Title
Tracking water movement to and from the ocean surface.

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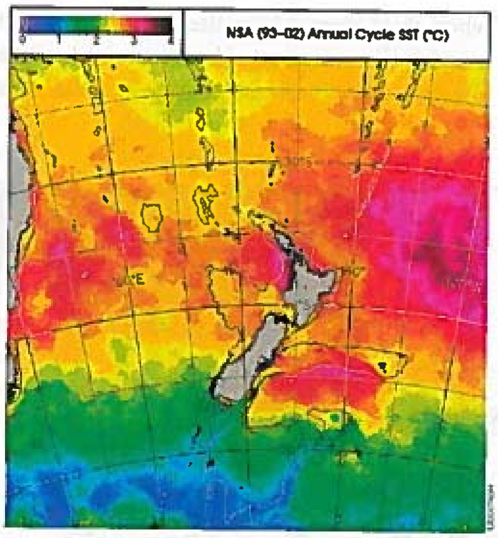


Fig. 2. Amplitude of the NSA annual cycle derived by an independent harmonic decomposition at every analysis grid point and mapped as an image. The 1000-m isobath is indicated.

features leads to more spatially uniform amplitudes. Exceptions are also evident, such as in the sub-Antarctic watermass south of the Chatham Rise, where the annual cycle displays an uncharacteristically large signal (and early phase), perhaps due to early summer stratification of the water column or advection of subtropical waters over the Chatham Rise. (A concomitant analysis of monthly mean chlorophyll-a data from the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) mission, lends some support to the advection suggestion.) Regardless of the explanation, though, the spatially varying features evident in SST data are robust and appear in climatologies derived from both 5 and 10 years of data.

SST data also allow testable hypotheses to be posed. For example, the location of the Sub-Tropical Front (STF) east of New Zealand is still unknown, but the NSA suggests that it dips southward east of the Chatham Rise. Recent research voyages have found evidence to support this hypothesis.

A comparison of the NSA and NOAA Pathfinder SST reanalysis datasets indicates that the former is warmer (mean difference over the region is 0.216°C), but the location and magnitudes of all features, including those in the highly varying Antarctic Circumpolar Current (ACC), are identical. Given the difference in resolution of the Advanced Very High Resolution Radiometer (AVHRR) data sources utilized (4 km for Pathfinder, 1 km for NSA) and the completely different cloud-detection methods employed in the Pathfinder (decision tree) and NSA (Bayesian) data, this is an encouraging result.

Last, while some evidence of ocean warming has previously been reported in this region, a watermass-dependent analysis of SST anomalies over the region, and the period 1985 to the present, reveals only ENSO-related climate signals. There is no evidence of ocean warming.—Michael J. Uddstrom (National Institute of Water and Atmospheric Research). *"Ten Years of High-Resolution Sea Surface Temperatures—What Have We Learned?"*

TRACKING WATER MOVEMENT TO AND FROM THE OCEAN SURFACE

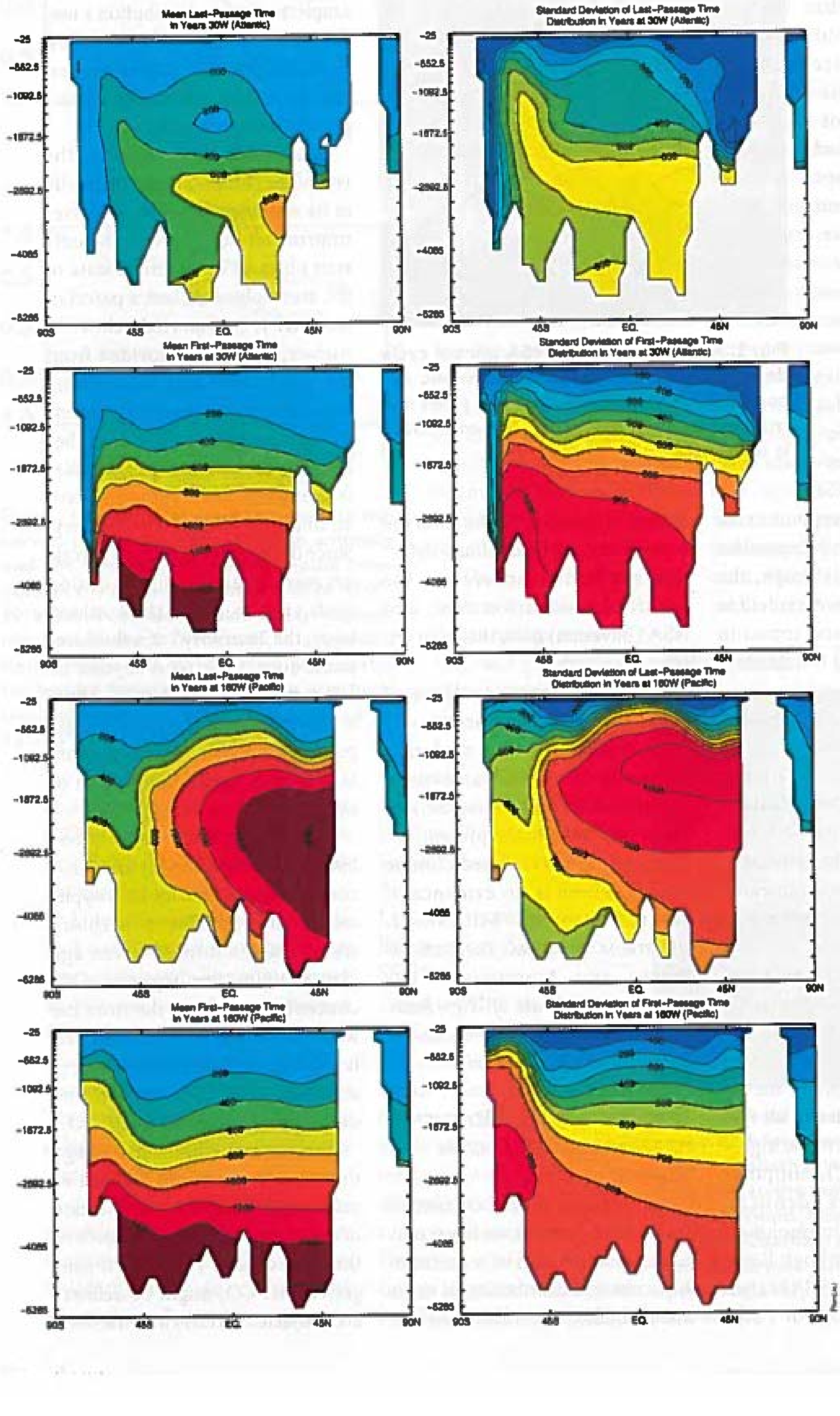
Using an ocean general circulation model and its adjoint, we have computed, as a function of location in the ocean, the distribution of times when fluid elements made their last, as well as when they will make their first, contact with the surface mixed layer. Varying atmospheric conditions, under climate change for example, make this distribution a useful tool in modeling studies, evaluating oceanic carbon sequestration, and understanding ocean–atmospheric interaction.

The ocean interacts with the rest of the climate system primarily at its surface, where air–sea fluxes imprint on fluid parcels the current physical or chemical state of the atmosphere. When a parcel of seawater is transported below the surface, it remains shielded from the atmosphere until it resurfaces and communicates past conditions to the atmosphere. The delay between successive visits to the surface imparts to the climate system an important long-term memory. Since the properties of fluid parcels get reset by air–sea fluxes during each visit to the surface mixed layer, the "memory" of a fluid element does not extend beyond its last contact with the surface. Thus, a distribution of the first and last passage times to and from the surface layer is useful description of ocean transport.

Two examples from the problem of increasing atmospheric CO_2 concentrations provide nice applications. It is possible to inventory water masses into different age classes using atmospheric CO_2 concentrations from the time the water last visited the surface mixed layer. This can lead to better understanding of the invasion into the deep ocean of anthropogenic CO_2.

In contrast, the first-passage time distributions can be used to understand when the current state of the ocean will become known to the atmosphere. It has been suggested that CO_2 might be deliberately injected directly into the deep ocean as a way of mitigating atmospheric increases. The first-passage time distribution can determine when fluid elements in the deep ocean will be transported by ocean currents and mixing processes back to the surface mixed layer, where their CO$_2$ will be able to leak into the atmosphere.

In general, this information can lead to concise and useful model diagnostics for comparing ocean circulation simulations under different climate forcing or physical parameterizations.—FRANCOIS PRIMEAU (UNIVERSITY OF CALIFORNIA, IRVINE). *"Characterizing Transport Ti-*



Meridional cross sections of the mean and std dev of the first and last passage time distributions in the Atlantic and Pacific Ocean in units of years as computed using the coarse resolution version of the ocean component (NCOM) of the CCMA climate model. The left panels show the mean and the right panels show the standard deviation. The solid contour intervals are 200 yr for the case of the mean and 100 yr for the case of the std dev. The dotted contours indicate 50-yr intervals. The waters in the Atlantic are generally younger than those in the Pacific reflecting the presence of deep convection in the North Atlantic and its absence in the North Pacific. The difference between the Atlantic and Pacific is not so pronounced in terms of the first-passage time.

mescales between the Surface Mixed Layer and the Deep Ocean with an OGCM and Its Adjoint."

SEA SURFACE TEMPERATURE INFLUENCES ON AFRICAN RAINFALL VARIABILITY

Using both observational and idealized modeling results, we show that anomalous sea surface temperature (SST) gradients during the early austral summer in the southwest Indian Ocean (SWIO) are the most important pattern controlling southern African rainfall variability. This is part of a broader effort to assess the association between extreme rainfall events in Africa and variability in the Indian Ocean that is not related to the El Niño–Southern Oscillation (ENSO).

Modification of the SST gradient with warming in the south and cooling in the north of the SWIO produces circulation anomalies favorable for wet conditions over southern Africa (see Fig. 1a), whereas a modification with cooling in the south and warming in the north favors dry conditions. The atmospheric response to the SSTs in Fig. 1a is a spinup of the Indian Ocean anticyclone, enhanced moisture flux across the African coastline through the lowest 3 km of the atmosphere, moisture flux convergence into the most southerly location of the ITCZ over Africa, and consequent enhanced convection (Fig. 1b). Reversal of the SST gradient leads to a symmetrically opposite response. The cooling shown in Fig. 1a is sufficient to induce this pattern of atmospheric response on its own; the warming, by contrast, is insufficient to do so on its own. In the case of the cooling alone, however, the response is weaker than is the case for both the warm and cool SST anomalies.

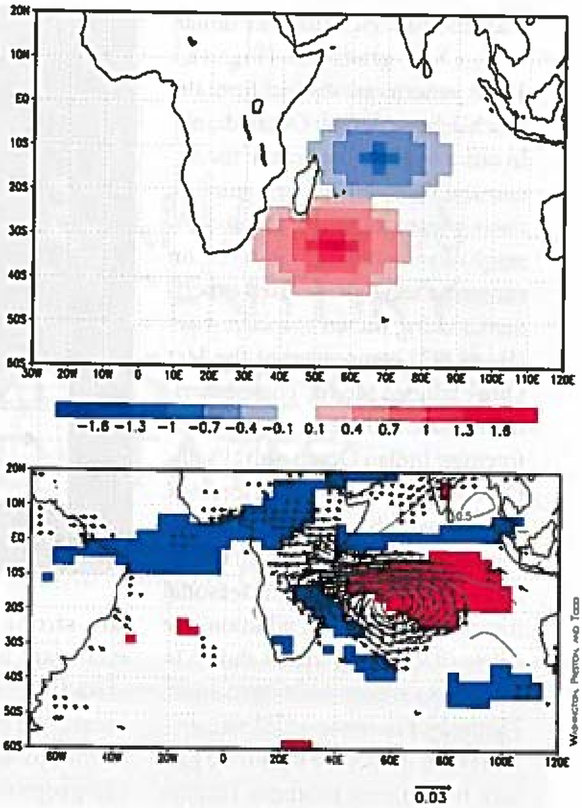


FIG. 1. (a) Idealized SSTAs in °C associated with anomalously wet conditions over southern Africa in the austral summer. The patterns are linearly independent from ENSO. The wet years of 1974 and 1976 characterize this pattern. (b) Circulation response in the Met Office model HadAM3 to the idealized SSTAs in (a). Vectors are moisture flux anomalies, lower specific humidity (red), and high specific humidity (blue), at 700 hPa. Only statistically significant fields (0.05 level) are shown.

These anomalies in the SWIO exert a much more marked influence on the atmosphere than idealized (canonical) remote ENSO forcing from the Pacific or the Pacific and the Indian Ocean (Fig. 2). In all, these results reinforce the importance of Indian Ocean SST patterns in affecting southern African rainfall variability, suggesting that the extremely wet years of 1974 and 1976 related not only to Pacific but more regional SST forcing. Results also indicate that the atmosphere dynamics are very sensitive to the location of the SST warm and cool pools.

To obtain these findings, we removed ENSO signals from observational data to establish global and local-scale non-ENSO-related teleconnection patterns associated with observed southern African summer [January–February–March (JFM)] rainfall variability. This re-

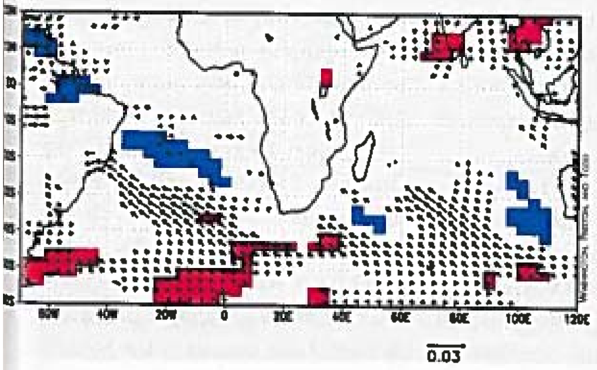


FIG. 2. Circulation response in the Met Office model HadAM3 to the idealized La Niña Pacific and Indian Ocean-only SSTAs. Vectors are moisture flux anomalies, lower specific humidity (red), and high specific humidity (blue), at 700 hPa. Only statistically significant fields (0.05 level) are shown.