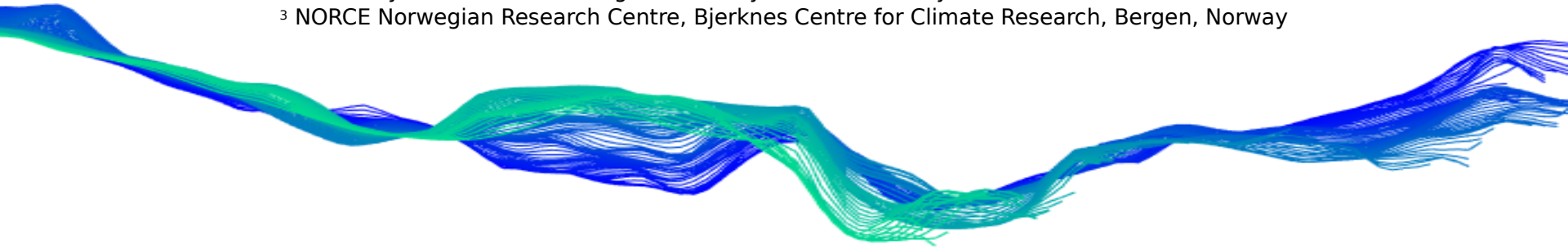
Temporal Changes in Interior Dissolved Inorganic Carbon

Lydia Keppler[1], P. Landschützer[1], N. Gruber[2], S. K. Lauvset[3]

[1] Max-Planck-Institute for Meteorology, Hamburg, Germany
[2] Environmental Physics, Institute of Biogeochemistry and Pollutant Dynamics, ETH Zurich, Zurich, Switzerland
[3] NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Bergen, Norway



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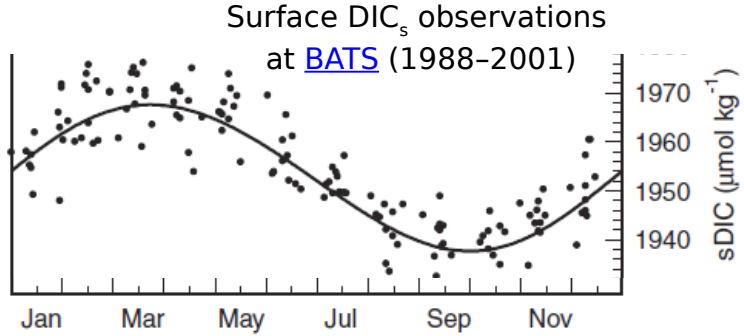
Climate-Carbon Interactions in the Current Century

Oceanic carbon is highly variable

- The **seasonal** cycle is the largest signal in the natural carbon cycle in the ocean

  → What does the dissolved inorganic carbon (DIC) seasonal cycle look like at global scale?

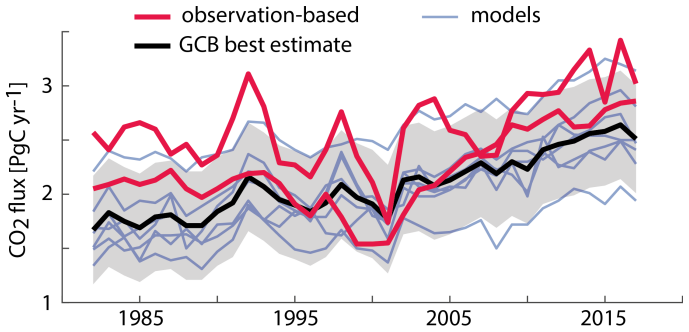
  → Can we estimate the biological draw-down of carbon (spring-to-fall NCP)?



Adapted from Sarmiento & Gruber (2006)

- Air-sea flux: **large interannual to decadal** variability

  → Is this reflected in the DIC pool?

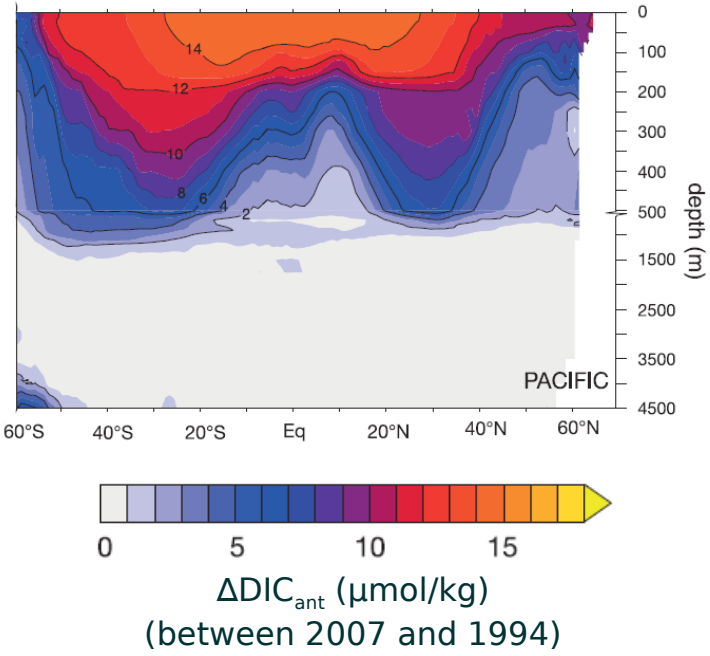


Adapted from Global Carbon Budget 2017

Previous global observation-based studies of oceanic carbon

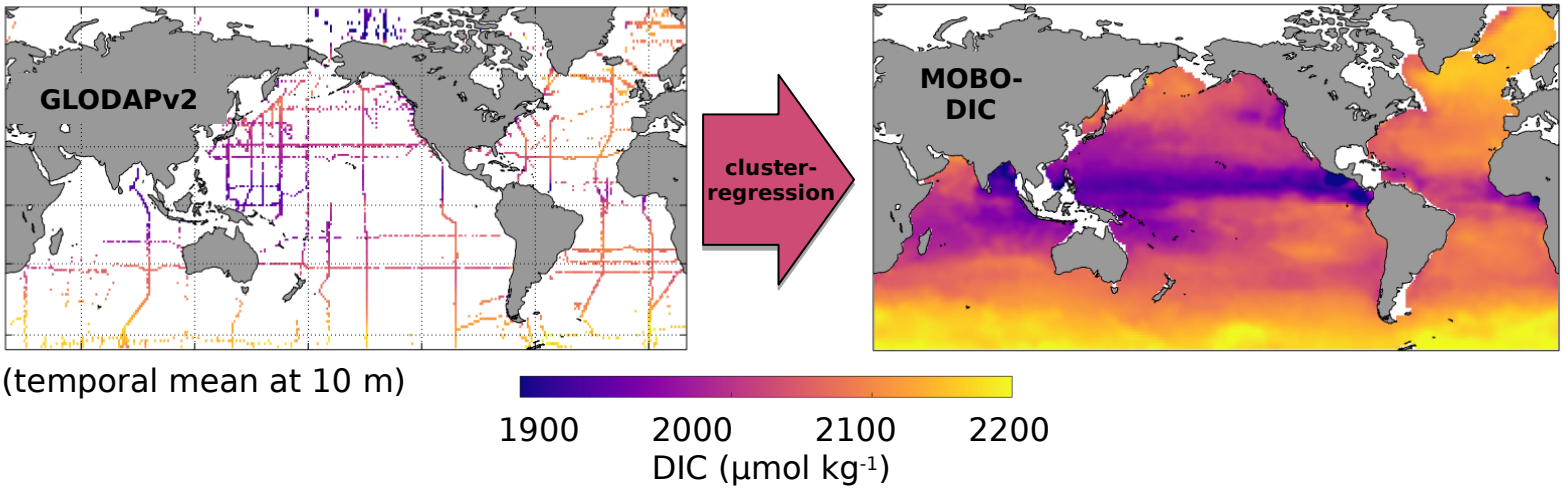
- **Surface products** (e.g., Landschützer et al., 2014)
- **Interior DIC climatology**, not time-varying (Lauvset et al., 2016)
- **Monthly climatology** of DIC (Broullón et al., 2020)
- **Decadal** changes of interior $\mathbf{C_{ant}}$ (e.g., Gruber et al., 2019)

→ We want **time-varying** (monthly to interannual) mapped fields of **total contemporary DIC** (natural + anthropogenic) at global scale



Adapted from Gruber et al. (2019)

Mapped Observation-Based Oceanic DIC (MOBO-DIC)

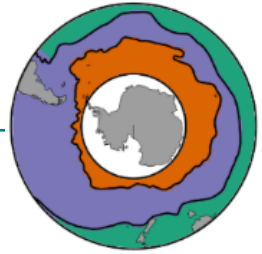


- Adaptation of SOM-FFN by Landschützer et al. (2014)
- **MOBO-DIC_monthly_clim** (Keppler et al., 2020a): Monthly climatology; until 2000 m
- **MOBO-DIC_2014-2018**: Monthly fields from 2004 through 2018, until 1500 m (in prep.)

Adapted from Keppler et al. (2020b)

Validation with independent observations

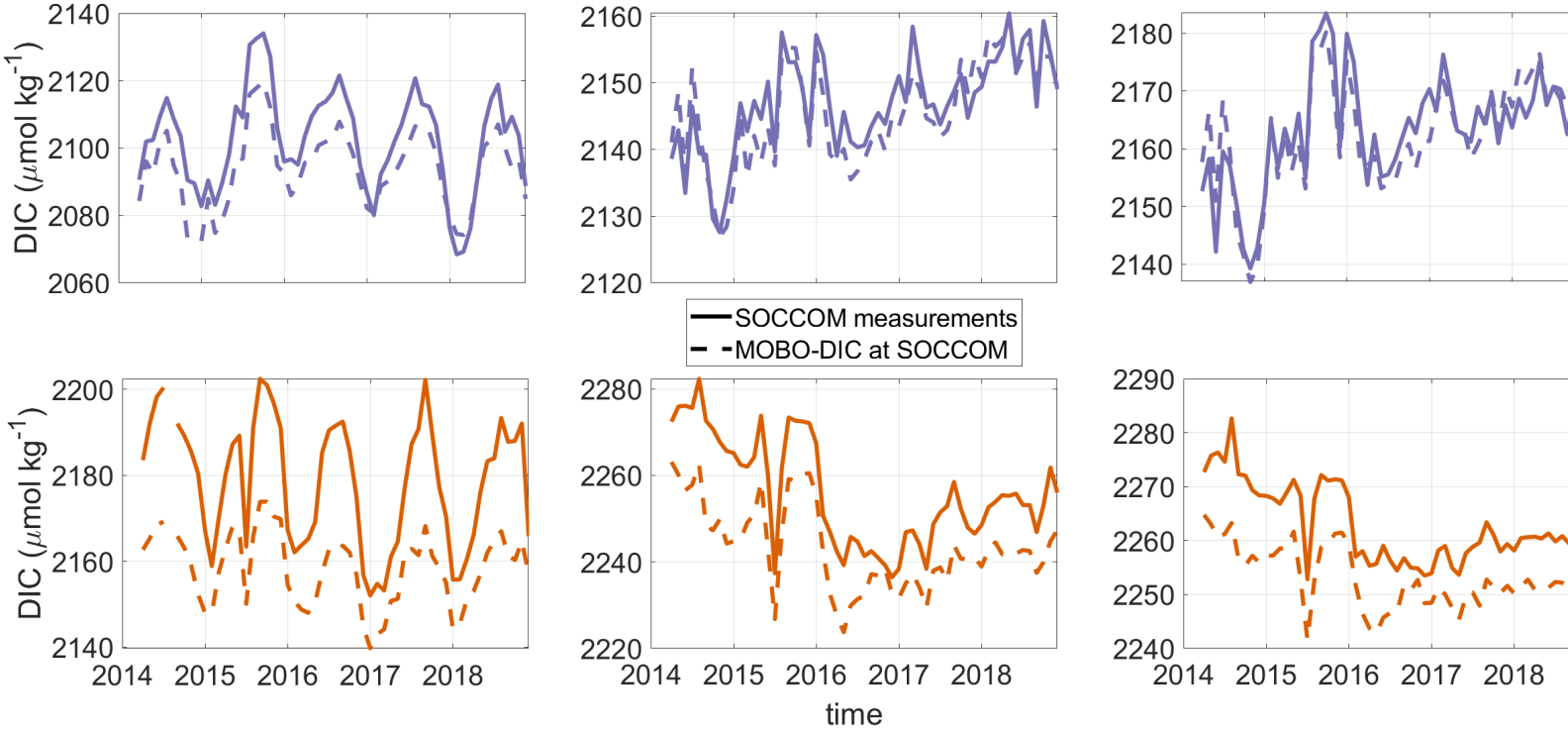
SOCCOM floats



depth: 10 m

depth: 300 m

depth: 500 m



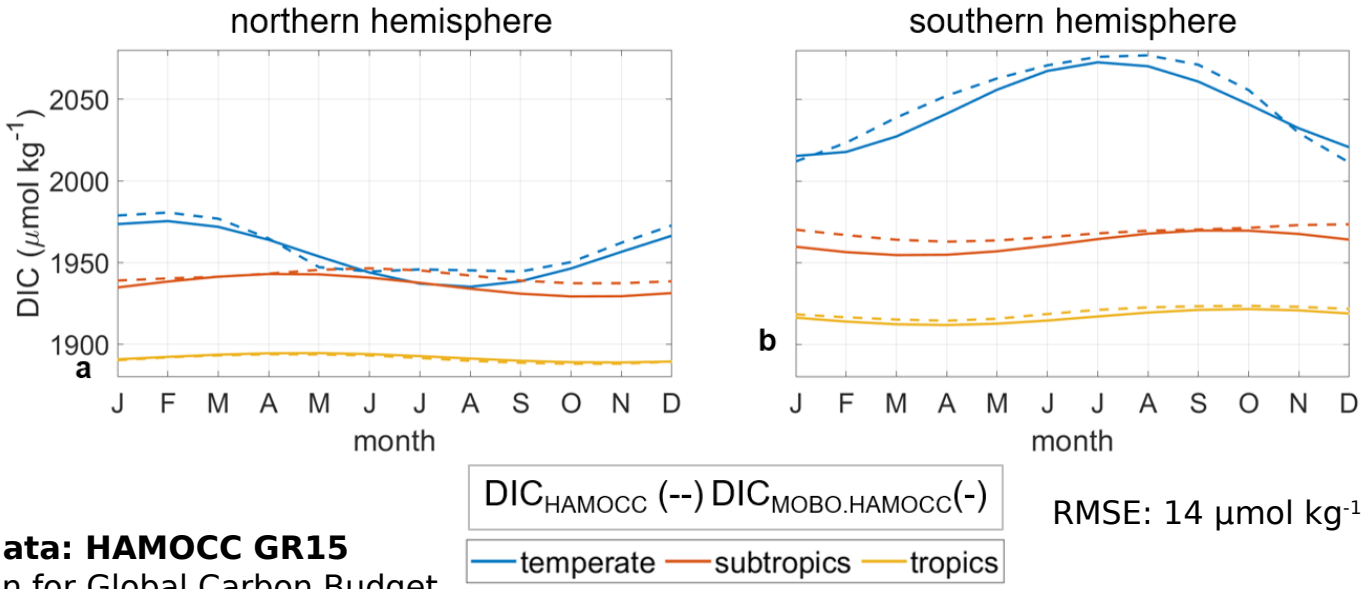
RMSE:
8 µmol kg^{-1}

Bias:
3 µmol kg^{-1}

RMSE:
18 µmol kg^{-1}

Bias:
11 µmol kg^{-1}

Validation with synthetic data

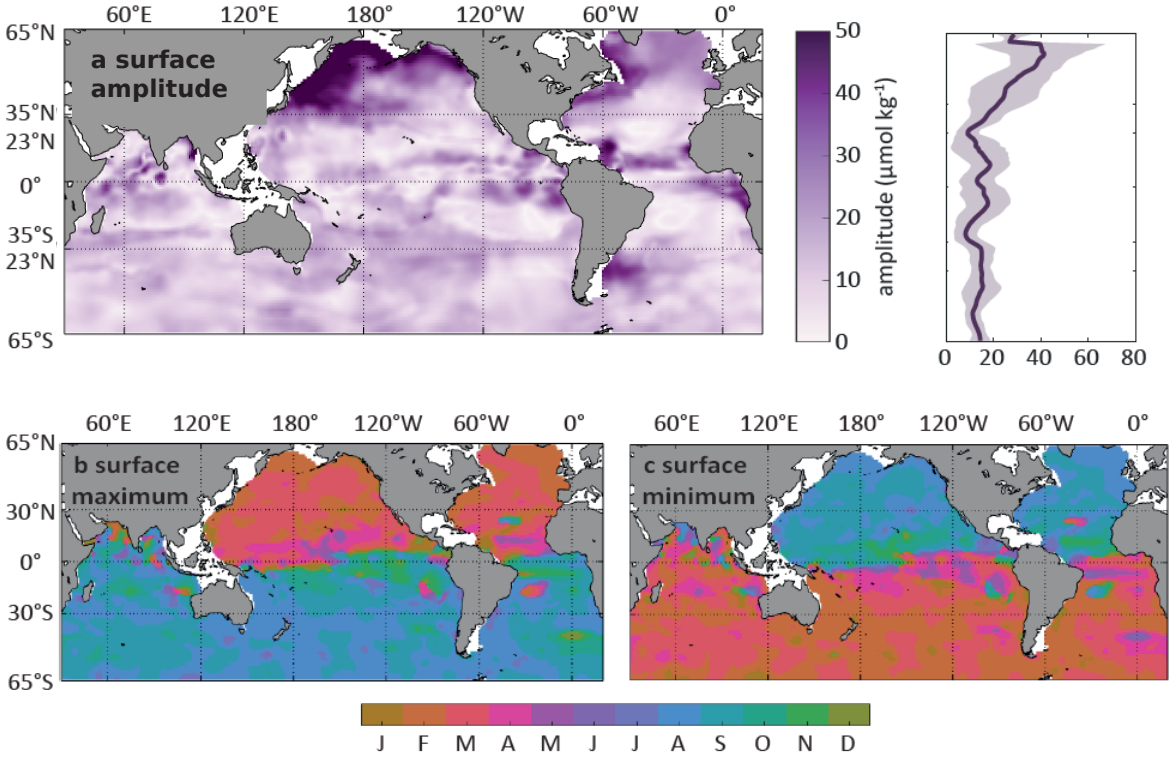


RMSE: 14 µmol kg^{-1}

Synthetic data: HAMOCC GR15
- Hindcast run for Global Carbon Budget
- Forced with reanalysis atmosphere

Adapted from Keppler et al. (2020b)

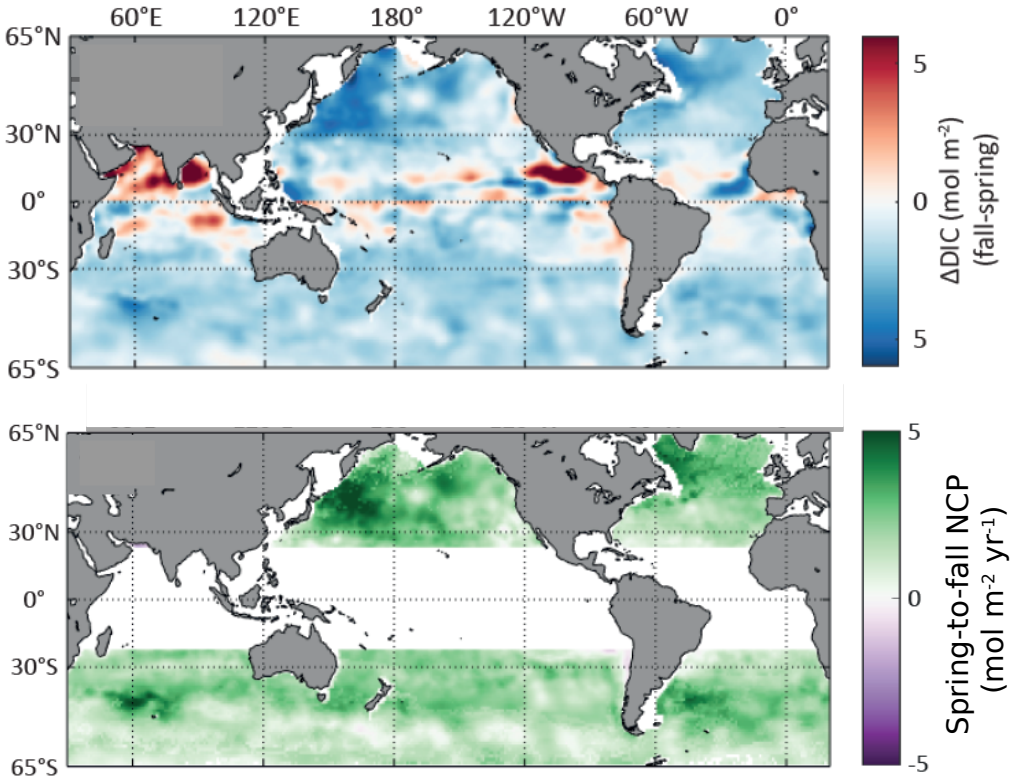
Seasonal cycle of surface DIC



- **Spring Maximum:** due to deep mixing throughout winter
- **Fall Minimum:** due to biological draw-down of carbon throughout summer

Adapted from [Keppler et al. (2020b)]

Spring-to-fall NCP



Adapted from [Keppler et al. (2020b)]

Spring-to-fall NCP based on:

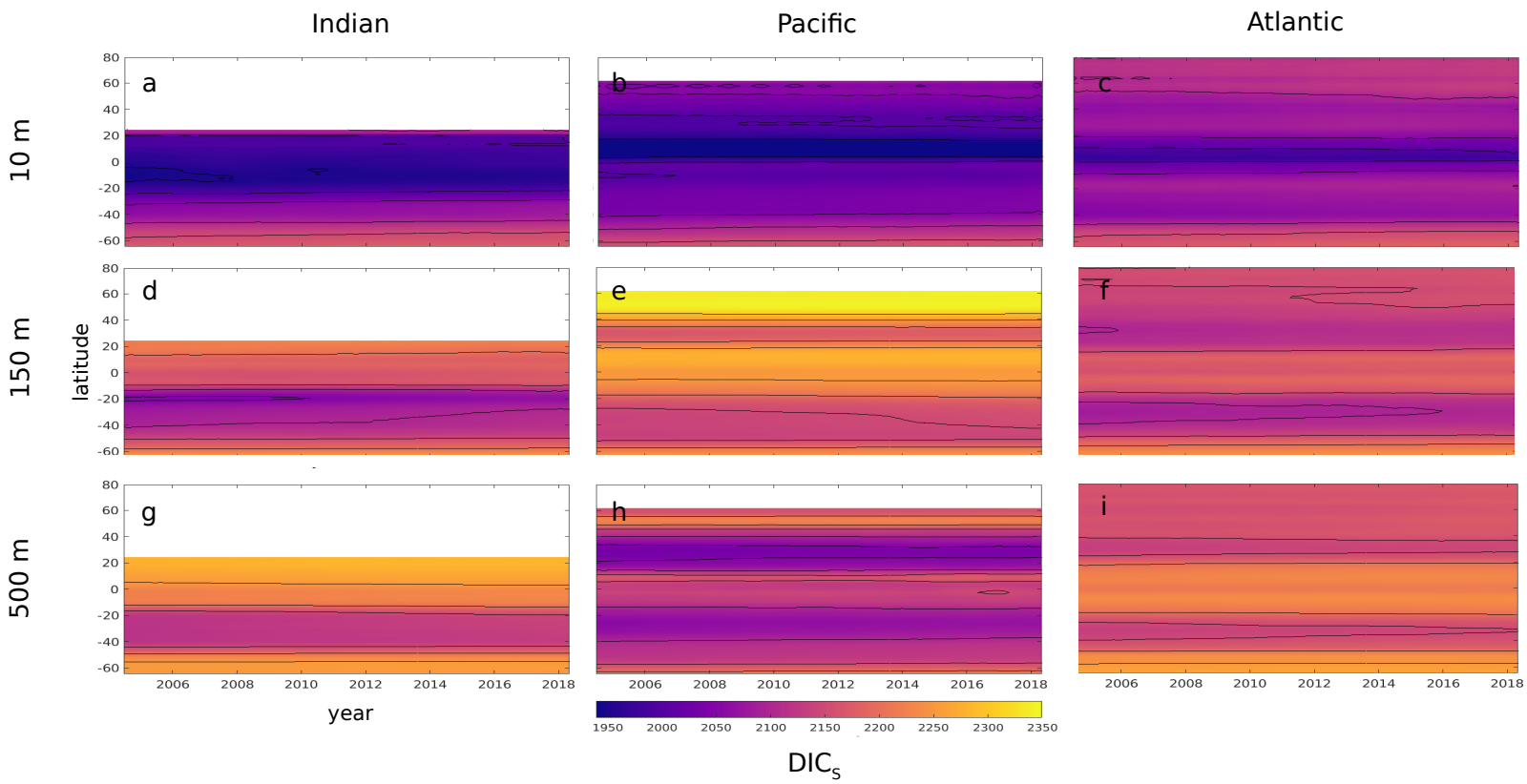
- ΔDIC
- Air-sea CO_2 flux
- Vertical diffusive flux
- Entrainment flux
- [neglecting horizontal transport]

Mean spring-to-fall NCP in the mid-latitudes: 1.9±1.3 mol m^{-2} yr^{-1}
i.e., 3.9±2.7 Pg C yr^{-1}

Upscaled globally:
8.2±5.2 Pg C yr^{-1}

Previous estimate by Lee et al. (2001):
6.7 or 8.0 ±2.7 Pg C yr^{-1}

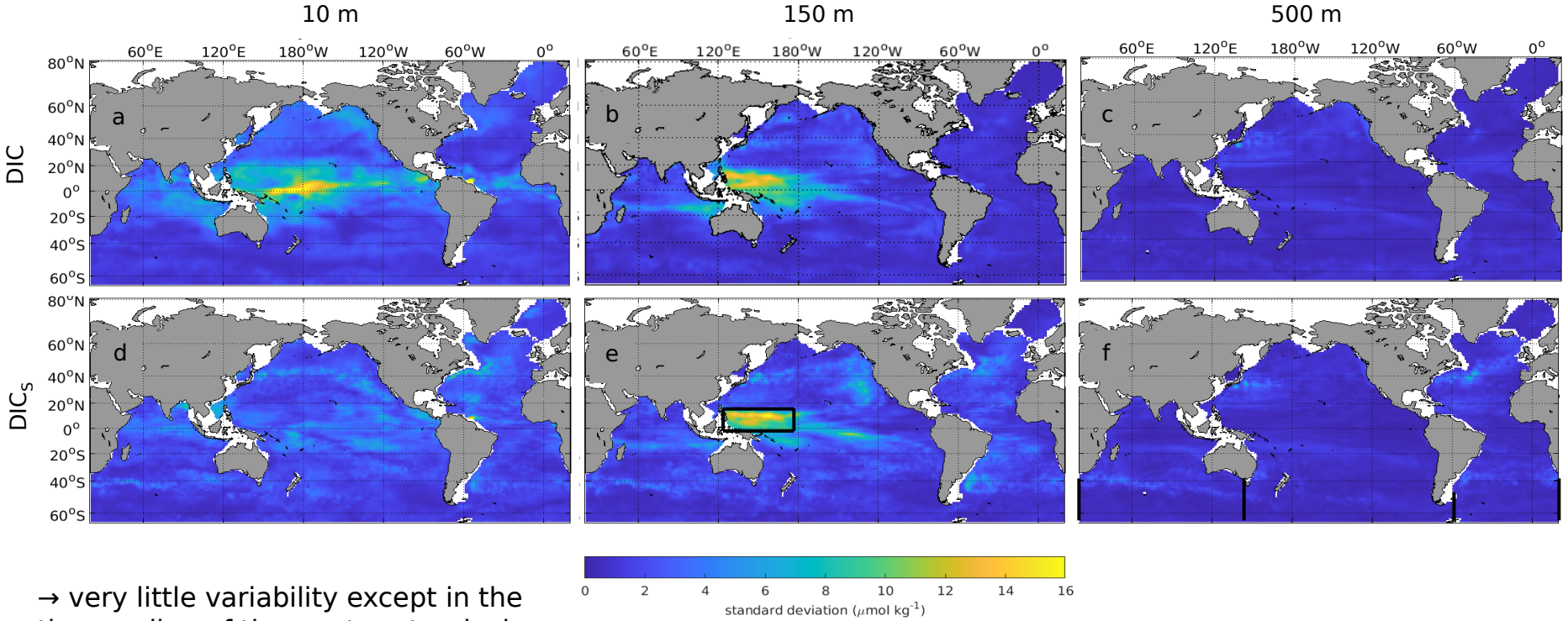
Interannual variability



Adapted from Keppler et al. (in prep.)

Interannual variability

Standard deviation in the time dimension of detrended, de-deasonalized DIC and DIC_S



→ very little variability except in the thermocline of the western tropical Pacific

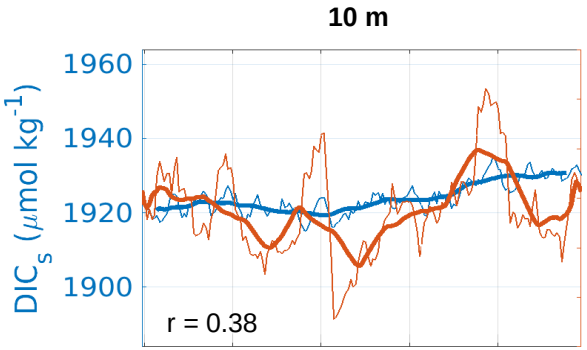
Adapted from Keppler et al. (in prep.)

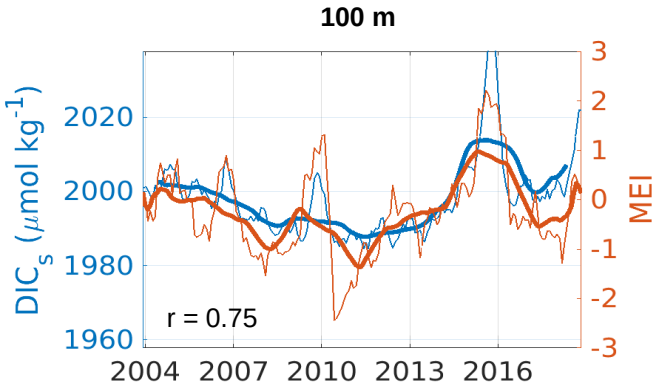
Link to the El Niño Southern Oscillation

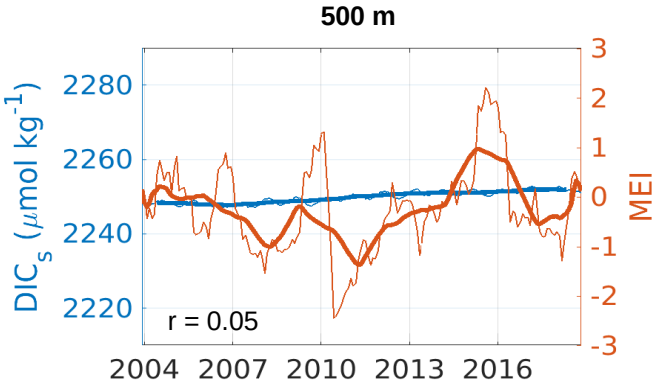
DIC_s in the western tropical Pacific and MEI

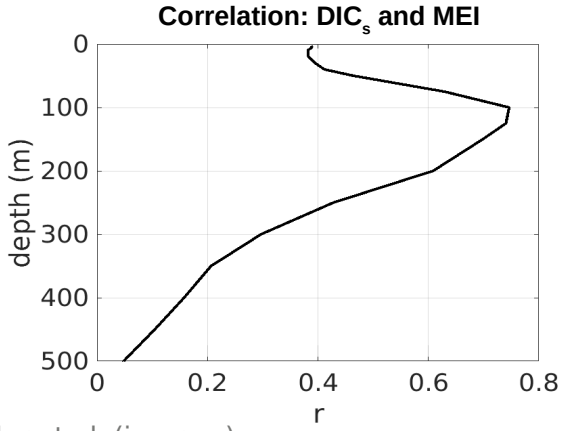
Smoothed with 12-month moving average

- DIC_s in the western tropical Pacific (black box in slide 10e) is highly correlated with the Multivariate El Niño Index (MEI)
- Mostly in the thermocline (50 to 250 m)
- Increase in DIC_s in the upper 1500 m due to change of 1 unit in MEI: (based on the slope of the regression):
  0.3 PgC (1.6 mol kg^{-1}) in the western tropical Pacific;
  1.2 PgC (9.6 mol kg^{-1}) globally









Adapted from Keppler et al. (in prep.)

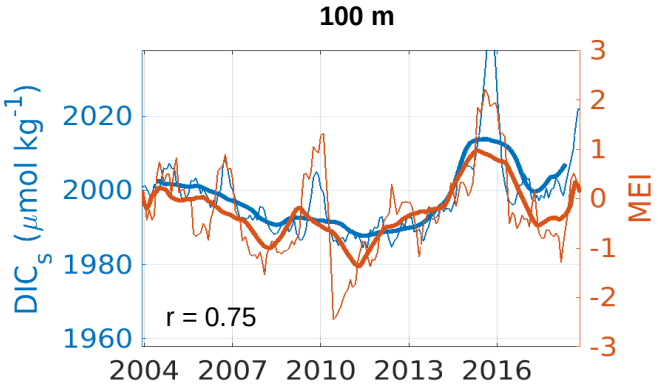
Link to the El Niño Southern Oscillation (cont.)

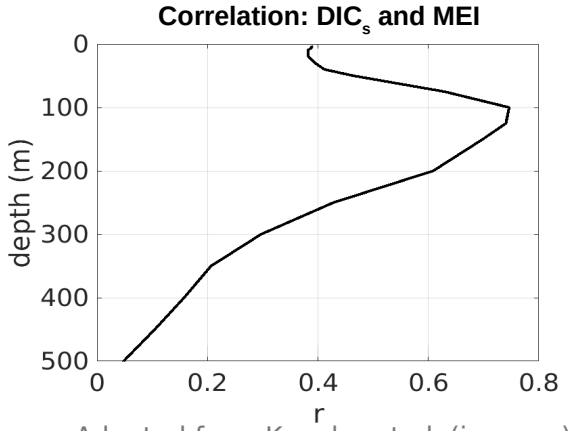
→ Mechanism:

- During El Niño years (+ MEI) the tradewinds weaken, the warm pool in the the western tropical Pacific moves east, SSTs increase, and the thermocline flattens (shallower in the west)
- **At the surface**, this results less carbon uptake (as CO_2 is less soluble in warmer waters), but the effect at the surface is buffered by mixing and biology
- **The shallower thermocline** in the weastern tropical Pacific results in more DIC in between 50 and 250m in this region (DIC stored at depth comes up)
- **In the deeper water**, the signal reduces due to mixing and transport

Why is there no signal in the Peruvian Coastal Upwelling System?

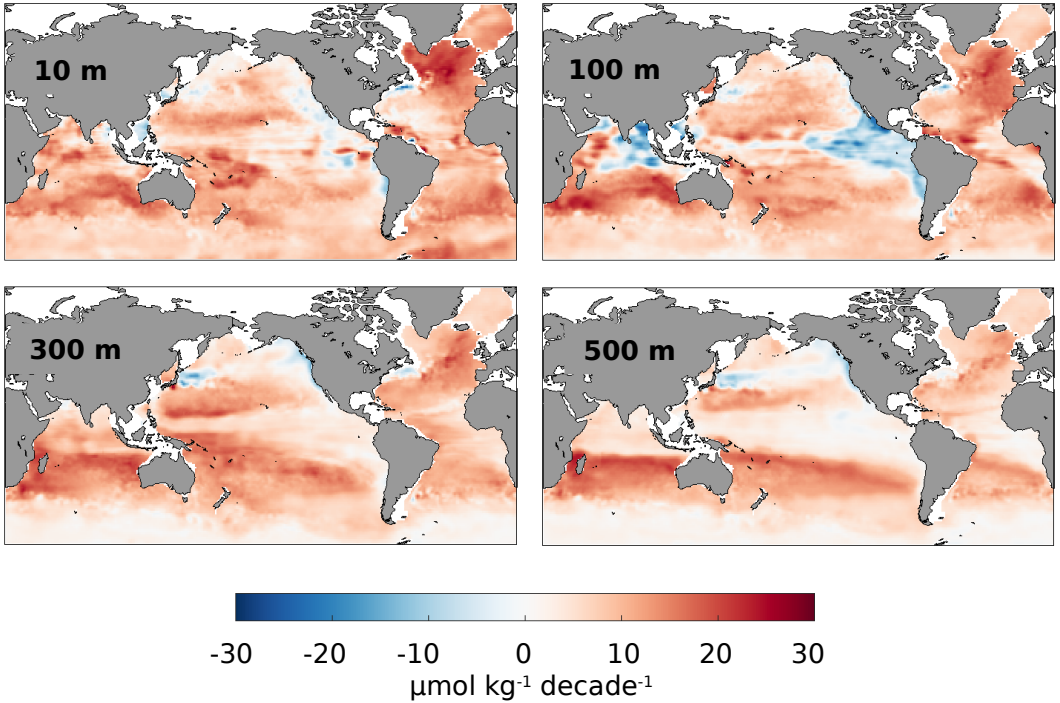
- Here, two processes compete and cancel out: less upwelling during El Niño leads to less DIC in the upper waters; concurrently, a deeper thermocline here results in more DIC in the upper waters;

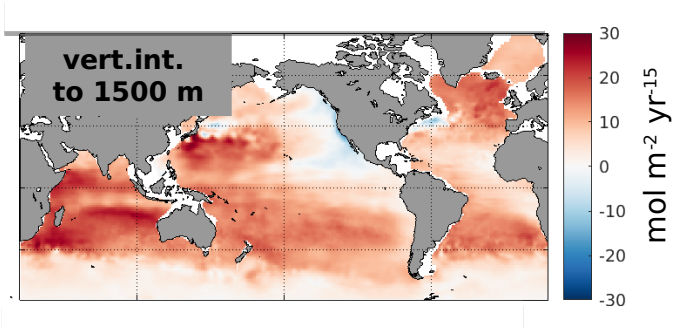




Adapted from Keppler et al. (in prep.)

Trend in DIC_s (2004 through 2018)





- Overall: increase of 25 Pg C decade^{-1} (+ deep + coastal)
- Compared to 26 Pg C decade^{-1} in C_{ant} from 1994 to 2007 (Gruber et al., 2019)
- Soon possible to compare total DIC and C_{ant} in the same time period and domain (Müller et al., in prep., see EGU21-10161)

Adapted from Keppler et al. (in prep.)

Summary

- **New paper out**: Seasonal Carbon Dynamics in the Near-Global Ocean (Keppler et al., 2020)
- **New data set**: Monthly climatology of Mapped Observation-Based Oceanic DIC (MOBO-DIC) → NCEI-OCADS
- **Seasonal surface DIC amplitudes** range from 0 to more than 50 µmol kg^{-1} (spring maximum, fall minimum)
- MOBO-DIC yields a **spring-to-fall NCP** in the euphotic zone of the mid-latitudes of 3.9±2.7 Pg C yr^{-1}
- **Interannual variability of interior DIC** mostly weak; exception: sub-surface tropical Pacific (link to ENSO)
- **Increase of total DIC_s** from 2004 through 2018 (upper 1500 m): 25 Pg C $decade^{-1}$