A modified upper ocean mixing scheme for the Bay of Bengal

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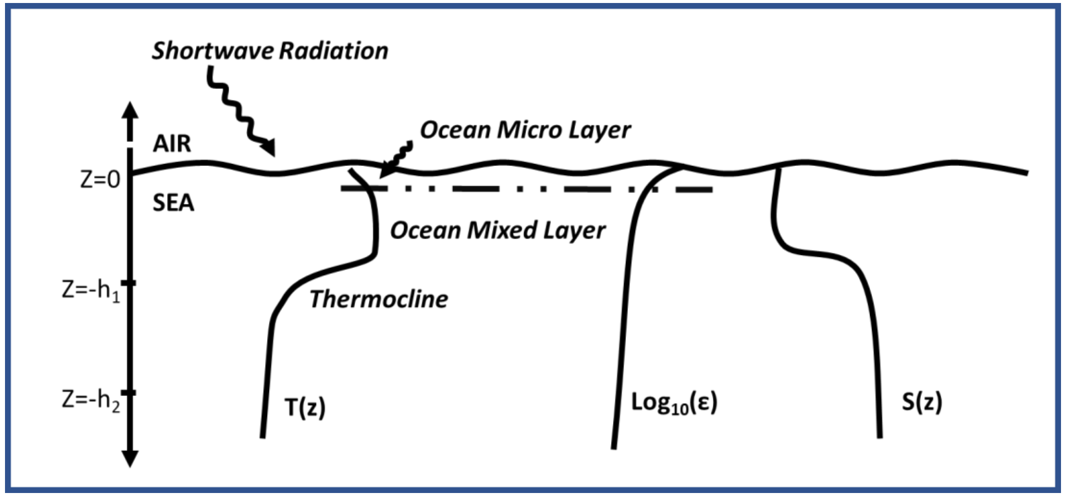
Ocean mixing : a possible culprit of model biases

Schematic of Ocean Boundary Layer



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Oceanography

Vertical mixing in the ocean

D. J. Webb & N. Suginohara

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A generalized model flowchart

adapted from PWP model

Wind Stress and Heat Flux

Free convection

$$\frac{\partial \rho}{\partial z} \geq 0$$

ρ profile is adjusted to static stability

τ absorbed within ML, momentum stepped forward in time

Mixed layer entrainment

$$R_b = \frac{g \Delta \rho h}{\rho_0 (\Delta \boldsymbol{V})^2} \geq 0.65$$

Shear flow instability

$$R_g = \frac{g \, \partial \rho / \partial z}{\rho_0 (\Delta \boldsymbol{V} / \partial z)^2} \geq 0.25$$

The diffusivities are calculated subsequently which are functions of Richardson number(R_f)

History of Flux Richardson number (R_f)

Turbulent transport of heat and momentum from an infinite rough plane

By T. H. ELLISON
Sidegarth, Heswall, Cheshire

(*Received* 22 *January* 1957)

SUMMARY

In the first part of the paper the dimensional laws governing the processes of heat and momentum transport from an infinite rough plane are assembled and their consequences set out. In the second part, the detailed equations for the turbulent energy, the mean square temperature fluctuation and the covariance of temperature and vertical velocity are used, together with some speculative assumptions concerning the dissipative action of the turbulence, to derive a series of relations between the turbulent intensities and the *Austausch* coefficients. One of these relations indicates that the flux form of the Richardson number cannot exceed a critical value which is about 0·15. It follows that in

The critical condition for the maintenance of turbulence in stratified flows

By S. P. S. ARYA
University of Washington, Seattle, Washington

(Manuscript received 11 January 1971; in revised form 17 August 1971. Communicated by Professor R. G. Fleagle)

SUMMARY

Theoretical models for predicting the critical Richardson number for the maintenance of turbulence in a stratified atmosphere are re-examined in the light of recent observations. It is proposed that the critical condition may first arise from the failure of the maintenance of steady shear in the presence of buoyancy forces. An expression for the critical flux Richardson number is derived from the consideration of the equations of Reynolds stress and turbulent energy. This gives a range of 0·15 — 0·25 for R_{fcr}, in agreement with the results of direct observations.

Estimates of the Local Rate of Vertical Diffusion from Dissipation Measurements

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(Manuscript received 16 June 1978, in final form 2 July 1979)

ABSTRACT

Scaling of the turbulent energy equation suggests the balance of terms in the ocean is between turbulent production, dissipation and the loss to buoyancy. In this paper two models for the source of oceanic turbulence are considered; namely, production by the Reynolds stress working against a time variable mean shear, and the gravitational collapse of Kelvin-Helmholtz instabilities. Both of these shear instabilities are believed to be important in the ocean. Using values for the critical flux Richardson number and the measurements from studies of Kelvin-Helmholtz instabilities, the efficiency of turbulent mixing is shown to be comparable for the two models. Therefore, a general relationship between the dissipation rate and the buoyancy flux due to the small-scale turbulent velocity fluctuations is derived. The result is expressed as an upper bound on the value of the turbulent eddy coefficient for mass $K_\rho \leq 0.2\epsilon/N^2$. Values of K_ρ are calculated from recent oceanic measurements of energy dissipation. Isopycnal advection and doubly diffusive phenomena are not included in the model.

Dye release experiments, moored microstructure instruments, shear probes on turbulence profiler, etc all give validation of $R_f \approx 0.2$.

Flux Richardson number (R_f) definitions

$$K_m = -\frac{\overline{u'w'}}{\mathrm{d}\overline{u}/\mathrm{d}z},$$

$$K_s = -\frac{\overline{\rho'w'}}{\mathrm{d}\overline{\rho}/\mathrm{d}z},$$

$$K_\rho = \left(\frac{R_f}{1-R_f}\right)\frac{\epsilon}{N^2},$$

$$R_f = \frac{B}{P},$$

$$R_f^{II} = \frac{B}{m} = \frac{B}{B+\epsilon},$$

$$R_f^{*} = \frac{\epsilon_{PE}}{\epsilon+\epsilon_{PE}}.$$

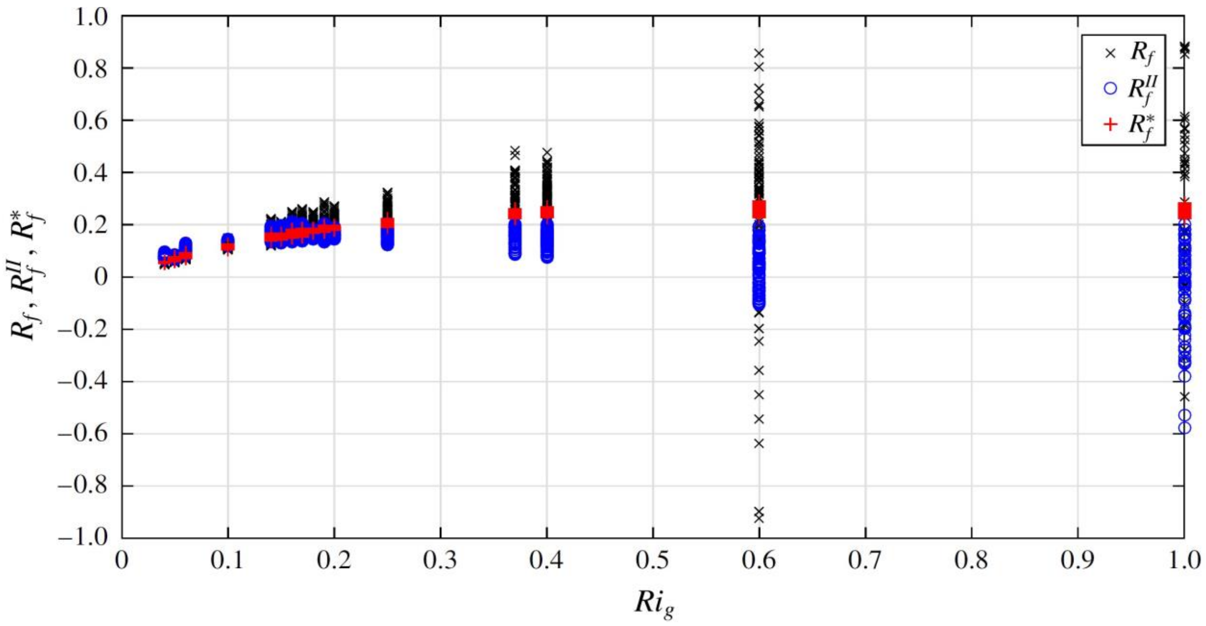
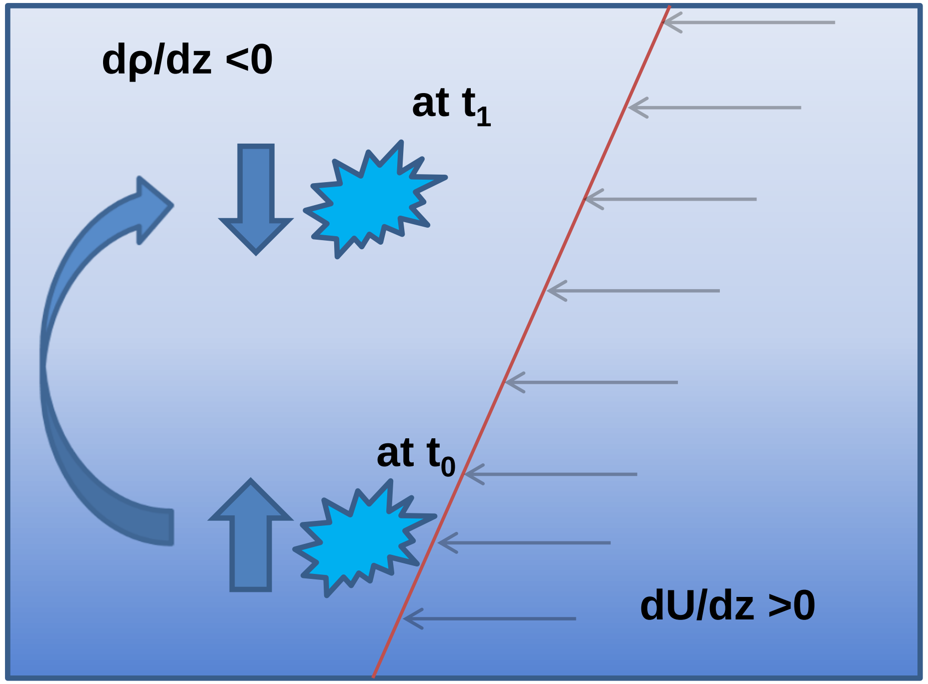


FIGURE 1. Comparison of the flux Richardson numbers R_f, R_f^{II} and R_f^* as functions of the gradient Richardson number Ri_g, computed from the DNS data of Shih *et al.* (2005).

The reversible and irreversible components were identified by Venayagamoorthy et al (2010, 2016)

Reversible mixing



- In strongly stably stratified conditions,
  - low TKE
  - parcel does not diffuse
  - parcel comes back to original position
  - **reversible flux**

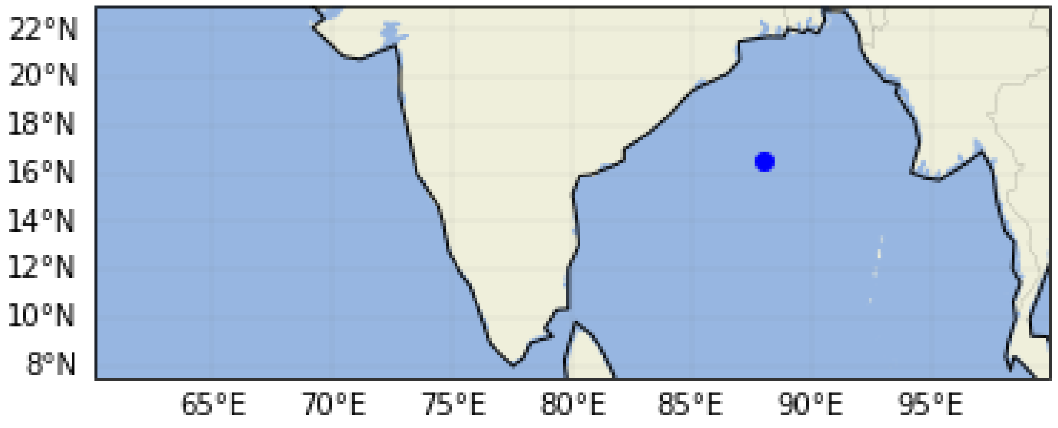
- The models do not take this into account thereby overestimating the mixing.

Model Simulations

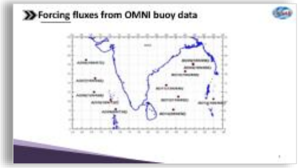
- 1-D **k-ε mixed layer model**
- Location - Bay of Bengal (16°N, 88°E)
- Resolution – 5m, total depth – 250m
- Hourly forcing variables :

  – Shortwave radiation, precipitation, winds,

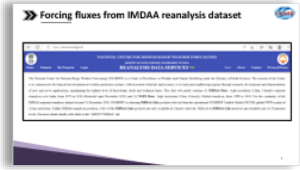
  air temperature, humidity at hourly frequency



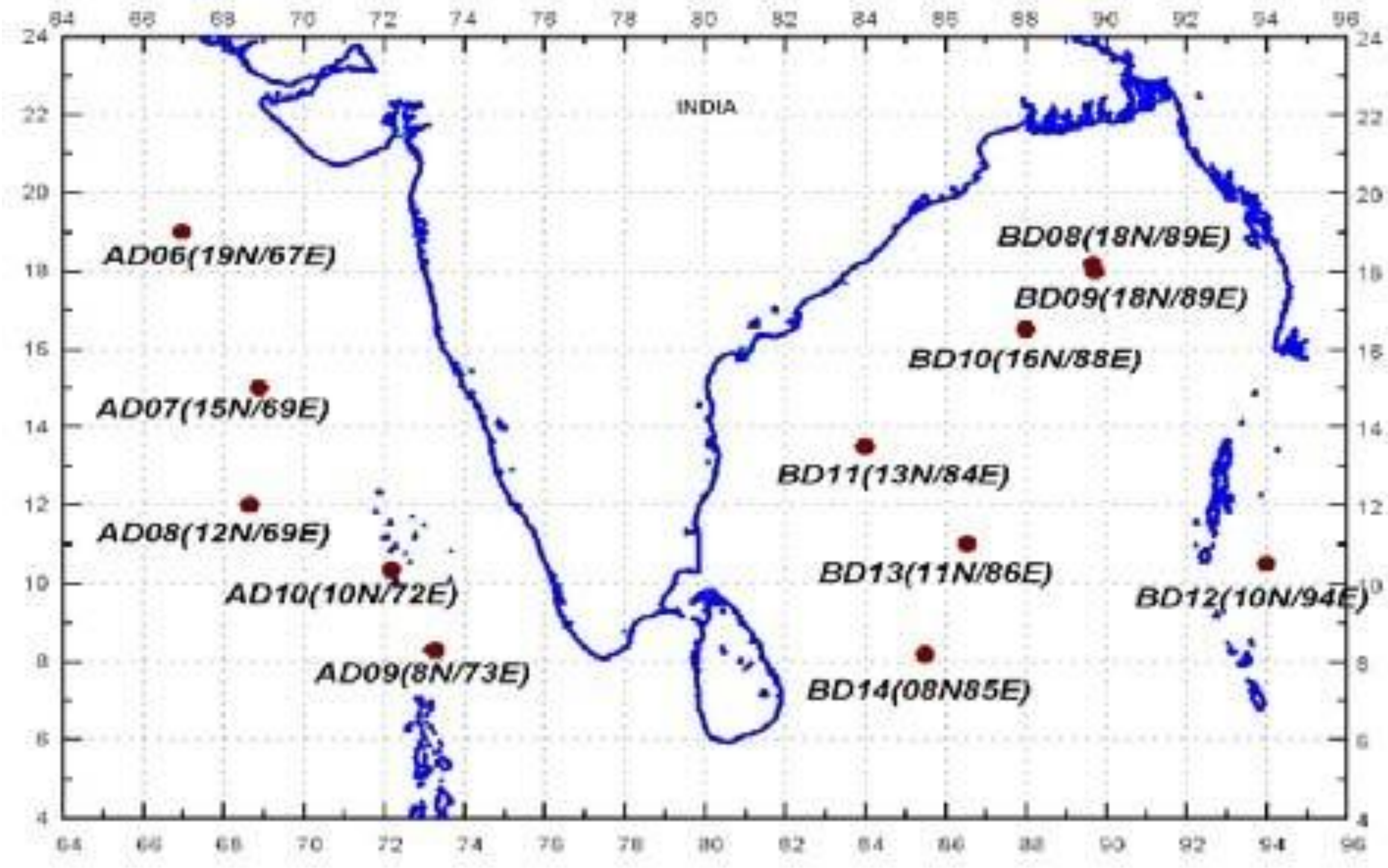
- CTRL run : Model simulation with conventional k-ε model
- EXP run – Model simulation with modified k-ε model
- **Run 1** : Forcing data from a buoy



Run 2: Forcing data from IMDAA Reanalysis dataset



Forcing fluxes from OMNI buoy data



Forcing fluxes from IMDAA reanalysis dataset

https://rds.ncmrwf.gov.in

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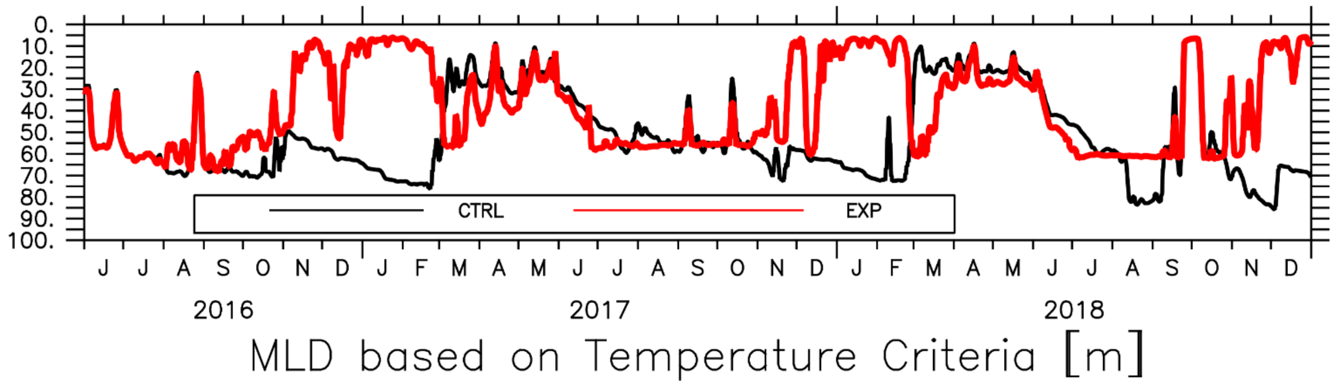
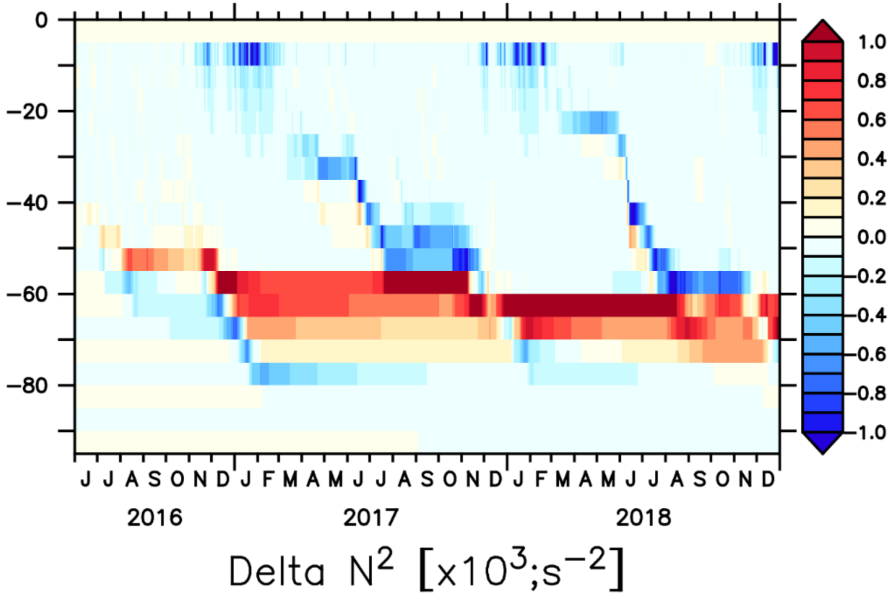
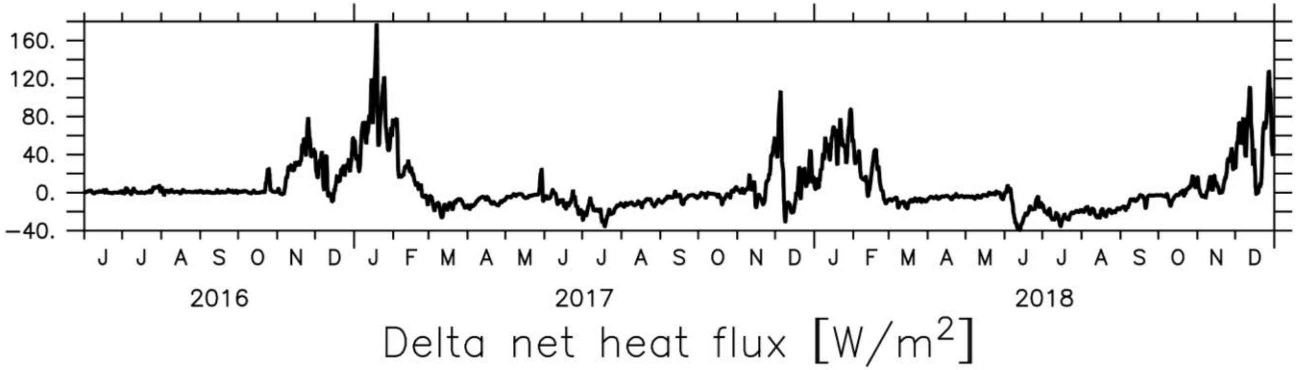
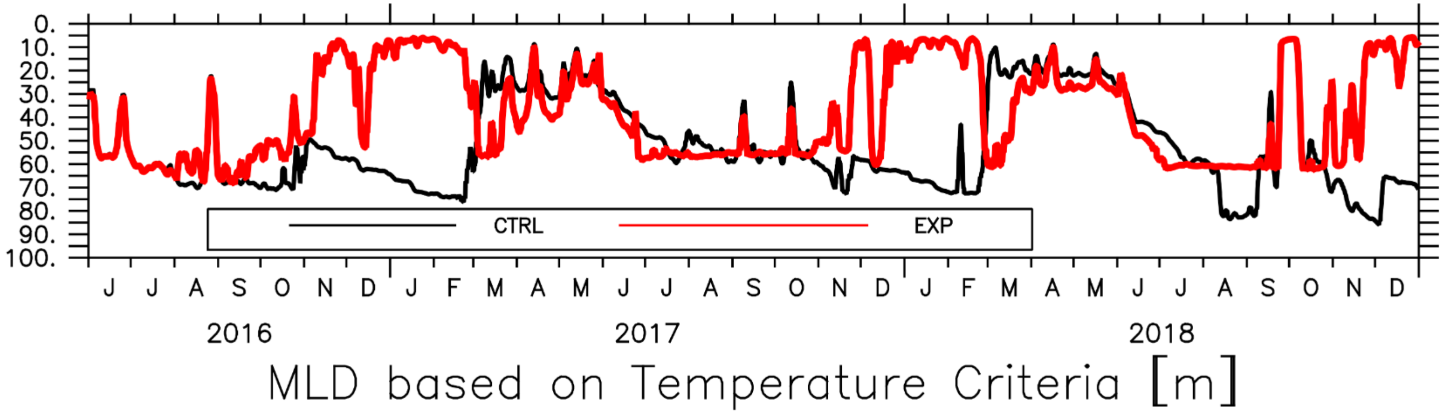
Sensitivity with k-ε model (Experiment - control)







Conclusion



Argo has spatial coverage but 10-day frequency.

Moorings have high frequency but sparsely located.

Need of high resolution spatial and temporal observational data for such sensitivity experiments.