Impact of climate variability on methane emission trends in monsoon Asia

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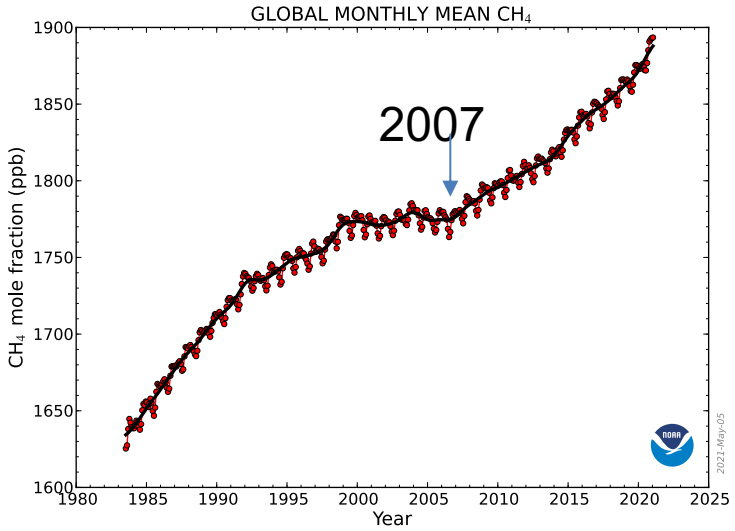
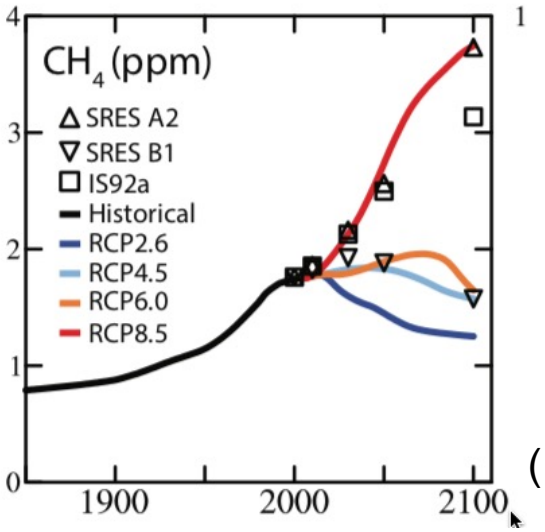
NIES SOC 衛星観測センター Satellite Observation Center

Background Atmospheric methane concentrations increase

- Methane has a 28-fold greater global warming potential than CO_2 over 100 years.
- Currently, the level of methane in the atmosphere is over 150% higher than pre-industrial times (cf. 1750), and it contributes more than 20% of the global warming produced by all greenhouse gases.
- Methane has a relative shorter lifetime (~10 years), higher global warming potential than CO_2 (~100 years), that makes it a good choice for mitigation.
- Rapid CH_4 concentration growth was observed since 2007.



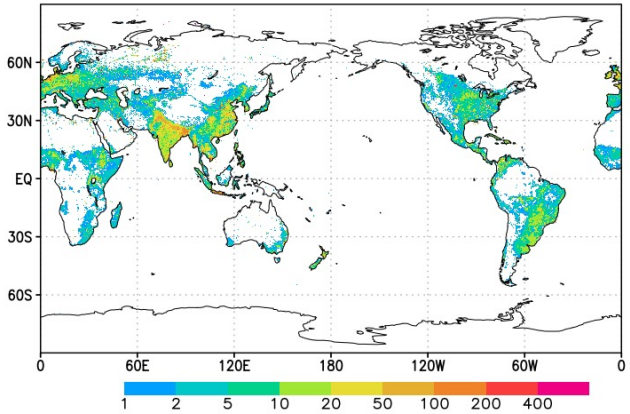
(*Ed Dlugokencky, NOAA/GML (gml.noaa.gov/ccgg/trends_ch4/)*)



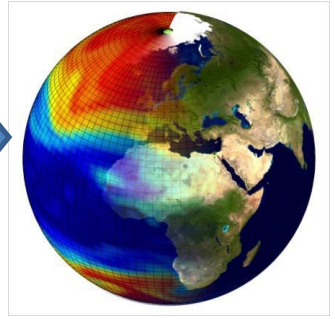
(IPCC., *2018*)

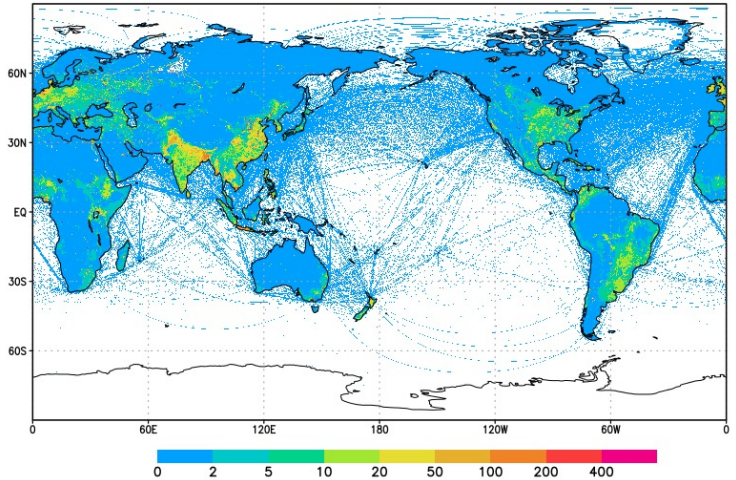
More accurate quantification of the national emission budgets is the core to global stocktake and to evaluate the implementation of the Paris Agreement.

Approaches for quantifying methane emission



Atmospheric modeling



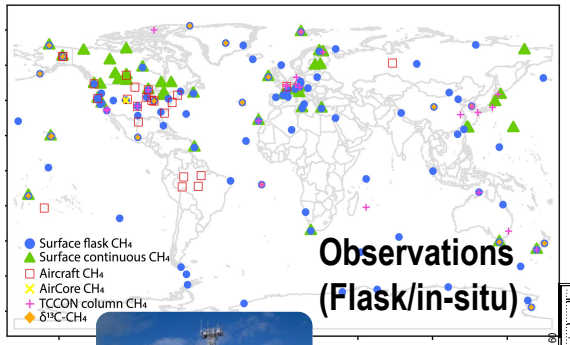


Bottom-up (BU)

Top-down (TD)

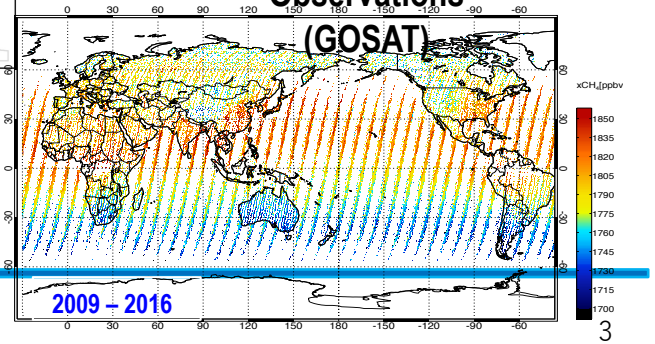
Emission inventories: Agriculture and waste related emissions, fossil fuel emissions (EDGAR4.3.2,BP, GAINS, CEDS, USEPA, FAO).Fire emissions (GFED4s, GFAS,QFED,FINN, FAO). Biofuel estimates

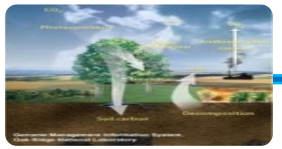
Biogeochemistry models & data-driven methods: Ensemble of 12 Wetland models. Model for Termites emissions. Other sources from literature



Observations (Flask/in-situ)

Observations (GOSAT)





Methods Inverse model setup

NTFVAR, coupled Eulerian-Lagrangian transport model (NIES-TM resolution 2.5° × 2.5° + FLEXPART model resolution 0.1° × 0.1°) (Maksyutov et al., *Atmos. Chem. Phys.*, 2021)

- Prior fluxes, sinks:

1) Anthropogenic emissions (EDGAR v5).
2) Biospheric emissions (VISIT)
3) Biomass burning (GFASv1.2) (daily)
4) Termites, ocean, geological as in Transcom-CH_4
5) 3D monthly OH, O1D, Cl as in Transcom-CH_4

- Prior uncertainty:

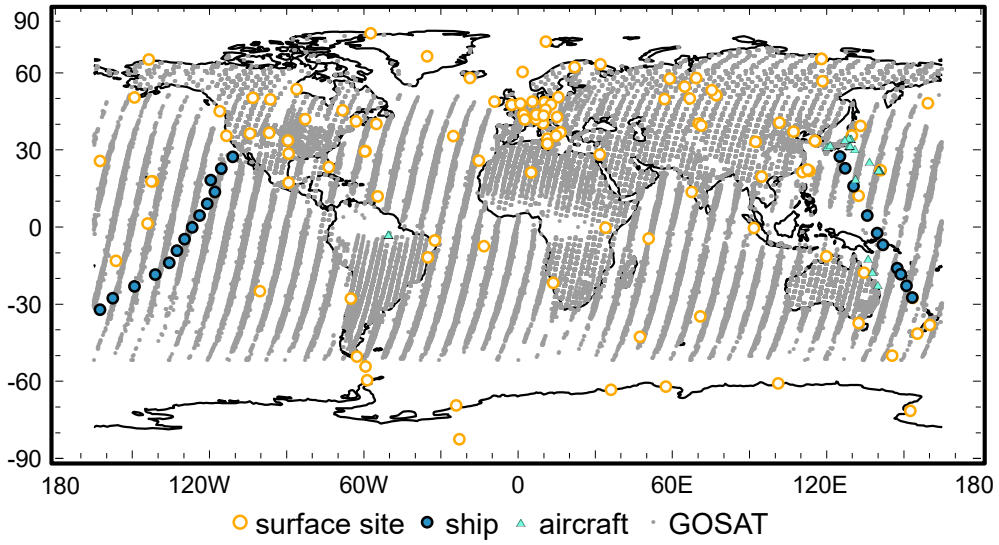
anthropogenic: monthly EDGAR (multiplied by 0.3)

natural: VISIT wetland emissions (multiplied by 0.5)

- Inversion period: 2009 – 2018

- Observations:

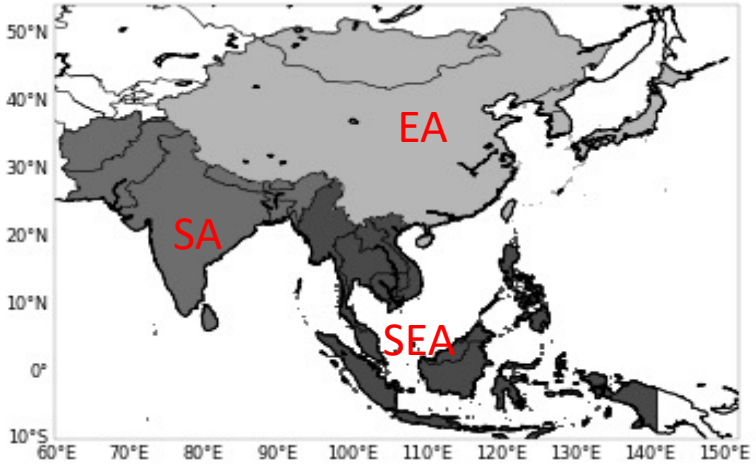
1) GOSAT GOSAT retrievals (NIES, Level 2 retrievals, v. 02.72)
2) Ground CH_4 observations from WDGCC, surface sites, aircraft and ship observations.

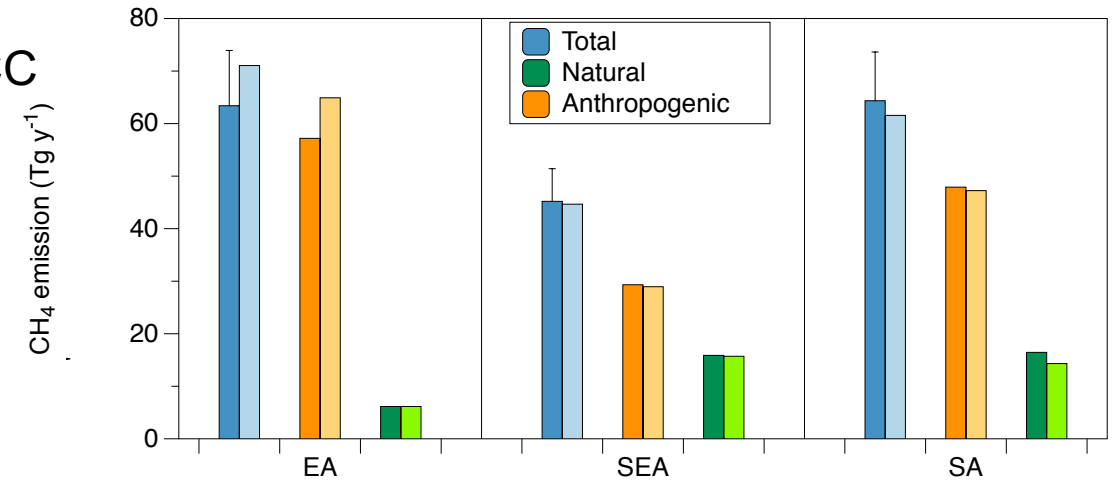


(Wang et al., *Environ. Res. Lett., 2021*)

Results Inversion optimized CH_4 emissions

- Large CH_4 emissions in East Asia (EA), South Asia (SA) and South-eastern Asia (SEA)
- Total CH_4 emission 172 (with an uncertainty of 25) (Tg yr^{-1})
  ~30% of global total 560 (Tg y^{-1})
- Less than ten countries report inventories to UNFCCC
  Science supports for national reporting and Independent Global Stocktake

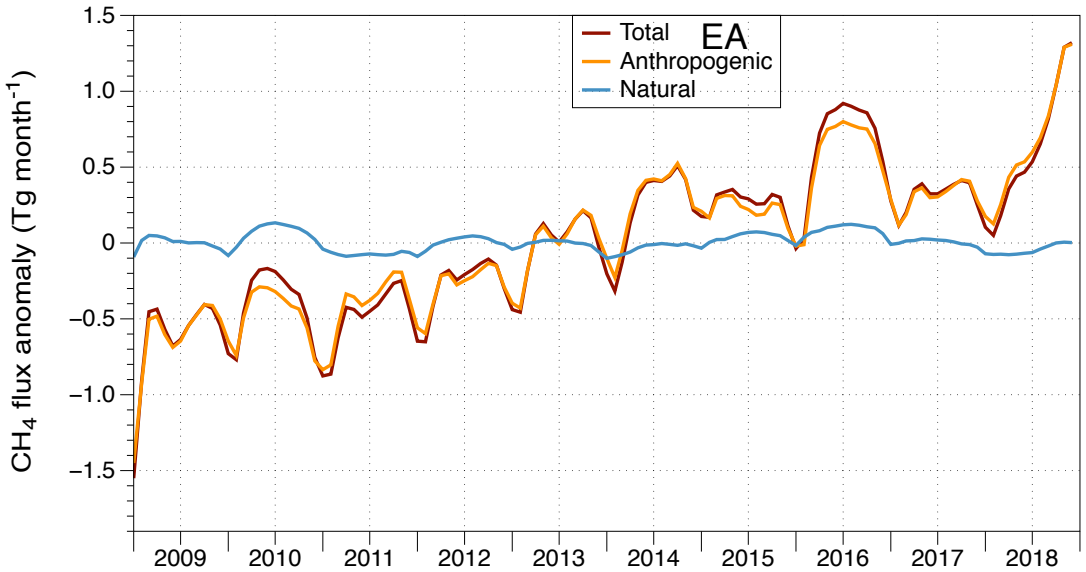


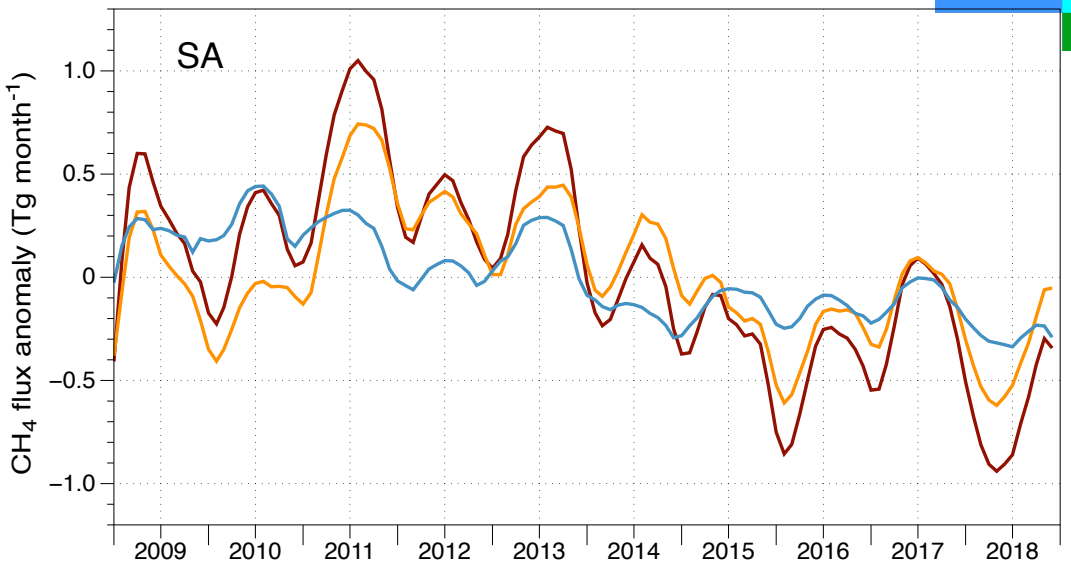


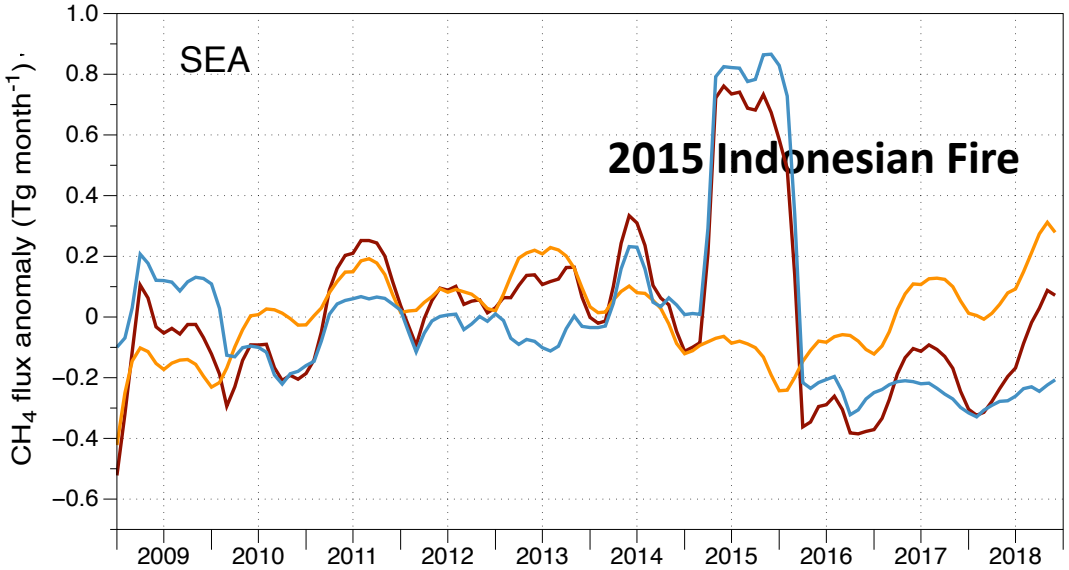
- The average (2009-2018) optimized annual total CH_4 emissions
- Anthropogenic emissions >78% in the study area, 90% in EA, 65% in SEA, and 74% in SA

Anomalies in subregions

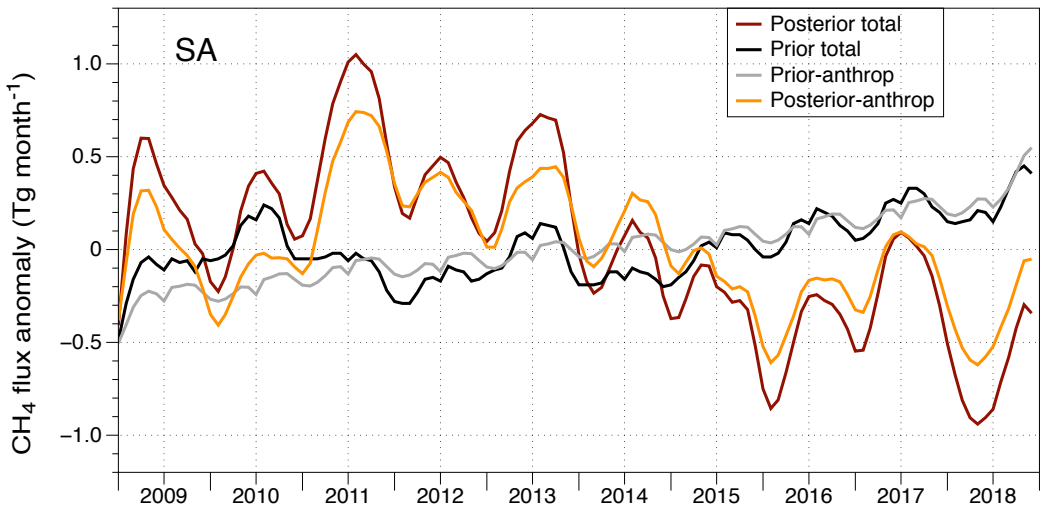
- Statistically significant increasing trend in EA anthropogenic emissions in 2009-2018 is detected.
- Statistically significant decreasing trends in SA anthropogenic and natural emissions in 2009-2018 are detected.

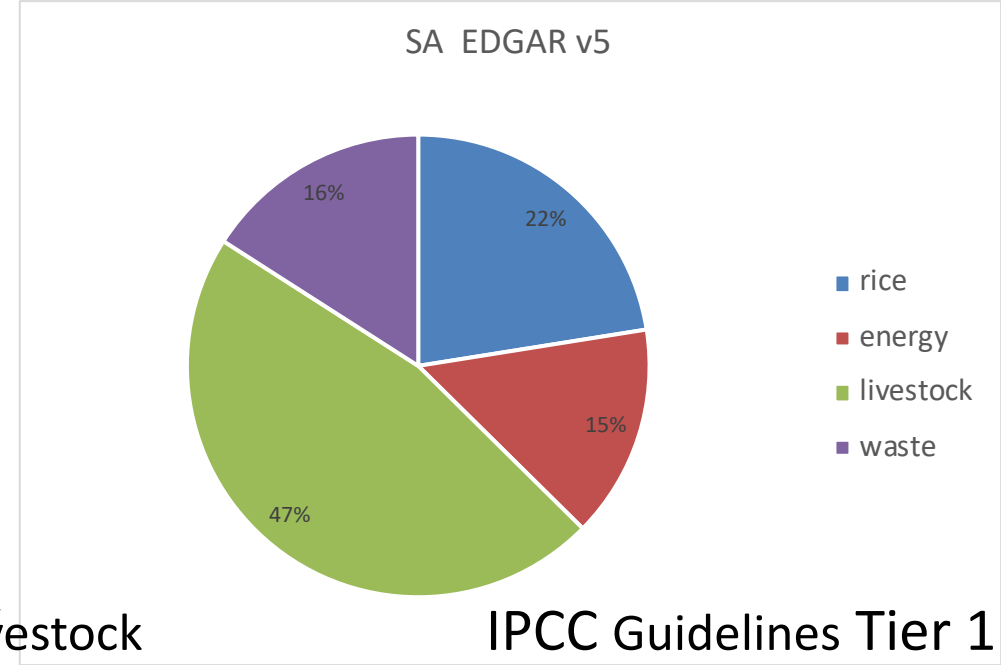






Emission changes in SA





- statistically significant increasing trends in prior total and anthropogenic emissions
- statistically significant decreasing trends in posterior total and anthropogenic emissions

Some impacting factors beyond the calculation of emission inventory

livestock IPCC Guidelines Tier 1 Tier 2

Emission Factor (kg/head/yr) • Population (head) / (10^6 kg/Gg) = Emissions Gg/yr.

Rice activity data, process-based model

$$F_T = \Sigma_i \Sigma_j \Sigma_k E_{ijk} \bullet A_{ijk} \quad (1)$$

Where:

E_{ijk}: the methane flux measured under a specific set of different biological, chemical and physical factors (i,j,k) that control methane emission and

A_{ijk}: the corresponding areal extent.

Waste first order decay

EQUATION 1

Methane emissions (Gg/yr) = (MSW_T • MSW_F • MCF • DOC • DOC_F • F • 16/12-R) • (1-OX)

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Global impacts of El nino-Southern oscillation 137 years (1880–2016)

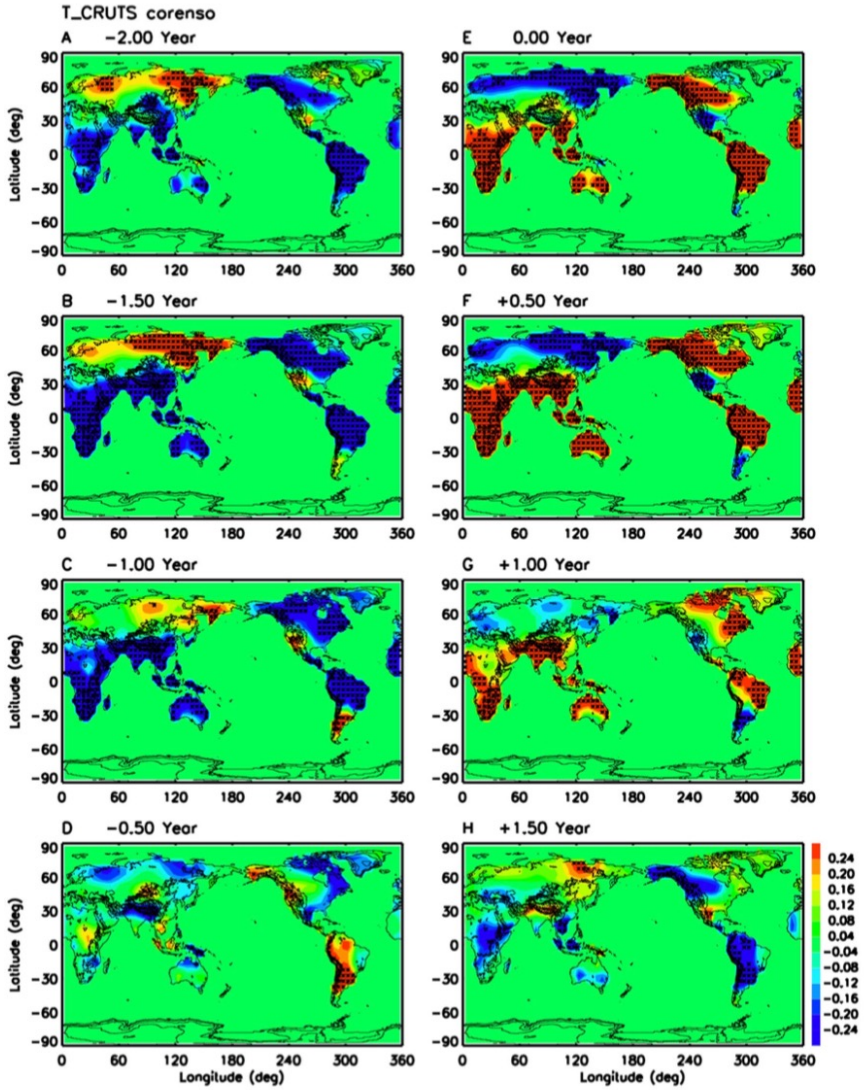


Figure 2. Same as Fig. 1 but for CRUTS land surface air temperature for 1901–2014.

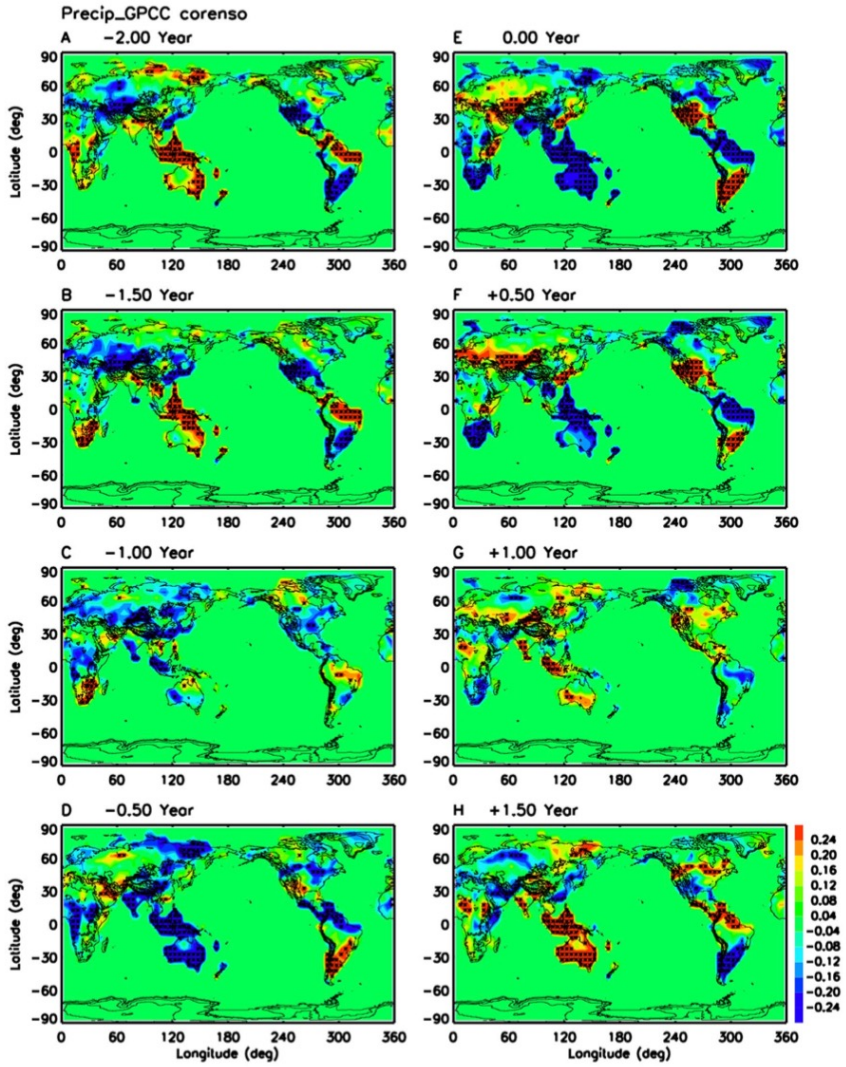
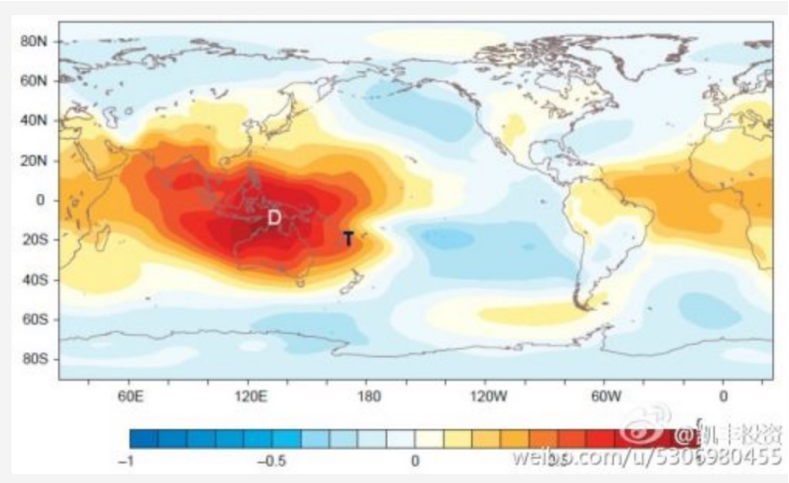


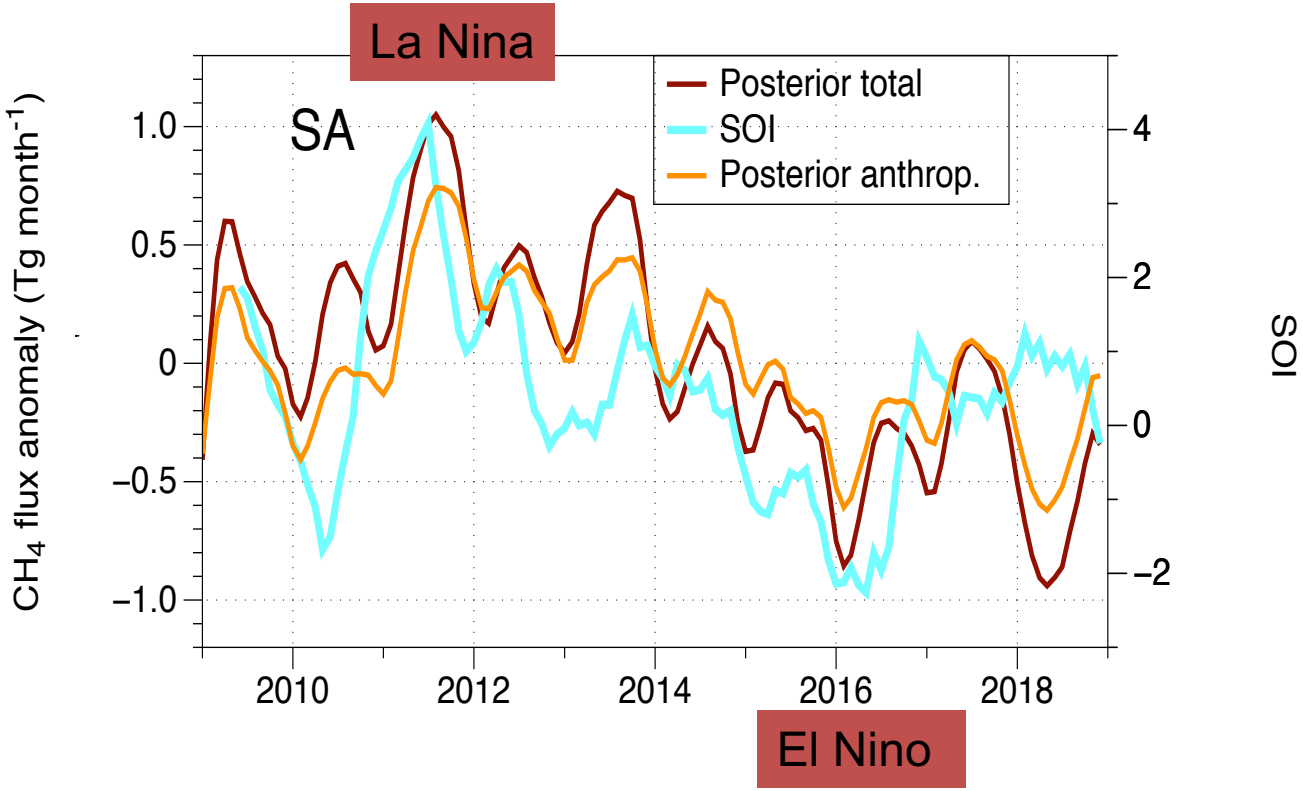
Figure 3. Same as Fig. 1 but for GPCC land surface precipitation for 1901–2013.

(Lin et al., *scientific reports*, 2019)

Connections between CH_4 fluxes and SOI

The Southern Oscillation Index (SOI) is a standardized index based on the observed sea level pressure differences between Tahiti and Darwin. Prolonged periods of negative (positive) SOI values coincide with abnormally warm (cold) ocean waters across the eastern tropical Pacific typical of El Nino (La Nina) episodes.





(Wang et al., *Environ. Res. Lett., 2021*)

Summary

- Our high-resolution (0.1°× 0.1°) inverse model has the capacity to evulate regional GHGs emissions.
- Interannual variations in CH_4 fluxes in monsoon Asia are influenced by ENSO climate variations.
- The interannual variability in CH_4 flux anomalies is larger in SA compared to EA and SEA. The Southern Oscillation Index (SOI) correlates strongly with interannual CH_4 flux anomalies for SA.
- In contrast to the prior emission, the posterior emission shows a significant decreasing trend in SA. The flux decrease is associated with the transition from strong La Nina (2010–2011) to strong El Nino (2015–2016) events, its accompanying effect of the Asian monsoon system, which drives the patterns of temperature and rainfall.
- The contribution of climate variability driving interannual variability in natural and anthropogenic CH_4 emissions should be further quantified, especially for tropical countries.
- More impact factors should be taken into account for global stocktake, better interperating CH_4 budgets change rate from the five-yearly stocktake and evaluating mitigation strategies.

Thank you