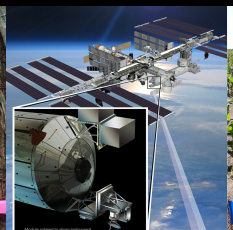
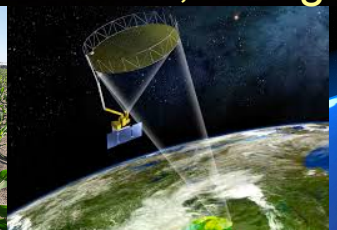
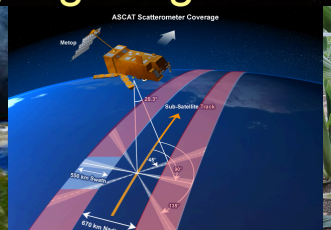
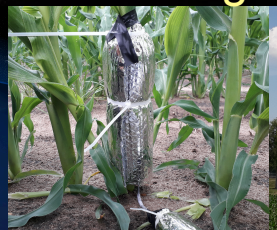
Advances in using radar to observe vegetation water dynamics

Susan Steele-Dunne*, Paul Vermunt, Saeed Khabbazan,
Ashwini Petchiappan, Jasmeet Judge, Mariette Vreugdenhil,
Sebastian Hahn, Wolfgang WagnerJasmeet Judge



Background: Radar

Radar uses microwaves:

- Wavelengths of mm to meters
- Frequencies of 1-14 GHz well-suited to soil and vegetation monitoring
- Independent of solar illumination
- Independent of cloud cover

=> *Reliable data*

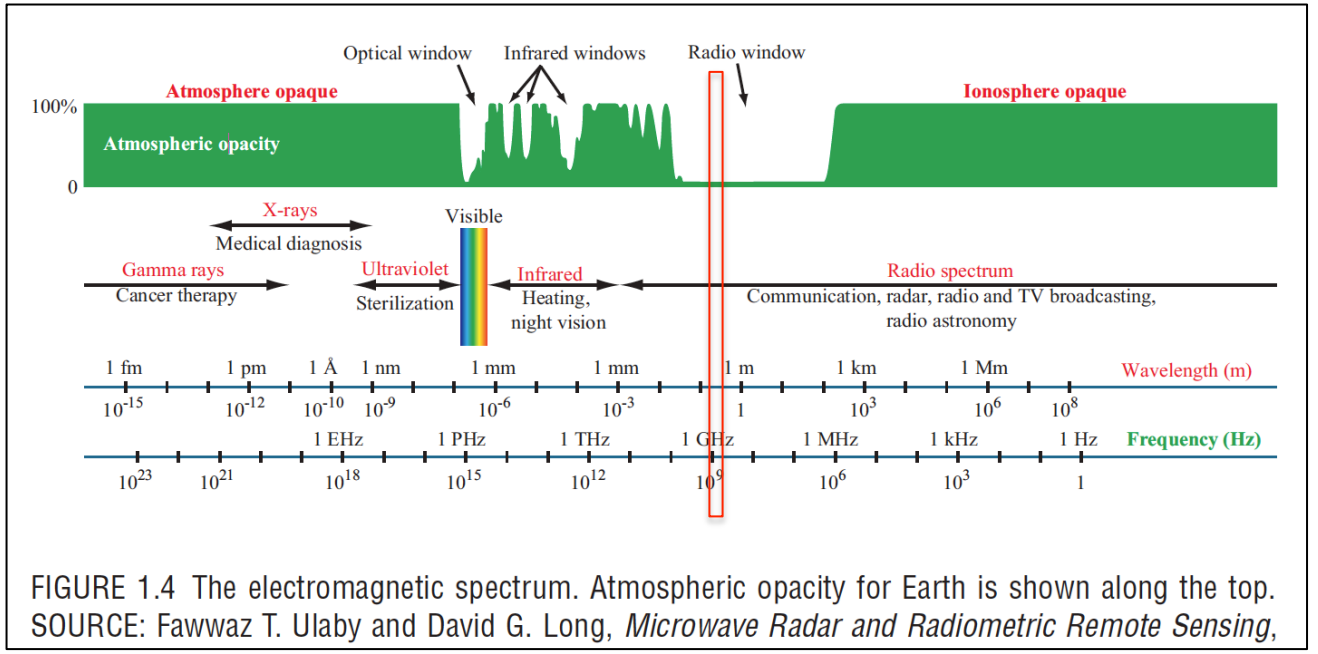
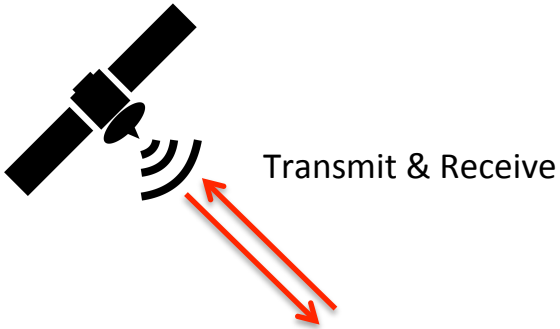


FIGURE 1.4 The electromagnetic spectrum. Atmospheric opacity for Earth is shown along the top. SOURCE: Fawwaz T. Ulaby and David G. Long, *Microwave Radar and Radiometric Remote Sensing*,

Steele-Dunne et al. (Remote Sensing, 2017)

Background: Radar

Radars are *active* sensors



- A radar instrument transmits a microwave pulse and receives the backscattered signal.
- The backscattered signal is influenced by system characteristics e.g. frequency, polarization, incidence angle etc..
- It is also influenced by the dielectric properties and structure/geometry of the surface.

This sensitivity to dielectric properties and structure is what makes radar useful for monitoring vegetation.

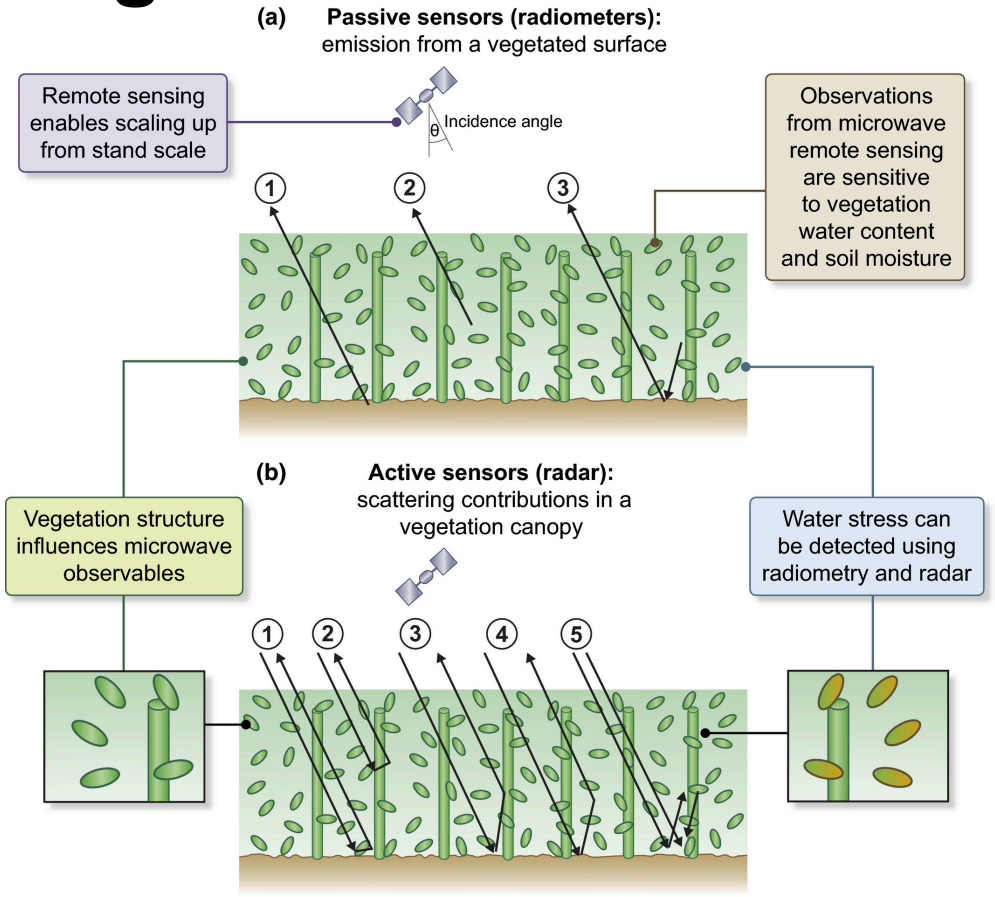
TU Delft

Konings, Rao & Steele-Dunne (New Phytologist, 2019)

Radar & Vegetation

- The dielectric constant of vegetation constituents is primarily sensitive to their water content.
- Radar is influenced by the amount of water in the vegetation and where it is stored.

=> Radar observations reveal dynamics of water storage in vegetation.



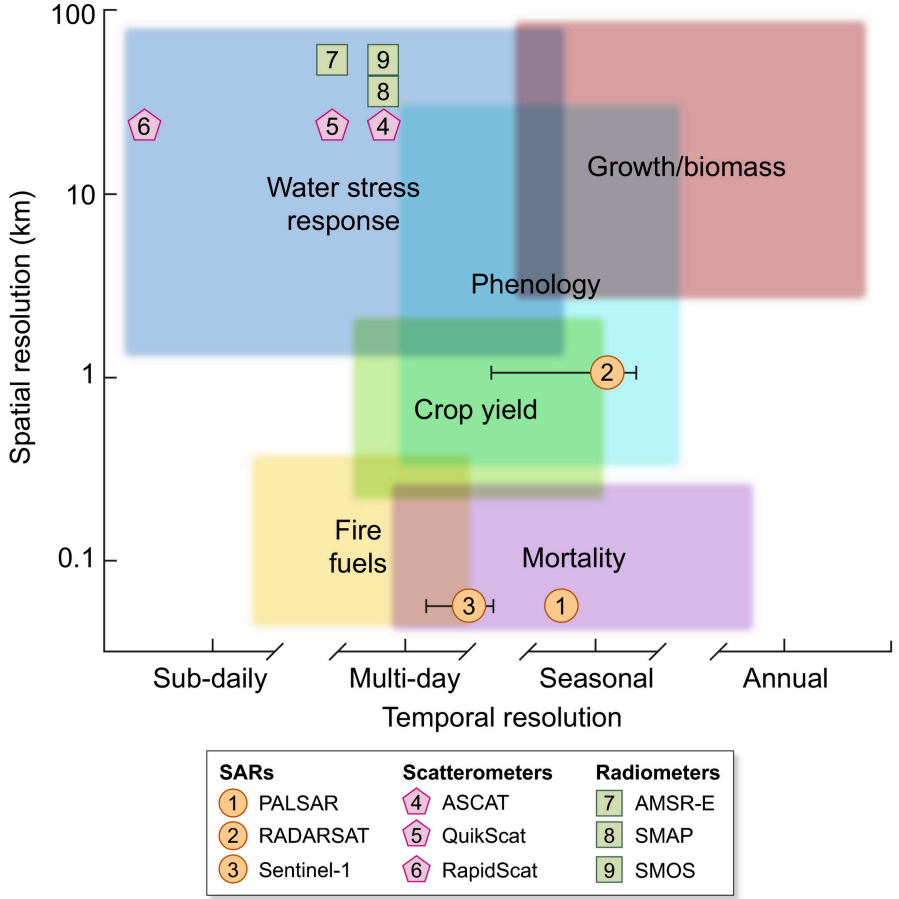
Konings, Rao & Steele-Dunne, New Phytologist (2019)

TU Delft

Radar & Vegetation

- Spaceborne scatterometers provide coarse resolution imagery
- Synthetic Aperture Radar (SAR) provides finer scale resolution imagery
- Both have been used for a wide range of applications related to vegetation

Improvements in temporal and spatial resolution stimulates new applications monitoring faster dynamics e.g. water stress response.

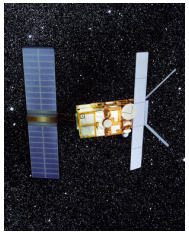


Konings, Rao & Steele-Dunne, New Phytologist (2019)

TU Delft

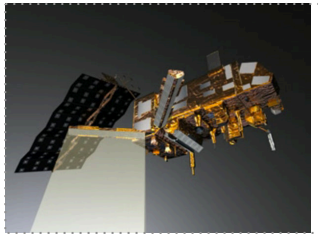
Spaceborne Radar: ASCAT

The Advanced Scatterometer is part of a series of operational instruments since 1991, and planned beyond 2030.
=> *Potential climate data record*



ERS-1

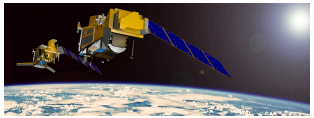
ERS-2



Metop-A

Metop-B

Metop-C



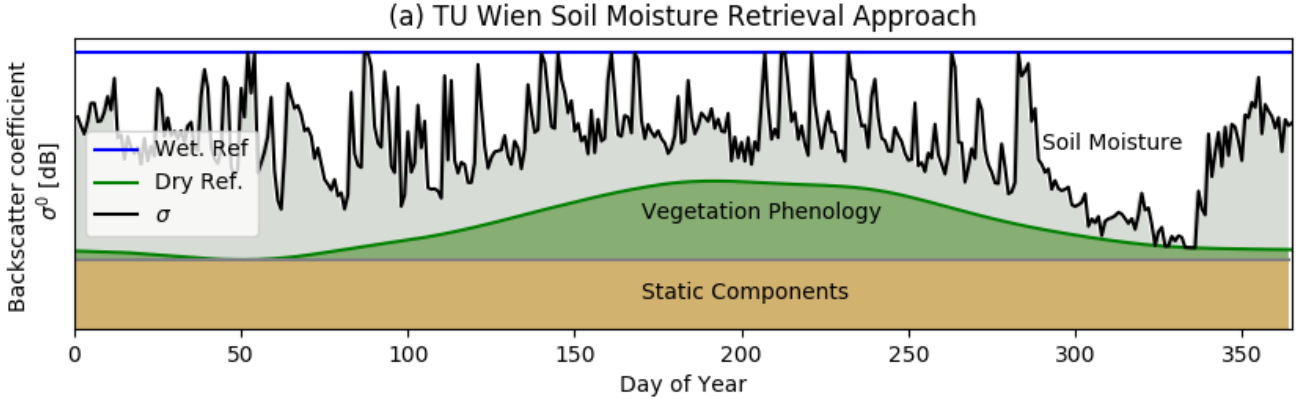
Metop-SG-B

1990 2000 2010 2020 2030

[Steele-Dunne et al. (RSE, 2019)]

TU Delft

ASCAT Dynamic Vegetation Parameters (DVP)



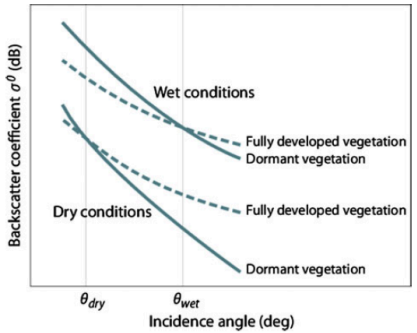


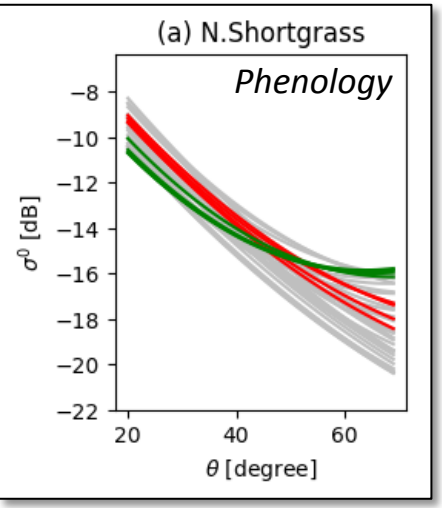
Figure 4: Illustration of the $\sigma^0(\theta)$ dependency on vegetation and soil moisture. Adapted from WAGNER et al. (1999a).

- ASCAT Dynamic Vegetation Parameters (DVP) refer to the slope and curvature of the 2nd order polynomial describing backscatter as a function of incidence angle.
- They are used in the TU Vienna Soil Moisture Retrieval algorithm to account for the effect of vegetation.
- These can now be estimated dynamically providing new insight into vegetation water dynamics

TU Delft

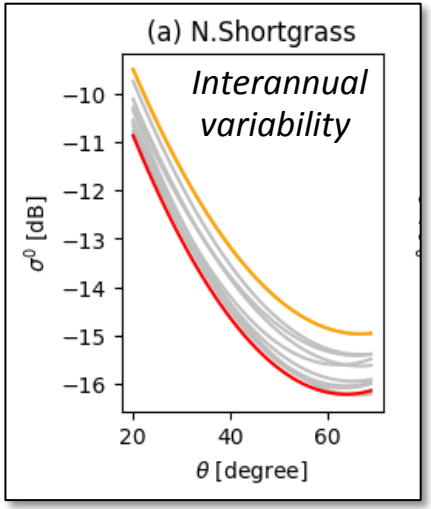
[Steele-Dunne et al. (RSE, 2019)]

ASCAT DVP in North American Grasslands

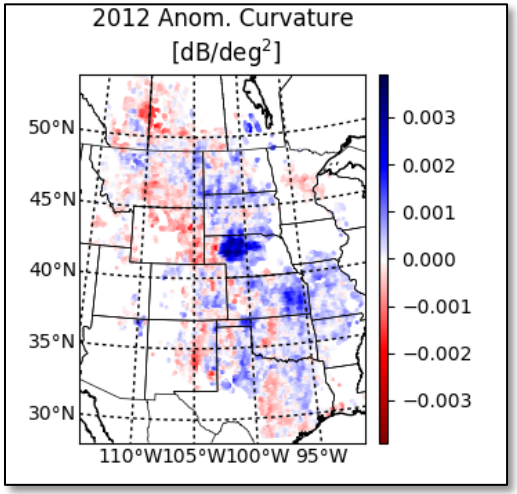


- Red lines are start of growing season.
- Green lines are biomass peak.

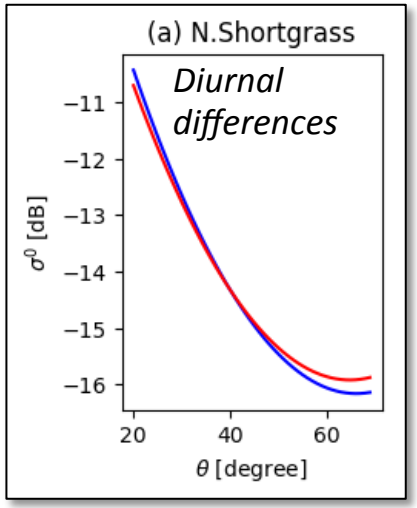
=> Seasonal change in vegetation density



- Curve for max biomass period in each year.
- Red curve is most severe drought.
- Vertical offset due to dry soil moisture
- Curve rotation due to drought effect on vegetation.



- Strong positive anomaly observed indicates influence of 2012 drought on Nebraska Sandhills.



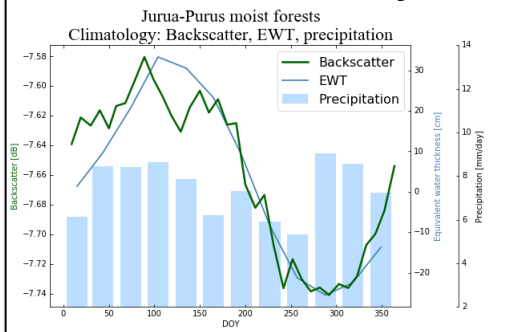
- Rotation of curve corresponds to change in vertical distribution of moisture between morning and evening overpasses.

TU Delft

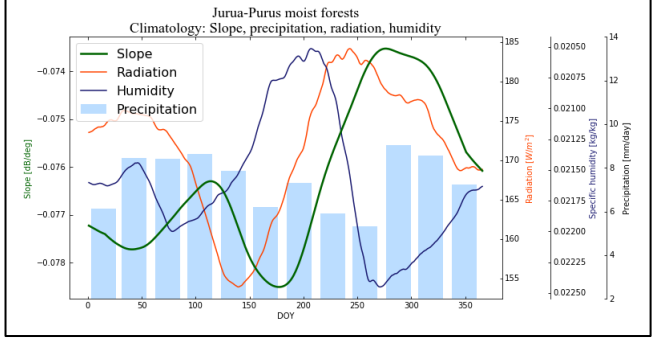
[Steele-Dunne et al. (RSE, 2019)]

ASCAT DVP in Amazon Region

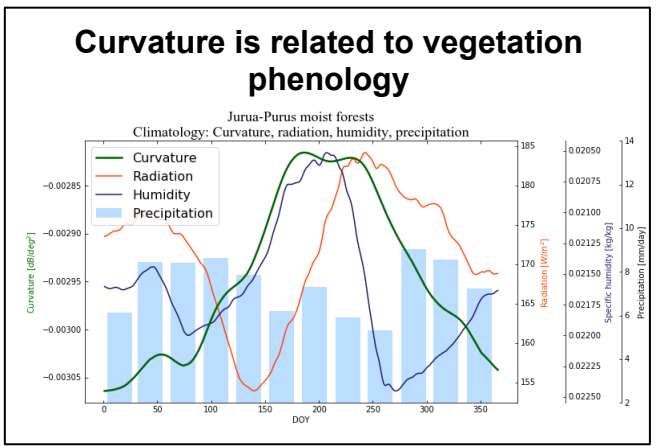
Backscatter is related to moisture availability



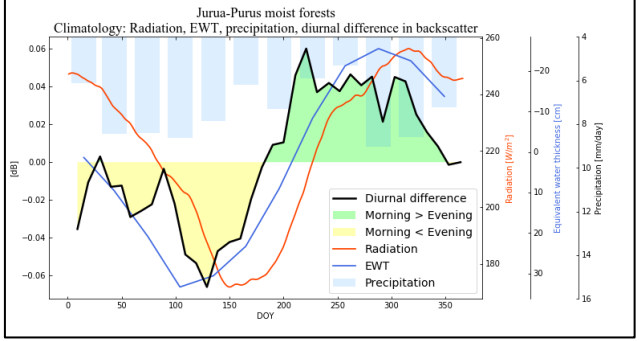
Slope follows moisture demand



Curvature is related to vegetation phenology



Diurnal differences influenced by moisture demand & availability



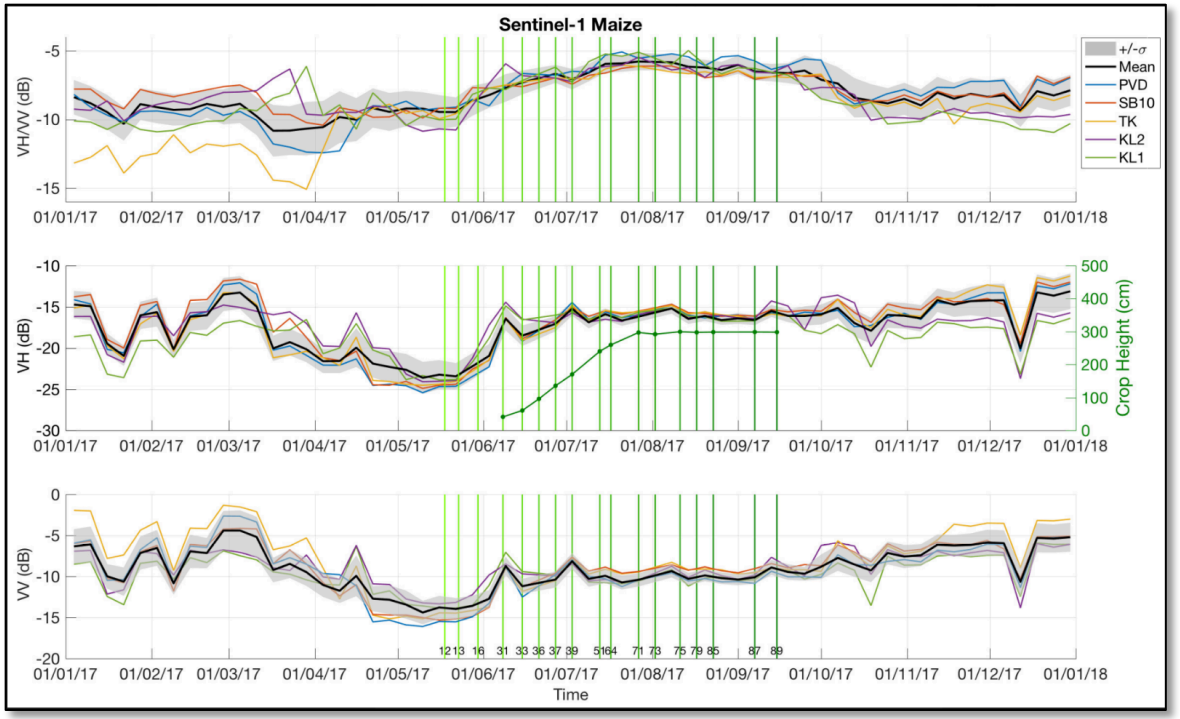
Petchiappan et al. (in prep.)

TU Delft

https://meetingorganizer.copernicus.org/EGU2020/EGU2020-11398.html

Spaceborne SAR: Sentinel-1

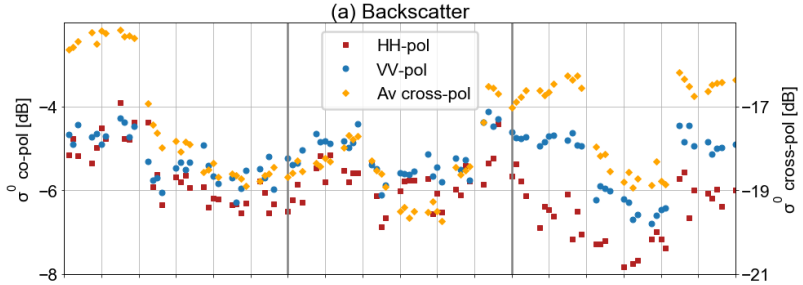
- ESA's Sentinel-1 mission provides imagery every 1-2 days in the Netherlands. We can monitor crop development like never before.
- Radar provides a new perspective on the impact of drought on vegetation water content.

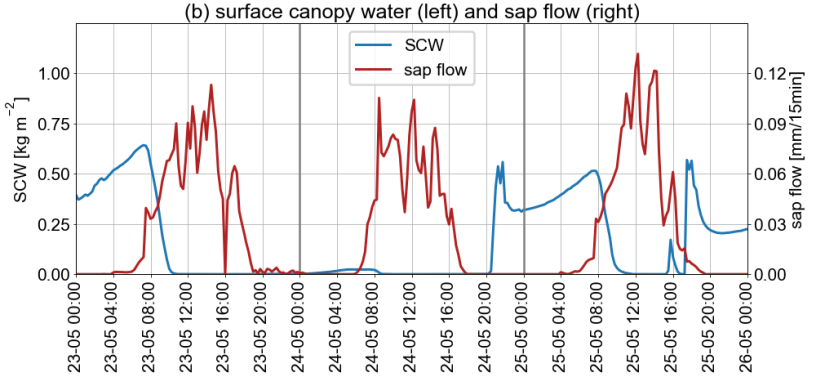


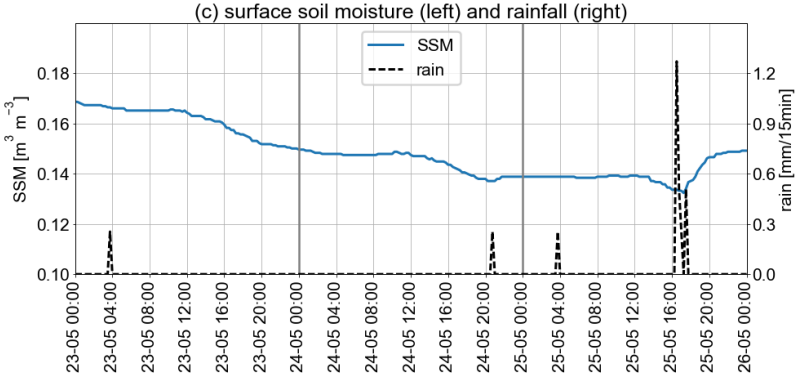
Khabbazan et al. 2019

Rapid Plant Water Dynamics

Our latest field experiments demonstrate the sensitivity of sub-daily radar backscatter to surface and internal vegetation water content





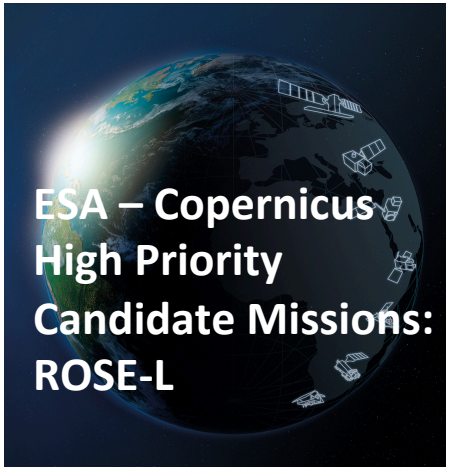


TU Delft

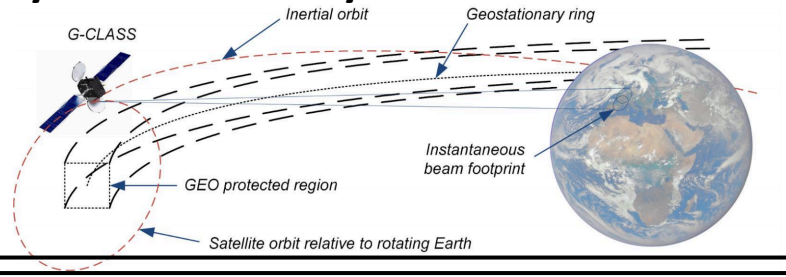
https://meetingorganizer.copernicus.org/EGU2020/EGU2020-13128.html

Future Opportunities

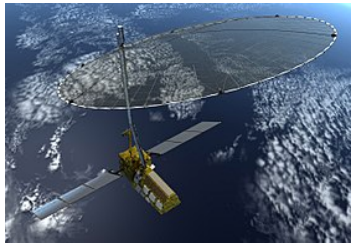
- Planned and candidate missions will provide new perspectives on vegetation.
- Sub-daily SAR will allow global monitoring of rapid vegetation water dynamics



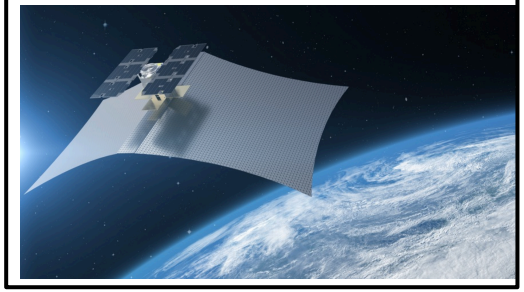
Hydroterra: Geosynchronous Radar

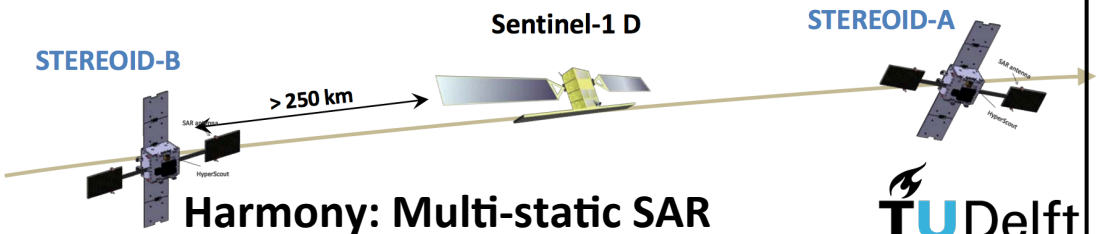


NISAR
(L- & S-Band)



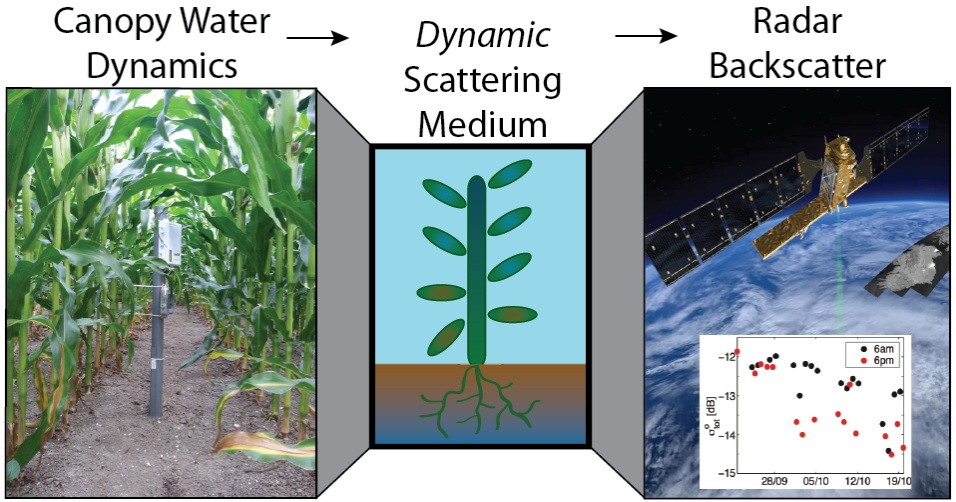
Commercial constellations





Future Challenges

- Key challenge is to represent vegetation as a living, dynamic scattering medium in microwave models.
- Address mismatch in modeled states & parameters between hydrology/physiology models and microwave modeling models.
- Improved process understanding of water transport in vegetation and its influence on backscatter



Conclusions

- Radar observables are sensitive to water content of vegetation.
- Current spaceborne scatterometer and SAR missions provide insight into vegetation water dynamics.
- Radar can sense sub-daily changes in surface and internal vegetation water content.
- Planned and candidate SAR missions provide exciting new perspectives on vegetation, particularly sub-daily processes.
- Key challenge is to reconcile hydrology/plant physiological understanding of vegetation water dynamics with radiative transfer modeling.

References

- Steele-Dunne, Susan C., Heather McNairn, Alejandro Monsivais-Huertero, Jasmeet Judge, Pang-Wei Liu, and Kostas Papathanassiou. "Radar remote sensing of agricultural canopies: A review." IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 10, no. 5 (2017): 2249-2273.

- Konings, Alexandra G., Krishna Rao, and Susan C. Steele-Dunne (2019). "Macro to micro: microwave remote sensing of plant water content for physiology and ecology." New Phytologist, doi:10.1111/nph.15808.

- Steele-Dunne, Susan C. , Sebastian Hahn, Wolfgang Wagner, and Mariette Vreugdenhil (2019). "Investigating vegetation water dynamics and drought using Metop ASCAT over the North American Grasslands." Remote Sensing of Environment 224 (2019): 219-235.

- Khabbazan, Saeed, Paul Vermunt, Susan Steele-Dunne , Lexy Ratering Arntz, Caterina Marinetti, Dirk van der Valk, Lorenzo Iannini, Ramses Molijn, Kees Westerdijk, and Corné van der Sande (2019). "Crop monitoring using Sentinel-1 data: A case study from The Netherlands." Remote Sensing 11, no. 16: 1887.

email: s.c.steele-dunne@tudelft.nl
website: m-wave.tudelft.nl

TU Delft