Satellite Characterization of Biomass Burning and Smoke Emissions in Africa

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Fires in West Africa from Aqua-MODIS 29-Dec-2004, 13:40 UTC (Courtesy: NASA EarthObservatory)
➢ African Overview.


➢ Fire Radiative Power (FRP) Characterization.

➢ Estimating Smoke Emissions from FRP.

➢ Application of Emissions to Atmos Modeling.
Africa in the global map of “Income per capita” and “Life Expectancy”

Source: http://gapminder.org/
Africa in the global map of “Income per capita” and “Life Expectancy”

Source: http://gapminder.org/
Some Factors responsible for “Poverty” and “Death” in Africa

- Disease outbreaks
- Water pollution and scarcity
- Air Pollution from Agricultural Fires and Dust
- Drought (massive starvation)
- Desertification (global change)
- Flooding
- Invasive Species (e.g. Locusts)
- Poor Planning and Poor Technology
- Poor Management
- Wars and bad political systems.
“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.”
African Air Pollution

(NASA Earth Observatory: The seasonal agricultural burning in tropical Africa dotted the continent with fires on January 17, 2007.)

“Although the fires are not necessarily immediately hazardous, such large-scale burning can have a strong impact on weather, climate, human health, and natural resources. Also obvious in the image is the dust spreading west-southwest from the Bodele Depression at the southern edge of the Sahara Desert. The remains of an ancient lake bed, the Bodele Depression is probably the largest single source of windblown dust in the world.”

REPORTS

Measurement of the Effect of Amazon Smoke on Inhibition of Cloud Formation

Ban Koren,1,2,3 Varun J. Kodwani,1 Lucien A. Reuer,1 John V. Martius1,3

Amazonian fires have been modelled to reduce cloud formation by absorbing sunlight, thereby cooling the surface and reducing the local climate. In contrast, the seasonal agricultural burning in tropical Africa dotted the continent with fires on January 17, 2007. Although the fires are not necessarily immediately hazardous, such large-scale burning can have a strong impact on weather, climate, human health, and natural resources. Also obvious in the image is the dust spreading west-southwest from the Bodele Depression at the southern edge of the Sahara Desert. The remains of an ancient lake bed, the Bodele Depression is probably the largest single source of windblown dust in the world.”
Satellite remote sensing of fires

California fire as seen from Terra-MODIS on 26-Oct-2003

- Where?
- How Big?
- Where to deploy crew?
- How much smoke emitted?
- What is it doing?
Regional Distribution of Fire Categories

Comparison with Peak Months in Other Regions

Africa : ~0.05 W/m²
Asia : ~0.03 (Indochina)
others < 0.005

S. America : ~0.02
Australia : ~0.01
N. America : ~0.005
Siberia : ~0.004
Europe : ~0.002

Ichoku et al., RSE, 2008 (In Press)
Traditional Emissions Estimation Approach

Emissions = Emission Factor (EF) × Biomass Mass (BM)

BM = A × B × α × β

Where,
A = Area burned
B = Biomass density
α = Above ground biomass proportion
β = Combustion Efficiency

FRE-based smoke emissions estimation approach

(1) Emissions = EF × BM (from FRE)  [Wooster]
(2) Emissions = Emission Coeff. (Ce) × (FRP or FRE)  [Ichoku]
Fire Radiative Energy and Burned Biomass

Spectro-Radiometer or IR Camera

Spectro-radiometer FOV


Fire Radiative Power (MW)

Biomass Combusted (kg) ~ 0.366 * FRE (MJ)

\[ r^2 = 0.97 \quad n = 36, \quad p < 0.0001 \]

• herbaceous fuels
• woody fuels
SEVIRI 5-Day Active Fire Mapping

15 mins frequency

September 2003

SEVIRI observed
MODIS observed
MODIS area-weighted

Wooster et al., 2005 (JGR); Roberts et al., 2005 (JGR)
MODIS Regional Covariance between Fire Radiative Energy release rate and smoke aerosol emission rate (Slope is Coefficient of Emission, $C_e$)

**West Africa: MODIS 10x10-km pixels containing fire in 2002**

**Guinea (West Africa zone B) fires, 2002**

**Ghana (West Africa zone E) fires, 2002**

**West Africa regional fires, 2002**

Ichoku & Kaufman, 2005, IEEE-TGARS
GOCART simulations of smoke emissions with MODIS Fire Radiative Power

BBCI: Daily average of Δτ for OC on July 1, 2004

BBCI: Daily average of Δτg on July 1, 2004

BBCI: Daily average of Δτ for BC on July 1, 2004

Optical_Depth_Land_And_Ocean_Mean

MODIS/Terra MOD08_D3.A2004183.D04.2004184171925.hdf
Advantages of MODIS+SEVIRI for Africa

- MODIS and SEVIRI are currently the only space-borne sensors that measure fire strength (i.e. Fire Radiative Power, FRP).

- MODIS covers the globe 4 times daily at strategic times, SEVIRI covers Africa every 15 minutes.

- MODIS measures FRP at 1-km resolution (good for biomass burning monitoring), SEVIRI measures at 4-km but data can be adjusted to fill up MODIS temporal gaps.

- Data products are free.

- SEVIRI can be acquired in real time. A reasonable investment in Direct Broadcast (DB) systems can ensure near real-time data availability from MODIS.

- MODIS-like sensor (VIIRS) on NPOESS will provide continuity for good spatial resolution.
What can we do?

African population density

Site facilities of type SERVIR at Regional (not Local or National) Centers to cover the populated areas of Africa.

Well-coordinated strategic utilization of Earth Observation (EO) data to provide early warning and monitoring of the environment.

Engage the regional or international organizations actively to provide support and encourage application.

Advantages to Africa
- Share resources cost-effectively.
- Utilize EO for Societal Benefit.
- Mitigate adverse factors.

Monitoring & Early Warning Systems for Africa

http://www.britannica.com/eb/art-65614/Population-density-of-Africa
Conclusions

- Fire Radiative Power (FRP) from satellite is directly related to fire strength, biomass consumption, and smoke emissions.

- FRP is advantageous for estimating burned biomass and smoke emissions: quantitative, more direct, fewer assumptions, less uncertainty, higher accuracy, wide range of scales: spatial (local, regional, and global) and temporal (real-time, daily, monthly, etc.).

- Great potential for varied and far-reaching real-time and long-term applications: e.g. fire effects and pollutant dispersion forecasting for planning sustainable economic and environmental development.