L-band observations from space: new observations linking the Water and Carbon cycles

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(3) Globeo, Toulouse, France

ESA 4th Carbon from Space 2022

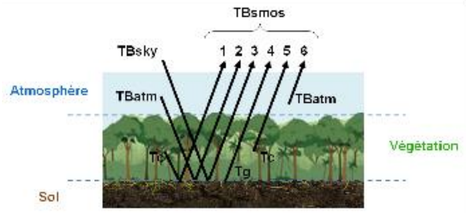
SMOS soil moisture and vegetation optical depth

- **Passive microwaves sensors measure the thermal emission from the Earth, which at these frequencies depends mainly of soil moisture and temperature**
- **The radiation is affected by the vegetation water content and structure creating a vegetation optical depth (VOD)**

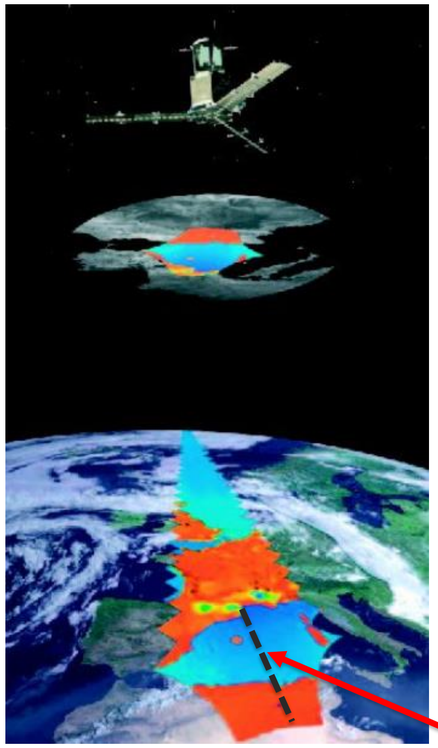
The Vegetation Optical Depth (τ), is frequency dependent

X band λ= 3 cm | L band λ= 21 cm | P band λ= 70 cm | VHF λ>3 m

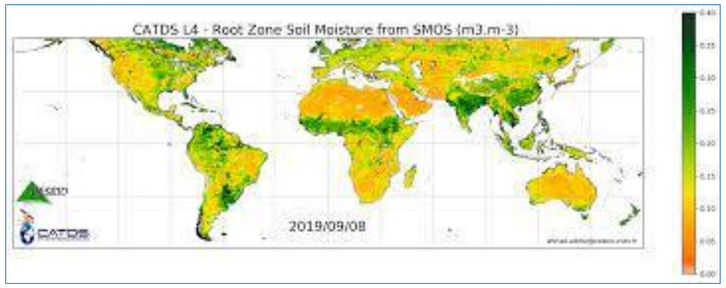
©Biomass, Thuy Le Toan

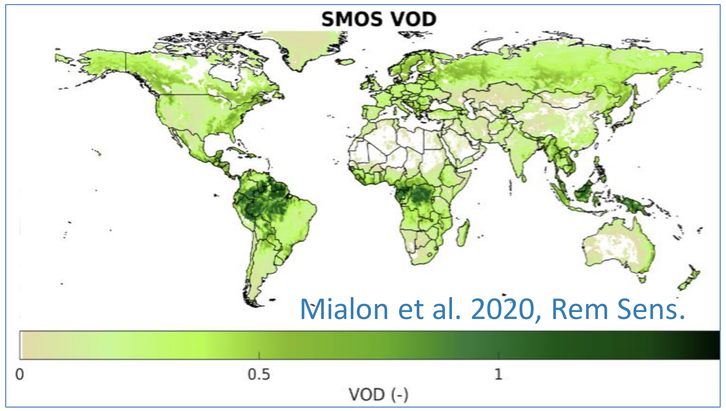


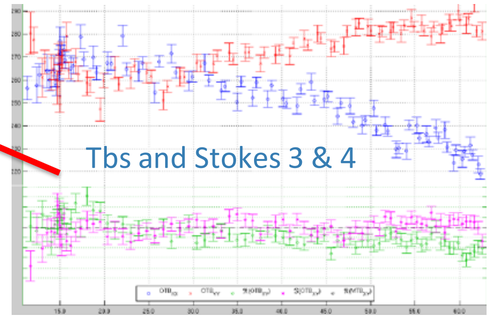
Kerr et al. (2012. TGARS)



Multi-incidence angle observations







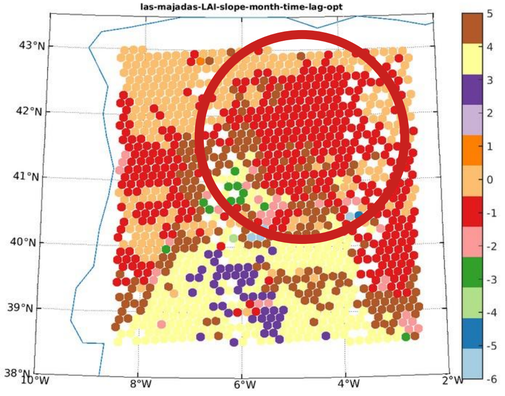
10º Incidence angle 60º

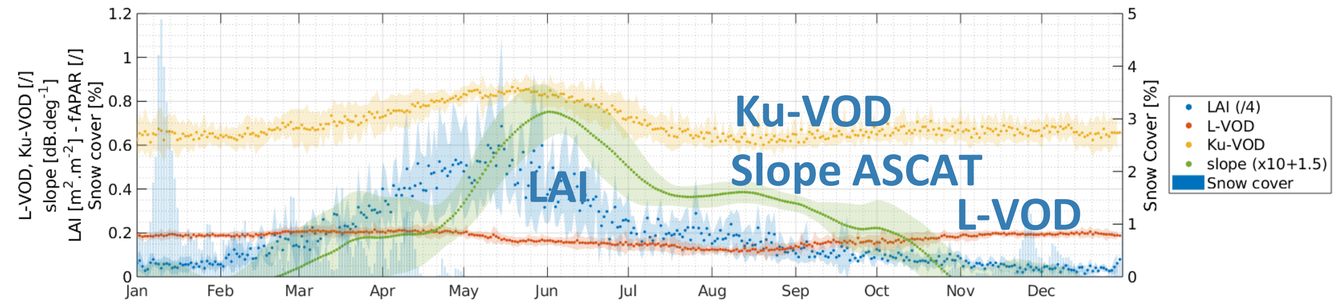
LAI, SMOS L-VOD, AMSR2 Ku-VOD, ASCAT slope

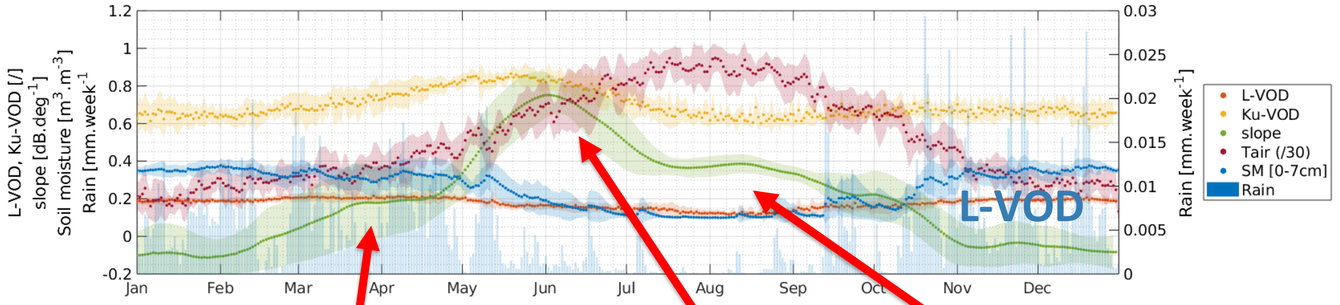
Land Carbon Constellation project esa

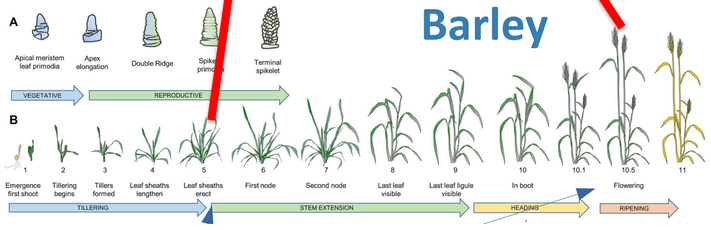
LM 103 px > 90% croplands

See **Segarra et al., 2020** for wheat phenological stages in the region









Wheat, Barley

Rye, Maize, artifact ?

Crops
Relative surface

Barley	12
Wheat	9
Rye	9
Peas	4.7
Natural veg	3.4
Grasslands	3
Maize	2.5
…	

- LAI cycle shorter than Ku-VOD and ASCAT-slope
- ASCAT-slope second peak at the end of the summer…
- Low amplitude cycle of L-VOD. Could be more related to water availability than to crops cycles

Pique et al. (in prep)

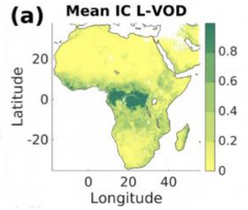
CESBIO GlobEO Global Earth Observation Cerema CLIMAT & TERRITOIRES DE DEMAIN

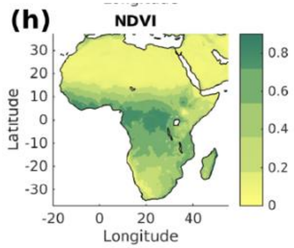
High sensitivity of L-VOD to AGB

SMOS + Veg
esa stse
support to science element

2011-2012 average

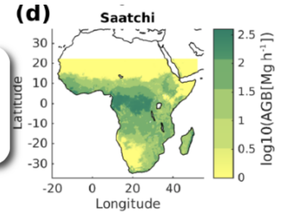
SMOS L-VOD
INRA-CESBIO (IC)
Fernandez-Moran et al.,
Rem. Sensing 2017

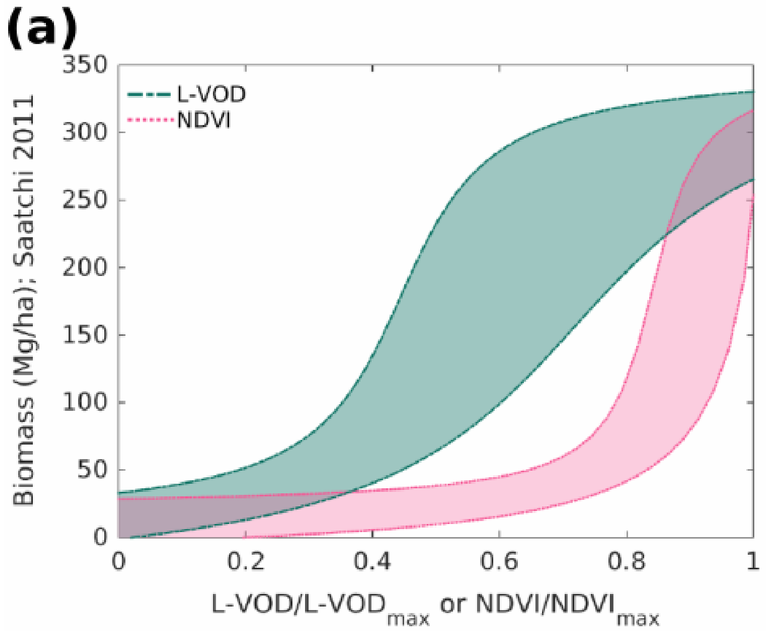


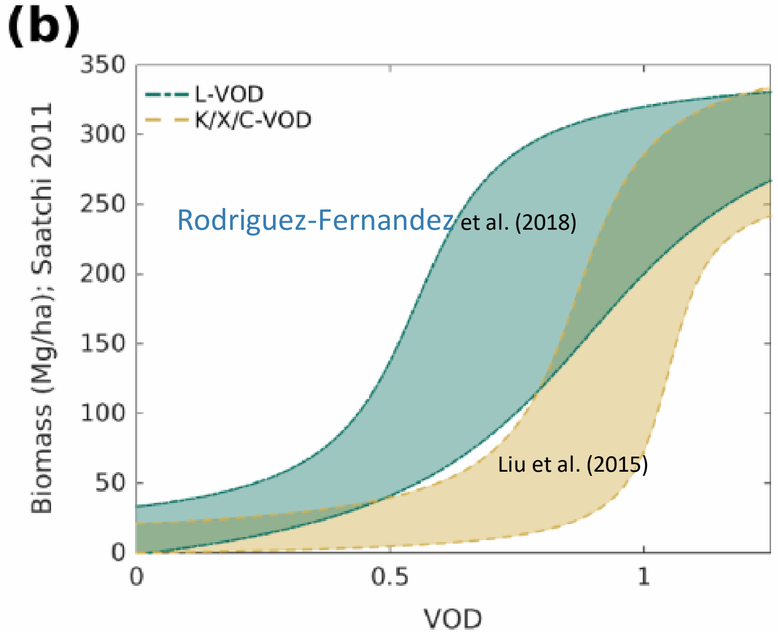


MODIS

Lidar, C-band
SAR, in situ
plots
Circa 2000





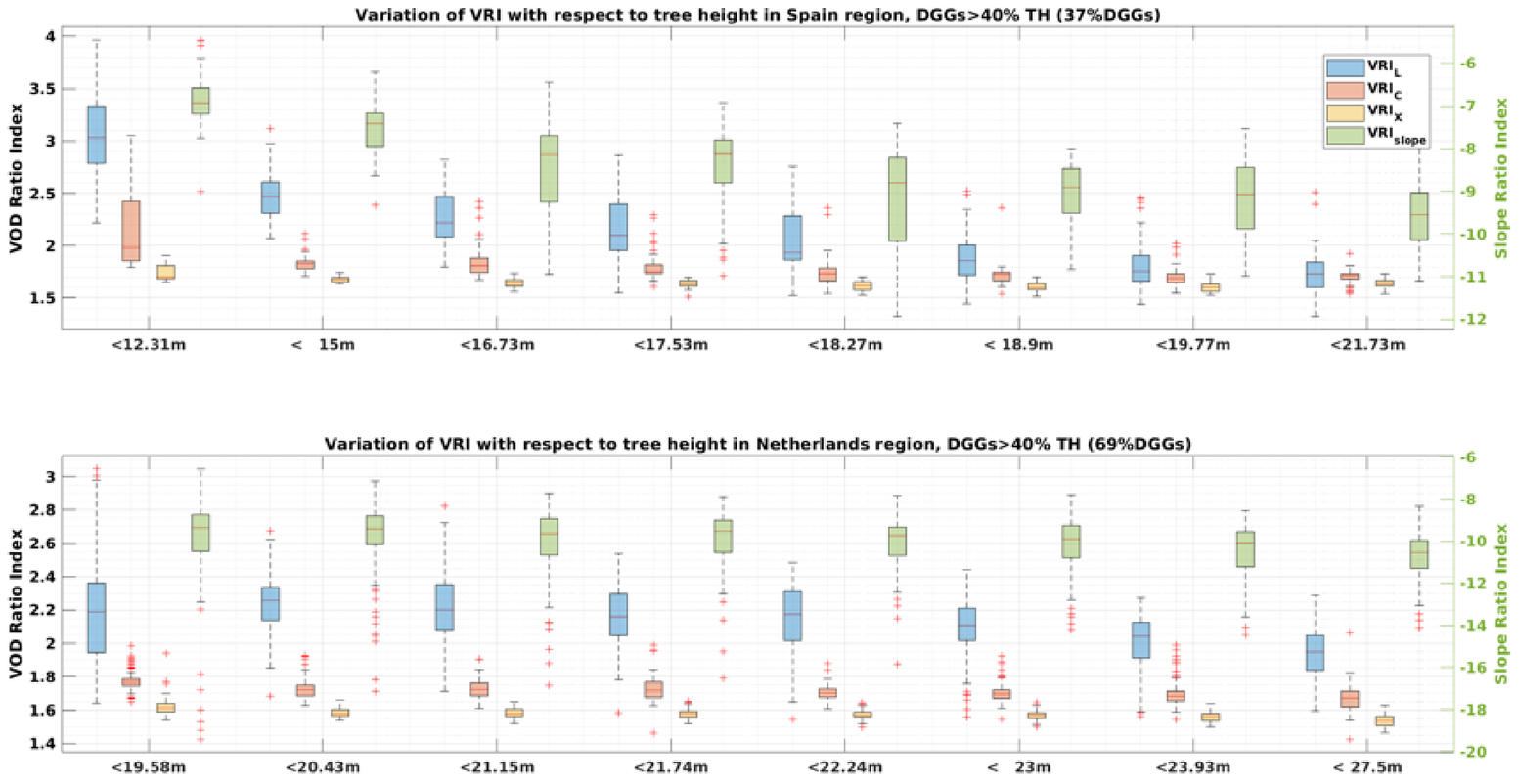


Rodriguez-Fernandez et al. (2018, Biogeosciences)

$$AGB = \frac{a}{(1 + exp(-b\,(vod - c)))} + d,$$

CESBIO GlobEO Global Earth Observation Cerema CLIMAT & TERRITOIRES DE DEMAIN

VOD ratios versus tree height

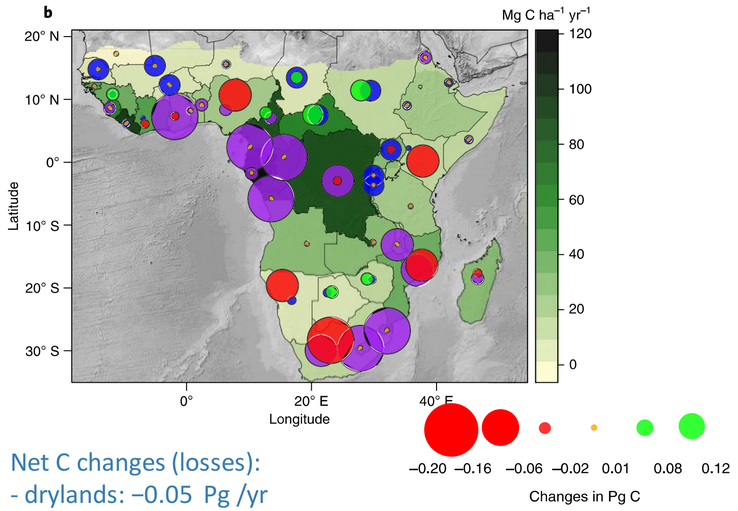


Pique et al. (in prep)

- The ratio VOD-x / VOD-ku almost constant: both X and Ku bands are sensitive to the most superficial layer of vegetation.
- The ratio VOD-L / VOD-ku is more dynamic with Three Height: measurements in L-Band provide information of different vegetation layers (at least under TH < 21 m)
- Trends confirmed by complex permittivity model. (Schwank et al. (in prep))

Using a spatial correlation to infer the temporal behavior…

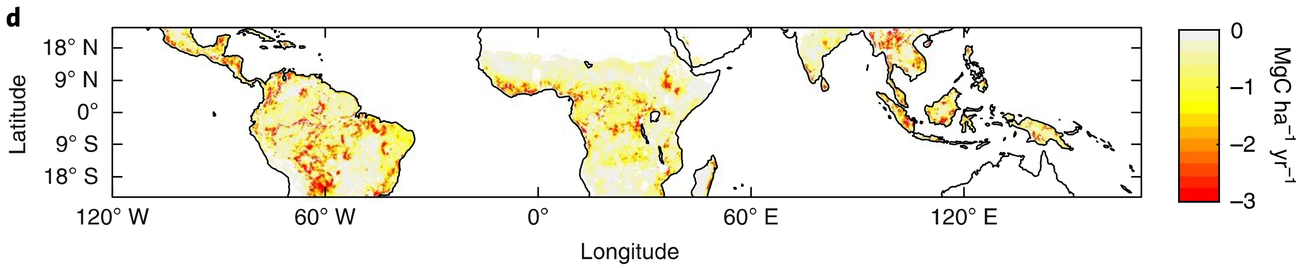
Brandt et al. , 2018, *Nature Ecology Evolution*



Net C changes (losses):
- drylands: −0.05 Pg /yr
- Humid areas −0.02 Pg /yr

Drylands showed a share of the total pool of African carbon stocks of 20% in L-VOD but only 6% in LPJ-GUESS and 8% in ORCHIDEE-MICT

C losses 2010-2016, Fan et al., 2019*, Nature Plants*

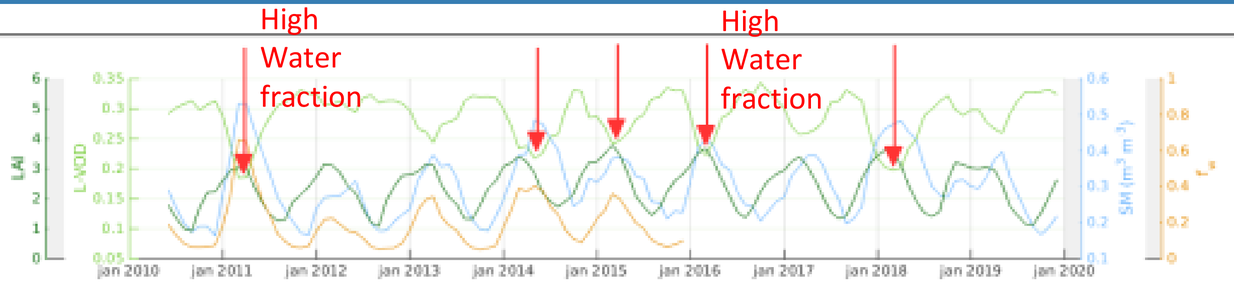


The aboveground carbon changes estimated by VOD in the tropical region during 2010-2016 indicate the tropical region acts as a net carbon source of 0.11 Pg/yr during 2010-2016. The declines in tropical aboveground carbon were found mainly in eastern America, African drylands and Indonesia.

Brandt et al. 2018, **Satellite-Observed Major Greening and Biomass Increase in South China Karst During Recent Decade,** *Earth's future.*
Brandt et al. 2018, **Satellite passive microwaves reveal recent climate-induced carbon losses in African drylands**, *Nature Ecology and Evolution*
Bastos et al. 2018, **Impact of the 2015/2016 El Niño on the terrestrial carbon cycle constrained by bottom-up and top-down approaches,** *Phil. Trans. of the Royal Society B*
Fan et al. 2019, **Satellite-observed pantropical carbon dynamics**, Nature Plants
…
Wigneron et al., 2020, **Tropical forests did not recover from the strong 2015–2016 El Niño event,** Science Advances
Qin et al. 2021, **Carbon loss from forest degradation exceeds that from deforestation in the Brazilian Amazon,** *Nature Climate Change*
…

VOD and AGB: Effect of inundated areas

Time series over seasonally inundated areas:
anomalous decrease of L-VOD during floods.



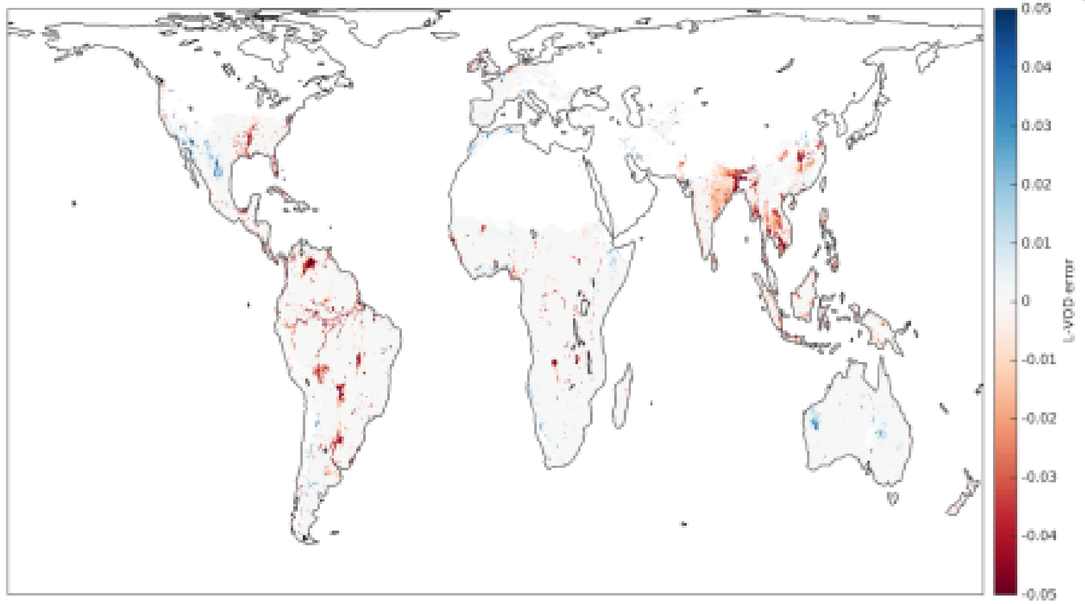
Time series of LAI, L-VOD, Soil Moisture, and water fraction over the Pantanal wetland (South America).

Modelling experiment in order to understand the impact of dynamic surface water on L-VOD retrieval.

Results :

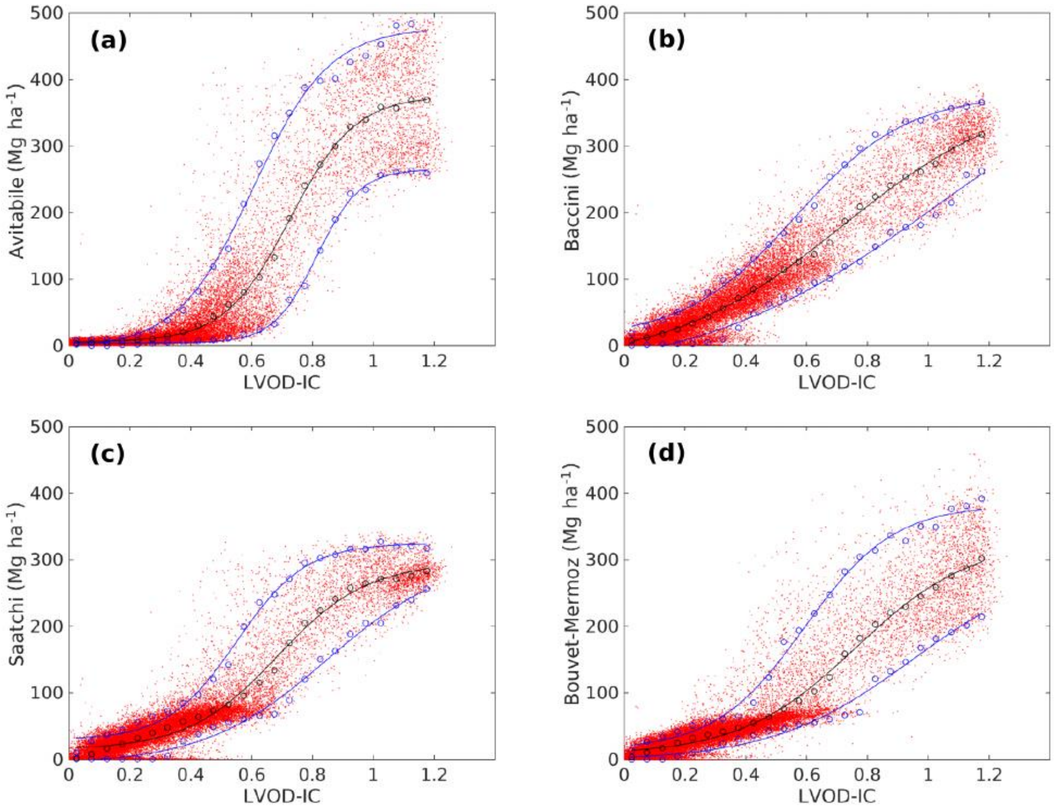
- L-VOD is underestimated during floods, by ~10 % over flooded forests, up to 100 % over flooded grasslands.
- L-VOD/AGB relationship : AGB is also underestimated, by 15/20 Mg ha^{-1} and up to 50 Mg ha^{-1} temporarily.

Bousquet et al. (2021, RSE)



Computation of the yearly mean L-VOD error at the global scale due to floods.

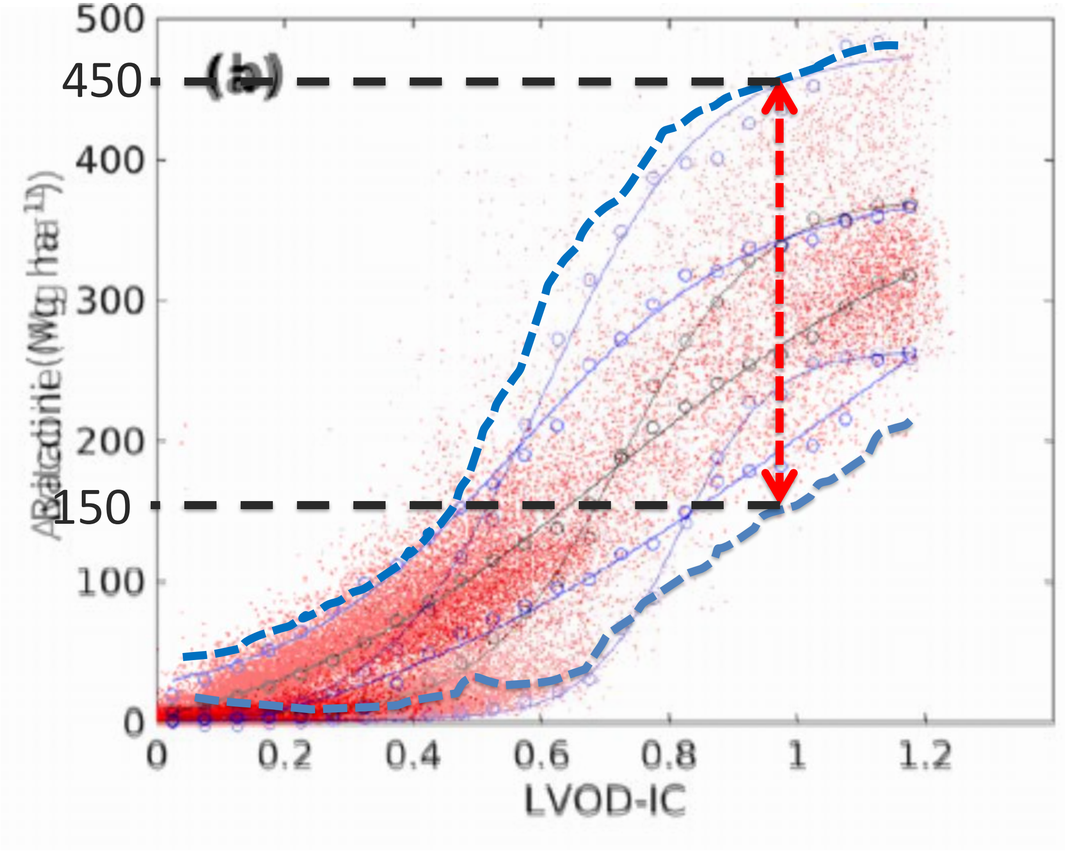
VOD and AGB: uncertainties



Rodriguez-Fernandez et al. (2018, Biogeosciences)

- AGB maps used as reference have many uncertainties, including those using currently available SAR data, which saturates in dense forest
  a) Avitabile.
  b) Baccini.
  c) Saatchi.
  d) Bouvet-Mermoz.
- Which one to chose ?
- How to take into account the large dispersion ?
- What period should be used to compute the relationship ?

VOD and AGB: uncertainties



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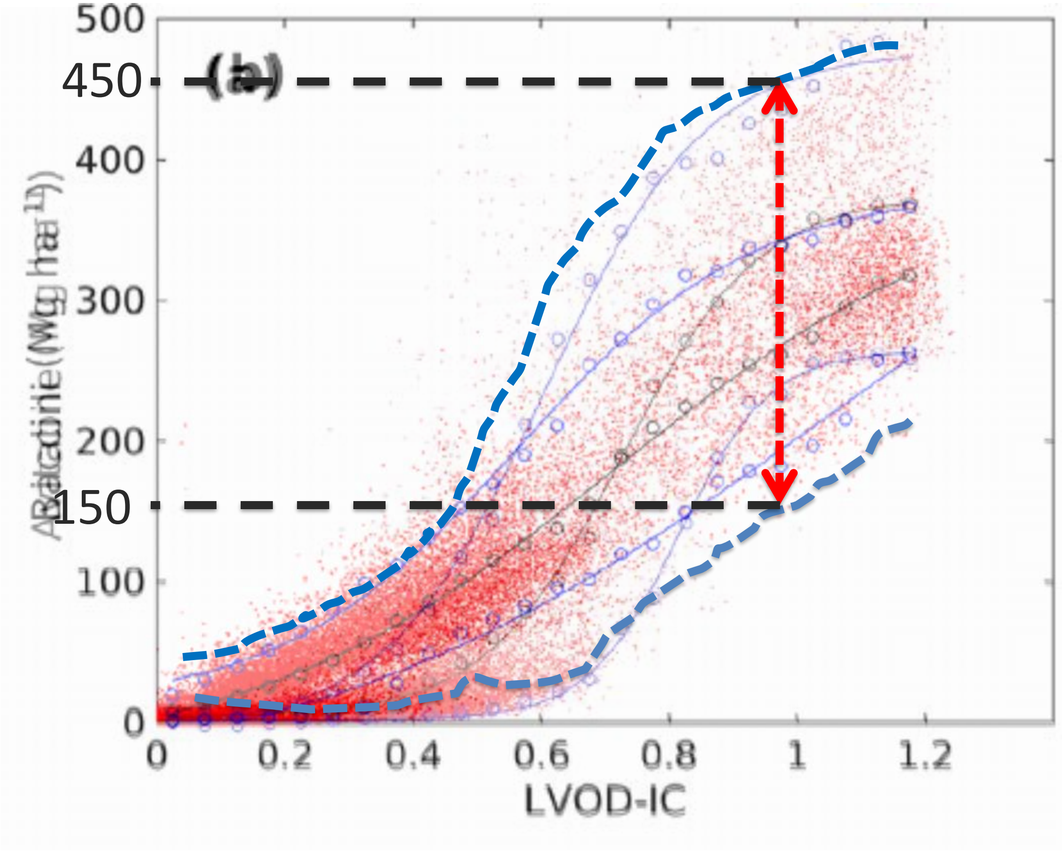

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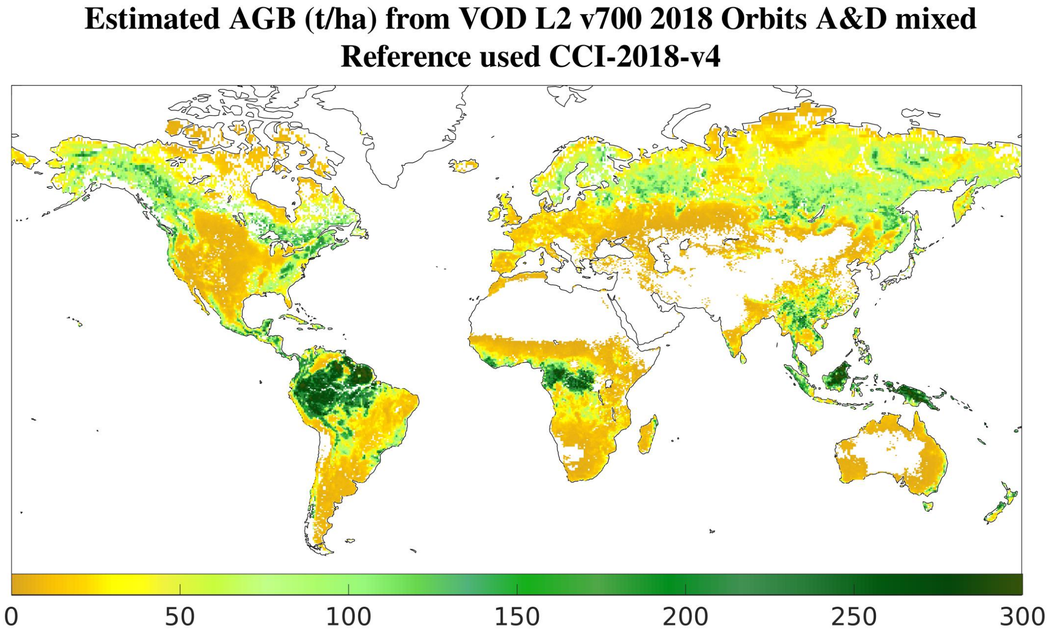
Interannual Variations of Vegetation Optical Depth are Due to Both Water Stress and Biomass Changes

Alexandra G. Konings[1], Nataniel M. Holtzman[1], Krishna Rao[1], Liang Xu[2], and Sassan S. Saatchi[3]

Geophysical Research Letters

RESEARCH LETTER
10.1029/2021GL095267

VOD and AGB: uncertainties



- **Yearly AGB maps from VOD maps with respect different recent AGB data sets will be freely distributed by**

CATDS
Centre Aval de Traitement des Données SMOS

Based on
SMOS level 2 VOD version 700
Biomass of reference:
- CCI version 4
- Avitabile et al.
- Next : Saatchi et al., Tree Height (GEDI/Icesat2)

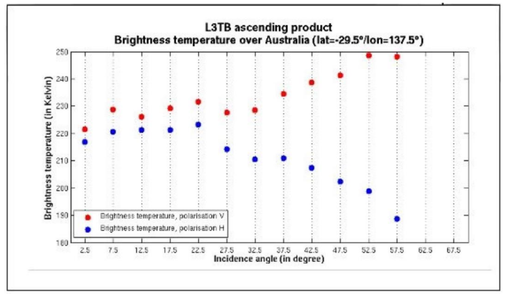
- Info and Technical Note:
https://www.catds.fr/Products/Available-products-from-CEC-SM/L4-Land-research-products/L4-Above-Ground-Biomass

- Data: https://data.catds.fr/cecsm/Land_products/L4_Above_Ground_Biomass/

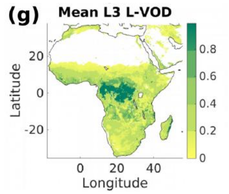
- Boitard et al. 2023, in prep. for ESSD

SMOS AGB without VOD

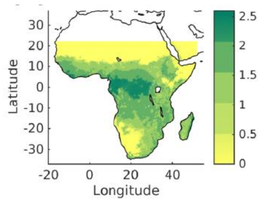
SMOS brightness temperatures

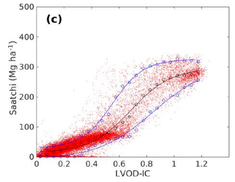


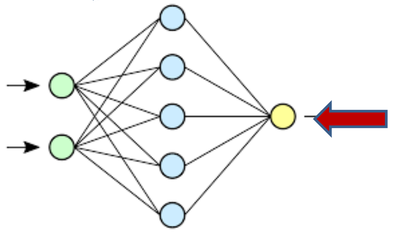
L-VOD



Biomass reference





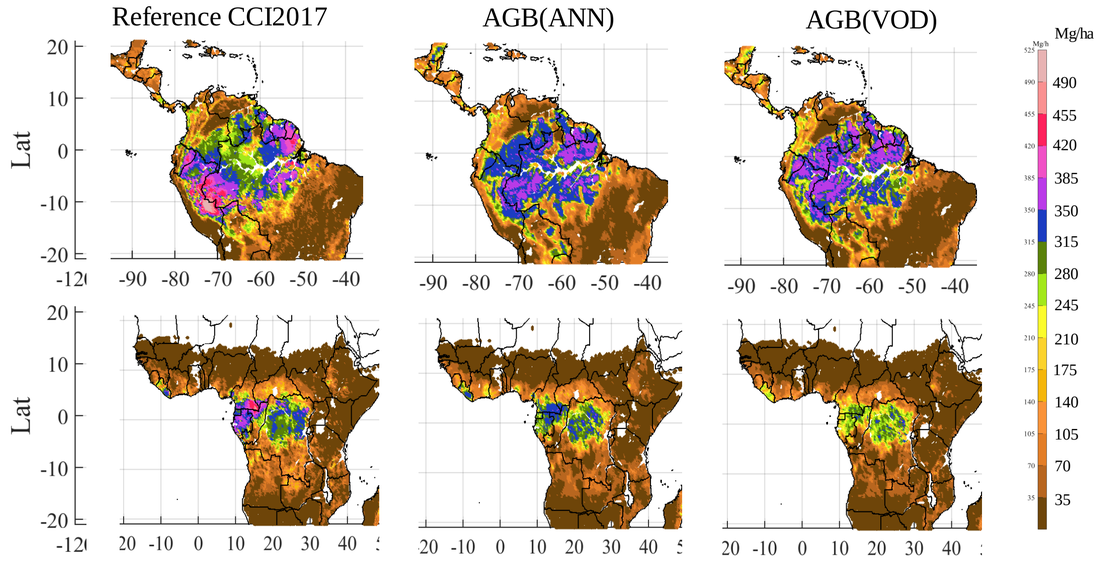


SMOS Biomass

Using several years of AGB for the training simultaneously

- **ESA CCI Biomass**

Rodriguez-Fernandez et al. (2019, IGARSS)
Salazar-Neira et al. (2022, IGARSS)
Salazar-Neira et al. (2023, JSTARS) - accepted



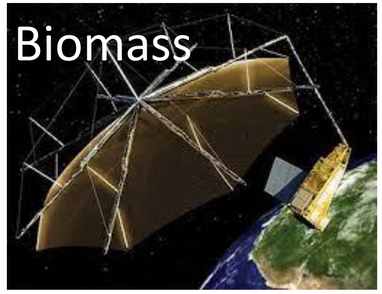
What next?

- **Using different reference maps.**
- **Multi-frequency approach (a first sensitivity analysis on this subject by Prigent et al 2021)**
- **Application – carbon stock evolution.**

Summary

- **L-band observations allow to link components of both the water and carbon cycles**
- **L-VOD provides complementary information to radar, lidar and optical observations and VOD measured at other wavelengths**
- **Useful for a wide range of applications but …** should be used with care !
- **Future ?**
  - **Biomass P-band SAR** (Le Toan et al. (2011, RSE)
  - **Multi-incidenc angles L-band measurements with increased resolution:**

SMOS-HR (Rodriguez-Fernandez et al. 2022, IGARSS)



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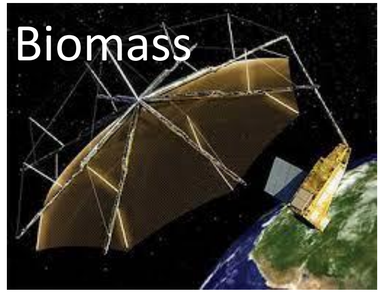
@NemesioRF

@SMOS_satellite

Summary

Thanks!



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