→ 2018 OCEAN SALINITY SCIENCE CONFERENCE

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Investigating forced ocean change using a neutral density framework

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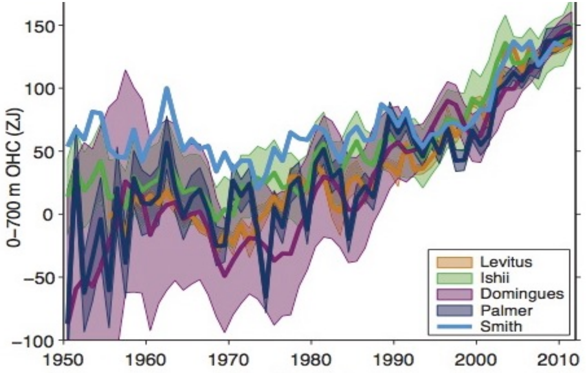
Observed change

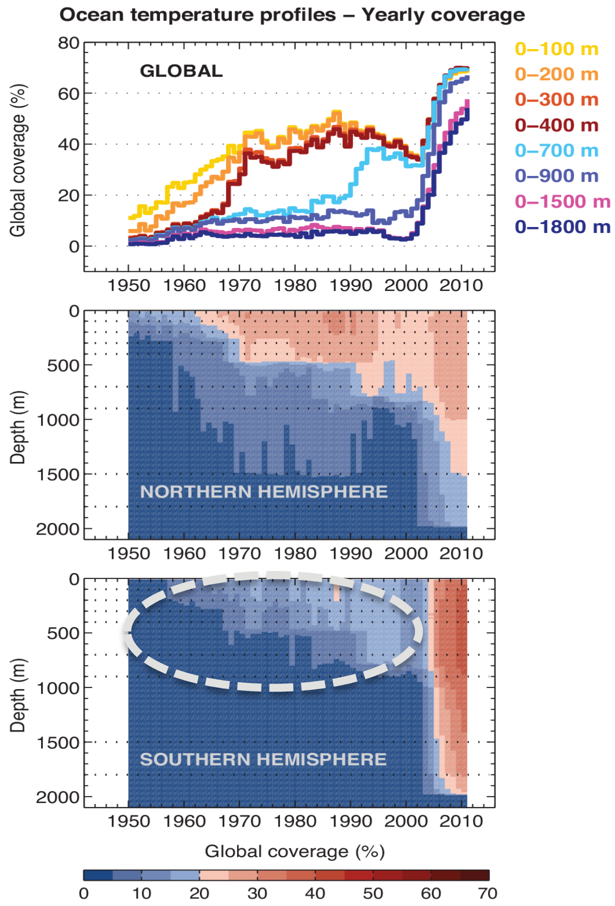
- Observations show clear upper ocean warming since ~1970
- Intensification of the hydrological cycle due to anthropogenic forcings

Ocean heat content change



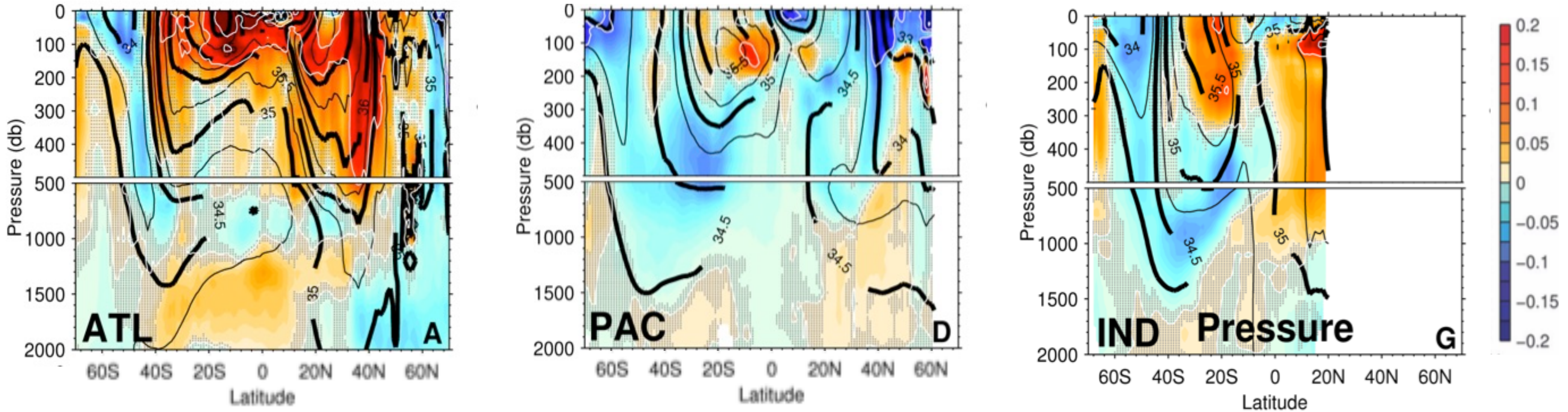
IPCC AR5 Chapter 3 (2013)

- Quantification limited by sparse observations (e.g. Southern Hemisphere)
- Models can help



Observed zonally averaged salinity changes

Zonal salinity change (2000-1950)

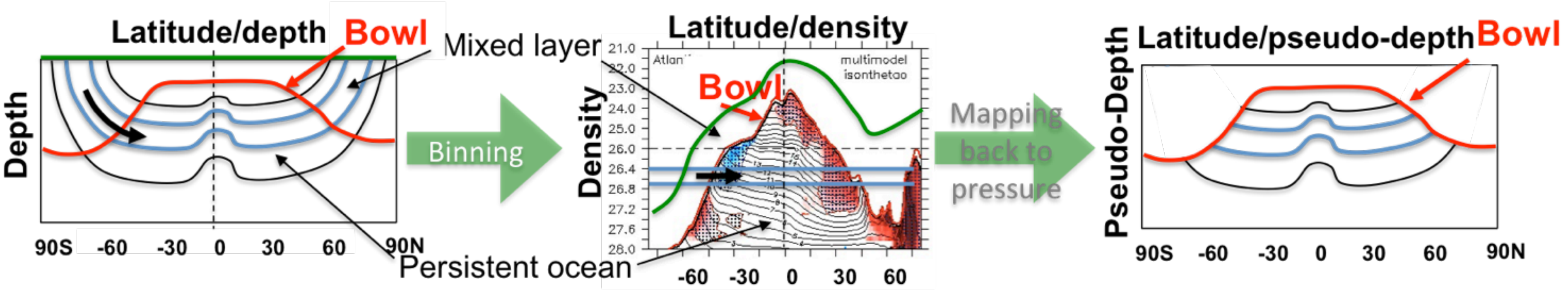


- Adiabatic vs. diabatic change ?
- Climate change signal vs. natural climate variability noise ?
- Zonal means slice through different water masses

Durack & Wijffels (2010)
Black contours : climatological mean
Color : temporal tendency

The density framework

- Density: natural coordinate of the ocean to focus on heave-free diabatic changes
- More physical zonal means
- Enhance signal/noise (remove heave, mixed-layer processes)
- Binning on neutral density: water mass centric view



In this talk

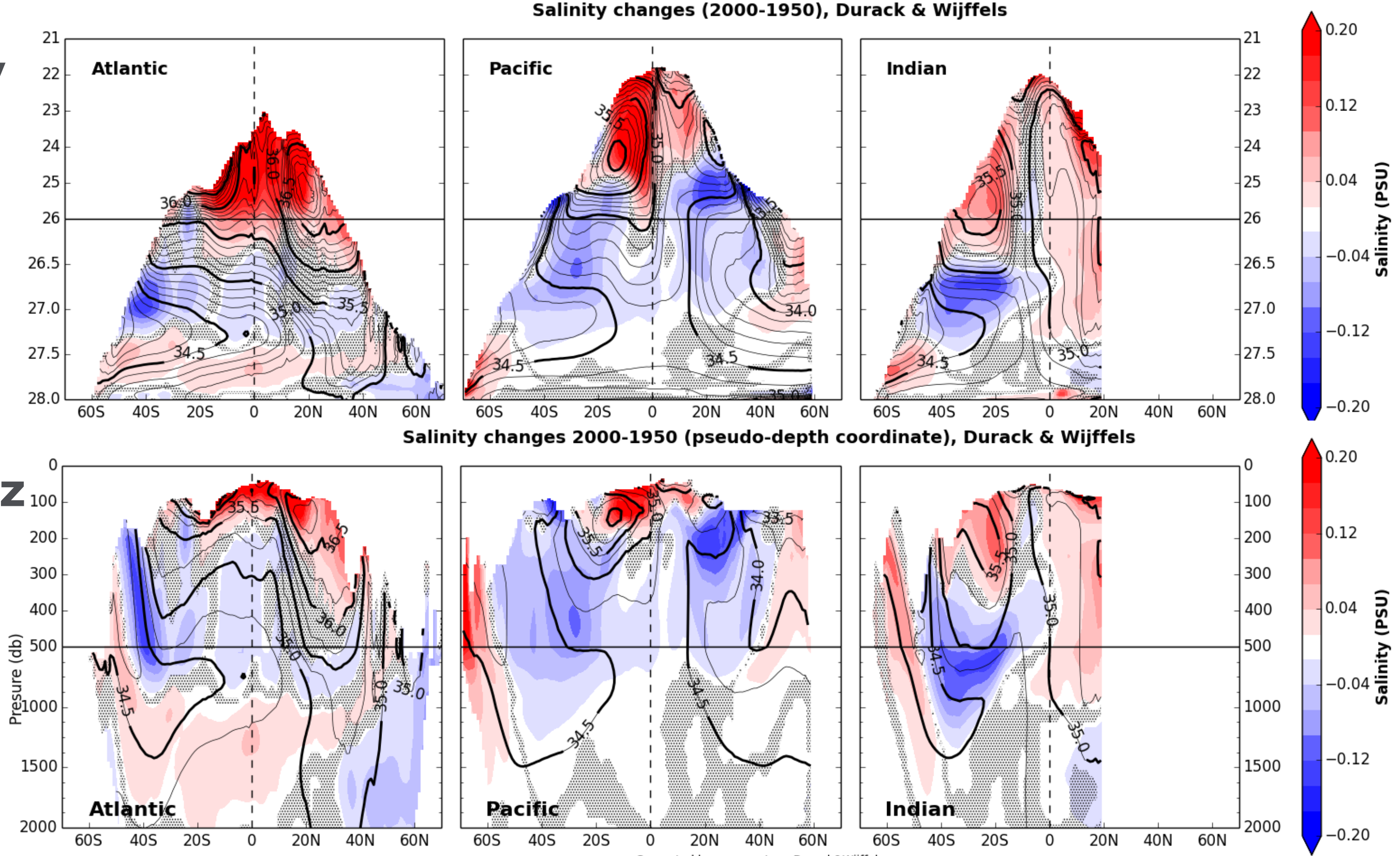
- Identify robust structures of S change in the ocean interior over the last decades
- Density binning of CMIP5 suite of simulations
- Attribute part due to human activity and in particular to CO2 emissions
- Compute Time of Emergence (ToE) of global and regional salinity signal

Ocean interior changes from observational analysis

Zonal salinity change between 1950 and 2000, below bowl

Density

Pseudo-z

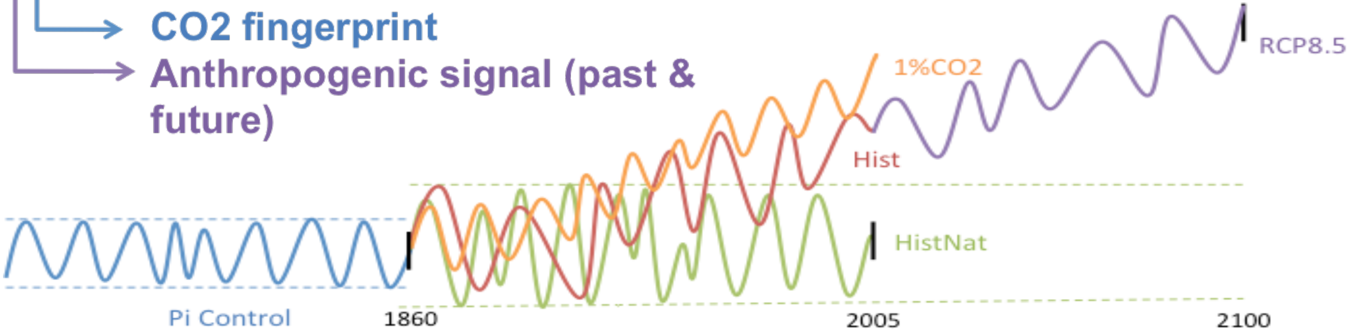


CMIP5 simulations

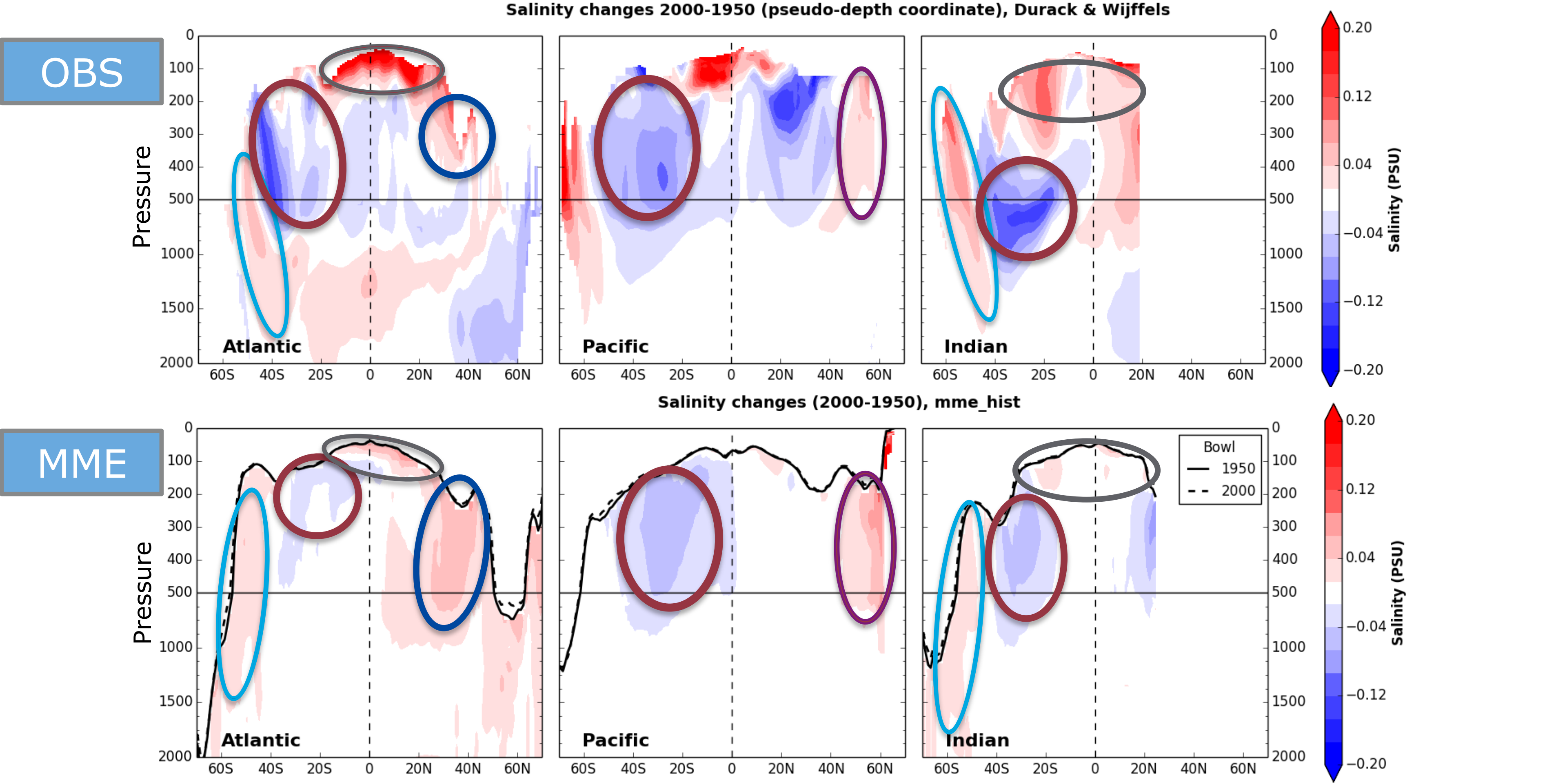
	Natural forcings	Other ext. forcings	Nb of models	Nb of runs	Time period
Hist	✓	**Anthropogenic** (CO2, aerosols, land use)	14	82	1860-2005
Hist + RCP8.5	✓	**Anthropogenic**	11	35	1860-2100
HistNat	✓	✗	14	54	1860-2005
1%CO2	✗	**1%CO2/year**	15	15	140 years
Pi Control	✗	✗	15	15	140 years

CO2 fingerprint

Anthropogenic signal (past & future)

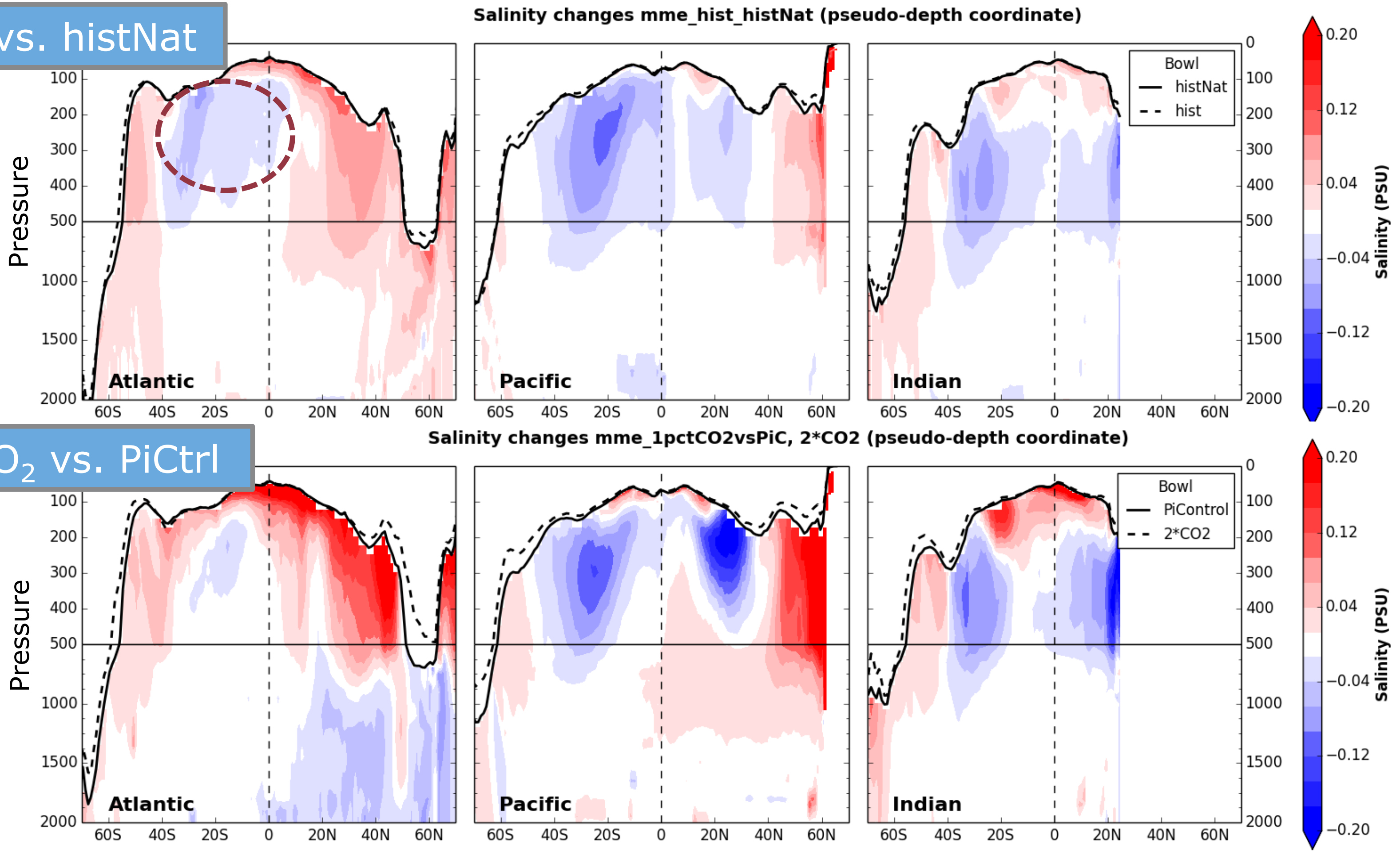


Models vs. Observations for 2000-1950



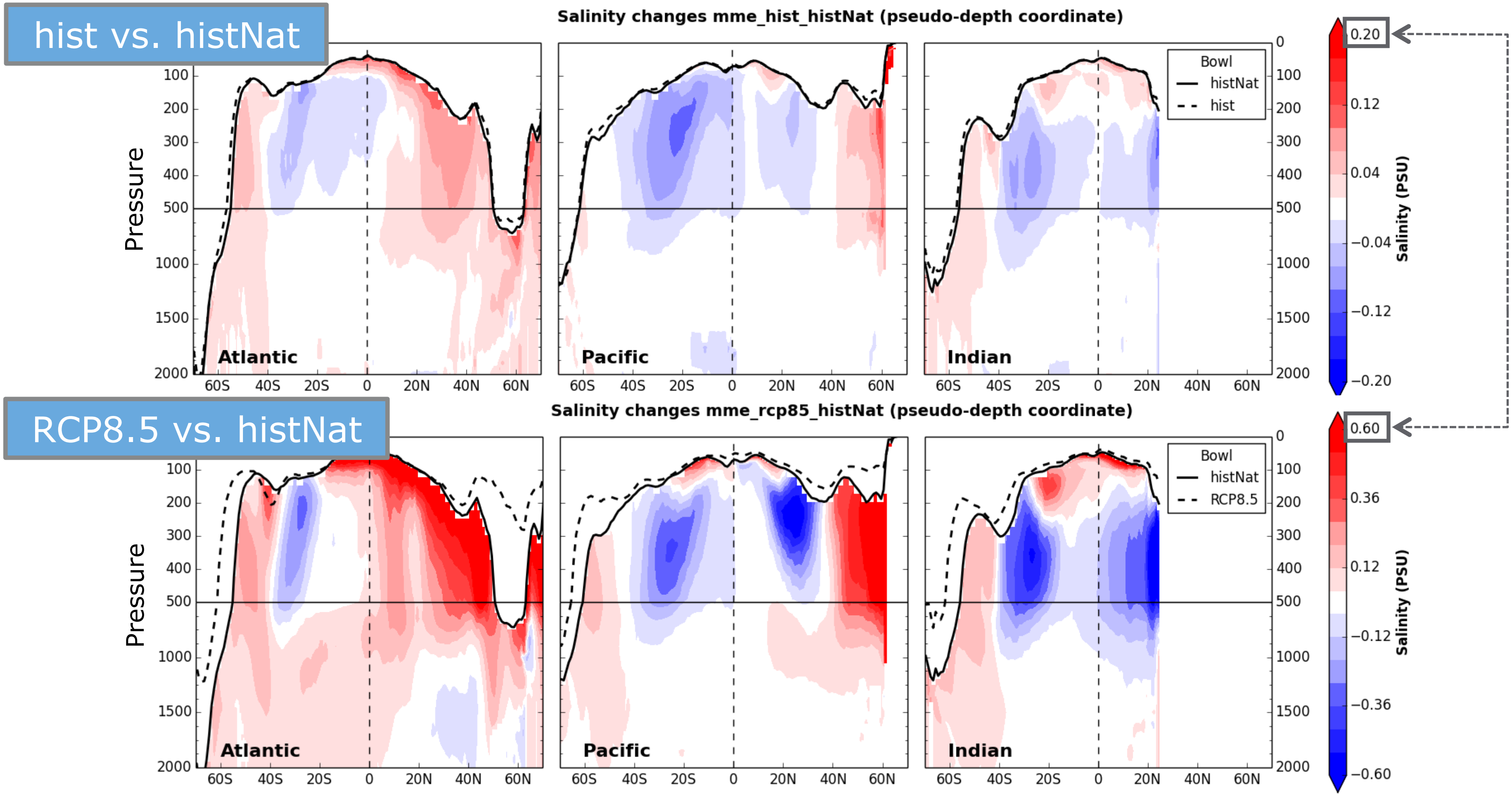
Anthropogenic and CO_2 fingerprint

hist vs. histNat



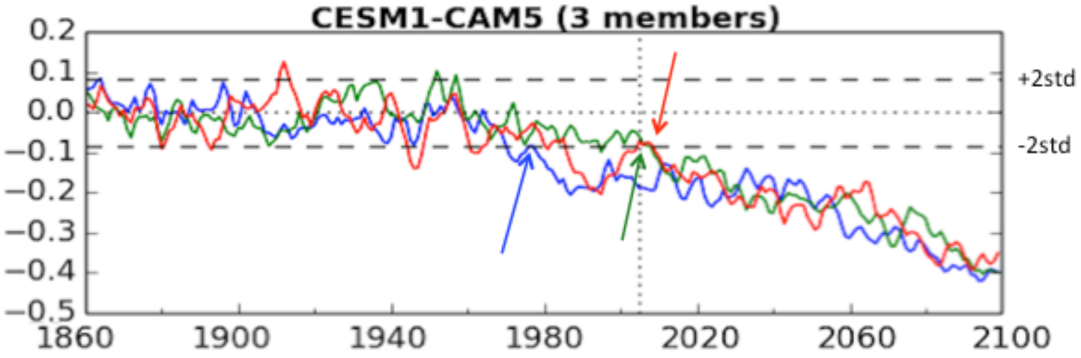
2*CO_2 vs. PiCtrl

Projected anthropogenic signal: RCP8.5 scenario



Time of Emergence (ToE)

ToE = time at which the forced signal last emerges from the noise of climate variability (2 x interannual std)



Anthropogenic salinity evolution in the Atlantic Southern Subtropics
Colored lines = signal of climate change
Dotted lines = threshold of climate variability

Pure CO2 ToE

Signal = 1%CO2 – PiControl

Noise = 2*std(PiControl)

Anthropogenic ToE

- Historical period

Signal = hist – histNat

- Projection period

Signal = RCP8.5 – mean(histNat)

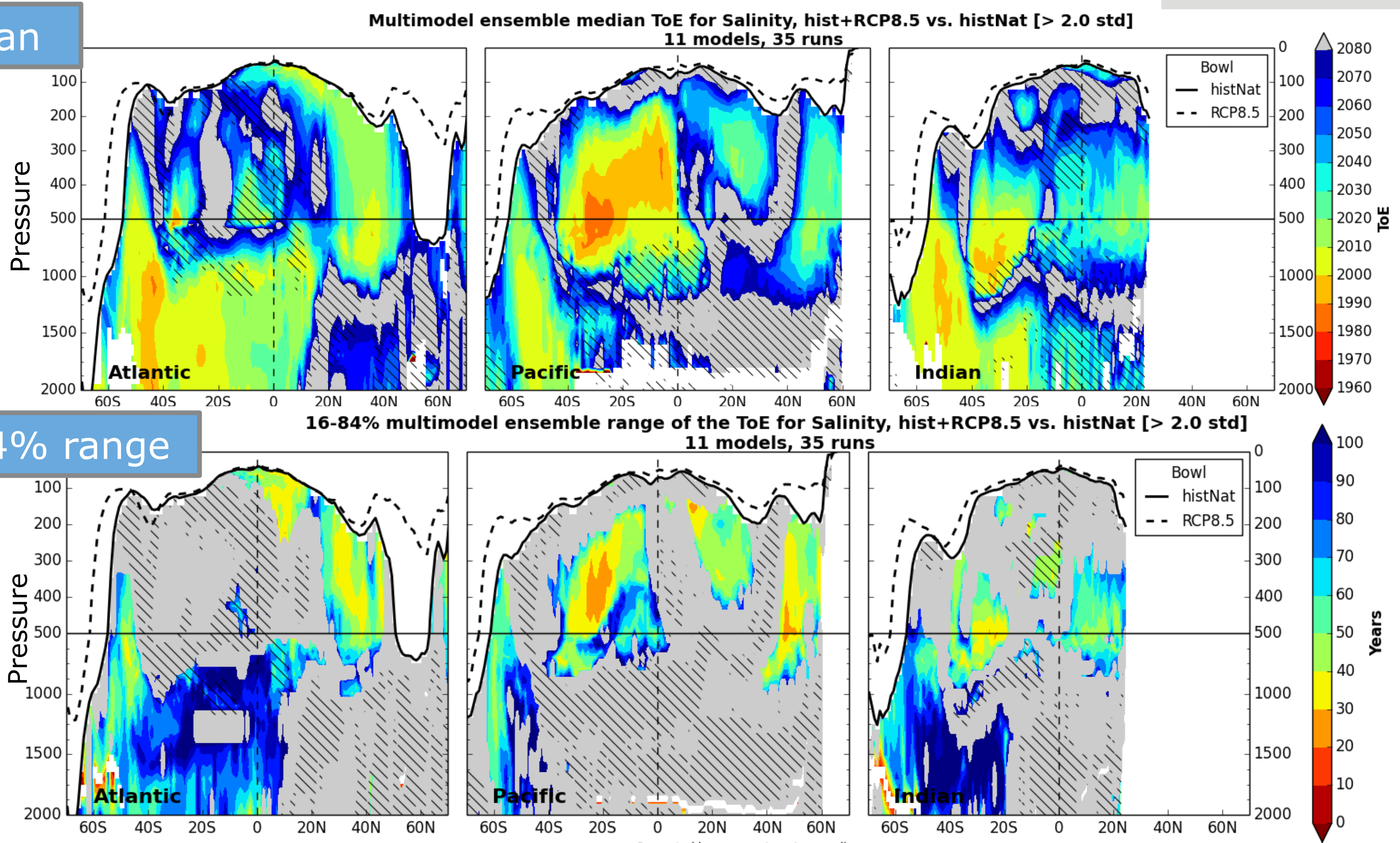
Noise = 2*std(histNat)

Zonal ToE distribution (hist+rcp8.5 vs. histNat)

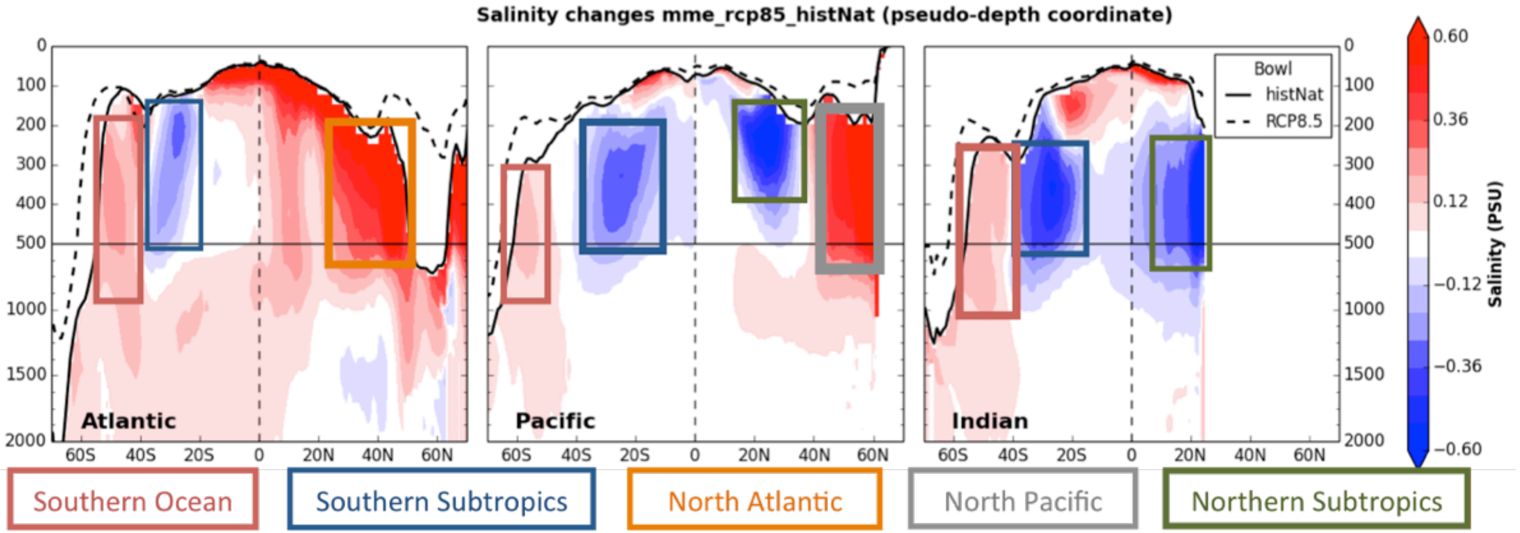
Grey = no emergence
Hatches = no agreement between models

Median

16-84% range



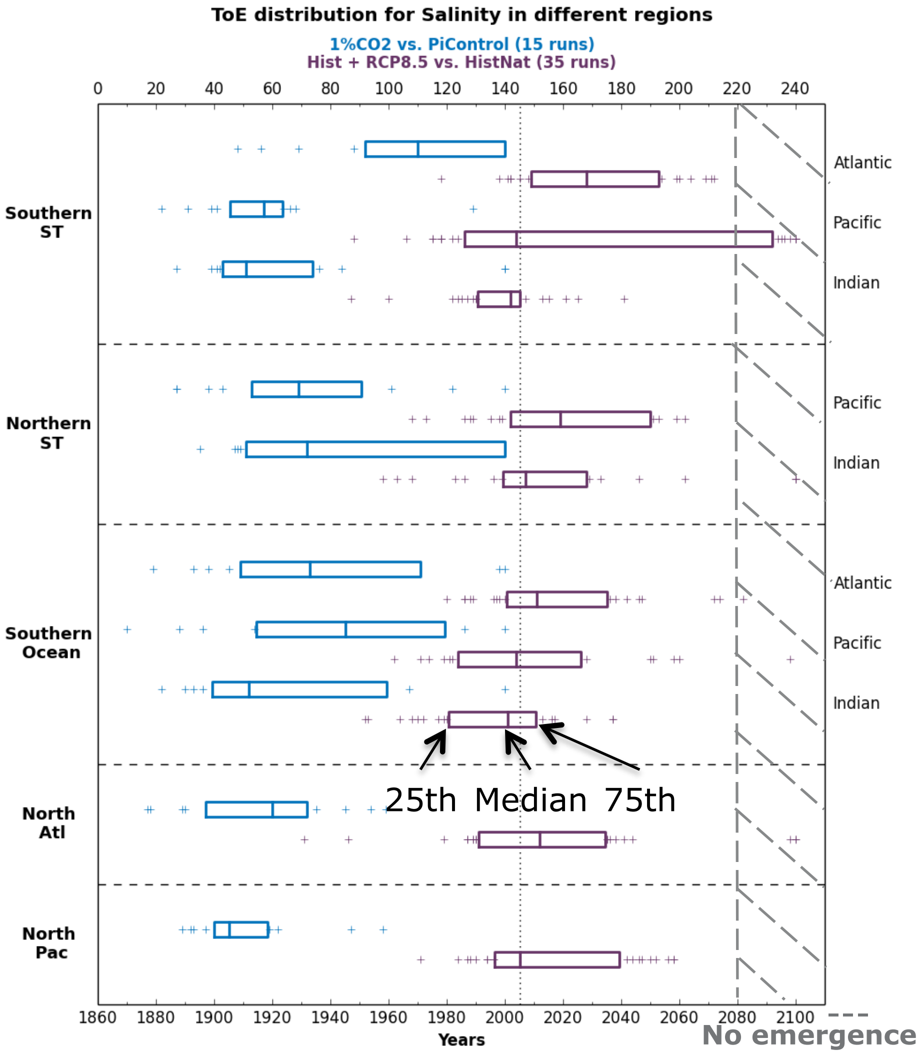
Manual fingerprinting



- Boxes coordinates fixed per model to follow the signal
- Signal and noise averaged in the box
- One ToE for each simulation → Statistical distribution of ToE per region

Regional ToE distribution

- Anthropogenic ToEs later vs. CO2
- ToE distribution: model sensitivity / intensity of internal variability
- Majority of the anthropogenic signal emerges between end 20th century – beginning 21st
- Large distributions + late outliers: change in the evolution of the signal caught by the boxes
- Atlantic southern subtropical region : later ToE distribution → consistent with the zonal distribution of ToE



Conclusion

- Using **models** to constrain missing observations is a promising approach
- **Density binning** provides a heave-free view of the signal and gives more physical zonal means

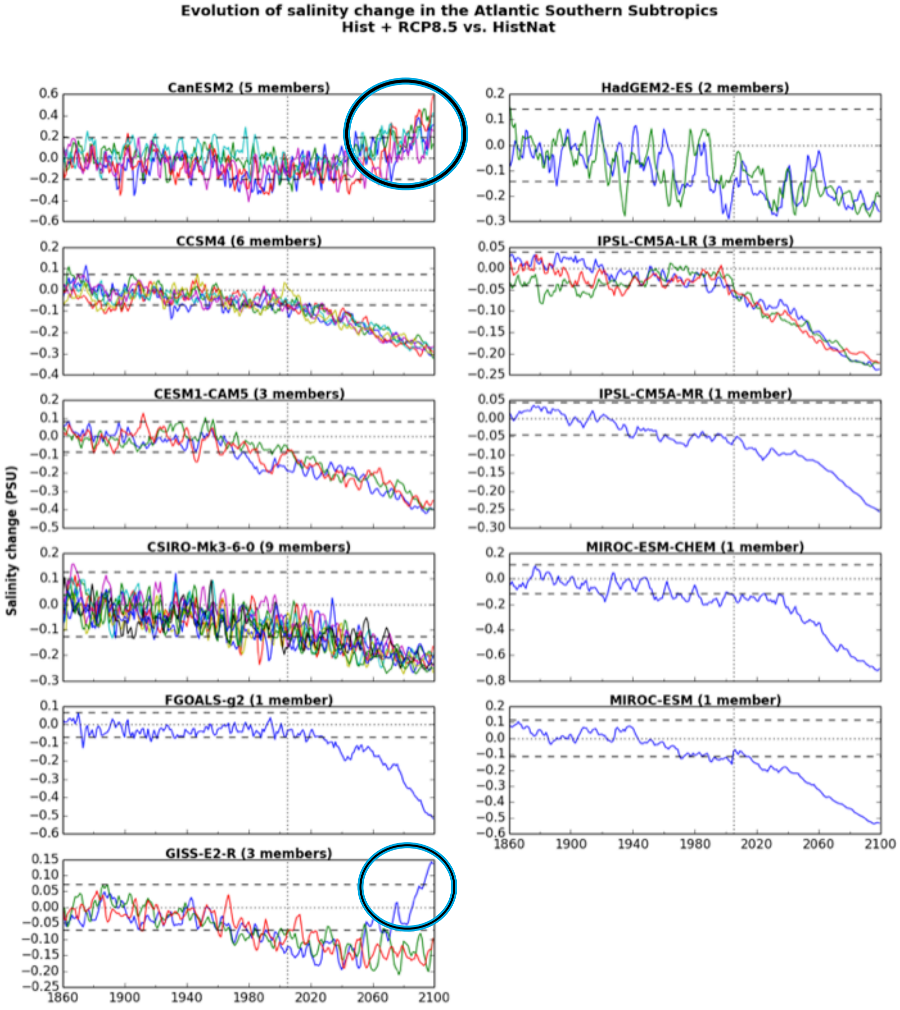
- Coherent salty/fresh/salty human-driven tripole in Southern Hemisphere:
  - Associated to tropical expansion
  - Emerges from variability early 21st century
  - Mostly CO2 driven
- Atlantic ocean exhibits marked difference to other basins
  - Earlier ToE at depth, later ToE in Southern sub-tropics
  - Could be driven by aerosols and/or land use changes

Thank you !

- Many regions may need many more years/decades of observation to detect human influence but we can anticipate and quantify this delay
- More precise quantification of ToE distribution needs more precise fingerprinting

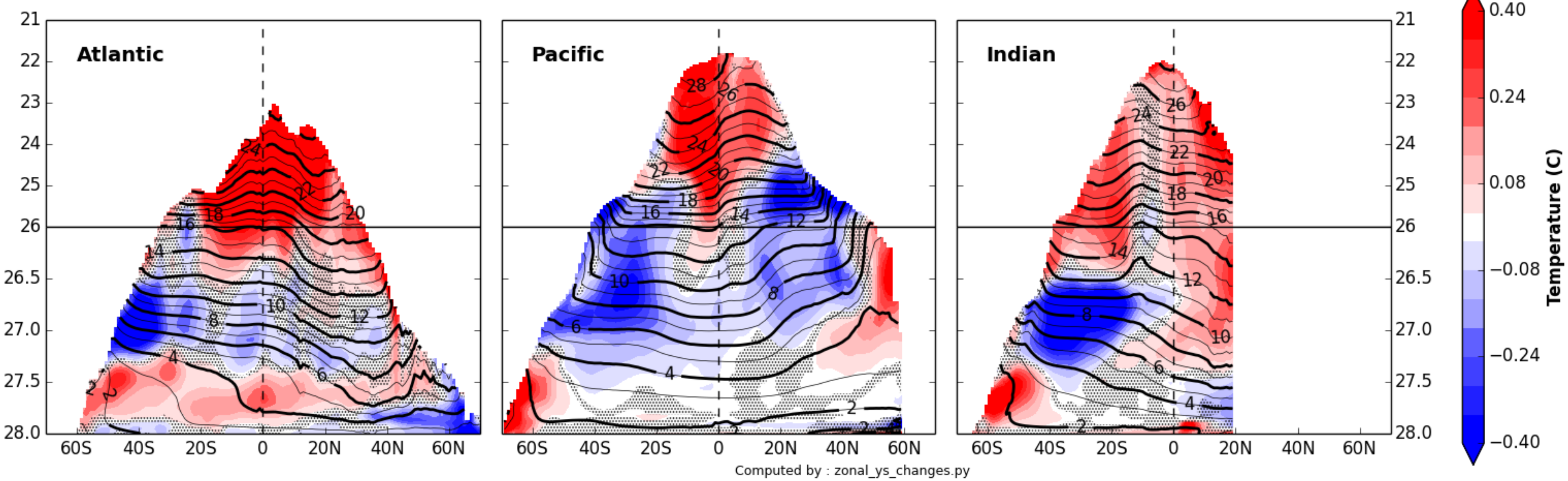
ADDITIONAL MATERIAL

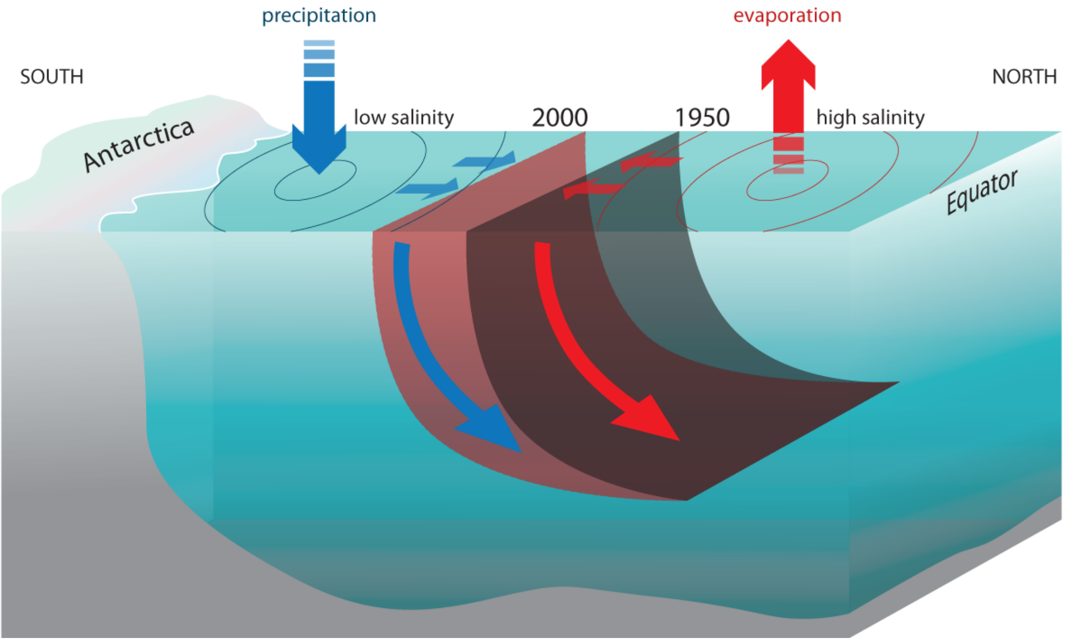
RCP8.5 - HistNat



Boxes fixed in time and space : possible mistakes on the signal they are catching
→ Signals of opposite sign are excluded

Temperature changes (2000-1950), Durack & Wijffels





- Surface warming leads to poleward migration of isopycnals
- Change of properties along isopycnals will depend on mean change of T/S across isopycnals