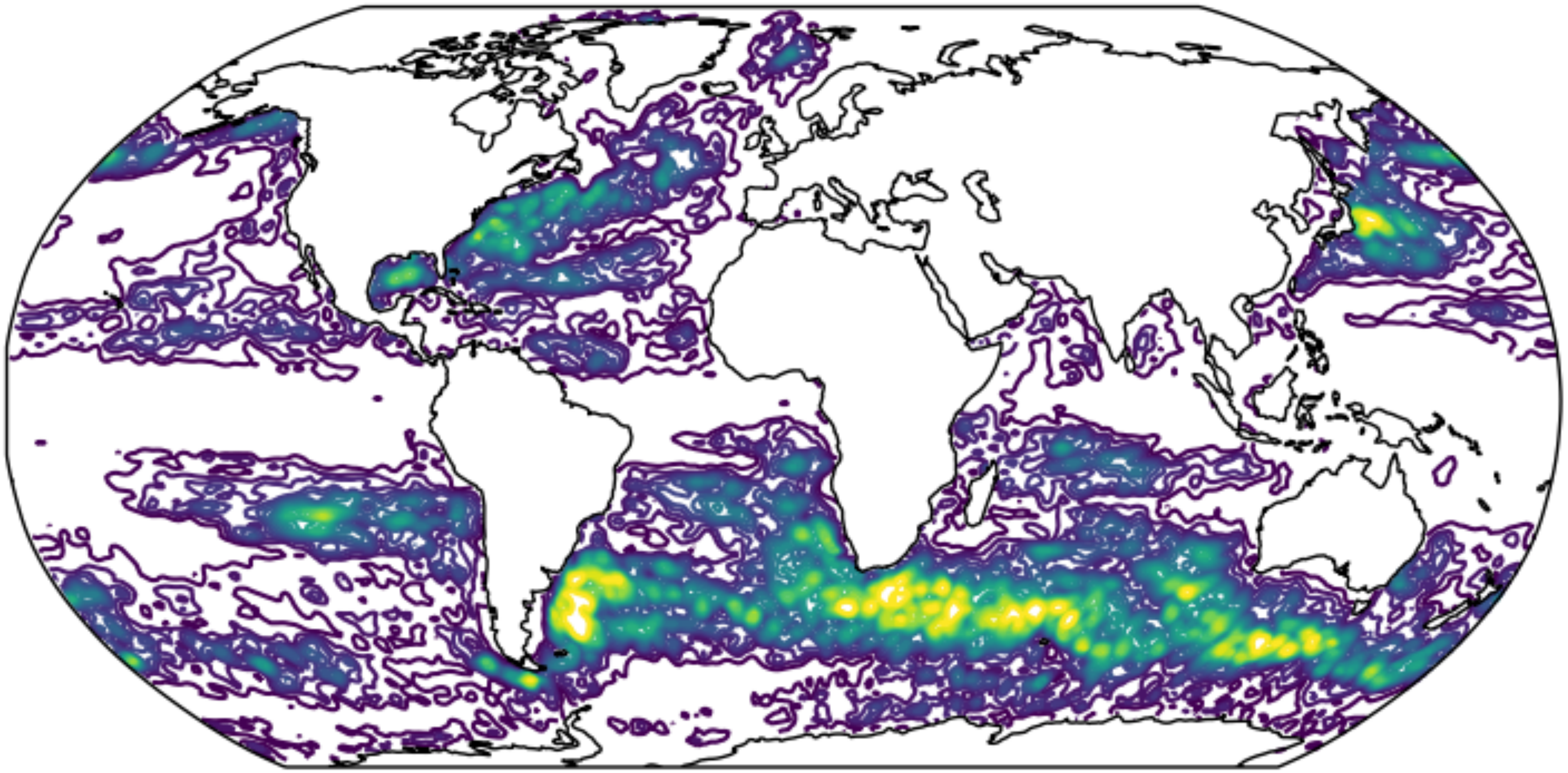
Quantification of Chaotic Intrinsic Variability of Sea–Air CO_2 Fluxes at Interannual Timescales



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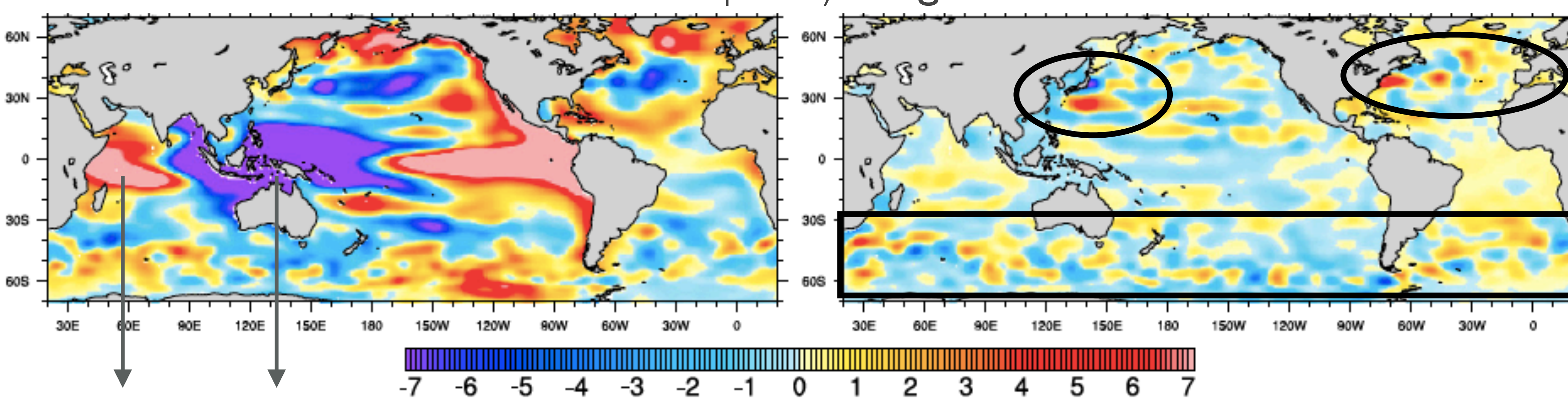
Sea Level Anomalies from Sérazin et al. (2015)

Low-Frequency signals exist in the ocean even if not present in the atmo forcing

FULL ATMOSPHERIC FORCING

SEASONAL ONLY

Low-frequency **Large-scale**



Still LF Large-scale in eddy-active regions

IOD, ENSO, PDO directly forced by the atmo

Context

In forced HR (0.25°) ocean runs + under seasonal atmospheric forcings:

- physical fields (**SSH**: Penduff & al, 2011 ; Sérazin & al, 2015,
  OHC: Sérazin & al, 2017),
- climate-relevant indices (**AMOC**: Leroux & al, 2018),

are significantly affected by large-scale (> 500 km)
and low-frequency (2 years < t < 20 years) **Chaotic Intrinsic Variability** (**CIV**)

Estimation of **CIV** is useful to

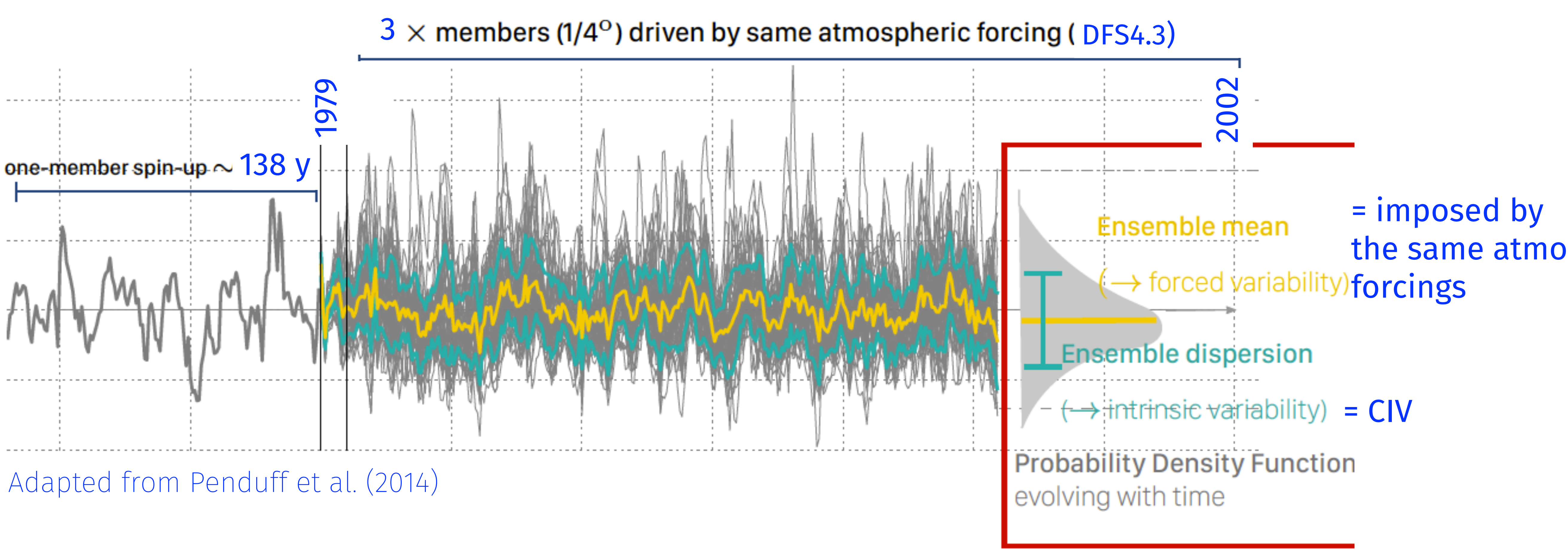
- disentangle the anthropogenic forcing from the natural variability
- accurately predict oceanic variability

Motivation and framework

➜ Does Chaotic Intrinsic Var affect biogeochemical tracers ?

Numerical framework needed to isolate CIV:

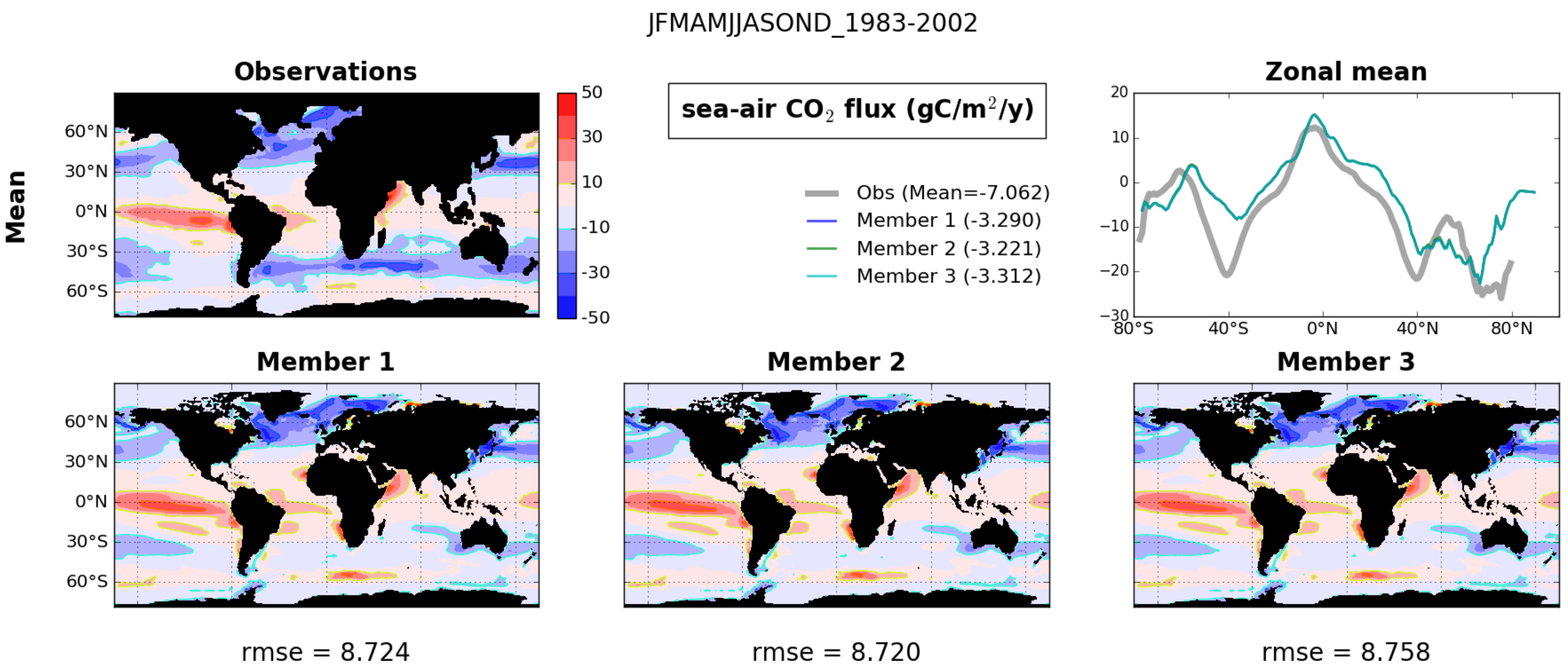
- HR (**0.25°**): viscosity lowered ➞ ocean non-linearities and mesoscale activity
- An **ensemble** of **forced ocean** runs: all members driven by the same atmo forcing



Adapted from Penduff et al. (2014)

Method

3 members
of global and **forced**
ocean-biogeochemical simulations NEMO-PISCES
at a 0.25°

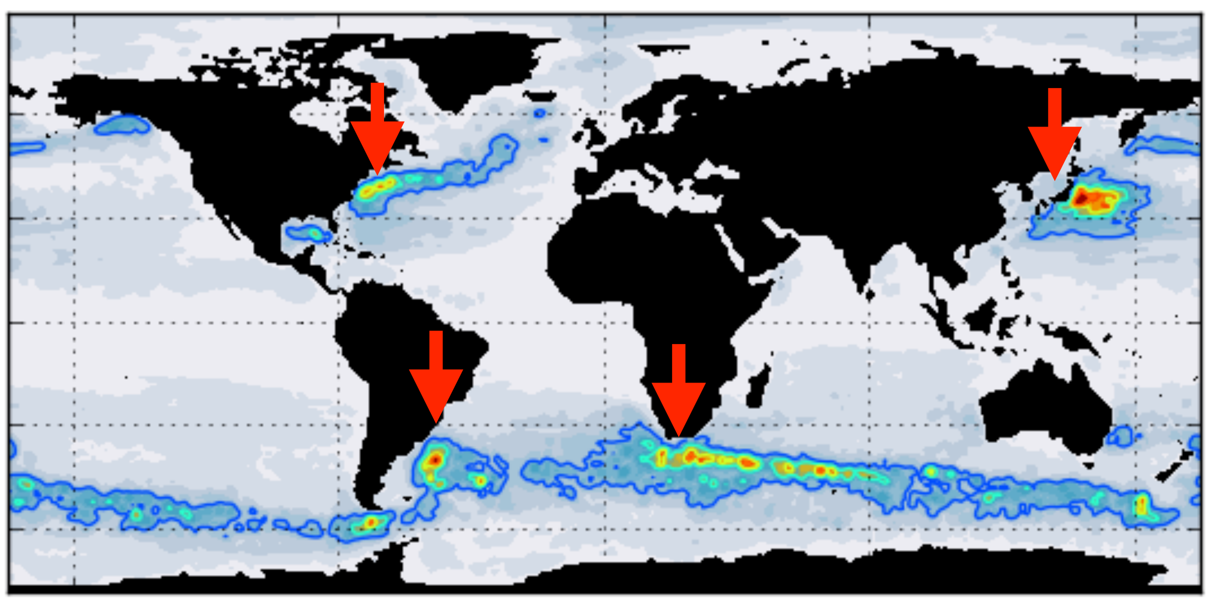


3 members ?

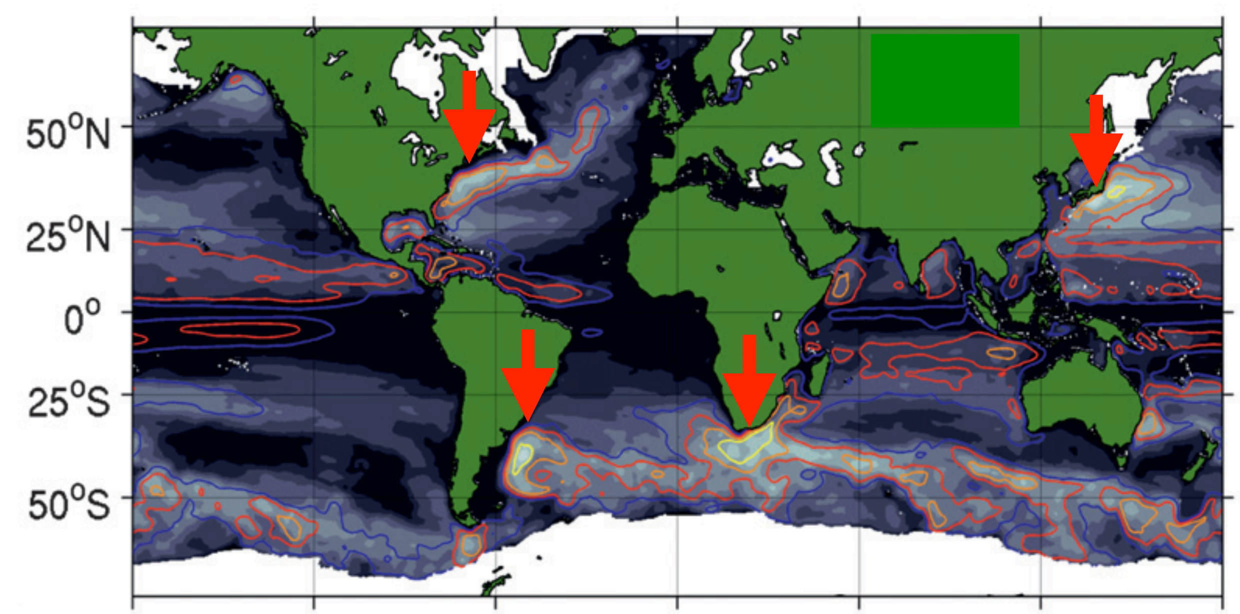
AMOC CIV estimation:
Hirschi et al (2013), only 2 members ~ Leroux et al (2018), 50 members

CIV of SSH (amplitude, spatial pattern) of our small ensemble is consistent with results of Penduff et al. (2011)

CHAOTIC INTRINSIC VARIABILITY OF SSH



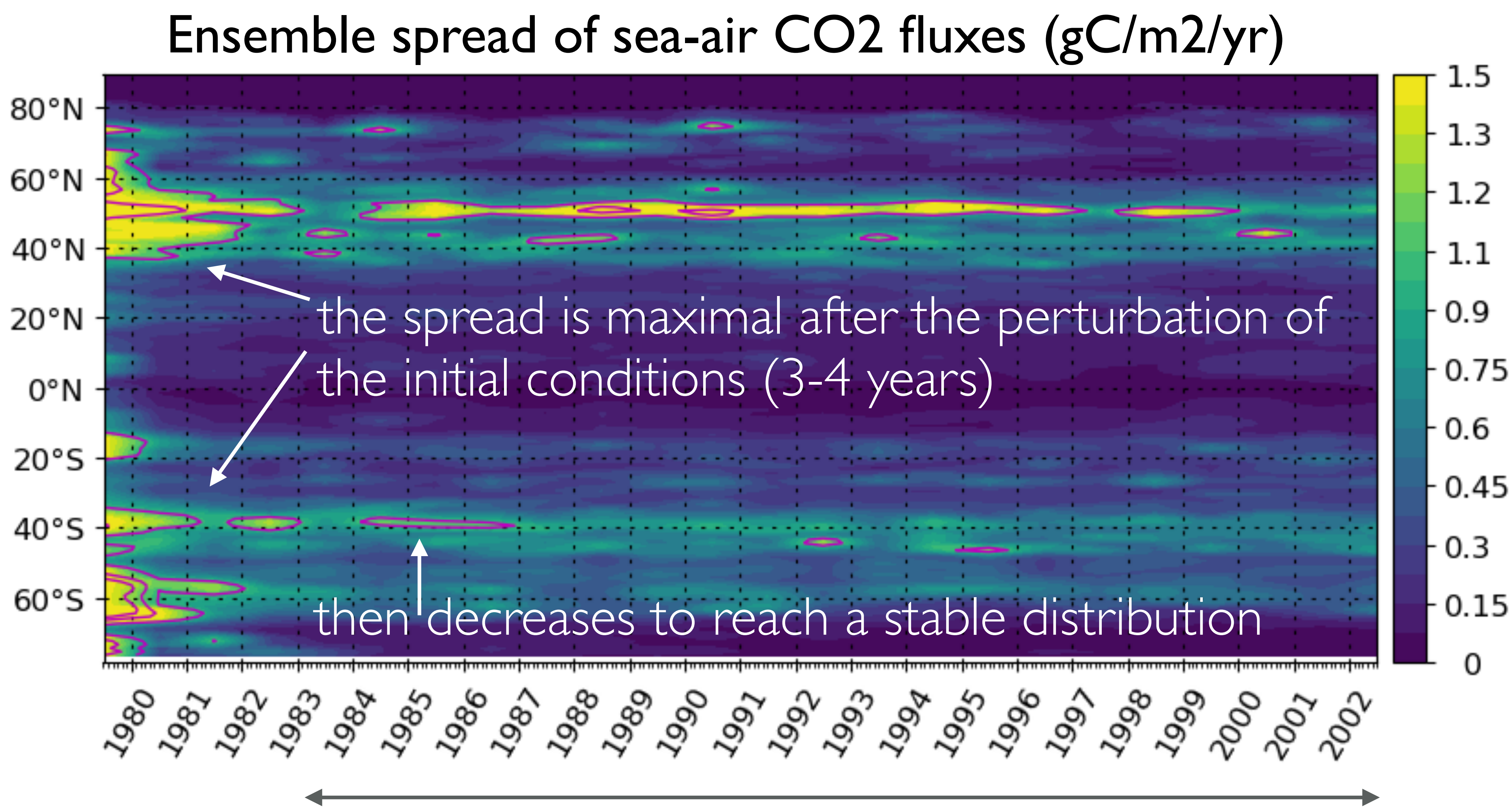
Gehlen et al. (2020)



Penduff et al. (2011)

Method

To build our ensemble:
Initial perturbation of the members in 1979 = initial adjustment between the
model state (which differs in each member) and
the current forcing (which is the same in all members)

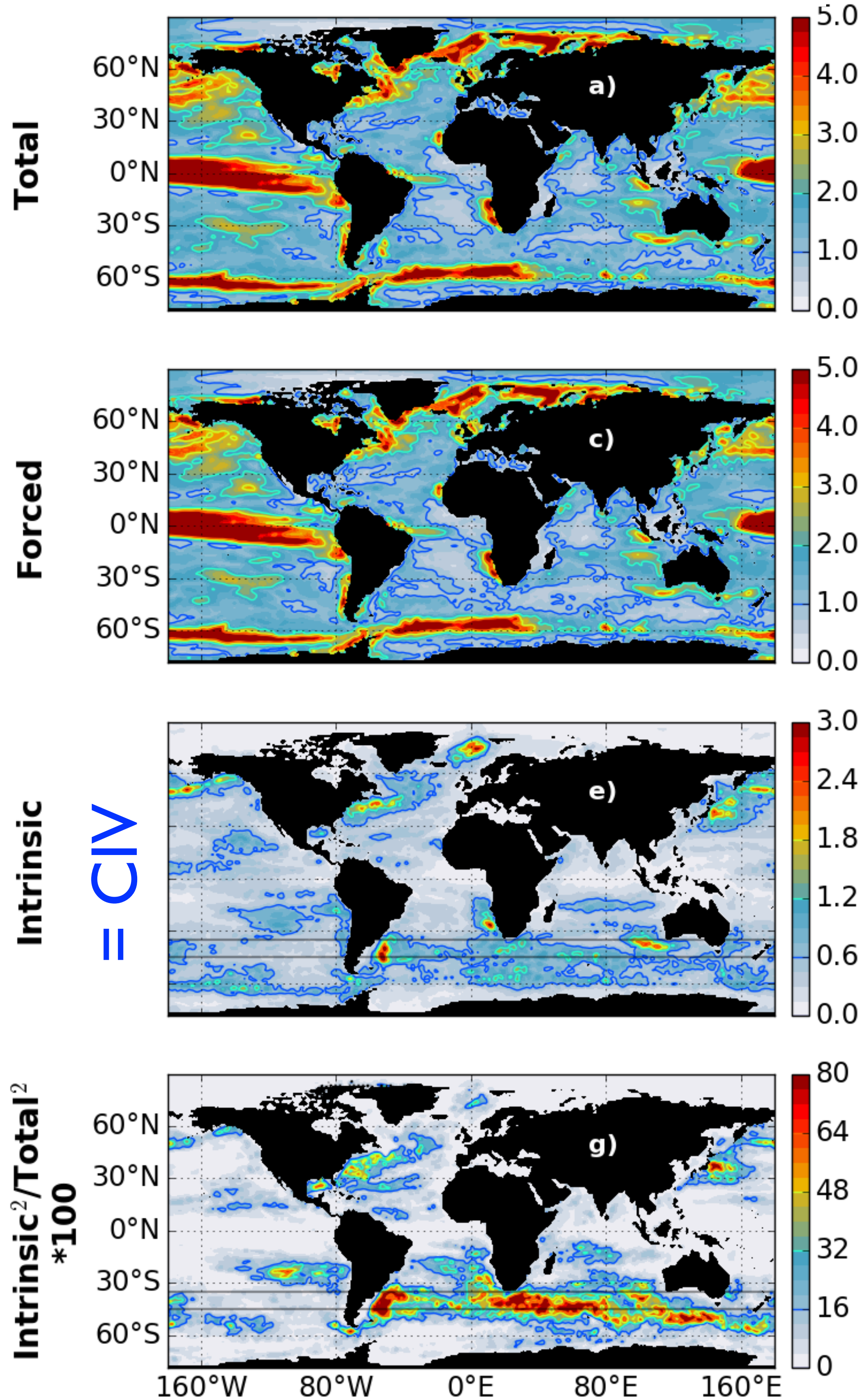


Results

(**Total variability**)^2
=
(Forced var)^2
+
(CIV)^2

: sum of squared standard deviations

Sea-air CO2 fluxes (gC/m2/yr)

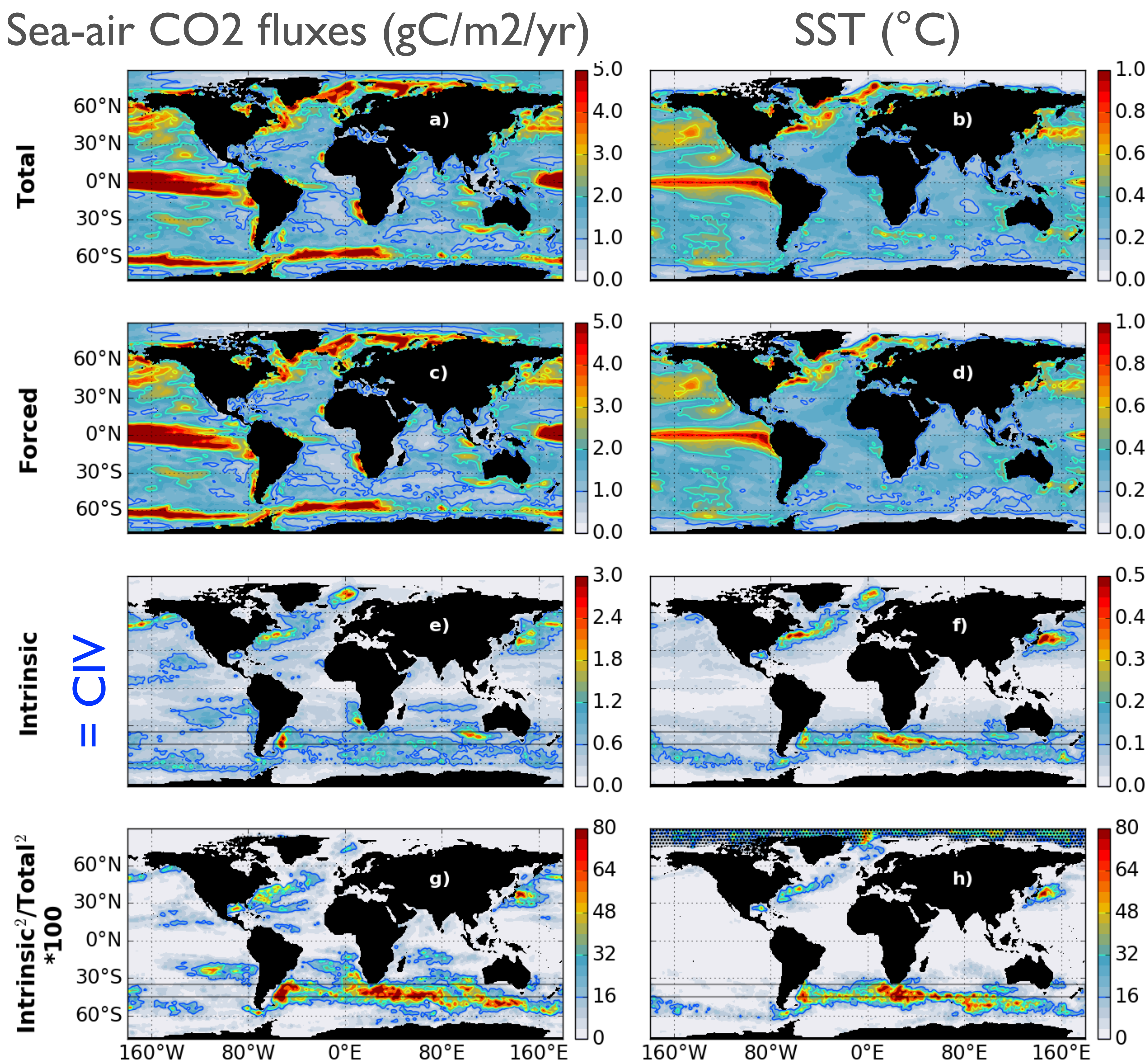


Forced var = major contributor to Total var

Patterns of Forced var = patterns of Total var

CIV strong in eddying regions:
- Southern Ocean
- western Boundary currents

Results



CIV patterns of sea-air CO2 fluxes are close to those of SST

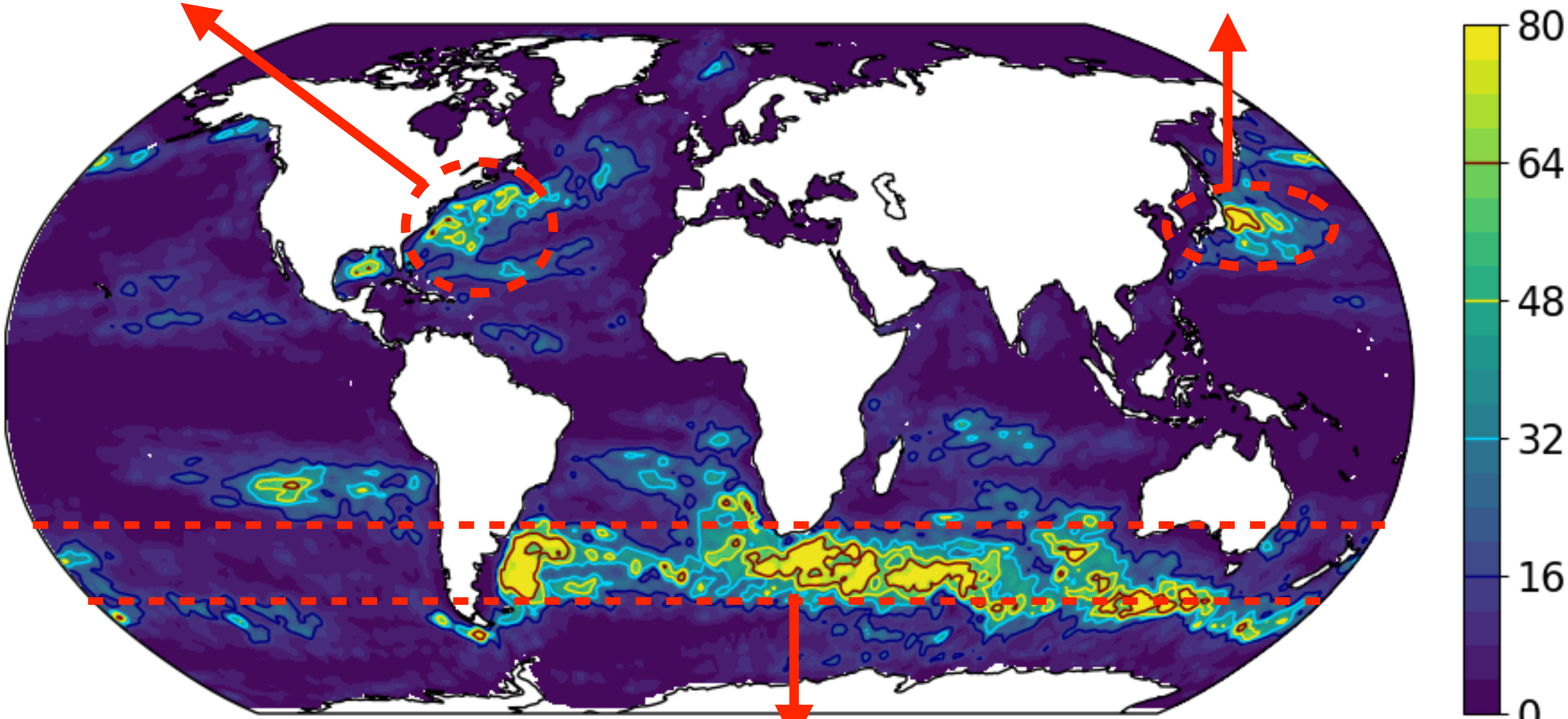
Mean ratio $(\mathrm{CIV})^2$ / $(\mathrm{Total\ variability})^2$ [%] **over regions**

Sea-air CO2 fluxes (gC/m2/yr)

Global ocean (78°S to 90°N) = 5.5%

Gulf Stream = 16%

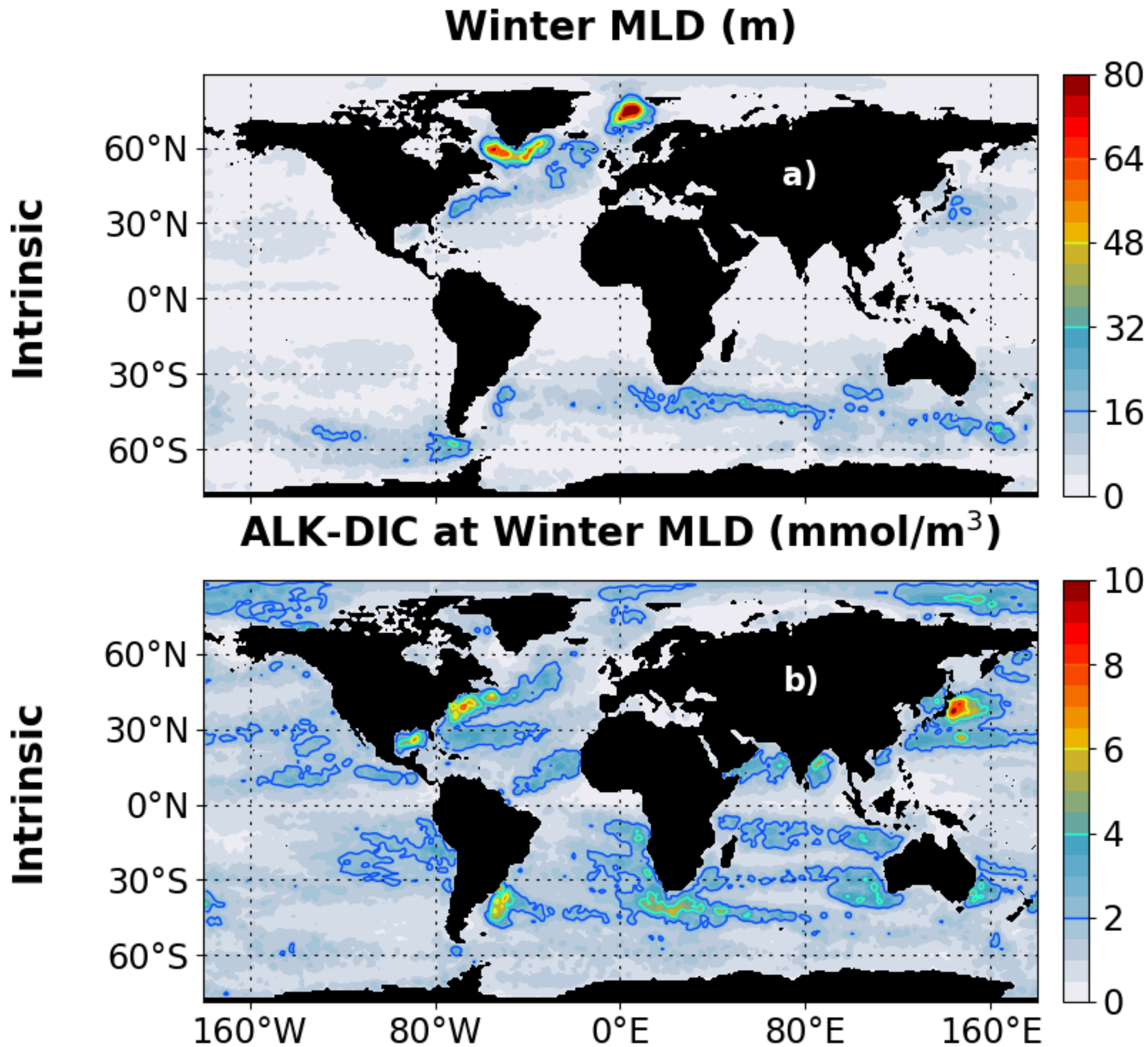
Kuroshio = 22%



Southern Ocean (35-45°S band) = 20%

The ratio of CIV to Total var ranges between 16 and 22% in eddy-active regions

Drivers of Sea-air CO2 fluxes CIV



ALK-DIC ~ [CO_3^{2-}]

CIV patterns for sea-air CO2 fluxes
~ CIV patterns for winter MLD
~ CIV patterns for [CO_3^{2-}]
over Southern Ocean, Gulf Stream and Kuroshio

In regions of high eddy kinetic energy: CIV of SST reaches 0.5°C while those of [CO_3^{2-}] range between 2 and 5 $mmol/m^3$

Conclusions

Interannual chaotic intrinsic (CIV) variability propagates from physical to chemical tracers in areas of strong mesoscale activity:

- It contributes significantly to interannual variability of sea–air CO_2 fluxes over the Southern Ocean and western boundary current systems

  ↓

  between 35°S and 45°S, CIV amounts to 23.76 TgC/yr
  ~ 50% of the atmospherically forced variability

- Locally, CIV contribution to the total interannual variance of sea-air CO_2 fluxes exceeds 76%

- Outside eddy-active regions its contribution to total interannual variability is below 16% and sea–air CO_2 fluxes is prominently driven by atmospheric forcing

Thanks !

Reference:

Gehlen, M., Berthet, S., Séférian, R., Ethé, C., & Penduff, T. (2020). **Quantification of chaotic intrinsic variability of sea−air CO2 fluxes at interannual timescales.** *Geophysical Research Letters*, 47, e2020GL088304. https://doi.org/10.1029/2020GL088304

Results

Sea-air CO_2 fluxes (gC/m2/yr)	$(CIV)^2$ / $(\text{Total variability})^2$ [%]
Global ocean 78°S to 90°N	5.5
Midlatitude Southern Ocean 45–35°S	20
Gulf Stream 70°W, 40°W to 35°N, 50°N	16
Kuroshio 140°E, 170°E to 30°N, 45°N	22

The ratio of CIV to Total var ranges between 16 and 22% in eddy-active regions