Application of Extended Range Prediction ocean ensembles in developing Marine Biogeochemistry deliverables: A future perspective

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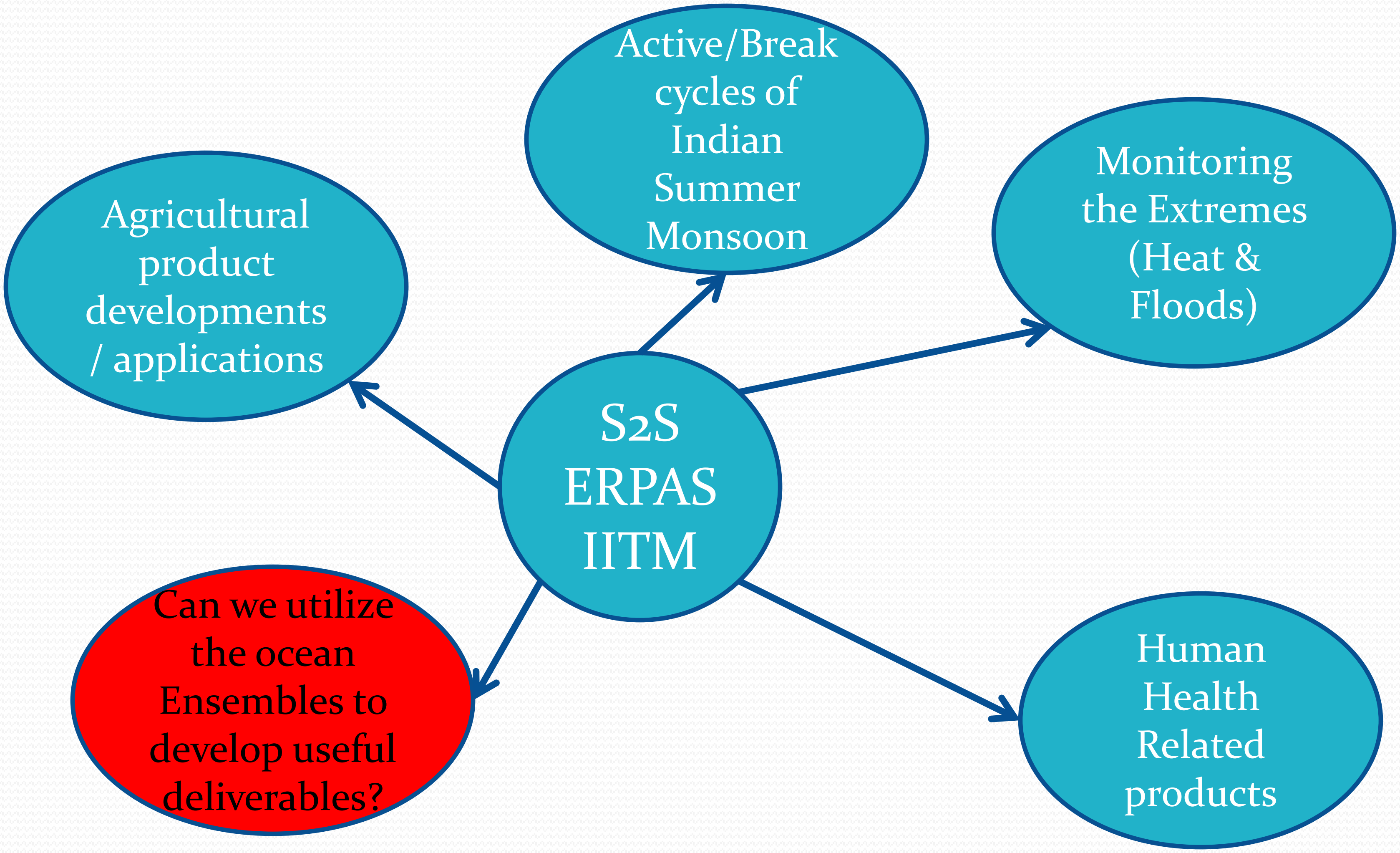
S2S at @IITM ERPAS applications



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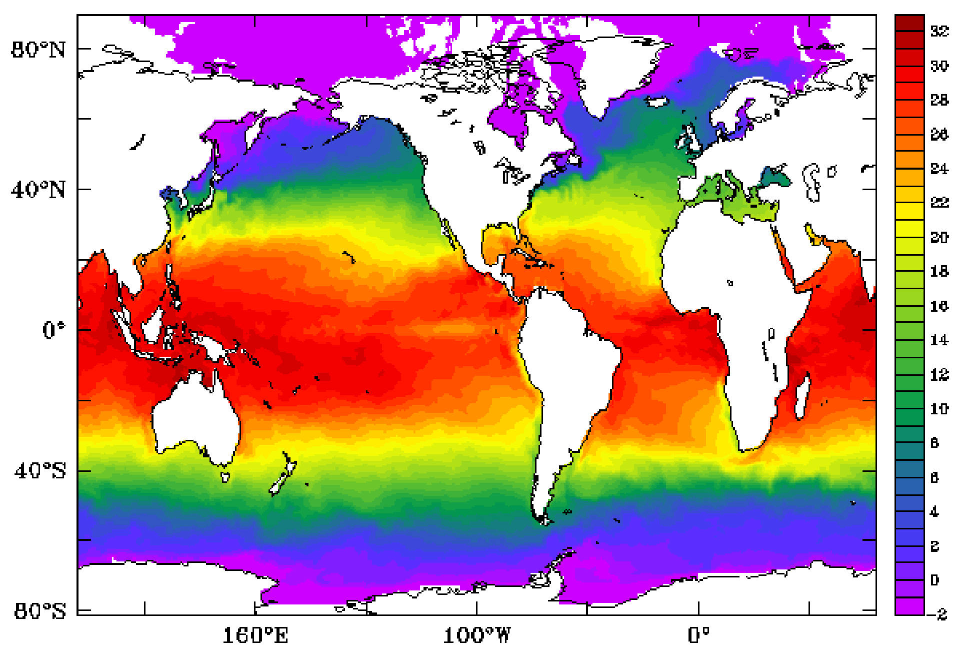
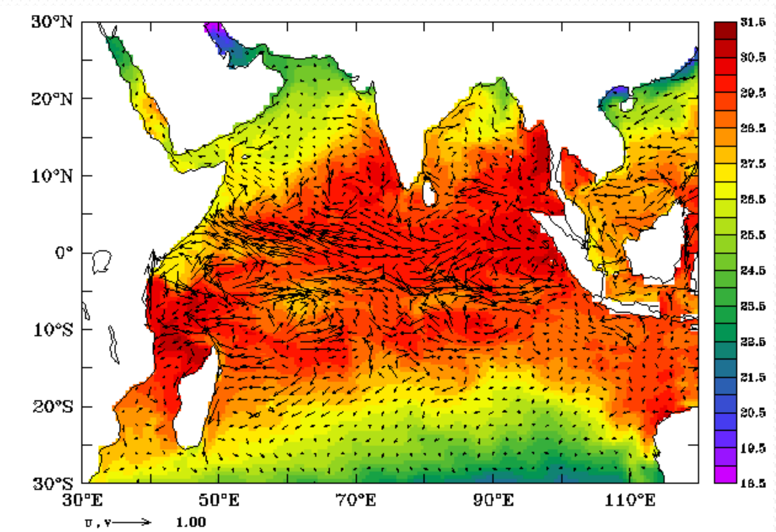
IITM ERPAS Ocean Ensembles

- There are 8 ensembles run with coupled models.
    - CFSv382 and CFSv126 with common ocean resolutions
- The ocean is at 0.5x0.5 degree resolutions
- It has 40 vertical levels where 25 levels are in upper 250 m
- Initialized with I.C. developed at INCOIS
- Forecast is done every Thursday and ensembles are available for further research



SST of Ocean Component of CFSv2



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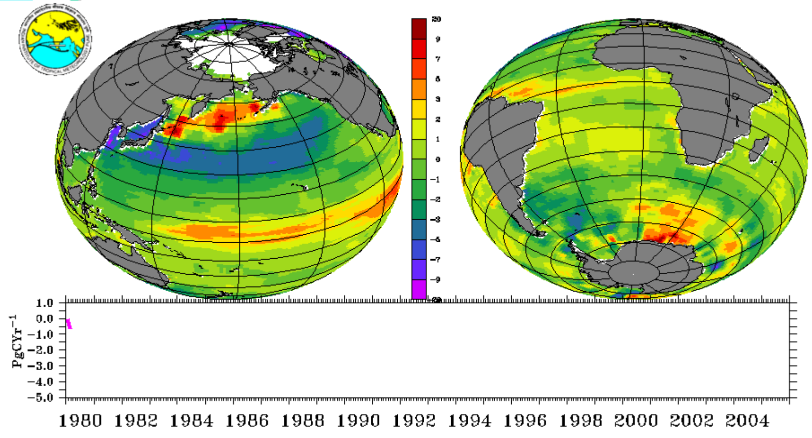
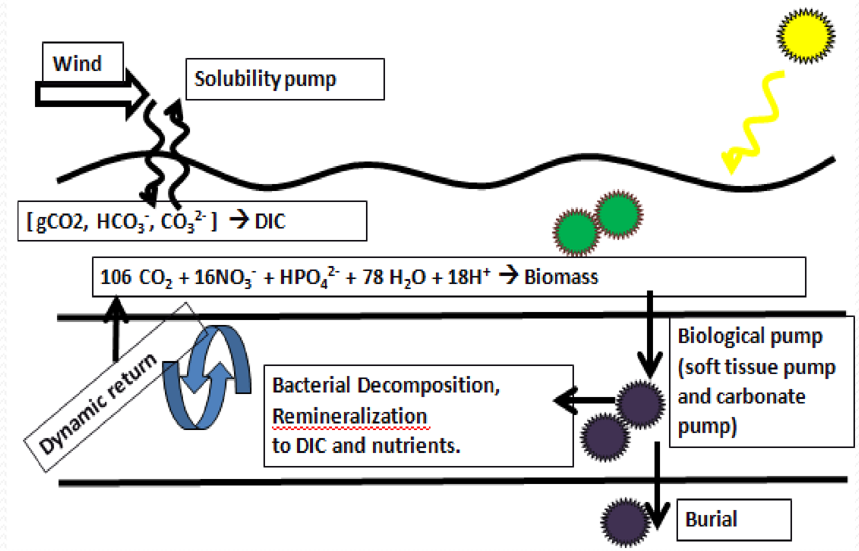
IITM ERPAS Ocean Ensembles

- Ocean Ensembles produced by the ERPAS systems are, however, not well explored
- There are potential applications for the ocean ensembles
- One such application is the development of marine ecosystem related variables
- As a first attempt we have come-up with ocean Biogeochemistry deliverables with models driven by ERPAS ocean ensembles.

Ocean Tracer Transport Model-BGC @ IITM





$$\frac{\partial C}{\partial t} + \mathbf{U}\cdot\nabla_H C + W\frac{\partial C}{\partial z} = \frac{\partial}{\partial z}K_z\frac{\partial}{\partial z}C + \nabla_H\cdot(K_h\nabla_H C) + \phi$$

$$\nabla_z\cdot\left[C\frac{\partial}{\partial z}\left(K_h\nabla_z\frac{\rho}{\rho_z}\right)\right] - \frac{\partial}{\partial z}\left[C\nabla_z\cdot\left(K_h\nabla_z\frac{\rho}{\rho_z}\right)\right]$$

$$K_x(\sigma) = h w_x(\sigma)G(\sigma).$$

$$G(\sigma) = a_0 + a_1\sigma + a_2\sigma^2 + a_3\sigma^3.$$

$$w_x = \kappa(a_x u^{*3} + c_x\kappa\sigma w^{*3})^{1/3} \quad \text{if} \quad \sigma < \varepsilon,$$

$$w_x = \kappa(a_x u^{*3} + c_x\kappa\varepsilon w^{*3})^{1/3} \quad \text{if} \quad \varepsilon \le \sigma < 1.$$

(a) Ocean Tracer Transport Model (OTTM) by Valsala et al., (2008)

(b) OCMIP-II Biogeochemistry by Orr et al., (1999)

(c) Modified Parameterization of Net Community production (NCP) by Sreeush et al., (2019, 2020)

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OCMIP-II BGC model

$$J_{prod} = \frac{1}{\tau}([PO_4] - [PO_4]^*)$$ <= Zc

$$J_{PO4} = \sigma J_{prod} - \kappa[DOP]$$ > Zc

$$NP = -\int_{Zc}^{0} J_{JPO4}\, dz$$ (New Production)

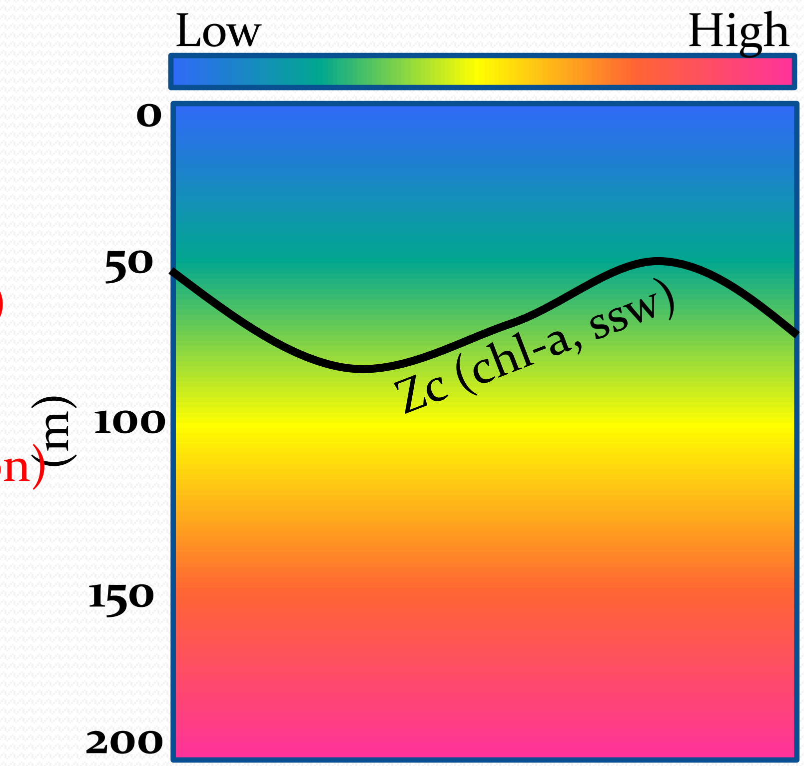
$$EP = (1-\sigma)\int_{Zc}^{0} J_{prod}\, dz$$ (Export Production)

$$J_{PO4} = -\frac{\partial F}{\partial Z} + \kappa\,[DOP]$$ (Sink of PO4)

$$F_{(z)} = EP\left(\frac{Z}{Z_c}\right)^{-a}$$ (Export Flux)

(Orr et al., 1999)

Schematic of PO4 profiles



After Sreeush et al., (2018)

Sea-to-air CO_2 fluxes, DIC and Alkalinity FW Fluxes

$$\Phi_{DIC} = K_w\left(pCO_{2_{ocean}} - pCO_{2_{air}}\right) - (P - E + R)\frac{DIC_g}{dz}$$

$$\Phi_{ALK} = -(P - E + R)\frac{ALK_g}{dz}$$

Kw = piston velocity (function of square of wind speed, SST, and CO_2 solubility in water)

pCO_2 is the partial pressure of CO_2

(P-E+R) is the fresh water fluxes in ms^{-1}

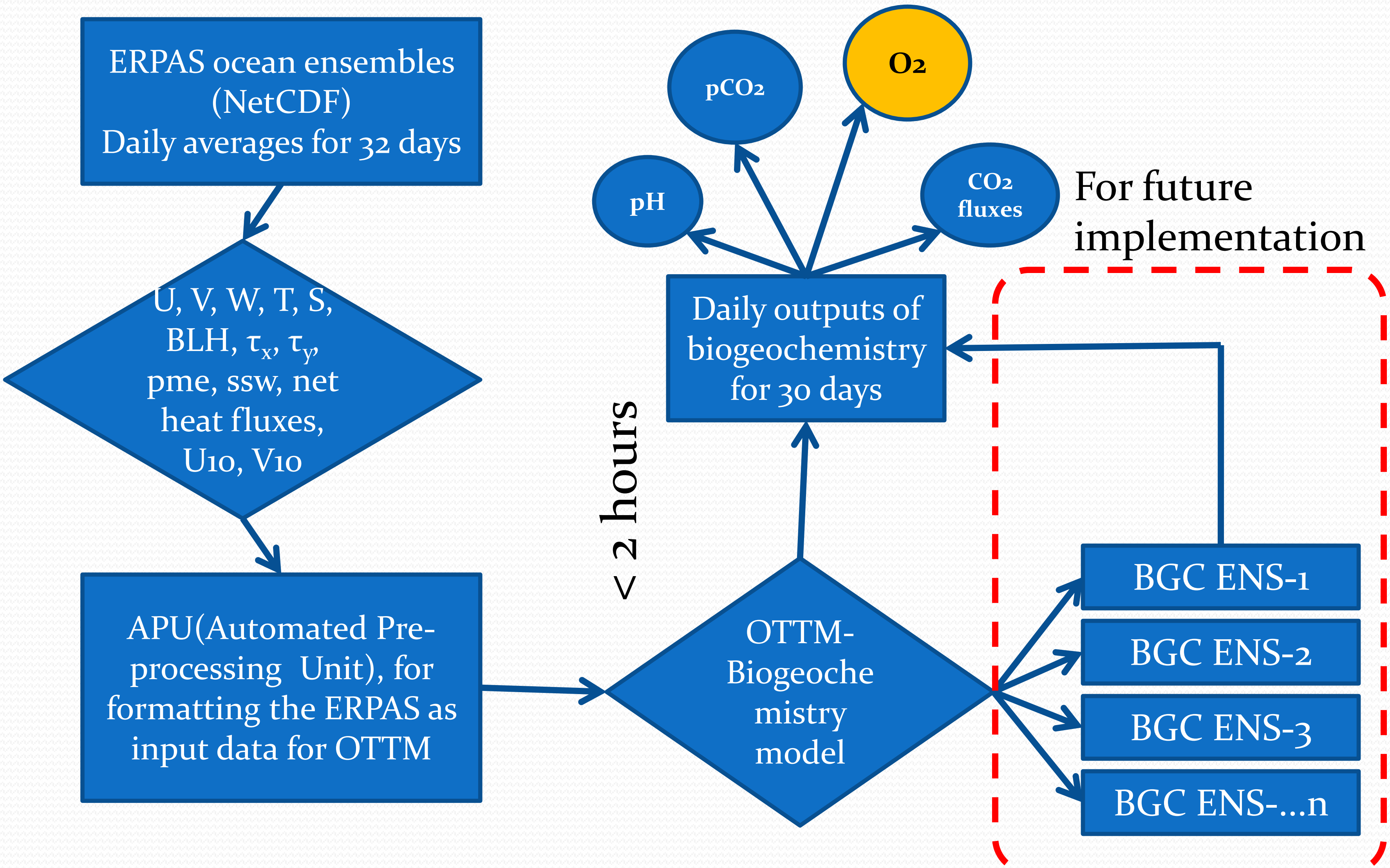
(Wannikhopf et al., 1993)

Input data to run OTTM

- IITM-ERPAS ocean ensemble data at native grid of 720 x 410 x 40

- Input data:
  - U, V, T, S, BLH, PME, τ_x, τ_y , SSH and P-E
  - W is determined from mass conservation

The OTTM-ERPAS-BGC System



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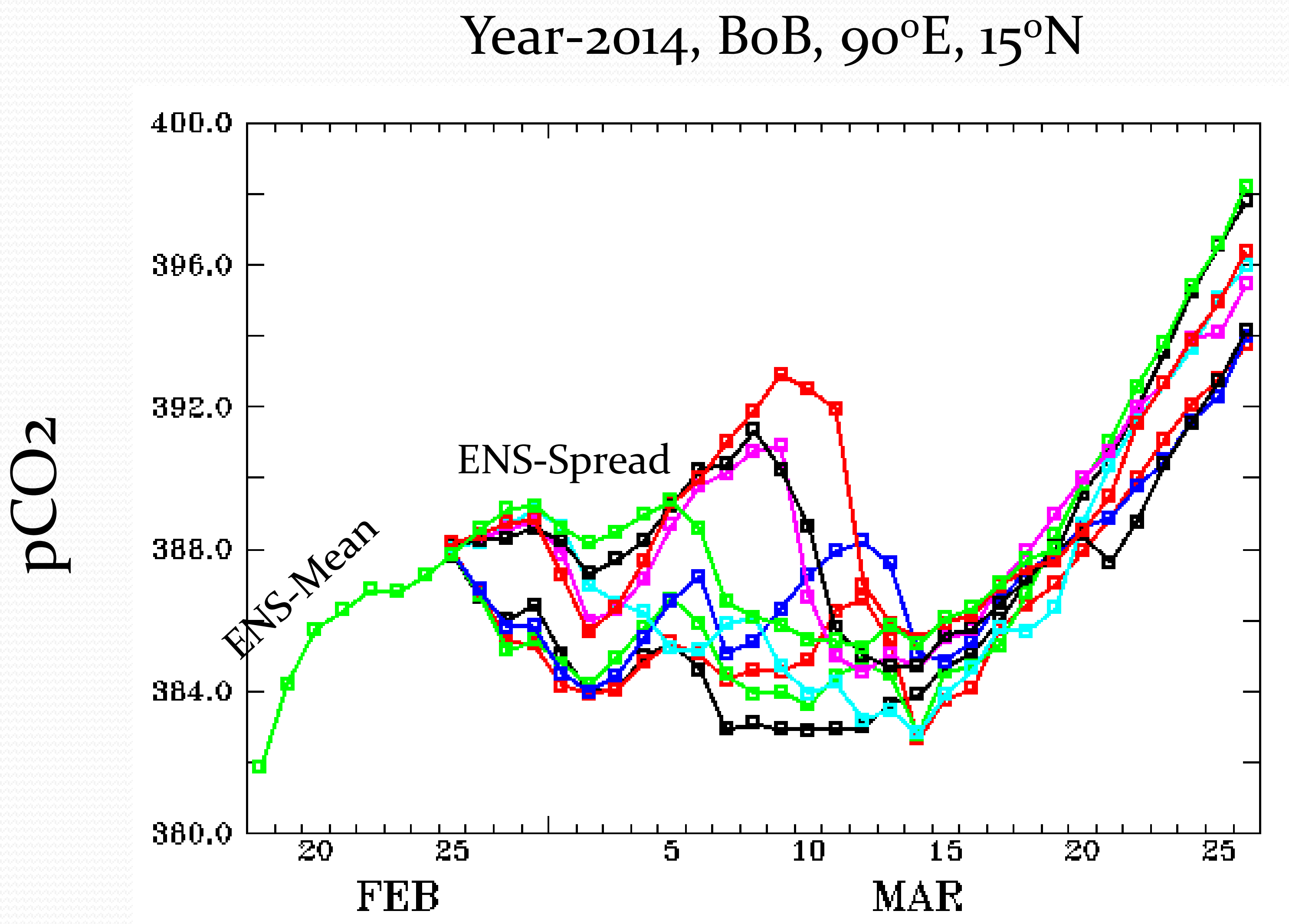
Experiments

- We have done a test case of OTTM-ERPAS-BGC for Jan-Mar of 2013, 2014, 2015, 2016
- Presenting here few initial outcome from 24-Feb-2014 run
- At first we have a task of validating our product
- Observations to validate the ocean BGC is really challenging

OTTM-ERPAS-BGC outputs



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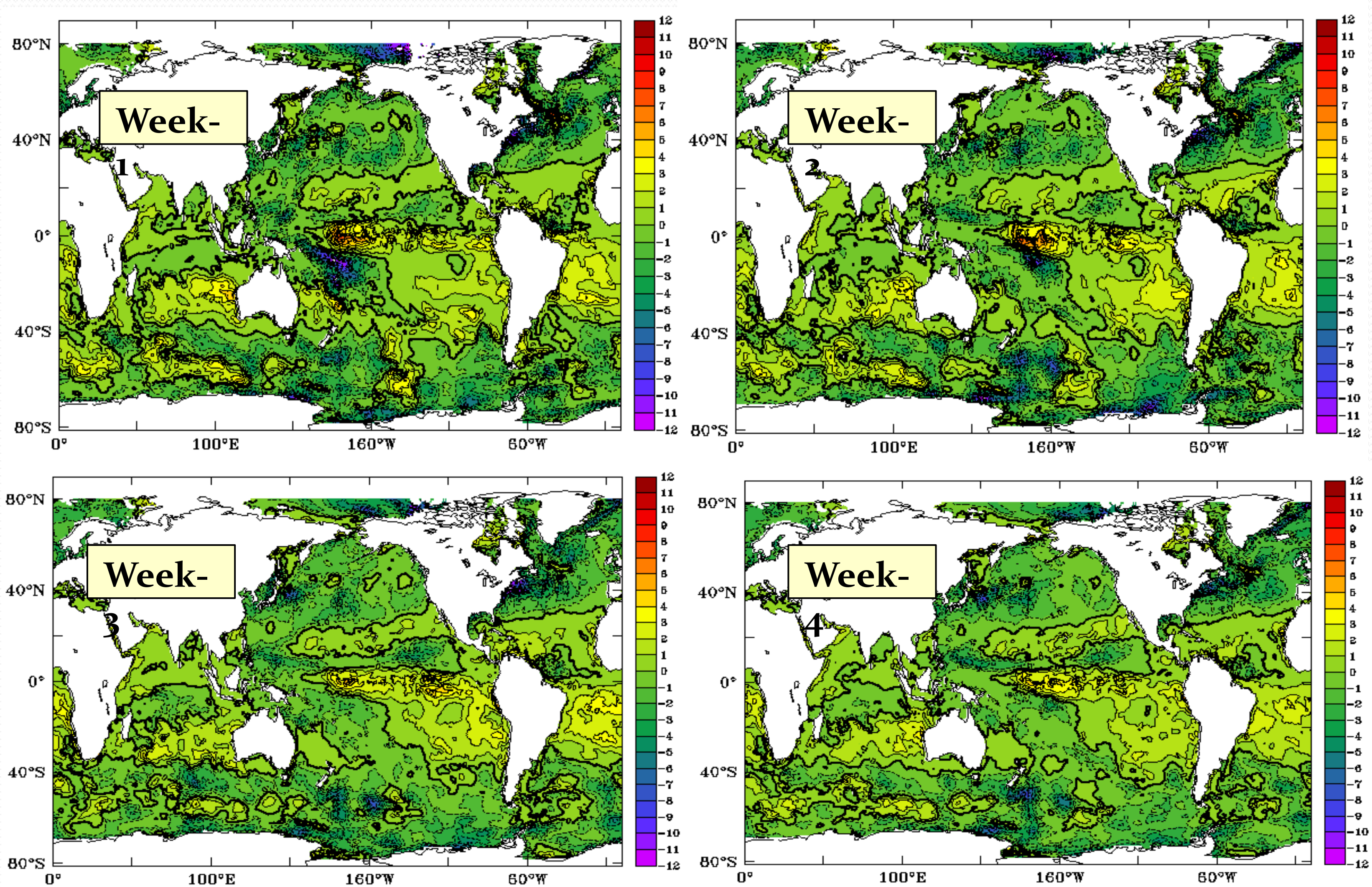
OTTM-ERPAS-BGC outputs

Sea-to-air CO2 fluxes 03-Mar-2014



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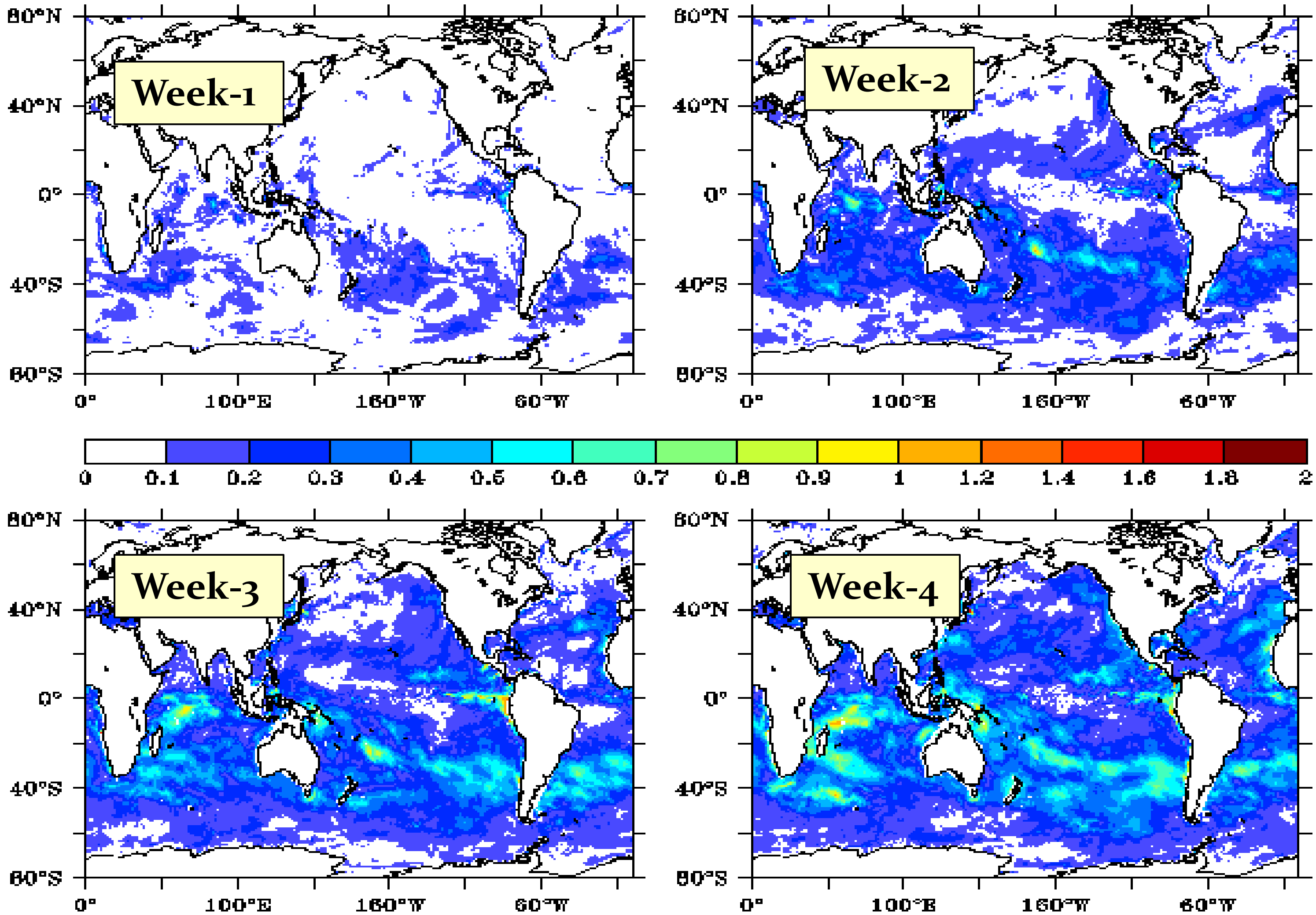
OTTM-ERPAS-BGC outputs

CO2 fluxes Ensemble Variances (24-Feb-2014 run)



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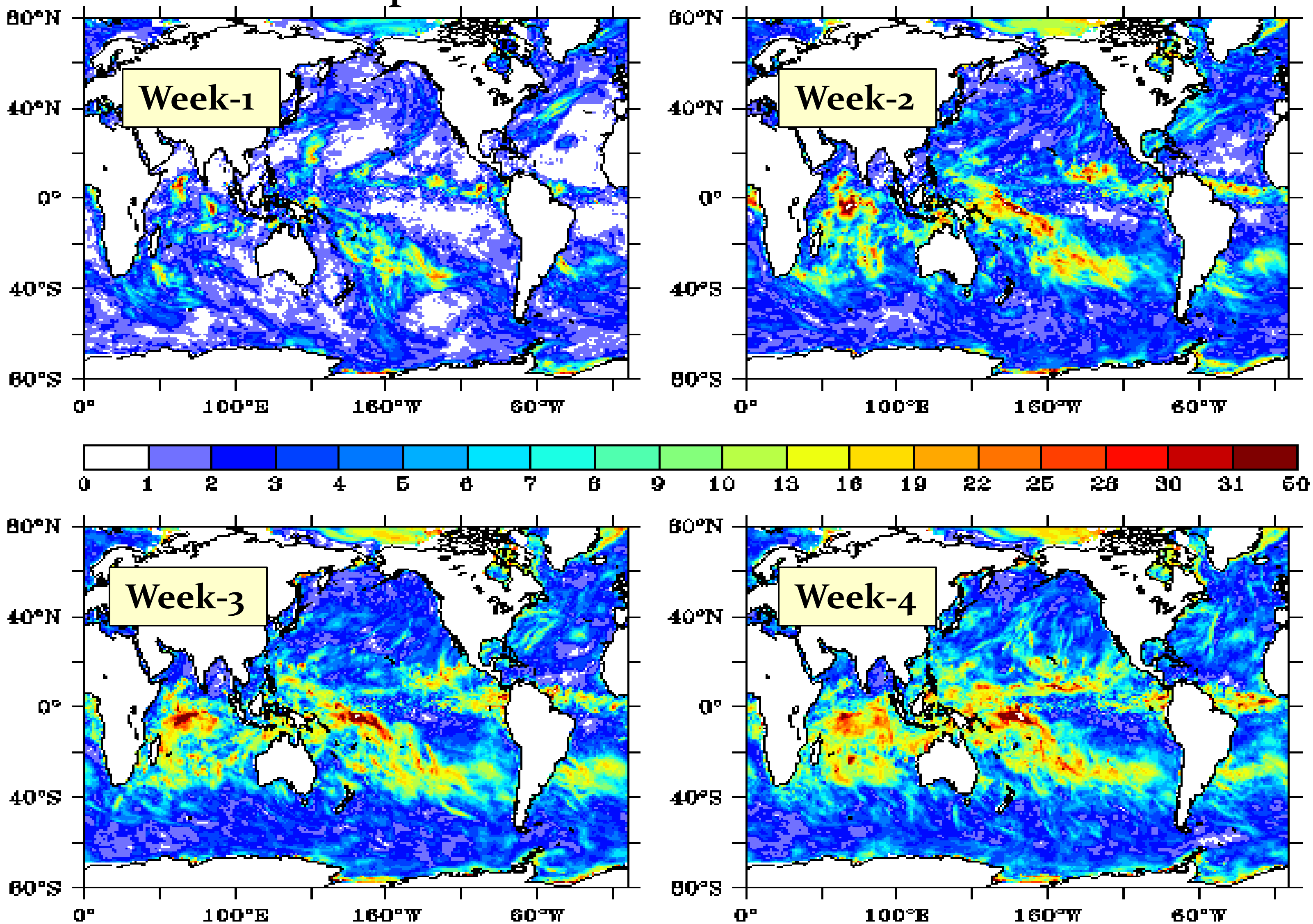
OTTM-ERPAS-BGC outputs

pCO_2 Ensemble Variances



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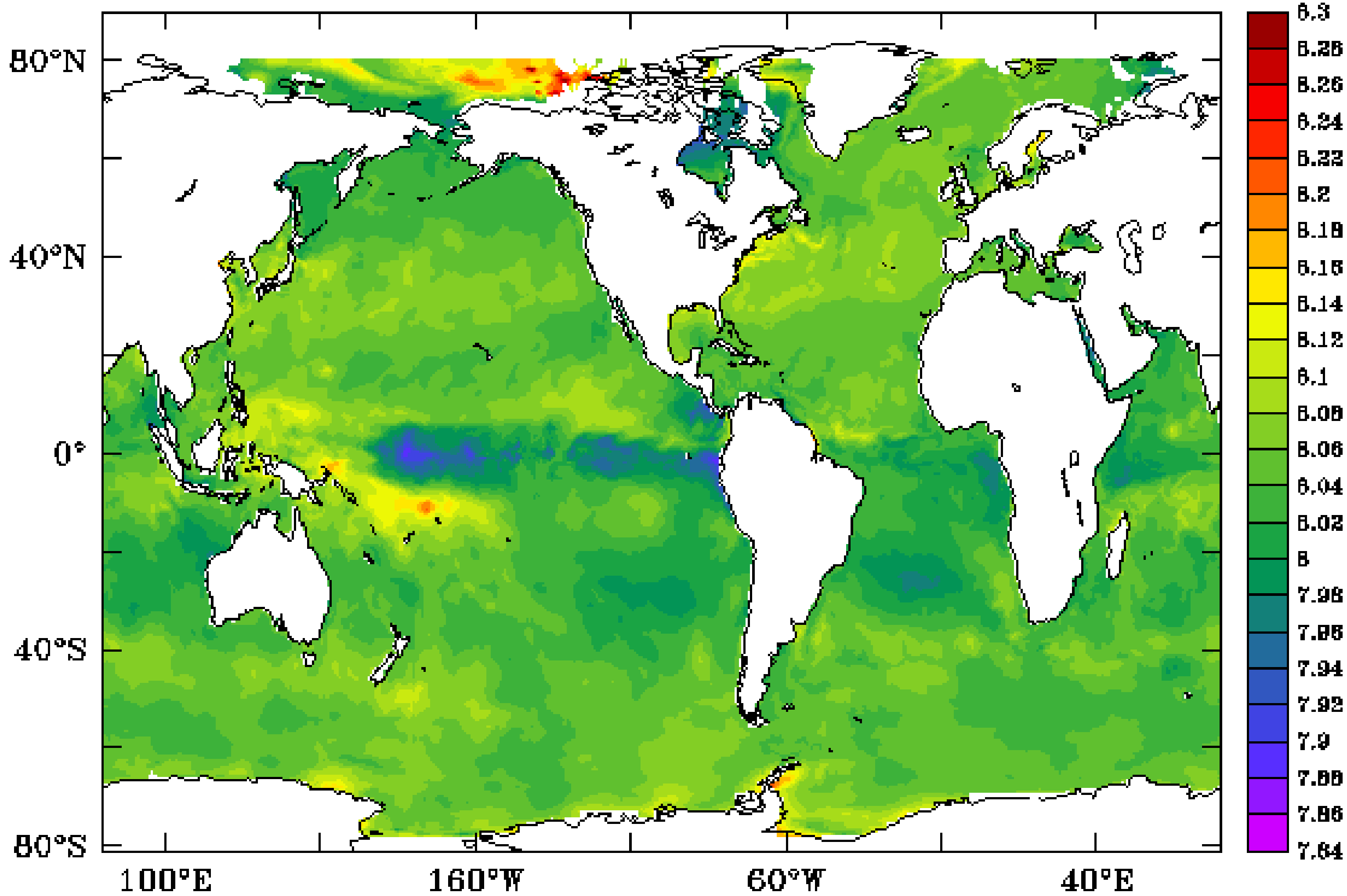
OTTM-ERPAS-BGC outputs

Surface Ocean Acidity (pH) Week-1



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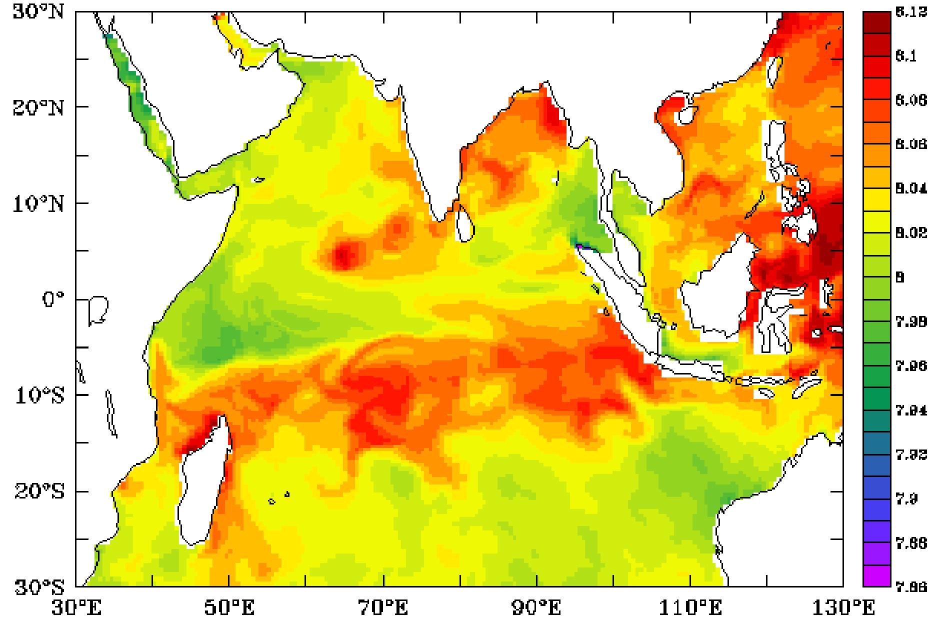
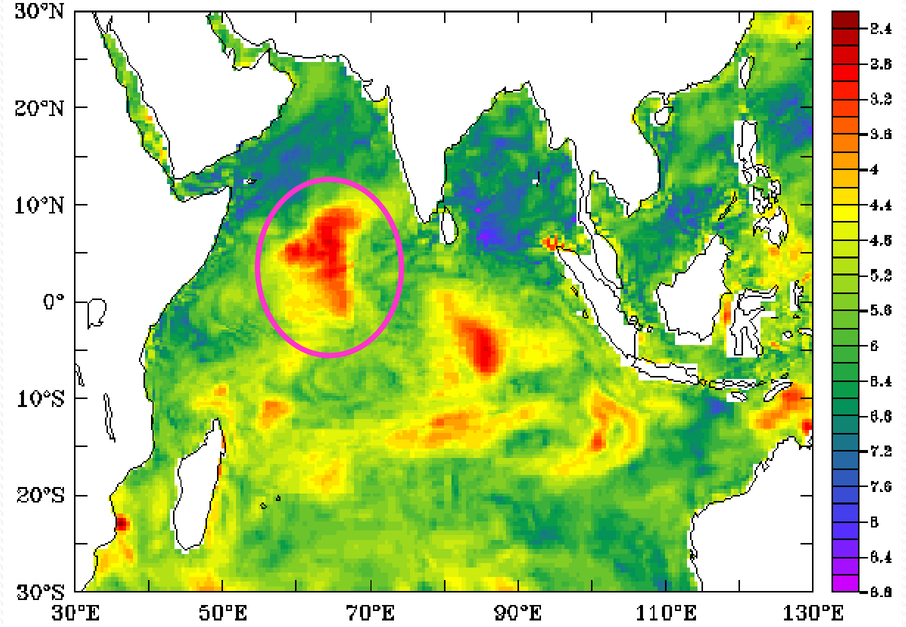
OTTM-ERPAS-BGC outputs

Surface Ocean Acidity (pH) Week-1



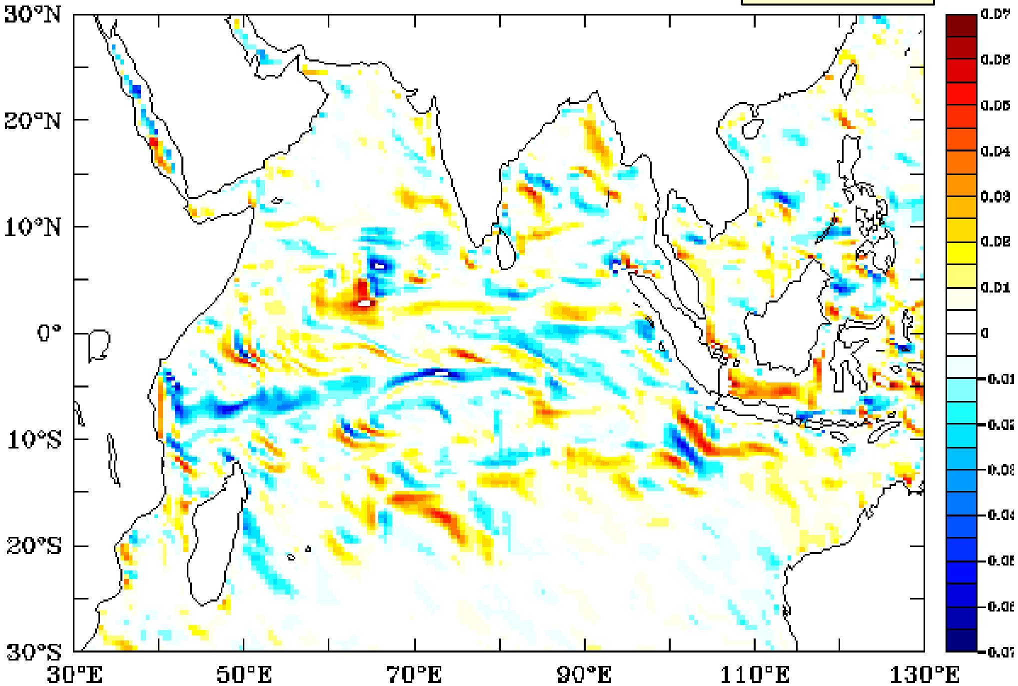
Surface Ocean Acidity Week-1 hotspots

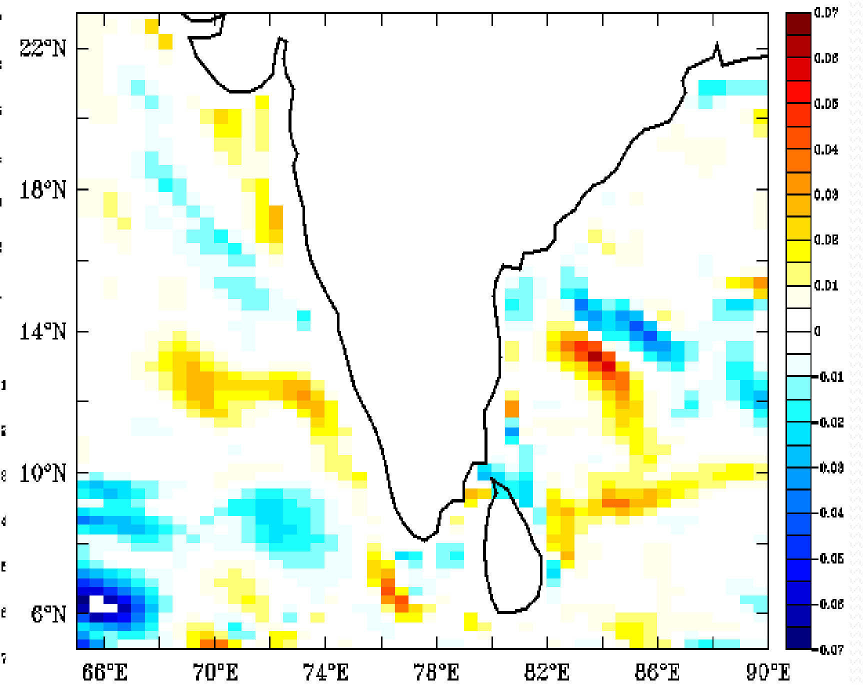


OTTM-ERPAS-BGC outputs

Surface Ocean Acidity (pH) gradient (pH degree^{-1})

Week-1





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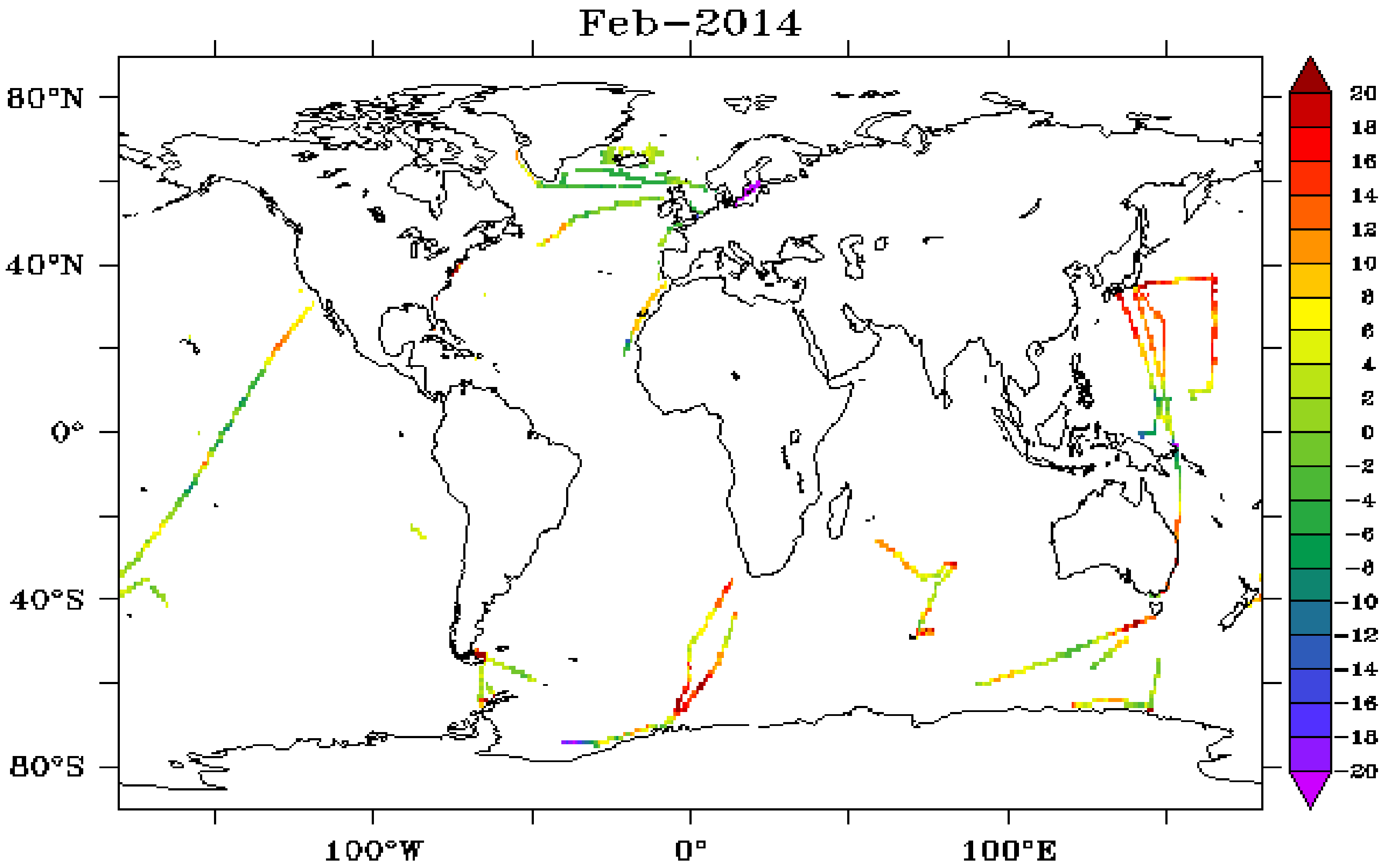
OTTM-ERPAS-BGC outputs

Surface Ocean pCO2 comparison with observation. Error in a month.



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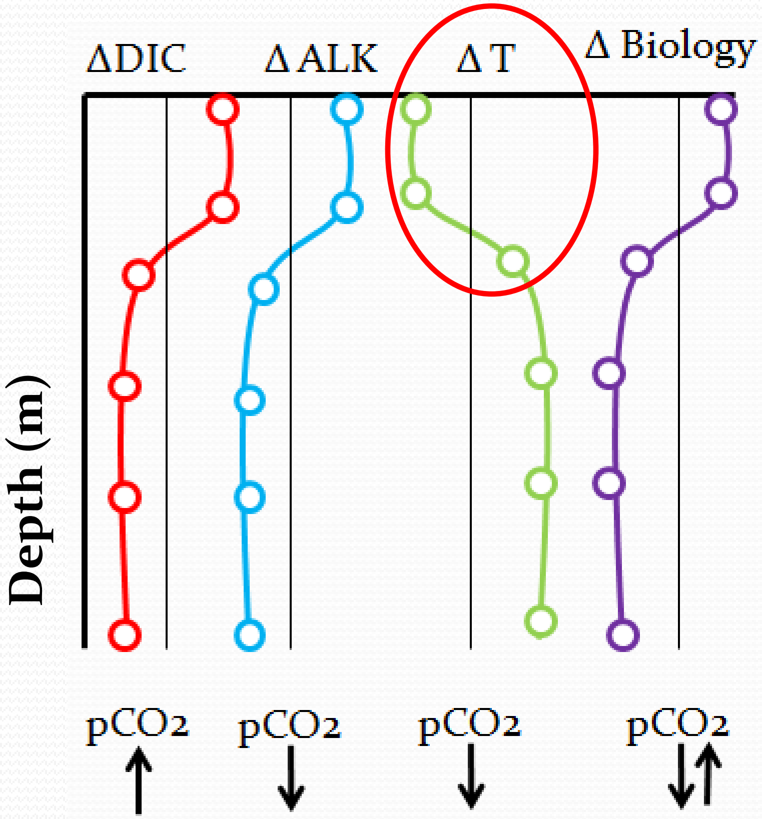
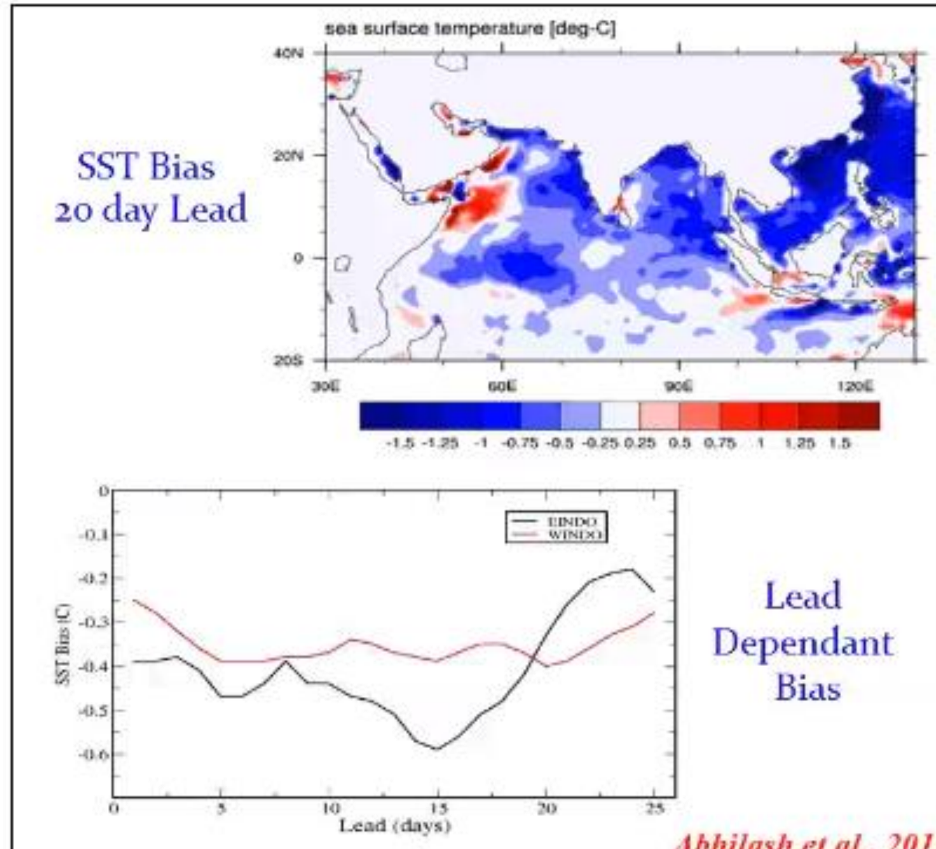
Challenges and model errors

$$\frac{dpCO_2}{dt} = \frac{\partial pCO_2}{\partial T}\frac{dT}{dt} + \frac{\partial pCO_2}{\partial DIC}\frac{dDIC}{dt} + \frac{\partial pCO_2}{\partial ALK}\frac{dALK}{dt} + \frac{\partial pCO_2}{\partial S}\frac{dS}{dt} + (\text{minor ions})$$





Abhilash et al., 2013

An SST error of ±1ºC can cause a ±10 μatm error in pCO2 in tropical waters

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Conclusion

- Who all are the beneficiaries of such products
  - pCO_2, sea-to-air CO_2 fluxes forecast for 30 days may not be beneficial to any particular community
  - Acidification and its gradients can be beneficial for fishery applications
  - Acidification (pH) data is useful for SONAR communication and may find potential beneficiaries in Navy operations (under communication)
  - Oxygen, an extended module to OTTM, may attract more beneficiaries such as fishery community

Thank You