Mini-Projects ocean

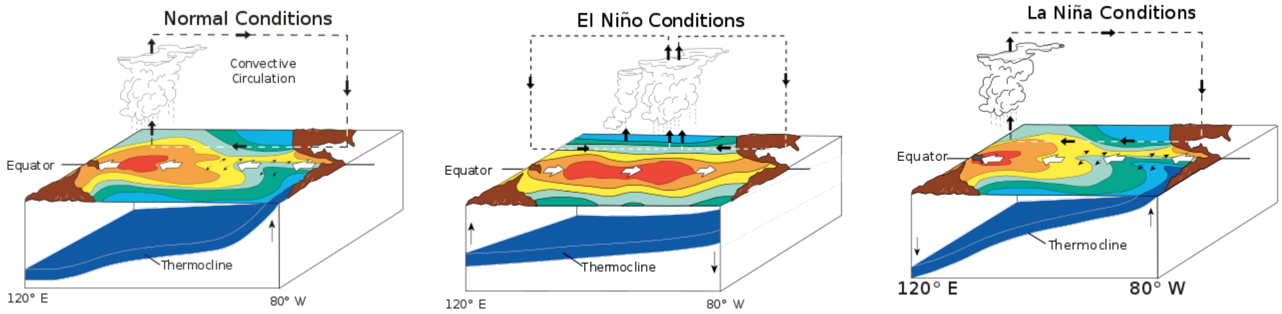

Figure: precipitations, sea surface temperature and thermocline slope in the tropical Pacific ocean for normal conditions (left), El Niño conditions (middle), and La Niña conditions (right).

First of all, let's make a brief introduction on the goals of this "mini-project". It is designed to make you understand some theoretical concepts you have learned during the year. It's one thing to understand the equations, it's another thing to understand how they apply in real world. This is all the beauty of modelization. Well, the word beauty might be an overstatement but you'll see by yourself. Basically an ocean model resolves the equations of fluid dynamics that have no analytical solutions (except if you simplify them to the extreme). You can twist, modify, transform, refashion, simplify a model to better comprehend a specific process. Here we propose to study the equatorial pacific ocean since it hosts a phenomenon of climate importance: El Niño Southern Oscillation. We have designed for you an equatorial Pacific box (called PAC2) which is an extraction of a global model at low resolution (2 deg in longitude). We first suggest you to run it on your laptop to produce what we call hindcasts for the period 1994-1998 (i.e. a numerical representation of the equatorial pacific ocean during this period). You will analyze the development of El Niño and La Niña events. Given the importance of waves in the triggering of those events, we then propose to simplify the box at the extreme, so that you will have at your disposal a perfect tool to study and visualize the waves that propagate in this basin. For instance you will have the opportunity to simulate and characterize barotropic waves, and the famous Rossby and Kelvin waves.

To ease this online course, we provide hereafter some kind of to-do-list but we do not want this course to be formal and too didactic. So the list does not have to be strictly followed. We want you to have some fun playing around with a model. So, if you want to do other analysis, other runs or even if you feel confident enough to start your own project, we will be happy to help you.

1. El Niño Southern Oscillation (ENSO)

The simulation uses the ocean model NEMO with imposed surface boundary conditions (i.e. no coupling with an atmospheric model). The simulation spans 5 years (from 1994 to 1998) to cover one of the strongest ever recorded El Niño followed by La Niña.

In order to simplify (and shorten) the simulations, a regional configuration is chosen that covers the equatorial and tropical Pacific Ocean (instead of the entire ocean). The resolution is a generic 2 deg with a latitudinal refinement in the equatorial band up to 1/2 deg to better represent tropical instability waves.

- What is required to run the model?
    - domain, initial state, surface and lateral boundary conditions? => check that you have all the files needed.
    - the default parameters of the model (common to all type of simulations) are written in the file namelist_ref. And the specific parameters for this particular Pacific Box configuration are overwritten by namelist_cfg. In particular you will find the time step of the model (here rn_Dt=5400s), the time integration (from nn_it000 to nn_itend), the name of domain file (cn_domcfg) etc.
- Run the model for the period 1994-1998. To do so, you can either run the simulation for the 1st year (all is set already). Or you can run all the years at once by changing nn_itend. See the document "how-to-survive-NEMO" for more info
- Characterization of the normal conditions (i.e. 1996)
    - Characterize the normal atmospheric forcing (trade winds, convection…).
    - Characterize the equatorial circulation (warm pool, equatorial upwelling, Equatorial undercurrent…).
    - Can you correlate the ocean upwelling/downwelling to the wind stress (via Ekman transport)?
    - Can you explain which processes drive the currents?
    - Can you see the tropical instability waves?

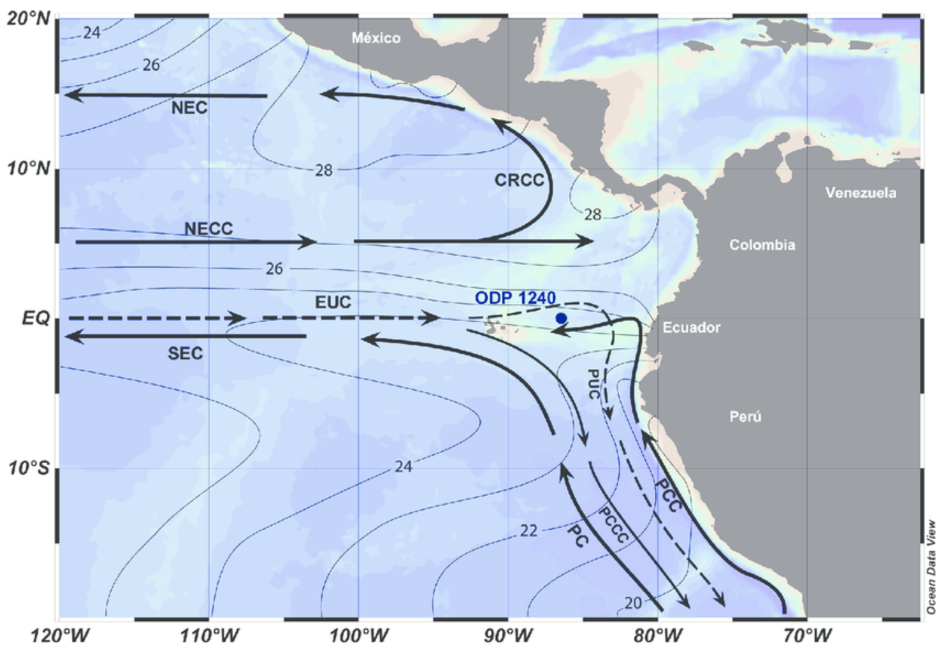

Figure: Surface and subsurface currents in the Eastern Equatorial Pacific Ocean. Surface currents: PC: Peru Current; PCC: Peru Coastal Current; PCCC: Peru–Chile Countercurrent; SEC: South Equatorial Current; NEC: North-Equatorial Current; NECC: North-Equatorial Countercurrent and CRCC: Costa Rica Coastal Current. Subsurface currents: EUC: Equatorial Undercurrent and PUC: Peru Undercurrent (Fiedler and Talley, 2006; Kessler, 2006; Mix et al., 2003).

- Characterization of ENSO

    - Characterize the beginning of El Niño (westerly wind burst in the Western Pacific in March 1997) with plots of surface wind stress and ocean currents. These wind gusts trigger Rossby and Kelvin waves.
    - Show the propagation of these waves with Hovmöller diagrams of sea surface height (time versus ssh). Kelvin waves propagate eastward at the equator, and retroflect into Rossby waves propagating westward with max at about 5deg north and south of the equator.
    - Characterize El Niño at its peak (Dec.-Jan) by looking at the thermocline, sub-surface current, sea surface temperature, precipitations and their differences with normal conditions.
    - Determine the transition between El Niño and La Niña (date, rapidity…) and characterize La Niña briefly
- impact of the Westerly Wind Burst on the initial phase of ENSO
    - remove the wind gusts, and analyse the new simulation
    - impact on the sea level (equatorial waves), the equatorial current, the displacement of the warm pool, the equatorial stratification

Notes

- observation of precipitation: https://gpm.nasa.gov/data/imerg/precipitation-climatology
- observation, reanalysis and forecast: https://climatereanalyzer.org/
- near real time reanalysis: https://earth.nullschool.net
- netcdf viewers
    - panoply: https://www.giss.nasa.gov/tools/panoply/
    - ncview
    - python, matlab, ferret…
- netcdf manipulations:
    - cdo (type cdo -h ou cdo -h xxx for help)
    - nco (ncra, ncks, ncrcat, ncap2…)