Human-induced changes to the global ocean water-masses and their time of emergence

(in review, NCC)

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EGU 2020 - Sharing Geoscience Online

OS1.6 Improved Understanding of Ocean Variability and Climate

→ Chat session: Friday, 8 May 2020, 08:30–10:15

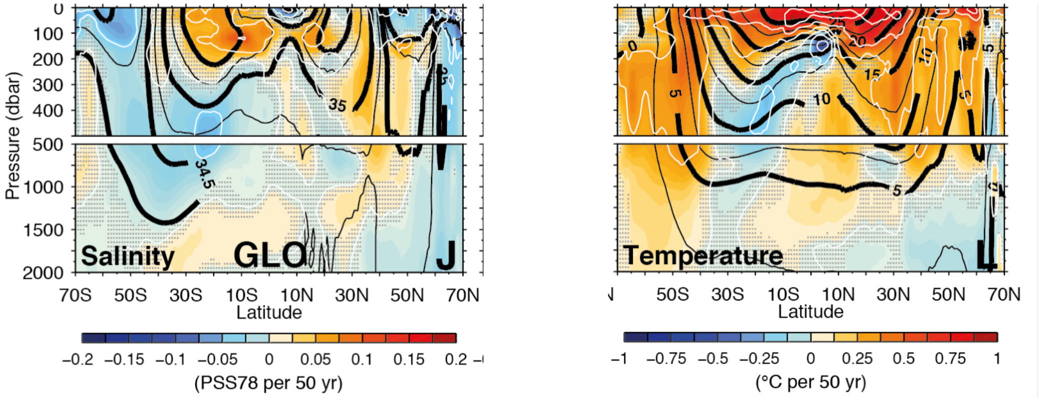
→ Zoom Meeting: Wednesday, 13 May 2020, 14:00-17:00

Context

Observed multi-decadal physical changes in the ocean

Intensification of mean salinity field

Ocean heat uptake



Zonally-averaged linear trends of salinity and potential temperature changes.
From IPCC AR5 (Rhein et al. 2013), Figure 3.9.

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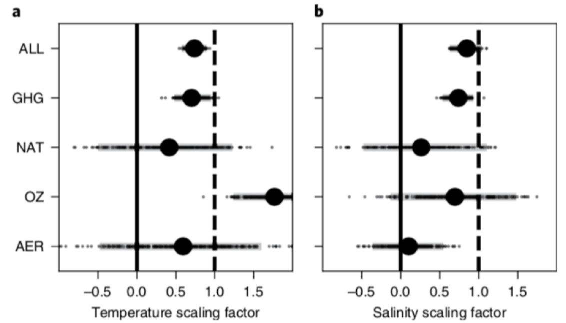
Human-induced

Background internal variability

Natural forcings

D&A studies in the ocean since the 2000s



Detection and attribution scaling factors.
From Swart et al. (2018)

Problem

Regions where anthropogenic signal still undetected, especially at depth

?

→ Poor observational coverage

→ Weak changes

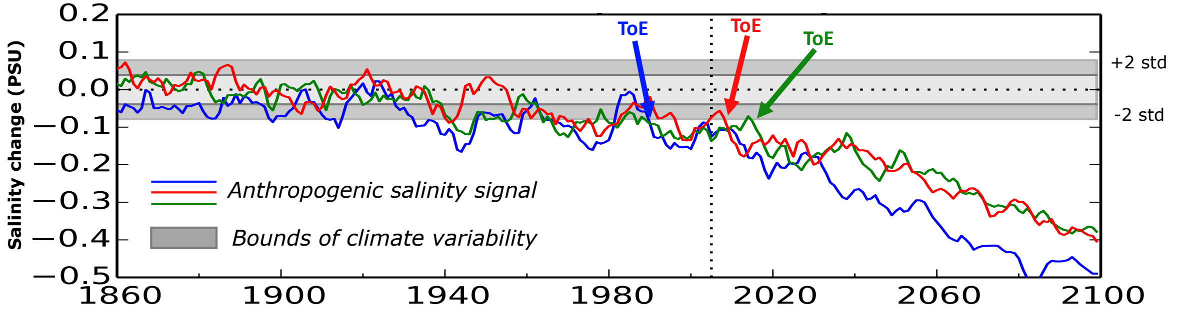
→ Natural variability

Question

Where and when do human-induced changes to the ocean interior water-masses emerge against background climate variability?

Time of Emergence (ToE)

ToE: Time at which the forced signal last emerges from the noise of climate variability



Previous Time of Emergence studies focused on…

SAT	Precipitation	SLR	Biogeochemistry
• Mahlstein et al. (2011, 2012) • Diffenbaugh and Scherer (2011) • Hawkins and Sutton (2012) • Mora et al. (2013) • Diffenbaugh and Charland (2016) • Lehner et al. (2017)	• Giorgi and Bi (2009) • Mahlstein et al. (2012)	• Lyu et al. (2014)	• Keller et al. (2014) • Rodgers et al. (2015) • Frölicher et al. (2016) • Henson et al. (2017) • Turk et al. (2019) • Schlunegger et al. (2019)

→ Building an integrated understanding of the anthropogenic ToE in the Earth System

→ Lack of knowledge for physical variables in the ocean

Method

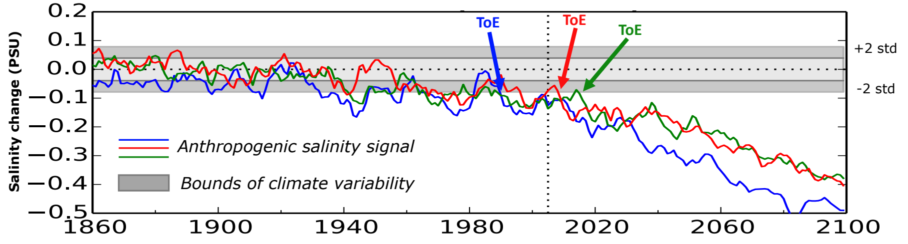
- 11 CMIP5 models, 35 members

- All outputs are binned in density
  - More physical zonal means to follow water-masses in each basin
  - Ocean circulation naturally flows along density surfaces
  - Some vertical movement of isopycnals (“heave”) due to transient dynamical change
  - Analysis of T/S changes along density surfaces $\alpha\theta'_{|n} = \beta S'_{|n}$ → same signal, same ToE (salinity presented here)
  - Calculations done in density, remapping to pseudo-z for visualization purposes

- Time of Emergence
  - Period of analysis: 1860-2100
  - “Signal”(t) = (historical + RCP8.5) - $\langle \text{historicalNat} \rangle_t$
  - ”Noise” = $2*\text{std}_{\text{historicalNat}}$ (detection at the 95% CL)

  → Conservative estimate
  - Computed locally (gridpoint by gridpoint) + regionally in model-specific boxes

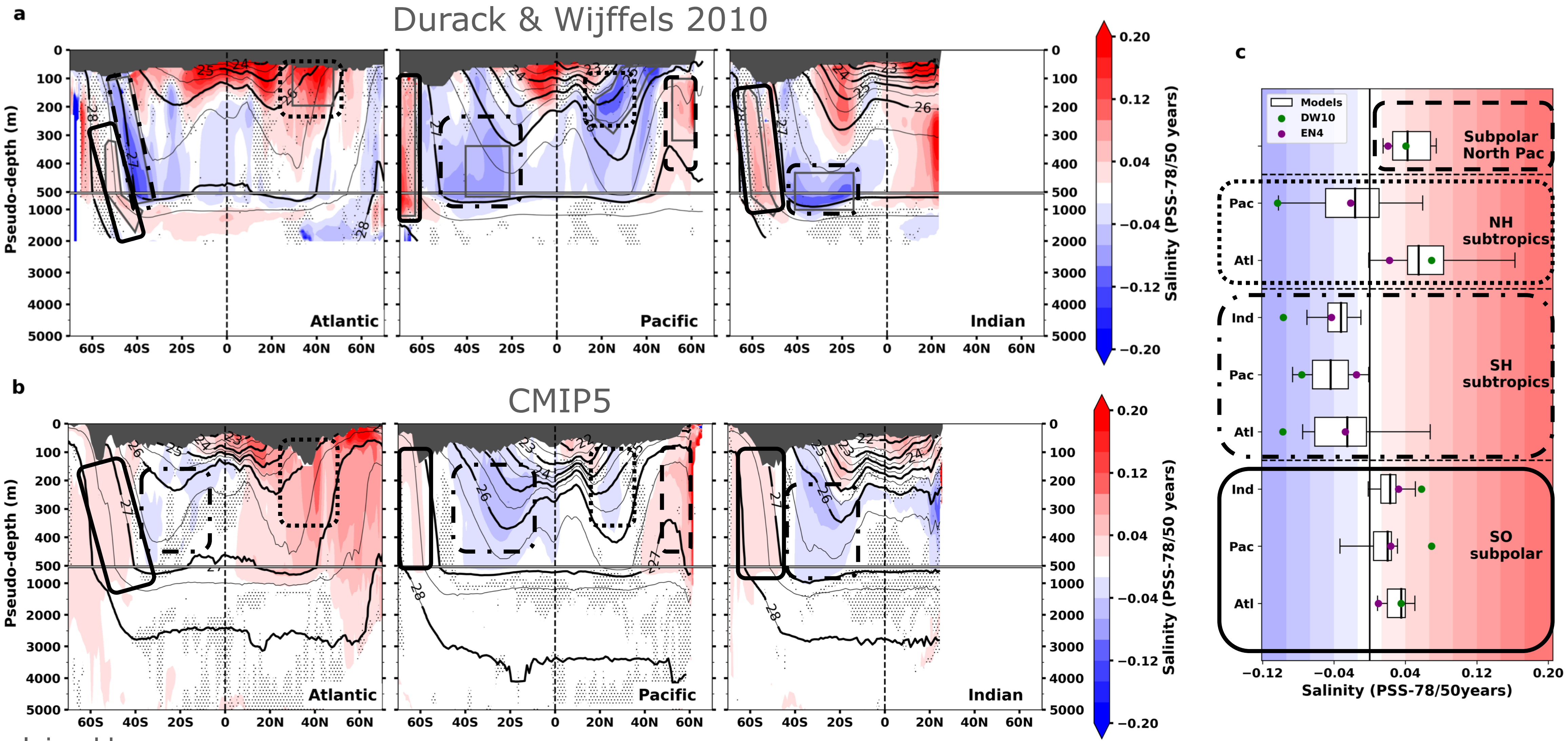
ToE: Time at which the forced signal last emerges from the noise of climate variability



Historical changes (1950-2008)

OBS

MMM



Possibly explained by:

→ Surface warming displacing isopycnal outcrops polewards

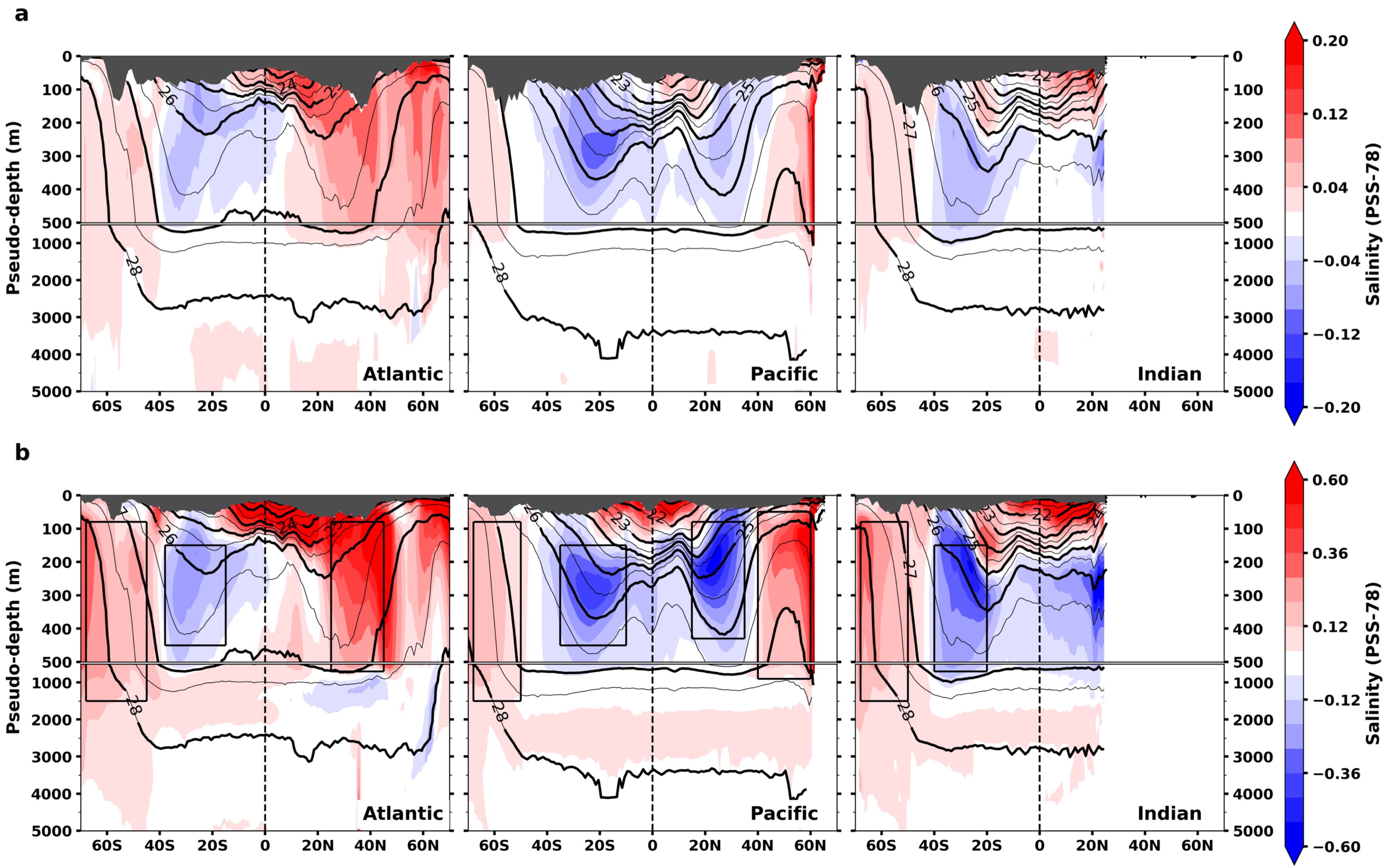
→ Hydrological cycle amplification (E-P)

Anthropogenic changes 20th – 21st century

Anthropogenic 20th
hist - histNat

Amplification of the patterns of change

Anthropogenic 21st
RCP8.5 - histNat

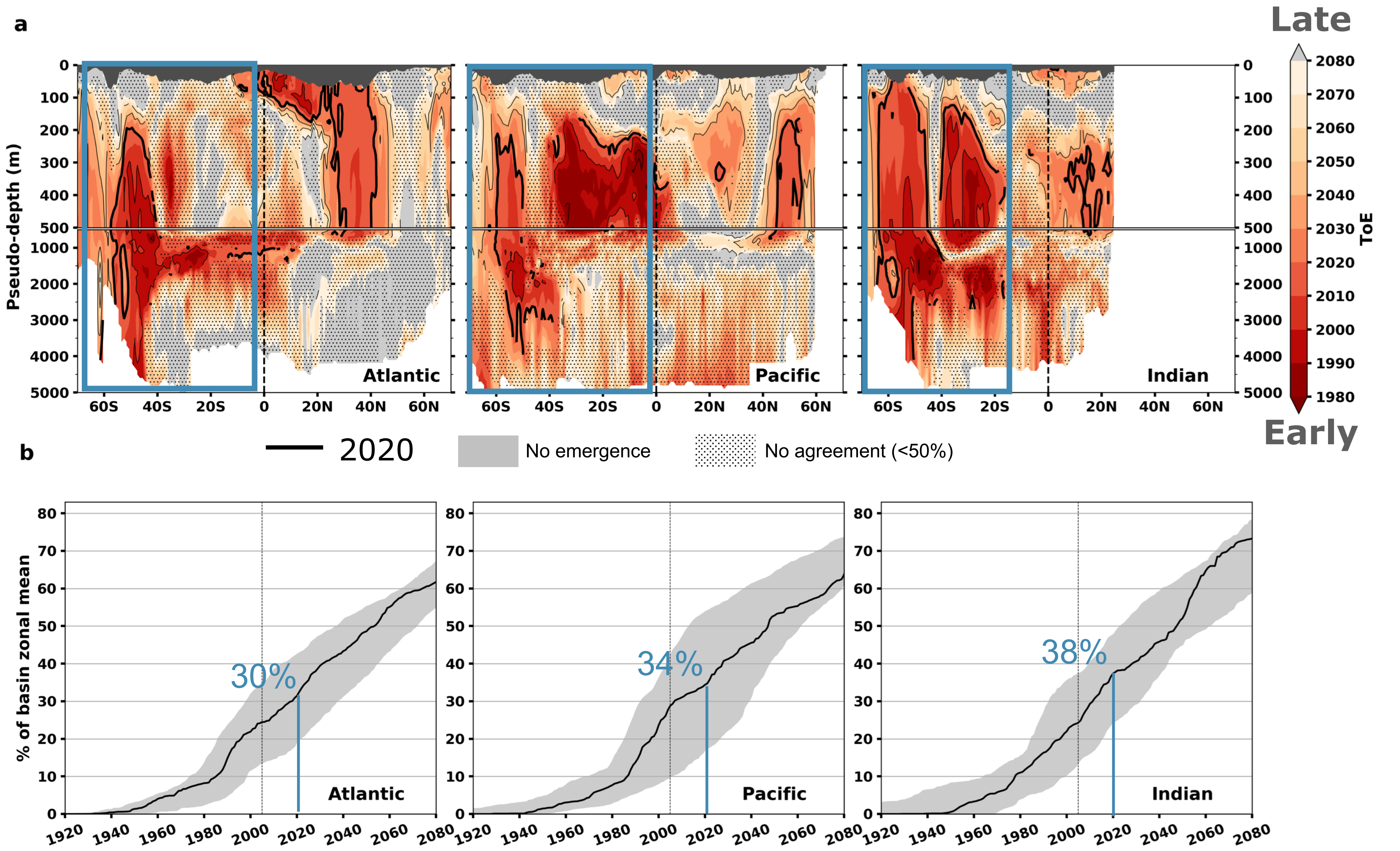


Time of emergence of anthropogenic change

ToE
Median of 11 models, gridpoint by gridpoint

- By 2020, most of the identified forced patterns have already emerged
- Predominance of the Southern Ocean (historically most poorly sampled)

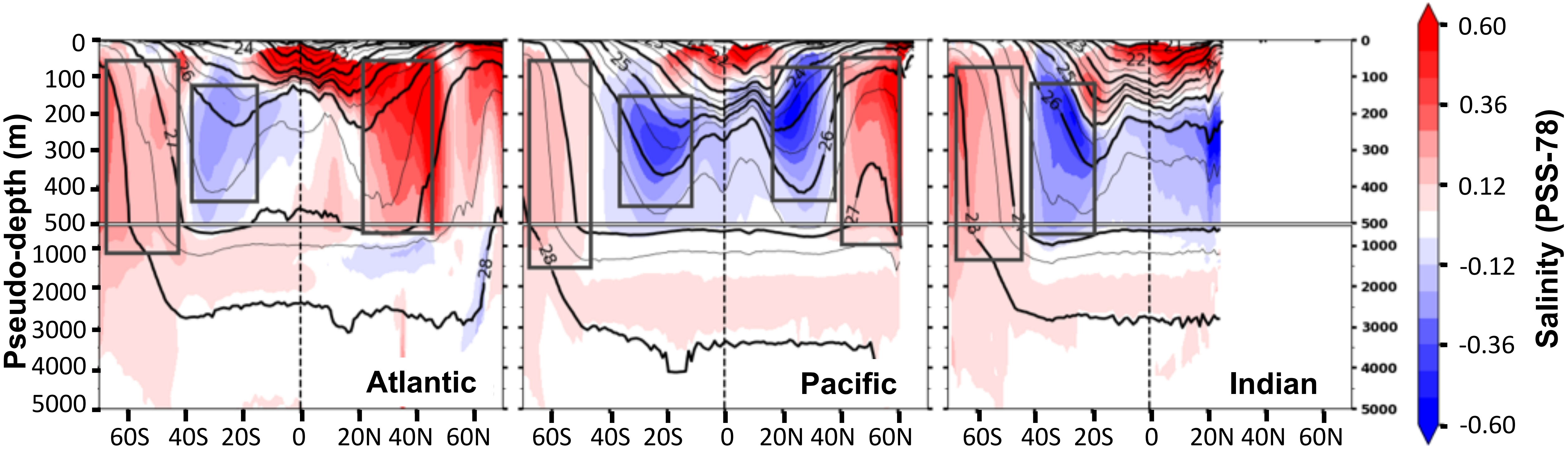
Percentage of basin emergence



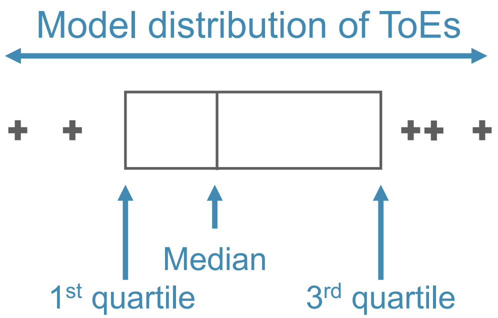
Time of emergence of anthropogenic change (2)

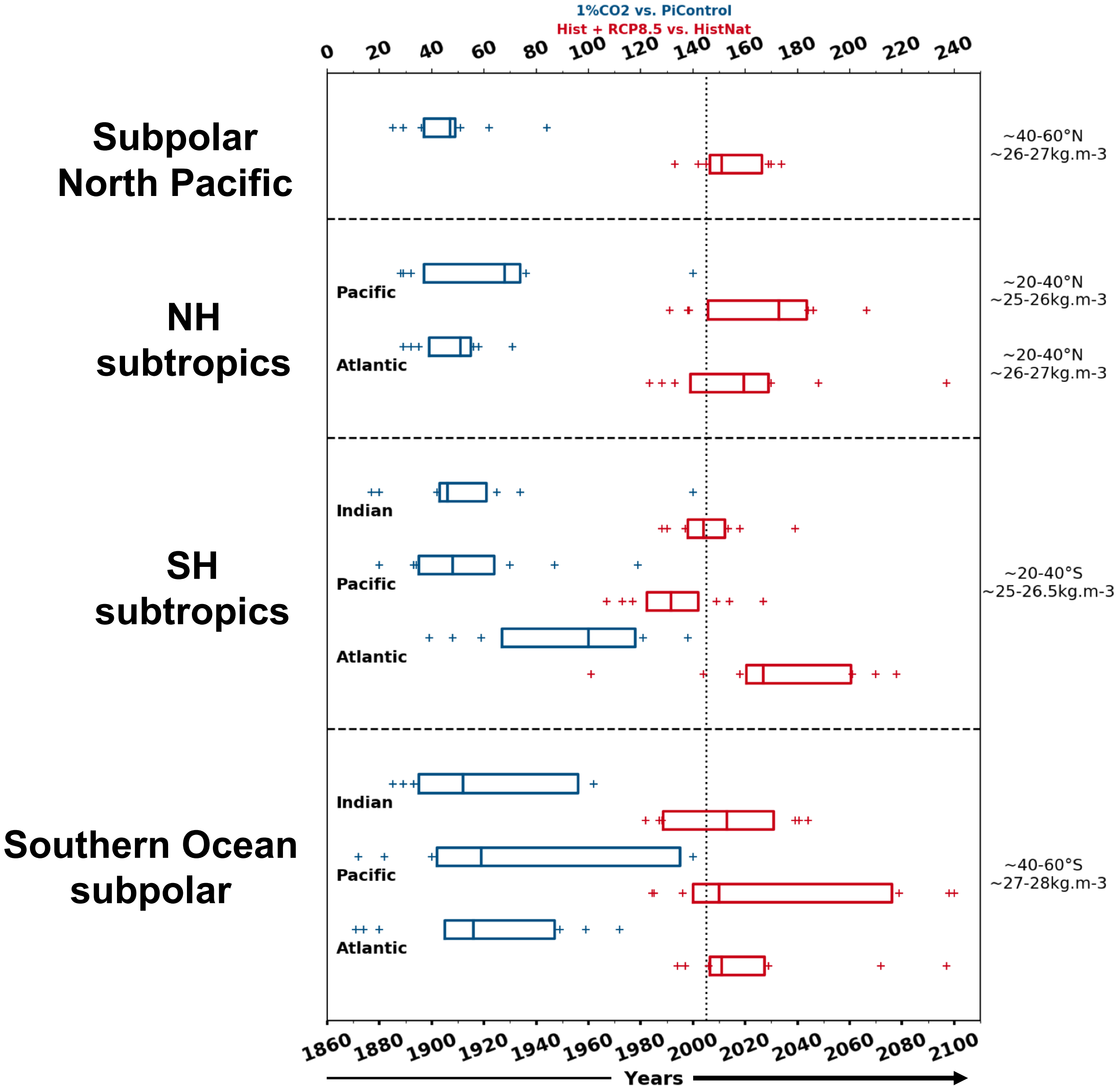
Local → Regional

- Capture the regional patterns of change in model-specific latitude/density boxes
- Less noisy



Time of emergence of anthropogenic change (2)





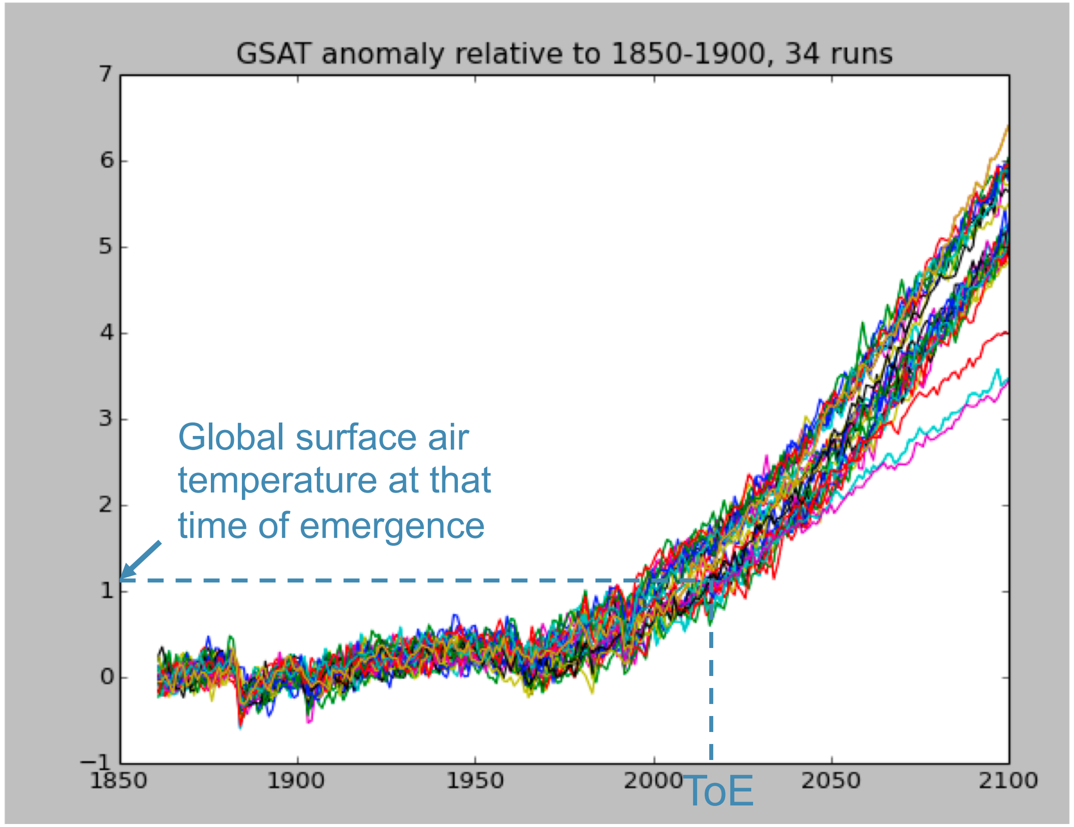
Red = anthropogenic
Blue = 1pctCO2

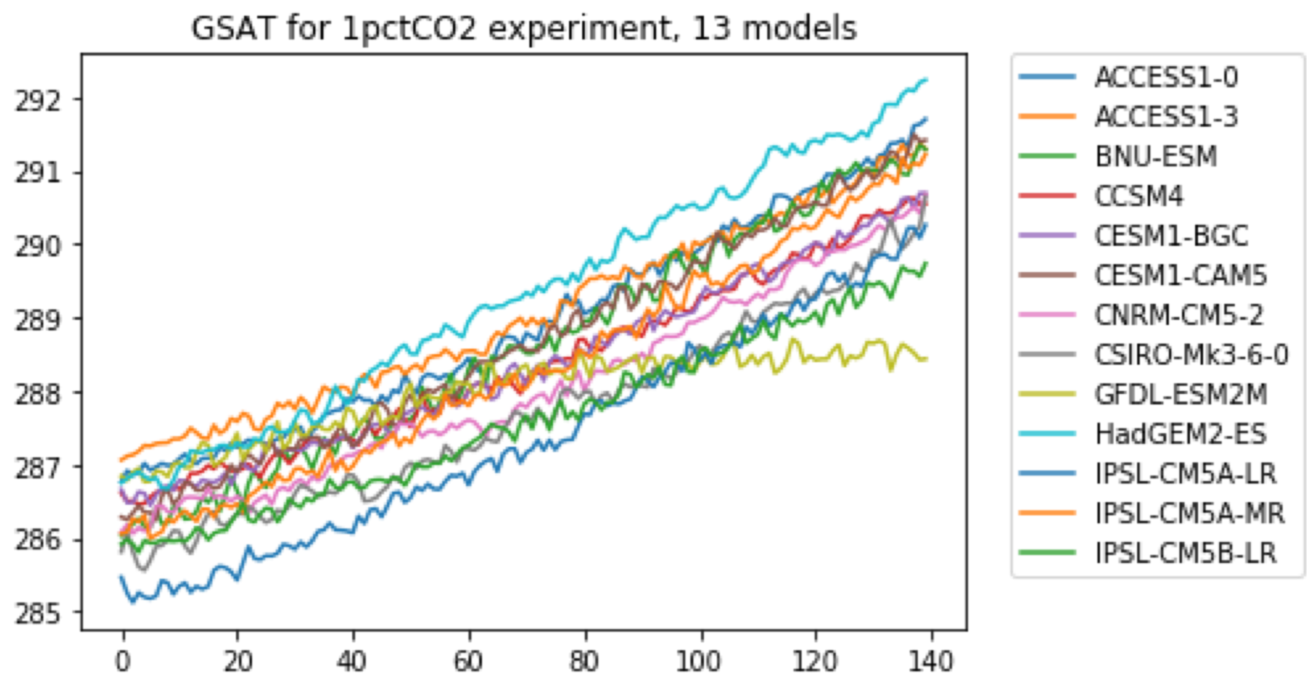
→ Two different time scales

Time of emergence of anthropogenic change (2)

Time of emergence → Global surface warming at emergence

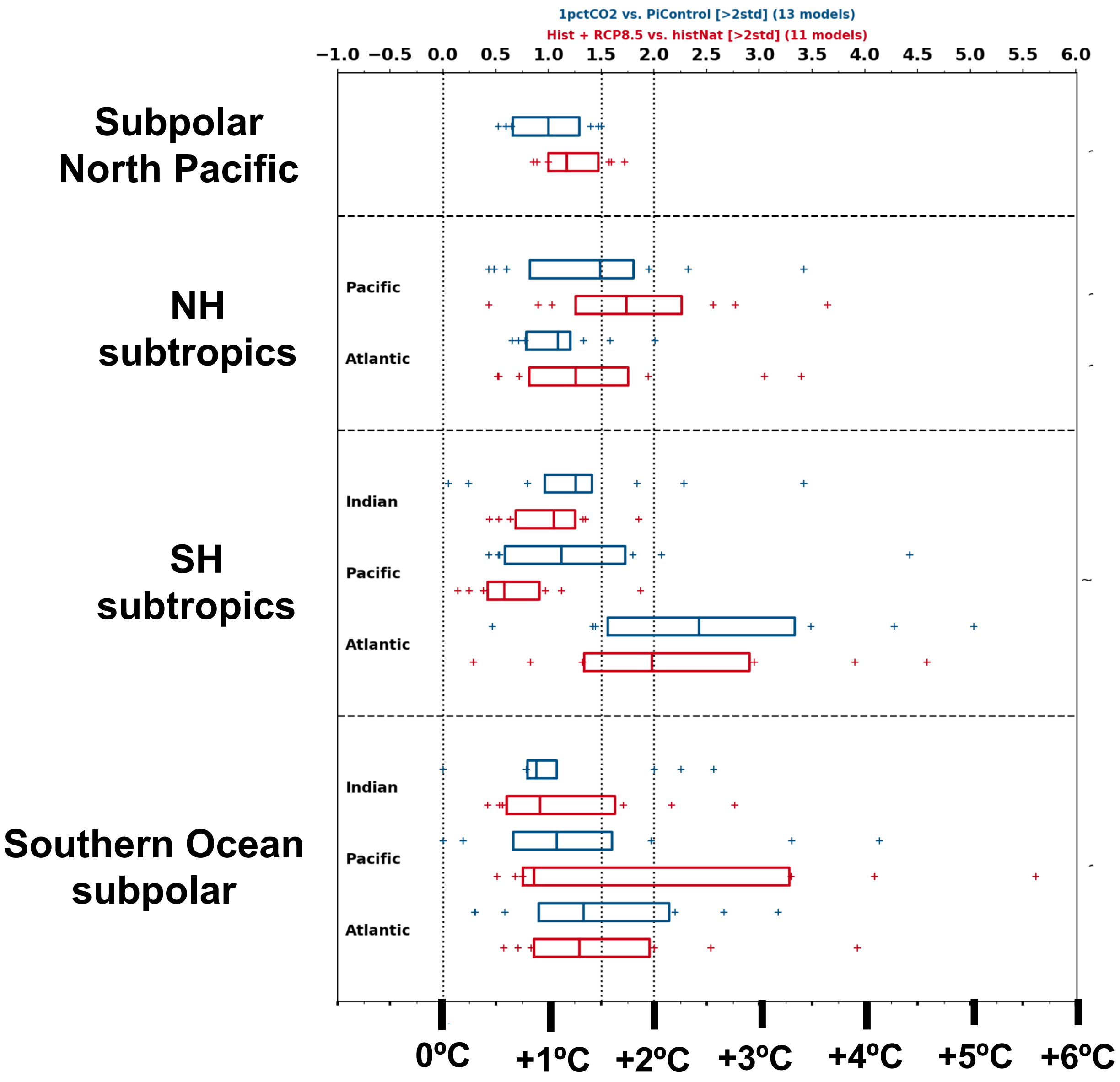
- Different models have different climate sensitivity
- Compare several forcing scenarios (RCP8.5, 1pctCO2)





Time of emergence of anthropogenic change (2)

- Most simulations predict signal emerges between +0.5ºC-2ºC
- Over 75% probability for signal to emerge before +1.5ºC in the subpolar North Pacific, and southern subtropical Indian and Pacific
- Northern Hemisphere subtropics emerge later, except Atlantic
- Very good agreement between 2 forcing scenarios (1pctCO2, RCP8.5)



Red = anthropogenic
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Summary and key results

- Human-induced S/T change patterns emerge from natural variability between the end of the 20th century and first decades of the 21st century (=now), i.e. before a +2°C global warming

- In 2020, 30-40% of the Atlantic, Pacific and Indian basins have emerged

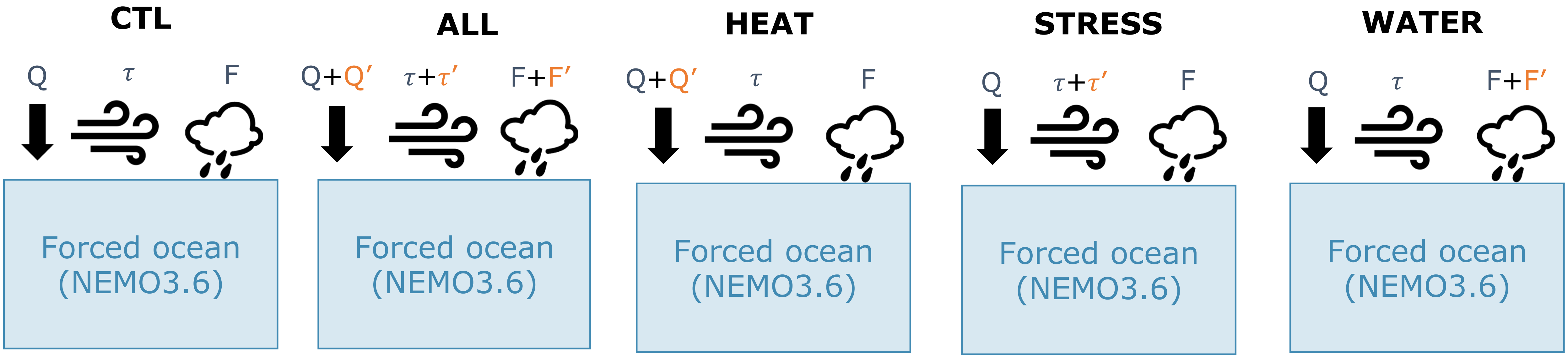
- Earlier emergence of the Southern Ocean
  → coherent in the subtropics (ventilated region, heat and carbon storage, observed change already detected/attributed)
  → model probably deficient in the subpolar region (e.g. open convection)

- Use such diagnostics to help guide the future development of a global ocean observation system targeted at monitoring and detecting forced ocean changes

Perspectives

Understand the mechanisms leading to the emergence of anthropogenic temperature and salinity change in the ocean interior

- Physical role and time scales of the different surface fluxes (heat, freshwater, wind stress) under historical and future anthropogenic forcings (i.e. realistic time scales of anthropogenic forcings)
- Ocean's role and time scales in modulating this anthropogenic forcing through:
  - Excess vs. redistributed heat and salt (passive vs. circulation changes)
  - Ocean interior processes leading to T/S changes



Thank you for your attention

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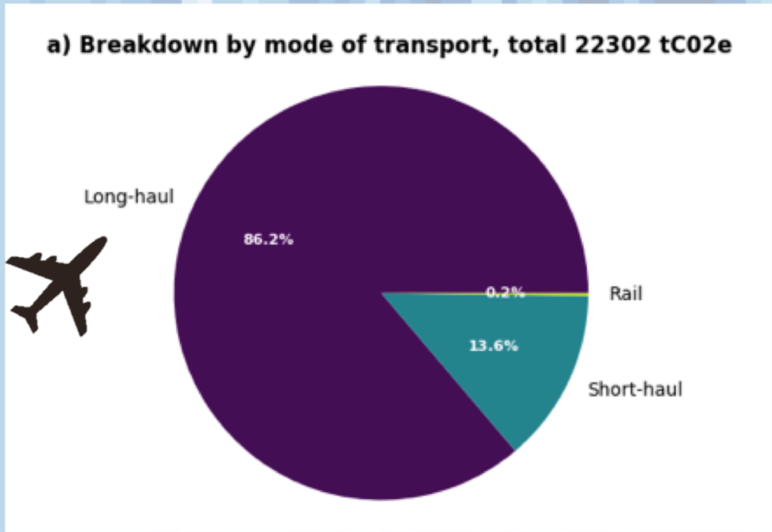
EGU 2019
22,302 tCO_2e = 1.4 tCO_2e per scientist



https://github.com/milankl/CarbonFootprintEGU

Is this how we as climate scientists want to keep on doing research? Have we been leading in mitigation actions?
→**Let's make a change NOW by #flyingless!**

A great webinar to watch during lockdown:
Kevin Anderson (08/04/2020):
Laggards or Leaders? Academia and its responsibility in delivering on the Paris commitments
https://aag.secure-abstracts.com/AAG%20Annual%20Meeting%202020/sessions-gallery/26738