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The major forcing for models of coastal sediment transport is derived from the waves. Typical 2-D and 3-D numerical model will take wave conditions at an offshore boundary and shoal the waves across the model domain through the application of a wave transformation model. The resulting wave characteristics then enter into the flow dynamics largely through radiation stress and bottom stress terms. Due to their contribution to bottom stress terms, they are also fundamental in sediment dynamics. As the wave transformation models utilized in this type of scenario are solved at each grid point, they are typically applied at relatively fine space scales, O(m). This is in contrast to the larger scales, O(km), over which such models are tested and validated. Similarly nearshore circulation models are typically validated on simulated geometries with idealized bathymetry. Thus the adequacy of existing wave transformation models for inclusion in models of coastal sediment transport is poorly tested.

In order to investigate this problem, standard wave transformation models have been run on real straight coast bathymetry with a grid spacing of 10m. Uniform waves are input on the seaward boundary and shoaled up to the break point. The results indicate remarkable longshore variation in both amplitude and incidence angle. To illustrate the significance of the longshore variability, the results are fed into a simple one-dimensional longshore current model. In this straight coast environment, the predicted longshore currents vary by a factor of 4. This result highlights the strong level of variability input into coastal sediment transport models by such wave transformation schemes. To further understand the source of this variability, the role of input spectral shape is investigated. The importance of different aspects of shoaling physics is also examined through the selective inclusion of wave interactions and wave diffraction. A comparison with field data will also be performed in order to estimate how real is the variability.

OS21K HC: 319 B Tuesday 0830h

Indian Ocean and Indonesian Throughflow Variability From Models and Observations III

Presiding: **R Murtugudde,** ESSIC/Univ of Maryland**; J T Potemra,** University of Washington

OS21K-01 0830h

The Indonesian Throughflow [ITF]: how Warm is it? Where Does it go?

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Temperature and ocean current time series obtained within the Makassar Strait from December 1996 to July 1998 are used to calculate ITF heat transport and to assess its influence on Indian Ocean heat divergence. The transport weighted temperature of the flow through Makassar Strait, which is the ITF primary channel, is approximately 15C. The mean heat transport averages 0.55 PW relative to 0C, and 0.41 PW relative to 4C. Heat transport appears to vary with ENSO phase, lower during El Nio, higher during La Nia. In the Indian Ocean, ITF water within the thermocline is advected westward by the South Equatorial Current (SEC), near 12S. Upon reaching the western boundary the SEC bifurcates. The fate of the north turning component varies with season. In the boreal summer, the Somali Current transports ITF water well into the northern hemisphere. However, some ITF thermocline water turns eastward before reaching the equator, entering the South Equatorial Counter Current (SECC) near 5S. The SECC and SEC form the Southern Equatorial Gyre, within which summer Ekman induced upwelling transfers ITF water from the thermocline into the surface layer, to eventually be transferred to the south. In winter the SECC route at 5S persists, though the Somali Current reversal prohibits spreading across the Equator. The southward flowing limb of the SEC bifurcation persists throughout the year. ITF thermocline water passes through the Mozambique Channel towards the Agulhas Current. For realistic consideration of the ITF component within the Agulhas Current, the heat flux divergence of ITF waters within the Indian Ocean north of 30S is found to be insignificant. Our results provide support for model studies and hydrographic geostrophic inverse calculations that indicate the ITF heat, derived from the Pacific Ocean, is ultimately lost to the atmosphere in the southwest Indian Ocean.

OS21K-02 0845h

Teddies and the Origin of the Leeuwin Current

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The outflow from the Indonesian Seas empties approximately 57 Sv of surface Indonesian Throughflow water into the southern Indian Ocean (at roughly 12S). Using an analytical nonlinear one-and-a-half-layer model, it is shown that, immediately after emptying into the ocean, the outflow splits into two branches. One branch carries approximately 13 percent of the source mass flux and forms a chain of high amplitude anticyclonic eddies (lenses) immediately to the west of the source. The second branch carries the remaining 87 percent of the mass flux via a coastal southward flowing current. These results are in agreement with numerical simulations. It is suggested that the eddies recently observed to the west of the Island of Timor are a result of the above eddies generation process and that our new nonlinear process also explains why some of the Indonesian Throughflow water forms the source of the Leeuwin Current.

OS21K-03 0900h

On the Splitting of Main Currents in the Indonesian Seas

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A regional baroclinic model of the Indonesian Seas circulation, based on the Princeton Ocean Model, has been developed. Fifteen levels in the vertical has been chosen to resolve the vertical structure of the circulation. The horizontal resolution of about 10km provides a sufficiently accurate description of the bottom topography in the area. Four ports were introduced to simulate the Mindanao Current inflow into the region; the North Equatorial Counter Current outflow to the Pacific; the North Guinea Coastal Current inflow into the region; and the resultant outflow to the Indian Ocean. The normal velocity at the ports was specified parametrically using a simple distributions in the vertical and horizontal directions. The parameters were adopted in such a way to make these distributions compatible with observations. The tangential velocity at the ports was prescribed zero. The action of local winds is easily incorporated into the model. The temperature and salinity at the ports are taken from the Levitus data.

The results of barotropic experiments showed that the splittings of simulated currents between the Lombok Strait and the Flores Sea and between the Makassar Strait and the Malucca Sea differ substantially from the splitting schematics based on the analysis of observations. The analysis of baroclinic experiments is presented to reveal the influence of baroclinicity on the structure of splitting patterns. The effect of local winds is studied as well.

OS21K-04 0915h

Model of Kelvin Wave Transmission Through a Strait: Application to Lombok Strait

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Observations have shown that Kelvin waves generated in the equatorial Indian Ocean and propagating down the Indonesian coast can significantly impact the branch of the Indonesian Throughflow passing through the Lombok Strait. However, the extent to which these waves can impact the straits further down the coastal waveguide is still uncertain. A $1\frac{1}{2}$-layer numberical model study by Qiu et al. (1999) showed virtually all of the Kelvin wave energy in the 30-85 day intraseasonal band propagating through the Lombok Strait, even though the model strait had a width of only $\frac{1}{3}$ of the local Rossby radius R. More than $\frac{1}{2}$ of a Kelvin wave's energy flux is carried by the part of the wave further offshore than $\frac{R}{3}$-how is this energy able to 'squeeze through' such a narrow gap?

A solution for a strait with idealized dynamics and geometry was found using a combination of numerical and analytical techniques. This solution verifies the plausibility of the above phenomenon, while providing physical insight to the cause. The key to understanding is that a Kelvin wave passing from a narrow channel into an open sea will always reflect part of its energy back along the channel. In the case of a strait between two seas, this necessarily sets up a resonance condition similar to the classical optics problem of multiple beam interference. The solution then becomes sensitive to the channel length to wavelength ratio ($\frac{L}{\lambda}$), with a resonance peak near $\frac{L}{\lambda}$=0. In particular, a strait od any width will tend toward 100% transmission as the wave frequency tends to zero, as long as the dynamics remain linear and inviscid. An idealized simlation of the Lombok Strait shows that this limit is indeed approached even in the relatively high frequency intraseasonal band investigated by Qiu et al.

OS21K-05 0930h

Baroclinic structures of the Indonesian Throughflow and the Indian Ocean in numerical ocean models

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The baroclinic structures of the Indonesian Throughflow affect the structure in the Indian Ocean and vice versa. Tally (2001) showed the distinct low sanliity intermediate water from the Indonesian Seas, which is different from the Anterctic Intermediate water in the Indian Ocean. Spall (2001) suggested that dissipation along the west coast of Australia may significantly influence the vertical structure of the Indonesian throughflow and circulation around Australia, and hence the property flux between the Pacific and Indian Oceans. In this study, vertical distribution of the Indonesian Throughflow in association with baroclinic structure in the Indian Ocean is investigated using a layer model and a GCM. Sensitivity to flux, diapycnal mixing, and topography are tested. Diapycnal mixing is especially crucial to the intermediate circulations. Both in the layer model and GCM, there is a deep maximum of the Throughflow transport corresponding to the inflow from the Antarctic Intermediate Water of the Pacific Ocean. This flow forms a zonal jet in the Indian Ocean and separates from the AIW in the southern Indian Ocean. If this deep core is artificially blocked, the AIW from the southen boundary dominates in the Indian Ocean.

OS21K-06 0945h

SST dynamics in the warm water pool of the eastern Indian Ocean

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The warm water pool (where the sea surface temperature (SST) exceeds 28°C) in the eastern Indian Ocean has important implications to monsoonal climate system and its variability. The dynamics governing SST variability on seasonal-to-interannual timescales are investigated by using in situ measurements, satellite observations, and a newly calculated surface flux product. In particular, the study has inferred the relationships between SST and upper ocean thermocline and between SST and satellite sea surface height (SSH). The analysis indicates that SST dynamics in the warm water pool of the eastern Indian Ocean differ from those of the western Pacific Ocean.

OS21K-07 1020h

Heat and Salt Storage Variability In the Indian Ocean from TOPEX/Poseidon between 1993 - 2000

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Estimates of the heat and salt budget computed using TOPEX/Poseidon (T/P) altimetry , Reynolds SST and hydrographic data (World Ocean Atlas; WOA98) are used to study the redistribution of heat and salt storage of the Indian Ocean. The accuracy of derived temperature and salinity is evaluated using hydrographic data collected on WOCE Transindian Ocean Section I1 hydrographic data. Significant seasonal and interannual variability is found in the Indian Ocean Sector. Except the seasonal change in solar radiation and the rainfall, the major ocean processes that affect the heat and salt storage redistribution include monsoon-related upwelling and Ekman pumping, seasonal change of ocean circulation, propagation of Rossby wave and Kelvin wave. Significant interannual heat storage variability could be found during this period (1993 - 2000). EOF analysis shows that the first four EOFs explain nearly 60 % of the total variance of the heat storage variability with the interannual mode to be the first dominant mode. The salt storage variability is not consistent with the heat storage variability, the dominant mode explains 1/3 of the total variance of the salt storage variability in the Indian Ocean. This mode is attributed to the seasonal climate change between hemispheres. The heat and salt storage during the 1997 - 1998 Dipole years are also studied. The significant heat storage change could well explain the dominant heat storage interannual mode. The heat storage anomaly from the regular year during 1997 - 1998 is in the same order of the annual variability of the heat storage variability while the salt storage anomaly is much less than the annual variability of the salt storage.

OS21K-08 1035h

Impact of Intraseasonal Atmospheric Forcing on Eastward Surface Jets in the Equatorial Indian Ocean

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Nonlinear and linear versions of an intermediate ocean model are used to investigate the impact of intraseasonal atmospheric forcing (20–90 day periods) on the eastward surface jets that develop along the Indian Ocean equator during the spring and fall, the Wyrtki jets (WJs). Both the spring and fall WJs exhibit a strong intraseasonal variability, with a perturbation amplitude of 40–60 cm/s during JASMINE period. The intraseasonal fluctuation of WJs is driven primarily by intraseasonal zonal winds, which has a basin scale and possesses a significant seasonality. The intraseasonal winds can cause a lower frequency currents that rectify the WJs strength due to the asymmetric property of the positive and negative phases of the intraseasonal forcing and to the nonlinear response of the ocean to the winds. Strength of the WJs can vary by 10–40 cm/s (10–40 percent of the climatological WJs amplitude) because of the intraseasonal winds, and therefore the basewide heat and salt transport associated with the WJs can be considerably affected. The rectified WJs by the intraseasonal winds may generate variabilities in zonal SST gradients at the equator and therefore potentially influence the air-sea interaction at seasonal-interannual time scale.

OS21K-09 1050h

Observations of the Great Whirl

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The summer monsoon winds blow as a steady, southwesterly jet off Somalia and across the Arabian Sea between June and September each year. This "Findlater Jet" drives a complex pattern of ocean currents, which is dominated in the west by an intense, northward boundary flow (the Somali Current) and a quasi-steady, anti-cyclonic eddy called the Great Whirl. Previous understanding of the structure of the Great Whirl is that of a shallow, surface-intensified feature, although observations, particularly deep ones, are scarce. In addition ship drift data and modelling studies have illustrated the Great Whirl as stationary (once developed), with some interannual variability.

Recent observations have changed these ideas dramatically. Direct velocity measurements have revealed strong currents of order 10 cms^{-1} at 3000 m depth in the Great Whirl, and satellite altimetry has shown intense variability on short time scales. The position and shape of the Great Whirl changes over periods less than 10 days and 30-40 day period fluctuations modify its velocity field. We use these observations, plus GCM simulations, and analogy to process models to gain insight into the possible mechanisms governing the variability and penetration of the Great Whirl. For instance, it is proposed that the Great Whirl is an inertial recirculation of the Somali Current, consistent with observations that the Somali Current dies back with the winds, while the Great Whirl lasts well into November, spinning down only as a result of eddy viscosity. In addition we hypothesise that the Great Whirl itself instigates a Rossby wave mode through its internal instabilities, producing the 30-40 day variability in its velocities.

OS21K-10 1105h

The Agulhas Return Flow as Studied from Altimetry, Hydrography and Mooring Data

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A hydrographic study was carried out in the South West Indian Ocean from 6th January to 21st February, 1995 on RRS Discovery as part of the World Ocean Circulation Experiment. This dynamic region is a poorly surveyed part of the world's oceans. The cruise objectives included: the recovery of eight moorings deployed two years earlier between the Agulhas Plateau and Crozet Island; surveying the Agulhas and Subtropical Fronts between 30E and 50E; and surveying the Subantarctic Zone north of the Crozet Plateau between 30E and 50E. Some sections of the survey track, in particular across the Agulhas Return Current near 45E, were run along TOPEX/POSEIDON altimeter tracks. We examine ocean variability of this region as observed by the altimeter in relation to the hydrographic data collected during the cruise and the long time series mooring data collected during the cruise. We also present an analysis of the combination of remotely sensed data and hydrography as it relates to the dynamics of the ocean fronts in the region.

OS21K-11 1120h

Large-Scale Forcing of the Agulhas Variability: The Seasonal Cycle

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In this presentation we will examine the kinematics and dynamics of the seasonal cycle in the western Indian Ocean from and eddy-permitting numerical simulation. The analysis of the model results indicates that the transport of the Agulhas Current has a seasonal variation with a maximum at the transition between the austral winter and spring and a minimum between the austral summer and autumn. Regional and basin-scale mass balances indicate that although the mean flow of the Agulhas Current has a substantial contribution from the Indonesian throughflow, there appears to be no dynamical linkage between the seasonal oscillations of these two currents. Instead we found evidence that the seasonal cycle of the western Indian Ocean is the result of the oscillation of barotropic basin modes directly forced by the wind.

OS21K-12 1135h

The Seasonal Variability of the South Indian Ocean in POCM and T/P

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In this study we compare the annual cycle of sea surface heights (SSHs) obtained from an eddy permitting global circulation model (POCM-4C) with observations from TOPEX/POSEIDON mission in the South Indian Ocean and for the period 1993 to 1998. The analysis includes model/data comparisons of wave propagation, EOFs, and harmonics. Model and observations compare well except in a narrow region close to the equator where the amplitude and phase of the model anomalies differ from the observations. The westward propagation of SSHs anomalies appear to be affected by the bottom topography, both in the model and in the observations. The amplitudes of the modeled seasonal component are lower than those observed but their spatial distributions compare well. Our analysis indicate that the main forcing for the annual cycle are the wind stress curl and the discharges associated with the Indonesian Throughflow.

OS21L HC: 317 B Tuesday 0830h

Linking Modern and Past Biogenic Fluxes I

Presiding: **R Francois,** Woods Hole Oceanographic Institution**; R A Jahnke,** Skidaway Institute of Oceanography

OS21L-01 0830h

Global Synthesis of Organic, Inorganic Carbon Particles and Opal Fluxes at the Ocean Interior

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We have identified published results/data from 228 individual sediment traps, most of them samples collected in time-series for about one year or more, deployed at 136 locations in the world ocean as of 2001. We estimated the recycling of Corg, Cinorg and Sibio in deep water below 1.5 km by comparing fluxes measured at different depths, after correction for trapping efficiency using a radiochemical method on key samples. By using this relatively coherent export data set we constructed 2^{o}-grid model of the global ocean particle flux at the interior and to the floor, then we estimated the "total global export" of Corg, Cinorg and opal. Finally, by applying global biogeochemical ratios, we propose a hypothesis regarding the provincialism of the biological pump in the global oceans that explains the functional difference and the efficiency in exporting atmospheric CO2-carbon to the oceanic interior. Such oceans functional provincialism at present involves applications to paleoproxy in understanding global change in time and space.

OS21L-02 0845h INVITED

Comparing Productivity Maps from Inverse Modeling with Satellite Based Estimates: Examples from the Southern Ocean and North Atlantic

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