FY14 Information Sheet. In FY2014, CM will have two competitions. The first, Data Sets and Indicators, will comprise two elements: (a) Data Sets for Weather/Climate Extremes; and (b) Ocean Climate Indicators. The second competition will focus on Paleoclimatology Proxy/Multi-proxy Reconstructions and Analyses. This call for proposals does not include support for field measurements in either of these competitions.

1. Data Sets and Indicators

(1a) Data Sets for Weather/Climate Extremes

Proposals are invited for the development and enhancement of long-term, continuous, and consistent high-resolution data sets that address weather/climate extremes in the physical climate system, including the degree to which these extremes may have changed over time or be expected to change in the future, e.g., exhibit characteristics outside their historical range.

Climate extremes encompass the large-scale natural modes of variability of the climate system (e.g., ENSO, PDO, NAO, AO, etc.), which have dynamic linkages to the extreme events that are experienced at smaller space and time scales, i.e., remote forcing of regional or local weather events. The highest priority for this activity is on those aspects of the physical climate system that have the potential for severe impacts on human and natural systems (e.g., energy, agriculture, forestry, water, health, transportation, fisheries) due to air temperature and precipitation-related extremes, as well as associated phenomena that drive, or are driven by, these extremes (e.g., tropical and extratropical storms; floods; droughts; heat waves).

Candidate data sets may have existing deficiencies in the form of gaps, inhomogeneities, or biases that will need to be addressed to maximize the utility of the proposed data set for climate studies and applications. Successful proposals, which can also consider the output of model runs, will need to provide a detailed discussion of any planned enhancement processes and also include a component that demonstrates the expected utility of the resulting data set, through diagnoses that reveal new insights of underlying processes of weather/climate extremes.

Funded Proposals:

- (Barnston) Diagnostics, Trends and Climate Model Projections of U.S. Summer Heat Waves
- (Marks) Atlantic Basin Tropical Cyclone Database Reanalysis and Estimation of “Missed” Major Hurricane and Overall Activity
- (Robinson) Toward Improved Understanding of Extreme Snow Melt Runoff Events Under Past, Present, and Future Climate
- (Seidel) A Comprehensive Atlas of Mid-Winter Sudden Stratospheric Warmings and Associated Surface Climate Extremes.
- (Sheffield) Development of a global flood and drought catalogue for the 20th and early 21st centuries based on improved assessment of the global terrestrial water cycle and its extremes
- (Timmerman) Dynamics and seasonal predictability of extreme sea level variability in the tropical western Pacific

(1b) Ocean Climate Indicators

Proposals are invited to produce observation-based global and (preferably) regional indices that facilitate monitoring the status, trends, extremes, and variability of ocean physical properties over time scales of weeks to decades for the benefit of research, predictions, and decision-makers. Such indices should take full advantage of the global ocean observing assets that NOAA and its partners deploy in the open ocean (e.g. http://oco.noaa.gov). These indices may be single-parameter, multi-parameter, or be designed to capture 'compound events' that involve multiple impacts. The indices can be developed from climate-quality data sets produced as part of the proposed effort, or derived from established data sets that have demonstrated their usefulness in climate studies.

When necessary, observation-based ocean syntheses may be used to develop such indices. Successful indices could become part of a nascent Climate Indicators program (USGCRP) and/or ocean monitoring efforts lead by the IOC, CLIVAR, and others (e.g. http://ioc-goos-oopc.org/state_of_the_ocean/).

The stakeholder(s) for a proposed index should be identified, and use of the developed indices must be demonstrated and evaluated. The project should have a strategy to address the scientific robustness (e.g. through publications and/or feedback from the wider community) of the proposed indices. An index should not duplicate an index currently produced or reported on by other groups, although an index may modify or extend an existing index to increase its usefulness. Providing estimates of uncertainty would also be helpful. Proposals should address how the developed indices and relevant data will be made accessible to the wider community. Selected PIs should plan to cooperate (e.g. via teleconferences and/or annual meetings) with others developing a comprehensive ocean monitoring and indicators system.

Funded Proposals

- (Cronin) Air Sea Fluxes at NOAA Ocean Climate Station Reference Sites
- (Foltz) Continuous Records of the Mixed Layer Heat Budget in the Tropical Atlantic Ocean*
- (Goni) Ocean Indicators in the Tropical and South Atlantic Oceans
- (Lee) Tropical Pacific and Indian Oceans Climate Indicators: warm water volume, subtropical cells, Indonesian throughflow indices
- (Liu) Development of satellite-based surface fluxes of heat and moisture in the Arctic Ocean for understanding impacts of changing Arctic environments
- (Schmid) Transport in the upper branch of the South Atlantic Meridional Overturning Circulation
- (Weller) Ocean Climate Indicators for the Trade Wind Regions
- (Zilberman) Western Boundary Current Transport as a climate index

2. Paleoclimatology Proxy/Multi-proxy Reconstructions and Analyses
Proposals are encouraged that encompass high resolution, proxy/multi-proxy reconstructions that (1) identify and characterize historical extreme events that have severely stressed human or natural systems (e.g., the onset, duration, frequency, intensity, and decline of droughts or megadroughts); and/or (2) describe hemispheric changes in extreme events and the linkage of these changes to large-scale natural modes of climate variability.

Emphasis will be placed on using currently available measurements at sub-decadal resolutions as fine as seasonal, mining the time- and frequency-domain (including the low-frequency variability) information in multiple, well-calibrated proxies, and producing spatially complete data sets. Proposed proxies should have demonstrated relevance, i.e., maturity, for climate studies. Proposals that involve a field campaign(s) to collect data should be directed to programs other than the Climate Program Office.

Funded Proposals:
- (Hakim) Last Millenium Reanalysis Project*

1a - Weather/Climate Extremes

(Barnston) Diagnostics, Trends and Climate Model Projections of U.S. Summer Heat Waves.
A.G. Barnston, B. Lyon (Co-PI)

Consecutive days with extreme summer temperatures – heat waves – can cause myriad impacts ranging from adverse effects on human health, to a marked increase in energy and water demand, to deleterious consequences for agriculture. While several investigators have studied various aspects of heat waves in the United States (US), the approach has typically been to focus either on a particular extreme event (e.g., the 2011 Texas heat wave) or on a temperature-only based definition or definitions that include humidity. While progress has been made on connecting US heat waves to anomalous regional and large-scale atmospheric circulation features, our current understanding of the linkages between regional climate extremes and large-scale climate variations is far from complete. For example, the relationship between extreme summer temperatures and concurrent high humidity (an important consideration for impacts on human health) has not been thoroughly examined in observations or climate model projections.

Here we propose to undertake a comprehensive study of US summer heat waves and develop related products for display via a Web-based interactive analysis and display tool. We will consider multiple heat wave definitions by varying the intensity and duration thresholds required for identifying an event and will also consider heat wave definitions that include atmospheric moisture. Using quality controlled daily station data covering roughly the last eight decades, we will first evaluate the geographical occurrence and persistence characteristics of heat waves as a function of their definition. We will compare these results with model simulations of the recent observed climate from the Climate Model Intercomparison Project phase 5 (CMIP5), and for a shorter period, in the North American Regional Reanalysis (NARR). Recurrent and anomalous atmospheric circulation features will be examined on a regional basis, investigating whether they are in turn associated with large-scale circulation patterns possibly forced by anomalous sea surface temperatures (SSTs) offering some potential predictability. Conditional probabilities of heat waves given pre-existing land surface condition (e.g., drought) will be evaluated as a function of location and heat wave definition and an associated "joint extreme index" will be developed. Finally, secular trends in heat wave characteristics in observations and CMIP5 climate projections will be analyzed. The Web-based tool to be developed will allow users to select a region and period of interest, heat wave definition and desired heat wave characteristics in order to display associated time series and other statistics.

The proposed work directly addresses the COM FY14 focus on data sets for weather/ climate extremes. Our analyses map onto program element 1, "Data sets and indicators", sub-element (a). In addition, our diagnostic analysis will address the program's objective of discerning "…new insights of underlying processes of weather/climate extremes" while our Web-based analysis and display tool will meet the desired goal of transforming climate-related observations into informative products that will be made publically available. Via the IRI's Data Library all data sets and derived products from this work will also be downloadable in multiple formats suitable for use in other display platforms.

1a - Weather/Climate Extremes

(Marks) Atlantic Basin Tropical Cyclone Database Reanalysis and Estimation of "Missed" Major Hurricane and Overall Activity. F. Marks, Jr. (NOAA/AOML), C.W. Landsea (Co-I, NOAA/NWS/NCEP/National Hurricane Center), G. Vecchi (Co-I. NOAA/GFDL)

Hurricanes are arguably the single largest extreme weather event that impacts human society today as the over 1,500 lives lost during Hurricane Katrina in Louisiana and Mississippi and damages of at least $50 billion from Hurricane Sandy in the mid-Atlantic states will attest. A high quality database of historical hurricane activity is crucial for studies of importance to the general public, the business community, governmental groups, and emergency managers. In addition to applications for the above users, the North Atlantic basin tropical storm and hurricane database (or HURDAT) has been extensively utilized for meteorological applications as well as climate variability and change studies ranging from intraseasonal, interannual, decadal, and multidecadal timescales.

HURDAT currently extends back from present to 1851. However, this cornerstone database contains many systematic and random errors that need to be corrected. Additionally, as our understanding of tropical cyclones has advanced, analysis techniques have evolved over the years at NOAA's National Hurricane Center, leading to biases in the historical database that have not been addressed. Another difficulty in applying HURDAT to studies concerned with tropical cyclone events is the lack of exact location, time and intensity information for landfalling systems. Finally, due to incomplete observations in past hurricane seasons, tropical storms and hurricanes that existed over the open Atlantic may not have been included in the database. The comprehensive collection and analysis of historical observations that is proposed in this work will result in the addition of many of these "missing" storms to HURDAT.

This proposal details research that will focus on storms occurring during the satellite and aircraft reconnaissance era in the latter third of the 20th Century. Products to be provided include: the revised HURDAT; metadata files providing details about the individual changes to the database; a complete database of all raw observations of gale force winds or stronger; the Best Track Change Committee's comments and our team's responses; track maps for individual years; and specific detailed listing of U.S. and international tropical storms and hurricanes.

Additionally, work will be conducted that quantifies the amount of subsampling that likely occurs in the intensity and duration analyses of historic tropical cyclones because of limited observations of a primarily oceanic, mesoscale feature (i.e, the maximum 1 min winds and the central pressure). Previously publishes work has estimated the likely amount of "missed" tropical storm frequency as well as "missed" hurricane frequency (either wrongly considered to be only of tropical storm intensity or completely left out of HURDAT altogether) before the satellite era began. The new research will use similar methodology to analyze the likely frequency of "missed" major hurricanes, again either thought to be weaker than they actually were or not in HURDAT at all. Finally, a method for determining the undersampling present in the Accumulated Cyclone Energy (ACE) will be developed and applied in the pre- satellite era.

1a - Weather/Climate Extremes

(Robinson) Toward Improved Understanding of Extreme Snow Melt Runoff Events Under Past, Present, and Future Climate. D.A. Robinson (Rutgers), G.R. Henderson (Co-I US Naval Academy), D.J. Leathers (Co-I, U. of Delaware), T.L. Mote (Co-I U. Georgia)

The ablation of snow cover is an important contributor to crucial hydrologic variables such as streamflow, soil moisture, and groundwater supplies. In regions with discontinuous snow cover the number and magnitude of ablation events vary greatly from one season to another. Even in stream basins that are characterized by a single large melt event each season, estimates of the size and time of occurrence of peak flows changes dramatically from one year to the next. Seasonal variations in the frequency and magnitude of large ablation events are important as they can lead to severe environmental and societal consequences. These consequences may manifest themselves as snowmelt-induced floods, lack of streamflow in snowmelt fed rivers, and transport of pollutants or excess nutrients in rapid snowmelt events, to name a just few. Little research has been conducted on understanding the connection between the frequency and magnitude of ablation events and the role of global-scale atmospheric and oceanic forcings in their variation. Moreover, the pathways that link global-scale forcings to basin-scale snow hydrology are poorly understood as is the manifestation of snow-induced streamflow variability in future climate scenarios.

Using a combination of observational data and a suite of model-generated products, we propose to examine the climatology of significant snow ablation events across the United States east of the Rocky Mountains. Our analysis will include an examination of the influence of global-scale forcings (major atmospheric and oceanic teleconnections) on the frequency and magnitude of ablation events in several major drainage basins characterized by diverse snow cover climatologies, geographic locations and sizes. In addition, we will address the pathways by which global-scale anomalies influence individual basins using air mass and synoptic type analyses, and by modeling the surface energy fluxes associated with the diverse weather patterns associated with ablation. Finally, using Climate Model Intercomparison Project 5 model output, we will evaluate the ability of current general circulation models to accurately reproduce the observed ablation event climatology and to examine future climate scenarios for evidence of changes in the frequency and/or magnitude of ablation events for several major drainage basins across the eastern two thirds of the United States. These analyses will lead to the generation of several new and unique data sets for snow hydrology research including a comprehensive snow cover ablation data set, daily snow cover/atmosphere grids for North America, synoptic type analyses for the eastern United States, and model estimates of surface energy fluxes associated with major ablation episodes.

1a - Weather/Climate Extremes

(Seidel) A Comprehensive Atlas of Mid-Winter Sudden Stratospheric Warmings and Associated Surface Climate Extremes. D.J Seidel (NOAA ARL), A.H. Butler (Co-I, UC Boulder/CIRES; NOAA/ESRL).

Sudden stratospheric warmings (SSWs) are extreme climate events that involve large and rapid temperature increases and complete reversals of the climatological westerly winds in the boreal polar stratosphere. These events can propagate downward into the troposphere where they have substantial impacts on wintertime surface climate, such as extreme cold outbreaks in North America and Eurasia and extreme warming over Greenland and other regions of rapid ice change. While various diagnostics of SSWs have been proposed in the literature, there is no definitive long-term database of individual events. The development of a comprehensive atlas of SSW events would address at least three key issues. The first is inconsistencies in the historical record. Whereas one diagnostic based on zonal winds at 10 mb and 60°N yields no major SSWs during the 1990s, other diagnostics detect several major events during that decade. The second issue is stratosphere-troposphere coupling. Current diagnostics based on zonal winds yield stratospheric warming events that do not always propagate to the surface. The third issue involves the type and timing of SSWs. Recent literature suggests that “displacement”-type and “split”-type SSWs may cause different surface climate responses. A comprehensive SSW atlas would clarify the differences between these two types of warmings, including their surface impacts and the timescales of their downward propagation.

In response to the Climate Program Office FY2014 competition for *Climate Observations and Monitoring (COM)/Datasets and Indicators - Data Sets for Weather/Climate Extremes* and considering NOAA’s long-term climate goals, we will address weather/climate extremes in the physical climate system, in the sense both that (a) SSWs themselves are one of the most impressive extremes in the climate system and that (b) they influence surface climate extremes with the potential for severe impacts on human and natural systems. Currently there is no consistent database of SSW events, and tabulations that exist in the scientific literature are inhomogeneous regarding the frequency and occurrence of events. We propose to: (1) examine the three-dimensional structure of stratospheric variability in atmospheric reanalyses to determine the key components of major SSW events; (2) reveal new insights about which events couple to the surface; and (3) using these findings, develop a comprehensive multi- decadal atlas of major warmings in the historical record, including their type, timing, and spatial structure. The expected utility of the resulting dataset would be: (1) as a research tool to advance understanding and modeling of extreme events in the stratosphere and their coupling to wintertime tropospheric extremes; (2) as an observational record for evaluating representation of SSWs in climate model simulations of historical and future climate variations; (3) as a basis for improvement of the formal SSW definition, as well as an international monitoring and forecasting system for SSWs, through efforts with the international stratospheric community; and (4) as an education and outreach tool.

1a - Weather/Climate Extremes

(Sheffield) Development of a global flood and drought catalogue for the 20th and early 21st centuries based on improved assessment of the global terrestrial water cycle and its extremes.

Introduction to the Problem: Globally, flood and drought losses have increased tenfold over the second half of the 20th century, to $300B. This is partly due to increases in population and economic exposure but may be partly due to climate variability and change. Understanding the risk of flood and drought, and the climate and anthropogenic factors that control it, requires long-term historic records of the hydrological cycle and its extremes. Observational data from precipitation and streamflow gauges are sparse over many parts of the world, are often short-term and usually tainted by anthropogenic influences. Consequently, where flood risk estimates do exist they are often short-term, limited to developed nations and do not take into account non-stationarity in climate. Consistent drought risk estimates are essentially absent due to lack of data and standardized methods for drought identification.

Rationale: Given observed changes in flood and drought occurrence and the expectation for large changes in the future, there is an urgent need to provide improved estimates of past changes globally. Much progress has been made recently in quantifying the global terrestrial water cycle through merging of observations, remote sensing and modeling, with potential to provide improved assessment of the global risk of extremes. However, large uncertainties remain among datasets and the attribution of changes, especially for floods and droughts, as summarized in the 2012 IPCC Special Report on Extremes. Nevertheless, there is scope to improve current estimates on several fronts. We propose to develop a flood and drought catalogue for the 20th and early 21st centuries by merging the latest versions of in-situ and remote-sensing datasets with state-of-the-art land surface modeling to provide a continuous and consistent dataset of the terrestrial water cycle and its extremes. The dataset will form the basis for an analysis of the changing risk of floods and droughts and attribution to climate and anthropogenic factors.

Summary of Work: 1. Evaluate current estimates of the global hydrological cycle and its extremes by comparing existing observational, remote sensing and modeled datasets. 2. Develop a new sub-daily precipitation dataset for the 20th and early 21st centuries by merging remote sensing, gridded global and regional products, and station data. 3. Develop enhanced global land surface model simulations with the new precipitation dataset, new model processes, and higher spatial resolution. 4. Evaluate global flood and drought risk based on changes in occurrence and characteristics, and generate risk maps, under assumptions of stationarity and non-stationarity. 5. Develop a flood and drought catalogue for 1901-2014.
Relevance: This work directly addresses the key competition requirements to develop and analyze long-term, high-resolution, climate quality datasets with a focus on extremes. The work will assess the current state of knowledge based on global variability and change in the terrestrial hydrological cycle and its extremes, and will deliver improved global datasets and analyses of flood and drought risk in the context of climate change, that are important to many sectors, including water, agriculture and food security, energy production, infrastructure and ecosystem health. As such, it adheres to NOAA’s Next Generation Strategic Plan (NGSP) vision to “create and sustain enhanced resilience in ecosystems communities, and economies”.

1a - Weather/Climate Extremes

(Timmerman) Dynamics and seasonal predictability of extreme sea level variability in the tropical western Pacific. A. Timmermann, M. Widlansky

Recurring extreme sea levels in the tropical western Pacific are a well-known aspect of the El Niño-Southern Oscillation (ENSO) with sometimes damaging consequences for vulnerable communities and coastal ecosystems. As a result of major zonal and meridional mass redistributions in the tropical Pacific, sea level in the western Pacific can either rise (during La Niña) or drop (during El Niño) by up to 20–30 cm. Whereas many studies have focused on coastal inundations during La Niña events and their economic impacts, much less is known on the equally damaging sea level drops that expose shallow reefs and can lead to catastrophic coral die-offs. These sea level drops are most extreme in the southwestern Pacific where the events are locally referred to as ‘taimasa’— Samoan for “smelly reef”. Negative effects of taimasa on fishing yields can last for up to several years. In spite of potential societal impacts of ENSO-related sea level variability on Pacific islands, much uncertainty remains regarding its causes, regional manifestations, and potential seasonal to interannual predictability. We propose to study the mechanisms of interannual sea level extremes in the tropical western Pacific using a combination of tide gauge data, satellite altimeter observations, and ocean reanalyses. We will then assess the predictability of future sea level variability using the latest generation of climate models and available seasonal prediction products. Our research plan includes three particular components:

1. We will build on existing observation-based understanding of extreme sea level variability to develop a “Taimasa threat index”, indicating threatened coastal resources relative to different types of ENSO events.

2. We will develop a new framework for sea level forecasting based on a stateof- the-art coupled climate model initialized with three-dimensional ocean observations. Real-time forecasts of sea level will be produced.

3. Resulting forecasts will be served online through the NOAA-sponsored Asia Pacific Data Research Center and communicated to stakeholders. Our proposal seeks to better understand and predict sea level variability in the tropical western Pacific. The new index of sea level variability will provide the first assessment of coastal vulnerability to low sea levels and support resilience to future climate impacts. Our project will also communicate an early warning of
future sea level extremes—events, which may have devastating impacts on nearshore
ecosystems and coastal communities.

1b - Ocean Climate Indicators

(Cronin) Air Sea Fluxes at NOAA Ocean Climate Station Reference Sites. M.F. Cronin (NOAA/PMEL), Zhang (Co-I, NOAA/PMEL)

The ocean and atmosphere interact through air-sea fluxes. These fluxes are the most direct ocean climate indicators of how the ocean influences climate and weather, and their extremes, and how the atmosphere forces ocean variability. Through intense air-sea heat fluxes, the ocean supports and modifies tropical cyclones, winter storms and cold-air outbreaks, affecting weather and climate, locally, remotely and globally. These air-sea fluxes of heat and momentum (wind stress) in turn modify the ocean's currents and distribution of heat, with delayed feedbacks potentially providing predictability over timescales of up to several years. Air-sea fluxes from Numerical Weather Prediction (NWP) models, however, have large biases and uncertainties (Kubota et al. 2008, Tomita et al. 2010). It is well accepted that these errors must be identified and reduced in order to make progress with weather forecasts and climate projection. Only by understanding the nature of the error can the model be improved. Two NOAA Ocean Climate Station (OCS) buoys, the Kuroshio Extension Observatory (KEO) at 32.3°N, 144.5°E and Station Papa at 50°N, 145°W, have been measuring air-sea fluxes and upper ocean properties since 2004 and 2007 respectively. Both lie under the North Pacific storm track. Both observe frequent and severe winter storms and KEO also observes numerous Tropical Cyclones (TC) and typhoons, providing excellent reference time series for evaluating extreme air-sea interaction in NWP models. For more information on the OCS stations see: http://www.pmel.noaa.gov/OCS/. In this project, high-resolution air-sea flux reference time series will be computed from NOAA Ocean Climate Station (OCS) data and made publicly available through an easy-to-use webpage.

During year 1, air-sea heat, moisture, and momentum fluxes and all their components will be computed at these stations using the COARE v3.0 algorithm and made publicly available through a data delivery and display page similar to that offered by the PMEL TAO group: http://www.pmel.noaa.gov/tao/oceansites/flux/main.html. These ocean climate indicators will then be used to diagnose biases in fluxes produced by new NWP reanalyses (i.e. NCEP's Climate Forecast System Reanalysis and ECMWF Reanalysis-Interim). In years 2-3 of this project, we will upgrade to the COARE v3.5 algorithm, once it is fully developed. We will also increase the variables provided through the OCS flux website to include skin temperature, meteorological state variables adjusted to10-m height, and transfer coefficients. Likewise, analyses will be expanded to include comparisons and analysis of the ocean heat balances in the numerical ocean, with a focus on identifying processes affecting the distribution of heat in the ocean that may feedback onto the air-sea fluxes.

Air-sea fluxes are the most direct ocean climate indicators of how the ocean influences climate, weather, and their extremes. OCS buoys provide reference data sets for weather/climate extremes associated with typhoons and winter storms. This project will construct high quality reference time series of air-sea fluxes that will be used to assess and provide recommendations for improving state of the art NWP models.

1b- Ocean Climate Indicators

(Foltz) Continuous Records of the Mixed Layer Heat Budget in the Tropical Atlantic Ocean. G/ Foltz, C Schmid, R Lumpkin (NOAA/AOML)

The tropical Atlantic Ocean and surrounding continents have experienced several extreme climate events during the past two decades that have resulted in once-in-a-century droughts in the Amazon, extreme drought and flooding in Northeast Brazil, and unprecedented hurricane activity in the Atlantic basin. Almost all of these extreme events have been connected to highly anomalous sea surface temperatures in the tropical Atlantic. However, the mechanisms driving the extreme SST fluctuations are poorly known. While earlier modeling studies emphasized the importance of wind-induced evaporative cooling and positive wind-evaporation-SST feedback, recent work has revealed that other mechanisms such as aerosol- and cloud-induced changes in surface solar radiation and oceanic mixed layer dynamics need to be considered.

Empirical analyses of SST variability in the tropical Atlantic usually rely heavily on data from satellites, atmospheric reanalyses, and global hydrographic profiles. Direct measurements from the Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) are used much less frequently, despite the generally higher quality of the atmospheric measurements compared to those from satellites and reanalyses, and the enhanced temporal sampling rate of all PIRATA data. Part of the reason is that data from the PIRATA moorings is more difficult to interpret because of the presence of occasional gaps and biases in the time series.

A powerful quantitative tool for assessing the mechanisms responsible for SST variability is mixed layer heat budget analysis. Proper application of this technique to PIRATA data requires knowledge of several empirical parameters and, because of biases and gaps in the time series, involves collection of data from many independent sources. As a result, quantitative heat budget analyses are often based on arbitrarily chosen parameters, bias corrections, and gap- filling procedures. In this proposal we aim to address gaps and biases in the PIRATA records and avoid inconsistencies in the parameters chosen for heat budget analyses. The resulting product will be a consistent and continuous data set containing the main terms in the mixed layer heat budget of the tropical Atlantic Ocean during 1998-2013. The data set will consist of daily time series of each heat budget component from each of the 17 moorings of PIRATA. The product will be valuable for assessing the causes of extreme climate events in the tropical Atlantic, for validating ocean and climate models, and for diagnosing biases in coupled climate model simulations. A second component of this proposal is to create a gridded heat budget data set that extends back to the beginning of the satellite era (1982-2013), enabling analyses of how extreme events may be changing with time.

The proposed research will address the first goal of NOAA's Next Generation Strategic Plan (NGSP) of "*improved scientific understanding of the changing climate system and its impacts*" by providing a unique data set from which extreme climate events can be identified and their causes assessed.

1b - Ocean Climate Indicators

(Goni) Ocean Indicators in the Tropical and South Atlantic Oceans. G. Goni (AOML) Gustavo Goni (NOAA/AOML), S. Dong (CIMAS), M. Goes (CIMAS), F.J. Beron-Vera (U. Miami)

This effort supports the National Climate Assessment: Indicators System; and it is focused on providing in a coordinated fashion ocean indicators for ocean and climate state monitoring and numerical model evaluation. These indicators are focused on:

- The Meridional Overturning Circulation in the South Atlantic Ocean; and
- Variability in the state of the ocean, through key ocean currents and properties associated with the circulation in the South Atlantic Ocean.

This effort also supports the NOAA Next Generation Strategic Plan Long-term goal *Climate Adaptation and Mitigation: An informed society anticipating and responding to climate and its impacts*:

- Improved scientific understanding of the changing climate system and its impacts;
- Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions.

To accomplish this, we propose to utilize some of the longest ocean data sets in existence, including hydrographic and satellite observations, numerical model and reanalysis outputs, and theoretical efforts, many of which are currently being funded by NOAA/CPO. Integration of data and analysis of blended data will be key factors in this work, in order to maximize the value of the ocean observing system. Indicators distributed through this work will help improve scientific understanding of the ocean and climate system, and provide assessments of current states of the climate and ocean system for scientific analysis, numerical modeling comparisons, and identification of potential impacts to inform service, planning, and management decisions. The indicators proposed here will be provided with a summary analysis of their temporal and spatial variability, including maps showing assessments of their current states and uncertainties.

An important component of the proposed work is the monitoring of the Atlantic component of the Meridional Overturning Circulation (AMOC). The AMOC is characterized by a northward flow of warm water in the upper layers from the South Atlantic into the North Atlantic, sinking and formation of North Atlantic Deep Water at high latitudes, and a southward return flow of cold water at depth. The AMOC carries a significant fraction of the total global ocean-atmosphere northward heat flux. The majority of this heat is lost to the atmosphere in the mid-latitudes where warm water meets cold, dry continental air masses. Changes in the AMOC can have a direct and pronounced impact on a variety of climate phenomena, such as African and Indian monsoon rainfall, hurricane activity, and climate variability over North America and Western Europe. Thus, monitoring the AMOC variability in the South Atlantic and its major current systems is crucial for a) assessing numerical climate models, b) improving the understanding of important climate processes, and c) assessing future climate change. Therefore, this work will place emphasis on monitoring interbasin and interhemispheric water and mass exchanges in the Atlantic Ocean, and of the South Atlantic subtropical gyre variability.

1b - Ocean Climate Indicators

(Lee) Tropical Pacific and Indian Oceans Climate Indicators: warm water volume, subtropical cells, Indonesian throughflow indices. Lee (UCLA), M. McPhaden, (NOAA/PMEL), D. Zhang (NOAA/PMEL, UW) X. Wang (UCLA).

The tropical Pacific and Indian Oceans play important roles in climate variability and change in the Indo-Pacific sector and have global ramifications. In particular, Indo- Pacific upper ocean heat content regulates sea surface temperature (SST) to control ocean-atmosphere coupling. To a large extent, the upper ocean heat content is controlled by the shallow meridional overturning circulation cells that connect the tropical and subtropical regions, often referred to as the subtropical cells (STCs). The Pacific and Indian Ocean STCs linked by an atmospheric bridge (through the Walker Circulation) and oceanic tunnel (via the Indonesian throughflow, i.e. ITF). Our previous studies suggest that the STCs of the Pacific and Indian Ocean play opposite roles in regulating upper ocean heat content of the Indo-Pacific region on interannual and decadal time scales (at least since the early 1990s). A routine monitoring of upper ocean heat content, STCs, ITF, the relationships among these elements, and their relationships to climate mode indices and parameters are therefore important to the diagnostics, understanding, and prediction of climate variability and change in the Indo-Pacific domain.

Despite the important need for monitoring these oceanic features, there has been a lack of systematic effort to produce an inter-connected set of indicators for these features in a routine manner. The proposed effort aims to systematically develop and routinely produce a set of observation-based indicators to monitor the tropical upper oceans in the Indo-Pacific sector to facilitate ocean and climate research and to enhance the public's awareness of the societal relevance of ocean observations. Specifically, we will produce indicators to describe the state, variability, and trend of (1) upper ocean heat content using the well-established index of warm-water volume (WWV), (2) various branches of the Pacific and Indian Ocean STCs, and (3) the ITF. We will also develop indicators that describe the relationships among these indicators as well as their relationships to climate mode indices for the Indo-Pacific region. With NOAA/PMEL, we will work with various NOAA organizations and international programs to disseminate these ocean climate indicators to the research community and the general public through web/data services along with the corresponding description of societal relevance.

The proposed effort is highly relevant to 2014 NOAA FFO competition "1.
Climate Observations and Monitoring (COM) – Data Sets and Indicators", specifically, "b) Ocean Climate Indicators". That element of competition solicits proposals to "produce meaningful, authoritative climate-relevant and observation-based diagnostic indicators describing the status, trends, extremes, and variability of ocean physical properties over time scales of weeks to decades". This is because the proposed effort aims to produce well-established, physically important, societally relevant, observation- based ocean indicators to monitor upper ocean heat content and circulation that have strong implications to climate variability and changes.

1b - Ocean Climate Indicators

(Liu) Development of satellite-based surface fluxes of heat and moisture in the Arctic Ocean for understanding impacts of changing Arctic environments. Liu (Univ of Albany, SUNY)

Improving knowledge of exchanges of heat and moisture fluxes between the ocean and the atmosphere is critical to understanding energy and water cycle, and climate variability. This is particularly true in the Arctic Ocean, where rapid environmental changes are occurring. Surface turbulent heat and moisture fluxes in the Arctic Ocean have variability associated with a broad range of processes. However, observations of surface turbulent heat and moisture fluxes are extremely scarce in the Arctic Ocean. Extremely cold environment, seasonal sea ice, and the remoteness of the area make observations difficult to obtain. This contributes to current large uncertainty in estimates of northern mid- and high-latitude climate variability, hampers our understanding of critical air-sea interaction processes, and limits our ability to validate climate models used to project the 21st century climate. To date, there is no specific surface heat and moisture flux data set that can be recommended as adequate for Arctic Ocean applications.

This project targets the developing of a new satellite-based surface turbulentheat and moisture flux data set for the Arctic/subarctic Ocean from a combination of progress in satellite retrievals and a new approach to compute surface fluxes. This new flux data set is used to provide critical insight into impacts of rapid changes of Arctic environments on climate variability and meaningful evaluation of NOAA-supported climate model simulations. This new flux data set also serves as an important incremental step toward achieving globally balanced energy and freshwater budgets. This data-driven project will:

- Evaluate the accuracy and uncertainty associated with surface radiative fluxes and surface temperature for available satellite products using the assembled in-situ data.
- Create a new satellite-based surface heat and moisture flux data set by combining the best estimates of satellite-derived surface radiation fluxes andtemperature, and a recently developed flux algorithm based on the theory of maximum entropy productionthat is generalized to sea ice and water surfaces.
- Evaluate the new flux data set using the in-situ data base that we are currently assembling for the Arctic/subarctic Ocean and in the context of basin net heat and freshwater budgets.
- Produce a ~30 year new surface flux data set covering the Arctic/subarctic Ocean from 1983 to present, and make the data easily accessible to the research community.
- Use the new flux data set to document distribution and variability of the fluxes in the Arctic/subarctic Ocean, and further investigate impacts of the flux changes on atmospheric and oceanic processes in the Arctic, and their feedbacks on northern mid- and high latitude climate variability.\
- Use the new flux data set to evaluate the capability of the different versions of the GFDL coupled climate models to simulate surface fluxes of heat and freshwater in the Arctic/subarctic Ocean, and understand attributions to the disagreements.

This project directly addresses Competition 1 of Climate Observations and Monitoring (Data Sets and Indicators). The data set produced by this project provides “meaningful, authoritative climate-relevant and observation-based indicator addressing the status, trends, extremes, and variability in physical climate system over time scales of daily to decades”. This project is directly relevant to NOAA’s long-term climate goal towards “improved scientific understanding of the changing climate system and its impacts”.

1b - Ocean Climate Indicators

(Schmid) Transport in the upper branch of the South Atlantic Meridional Overturning Circulation. C. Schmid (NOAA/ AOML), Halliwell (NOAA/ AOML)

Studies based on climate models have shown that changes in the Atlantic MOC may relate to rain- fall patterns and decadal changes in hurricane genesis and intensity. Because climate models have limitations, for example due to their vertical and horizontal resolution, it is important to analyze observations and provide the results to the modeling community for assessment of their models. Estimates of the transports in the upper branch of the Atlantic Meridional Overturning Circulation (AMOC) at different latitudes will provide indicators for the monitoring of the AMOC itself as well as information that can be used for assessments of past, current and future states of the climate sys- tem. The estimated transports will also improve scientific understanding of this system, for example, through process studies and joint analyses of the variability of the transports in conjunction with other indexes (e.g. the North Atlantic Oscillation index). This, in turn, can help with identifying potential impacts on society and thus provide input for service, planning, and management decisions.

This proposal is focused on computing transport indexes for monitoring the Meridional Overturning Circulation in the South Atlantic Ocean at selected latitudes from Argo observations complemented with satellite observations and model fields. To accomplish this, a method for deriving three- dimensional fields of absolute velocity in the upper 2000 m of the ocean developed by the PI for the estimation of the climatological flow field (Schmid, 2013, submitted) will be employed to calculate seasonal estimates of the flow field during the Argo period. The method is based on situ observations from Argo, a project funded by NOAA/CPO, that are complemented with sea surface height from satellite altimetry. The plan is to use these fields in conjunction with fields of the Ekman trans- port to derive seasonal estimates of the volume transport in the upper branch of the MOC across selected latitudes, starting in 2000. The methodology will be evaluated by comparing the estimated transports with transport estimates from independent observations: (1) the estimates based on the XBT transects along 35S that were derived four to five times a year since 2002; (2) transports across 34.5S that are estimated from data collected by the South Atlantic Meridional Overturning Circu- lation (SAMOC) project; (3) transports across 26.5N that are estimated from data collected by the Rapid Climate Change-Meridional Overturning Circulation and Heatflux Array (RAPID/MOCHA). Two ocean model products produced by other groups will be analyzed to validate the realism of, and also to augment the scientific analysis of, the observation-based products.

1b - Ocean Climate Indicators

(Weller) Ocean Climate Indicators for the Trade Wind Regions. R. Weller (WHOI), A. Plueddemann (WHOI)

The focus of our proposal is on the development of ocean climate indicators for the trade wind regions. The trade wind regions comprise a regime that covers ~50% of the ocean surface, and is a key component of the climate system where the surface layer of the ocean and the lower atmosphere interact extensively. We are targeting indices to quantifying the following: 1) the state and variability of the upper ocean, such as temperature, salinity and mixed layer, 2) the state and variability of the surface forcing, including the subseasonal, seasonal, annual, and longer time scale variability of the surface meteorology and air-sea fluxes 3) the stability of the upper ocean and its sensitivity to perturbation by the atmosphere, 4) the capability of the upper ocean to influence the atmosphere, as through the heat content of the upper ocean, 5) the statistical properties of the surface forcing and upper ocean and their modulation in time, including extrema, means, variance, histograms, and spectra, and 7) significant covariability between the surface forcing and the upper ocean, such as wind-driven transport.

Central to our effort will be utilization of data from three long-term Ocean Reference Stations (ORS): Stratus at 20°S, 85°W which has been deployed since October 2000, NTAS at 15°N, 51°W which has been deployed since March 2001, and WHOTS at 22.6°N, 158°W which has been deployed since August 2004. These three sites occupy three characteristic and, we believe, potentially diagnostic locations in the trade wind regime. They provide data of known quality, with high vertical and temporal resolution in the upper ocean, with co-located, climate quality records of the surface forcing. We will validate the regional representativeness of these three sites and extend our results across the trade wind regime by utilizing the OA Flux, Argo float data, and HYCOM 1/25th degree ocean model fields. At the same time, we would use the ORS high temporal and vertical resolution data to examine any pitfalls that may be associated with using less well-sampled data sets to estimate the same indices and with using model-based analysis fields instead of observations.

With an understanding of the ability to compute indices from Argo and HYCOM we would investigate links between the indices at the three sites and patterns of variability across the trade wind regime and in regions within the trade winds. For example, we would look at ENSO and PDO modes of variability that might be isolated from the Pacific trade winds using empirical orthogonal functions (EOFs) and investigate how correlated their temporal variability is with indices based on the Stratus ORS. Or, we would examine to what degree Hawaii-regional indices, say of the local hydrological cycle, show correlation with indices from WHOTS.
We think that trade wind regional climate indicators will have value for diverse communities and would seek feedback during the project. These indices will be made available on our websites at WHOI and the University of Hawaii. They would also be shared via OceanSITES, the sustained ocean time series components of the ocean observing system, which maintains public access Global Data Assembly Centers (GDACS) at NOAA National Data Buoy

1b - Ocean Climate Indicators

(Zilberman) Western Boundary Current Transport as a climate index. N. Zilberman (UCSD, Scripps) D. Roemmich (UCSD Scripps), S. Gille (UCSD Scripps)

Western boundary currents (WBC) are highly variable swift meandering jets of large vertical extent flanked by recirculation gyres and mesoscale eddies. Observational arrays specifically designed to study WBCs are expensive, sparse in space and time, and present systematic limitations. New observational studies are required for a better understanding of volume transport in WBC systems.

WBCs are regions of intense air--sea interaction, where the ocean loses heat and moisture to the atmosphere and absorbs carbon dioxide. Modeling and data analysis studies have stressed the leading role played by WBCs in the distribution of heat, mass, and fresh water in the shallow Meridional Overturning circulation (MOC). Changes in WBC transport could have significant impact on the ocean capacity to buffer and regulate climate change. A better understanding of how climate change is affecting Earth's water cycle calls for significant improvement in WBC transport estimates.

This study will focus on the Kuroshio, East Australian Current, Gulf Stream, Brazil Current, and Agulhas Current. Our strategy is to combine complementary modern datasets to improve estimates of WBC transport. We aim to produce an ocean climate indicator from WBC transport anomalies at interannual and decadal time scales. High--resolution expendable bathythermograph (HRX) transects will be merged with Argo float profiles and trajectories to expand HRX shear estimates to 2000--m and assess absolute geostrophic velocity. HRX/Argo data will be combined with altimetric datasets to correct for uncertainties generated by unresolved mesoscale activity in HRX measurements. WBC transport variability prior to the 2004--2012 Argo era will be addressed using combined Altimetry/HRX data. This new ocean climate indicator will allow us to appraise our conceptualization of WBCs as key components of the heat transport in the MOC.

Relevance to competition: The proposed research will be a contribution to the Climate Observations and Monitoring (COM) Data Sets and Indicators program of NOAA focused on developing new Ocean Climate Indicators. Proposed research will aim to define a new set of ocean climate indicators to track variability in WBC transport. Our objectives are to reduce uncertainties in WBC transport, determine the atmospheric forcings governing WBC time--variability, and seek a relationship between WBC transport and climate change. This research will improve the simulation and prediction of meridional heat transport from the tropics to mid--latitudes in the shallow MOC. Results from our project will further our understanding of air--sea flux variability and storm track evolution along the path of WBCs. This will help assess the socio--economic vulnerabilities to climate driven storm genesis in WBC regions.

2 - Paleoclimate

(Hakim) Last Millenium Reanalysis Project. David M. Anderson (Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO NOAA's National Climatic Data Center Paleoclimatology Branch, Boulder, CO); Julien Emile-Geay (Department of Earth Sciences, University of Southern California, Los Angeles, CA); Gregory J. Hakim (Department of Atmospheric Sciences, University of Washington, Seattle, WA); David Noone (Department of Atmospheric and Oceanic Sciences, University of Colorado, Boulder, CO): Eric Steig (Department of Earth and Space Sciences, University of Washington, Seattle, WA)

Paleoclimate proxy data provide a critical reference history for Earth's climate. Analysis of such data has evolved from time series analysis to statistical reconstructions calibrated against the instrumental record. Although such data provide the only direct measure of climate history, interpretation is challenged by, among other factors, measurement and timescale noise, and a lack of complete physical constraints. Climate models provide a complementary perspective on Earth's climate history through simulations that attempt to replicate the information obtained from proxy data. Although such simulations contain the physical constraints from fluid dynamics, interpretation of such simulations is challenged by, among other things, model bias and a lack of constraints from the known proxy record. Over the past decade, the fusion of proxy data and climate simulations has progressed to the point where it is now possible to use data assimilation approaches similar to those used for reanalysis of observations during the instrumental record. Such approaches provide not only a reconstruction of the global mean surface temperature, but the spatial distribution and uncertainty in the temperature field, and potentially many others fields as well. Here we propose to use a data assimilation approach to extend the reanalysis time period to the last 1000 years. The product, the Last Millennium Climate Reanalysis, will revolutionize our ability to diagnose low-frequency climate variability and the statistics of extreme events. Moreover, such a dataset will provide "hindcast" information against which to measure the skill of models used in decadal climate predictions, which are critically important for evaluating projections of near-term climate change. Gridded reconstructions of multiple climate variables (temperature, pressure, precipitation), constrained by paleoclimate observations and consistent with the dynamical and thermodynamic constraints by general circulation models, will be a game-changer for climate science, extending the instrumental record by a factor of five to ten, yielding insight on trends and on changes in extremes across mean-state changes (e.g. between the "Medieval Warm Period" and "Little Ice Age" and the present). As part of the reconstruction effort, the team will involve the paleoclimate community through an advisory panel and annual workshops on topics related to the reanalysis effort. Relevant to the climate observation and modeling competition, the proposed reanalysis is a synthesis effort that aligns specialized paleoclimate data with the agency climate portfolio developed by the Climate Program Office in support of NOAA and U.S. Climate and Global change goals.