maintenance. We work particularly close with the New Zealand Meteorological Service and the attached PI-GCOS Technical Support Project to accomplish the later objective.

The PACRAIN data set has been used by many researchers for a variety of purposes (e.g. Delcroix et. al, 1996, Pingping Xie et al., 2007). The uses include incorporate into climate models, climate studies, and the verification of satellite rainfall algorithms.

It is our belief that by working directly with local Pacific island meteorological services, we bring tangible benefits to the global climate research community through data base development and enhancement. In turn, the local meteorological services also benefit directly through enhanced forecast products developed by the scientific community using these critical data sets.

2. ACCOMPLISHMENTS

2.1. Delivering vital rainfall data to the research community through on-line access of the PACRAIN database

Rain rate measurements over open ocean regions are very important in the assessment of satellite rain algorithms climate change and modeling of physical processes. Until recently, no Pacific island rainfall measurements have been available at resolutions less than one hour. Our new MetONE rain gauges tipping bucket gauges are equipped with data loggers and have been donated by the University of Oklahoma for this project. In turn, they have been given to the PI-GCOS Coordinator, headquartered at SPREP, for distribution to the various PNMS. We have deployed

over 50 of these gauges throughout the Pacific region during 2008. We are currently receiving rainfall tip data back from many PNMS and these data are inserted into the PACRAIN database. These data are particularly important in the understanding of basic tropical rain systems and consequently, more accurate global climate models. These data are all included in the PACRAIN database.

The achievement of this objective could not be accomplished without the close collaboration of the PI-GCOS Steering Group and the current PI-GCOS Coordinator. Other important collaborative groups are the Global Ocean Observing System (GOOS), the New Zealand Meteorological Service, and the New Zealand Institute for Research in Water and Atmosphere, the Australian Bureau of Meteorology, Meteo-France and the US National Weather Service.

PI-GCOS Tipping Bucket Project Web site and related web sites:
http://pacrain.evac.ou.edu (PACRAIN site)
http://srdc.evac.ou.edu (SRDC site)
http://sparce.evac.ou.edu (Schools of the Pacific Rainfall Climate Experiment, SPARCE)
http://www.pi-gcos.org/ (the P.I. initiated the PI-GCOS web site in collaboration with the GOSIC project at the University of Delaware. It now under the auspices of the NOAA National Climatic Data Center).

Figure 1. Installing a METONE Tipping Bucket Gauge at the Samoa Meteorological Service

2.2. Provide high spatial density world regional rain gauge datasets for use in satellite rainfall algorithm verification

EVAC maintains a database of selected high density raingauge network data for use in satellite rainfall algorithm assessment. Parts of our responsibilities include operating the Surface Reference Data Center (SRDC), which is associated with the Global Precipitation Climatology Project (GPCP). Our tasks in this capacity include identifying and collecting these data sets and making them available to researchers for this purpose. We also conduct studies on the errors involved when comparing satellite and rain gauge data. During 2008 we began research on the rain rate characteristics of tropical rainfall by developing a tropical point process model. The fit of the model at various temporal scales was tested using the data from the tipping bucket gauges.

The results of our research (Figure 2) indicate that the model is able to reproduce the rain rate statistics computed from Tongan METOne gauges quite well. This study would not have been

possible without the tipping bucket data. The model now can be further tested at other sites which will allow the assessment the statistical characteristics unique to tropical rainfall.

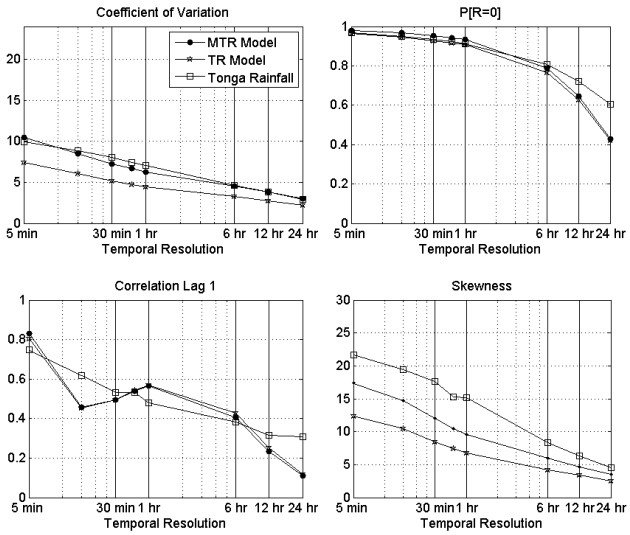


Figure 2. Comparison of the the newly developed rainfall model with Tongan rain rate statisitcs at different time resoltuions.

2.3. Maintain and Improve an Error-assessed PACRAIN Database

The core asset of PACRAIN and SPaRCE programs is the online rainfall database. This database contains historical data from several sources, and is updated monthly with the latest data from three sources: the National Climatic Data Center (NCDC), the National Institute for Water and Atmospheric Research (NIWA) in New Zealand, and the SPaRCE program. Additional updates are done as needed. The *pacusers* mailing list is maintained as a way to disseminate information and provide support to PACRAIN users (http://pacrain.evac.ou.edu/pacusers.html). Database changes are also cataloged online (http://pacrain.evac.ou.edu/changes.html). Some database statistics:

- ~2 million observations
- ~8 thousand observations added each month
- 839 sites
- monthly data with some records beginning in 1874
- daily records begin in 1942

Over the past few years the PACRAIN database has undergone a number of upgrades, and this trend continued in FY 2006. Previous upgrades focused on infrastructure, but the most recent improvements have been to the underlying data. The quality control of PACRAIN data is an ongoing process, and errors are corrected as they are discovered. A comparison of PACRAIN records to satellite data was performed in May to evaluate the accuracy of PACRAIN timestamps.

In addition to specific database upgrades, other routine activities continued throughout the year. The PACRAIN database continues to be upgraded on a monthly basis with data from the Schools of the Pacific Rainfall Climate Project (SPaRCE) project, the National Climatic Data Center, New Zealand Institute for Research in Water and Atmosphere (NIWA), and directly from

the individual PNMS. Also, several journal articles have been accepted into print which details the PACRAIN operations and objectives.

2.4. Current Status of PACRAIN Database

- More than 150,000 records added to the PACRAIN database, including almost 50,000 tipping bucket gauge observations.
- The PACRAIN data base was modified to allow for high-resolution tipping bucket gauge data.
- The high resolution tipping bucket gauges incorporating data loggers which are now operational (since last year) are located in these countries:

    - Cook Islands: 4
    - Kiribati: 6
    - Tuvalu: 4
    - Samoa: 3

- A total of 200 plastic rain gauges have been sent to various Pacific Island Meteorological Services.
- New software (a Microsoft Excel add-in) has been developed for use by the individual meteorological services for easy download of tip data from these gauges.
- Enhanced support of the PI-GCOS tipping bucket guge network through technical support and the distribution of supplies (data loggers, batteries, etc.)
- Preliminary design completed for new PACRAIN web site; new database functionality nearly complete

2.5. Survey of PACRAIN Usage

a) User Requests

Last year we conducted a survey of the users of the PACRAIN database. We maintain query log on our server which goes back 26 months. In that time, 98 users (distinct e-mail addresses, excluding us) have made 153 queries that returned 45 million records. Almost half of all queries return at least 1000 records. Most users are one-time visitors, and approximately 15% have made more than one query.

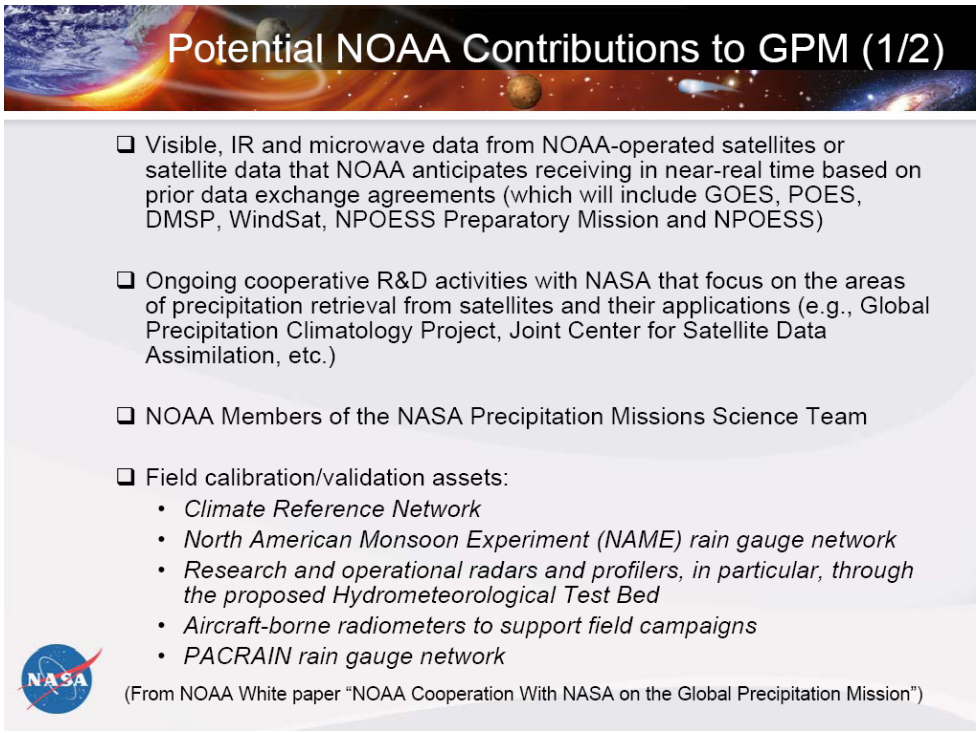
The server logs only go back one month. In that time, the full dataset has been downloaded 14 times, and the monthly update has been downloaded 11 times.

b) Institutional Usage

The PACRAIN database is hosted on NASA Goddard's Global Change Master Directory (http://gcmd.nasa.gov/records/GCMD_ATOLL_RAIN_PACIFIC.html) and linked from a number of project web sites such as PI-GCOS: http://www.pi-gcos.org/data_access.htm, UCAR's CISL Research Data Archive (http://dss.ucar.edu/datasets/ds484.0/), the U.S. Global Change Research Information Office (http://www.gcrio.org/datainfo/index.html). The PACRAIN dataset also makes up part (303 stations) of the Global Historical Climate Network (GHCN) (http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/index.php) developed and maintained by NOAA's National Climatic Data Center (NCDC). The dataset forms an intergral part of many

international project such as the Global Precipitation Climatology Project (GPCP). There are also many international organizations which link to our server (SOPAC, http://www.pacificwaterefficiency.com/links.html).

The PACRAIN dataset will also form a critical component of NASA Global Precipitation Measurement Program (GPM) (see below).



One of the most important operational use of the PACRAIN dataset is it's inclusion in the CMAP satellite/raingauge merged global precipitation estimates, managed by Pingping Xie from NOAA's Climate Prediction Center (see below).

The CPC Merged Analysis of Precipitation ("CMAP") is a technique which produces pentad and monthly analyses of global precipitation in which observations from raingauges are merged with precipitation estimates from several satellite-based algorithms (infrared and microwave). The analyses are are on a 2.5 x 2.5 degree latitude/longitude grid and extend back to 1979. These data are comparable (but should not be confused with) similarly combined analyses by the Global Precipitation Climatology Project which are described in ***Huffman et al*** (1997).

It is important to note that the input data sources to make these analyses are not constant throughout the period of record. For example, SSM/I (passive microwave - scattering and emission) data became available in July of 1987; prior to that the only microwave-derived estimates available are from the MSU algorithm (***Spencer*** 1993) which is emission-based thus precipitation estimates are avaialble only over oceanic areas. Furthermore, high temporal resolution IR data from geostationary satellites (every 3-hr) became available during 1986; prior to that, estimates from the OPI technique (***Xie and Arkin*** 1997) are used based on OLR from polar orbiting satellites.

c) Research Usage

The following list is an abbreviated list of sampled refereed journal articles citing use of the PACRAIN database :

Greene, J. S., M. Klatt, M. Morrissey, and S. Postawko, 2008: The Comprehensive Pacific Rainfall Database. J. Atmos. Oceanic Technol., 25, 71-82.

Greene, J. S., B. Paris, M. Morrissey, 2007: Historical changes in extreme precipitation events in the tropical Pacific region. *Climate Res.*, **34**, 1-14.

Xie, P. P., A. Yatagi, M. Y. Chen, et al., 2007: A gauge-based analysis of daily precipitation over East Asia. *J. Hydromet.,* **8**, 607-626.

Huffman, G.J., R.F. Adler, D.T. Bolvin, G. Gu, E.J. Nelkin, K.P. Bowman, Y. Hong, E.F. Stocker, D.B. Wolff, 2007: The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale. *J. Hydrometeor.*, **8**(1), 38-55.

Huffman, G.J., R.F. Adler, D.T. Bolvin, G. Gu, E.J. Nelkin, K.P. Bowman, Y. Hong, E.F. Stocker, D.B. Wolff, 2007: The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale. *J. Hydrometeor.*, **8**(1), 38-55.

Islam, M. N. and H. Uyeda, 2007: Use of TRMM in determining the climatic characteristics of rainfall over Bangladesh. *Remote Sens. Environ.,* **108**, 264-276.

Kidd, C. and G. McGregor, 2007: Observation and characterization of rainfall over Hawaii and surrounding region from the Tropical Rainfall Measuring Mission. *Int. J. Climatol.*, **27**, 541-553.

Delcroix, T., C. Henin, V. Porte and P. Arkin: Precipitation and sea-surface salinity in the tropical Pacific Ocean, Deep Sea Research I, Vol. 43, No. 7. pp. 1123-1141. 2006.

Brown, J. E. M., 2006: An analysis of the performance of hybrid infrared and microwave satellite precipitation estimates over India and adjacent regions. *Remote Sens. Environ.,* **101**, 63-81.

Matthews, A. J. and H. Y. Y. Li, 2005: Modulation of station rainfall over the western Pacific by the Madden-Julian oscillation. *Geophys. Res. Letters*, **14**.

Nicholson, S. E., B. Some, J. McCollum, et al., 2003: Validation of TRMM and other rainfall estimates with a high-density gauge dataset for West Africa. Part I: Validation of GPCC rainfall product and pre-TRMM satellite and blended products. *J. Appl. Meteor.,* **42**, 1337-1354.

Nicholson, S. E., B. Some, J. McCollum, et al., 2003: Validation of TRMM and other rainfall estimates with a high-density gauge dataset for West Africa. Part II: Validation of TRMM rainfall products. *J. Appl. Meteor.,* **42**, 1355-1368.

Xie, P. P., J. E. Janowiak, P. A. Arkin, et al., 2003: GPCP Pentad precipitation analyses: An experimental dataset based on gauge observations and satellite estimates. *J. Climate*, **16**, 2197-2214.

Kummerow, C., Y. Hong, W. S. Olson, et al., 2001: The evolution of the Goddard profiling algorithm (GPROF) for rainfall estimation from passive microwave sensors. *J. Appl. Meteor.*, **40**, 1801-1820.

Adler, R. F., C. Kidd, G. Petty, et al., 2001: Intercomparison of global precipitation products: The third Precipitation Intercomparison Project (PIP-3). *Bull. Am. Meteor. Soc*., **82**, 1377-1396.

Kummerow, C., J. Simpson, O. Thiele, et al., 2000: The status of the Tropical Rainfall Measuring Mission (TRMM) after two years in orbit. *J. Appl. Meteor.*, **39**, 1965-1982.

Adler, R. F., G. J. Huffman, D. T. Bolvin, et al., 2000: Tropical rainfall distributions determined using TRMM combined with other satellite and rain gauge information. *J. Appl. Meteor.*, **39**, 2007-2023.

Zeng, X. B., 1999: The relationship among precipitation, cloud-top temperature, and precipitable water over the tropics. *J. Climate*, **12**, 2503-2514.

Chapman, T., 1998: Stochastic modelling of daily rainfall: the impact of joining wet days on the distribution of rainfall amounts. *Environ. Model. Softw.*, **13**, 317-324.

Morrissey, M. L. and J. S. Greene, 1998: Uncertainty analysis of rainfall algorithms over the tropical Pacific. *J. Geophys. Res. Atmos.*, **103**, 19569-19576.

Waliser, D. E. and W. F. Zhou, 1997: Removing the satellite equatorial crossing time biases from the OLR and HRC datasets. *J. Climate*, **10**, 2125-2146.

Huffman, G. J., 1997: Estimates of root-mean-square random error for finite samples of estimated precipitation. *J. Appl. Meteor.*, **36**, 1191-1201

Ferraro, R. R., 1997: Special sensor microwave imager derived global rainfall estimates for climatological applications. *J. Geophys. Res. Atmos.*, **102**, 16715-16735.

Lin, B. and W. B. Rossow, 1997: Precipitation water path and rainfall estimates over ocean using special sensor microwave imager and International Satellite Cloud Climatology Project data. *J. Geophys. Res. Atmos.*, **102**, 9359-9374.

Maliekal, J. A. and T. J. Petroski, 1996: Evidence of secular changes in rainfall data from the tropical western and central Pacific over a 20-year period. *Geophys. Res. Letters*, **23**, 2621-2624.

Morrissey, M. L. and N. E. Graham, 1996: Recent trends in rain gauge precipitation measurements from the tropical Pacific: Evidence for an enhanced hydrologic cycle. *Bull. Amer. Meteor. Soc.*, **77**, 1207-1219.

Morrissey, M. L. and J. E. Janowiak, 1996: Sampling-induced conditional biases in satellite climate-scale rainfall estimates. *J. Appl. Meteor.*, **35**, 541-548.

d) Comments from Project Coordinators and PACRAIN USERS

From Dr. George Huffman, Mesoscale Atmospheric Processes Branch, NASA Goddard:
Dear Mark - It was good to catch up with your activities when we chatted at the 88th Annual Meeting of the AMS in New Orleans last week. The group of which I am part, the precipitation research group in the NASA/GSFC Laboratory for Atmospheres, will be very interested in seeing how the tipping bucket gauges work out.

This interest is, of course, a continuation of our long-term interest in, and use of, the PACRAIN data for various comparison and validation activities. As we produce and update the Global Precipitation Climatology Project (GPCP) monthly and daily products, and develop the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA; both in and after real-time), it is critical to understand how well the products are performing. The PACRAIN dataset is unique in providing us with a long, continuous record at many locations across the vast expanse of the tropical Pacific. One recent example is our use of the PACRAIN atoll data in

Huffman, G.J., R.F. Adler, D.T. Bolvin, G. Gu, E.J. Nelkin, K.P. Bowman, Y. Hong, E.F. Stocker, D.B. Wolff, 2007: The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale. *J. Hydrometeor.*, 8(1), 38-55.

The Kwajalein Island radar and the TAO/TRITON buoys provide additional unique data, but they cover a different scale and region, respectively, and cannot replace PACRAIN or replicate its period of record.

It is important to our work that the PACRAIN data are maintained in a coherent, accessible Web location that minimizes the amount of time we spend dealing with obtaining such data. This allows us to focus on our core activity - combining precipitation estimates from as many sensors as possible to establish a unified global record of precipitation.

Please let us know how the tipping bucket work is progressing.
George

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From John Janowiak, Climate Prediction Center:
As for PACRAIN, I think that it's an indispensable data base for calibrating and validating satellite precipitation algorithms. It is a unique resource that provides in situ measurements of precipitation over much of the tropical Pacific, which is a vitally important region where knowledge of rainfall amount and it's distribution is required for many reasons, particularly for assessing model precipitation forecasts. I've used the PACRAIN data to make quantitative assessments of satellite-derived precipitation estimates. These data are also used in CPC's CMAP global precipitation analyses.

John Janowiak
NOAA/NWS/NCEP/Climate Prediction Center
voice: (301) 763-8000 ext. 7537
email: john.janowiak@noaa.gov

From Pingping Xie, NOAA's Climate Prediction Center

Hi, Mark,

Your Pacific atoll gauge rainfall is extremely important for many of the research, development and operational activities at NOAA Climate Predictions. In addition to what have already covered in John's statement, I would like add that we also use your atoll gauge data as part of the inputs to the CMAP merged analysis of precipitation which is widely applied in climate monitoring, climate assessment, climate diagnostics, and climate model verifications. In one sentence, we absolutely need your atoll gauge rainfall data.

Pingping Xie, CPC

Letter from Dr. Thomas Peterson, NOAA's NCDC

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE DATA
AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER
151 PATTON AVE ROOM 120
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February 4, 2008

Prof. Mark Morrissey
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University of Oklahoma
Norman, OK 73019

Dear Prof. Morrissey,

As you know, we were delighted to be able to incorporate your Pacific Island rainfall data set, PACRAIN, into the Global Historical Climatology Network (GHCN) version 2 precipitation data set. Scientists all over the world have been downloading GHCN precipitation data free of charge from http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/ and using the data for a wide variety of analyses.

I just discussed the plans for GHCN version 3 precipitation data set and confirmed that PACRAIN is an integral part of global precipitation data as it provides important observations across a wide expanse of the globe where other sources of in situ precipitation measurements are sparse. In addition to being used in the monthly version of GHCN, PACRAIN has been incorporated into GHCN daily which has been used to provide valuable information on changes in extremes. Both GHCN data sets, which means both daily and monthly versions of your PACRAIN data, were used in analyses presented in the Nobel Prize winning Intergovernmental Panel on Climate Change's Fourth Assessment Report.

Thank you for your valuable contribution to these endeavors.

Regards,

Thomas C. Peterson

2.5. Enhancement of Educational Outreach Component of the SPaRCE Program

For the past 15 years the Schools of the Pacific Rainfall Climate Experiment (SPaRCE) project at the University of Oklahoma has been working directly with elementary and high school teachers around the Pacific. During this time, we have also worked informally with the Pacific island meteorological services to aid them with their own local educational outreach projects. However, given the age of the SPaRCE materials there is a need to upgrade them to include more relevant information, e.g. the PI-GCOS program, Global Warming, cyclones, cyclone preparation brochure, etc.

As the meteorological services in the Pacific islands continue to expand and enhance their technological capabilities, there is an increased awareness and appreciation by meteorological service personnel for the need of an educated public. For example, more cooperative climate observer networks are being proposed and implemented in these countries, modeled after the U.S. Cooperative Observers Network (e.g. in Vanuatu, Samoa, and Tonga). There are many challenges in implementing a sustainable cooperative observer program in the developing tropical Pacific island nations, one of which is the availability of easily understood educational materials that can be used by meteorological service personnel in recruiting and training potential observers. In addition, disasters such as the December 2004 tsunami have emphasized the need for a basic understanding of any potentially dangerous phenomenon, such as hurricanes, by the general public. The SPaRCE program is uniquely situated to be able to both continue collaborating directly with schools, and to aid the meteorological personnel in the islands to develop easily understood educational materials that can be used in a variety of circumstances. Additional funding for the SPaRCE program will be used to provide Pacific island meteorological services with low-cost rain gauges for their cooperative observer networks, and to hire a student to work with meteorological service personnel to develop and deliver educational materials aimed at both potential cooperative observers as well as the general public. In addition, these additional materials would be available through the Pacific-RANET project's satellite/internet broadcasts.

2008 Progress Related to the SPARCE Program

Completed:

- Significant update of raingauge data from SPaRCE schools
- Sent 100 new rain gauges and thermometers to schools
- Sent 125 rain gauges to Solomon Islands
- New recruitment documents created (application, teacher survey, site survey, etc.).
- Created a computer data base of schools and addresses.
- Additions to workbook.
- Letters sent to schools in which we have not received data from in over six months. From these letters. Replies with new data and new teachers are currently coming in.
- Development of a workbook supplement to send to schools along with the newsletter so they can add to the existing workbook four times a year.
- Newsletters sent out in March, June, September, and December.
- Mailed out 2009 data sheets with newsletter in September.

Ongoing Activities:

- Rewriting the SPaRCE brochure.
- Contacting various meteorological services for addresses of local schools.
- Working on sending out a large mailing to schools we have had in the past

and new schools (about 150 total + addresses from meteorological services), to join SPaRCE.

- Workbook updates.

3. PUBLICATIONS, WORKSHOPS, AND CONFERENCE PRESENTATIONS

3.1. 2008 Publications

Refereed Book Chapters

Morrissey, M.L. and J.S. Greene, 2007: "'Ground Validation for the Global Precipitation Climatology Project" in "*Measuring Precipitation from Space - EURAINSAT and the future*" Levizzani, Vincenzo; Bauer, Peter; Turk, F. Joseph (editors), 2007, Approx. 745 p., Hardcover ISBN: 978-1-4020-5834-9. P. 381-392.

Gruber, A., B. Rudolf, M.L. Morrissey, T. Kurino, J. Janowiak, R. Ferraro, R. Francis, A. Chang and R.F. Adler, 2007: 'The Global Precipitation Climatology Project" in "*Measuring Precipitation from Space - EURAINSAT and the future*" Levizzani, Vincenzo; Bauer, Peter; Turk, F. Joseph (editors), 2007, Approx. 745 p., Hardcover ISBN: 978-1-4020-5834-9. P. 25-36.

Journal Articles

Morrissey, M.L., 2008: Superposition of the Neyman-Scott Rectangular Pulses Model and the Poisson White Noise Model for the Representation of Tropical Rain Rates. *Journal of Hydrometeorology*: doi: 10.1175/2008JHM1039.1

Morrissey, M.L. and J.S. Greene, 2008: A theoretical framework for the sampling error variance for three-dimensional climate averages of ICOADS monthly ship data, *Theoretical and Applied Climatology*, doi 10.1007/s00704-008-0027-3

Greene, J.S., M. Klatt, M.L. Morrissey, and S. Postawko, 2008: "The Comprehensive Pacific Rainfall Database: An enhanced tool for research and education", *Journal of Atmospheric and Oceanic Technology*, 25, pp. 71-82.

Conference Presentations

Klatt, M., M.L. Morrissey, S. Postawko and J.S. Greene, 2007: "Assimilating tipping bucket rain gauge data into the PACRAIN database", presented at the 88th AMS Annual Meeting, New Orleans, January 24, 2008.