

Title: Indian Ocean Dipole and El Nino/Southern Oscillation impacts on regional chlorophyll anomalies in the Indian Ocean

Authors: J. C. Currie, M. Lengaigne, J. Vialard, D. M. Kaplan, O. Aumont, S. W. A. Naqvi, and O. Maury

1. Does the paper address relevant scientific questions within the scope of BG?

This paper addresses the scientific questions related to the interannual variability of some of the components and processes in the study of Biogeochemical Cycles in the Indian Ocean. This is within the scope of BG.

2. Does the paper present novel concepts, ideas, tools, or data?

This paper addresses the biological consequences of IOD and ENSO events in the Indian Ocean using a biophysical model. Earlier studies on this topic have not been carried out in detail to understand the relative impacts of IOD and ENSO on Chlorophyll.

Statistical tools have been used to isolate the effects of IOD and ENSO on Chlorophyll in different regions of the Indian Ocean.

3. Are substantial conclusions reached?

Satellite data is available only for a short-period to differentiate the effect of IOD and ENSO events. Results of the model simulations for 41 years have been used to understand and differentiate the effect of IOD and ENSO events on the physical (thermocline depth, wind stress) and biological processes (chlorophyll concentration), using statistical methods. Substantial conclusions have been reached on the relative impact of IOD and ENSO events on Chlorophyll (surface and integrated over euphotic zone) in six different regions during a few seasons.

Though some conclusions have been reached in different regions of the Indian Ocean during a few seasons, more understanding of the response of physical, biological and chemical processes to IOD and ENSO events are required at the surface and subsurface levels in the ocean.

4. Are the scientific methods and assumptions valid and clearly outlined?

Details of the model, forcing data and observational data sets are given in Section 2. Statistical tools and the results based on the statistical analysis are discussed.

What these statistical tools do and what is the exact meaning of the results can be described in more detail to understand the interpretation of the results. Eqns. 1-4 need to be explained properly for the reader's benefit.

There are a few assumptions that are contentious:

- a) As the model is an ocean only model, we wonder if a detailed statistical analysis of SST is warranted as it is determined mostly by atmospheric forcing.

- b) A more problematic assertion has been made on page 5854, second para. (“Attribution causes to model-data differencesstudy). The paper focuses exclusively on IOD and Nino3 and completely ignores the influence of ecosystem dynamics on the evolution of the chlorophyll field. As the study quickly moves to using model results as a proxy for reality, not using all the terms in the evolution of biogeochemical fields when they are available, is a serious problem. While we agree that it would be impossible to analyse all the biogeochemical compartments, we fear that the conclusions reached only on the basis of physics could be potentially very misleading.

I am not sure if IOD independent of ENSO ? Could the authors elaborate?

5. Are the results sufficient to support the interpretations and conclusions?

Results discussed may be sufficient for the interpretations and conclusions arrived in this paper.

Some more studies may be required on the subsurface properties and also on the other biogeochemical components and processes which influence the chlorophyll in the Ocean. For example, regenerated production, multnutrient limitation, grazing etc. Please see comment 4b.

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

Description of methodology, especially statistical methods and the meaning of results obtained after statistical analysis are not sufficient to be used by fellow scientists.

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

Authors indicate their new contribution in the Abstract.

8. Does the title clearly reflect the contents of the paper?

Title reflects the contents of the paper.

9. Does the abstract provide a concise and complete summary?

Abstract provides the summary of the paper.

10. Is the overall presentation well structured and clear?

Overall presentation is well structured

11. Is the language fluent and precise?

Language is fluent

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

Some of the formulae, symbols and abbreviations are not explained in detail.

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

Parts of the paper providing the description of the model and evaluation of the model from the earlier papers are not very clear. Discussion of results in some of the figures can be more precise.

14. Are the number and quality of references appropriate?

Looks reasonable

15. Is the amount and quality of supplementary material appropriate?

I could not access the Supplementary material

General Comments

This paper addresses the scientific questions related to the interannual variability of some of the components and processes of Biogeochemical Cycles in the Indian Ocean. The main focus is to understand the biological consequences of IOD and ENSO events in the Indian Ocean using a biophysical model. Study of chlorophyll anomalies driven by these two climate modes is essential since they are responsible for the significant interannual variabilities in different regions of the Indian ocean. Results of the model simulations for 41 years have been used to understand and differentiate the effect of IOD and ENSO events on the physical (thermocline depth, wind stress) and biological processes (chlorophyll concentration), using statistical methods. Earlier studies have not been carried out in this detail to understand the relative impacts of IOD and ENSO on Chlorophyll in different regions of the Indian Ocean. Statistical tools have been used to isolate the effects of IOD and ENSO on Chlorophyll. Description of the model, forcing data and observational data sets are given in the paper. Statistical tools and the results based on the statistical analysis are discussed. Most of the figures in the paper are based on the statistical analysis. However, what these statistical tools do when applied to the model results and observational data sets, and what is the exact meaning of the results are not described in detail to understand the concepts. Conclusions have been reached on the relative impact of IOD and ENSO events on

Chlorophyll (surface and integrated over euphotic zone) in six different regions during a few seasons based on physical processes.

Results discussed may be sufficient for the interpretations and conclusions arrived in this paper. Some more studies may be required on the subsurface properties and also on the other biogeochemical components and processes which influence the chlorophyll in the Ocean.

This kind of model study helps in improving the understanding of the interannual variability of productivity and carbon fluxes in the Indian Ocean.

Specific Comments

Abstract:

p.5843, Line 13: A previously unreported --- I believe Wiggert (2009) has already made this observation??

p.5843, line 18: ENSO and IOD cause significant and predictable --- Productivity is very specific term that refers to the rate of primary production and we take offence when it is loosely used to describe standing crop via chlorophyll abundance

1. Introduction

p.5844, lines 15-16: Yoder and Kennelly (2003) – Interannual modes of variability ascribed to ENSO Control, not IOD ??? – Please check the correctness of this statement.

p.5845, line 3: Subsurface temperature anomalies ---:

➔ ENSO and IOD influence both surface and subsurface properties - Is it true?

2. Data and Methods

Section 2.2

p.5848, line 24: some details on the extensive validation of OGCM required

p.5850, line 9: Seven-year spin-up – Is it enough?

Section 2.3 Methodology

Most of the figures are containing the results of statistical analysis and conclusions of the paper are based on the interpretation of results of statistical tools applied to data and model

outputs. Therefore, more details on the statistical tools are required to understand the concepts.

p.5852: A better description of the equations required

Section 3

p.5853, line 16: Kone et al (2009) --- emergent biogeographic provinces

Not clear; need a more specific mention of what exactly was compared; It would also be helpful to the reader who is more biologically-inclined (rather than physically) to get a birds-eye view of the performance of the model's biogeochemical aspects

p.5853, 2nd Paragraph: Anomalies are calculated for different climatology periods for model and data. Need a short explanation why this is so and how it would influence the results

p.5854, lines3-5: Model – data differences - See comment 4b

Discrepancies in Fig.2 is both in Coastal and Open ocean regions.

Section 4:

4.1: Physical Response

Discussion on relationship between SST variations and Thermocline depth → Some more physical processes may have to be studied.

p.5856 and p. 5857: Interpretation of ENSO and IOD impacts on Surface and subsurface variabilities, results in Figures 4 and 5 are not clear.

4.2 Biological response

p.5857, lines 17-24; p.5858, lines 14-18: Similar behaviour is not observed in SchI

p.5857, line 28: lack of significant relationship – Is it so?

p.5859, line 9: Difference between Figures 7e and f – why?

p.5859, lines 15-23: Are these results consistent with earlier studies?

Figures 9 (a-j), Tables 1 & 2 – Relative impacts of ENSO and IOD on Chlorophyll in six different regions are discussed.

IOD and ENSO do not show similar anomalies for SST, D20, IChI, SChI

Impact of SST and D20 on IChI and SchI – not very clear in different regions

Some results on IChI and SChI may be related to Subsurface properties of biological components

Tables 1 & 2 : Partial regression coefficients are given for different seasons for Ichl and SchI

Table 1: Coefficients corresponding to peak impacts of ENSO and IOD seasons are not provided (sometimes).

To describe the results on impacts of ENSO and IOD on Chlorophyll, many physical processes in the Ocean and Atmosphere are discussed. Sometimes these discussions look confusing.

Summary and Discussion

p.5864, lines 20-24: IOD forced decrease in IChl around the southern tip of India during October- December – What is the reason?

p.5864, lines 29-30; p.5865, lines 1-3: Chl and PP depend on several nutrients, not only Nitrate, Regenerated production is usually higher than the new production in the north Indian Ocean – some clarifications

Novel contribution in this study is the separation of impacts of ENSO and IOD in six regions in the Indian Ocean