from the ocean to the subpycnocline waters of the shelf, as well as the vertical flux to the surface layers. Uptake of nutrients is based on the historical distribution of chlorophyll and appears as a sink. Path, timing and nutrient ratios are used as diagnostics.

We use the Rutgers/UCLA Regional Ocean Model System (ROMS) with a grid resolution of 5 km horizontally and 24 levels vertically. A gridded bathymetry is derived from ETOPO5, and initial temperature and salinity are derived from the World Ocean Atlas (WOA98). Both nitrate and silicate are active in the model and initial distributions come from a newly developed, gridded, monthly nutrient and chlorophyll climatology for the Ross Sea that is created from observations from many cruises (mostly from the U.S. Southern Ocean JGOFS program) combined with WOA98 gridded fields. Monthly wind stress is from the ECMWF reanalysis climatology. Ice masked surface heat and salt flux are constructed from the SSM/I and ECMWF reanalysis climatologies using the COARE bulk flux algorithms. Vertical mixing in the interior and surface boundary layer uses the K profile parameter (KPP) scheme. Open boundaries use adaptive nudging (Marchesiello 2000) to monthly climatologies of temperature, salinity, nutrients as well as depth averaged circulation from the OCCAM global circulation model. Effects of the Ross Ice Shelf are imposed through nudging to climatological temperature and salinity in a buffer zone. Nutrients are removed from the near surface at rates that depend on the new gridded chlorophyll concentration as well as model nutrients.

The new biogeochemical climatologies show a strong seasonal variability in parts of the western Ross Sea, where data are available. Residual surface nutrients in summer are likely due to iron limitation. The climatologies can be used to compare individual cruises to long-term mean conditions and therefore quantify large-scale variations of biogeochemically relevant variables.

Model results show that nutrients enter the shelf along the NW shelf break (near Cape Adair) and along the eastern shelf break (Cape Colbeck). Surface nitrate is reduced from 30 to 6 uM in 20 days where the chlorophyll concentration is high, while silicate is reduced from 80 to 30 uM. Subpycnocline nutrients remain near initial levels of 30 and 75 uM, respectively. Surface nutrients in the model will continually decline to zero unless some process, like iron limitation, halts uptake even with nutrients.

OS41C-39 0830h POSTER

Relationships Between Spatial and Temporal Dynamics of two Euphausiid Species and ice and Water Masses in the Ross Sea

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The pelagic ecosystem of the Ross Sea is dominated by two similar and probably competing krill species: Euphausia superba (E.s) and Euphausia crystallorophias (E.c). The coexistence of the two populations implies that they have different dynamics in space and time, probably caused by the dynamics of ice and water masses. The paper presents initially the spatial distributions of the two populations, the ice cover and the water masses structure from late spring (Nov.1994) to early (Dec.1997) and full summer (Jan./Feb.2000). Then an attempt to explain the dynamics of the two species through that of ice and water mass is discussed.

Data on krill populations were collected from three large-scale acoustic surveys. They covered the western part of the Ross Sea, between the lat.70° and 77°S and long.164°E and 178°W. The multi-frequency and echo-integration methods were used to discriminate the two species, assess their biomass and determine their spatial distribution. During the acoustic survey of Nov.1994, the Ross Sea was completely covered with ice. The survey of Dec.1997 was conducted in partially ice-covered and relatively rough conditions, while the survey of Jan./Feb.2000 in ice-free waters and in stable weather conditions. During the acoustic surveys the Euphausiids were sampled using a 5m2 Plankton Hamburg Net (HPN) of 500/1000 m. From net samplings the biological parameters of each species were determined. As far as physical oceanography data are concerned, these include CTD casts, XBT launches and continuous surface temperature recordings. Although they were collected during the three cruises, the 2000 Expedition data are the only ones gained synoptically with the echo-survey and then the more integrable from acoustical, biological and physical point of view. Therefore our attention was particularly fixed on this last Expedition, during which 34 CTD stations were performed with a Sea Bird Electronics SBE 911plus probe, measuring temperature, salinity, density and fluorescence from the sea surface to the bottom (or at least 400 m), and 72 Sippican T7 XBT probes were launched, allowing for measurement of temperature from the sea surface to the bottom.

The krill density biomass has been mapped on the ice cover. In the last decade of Nov. it develops a noticeable frontier between the two species around lat. 75°S, where the marginal ice zone begins to form. The southern end of the environment (below 75°S) is dominated by E.c, while the Northern part (above 75°S) is dominated by E.s In Dec. the frontier between the two species widens: E.s. moves to North together with ice melting, while E.c moves slightly to South of 75°S. In Jan./Feb. the movement of E.s slows down, until it stabilises above 73°S. In the same period E.c moves North up to 73°S, where it stabilises. The krill density biomass has been plotted on the horizontal and vertical temperature field. Most part of the observed krill swarms is placed in relation to the surface waters. Where the last residual pack ice is present associated to colder surface waters, a separation of swarms has been observed. It would seem that the E.c swarms were connected mainly to the Ross Sea surface waters and E.s swarms were almost exclusively found in Antarctic Surface Waters, both being scantily present in the High Salinity Shelf Water, Circumpolar Deep Water and Warm Core. Deeper swarms were observed mainly close to shelf-break areas where a deeper mixed layer was present.

OS41C-40 0830h POSTER

SO GLOBEC meets APIS: The character of the midwater fish faunas of the eastern Ross Sea and the western Antarctic Peninsula Shelf

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The fish fauna of the Southern Ocean is comprised of two elements, an oceanic fauna comprised of midwater fish families found throughout the world ocean and an endemic fauna associated with the shelf and slope of the continent and outlying islands. The pelagic fish fauna of the shelf regions is of considerable interest. Apex predators such as seals and penguins feed in the upper 500 m and include fishes in their diet. In addition, fishes are potentially important predators of krill and zooplankton. The 500 m average depth of the water column associated with the Antarctic continental shelf would not exclude the oceanic species from being present based on depth alone, so on an a priori basis a mix of oceanic and endemic species would be expected, particularly at the shelf break. We examined the pelagic fish communities of the eastern Ross Sea, including the continental shelf region, and compared them to those found on the western Antarctic Peninsula (WAP) shelf. Thirty six midwater trawls were taken in the Ross Sea, including 22 MOCNESS tows, and thirty two MOCNESS trawls were taken on the WAP shelf. We found a profound difference between the two systems. Representatives of the classical midwater fauna, e.g. the myctophids and bathylagids were present in both systems seaward of the shelf break, but there the resemblance ended. The midwater families were found throughout the study region on the WAP shelf, including the fjord regions near the continent. In contrast, the midwater families stopped abruptly at the shelf break in the eastern Ross Sea. The most obvious difference between the two systems is the temperature structure of the water column, which is uniformly cold (approximately -2°C) from surface to bottom in the Ross Sea and warm (approximately 1°C) on the WAP shelf. It is tempting to conclude that temperature is excluding the oceanic species, but other factors are likely to play an important role as well. What is clear is that the character of the pelagic fish fauna between the two regions is quite different.

OS41D HC: Hall III Thursday 0830h

Equatorial Oceanography III

Presiding: **D Moore,** NOAA /PMEL**; D Turk,** International CLIVAR Project Office

OS41D-41 0830h POSTER

Yanai-Kelvin Wave Conversion in the Gulf of Guinea

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When a Yanai wave-packet, propagating eastward along the Atlantic Equator, enters the Gulf of Guinea, it transfers a fraction of its wave energy to a westward-propagating coastal Kelvin wave. This wave conversion occurs via localized linear resonance between the zonal wavenumbers, which vary zonally because of the nonuniform depth of the thermocline. When the Yanai wave strikes the African coast, it bifurcates into northward and southward coastal Kelvin waves. The northward wave follows the coast and re-enters the resonance region, where the same fraction is transferred back to a new Yanai wave, and so on. The conversion process has been studied analytically [J Fluid Mech 394 (1999) 175-192], by projecting a variational principle onto the local meridional eigenfunctions for fixed-frequency waves. We now report on two-dimensional computations of the full linear equations, for various initial or boundary conditions. We compare the simulation results with the previously obtained analytic formulation.

OS41D-42 0830h POSTER

The cross-equatorial structure of Tropical Instability Waves from a linearized stability analysis of the Pacific

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A linearized 2-mode projection model has been developed to understand observed characteristics of monthly variability in the Equatorial Pacific from TOPEX/POSEIDON measurements of Sea Surface Height (SSH). The 2-mode projection model is obtained from an equatorial beta plane model that has been linearized about a geostrophically balanced mean flow. The state variables from the model are projected on to the first 2 baroclinic vertical eigenfunctions. Because in situ measurements of currents in the equatorial Pacific are not available with adequate spatial and temporal resolution, the mean current structure used in the 2-mode projection model was obtained from the Parallel Ocean Climate Model (POCM). POCM was chosen because the monthly variability in the model SSH fields closely resembles that of TOPEX/POSEIDON in dispersion characteristics and cross-equatorial structure. The sensitivity of the 2-mode projection model to the mean equatorial currents is examined by individually increasing and decreasing the various components of the equatorial current system: the currents south of the equator, the currents north of the equator and north branch of South Equatorial Current (SECN). The eigenvectors and eigenvalues from this range of current structures are able to reproduce many of the characteristics (phase, amplitude, period, wavenumber and meridional structure) observed in TOPEX/POSEDON and POCM. The most surprising result is that the eigenvector amplitudes in the south depend only on the strength of the northern equatorial current system.

OS41D-43 0830h POSTER

Tropical Instability Wave Variability in the Central Tropical Pacific

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Shipboard ADCP measurements of currents in the Central Tropical Pacific are being continuously accumulated by numerous oceanographic cruises, most notably those of the TOGA-TAO mooring maintenance program. The data set now amounts to nine years of high-quality data scattered in latitude, longitude, and time. Removal of the first-order zonal structure through a fitted zonal trend allows us to obtain a robust monthly composite estimate of the seasonal cycle as a function of latitude and depth. Removal of this seasonal cycle from the data leaves residuals that include the interannual variability and higher-frequency variability such as instability waves. While the data are too sparse to track the interannual variability of currents with high fidelity, the intense contrast of the 1997/1998 ENSO warm/cold phases provides a higher signal/noise ratio. This allows us to compare the ocean in a low shear, low instability wave activity state with a high shear, high activity state. Composites of these two states are analyzed using the 2-D linear stability model of Proehl (1996) to elucidate the relationship between the structure and dynamics of the instability waves and the larger current structures which engender them.

OS41D-44 0830h POSTER

Tropical Pathways, Equatorial Undercurrent Variability and the 1998 La Nina

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In the equatorial Pacific Ocean, the transition from the 1997 El Nino to La Nina was very rapid. An outcrop of cold water appeared at the surface around 0°-125° W end of May-early June 1998 and resulted in a SST drop of 7°C in less than a month. This transition is analyzed using in situ data and an ocean general circulation model over the 1993-99 period. Simulated equatorial zonal currents, equatorial undercurrent (EUC) transport and EUC transport-weighted temperature are validated against TAO/TRITON data. Trajectories of particles issued from the outcrop of cold water are calculated backward in time using the 3-D simulated currents. All the particles came from two pathways (one in each hemisphere) that connect the subtropics to the equatorial upwelling region. The particles were brought in both hemispheres by the subtropical gyres into the western boundary currents. They were moved into the EUC, in which they were transported upward and eastward during approximately 20 months. They finally upwelled in spring 1998 from 80-m depth to the surface in about two months. None of the particles took a direct and shorter pathway from the subtropics to the EUC through the interior ocean The EUC has thus a direct influence in the rapid turn into La Nina in 1998. Large variations in transport (up to 60 Sverdrup) and in transport-weighted temperature (up to 3°C) of the EUC at 170°W are observed in TAO data and in the model. Prior to the 1997 El Nino, over most of 1996, the EUC was well established and transported water 1°C warmer than usual. After its collapse during the mature phase of the 1997 El Nino, the EUC strengthened and transported water 1°C colder than usual. The variations of the transport-weighted temperature of the EUC are partly related to the equatorial thermocline depth. Variability of the long-term thermocline circulation from the subtropics to the equator is much probably affected by the rapid variability of transport and transport-weighted temperature of the EUC.

OS41D-45 0830h POSTER

Simulation of the Interannual Variability in the Tropical Indo-Pacific Region With a Coupled GCM: Impact of the Model Horizontal Resolution

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The objective of this work is to analyze the main modes of variability in the tropical Indo-Pacific region at interannual time scale with a coupled GCM, and to investigate the possible effects that the horizontal resolution of the atmospheric component might have on the model simulation.

The study is performed by means of simulations carried out with the SINTEX (ECHAM4/OPA) coupled atmosphere-ocean general circulation model. The model is implemented without any flux correction.

To assess the impact of improved horizontal resolution on the simulated tropical variability, we have performed long experiments with three horizontal resolution versions of the atmospheric component (triangular truncation 30, 42 and 106).

The results indicate that the main general features of both the mean state and the principal modes of variability in the tropics are reasonably well reproduced by the model. An increase of the horizontal resolution of the atmospheric model component seems to actually have a beneficial impact on both the mean state and the interannual variability, especially in the equatorial Pacific.

OS41D-46 0830h POSTER

The Seasonal Cycle and El Niño Termination

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The processes that control the termination of El Niño are of forecast and scientific importance. We suggest that the seasonal cycle plays a fundamental role in the termination of El Niño, presenting a complement to 'Delayed-Oscillator' type mechanisms.

A prominent aspect of El Niño events (observed since the TAO array has been deployed) is thermocline shallowing that begins in the central equatorial pacific sometime between November(0) and January(+1) and propagates eastward in subsequent months. We suggest that this shallowing involves direct atmospheric forcing, independent of 'Delayed-Oscillator' processes. In this process the equatorially centered surface westerly wind anomalies are shifted by the seasonal solar-driven heating of water south of the Equator, driving thermocline shallowing to the east. This thermocline shallowing preconditions the termination of El Niño.

During moderate and weak El Niño events, easterly trades persist to some degree throughout the event. Once shallowing has been forced by the southward shift of equatorial westerly wind anomalies, SST quickly cools through upwelling of cold sub-surface water.

However, during strong El Niño events the cold tongue equatorial easterlies are weak or non-existent and there is insufficient upwelling to bring cool subsurface water to the surface to reduce SST as the thermocline shallows. Some mechanism is required to bring equatorial easterly winds back, to return SST to normal in these events. We suggest that, again, the seasonal cycle of solar heating and the associated large-scale surface wind changes are the likely mechanism.

Thus, the seasonal cycle appears to be fundamental to the termination of El Niño.

OS41D-47 0830h POSTER

A detection of an interannual air-sea coupled propagating signal along the subtropical font from low- to mid-latitudes over the North Pacific

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Seasonal dependent structures of interannual variations in the atmosphere and ocean and their interactions are examined with respect to the interannual propagating signal in sea surface temperature (SST) anomalies from Philippine coast to the central North Pacific. Periodically Extended Complex Empirical Orthogonal Function (PXCEOF) analysis for the high-pass filtered (periods < 8 year) revealed that the propagating signal is prominent in the winter and spring seasons, but obscured in the summer and autumn seasons, with the amplitude maxima of the PXCEOF approximately coincide with the subtropical front. Subsurface temperature analysis suggests that the thermal signature survive during summer and autumn seasons below the seasonal mixed layer, and re-emerges to the surface in the next winter. The signal takes 2-3 years from Philippine coast to the central North Pacific, and the dominant periodicity is about five years.

Propagating signatures are also prominent in wintertime surface meridional wind speeds in the atmospheric boundary layer to the west of dateline, and also net heat flux shows a coherent propagating feature. The net downward heat fluxes and meridional winds are in-phase, and they slightly lead the SSTs, indicating the thermal input from the atmosphere to the ocean drives the SST propagation. A simple heat budget model showed that the observed SST propagations are well explained by atmospheric thermal forcing to the ocean, but the meridional Ekman advection also contribute to produces maximal amplitude of the SST in the central North Pacific.

OS41D-48 0830h POSTER

The El Nino Onset of 2001 - or Not: Analysis of Tropical Pacific Surface Current and SST Variations During the Past Year.

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Using improved surface currents calculated monthly from satellite altimeter and wind data, we have closely monitored the tropical Pacific surface circulation during the past year. Monthly maps have been published in Climate Diagnostics Bulletin since January 2001. The velocity anomalies became generally eastward in the Spring 2001, and have persisted through the summer and remain so as of this writing (early November 2001). Anomalies computed since 1992 are dominated by an ENSO mode with strong eastward equatorial flow during the recent El Ninos. This mode has led the canonical ENSO SST mode by 2.5-3 months. A series of equatorial westerly wind events have also been occurring in the far western Pacific during the year, with the latest in October. In recent months, some climate forecast groups have predicted mild to moderate El Nino conditions for the 2001-2002 winter. These indicators have led us to anticipate that warm SST anomalies are imminent in the eastern Pacific, in the canonical El Nino pattern. So far, these anomalies have not materialized. Although moderately warm SST anomalies have persisted near the date line in recent months, SSTs in the eastern Pacific cold tongue have remained near or below normal. At the time of this conference in February 2002, there will be further indications of whether an El Nino is underway. This presentation will describe the evolution of surface circulation and other ocean conditions in the tropical Pacific during 2001, through January 2002, and identify features which relate to whether a 2001-2002 El Nino has begun, or not.

THU

OS41D-49 0830h POSTER

Does sea surface salinity monitoring improve statistical ENSO predictions ?

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A statistical model for El Niño/Southern Oscillation (ENSO) predictions is used to study the the potential impact of monitoring sea surface salinity (SSS) on the improvement of ENSO predictions. The interest of such a study is related with the proposed missions for remote sensing of SSS (SMOS mission of the European Space Agency (ESA) and AQUARIUS mission of NASA). This is one of the first studies focusing on the direct role of SSS in ENSO predictions.

The statistical model is constructed under the basis of the canonical correlation analysis (CCA). In the model, the NIÑO3 index is predicted from the monthly anomalies of tropical sea surface temperature, SSS, sea level, freshwater flux, and surface wind stress. The results indicate that sea surface salinity monitoring would have small impact on the statistical nowcast (reconstruction) of ENSO, but having a potential role on the 6-12 months forecasts. When the equatorial variability of the predictors is considered, the SSS has a clearly demonstrated impact for lead times of 7 to 20 months. On the other hand, the results indicate that the relative importance of tropical salinity for prediction may be under-estimated because of the lack of SSS data.

OS41D-50 0830h POSTER

Seasonal Forecast of El Nino using the ECCO Ocean State Estimation with an Adjoint Optimization Approach

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The ECCO ocean state estimation is used to forecast the global seasonal SST variations. Given the observed boundary forcings, SST and TOPEX sea level heights we estimate the optimal global ocean state by an adjoint optimization schema. The optimal ocean state and the boundary conditions corrections obtained by the optimization are use to forecast the evolution of the SST by forcing the MIT-ocean model with a statistical atmosphere model. In order to quantify the skill of our forecast we will analyze the tropical Pacific region. We will present a detailed analysis of the skill of our method and compare our forecast with alternative methods.

OS41D-51 0830h POSTER

Assimilation of Sea Surface Salinity in a Tropical OGCM : a Twin Experiment Approach

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Observing ocean surface salinity by satellite is a challenging issue for next years' oceanographic activities. It is motivated by the active role of salinity that is now well recognized in ocean dynamics and ocean/atmosphere exchanges. This is particularly evident in the case of the ENSO phenomenon in the tropical Pacific Ocean. Improvements of numerical simulations and predictions will mean that salinity observations must be taken into proper account in conjunction with temperature and altimetric data. The sensitivity of a primitive equation model of the tropical Pacific Ocean to Sea Surface Salinity (SSS) is studied through the use of a data assimilation technique in the rather academic "twin experiment" context. The data assimilation technique used, the SEEK filter, is derived from the conventional Kalman filter theory. Our study explains why such a sophisticated technique is necessary. Indeed, an empirical method such as the Newtonian relaxation method, used in the same conditions, fails to constrain both the observed (surface) variable and the other components of the state vector. Within the experimental context chosen, the assimilation of SSS data with the SEEK filter is able to constrain most of the model variables linked with the SSS signal. SSS information in particular appears relatively successful in restoring zonal velocity, which is an important variable in fresh pool migration, and in simulating a barrier layer in the convergence zones. The final analysis errors remain minor and stable over time. This is widely true when simulating satellite SSS observations based on the GODAE criteria (0.2 psu error, 200km, 10days), which shows the potential of these observations. To extend these results to a real context, the problem of model-data bias and unknown error covariances must be addressed as they are actually a strong limitation in assimilation performance when assimilating any real data set.

OS41D-52 0830h POSTER

Data Assimilation to Correct Wind-Stress Forcing Errors in the Tropical Pacific

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Ocean temperature analyses in the tropical Pacific are produced assimilating in situ temperature observations into an OGCM (OPA) using the incremental formulation of a four-dimensional variational (4D-Var) method. The 4D-Var scheme includes surface boundary conditions as control variables to allow correction of wind-stress forcing errors. This approach enables us to account for high-frequency wind-stress variations such as wind bursts which have not been captured in the atmospheric forcing fields.

The original version of the 4D-Var scheme treated the ocean initial conditions as control variables. In the current assimilation scheme, a wind-stress error term has been added to the cost function. Instead of the initial conditions, this scheme controls the surface boundary conditions. The formulation of the background error covariance for the forcing fields is based on an analysis of the spatial and temporal structure of forcing errors of different wind products (ERS, NCEP, ECMWF).

Identical twin experiments are conducted to test the assimilation scheme and to study the impact of forcing corrections on the ocean analysis in the tropical Pacific. Special attention is paid to equatorial wave dynamics and their relation to wind stress variations.

OS41D-53 0830h POSTER

How Accurate Are Equatorial Upper Ocean Currents Computed With a Model and Data Assimilation?

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At the equator, the vanishing Coriolis frequency eliminates the geostrophic balance. How then to describe monthly mean zonal currents at the equator? In situ upper ocean current observations are sufficiently accurate for the task. However, during 1996-1998 only 5 current measurement sites (147E, 165E, 170W, 140W, 110W) were maintained by the ENSO Observing System along the 17,000-km width of the equatorial Pacific Ocean. To describe currents elsewhere along the equator requires an ocean model and data assimilation system, i. e., numerical ocean analyses. Several tests were made to evaluate 1996-1998 monthly mean zonal currents computed at the National Centers for Environmental Prediction, in which surface and subsurface temperature measurements were assimilated into version 3 of the Geophysical Fluid Dynamics Laboratory modular ocean model. Computed and observed currents are compared. In April 1997 when a big Kelvin wave occurred, assimilation of temperature data provided a tremendous improvement in the vertical distribution of zonal current, i. e., u(z), at 140W and 110W. In addition, data assimilation improved the 36-month mean u(z) at 147E. However, addition of temperature data reduced the representativeness of the computed mean u(z) at 165E and 110W and had no impact at 170W and 140W; at each of these four sites the observed vertically integrated mean u(z) was greater than the computed current. With regard to temporal variability, data assimilation reduced the difference between the computed and observed depth-averaged standard deviations at 165E, 170W and 140W, which illustrated a positive influence of data assimilation; at 147E and 110W, data assimilation created too much variability in the computed currents. The depth-averaged root-mean-square (rms) difference between observed and computed currents revealed an impact of data assimilation at only 110W, where data assimilation increased the rms difference. How to create computed currents more representative of observations is the subject of ongoing numerical experiments (e. g., salinity, sea surface topography, winds), which will be described.

OS41D-54 0830h POSTER

The Time-Dependent Heat Budgets of the Tropical Warm-Water Pools

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Heat exchanges between the warm water pools of the tropical oceans and the overlying atmosphere play a central role in the evolving climate system of the earth. In 1982, Niiler and Stevenson and Walin considered the time mean heat budgets for these pools by analyzing volumes bounded by mean isotherms. So expressed, mean advection in and out of such control volumes do not contribute to the budgets; mean balance is achieved between air-sea exchange and fluxes across the bounding isotherm (chiefly by turbulence and penetrative short-wave radiation). Here we explore the time-evolving heat budgets of the warm-water pools with the goal of documenting the time-varying exchanges between the warm pools and atmosphere, and diagnosing the ocean heat fluxes escaping the pools on seasonal to interannual time scales. Integrating the heat equation over a time-varying ocean volume defined by a selected potential isotherm results in an equation relating the time rate of change in the pool's heat content to the rate of change in its volume, and the time-varying heat fluxes through the pool's bounding surface. Advection terms do not explicitly appear in this quasi-Lagrangian approach. Surface flux climatologies provide estimates of the time-varying air-sea exchanges and ocean temperature data are analyzed for pool volume, depth and heat content; the time-varying turbulent flux across the control volume is obtained as a residual (together with the accumulated errors).

We began by examining the seasonal cycle based on the Levitus *et al.* WOA98 monthly climatology. Several air-sea flux products were examined; because the SOC and untuned COADS products yielded more physically reasonable estimates of the diagnosed ocean heat flux, we adopted these. Seasonally, the Atlantic's 27^o C warm-pool heat content is maximum in September and minimum in January. In contrast, the Indian pool ($\theta >= 28^oC$) has maximum content in April and minimum in September. The Pacific 28^oC pool has minimum content in January-March with an extended maximum in April-November. These differences are related to the different geometries of the basins and warm pool locations and the respective seasonal surface forcing patterns. The dominant balance in the seasonally varying heat budgets of these warm pools is between the annual variation of air-sea exchange and the time-varying heat storage; the inferred turbulent heat flux is relatively steady in time, consistent with an effective vertical diffusivity of around 1 $cm^2 s^{-1}$. Interannual variations in the warm pools were quantified using available monthly temperature climatologies (Carton *et al.*; White *et al.*). These reveal marked interannual changes in pool volumes and heat content on ENSO and longer time scales with complicated phasing relative to the Southern Oscillation Index. Our ability to diagnose the varying turbulent heat fluxes on these time scales was impeded by incompatible air-sea flux estimates; none of the numerical weather model based monthly surface flux climatologies that we examined consistently yielded down gradient ocean heat fluxes when analyzed in conjunction with these ocean temperature climatologies. Though disappointing in the

short term, we suggest that time-dependent warm pool heat budget analysis constitutes a powerful diagnostic for validating future air-sea flux climatologies.

OS41D-55 0830h POSTER

Variability of the Tropical Western Hemisphere Warm Pool

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The paper describes and examines variability of the tropical Western Hemisphere warm pool (WHWP) of water warmer than 28.5°C. The WHWP is the second-largest tropical warm pool on Earth. Unlike the western Pacific warm pool, which straddles the equator, the WHWP is entirely north of the equator. At various stages of development the WHWP extends over parts of the eastern North Pacific, the Gulf of Mexico, the Caribbean, and the western tropical North Atlantic. It has a large seasonal cycle and its interannual fluctuations of area and intensity are significant. Surface heat fluxes warm the WHWP through the boreal spring to an annual maximum of SST and WHWP area in the late summer/early fall, associated with eastern North Pacific and Atlantic hurricane activities and rainfall from northern South America to the southern tier of the United States. Observations suggest that a positive ocean-atmosphere feedback operating through longwave radiation and associated cloudiness is responsible for the WHWP SST anomalies. Associated with an increase in SST anomalies is a decrease in atmospheric sea level pressure anomalies and an anomalous increase in atmospheric convection and cloudiness. The increase in convective activity and cloudiness results in less longwave radiation loss from the surface, which then reinforces SST anomalies. Both the Atlantic Walker and Hadley circulation cells show seasonal and interannual variations, associated with the WHWP.

OS41D-56 0830h POSTER

The Tropical Atlantic Upper Layer Circulation As Observed From Satellite And CLIVAR In Situ Measurements

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Ten years of TOPEX/Posdon altimeter sea level anomalies together with CTD, XBT, XCTD and ship-mounted ADCP data are used to investigate the variability of the upper layer circulation in the tropical Atlantic ocean between 1992 and 2000. Analysis of transports are also depicted, especially in the North Equatorial CounterCurrent area.

OS41D-57 0830h POSTER

The North Brazil Current Rings Experiment. Results from the inverted echo sounders array

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The Atlantic Meridional Overturning Circulation (MOC) of the global ocean is an important component of the Earth climate system because it accounts for a substantial fraction of the global meridional flux. Despite its small size, the Atlantic Ocean is responsible for over half of the heat transport carried by the global ocean. Cold, dense North Atlantic Deep Water is convectively formed at high latitudes and exported southward across the equator into the southern oceans. Most of this water eventually leaves the Atlantic basin and is replaced by warm water that flows northward across the equator. Modeling, observational and paleoclimatic studies demonstrate that this circulation is largely responsible for the importance of the North Atlantic Ocean circulation in the regulation of global climate. One of the major players in the inter-hemispheric transfer of mass and heat are the North Brazil Current, the western limb of the tropical gyre, and the rings shed at its retroflection. NBC ring shedding was thought to account for as much as one-third of the net warm water transport across the equatorial-tropical gyre boundary into the North Atlantic in compensation for the southward export of North Atlantic Deep Water. In order to study the precise mechanisms which contribute to NBC ring formation, the structure and dynamics of the rings themselves, and the role that they play in the inter-ocean exchange of heat and salt, and extensive field program started in November 1998 and ended in June 2000. Four hydrographic/velocity cruises took place during that period. An extensive array of moored instruments (14 inverted echo sounders, 1 current meter mooring and 1 CMM/CTD mooring) was deployed and recovered. Surface drifters were satellite tracked. RAFOS floats at different depths were launched and tracked acoustically. Altimeter data was collected to complement the observations. This presentation will focus in the results from the ship surveys and the inverted echo sounders array. The dynamic height field created from the IES time series allowed us to map in time and space the variability of the region. A total of 11 rings were observed and their shedding is correlated with the intensity of the NBC transport. Estimates of mass and heat transport by the rings indicate that the rings may carry more than one half of the MOC.

OS41D-58 0830h POSTER

Equatorial and Off-Equatorial Regime and Rossby Solitons Observed by Topex Altimeter

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Using nine years of Topex observations, a detailed statistical characterization of major components of equatorial Pacific dynamics on timescales a few months to a few years and spatial scales from about 600 km and longer is presented based on 2D spectral analysis of ungridded sea surface height (SSH) measurements. A wide variety of zonally propagating components of SSH variability, as well as non-propagating (steric-related) variations are quantified in the wavenumber-frequency plane. In addition to well known types of oscillations (at semi-annual, annual, and biennial timescales), we find considerable energy in baroclinic modes with periods seven to nine months, at about 1.5 years, and at certain inter-annual timescales. Meridional variations of amplitudes, phase speeds and other properties of wave systems are analyzed, and contributions of individual vertical and lateral modes are estimated. The analysis confirms an earlier finding that some of these systems represent equatorial solitons or modons. To better understand relationships between equatorial and extratropical oscillations, a 3D analysis of SSH variations at higher lats is also provided, which reveals a substantial meridional component in the wave velocity vector.

OS41D-59 0830h POSTER

Summer 2001 in the Eastern Pacific North Equatorial Countercurrent

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The North Equatorial Countercurrent (NECC) represented an enigma in equatorial oceanography until Sverdrup proposed a theory in 1947 that predicted a relatively weak and diffuse NECC flowing eastward against the prevailing winds. Recent drifter observations however, suggest a much narrower and more intense NECC that exhibits a strong seasonal modulation. In the summer of 2001 we decided to revisit the NECC in the eastern Pacific Ocean, executing a modern observational challenge to test the basic assumptions of the Sverdrup theory. Here we outline the survey strategy of our 6-week field campaign in June-July (a time of seasonal maximum eastward flow in the NECC) and discuss the large scale context for our observations. The regional satellite wind field shows the equatorial winds in the Intertropical Convergence Zone (ITCZ) shifting towards the north in May 2001, signaling the onset for the spinup of the NECC. The shipboard winds are of variable intensity, although primarily with a northward component, that drives a highly-variable surface Ekman flow. Perhaps having a more visible impact on our field results, particularly so in the surface drifting buoys, were winds that occurred to the east of our survey area in mid-June. These remote winds may have been related to order 500km anticyclonic disturbances in the NECC; the time scales were comparable to both the local inertial period and the typical periods of tropical instability waves. With the aid of satellite SST data we attempt to determine the nature of these oscillations. While the presence of strong transients may somewhat complicate our interpretation of the Sverdrup-type dynamics of the NECC flow during the time of our survey, we embrace the challenge and share some of our exciting preliminary results and expectations for future analysis.

OS41D-60 0830h POSTER

Three-dimensional Dynamics of Equatorial Subsurface Countercurrents

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The Subsurface CounterCurrents are permanent, symmetric, eastward countercurrents which are observed near 3 degrees in latitude in both Pacific and Atlantic equatorial oceans. They are the location of an important front of Potential Vorticity (PV). These jets are the poleward limits of the 13°C thermostad, which coincides with a near-zero PV region. It has been recently shown that these eastward jets result from an angular momentum redistribution within oceanic Hadley cells, which are forced by the equatorward shoaling of the thermocline. Here, we show the dependence of the jets' strength on the meridional thermocline slope in a three-dimensional high-resolution Primitive Equations model of the ventilated thermocline. PV fluxes, which govern (i) the dynamics of the inertial jets and (ii) mixing of PV and of all tracer fields within the oceanic Hadley cells, are diagnosed.

THU

OS41D-61 0830h POSTER

Southern Hemisphere Origins of Tropical Pacific Decadal Variability

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The structure and predictability of ENSO is highly affected by low frequency changes in the tropical Pacific Ocean. There is substantial evidence that a shift in the climate of the tropical and subtropical Pacific Ocean occurred in 1976-1977, followed by a period of more frequent and more intense El Niños. The origin of tropical Pacific decadal variability has largely been associated with the North Pacific. Recent modeling efforts indicate the tropical south Pacific plays an important role in the onset of climate changes such as the one in 1976. These model results also suggest a return to pre-1976 conditions may have begun in the mid-1990's.

A global ocean general circulation model with the Simple Ocean Data Assimilation (SODA) package run from 1948 to near present is used to investigate subsurface changes in the tropical and subtropical Pacific. The model assimilates surface and subsurface (XBT/MBT) temperature observations and is forced with the National Center for Environmental Prediction (NCEP) weekly reanalysis winds. Salinity is updated using a historical T/S relationship.

Subsurface temperature anomalies are used to investigate changes in the water column associated with decadal variability. In 1973, a negative anomaly appears between 10°S-20°S and 160°W-140°W that propagates to the western boundary and, in 1976, enters the equatorial undercurrent where it surfaces, altering sea surface temperatures. This negative anomaly persists in the tropical south Pacific through the mid 1990s. A similar pattern, with opposite sign, is observed to grow and intensify between 15°S-25°S and 170°W-140°W during the late 1990's. This positive subsurface anomaly may indicate a return to pre-1976 conditions.

OS41D-62 0830h POSTER

Processes Underlying Seasonal Chlorophyll Variability in the Tropical Pacific

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Since it began operation in September 1997, the SeaWiFS ocean color sensor has observed great variability in surface chlorophyll concentrations in the tropical Pacific. Seasonal variation emerges as an important mode of variation in EOF decomposition of nearly 4 years of monthly mean SeaWiFS chlorophyll between 10°N and 10°S. The first EOF mode, describing El Niño, accounts for 41% of the variance. The second mode, accounting for 15% of the variance, describes the seasonal cycle that is out of phase between waters on and near the equator (approximately 5°S to 4°N) and adjacent waters poleward of this latitude range. Seasonal variability defined by this mode is greatest along and north of the equator. In near-equatorial waters, positive chlorophyll anomalies of the seasonal mode peak during July-September. Poleward of this region, the out-of-phase seasonal chlorophyll anomalies peak during February-April. EOF decomposition of TOPEX sea surface height (SSH) shows similar spatial and temporal variation in the third EOF mode (10% of the variance) that describes seasonal variability. The relationship between seasonal variation in chlorophyll and SSH defined by EOF decomposition is peak seasonal chlorophyll during minimum seasonal SSH in both regions, consistent with the importance of thermocline depth to nutrient supply to the euphotic zone. Using satellite sea surface height and temperature, scatterometer winds, moored observations from Tropical Atmosphere Ocean (TAO) array, and numerical model simulations of the tropical Pacific using the Regional Ocean Modeling System (ROMS), we examine seasonal and spatial variation in processes influencing euphotic zone nutrient supply from the nutricline.

OS41D-63 0830h POSTER

CLIVAR in the Pacific Ocean

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Coupled atmosphere/ocean processes across the Pacific Ocean region exhibit perhaps the most pronounced interannual to decadal variability on the earth, and have a profound influence on climate around the Pacific rim and over the entire globe. The processes responsible span a range of time and space scales including phenomena such as ENSO, Indo-Pacific Decadal Variability and the Asian-Australian Monsoon system. There has been significant progress in understanding Pacific ocean variability and its influence on climate but there are many problems still to be solved. Essential for a better understanding and prediction of Pacific basin phenomena are observation systems and state-of-the-art models which will enable timely availability of high quality oceanographic and atmospheric data for monitoring and forecasting. The key to success in this enterprise is the coordination of international plans through the exchange of information.

The CLIVAR international research programme brings together oceanic and atmospheric scientists from the Pacific nations. It provides an umbrella for the international implementation of Pacific sector observations and modelling efforts with the goal of advancing our knowledge of the role of the Pacific ocean in global climate change. Strong collaboration with other international programs such as IGBP provides important link to bio-geochemical climate applications and the social impacts of climate change. The poster will summarise the present status of climate-relevant Pacific observations and highlight the need for an internationally co-ordinated approach.

OS41D-64 0830h POSTER

A New FSU Winds and Flux Climatology

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An objective technique is used to create a new monthly climatology for surface fluxes and related fields. The wind (pseudostress) products are improvements over the subjectively analyzed FSU winds. Fields of turbulent surfaces fluxes and the variables needed to calculate these fluxes are also generated. The fields are created through minimization of a cost function, which maximizes information from the observational data and minimizes smoothing. This approach ensures internal consistency between the turbulent fluxes and the related fields. Comparisons are made between the new FSU fields (based on volunteer observing ships and buoy observations), the old subjective FSU fields, individual TAO buoys, the DaSilva climatology (the background for the objective technique), the NCEP reanalysis, and fields based solely on the SeaWinds scatterometer observations.

The new (objective) FSU wind fields have stronger convergence zones (the ITCZ and SPCZ) as well as better zonal resolution. An ocean model, forced with a preliminary release of the winds, produced much more realistic currents than when forced with the old FSU winds. The new wind and flux products will be discussed.

OS41D-65 0830h POSTER

On the Search of a Statistical Correlation Between Tropical Pacific SST and Southeast U.S. Precipitation

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Previous studies have examined correlations between Tropical Pacific SSTs and US precipitation amounts. Correlations have been found on monthly, seasonal, and inter-annual time scales. However, many studies consider only the Western and Central parts of the country, an area that is directly affected by ENSO teleconnections. This study focuses on Southeast US precipitation and its correlations with Tropical Pacific SST at various time scales. Correlations were derived statistically between mean SSTs and mean precipitation amounts on monthly, seasonal, and annual time scales. Linear regressions were fit to better examine these correlations. Lack of fit tests, hypothesis testing, and confidence intervals were done to analyze the regression models. In addition, residual analyses were performed and are displayed graphically. Furthermore, a CCM3 model run was performed to determine how well the model simualtes observed SST and precipitation amounts. Finally, it was used to investigate precipitation pre-cursors, such as humidity, latent heat flux, and cloudiness.

OS41E HC: Hall III Thursday 0830h

Oceanic Internal Tides II

Presiding: **D Luther,** University of Hawaii at Manoa**; M A Merrifield,** Department of Oceanography, University of Hawaii at Monoa

OS41E-66 0830h POSTER

Theoretical Expression for an Ocean Internal Soliton Synthetic Aperture Radar Image and Determination of the Soliton Characteristic Half Width

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This study deals with the development of techniques for satellite synthetic aperture radar (SAR) ocean image interpretation. We derived a theoretical model of a radar image for a Korteweg-de Vries type ocean internal soliton and validated the model using ocean internal wave signals taken from ESR-1 SAR and RADARSAT SAR images. The results indicate that the model perfectly simulates ocean internal soliton signatures with double-sign variations of radar backscatter. On the basis of the model, we developed the curve fitting method and the peak-to-peak method for determining the internal soliton characteristic half widths, which then were used to calculate the internal soliton amplitudes. The test results indicate that ocean internal soliton amplitudes derived by the two metnods agree with in situ data acquired on the Portuguese Continental Shelf and in the South China Sea with reasonable accuracy. The role that wind fields play in ocean radar remote sensing was also analyzed.

OS41E-67 0830h POSTER

The Role of Internal Tides in Mixing the Deep Ocean

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Internal wave theory is used to examine the generation, radiation, and energy dissipation of internal tides in the deep ocean. Estimates of vertical energy flux based on Bell's (1975) linear model are adjusted to account for the influence of finite depth, varying stratification, and lateral variations in topography and tidal currents. Finite amplitude corrections to the linear model are also examined. Estimates along the Mid Atlantic Ridge in the South Atlantic Ocean suggest that the vertical energy flux of the M_2 internal tides is 3-5 mW m^{-2}. A small fraction of the energy flux, 1-2 mW m^{-2}, is generated at spatial scales less than 10 km, and this may dissipate locally as turbulence. Most energy, however, is generated as low modes associated with spatial scales of 20 to 100 km. The Richardson number of the radiated internal tide typically exceeds unity for these motions, so direct shear instability of the generated waves is not the dominant energy transfer mechanism. Wave-wave interactions are also ineffective at transferring energy from the large wavelengths that dominate the energy flux. Radiated low modes are likely influenced by topographic scattering, though general topography scatters less than 10% of the low mode energy to higher wavenumbers during each reflection. Thus, it appears that most low mode energy is radiated over O(1000) km distances, possibly contributing to mixing at locations far away from generation sites.