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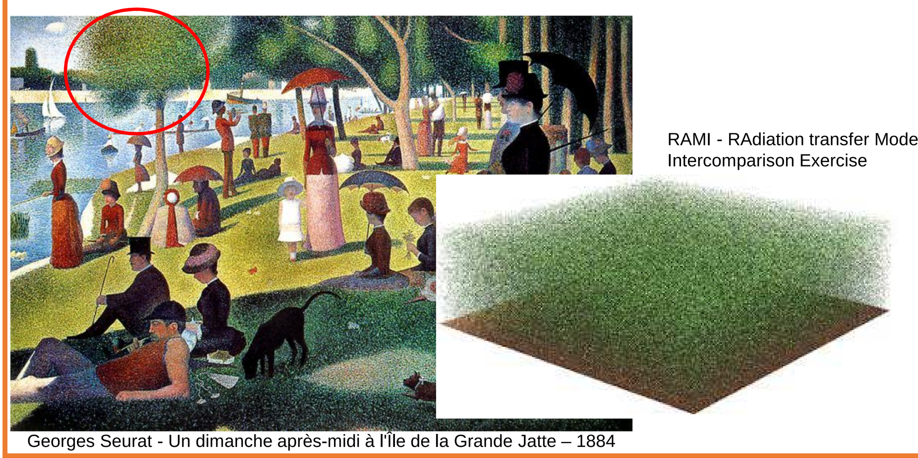
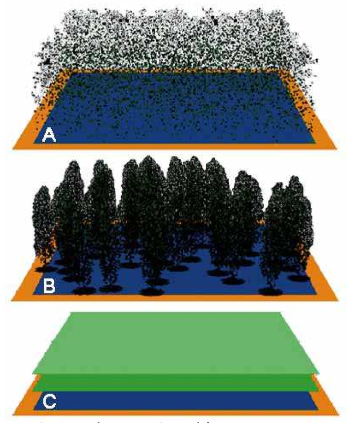
Foliage Clumping 101 – What and Why



Georges Seurat - Un dimanche après-midi à l'île de la Grande Jatte – 1884



Source image: S. Leblanc

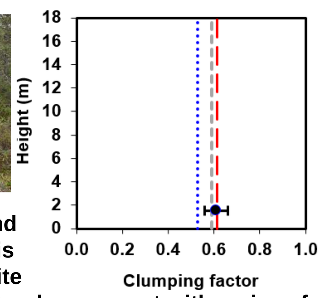
- leaves in canopies generally grouped into various sub-canopy structures, such as tree crowns, branches, and shoots in forests, foliage clumps in shrubs, and rows in crops
- these structures make the leaf spatial distribution non-random
- the foliage clumping index is used to quantify the degree of the deviation of this distribution from the random case (Nilson, 1971, AFM; Chen and Black, 1992, AFM)
- a key structural parameter of plant canopies; very useful in ecological and meteorological models (estimation of true LAI; separation of sunlit and shaded leaf groups; canopy-level GPP modeling; light availability)
- recently, first ever global clumping index maps from POLDER observations (Chen et al., 2005, RSE; Pisek et al., 2010, ISPRS), with MODIS (He et al., 2012,RSE), and over selected areas with MISR (Pisek et al., 2013, RSE)
- how do they compare, do they always match with field ground observations and if not, why not?

How

- vertical profiles of CI obtained by climbing scaffolding/flux towers and taking leveled digital hemispherical photos (DHP) along the climbed height
- at each profile, several series of DHP acquired using a Nikon CoolPix 4500 digital camera with a Nikon FC-E8 fisheye lens under diffuse illumination conditions, following the protocol of Zhang et al. (2005, AFM)
- extracted profiles of gap fraction from the blue channel at view zenith angle of 57° processed with the TRACWin software (v4.1.1) to obtain CLX method values (Leblanc et al., 2005, AFM)
- CLX method previously shown to get the most reliable clumping estimates at our Järvselja RAMI stands (Pisek et al., 2011, AFM)
- additional seasonal profiles of CI also collected over Yatir (Aleppo pine plantation), TONZI (blue-oak savanna), and Järvselja RAMI Scots pine and Honghe (rice paddy field) sites

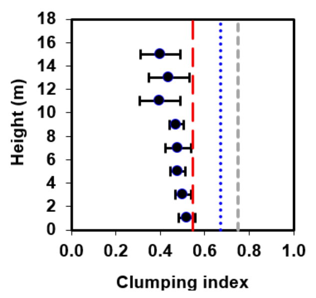
Vertical profiles

Sudbury, Canada
evergreen needleleaf (5.6 m)

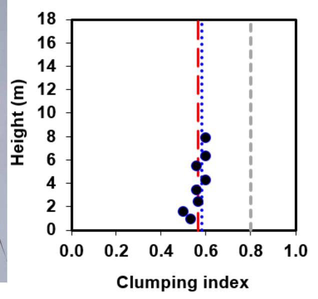


No pronounced second understory layer at this young black spruce site (tree height ~ 5.6m). Good agreement with series of in situ DHP measurements done at the breast height.

Hyytiälä, Finland
evergreen needleleaf

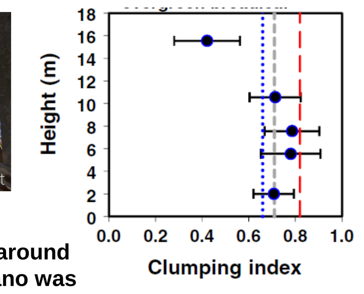


Sodankylä, Finland
evergreen needleleaf



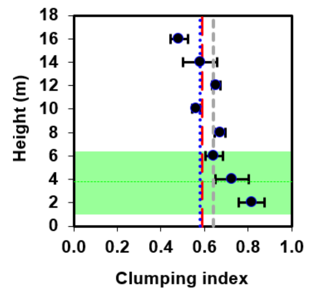
The ground is unobscured by understory tree/shrub layer and clearly seen from the top of the canopy. The similar level of clumping can be thus observed from just underneath the tree crowns all the way to the ground. The original MODIS CI value (0.67) is overestimated compared to the DHP data at Hyytiälä, because the GLC2000 land cover type is wrongly identified as a broadleaf forest. If the MODIS pixel with the Hyytiälä site is classified correctly as a needleleaf forest, the retrieved MODIS CI value (0.53) agrees well with the CI measured at the ground. The POLDER CI values are underestimated (lower, closer to random case clumping) due to the coarse (~6km) resolution of the sensor.

Castelporziano, Italy
evergreen broadleaf

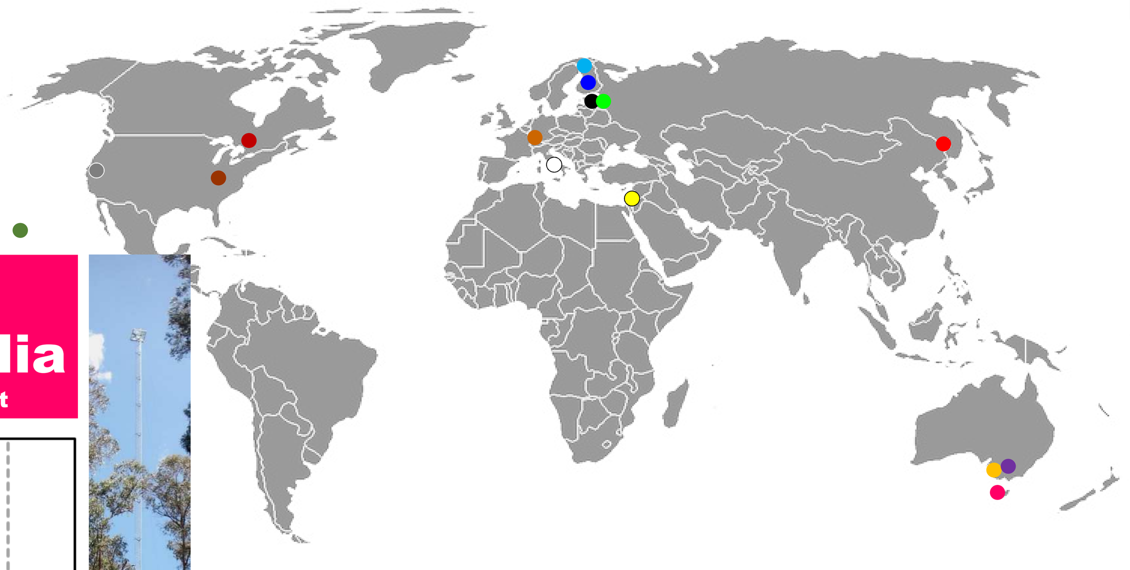


The state forest reserve around the tower at Castelporziano was large enough to occupy the full footprint of POLDER sensor, and POLDER CI value then offered the best match with the in situ measurements.

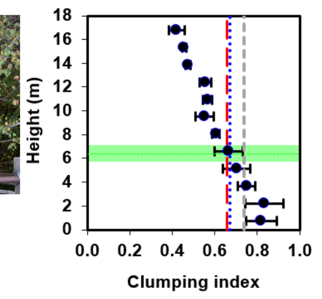
Thurston tower, HI, USA
native cloud rainforest



The large gaps between tree crowns at upper levels of the canopy (above; high clumping) may not be measured near the ground due to occlusion by lower vegetation of fern branches (below). This results in low gap fraction values near the ground and low (close to random distribution case) clumping.

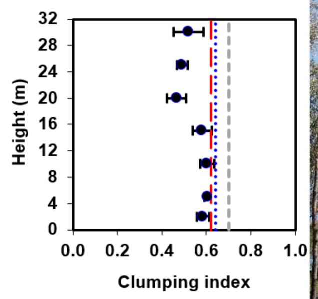


Järvselja, Estonia
hemiboreal mixed



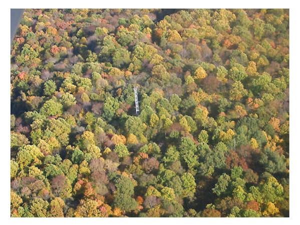
The ground visibility is limited by the presence of the suppressed tree layer around the Järvselja site. MODIS/MISR retrievals coincide with the field measurements taken just above the understory tree layer.

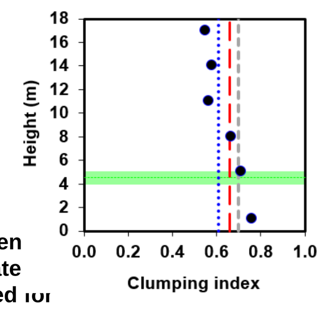
Warra, Australia
wet tall eucalypt



Low height (< 8m) CI values from the tower are not representative of the surrounding area. Understory has been cleared around the Warra tower during construction. Importantly, MISR/MODIS retrievals are still consistent with in-situ CI values measured at the level underneath the tree crowns (12-16m).

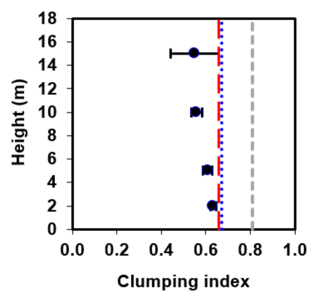
Morgan-Monroe State Forest, IN, USA
successional broadleaf



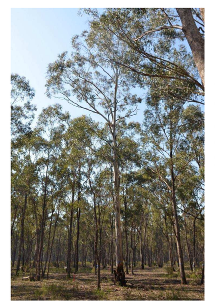


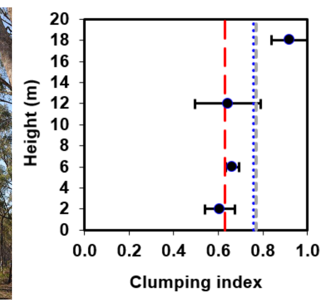
The best agreement between satellite and field CI estimate at MMSF site again achieved for observations taken above the understory layer.

Wombat, Australia
dry sclerophyll eucalypt



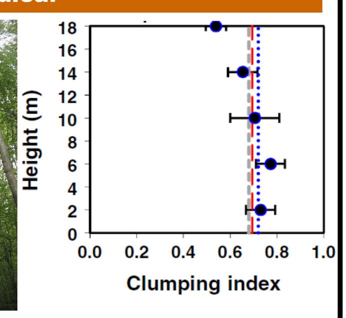
Whroo, Australia
dry sclerophyll eucalypt





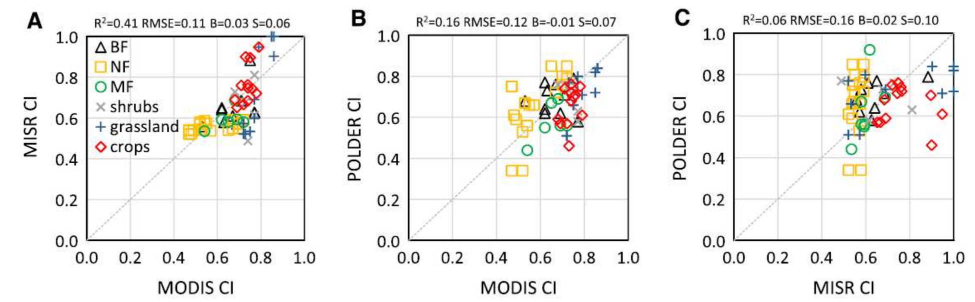
There is no understory layer present at Wombat and Whroo sites. MISR CI estimates match well with the near-ground level in situ measurements. Surrounding agricultural areas might bias the signal from the at lower spatial resolutions forest especially at Whroo, where both MODIS and POLDER CI values are similarly overestimated.

Hesse, France
temperate broadleaf



Results over Hesse document that CI retrievals from remote sensing data can match the ground in situ measurements in deciduous broadleaf forests if the land cover vegetation type is correctly assigned, the forest area is sufficiently large, and there is no pronounced shrub/tree understory layer.

Compare over LPV/VALERI sites

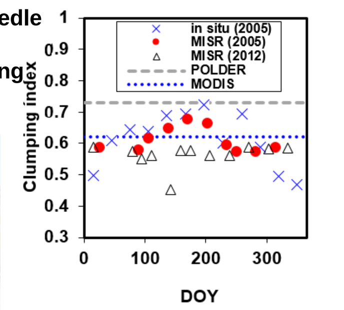


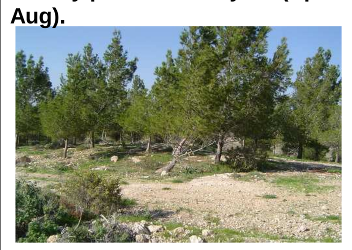
CI values from MODIS and MISR showed the best overall agreement. This is not surprising, since the two products use the same wavelength domain (visible red) for the CI retrieval and they are also the closest in resolution scale (500 m vs. 275 m).The gradually decreasing agreement between products from A to C confirmed the importance of using CI value appropriately matched to the scale of the application in question (Ryu et al., 2010).

Seasonal profiles

Yatir, Israel
Aleppo pine plantation

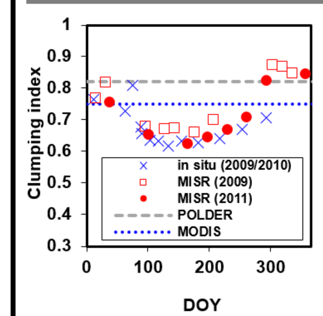
Annual dynamics caused by needle phenology and concurrency of needle growth and litterfall during the dry period of the year (Apr–Aug).





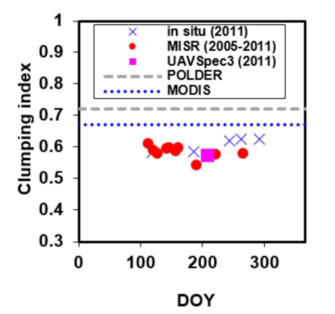
In 2012, Yatir intensively thinned due to massive drought-related mortality in 2012. This thinning increased the clumping at the landscape level and offset the decreasing clumping at the shoot level due to litterfall during the dry period of the year.

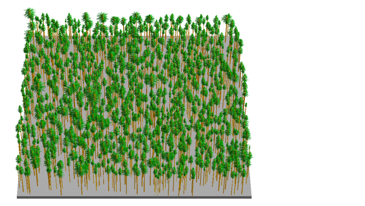
TONZI, CA, USA
blue oak savanna



With the canopy development at TONZI, the CI decreased which indicates increased clumping as the crowns thickened.

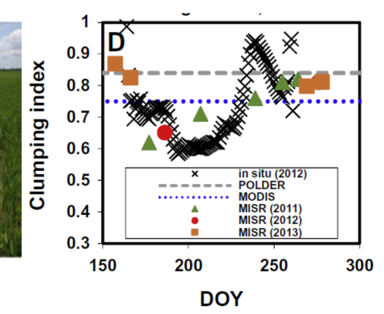
Järvselja RAMI, Estonia
evergreen needleleaf





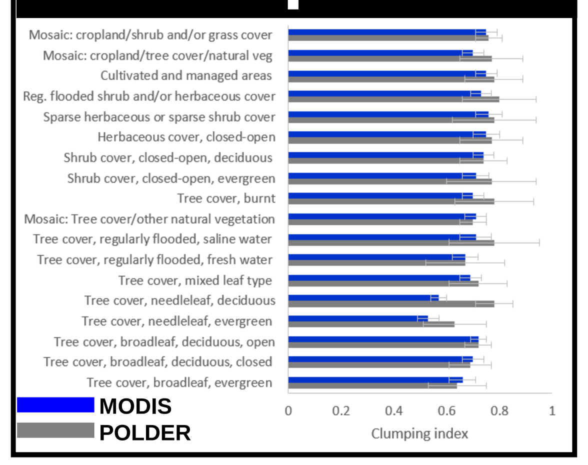
There were only three cloud-free MISR observations over the RAMI pine site in 2011 (April 24, May 8, and June 11). Similar to TONZI, the RAMI pine stand has not experienced any significant change in its structure during the recent years. The compiled successful MISR observations from 2005–2011 confirm the very stable structure of the RAMI pine stand.

Honghe, China
rice field



Frequent cloud cover allowed only two successful MISR retrievals over a rice field in Honghe area, NE China. However, their comparison with in situ measurements shows MISR red band is sensitive to the structural changes of agricultural crops with time as well.

GLCC 2000 global intercomparison



CI product characteristics

Name	spatial resolution	coverage	temporal profile	references
POLDER	~ 6 km	global	no	Pisek et al., 2010, ISPRS
MODIS	500 m	global	no	He et al., 2012, RSE
MISR	275 m	selected regions	possible	Pisek et al., 2013, RSE

Download the global MODIS clumping index map at 500 m resolution from here: (email me (janpisek@gmail.com) for POLDER map)

Get free pdf. of the full 2015 ISPRS article from here!

Conclusion

- satellite measurements respond to the structural effects near the top of canopies, while ground measurements may be biased by the lower vegetation layers
- caution should be taken regarding the misclassification in land cover maps as their errors can be propagated into the foliage clumping maps
- MODIS and MISR data with 275 m in particular can provide good quality clumping index estimates at pertinent scales for modeling local carbon and energy fluxes

References & Acknowledgments

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