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European Space Agency

Towards Near Real Time global GHG budgets

From CCI ECVs to actionable, timely, policy relevant information

Philippe Ciais and ESA RECCAP2 colleagues

LSCE
University of Exeter
MPI-BGC Jena
NASA Goddard Space Flight Center
Columbia University
ETH zürich
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INRAE
Tsinghua University
KAYRROS
JPL Jet Propulsion Laboratory California Institute of Technology

We've been steering by looking in the rearview.
Advances (spurred by COVID) offer decision makers timely feedback to support more agile and adaptive management of carbon emissions and natural sinks.

Bastos *et al.*
Carbon Balance and Management (2022) 17:15
https://doi.org/10.1186/s13021-022-00214-w

Carbon Balance and Management

COMMENT Open Access

On the use of Earth Observation to support estimates of national greenhouse gas emissions and sinks for the Global stocktake process: lessons learned from ESA-CCI RECCAP2

Ana Bastos[1*], Philippe Ciais[2], Stephen Sitch[3], Luiz E. O. C. Aragão[3,4,5], Frédéric Chevallier[2], Dominic Fawcett[3], Thais M. Rosan[3], Marielle Saunois[2], Dirk Günther[6], Lucia Perugini[7], Colas Robert[8], Zhu Deng[9], Julia Pongratz[10,11], Raphael Ganzenmüller[10], Richard Fuchs[12], Karina Winkler[12,13], Sönke Zaehle[1] and Clément Albergel[14]

Comparing inversions with UNFCC inventories

https://doi.org/10.5194/essd-2021-235
Preprint. Discussion started: 13 August 2021

Open Access Earth System Science Data Discussions

Comparing national greenhouse gas budgets reported in UNFCCC inventories against atmospheric inversions

Zhu Deng[1,*], Philippe Ciais[2,*], Zitely A. Tzompa-Sosa[2], Marielle Saunois[2], Chunjing Qiu[2], Chang Tan[1], Taochun Sun[1], Piyu Ke[1], Yanan Cui[3], Katsumasa Tanaka[2,4], Xin Lin[2], Rona L. Thompson[5], Hanqin Tian[6], Yuanzhi Yao[6], Yuanyuan Huang[7], Ronny Lauerwald[8], Atul K. Jain[9], Xiaoming Xu[9], Ana Bastos[10], Stephen Sitch[11], Paul I. Palmer[12,13], Thomas Lauvaux[2], Alexandre d'Aspremont[14], Clément Giron[14], Antoine Benoit[14], Benjamin Poulter[15], Jinfeng Chang[16], Ana Maria Roxana Petrescu[17], Steven J. Davis[18], Zhu Liu[1], Giacomo Grassi[19], Clément Albergel[20], and Frédéric Chevallier[2]

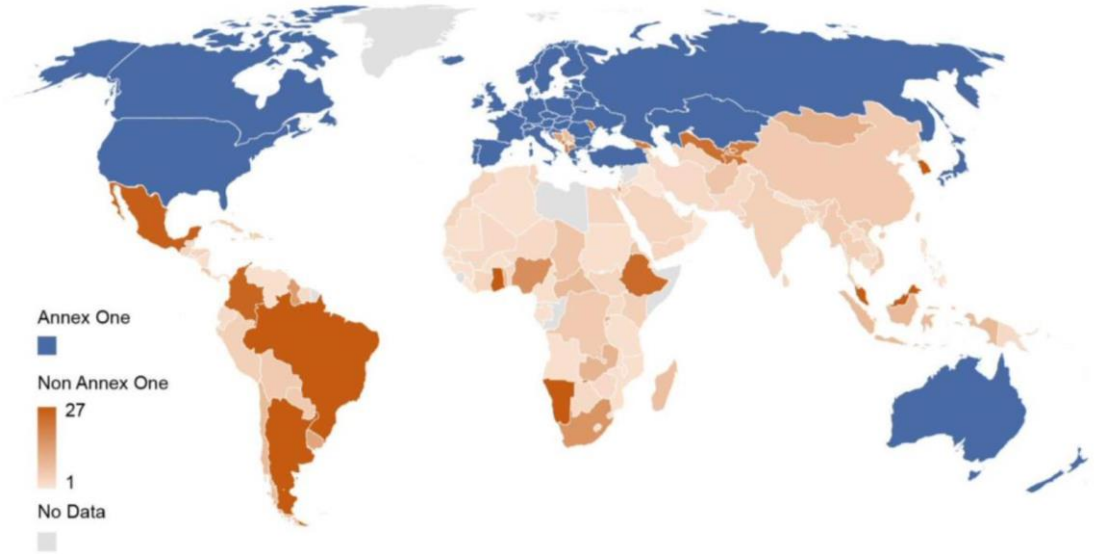


Figure 2. Numbers of years covered by national inventories reports (NC+BUR) in each non-Annex I country; Emissions from Greenland are reported by Denmark.

In this study, a new methodology to use inversions and make them comparable with UNFCCC reports was presented for the three gases

Significant **differences** were found, especially for lower UNFCCC emissions of **CH_4 in the fossil sector**
This work had an impact at the COP26 through an article in the Washington Post

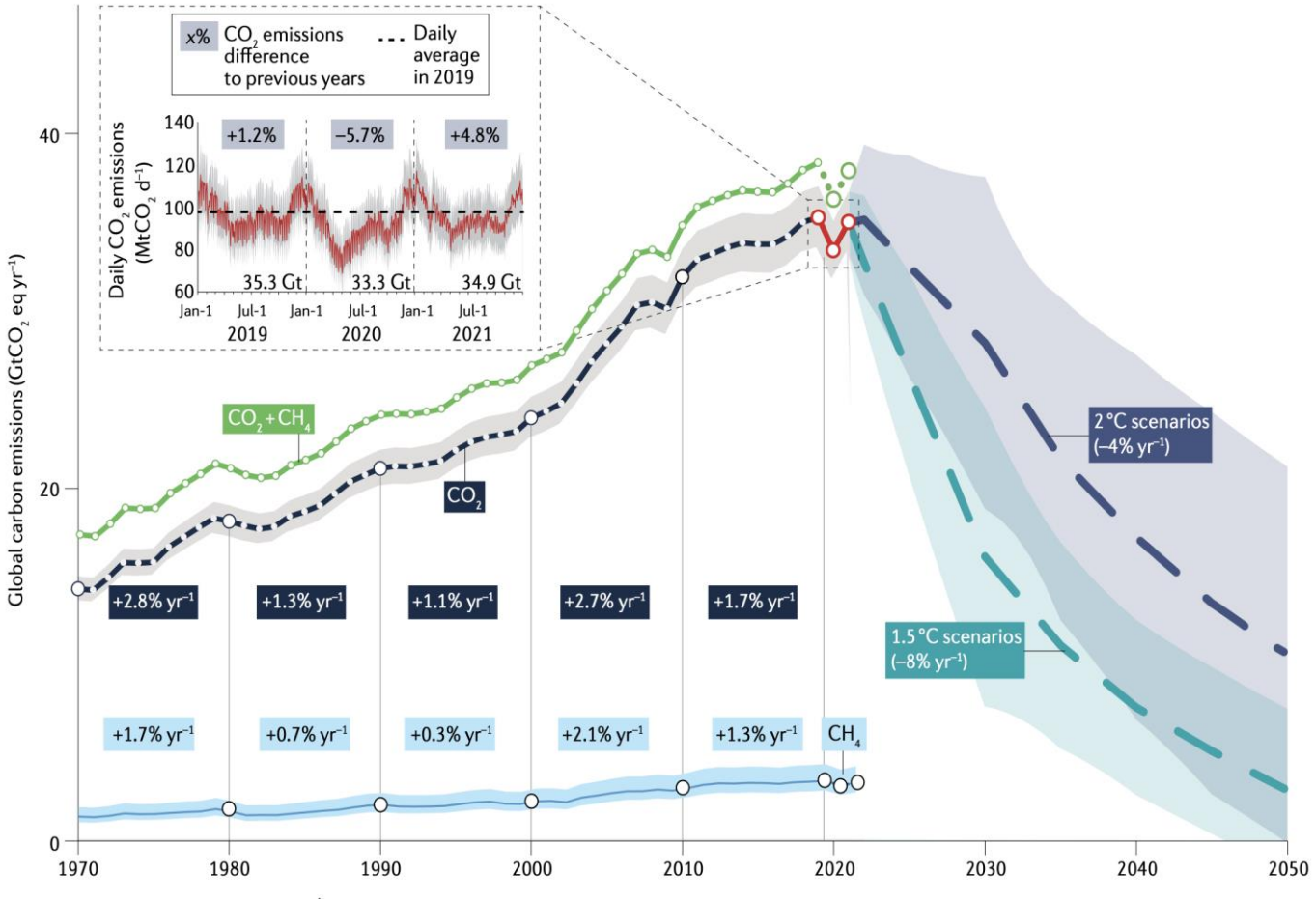
Current status

- Annual analysis of the global CO_2 budget by the Global Carbon Project
  - Annual estimates for year n-1
  - Based on ocean and land models, and annual fossil emissions (per country)
- Global CH_4 budget by GCP
  - Decadal estimates
  - Combination of multiple inversions and bottom-up inventories
  - Last update to 2017, current update planned to extend to 2020
- Global N_2O budget by GCP
  - Decadal estimates
  - First publication in 2020
  - Last update to 2018, current update planned to extend to 2019
- UNFCCC submissions
  - Latency of 1+ years for Annex 1 countries
  - Latency of 10+ years for non Annex 1 countries

Towards near real time GHG budgets ?

- New estimates of fossil emissions area => available in NRT
  - CH_4 Kayrros Global Methane Watch
  - CO_2 Carbon Monitor daily national budgets & emissions maps at 10 km
- New global inversions of CO_2 and CH_4 fluxes => each 4 month
  - Use NRT in-situ concentration data from NOAA, ICOS, RAMCES networks
  - Satellite XCO_2 and XCH4 from OCO2 and GOSAT
  - Copernicus CAMS results are already available for CO_2
- **Attribution** of top-down flux anomalies using bottom up information
  - Land observations and models
  - Ocean observations and models

Near real time Carbon Monitor fossil CO_2 emissions



Monitoring global carbon emissions in 2021

Zhu Liu[1]✉, Zhu Deng[1], Steven J. Davis[2], Clement Giron[3] and Philippe Ciais[4]

Following record-level declines in 2020, near-real-time data indicate that global CO_2 emissions rebounded by 4.8% in 2021, reaching 34.9 $GtCO_2$. These 2021 emissions consumed 8.7% of the remaining carbon budget for limiting anthropogenic warming to 1.5 °C, which if current trajectories continue, might be used up in 9.5 years at 67% likelihood.

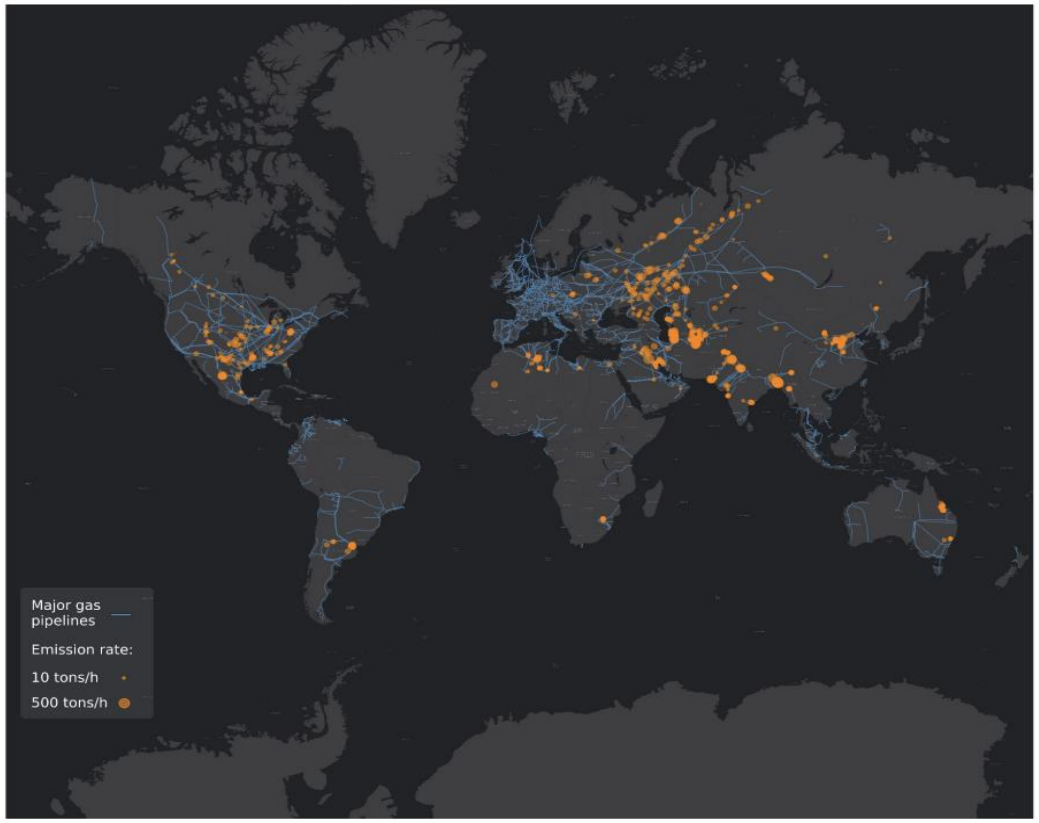
21 peer reviewed publications / preprints since June 2020

More than 30 researchers working on different datasets

Operational management

All data freely available
https://carbonmonitor.org

Sentinel-5P near-real time monitoring of CH_4 emissions for ultra-emitters



RESEARCH

GREENHOUSE GASES

Global assessment of oil and gas methane ultra-emitters

T. Lauvaux[1]*, C. Giron[2], M. Mazzolini[2], A. d'Aspremont[2,3], R. Duren[4,5], D. Cusworth[6], D. Shindell[7,8,9], P. Ciais[1,10]

Methane emissions from oil and gas (O&G) production and transmission represent a considerable contribution to climate change. These emissions comprise sporadic releases of large amounts of methane during maintenance operations or equipment failures not accounted for in current inventory estimates. We collected and analyzed hundreds of very large releases from atmospheric methane images sampled by the TROPOspheric Monitoring Instrument (TROPOMI) between 2019 and 2020. Ultra-emitters are primarily detected over the largest O&G basins throughout the world. With a total contribution equivalent to 8 to 12% (~8 million metric tons of methane per year) of the global O&G production methane emissions, mitigation of ultra-emitters is largely achievable at low costs and would lead to robust net benefits in billions of US dollars for the six major O&G-producing countries when considering societal costs of methane.

Global coverage

Ultra emitters > 20 tCH_4 per hour with TROPOMI

Represents 5 to 80% of national emissions from inventories

Lower detection of leaks > 5 tCH_4 per hour using PRSMA, Sentinel-2, Gaofeng …

LSCE

KAYRROS

Near real time estimates of fossil CH_4 regional emissions for major extraction basins (represents ≈ 35% of emissions)

Tropomi + high resolution atm inverse models

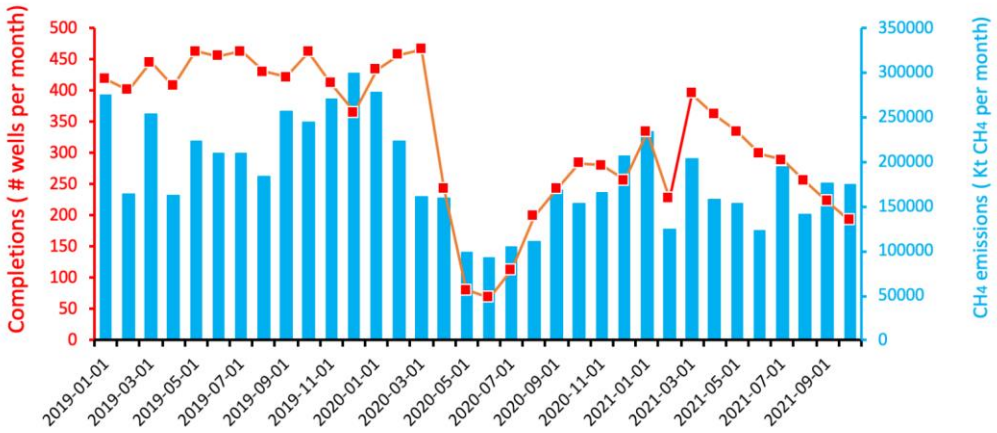
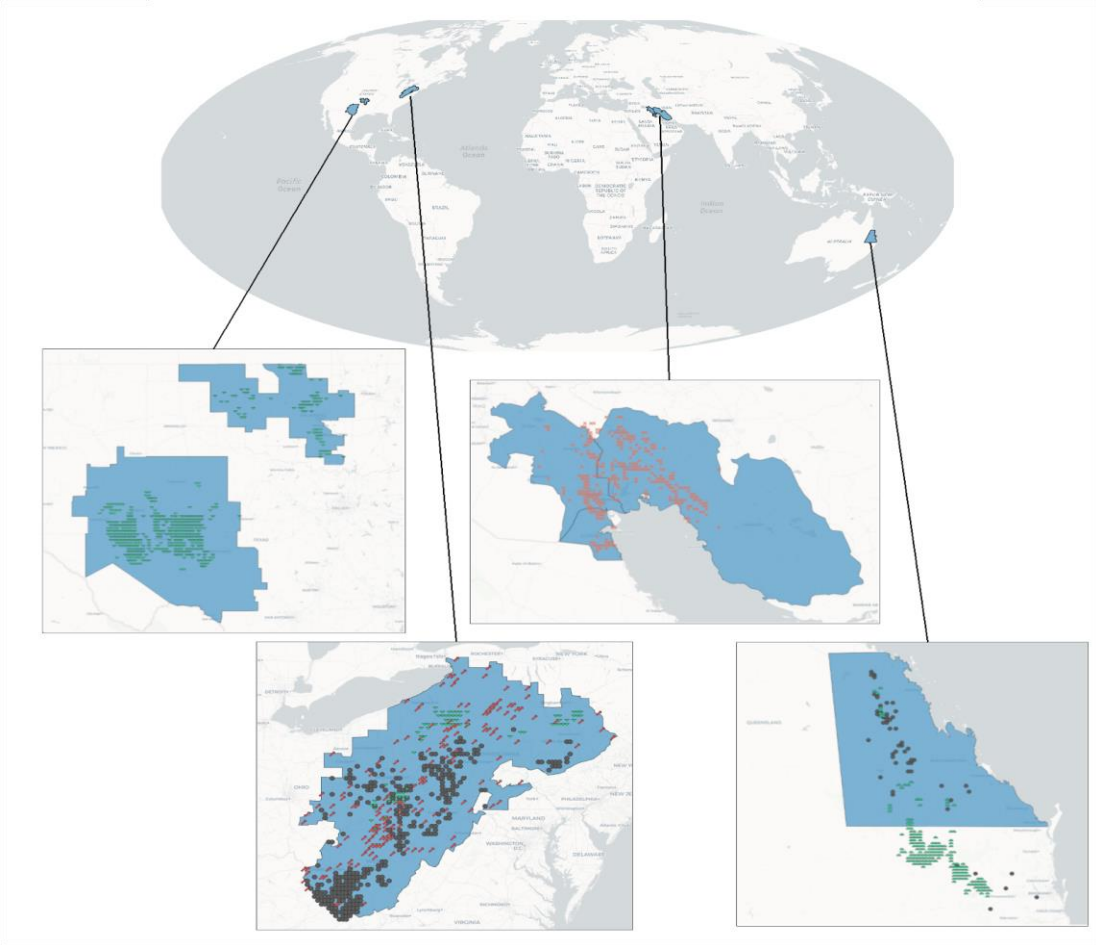


Figure 2. Emissions of CH_4 (blue) from the Permian shale oil and gas basin in the US and well completion rates (red).



Coverage : seven major oil, gas, coal basins representing 25% of global fossil CH4 emissions

KAYRROS

From near real time emissions to full GHG budgets over land and ocean

=> **National assessments of emissions and sinks at 4 months intervals**

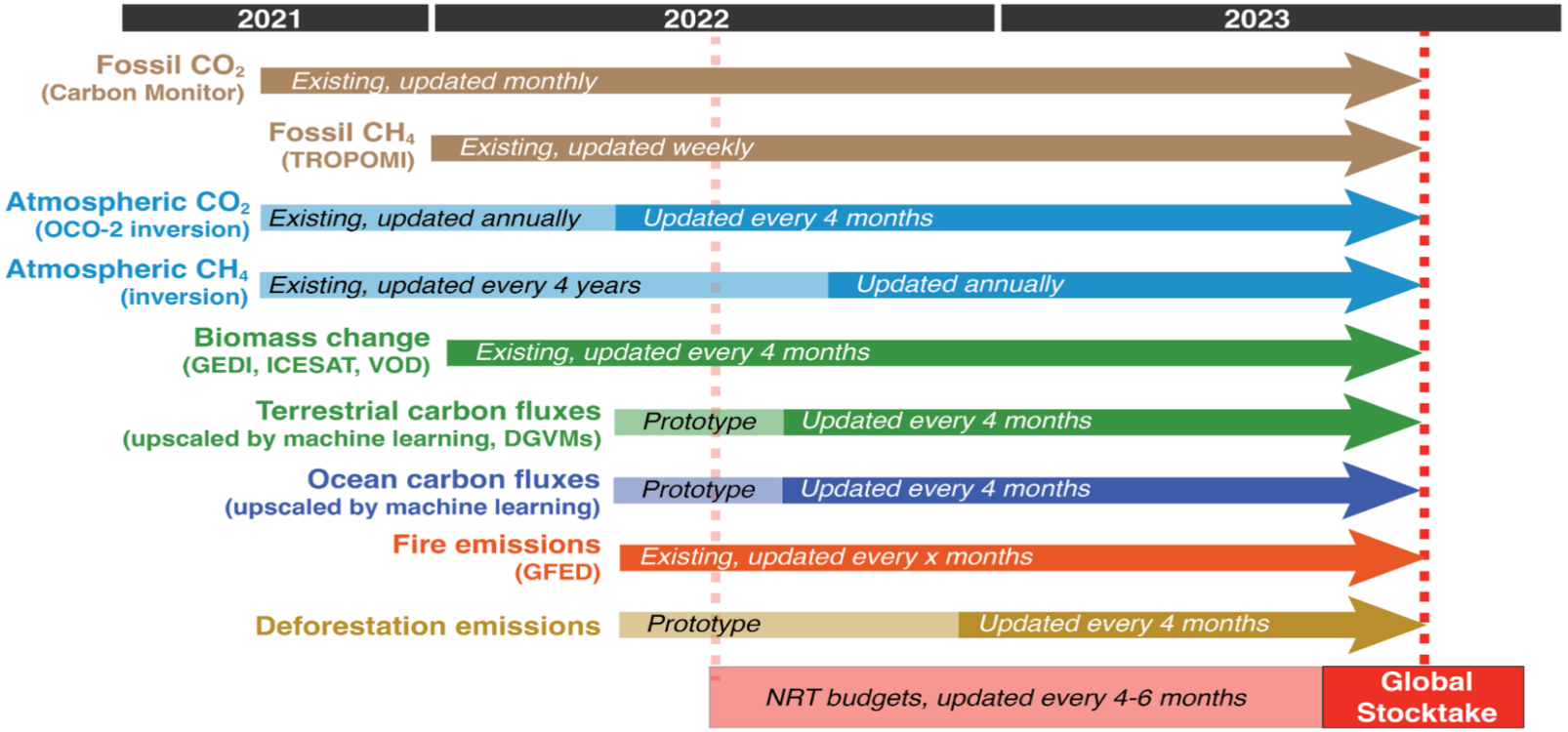


Figure 1. Component of a 'near-real-time' analysis system that could deliver observation-based estimates of global and national GHG budgets for the Global Stocktake in 2023. The timeline separates existing components, and prototypes being tested by research groups involved in this paper to deliver regular updates of key fluxes with a latency of four months.

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Near Real time attribution of national budgets into components

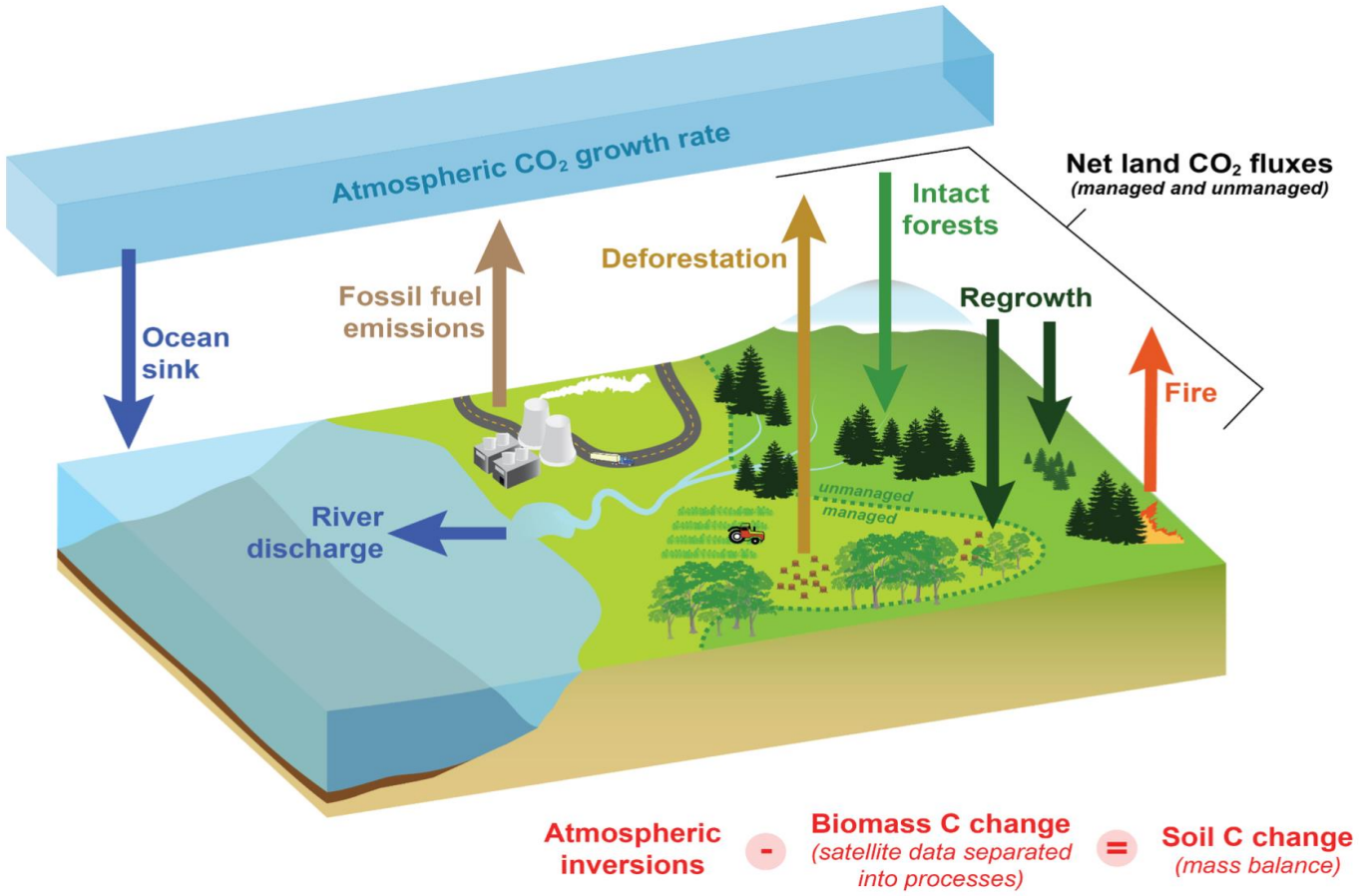


Figure 3. Closure and attribution of national CO_2 budgets achieved by combining top-down inversion estimates of net land CO_2 fluxes, biomass carbon stock changes from satellites, lateral fluxes from rivers, crop and wood trade, fires and deforestation emissions. The proposed approach infers non-measurable soil carbon stock changes from mass balance between total CO_2 fluxes from top-down inversions and measurable carbon stock changes in biomass.

Inversions
⇒ Total CO_2 fluxes

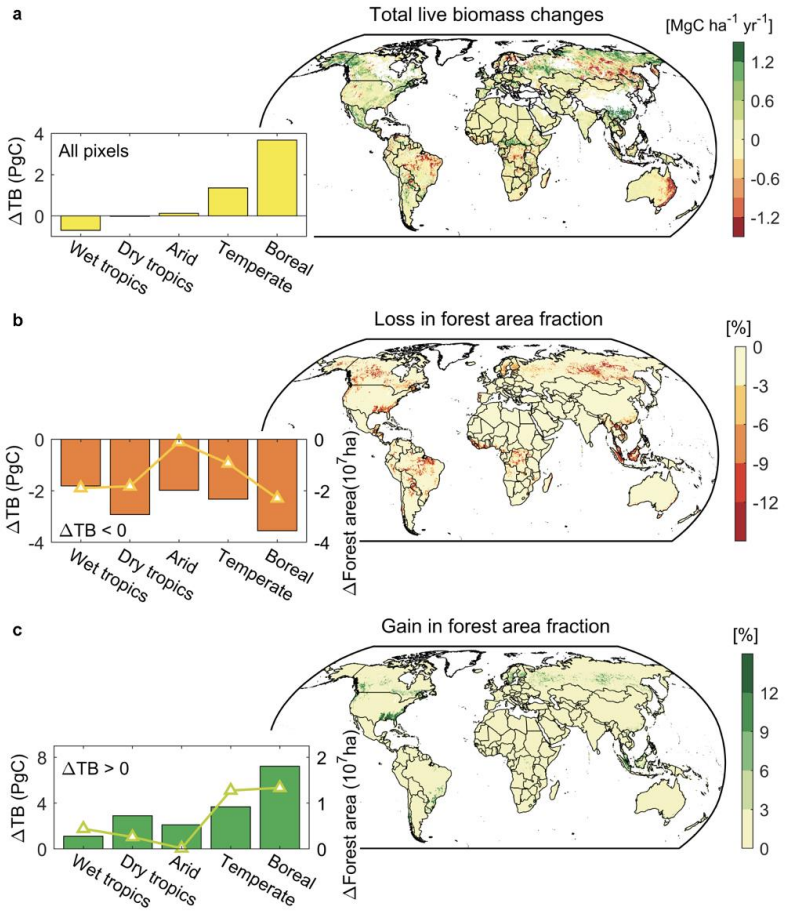
Then correction of lateral fluxes
⇒ Net land carbon stocks change

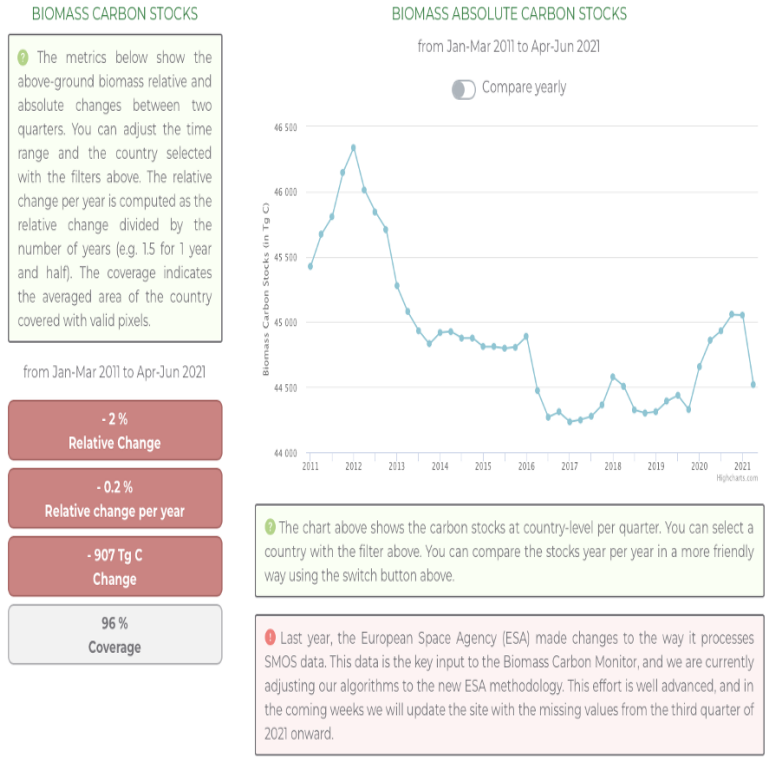
Global NRT biomass C change
from VOD and optical sensors

Then observable C losses in NRT
- Fire emissions
- Deforestation CO_2 emissions

⇒ **Residuals.**
- **Forest growth / regrowth sink**
- **Soil C storage change**

Global NRT monitoring of biomass C changes with satellites





Global coverage
20 km resolution

Updated each 4 months

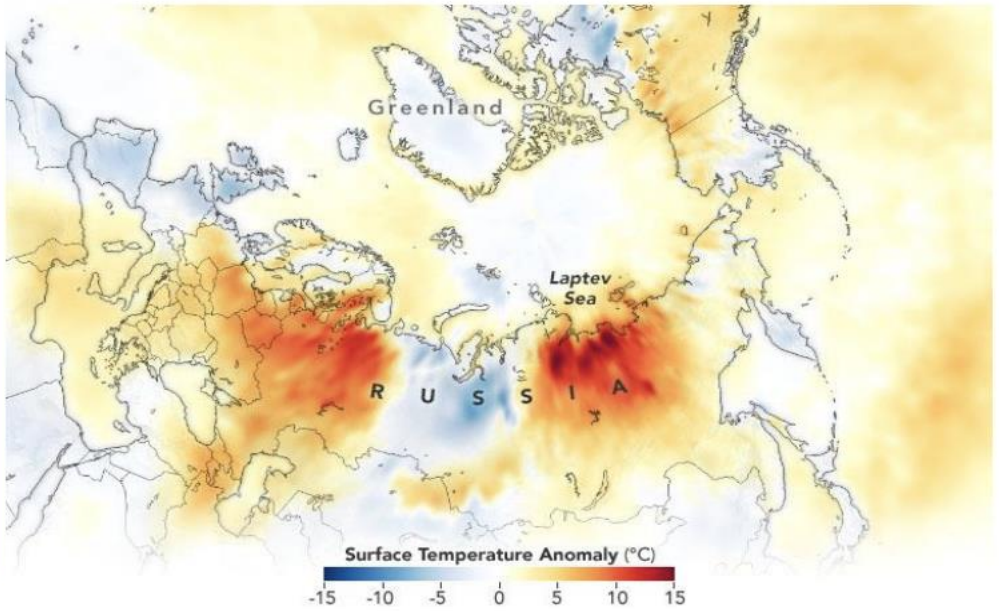
National data freely available

JP Wigneron and H Yang

www.kayrros.com/biomass-watch/

Global NRT monitoring of fire C emissions with satellites

Abnormal 2021 fires over northern high-latitudes



Surface Temperature Anomaly (°C) during June 18-25 of 2021 compared to average temperatures of the same time period 2003-2013

Active fires – burned area = bottom up emissions

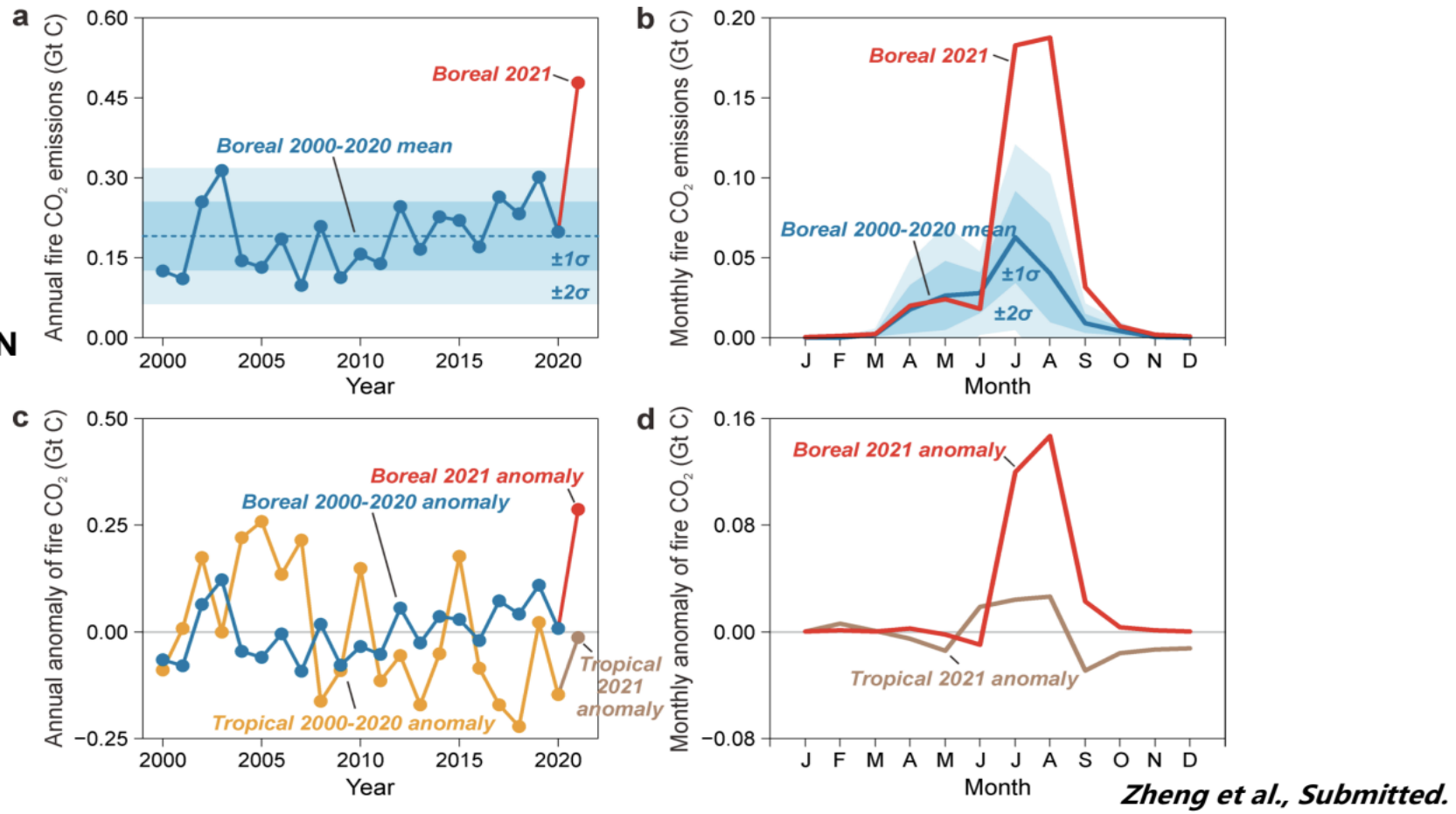
Carbon monoxide (MOPITT, TROPOMI, IASI) = top down emissions

Global NRT monitoring of fire C emissions with (CO) satellites

Inversion estimates of boreal and tropical fire carbon emissions

Boreal: north of 50°N

Tropics: 23°S - 23°N

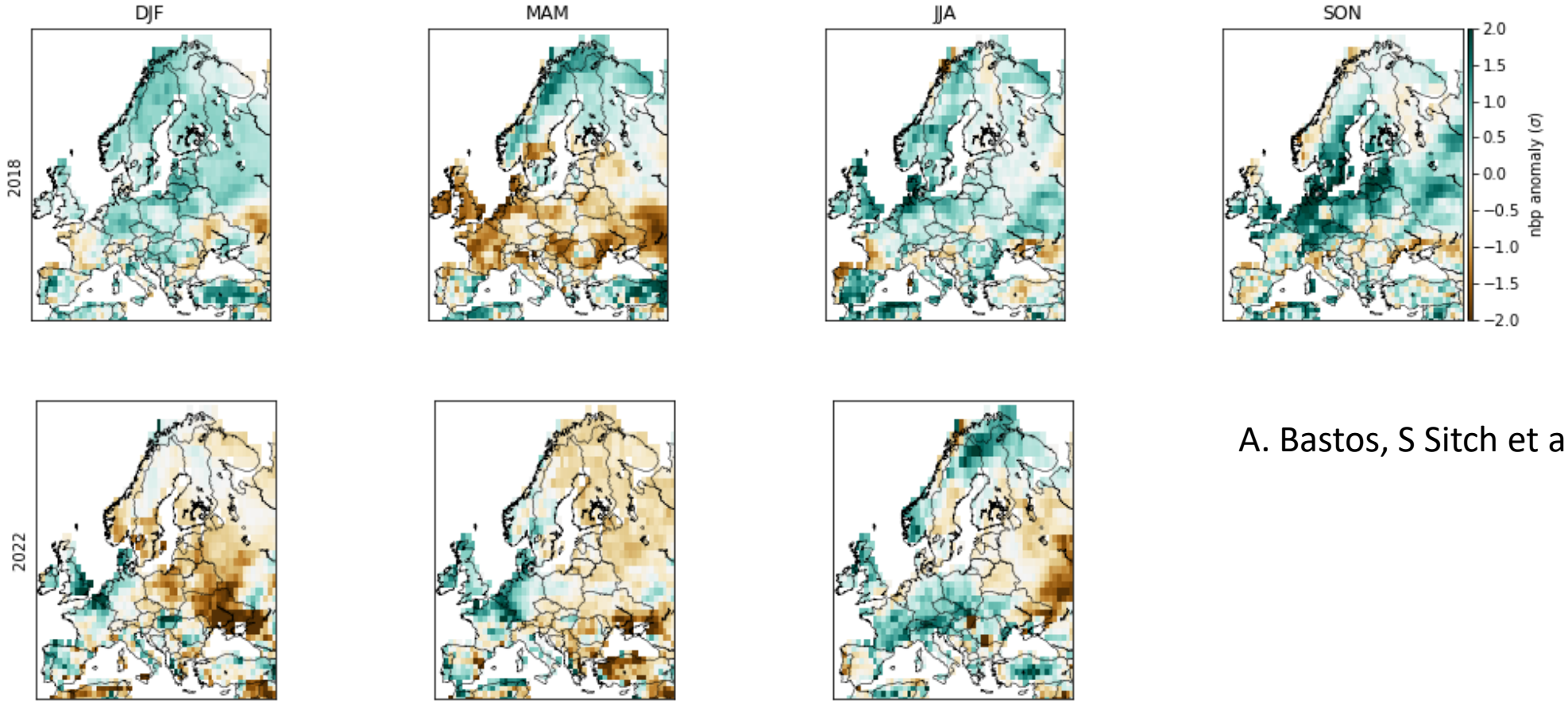


Zheng et al., Submitted.

Global NRT modeling and attribution of C flux anomalies

Example : the drought of 2022 in Europe, China …

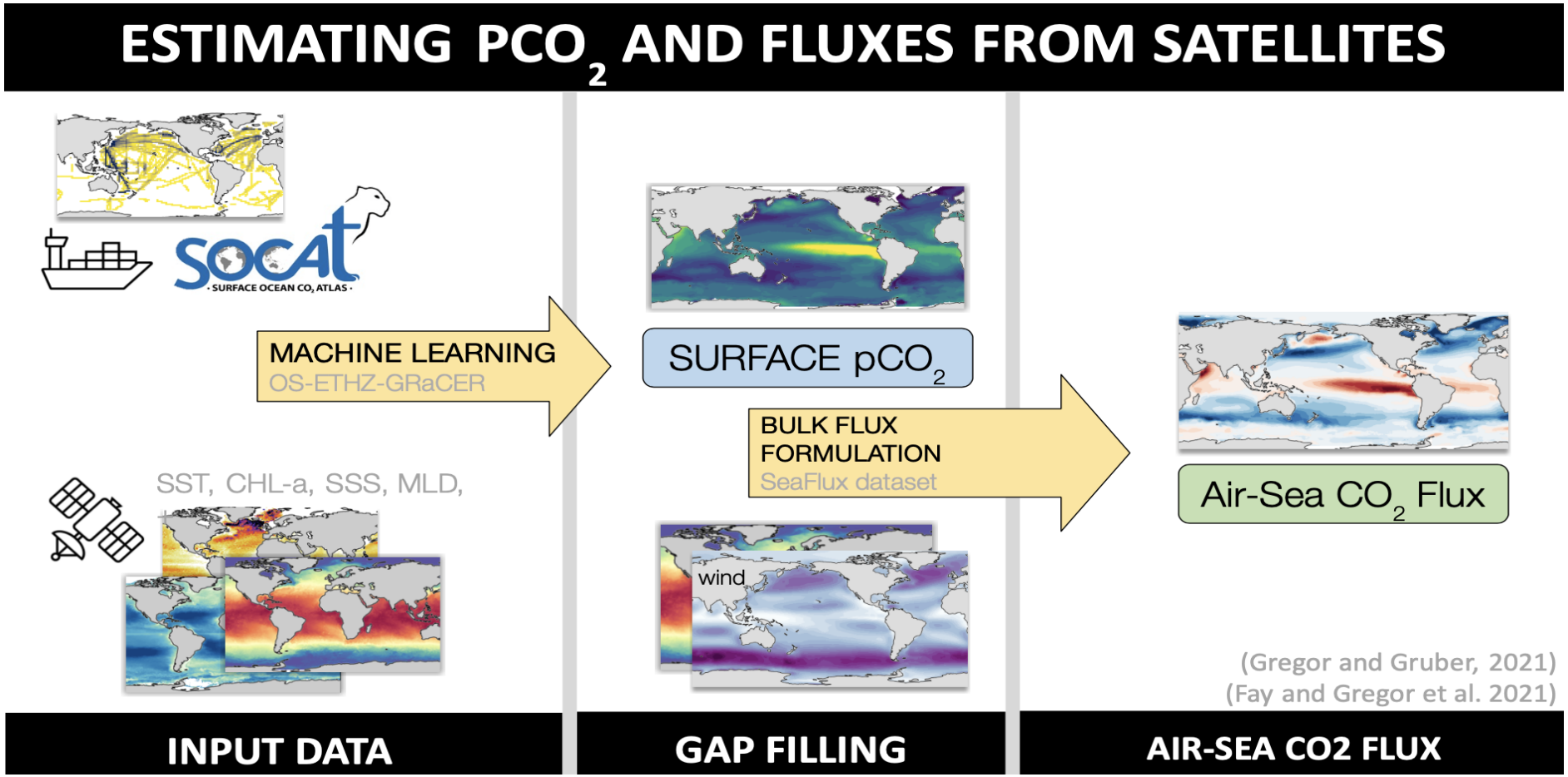
2022 in perspective: NBP (net C flux anomaly)
with the same global vegetation models used for the annual buget and future projections



A. Bastos, S Sitch et al.

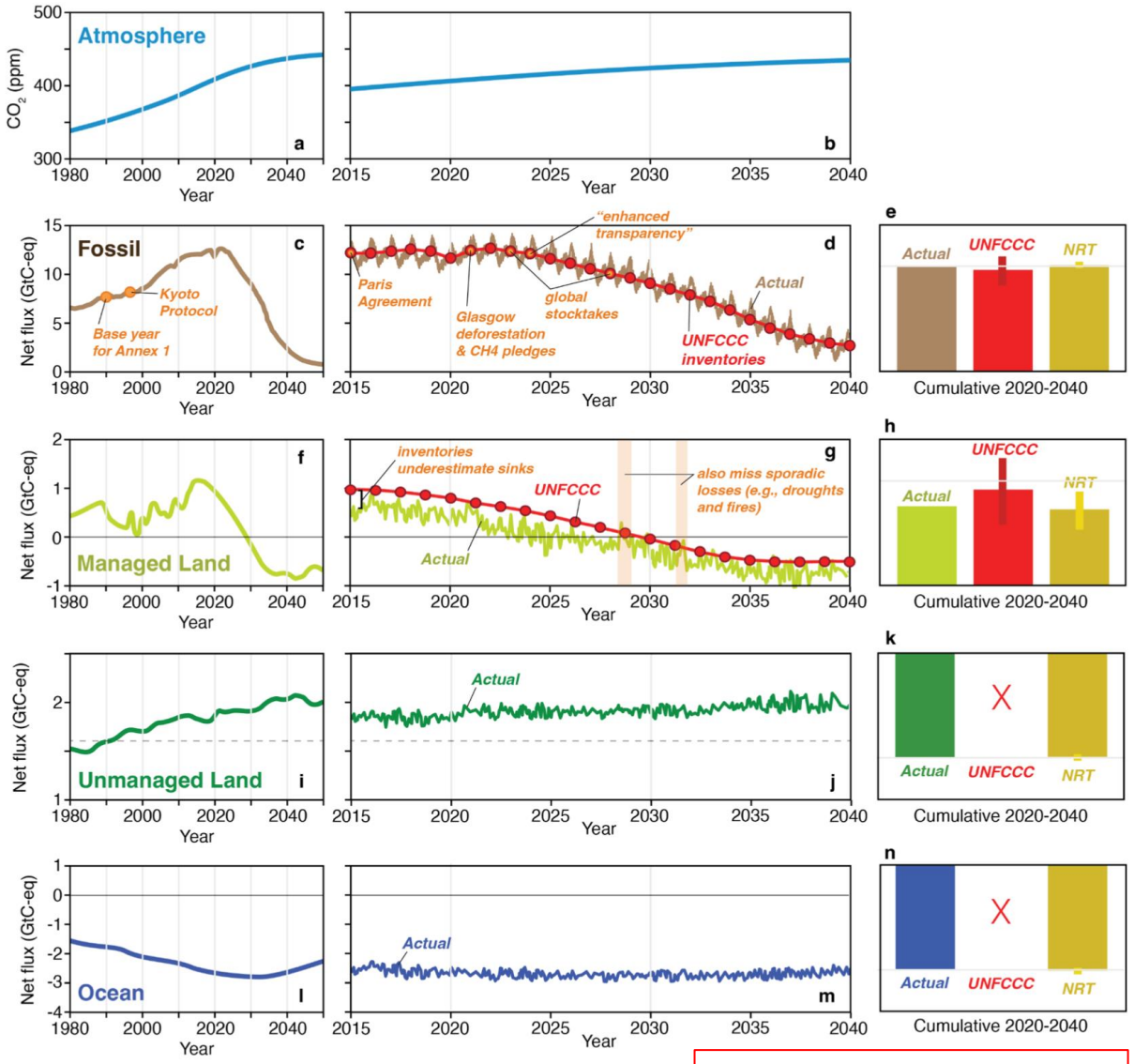
Near real time air-sea CO_2 fluxes

Based on Ml, surface in situ pCO2 and satellte observations of the ocean surface SST, CHl, SSS, MLD



L Gregor and N Gruber, ETH ; G Mc Kinley Columbia University

Conclusion



Near real time global CH4 and CO2 budgets are now possible

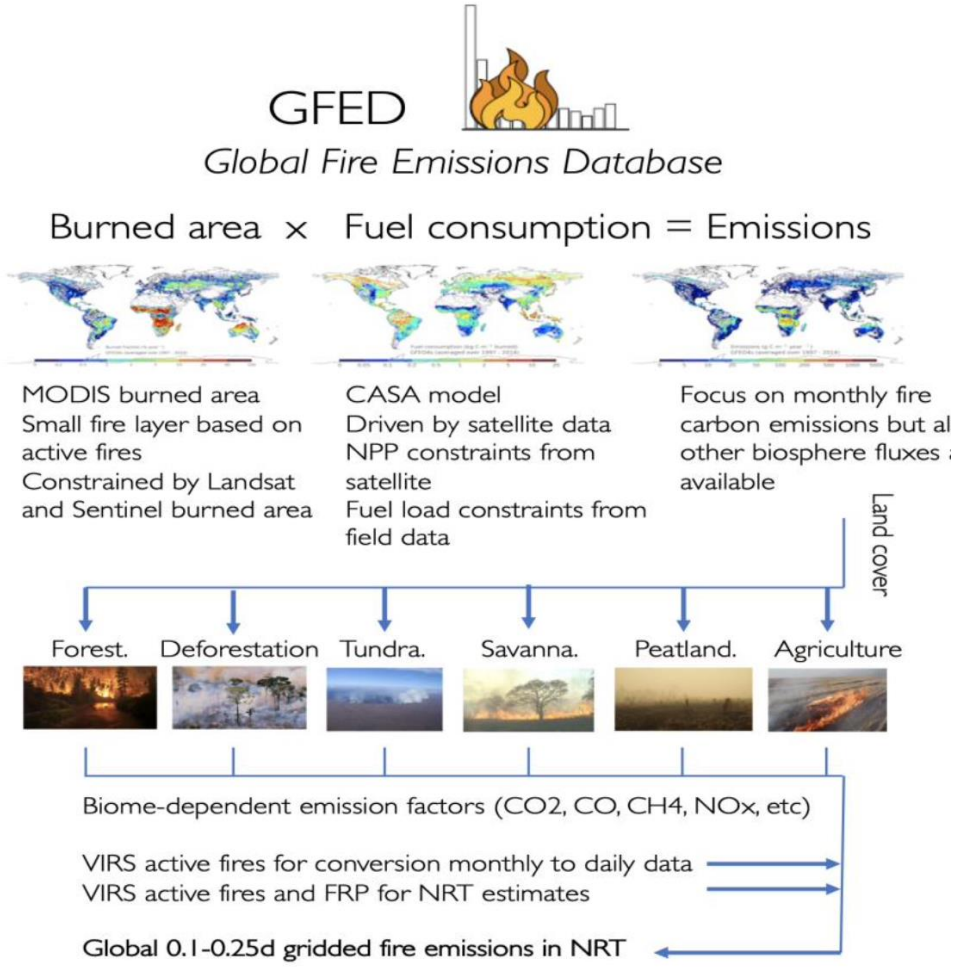
Coverage and separation of managed / unmanaged land

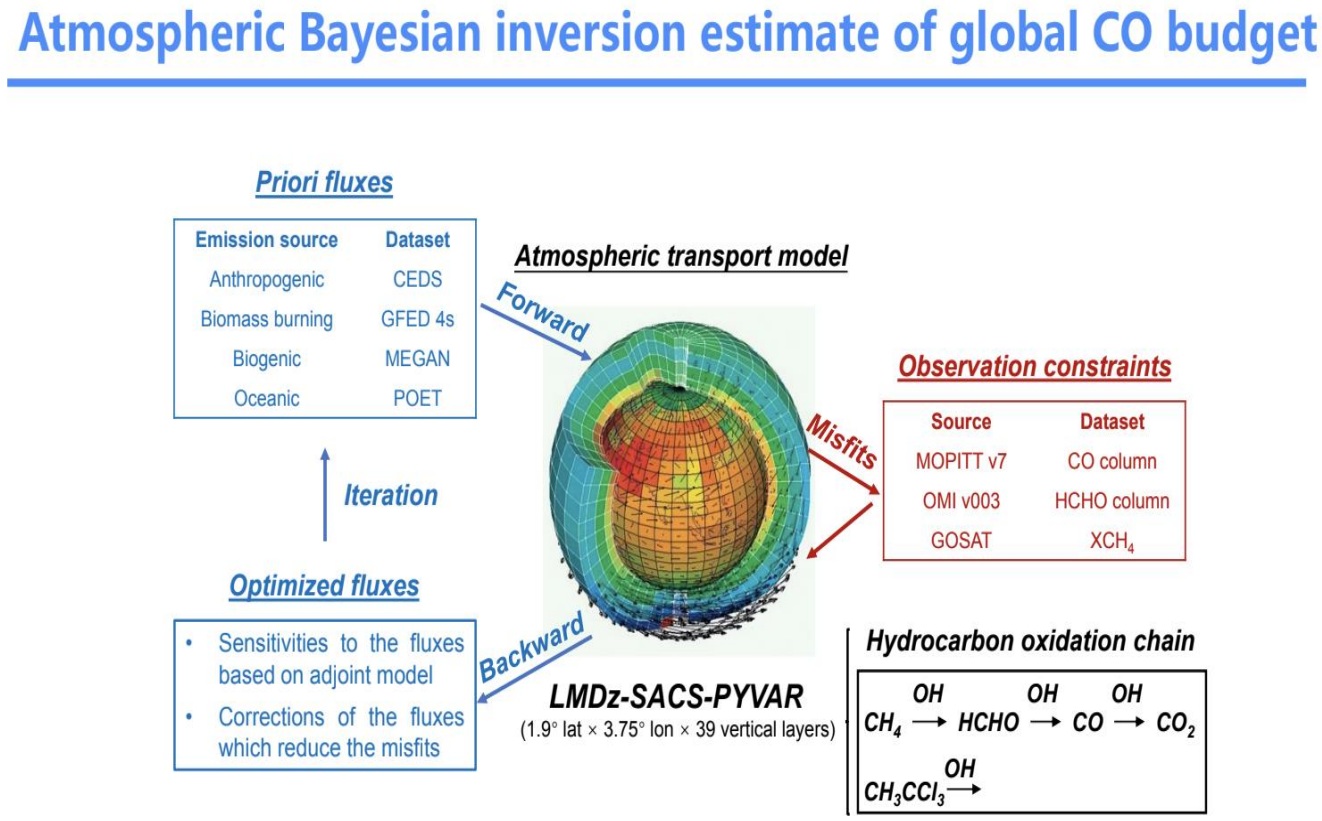
Understand extreme events and evaluate emerging carbon feedbacks

Impacts of extreme weather events and economic shocks on fossil CO2 and CH4 emissions

Near real time Fire CO_2 emissions

Two approaches : new GFED5 satellite based (VIIRS) daily emissions and global NRT CO inversion from MOPITT





Zheng et al., ERL, 2018; Zheng et al., GRL, 2018; Zheng et al., ESSD, 2019.