NOAA Physical Sciences Laboratory Strategic Plan 2021-2025 DRAFT

1. Introduction: The Challenge

All countries experience adverse socio-economic and environmental impacts from extreme events in the earth system and subsystems including the atmosphere, landscapes, oceans, and the cryosphere. Weather and climate extremes include floods, drought, heat waves and tropical storms affecting economic sectors, livelihoods and ecosystems.

To illustrate, from 1980–2019, the U.S. sustained 258 separate billion-dollar weather and climate-related disasters with over $1.75 trillion in insured losses and more than 13,000 fatalities (NCEI, 2020). Similarly, US marine and coastal regions¨ including territories in the Pacific and Caribbean encompasses a wide range of ecosystems¨ from tropical coral reefs to Arctic waters covered by sea ice. In 2016 the US Ocean and Great Lakes economy accounted for 154 000 business establishments, 3.3 million employees, and $129 b in wages. In 2018, America's Ocean economy contribute $373 b to the US annual GDP. The resilience of the nation's marine ecosystems and coastal communities depend on healthy marine species, including protected species such as whales, sea turtles, corals, and salmon and are critical to human health and coastal economies. Decisions involve balancing of growing the Blue Economy (e.g., aquaculture, domestic fisheries, recreation, maritime commerce) with conservation of vital ocean and coastal resources.

Weather, climate and ocean sciences are increasingly called upon to steadily advance the certainty of knowledge of interactions within the physical and natural world, and to help the Nation cope with many uncertainties in urgent technological, societal and environmental decisions in the present and into the future. The (combined) modulating factors of internal atmospheric variability, subseasonal to interannual (MJO, ENSO), decadal-scale variations (AMO, NAO etc.) and long-term trends among others introduce significant complexity and uncertainty in estimating the likelihood of climate risks of specific magnitudes in specific locations (IPCC 2012, Hoskins 2013, Dole et al 2014, BAMS Extremes Series, Palmer and Stevens, 2019). In addition, the physical and socioeconomic impacts of compound and cascading extreme events (such as simultaneous heat and drought, or flooding associated with high precipitation on snow or waterlogged ground) can be greater than the sum of the parts and moves the research questions beyond the forecasting of single events.

The Nation's dependence on physical and natural systems that are impacted by weather and climate extremes, illustrate both the risks and opportunities involved. Analyses and predictions of weather, air quality, sea ice, soil moisture, ecosystem functioning, and many other components of the Earth system are critical for decision making across a wide range of sectors and timescales (NASEM 2020).

The value such information includes the opportunities to reduce or avoid losses through better anticipation, the dividends that accrue from having avoided the loss (i.e. lower recovery costs, opportunities for investments) and, the co-benefits for sectors and communities in managing and designing resilient infrastructure, health, and resource management. Anticipating potential surprises, quantifying probabilistic risks, and addressing compounding and systemic risks are the very real challenges that a varying and changing weather and climate system poses for science and for the Nation. Further improvements in these predictions will need to be guided by a clear understanding of what aspects of the Earth system are predictable, and where new sources of and limits to that predictability exist across multiple temporal and spatial scales. Within the above context, NOAA's mission is to understand and predict changes in climate, weather, oceans, and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources (NOAA 2020). NOAA's vision for achieving its mission captures the societal benefits of research and development (R&D) as a future with healthy and thriving ecosystems, communities, and economies that are resilient to existing risks and in the face of change.

2. PSL Vision and Mission

NOAA Research and Development (R&D) serves NOAA's mission "to understand and predict changes in climate, weather, oceans, and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources". NOAA's R&D priorities lie within three key areas:

(i) Reducing societal and economic impacts from hazardous weather and other environmental phenomena
(ii) Sustainable use and stewardship of ocean and coastal resources
(iii) A robust and effective research, development, and transition enterprise

In support of the NOAA Mission, the Office of Oceanic and Atmospheric Research seeks to

- Explore the Marine Environment
- Detect changes in the Ocean and Atmosphere
- Make forecasts better
- Drive Innovation

PSL directly engages NOAA's long-term, strategic goals by conducting purposeful, end-to-end research strengthening and improving NOAA's abilities to meet evolving national needs. The mission of **NOAA Physical Sciences Laboratory (PSL)** within the above broader goals of the NOAA R&D and OAR strategies, is to conduct scientific research to observe, understand, model, predict and forecast weather, water and climate extremes and their impacts to inform early warning, preparedness and resilience.

The PSL vision is one of '*an informed society that uses science-based environmental intelligence to effectively anticipate and respond to threats and opportunities related to weather, water and climate extremes in a changing environment*. Critically the practice, behind this vision, is to support NOAA Initiatives and position NOAA *to provide the early warning to inform preparedness for disaster risk reduction, resource management and investments, to increase the resiliency of the nation, its ecosystems, communities, and economies* ***by diagnosing the predictability of extremes across multiple***

timescales and by predicting the nation's path through a varying and changing climate.

3. Purpose and Scope of the Strategic Plan

On October 1, 2005, the Climate Diagnostics Center, the Environmental Technology Laboratory, and the Aeronomy Laboratory's Tropical Dynamics & Climate Division merged into the Physical Sciences Division of the Earth System Research Laboratory. As part of the transition, the ETL Optical Remote Sensing Division moved to the ESRL Chemical Sciences Division. This merger brought together a combined expertise in:

- weather and climate dynamics, diagnostic and modeling analyses,
- physical observations, monitoring and related technology development, and
- physical process understanding and research, that will help ESRL meet critical NOAA objectives in climate and weather research.

On April 2, 2020, NOAA designated the four divisions of the Earth System Research Laboratory in Boulder as full laboratories within the NOAA Oceanic and Atmospheric Research line office to meet recent shifts in mission-essential priorities. The Physical Sciences Laboratory and the three other laboratories retained their core research missions, and continue to collaborate closely with each other and other NOAA Research laboratories to improve understanding and ability to predict changes in Earth's atmosphere, climate and weather.

PSL's collaboration across the Earth System Research Laboratories brings together integrated expertise in weather and climate physical observations, modeling, analysis and applications.

Drawing on its the scientific knowledge and subject matter expertise, PSL, will over the next five years, actively pursue science research and development to improve observations, understanding, modeling and predictions focused on the physical science basis in three use-inspired research themes: Extremes with a specific focus on S2S timescales, Water Resources, and Marine Resources. As employed by PSL, use-inspired science consists of scientific investigation whose rationale, conceptualization, and research directions are driven by the potential use to which the knowledge will be put (Stokes, 1997). The specific goals and objectives of the themes were developed through a series of internal workshops in which PSL strengths, capabilities and opportunities for scientific advancements were matched to relevant NOAA mandates and goals, and are discussed in greater detail below. Robust partnerships are key to the development and implementation of successful collaborations for use-inspired research. PSL partnership mechanisms occur across NOAA Line Offices, Cooperative Institutes, regional activities interagency activities, international engagements, Memoranda of Agreement undertaken by NOAA, the Educational Partnership Program (EPP), among others. Illustrative examples of specific partnerships are provided below. PSL will use this document, the PSL Strategic Plan (hereafter, the PSP), for planning and prioritizing projects and guiding NOAA’s investments for R&D across the budget horizon, to rigorously characterize and predict weather, water, and climate extremes and their uncertainties to support NOAA's mission, and develop new process understanding, observing, and modeling capabilities to predict conditions associated with too much or too little water for early warning, preparedness, resource management, and adaptation. The guiding principles and drivers for the PSL Strategic Plan in the context of NOAAs' mission scientific integrity policies, and legislative drivers are provided in the next section.

4. Guiding Strategic Principles and Drivers

In directing, formulating, and evaluating its R&D endeavors, PSL follows NOAA’s principles outlined in NOAA Administrative Order (NAO) 216-115A3) and NOAA mandates under National Legislative Drivers. These principles are embedded within the PSL organizational and scientific culture, and include:

1.Mission Alignment: PSL serves NOAA’s mission “to understand and predict changes in climate, weather, oceans, and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources”.

2.Transitioning Research into Operations and Application and other Uses(R2X)

3.Research Balance to optimally achieve NOAA’s strategic objectives while continually strengthening the quality, relevance, and performance of its R&D products as investments in the future;

4.Partnerships that engage and leverage interagency, academic, public-private, and other partnerships for enhanced innovation, stakeholder input, and return on investment for the American public.

5.Facilities and Infrastructure: Maintain and improve the “hard” assets that enable R&D. These “hard” assets include laboratories and science centers, ships, aircraft, high performance computing capacity, satellites, and buoys. These platforms

6.Workforce Excellence that involves hiring and training an inclusive scientific workforce through outreach events, internships, fellowships, and professional development opportunities. and support a diverse recruitment pool to maintain the flow of scientists into the NOAA workforce.

7.Scientific Integrity to produce credible, relevant and reliable R&D results, in accordance with NOAA’s Scientific Integrity Policy, NAO 202-735D5

8.Accountability: PSL will regularly evaluate its R&D and adjust activities and priorities as needed in line with the NAO 216-115A.

NOAA will use metrics that cover a broad research portfolio to indicate outputs and outcomes of R&D activities.

Legislative Drivers

1. Title II, Section 201(h)(1) of United States Congress enacted PL115-25, with the short title, “Weather Research and Forecasting Innovation Act of 2017, “To improve the National Oceanic and Atmospheric Administration’s weather research through a focused program of investment on affordable and attainable advances in observational, computing, and modeling capabilities to support substantial improvement in weather forecasting and prediction of high impact weather events, to expand commercial opportunities for the provision of weather data, and for other purposes.”
2. National Integrated Drought Information System Act Of 2006 (PL. 109-430) and Reauthorization Acts of 2014 and 2019 establish and maintain a National Integrated Drought Information System within NOAA to improve drought monitoring, forecasting, and early warning capabilities and to determine the contribution of weather events to reducing the severity or ending drought conditions.
3. The Secure Water Act (Subtitle F of Public Law 111–11, March 30, 2009) identified NOAA as a source for the credible science required by other agencies, state, and local decision makers, and the private sector, and to provide “the best available scientific information with respect to presently observed and projected future impacts of global climate change on water resources.”
4. Magnuson-Stevens Fishery Conservation And Management Act Public Law 94-265, as amended through October 11, 1996 “to assure that the national fishery conservation and management program utilizes, and is based upon, the best scientific information available” (101-627, 104- 297) Conservation and management measures shall be based upon the best scientific information available.”
5. Marine Mammal Protection Act, sec. 1371 “The Secretary, on the basis of the best scientific evidence available and in consultation with the Marine Mammal Commission, is authorized and directed from time to time, having due regard to the distribution, abundance, breeding habits, and times and lines of migratory movements of such marine mammals.”
6. marine resources and engineering development act of 1966 (Pub. L. 89-454) to “develop, encourage, and maintain a coordinated, comprehensive, and long-range national program in marine science for the benefit of mankind, to assist in protection of health and property, enhancement of commerce, transportation, and national security, rehabilitation of our commercial fisheries, and increased utilization of these and other resources.”

5. PSL Research Themes: Goals and Objectives

PSL research strives to identify new sources of predictability as a foundational scientific underpinning for the delivery of NOAA services. As noted above PSL will pursue a use-inspired research strategy that balances responsiveness to needs of existing climate, weather and water services with innovation of new capabilities in anticipation of future service needs PSL's three research themes are summarized as follows:

1. Physical Science for Predicting Extremes. PSL will characterize and advance prediction of extreme weather and climate, with a focus on extreme event prediction on subseasonal to seasonal timescales to improve forecasting
2. Physical Science for Water Resource Management: enhance targeted observations, observation-based understanding, and modeling capabilities to forecast hydrologic extremes (too much or too little water) critical to manage water resources
3. Physical Science for Marine Resource Management increase targeted observations, process understanding and prediction of environmental conditions impacting the marine resources.

The goals and objectives within each theme are elucidated in detail below. Given PSL's historical emphases, including in its earlier incarnations these are listed in order of level of development to date.

Research Theme 1: Physical Science for Predicting Extremes

Given the impacts of serious risks to health, economic development, and food security, improved prediction extreme weather and climate specifically on subseasonal-to-seasonal (S2S) time scales is a high priority to help NOAA meet mission responsibilities to provide early warning and informed preparedness. Subseasonal-to-seasonal forecasting bridges the gap between the more-mature weather forecast and seasonal prediction. S2S has received much less attention than medium and seasonal prediction despite the considerable socioeconomic value that could be derived from such forecasts. The S2S time range is critical for proactive disaster mitigation efforts, since these efforts often take several weeks to implement. S2S is considered a challenging forecast time range since the lead time is sufficiently long that much of the memory of the atmospheric initial conditions is lost, while too short for the variability of the ocean to have a strong influence.

PSL's major roles will include providing an understanding of the processes driving predictability of extremes, contributing key data sets and diagnostic tools to facilitate this understanding, and developing many of the advanced algorithms that will underpin the Unified Forecast System as configured for S2S forecasts (Figure 1). PSL intends to perform research to answer many fundamental S2S prediction questions that relate to the prediction of extremes.

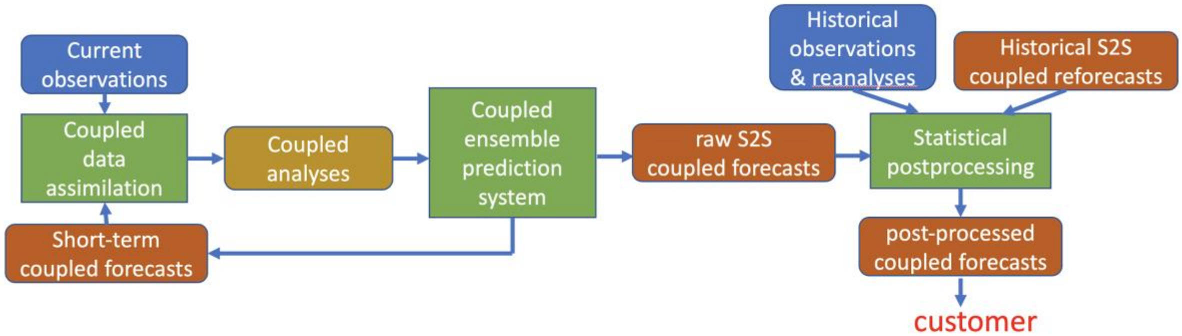

Figure 1: A high-level schematic of an S2S prediction system. Improved initial conditions for S2S forecasts are generated by a coupled data assimilation system that adjusts prior forecasts to newly available observations. The coupled analyses initialize a coupled ensemble prediction system. These raw forecasts are statistically postprocessed to provide high-quality guidance to customers such as NWS forecasters.

Goal 1.1: Improved knowledge of limits of S2S predictive skill

Quantifying the upper limits to potential skill helps NOAA determine what customers can expect with improved S2S prediction systems and whether the prediction skill is near or far from the upper limits. If NOAA's actual prediction systems are far from those limits, this suggests that with resources, prediction system improvement is possible. If NOAA's current forecasts are near that limit, resources can be rededicated to other more pressing needs.

There is increasing evidence that there are slowly varying phenomena like soil-moisture anomalies, tropical Pacific sea-surface temperature anomalies (El Niño) and stratospheric processes (Quasi-biennial Oscillation) that can affect the frequency and distribution of S2S common and extreme events in predictable ways, even if the specific dates of these phenomena cannot themselves be predicted. These are sometimes "forecasts windows of opportunity" where predictive skill is possible only when the anomaly is large.

Objectives:

- Use PSL-generated tools and data sets to quantify S2S predictability limits, forecasts windows of opportunity, and communicate this understanding to the broader community.
- Develop, maintain, and provide community support for a variety of tools and data sets that are used in part to quantify of predictability at S2S time scales (see Table 1).
- After major extreme events of US significance, conduct attribution studies to understand the sources of predictable skill, and determine how far ahead useful predictions were possible.

Goal 1.2: Advanced understanding of sources of predictive skill and their impact on prediction of extremes

At S2S leads of several weeks to two years, the chaotic growth of atmospheric initial-condition errors during the forecasts makes deterministic prediction unrealistic. Still, slowly varying phenomena such as El Niño may change the frequency and location of extreme weather events in predictable ways. Relevant questions include: *What are the specific slowly varying phenomena that change the frequency and location of extreme events at S2S time scales? Do these phenomena interact in predictable ways? If these phenomena are predicted well, how much potential forecast skill is possible from each phenomenon? Will the predictive skill of S2S extremes arises from shifts of the mean as opposed to changes of variance or shape?* An understanding of our skill gap in predicting these phenomena can guide the investment of resources.

Objectives:

- Identify new slowly varying components of the earth system and component interactions that modulate S2S weather variability.
- Determine what predictable changes in extreme events happen with individual variations and interactions of the components in various phases.
- Identify how much predictive skill for extremes at S2S time scales arises from shifts of the mean as opposed to changes in the higher moments of probability distributions.

Goal 1.3: An improved knowledge of key physical processes in the coupled climate system

Realistic S2S predictions may require understanding and properly simulating even small-scale, quickly changing phenomena. For example, clusters of tropical thunderstorms drive global wind patterns, so their mis-modeling can result in mis-estimation of those wind patterns and the resulting interactions between the atmosphere and ocean, land, and sea-ice anomalies. PSL is advancing the understanding of these processes across scales as a precursor to improving their representation in prediction systems, and advancing the development of supporting data sets.

Additionally, on S2S timescales, forecast systems need to adequately represent the coupling between the components of the climate system. Mis-representation of these couplings degrades longer-lead forecasts of ocean, land, and sea-ice conditions that modulate S2S weather extremes.

Objectives:

- Identify the physical processes that must be modeled correctly in order to generate realistic simulations of S2S weather variability including random processes that are occurring below the grid scale of the model and propagate that uncertainty upscale to larger scales of motion.
- Develop diagnostic capacity for comparing observations, forecasts, and analyses for the purpose of more rapidly identifying the sources of systematic errors in the prediction system.
- Develop and test improved conceptual models for the unresolved atmospheric processes and use the conceptual models to improve the physical representation of these processes in prediction systems.
- Determine how faithfully current algorithms simulate known key processes such as cloud-microphysics and associated cloud-radiative feedbacks, fluxes between coupled state components, deep convection, and the atmospheric boundary layer including comparisons of model processes with observations and against the processes simulated in cloud-resolving models.

Goal 1.4: An improved NOAA S2S forecast system

NOAA's current generation prediction system has many deficiencies, including major systematic errors in key phenomena such as El Niño/Southern Oscillation. PSL will be a major contributor to S2S forecast system improvement through developments that feed into the UFS, leveraging its past experience. PSL will determine *what physically based numerical weather-climate prediction algorithms will result in improved state estimates, reduced systematic errors, and improved probabilistic predictions of extreme and high-impact weather.* PSL will closely collaborate with NWS and transfer model developments for operational use in the NWS.

Coupled data assimilation will be necessary for the initialization of the atmosphere, ocean, sea-ice, and land states in physically consistent ways. Ensemble prediction systems will be used to provide multiple forecast scenarios to help identify the probabilities of extreme events. Given that challenging systematic errors are likely to be non-negligible for the next several decades, statistical postprocessing of the ensembles will be necessary to correct bias and isolate the predictive signal from the sampling variability.

Objectives:

- Produce coupled and century-long integrated earth-system reanalysis data sets vital to S2S reforecast initialization, model validation, and process understanding.
- Generate seasonal reforecasts for use in postprocessing, attribution studies, and model forecast skill evaluation.
- Improve techniques for performing weakly and then strongly coupled data assimilation algorithms for coupling between ocean and atmosphere, ocean and sea ice, and land and atmosphere.
- Develop tools and process level diagnostics for diagnosis of systematic errors in the forecast models.
- Develop improved ensemble prediction systems that focus on the treatment of model uncertainties in the coupled state and its interactions.
- Perform objective forecast evaluations of methods developed by other NOAA partners for purposes of determining which system improvements are suitable for operational use.
- Develop improved parameterizations of the effects of sub-gridscale phenomena on the resolved weather, such as improving the parameterization of deep convection that are important for properly simulating the MJO of tropical circulation and convection and its impact on mid-latitude weather and extremes.

Goal 1.5: Advanced atmospheric science for renewable energy

Renewable energy from solar and wind sources is an important part of the Nation's overall energy portfolio, and continues to grow every year requiring improved forecasts from weather to seasonal time scales that are tailored specifically for the renewable energy community. In addition, one of the largest uncertainties in developing a future energy system that uses large amounts of wind and solar energy will be the impact of wind and solar energy droughts that determine the amount of storage and transmission required to make the system function reliably.

PSL will develop an S2S predictive capability for renewable energy forecasting through improved observation-based understanding and prediction of boundary layer processes. PSL will further develop knowledge on the characteristics of wind and solar energy droughts and how their occurrence is expected to change over the next few decades.

Objectives:

- Identify the causes of deficiencies in the prediction of low-level winds and solar radiation components in the forecast model using observations and process models.
- Improve model physics and data assimilation systems to advance understanding of sub-grid scale processes important for wind and solar energy forecasts.
- Develop techniques to characterize and estimate uncertainties in renewable energy forecasts.
- Quantify the location, magnitude, duration and spatial extent of wind and solar energy droughts, including their coexistence, over the past 100 years utilizing long-term reanalysis and the next few decades utilizing decadal predictions.
- Understand the relationship between recognized modes of climate variability (e.g. MJO, ENSO, PDO, AMO, etc.) and renewable energy resources.

Research Theme 2: Physical Science for Water Resource Management

Accurate water monitoring and predictions are critical for a variety of societal needs including agriculture, water supply, energy, water security, and public safety. Stakeholders need information ranging from current conditions to hours to seasons and beyond. NOAA's new National Water Model (NWM) provides an opportunity to improve water prediction at unprecedented time and space scales. However, significant challenges remain in terms of characterizing uncertainty in the hydrologic forcings, coupling between atmosphere-terrestrial- coastal systems, as well as how to communicate information to stakeholders to inform risk management.

PSL will focus on the identification of physical processes responsible for uncertainty in water predictions and projections in the atmosphere, land, and coastal environments. These efforts will inform progress toward NOAA's strategic implementation of a Unified Forecast System (UFS) that explicitly integrates national water modeling efforts. This work will include the deployment and analysis of observations, along with regional modeling studies to identify key physical processes, quantify uncertainty in water forecasts, and develop use-inspired and actionable water resource information for stakeholders inside and outside of NOAA.

Over the next 1-3 years, PSL will develop a rapid diagnostic assessment capability to quickly examine QPF and streamflow errors from extreme events of interest. PSL will also continue to focus on improving QPE, taking advantage of existing expertise in precipitation in complex terrain to optimally integrate advanced radar and numerical model data. These activities will directly address extreme rainfall prediction challenges faced by WPC and OWP. PSL will further expand its work in quantifying and characterizing streamflow prediction errors produced from both deterministic and probabilistic atmospheric forecasts.

The strategic direction of PSL water research over the next 3-5 years will directly support the NOAA OAR and PSL mission to improve observations, understanding, modeling and predictions of weather, water and climate extremes, and their related impacts. The research will aim to advance our understanding of surface processes and atmospheric coupling, paving the way for development of fully coupled atmosphere, terrestrial and coastal modeling with physically consistent forcing. Key scientific questions that will be addressed include quantifying when fully coupled earth system modeling is needed, versus where, e.g., offline hydrological simulations more efficiently leverage compute resources. PSL will also advance understanding of snow processes, from precipitation microphysics to snowpack evolution and melting. The research will also lead to the development of improved land-atmosphere data assimilation systems for global and regional-scale models.

Goal 2.1: Improved forecasts of precipitation and hydrologic impacts

Unlike other atmospheric forecast metrics, precipitation forecasts (QPF) have not shown steady improvement over time. The reasons for the lack of improvement are complex, and include shortcomings in physical parameterizations, inadequate resolution of precipitation processes in forecast models, and uncertainty in QPE with which to accurately benchmark QPF. In order to improve the modeling of both precipitation and hydrologic impacts, process diagnostics are necessary to obtain a comprehensive understanding of how well atmospheric and hydrologic models are simulating critical physical processes. These types of studies also serve to illuminate which and where essential observations are needed.

Objectives:

- Develop improved QPE using state-of-the-art gap-fill radars to augment traditional NEXRAD coverage and short-term forecasts from high-resolution numerical models.
- Develop a hydrometeorology “rapid response” capability that allows for a relatively quick assessment of forecast errors (e.g. for QPF) in extreme events.
- Advance QPF process understanding through focused field campaigns (e.g., ENRR) to explore model sensitivity to coupled processes, orographic effects, etc.
- Advance statistical post-processing techniques to bias correct precipitation forecasts and projections at time scales ranging from hours to decades.
- Explain the underlying causes of recent extreme precipitation events and assess their predictability.

Goal 2.2: Improved physical process understanding through water budget analysis of specific watersheds

Budget studies of variables such as total water/moisture (e.g., precipitation minus evaporation - P-E) and total energy are useful in identifying model deficiencies, and can improve understanding of both real-world and model representation of precipitation (rain, snow, and mixed phase processes) and drought processes. Specifically, a basin approach for budget analysis can reveal where models fail on smaller space and timescales and inform targeted observing strategies to address such deficiencies. Advancing the use of hydrometeorology observations, including remotely-sensed data for soil moisture and snow, and modeling in watersheds across the United States will deliver improved scientific information for managing water resources, for protecting lives and property, and informing preparedness.

Objectives

- Develop an observational strategy to constrain all components of the water cycle within a hydrologic basin.
- Advance the use of hydrometeorology observations, including remotely-sensed data for soil moisture and snow, and modeling in watersheds across the United States; combine process models with observations to understand regional, basin-scale processes in a physically constrained manner.
- Examine budget closure using existing and/or targeted, experimental observations, complementing efforts to develop pointed diagnostic tools for evaluating such observations and model forecasts.
- Evaluate critical hydroclimatic processes in Global Climate Models utilizing observations and regional models (e.g., National Water Model)

Goal 2.3: Improved water monitoring and forecasts through advanced understanding and modeling of land surface and snow processes

Advancements in both monitoring and forecasts of water extremes require an adequate representation of land surface processes in both atmosphere and terrestrial prediction models. Snowfall and snow on the ground are critical hydrometeorological variables, because of their importance for water resources in the Western US, their impact on transportation, their relevance to the global water and energy budget, and their vulnerability to climate change.

Objectives:

- Improve understanding of processes that control snowfall and snowpack evolution, especially in complex terrain and for mixed-phase extreme events.
- Pursue development of innovative remote sensing techniques to retrieve soil moisture for model evaluation and improved understanding of physical processes.
- Develop coupled data assimilation techniques across atmosphere and land surface, and snow data assimilation in both global (GFS) and regional (National Water Model) scale models.
- Develop methods for S2S predictions of snowpack for a seasonal snowfall outlook.
- Explore the viability of probabilistic statistical models of land surface processes (soil moisture), leveraging land surface “memory” to improve S2S forecasts.

Goal 2.4: Advanced understanding, monitoring and prediction of droughts

Drought touches many sectors of the economy and is responsible for some of the largest financial impacts from extreme events. Building resilience and preparing communities requires a better knowledge of the conditions conducive to the onset, duration, intensity, extent, and end of droughts. Moreover, characterizing drought -- by definition 'abnormally dry' conditions -- requires a representative climatology to accurately categorize the severity of a drought event; long records exist in coarse-resolution reanalysis datasets but high-resolution operational forcing datasets currently lack such long historical records.

Physical processes responsible for drought can vary across time and space scales. For example, flash drought can be triggered by local/regional precipitation deficits and/or increases in evapotranspiration and/or evaporative demand, whereas longer-term drought may be controlled by large-scale patterns such as El Niño, which may be far removed from the area experiencing drought conditions. Further process understanding is required to assess the implications of using temperature as a proxy for the evaporative process for (flash) drought monitoring and prediction.

Objectives:

- Develop a forcing data set for NOAA's National Water Model that can be used to construct a history of drought spanning many decades.
- Assess the performance of NOAA's National Water Model for predicting soil moisture and streamflow anomalies at a range of forecast lead times.
- Improve current and develop new tools and indicators for drought monitoring.
- Advance research on occurrence and prediction of flash droughts.
- Explain the underlying causes of drought events, including compounding factors, and assess their predictability.

Research Theme 3: Physical Science for Marine Resource Management

U.S. coastal regions, including the U.S. territories in the Pacific and Caribbean, host a rich diversity of marine resources spanning from the tropics to the Arctic. Marine resources and ecosystems are critical to commerce, human health and coastal tourism. For example, in 2016 commercial landings by U.S. fishers exceeded 9.5 billion pounds valued at $5.3 billion, and approximately 371.6 million fish were caught by recreational fishers. U.S. Coastal regions also support many additional aspects of the blue economy including aquaculture, energy (e.g., wind power generation), maritime transportation and tourism. As pressures on marine resources continue to rise, there is a concomitant need for improved observations and prediction of weather, climate and water conditions impacting the marine environment. In addition, a better understanding of processes at the air-land-sea interfaces are critical to predicting coastal flooding and sea ice conditions, offshore energy development, protecting wetlands and managing fish, such as salmon, that live in both salt and fresh water.

Over the past ~10 years PSL has conducted research, developed products and tools, and informed scientists and decision makers on processes that influence marine resources. PSL will expand these efforts to better understand the environmental conditions and physical processes that influence marine resources and broaden our interdisciplinary collaborations with the marine ecology, hydrology and coastal dynamics communities. We will focus on improving forecasts for U.S. coastal regions, including river systems that reach the ocean and for the Arctic, on time scales ranging from days to years. This includes developing a better understanding of extremes, such as marine heat waves and coastal flooding, and the ability to predict them. PSL will apply its multifaceted observational capabilities and in-depth understanding of system dynamics to marine resource applications. Field programs in conjunction with model development and testing will be used to develop observational products and improve forecasts.

Goal 3.1 Improved ocean forecasts, especially along US coasts and in the Arctic

Skillful prediction of physical, biogeochemical and ecological variables can inform planning for a number of marine resource sectors (e.g., fisheries, aquaculture, shipping, energy, tourism and public health) on a range of timescales, from nowcasts that aid immediate risk avoidance to climate projections that inform long-term planning and prioritization. Independent of the modeling technique being used to generate forecasts, it is key that (i) regional predictability be linked mechanistically to physical forcing, for example through large-scale climate variability, such as those associated with ENSO teleconnections; (ii) forecast skill be thoroughly and rigorously evaluated to provide confidence for use in marine applications; and (iii) efforts leverage PSL's observational expertise

Objectives

- Develop and implement methods to improve the connection of forecasts across global, basin and regional scales; including dynamical and statistical downscaling methods to bridge these scales.
- Improve and evaluate regional coupled models, including PSL's Coupled Arctic Forecast System that includes land, atmosphere, ocean and ice components; resolve coastal variability (≥ 10 km resolution) may soon be feasible.
- Developing empirical forecast methods (e.g., Linear Inverse Models, model-analog approaches) to predict and forecast environmental conditions impacting marine resources, and to use as tool to assess when the system is predictable (conditional skill) and predictability limits; advance their application to include biological variables.

Goal 3.2 Advanced knowledge and modeling of atmosphere-ocean interactions

Marine resources strongly depend on atmosphere-ocean-ice interactions, especially in coastal regions, which are influenced by both large-scale and regional processes. A key process along most of the US west coast is upwelling of cold nutrient rich waters, which is affected by more than just the local wind-driven transport.

The atmosphere and ocean are coupled via surface fluxes that are generally computed using bulk parameterizations for both physical processes, i.e. wind stress, sensible, and latent heat flux and chemical properties including trace gasses (O_2, CO_2) and aerosols. PSL is a leader in measuring and developing flux parameterizations (the NOAA COARE algorithms), which have been used in a wide range of studies relevant to marine resource. In recent years great progress has been made by integrating the flux parameterizations with wave model outputs in fully coupled systems.

Objectives:

- Advance understanding on how upwelling is influenced by regional factors including the local topography (e.g. mountains, shape of the coastline), ocean eddies and thermocline variability, and by climate variability associated with continent-ocean contrasts, ENSO, the Pacific Decadal Oscillation (PDO) and the Madden-Julian Oscillation (MJO).
- Advance understanding of how climate phenomena influence warm season processes, such as the position and strength of the subtropical atmospheric high and its link to near-shore winds.
- Develop physically/chemically consistent fluxes that adapt to the unique climate of the coastal regime, including accounting for wind fetch, the height and direction of surface waves and the influence of upwelling of cold water, which reduces wind stress by increasing the hydrostatic stability.
- Enhance the use of key terrestrial atmospheric, ship-based oceanography and biogeochemical measurements to obtain a better understanding of coastal processes and improve air-sea flux parameterizations.
- Improve the wave model so that it produces observed wind-stress, whitecap and stress vector behavior; use observations to guide the representation of gas exchange and bio-relevant aerosol production in the coastal zone.
- Develop deployment strategies for observational campaigns that target specific model problems that are critical for marine resources.

Goal 3.3 Assessment, Attribution and Predictability of Ocean Extremes

Several regions along the United States coastline have recently experienced unprecedented high-water temperatures, while others have endured high water levels and coastal flooding. Climate variability, such as the MJO, ENSO, and the PDO, as well long-term change, are key factors that contribute to extremes. By collaborating with experts in ocean biogeochemistry, fisheries and coastal processes PSL can address extremes that are societally relevant and of high priority.

Objectives:

- Improve understanding of extreme conditions, such as marine heat waves, coastal inundation, regime shifts and tipping points, to support more skillful forecasts of environmental conditions relevant to marine resources.
- Improve the prediction of marine/coastal extremes through diagnosis of the factors contributing to marine extremes; including diagnosing their initiation, evolution and spatial patterns, and their precursors utilizing tools developed at PSL.
- Advance research on ocean processes associated with the origin and evolution of extreme ocean conditions using observations and oceanic and/or coupled reanalyses, and assess how they will change in future projections.
- Develop approaches that link the occurrence and/or change in environmental conditions (e.g. ocean heat waves) with extremes in marine resources, such as a rapid decline in fish stocks or coastal flooding events.
- Utilize high-resolution regional ocean models as an effective dynamical downscaling approach for predicting and projecting the influence of climate variability and change on specific regions, such as the Bering Sea, US west coast and northeast US shelf.

Goal 3.4: Integrated physical knowledge of water resources at the coastal interface

PSL has conducted detailed studies of hydroclimate including precipitation and rivers that discharge into estuaries. PSL will use its expertise in coastal precipitation issues, air-sea-land fluxes and assimilation of data from observing networks to develop habitat conservation recommendations, plan reservoir releases and design infrastructure to meet NMFS and NOS statutory requirements and improved river flows for habitat management and protection of diadromous species, like salmon.

Wave properties are an important forecast variable for marine operations and storm dynamics and storm surge, but also influence upwelling and other ocean processes through their effect on the surface wind stress.

Objectives:

- Advance research to develop a more holistic approach to modeling the coastal environment by coupling different components of the earth system, including coupling between the atmosphere and ocean and surface waves. Combine coupled model development (focused on wave dynamics) with a coastal air-sea flux observation program.
- Improve model treatment of hydrologic processes including orographic precipitation, which is critical for local flooding, and the National Water Model, for use in general hydrology applications.
- Improve treatment of water temperature and biochemical properties for lakes, rivers, estuaries, and harbors, including adding/improving water management tools for reservoirs/hydro operations; add prognostic equations for heat, water and chemical conservation budgets to, for example, the National Water Model.

Appendix 1: A list of PSL capabilities and how they contribute to improving prediction and predictability estimation for extremes on S2S timescales.

PSL capability	**Common uses**
Reanalysis and reforecast generation (e.g., 20th Century Reanalysis, Global Ensemble Forecast System reanalysis and reforecast)	Diagnosis of climate variability; initialization of atmospheric forecasts for past cases; development of statistical postprocessing algorithms.
Linear-Inverse Models and other Empirical-Dynamical Models	Estimating the time limit of predictable skill due to linear processes. Estimating state-dependent predictability. Estimating the contribution from potential sources of predictive skill (ocean, sea ice, stratospheric anomalies, etc.). Estimating the effects of changes in variance, skew, and higher moments.
Interpretation of model tendencies from dynamics and parameterizations	Detection of sources of systematic error in the prediction system.
Perfect-model and imperfect model predictability experiments.	Provides a high-end estimate of the predictability including potential predictability related to non-linear effects.
Running seasonal prediction systems as cycled data assimilation and short-range forecasts to illuminate bias.	Since biases in 2-day and 2-month forecasts are often similar, this provides a computationally inexpensive way of detecting S2S prediction system systematic errors.
Nudging experiments, e.g., nudge forecasts to tropical analyses so that tropical model state is practically perfect.	Illuminates the potential improvement possible in one phenomenon of interest (say, S2S precipitation in the mid-latitudes) due to perfect predictions of another phenomena of interest.
Observing systems: building, deploying, collecting, serving data.	Provides a robust ground truth for a model and its underlying processes, enabling the development of more sophisticated models and parameterizations.
Diagnostic capacity, e.g., PSL map room.	Facilitates PSL and external researchers to view reanalyses, predictions and plot them in ways that illuminate atmospheric processes and sources of model error.

Observations, Data and Engineering in support of Research

PSL's strategy builds from its outstanding capabilities in developing and applying problem-focused observations and its extensive partnerships within NOAA and externally to achieve the rapid and effective progress in PSL's core scientific expertise in physical processes, phenomena, predictability and predictions.

Problem-focused observations are central to the observational process research conducted at PSL. They provide the core capability required to identify and quantify the roles of various physical processes in the Earth system, often in harsh and challenging conditions. PSL's observational activities have three critical facets: development, applications, and synthesis. To address a specific scientific question, PSL scientists and engineers develop, test, and apply innovative measurement techniques and observational platforms. A primary application of the observations is to improve understanding of key physical processes. Specific observational platforms and measurements are problem-dependent, and may be deployed on land, sea, ice, or in the air in process studies and field experiments in which NOAA is participating. PSL also conducts long-term observations in the Arctic to better understand Arctic processes and monitor climate change, along the Pacific coast to better monitor and understand Atmospheric Rivers and related processes that lead to extreme precipitation and flooding events, and across the world's ocean to better understand and characterize air-sea fluxes. In addition to direct observations and measurements, PSL scientists develop and apply methods to assimilate observations within models to create objective, quantitative representations of past atmospheric conditions, or atmospheric reanalyses, that now extend back well over a century. This work continues to open opportunities for a vast range of new research and applications.

In recent years, PSL has relinquished custodial responsibility of three federal properties, the Boulder Atmospheric Observatory 300m Tower, the Erie 1 Field Site, and the Platteville Atmospheric Observatory Profilers Site. PSL field testing and staging area is now consolidated at the U.S. Department of Commerce Table Mountain Field Site that is managed by the National Telecommunications and Information Administration (NTIA). Incremental changes and enhancements to the PSL Table Mountain facility are anticipated to continue.

PSL will also focus on identifying the observations are most needed for process understanding and improving predictions.

For instance, additional observations may be necessary to accelerate the rate of improvements in S2S predictions. A variety of observations are necessary for data assimilation systems, used both for integrated earth system reanalyses as well as for initializing seasonal forecast systems. Long time series of observations and gridded reanalysis products derived from them are also essential for training empirical-statistical models that are used in predictability research. Observations also provide the foundation for improved process understanding, a necessary first step toward model system improvement. In particular, observations of processes that span or connect components of the earth system could be used to evaluate coupled processes in coupled earth system models, necessary for S2S prediction.

PSL's long history in unique instrument development, including mobile surface-flux stations developed for the MOSAiC campaign, air-deployable micro-buoys for hurricane prediction improvement, air-sea flux measurement systems, snow-level radars, and unmanned aircraft measurement of soil moisture. PSL's expertise is particularly well-suited to process-focused observational deployment for model physics improvement.

Objectives:

- Use data assimilation diagnostics such as "Forecast Sensitivity Observation Impact" to determine which observations are producing the most impact on improving the initial condition of the coupled state.
- Participate in field programs that are focused on collecting observations that will help diagnose the systematic errors in S2S prediction systems, programs such as MOSAiC and EUREC4A.
- Build new and deploy observing systems for these field programs.
- Provide the collected data to the community for model diagnostics, verification, and assimilation purposes.

Research image: e.g. the MOSAiC campaign?

PSL Observing infrastructure will continue to develop in-house, to partner with the academia and private sector community, and to purchase and tailor the research quality instrumentation and observing equipment that is needed to collect the needed monitoring and targeted field campaign observations. PSL deploys an evolving wide range of instruments in support of field and process studies to advance process and predictive understanding, to enhance models and to develop the experimental forecasts and projections needed by the nation to manage weather, water and climate extremes and their impacts.

Information Technology

PSL's IT infrastructure will continue to evolve and adapt to internal and external pressures. The mandatory and maximum telework has led PSL to re-examine its desktop and laptop strategy. PSL is currently reviewing its long-term strategy to provide inhouse high performance research and analysis computer and data storage capabilities with the recognition of a need to upgrade this infrastructure in the next five to ten years within the context of the emerging cloud computing and storage opportunities.

6. Partners and stakeholders: The PSL approach and examples

As noted above, PSL's vision is for an informed society that uses and effectively applies, through actionable research, information and services, environmental intelligence related to weather, water and climate extremes. The fundamental and distinctive characteristics that drive PSL actions, or what has been described as "the DNA of PSL" is its focus on use-inspired science closing the end to end to end loop from research to operations and back. PSL has long recognized (as part of its inheritance from earlier incarnations as PSD and CDC) that closing this loop is a dynamic and collaborative learning process based on continuous interactions on problem definitions and identification of appropriate entry points for model improvement and applications. The transition of credible, relevant, and authoritative research-based knowledge and products is the goal and outcome. PSL choice of problems, research foci, and partners are closely matched to the PSL vision, mandate and capabilities avoiding over commitment, overreach and mission creep. In fulfilment of its part of the NOAA mission, PSL will continue to work with existing and with new partners, clients and stakeholders to develop and transition research advances into NOAA services and information products to support public and decision-maker needs in extremes, water and marine resources. Bridging the linkages across science, quality control standards and practice occurs through PSL's interaction with designated services providers who work within their networks of customers and stakeholders such as the NWS, NOS, NMFS, NESDIS, which includes boundary groups such NIDIS, the RISAS, RCCs, and through direct connections of PSL, in specific cases, with other Federal, State, tribal, and local organizations cognizant of NOAA drivers and mandates. Some illustrative examples relevant to PSL themes, are provided below. Through work with representative clients and stakeholders, PSL gains insight into what key decisions are being made from its research.   Information flows in multiple directions including with others influencing the process (e.g. to NOAA and OAR leadership) for instance experimental guidance is sent to the customers in collaboration with NOAA services partners, and feedback from them helps PSL refine the products to be optimally useful before operational use.

Across NOAA

National Weather Service/EMC
The fundamental mission of the NCEP/NWS Environmental Modeling Center (EMC), in close collaboration with our partners and stakeholders, is to maintain, enhance and transition-to-operations advanced numerical guidance systems for the Nation's weather/water/climate enterprise and the global community for the protection of life/property and the enhancement of the economy.
PSL works with the EMC to improve ensemble prediction systems that underly most medium-range and S2S predictions.
Reanalysis/reforecast datasets for the UFS are to bias-correct and calibrate operational ensemble predictions. These data sets anchor the statistical postprocessing of a variety of weather subseasonal forecast products, including CPC 6-10 and 8-14 day forecasts,

MDL National Blend of Models forecasts, National Water Center hydrologic forecasts. PSL provides Skill metrics that are critical for developing UFS

NWS/Climate Prediction Center
CPC delivers real-time products and information that predict and describe climate variations on timescales from weeks to years thereby promoting effective management of climate risk and a climate-resilient society through a variety of projects, provide algorithms that produce improved probabilistic forecasts on time scales of weeks to months including S2S forecast improvements. PSL is a key partner in providing the algorithmic advances that help CPC produce more accurate forecasts to help them serve a variety of S2S customers.

NOAA Fisheries
NOAA Fisheries is responsible for the stewardship of the nation's ocean resources and their habitat. Seafood harvested from U.S. federally managed fisheries is inherently sustainable as a result of the U.S. fishery management process. Using the Magnuson-Stevens Act as the guide, NOAA Fisheries works in partnership with Regional Fishery Management Councils to assess and predict the status of fish stocks, set catch limits, ensure compliance with fisheries regulations, and reduce bycatch. Under the Marine Mammal Protection Act and the Endangered Species Act, NOAA Fisheries works to recover protected marine species while allowing economic and recreational opportunities. PSL provides climate data and model output to support NMFS activities

Climate Program Office: The National Integrated Drought Information System
The National Integrated Drought Information System (NIDIS) program was authorized by Congress in 2006 (Public Law 109-430) with an interagency mandate to coordinate and integrate drought research, building upon existing federal, tribal, state, and local partnerships in support of creating a national drought early warning information system.

The NIDIS program office, under the NOAA Climate Program Office, is physically housed NOAA's David Skaggs Research Center in Boulder. The goals, design and implementation of NIDIS was developed in close collaboration with PSL and PSL is actively engaged in research to support an effective NIDIS.
PSL hosts NIDIS and is engaged in improving drought early warning in support of NIDIS, including standing up flash drought detection, quantifying and verifying Evaporative Demand Index, understanding early warning potential across NIDIS' regional drought early warning information (sub)systems, and the advances in NIDIS design to support drought risk management.

Federal Partners

U.S. Department of the Interior/Bureau of Reclamation
The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. Its increasing concerns are to assist in meeting the increasing water demands of the West while protecting the environment and the public's

investment in these structures, and fulfilling our water delivery obligations, water conservation, water recycling and reuse, and developing partnerships with our customers, states, and Native American Tribes, and in finding ways to bring together the variety of interests to address the competing needs for our limited water resources. PSL provides critical information, data and model output for Reclamation to evaluate whether dams and other structures are safe to operate or need upgrading considering climate variability, including extreme precipitation events and long-term change, weather and climate information to improve decision making on when to hold and release water from dams, and Evaluating hydrologic information (existing conditions and forecasts) that can augment existing resources (e.g., RFC inflow and runoff forecasts)

US Agency for International Development Famine Early Warning Systems Network
PSL's work on the global drivers of extreme events including droughts, floods is sought out by a number of internationally-focused US and other agencies. A major PSL effort in this arena is drought-related research in support for the Famine Early Warning System Network (FEWSNet). FEWSNet provides objective, evidence-based analysis to help government decision-makers and relief agencies plan for and respond to humanitarian crises. PSL partners in FEWSNet include NOAA/Climate Prediction Center, U.S. Geological Survey Earth Resources Observation Center, NASA Goddard Flight Center. Academic partners include the University of California Santa Barbara and the University of Maryland. This partnership, in which PSL is central, produces outlooks of likely agro-climatic conditions up to 9 months into the future to aid in the development of likely food security scenarios. USAID uses these food security scenarios to mobilize humanitarian assistance efforts. PSL's research informs on the likelihood of extreme events, either through leveraging information about current conditions or short-term outlooks, that may lead to food security shocks.

State/Regional Agencies
PSL works with several State and Regional Agencies across the U.S., from the Western States Water Council to the Missouri River Basin Interagency Roundtable. These latter efforts are, for instance, implementing arms directly linked to the Western Governors regional goals and the Mississippi River Town and Cities Initiative, a consortium of over 80 Mayors focused on anticipating and managing drought, wildfire and flood risks and their impacts on disaster risk management and trade, among other issues. Rather than listing all of PSL's partners at Regional State, Local agencies, the depth of PSL's partnerships and contributions can be best illustrated through its collaboration with the State of California. California is on the "ragged" edge of climate, with a Mediterranean environment that often suffers from either too much or too little precipitation leading to massive flooding, dangerous debris flows, and on the flip side, extended droughts. PSL partnerships operate across the state and are exemplified by its collaborations with the California Department of Water Resources and Sonoma County.

California Department of Water Resources
The mission of the California Department of Water Resources (CA-DWR) is to sustainably manage the water resources of California, in cooperation with other agencies, to benefit the state's people and protect, restore, and enhance the natural

and human environments. PSL researchers work in concert with the California Department of Water Resources (CDWR) to deploy hydrologic observations in order to understand the processes such as atmospheric rivers that result in major flooding events.

PSL also is generating for CDWR experimental forecasts of western US seasonal precipitation for purposes of estimating reservoir inflows

Research image: Bellier/Scheuerer's work on statistical postprocessing of hydrologic forecasts, suitable for use by hydrologists to drive their ensemble streamflow predictions. FIRO? Kelly's work on extreme precip limits?

PSL provides a 21st-century network of observations to help forecast and mitigate flooding and improve water resource management as part of CA-DWR's Enhanced Flood Response and Emergency Preparedness (EFREP) initiative. Ensuing conversations with DWR showed that there was increased interest in exploring the value of hi-res ensemble forecasts (HRRRE) as input into their own hydro model (HEC-HMS) in selected small basins where the RFC forecasts were not skillful and the global model QPF was too coarse for the size of the watershed (only covered by a few GFS pixels). Ongoing areas of research inspired by CA-DWR includes the question "can HRRRE provide more reliable rain-snow transition in these basins and better overall QPF?

Sonoma County Water Agency
The mission of Sonoma Water is to effectively manage the water resources in our care for the benefit of people and the environment through resource and environmental stewardship, technical innovation, and responsible fiscal management. Sonoma Water is a regional leader in water resources management. Sonoma Water is very forward thinking in terms of how it manages its reservoirs. The Russian River has been a focus area for PSL's engagement and leadership in Forecast Informed Reservoir Operations (FIRO). FIRO is a management strategy that uses data from watershed monitoring and modern weather and water forecasting to help water managers selectively retain or release water from reservoirs in a manner that reflects current and forecasted conditions. PSL contributions include
• Observations and monitoring to improve understanding of extreme precipitation behavior, impacts, prediction and flood risk.
• Improved reliability and skill of extended weather forecasts for atmospheric rivers and for probability of extreme precipitation events.
• Operational and experimental hydrometeorological modeling and probabilistic forecasts at the appropriate spatial and temporal scales to inform reservoir operations.

In a complementary area, evaluating how well or poorly the National Water Model (NWM) simulates changes in soil moisture can lead to decisions about how to improve the land/surface model component of the NWM, and guided toward improving water management and maintaining healthy habitat for salmonid species.

7. Advancing NOAA's' Mission into the Future

PSL will advance the NOAA Mission in three critical areas (1) A commitment to diversity, (2) Integration across Themes, and (3) Anticipating future NOAA initiatives

- *A commitment to diversity*

  In pursuing use-inspired research on complex problems, PSL is committed to the view that creativity and innovation require a diversity of perspectives and of people. PSL's interests are in retaining and supporting a diverse workforce, creating and maintaining an inclusive work environment, and cultivating a safe and supportive workplace environment that promotes creativity and vitality. The PSL Director has established (1) the PSL Research Council and Science Board to provide more inclusive forums and (2) launched of the PSL Integrating Research Activities that provide all division scientists opportunities to insert a role for their scientific expertise and research interests into high priority research PSL. PSL's challenge in ensuring an inclusive and supportive workplace is encapsulated by the former NOAA Administrator Dr. Kathy Sullivan's statement that she existed as "an edited version of herself" in order to fit in the astronaut culture and agency. PSL will continue to sustain a working environment where individuals do not feel they have to operate as edited versions of themselves. Using OPM's Government-Wide Diversity & Inclusion Strategic Plan and other guidance, PSL will continue to provide opportunities for existing staff and broaden the net of talented prospective applicants across gender and under-represented groups.
  (add figures and statistics on PSL's present distribution of employees)

- *Integration Across Themes*

PSL scientists will dedicate more of their time in the future conducting research needed to address the following NOAA Integrated Initiatives in support of OAR mission priorities

<u>Unified Forecast System and Environmental Prediction Innovation Center Research</u>
PSL will leverage subject matter expertise distributed across PSL's three research themes to remove key deficiencies and accelerate improvements in NOAA operational forecasts spanning local to global domains on time scales ranging from sub-hourly analyses to seasonal.

<u>Water Initiative Research</u> PSL will leverage subject matter expertise distributed across PSL's three research themes to pursue research and development that enables NOAA to deliver to people and governments better access to the water information needed to make informed decisions to address water-related risks and manage water resources more efficiently and effectively.

<u>Precipitation Prediction Grand Challenge Research</u> PSL will leverage subject matter expertise distributed across PSL's three research themes to pursue research and development to advance NOAA's ability to deliver accurate precipitation forecasts of

when will it rain, where will it rain, how much will it rain and will the precipitation fall as rain, snow, or sleet.

Climate and Fisheries Research PSL will leverage subject matter expertise distributed among PSL's three research themes and in partnership with NMFS and NOS to pursue research and development to better observe, monitor, understand and predict changes in the marine conditions impacting productivity, distribution, abundance, recruitment, survivorship, and movements of living marine resources, with significant implications for fisheries and protected species management.

National and International Assessments and Agreements
PSL will continue to contribute to regional, national and international scientific assessments and draw on its thematic and other research to support the science needed to implement collaborative partnerships, memoranda and initiatives of relevance to the NOAA and OAR missions and being undertaken by NOAA and its partners on behalf of the US Government, such as through the World Meteorological Organization.

- *Anticipating Future NOAA Initiatives*

PSL will continue to develop it Web-based tools in support of research and foster. knowledge integration across themes. In the spirit of innovation and use-inspired research PSL will conduct research to chart a path to potential future NOAA initiatives.

These include but are not limited to:

Potential NOAA initiative on Renewable Energy - *science in support of energy independence and air quality*
Leverage subject matter expertise distributed across PSL's three research themes to pursue research and development to improve solar and wind renewable energy forecasts to better design and manage the nation's electric energy grid by improving the representation of the boundary layer and key processes in the NOAA UFS.

Potential NOAA initiative on the Arctic - *science in support of commerce, national security[1], fisheries management*
Leverage subject matter expertise distributed across PSL's three research themes to pursue research and development to improve the monitoring, understanding and prediction of coupled Arctic system to improve NOAA forecasts of sea ice and other critical environmental conditions impacting natural resources, commerce and national security (e.g., fisheries management, protected and endangered species, mineral and energy exploration, shipping and transportation, military operations) as well as to enhance understanding the influences of the Arctic region on the predictability of lower latitude weather, water and climate extremes.

---

[1] The Arctic and U.S. National Security CONFERENCE PROCEEDINGS December 4, 2018 - Washington, DC