Estimating and predicting global ocean and terrestrial carbon uptakes in a decadal time scale

Michio Watanabe[1], Hiroaki Tatebe[1], Hiroshi Koyama[1], Takahito Kataoka[1], Tomohiro Hajima[1], Masahiro Watanabe[2], and Michio Kawamiya[1]
[1]Japan Agency for Marine-Earth Science and Technology (JAMSTEC), [2]The University of Tokyo
Email: michiow@jamstec.go.jp

In this study,

- The observed physical data were assimilated into an Earth system model.
- The assimilation runs show a higher correlation with the observations for air–sea CO_2 fluxes than the unassimilated historical runs.
- We conducted hindcast runs using initialized fields by data assimilation, and showed the effectiveness of initialization for decadal prediction of the carbon cycle.

Backgrounds

- Internal climate variability

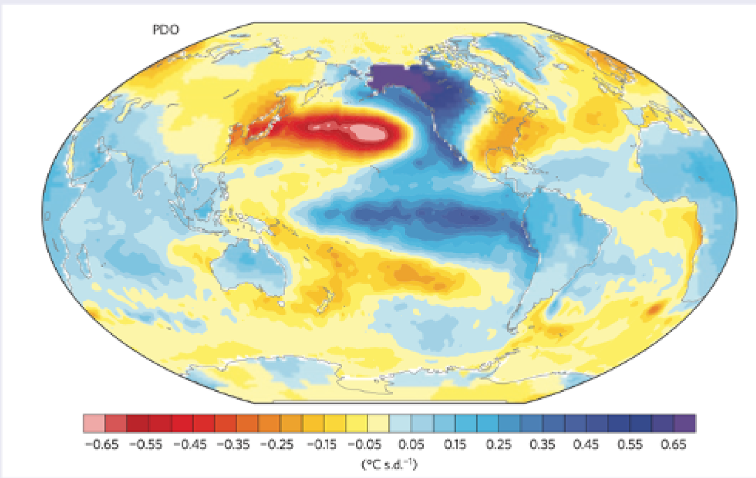


Figure: Variation patterns of sea surface temperature (SST) and land surface temperature (LST) associated with Interdecadal Pacific Oscillation (IPO). After Trenberth et al. (2014)

- There exists interannual-to-decadal timescale internal variabilities in Earth's climate
- e.g., Interdecadal Pacific Oscillation (IPO), El Niño/Southern Oscillation (ENSO)

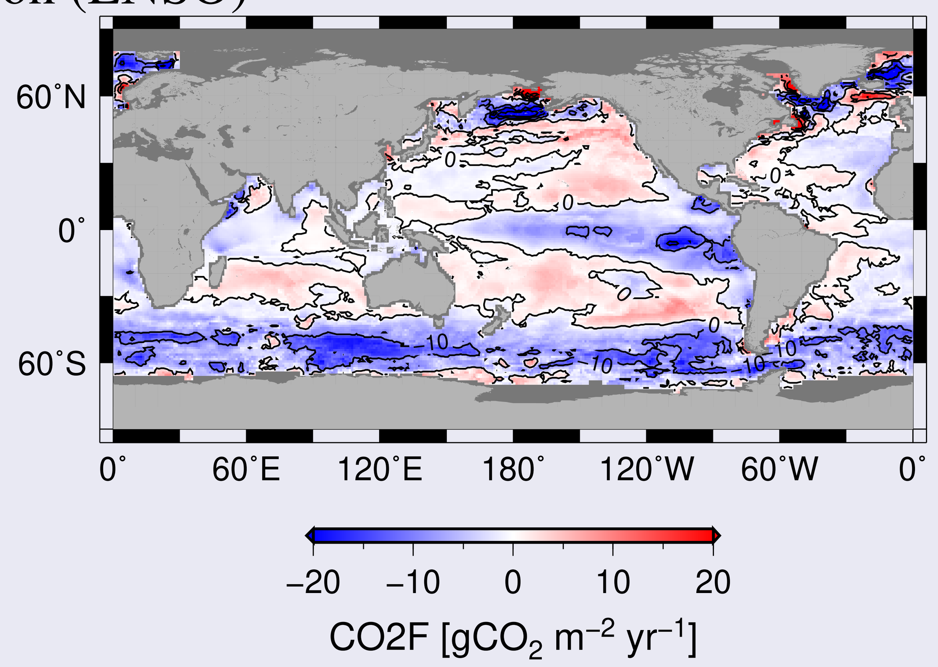


Figure: Variation pattern of air–sea CO_2 flux derived from observation-based dataset SOM-FFN by Landschützer et al. (2014). EOF second mode.

- Air–sea and air–land carbon flux is affected by multiple internal climate variabilities.
- In order to predict the carbon cycle on a scale of several years to a decade, the phase of internal climate variability in the model needs to be adjusted to reality (i.e., model initialization).
- The number of obs. on air–sea and air–land CO_2 fluxes are limited. Data assimilation may be a useful technique for estimating historical fluxes using models.

Methods

- Earth system model (ESM)

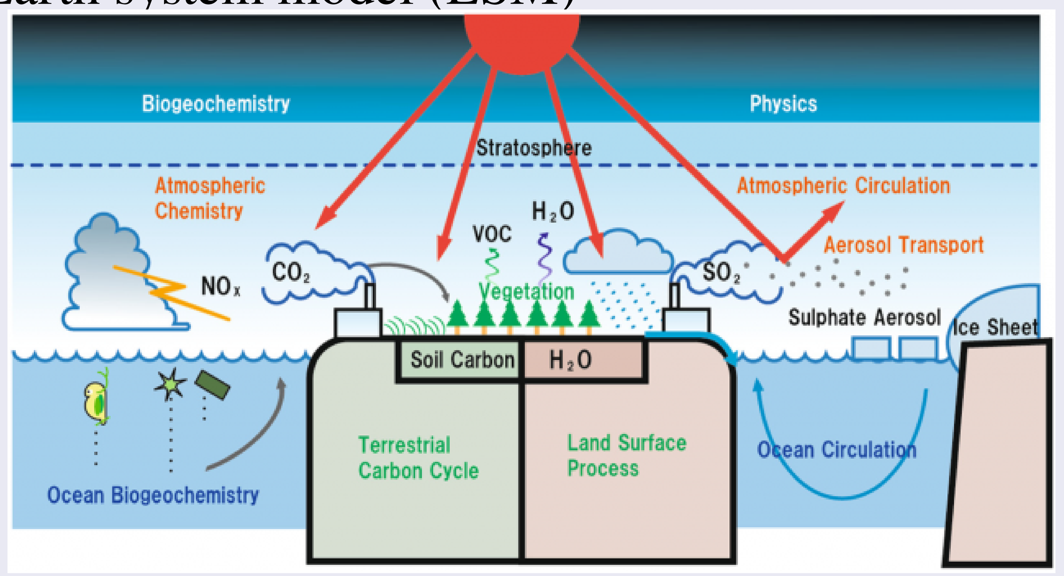
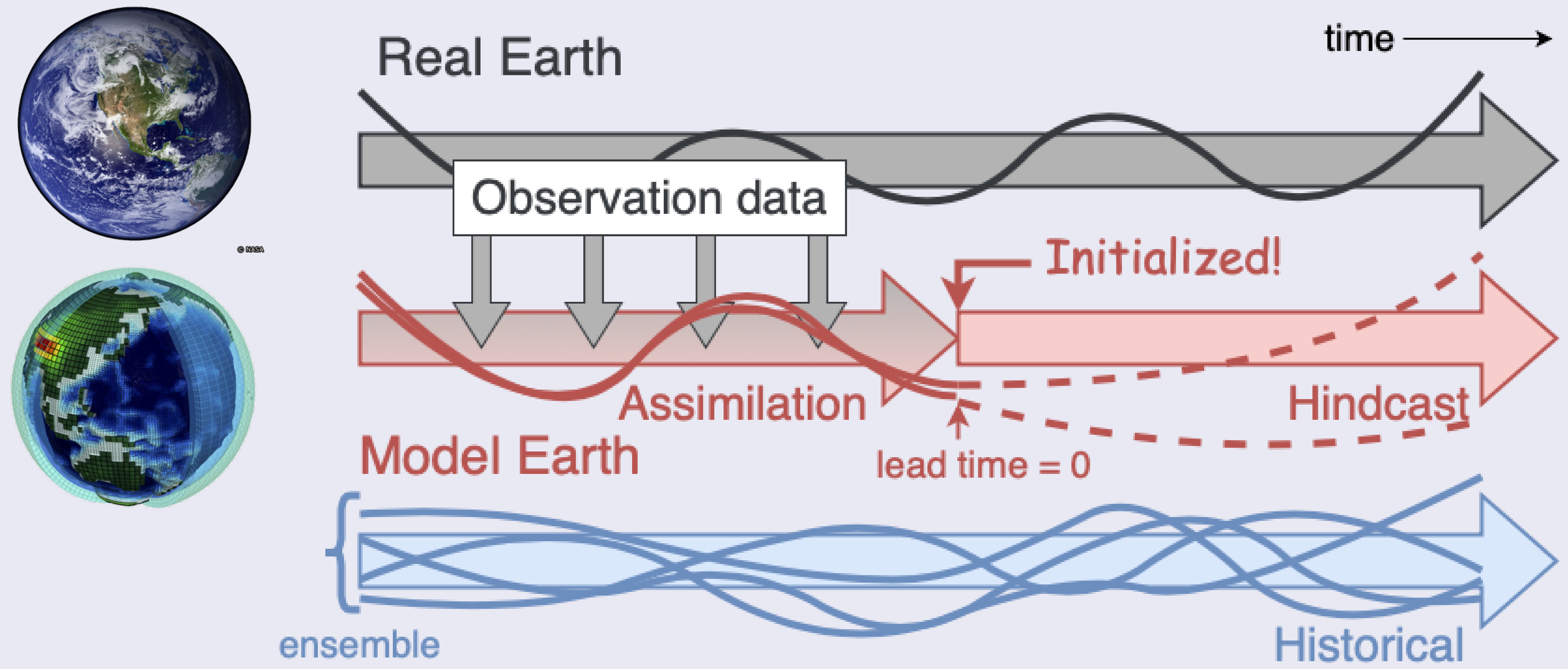


Figure: Components of MIROC-ES2L. After Hajima et al. (2014)

- MIROC-ES2L (Hajima et al., 2020)
- ESM developed for CMIP6 that can represent the carbon cycle.
- 10 ensemble members

- MIROC-ES2L with model initialization system (Watanabe et al., OS, 2020, doi:10.5194/os-16-1431-2020)



- Assimilation method: Incremental Analysis Update (Bloom et al., 1996)
- Ocean: monthly temperature & salinity (Ishii and Kimoto, 2009).
- Atmosphere: 6 hourly wind & temperature (JRA55, Kobayashi et al., 2015)
- For reference, we use
  - Observation based SOM-FFN (air–sea flux; Landschützer et al., 2014)
  - Global carbon budget (GCB) (air–land flux; Friedlingstein et al., 2019)

Results: Assimilation

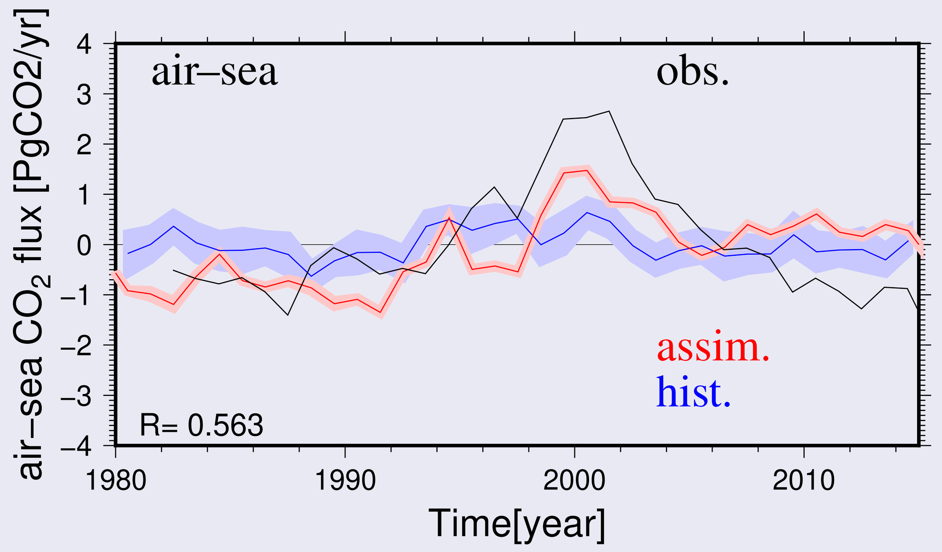


Figure: Globally integrated air–sea CO_2 flux. Data are detrended and upward positive. Shading represents ensemble spread (1 s.d.).

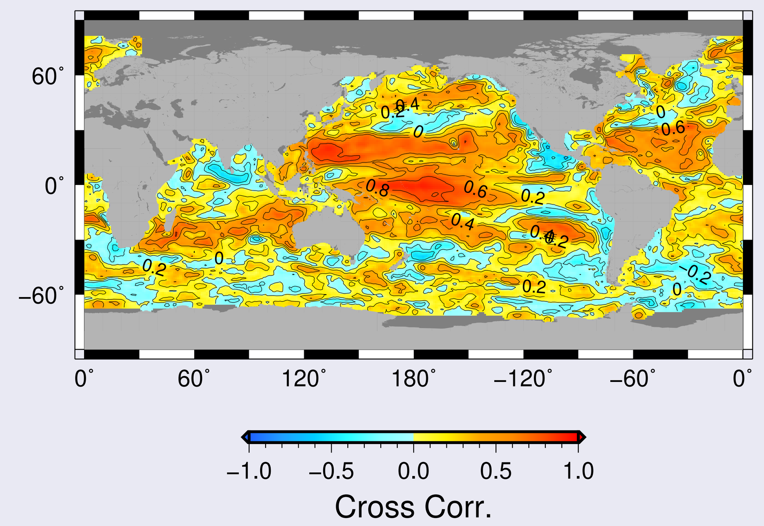


Figure: Correlation map of air–sea CO_2 flux between the observation and the assimilation run.

Results: Assimilation (*continued*)

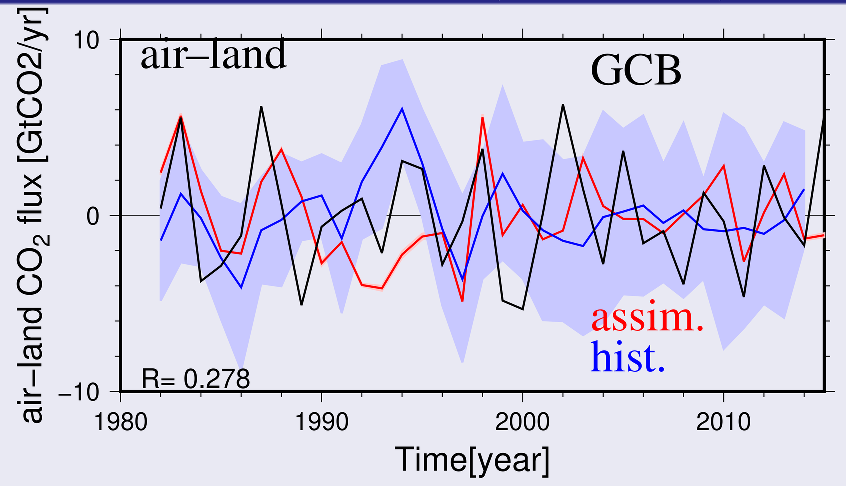


Figure: Globally integrated air–land CO_2 flux. Data are detrended and upward positive.

- The assimilation run shows the higher correlation in air–sea flux than the historical run. (2nd column)
- High correlation in low and mid latitudes. (2nd column)
- Correlation of air–land flux is relatively small. Further model development is needed.

Results: Hindcast

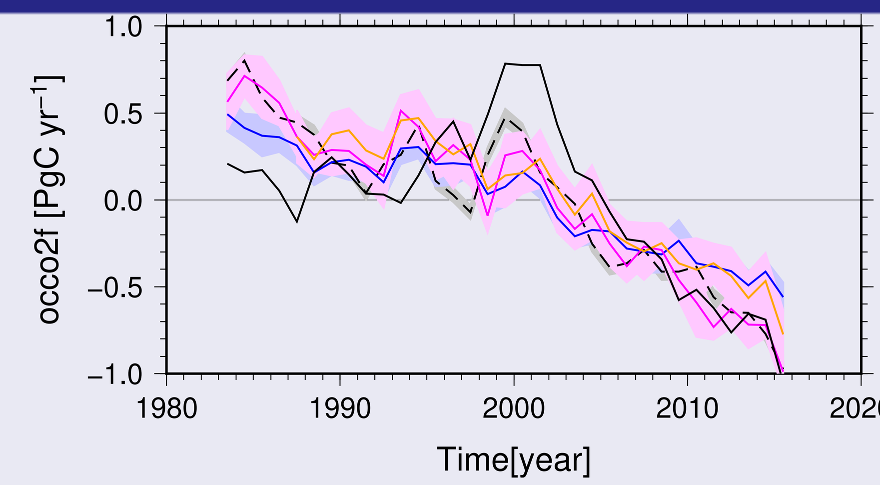


Figure: Globally integrated air–sea CO_2 flux. Upward positive and not-detrended.

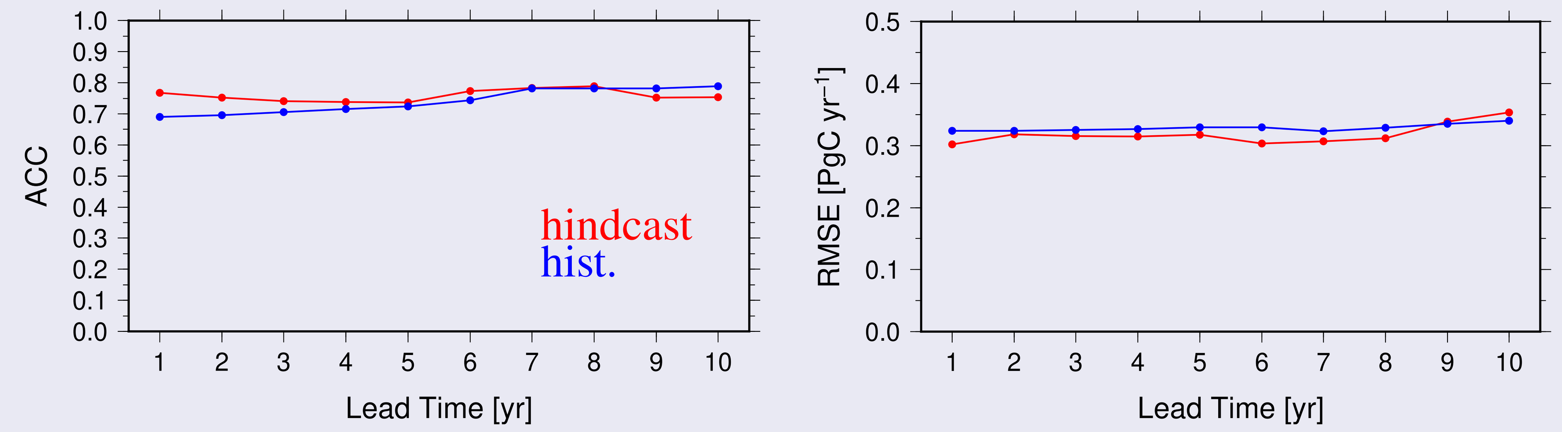


Figure: (left) Correlation and (right) error of air–sea flux to obs. as a function of lead time.

- Higher correlation and lower error for lead time of 1–6 yrs
- This indicates the effectiveness of initialization.

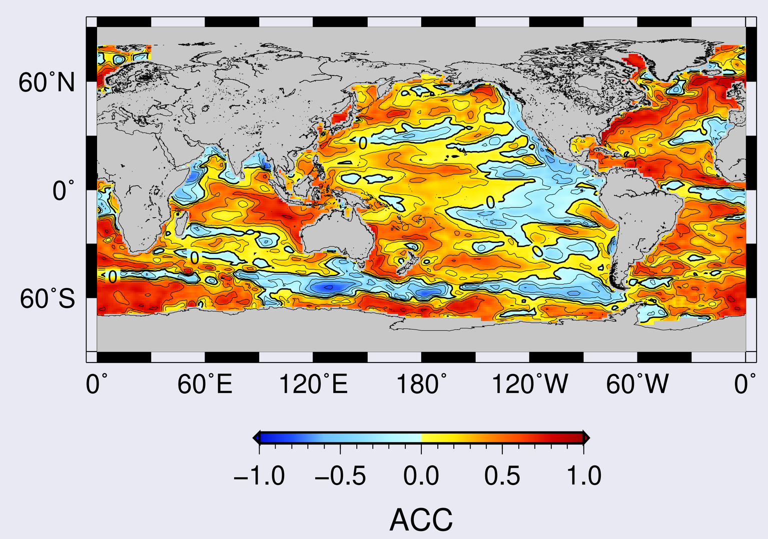


Figure: Correlation map of air–sea CO_2 flux between hindcast (l.t. 2yrs) and obs.

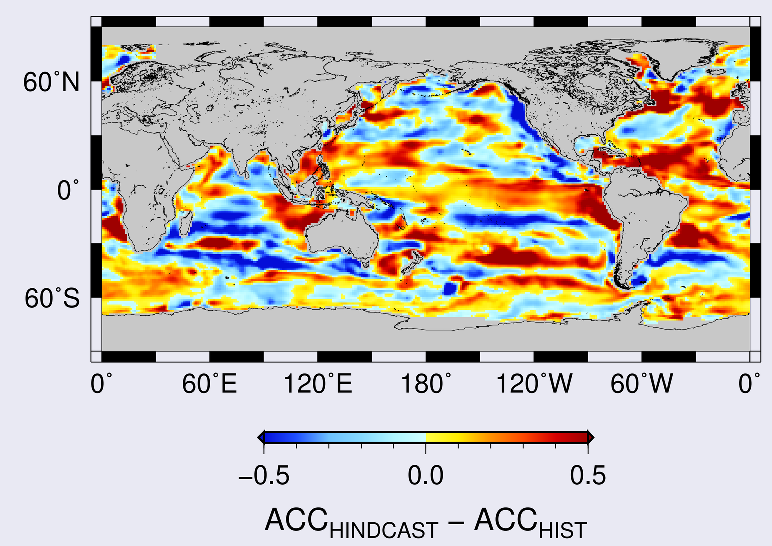


Figure: Difference in correlation coefficient between hindcast (l.t. 2yrs) vs obs. and historical vs obs.

- The effect of initialization is seen on a global scale. (red color in right fig.)
- Especially noticeable in the equatorial Pacific.
- For model comparison, see Ilyina et al. including Mi. Watanabe (GRL, 2020, doi:10.1029/2020GL090695)