Interocean Exchanges, as Seen in Observations and Models

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LONG-TERM GOALS

The long-term goals are to refine observational based, conceptual models of interocean exchange processes and their larger scale impact, and to investigate their representation in global and regional numerical simulations.

OBJECTIVES

During fy03 two specific aspects of the topic are studied: 1. the velocity and temperature profile of the Indonesian Throughflow (ITF), the ITF impact on the Pacific and Indian Oceans circulation and stratification; and 2. the Agulhas Retroflection and its impact on the South Atlantic.

APPROACH

Observational data to be used include the archived hydrographic stations, satellite-derived data, and the growing base of surface drifter and Argo float data. Models to be used for comparison are: 0.1° POP, ECCO, GFDL, and NRL 1/16 ° NLOM. A series of observational based metrics will be developed that the models must get right. Rather than work directly with model data I will interact with modelers who are familiar with the details and assumptions characteristic of 'their' models.

WORK COMPLETED

1. Gordon 2003 [News & Views] presents a brief overview of the large scale importance of the Agulhas Retroflection and Indian to Atlantic leakage. The influence of the Agulhas system of currents and eddies around southern Africa extends far beyond the immediate region, reaching into the Atlantic meridional overturning circulation.

2. Gordon et al 2003 [in press] discusses the probably mechanism produces a relatively cool transport weighted temperature for the Indonesian Throughflow.

3. The reviews of the Gordon & Giulivi JES paper "Interannual Variability of Sea Surface Height in the Japan/East Sea" were favorable. The revised version is now pending at Deep-Sea Research.

4. In a pair of 'in press' papers [Kamenkovich et al 2003 and Burnett et al 2003] we investigate the balance of momentum and energy within the Indonesian Throughflow.

5. A draft of a paper [Gordon and Giulivi] has been prepared which uses the archived hydrographic data in the SE South Atlantic [Cape Basin] to determine the ratio of cyclonic to anti-cyclonic eddies

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14. ABSTRACT
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15. SUBJECT TERMS

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and associated T/S properties. The surprise is: there are roughly equal numbers of cyclonic and anti-cyclonic eddies and they are compose of Indian Ocean water. There are a few cyclonic eddies composed of South Atlantic water, but not as much as conventional wisdom might suggest.

RESULTS

1. Agulhas Retroflection (Fig 1).

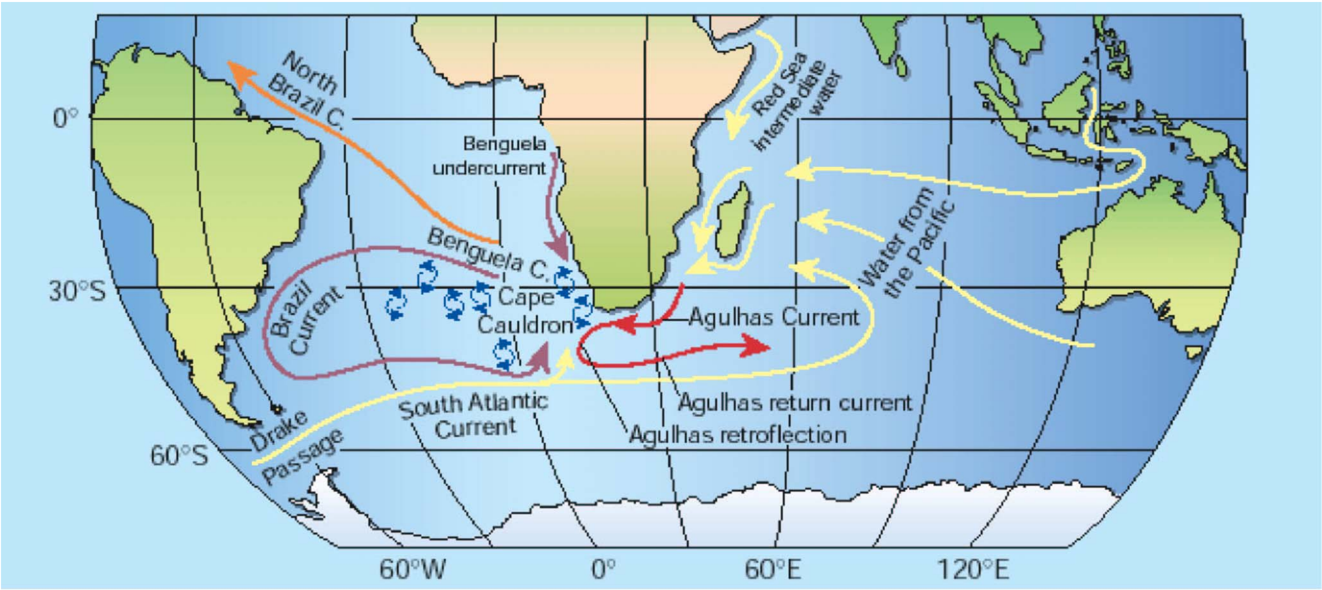

Fig 1 [From Gordon, 2003] The Agulhas system and associated flow patterns. The Agulhas Current draws water from the Pacific Ocean through the Indonesian throughflow and Drake Passage, and from the Tasman Sea. It abruptly turns back towards the Indian Ocean near 20° E. Here, at the Agulhas retroflection, 'leakage' of water occurs within an array of cyclonic (clockwise) and anticyclonic (anticlockwise) eddies that are injected into the vigorous stirring and mixing environment of the Cape Basin. The South Atlantic Current adds water to the cauldron, as does the subsurface flow of the Benguela undercurrent along the west coast of Africa, and salty Red Sea water along the east coast. A blend of these waters spreads into the Brazil and North Brazil currents. The latter is part of the large-scale 'overturning circulation' induced by the formation of North Atlantic Deep Water.

2. Cool Indonesian Throughflow as a consequence of restricted surface layer flow: Approximately 10 million m^3sec^{-1} of Pacific Ocean water pass into the Indian Ocean through the Indonesian seas. Ocean current and temperature measurements indicate that the Indonesian throughflow temperature within Makassar Strait, the primary throughflow pathway, is far cooler than earlier estimates. The Indonesian Throughflow is not 24°C as proposed 20 years ago, but closer to 15°C. Why is the Indonesian Throughflow cool? Ocean current and stratification data with satellite measurement of wind suggest the reason. It appears that the contribution from the warm layer is attenuated (Fig. 2). We find that during the boreal winter monsoon the wind drives buoyant, low salinity Java Sea surface water into the southern Makassar Strait, resulting in a northward surface layer

pressure gradient within the strait, blocking southward flow of warm surface water (Fig 3). The summer wind reversal transfers more saline Banda Sea surface water into the southern Makassar Strait, eliminating the northward pressure gradient. Surface layer retardation obstructs Pacific warm surface water from flowing freely into the Indian Ocean, influencing El Niño characteristics and yielding a cooler Indian Ocean sea surface, which may weaken the Asian monsoon. Coupling of the Southeast Asian freshwater budget to the Pacific and Indian Ocean surface temperature by the proposed mechanism may represent an important negative feedback within the climate system.

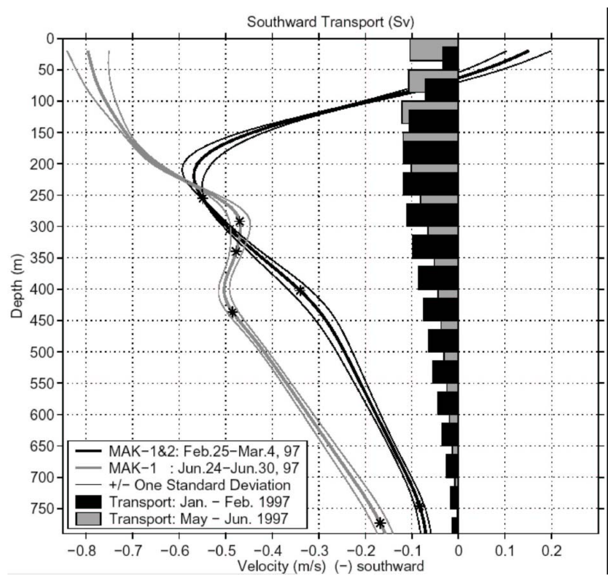

Figure 2 The Indonesian Throughflow is cooler than initially expected because the transport peaks within the thermocline. The very warm surface layer has reduced transport.

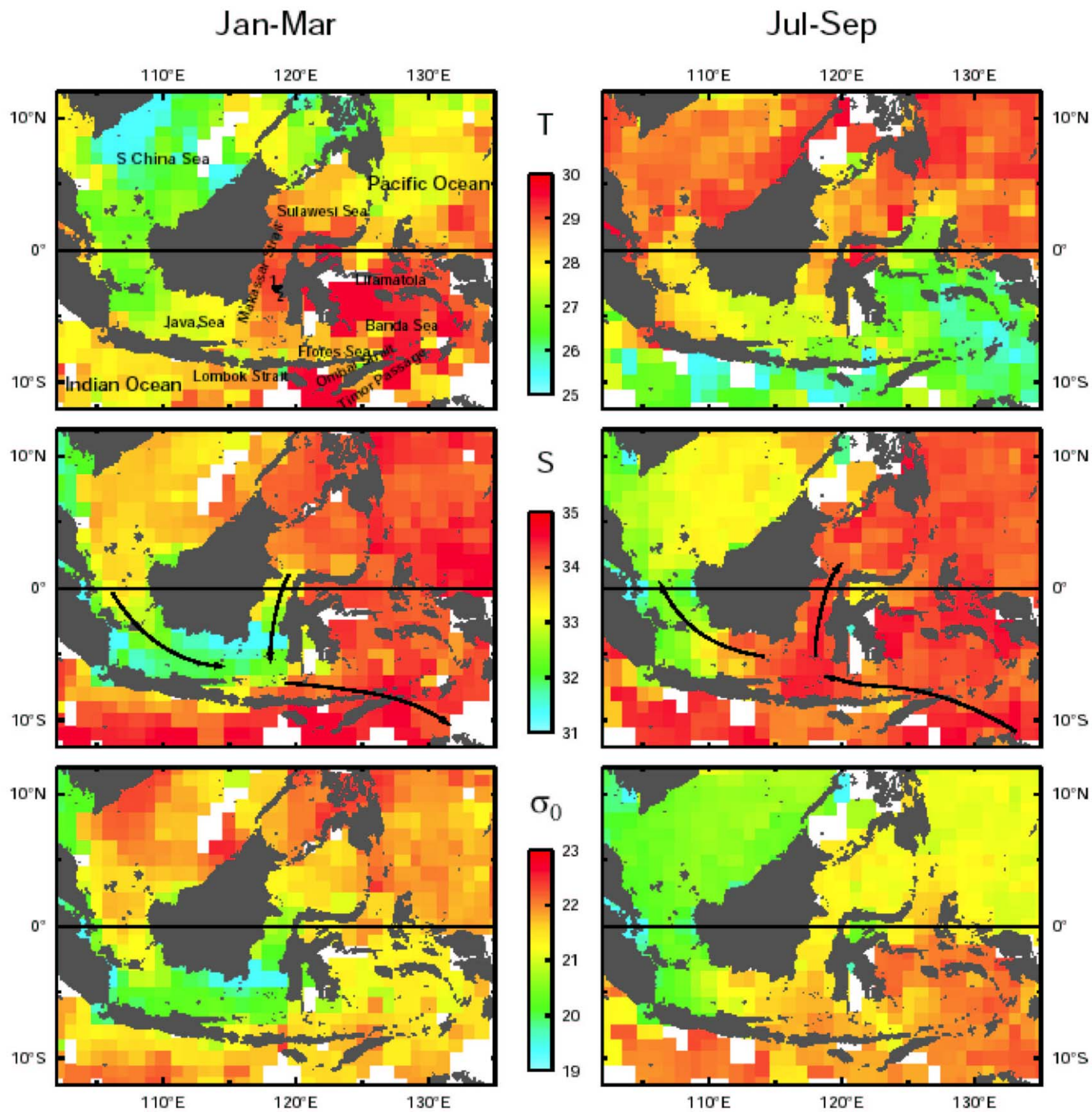

Figure 3: Summer and winter temperature (T), salinity (S) and density (σ-0) of the Indonesian seas, upper 20 m average. The prevailing monsoon winds are shown on the salinity panels; place names and the location of the two Makassar Strait moorings are shown on the January-March temperature panel. On November 23, 1996 the current meter mooring #1 was deployed at 2° 52'S, 118° 27'E in the 2137 m deep, 45 km wide Labani Channel of the Makassar Strait. Mooring #2 was deployed on 30 November just east of MAK-1 at 2° 51'S, 118° 38'E. During northwest monsoon, January to March the Java Sea low salinity surface water shifts into the southern Makassar Strait. During southeast monsoon, July-September the southern Makassar Strait surface layer is more saline, less buoyant, as the southeast monsoon winds return the low salinity water into the Java Sea. The buoyant surface water of the southern Makassar Strait inhibits southward transport within the surface layer during the northwest monsoon, despite southward wind with the Strait, cooling the temperature of the Indonesian Throughflow.

In December I meet with Julie McClean [Naval Postgraduate School] to see if the new 0.1 global model supports the hypothesis of the ITF concept and investigate the consequences to the Indian Ocean.

3. In the Kamenkovich et al 2003 and Burnett et al 2003 papers, we find that the Indonesian Throughflow is controlled to a significant level by local forces, as wind and bottom form stress. While the interocean pressure head does not seem to form a unique relationship to the throughflow, its seasonal variability is in phase with the throughflow.

4. In the Gordon and Giulivi paper [draft form] we determine the ratio of cyclonic to anti-cyclonic eddies and associated T/S properties. The surprise is: there are roughly equal numbers of cyclonic and anti-cyclonic eddies and they are compose of Indian Ocean water. There are a few cyclonic eddies composed of South Atlantic water, but not as much as conventional wisdom might suggest. In January I'll work with Matano [OSU] to combine obs and model data to see if we can trace the pathway of Indian Ocean water in the South Atlantic, and the role of the varied types of eddies in determining the paths.

IMPACT/APPLICATIONS

Cool ITF: The seasonal shift of low salinity Java Sea water into the southern Makassar Strait acts as a "freshwater plug" during the northwest monsoon, which effectively inhibits the Makassar Strait surface water from freely flowing southward. The cool ITF is a direct result of suppressed surface layer flow since deeper, colder layers then dominate the full-column transport. During the southeast monsoon the "freshwater plug" is removed, allowing southward transport in the surface layer, though northward wind is expected to hinder this effect. Changes in the freshwater budget of the western Indonesian seas and Southeast Asian monsoon winds would be expected to alter the intensity of the "freshwater plug." Greater amounts of freshwater expelled from the Java Sea into the southern Indonesian seas would induce a colder ITF (lesser amounts warmer ITF). As the regional precipitation changes with the phase of ENSO, Asian monsoon and at longer temporal scales, the ITF temperature may adjust accordingly. A strong "freshwater plug" would reduce transfer of the western Pacific's warm pool into the Indian Ocean, with potential feedback to ENSO. The Indian Ocean surface layer would receive less Pacific heat, affecting its surface temperature and altering the pattern of heat and water vapor exchange with the atmosphere, presumably influencing the Asian monsoon and Indian Ocean dipole. Freshwater inflow to the South China Sea may be used as a predictor of near future monsoon behavior [maybe ENSO too].

RELATED PROJECTS

An international co-operative effort known as the International Nusantara Stratification and Transport (INSTANT) program is planned to study the velocity, temperature and salinity of the ITF through simultaneous mooring deployments in both the inflow and outflow passages. INSTANT is a co-operative program involving Indonesia, United States, Australia, France and the Netherlands.

PUBLICATIONS

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Burnett, H.W., V.M. Kamenkovich, A.L. Gordon, and G.L. Mellor (2003) Part I: The Pacific/Indian Ocean Pressure Difference and its Influence on the Indonesian Seas Circulation. J. Mar. Res. (in press).

Gordon, A. L. and C. F. Giulivi [2003] Pacific Decadal Oscillation and Sea Level in the Japan/East Sea. Submitted to deep-sea res (under review)