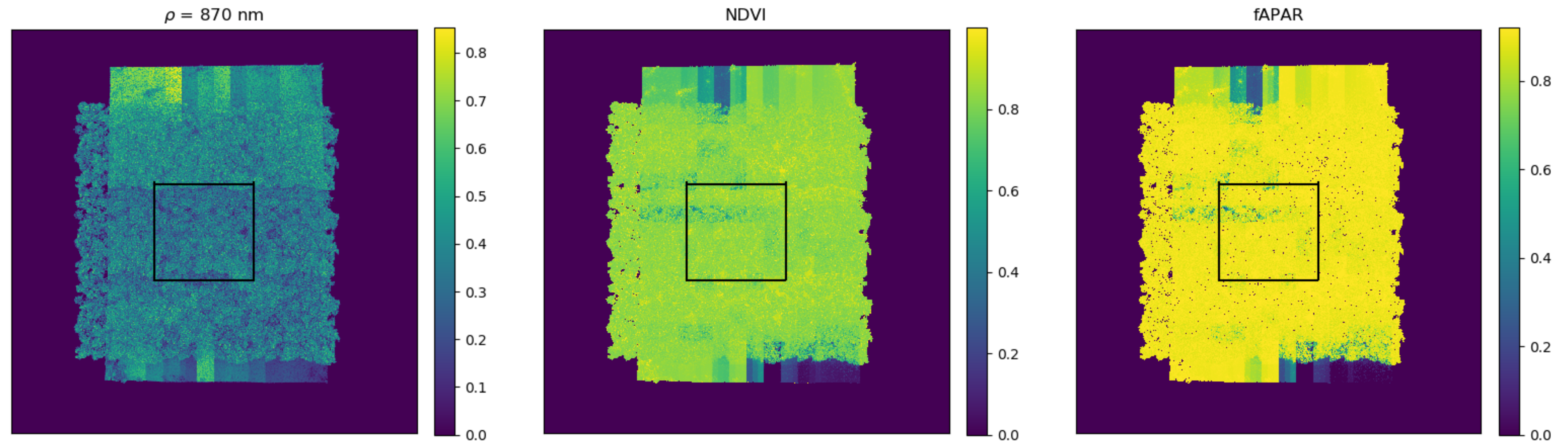
Preliminary work towards 3D forest model-assisted validation of the Sentinel-2 SNAP fAPAR product



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Modelling canopy-level photosynthesis

Applications in:

- Terrestrial carbon modelling
- Agricultural modelling
- Hydrological modelling
- Energy balance modelling

Mechanistic (e.g. Farquhar et al 1980)

Production efficiency

$$GPP = F \times PAR \times \varepsilon$$

Difference between these relates to scaling to the canopy level

fAPAR is a key component of both approaches!

Problems with satellite fAPAR products

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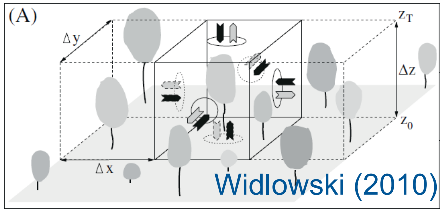
- Multiple definitions
- Algorithm assumptions
- From different sensors
- Data inputs

PAR = photosynthetically active radiation

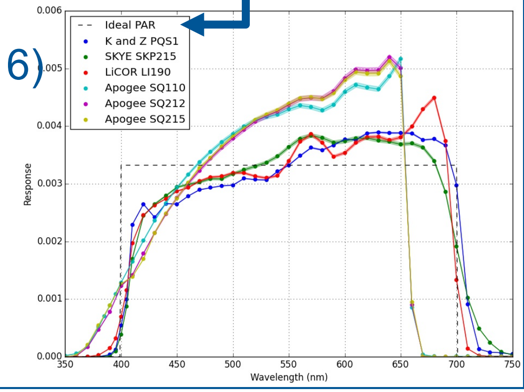
400 – 700 nm

fAPAR = fraction of absorbed PAR

GCOS: required measurement uncertainty: 10% or 0.05 (WMO 2016)



Widlowski (2010)

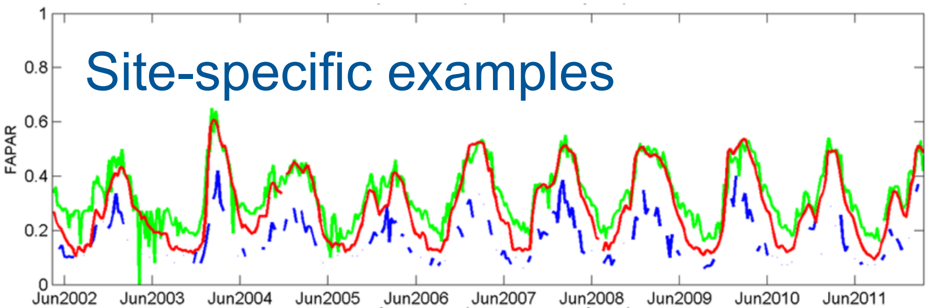


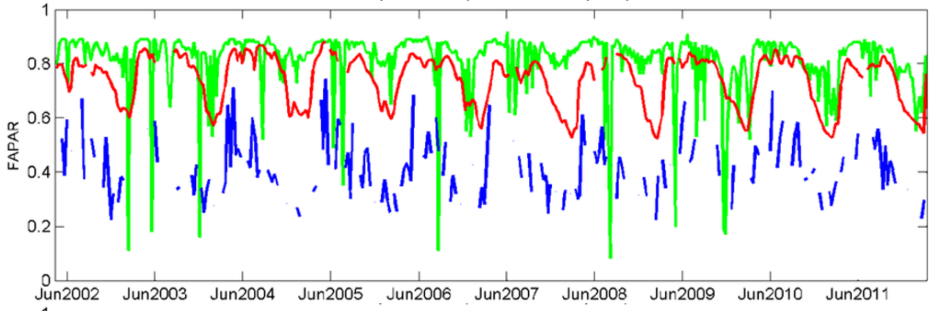
In situ methods use PAR sensors to measure these fluxes

We need a validation strategy that addresses these issues

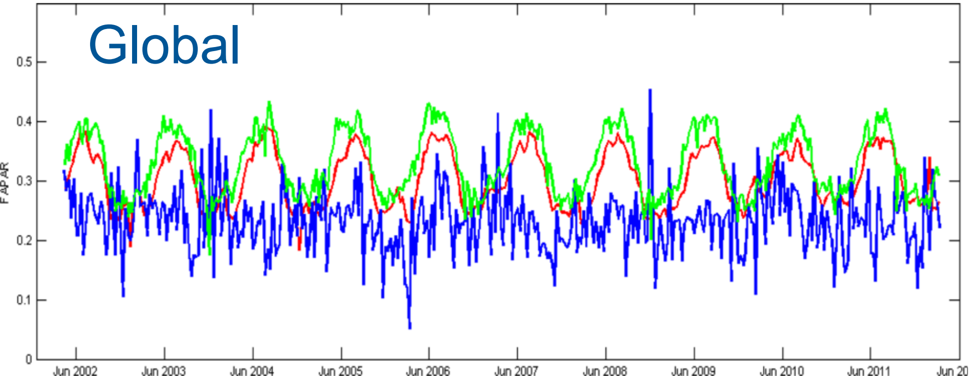
All plots from Weiss et al (2014)

Site-specific examples





Global



Proposed validation strategy

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Wytham Woods, UK

Virtual Wytham Woods as per Calders et al (2018)

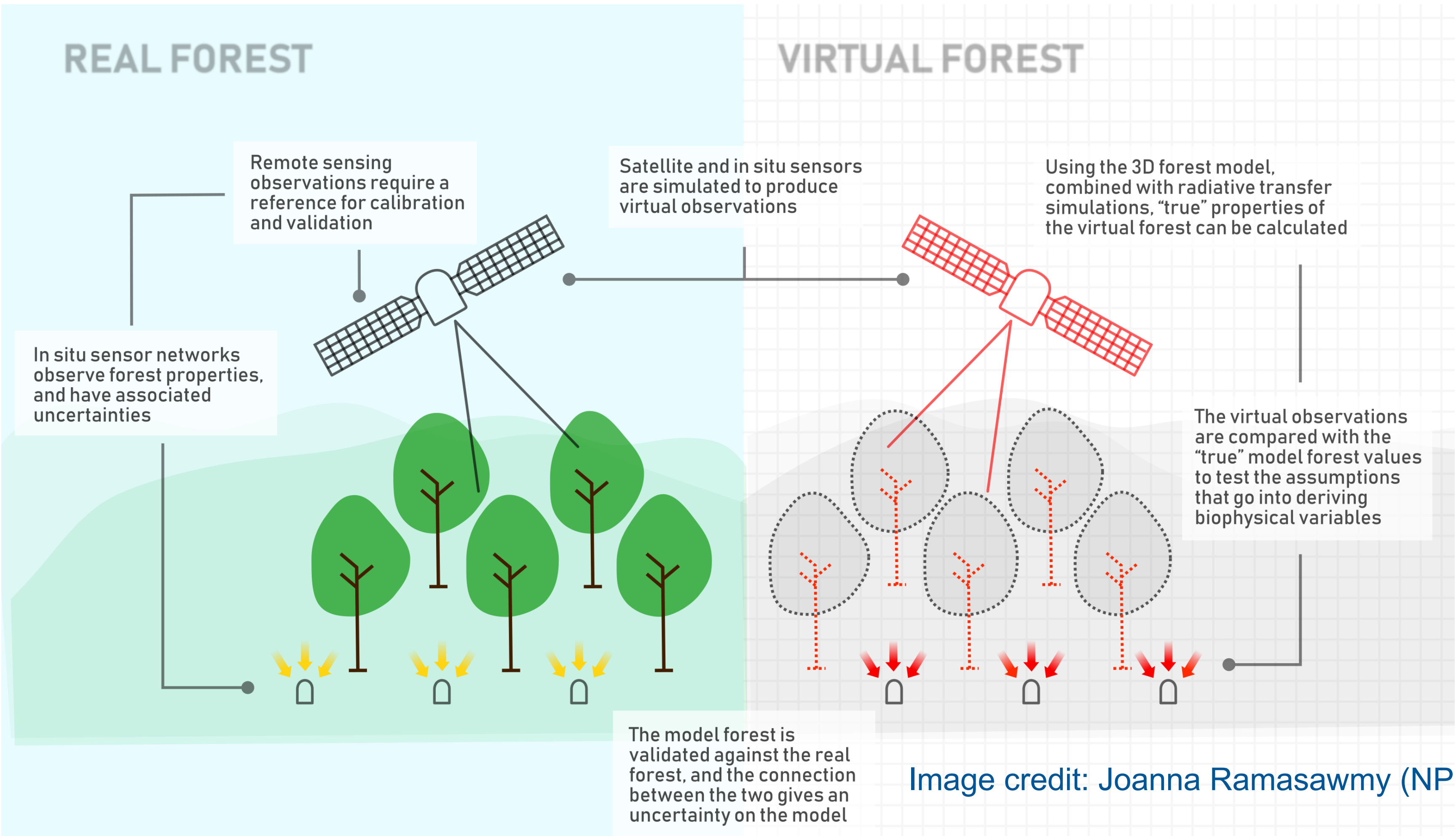

Image credit: Joanna Ramasawmy (NPL)

How does this approach help?

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PAR sensor network	S2 fAPAR product
Natural sky conditions	Natural sky conditions
Full canopy	1D canopy
	Effective fAPAR
	Green fAPAR

Using this approach we can homogenise the two quantities – i.e. conduct simulations using a 3D radiative transfer model which identify the difference because of the conditions present or the assumptions made by the product.

Methods

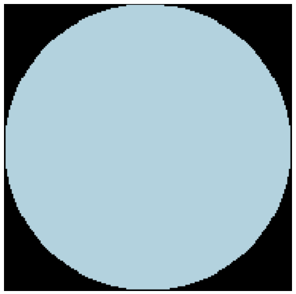
3D forest model of Wytham Woods from Calders et al (2018)

4-flux PAR network at Wytham Woods (below)

Comparison of a simulated (using 3D radiative transfer model (Librat – Lewis 1999)) and real hemispherical photograph from identical locations (below)

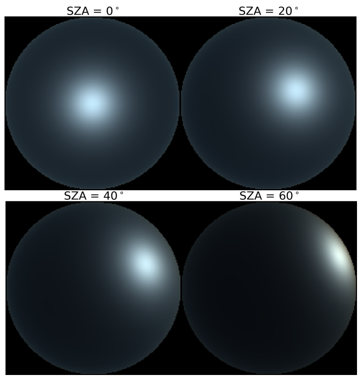
Experiments

Illumination conditions



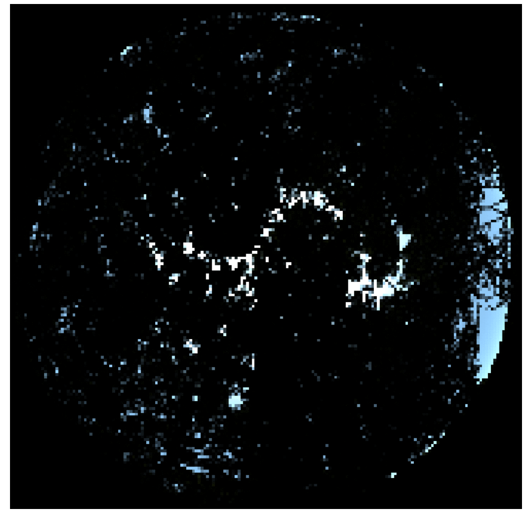
Diffuse (above)

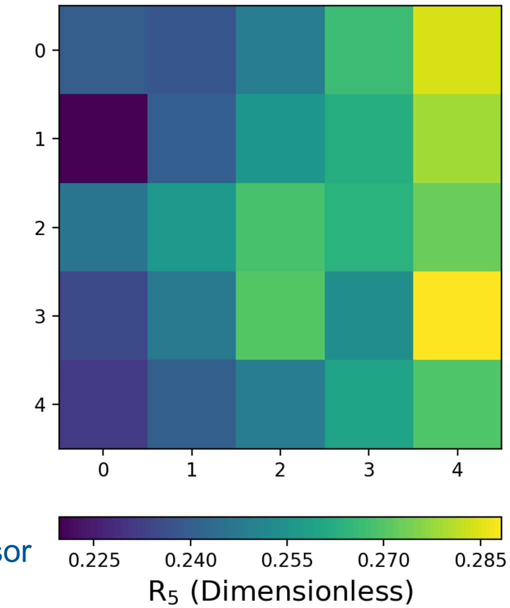
Direct (not shown)



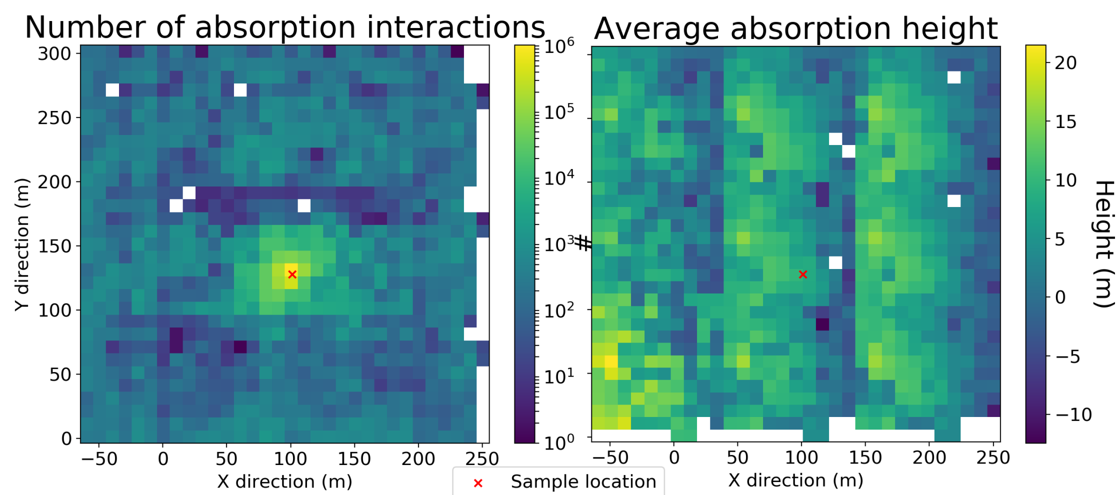
Natural sky (above)

Sensing options

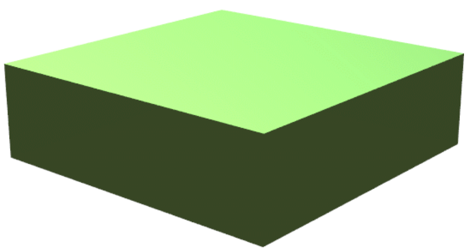




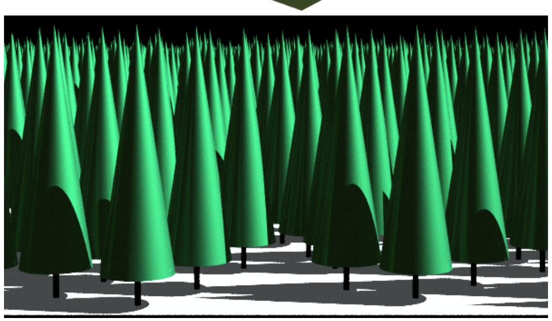
In situ sensor (above); satellite sensor (right); true absorption (below)



Absorption media



(Left) both images are from JRC (2018)



Common assumption biases (green fAPAR)

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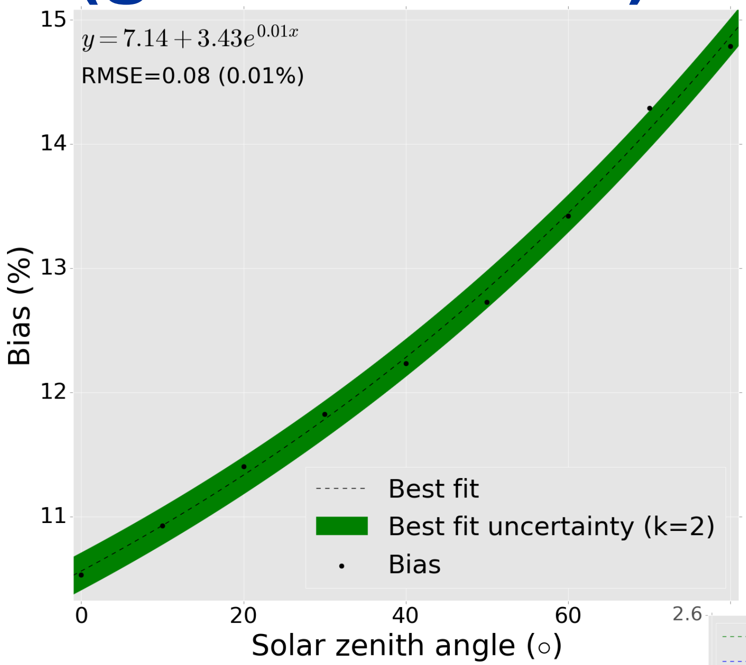
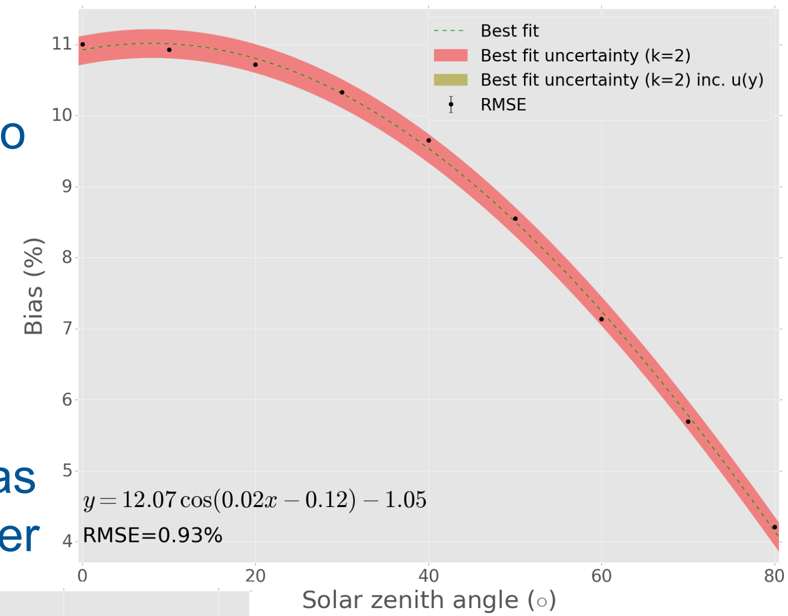
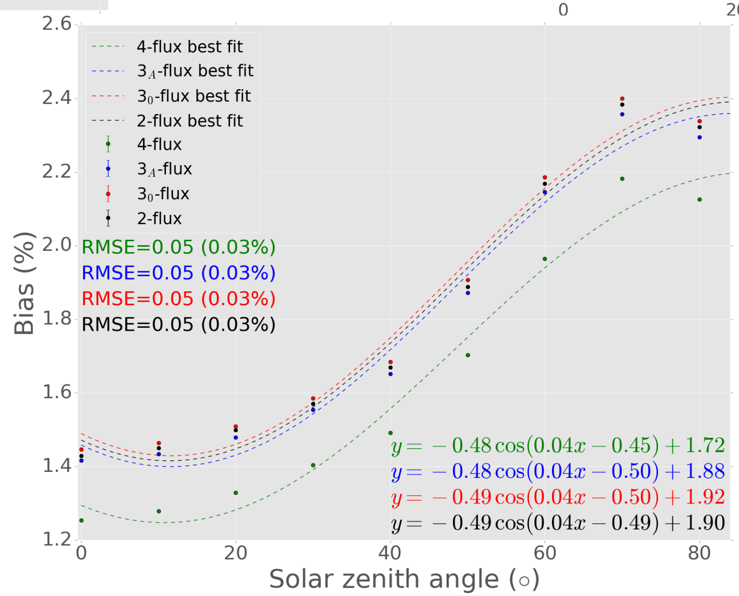


Convenient functions show we don't need to simulate every SZA

(Below) PAR sensor simulations estimate the bias to be much lower



(Above) True difference gives values much larger than GCOS requirements; therefore corrections must be made!



(Above) Satellite modelled difference is generally much smaller although reasonably close at low SZA

Conclusions

- Biases arise out of deviations between the satellite fAPAR product model and reality
- The magnitude of the biases depends on the observing system
- The biases can be larger than GCOS requirements and therefore need to be corrected to conduct good quality validation activities

References

- Calders, K., Origo, N., Burt, A., Disney, M., Nightingale, J., Raumonen, P., Akerblom, M., Malhi, Y. and Lewis, P (2018) Realistic forest stand reconstruction from Terrestrial LiDAR for Radiative Transfer Modelling. *Remote Sensing*, **10**(18): 1-15
- Farquhar, G., von Caemmerer, S. & Berry, J. (1980) A biochemical model of photosynthetic CO2 assimilation in leaves of C3 species. *Planta*, **149**(1):78-90
- JRC (Joint Research Centre) (2018) Radiation Model Intercomparison. http://rami-benchmark.jrc.ec.Europa.eu/HTML/RAMI3/RAMI3.php [Accessed: 20/09/2018].
- Lewis, P. (1999) Three-dimensional plant modelling for remote sensing simulation studies using the Botanical Plant Modelling System, *Agronomie*, **19**(3-4):185-210
- Weiss, M., Baret, F., et al (2014) Online validation exercise (OLIVE)): a web based service for validation of medium resolution land products. Application to fAPAR products. *Remote Sensing*, **6**(5):4190-4216
- Widlowski, J-.L. (2010) On the bias of instantaneous FAPAR estimates in open-canopy forests. *Agricultural and Forest Meteorology*, **150**(12):1501-1522
- WMO (World Meteorological Organisation) (2016) The Global Observing System for Climate: Implementation Needs. GCOS-200 (GOOS-214)