G. Research Products

ESRL Physical Sciences Laboratory Review

David Skaggs Research Center
Boulder, Colorado
March 9-12, 2010

GSD Research Products

A list of research products, information and services, and an assessment of their impact by end users, including participation or leadership in national and international state-of-science assessments.

The following descriptions are arranged under their respective GSD mission theme.

Environmental Information Systems

GSD is collaborating with PSD to establish Hydrometeorological Testbeds (HMTs) in the U.S. to accelerate the infusion of new technologies, models, and scientific results from the research community into daily forecasting operations of the National Weather Service (NWS) and its River Forecast Centers (RFCs). Through ESRL collaboration with the California Department of Water Resources Office of Hydrology, Western Region Forecast Offices, and the National Severe Storms Laboratory, the first HMT was established in the western U.S. to address the hazards associated with land-falling atmospheric rivers. The purpose of this HMT is to design and support a series of field and numerical modeling experiments that help to better understand and forecast precipitation in the Central Valley area of California. The impacts of this effort cover the range of extreme drought conditions to normal rainfall to severe flooding conditions, leading to significant information for improved water management and earlier warning times for flooding and associated landslide potential in surrounding areas. Following the success of the HMT in California, the next HMT is being established in the southeastern U.S. to address the unique hydrometeorology challenges from winter storms, summer convection, and land-falling tropical storms and hurricanes in this region.

Observation Systems and Assessments

- For approximately five years (1999 – 2004), a GSD scientist served as a member of the Expert Team on Observational Data Requirements and Redesign of the Global Observing System, under the Commission on Basic Systems, World Meteorological Organization. This team was charged with writing the Statement of Guidance Regarding Observational Requirements of Regional Numerical Weather Prediction. In 2002, the Expert Team produced "Recommendations for the Evolution of the Global Observing System." This document made high-priority recommendations regarding satellite and ground-based observing systems for the following application areas: global and regional numerical weather prediction, synoptic meteorology, NowCasting and very short-range forecasting, aeronautical meteorology, hydrology, seasonal to inter-annual forecasting, coastal marine services, ocean weather forecasting, and atmospheric chemistry. The document was disseminated to the national weather service of every World Meteorological Organization (WMO) member country. One recommendation was implemented in the form of a carefully orchestrated doubling in the number of automated reports from commercial aircraft worldwide. This had the effect of a readily discernible improvement in the accuracy of Northern Hemisphere forecasts.
- A GSD scientist was one of two principal authors of Cost and Operational Effectiveness Analysis for the NOAA Profiler Network, 2003–2004, a report mandated by the U.S. Sen-

ate Appropriations Committee. This report was instrumental in preserving a network of wind-profiling radars in the central U.S. that contribute toward more accurate weather forecasts, severe weather watches, and warnings. It also laid the groundwork for an upgrade of the network, currently in progress. It was shown that when profiler data are withheld from U.S. forecast models, the accuracy of wind forecasts degrades by roughly 15% in the mid-troposphere.

- A GSD scientist assisted the National Weather Service Office of Science and Technology in setting requirements for an integrated upper-air observing system in the continental U.S. by serving as principal author of "A Phenomenological Approach to the Specification of Observational Requirements," 2005. This document examined the time and space scales of high-impact weather phenomena and inferred the spatial density and temporal frequency of observations appropriate for the detection, monitoring, and prediction of these phenomena. Though this work has not yet affected operational weather services, it is crucial in gaining budgetary support for observing systems that will improve these services. It is one of very few documents that put observational requirements on a defensible, quantitative basis.
- A GSD scientist was a major contributor to a 2009 report by the National Academy Committee on Developing Mesoscale Meteorological Observations to Meet Multiple National Needs report. The report, published by the National Academy Press, was titled "Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks." The report has been seminal in joint planning for an improved nationwide observing capability by the American Meteorological Society and government, private, and academic sectors. It has attracted the involvement of the Office of the Federal Coordinator for Meteorology. Key recommendations are to: 1) develop comprehensive metadata for all observing systems; 2) support first those observing systems that meet multiple needs; 3) improve vertical profiling capability, particularly close to the earth's surface; and 4) plan for distributed architecture and management of the network of networks.
- A GSD scientist has served as a member World Meteorological Organization (WMO) Commission for Instruments and Methods of Observations (CIMO) since 2006, and began serving as chairman of the WMO CIMO Expert Team on Remote-Sensing Upper-Air Technology and Techniques in 2009. The primary purpose of the CIMO Expert Team is to further the development and implementation of the WMO Integrated Global Observing System. The responsibilities of this Expert Team include the preparation of guidance and international standards for the location, data exchange and operation of the ground-based remote sensing systems including:
    1. Weather radars;
    2. Wind profilers;
    3. Global Positioning System (GPS)/Global Navigation Satellite System (GNSS) receivers;
    4. Microwave, infrared, and ultraviolet radiometers, spectrometers and interferometers;
    5. Lidars;

6. Lightning detection systems.

The CIMO Expert Team is also responsible for coordinating intercomparisons of data and products among WMO Members and assessing the status, implementation and evolution of observing systems. The Chair of the CIMO Expert Team interfaces with other expert team leads to coordinate actions associated with the Global Observing Systems including the Global Climate Observing System. This work impacts the international upper-atmospheric observing system communities and other scientific communities that utilize observing systems in weather and climate research.

- A GSD scientist has served on the International Association of Geodesy Working Group on Numerical Weather Prediction for Positioning (IAGWG 433) since 2007. The primary purpose of the working group is to assist the international geophysical and geodetic communities in utilizing global numerical weather prediction model data and products to improve international positioning, navigation and timing using Global Navigation Satellite Systems (GNSS). This group has participated in developing improved neutral signal delay mapping functions for very high (mm-level) Global Positioning System (GPS)/Global Navigation Satellite System (GNSS) positioning and evaluating the impact of these mapping functions on positioning accuracy and precision. The work impacts the monitoring of sea level changes, changes in the elevation of the continents, monitoring seismic faults, and detecting evidence of crustal motions associated with the generation of tsunamis close to shore.
- A GSD scientist has been a Technical Expert for the U.S. delegation to the World Meteorological Organization (WMO) Aircraft Meteorological Data Relay (AMDAR) panel for seven years. The AMDAR panel encourages and coordinates the gathering of weather data from commercial aircraft worldwide. The work of the panel has resulted in a doubling in the number of AMDAR observations (to approximately 250,000 observations per day worldwide) since 2001, and increased data quality. Several new nations are now contributing AMDAR data, increasing its geographic coverage, thanks to the panel's efforts. AMDAR data are a critical input to numerical weather prediction models that have improved forecasts relevant to hazardous weather events, as reported in refereed publications.
- GSD worked with Devon Energy Corporation of Oklahoma City, Oklahoma, the Louisiana State University, and the National Weather Service Forecast Office in Lake Charles, Louisiana to deploy GPS receivers and associated weather sensors on two Devon Energy offshore platforms in the Gulf of Mexico. These systems are providing the first continuous far-offshore water vapor observations to improve local and regional weather forecasting in the Gulf of Mexico. NOAA research will use this data to validate offshore weather predictions, investigate the accuracy of polar orbiting satellite water vapor estimates, and for hurricane research. Louisiana State University and NOAA's National Geodetic Survey will use these observations for geodesy, surveying, and water level monitoring in and along the U.S. Gulf coast.
- GSD scientists collaborated with the National Weather Service (NWS), the National Environmental Satellite, Data, and Information Service, and the Cooperative Institute for Research in the Atmosphere (CIRA) to develop an innovative technique that combines the land-based GPS-Meteorology water vapor data produced by ESRL with polar orbit-

ing satellite-based Special Sensor Microwave/Imager (SSM/I) and Advanced Microwave Sounding Unit (AMSU) water vapor information over the oceans. This capability was successfully transferred to NWS operations and is now displayed on *Advanced Weather Interactive Processing System (*AWIPS) workstations in all Weather Forecast Offices, providing forecasters and decision makers with a heretofore-unavailable view of moisture in the atmosphere offshore and how it will impact the onshore areas of the U.S. This capability has already made a significant contribution to forecasting the affects of atmospheric rivers making landfall along the Pacific coast of North America.

- GSD is collaborating with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) Center for Satellite Applications and Research (*STAR*) to develop bias corrections for Geostationary Operational Environmental Satellite (GOES) water vapor products used in the *Advanced Weather Interactive Processing System (*AWIPS). Current activities focus on evaluating a new retrieval algorithm and observing/troubleshooting detector problems in GOES 12 and the implications in the water product. This work facilitates the transition of NOAA research into operations and improves the accuracy and utility of satellite observations in weather forecasting and climate monitoring.
- GSD is collaborating with the National Weather Service International Office, the U.S. National Coordination Office for Positioning, Navigation and Timing, and the South African Weather Service's South African Survey Directorate. This collaboration provides for the transfer of the science and technology needed to use GPS signal delays for weather forecasting in South Africa and enlists the South African Weather Service to help spread this data source over the African Continent.

Local to Global Data Assimilation and Model Development

- GSD scientists developed the Scalable Modeling System (SMS) that is used operationally by the National Weather Service and the international research community. SMS is a tool that is used to parallelize atmospheric and ocean numerical models efficiently for both shared and distributed memory computing systems. The result is that the time and effort required to parallelize software to run on massively parallel processing systems has been reduced significantly. Groups worldwide are using SMS to parallelize, debug and efficiently run their models on a variety of high-performance computing systems. SMS also continues to serve ESRL model development efforts, particularly in the development of Flow-following Finite-volume Icosahedral Model (FIM) and Non-hydrostatic Icosahedral Model (NIM), and ongoing work to be able to run these new models on supercomputers comprised of GPUs.
- GSD provides the Local Analysis and Prediction System (LAPS) to more than 150 group and individual users in support of data assimilation, nowcasting, as well as mesoscale model initialization and post-processing. The LAPS user base includes federal agencies, state agencies, private entities, academic institutions, and international agencies. LAPS is a highly portable system with adjustable horizontal, vertical, and temporal resolution that runs on inexpensive hardware (including desktops and laptops), providing the capability to blend a wide variety of global, national, and local datasets into analyzed grids. LAPS benefits forecasters, decision makers, and researchers with high-resolution frequently

updated weather information for a wide variety of settings.

Science Education and Outreach

A GSD scientist headed the Interim Editorial Board for the Bulletin of the American Meteorological Society (BAMS) in 2001 with the charge to completely remake BAMS. The activity of the Board culminated in the hiring of a new Editor-in-Chief and transformation of BAMS to the publication that it is today.

Aviation Weather Research Program

- GSD-developed tools are supporting Federal Aviation Administrative (FAA) requirements at the Air Route Traffic Control Centers (ARTCCs) in Fort Worth, Texas, Leesburg, Virginia, and Anchorage, Alaska. The Weather Information Decision Aid (WIDA) is employed in Fort Worth, Texas and Leesburg, Virginia to help FAA Air Traffic Managers make traffic flow decisions during impending adverse weather. The WIDA helps to provide a safer and more efficient use of the National Air Space, reducing the number and extent of weather-related delays at the Dallas-Fort Worth Airport. The Volcanic Ash Coordination Tool (VACT) is employed in Anchorage, Alaska to allow production and dissemination of volcanic ash alerts to the FAA through coordination of the Alaska Aviation Weather Unit and the Alaska Volcano Observatory. Since volcanic ash can cause aircraft engines to flame out, use of the VACT results in safer skies over the Anchorage ARTCC air space. Collaboration with the University of Alaska to use their volcanic ash dispersion modeling and with the U.S. Geological Survey at the Alaska Volcano Observatory to use their satellite imagery enhancement software, all incorporated on AWIPS workstations, enables forecasters at the Alaska Center Weather Service Unit to provide volcanic ash warnings to Anchorage ARTCC traffic managers within five minutes of a volcanic eruption.
- GSD scientists manage a portal that provides automated weather reports from commercial aircraft to end users worldwide. This data is used in real-time by forecasters at more than 15 foreign national weather services, as well as by the U.S. National Weather Service and U.S. military weather services. Access to this portal has demonstrably improved forecasts of hazardous weather events.

Other

A GSD scientist is serving as a core team member and subject matter expert on two NOAA-wide projects – 1) NOAALink, a collaboration with multiple U.S. government organizations and private companies to enable the use of leading-edge technologies to manage and deliver information to citizens and businesses; 2) the American Recovery and Reinvestment Act Climate Computing and Modeling project to help accomplish supercomputing procurement that will support climate change research.

PSD Research Products

A list of research products, information and services, models and model simulations, and an assessment of their impact by end users, including participation or leadership in national and international state-of-the-science assessments

Assessments

PSD scientists have contributed to a number of national and international assessments and working groups that address critical issues in climate variability and predictability, water resources, global observing, Arctic change, extreme events, and drought. In particular, PSD scientists have worked with the Federal Climate Change and Water Working Group (C-CCWWAG), the U.S. Climate Variability and Predictability (CLIVAR) Program, the Global Climate Observing Systems (GCOS) Program, the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) Program, and many others. They have served as lead authors and reviewers for the IPCC Fourth Assessment and Climate Change Science Program (CCSP) Synthesis and Assessment Product. They have also contributed to the World Climate Research Program (WCRP) Stratospheric Processes and their Role in Climate (SPARC) 2010 Chemistry Climate Model Validation (CCMVal) Report and World Meteorological Organization/United Nations Environmental Programme 2010 Scientific Assessment of Ozone Depletion. A representative listing of these activities can be found in the PSD Collaborations, Partnerships, and Scientific Input page. Individual contributions can be found in the Service section of the review supporting documents.

Research Data Sets

PSD archives a wide range of internal data spanning gridded global climate datasets extending hundreds of years to real-time wind profiler data at a single location. The data itself and products derived from this data, organized by type, are available to scientists and the general public through the PSD Climate and Weather Data web site. PSD also archives data associated with collaborative projects. These are available to the general public through the PSD Collaborative Data Projects web site. Both are used widely by NOAA and non-NOAA researchers as evidenced by numerous email requests for information and assistance. Several representative examples are listed below.

El Niño Outlooks

PSD scientists developed Seasonal Linear Inverse Modeling forecasts of El Niño**.** These forecasts are used by the International Research Institute and NOAA's Climate Prediction Center in their monthly El Niño outlooks.

El Niño Southern Oscillation (ENSO) Index

A PSD affiliate has been producing an experimental Multivariate ENSO Index (MEI) on a monthly basis since 1997. The MEI is based on the six main observed variables over the tropical Pacific: sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C). The MEI site is available to the public. It experiences heavy traffic suggesting it is a useful measure of ENSO state.

Coral Watch

PSD scientists and collaborators developed weekly forecasts of tropical SSTs that are used by Coral Watch to forecast potential damage to corals in the tropical oceans.

20th Century Reanalysis Project

Using the EnKF, PSD and collaborators have produced the 20^{th} Century Reanalysis Project dataset, the first reanalysis dataset spanning 1871–2008, using only surface observations. This dataset will facilitate the analysis of climate and climate variability, especially in the early 20^{th} century, where previously no reanalysis products were available. Using the dataset, investigators have shown that early 20^{th} century El Niño events may have been as strong as late 20^{th} Century, revising ideas about trends in ENSO activity. Investigators have also used the dataset to show that the 1920's-1940's Arctic warming was consistent with natural variability.

Surface Flux Analysis Data Archive

PSD scientists and collaborators developed and maintain the Surface Flux Analysis (SURFA) data archive of operational numerical weather prediction global flux fields as part of a World Climate Research Program (WCRP) to improve treatment of fluxes in climate models.

Tropical Eastern Pacific Synthesis Data Set

PSD scientists and collaborators developed and maintain the Tropical Eastern Pacific Synthesis Dataset, which consists of two synthesis data sets containing observations of air-sea fluxes and cloud/radiative properties from nine years of cruises (1999–2007) in the Eastern Equatorial Pacific. The datasets are from Eastern Pacific Investigation of Climate (EPIC) Extended Monitoring cruises from fall 1999 through fall 2007. These observations were made as part a joint ESRL, NOAA Pacific Marine Environmental Laboratory (PMEL) and Woods Hole Oceanographic Institution (WHOI) climate monitoring project funded by the Climate Prediction for the Americas (CPPA) program in NOAA's Climate Program Office.

Marine and Air-Sea Interaction

PSD has a number of scientists investigating multiple issues in air-sea/ice interaction associated with the transfer of momentum, heat, moisture, trace gases, and particles at the wavy interface of the ocean. The principal focus is on fluxes: measurement techniques, studies of fundamental physical processes, and development of simplified representations of those processes. This group also deals with the scope of interactions (atmospheric or oceanic) from the micro to boundary-layer scales. Data is primarily collected during two multi-week ocean cruises per year, one in June–August and a second in November–February. Cruise data are available to the public.

Hydrometeorology Testbed (HMT)

NOAA's HMT project relies on a wide variety of observations. Instrumentation includes a various radar systems, soil moisture sensors, rain gauges, disdrometers, GPS integrated water vapor measurements, radiometers, pyranometers, etc. Descriptions of the instrumentation and associated data can be found on the PSD Weather and Climate Data page.

Arctic Observations

PSD has a long history of involvement with Arctic observations through collaboration with the Study of Environmental Arctic Change (SEARCH) Program. To better understand the mechanisms that control the changing Arctic climate, PSD coordinates the deployment of Intensive Arctic Atmospheric Observatories (IAAOS), where observations of such things as cloud properties, atmospheric and surface radiation, aerosols, gases, and synoptic weather patterns are collected. Detailed measurements taken with instruments such as radar, lidar, and radiometers allow for a better understanding of why change is occurring, and also provide calibrated, long-term high-quality measurements that will better track the long-term trends that are presently difficult to determine accurately in the remote polar regions of the planet. Our primary observation sites are the North Slope of Alaska, Eureka, Canada and Tiksi, Russia, with further expected deployments.

Western Boundary Current

The U. S. *Climate Variability and Predictability Research Program* (CLIVAR) Western Boundary Current Working Group was formed in January 2007. The group was charged with identifying shortcomings in the atmosphere, ocean, and coupled models that need to be addressed to accurately model western boundary current atmosphere-ocean interaction. A PSD scientist is a member of that group. PSD has developed and hosts a Western Boundary Current Analysis web page.

Web Products and Tools

PSD has created a wide array of web products and tools. These products include various displays of climate, weather, and instrument data, experimental forecasts, and analysis and monitoring tools. They are available to the general public via the PSD Web Products and Tools website, and are used widely as evidenced by numerous email requests for information and assistance.

Algorithms

Radiative Transfer

PSD scientists and collaborators released a new version of the International Intercomparison of Three-Dimensional Radiation Codes (I3RC) Community Monte Carlo Model for computing radiative transfer in three-dimensionally varying atmospheres. This was the second complete release. The release of this model coincided with a paper comparing the relative efficiency of several classes of methods for solving these problems. The associated I3RC users' group has more than 70 members and the model has been used in several papers.

Climate in the Interior West – The Western Water Assessment (WWA)

The WWA is one of seven Regional Integrated Sciences and Assessments (RISA) programs funded by the NOAA Climate Program Office. WWA was established in 1999 as a joint effort between CIRES and the Climate Diagnostics Center, one of PSD's predecessor organizations. That relationship continues today with PSD. The WWA Director and Deputy Director, and key staff members (some shared) are embedded within PSD. The WWA research products noted below are a result of this collaborative relationship.

TreeFlow: Paleohydrologic Data, Workshops, and Web Resource

Multicentury reconstructions of annual streamflow (paleohydrologies) from tree rings provide more complete information about past hydrologic variability than gage records and thus a more robust baseline for planning. The TreeFlow project has helped transform paleohydrology into accessible and widely used information for water resources planning in the WWA region. TreeFlow began as a NOAA-Office of Global Programs-funded project in 2002 and started receiving WWA support in 2003. The initial focus was on data development in partnership with water. As the paleohydrology data network reached a critical mass (now over 30 gauge reconstructions in CO, WY, UT, NM), efforts turned to outreach through a series of 12 technical workshops to over 200 water managers and stakeholders around the region. The integrated TreeFlow web resource was recently expanded to cover most of the western US and is now a cross-RISA product with support from the Climate Assessment of the Southwest (CLIMAS) and the Climate Impacts Group (CIG). A recent WWA evaluation effort confirmed the decision support utility of both these outreach efforts and the paleohydrology data themselves.

Climate Change in Colorado Assessment

In 2008, WWA synthesized the climate change science important for Colorado's water supply in response to a request (and subsequent commission) from the state of Colorado's Water Conservation Board (CWCB). Compiling the report required outreach to the full spectrum of WWA's networks of researchers and water decision makers, and tapped the talents of virtually every WWA researcher as either an author or reviewer. The report received significant attention in the media, was a finalist for the Governor's Research Impact Award, and has become the basis for many subsequent discussions about adaptation planning throughout the state.

USGCRP Synthesis and Assessment Products/IPCC Fourth and Fifth Assessment Report

WWA researchers have been in key leadership roles for the U.S. Global Change Research Program (USGCRP) Synthesis and Assessment Products, and for the Intergovernmental Panel on Climate Change (IPCC). The WWA Director was a lead author for the Unified Synthesis Product, and WWA Deputy Director was the staff scientist for Working Group I of the IPCC Fourth Assessment Report. Currently, both are involved in preparations for the Fifth IPCC Assessment.

Intermountain West Climate Summary

The Intermountain West Climate Summary (IWCS) is WWA's most prominent outreach and education product; it is distributed to over 400 water and resource managers and decision makers and downloaded over 800 times a month. By improving awareness and understanding about climate, the IWCS helps WWA facilitate a dialog among users, researchers, and operational providers of climate information with the ultimate goal of providing enhanced climate services. The IWCS provides the latest climate observations and forecasts for Colorado, Wyoming, and Utah in a single, compact, web-based format. Archives of IWCS including a list of feature and focus articles.

Water Cycle Research – The NOAA Hydrometeorology Testbed

The creation of HMT is, in and of itself, a significant accomplishment: it represents a new way of conducting research, one that helps to bridge the oft-cited gulf between operations and research. It also helps to underscore the often over looked fact that research is a service. In this spirit a number of key research findings from HMT are shared herein.

Atmospheric Rivers: HMT has contributed to significant advances in our understanding of processes leading to extreme rainfall in complex terrain. In particular, HMT research has shown that most extreme rainfall events on the West Coast are associated with atmospheric rivers (ARs), and has documented and characterized atmospheric river structure and its importance to flooding and water supply. Our research has identified and quantified moisture flux thresholds leading to heavy precipitation.

Atmospheric River Observatories (AROs)

PSD scientists have designed and deployed the atmospheric river observatory (ARO) concept, which has been used extensively in NOAA's HMT to provide measurements of atmospheric rivers over land and the resulting orographic precipitation enhancement. Observations from AROs, along with numerical model output, are integrated into the Coastal Atmospheric River and Early Warning System, and allow forecasters to monitor the AR conditions that lead to heavy precipitation and to gauge how well the forecast model is replicating those conditions. A transportable ARO has also been developed and is presently deployed in Washington State supporting Weather-Climate Studies.

State-of-the-Art Precipitation Analyses in Complex Terrain

Monitoring and quantifying precipitation in complex terrain is a high priority because of the simultaneous needs of managing water resources and protecting lives and property from flooding. Yet, in the mountainous west, quantitative precipitation estimation (QPE) remains a significant challenge. Research in PSD has led to a number of developments in this area. For example, using vertically pointing rain profiling radars, PSD developed an algorithm that distinguishes between deep precipitation involving ice processes and a shallow warm rain process involving little or no ice. This work has alerted forecasters along the West Coast to a rainfall process that is mostly undetected by the operational WSR-88D (NEXRAD) radar network. This shallow, warm, "non-bright-band" rain, produces ~25-35% of total precipitation in key areas and yet is very shallow, often beneath the current NEXRAD radar coverage. During the winter of 2008/2009, the Monterey WFO dedicated one of their 32-inch flat panel screens to display radar reflectivity observations from a precipitation profiling radar deployed to Pt. Sur, CA, to detect these shallow precipitation echoes.

Other noteworthy contributions include the development of advanced polarimetric X-band radar algorithms; polarimetric techniques to correct for attenuation of the radar signal; techniques to correct for bright band contamination and/or beams in the snow above the bright band in quantitive precipitation estimates, using specific vertical profile of reflectivity (VPR) adjustments. Key results are being used to improve National Mosaic and Multisensor QPE system at NSSL (NMQ/Q2). These efforts also support the NWS-Distributed Model Intercomparison Project (DMIP) evaluations of various streamflow models; including especially next-generation distributed hydrologic models.

New Demonstration Performance Measures

HMT has led to the development of prototype, demonstration performance measures: (i) Current verification of precipitation forecasts to not adequately account for extreme events. HMT has developed a new measure for extreme QPF. It was initially developed on the West Coast, but the technique is now applicable across the entire United States; (ii) A new measure to track snow level forecasts has been developed. In complex terrain, small changes in the elevation at which rain turns into snow, can produce significant changes in runoff. Prior to this, a performance measure for snow-level forecasts did not exist.

Observing Systems

PSD uses a wide variety of observing systems to collect the data needed to better understand weather and climate processes. These systems continuously evolve in response to user feedback and new scientific priorities. They are used in both research and quasi-operational settings. Those used primarily for research applications are described below.

Spaced-Antenna Mobile Profiler

PSD is developing a small mobile wind profiler capable of measuring high-resolution boundary layer winds in extreme clutter environments. This profiler will use spaced antenna technology coupled with NOAA's low sidelobe antenna design to produce high-time resolution wind profiles in locations where there is too much ground clutter interference for traditional wind profilers. In addition, the profiler is designed as a Frequency Modulated-Continuous Wave (FM-CW) radar. FM-CW radars allow for wind measurements at lower altitudes and with higher-range resolution than traditional profilers. FM-CW radars are also capable of better sensitivity than pulse-modulated radars; therefore, the mobile profiler is designed with a lower transmit power than other spaced antenna radars. Planned uses for the new profiler are fire weather forecasts and dispersion model initialization.

Sodar

PSD has developed an inexpensive acoustic radar (sodar) based around personal computers with sound cards. A sodar based on this design is currently used by the NWS to detect the top of the fog layer in the San Francisco Bay area. This measurement is used operationally to forecast when the fog will burn off and allow aircraft to land. PSD also developed a bistatic sodar capable of measurements as low as two meters. These sodars are currently in use in Greenland and Colorado. Measurements of low-level temperature inversion layers produced by these sodars are valuable in understanding chemical processes near the Earth's surface.

S-Band Rain Profiler

PSD developed a vertically pointing radar that produces high resolution profiles of precipitation. Designed with a wavelength of 10cm, there is very little attenuation due to rain. In addition, the radar has over ten orders of magnitude (100 dB) of dynamic range. This allows the radar to make measurements during extreme rainfall events. S-band radar data is used to study rain microphysics, melting layer height, and storm dynamics.

Buoy-Mounted Wind Profiler

PSD developed and demonstrated an ocean buoy mounted wind profiler. A patented technique was developed to correct for buoy motion and produce wind profiles. A prototype radar was constructed and tested on a buoy near Scripps in San Diego. The prototype produced Doppler spectra in real time that were later processed into wind profiles. Applications of a buoy-mounted profiler include the measurement of offshore marine boundary layer depth, low-level jet observations, offshore melting layer detection, timing of frontal passages, hurricane prediction, and initialization of dispersion models.

Radar Wind Profiler Networks

The ESRL/PSD engineering staff is a world-class leader in developing wind profiler technology. They designed, built, and maintain a pool of 15 boundary-layer and troposphere wind profilers that can be deployed for weather and air quality field studies. Data from these networks have been used in air trajectory analyses, boundary-layer depth detection, snow-level detection, boundary-layer turbulence measurements, precipitation microphysics retrievals, coupled ocean-atmosphere processes, as well as research in polar, mountain, tropical, and mesoscale meteorology. The wind profile data is also assimilated into numerical weather prediction models.

449-MHz Wind Profiler Radar

ESRL/PSD engineers designed the first-of-its kind ¼-scale 449-MHz wind profiling radar to provide boundary-layer and lower troposphere wind profiles in the arctic environment, where boundary-layer wind profilers had proven to give inadequate height coverage. This instrument design was later adapted for the U.S. Air Force's Tethered Aerostat Radar System (TARS), and eight ¼-scale 449-MHz radars subsequently have been installed along the U.S. southern border at TARS sites. The transportability of these radars also allows them to be used in research field campaigns, such as the HMT Program, the Integrated Ocean Observing System (IOOS) coastal wind profiler technology evaluation, and the North American Monsoon Experiment (NMAE).

FM-CW Snow-Level Radar

The NOAA FM-CW (Frequency Modulated Continuous Wave) snow-level radar is a low-cost alternative to the pulsed S-band radars used by NOAA PSD for precipitation profiling and snow-level determination. These newer FM-CW radars were designed specifically for snow-level determination, using our experience in developing pulsed S-band radars and FM-CW radars. Some of the FM-CW techniques we are using were developed by our laboratory in the 1970s. However, modern electronics and signal-processing techniques have made it much easier to use FM-CW technology in today's radars. The software for the radar utilizes much of the same Doppler signal processing used in the other commercial and research vertically-pointing radars. Snow-level determination is done using the automatic algorithm developed the NOAA PSD and CIRES researchers.

X-Band Radar

PSD maintains and operates an X-band radar primarily for observations of the ocean surface, rain, snow, storm airflow patterns, and for hydrometeorological applications. It has Doppler, dual-polarization, and full scanning capability, including the ability to scan below the horizon for ocean work. Fine-scale measurements are possible with selectable range resolution from 7.5 to 150 meters. Polarization options include switching between H and V, or using the "split" H/V, configuration that has been proposed for future NEXRAD upgrades. The polarization measurements include differential phase (Kdp), and differential reflectivity (ZDR), which can used for more accurate estimates of rainfall rate and identification of precipitation particle types. The radar is transportable in North America on its own trailer bed or it can be shipped overseas in standard sea containers.

Electronically-Stabilized Radar Wind Profiler

PSD maintains a 915-MHz radar wind profiler incorporating an electronically-stabilized, phased-array antenna and real-time motion compensation initially designed for operation aboard the NOAA Research Vessel Ronald H. Brown (RHB). Although no longer deployed on the RHB, the radar and associated technologies are used to provide real-time motion compensation for a variety of systems intermittently deployed for shipboard operations.

Airborne W-Band Sea Spray Radar

PSD has developed a compact W-band radar for use on an airborne platform to observe sea spray. The radar has participated in two recent shipboard field programs in the Pacific to help understand the role clouds play in atmospheric radiation and climate physics. The airborne radar will look downward to observe sea spray under high wind conditions, a key factor associated with hurricane intensification.

Boulder Atmospheric Observatory (BAO)

Completed in 1977, the PSD BAO is a unique research facility for studying the planetary boundary layer and for testing and calibrating atmospheric sensors. The centerpiece of the facility is a 300-m tower instrumented at five levels with slow-response temperature and wind sensors, a variety of remote sensing systems, and a real-time processing and display capability that greatly reduces analysis time for scientists. The BAO has been the host of several large national and international experiments and numerous smaller ones. For the last 20+ years, the BAO has been a part of the world Baseline Surface Radiation Network critical to NOAA's Global Monitoring Division (GMD) and their efforts to improve evaluations of atmospheric radiative transfer for climate research. The Baseline Surface Radiation Network (BSRN) is a project of the World Climate Research Programme (WCRP) aimed at detecting important changes in the Earth's radiation field, which may cause climate changes. In the last several years, the BAO has become a part of the Tall Tower Network and Carbon Tracker System. The Tall Tower sites are part of the North American Carbon Program and are a primary data source for ESRL's Carbon Tracker CO2 data assimilation system.

GPS Technologies

PSD researchers, in collaboration with colleagues from the Jet Propulsion Laboratory at the California Institute of Technology, NASA Langley Research Center, University of Colorado at Boulder, the Applied Physics Laboratory at Johns Hopkins University, and Purdue University, have shown that weakly reflected GPS signals from water and land can be detected by airborne instruments and used to map ocean surface topography (e.g., storm surge), measure ocean waves and surface winds, soil moisture, and sea ice. This technique has been tested and offers a relatively inexpensive way to measure a variety of geophysical parameters over broad areas.