Using Giovanni in Investigating the Links between Environmental Processes and Drought in Northern sub-Saharan Africa

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Aqua-MODIS image of January 17, 2007 (NASA EarthObservatory)
Outline

➤ Sub-Saharan African Environment and Drought
➤ Hypothesis and Study Design
➤ Exploratory Data Analysis and Preliminary Findings
➤ Ongoing Detailed Analysis and Modeling Efforts
➤ Future Outlook
“Although the droughts have had climate experts scratching their heads, the impacts have been obvious. During the worst years, between 1972 and 1975, and 1984 and 1985, up to a million people starved to death.”
Lake Chad: poster child of African Sahel Droughts

Fires ➔ Bare Soil ➔ Dust ➔ Desertification

Terra-MODIS image of 7 February 2008 at 12:40 UT
Forest Reserves Under Pressure in Ghana

In the 1973 image the vegetation inside and outside the protected areas appears green and robust.

In the 2002/2003 dramatic change is apparent; some of the northern reserves have been decimated and the northern edge of the forest zone has moved south.
Lack of interest in global change issues, non participation in mitigation efforts, More biomass burning to survive.

Human suffering, poverty, frustration, and wars; with regional and global ramifications

Rapid global climate change

Drought
- Lack of water
- Lack of rain, deeper water exploitation
- Low evaporation, low cloudiness

Biomass Burning
- Surface heating, vegetation drying
- Intense heat and smoke
- Existing vegetation obliterated

Increased Desertification
- Drying of vegetation
- Increased surface albedo & dust

Climate Forcing
- Large change in atmospheric composition and circulation
- Less cloudiness, higher surface albedo

Reduced Precipitation
- Weak or stunted new vegetation
- Atmospheric heating, cloud evaporation

Low food production, rapid depletion of available resources, poor health
Science Questions:

- To what extent does the seasonal biomass burning affect land-cover and ecosystem changes, smoke and dust emissions, atmospheric heating rates, and the consequent climate forcing in the NSSA region?

- How do these surface and atmospheric changes affect soil moisture content and retention, as well as rainfall variability and surface runoff?

- What are the links between the surface and atmospheric hydrologic processes induced or modified by biomass burning and the drying of Lake Chad, and what is the status and trend of the ground-water reserves in the greater Lake Chad basin and surrounding regions?

- What is the future of the regional climate and ecosystem balance, and how can the current degradation trend be mitigated to enhance societal benefits both in the present and the future?
Data Sources (NASA Giovanni)
NDVI => Terra/Aqua MODIS
Fire Radiative Power (FRP) => Terra/Aqua MODIS
Aerosol => Terra/Aqua-MODIS
Carbon Monoxide => Aqua-AIRS
Precipitation => TRMM
Soil Moisture => Aqua AMSR-E
Surface Evaporation => MERRA
Regional Data Analysis Based on Rough Ecosystem Segmentation

Map showing regional data analysis based on rough ecosystem segmentation. The map is divided into regions labeled NW, MW, SW, NC, MC, SC, NE, and ME, each with a specific symbol (O for NW, + for NC, Δ for NE, etc.).

A graph below the map displays NDVI values over time from Sep-02 to Sep-10.
Regional Data Analysis Based on Rough Ecosystem Segmentation

FRP

Land Area

Ichoku et al (2008) RSE

Corrected Daytime Aqua Tot FRP over Land Area [MW/km²]

- NW
- NC
- NE
- MW
- MC
- ME
- SW
- SC
- SE

RSE
Regional Data Analysis Based on Rough Ecosystem Segmentation

![Regional Data Analysis Based on Rough Ecosystem Segmentation](image)

- NW → O
- MW → O
- SW → O
- NC → +
- MC → +
- SC → +
- NE → Δ
- ME → Δ
- SE → Δ

![Graph showing precipitation data](image)

- Precipitation [mm/hr]
- Sep-02 to Sep-10
- NC, MC, SC
Regional Data Analysis Based on Rough Ecosystem Segmentation

Precipitation graph showing data from Sep-02 to Sep-10 for different regions.

Legend:
- NE: Red triangles
- ME: Black squares
- SE: Blue triangles

Graph indicates variability in precipitation across different months and regions.
Regional Data Analysis Based on Rough Ecosystem Segmentation

![Regional Data Analysis Diagram]

- NW → O
- NC → +
- NE → Δ
- MW → O
- MC → +
- ME → Δ
- SW → O
- SC → +
- SE → Δ

**Precipitation Data**

- NW
- MW
- SW

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</table>
Regional Data Analysis Based on Rough Ecosystem Segmentation

Evaporation from Land [kg/m²/hr]
Preliminary Findings

- Time Series Analysis of Regionally Aggregated Monthly Mean Satellite Measurements Shows That:
  - Fire activity appears to show a slightly decreasing trend in the Central and Eastern parts of the NSSA region starting in 2006/7.
  - This decrease in fire activity coincides with precipitation: increase in the Western, no change in the Central, and decrease in the Eastern parts of the NSSA.
  - Surface evaporation minima appear to have increased during the same period in the Western and Central parts.
Hypothesis: the impact of biomass burning on albedo will depend on landcover type.
Smoke Particulate Emissions from fires
in Northern Sub-Saharan Africa during Dec 2009

Total emissions: 2.98 Tg

Mass of emissions [g/m^2]
Fire and Plume Observation and Modeling Synergy

MODIS

CALIPSO

WRF/Chem 2008-02-04 01:00:00

WRF/Chem(800m) 2008-02-04 01
Land cover change around Lake Chad

(a) Maps showing land cover changes from 1979 to 2006.

(b) Bar charts illustrating the percentage area of different land cover types for the years 1979, 1991, and 2006.
Groundwater Field Survey in the summer of 2009
Plans

- Continue detailed data analysis and modeling to understand the different aspects of the issue.

- Closely coordinate the different components of the study to establish linkages in a coherent manner.

- Publish results in peer-reviewed literature.

- Collaborate with and share data and knowledge with various regional and local subject matter experts.

- Provide applicable findings to relevant agencies and organizations for use in decision making.