An Investigation of Interannual Variability of Ozone over Africa Determined from Satellite Measurements

Jack Fishman¹, John K. Creilson¹,², Amy E. Wozniak¹,²,³
¹ NASA Langley Research Center, Hampton, Virginia USA 23681
² SAIC, Hampton, Virginia USA 23666
³ NASA Goddard Space Flight Center, Greenbelt, Maryland USA 20771

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Road Map

• History Behind Use of Satellites to Study Tropospheric Air Pollution

• Tropospheric Ozone Residual (TOR) Methodology and Climatology (Fishman et al., 2003)

• Previous Studies:
  - Intercontinental Transport of Tropospheric Ozone (Creilson et al., 2003)
  - Interannual Variability of Tropospheric Ozone over India and Asia

• Current Study: Interannual and Seasonal Variability of Tropospheric Ozone over West Africa and its Relationship to Climate Indices (NAO and ENSO)
In the late 70’s, Paul Crutzen led a team of NCAR scientists that made comprehensive measurements of trace gases where tropical biomass burning was occurring and found considerably higher concentrations than what had been published previously.

**Can the 10-20 DU enhancement be identified with TOMS total ozone measurements?**

Enhanced Total Ozone Observed in Conjunction with Biomass Burning in 1980 Episode

(from Fishman, Minnis & Reichle, JGR, 91, 1986)
Separate Stratosphere from Troposphere to Compute Tropospheric Ozone Residual (TOR)

TOR Technique:

TOMS Total O3 – SCO (from SBUV)
Global Distribution of Tropospheric Ozone Residual (TOR) Identifies Several Regions of Enhanced Photochemical Smog (Climatological TOR: 1979-2000)

Regional “Hotspots” of Tropospheric Ozone

December - February

March - May

June - August

September - November

(Dobson Units (DU))

(From Fishman et al., 2003)
Previous Studies have shown a strong relationship between TOR over Western Europe and the North Atlantic Oscillation... (From Creilson et al., 2003)
Springtime TOR Variability Over North Atlantic Linked to Transport Patterns Modulated by the North Atlantic Oscillation (NAO)

Spring 1990 – Positive NAO

Spring 1980 – Negative NAO

(From Creilson et al., 2003)
Interannual Variability of Western Europe Springtime TOR and Spring NAO Index

1986, 1990, 1992 Highest TOR Years

$R = +0.61$

Dobson Units

NAO Index

(From Creilson et al., 2003)
...as well as between Ozone Pollution over Northern India and both Population & Phase of ENSO
Population and Ozone Pollution Strongly Correlated in India and China
Interannual Variability Linked to El Niño – Southern Oscillation

June 1982 - Strong El Niño Year

June 1999 - Strong La Niña Year

Dobson Units (DU)

R = +0.63

TOR Anomaly

Nino Region 4 SSTA
We also see Significant Interannual and Seasonal Variability over Regions of West Africa
Seasonal Depictions of Climatological West African Tropospheric Ozone Residual

DJF

MAM

JJA

SON

Dobson Units
West Africa Monthly TOR Climatology
20W to 20E

North to South Seasonal Migration Of TOR Evident
Significant TOR Interannual Variability Evident between North and South of the ITCZ: Potential Linkage to Phase of the El Niño
Strong Difference Seen in Outgoing Longwave Radiation Between June of 1982 (El Niño) and June of 1984 (La Niña)

Positive Versus Negative Anomaly over the Same Region
West Africa June TOR for 5-10N and 5-10S

Interannual variability shows an almost inverse relationship.
Other definitions include Sea Surface Temperature Anomalies (SSTA) in various regions of the Pacific:

Niño 1+2: Off coast of Ecuador; Niño 3: Eastern Pacific; Niño 4: Western Pacific; Niño 3.4: Central Pacific
Consecutive Month Interannual Variability (5N-5S) Shows Strong Relationship With Different Phases of the North Atlantic Oscillation: Potential ITCZ-NAO Connection

April

May

\[ R = +0.63 \]  
Inverse Relationship

\[ R = -0.70 \]
Phase of the North Atlantic Oscillation Controls Transport Strength, Speed, and Direction

Differing effects between Positive and Negative Phase

Positive Phase of the NAO

Negative Phase of the NAO
SUMMARY

• Pioneering Research into Tropospheric Ozone Led to Discovery of Tropospheric Signal in TOMS
  - 20 Years of Tropospheric Ozone (TOR) Data now available at http://asd-www.larc.nasa.gov/TOR/data.html

• Previous Work Has Shown both Regional Utility and Interannual Variability of TOR Dataset

• Current Study Spotlights Strong Relationships between West African Pollution and BOTH the NAO and ENSO
  - April TOR-NAO: $R=+0.63$; May TOR-NAO: $R=-0.70$
  - June TOR-ENSO: $R=+0.78$

• Further Investigation Utilizing GCM Needed to Help Explain Significant Dual Coupled Climate-TOR Relationships