Advantages of multifrequency microwave satellite sensors: what do microwave indices show in Argentina and Australia Ecosystems?

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Remote Sensing & Evapotranspiration

Characterization of evapotranspiration (ET) processes is essential in understanding the energy and water cycle and the responses of terrestrial systems to climate change and extreme events. ET depends upon the availability of both water and energy to change the state of water stored at the soil, the vegetation and the atmosphere. At regional scale, widespread ET estimations from remote sensing data are based on the water balance equations using measurements at visible (VIS) and near-infrared (NIR) wavelengths as proxies. However, optical data presents some limitations related to the low temporal resolution (mostly due to the sensitivity to cloud and aerosols) (Min and Li, 2006; Li et al., 2009). To overcome the limitations of the optical estimations of ET, a new technique that links vegetation properties and ET fluxes under all-sky conditions to microwave data was proposed by Min and Li (2006) and Li et al. (2009). Although characterized by coarser spatial resolutions, passive microwave sensors can be useful for large scale applications, since they present shorter revisit times and are less affected than optical systems by atmospheric conditions. In particular, microwave indices are known to be sensitive to vegetation moisture and structure (Ferrazzoli and Guerriero, 1996; Min and Li, 2006; Barraza et al., 2013). Moreover, it was found experimentally that the Emissivity Difference Vegetation Index (EDVI) (Li et al., 2009) is sensitive to vapor deficit pressure, water potential and carbon dioxide concentration, the same variables that determine canopy resistance.

Objectives

In this framework, it is interesting to investigate the potential of microwave indices derived from different platforms to obtain information about vegetation and soil dynamics for different types of ecosystems. For six different ecosystems in the north and southeast of Australia and the northwest of Argentina, we evaluated:

1) the daily and seasonal patterns of microwave indices;
2) relative contributions of the soil and vegetation canopy to the total microwave emissivity;

Microwave indices

We processed microwave data collected by AMSR-E and Windsat in both ascending and descending passes from 2007 to 2009 in order to closely look at the hourly behavior of radiometric signatures. Furthermore, we used microwave data collected by AMSR2 and Aquarius/SAC-D at beam 3 in ascending passes from 2012 to 2013.

Index	Formulation	Reference
Frequency index	$\mathrm{FI} = \frac{\mathrm{Tbv\ (Ka\ band)} - \mathrm{Tbv\ (Xband)}}{\mathrm{Tbv\ (Ka\ band)} + \mathrm{Tbv\ (Xband)}} * 2$	(Ferrazzoli and Guerriero, 1996)
Polarization Index	$\mathrm{PI} = \frac{\mathrm{Tbv\ (X\ or\ L\ band\ )} - \mathrm{Tbh(X\ or\ L\ band)}}{\mathrm{Tbv\ (X\ or\ L\ band)} + \mathrm{Tbh(X\ or\ L\ band)}} * 2$	(Paloscia and Pampaloni, 1986)

Table 2. Spectral indices calculated. Including their shortened acronym, mathematical formulation and references, Tb is the brightness temperature and v means vertical polarization and h means horizontal polarization.

Hourly Components

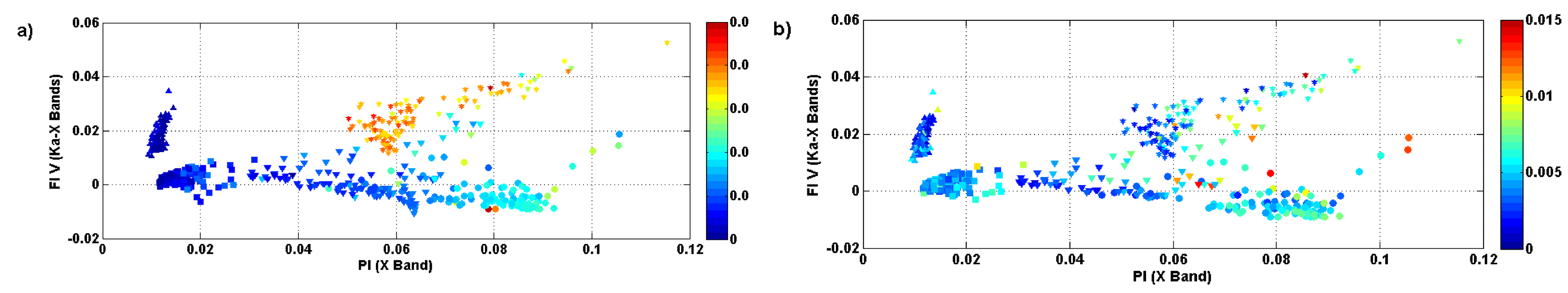

Figure 5. Mean daily FI and PI (X Band) scatter plot for 2007-2009. This Figure shows the hourly component of both indices. In (a) the colorbar represents the standard devotions of daily PI values, and in (b) the colorbar represents the standard deviations of daily FI values. The markers are: upward-pointing triangles are Open forest (Dry Chaco Forest), six-pointed stars (hexagram) are Open woodland savanna (Howard Spring), downward-pointing triangles are Mulga (Alice Spring), circles are Grassland (Sturt Plain) and squares are Wet temperate sclerophyll eucalypt (Tumbarumba).

Summary of Seasonal and Hourly Components

Table 3. Summary of FI and PI (X Band) hourly and seasonal components.

Site	PI average	PI long term variations	PI daily variations	FI average	FI long term variations	FI daily variations
Chaco Forest	0.011 (Low)	0.0061- 0.015 (Slight decrease in summer due to higher attenuation of soil emission)	0.001 (Low)	0.0178 (Low)	0.01 (summer) – 0.025 (winter).	<0.005 (Slight, with maximum at 7.00 am, minimum at 2.30 pm)
Tumbarumba	0.0168 (Low)	0.01-0.0354 (Low)	-0.0106-0.0226 (Low)	0.0027 (Low)	-0.0113- 0.0226 (Low)	<=0.005 (Low)
Howard Spring	0.066 (High value, since soil emission is important)	0.024– 0.137 (Clearly increases with soil moisture. Vegetation attenuation is moderate)	0.015-0.025 (High)	0.0249 (Slightly higher than in dense forests. There is a complex combination of surface effects, volume effects within sandy soil and volume effects within vegetation)	0.0064(winter).-0.0638(summer) (Increases with soil moisture.)	0.01 (Strong effect due to thermal cycle of temperature in sandy soil at different depths.)
Alice Spring	0.077 (High. Soil emission is important due to absence of trees)	0.0303– 0.118 (Strong)	0.005-0.02 (Low when the vegetation is more developed, high when the vegetation is less developed. Clearly related to thermal cycles of sandy soil at different depths.)	0.0037. (Combination of sandy soil effects)	-0.0129- 0.035 (Moderately increases with soil moisture.)	0.0075 (Low when the vegetation is more developed, high when the vegetation is less developed. Clearly related to thermal cycles of sandy soil at different depths.)
Sturt Plain	0.0534 (High. Soil emission is important due to absence of trees)	0.022– 0.094 (Strong)	0-0.01 (Low when the vegetation is more developed, high when the vegetation is less developed. Clearly related to thermal cycles of sandy soil at different depths.)	0.0019 (Combination of sandy soil effects)	-0.0085- 0.035 (Moderately increases with soil moisture.)	<=0.005 (Low when the vegetation is more developed, high when the vegetation is less developed. Clearly related to thermal cycles of sandy soil at different depths.)

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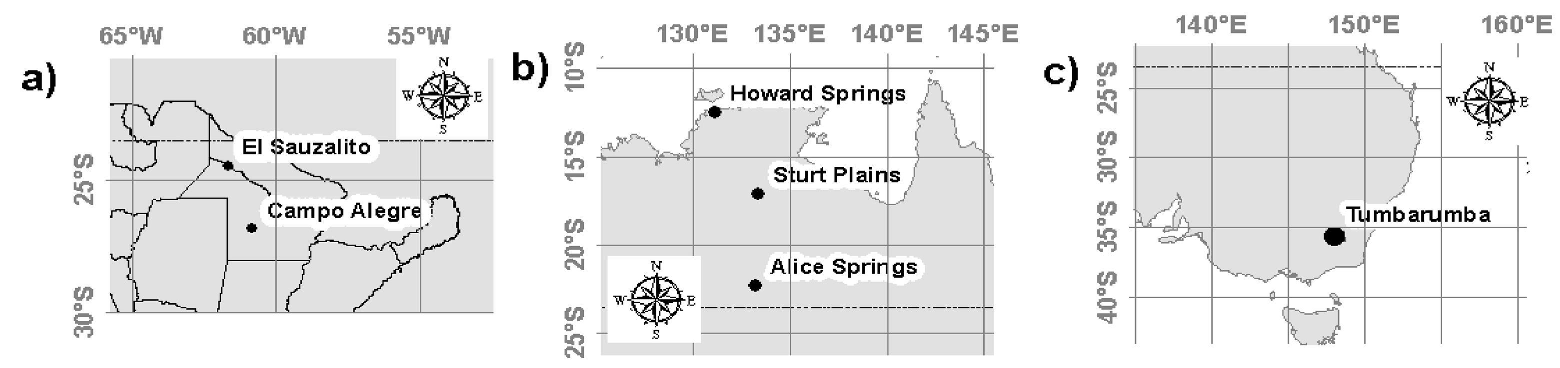
Study Areas

Table 1. Summary of study areas characteristic.

Name	LAI	Stem density (1/ha)	Ecoregion	Land cover	Prec. (mm/year)
Howard Springs	1.04 ± 0.07	661	Mediterranean forests, woodlands and shrubs	Open woodland savanna	1750
Alice Springs	Overstory 0.18-0.3 understory 0.04 - 0.32	820	Deserts and xeric scrublands	Semiarid acacia	305.9
Sturt Plains	0.39	-	Deserts and xeric scrublands	Low grassland plain	640, 535
Tumbarumba	2.47	850 ± 170	Wet temperate sclerophyll eucalypt	Cold temperate forest	1000
El Sauzalito	1-3	133	Dry Chaco Forest	Xerophytes forest	500
Campo Alegre	2.5	130	Dry Chaco Forest	Xerophytes forest	700

Figure 1. Locations of the Study areas in (a) Argentina and in (b, c) in Australia.



Seasonal components

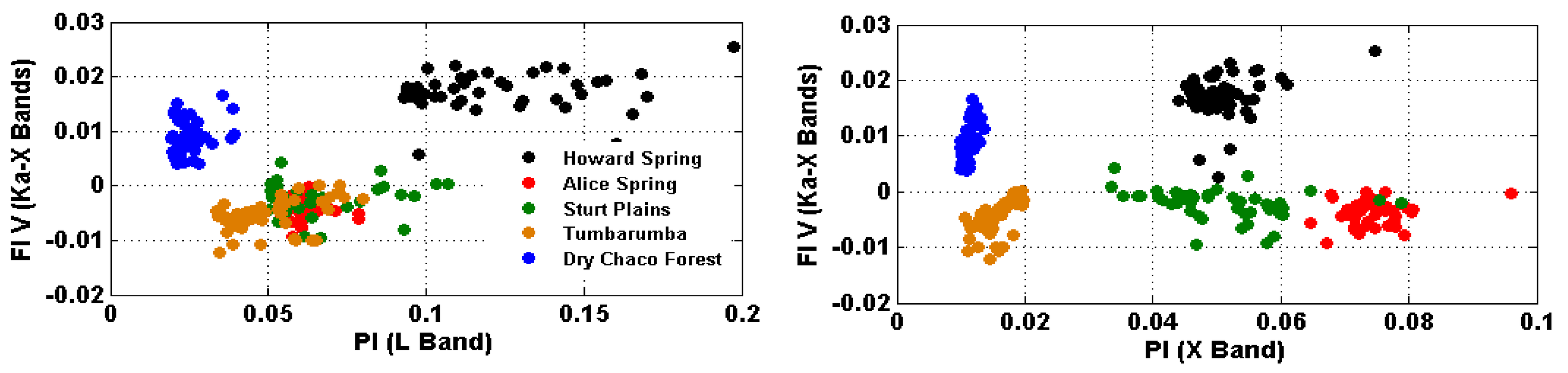
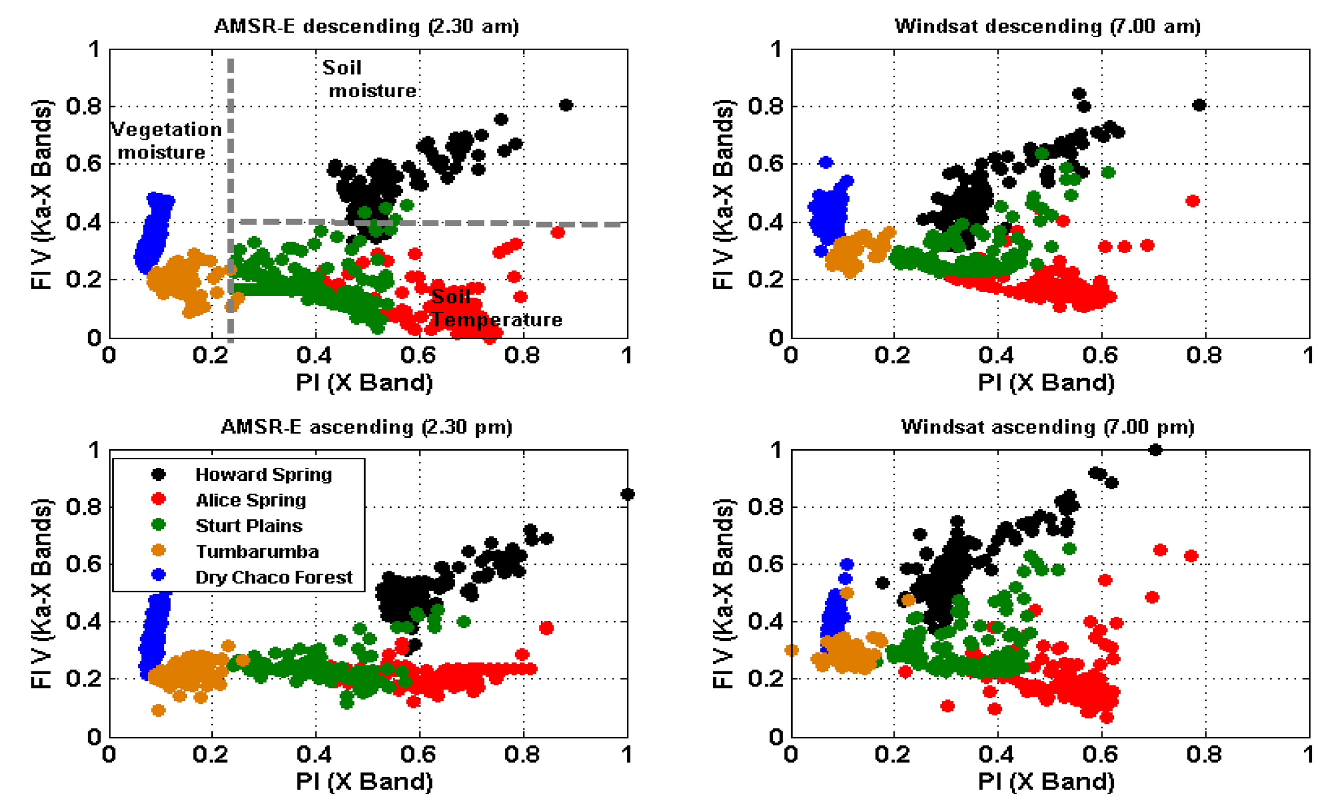


Figure 2. 8-days FI and PI (X and L band) scatter plot for scatter plot for 2007-2009 (a) and 2012-2013 (b, c). This figure shows the seasonal components of both indices. The selected sites represent Open forest (Dry Chaco Forest), Open woodland savanna (Howard Spring), Mulga (Alice Spring), Grassland (Sturt Plain) and Wet temperate sclerophyll eucalypt (Tumbarumba).

Figure 3. 8-days FI and PI scatter plot for 2007-2009. This figure shows the seasonal components of both indices. The selected sites represent Open forest (Dry Chaco Forest), Open woodland savanna (Howard Spring), Mulga (Alice Spring), Grassland (Sturt Plain) and Wet temperate sclerophyll eucalypt (Tumbarumba).



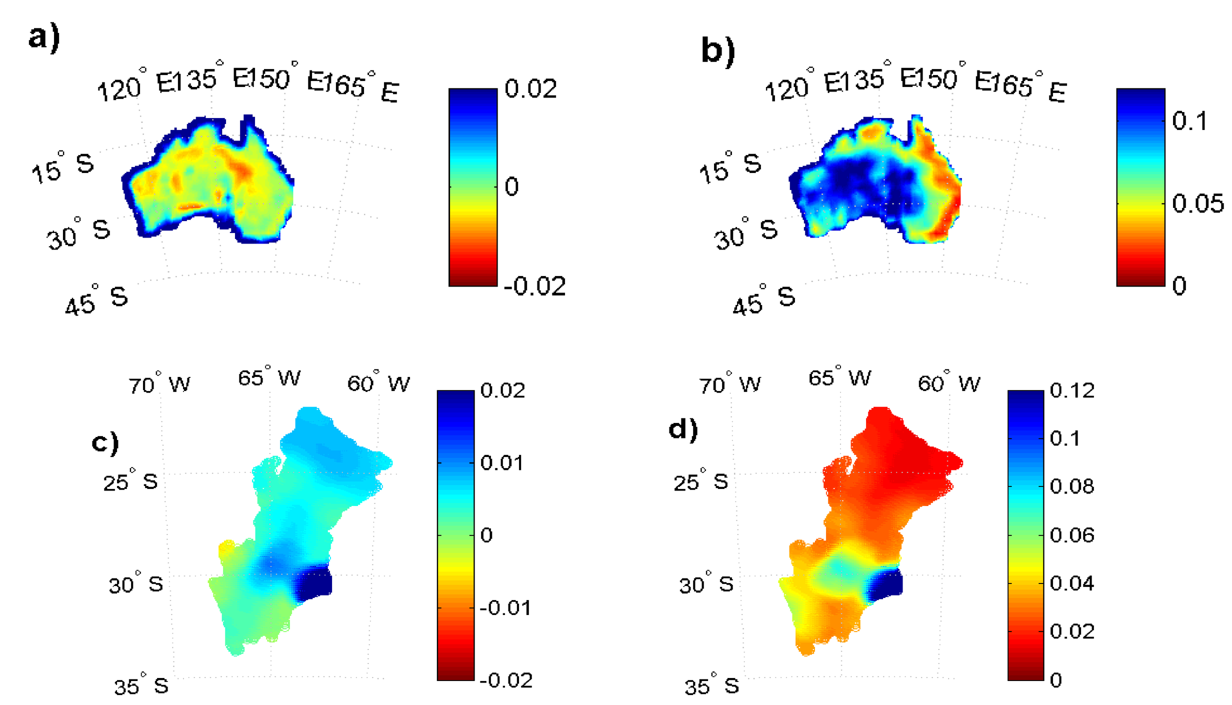


Figure 4. Annual (2012-2013) microwave indices for Australia. FI mean values for Australia (a), PI mean values for Australia (b), PI mean values for Chaco Forest in Argentina (c) and PI mean values for Chaco Forest in Argentina (d) from AMSR-2 L1B brightness temperature product.

CONCLUSION

- **The dynamic range and the absolute value of PI (band L) calculated using Aquarius / SAC-D data is higher due to the less attenuation. The FI (X and Ka bands) vs PI (L band) has not been successful in distinguishing different ecosystem.**
- **The FI(X and Ka bands) vs PI (X band) scheme was found the best approach to show the main biophysical processes involved.**
- **In dense vegetated areas both PI and FI mainly depend on the canopy properties. In areas characterized with intermediate LAI values, soil effects dominate FI and PI dynamics, due to soil moisture changes in sandy soils. Finally, in the less dense vegetated areas, FI is mostly dependent on the complex dynamics of soil condition, and PI seasonality is associated to phenology.**
- **These results are relevant, since vegetation and soil conditions are components of the overall water balance and surface radiation budget, which effectively modulates evapotranspiration.**

Acknowledgment

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