ESCI 485 – Air/sea Interaction
Lesson 9 – Equatorial Adjustment and El Nino
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Reference: *El Nino, La Nina, and the Southern Oscillation*, Philander

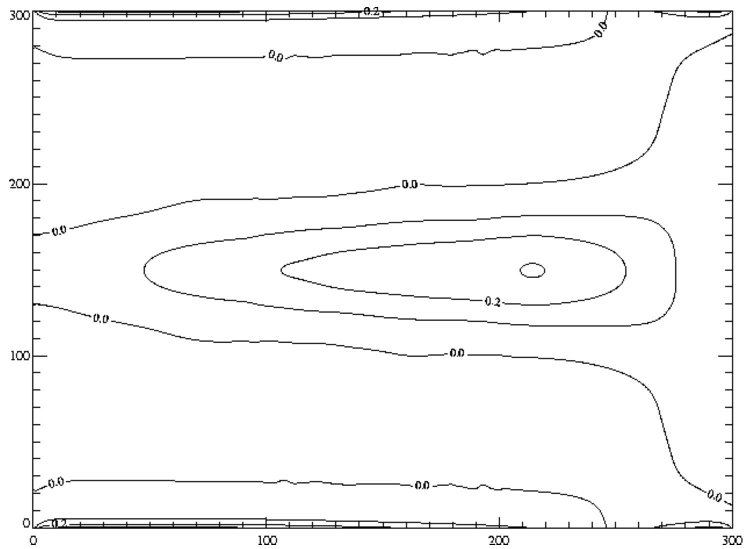
THE TWO-LAYER SHALLOW WATER MODEL

- **The ocean can often be simplistically represented as a two-layer fluid. We can thus study certain aspects of ENSO and also ocean adjustment to monsoons with a two-layer shallow-water model.**
- **Since it is the baroclinic mode that is of most importance for the ocean (the barotropic radius of deformation is much too large), we can use the concept of equivalent depth, and use the shallow water equations for a single layer of fluid of this equivalent depth.**
- **For the Pacific Ocean reasonable values to use are**

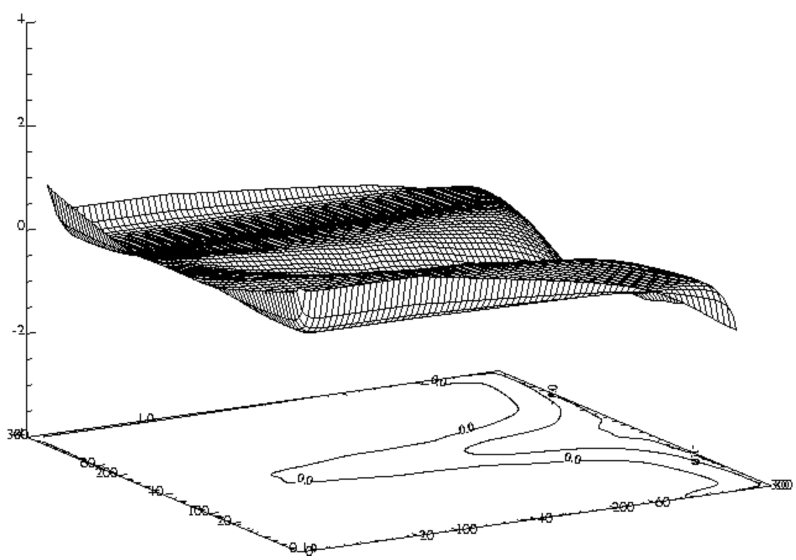
$$g'/g = (\rho_2 - \rho_1)/\rho_1 = 0.002$$
$$H_2 = 100\,m$$
$$H_e = 20\,cm$$
$$c_e = 1.4\,m/s$$

ADJUSTMENT TO UNIFORM WESTERLY WINDS

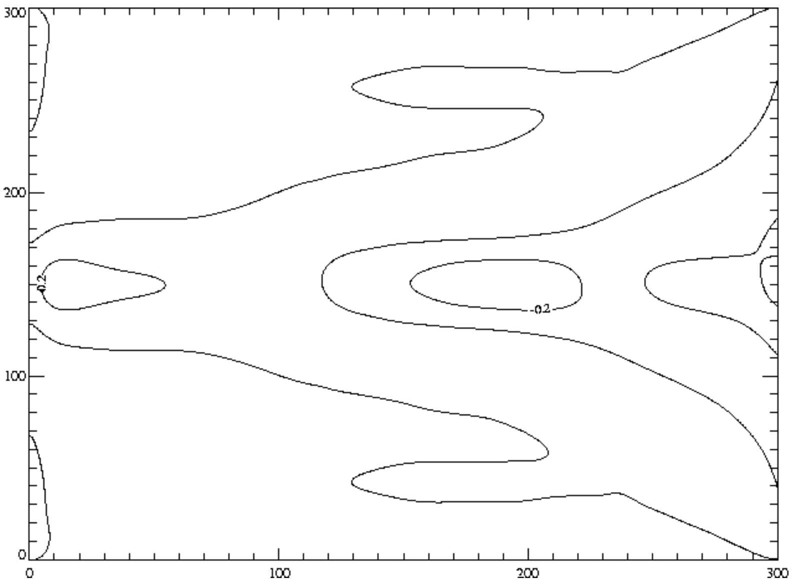
- **Twice a year in the Central Indian Ocean there are westerly winds present.**
    - **These winds occur during the transition season between the SW and NE monsoon.**
- **One the westerly winds begin, a narrow, westerly jet of current forms along the equator.**
- **After a few weeks the jet suddenly reverses directions, even though the winds stay westerly!**
    - **The reversal in direction begins in the east, and then propagates westward.**
- **We can model this process using the two-layer model, with quite astounding results:**
    - **The westerly winds quickly generate a narrow equatorial westerly jet (see u-contours below).**



- Associated with the jet is a depression of the thermocline along the equator (see diagram below).



- The width of this equatorial disturbance is of the order of the radius of deformation.
- An equatorially trapped Kelvin wave is generated at the western boundary and propagates eastward.
- A pair of equatorially trapped Rossby waves are generated at the eastern boundary and propagate westward.
- It is the Rossby waves that cause the reversal in the current. The reversal begins in the East and propagates westward (see u and thermocline depth diagrams below).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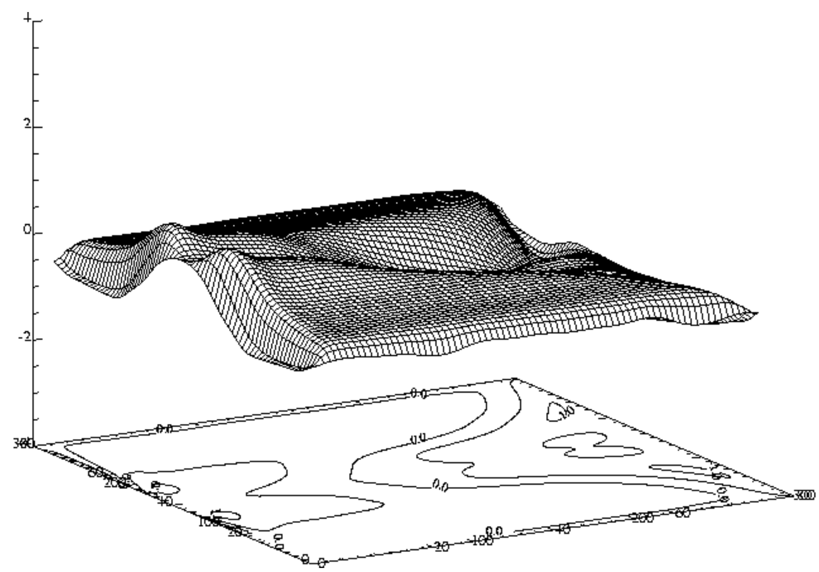
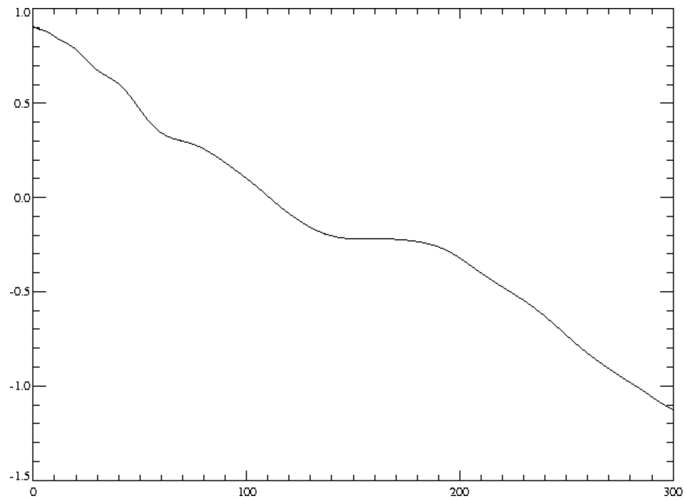
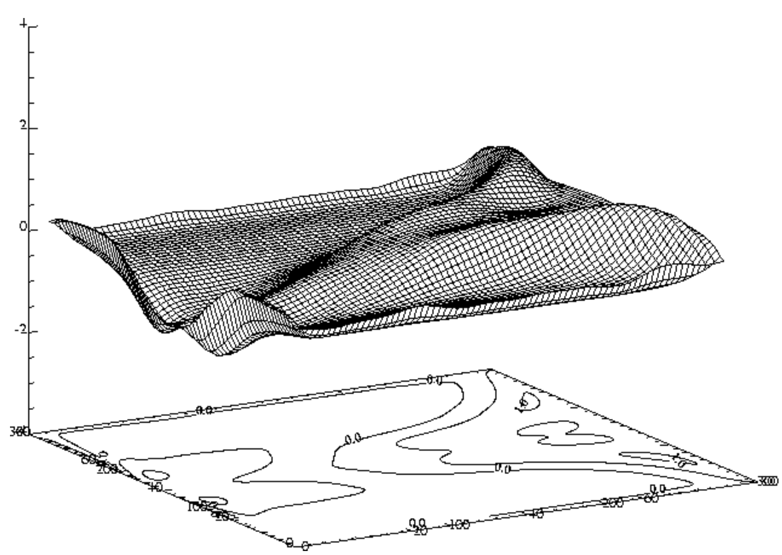


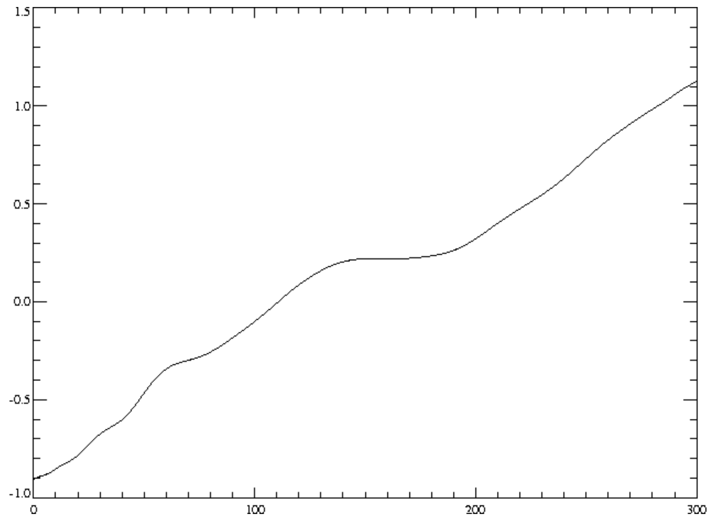
- After a time the system tends toward equilibrium, with a depressed thermocline in the east and an elevated thermocline in the west. The diagram below shows thermocline depth along the Equator; West is to the left and the vertical axis is thermocline depth.



- **The Equatorial regions adjust much more quickly than do the higher latitudes.**
  - The timescale for adjustment of the Equatorial Pacific to large-scale wind changes is ~ 450 day.
  - For the midlatitudes, the timescale is ~ 1 decade!
- **Adjustment to uniform easterly winds proceeds in a similar fashion to that for westerly winds.**
  - The plot below shows the thermocline depth at sometime after the winds have been blowing.



- **The diagram below shows thermocline depth along the Equator at a later time when equilibrium is closer; West is to the left and the vertical axis is thermocline depth.**



EL NINO, LA NINA, AND THE SOUTHERN OSCILLATION

- **Under "normal" conditions the easterly winds in the tropics result in an elevation of the thermocline (and cold surface waters) in the eastern tropical Pacific ocean, and a lowering of the thermocline (with warm surface waters) in the western tropical Pacific.**
- **During an El Nino event the trade winds weaken or even reverse direction. We've already seen that the tropical oceans adjust relatively quickly to changes in equilibrium. The response during El Nino is a progressive lowering of the thermocline from west to east.**
  - **The lowering of the thermocline is believed to be in part the result of an equatorially trapped Kelvin wave traveling along the thermocline from west to east.**
- **El Nino occurs in conjunction with the *Southern Oscillation*, a shift in the pressure patterns between the eastern and western tropical Pacific.**
- **El Nino and the Southern Oscillation are closely linked. This is why the phenomenon is often abbreviated and referred to as *ENSO*.**
- **ENSO really isn't an abnormal phenomenon. It can be thought of as just one of several stable global climate modes. For reasons not completely understood, the**

general circulation of the ocean/atmosphere system switches periodically between modes.

- **The question then becomes, "Why aren't the shifts regular and predictable"?**
  - **The reason is because "weather" is superimposed upon these climate modes. The entire system is non-linear (perhaps chaotic?), so the response to "weather" cannot be predicted.**