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Projected response of Arabian sea Oxygen Minimum Zone to climate change: Preliminary insights from downscaled experiments

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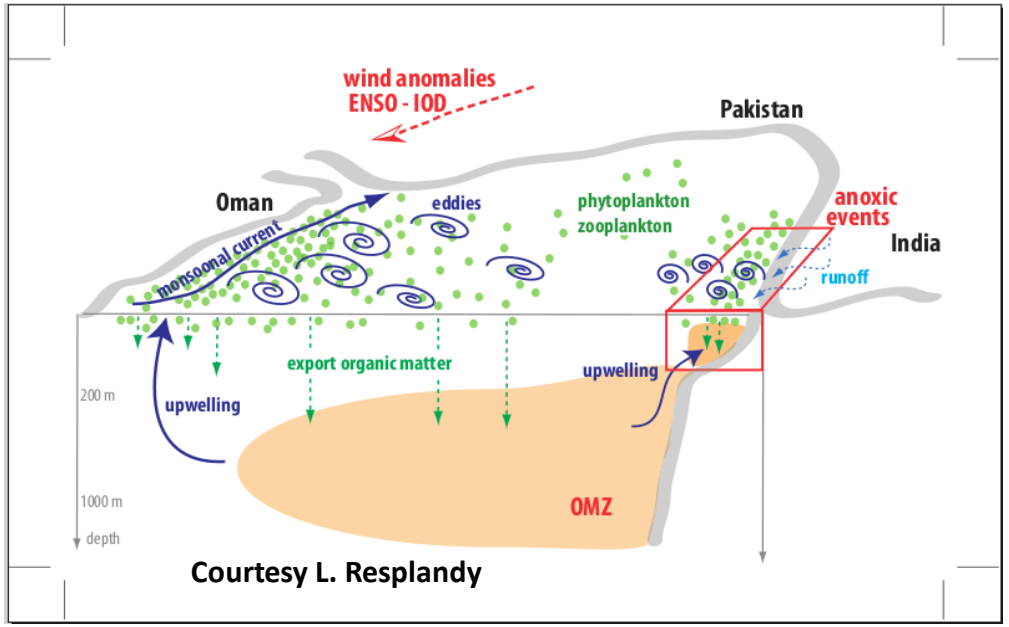
Abstract

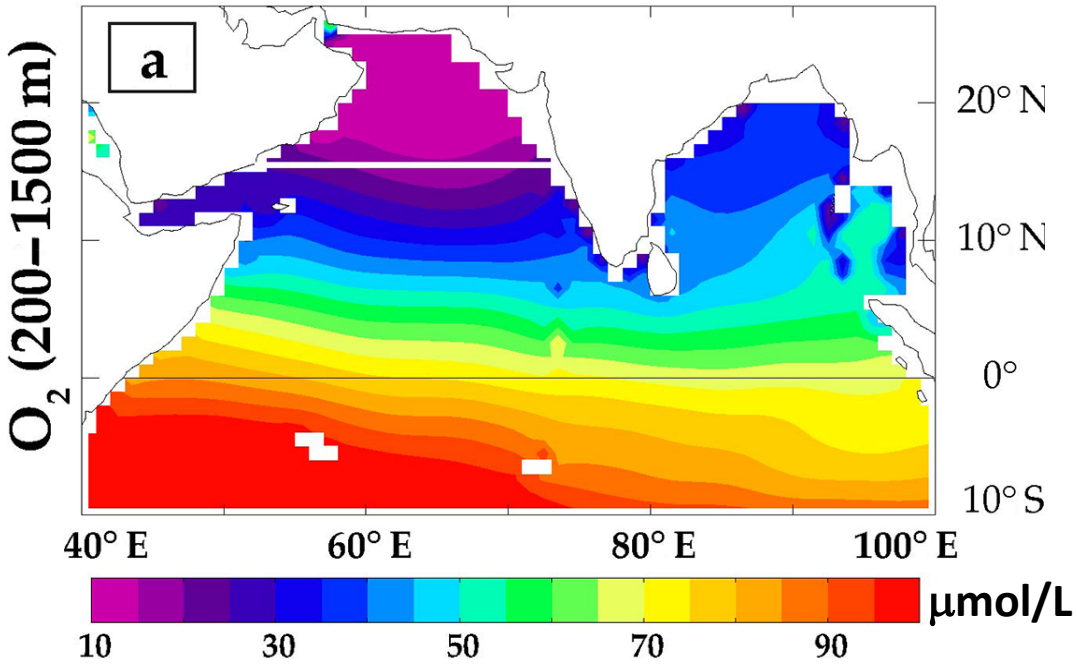
The land-locked northern boundary and seasonal high productivity in the Arabian sea (AS) leads to the formation and the maintenance of one of the most intense and thickest open ocean oxygen minimum zones (OMZ) there (S1). Earlier studies based on both observation and model sensitivity experiments have reported that this perennial OMZ is highly sensitive to the strength of the monsoonal circulation and surface heating. Model simulations from the fifth phase of Coupled Model Intercomparison project (CMIP5) indicate significant changes in the Indian monsoonal circulation and the atmospheric heat fluxes under climate change. However, the future projection of AS OMZ under climate change remains largely uncertain and ill-understood. This is mainly due to a poor representation of the AS OMZ in the CMIP5 simulations and an important spread in their future oxygen projections for the region (S2). Here we explore how downscaling CMIP5 global simulations with a high-resolution configuration of the Regional Ocean Modeling System (ROMS) model coupled to a nitrogen-based NPZD ecosystem model can help improving the representation of the AS OMZ and reduce the spread in CMIP5 projections. To this end, we performed a climatological "reference" simulation, i.e., the control simulation, where ROMS is forced with observed atmospheric and lateral boundary conditions (ROMS_CTL), and a set of corresponding downscaled sensitivity experiment where ROMS is forced with atmospheric and lateral boundary conditions derived from global CMIP5 simulations (ROMS_HIST & ROMS_RCP85). For the downscaling experiment, we chose one of the best performing models (MPI-ESM-LR) from the CMIP5 database based on their skill in simulating the present day (historical) climatology. The control simulation has been extensively validated against the observations for its skill in simulating the physical and biogeochemical variables (S3 & S4). We find that the downscaled experiments improve the representation of different classes of oxygen (Oxic - O2 > 60mmol/l; Hypoxic - 60μmol/l >= O2 > 4μmol/l; and the Suboxic - 4 μmol/l > O2 > 0 μmol/l) within the 0-1500m depth range (S5). In particular, the downscaled experiments simulate a much smaller fraction of suboxic waters relative to hypoxic and oxic fractions, in agreement with observations.

Introduction (S1)

Vertical view of Arabian sea OMZ from Equator & associated processes



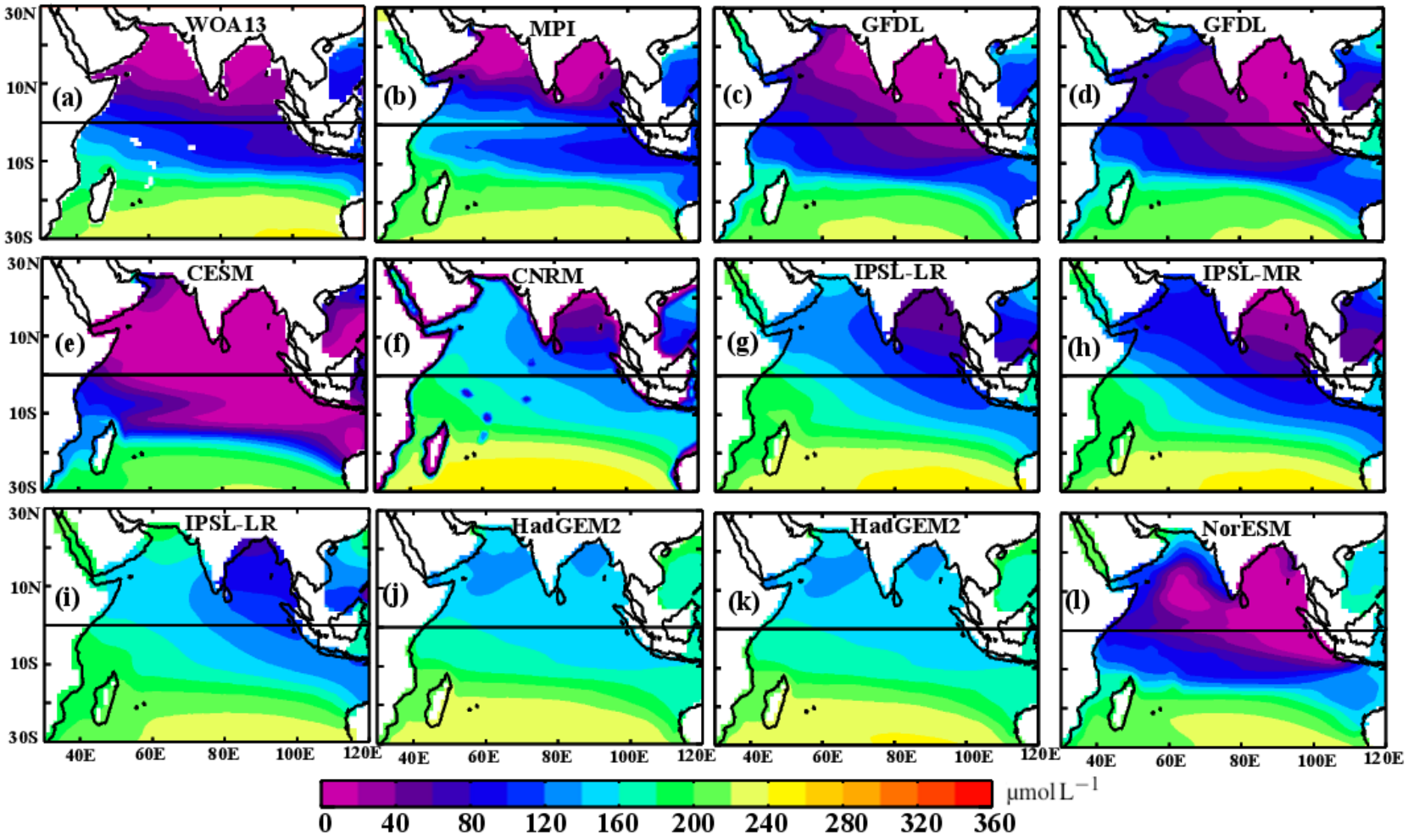
Dissolved O2 averaged between 200-1500m



- Arabian sea hosts one of the thickest and perennial open ocean oxygen minimum zones
- <u>Formation:</u> Lack of ventilation due to land-locked northern boundary and the seasonal high productivity
- <u>Consequences:</u> Important influence on the coastal ecosystems through seasonal upwelling – leading to seasonal hypoxia/anoxia along the west coast of India and coast of Oman => impacts the fisheries and economy

Arabian sea OMZ in the CMIP5 Historical (S2)

Annual dissolved oxygen averaged between 200-600m from WOA13 and CMIP5 HIST models



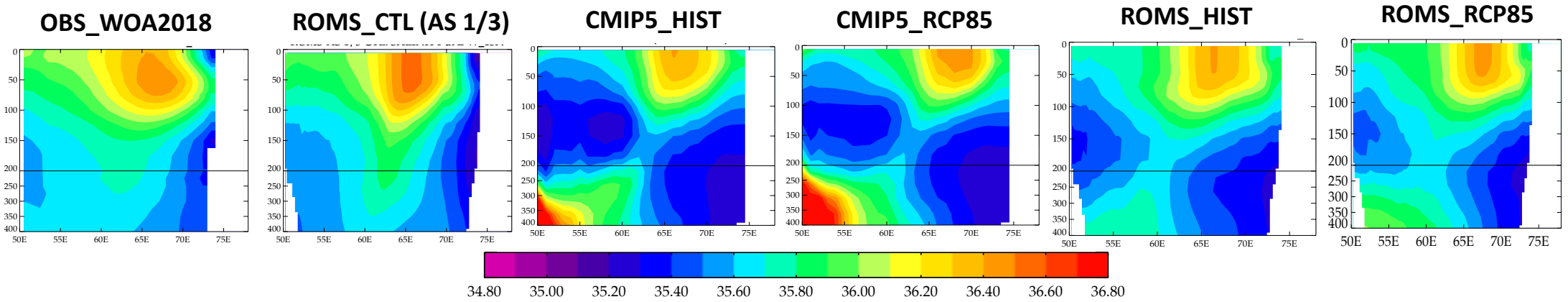
- In general the mean state is very poorly represented in CMIP5
- Only annual outputs are available

Goal of this study: Can we improve the mean state representation of AS OMZ by downscaling the CMIP5 models?

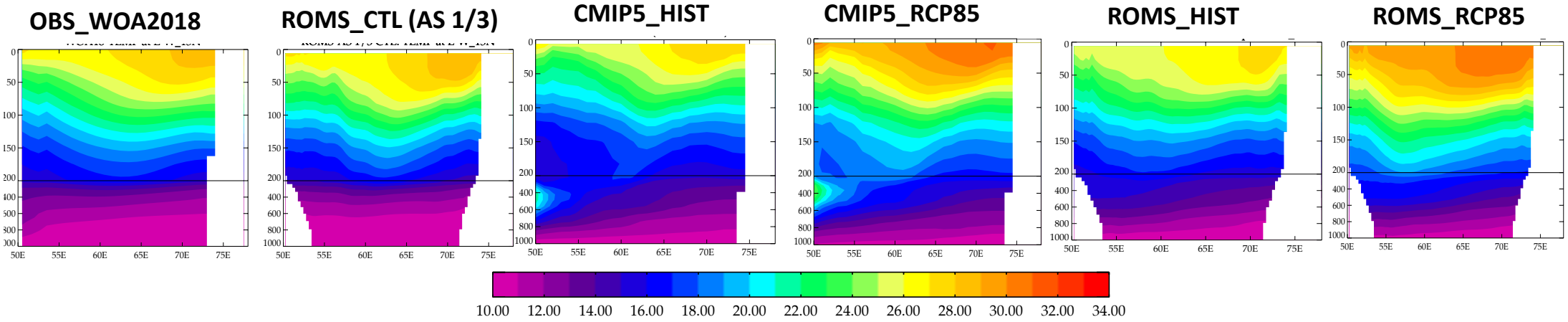
Methodology: Force the regional configuration of ROMS with the surface fluxes and the boundary conditions extracted from parent CMIP5 simulation – downscaled experiments

Mean state comparison of downscaled experiments: Physical variables (S3)

Annual mean zonal distribution of Salinity (PSU) at 15N from Observations and simulations



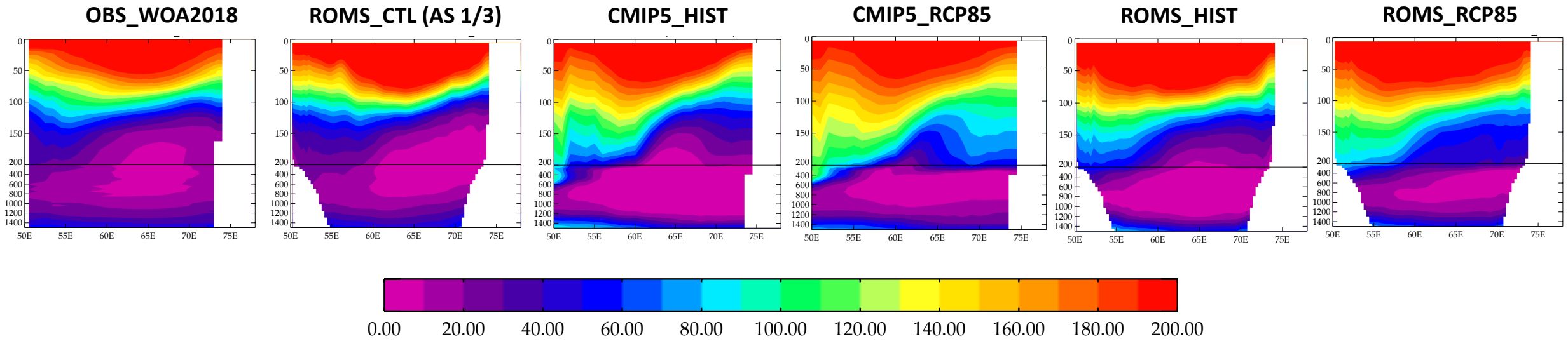
Annual mean zonal distribution of Temperature (°C) at 15N from Observations and simulations



- **ROMS_CTL realistically captures the observations (ROMS_CTL v/s OBS_WOA2018)**
- **The downscaled ROMS experiments shows only a slight improvement (ROMS_HIST v/s OBS_WOA2018) in the mean state representation compared to the parent CMIP5 (CMIP5_HIST v/s OBS_WOA2018)**

Mean state comparison of downscaled experiments: Oxygen (S4)

Annual mean zonal distribution of Oxygen (µmol/L) at 15N from Observations and simulations



- **ROMS_CTL realistically captures the observations (ROMS_CTL v/s OBS_WOA2018)**
- **The downscaled ROMS experiments shows only a slight improvement (ROMS_HIST v/s OBS_WOA2018) in the mean state representation compared to the parent CMIP5 (CMIP5_HIST v/s OBS_WOA2018)**
- **Currently we are assessing in detail the performance of the downscaled experiments including the projected changes**

Comparison of volume fractions of Oxic, Hypoxic and Suboxic waters (S5)

Model	Oxic	Hypoxic	Suboxic
ROMS_CTL	36.93	50.78	12.29
ROMS_HIST	37.58	46.62	15.8
ROMS_RCP85	45.52	46.37	8.11
OBS_WOA2018	28.12	68.56	3.32
CMIP5_HIST	29.7	45.91	24.39
CMIP5_RCP85	34.3	50.45	15.25

- **In all cases hypoxic water occupies larger volume in the 0-1500m layer**
- **Both in HIST & RCP85, the downscaling increases the oxic fraction and reduces the suboxic fraction as compared to parent CMIP5 simulation**
- **In comparison to oxic & suboxic waters, the difference in the hypoxic volume fraction is small between the downscaled and original simulation**

Oxic - O2 > 60µmol/l
Hypoxic - 60µmol/l >= O2 > 4µmol/l
Suboxic - 4 µmol/l > O2 > 0 µmol/l)

Preliminary insights from the downscaled experiment study (S6)

- **The downscaled experiments show marginal improvement in the mean state distribution of both physical and biogeochemical variables compared to the parent CMIP5 simulation**

- **For the Arabian sea OMZ, the downscaling improved representation of different classes of oxygen within the 0-1500m**

Suggestions are welcome

THANK YOU