Impact of changes in the Indonesian Throughflow on global climate evolution: a modeling approach

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Courses and meetings attended

- Introductory course to Marine Sciences: physical oceanography, use of geochemical proxies.
- Scientific writing skills course.
- PhD days in Marine Sciences: poster presentation.

CENOZOIC EVOLUTION OF THE INDONESIAN GATEWAY:

IMPACT ON CLIMATE AND CORAL REEFS

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1. INTRODUCTION

Our work is encompassed in an interdisciplinary project called THROUGHFLOW (http://ipaeg.org/throughflow) aimed to reconstruct the evolution of the IT *("Indonesian Throughflow")* and the origins of marine biodiversity in South East Asia.

The present-day IT transports around 10-15 Sv of warm, low-salinity water from the Pacific to the Indian Oceans. The flow enters the Indonesian archipelago through the Makassar Strait and afterwards reaches the Indian Ocean through three different gateways: Lombok, Ombai and Timor Straits (Figure 1). The IT is a key component in the global thermohaline circulation and its variability has an important impact on global climate.

South East Asia contains the most diverse marine ecosystems on Earth. The purpose of our study is determining the origins of this diversity and establishing how it is linked to the tectonic and oceanographic evolution of the region.

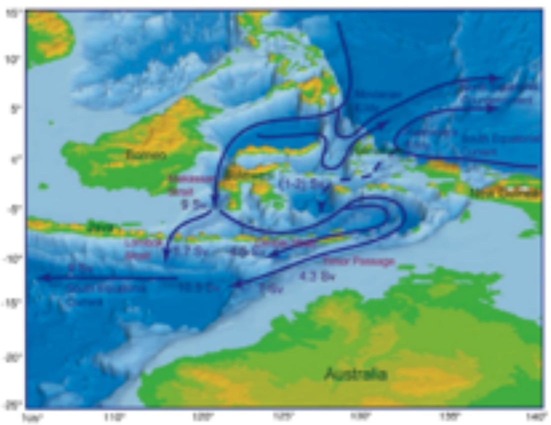

Figure 1. Present-day IT. Indonesian archipelago and the main four gateways of the Indonesian current: Makassar Strait, Lombok Strait, Ombai Strait and Timor Passage (extracted from Kuhnt et al., 2004).

Figure 2. (top left) coral samples from the THROUGHFLOW fieldtrip in East Borneo, December 2010 (© Frank Wesselingh) (bottom left) coralline algae: Mesophyllum lichenoides (© Mirella Coppola di Canzano) (right) mollusk: Babelomurex Sp. (© Sonja Reich).

2. DATA

During our first network fieldtrip we were settled in East Borneo, on the west coast of the Makassar Strait, a key location of the IT. The onshore outcrops we visited provided us with an invaluable record of climatic, biotic and stratigraphic information for the Miocene. We collected stratigraphic samples as well as fossil coralline algae, corals, bryozoans, mollusks and foraminifera (Figure 2). These data will allow us to reconstruct the past shallow marine ecosystems of the region and also to infere the past climatic conditions such as sea temperature, salinity or precipitation patterns.

3. OBJECTIVES AND METHODS

The contribution of our group to the THROUGHFLOW Network Project is the reconstruction of the IT and the climatic conditions in different key time periods by means of CCSM3 ("Community Climate System Model version 3").

Model description:

CCSM3 is a coupled climate model developed at NCAR ("National Center for Atmospheric Resarch"), with four different components: atmosphere, land, ocean and sea-ice.

Experimental design:

- Simulation of the deep water passage closure around 25Ma (Figure 3). Two experiments:

1. Late Oligocene: topography/bathymetry for 30Ma.
2. Early Miocene: topography/bathymetry for 20Ma.

- Simulation of Middle Miocene Antarctic glaciation impact in the IT region. Different experiments varying sea level and continental ice-sheets volume and extent (Figure 4).
- Sensibility study of Oligocene climate to changes in atmospheric CO_2 concentrations. Three experiments, with CO_2 = 600 ppmv, 280 ppmv and 1500 ppmv respectively.

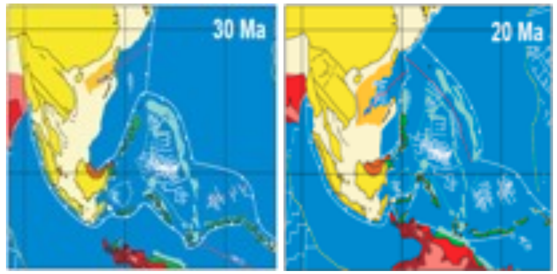

Figure 3. Reconstructions of the Indonesian Gateway for 30Ma and 20Ma (extracted from Kuhnt et al., 2004).

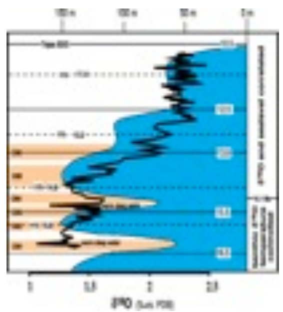

Figure 4. Miocene sea level fall caused by expansion of the Antarctic Ice Sheet between 15Ma and 13Ma (extracted from Holbourn et al., 2004).

ACKNOWLEDGEMENTS

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REFERENCES

W. Kuhnt, A. Holbourn, R. Hall, M. Zuvela, R. Käse, *Neogene history of the Indonesian Throughflow*, American Geophysical Union, Geophysical Monograph, vol. 149, pp. 299-320, 2004.

A. Holbourn, W. Kuhnt, J. A. Simo, Q. Li, *Middle Miocene isotope stratigraphy and paleoceanographic evolution of the northwest and southwest Australian margins*, Palaeogeography, palaeoclimatology, palaeoecology, vol. 208, pp. 1-22, 2004.

NCAR Community Climate System Model (CCSM3)

Atmosphere & Land Surface

- T42 (~2.8° lat-lon), 26 levels

Coupler

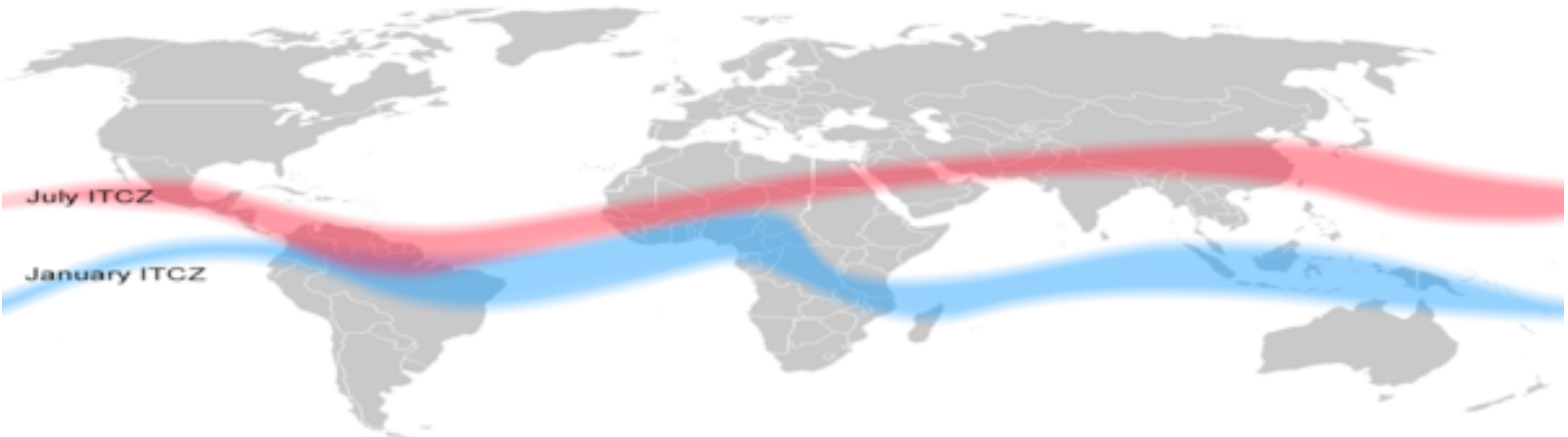
Ocean & Sea Ice

- longitudinal resolution: ~1°
- latitudinal resolution: ≤ 1°, 0.3° in the tropics (incl. ITF)
- vertical resolution: 40 levels, to 5.5 km depth

Effects of glaciation on the tropical rain belt position

To test if middle-Miocene increasing glaciation in Antarctica led to a northward shift of the tropical rain belt in the ITF region (Holbourn et al., 2010).

- Two CCSM experiments for 14 Ma, varying sea level and Antarctic continental ice-sheets volume and extent.



Summary of my work

- Get setup tools for CCSM3 from National Center for Atmospheric Research (NCAR).
- Take example data to test the software.
- Set up compiler options and libraries to compile the code.
- Edit scripts: data and code paths, define grid resolutions and other parameters.
- Run the code to generate input files for CCSM3.

Required data as input for the model setup

- Topography/bathymetry data for middle Miocene:
  - Nick Herold from Earthbyte Group: global data.
- Vegetation data for middle Miocene (including continental ice distribution).
  - Local data for Indonesian region from Bob Morley.

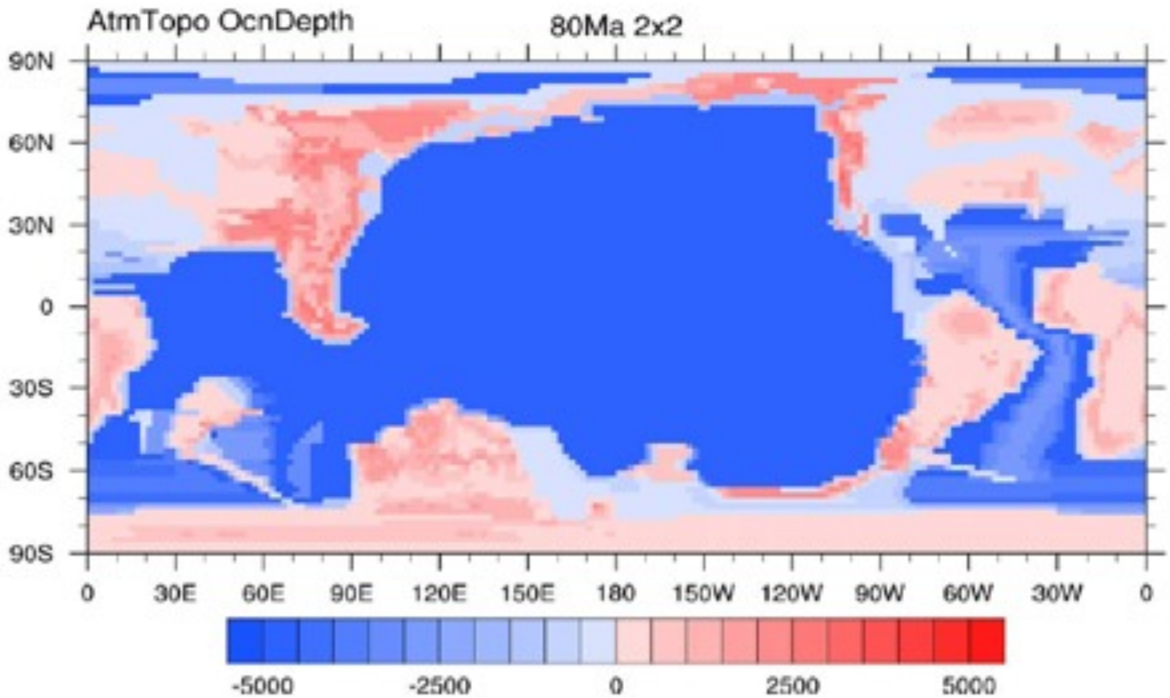


Figure 5. Height about sea level (m) for the late Cretaceous (80 Ma).
Data are at 2x2 degree latitude/longitude resolution.

Figure extracted from "CCSM3 for paleoclimate applications" (NCAR)

Initial conditions settings

For deep time simulations, often little information is known about initial conditions. Two choices:

- rough approximation.

    - let the model calculate it itself.

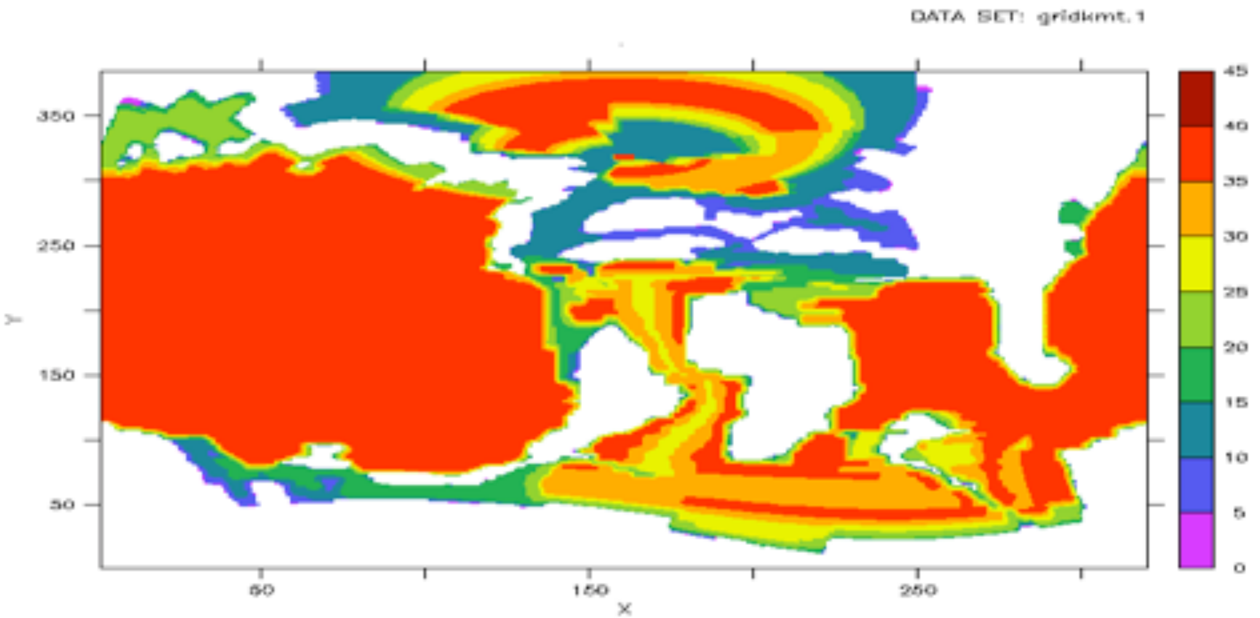
- Sea ice: “no ice” initial state, allow the model to simulate the ice state.
- Ocean: global averaged temperature and salinity profiles.
- Atmosphere: prescribed temp at equator and poles, the rest made by the model (for instance: surface pressure from topography data.
- Land: arbitrary initial state.

Detailed setup procedure

Ocean/Sea-ice:

- Ocean grid file (defines horizontal grid).
- Bathymetry file (topography/bathymetry).

Depth levels from bathymetry file



Axis show the model grid coordinates X and Y, that do not correspond to longitude and latitude

Detailed setup procedure

Land:

- Plant types, soil color & texture, heights, lakes & wetlands, continental ice (vegetation).
- Runoff directional dataset: direction for runoff flow at each point (topography/bathymetry).

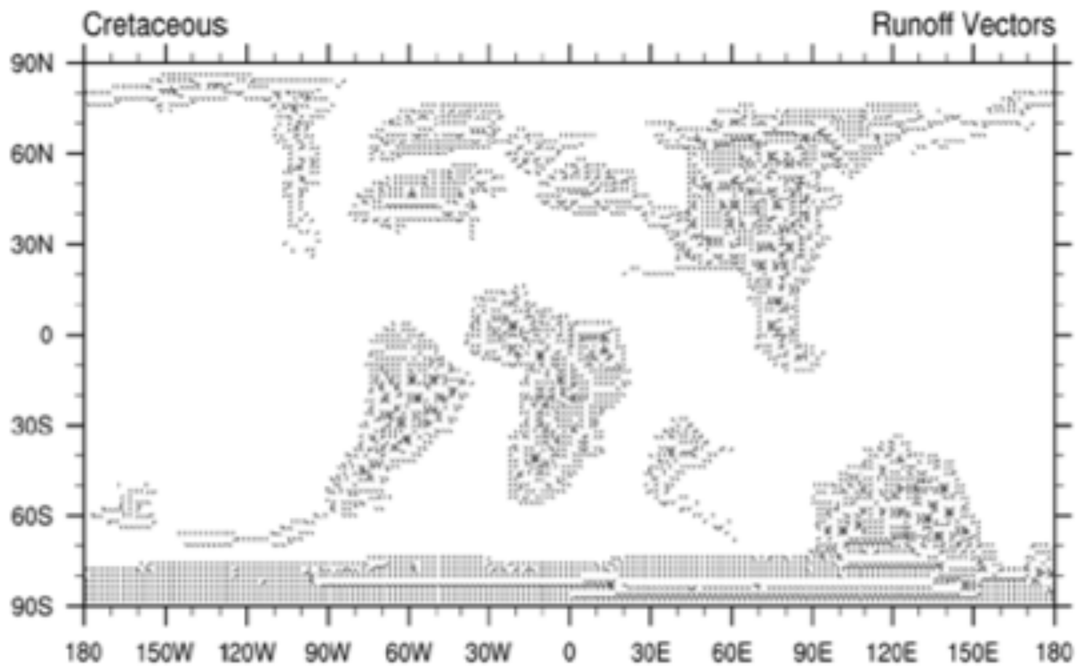


Figure 7. River Runoff
Example plot of runoff vectors for 80 Ma for a 2x2 degree RTM resolution grid.

Figure extracted from “CCSM3 for paleoclimate applications” (NCAR)

Detailed setup procedure

Coupler:

- Mapping files between atmosphere and ocean grids (uses kmt file, so indirectly also bathymetry).

- Mapping file from river transport model grid and ocean grid.

Plans for the next months

Courses:

- Presentation skills course, June.
- Statistical methods applied to data analysis, August.

Work:

- Get vegetation data for middle Miocene.
- 2 versions of vegetation file: big and small ice sheets.
- Run the model set-up package using my data.
- Initialize the CCSM3 model with the files generated.
- Run CCSM3 with the two middle Miocene configurations and analyze the results.