Utilization of earth observation data for furthering Earth System Models' validation and sophistication in Japan's climate model development project, TOUGOU

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Aim and Scope: The emission mitigation target and success of the ambitious Paris Agreement rely, to some extent, on our ability to derive climate responses to the changes in ambient CO_2 concentration, resulting from the projected changes in anthropogenic and natural fluxes. The complex earth system models (ESMs) are being developed to predict the natural capacity of the land and ocean to uptake CO_2 from atmosphere and maintain carbon storage in their ecosystems. In addition, one of the new challenges in developing next generation ESMs is to explicitly simulate the non-CO_2 GHGs cycles. The top-down (inversion) estimation of sources and sinks are expected to support the evaluation of historical simulations and refine carbon-nitrogen-phosphorus cycles of ecosystem functioning in the ESMs.

Data and Methods:

- We used in situ CO_2 data from NOAA/GMD, www.esrl.noaa.gov/gmd/ccgg; and remote sensing XCO_2 data from GOSAT_v2.81_GUsub, https://data2.gosat.nies.go.jp, and OCO-2_v9r, https://co2.jpl.nasa.gov/download/?dataset=OCO2LtCO2v9&product=LITE).
- Inverse model MIROC4-ACTM estimated CO_2 fluxes for 84 regions of the globe using in situ observations from 36 remote marine sites, located sparsely.
- Earth system model MIROC-ES2L simulates CO_2 flux components from land biosphere, land-use change and oceanic exchange.
- We attempt validation of MIROC-ES2L and MIROC4_Inv fluxes using dry-air total column mole fraction (XCO_2) observations from GOSAT and OCO-2 which offer global coverage, albeit at lower precisions than the in situ observations.

3. Results and discussion:

Overview of the CO_2 fluxes in the recent decades:

Figure 1 shows rapid increase of CO_2 emissions due to fossil fuel consumption, and which is offset up to 50% by the increased uptakes by the terrestrial and oceanic ecosystems in varied amount in different latitude bands.

Figure 2 shows stronger CO_2 flux seasonality by the Inversion compared to that simulated by the ESM, particularly over the northern mid-latitudes.

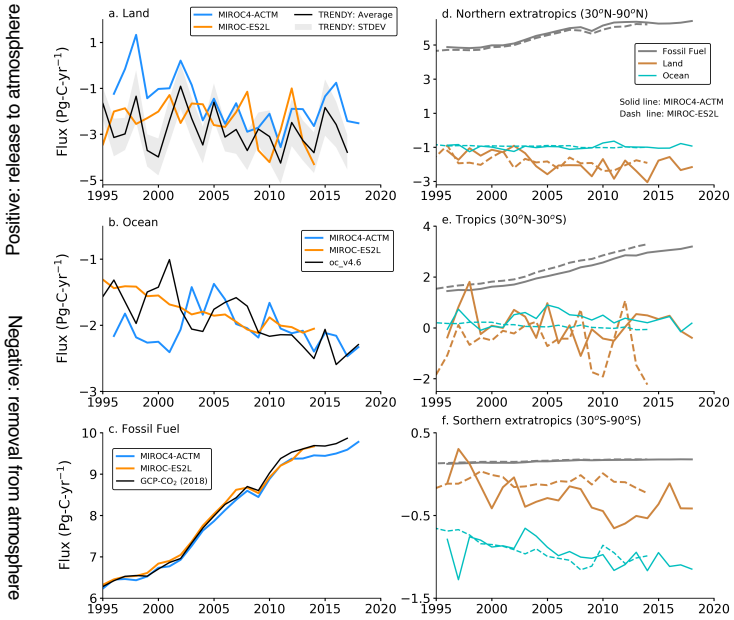

Figure 1: Time series of global (left column) and hemispheric (right column) total CO_2 fluxes for land and ocean as estimated by the MIROC4-ACTM inversion and MIROC-ES2L simulation along with the fossil fuel emissions from independent data sources. The global total results are compared to TRENDY land ecosystem model mean and spread, an ocean flux data product (MPI-BGC, JENA), and GCP-CO_2 (2018) anthropogenic emissions.

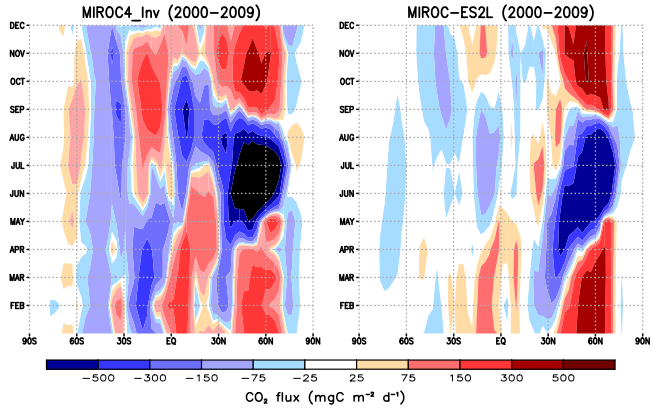

Figure 2: Zonal mean meridional and seasonal variations in CO_2 fluxes as estimated by MIROC4_Inv and simulated by MIROC-ES2L

Evaluation of the XCO_2 simulations by MIROC-ES2L and MIROC4-ACTM:

Figure 3 seasonal variations and annual increase in atmospheric CO_2 (total column) due to the residual anthropogenic CO_2 emissions as measured by the remote sensing instruments GOSAT and OCO-2

The region-aggregated time series comparisons (*Figure 4*) helps identify the regions that require more attention for future developments of the ESMs (e.g., inclusion of more processes) and Inversions (e.g., increase of in situ network).

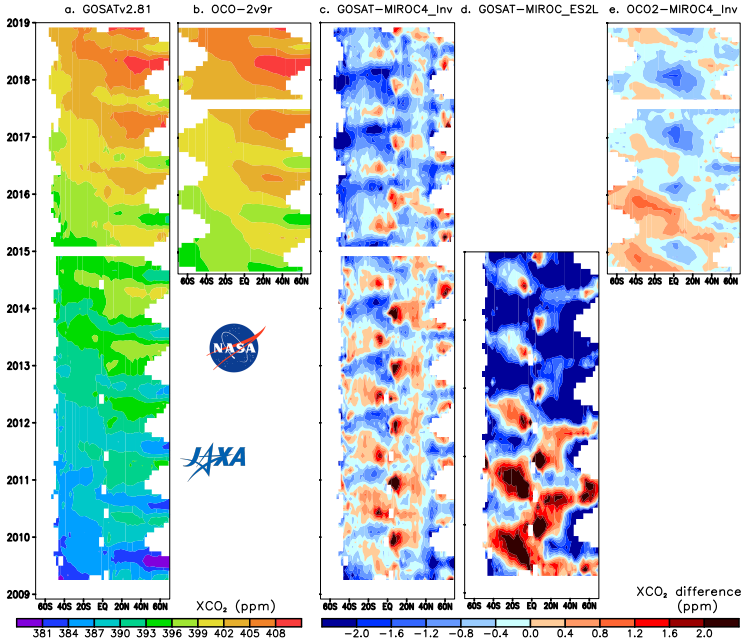

Figure 2: Time evolution of zonal mean meridional gradients of XCO_2 as measured by GOSAT, OCO-2 in comparison with two MIROC simulations.

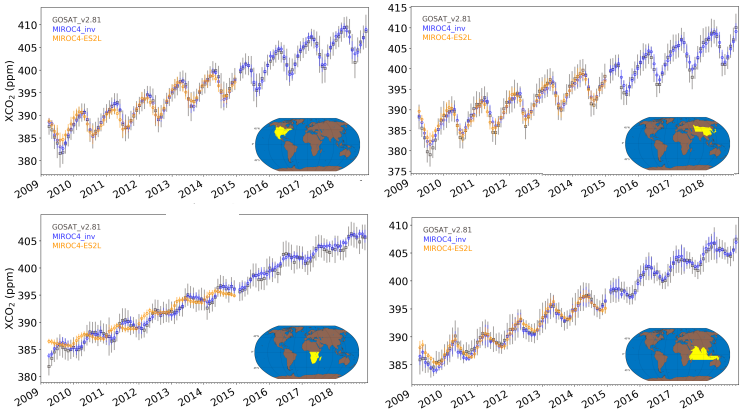

Figure 4: Time series XCO_2 for various parts of the world. Values are aggregated over the regions highlighted by yellow. These show the importance of greater observational data coverage, for conducting better inversion of regional CO_2 sources and sinks, e.g., the mismatch between the seasonal cycle phase and amplitude over Southern Africa is more evident than Temperature North America (tropical land regions are particularly data void).

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