Ocean Reference Stations

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Project Summary

Rationale: The Woods Hole Oceanographic Institution (WHOI) Ocean Reference Station project is carried out to provide critical, sustained observations of a key region of the ocean – the trade wind region. As the earth sits in space, sunlight heats the earth in a broad, equatorial region. The ocean and atmosphere both are driven by the thermal gradients between the equator and the poles; the oceans, with their ability to store, transport, and release heat and moisture to the atmosphere, play an important role in weather and climate. Air that is heated rises at the equator and descends in the subtropics, resulting in broad regions of winds flowing from the east to the equator. Around the globe these easterly trade wind regions cover roughly 50% of the ocean surface, in a wide belt spanning the equator. These regions are where the equatorial concentration of solar heating leads to net ocean heating and where in turn large evaporation and accompanying latent heat flux provides energy and moisture to drive the atmosphere over a range of scales, from the general Hadley circulation that is the source of the trade winds down to intense hurricanes intensified by that heat and moisture. They are also where the ocean provides CO_2 to the atmosphere in contrast to the higher latitudes where the ocean gains CO_2 from the atmosphere. Integrated across the expanse of the trade wind regions, errors and uncertainties in the exchange of heat, freshwater, momentum, and compounds such as CO_2, can challenge our ability to understand the way in which the atmosphere and ocean interact and how that interaction should be represented in models used to predict weather and climate variability.

To provide sustained, climate-quality observing of the trade wind region, we have developed surface moorings with the capability of making sustained, accurate observations at the sea surface and in the water column and have chosen and occupied three key trade wind sites. These surface moorings are known as Ocean Reference Stations (ORS). The three sites, shown in Figure 1, are the Stratus ORS, the NTAS (Northwest Tropical Atlantic Station) ORS, and the WHOTS (WHOI Hawaii Ocean Timeseries Site) ORS. Together, the three sites form a comprehensive array in two ways. First, they sample distinct branches of the trade wind regime. The black squares in Figure 1 are the positions of NTAS and Stratus relative to WHOTS based on their position within the trade wind system; note that Stratus, at the furthest distance from the region of convergence between the Northeast and Southeast Trades, samples the region of descending atmospheric flow in the Hadley circulation and the origin of the trade winds, while NTAS, samples they trade winds close to the convergence zone which is the ascending branch of the Hadley circulation, and WHOTS samples the fully developed trade winds in between. Second, the three sites have regional attributes. Stratus is under the persistent marine stratus clouds that characterize the region offshore of northern Chile, in a cool eastern boundary current regime and, due to the proximity of the Andes, away from the tracks of energetic synoptic weather systems; atmospheric, oceanic, and coupled models continue to fail to correctly represent the physics at work there and typically yield sea surface temperatures that are too cool. NTAS lies in the North Atlantic trade wind regions through which the hurricanes that reach eastern North America track, and accurate representation of how the ocean's heat and moisture in this region fuel the growth of those hurricanes is needed. WHOTS, close to the Hawaiian Islands where the Keeling time series documents the increase of atmospheric CO_2, provides not only a critical benchmark time series of oceanic CO_2 but also an emerging record of links between changes in the regional hydrological cycle (rainfall, evaporation) and the variability and dynamics of the upper ocean there due to changes in ocean salinity.

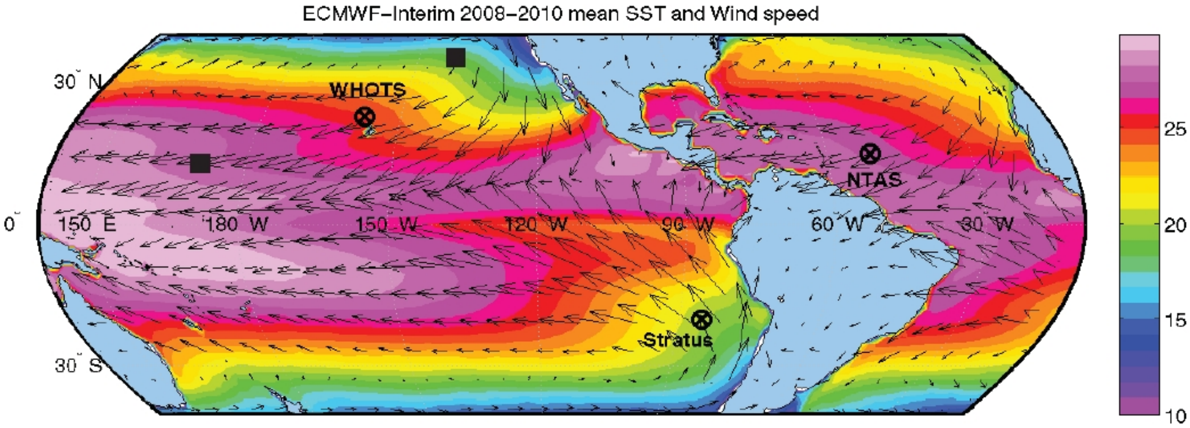

Figure 1. SST (colors) and surface wind vectors from the ECMWF-Interim reanalysis for the period 2008-2010. The positions of the Stratus, NTAS and WHOTS ocean reference station buoys are indicated. The corresponding virtual positions of the Stratus and NTAS buoys, relative to the North Pacific Hadley circulation and SST, are indicated by black squares. From Dr. Roger Lukas, Univ. of Hawaii, partner at WHOTS.

The reasons for our approach, the use of surface moorings for sustained observations, are: 1) the need to obtain high temporal resolution, sampling down to minutes to record high amplitude, short-lived events in the surface meteorology, air-sea fluxes, and upper ocean structure, 2) the need to sample with high vertical resolution in the stratified upper ocean that is in close contact to the atmosphere and links the upper ocean to the interior of the ocean, 3) the need to sample a changing environment in a sustained way, and 4) the need to provide continuous time series at a point for validation, verification, and calibration of models and remote sensing methods. Designing and building a surface mooring, developing and using accurate instruments with low-power consumption that can run unattended, instrumenting the surface buoy with these meteorological and pCO2 sensors and the mooring line with temperature, salinity, velocity, and other ocean sensors, and carrying out on-site verification of the moored instrumentation when the ship services the mooring each year are the best technical approach and the one we use at the three ORS. The resulting meteorological and oceanographic observations provide a set of high quality air-sea fluxes of heat, freshwater and momentum as well as upper ocean heat and salt content. The scientific rationale for the collection of these flux products is manifold: 1) to describe the upper ocean variability and the local response to atmospheric forcing; 2) to motivate and guide improvement to atmospheric, oceanic, and coupled models; 3) to calibrate and guide improvement to remote sensing products and capabilities; and 4) to provide anchor points for the development of new, basin scale fields of the air-sea fluxes. Model, satellite, and climatological fields of surface meteorology and air-sea fluxes have large errors; high quality, in-situ time series are the essential data needed to improve our understanding of atmosphere-ocean coupling and to create more accurate global fields.

Scope: The work done under this project accomplishes seeks to do the following: 1) maintain long-term surface moorings, known as Ocean Reference Stations, in three key trade wind locations, one in the North Atlantic, one in the North Pacific, and one in the South Pacific, 2) use the data from these moorings to accurately quantify the local climatologies and variability of the air-sea fluxes, sea surface temperature, surface currents, upper ocean heat content and transport, and, with NOAA partners, the air-sea flux of carbon dioxide, and 3) use the data collaboratively to improve understanding of the processes and dynamics at these sites and thus the numerical models of the atmosphere, the ocean, and the coupled atmosphere-ocean applicable to these regions.

Three Ocean Reference Stations are being maintained: A site at 20°S, 85°W under the stratus cloud deck off northern Chile (Stratus), the Northwest Tropical Atlantic Station (NTAS) at 15°N, 51°W, and a site north of Hawaii near the Hawaii Ocean Time-series (HOT) site at 22.75°N, 158°W known as the WHOI Hawaii Ocean Time-series Station or WHOTS. Moorings at the Stratus and NTAS sites were first deployed in 2000 and 2001, respectively, and became long-term Ocean Reference Stations. WHOTS was established in 2004, in collaboration with investigators that have made shipboard and moored observations in that region in recent years. Each of these sites is visited once per year. Before the cruise the new instruments are calibrated and prepared and the surface buoy and mooring are built. During the year, real time data flow and quality is monitored. After the cruise, instruments are calibrated and refurbished, data are recovered and processed, and the cruise is documented.

Anticipated data, products, outcomes: In FY2012, the WHOI Ocean Reference Station project carried out cruises to each of the three sites to recover moorings in service for a year and deploy new moorings NTAS was serviced by the NOAA Ship Ron Brown in November 2011. Stratus was serviced by RV Melville on a cruise from Valparaiso, Chile to the Galapagos in May-June, 2012. WHOTS was recovered and redeployed in July, 2012 on the NOAA Ship Hi'ialakai. Each cruise resulted in the collection of the internally recorded data on the instrumentation on the buoy and the mooring line and supporting data sets from the ships, such as meteorological data for comparison with the buoy meteorological data. From the deployment of a new buoy, onward, the surface meteorological data are available in near-real time, with hourly averages typically telemetered via Service Argos. The WHOI Ocean Reference Station data are not placed on GTS; instead they are used as independent data for validation of models by users such as ECMWF (European Centre for Medium Range Weather Forecasts) and NCEP (National Centers for Environmental Prediction).

The web sites associated with the three WHOI Ocean Reference Stations are the primary means for documenting work each year, sharing real time data, and providing archived data. The key Web Sites are: NTAS – http://uop.whoi.edu/projects/NTAS/ntas.html; Stratus – http://uop.whoi.edu/projects/Stratus/stratus.html; and WHOTS - http://www.soest.hawaii.edu/whots/ and http://uop.whoi.edu/WHOTS/projects/whots.html. For each site the WHOI web page provides an overview, detailed description (with links to mooring diagrams and technical reports), access to real time data, and access to archived data. Real time data are quality controlled on an ongoing basis, and sensors that degrade are flagged, with data removed from real time access. After the moorings are recovered, quality control and processing is directed first to develop high quality time series of surface meteorology and air-sea fluxes; these time series are typically available within twelve months of recovery, allowing post-deployment sensor calibrations to be completed first. The present new year of surface meteorology and air-sea fluxes is then merged with previous time series to make continuous time series; this is the products that are most requested by various users. Processing and preparation of data files for the ocean sensors then follows, with temperature and salinity done first. Work on the velocity data provides the most challenge due to the impacts of biofouling and fishing gear on current meters and the greater complexities of quality controlling current meter data.

Intended Users: The users of Ocean Reference Station data are: 1) Numerical Weather Prediction (NWP) centers, including the National Centers for Environmental Prediction (NCEP) in the United States, the European Centre for Medium-Range Weather Forecasts (ECMWF) in Europe, the Centre for Australian Weather and Climate Research (CAWCR); 2) climate modeling groups and groups analyzing the realism of climate models, NCAR (National Center for Atmospheric Research) in the U.S. and the international SURFA (Surface Flux Analysis) project where ORS data are used as validation truth for examining the performance of many different climate models from different countries; 3) those analyzing and assessing the realism of satellite retrievals at the sea surface (sea surface temperature) and of surface meteorology (e.g., winds) and surface waves, including investigators at NASA (National Aeronautics and Space Administration) and ESA (European Space Agency); 4) those working to developed gridded fields of air-sea fluxes of heat, moisture, and momentum to accurately determine and monitor these fields on a global basis, including Dr. Lisan Yu at WHOI, whose OAFlux project uses the ORS data to validate the OAFlux fields; 5) investigators and researchers studying air-sea interaction, cloud physics, and upper ocean dynamics at key locations, such as under the marine stratus clouds off Chile (Stratus) and in trade wind locations such as NTAS and WHOTS; 6) investigators working under VOCALS (VAMOS Ocean Cloud Land Atmosphere Study, where VAMOS is the Variability of the American Monsoon Systems of the international CLIVAR (Climate Variability research program)), which has focused on improved understanding and prediction of the marine stratus and its impacts on climate over the Americas; and 7) ocean model developers and users at US research and operational model centers, who use the time series of ocean variability at the ORS to examine the realism of ocean models and the time series of surface fluxes to evaluate the forcing fields they use to drive their ocean models.

Users of the ORS platforms in addition to our effort include: 1) the National Data Buoy Center (NDBC), an NDBC surface wave package is installed on the Stratus and NTAS ORS to provide surface wave data in the extremely data sparse eastern South Pacific and the northwest tropical Atlantic, 2) NOAA PMEL (Pacific Marine Environmental Laboratory), which has installed instrumentation to measure carbon dioxide in the surface waters at the Stratus and WHOTS ORS, and 3) investigators from WHOI, LDEO (Lamont-Doherty Earth Observatory of Columbia University), the Institut fur Meereskunde an der Universitat Kiel (IFMK), and Dr. Sam Laney (WHOI, funded by NASA to study ocean color) who have installed or will be installing instrumentation to study ocean mixing, oceanic oxygen minimum layers, and ocean color.