FY17 Competition Information Sheet

In FY17, the Climate Monitoring program is soliciting research proposals for the following two competitions that will produce observation –based products or indices around two topics: (1) Ocean Climate Information and (2) Global Climate Indicators and Data for Assessment. This call for proposals does not include support for field measurements in either of these competitions. Projects for both Competitions should be at a funding level between $75,000 - 150,000 per year. Two or three year proposals are requested for Competition 1. Proposals of one or two years are requested for Competition 2.

1) Ocean Climate Information for the Scientific Community

Value-added Ocean Climate Products: While observing systems routinely provide data and related metadata, raw data alone are often insufficient to realize the full value of these observations. Within the Climate Observation Division (COD), one of the roles of the Climate Monitoring program is to support carefully developed and tailored value-added climate products and indices of observed climate variability and change on global to regional scales. These products add value and context to the wide range of observations supported by the Division. and provide critical information to stakeholders and decision makers that need to monitor and respond to changes in earth's climate.

Projects are solicited that utilize ocean observing assets from NOAA (http://cpo.noaa.gov/ClimatePrograms/ClimateObservation.aspx) and others to create global or regional ocean indices or products targeted toward the scientific community to advance the monitoring and understanding of large-scale features and variability of the ocean climate system, and contribute to better understanding the important two-way relationship between the world's oceans and climate.

Target Stakeholders: The Climate research community: COD's observations and products seek to meet the needs of wide variety of stakeholders. This call specifically seeks products that provide information on essential ocean variables (e.g. http://ioc-goos-oopc.org/obs/ecv.php) tailored to research investigations and scientific monitoring. Example targets could be (1) Monitoring key variables to inform the understanding of regional ocean variability and/or change (2) identifying and characterizing model biases critical for diagnosing changes in climate-relevant features . Development of indices that focus on variables as part of a short-term process study are not suitable for this call. New indices that use long term ocean records and/or synthesize these with new and multiple data sources are encouraged. Proposers are encouraged to review the current set of pilot ocean indicator projects funded by the program in FY14:
http://cpo.noaa.gov/ClimatePrograms/ClimateObservation/ClimateMonitoring/Fundedprojects.aspx.
Projects should identify a research stakeholder/ user community in the proposal and include a discussion of how the community will be involved in the process by which the products will developed, evaluated, and made accessible.

Criteria for Product Evaluation: Successful proposals will address the following criteria:
(1) Indices or products created will address or inform one or more of the Climate Observation Division's Guiding Questions for Observing and Monitoring (COD Strategic Plan,p.5,http://cpo.noaa.gov/sites/cpo/COD2/COD%20Strategic%20Plan_June2015_publicdraft%20(1).pdf).
(2) Proposals should clearly show a pathway by which information gained from these projects would benefit a particular set of stakeholders (e.g. forecasting or decision making).

(3) Projects will identify a scientific stakeholder community or research partner that will form the user community for the data. Partnerships beyond the PIs own research group are strongly recommended; and collaborations with modeling groups are particularly encouraged. Projects must include an engagement and dissemination plan that will describe explicitly how research results and products will be evaluated by and provided to the broader scientific community. A representative from that stakeholder community should be included in the proposal as a co-PI or collaborator (as appropriate).
(4) Projects will document a pilot activity demonstrating the application of proposed indice information
(5) PIs will be expected to work with NOAA, JCOMM, GOOS, and others to make these products accessible and update them routinely (include 1 trip per year to an international meeting to coordinate indices work). Successful indices that have demonstrated value and use to the scientific community by the end of the project may be continued beyond the proposal period.

Funded Proposals

- (Banks) Indices of climate variability and climate change using long-term physical and ecological ocean observations from the northern California Current.
- (Bourrasa) 20th Century Atlantic Surface Wind Indices
- (Foltz) A tropical upper-ocean stratification data set for climate and hurricane research*
- (Kaplan) Interpolation of Subsurface Ocean Properties and Indices of Climate Variability
- (Neilsen-Gammon) ENSO Indices For a Changing Climate

FY17 Competition Information Sheet (continued)

2) Global Change Climate Indicators and Data Products for Enhanced Understanding

Supporting the USGCRP Sustained Assessment Process: NOAA is a major contributor to U.S. National Climate Assessment (NCA) (http://nca2014.globalchange.gov), a central member of the U.S. Global Change Research Program (USGCRP), and intends to continue supporting future NCA activities. Projects are solicited through this competition to develop and test indicators which could provide a clear and concise way of communicating to the public and decisionmakers the status and trends of physical drivers of the climate system as part of the USGCRP Indicators system (http://www.globalchange.gov/explore/indicators). These indicators enable continued monitoring of climate change and variability as part of a sustained assessment process.

National Climate Assessments (NCA) analyze historical trends in global change and project major trends for the subsequent 25 to 100 years, covering physical, chemical, biological, and social systems. These Assessments provide integrated analyses of impacts and vulnerability to climate change, addressing both specific sectors (i.e., natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity) and geographical regions. The Indicators program is meant to supplement these periodic assessments by providing sustained information between NCAs.

We are soliciting proposals for the development and testing of potential climate indicators that address the needs expressed in the NCA vision for a national system of indicators. This vision was developed over a series of workshops on ecological, physical, and societal indicators in 2010 (ecological) and 2011 (physical, societal). Links to these workshop reports and other NCA workshops may be found on the NCA website. A summary report on the indicator system development describes the process and recommends a set of potential indicators for inclusion in the system[2].

Priorities areas for Indicator Development: Projects proposed in response to this competition will concentrate on physical climate indicators, particularly those that are built upon NOAA's observing and data assets. Indices should be scientifically and societally relevant – examples include temperature trends throughout the atmosphere and ocean, sea level, and climate-related changes in marine and coastal environments – and be able to clearly document a connection between the metric/variable and climate variability and change. Indicators must be aligned with one of NOAA's broad societal challenge areas: (a) climate impacts on water resources, (b) coasts and climate resilience, (c) sustainability of marine ecosystems, and (d) changes in extremes of weather and climate. This solicitation will prioritize Indicators that enhance the Climate and Observation Monitoring program's foci of ocean climate, Arctic issues, and climate extremes.

Indicator Criteria: Successful proposals will develop indicators that:
(1) Explicitly address needs or gaps in the USGCRP Indicators pilot[3]. Proposers should consult the USGCRP reports Developing Indicators of Climate Change[4] and the Physical Climate Indicators workshop report[5].
(2) Must be able to be tracked over time using federally-sourced data currently available and/or expected to be available in the future. Indicators may be related to a single environmental variable, or could consist of several aggregated variables. Indicators that draw exclusively or largely on NOAA data or products will be prioritized.
(3) Can be readily incorporated into the USGCRP system. Potential indicators should assess their readiness against the criteria established by the US Environmental Protection Agency for Climate Change Indicators[6].

(4) Can be useful by those who will be drawing on the NCA to make decisions related to impacts, adaptation, vulnerability, and mitigation associated with climate and global change. Projects that directly involve user groups or stakeholder communities in testing or assessment of the indicators are preferred. Indicators that are likely to be of use only to the scientific research community are not appropriate for this solicitation.
(5) Have clear prospects for continued updates without support from CPO programs, i.e., indicators are composed of/dependent upon readily available and routinely updated public data.

Transition Plan: Investigators are expected to work with the USGCRP Indicators working group and its technical partners to plan how successful indicators can be transitioned into the operational system. This will include making available data and any scripts to the technical team responsible for development of the indicator system -- standards will be collaboratively determined once projects are funded. Proposals should include an outline of a transition plan section, including:

- Documentation of the data and metadata formats;
- Availability of the data on which the indicators will rely;
- Expected scope and types of indicators to result from the project;
- The readiness of indicators for deployment in the indicator system (whether currently in the research, development, or demonstration phase);
- Proposed post-project update procedures; and
- Detail regarding scripts and data products that will be transitioned to the technical coordinating team to enable continued updating of the indicators after the project concludes.

Preference will be given for open-standard and machine readable data that will lend itself to routine access and updating.

Funded Proposals

- (Arugez) Developing a Record Temperature Ratio Index for the U.S. and the Globe
- (Chung) Developing a Global Aerosol Index
- (Evan) Development of a Western US Mountain Snowpack Climate Indicator
- (Lee) Developing extreme event climate change indicators related to human thermal comfort*
- (Robinson) Enhanced Historical Monitoring of Snow Cover Across Northern Hemisphere Lands
- (Wahl) An indicator for U.S. coastal extreme sea levels
- (Walsh) Arctic Indicators for Assessment and Enhanced Understanding*

1 - Ocean Climate Information for the Science Community

(Banks) Indices of climate variability and climate change using long-term physical and ecological observations from the northern California Current. M. Banks (CI Marine Resource Studies, Hatfeild Marine Science Center, OR), W. Peterson (NOAA/Fisheries, NW Fisheries Science Center).

For decades (1940s-1990s), much of the oceanographic research in the California Current was focused on the effects of upwelling (and El Niño events when they occurred) on biological productivity. With the discovery of the Pacific Decadal Oscillation (PDO) (Mantua et al. 1997), the scientific paradigm shifted to focus on effects of low-frequency variability (PDO) on productivity of fisheries of the NE Pacific. Soon after, the North Pacific Gyre Oscillation (NPGO) was discovered, and shown to be another important driver of ecosystem variability (Di Lorenzo et al. 2008). We know for the northern California Current (NCC), that conditions for optimal biological productivity are negative phase of the PDO, positive phase of the NPGO and strong upwelling, but these factors are not always in synergy.

Coastal upwelling plays a key role in local productivity because this is the process that leads to high primary production in the California Current. However, a linear food chain (windsupwellingnutrientsphytoplanktonzooplankton fish) is clearly not the appropriate model because the dynamics controlling upwelling in the coastal ocean are complex and include processes that are not driven entirely by alongshore winds (DiLorenzo 2015), but by basin-scale variability in winds and transport associated with the PDO, ENSO and NPGO (Chhak and Di Lorenzo 2007). Our understanding of linkages between upwelling and and basin-scale variability in winds and transport is especially poor in the NCC (north of 38-40°N), disallowing informed arguments as to how climate change might affect biological productivity.

We propose to explore linkages between the basin-scale drivers and local coastal upwelling by (i) developing new indicators of upwelling -- the dates of “biological spring and fall transitions” (the dates when the food chain has transitioned from a winter (summer) downwelling (upwelling) plankton community, and length of the upwelling season (the difference between the fall and spring dates), (ii) determining if these dates change with phase of the PDO and NPGO for shelf/slope water of the NCC north of 40°N, and (iii) using historical and contemporary data, determine if interactions of coastal upwelling with the PDO and ENSO have changed historically.

This project will produce a better understanding of the influence of basin-scale forcing on coastal upwelling. It will also produce a set of ecological indices that demonstrate how variables related to productivity respond to upwelling: nutrients, phytoplankton, zooplankton and krill. Our indicators have been and will continue to be used to track the effects of climate variability and change in the NCC on the productivity and food chain structure of the NCC, and will do so through peer reviewed publications, our website, and in the California Current Integrated Ecosystem Assessment. Furthermore, this work will advance understanding of ecosystem response to variability of the ocean climate system at seasonal, interannual and decadal time scales, and addresses the CPOs climate research portfolio climate intelligence (observations and monitoring) and climate resilience (sustainability of marine ecosystems).

1 - Ocean Climate Information for the Science Community

(Bourassa) 20th Century Atlantic surface wind indices. M. Bourassa (Florida State University-FSU), S. Smith (FSU)

Our project, will improve ship winds in the long-term marine climate record and use the wind directions and speeds to develop climate indices related large scale circulation and select smaller scale process that impact weather on land in the continental United States. Specifically, wind-related indices will be developed to identify and quantify variations in atmospheric circulation patterns over the oceans, with the goals of linking these to changes in precipitation over terrestrial regions, storminess, and coastal upwelling. In many regions of the globe, the direction and magnitude of the wind is important for evaporation, transport of moisture from the oceans to surrounding land masses, and local rainfall (or lack of rainfall). Storminess (e.g., a measure of cyclone frequency and/or intensity in a region) impacts maritime shipping and coastal zones, and also contributes to water availability for commercial and recreational applications locally and in regions down wind and down stream. Coastal upwelling, which is highly variable and plays a large role in primary productivity and aquatic resources, is also controlled by wind speed and more importantly by wind direction (relative to the coastline and bathymetry). The value of these indices will be greatly enhanced by the long length of the time series of the indices, from the late 1800s to 2014. The proposed activity will result in a set of bias-corrected and height-adjusted wind observations, most with associated uncertainty estimates.

All information will be documented and published for use by the wider marine climate community. The beneficiaries of these value-added ship wind records include the reanalysis modeling community and the users of reanalysis products. The U.S., European Centre for Medium-Range Weather Forecasts (ECMWF), and UK MetOffice have expressed interest in assimilating surface wind observations in future reanalysis models. Having access to bias adjusted data with known uncertainties will aid these efforts. It is also anticipated that access to the value-added wind observations via the International Comprehensive Ocean-Atmosphere Data (ICOADS) Set Value-Added Database (IVAD) at NCAR will have a positive downstream impact on the wide range of marine climate and other research activities that use ICOADS as a foundational dataset (Freeman et al. 2016). The project will also bring together members of the marine climate community to discuss issues and challenges associated with wind observations on ships, with a goal of developing community consensus on bias adjustments and uncertainty analyses needed to benefit future modeling and climate research activities.

Developing long-term wind direction and speed indices along well-sampled ship tracks and combining results for different regions ((GoM), Caribbean, N/S Atlantic) will support assessment of variations in large scale oceanic and atmospheric circulation patterns. Investigators will show how the indices can be used to evaluate and monitor variations in moisture transport (and associated inland precipitation), storminess, and coastal upwelling in regions around the Atlantic Ocean basin. Combining indices from different locations can provide an indicator of the strength of the Bermuda High and could be used as a proxy for this circulation when surface pressure data are limited. Indices can be continued forward in time to support decision makers that need to monitor variations in both the winds and the regional impacts on precipitation, storminess, and upwelling. Wind direction and speed indices will benefit climate and reanalysis models by providing long-term benchmarks of the regional wind patterns that can be used to evaluate model estimates of the Atlantic general circulation for the past century.

1 - Ocean Climate Information for the Science Community

(Foltz) A tropical upper-ocean stratification data set for climate and hurricane research. G. Foltz (AOML), K. Balaguru (PNNL), B. Chapron (IFREMER), N. Reul (IFREMER), C. Montegut (IFREMER).

Surface heating, weak winds, and freshwater input from rainfall and rivers generate strong upper ocean stratification in the tropical oceans. Temperature stratification acts to increase the stability of the water column, reducing the efficiency with which the wind and surface buoyancy flux generate vertical mixing. A stronger decrease in temperature with depth also enables more efficient cooling of the ocean's surface for a given vertical mixing rate because of the availability of colder water near the surface. In contrast, stable salinity stratification can only act to reduce vertical mixing rates and hence increase sea surface temperature (SST). Therefore, quantification of the roles of temperature and salinity stratification in generating SST changes is not straightforward and has been the subject of a considerable amount of research. Because stratification affects tropical SST on multiple timescales, it is a crucial parameter for assessing the ocean's impacts on weather and climate.

There is growing evidence that salinity plays an active and significant role in the ocean's response to phenomena such as tropical cyclones, the Madden-Julian Oscillation, and ENSO. Previously, observational analyses of the role of ocean stratification in weather and climate have relied mainly on in situ data from platforms such as moorings and Argo floats. However, these measurements are limited in terms of their spatial and temporal sampling. In contrast, satellites sample the global tropics generally every 1-7 days. The ongoing satellite measurements of SST, sea level, and chlorophyll concentration, and the growing record of satellite surface salinity from the Soil Moisture and Ocean Salinity (SMOS) mission, present an opportunity to infer tropical ocean stratification from satellite data. The main aim of this proposal is to create a satellite based, high temporal and spatial resolution data set of upper-ocean stratification going back to 2010, the start of the SMOS campaign. An important component of the proposal will be the use of in situ profiles of temperature and salinity from platforms such as Argo, moored buoys, and gliders, to create a statistical model that translates satellite-based surface measurements to near surface ocean temperature and salinity stratification. The satellite-based stratification product will be used to create global maps of tropical cyclone dynamic temperature, a parameter that explicitly accounts for the influence of upper-ocean temperature and salinity on tropical cyclone intensification and is a significant improvement over previous methods.

This proposal is directly relevant to Competition 1 of the Climate Observations and Monitoring (COM) Program's announcement. We will use ocean observing assets from NOAA, specifically measurements from Argo floats and tropical moored buoys, to create global ocean products targeted toward the scientific community. In direct response to the COM Program's proposal call, the products will advance the monitoring and understanding of the large-scale features and variability of the ocean climate system. The proposal will address several of the Climate Observation Division's “Guiding Questions for Observing and Monitoring,” including the ocean’s role in climate variability and change, including extremes such as tropical cyclones (Question #1) and the processes governing the global ocean’s temperature, salinity, and ocean atmosphere interactions and how those interactions are changing (Question #5).

1 - Ocean Climate Information for the Science Community

(Kaplan) Interpolation of subsurface ocean properties and indices of climate variability. A. Kaplan (Columbia), Y. Kushnir (Columbia), M. Cane (Columbia)

Subsurface ocean data are very sparse, especially in the pre-ARGO period, and more so before 1970s. Yet, subsurface ocean temperature and salinity variations are crucial for understanding the wide range of climate phenomena: ocean response to the atmospheric increase in greenhouse gases, sea level rise, subsurface dynamics of ENSO events, and changes in the ocean circulation. Existing estimates of major integral characteristics of subsurface ocean, like upper ocean heat content (UOHC) of the top 700 m from 1950s to present, produced by different authors disagree with each other even in their annually-averaged global means. Counterintuitively, using ocean models for interpolating over missing data has been making the spread between different estimates even larger, which compounds the problem.

The need is obvious for a reliable objective analysis of historical subsurface ocean observations that would reconcile the data with general dynamical constraints and had verifiable uncertainty estimates for analyzed fields. Time series of climate variability indices and their uncertainties, for specific climate phenomena (e.g., UOHC variations, AMOC, or subsurface ENSO dynamics) could then be derived in a self-consistent way. Reduced space approach will be used as the main methodological framework, as it was successful in extracting large-scale climate variability from sparse and erroneous observations in earlier applications, and it produced verifiable uncertainty estimates. Here the method is augmented by using potential density as a vertical coordinate and including a “weak” dynamical constraint in the form of approximate conservation of the Bernoulli function. Brief summary of the work to be completed. We plan to use subsampled data from ocean reanalyses and high resolution ocean simulations (Year 1) and ARGO data (Year 2) to determine the appropriate spatial and temporal resolution and the corresponding temporal extent for applying (Year 3) the modified reduced space objective analysis method to the latest edition of the World Ocean Database (WOD13). The method modifications (incorporation of the dynamical constraints) will be tested and fine-tuned in experiments with subsampled data on Years 1 and 2. Target indices of global and regional UOHC and of subsurface ENSO variability, as well as their uncertainties, will be computed for a suite of analyses that optimize either temporal/spatial resolution or the temporal extent and are based on the full ARGO and WOD13 temperature and salinity data sets.

Project utilizes WOD13, NOAA’s ocean observing asset, incorporating other NOAA and international data (e.g., ARGO, XBTs), to develop a value-added version that targets the climate research community, especially those monitoring/evaluating subsurface ocean state and monitoring/forecasting ENSO. Subsurface temperature and salinity are OOPC-identified essential climate variables. Project addresses Guiding Questions for Observing and Monitoring #3 (data for improving the skill of intraseasonal to interannual predictions) and #4 (changes in the ocean heat content) from the NOAA CPO Climate Observation Division’s Strategic Plan. It also contributes towards the first two objectives of NOAA’s long-term goal in “Climate Adaptation and Mitigation”(NOAA’s Next-Generation Strategic Plan, p.5). Improved interpolations of subsurface ocean data, with reliable uncertainty estimates for interpolated fields and derived indices, facilitate the research towards competition objectives.

1 - Ocean Climate Information for the Science Community

(Nielson-Gammon) ENSO indices for a changing climate. J.W. Nielson-Gammon (Texas A&M)

The El Niño-Southern Oscillation (ENSO) is a complex, coupled, multi-dimensional phenomenon. In the face of this complexity, there is value in quantifying ENSO's strengths and potential impacts by a single index. At present, many such indices are in use, ranging in complexity from mean temperature anomalies in a single patch of tropical water to the leading principal component of the coupled climate system. This variety of indices makes it difficult to compare the results from different studies. Also, none of the common indices simultaneously capture the effects of ENSO and the background climate state in driving atmospheric responses such as drought and flood in diverse areas of the globe. Most fundamentally, none of the indices in common use are robust to large-scale changes in the climate system.

We propose to develop a simple ENSO index based upon the difference in sea surface temperature beneath those portions of the tropical Pacific that are most subject to interannual ENSO-driven variations in outgoing longwave radiation and precipitation, such as the ocean temperature in the NINO 3.4 region minus the ocean temperature over the maritime continent. We will develop a specific definition based on the robustness of the large-scale atmospheric response to changes in value of indices defined in different ways. We will develop and analyze historic index time series, and compare the magnitude of correlations with and nonlinear responses in remote climate variability when ENSO is defined using the new index versus existing indices. We will investigate the applicability of this index to the ENSO-like phenomena simulated in global climate models, and we will determine whether the new index provides a more useful measure of ENSO when considering simulated ENSO events and associated atmospheric responses in different steady and time dependent climate states.

The proposed project directly addresses the focus area requirement "to create …regional ocean indices…targeted toward the scientific community to advance the monitoring and understanding of large-scale features and variability of the ocean climate system, and contribute to better understanding the important two-way relationship between the world's oceans and climate." The project directly furthers NOAA's long-term climate goal by improving scientific understanding of the changing climate system and its impacts, helping to quantify ENSO states in present and future climates, and helping the public better understand ENSO, its impacts, and the risks associated with changing climate system responses to ENSO.

2 - Global Change Climate Indicators and Data Products for Enhanced Understanding

(Arguez) Developing a Record Temperature Ratio Index for the U.S. and the Globe. A. Arguez (NCEI), I. Durre (NCEI), K. Gleason (NCEI), R. Vose (NCEI)

Communicating climate indicators to the public and decision-makers requires using constructs that are intuitive. One such construct is a temperature record: the warmest or coldest condition experienced for a given temporal scale. Two major problems with diagnosing meaningful temperature records are (1) the need for a long period of record and (2) the need for the time series to be free of inhomogeneities (i.e., artificial shifts due to changes in observing practices). The recent development of high-quality grids of daily minimum temperature (tmin) and daily maximum temperature (tmax) over the contiguous U.S. (CONUS) provides an opportunity to create intuitive indicators of climate change based on record warm and record cold events.

For this project, we propose to (a) extend the U.S. gridded daily temperature product (currently in late stage development at NOAA's NCEI) back to 1950, (b) develop a U.S. Record Temperature Ratio Index based on tmax and tmin, and (c) develop a Global Record Temperature Ratio Index based on monthly mean tmax and monthly mean tmin.

Our proposed deliverables are based on NOAA/NCEI's datasets, will be transitioned to operations (i.e., continued updates) by NCEI's Monitoring Section, and will be stewarded (including archival) by NCEI. The products are designed to be intuitive and clear indicators of climate change for consumption by the public and decision makers, and reflect requirements received from proactive engagement of the energy and HVAC&R industries. This proposed project addresses the broad societal challenge area of climate extremes and would broaden the existing USGCRP focus on both U.S. and Global surface temperatures to incorporate occurrences of tmax and tmin records. We will provide ratio indices for individual U.S. states and National Climate Assessment regions, and therefore envision these time series being welcome additions to the NCA.

2 - Global Change Climate Indicators and Data Products for Enhanced Understanding

(Chung) Developing a Global Aerosol Index

2 - Global Change Climate Indicators and Data Products for Enhanced Understanding

(Evan) Development of a Western US Mountain Snowpack Climate Indicator. A. Evan (UCSD, SCRIPPS).

Arguably one of the most important manners by which global climate change impacts society is forced changes to the hydrological cycle, and while one particular event cannot be attributed to climate change, the current drought in California and the Southwest US has heightened awareness of possible societal impacts resulting from such systematic changes to the climate system. At present, the exact manner by which climate change affects precipitation in the western US is not completely understood, and this is at least in part due to the large influences of natural variability like El Niño and the Pacific Decadal Oscillation, as well as the high degree of complexity in modeling precipitation processes. As such, there is a need for a long term and high quality climate indicators that provide near--real--time information about the hydrological cycle, and how the hydrological cycle is changing on interannual to decadal time scales. Among the various possible indicators that may fall into such a category, metrics that communicate information on the state of mountain snowpack are of critical importance, especially since snowpack is a hugely important source of freshwater.

Here we propose to create a climate indicator of Western United States snowpack. The benefits of such a climate indicator are numerous. For example, snowpack is a measure of water storage, reflective of both precipitation and temperature, and thus more accurately represents the availability of water to western US communities than do measures of precipitation alone. In addition, snowpack has been measured across the western US to a high degree of accuracy for several decades, and snowpack measurements in remote locations are likely more robust than snowfall (stake) measurements. Such long--term snowpack measurements are made via the Natural Resources Conservation Service and National Water and Climate Center SNOw TELemetry (SNOTEL) program, and thus the project summarized here leverages other sources of federal funded and managed data products that are freely available and updated on an hourly to daily basis.

2 - Global Change Climate Indicators and Data Products for Enhanced Understanding

(Lee) Developing extreme event climate change indicators related to human thermal comfort. C. Lee (Kent State University)

Among the myriad consequences of climatic change, one of the major adverse impacts is increased human health vulnerability. While changes in the averages of many climatological variables have received ample attention in this regard, the extremes of these variables are arguably even more impactful upon many societal sectors, yet are not currently included as climate indicators. Trends in near-surface multivariate weather types have also not been fully explored despite the proliferation of research linking these categorical variables to human health outcomes. Recent research has also suggested a link between secular trends in extreme mid-latitude events and changes to atmospheric circulation due to Arctic amplification.

The proposed research is a multifaceted effort to address these interrelated gaps in the indicators program. We propose to develop and test seven different climate change indicators related to human thermal comfort, including: three different extreme temperature-based indicators, two different classifications of weather types, extreme dew point events, and the overlying circulation patterns connected with all of these events. Each of these indicators will be evaluated in terms of historical changes in frequency, persistence/duration, and spatial coverage – all of which play important roles in influencing human thermal comfort.

Spanning North America, we will collect data from the North American Regional Reanalysis project for near surface temperature, dew points, and winds; along with circulation data via sea-level pressure (SLP) and 500mb geopotential heights (z500). Two currently-available weather typing classification systems will also be obtained: the spatial synoptic classification and the gridded weather typing classification. Various methods for the identification of extreme weather events will be examined including duration-intensity indicators. Regional-scale circulation patterns for SLP and z500 will be classified using self-organizing maps. Trends in the frequency of the potential climate indicators noted above will be calculated using Poisson-based generalized linear models, while trends for duration and spatial coverage will be examined using Theil-Sen slope estimates.

This research directly addresses major gaps in the USGCRP climate indicators program by developing and testing seven different potential climate indicators (each of which will be tested in regards to changes in three different characteristics: frequency, duration/persistence, and spatial coverage) – the explicit focus of this Federal Funding Opportunity. Further the proposed research is directly aligned with NOAA's agency-wide focus on extreme weather and climate. Additionally this research would have the potential for important broader-scale impacts, as many systems (human health, agriculture, ecosystems, etc.) are critically affected by these extreme weather events, weather types and circulation patterns.

2 - Global Change Climate Indicators and Data Products for Enhanced Understanding

(Robinson) Enhanced Historical Monitoring of Snow Cover Across Northern Hemisphere Lands. D.A. Robinson (Rutgers University)

This proposed two-year effort entitled "Enhanced historical monitoring of snow cover across Northern Hemisphere lands" intends to generate an improved satellite climate data record of weekly snow cover extent, a dataset of carefully selected station snow cover observations extending well back into the 20th century, and a suite of snow cover indicator products using both satellite and station data. Project efforts will lead to improved understanding of snow cover variability and trends at higher spatial and longer temporal scales than previously available. Data and products generated through this initiative will serve user communities interested in assessing climate variability and change, understanding the role of snow in the climate system, verifying snow as depicted in climate models, and for applied studies in water resources, energy, engineering and other fields.

Snow cover is an important component of the earth's climate system, affecting boundary layer climate variables such as atmospheric temperature, atmospheric moisture, sensible and latent heat fluxes, and radiative fluxes. The water content and subsequent ablation of a snow pack is also important to the hydrology of a given region, influencing stream flow, flooding (timing and intensity), soil moisture, water resources, vegetation distributions and agricultural productivity.

Specific project objectives include: 1) re-digitization of NOAA weekly snow maps for the 1981-1999 interval to 24 km resolution, more than doubling the availability of high- resolution gridded snow extent data for regional application, as these data will be merged with 24 km resolution gridded data already available from 1999-present; 2) development of a dataset of snow depth observations using key indicator stations identified from the NOAA Global Historical Climate Network-Daily database to improve confidence assessments of the satellite snow maps, improve regional extent estimates prior to the satellite era, and provide historical time series of snow depth across multiple snow environments; and 3) generate snow cover indicator products such as snow extent and depth, snow cover onset, melt off, seasonal duration, and intra-seasonal fluctuations for regional, national and global climate assessments.

The proposed objectives fit well within the NOAA Climate Monitoring Program COM2 initiative: Global Change Climate Indicators and Data Products for Enhanced Understanding, as well as NOAA's overall long-term climate goals. The project will build on NOAA's observing and data assets and NOAA and more GCRP-wide interests in monitoring Arctic issues and climate extremes. The current version of the Rutgers snow cover product is employed as a key indicator by the U.S. Environmental Protection Agency and has been the "work horse" product in Intergovernmental Panel on Climate Change and U.S. climate assessments.

The Global Snow Lab at Rutgers is well suited to undertake this endeavor. We have considerable experience with the NOAA snow extent product, serving as a watchdog for this product extending back over more than 25 years and generating the premiere climate data record to date for this product. We also have a long history of scrutinizing and employing station snow observations in climate studies, and undertaking such studies.

2 - Global Change Climate Indicators and Data Products for Enhanced Understanding

(Wahl) An indicator for U.S. coastal extreme sea levels. T. Wahl (University of Central Florida), D. Chambers (University of South Florida)

The U.S., with close to 40% of the population residing in coastal counties and 17 port cities with populations in excess of 1 million, is particularly vulnerable to coastal extreme sea levels. Understanding how and why extreme sea levels have changed in the past and how they may change in the future due to changes in mean sea level (MSL) and storminess is crucial to plan effective and sustainable adaptation and coastal management strategies. In this regard, research on both MSL and changes in the storm surge climate (SSC) has mostly focused on quantifying, understanding, and ultimately projecting, long-term trends. This ignores the fact that there are substantial variations at decadal to multi-decadal time scales superimposed onto these long-term trends. These shorter-term variations have the potential to significantly increase or decrease the likelihood that flood-, erosion-, or other critical levels (e.g. salt water intrusion, ecosystem degradation, transportation interruption) are exceeded in a particular period. Therefore, it is important to also track, understand, and ultimately predict multi-decadal variations in MSL and storm surge water levels relative to centennial long-term trends at regional and local scales.

We propose to address this issue by developing separate indicators for multi-decadal MSL and storm surge variability which are then aggregated. Throughout the project we will use various physical observational data sets that are distributed and routinely updated by NOAA and other government agencies, including tide gauge observations and atmosphere/ocean reanalysis. Indicator time series will be obtained through filtering techniques and, in case of storm surges, state-of-the-art non-stationary extreme value models. The links to large scale climate change and variability will be established through multiple regression models and will be used to test to what extent climate models are capable of reproducing the observed decadal fluctuations. This will allow conclusions about the predictability of the aggregated coastal extreme sea level (CESL) indicator into the future. The new indicator can track and inform a broad audience about the current and potentially changing state of the two main physical drivers in the climate system affecting coastal flood risk. For 17 major U.S. port cities we will exemplarily demonstrate how the aggregated indicator modulates flood impacts.

Throughout the project we will use readily available climate-related observations to create a tailored, informative, and applicable climate product, which is one of the main goals of NOAA's Climate Monitoring (CM) program. Coastal change and extreme events, as potential indicator categories, and sea level, as a metric of public concern, are prominently highlighted in the U.S. Global Change Research Program's (USGRP) Physical Climate Indicators workshop report (NCA, 2011). The proposed CESL indicator is aligned with several of NOAA's broad societal challenge areas and long-term climate goals (1) changes in extremes of weather and climate, (2) coasts and climate resilience, and (3) sustainability of marine ecosystems. The new indicator will help communities to assess and mitigate flood risk and hence be of great public and inter-sectoral interest, including other federal agencies such as the U.S. Army Corps of Engineers (USACE) and U.S. Geological Survey (USGS), as well as USGCRP's Adaptation Science Interagency Workgroup (ASIWG).

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(Walsh) Arctic Indicators for Assessment and Enhanced Understanding. J. Walsh (University of AK, Fairbanks), U. Bhatt, H. Eicken, V. Romanovsky (University of AK, Fairbanks)

The proposed project will develop a set of cryospheric and related climate indicators for the Arctic in support of the National Climate Assessment and other relevant uses. The indicators will capture variability of key Arctic climate system components: sea ice, snow cover, glaciers, permafrost and vegetation. Storminess will also be included among the indicators because the impacts of Arctic storms are closely tied with sea ice and coastal impacts. Several criteria enter into the choice of these indicators: (1) the extent to which changes in the indicator variable impact humans and ecosystems, (2) the potential for this project to add value to existing metrics or indicators, (3) conduciveness to straightforward communication, (4) synergies with NOAA products and datasets and (5) readiness of the key product or information.

The proposed project will be guided by the COM2 mandate "to develop and test indicators which could provide a clear and concise way of communicating to the public and decision-makers the status and trends of physical drivers of the climate system as part of the USGCRP indicators system". All the developed indicators will be updateable at yearly or more frequent intervals, thereby providing sustained information between the periodic NCA reports. Criteria for indicator selection will be stakeholder relevance and NOAA synergies. Pan-Arctic sea ice extent is routinely tracked by NOAA through the National Snow and Ice Data Center and by other international groups. Notable user-relevant gaps in the available indicators are (1) easily accessible and viewable records of historical and near-real-time values of open water season length for particular subregions of the Arctic and (2) indices of freeze-up and break-up of ice cover, on a regional basis and relative to historical norms and (3) longer-term (pre-satellite) information to provide historical context for recent regional extremes of sea ice. Snow cover on a regional basis will be evaluated from the NOAA CDN records of weekly snow coverage. The focus will be on snow cover duration, specifically snow-on and snow-off dates on a regional basis. Indicators of glacier change will be yearly mass-balance data deduced from satellite measurements of equilibrium level. Permafrost does not have comprehensive surface observation networks conducive to indicator development. Instead, we will combine accumulated degree-days from atmospheric reanalyses, together with snow duration data for permafrost, to produce metrics of permafrost relevant atmospheric/surface forcing on an annual and regional basis. The permafrost indicator inputs will include reanalysis-derived mean annual air temperatures and thawing-degree–days averaged over subcontinents. The vegetative indicators will be based on satellite derived productivity metrics and a wildfire potential index over the major Arctic biomes. Finally, an impacts-relevant indicator of Arctic storminess will be developed by a spatial aggregation of wind speed threshold exceedances.

Stakeholder engagement to assess and refine the indicators will include Alaskan communities developing climate adaptation plans, barge operators in Alaska and Canada, and wildfire managers. The indicators developed here will be made available through the online visualization system of the Arctic Collaborative Environment and will be transitioned to operational use by working with the USGCRP indicators working group.