

ESA CLIMATE CHANGE INITIATIVE (CCI) in support of Terrestrial Carbon science

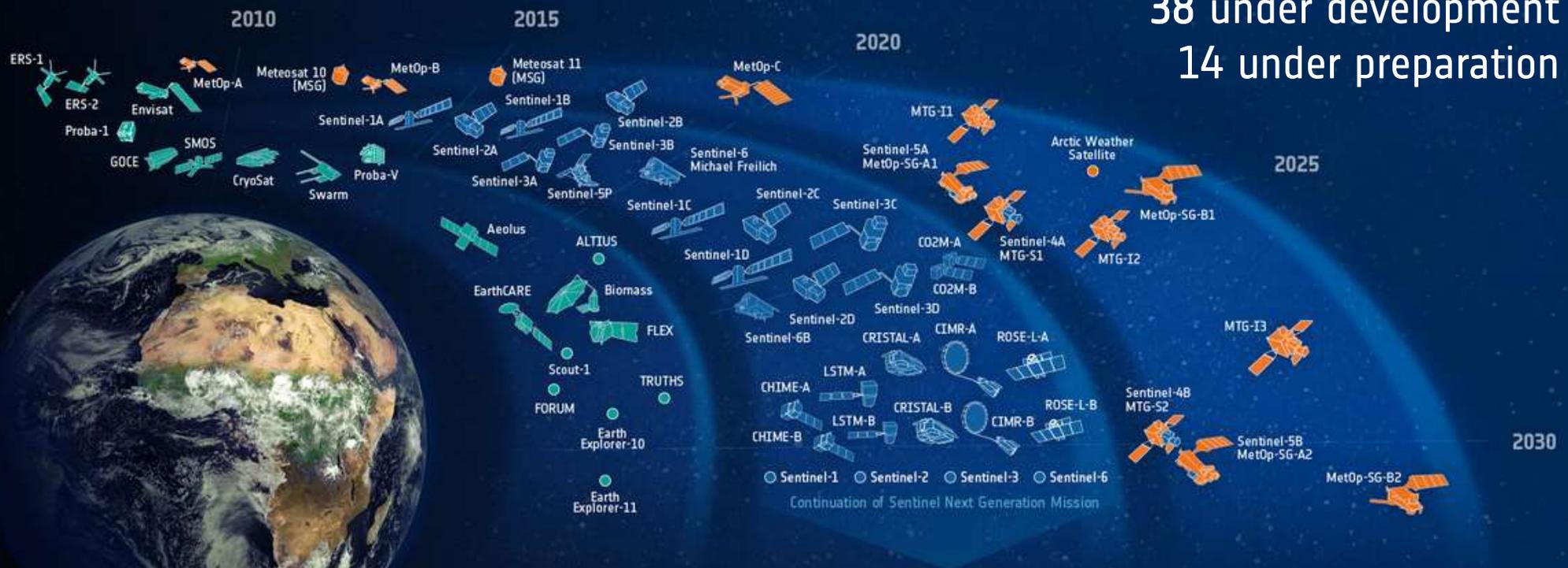
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ESA-DEVELOPED EARTH OBSERVATION MISSIONS

16 in operation
38 under development
14 under preparation



Science

Copernicus

Meteorology



ESA Climate Change Initiative projects



23 ECV projects, 2 budget closure projects, a data support project a climate modelling project and a fellowship call currently comprise the CCI.



climate modelling
user group
cci



climate change initiative

Oceanic



sea level
budget closure

Terrestrial



reccap-2

Atmospheric

Research Fellowships

Open Data Portal

Toolbox

Tablet App

Education Resources

ESA CCI in support of Terrestrial Carbon science



biomass
cci

Sc. leader: Shaun Quegan (Univ. Sheffield)
Tech. Officer: Frank Martin Seifert



fire
cci

Sc. Leader: Emilio Chuvieco (Univ. Alcalá)
Tech. Officer: Clement Albergel



**land surface
temperature**
cci

Sc. Leader: Darren Ghent (Univ. Leicester)
Tech. Officer: Simon Pinnock



lakes
cci

*Sc. Leader: Jean-François Crétaux (Legos),
Stefan Simis (PML)*
Tech. Officer: Clement Albergel



land cover
cci

Sc. Leader: Pierre Defourny (UCLouvain)
Tech. Officer: Oliver Arino



**high resolution
land cover**
cci

Sc. Leader: Lorenzo Bruzzone (Univ. Trento)
Tech. Officer: Oliver Arino



permafrost
cci

Sc. Leader: Annett Bartsch (b.geos)
Tech. Officer: Frank Martin Seifert



**greenhouse
gases**
cci

Sc. Leader: Michael Buchwitz (Univ Bremen)
Tech. Officer: Christian Retscher



reccap-2
cci

*Sc. Leader: Phillippe Ciais (LSCE),
Ana Bastos (MPI)*
Tech. Officer: Clement Albergel



climate change initiative

→ BIOMASS

Role of above Ground Biomass in global carbon cycle

- **Source:** loss under Land Use Change or by degradation
- **Sink:** forest growth

Wider role in understanding and predicting climate

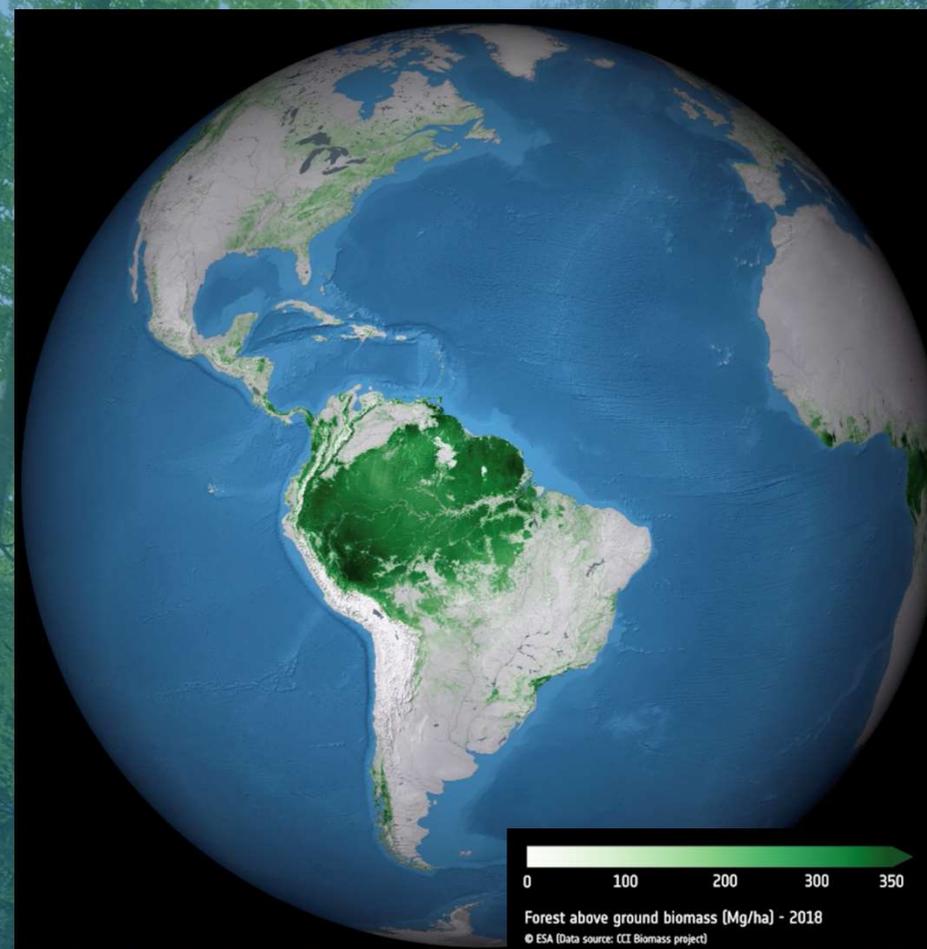
- Model initialisation and testing, estimation of Carbon turnover, inferring forest disturbance regime [...]

Contributor to the Paris Agreement GST

- National Determined Contributions
- More robust and transparent reporting in the UNFCCC
- Overall reliance of natural sinks for climate mitigation
- Carbon-Climate feedbacks, hot spots, tipping points, ecosystem collapse



biomass
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→ BIOMASS

New maps for 2010, 2017, 2018 (2020 under development)

- Sentinel-1, Envisat's ASAR, ALOS-1 & ALOS-2, [...]
- 100 m spatial resolution, provision of standard deviation

Address temporal consistency

- integration of additional data streams (SMOS* / ASCAT Vegetation Optical Depth)

Data also being used by CCI fellows

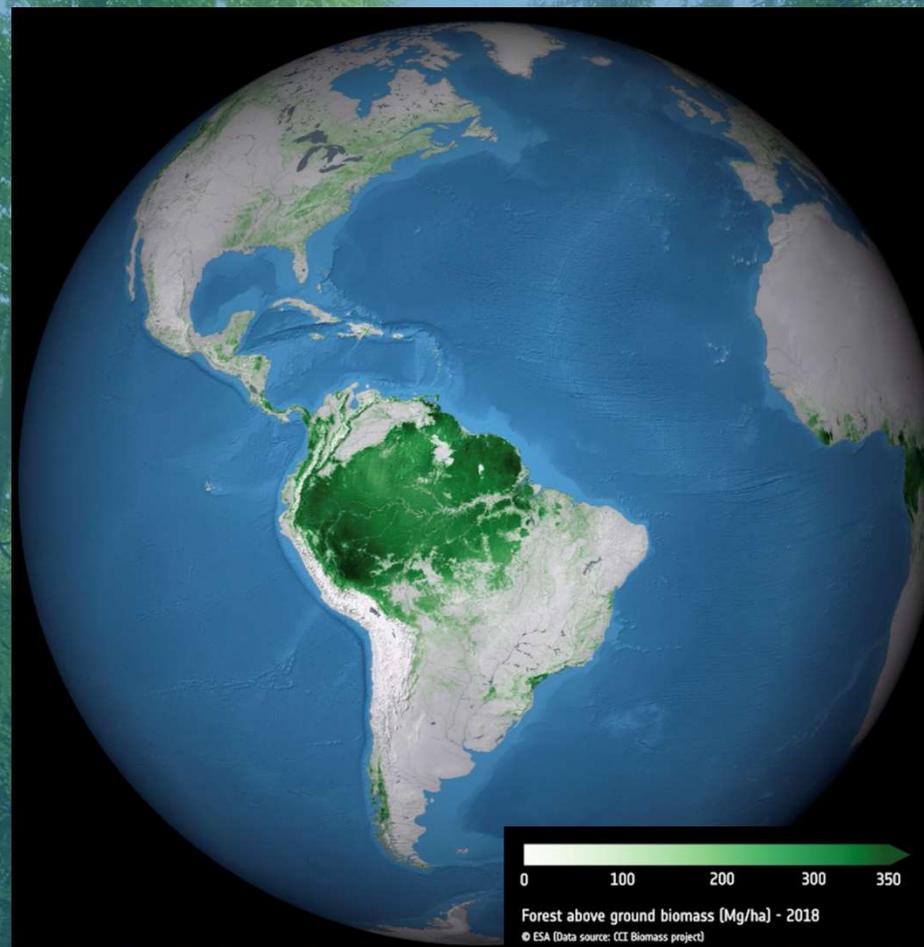
- Christin Abel: *Response and resistance of global tropical drylands to increasing aridity*
- Nicolas Labriere: *Carbon emissions and uptake from vegetation change in the tropics*



biomass
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*Qin, Y., Xiao, X., Wigneron, JP. *et al.* Carbon loss from forest degradation exceeds that from deforestation in the Brazilian Amazon. *Nat. Clim. Chang.* **11**, 442-448 (2021). <https://doi.org/10.1038/s41558-021-01026-5>

https://www.esa.int/Applications/Observing_the_Earth/Space_for_our_climate/Forest_degradation_primary_driver_of_carbon_loss_in_the_Brazilian_Amazon



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→ FIRE

25%-35% of GHG result from biomass burning

Fire_CCI key variable is "burned area"

2 global products

- *Pixel products: date of detection, confidence level, land cover*
- *Grid product: sum of burned area, standard error, fraction of burnable area, fraction of observed area, number of patches, and sum of burned area for each land cover*

Small Fire Database over Sub-Saharan Africa, demonstrator over the Amazon, several products under development



Product name*	Data	Period	Spatial resolution	Domain
FireCCI51	MODIS	2001-2020	250m 0.25°	Global
FireCCISFS11/20	Sentinel-2	2016 2019	20m & 0.25° 20m & 0.05°	Sub-Saharan Africa
FireCCILT11	AVHRR-LTDR	1982-2018	0.25°	Global
FireCCS1SA10	Sentinel-1	2017	40m	Demonstrator Area in the Amazon
Case Study	Sentinel-1	El Niño 2015-2016	~ 10m at the Equator	Indonesia

Products currently under development*
Global product based on Sentinel-3 SYN data for 2019-2020
Test sites in Africa based on Sentinel-1 and a combination of S1 & S2 data for 2019
Global products based on merged reflectance or merged burned area outputs

* <https://climate.esa.int/en/projects/fire/data/>

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→ FIRE

Importance of small fires and their carbon emission

- Over Africa 90% more small fires (<100 ha) were detected with Sentinel 2 than with MODIS in 2016
- Contribute to 2.02 million km² of the 4.89 million km² total burned area detected

Corresponding Fire C emission estimated are 1.44 PgC

- 31-101% higher than previously thought
- 14% of global C emission from FF burning

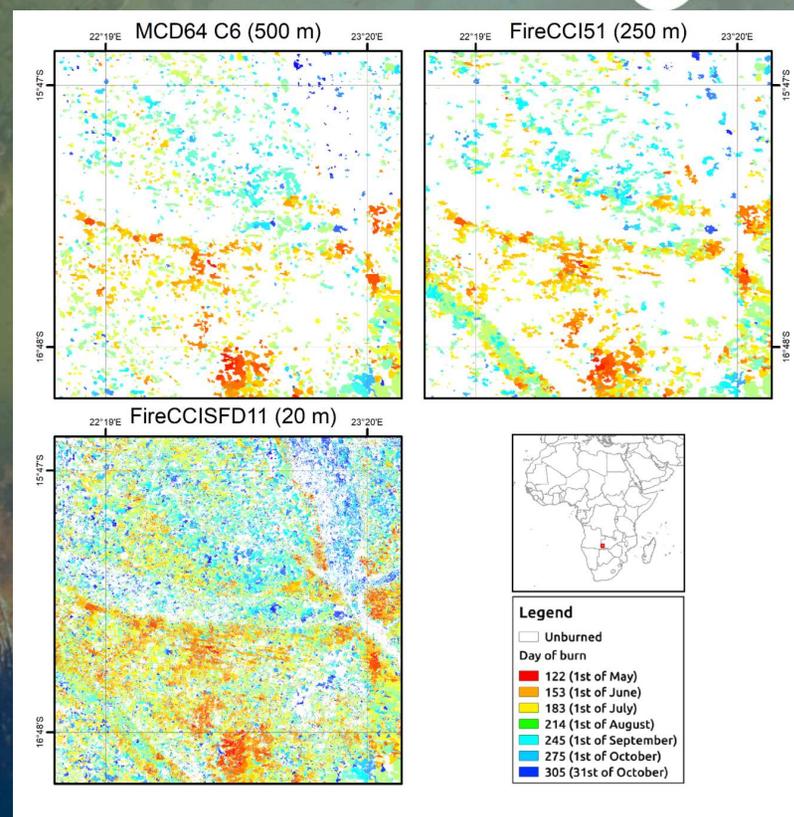
Critical driver of BA in Sub-Saharan Africa

- Raises the contribution of biomass burning to global GHG and aerosols



fire
cci

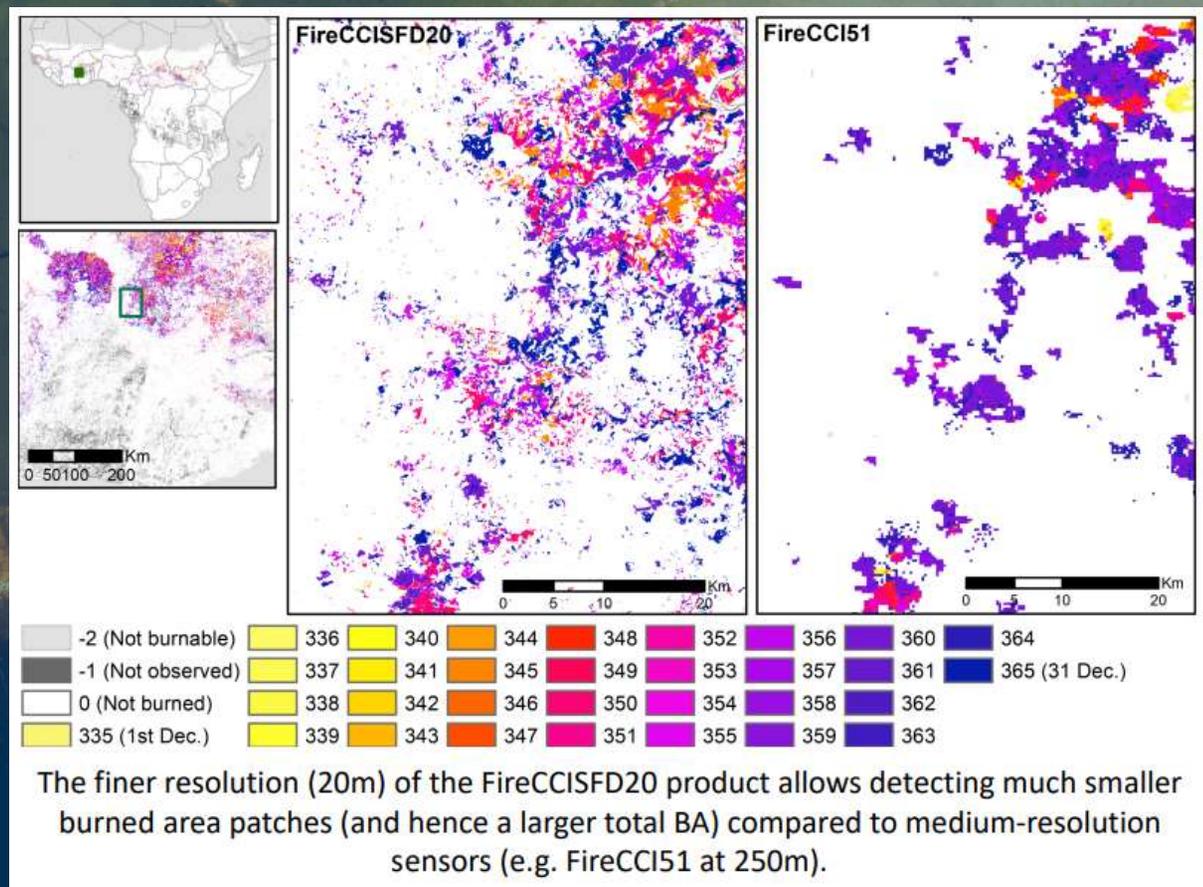
Ramo, R., et al: **African burned area and fire carbon emissions are strongly impacted by small fires undetected by coarse resolution satellite data**, Proceedings of the National Academy of Sciences Mar 2021, 118 (9) e2011160118; DOI: 10.1073/pnas.2011160118



The finer resolution (20m) of the FireCCISFD11 product allows detecting much smaller burned area patches (and hence a larger total BA) compared to medium-resolution sensors (e.g. FireCCI51 at 250m)

climate change initiative

→ FIRE

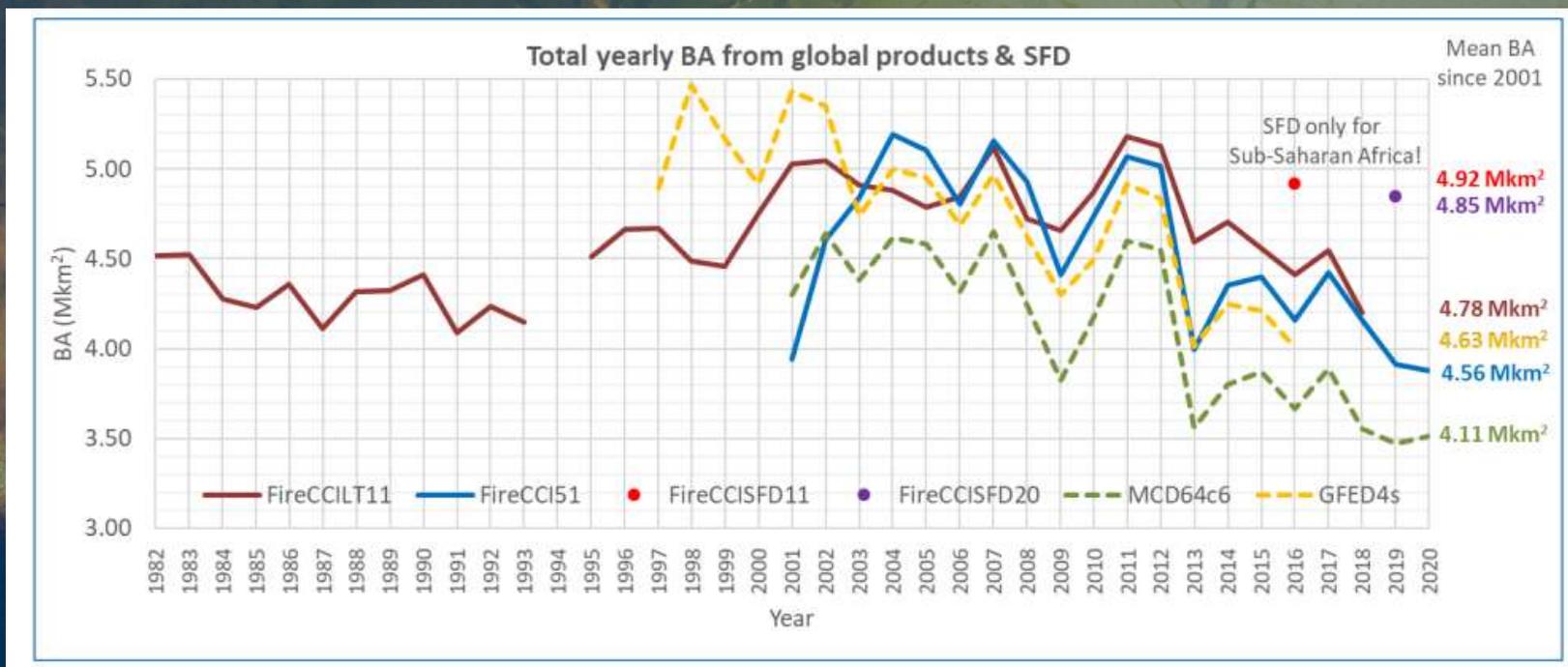


The finer resolution (20m) of the FireCCISFD20 product allows detecting much smaller burned area patches (and hence a larger total BA) compared to medium-resolution sensors (e.g. FireCCI51 at 250m).



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→ FIRE



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→ LAND SURFACE TEMPERATURE

LST is an important variable within the Earth climate system

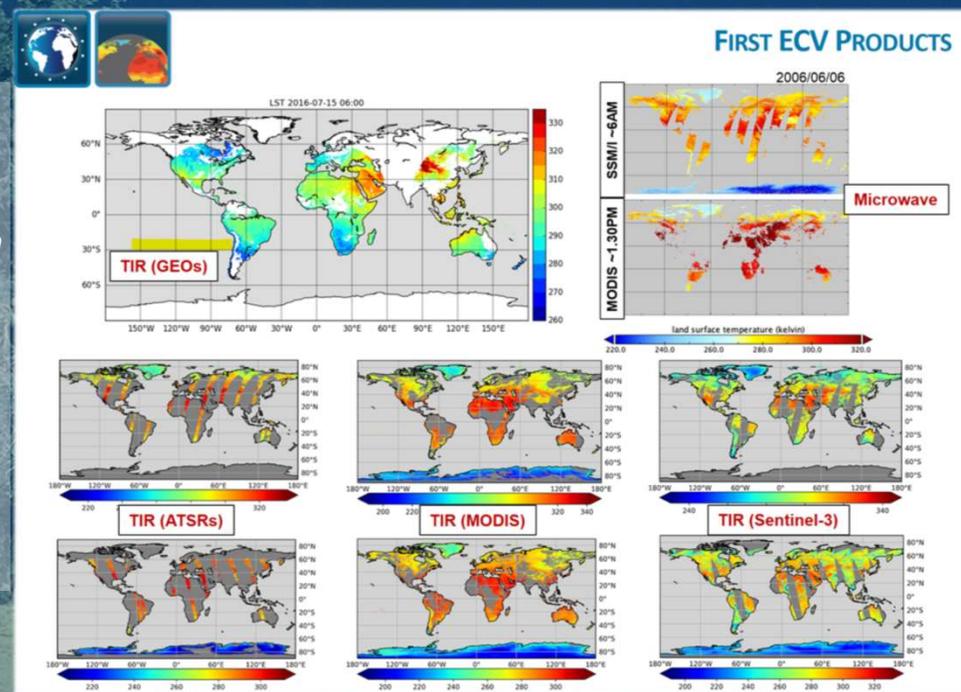
- Evaluation land surface-atmosphere exchange processes
- Valuable metric of surface state
- Useful to constrain estimates of terrestrial carbon uptake through data assimilation in ESM

LST_CCI: Provide an accurate view over the past 20-25 years (ATSR_2, AATSR, MODIS, Sentinel-3A, SEVIRI SSM/I, ATSR CDR)

User case study: The role of LST characteristics in the data-driven simulation of terrestrial carbon fluxes



land surface temperature cci



climate change initiative

→ PERMAFROST

Develop and deliver permafrost maps as ECV products

→ *Depth of active layer, Permafrost temperature, Rock glacier kinematics*

Permafrost model that compute the ground thermal regime constrained by EOs such as LST, SWE, Land Cover

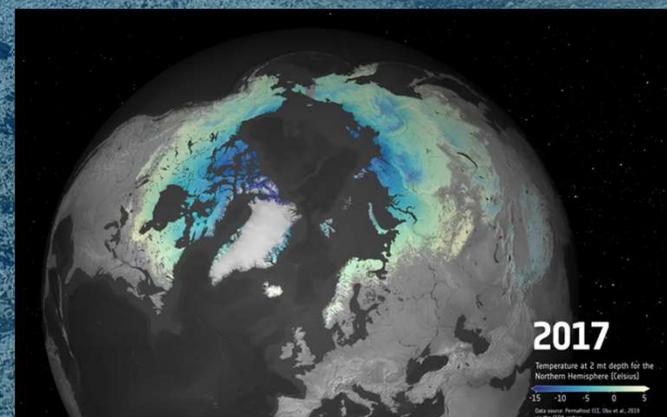
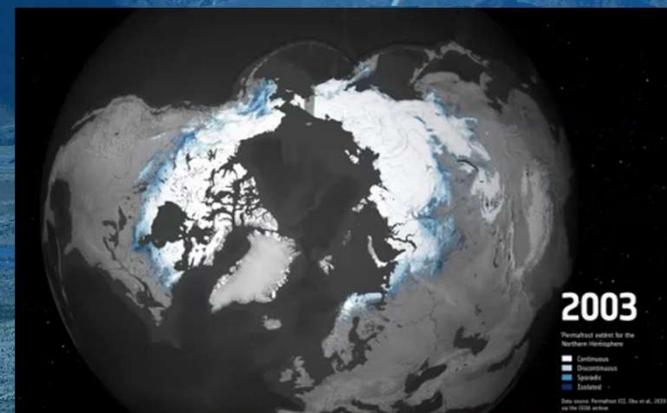
→ *Strong link to other ESA projects*

21-year satellite-derived record detailing the annual changes to the northern hemisphere permafrost soils from 1997-2018

→ *longest satellite permafrost record currently available*



**permafrost
cci**



climate change initiative

→ PERMAFROST

Tracking the loss of permafrost using satellite data

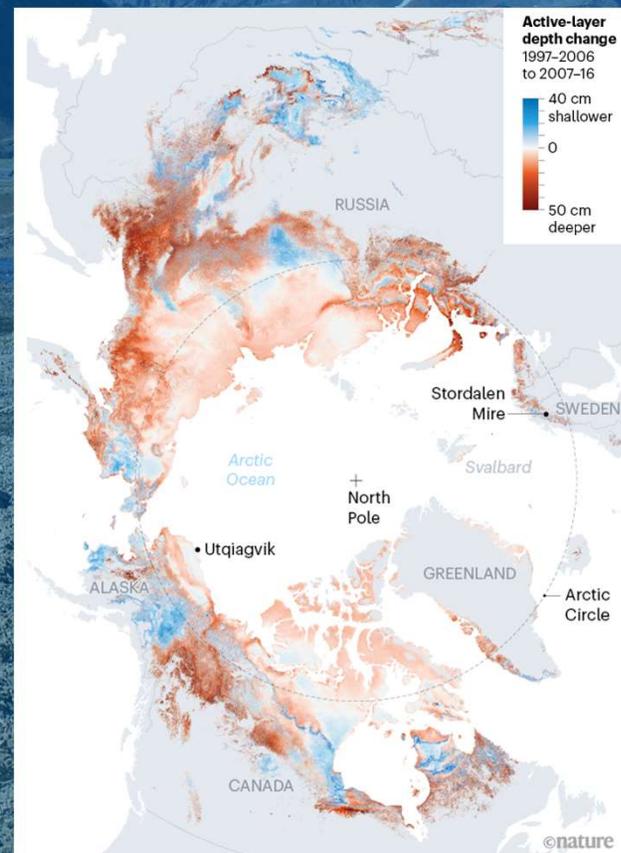
North Hemisphere active layer thickness deepened by 2.5cm (2007-2016) compared to previous decade, 5% NH area by 30cm

- Destabilizes the landscape
- Makes more carbon available to microbes in the soil, producing carbon dioxide and methane



permafrost
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‘How microbes in permafrost could trigger a massive carbon bomb’



Data from Permafrost CCI: Obu et al.

Nature 591, 360-362 (2021)

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land cover
cci



high resolution
land cover
cci



greenhouse
gases
cci



lakes
cci

LU & LCC are crucial to support GST

→ Role of land for storing carbon and its future potential for offsetting carbon emissions

*LC: series of annual maps, 300 m, 1992-2019,
Consistent analysis-ready annual PFT maps for climate modelling

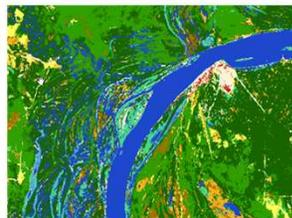
HRLC: static map at subcontinental level at 10m, long-term record of regional maps at 30m in the sub-regions every 5 years (change information yearly)

2015 ESA CCI MRLC at 300m

Sentinel-2 image

2019 ESA CCI HRLC map

Amazonia
(tile 21KUQ)





land cover
cci



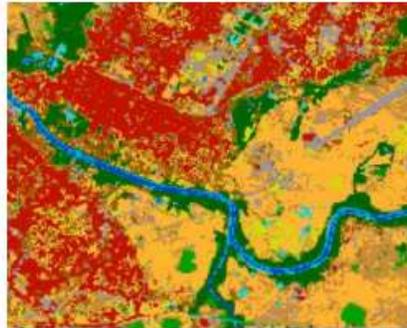
high resolution
land cover
cci



- Tree cover broadleaved
- Tree cover deciduous
- Shrub or herbaceous cover flooded
- Mosaic tree and shrub
- Shrub or herbaceous cover flooded
- Mosaic herbaceous cover
- Mosaic natural vegetation
- Grassland
- Cropland
- Urban areas
- Water bodies



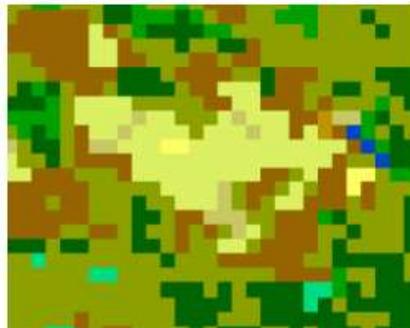
CCI medium resolution



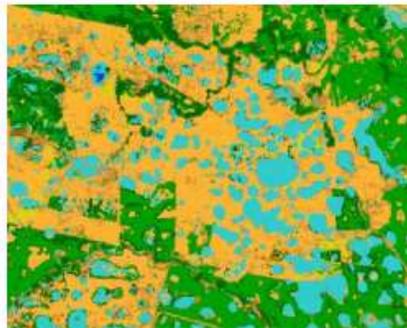
CCI high resolution



Google Image



CCI medium resolution



CCI high resolution



Google Image

- Evergreen broadleaved
- Deciduous broadleaved
- Shrub or herbaceous cover flooded
- Mosaic tree and shrub
- Shrub or herbaceous cover flooded
- Mosaic herbaceous cover
- Mosaic natural vegetation
- Grassland
- Cropland
- Herbaceous vegetation aquatic or regularly flooded
- Bare areas
- Build up
- Open water seasonal
- Open water permanent



ESA CCI in support of Terrestrial Carbon science



land cover
cci



high resolution
land cover
cci



greenhouse
gases
cci



lakes
cci

LU & LCC are crucial to support GST

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*Further develop retrieval algorithms needed to generate new high quality satellite-derived CO₂ and NH₄ atmospheric data products

→ column-averaged dry-air mole fractions (molecular mixing ratios) of CO₂ and CH₄

2015 ESA CCI MRLC at 300m

Sentinel-2 image

2019 ESA CCI HRLC map

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ESA CCI in support of Terrestrial Carbon science



land cover
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high resolution
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greenhouse
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LU & LCC are crucial to support GST

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→ column-averaged dry-air mole fractions (molecular mixing ratios) of CO₂ and CH₄

(See also presentation from C. Retscher 23/06/2020)

Lake Water Level*, Lake Water Extent, Lake Surface Water temperature*, Lake Ice Cover and Lake Water-Leaving Reflectance

→ Several user cases studies (incl. brownification in Scandinavian Lakes)

→ Potential to investigate methane emission from Lakes

2015 ESA CCI MRLC at 300m

Sentinel-2 image

2019 ESA CCI HRLC map

Amazonia
(tile 21KUQ)



ESA CCI RECCAP2 Cross-ECV project



reccap-2
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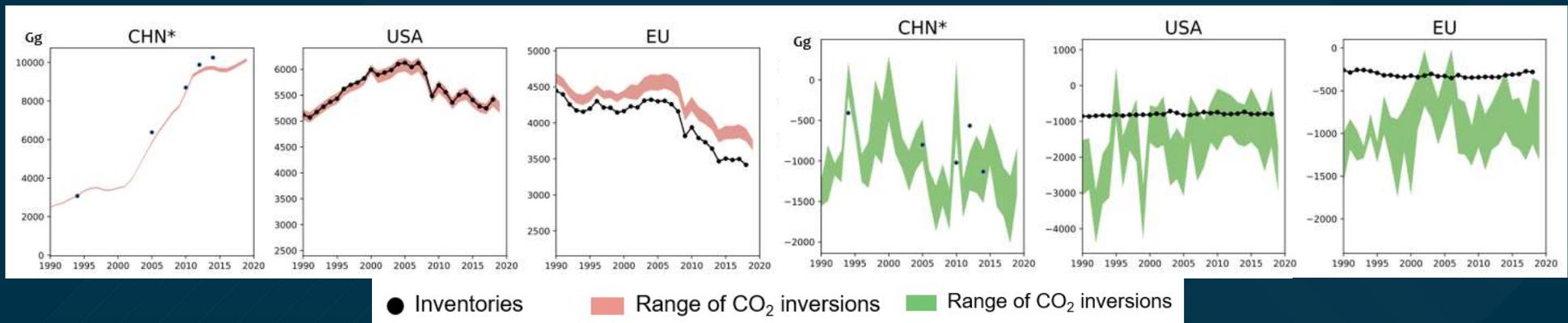
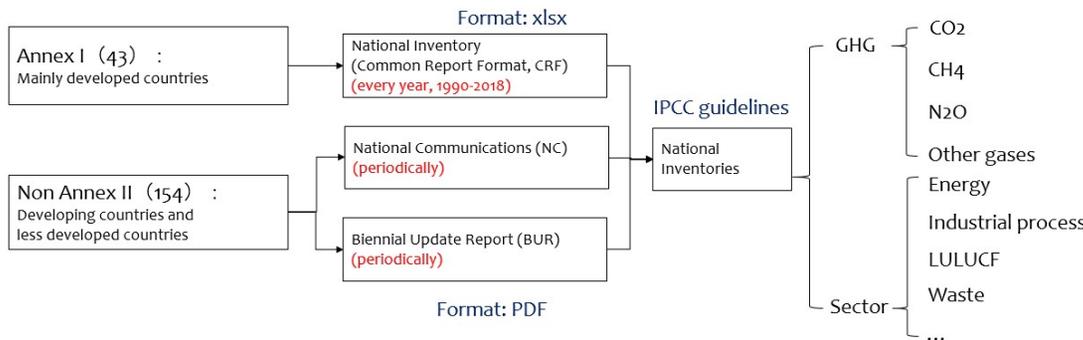
- (i) Evaluate the feasibility of producing at least every two years updated estimates of **GHG balance (natural and anthropogenic) at country level** constrained by EO data using ensembles of top-down atmospheric inversions and bottom-up land surface models.
- (ii) Improve the **consistency** between estimates of total greenhouse budgets produced in (i) against **official estimates of national anthropogenic emissions and land sinks** reported by countries to the UNFCCC as national communications, annually for Annex 1 countries and bi-annually for non-Annex 1 countries.
- (iii) To promote a dialogue with national inventory agencies to identify the largest **sources of uncertainty** in inventories and how the **uncertainty provided by ESA-CCI datasets can support uncertainty estimation**.
- (iv) To scope the information that could be delivered by EO data products and priority requirements for data products that would help to **improve/support national inventories**.



ESA CCI RECCAP2 Cross-ECV project



reccap-2
cci

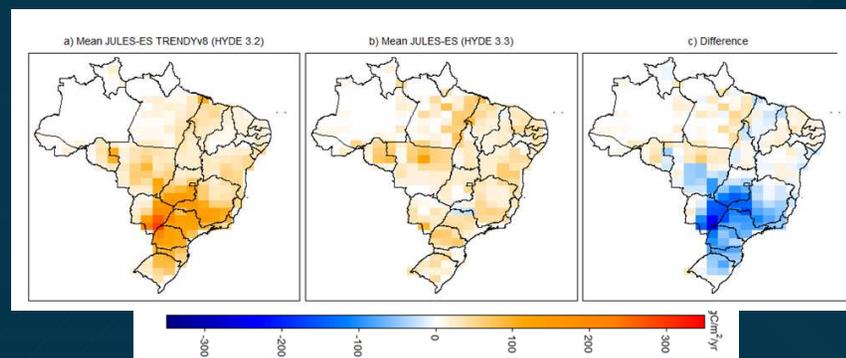
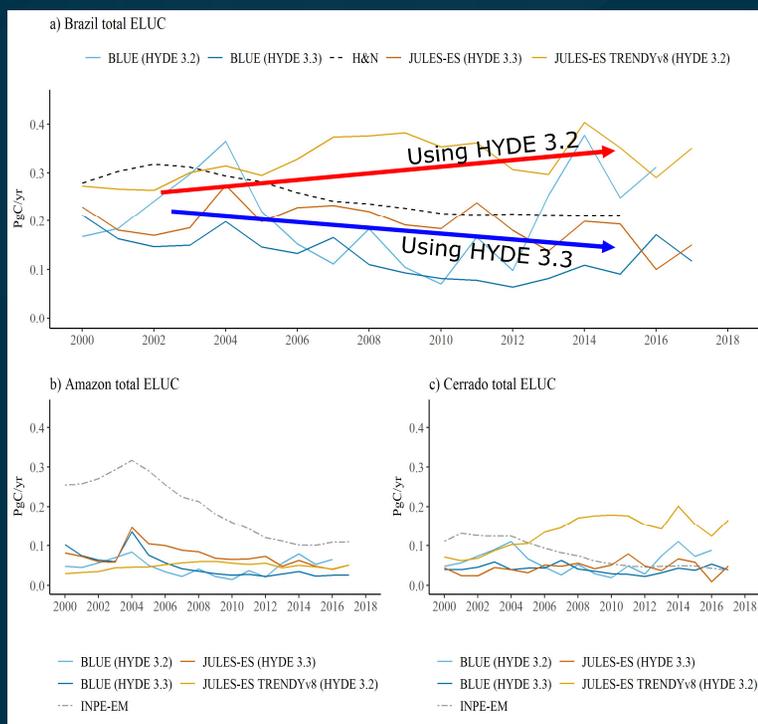


Monitoring Land Use Change CO₂ emission (ELUC) using EO

Simulate ELUC over Brazil using DGVM and book-keeping approach with

- HYDE3.3 a land use data based on new FAO inventory estimates and based on *multi-annual ESA CCI land cover maps*
- HYDE3.2 based on land cover from 2010

- HYDE3.3 permits to simulate a declining ELUC trend over Brazil when applied as an input to a global book-keeping model (BLUE) and a process-based Dynamic Global Vegetation Model (JULES)
- ➔ Good agreement with in-country and other global estimates (H&N), unlike the use of HYDE 3.2



- Spatially, the main differences between the ELUC simulations are in the southeast of Brazil and the arc of deforestation in Amazonia

Aerosols released from Australian bushfires triggers algal blooms



EXTREME BURNING

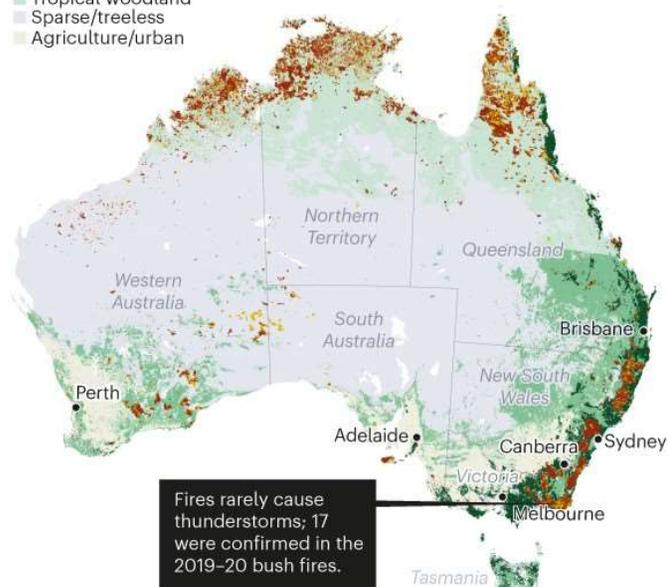
The 2019-20 Australian bush fires destroyed millions of hectares of vegetation. The geographic extent was so immense that it exposed the nation's fire monitoring system as a thing of the past. Because individual states and territories record bush fires in different ways, there are data gaps and inconsistencies that make it difficult to accurately assess the fires' scale and environmental impact.

Land type

- Forest
- Temperate woodland
- Tropical woodland
- Sparse/treeless
- Agriculture/urban

Area burnt (2019-20)

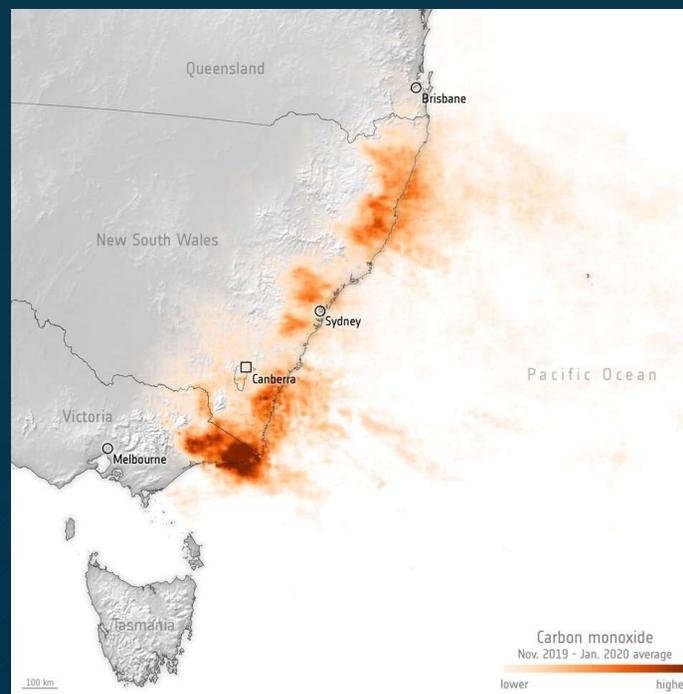
- Satellite estimate (30.38 million hectares)
- Government estimate (39.8 million hectares)



Fires rarely cause thunderstorms; 17 were confirmed in the 2019-20 bush fires.

<https://doi.org/10.1038/d41586-020-02306-4>

- Satellite fire data and modelled quantities of standing biomass : 275 million tonnes of carbon dioxide
- Calculated from TROPOMI: 715 million tonnes



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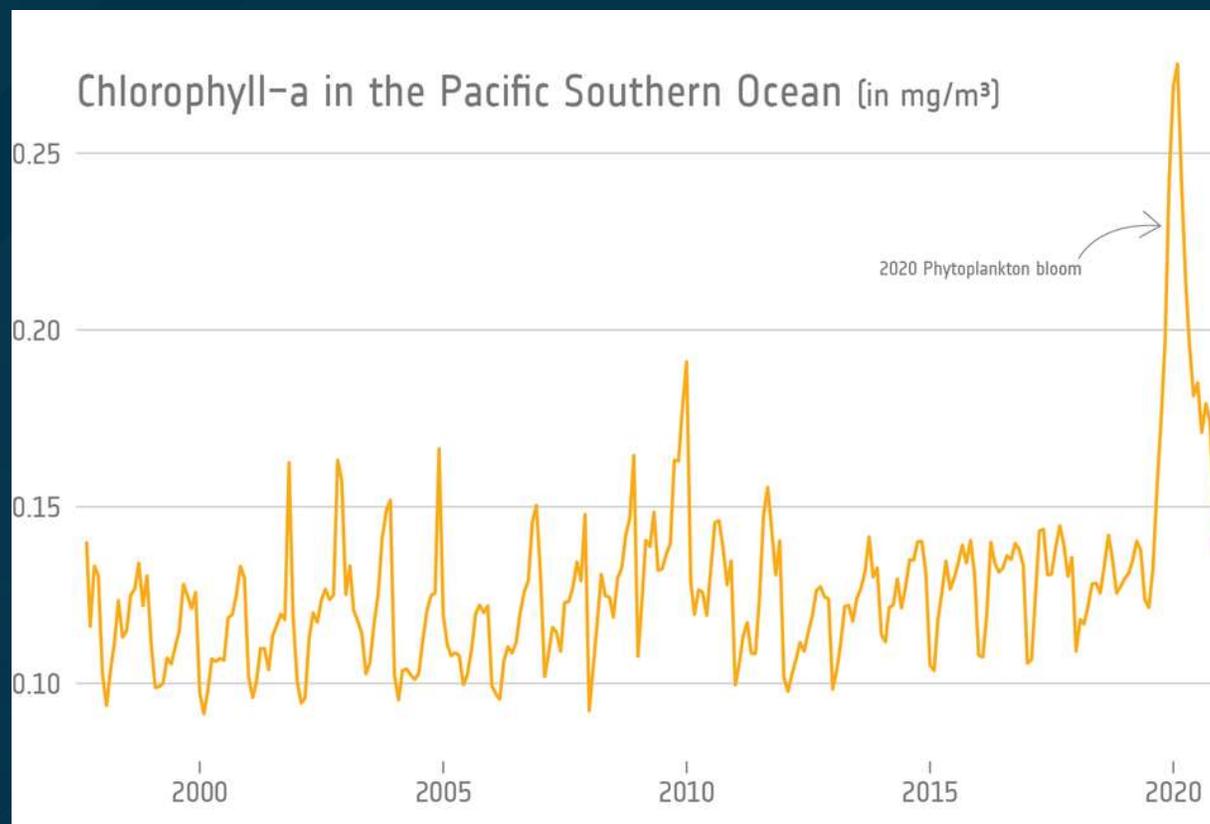


Aerosols released from Australian bushfires triggers algal blooms

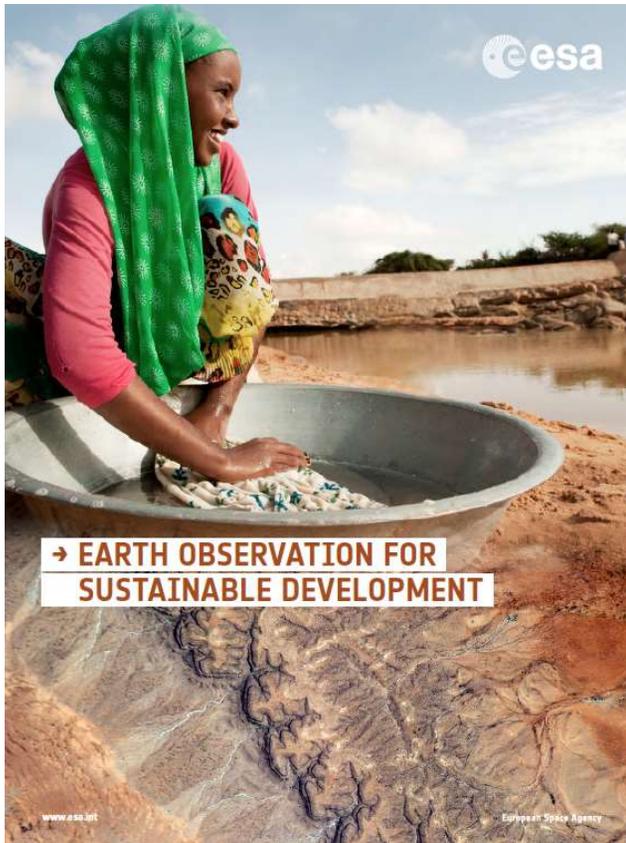


Vast plumes of smoke which are rich in nutrients, were swept away over the ocean

These aerosols had infused the waters with iron, nourishing phytoplankton which then absorbed carbon dioxide equivalent to as much as 95% of the emissions from the fires



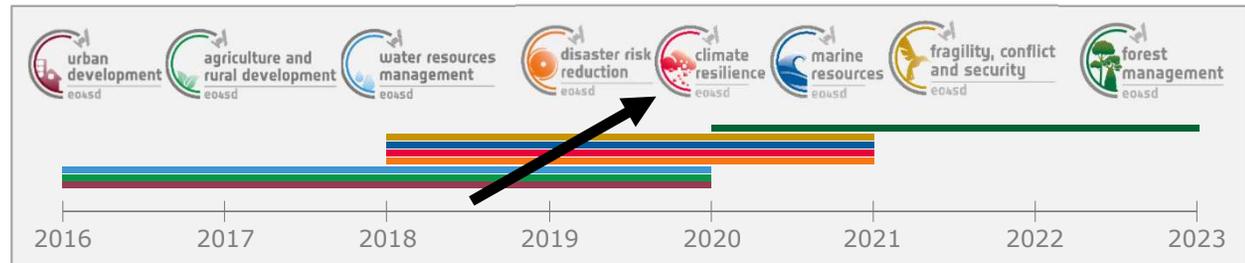
ESA EO programs in support of Intl. Development



- **eoworld:** 2008-15
Small-scale **demonstrations of EO services** in support of IFI projects to raise awareness



- **EO4SD:** 2016-23
Consolidate requirements, engage stakeholders (IFIs & client states) via regional demonstrations of EO



- **GDA:** 2020-25 | **Space for IDA**
Mainstream & transfer EO into operational working processes & financing of ODA/development aid as 'best-practice' source of geo-information



A circular satellite image showing a large river delta with a complex network of channels and floodplains, surrounded by green vegetation and brownish terrain. The image is set against a teal background.

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<https://climate.esa.int/>