POTENTIALS FOR DETECTING CANOPY WATER STRESS USING GEOSTATIONARY MSG-SEVIRI SWIR DATA

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Water; primary potential climatic constraint to plant growth (40% of Earth's Terrestrial Surface)

Outline:

- EO-based Canopy Water Stress detection
- In situ measured Canopy Water Stress
- Results & validation
  - from point observations
  - validation in the spatial domain
EO-based Canopy Water Stress detection

Absorption by leaf water occurs in SWIR
- Shortwave infrared reflectance is negatively related to leaf water content
- Increased reflectance in SWIR is the most consistent leaf reflectance response to plant stress in general, including water stress.

Prospect+Sail models; Zarco-Tejada and Ustin 2001

SWIR reflectance influenced by:
- Leaf water content
- Leaf internal structure
- Leaf dry matter content

NIR reflectance influenced by:
- Leaf internal structure
- Leaf dry matter content

Leaf pigments
- Chlorophyll
- Carotene

Cell structure
- Water content
- Water absorption

MSG Band 1
- Band 2
- Band 3

Water vapour absorption

CW = 0.001

CW = 0.03

Transmission function

Reflectance

Wavelength (μm)

Band 1
Band 2
Band 3
Band 4
Band 5
Band 6
EO-based Canopy Water Stress detection
- Water Stress index development

Physically based studies;
Tucker, 1980;
Fourty and Baret, 1997

Laboratory measurements;
Hunt, Rock, & Nobel, 1987
Carter, 1994

Physically – Empirically applied to sat sensors…
Hunt and Rock, 1989 – Landsat TM
Gao, 1996 - AVIRIS
Serrano, Ustin, Roberts, et al., 2000 - AVIRIS
Zarco-Tejada and Ustin, 2003 - MODIS
Ceccato et al., 2001; 2002 - SPOT VGT.
Fensholt and Sandholt, 2003 - MODIS
Rubio et al., 2006 - MODIS
Trombetti et al., 2008 – MODIS
Fensholt et al. 2010 – SEVIRI MSG

- Water Stress index development

**Moisture Stress Index**

\[
MSI = \frac{\text{Band 6}}{\text{Band 4}}
\]

**Normalized Difference Water Index**

\[
NDWI = \frac{\text{Band 4} - \text{Band 5}}{\text{Band 4} + \text{Band 5}}
\]

**Simple Ratio Water Index**

\[
SRWI = \frac{\text{Band 4}}{\text{Band 5}}
\]

**Shortwave Infrared Water Stress Index**

\[
SIWSI = \frac{\text{Band 6} - \text{Band 2}}{\text{Band 6} + \text{Band 2}}
\]

**Normalized Difference Water Index 7**

\[
NDI7 = \frac{\text{Band 4} - \text{Band 7}}{\text{Band 4} + \text{Band 7}}
\]

**Shortwave Infrared Ratio**

\[
SWIRR = \frac{\text{Band 6}}{\text{Band 7}}
\]

**Shortwave Infrared Water Stress Index**

\[
SIWSI = \frac{\text{Band 3} - \text{Band 2}}{\text{Band 3} + \text{Band 2}}
\]
Variable performance validation

From the Dahra test site in semi-arid Senegal
Dahra test site setup

Since 2004
- Air temperature,
- Relative humidity
- Wind speed
- Net radiation
  Global radiation
- Ground heat flux

↓

Full surface energy balance
Flux profile estimates of latent and sensible heat

Since 2002
- Precipitation & surface temperature
- Soil moisture & soil temperature profiles
- Sensor specific reflectances, matching various sensors for estimation of spectral vegetation indices & fAPAR.

Ancillary sampling:
biomass, vegetation height, root depth etc.

Measurements every 15 minutes
Dahra test site setup

Since 2008
- LST (collaboration with Institute of Technology (KIT) Institute for Meteorology and Climate Research (IMK) Atmospheric Trace Gases and Remote Sensing (ASF)
- Poster: Rasmussen, Mads, O. et al. Intercomparison between SEVIRI LST-products And comparison with in situ LST measurements
Eddy Flux Tower

Since 2010
- ASD spectroradiometers (350-1800 nm)
- Eddy covariance fluxes (water and carbon)
  Collaboration with University of Lund
Can SWIR based canopy water status be detected in the field?

Prospect+Sailh models; Zarco_Tejada and Ustin 2001

Reflectance (%) vs. DOY for different dates:
- DOY 238
- DOY 240
- DOY 242
- DOY 244

Soil moisture vs. NDVI for different DOY:
- NDVI ASD NADIR MSG config
- Soil moisture 5cm

Wavenumbers (nm) vs. Reflectance (%):
900 1400 1900 2400

Cw (water thickness): 0.001, 0.03

Prospect+Sailh models; Zarco_Tejada and Ustin 2001

INSTITUTE OF GEOGRAPHY
UNIVERSITY OF COPENHAGEN
MSG SEVIRI data University of Copenhagen
SMAC corrected (MOD08 input), reflectances BRDF (NBAR)

Proud, S. R. 2010…

Poster: Evaluating the effectiveness of producing BRDF models from SEVIRI surface reflectance data.
Dahra test site in Senegal 2008

MODIS NDVI 500m resolution

Terra MODIS NDVI
Aqua MODIS NDVI
IN situ MODIS NDVI

MODIS 500m
\( y = 1.01x - 0.02, R^2 = 0.99 \)
MODIS 250m
\( y = 0.99x - 0.01, R^2 = 0.99 \)

Terra MODIS
\( y = 0.92x + 0.009, R^2 = 0.70 \)
Aqua MODIS
\( y = 0.95x + 0.001, R^2 = 0.76 \)
Comparing MSG SEVIRI vegetation indices with in situ measurements
Evaluation of EO-based SIWSI from in situ measurements - 2008

Above ground Biomass (g/m²)

In situ soil moisture 10cm
MSG NDVI (daily BRDF)
MSG SIWSI (daily BRDF)
MODIS NDVI daily (Terra)
MODIS NDVI daily (Aqua)

In situ NDVI (MODIS config. Daily av g)
Root depth
Aboveground Biomass

Soil moisture (Vol %)

NDVI and SIWSI indices
Evaluation of EO-based SIWSI from in situ measurements – 2006

- In situ soil moisture 10cm
- MSG NDVI (daily BRDF)
- MSG SIWSI (daily BRDF)
- MODIS NDVI daily (Terra)
- MODIS NDVI daily (Aqua)
- MODIS SIWSI daily (Terra)
- MODIS SIWSI daily (Aqua)
Evaluation of EO-based SIWSI from in situ measurements - 2007

- In situ soil moisture 10cm
- MSG NDVI (daily BRDF)
- MSG SIWSI (daily BRDF)
- MODIS NDVI daily (Terra)
- MODIS NDVI daily (Aqua)
- MODIS SIWSI daily (Terra)
- MODIS SIWSI daily (Aqua)
Evaluation of EO-based SIWSI from in situ measurements - 2009

- In situ soil moisture 10cm
- MSG NDVI (daily BRDF)
- MSG SIWSI (daily BRDF)
- MODIS NDVI daily (Terra)
- MODIS NDVI daily (Aqua)
- MODIS SIWSI daily (Terra)
- MODIS SIWSI daily (Aqua)
Evaluation of EO-based SIWSI from in situ measurements - 2008
- Spatio-temporal Evaluation of SIWSI (20 pixels, 320 km²) using NOAA RFE rainfall as surface water status indicator
- Spatio-temporal evaluation of MSG SIWSI using a hydrological model (Mike-She distributed model)

- Is the model able to simulate water status at the Dahra test site?

- Are model inputs (RFE rainfall) reliable?
- Spatio-temporal evaluation of MSG SIWSI using a hydrological model (Mike-She distributed model)

Preliminary data analysis…
Correlation between MSG SIWSI and MSH ETa (DOY 252-264)

mean r-value = -0.67

Legend
- Dahra test site
- Country borders
- River catchment

r value
- High ≥ 1
- Low ≤ -1

Correlation between MSG NDVI and MSH ETa (DOY 252-264)

mean r-value = 0.31
Conclusions and perspectives

- SWIR sensitivity to Canopy water content (semi-arid grass land)
- MSG sensitivity on a daily scale
- Biomass dependancy
- SWIR based indices complementary to VIS/NIR approaches
- SWIR based indices more robust to atm correction than VIS/NIR