Estimates of leaf area index using Hemispheric photos and MODIS

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Outline for talk

- Background
- Remarks on JB
- Field campaign
- Results
- MODIS disasters
- Summary

Background

•**Leaf Area Index** is the one-sided green leaf area per unit ground surface area in broadleaf canopies

- High quality LAI products are needed for water and carbon balance modeling at the regional to continental to global scales
- Validation of moderate scale remote sensing LAI products are seldom done using ground-based LAI measurements
- Assessment of MODIS Collection 5 LAI/fPAR products needed for savannas regions of Australia
- Such validation work presented us with numerous logistical obstacles but also opportunities for initial observations of the vegetation structure and composition

Moderate Resolution Imaging Spectroradiometer (MODIS)

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Renewed interest in DHPs

- Inexpensive
- Easy to use (illumination conditions)
- No reference measurements needed
- Possible use over low vegetation canopies
- Direct evaluation of the quality of measurements (images)
- Possible distinction between green and non-green elements
- Possible to derive clumping information

Advantages of digital hemispheric photos

System	Illumination conditions	Spectral domain	Zenith angles	Azimuthal coverage	Gap size distribution	Post processing	Computer resources
DEMON	Direct	430 nm			No	No	Low
Sunfleck ceptometer	Direct, diffuse	PAR			Yes	Yes	Low
Accupar	Direct, diffuse	PAR			Yes	No	Low
LAI-2000	Diffuse	< 490 nm	5	range	No	No	Low
TRAC	Direct	PAR			Yes	No	Low
DHP	Direct, diffuse	Selectable	range	range	Yes	Yes	High
MVI	Diffuse	VIS, NIR	range	range	Yes	Yes	High
Ideal	Direct, diffuse	VIS, NIR	range	range	Yes	Yes	-------

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Clumping of leaves: Unclumped vs. *Clumped* LAI

- *Effective* LAI assumes a Poisson spatial distribution of leaves in the canopy
- *True* LAI incorporates a clumping distribution of leaves
- With a “clumped” distribution of leaves in the canopy, the LAI is higher than the unclumped LAI, $\mathbf{LAI_{clumped} = \Omega * LAI_{unclumped}}$
- But not all leaves are equal in the canopy!

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Remarks on LAI

- Converting from PAI to LAI is not trivial.
- LAI (as sensed from above) generally has leaves covering stems and trunks in closed canopy forests.
- For savannas, it all depends on the tree architecture and cover.
- The clumping coefficient **Ω** is poorly measured and a large source error in LAI measurements (Weiss et al. 2004).
- The particular LAI used (in models) depends on the purpose.
- Represents a potential divide between the measurement community and the others.

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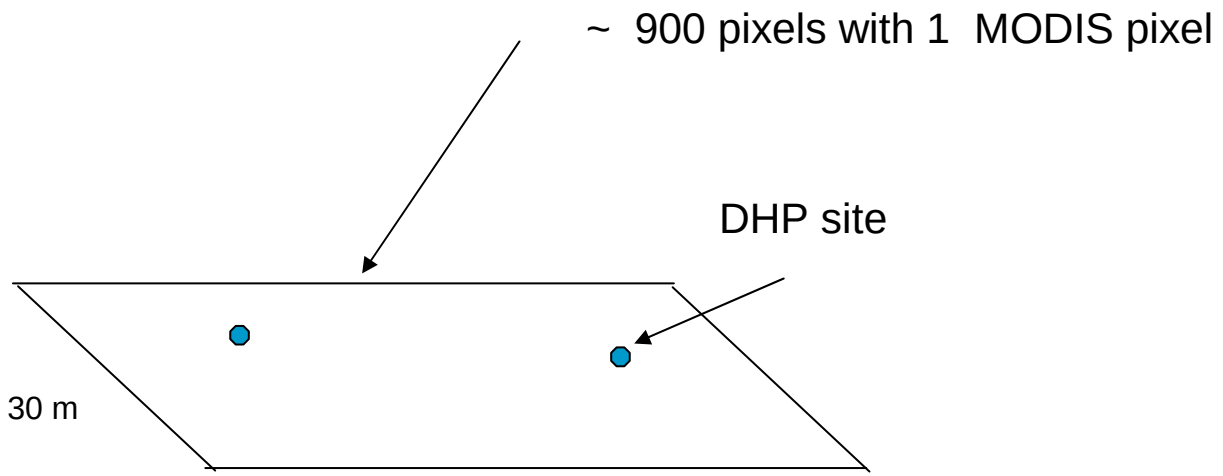
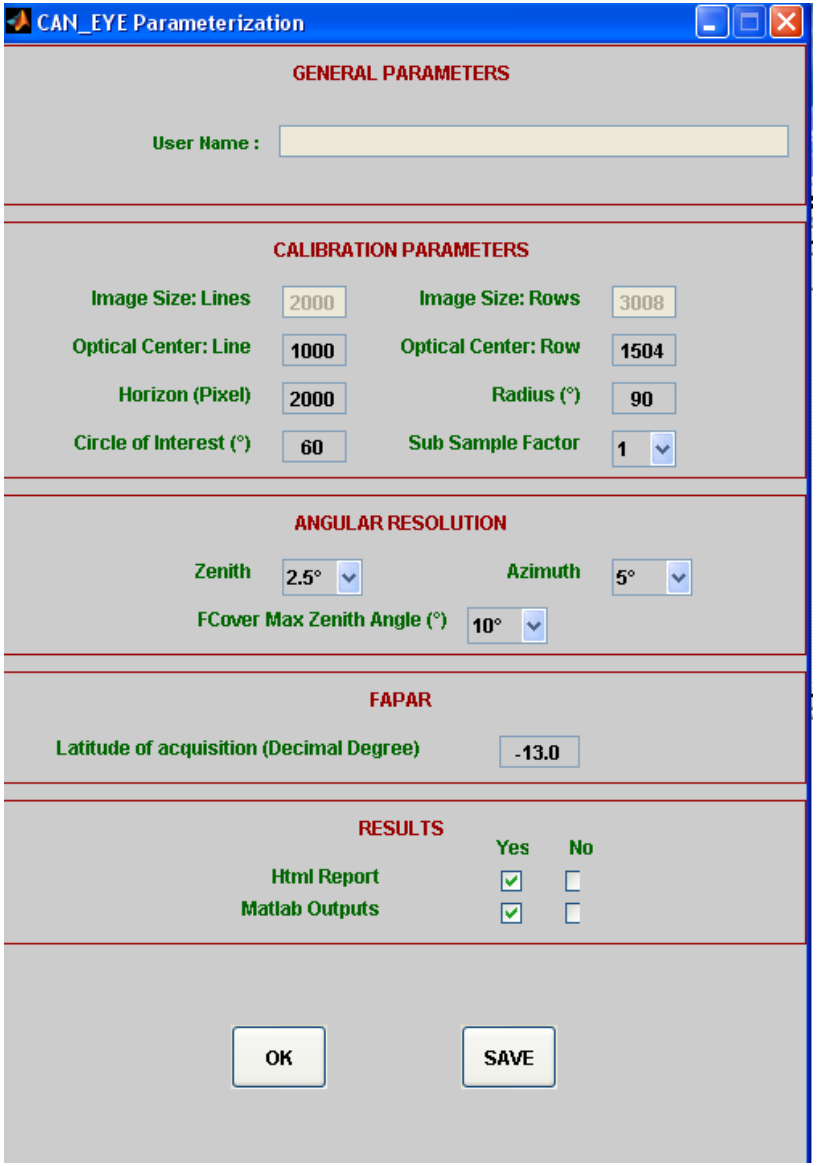
Reference Maps (Morrisette et al. (2006)

- To assess the spatial variability of LAI, use data from a high resolution remotely sensed product, e.g. LANDSAT ETM (30 m)
- Develop relationship between NDVI and LAI
- Map LAI at 30 meters to compare with ground measurements

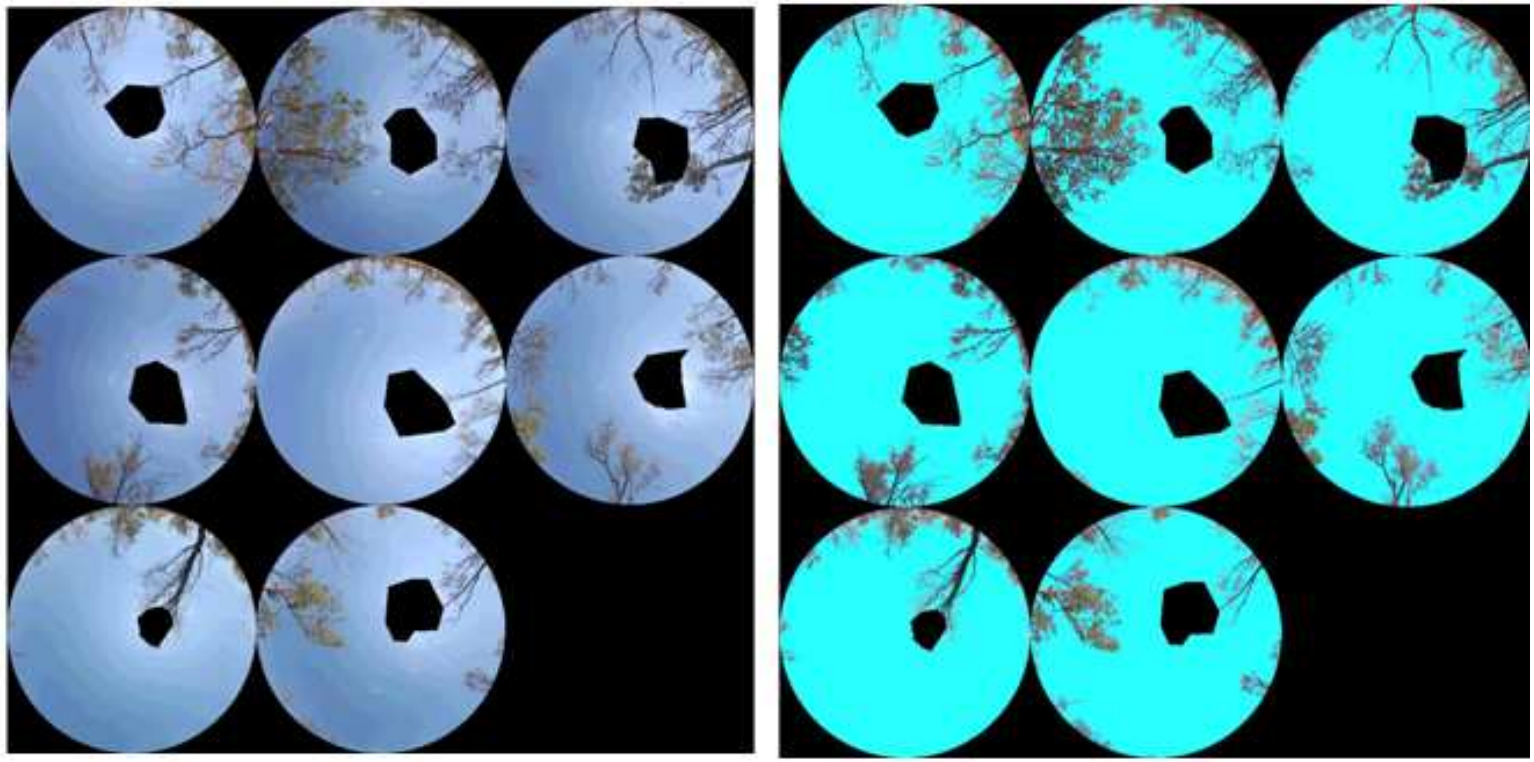


CAN-EYE 5.0 Software



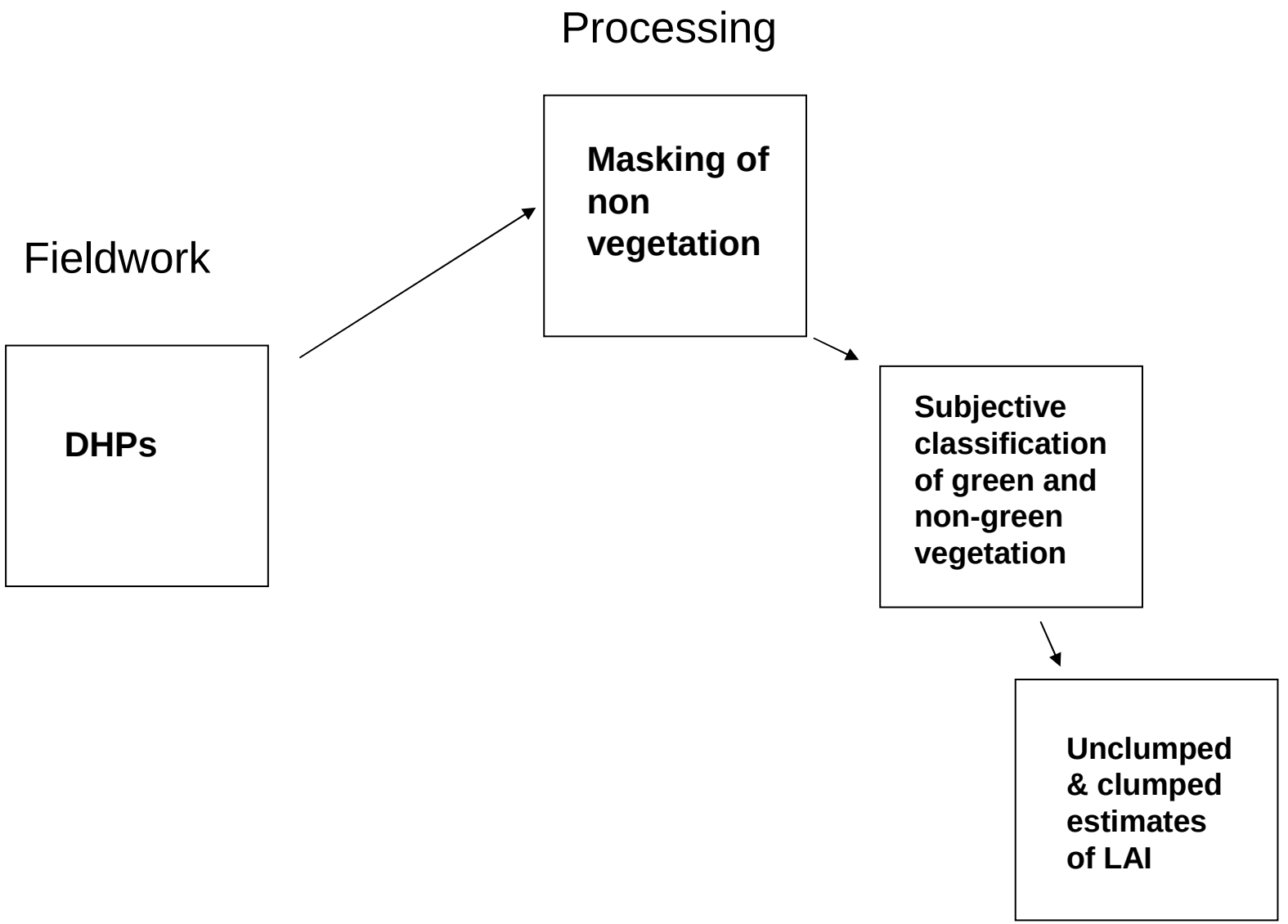
Perfect to not-so-perfect hemispheric photos

Typical Classification using CAN_EYE 5.0 software

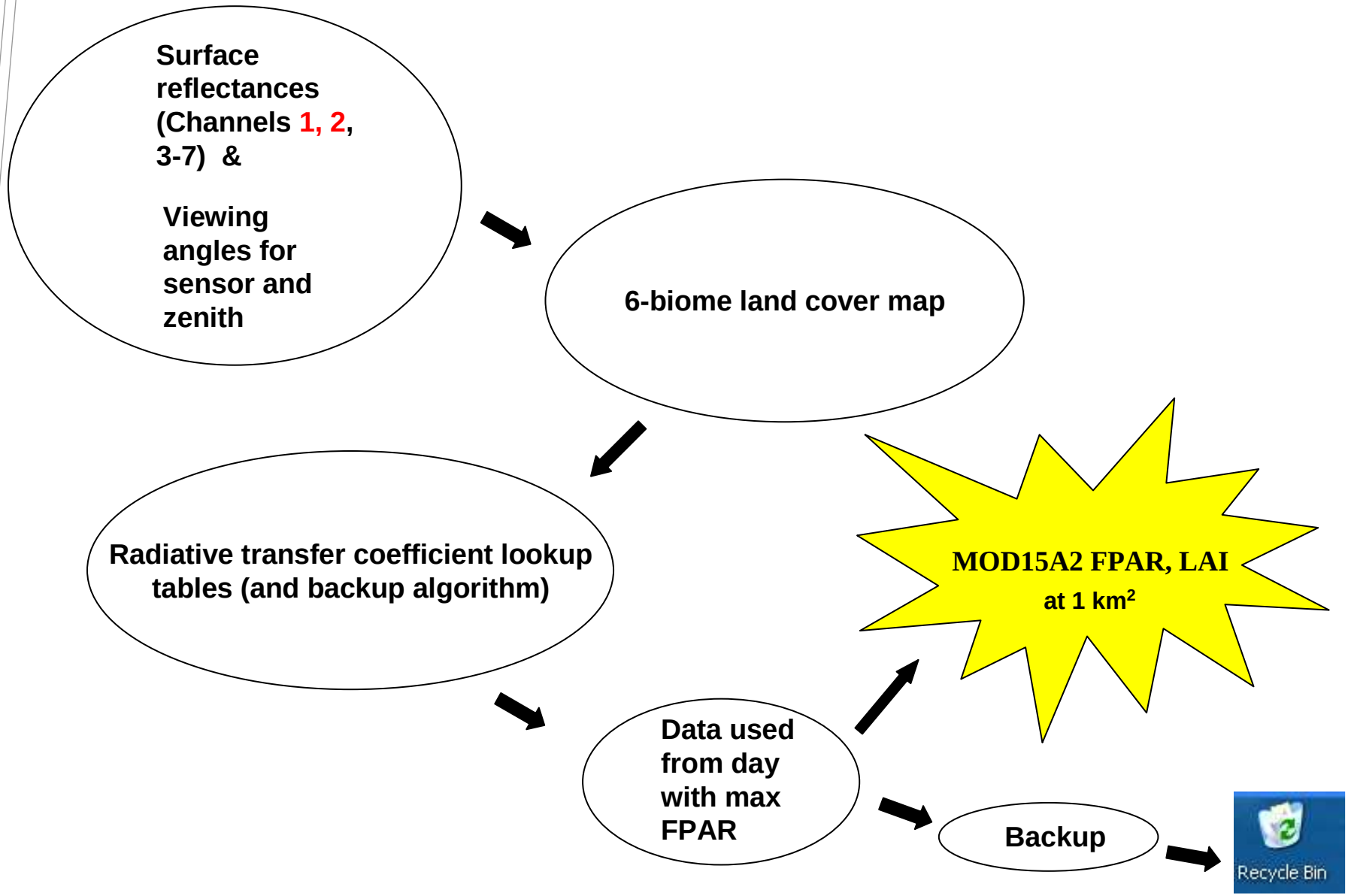


Unclassified hemispheric photos → Two state classification by "filling in the sky"

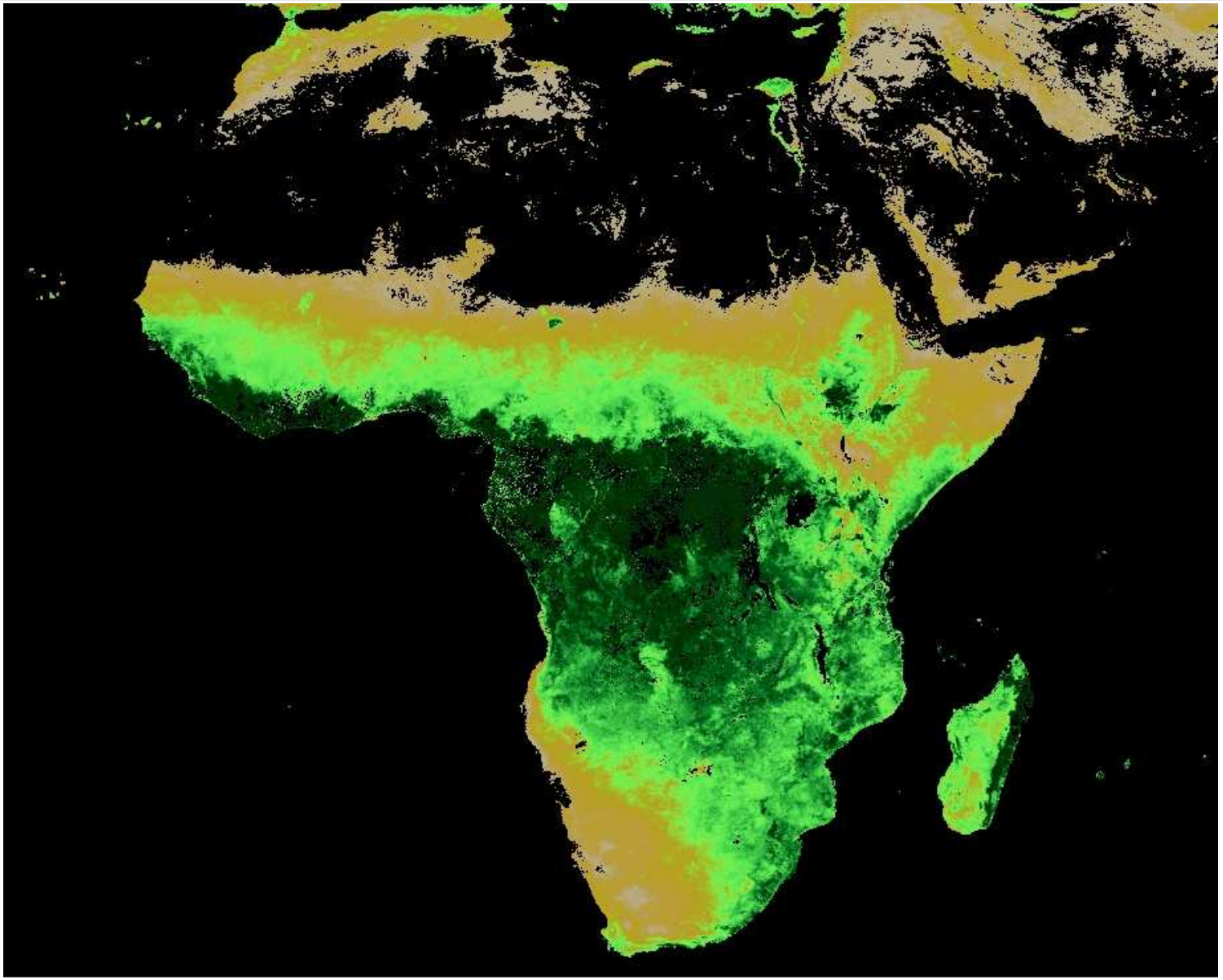
Essential steps in the process



MODIS: from daily surface reflectances to 8-day LAI



Currently monthly MODIS LAI



Other remotely sensed LAI products

- CYCLOPS
- GLOBCARBON
- ECOCLIMAP
- AVHRR

- Several recent papers suggest better performance for CYCLOPS than MODIS (Baret et al. 2008, Garrigues et al. 2008).

- But, MODIS has a much more friendly user interface than the others.
- And, MODIS is processed up to date.

Savanna Field Campaign

- 1 September-18 September, 2008
- Darwin-Tennant Creek, NT (~900 km) along the Northern Tropical Terrestrial Transect
- Participants from CSIRO, Monash University, Charles Darwin University, Flinders University, RMIT, and various Europeans
- Field measurements coordinated with low level aircraft flights measuring CO_2 and H_20 fluxes, LIDAR and hyperspectral sensors for vegetation structure, and PLMR for soil moisture (coordination meeting 15-16 April in Melbourne).
- We focused our efforts on comparing ground-based measurement of leaf area index with values derived from MODIS Collection 5 LAI/fPAR.
- This allowed us to actually visit the maximum number of landscapes in the Northern Territory during the campaign.

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Principal Research Questions

- How much improved (if any) are LAI estimates using MODIS Collection 5 (MC5) compared with Collection 4 (MC4) in savanna regions of Australia?
- Is there an LAI offset different from zero at low LAI values?
- How well does MC5 LAI compare with ground-based estimates derived from hemispheric photos?
- Does clumping matter?
- What is the pattern of LAI along the NATT?

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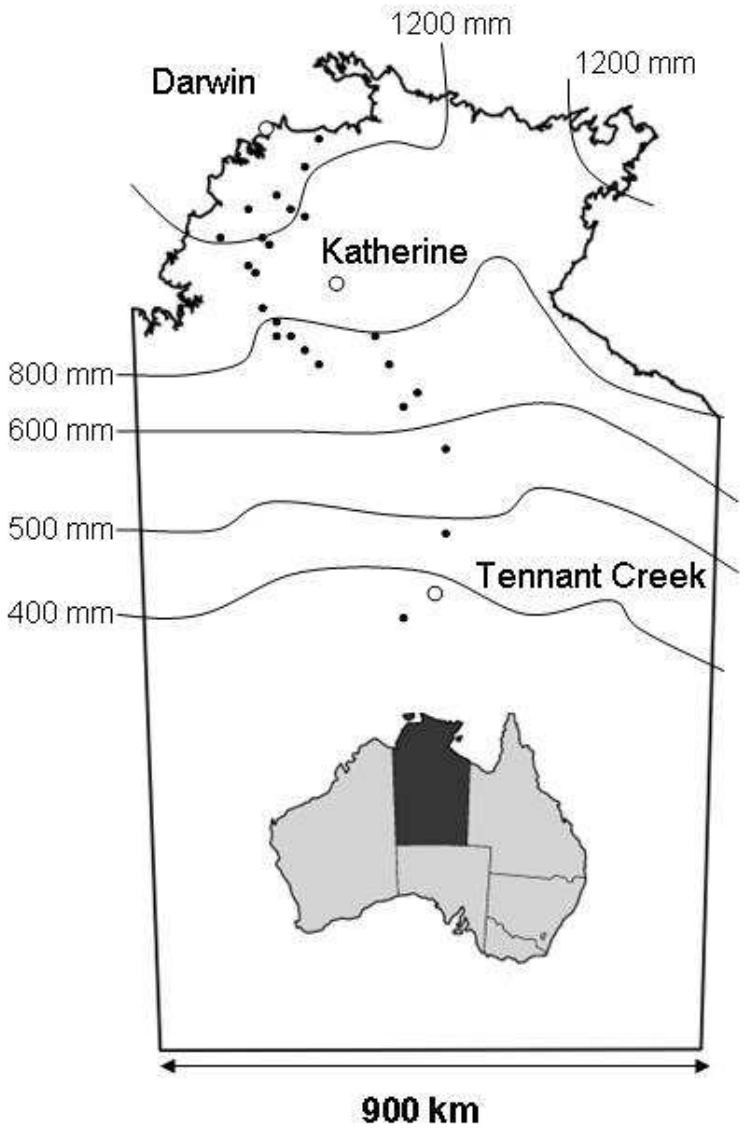
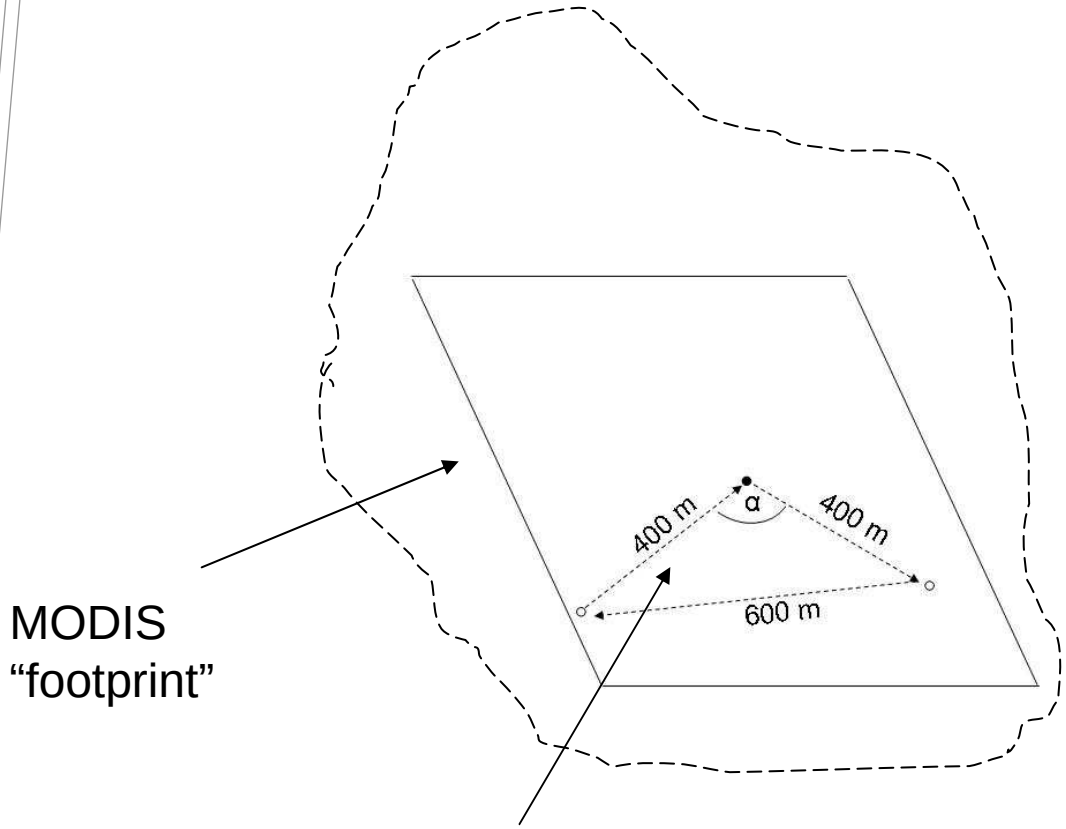
Field sites and rainfall gradient



MODIS pixels & sampling



MODIS
“footprint”

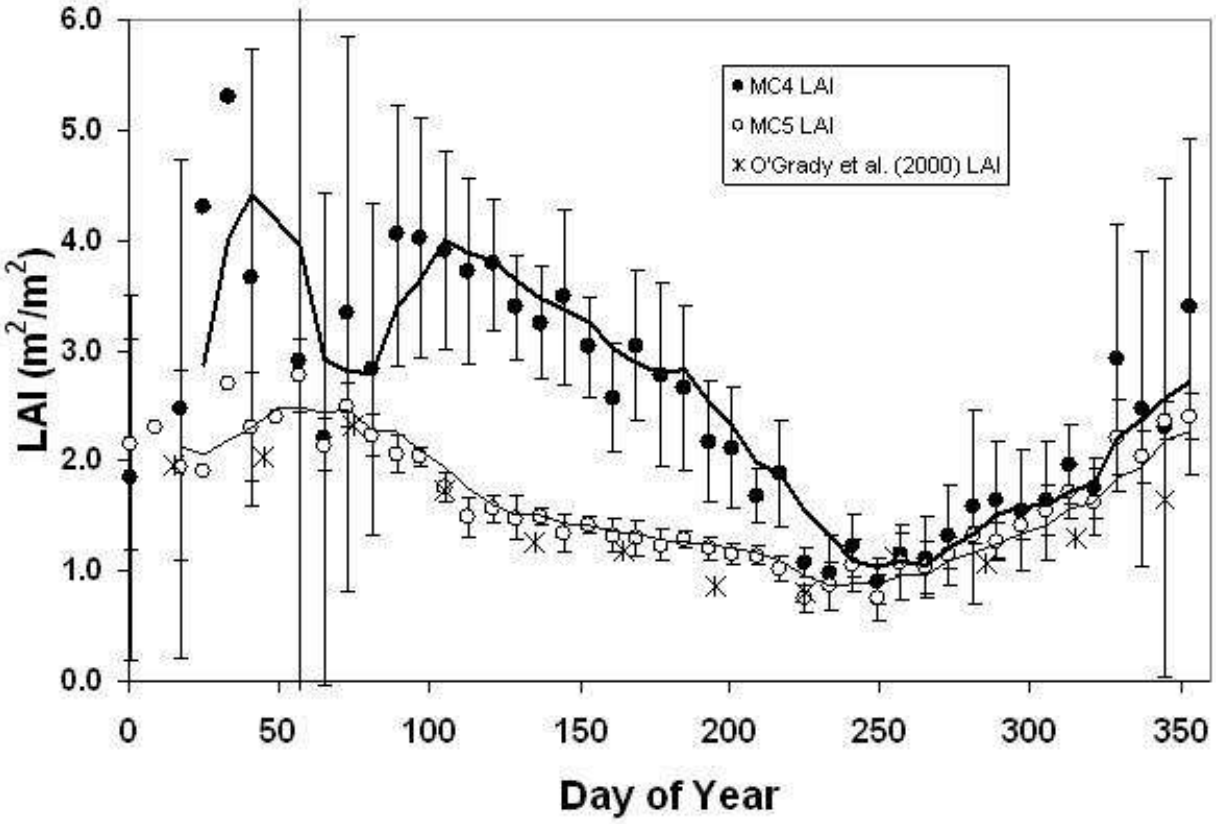
Field
sampling

Photographer: Steve Zegelin

Photos taken ~ every 20 meters
along transects

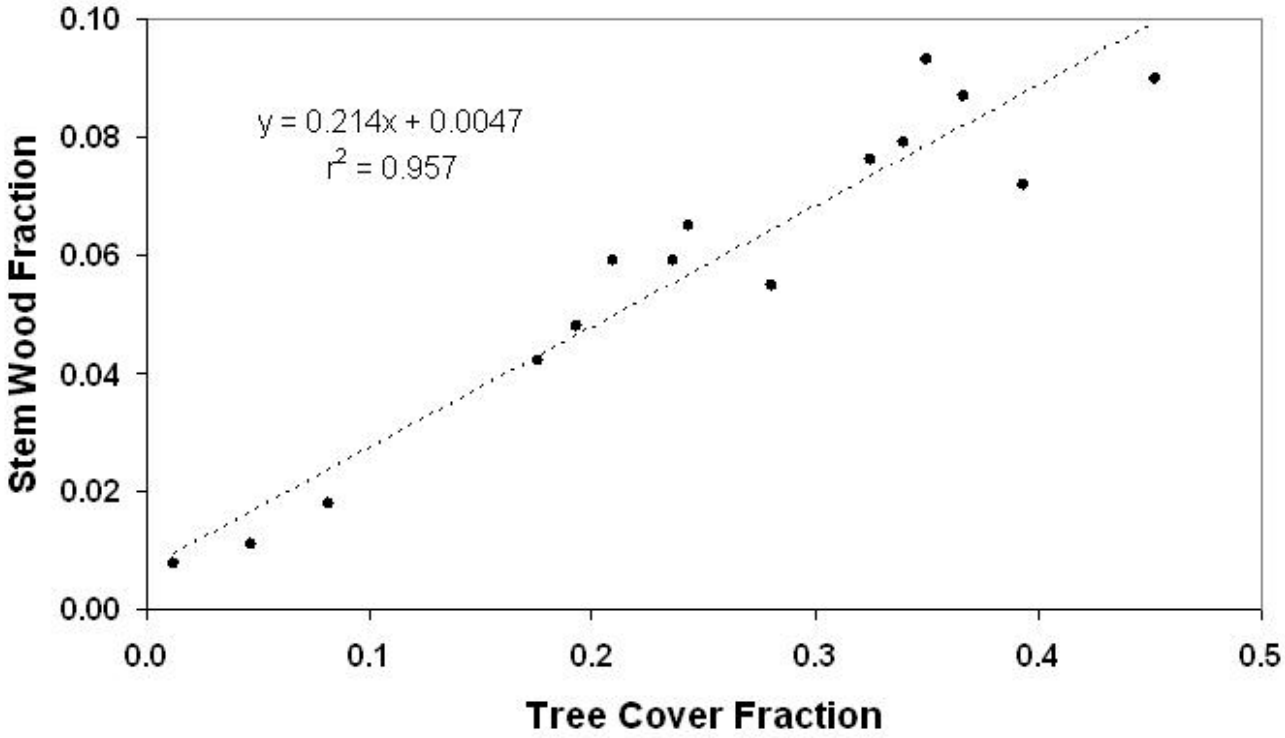
Result 1: Comparison of MODIS Collection 4 and 5

LAI Mean +/- 1 SE



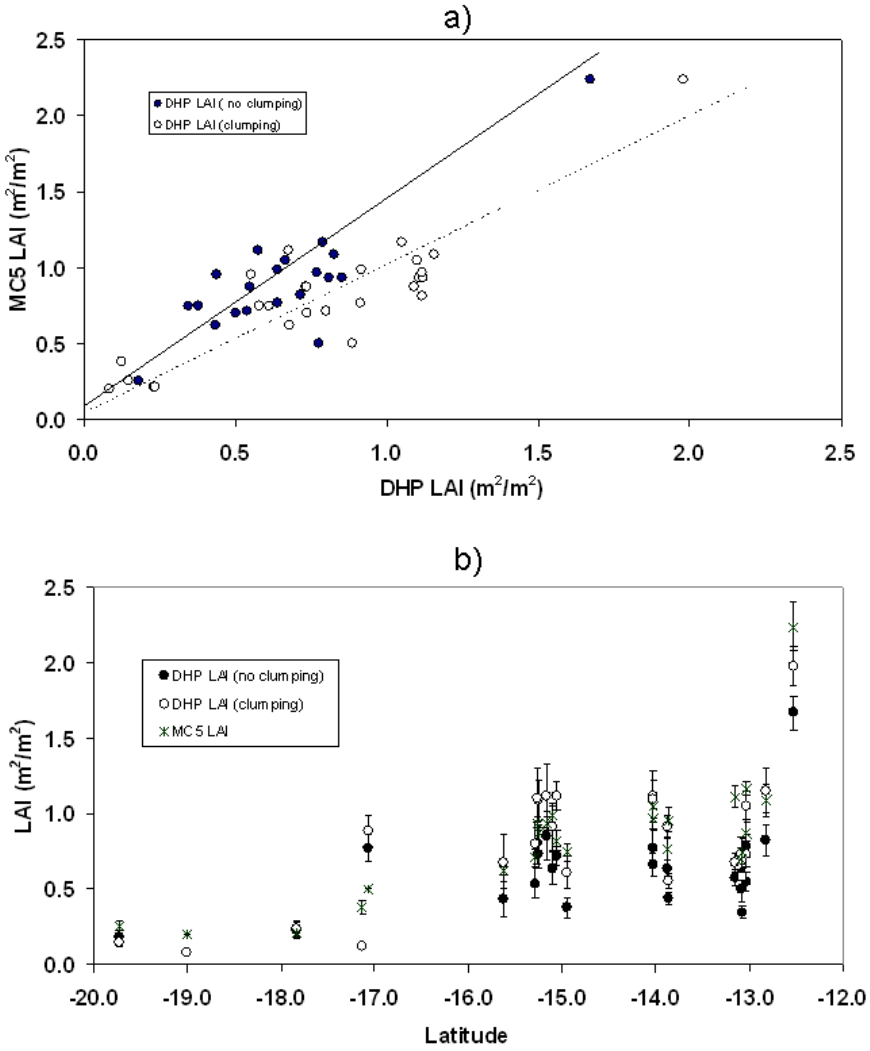
Sea et al. (2009) Remote Sensing of Environment in revision

Result 2: Stem LAI ~ 20% of total LAI



Sea et al. (2009) Remote Sensing of Environment in revision

Result 3: Comparison of MODIS to hemispheric photos



For clumped LAI, SMA regression, $r^2 = 0.89$, error dominated by unsystematic component

Error bars are 95 % confidence intervals

Sea et al. (2009) Remote Sensing of Environment in revision

Result 4: Leaf area index where there should be none!

Table 1. LAI offset sampling sites in the Northern Territory.

Site	Latitude	Longitude	Description	Ground LAI	MODIS LAI
1	-14.0103	131.3646	Bare	0.0	0.3
2	-14.0631	131.3167	Senescent	0.0	0.5
3	-17.1517	133.3485	Senescent	0.0	0.2
4	-17.8974	133.9301	Bare	0.0	0.2
5	-17.9918	134.0157	Senescent	0.0	0.2
				0.0	Mean = 0.28 Std = 0.13

Sea et al. (2009) Remote Sensing of Environment in revision

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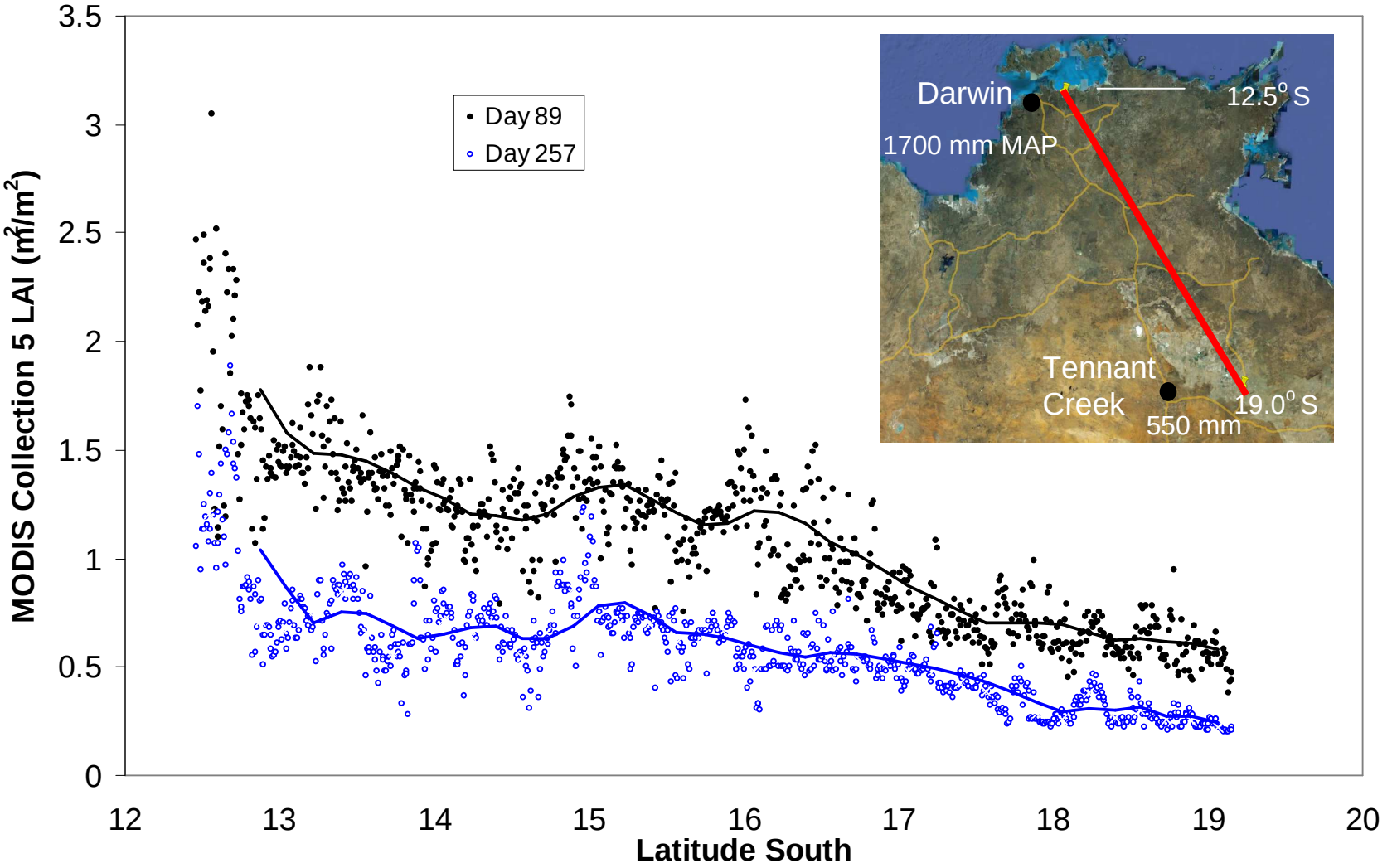
Result 5: LAI along the rainfall gradient

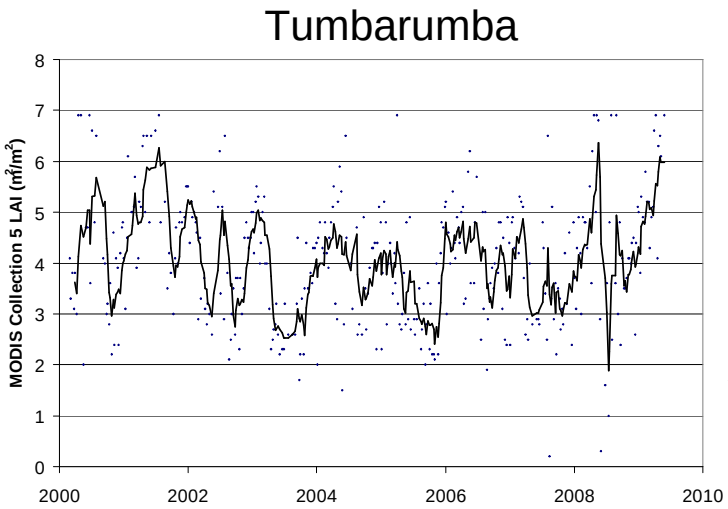


Data via DAAC ONRL MODIS website

Potential Errors in MODIS LAI

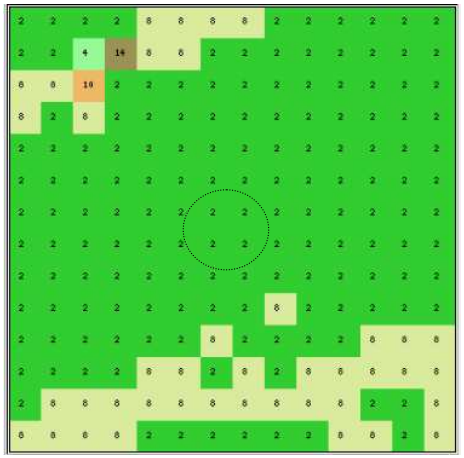
- Errors in the radiances
- Incorrect biome classification
- Inherent problems of treating classes as homogeneous, e.g. deciduous African savannas & evergreen Australian savannas
- Structural problems in the model, e.g. reliance on backup model

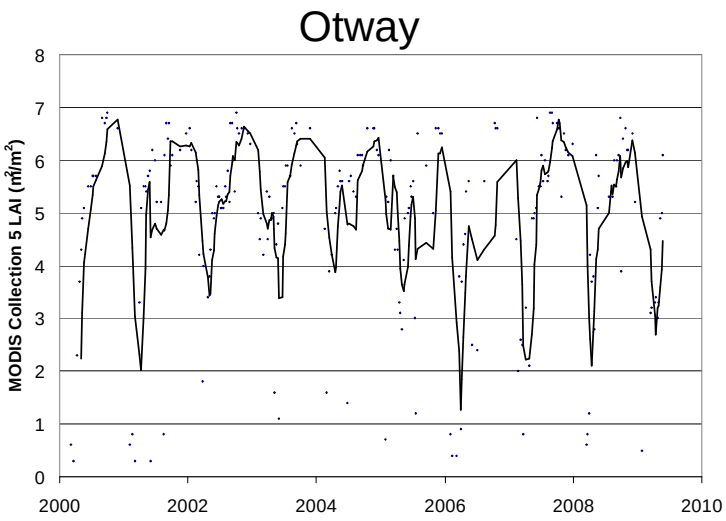
MODIS disasters: Tumbarumba & Otway:

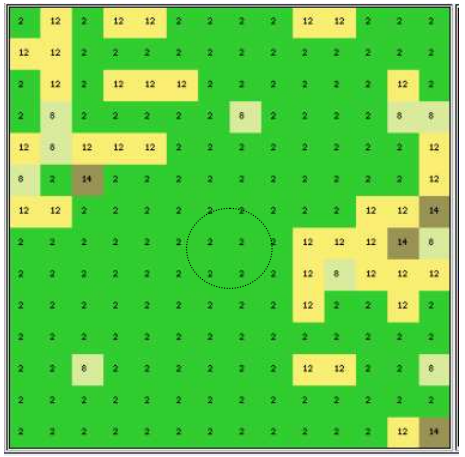


Land Cover

Evergreen Broadleaf Forest (green)







Summary

- The choice of equipment for LAI measurement depends on site and research requirements, and budget.
- Beware of the caveats, especially the difficulties in measuring clumping index.
- Our results show that MODIS Collection 5 does a reasonably good job at estimating LAI and compares well with DHPs
- Our results suggest that DHPs should incorporate clumping for comparison to MODIS LAI OR that MODIS is able to capture clumping of vegetation.
- Some disasters remain for MODIS LAI, with estimates not passing the Leuning Laugh Test (LLT).

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