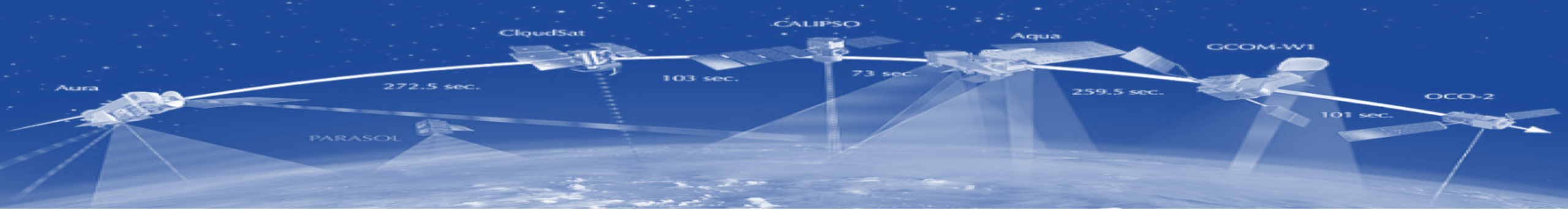

Attribution of the surge of global methane in 2020 using inverse analysis of GOSAT observations

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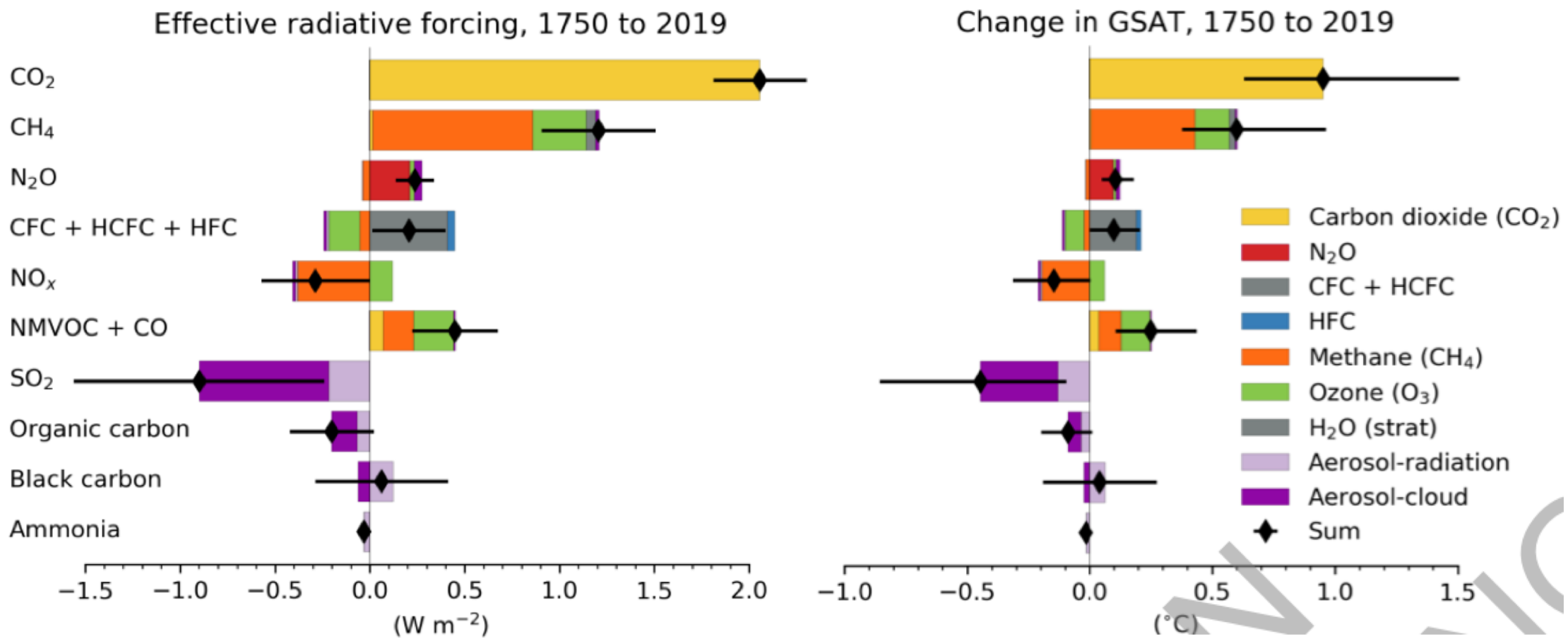
Climate impacts of CH_4



CH_4 contributed to a 1.2 W m^{-2} radiative forcing and 0.6°C increase of global mean surface air temperature.

Methane mitigation has the greatest potential to slow warming over the next 20 years.

(*IPCC AR6*, 2021)

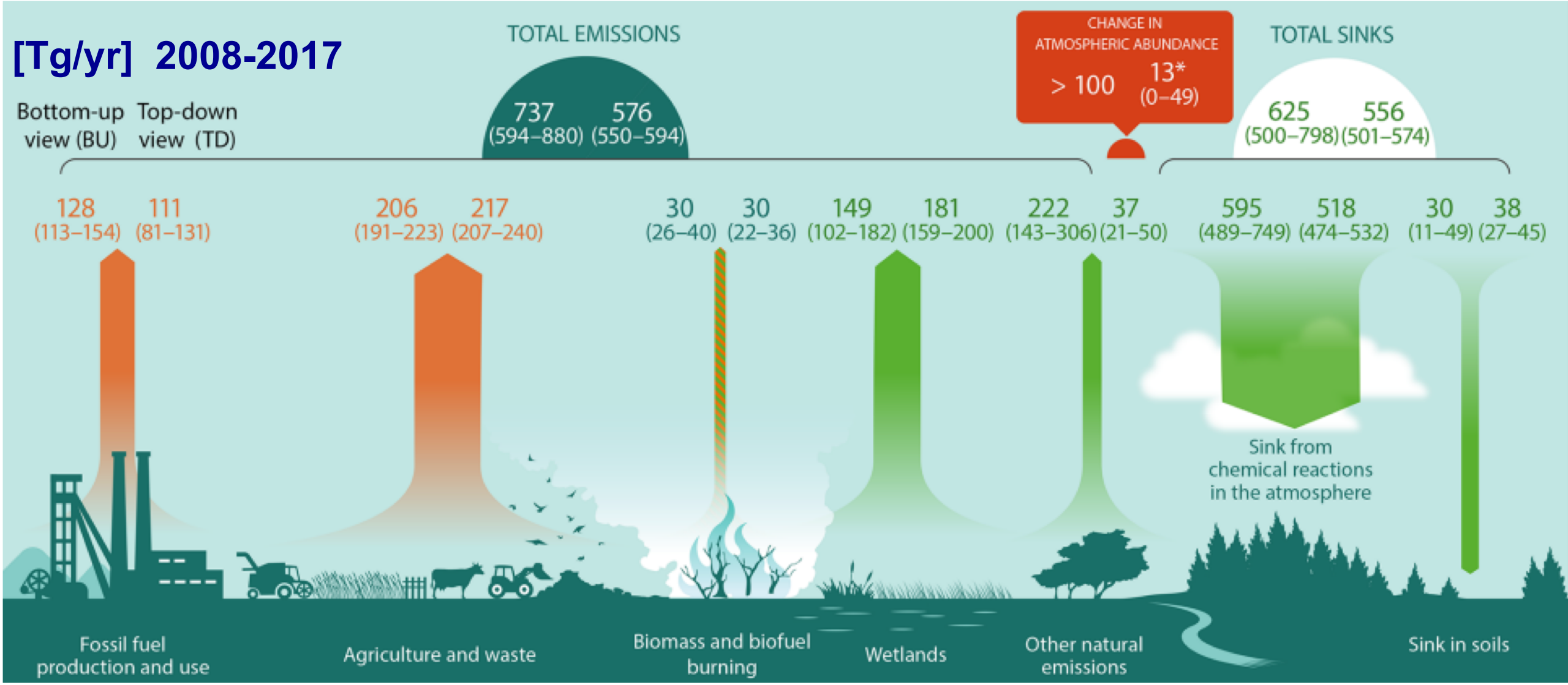
US and EU announce global pledge to slash methane

(Picture from USA Today)

The Global Methane Pledge was formally launched on Nov 2.

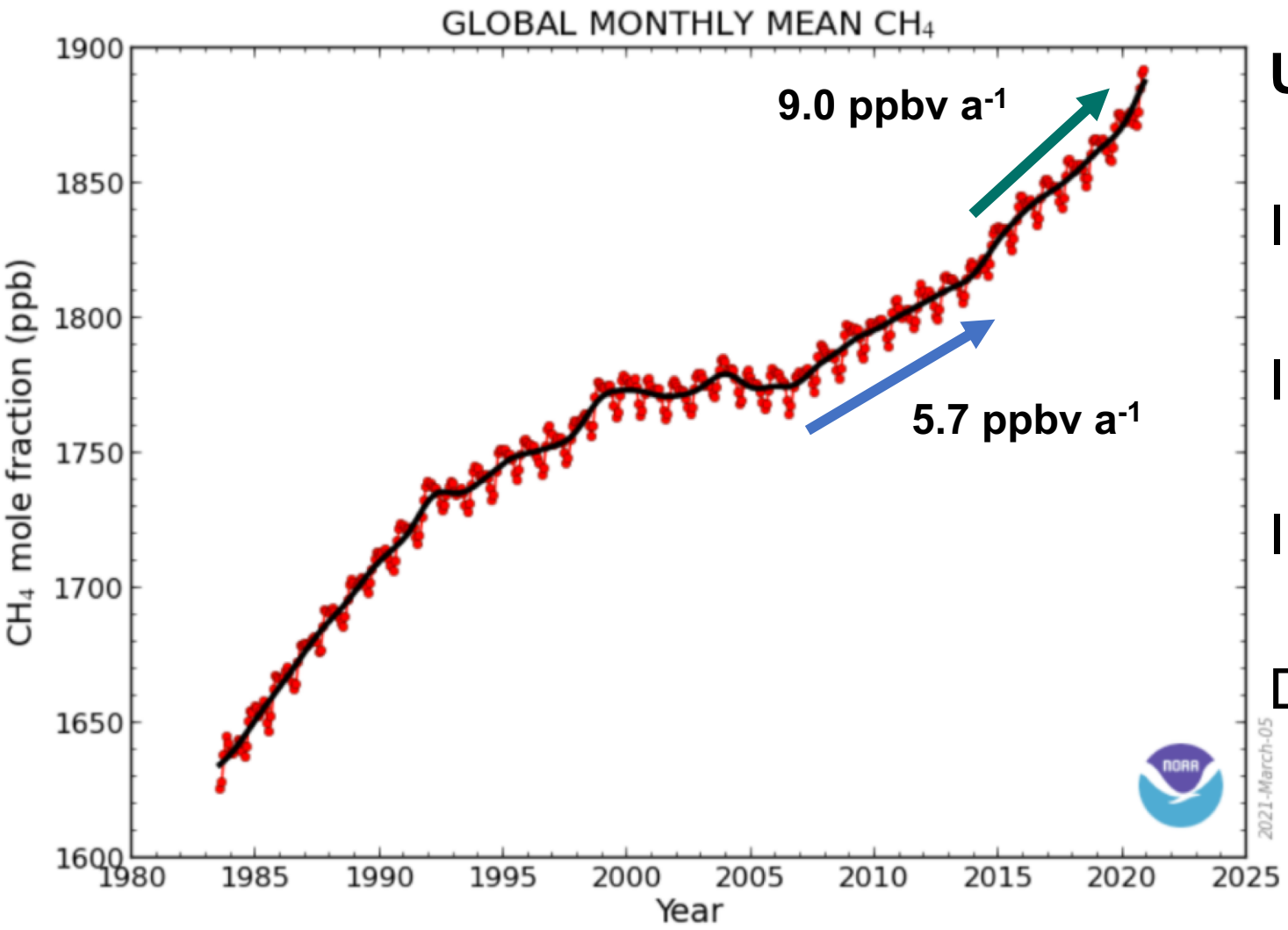
More than 100 countries agree to cut methane emissions by 30% (0.2°C) by 2030

Global burden is balanced by the sources and sinks



(*Saunois et al.*, 2020)

Surge of CH_4 in 2020



Unknown causes

Increasing biogenic emissions

(*Schaefer et al.*, 2016)

Increasing fossil fuel emissions

(*Hausmann*, 2016; *Helmig et al.*, 2016)

Increasing wetlands & livestock

(*Maasakkers et al.*, 2019)

Decreasing sink via OH

(*Turner et al.*, 2017; *Rigby et al.*, 2017)

Record high annual increase of 14.7 ppbv in 2020.

Surge of CH_4 in 2020

The New York Times

Global Methane Emissions Reach a Record High

Scientists expect emissions, driven by fossil fuels and agriculture, to continue rising rapidly.

BBC NEWS

Climate change: Greenhouse gas build-up reached new high in 2020

The Guardian

Methane rises to highest level on record

Livestock farming and fossil fuels are main causes of rise in gas, which is 28 times more powerful than CO2 at trapping heat

THE HILL

CO2, methane emissions surged 2020 despite pandemic: NOAA

Decreasing NO_x could decrease OH and the methane sink

Sources

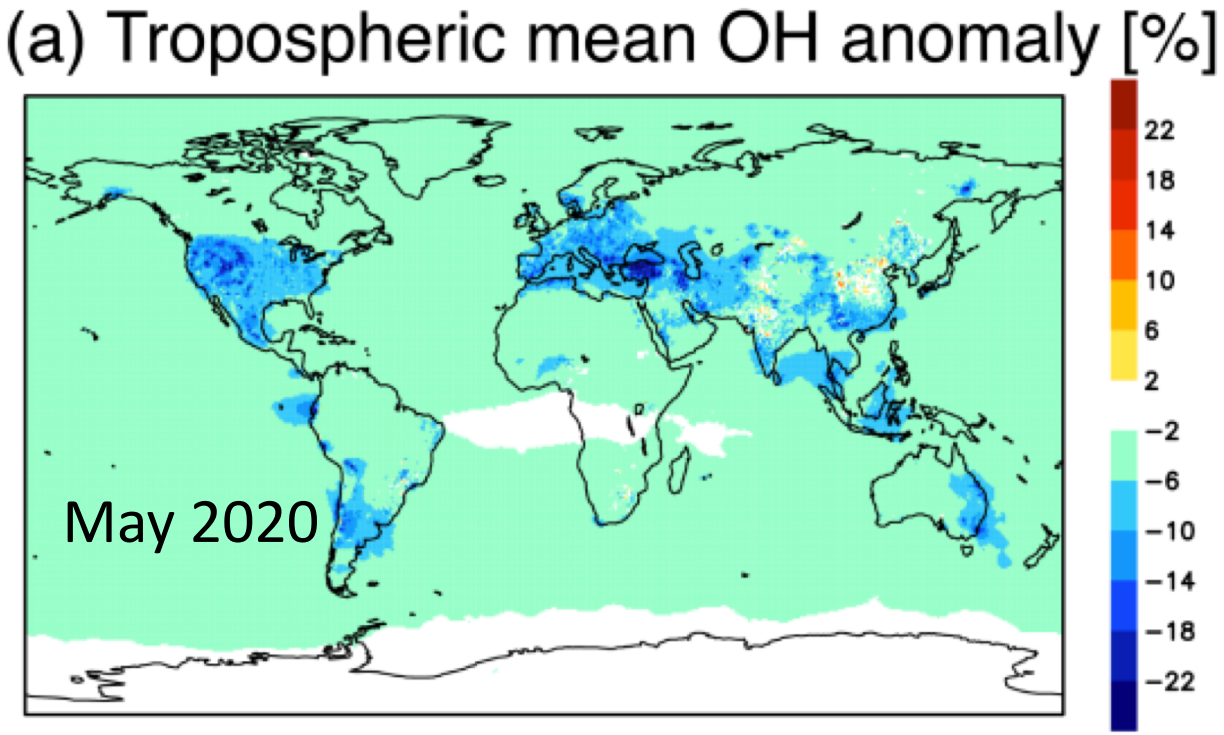
CH_4 from oil and gas declined during COVID-19 in the US Permian Basin.

(*Lyon et al.*, 2021)

Reduced maintenance in landfills and oil and gas infrastructure can lead to new leaks.

(*Laughner et al.*, 2021)

Sinks

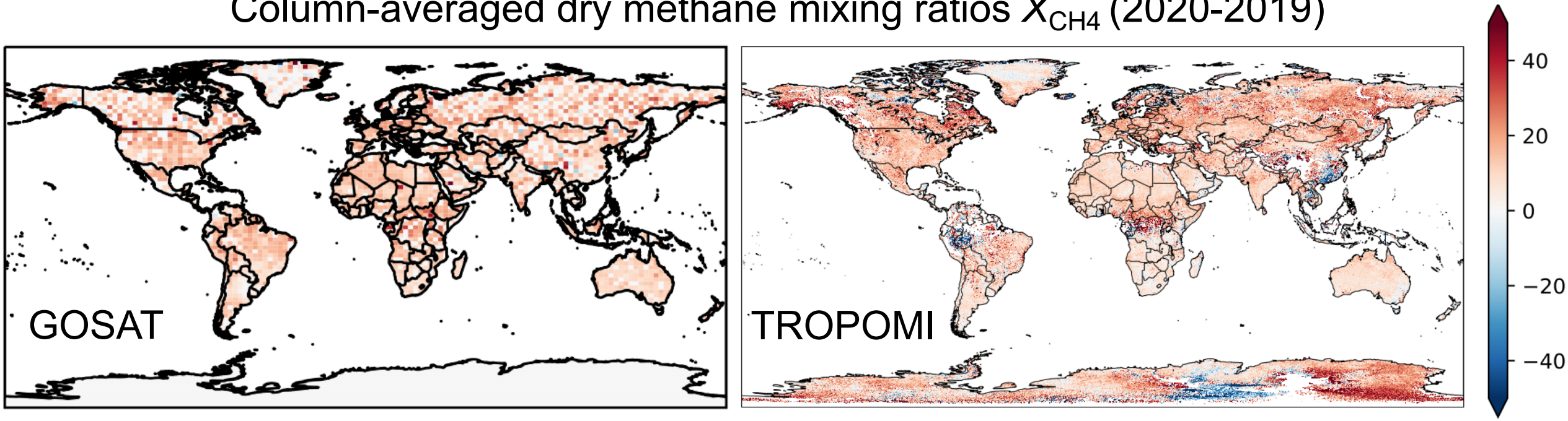


The maximum reduction of the tropospheric global mean OH occurs in May 2020, by 4%, can increase methane lifetime by 4 months.

(*Miyazaki et al.*, 2021)

Generally consistent changes in X_{CH4} between TROPOMI and GOSAT

Column-averaged dry methane mixing ratios X_{CH4} (2020-2019)



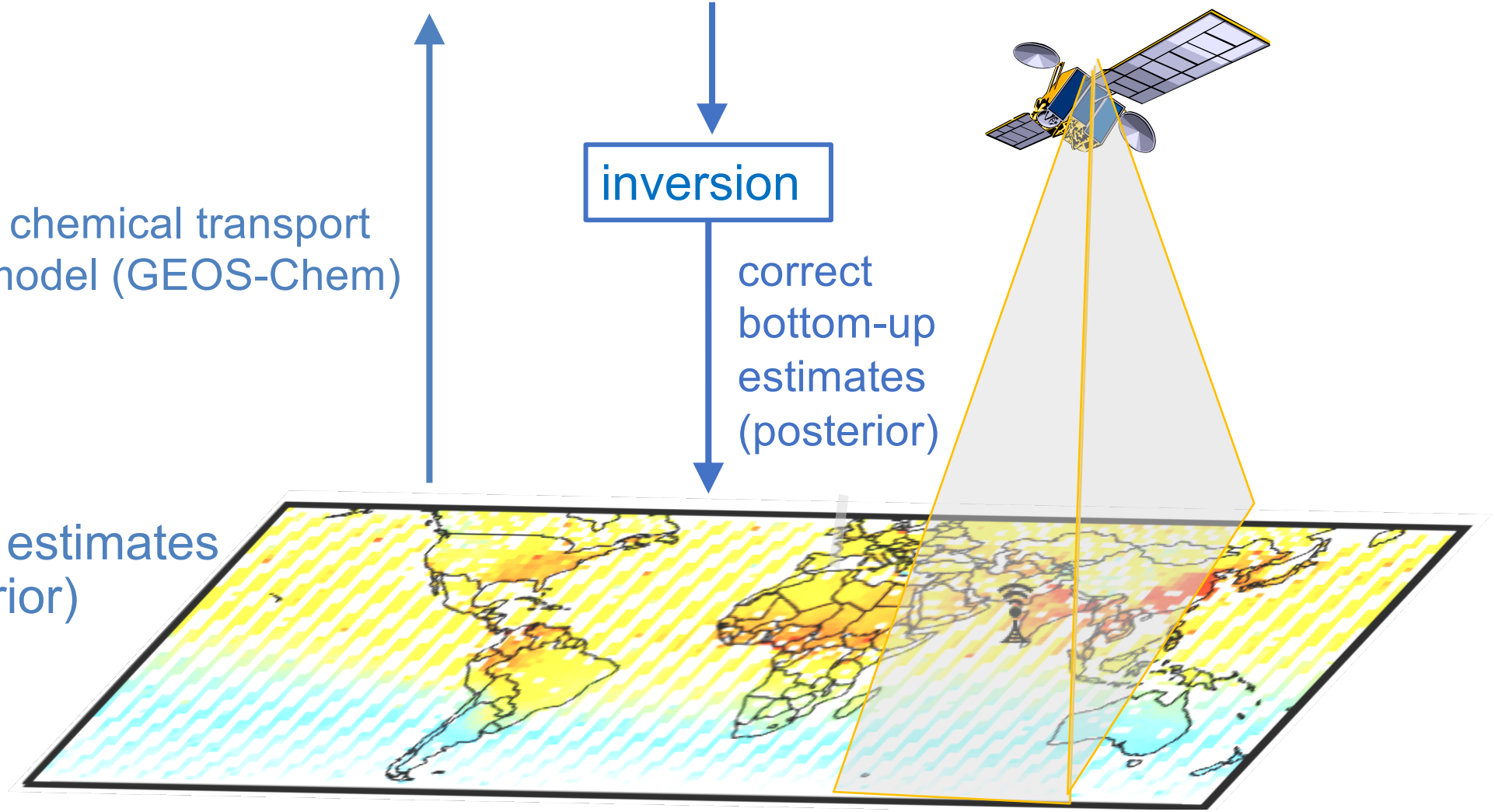
Weaker increase /decrease in southeast China (rice).

Stronger increase in Northwest US, Europe, and wetland regions (DRC, South Sudan, and Alaska)

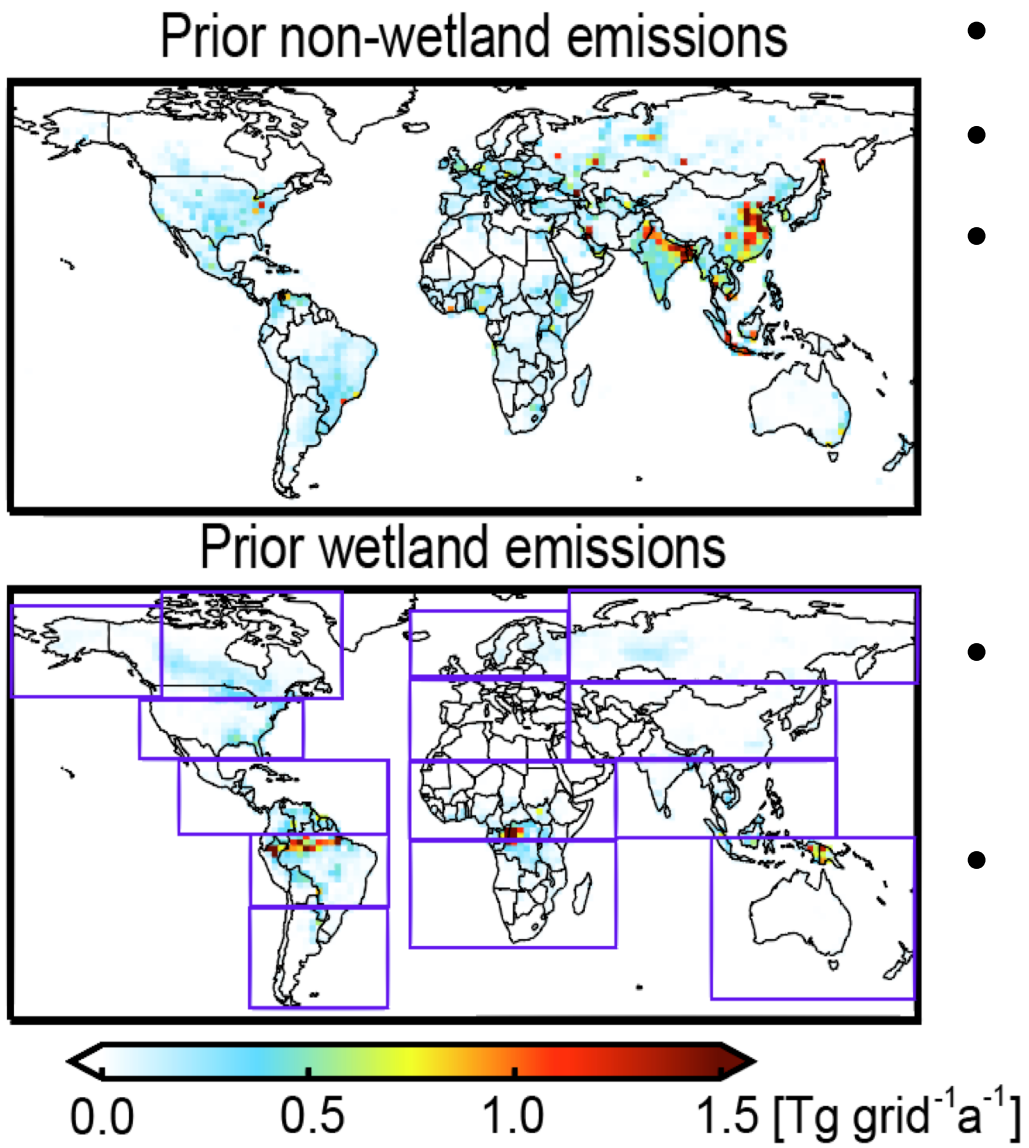
Use GOSAT observations to estimate emissions through inverse methods

Top-down estimate

predicted concentrations ⟷ observed concentrations



Inverse modeling of global methane sources and sinks



- GEOS-Chem v12.5.0, 2° × 2.5° resolution
- Whole year of 2019 & 2020
- EDGARv4.3.2 as global default;
  EPA greenhouse inventory for CONUS;
  oil, gas, and coal from GFEI;
  wetland from WetCHARTs
- Initial conditions on Jan 1, 2019 and Jan 1, 2020 are scaled to match GOSAT
- No correction on stratosphere – smaller biases at 2° × 2.5° & low latitudes

(Stanevich et al., 2019)

Analytical inversion of the sources and sinks of methane

Description	Variable
State vector	**x**
Jacobian matrix	**K**
Satellite observation	**y**
Observational error covariance matrix	$\mathbf{S_o}$
Prior error covariance matrix	$\mathbf{S_a}$

Cost Function (Gaussian errors, uncorrelated obs & prior errors):

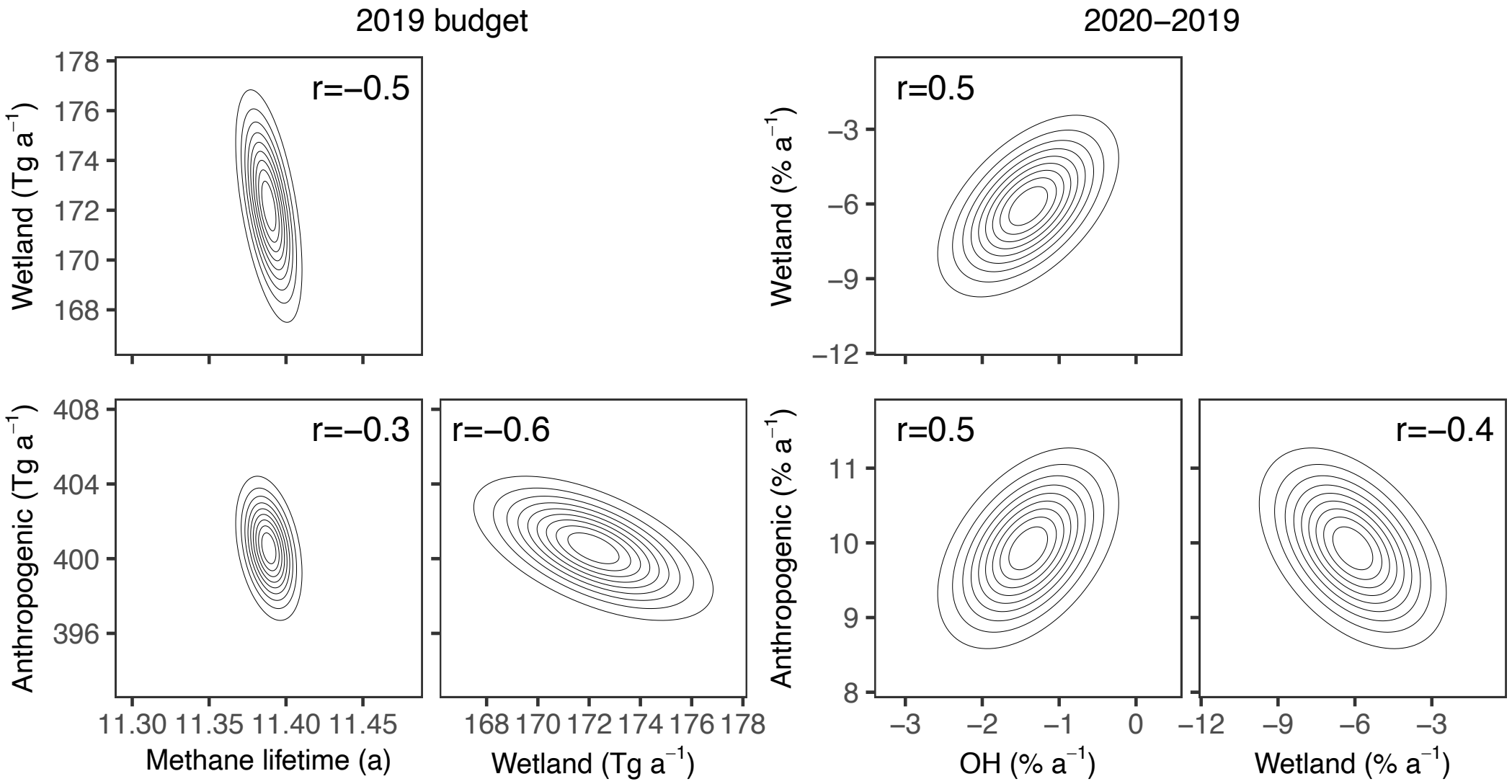
$$J(x) = \frac{1}{2}(\boldsymbol{x} - \boldsymbol{x}_a)^T \mathbf{S_a}^{-1}(\boldsymbol{x} - \boldsymbol{x}_a) + \frac{1}{2}\gamma(\boldsymbol{y} - \mathbf{K}\boldsymbol{x})^T \mathbf{S_o}^{-1}(\boldsymbol{y} - \mathbf{K}\boldsymbol{x})$$

Regularization parameter γ = 0.5 (L-curve test):

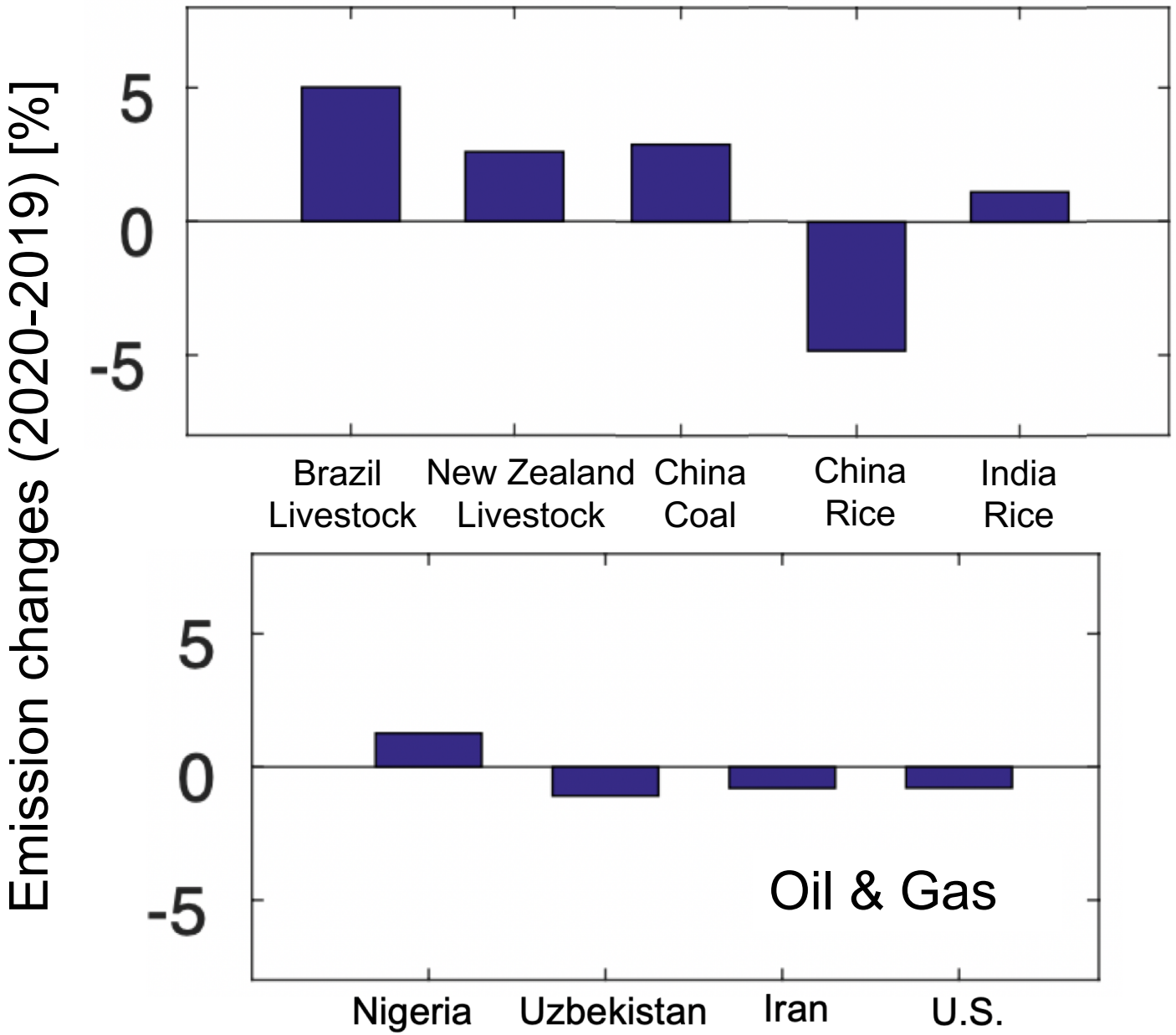
- accounts for the effect of error correlation not shown in $\mathbf{S_o}$

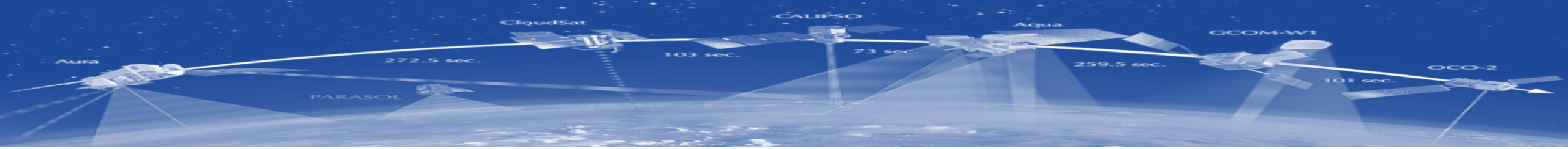
Analytical solution: $\hat{\boldsymbol{x}} = \boldsymbol{x}_a + \left(\gamma \mathbf{K}^T \mathbf{S_o}^{-1}\mathbf{K} + \mathbf{S_a}^{-1}\right)^{-1} \gamma \mathbf{K}^T \mathbf{S_O}^{-1}(\boldsymbol{y} - \mathbf{Kx})$

Global CH_4 imbalance increases by 71% from 2019 to 2020



Major changes in anthropogenic CH_4 emissions





Summary

- A global inversion of GOSAT methane observation shows a 71% increase of methane imbalance from 2019 to 2020, 29% of which are attributed to decreases in global OH concentrations.

- 71% of the increase in methane imbalance is attributed to increase in major anthropogenic sources, offset by reductions in rice and wetland emissions.