Remote Sensing of Drought Impacts in Tropical Forests

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Outlines

- What Happened During Recent Droughts in Amazonia?
- What Was the Response of Similar Droughts in Africa?
- How do we monitor impacts of droughts in future?
Amazon Forest Unexpectedly Resilient to Drought!

Saleska et al., 2007
Second ‘100-year’ Amazon drought in 5 years caused huge CO2 emissions. If this pattern continues, the forest would become a warming source.

Lewis et al., 2011
Drought In Amazonia

TRMM Data 1998-2010 Rainfall and Water Deficit

if $WD_{n-1}(i,j) - E(i,j) + TRMM_n(i,j) < 0$
then $WD_n(i,j) = WD_{n-1}(i,j) - E(i,j) + TRMM_n(i,j)$
else $WD_n(i,j) = 0$

(Saatchi, Asefi, Malhi et al., In Review)
Drought In Amazonia

Xu et al., 2011
Impact of Drought on the Forest

Saleska et al., 2007

Samanta et al., 2010

Xu et al., 2011
Impact of Droughts from Aerial Photos

Changes of Canopy over Emerging Crowns

Intense of Drought Mixed with Surface Fire
QSCAT Sensitivity to Canopy Water Content

\[ \sigma_p^0 = \gamma_p \left[ \frac{1 - \exp(-\alpha_p W_c \sec \theta)}{\sqrt{W_c}} \right] \]

- \( W_c \): canopy water content
- \( \gamma_p \) and \( \alpha_p \): forest type calibration parameters
- \( p \): polarization (H,V)
- \( d_c \): canopy penetration depth

Simulated Monthly Variation QSCAT ±10 change in canopy water content
Impact of Drought on Vegetation

2005 Seasonal Water Deficit Anomaly (Jul-Aug-Sep)

2005 Seasonal QSCAT Anomaly (Jul-Aug-Sep)
Seasonal variation of chlorophyll fluorescence, $F_s$ (W/m²/sr/μm), retrieved from GOSAT in 755 nm over Amazonia during June 2009 - May 2010.
New global observations of the terrestrial carbon cycle from GOSAT Patterns of plant fluorescence with gross primary productivity
Frankenberg, GRL (2011)

A look at water stress response of the Amazon

Seasonal variation of chlorophyll fluorescence, Fs (W/m²/sr/μm), retrieved from GOSAT in 755 nm over Amazonia during June 2009-May 2010.
A look at water stress response of the Amazon

Lee, Frankenberg, Saatchi et al, under review (2011)

\[ r^2 = 0.73 \]

Vapor pressure deficit (hPa)

2010 drought
CRU & TRMM Data

Historical Perspective
TRMM Rainfall Anomalies in Africa

(Asefi and Saatchi, In Review)
Seasonal Anomalies of Canopy Water Content (QSCAT)
TRMM Water Deficit and Rainfall
Why Forests in Africa Do not Response to Droughts as strongly?

Possible Explanations

• Forests in Africa do not experience a strong dry season.

• Forests have experienced strong climate variability in the past.

• Forests are in general drier and open and more resilient to droughts
The corresponding month that MWD has occurred

13 years overall

look

2005

2006

2007
The corresponding month that MWD has occurred

13 years overall look

2005

2010
CRU rainfall and TRMM comparison

MWD 1998-2010

DMD 1998-2010

MWD CRU (1971-2000)

DMD CRU (1971-2000)

MWD = Maximum Water Deficit

DMD = Dry Months Duration Rainfall < 100 mm
Distribution of Available Stations in CRU Data

1930

1970

1990

2000

2009

Location of Stations

Malhi & Wright 2004
MODIS Surface temperature Distribution

Climatology (2001-2009) of MODIS Day Time LST

Climatology of (2001-2009) MODIS Day Time LST warmest quarter

Asefi and Saatchi, In Review
MODIS LST Seasonal Anomaly
Water & temperature are Decoupled

2010 TRMM Water Deficit Anomaly

2010 MODIS LST Anomaly
Areas With largest Variability in Canopy Water Content

10 years average (Max-Min) QSCAT Intensity

10 years average Min. QSCAT Intensity
Evapotranspiration Distribution

Computed from Temperature and Rainfall
Annual fluorescence average

Frankenberg, & Saatchi et al, GRL (2011)

A Chlorophyll a fluorescence at 755 nm, June 2009 through May 2010 average
Summary

Forests in Africa Appear to be More Resilient to Droughts than Amazonia

- In Amazonia, extent and persistence of rainfall anomalies were the main cause of extensive drought in the basin.

- In Africa, Water Deficit anomalies were less persistence and but relatively more common.

- In Amazonia, rainfall of driest quarter and accumulative water deficit were the two main signals for detecting droughts.

- In Africa, rainfall patterns are more uniform during the year and there is no strong dry season (contrast between wet and dry).

- In Amazonia, canopy water content stayed low after the 2005 drought suggesting a long-term and extensive water stress on forest canopy. Canopy water content response was significantly correlated with rainfall anomalies.

- In Africa, Canopy water content anomalies were not strong even after a severe water deficit anomaly.

- In Amazonia, surface temperature anomalies were coupled with water deficit anomalies.

- In Africa, surface temperature and water deficit were decoupled.

- In Amazonia, canopy water content, ET, and surface temperature are higher than in Africa.
Eastern Congo Forest Biomass Distribution

![Map of Eastern Congo Forest Biomass Distribution]

**AGLB Mg/ha**
- **0-25**
- **25-50**
- **50-75**
- **75-100**
- **100-125**
- **125-150**
- **150-200**
- **200-250**
- **250-300**
- **300-350**
- **350-400**
- **> 400**