Satellite passive microwave remote sensing for estimating diurnal variation of Canopy water content, as a proxy of evapotranspiration, in the Dry Chaco Forest, Argentina.

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INTRODUCTION

- **Vegetation moisture, coverage and soil moisture affect mesoscale circulation and water and energy cycle.**

- **They also represent the response of land surface to atmospheric water flux (Evapotranspiration-ET), radiation and other atmospheric forcing.**

Most of the remote sensing techniques for estimating ET are based on **visible and near- infrared** wavelengths.

•Strongly influenced by clouds and aerosols
•Saturation problems

New approach based on **microwave passive remote sensing (Min and Li, 2008)**

•Applicable both at day and night times under all weather conditions
•No saturation
• Better theoretical sensitivity

OBJECTIVE

Evaluate the potential to estimate a proxy of Evapotranspiration in a dry forest by monitoring diurnal variations of Canopy water content (CWC), using multitemporal passive microwave remote sensing observations.

1. Daily trend (Compare Optical and Microwave indexes)
   - Leaf Water Content (LWC (g H_2O/ g fresh weight))
   - Leaf area index (LAI),
   - CWC (g H_2O /g fresh weight: stem, leaf and branches)

2. Diurnal trend (Microwave index).
   - CWC (g/g)

INSTRUMENTS

Optical: MODIS land surface reflectance product at 500m spatial resolution from AQUA (MYD09A1) (2.30 pm)

Microwave: AMSR-E and WINDSAT data from 2008-2009 at X and Ka bands, four observations per day at four different local times (2.30 am, 7.00 am, 2.30 pm and 7.00 pm).

AMSR-E and MODIS data have been downloaded from the National Aeronautics and Space Administration (NASA) site http://reverb.echo.nasa.gov/, and WINDSAT data have been provided by U.S Navy.

METHODOLOGY

Vegetation index

$$NDVI = \frac{nir - red}{(nir + red)}$$

$$NDWI = \frac{nir - swir}{(nir + swir)}$$

$$FI = \frac{T_{b\kappa(f2)} - T_{b\kappa(f1)}}{0.5(T_{b\kappa(f2)} + T_{b\kappa(f1)})}$$

where *Tb* indicates brightness temperatures, *k* means vertical *(v)* polarization, *f* indicates frequencies, with *f2 (Ka band)* higher than *f1 (X band)*.

Radiative transfer model

PROSAIL (PROSPECT+ SAILH) model : we generated the synthetic canopy reflectance in the 400-2500 nm range, using input variables that are site specific for Dry Chaco Forest . Input variables can be subdivided in two groups:

1. available ground truth (Cm, Cw, Leaf angle, ts, tv, ps,)
2. reasonable guesses based on field expertise (N, Cab)

Modification of **Ferrazzoli & Guerriero model (1996)** has been used to simulate the variations of FI with CWC and LAI
Available information about forest structure in the study area:

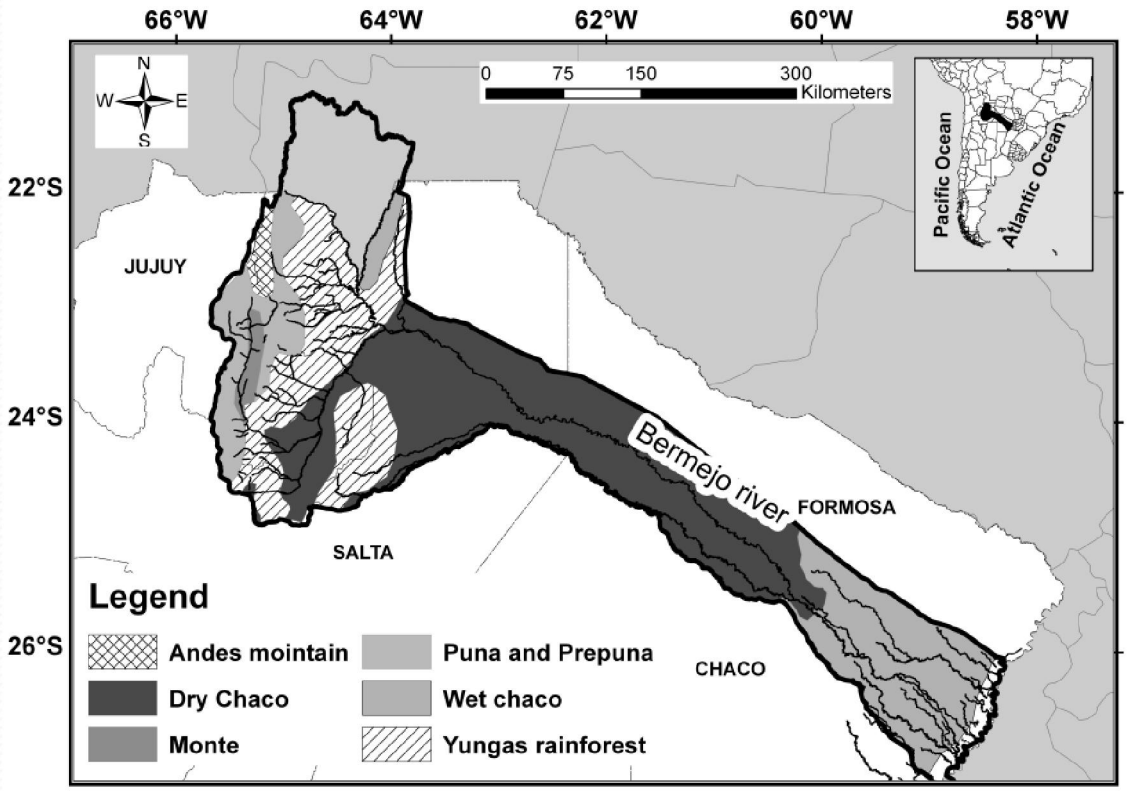
- biomass, dry matter density,
- gravimetric moisture content of woody matter
- Diameter at Breast Height distribution

STUDY AREA

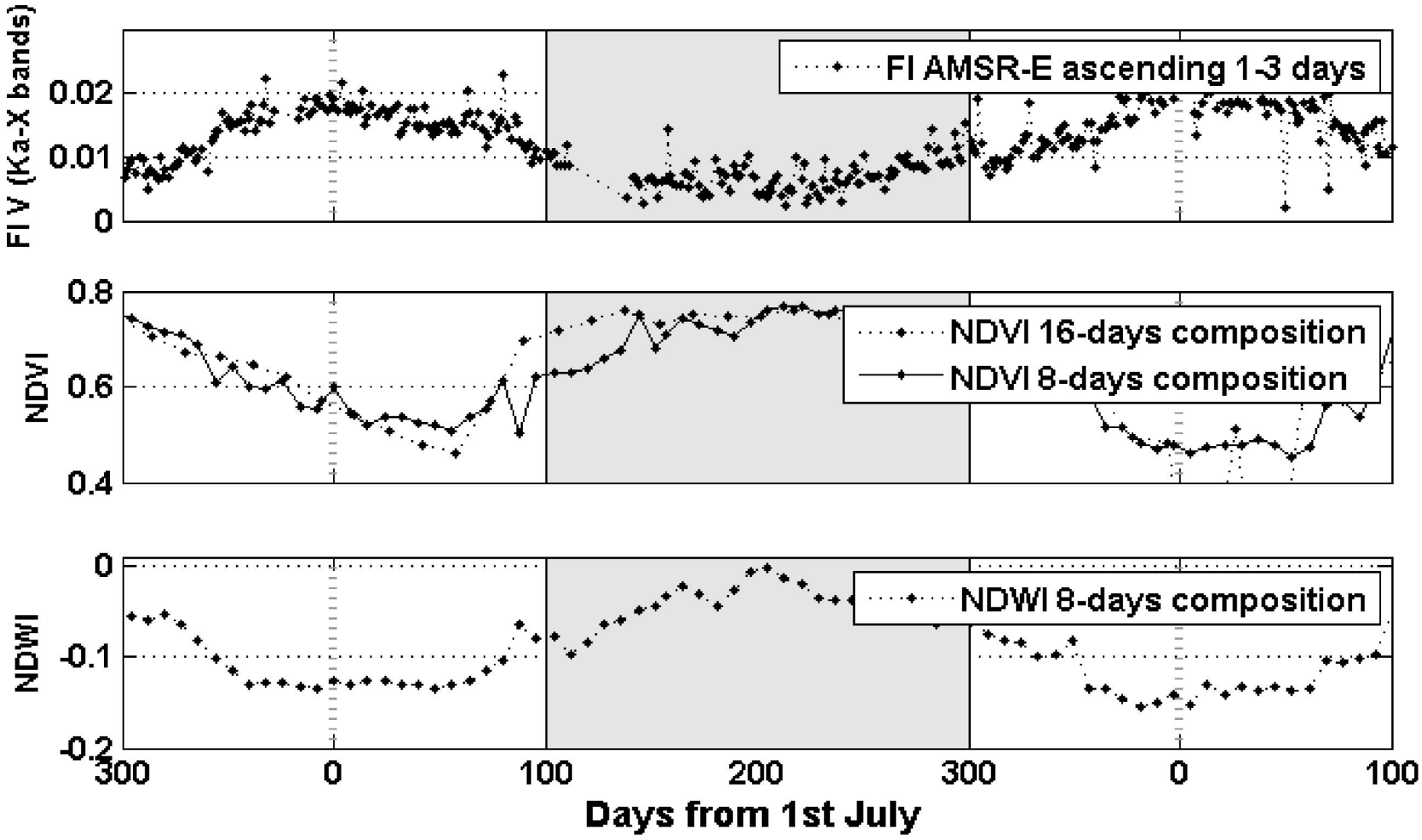
- Bermejo River Basin in Argentina (22-27 S, and 58-66 W). **This Basin includes the Chaco Plain, which is a dry forest phytogeographic region.**

- The total extent is of more than 100 millions of hectares.

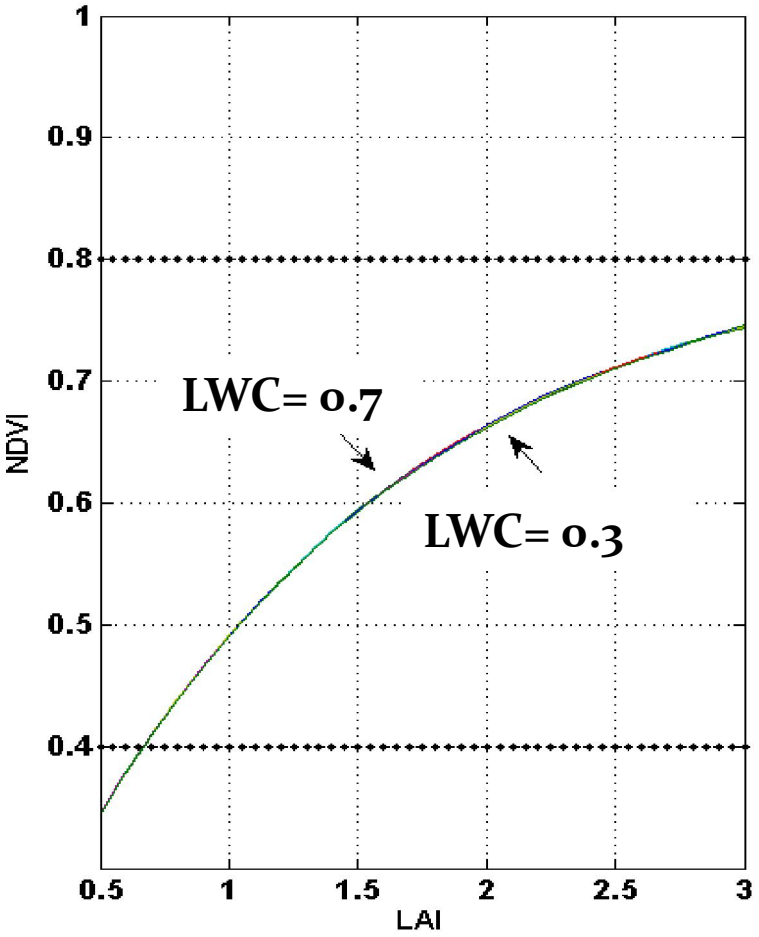
- **The study area has several important characteristics for microwave signal analysis: large homogeneous sites covered by forest with biomass that varies between 70–110 tn/ha.**



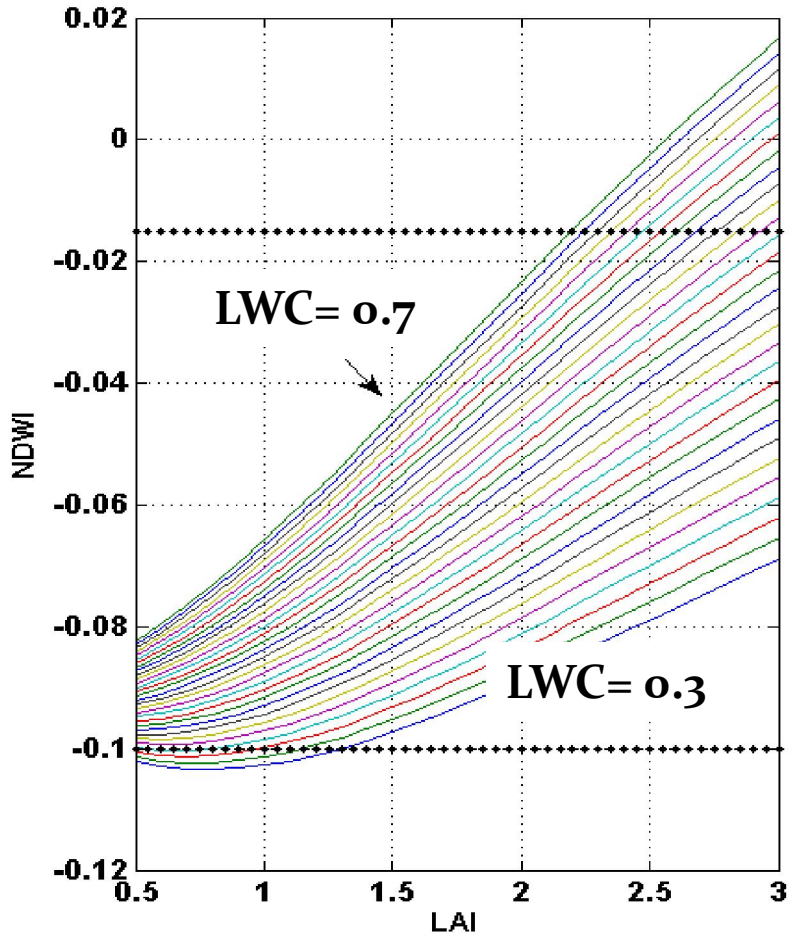
AVAILABLE DATA:



RESULTS: PROSAIL MODEL

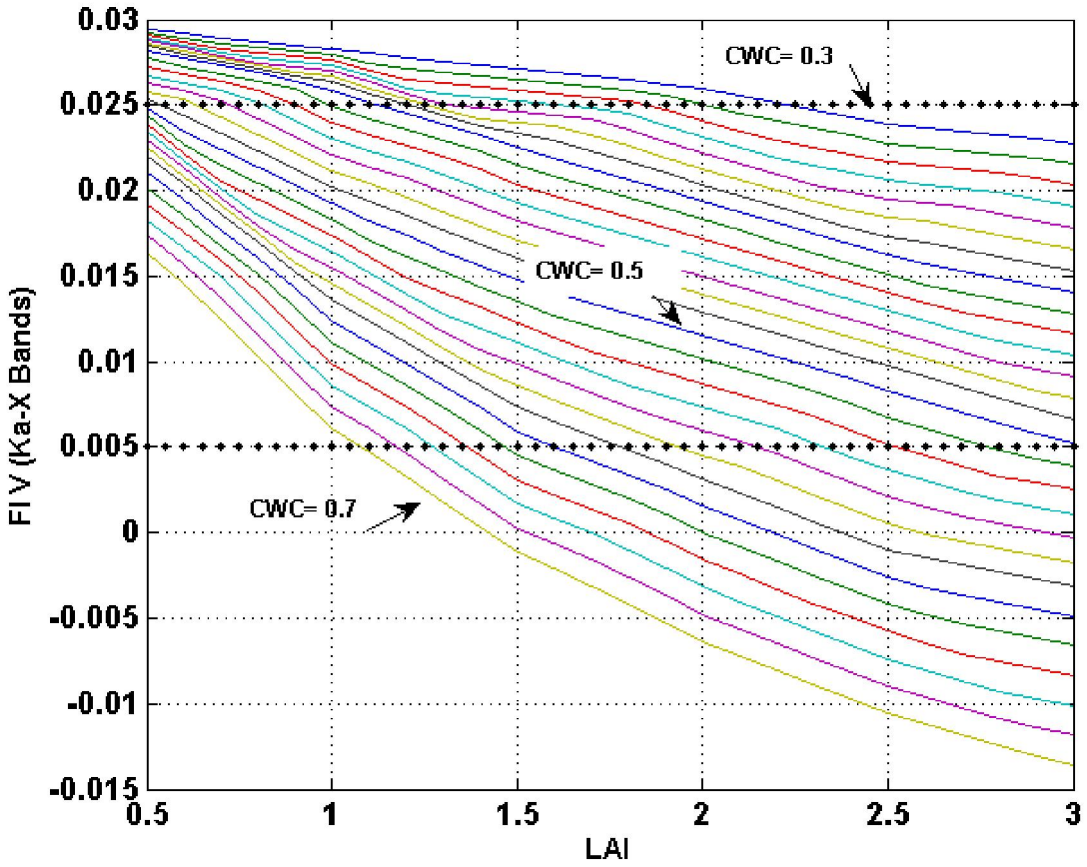


Annual trend:
NDVI: 1. LAI



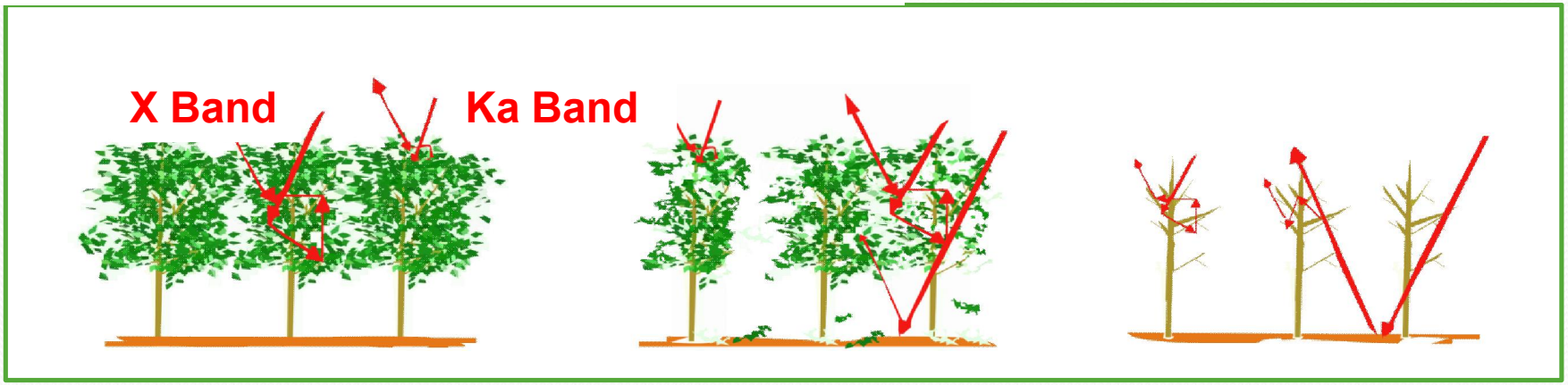
Annual trend:
NDWI: 1. LAI
2. LWC

RESULTS: MICROWAVE MODEL

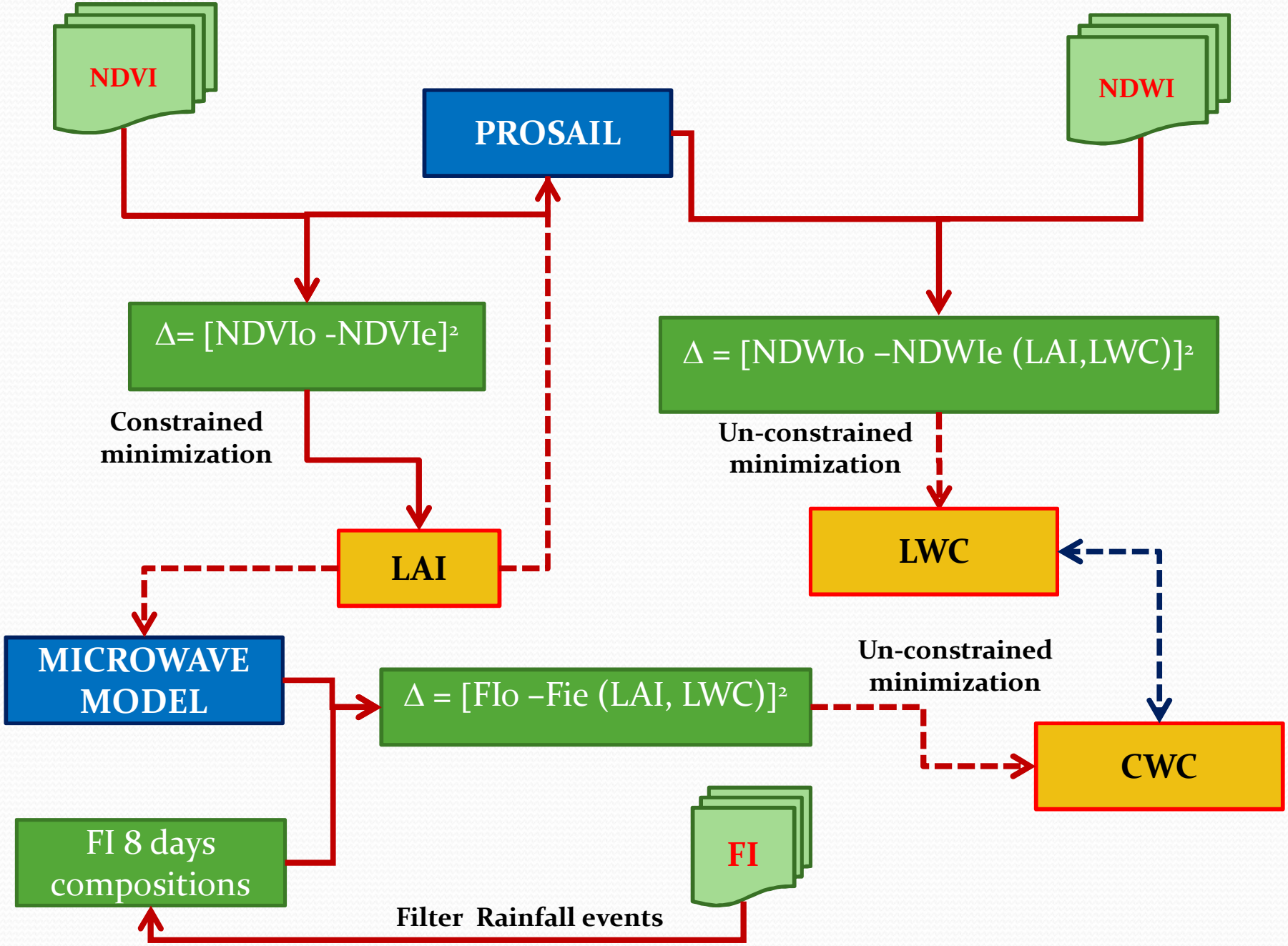


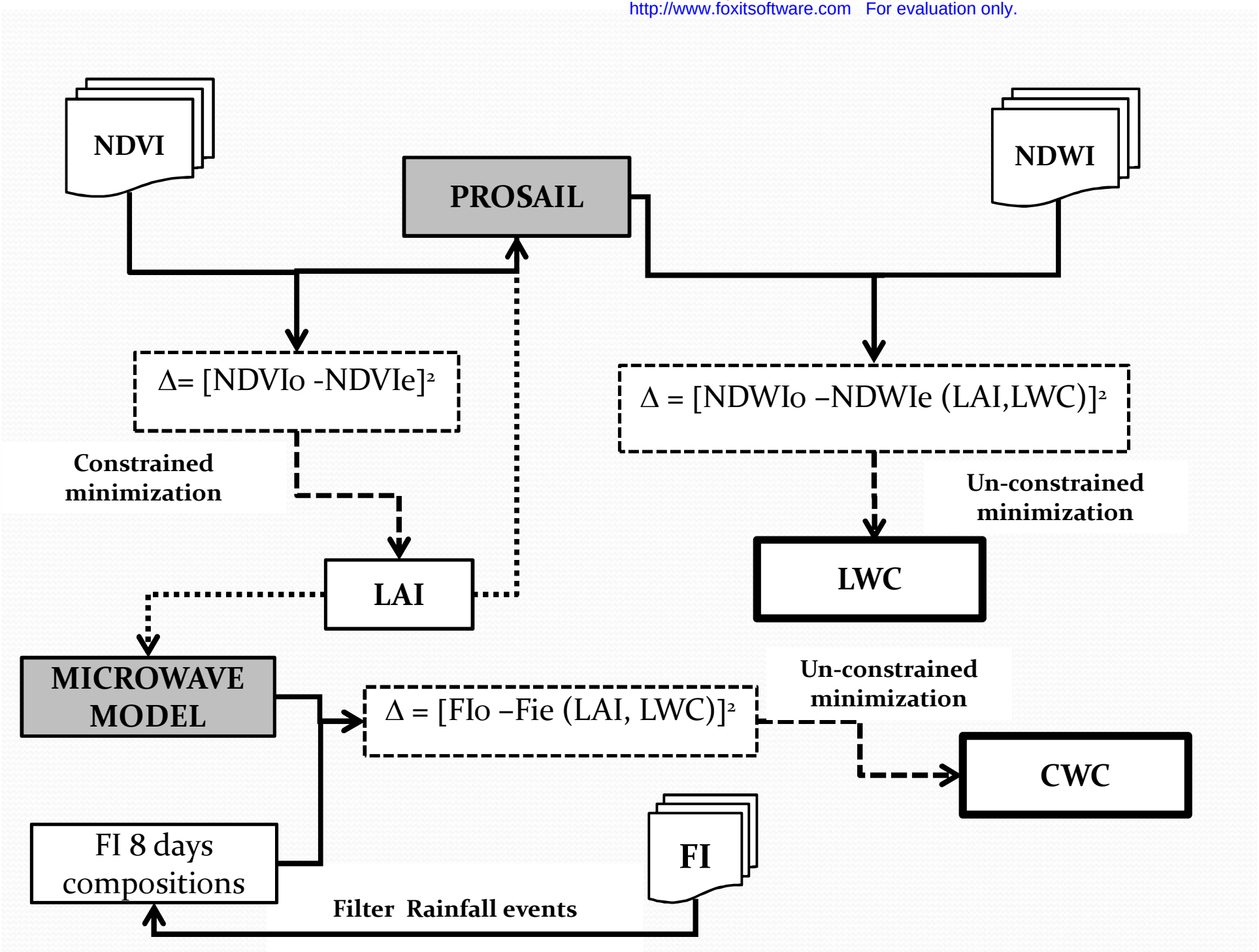
Annual trend: 1. LAI
2. CWC

Shows the simulated and observed trends of FI, computed using 37 and 10.6 GHz AMSR-E channels, as a function of CWC and LAI. **As expected, FI decreases with LAI, due to scattering at Ka band. For the same reason, FI decreases with increasing CWC.**



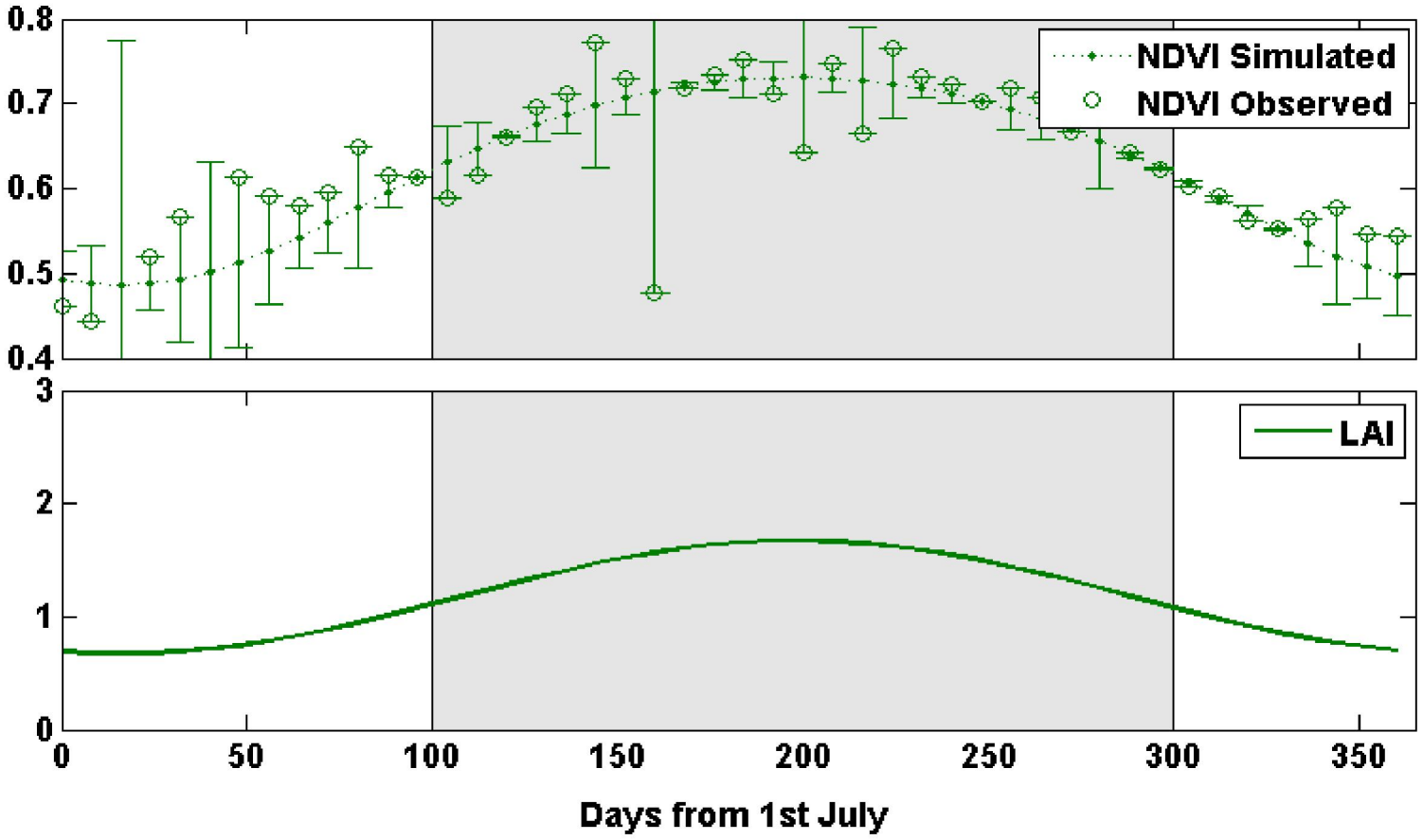
METHODOLOGY



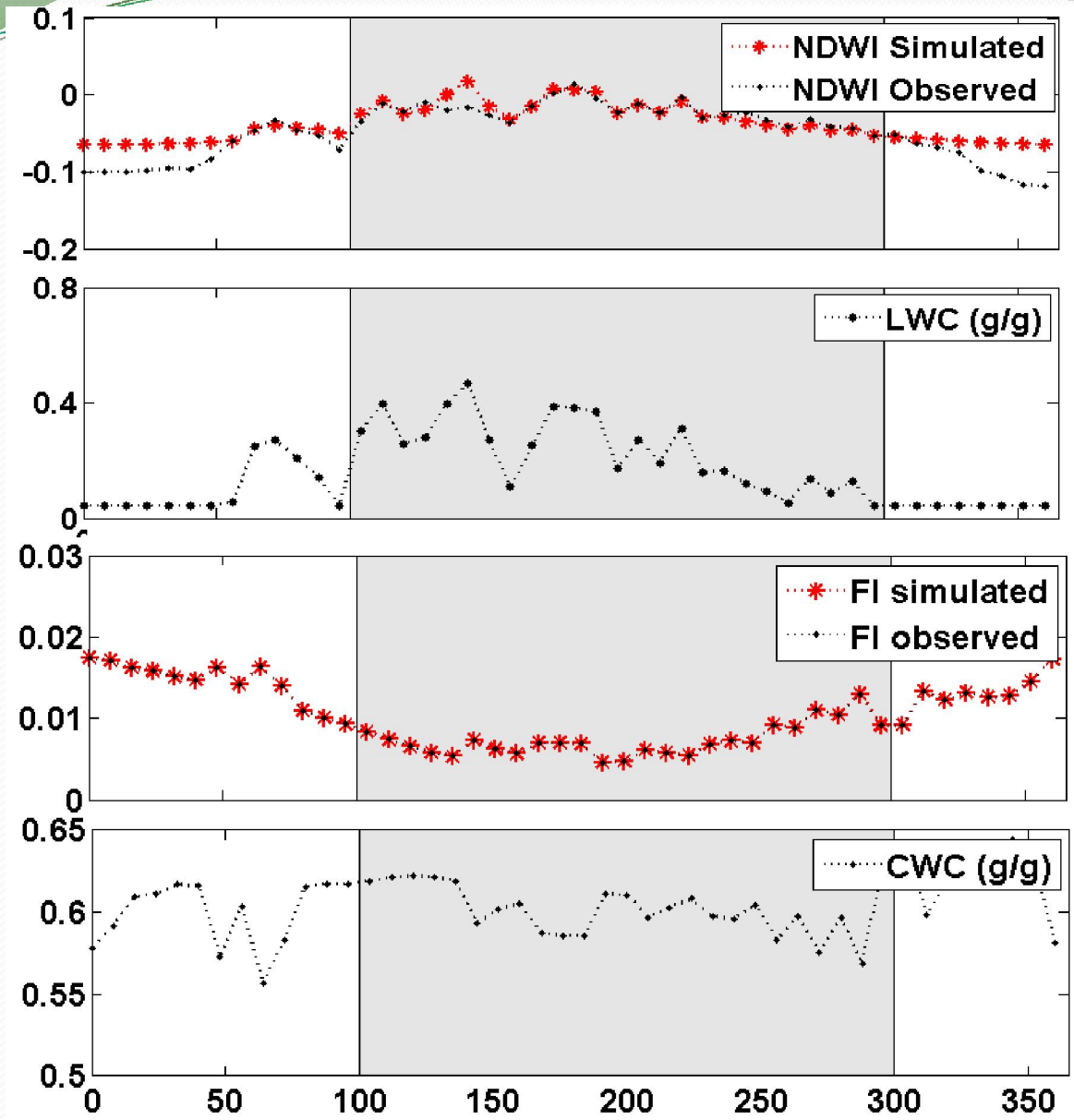


RESULTS: Daily trend (canopy level)

LAI= f (NDVI)



RESULTS: Daily trend (leaf level + canopy level)



Large short term LWC variations is observed. This is most probable due the fact that NDWI observations are noisy in this area.

The small 8-day variations in FI can not be explained unless a daily change in CWC is assumed.

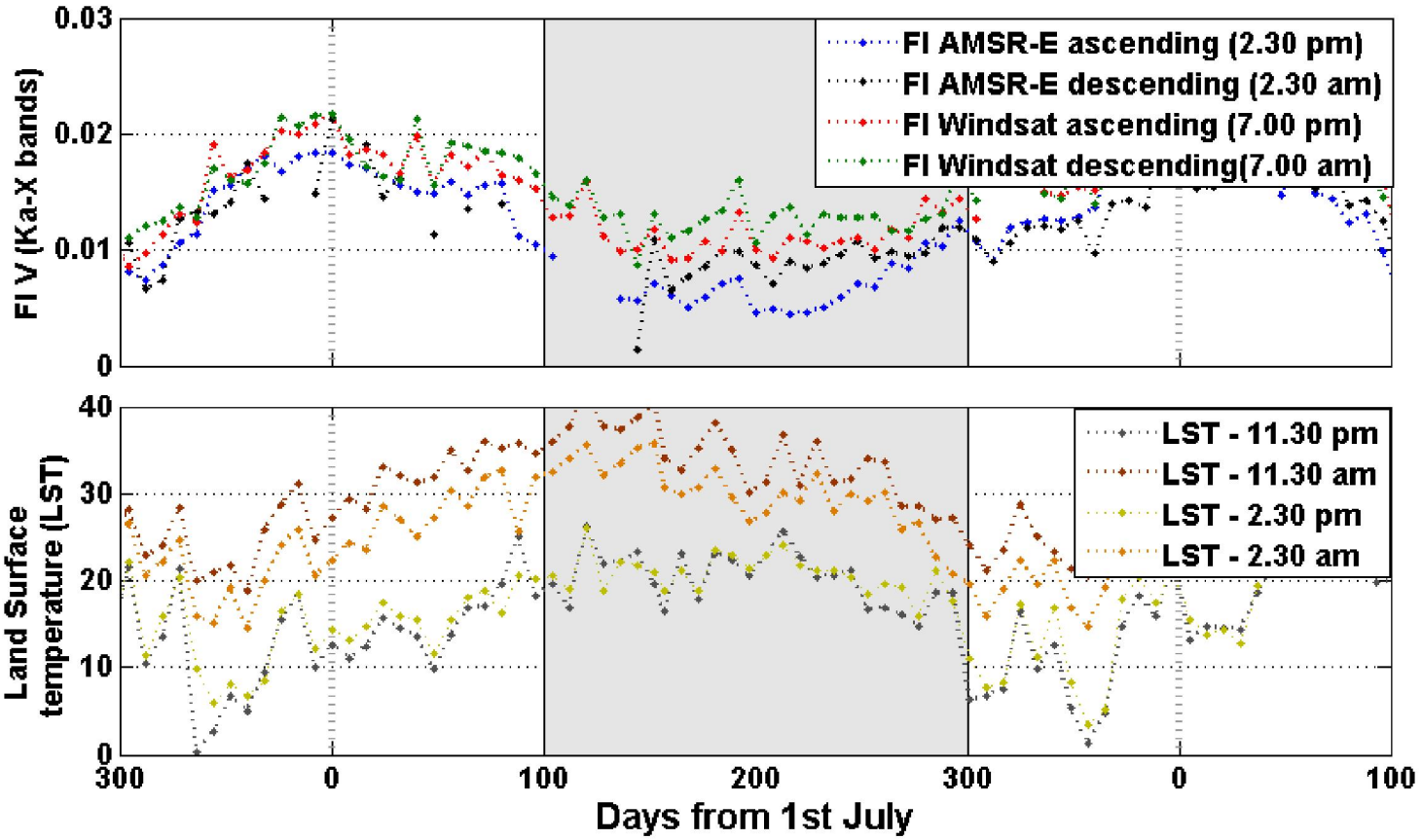
Therefore, FI support a short term CWC variation for Chaco area.

LWC and CWC shows a negative tendency between the growing season period.

RESULTS: Daily trend + Diurnal trend

Daily

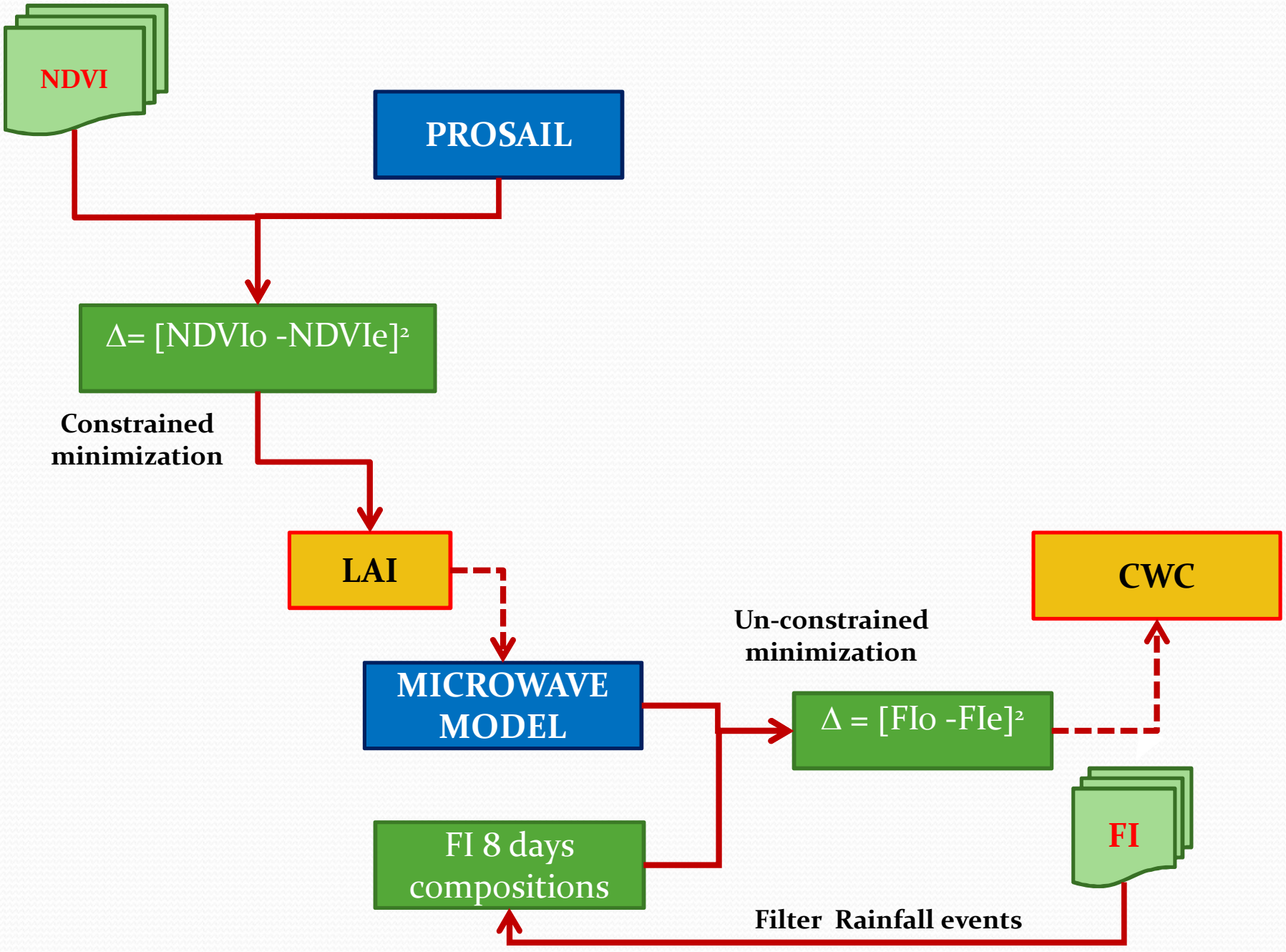
Diurnal



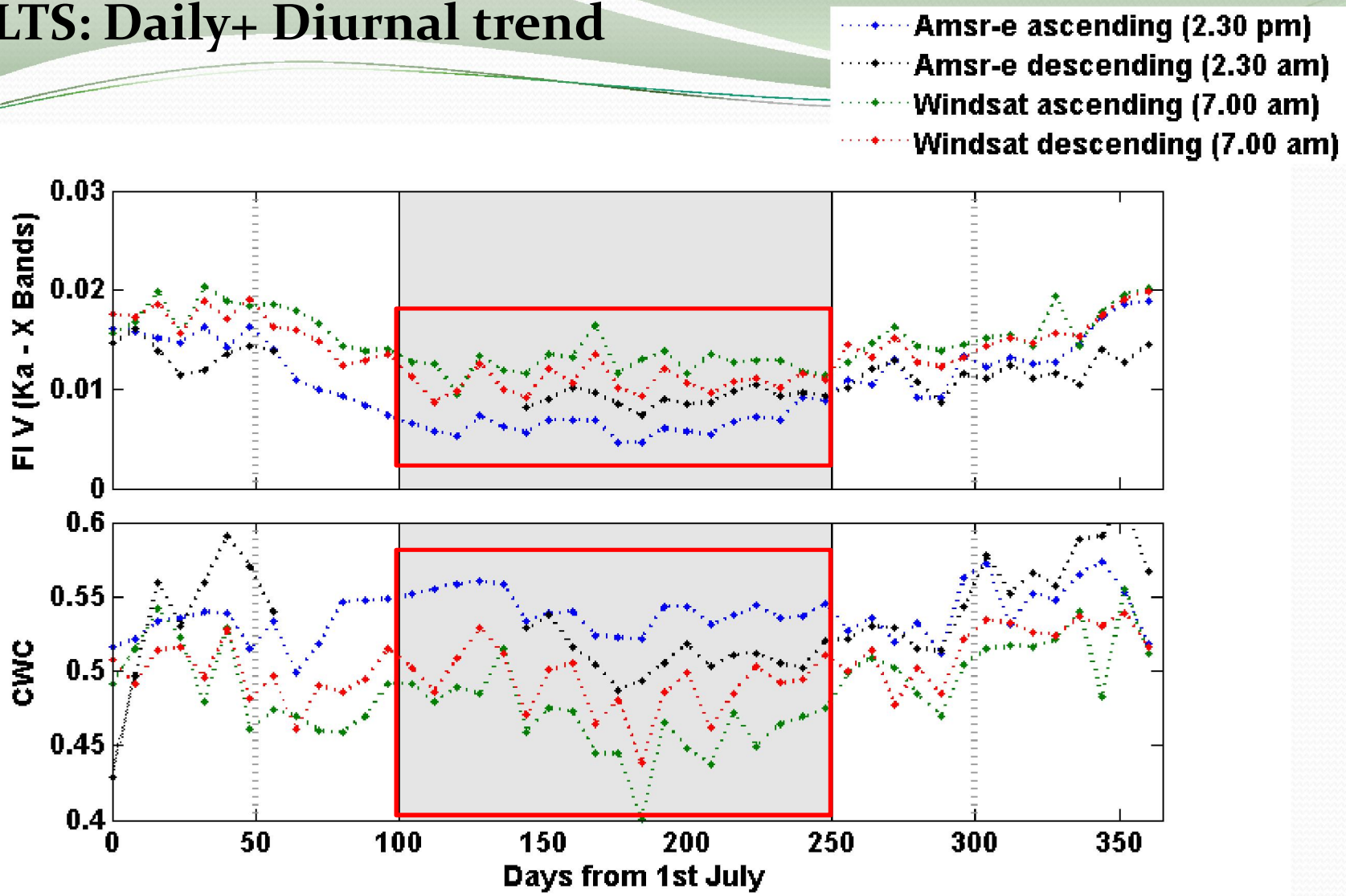
1. **A daily component**: The annual behavior shows a range increase in summer and a decrease in winter, being correlated with vegetation annual growing season (foliation/defoliation).

2. **A diurnal component**: represents changes of environmental conditions, such as water vapor deficit, water potential and carbon dioxide concentration.

METHODOLOGY



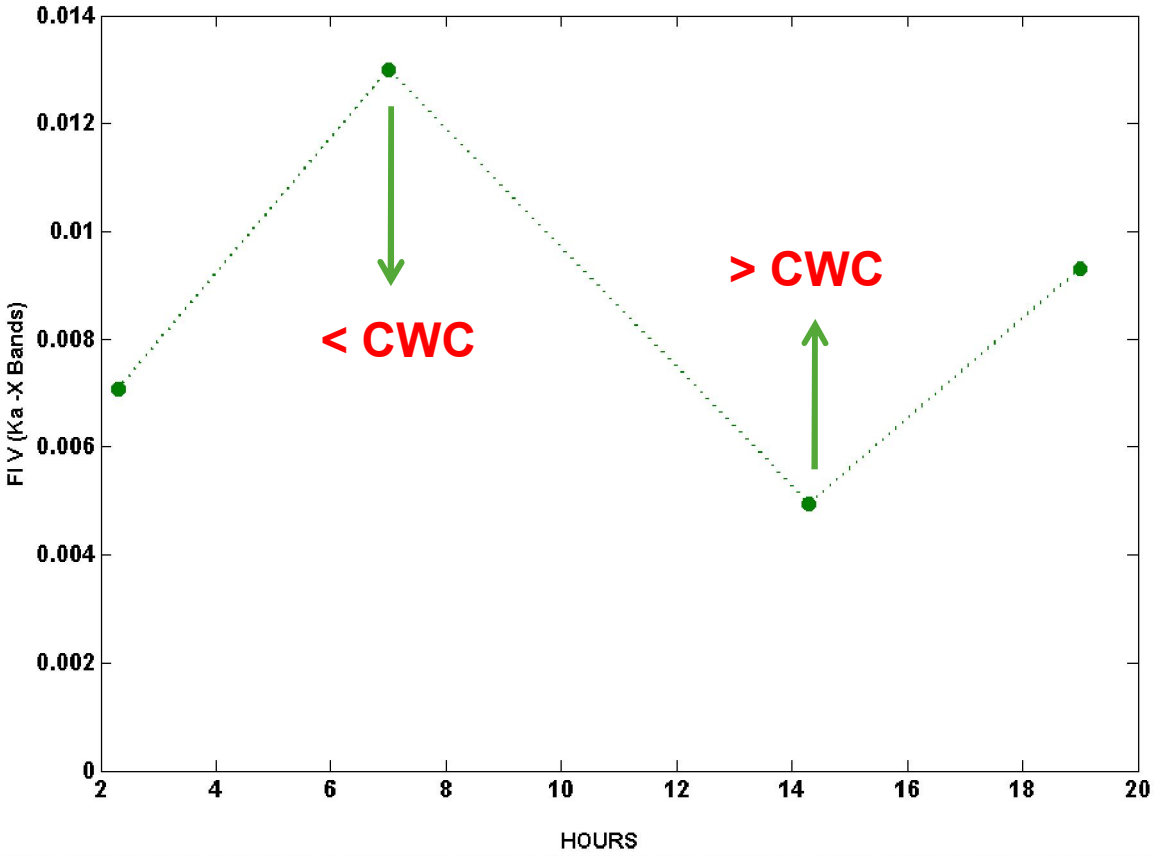
RESULTS: Daily+ Diurnal trend



According to the interaction model, these observed changes of FI correspond to an increase in CWC from ~0.4 g/g to 0.5 g/g in six hours (7.00 am - 2.30 pm) and then a similar decrease for the 2.30 pm to 7.00 pm period.

Diurnal TREND:

- We hypothesize that these hourly variations (an increase of CWC during the sunny hours) could be related to the diurnal patterns of water use :
  - this could indicated a lag time period between maximum transpiration rates and water store in stem .



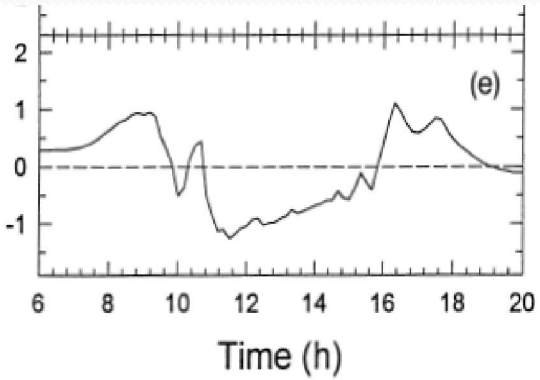


Figure 2. Difference between crown sap flow and basal sap flow for the same species on the same representative days as in Fig. 1. Positive values indicate time periods when water transpired was preferentially withdrawn from the stem water storage, and negative values indicate time periods when water from the soil was refilling stem storage.

Goldstein *et al.1998*

Summary

- **Data used:**
  - For the study area, four time series were analyzed: MODIS NDVI and NDWI (8 days) and AMSR-E and Windsat FI (between one and three days).

- **Analysis performed**:
  - We used two interaction models for optical (PROSAIL) and microwave (Ferrazzoli, 1996) data. Input variables were derived from ground truth when possible, and reasonable guesses based on field expertise in the other cases.
  - Estimation of biophysical parameters (LAI ,LWC, CWC) were implemented using standard minimization procedures.
    - LAI minimization was constrained to a single annual trend.
    - LWC and CWC estimation were not constrained.
  - LAI was estimated from NDVI data, assuming a constant LWC.
  - LWC and CWC was estimated from optical (NDWI) and microwave (FI) data respectively. Both estimations were compared.

CONCLUSIONS ARRIVED TO:

- **DAILY TREND:**

- The yearly cycle of leaves, which is expressed by LAI, subject to long term variations.
- FI data support a short term CWC variation for Chaco area.

- **DIURNAL TREND**:

- FI hourly variations could not be related to sensor artifacts or atmospheric variations (AMSR-E and Windsat are instruments of a very low noise , and the area presents low SD).
- These changes in FI should be related to CWC changes.
- This approach is at least extensive to other deciduous forests with similar characteristics.

WORK IN PROGRESS

Additional work is needed in order to clarify the relation between vegetation phenology, CWC Diurnal trend and ET in this area.

Future work

Validation:

1. **Model :**

• Evaluating the correlation between diurnal differences in CWC to Potential evapotranspiration models.

• Evaluate other optical models to estimate LWC.

2. **In-situ measurement (eddy covariance flux tower):**

• Since the high cost of EC flux tower and logistic problems in Chaco forest, we are working and collaborating to validate this hypothesis in others dry forest areas which present long history of ground truth (Australia).