ESRL Physical Sciences Division 2015 Review Themes

Theme I: Observing the Physical System

Observations are critical for monitoring, analyzing, interpreting and predicting atmospheric, oceanic, cryospheric, and land surface processes. NOAA's Physical Sciences Division (PSD) has expertise in the design, testing, deployment, and maintenance of in situ and remote sensing observing systems that advance an observation-based process understanding of current environmental conditions, how these conditions may be changing, and why. PSD collects research-quality observations of key environmental data that provide critical information on boundary and surface layer fluxes between and among the atmosphere, ocean, sea-ice, and land. PSD makes strategic use of observations to advance scientific understanding of physical processes controlling high-impact extreme weather and climate events that include flux measurements in tropical cyclones and vertical profiles of atmospheric systems for nowcasting the intensity and duration of extreme precipitation. Advances in PSD's observation-based scientific understanding are used to guide development of physical process-based parameterizations that can improve the skill and reliability of global and regional forecast models.

PSD observations of key parameters range from the microscale to the synoptic scale, and include air-sea/ice/land fluxes, cloud and sea-spray microphysical properties, surface and cloud radiation, tropospheric winds, precipitation processes, soil moisture, and aerosols. PSD observations span the globe including the Arctic, the Tropical Western Pacific and the Western U.S. PSD's engineering expertise has made it possible to obtain these kinds of measurements from land-based sites, research aircraft, and research vessels at sea. Ship-borne observing systems have been used to investigate air-sea transfer processes in the tropical ocean to better understand and to improve parameterization of these interactions in climate models. Long-term Arctic atmospheric observatories have been established to better monitor and understand changing conditions in the Arctic. PSD advances observing technologies including the development and deployment of a novel radar system for measuring the ocean's sea spray layer from aircraft. PSD operates a fast deployable wind/precipitation profiler and surface meteorological network that is currently deployed across California and the Pacific Northwest to support the monitoring and improved prediction of heavy precipitation events, to help address associated flooding and water resource management challenges, and to improve wind energy resource forecasts as part of a Wind Forecast Improvement Project. PSD has developed unique cloud and precipitation profiling radars that have allowed new findings about the structure and evolution of precipitating cloud systems. PSD also develops new observation techniques based on using electromagnetic signals of opportunity such as Global Navigation Satellite System that have the potential to provide inexpensive measurement of soil, snow, ice, and vegetation parameters over the land and sea-state and wind over the ocean.

Theme II: Understanding the Physical System

An integrated understanding of Earth system processes spanning weather and climate timescales is essential to improve the quality of environmental intelligence NOAA delivers to the nation. PSD research describes, interprets, and assesses the predictability of weather, climate, and water variations and trends on time scales ranging from hours to a century. PSD applies innovative diagnostic methods to advance capabilities to detect, understand, explain, and predict extreme events, and trends in the extremes. Understanding how atmosphere, ocean, land, and cryospheric conditions are currently being impacted and may be affected in a changing climate not only provides early warning and informs preparedness, but also identifies prospects for improved forecasts and projections. PSD's efforts to improve current knowledge of the water cycle will advance capabilities to fully understand the linkages between weather, climate, and water. The collective understanding from PSD research provides the foundation to create effective and credible scientific knowledge that is needed to inform policy, planning, and decision making in the management of current and future risks.

Carefully crafted attribution studies carried out by PSD scientists are critical for establishing the principal causes or physical explanation for observed conditions and phenomena. For example, analyses of hydro-meteorological measurements made by PSD scientists have increased the capability to more accurately measure and predict precipitation, increasing the understanding of the evolution of droughts, floods, and stream flows from the short-term (e.g., extreme precipitation events over hours and days) to the long-term (e.g., estimating streamflow for the Colorado River in the coming years). Observation based studies have determined the presence and importance of super-cooled liquid water in Arctic clouds that have profound impacts on sea-ice extent and seasonal snow extent. Reanalysis datasets and web-based atmospheric and oceanic data visualization and analysis tools, both developed and assessed by PSD scientists, contribute to the investigation and understanding of the physical system, and are a mechanism for PSD science to extend to the broader scientific community.

Theme III: Modeling the Physical System

Observations and physical process understanding are transformed into predictive capabilities through numerical modeling. PSD develops and applies data assimilation systems that couple atmospheric, oceanic, and land data in global and regional earth system modeling to advance analysis, forecast, and prediction capabilities. PSD advances the scientific basis to provide early warning and inform preparedness across weather and climate time scales through efforts to improve global and regional forecast and prediction modeling systems. Approaches such as development of new parameterizations as well as pre- and post- processing are applied in global and regional forecast and prediction modeling systems to advance forecast and prediction capabilities. Collectively, PSD's assimilation, development, analysis, and modeling research are critical to meet NOAA's mission responsibilities to understand and predict changes in climate, weather, oceans, and coasts, and to share that knowledge and information with others.

PSD continues its long-term relationship with the NOAA National Centers for Environmental Prediction to improve forecasts. PSD developed, maintains and continues to improve the Ensemble Kalman filter data assimilation system now used operationally for global weather prediction. PSD also developed a set of stochastic parameterizations designed to represent model uncertainty in the operational NCEP global prediction model. In the realm of improved parameterizations, PSD developed an air-sea coupling module for NCEP's operational hurricane prediction model that includes an advanced sea-spray parameterization scheme to account for the complexity in air-sea interaction under high winds. It also developed a research platform to evaluate the cloud parameterization schemes in NCEP's global and regional prediction models using observations of cloud microphysics properties. Through the NOAA Wind Forecast Improvement Project, PSD is also working with the Department of Energy to improve the skill of NOAA's short-term weather forecast models at predicting foundational weather parameters (for example, wind speed, turbulence intensity, and icing conditions) that impact wind energy generation.

Theme IV: Research to Applications, Operations and Services

The transition of research findings, products and methods into applications, operations and services is fundamental to ensure the best available science is being applied to support NOAA mission responsibilities. To address growing service demands and needs for increased accuracy of weather, climate, and water information, PSD works closely with the NOAA service line offices and external federal, state, and local partners to accelerate the timely transfer of research advances into operational settings and the delivery of information for use in policy, planning, and decision making.

PSD works closely with the NOAA National Weather Service (NWS) to incorporate weather, climate, and water research into operations, including: implementation of testbeds to prototype new observations, models, and algorithms, data assimilation techniques, regional prediction capabilities, air-sea heat flux parameterizations, post-processing forecast tools and techniques, seasonal and subseasonal climate, drought, and hazard outlooks, monitoring analyses, and El Nino Southern Oscillation (ENSO) diagnostic discussions. PSD partners with the NOAA National Marine Fisheries Service (NMFS) to develop actionable information in the form of science-based climate and weather knowledge that has been transformed to be readily understandable and immediately available to support water resource decision making. PSD also collaborates with groups such as: the US Bureau of Reclamation (USBR), the U.S. Agency for International Development (USAID), the U.S. Army Corps of Engineers (USACE), the U.S. Department of Defense (DOD), the U.S. Department of Energy (DOE), the State of California Department of Water Resources (CA-DWR) and Sonoma County Water Agency (SCWA), and the National Integrated Drought Information System (NIDIS) to provide the best available weather, climate, and water science to inform policy and management decisions. PSD leads an international consortium of Arctic Observatories that network to provide detailed pan-Arctic information on the state of the Arctic atmosphere that will inform the WMO Polar Predication Project. In addition, PSD conducts research on how stakeholders use weather, climate, and water information to assess what is needed for the information to be usable and actionable, thus linking management planning processes and operational issues with potential uses of weather, climate, and water forecasts and information.