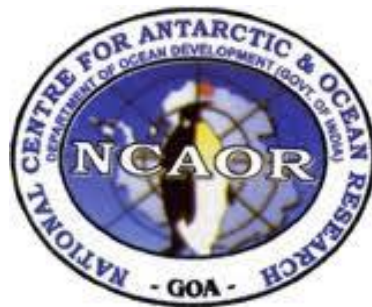


Cruise Plan

12th Southern Ocean Expedition (2023)



National Centre for Polar and Ocean Research (NCPOR)

Headland Sada, Vasco-da-Gama, Goa-403804, India

**Multi-institutional & Multidisciplinary investigations in the
Indian sector of Southern Ocean**

Background

Southern Ocean (SO) is a unique region which tends to have a global scientific relevance in terms of its role in climate change, its distinct physical, chemical properties and the related biological processes. In the light of the biogeochemical perspective, the SO in general and the Indian sector of the SO (ISSO) in particular, is still an understudied region. With the existing knowledge of SO it is quite impractical to derive any conclusion that can be useful for scientific understanding or societal benefits. Hence, a long term continuous study needs to be planned and executed on all interdisciplinary areas so as to obtain comprehensive understanding of the ISSO as well as its influence on Tropical Indian Ocean (TIO) and climate. As seen from available literature the studies that have been carried out in the ISSO are sparse; whereas most of the studies in the ISSO are confined to the Australian and African sectors. Long term monitoring in the ISSO would facilitate better understanding of the interactions between polar, subtropics, and tropics regions which would help us explaining the role of various processes occurring in the ISSO ecosystem in global climate change.

In order to understand the processes those are involved in modulating the climate variability in a regional as well as global scale and its implications on the living resources and biogeochemical cycles, Indian SO research program was initiated in 2004. This program was initiated by the Ministry of Earth Sciences (MoES) to pursue multi-disciplinary, multi-institutional research activities addressing various key scientific components including air-sea interactions, lower atmospheric processes, hydrodynamics, biogeochemistry, biodiversity (bacteria, plankton and higher marine organisms) etc. Since its inception in 2004, National Centre for Polar and Ocean Research (NCPOR) is the national nodal agency for planning, coordinating and executing the Indian Scientific Expedition to Southern Ocean (ISESO). Till date 11 expeditions are being carried out addressing some of the above mentioned research components. The results obtained from these expeditions are quite encouraging as they provided some significant data/information on various physical, biological and biogeochemical processes occurring across the various frontal zones in the SO. However, the information gathered from these expeditions are not sufficient to establish the influence of SO on global climate and also at what extent the SO processes respond to or drive climate variability. This underscores the need for sustained observations from the SO to understand the physical and biogeochemical processes responsible for climate variability.

Science plan for ISESO 2022-23

The SO plays a major role in the climate system, and is recognized as the oceanic body most sensitive to climate change. Changes in the SO would therefore have global implications. Hence sustained and multi-disciplinary observations are required to detect, interpret and re-

spond to the changes in the SO. Large amount of mass and heat transport is being occurred between Tropics, Subtropics and Polar regions due to the ocean and atmospheric circulations. The eastward flowing Antarctic Circumpolar Current (ACC) is the primary mode one by which water, heat and other properties are exchanged between the ocean basins through diapycnal mixing. Considering ACC as the boundary between tropics and polar oceans, measurements on the meridional heat transport between SO and tropical ocean is needed to assess its impact on tropical climate.

The SO research programme is mainly focusing on the “*Role and response of Southern Ocean to the regional and global climate variability*”. Previous ISESOS (2004-2020) have attempted to understand the spatial and temporal variability of different fronts as well as the coastal processes in the ISSO based on the hydrographic data collected along various transects between 40°E and 80°E. Last five year’s ISESOS (2011-12, 2012-13, 2014-15, 2016-17, 2019-20) were mainly focused on the Subtropical Front (STF) to Polar Front (PF) and in the Prydz Bay (PB) region. Detailed studies on air-sea interaction, hydrodynamics, food web dynamics and biogeochemistry were carried out in the above regions of the ISSO for a comprehensive understanding of the seasonal and inter-annual variability of the physical, biological and geological parameters of this dynamic regime. The Particulate Organic Matter (POM) biogeochemistry and remineralisation influence the elemental cycles and the biological pump. The diverse spatio-temporal biogeochemical characteristics of the various fronts in SO are need to be addressed time to time for understanding the role of SO in global ocean biogeochemistry. The changes in the oceanic hydrography and biogeochemical properties are consistently associated with long term global climatic changes. Further the exchanges of carbon and heat between the Tropics and Polar Regions are highly relevant component to be addressed in the present global warming scenario.

The SO absorbs huge amount of carbon dioxide (CO₂) and transports it to the deep ocean. It is a significant sink for anthropogenic atmospheric CO₂ and is a potential site for enhanced carbon sequestration. Model and a few observations studies shows that almost 40% of the human-induced CO₂ was absorbed from the atmosphere into the SO, making it one of the most significant region in the world. The excess sink of CO₂ in the SO may influence the carbonate chemistry which will have implications on the biogeochemistry of the SO. These processes may result in strong feedback on the nitrogen and oxygen cycling which are closely coupled with carbon cycle. The increase in uptake of CO₂ may also affect the ecosystem functioning by gradually reducing the pH, affecting the calcareous organisms and the overall biota of the SO ecosystem. In the recent climate observations focusing on CO₂ measurements in the ISSO is need to be initiated.

Hence, during the forthcoming ISESO, the focus will be given on the air-sea exchange and biogeochemical cycling of CO₂ as well as the observation of anthropogenic CO₂ inventories of the ISSO.

Ocean sequestrates ~30% of the global emitted anthropogenic CO₂. The global ocean has taken up nearly 165 ± 20 petagrams of carbon (PgC) emitted since the pre-industrial era (Le Quéré et al., 2018). The contemporary global ocean CO₂ sink is estimated to be 2.5 ± 0.6 Pg C yr⁻¹ (Friedlingstein et al., 2019). The mid-to-high latitude oceans are the major venues of storage of anthropogenic CO₂ in the ocean due to mixing and subduction processes. The SO is a major region where these processes sequester many anthropogenic CO₂, thus plays a major role in the global carbon sequestration and cycling, strongly influences global climate patterns. The ISSO has a significant contribution to storing the anthropogenic CO₂. Gruber et al. (2019) have demonstrated the growth of anth- CO₂ in the ISSO. Monitoring the anth-CO₂ inventories of the SO is always important to find the net changes in the role and capacity of oceans in sequestering the anth- CO₂ under a changing climate. Indian expedition to ISSO passes through multiple thermohaline fronts (Agulhas return front-ARF, Southern Subtropical Front-SSTF, Sub Antarctic Front –SAF and Polar Front-PF) and the coastal waters of Antarctica. The planned expedition targets to observe carbonaceous species such as vertical profiles of dissolved inorganic carbon, total alkalinity, nitrate, nitrite, phosphate and oxygen. With this, one may calculate the anth- CO₂ component of the dissolved inorganic carbon by the conventional ΔC* method of Gruber et al. (2019).

The partial pressure of CO₂ (*p*CO₂) is one of the factors that control sea-air CO₂ exchange. Surface CO₂ flux is proportional to the down gradient of *p*CO₂ in the atmosphere hence measurements of *p*CO₂ is generally used for the estimates of observation-based global air-sea carbon flux. The surface ocean *p*CO₂ is affected by CO₂ production/consumption due to biological activities, dilution by sea ice / glacial melt waters, temperature changes, and mixing with ambient water masses. The decrease of the solubility of CO₂ with increasing water temperature and salinity, in turn, increases *p*CO₂ in the ocean. Hence, multidisciplinary observations need to be conducted to understand the SO's role in the global carbon cycle.

Considering the significance of CO₂ studies in the present climate change scenario, the following objectives are worth attempting in the current expedition

Main objectives for ISESO 2023

- *Influence of thermohaline fronts on Air-Sea CO₂ dynamics in the Indian Sector of Southern Ocean.*

- *Does upwelling of deep water influence the dissolved CO₂ concentrations?*
- *How does melt water during summer influence the local dynamics of Air-Sea CO₂ exchange?*
- *To observe the recent changes in the anthropogenic CO₂ inventories of the Indian Ocean sector of the Southern Ocean.*
- *To study the climate impacts on the changes in the anthropogenic CO₂ inventories of the Indian Ocean sector of the Southern Ocean by comparing it with past observations.*

Further the samplings during this expedition will be made for physical chemical, biological and geological studies with the scientific themes like Atmospheric sciences, Water column dynamics, Biogeochemistry, Food-web dynamics and Palaeoclimatic studies

Studies on atmospheric sciences will be mainly concentrated on *aerosol studies, wind stress, momentum flux, vertical atmospheric structure etc.*

The water column dynamics studies include *i) Thermohaline structure and the influence of melt-water/fresh water on it, water masses characteristics - bottom water, Heat budget variability, Current variability and influence of physical processes on biological production*

Further the studies shall be concentrated on *i) ¹⁴C-based primary production ii) ¹⁵N-enriched primary production iii) Measurements of bio-optical parameters iv) Phytoplankton biomass v) Macro-nutrients dynamics iii) Microbial uptake rates of organic carbon iv) Organic carbon inventory (TOC, POC, carbohydrates) and v) pCO₂ measurement vi) Si accumulation and cycling in Southern Ocean.*

The major components which will be addressed in the Food web dynamics are *i) Phytoplankton diversities through taxonomic studies ii) Phytoplankton diagnostic pigment studies through HPLC iii) Micro- and meso-zooplankton standing stock, diversity and migration iv) Zooplankton productivity v) Evaluation of proximate biochemical composition of major zooplankton groups and vi) Distribution of microbial biomass.* Collection of sediment core at coastal area of Antarctica for *diatom and dinoflagellates cyst analysis*

Plaeoclimatic studies: Southern Hemisphere Annular Mode's (SAM) impacts on modulation of the Indian Ocean SST are attributed to the tele-connection between south Asian Monsoon and the South Pole. *A solid paleoclimate record encompassing past SST from the Polar waters as well as progressively north of it will be highly directive to address the tropical - polar tele-connection.* In this pursuit, in the 12th ISESO it is planned to acquire necessary marine samples in the form of water samples as well as sediment core from desired latitudes.

Towards achieving these goals, subsequently, the 12th ISESO will be launched during early January 2023 to have a comprehensive study in the region southwards of 40°S upto the coastal waters of Antarctica.

Research proposals relevant to the above focal themes are invited from research organizations, universities and other institutions engaged in R&D activities. The cruise track for the expedition is attached. The PIs, while proposing their research plan, may make sure to indicate the type of samples required, the exact sampling location and facilities/equipment required for collection, analysis and storage. It may be noted that no deviation from the objectives as well as sampling strategies will be allowed as this would hamper the progress of the expedition. It is desirable that the PI/Co-PI may participate in the expedition along with the team. The names of participants and their designation may be indicated in the proposal. The proposal in the enclosed format may be sent on or before **10 July, 2022** to,

Dr. N. Anilkumar,
Scientist 'G' & Group Director, Ocean Science Group
National Centre for Polar & Ocean Research,
(*Ministry of Earth Sciences*)
Headland Sada, Vasco-da-Gama, Goa. 403 804
Phone: 0832-2525513
E-mail: anil@ncpor.res.in; anilncaor@gmail.com

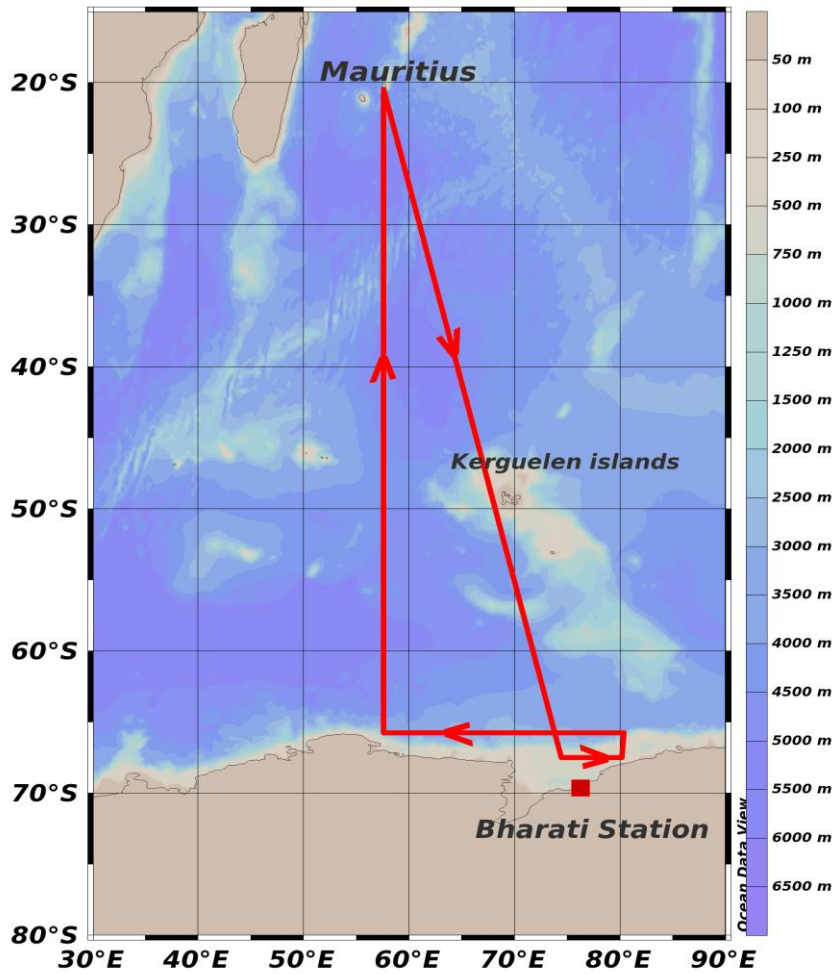
With a copy to,

The Director,
National Centre for Polar & Ocean Research,
(*Ministry of Earth Sciences*)
Headland Sada, Vasco-da-Gama, Goa. 403 804
Tel: 0832-2525501, Fax: 0832-2520877
E-mail: director@ncpor.res.in

The proposals will be reviewed by an expert committee constituted by Director, NCPOR and the PI will be intimated the date for presentation of the research proposal to this expert committee sufficiently in advance. It is requested that PIs who have participated in the previous SO expedition may also present the results of their study at the time of project presentation. It is also suggested that those who have participated in the earlier expedition

and if interested to participate in the forthcoming ISESO, may submit a proposal as a continuation of the studies carried out by them in the earlier SO expedition.

Priority will be given to the proposals oriented towards the studies on CO₂ and heat exchanges in the ISSO region.



Tentative cruise track for ISESO 2023