Reconciling systematic differences between observed and simulated ocean deoxygenation

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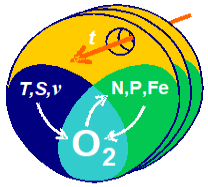
GEOMAR & University of Kiel, Germany

GO$_2$NE
Global Ocean Oxygen NEtwork

GEOMAR



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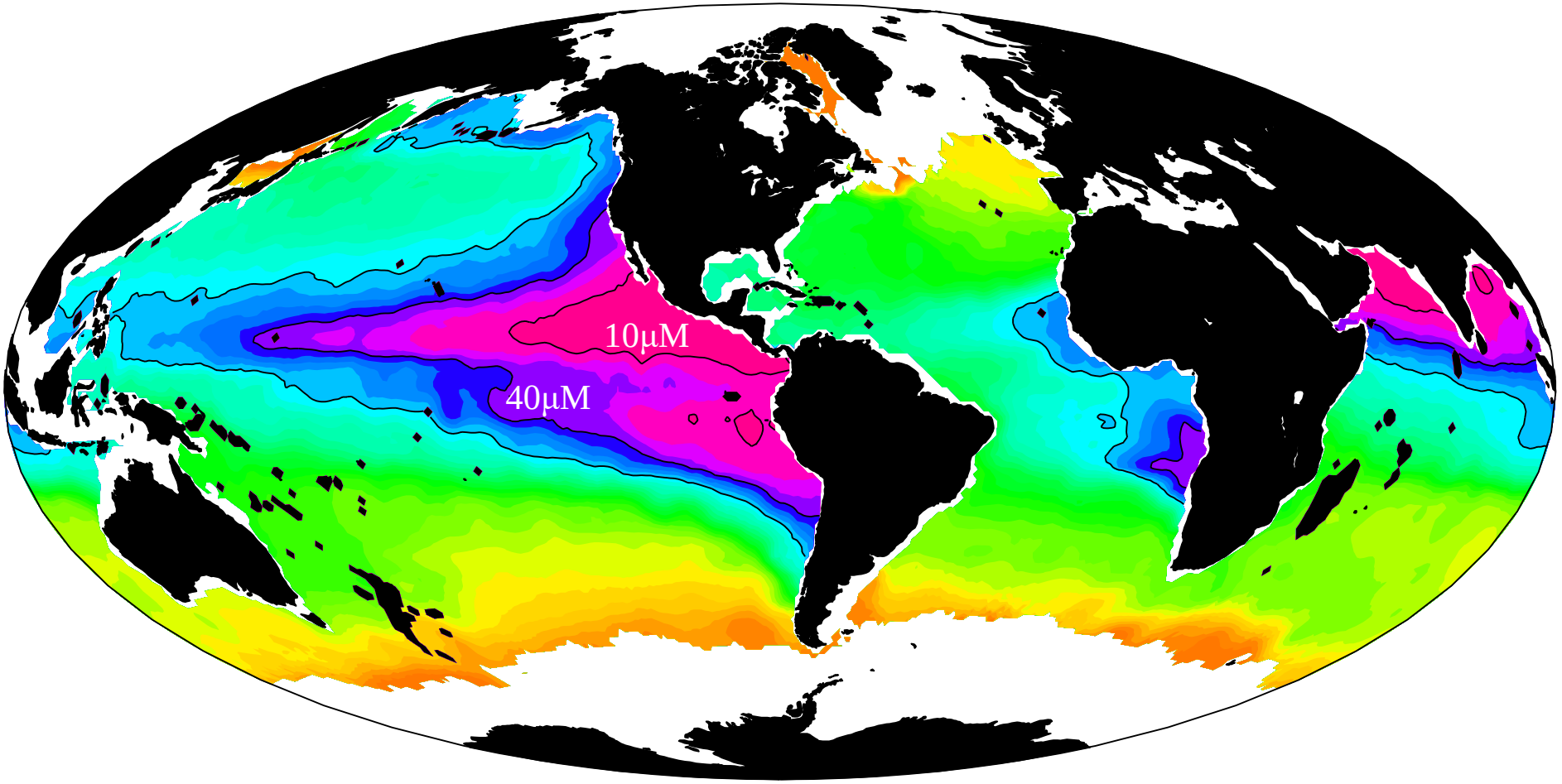
Dissolved Oxygen

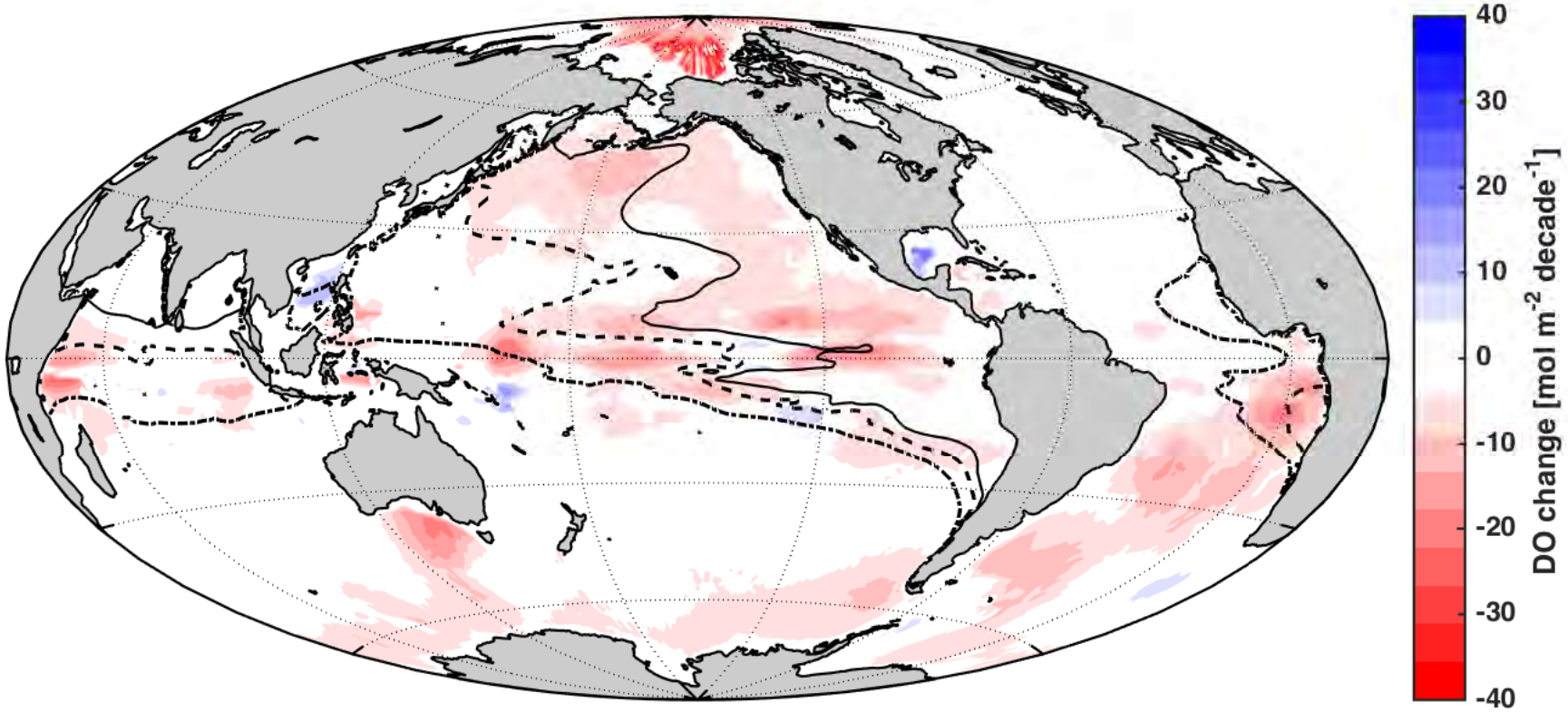


O_2 on σ=26.9 isopycnal

Atmospheric inventory		Oceanic inventory
37.500 Pmol	99.4% 0.6%	227 Pmol

Oxygen change (1960-2010)

Observational estimate:
Oceanic O_2 loss: ~1 Pmol/decade,
i.e. ~2 % during past 50 years.



vertically integrated O_2 change

(Schmidtko et al., Nature 2017)

Oxygen change (1960-2010)

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What do the models say?

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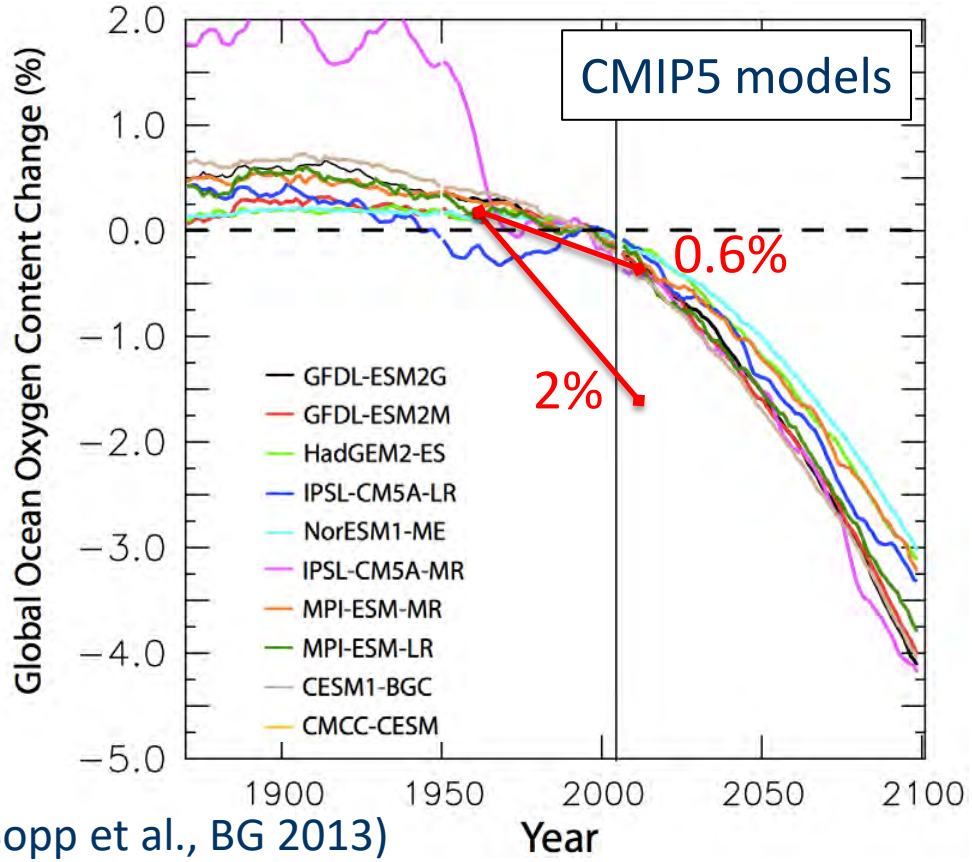
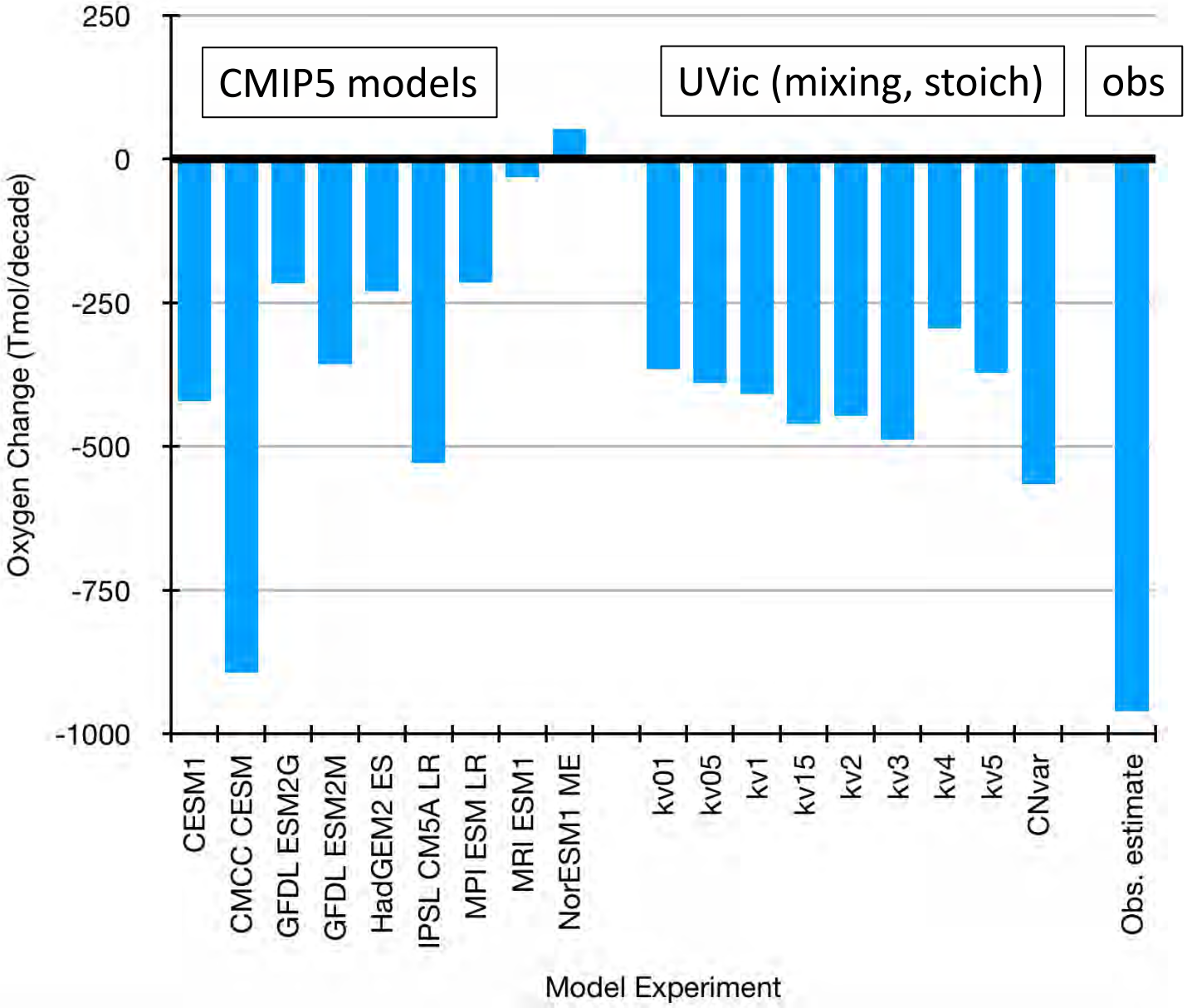


(Bopp et al., BG 2013)

O_2 loss in CMIP5 models:
~0.3 Pmol/decade.
(0.12 Pmol/decade in NCAR large ensemble)

Models underestimate obs. trend estimate by factor 2 or more.

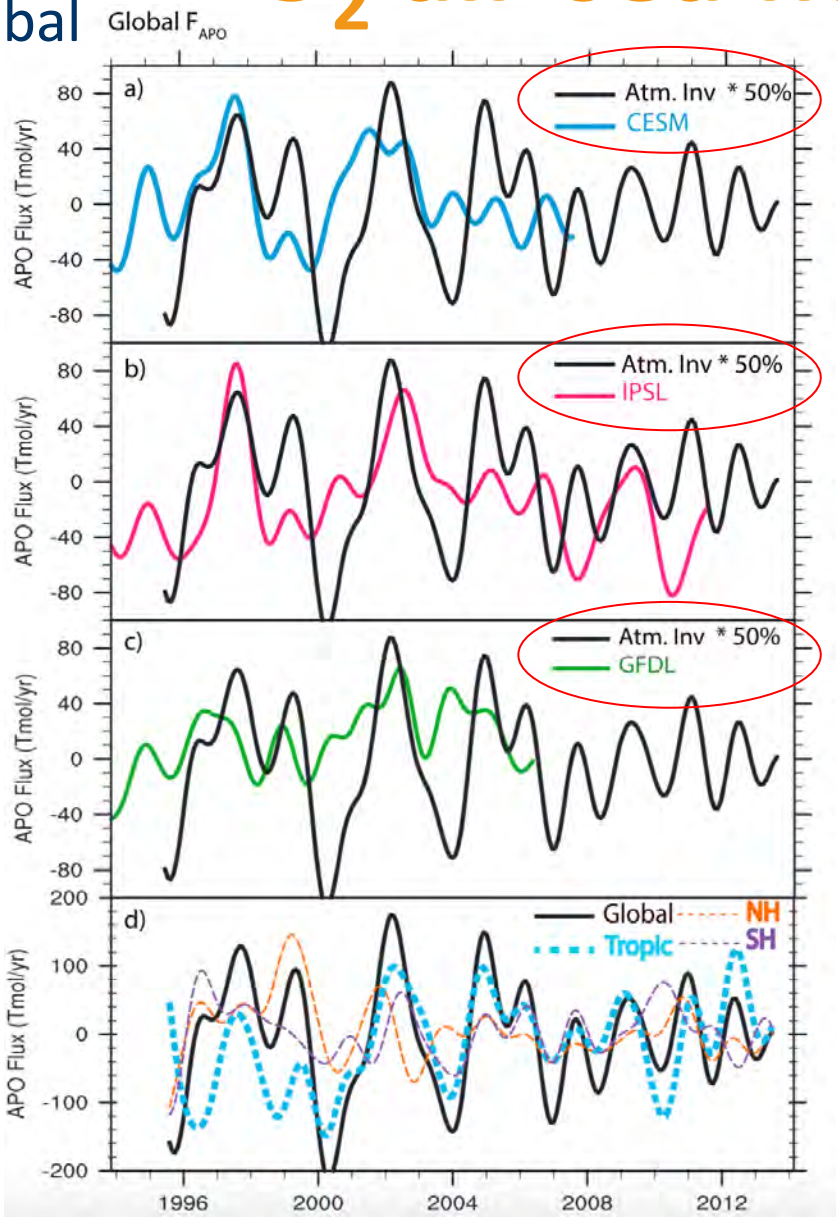
Oxygen change (1960-2010)



Have not been able to reach observed O_2 loss.

O_2 air-sea flux variability

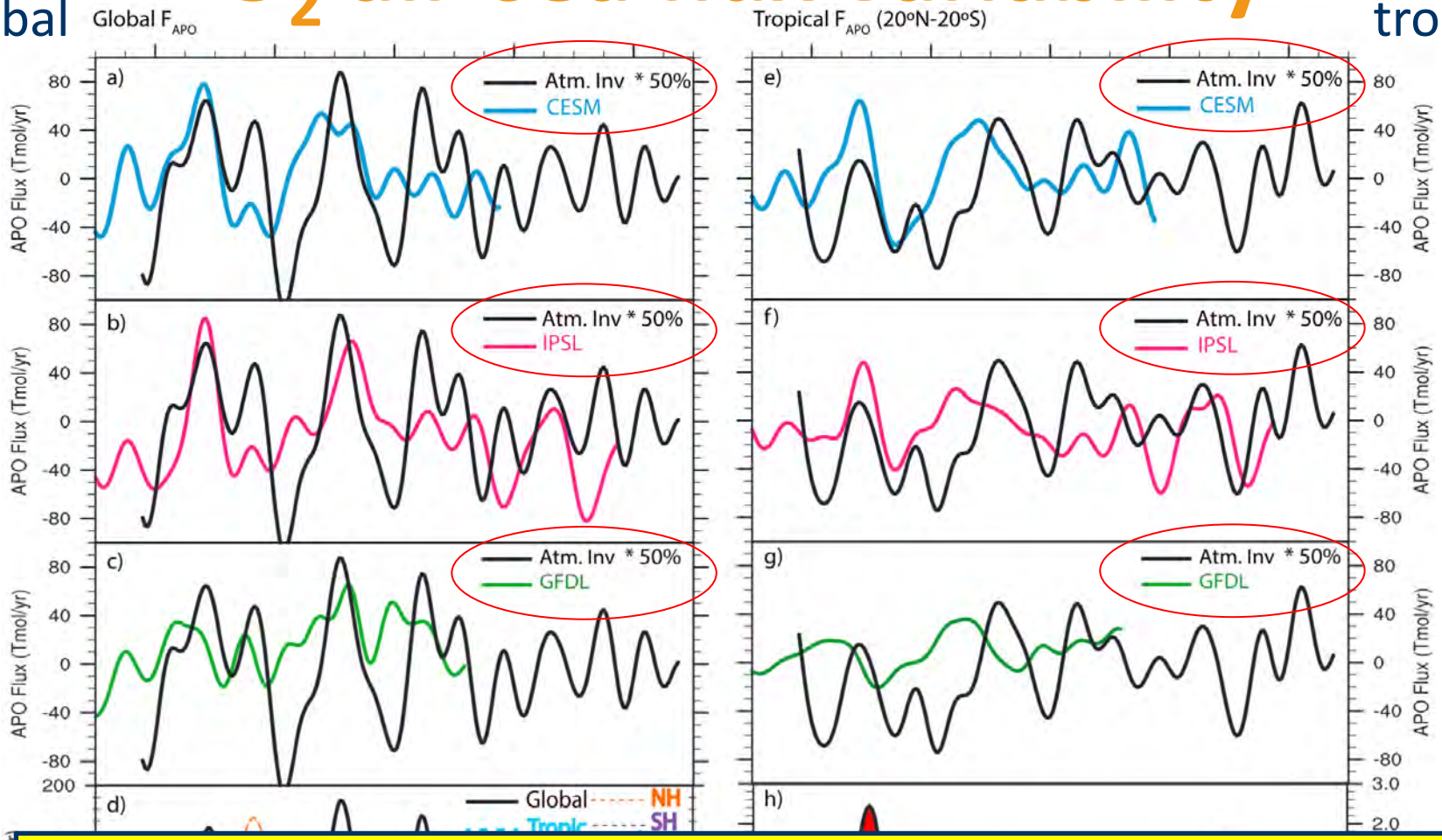
global



(Eddebbar et al., GBC 2017)

O_2 air-sea flux variability

global

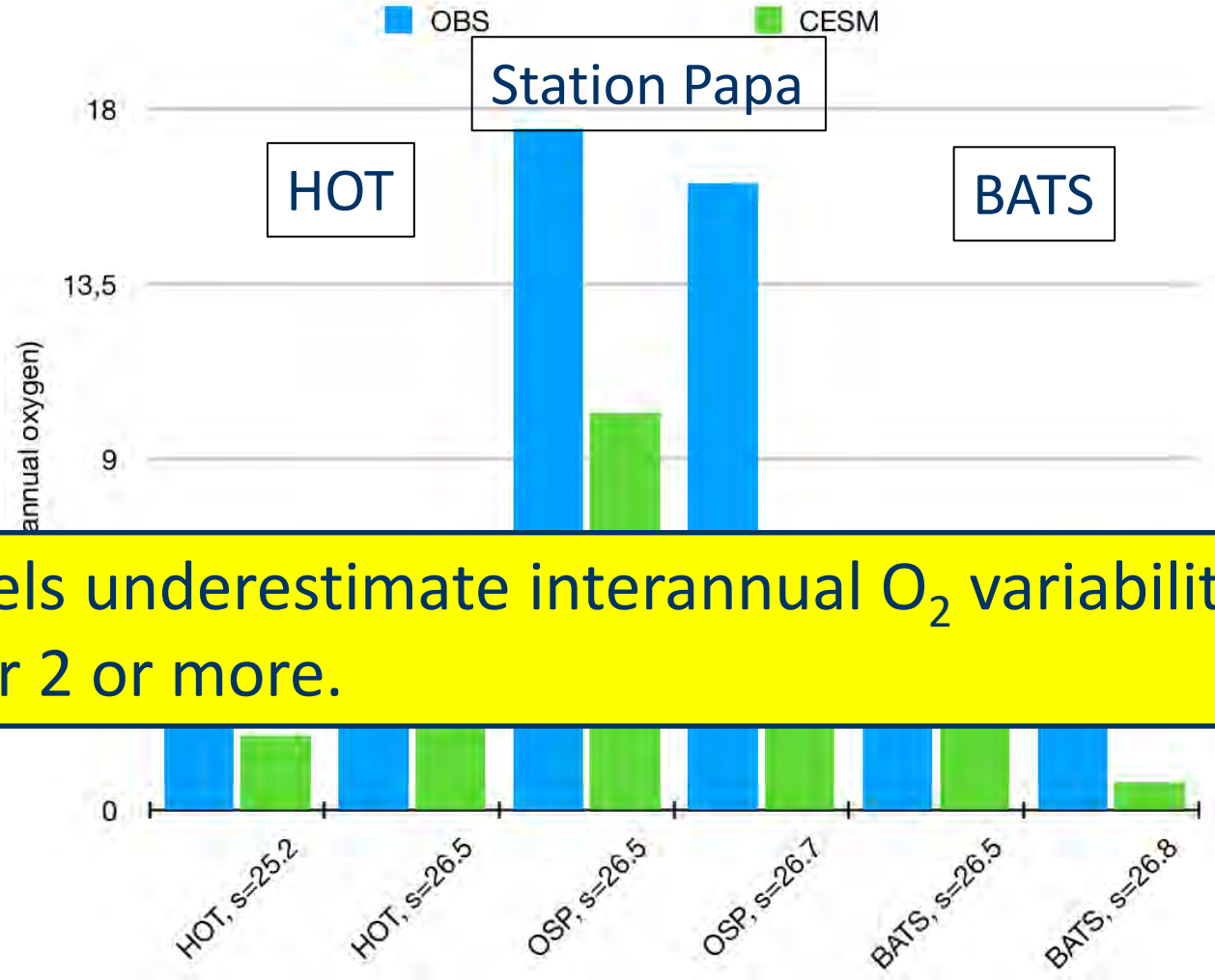


tropical

Models forced with realistic atmospheric forcing (CORE-2) underestimate interannual O_2 air-sea flux variability by factor 2 or more.

(Eddebbar et al., GBC 2017)

O_2(annual mean) variability at time-series sites



Models underestimate interannual O_2 variability by factor 2 or more.

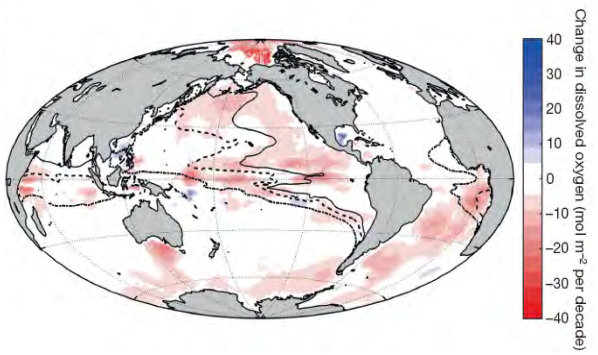
(after Long et al., GBC 2016)

Conclusions (i)

- Wherever we look, (global) models underestimate O_2 variability & trends on annual to multi-decadal timescales

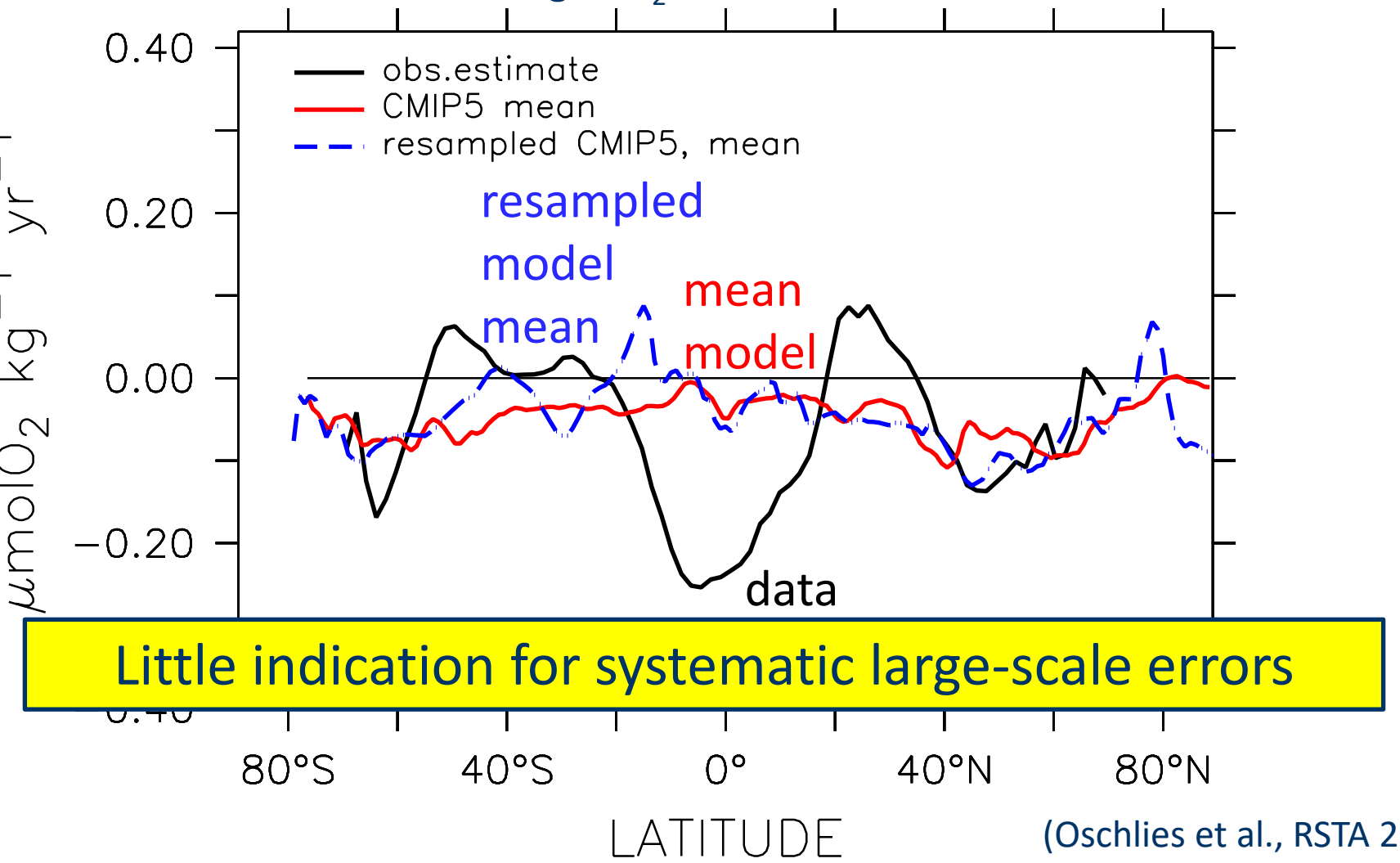
Possible causes for systematic model underestimate?

- Mapping? Data treatment?



Mapping

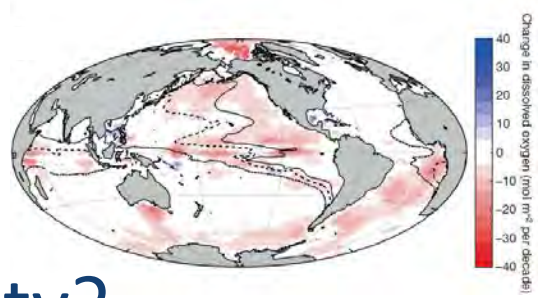
Past 50 yrs (1960 – 2010) zonally averaged O_2 trend at z=300m



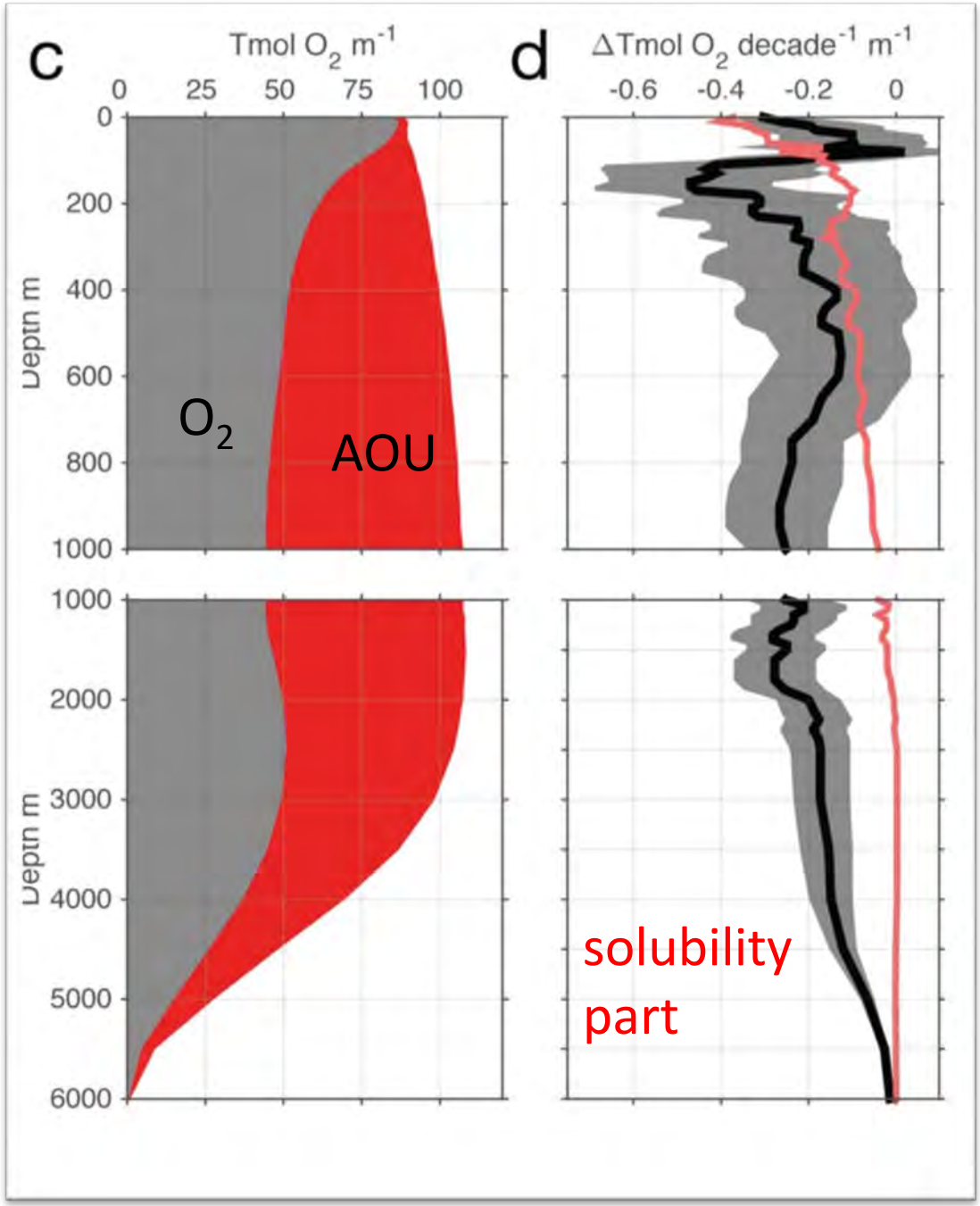
Little indication for systematic large-scale errors

(Oschlies et al., RSTA 2017)

Possible causes for systematic underestimate?



- Mapping? Data treatment?
- Abiotic vs biotic part? → Solubility?



Total and solubility part of O_2 change

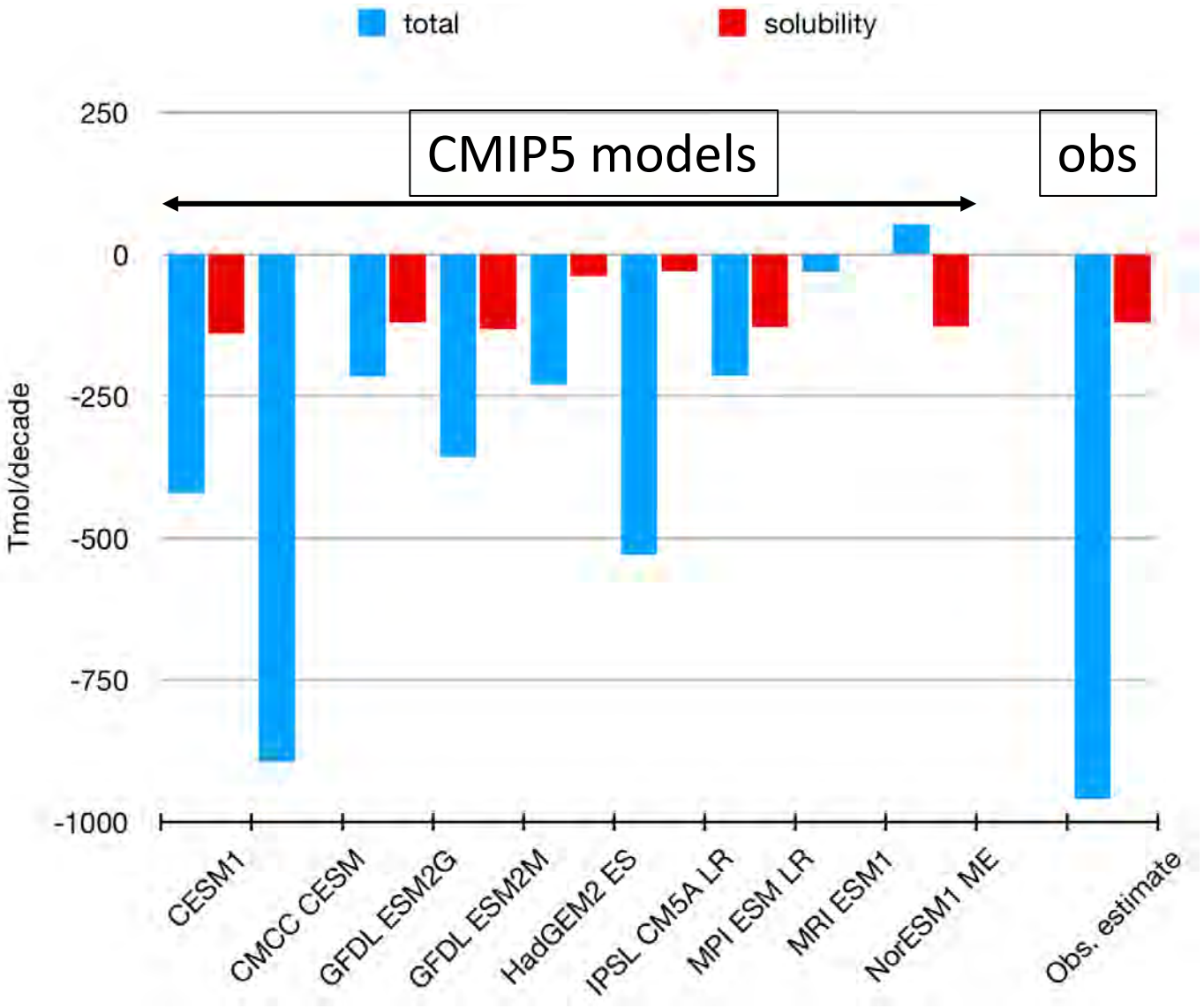
Less DO loss in upper water column than to be expected from warming

300-600m DO loss equivalent to loss expected from solubility changes

Deep ocean oxygen loss (75% of total below 1000m) not related to solubility change

(Schmidtko et al. 2017)

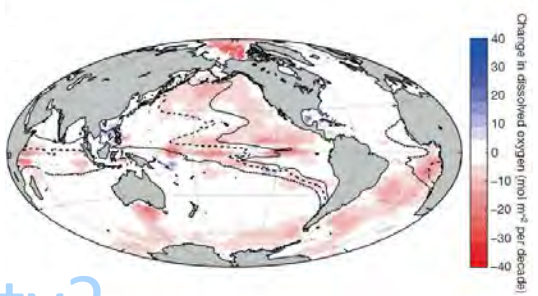
Total and solubility part of O_2 change



Good CMIP5 model-data agreement for solubility-driven part!

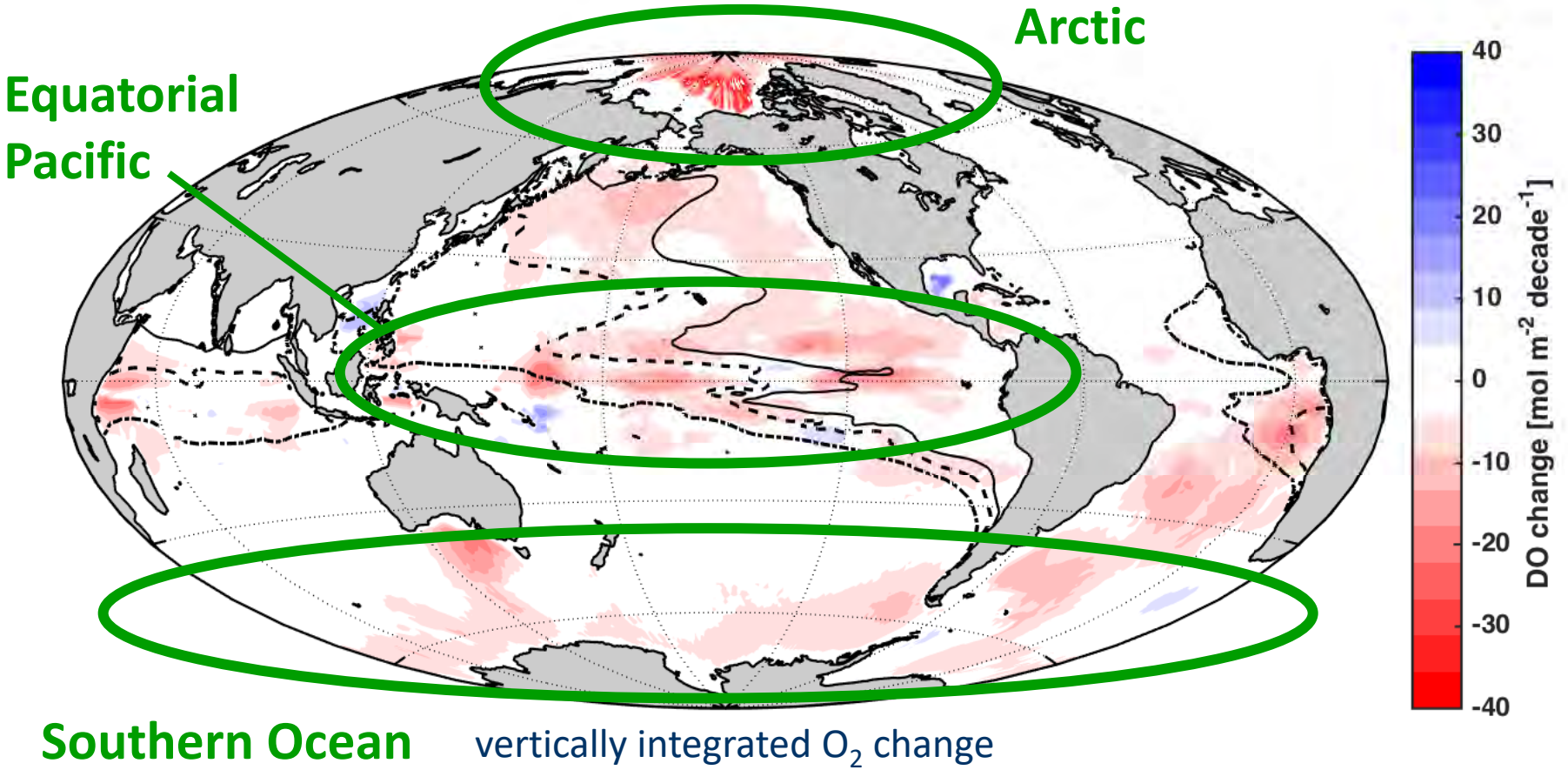
→ Abiotic O_2 trends OK.

Possible causes for systematic underestimate?



- Mapping? Data treatment?
- Abiotic vs biotic part? → Solubility?
- Oxygen Utilisation part:
  Biology or circulation?

Regions of above-average O_2 decline



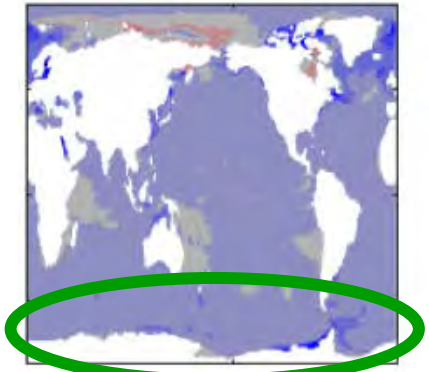
vertically integrated O_2 change

Changes in circulation? Biology?

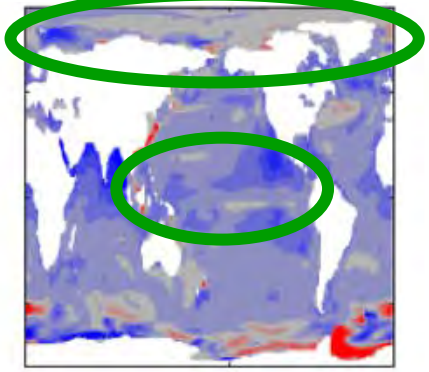
(Schmidtko et al. 2017)

CMIP5 oxygen trends

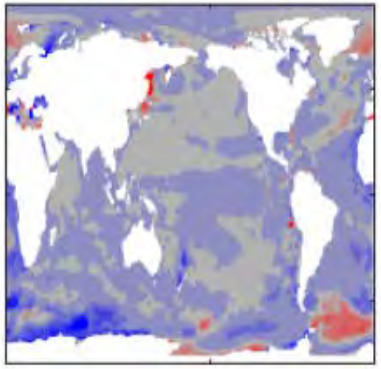
CESM1 BGC



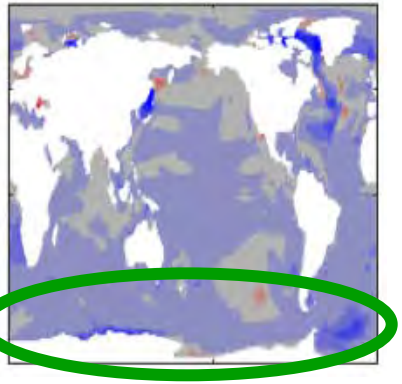
CMCC CESM



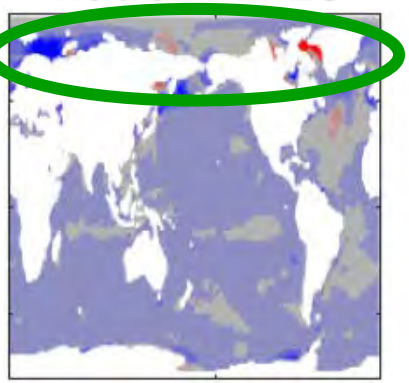
GFDL ESM2G



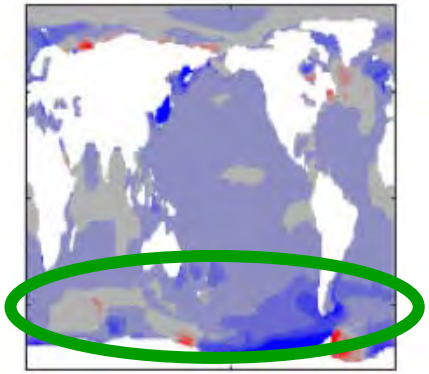
GFDL ESM2M



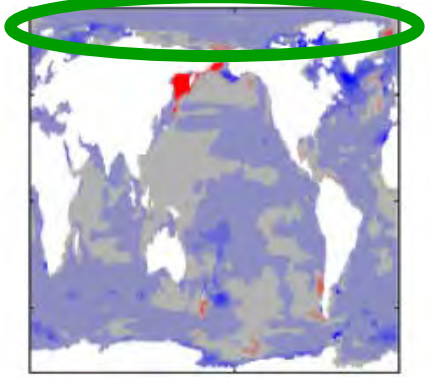
HadGEM2 ES



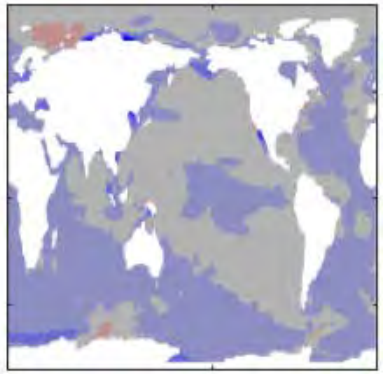
IPSL CM5A LR



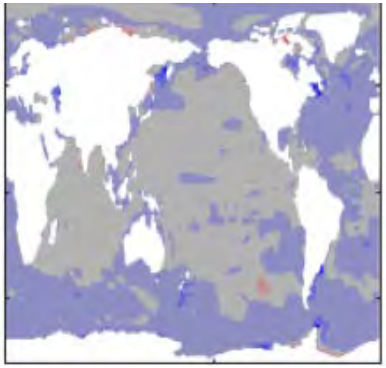
MPI ESM LR



MRI ESM1

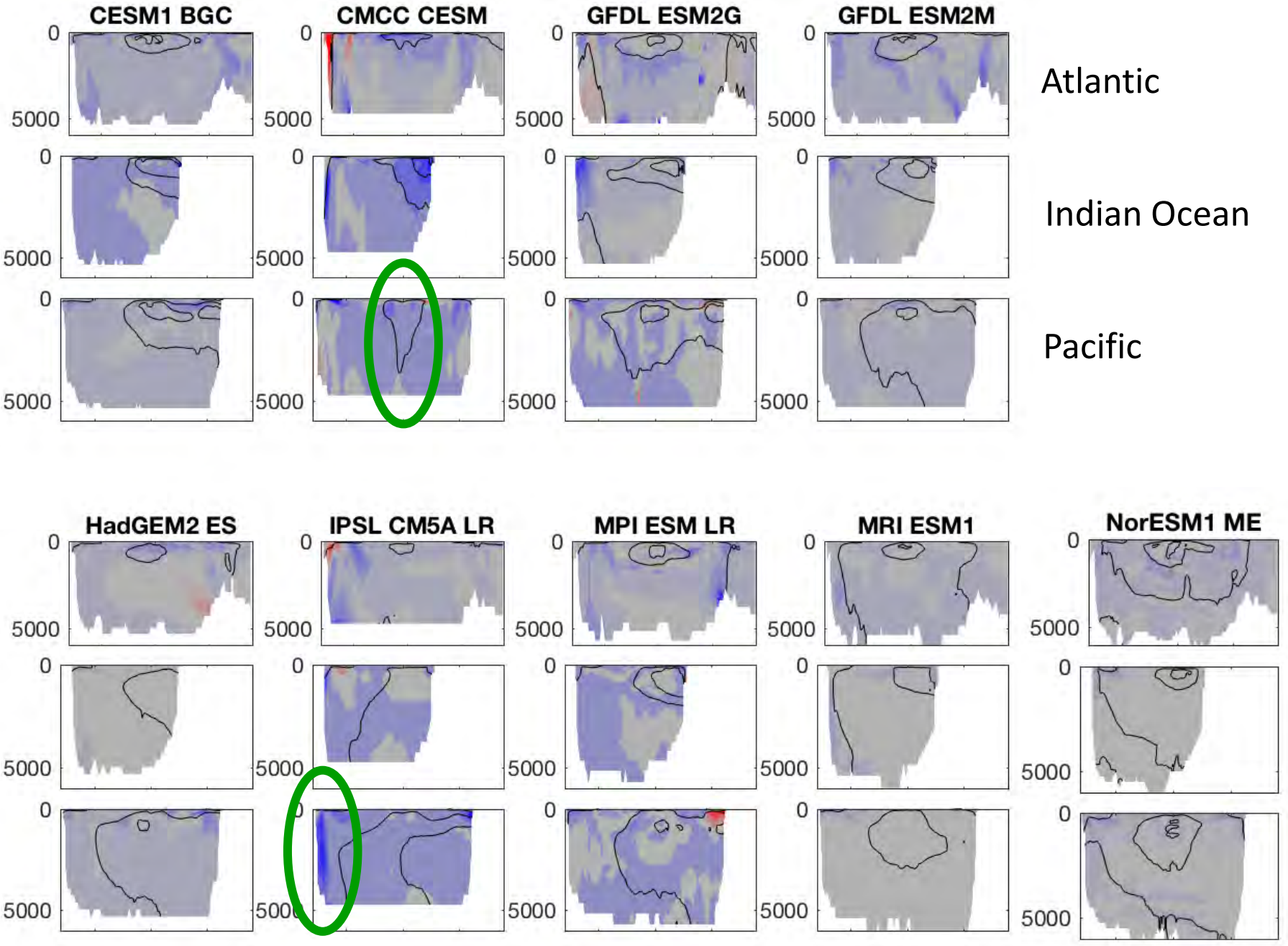


NorESM1 ME

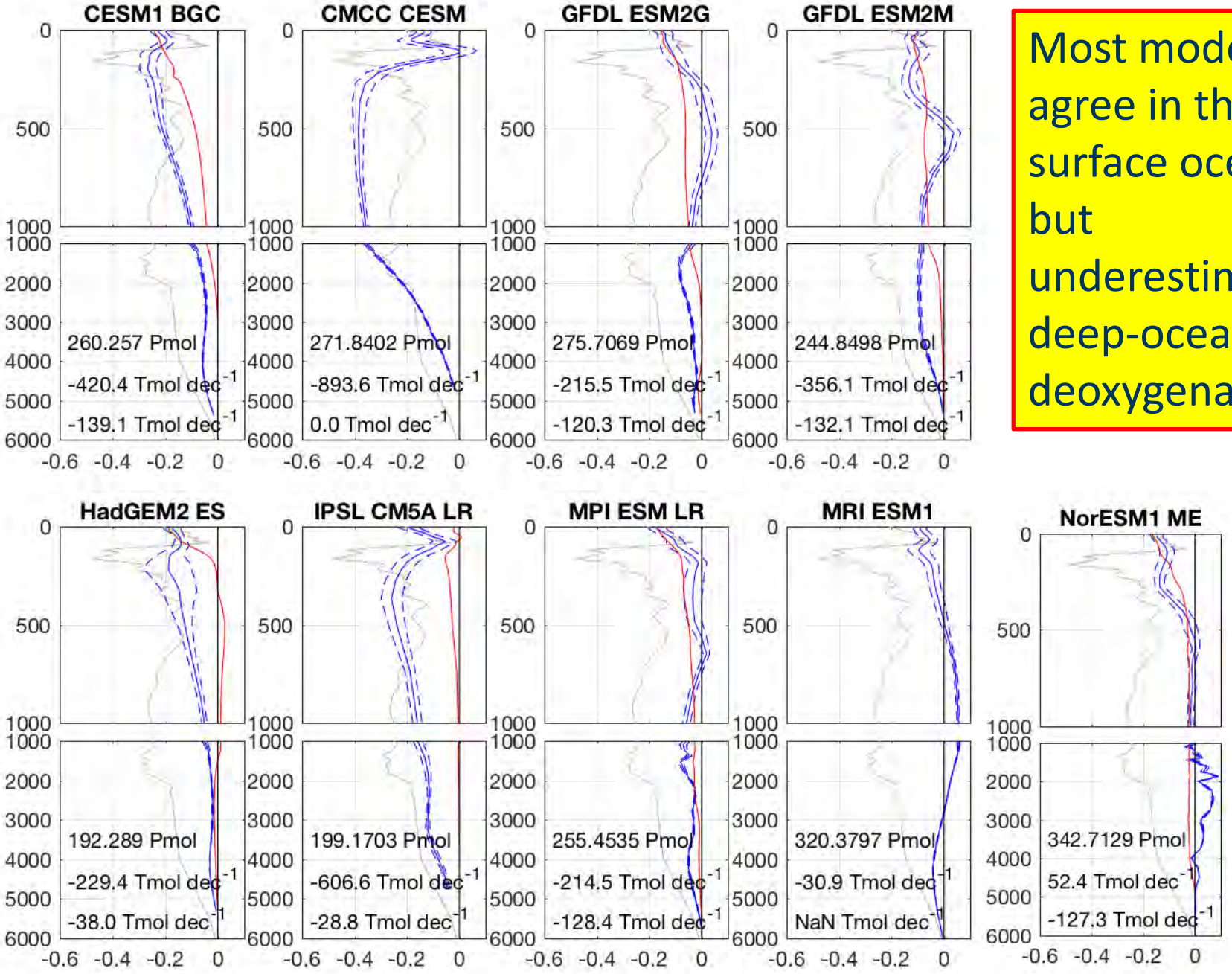


Little agreement among models for Arctic & Trop.Pac. & Southern Ocean O_2 change

CMIP5 models



CMIP5 models



Most models agree in the surface ocean, but underestimate deep-ocean deoxygenation.

Conclusions (ii)

- Wherever we look, (global) models underestimate O_2 variability & trends on annual to multi-decadal timescales.
- Good agreement for solubility-driven part.
- Most models underestimate deep-ocean deoxygenation.
- Need to understand impact of circulation changes, particularly in the deep ocean.
- Overlooked biogeochemical feedbacks?

Thank you!