Environmental factors and population dynamics as determinants of meningococcal meningitis epidemics in the Sahel: an investigation of NASA and NOAA products

EARTH SCIENCE APPLICATIONS FEASIBILITY STUDIES
1 year: Sept 1st, 2009 – Aug 31st, 2010

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GISS: J. Perlwitz, R. Miller
JPL: O. Kalashnikova

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Meningococcal Meningitis - a few facts

- Human to human transmitted bacterial infection of the meninges

- Consequences
  - if untreated, can lead to fatality rates greater than 50%
  - despite treatment, at least 10% of patients die within 48 hours of onset of symptoms
  - 10–20% of survivors develop severe neurological sequela

- Highest activity is concentrated in sub Saharan Africa
  - each year affects close to 400 million people in 25 countries
  - the largest recorded outbreak, in 1996, caused 250,000 cases and almost 25,000 deaths and at least 50,000 persons suffered permanent disability

- Current WHO Strategy
  - reactive mass vaccination with a meningococcal polysaccharide vaccine (Men Ps), to halt the outbreak, and effective case management through antibiotic treatment, to curb the lethality

Environmental determinants

• Highly seasonal (dry season)
• Dry and dusty environment *(Lapeyssonnie, 1963)*
• Negative correlation with rainfall *(Jackou-Boulama et al., 2005)*
• Onset related to seasonal wind pattern *(Sultan et al., 2005)*
• Interannual variability related to dust, rainfall, NDVI *(Thomson et al., 2006)*

Other determinants

• herd immunity (after epidemics, vaccination, lack of immunity due to migration)
• population density (indoors crowding, gatherings)
• age groups

*Risk map of Meningitis Epidemic Outbreaks. Based on environmental suitability *(Molesworth et al. 2003)*
Mean Seasonal Cycle of Atmospheric Circulations in West Africa

- **N Hemisphere winter**
  - dry season in the Sahel
  - NEasterly winds (Harmattan) bring dry and dusty air from the Sahara
  - favorable conditions for meningitis

- **N Hemisphere summer**
  - rainy season in the Sahel
  - NEasterly winds (Harmattan) retreat to the north and are replaced by moist and dust–free SWesterly monsoon flow
  - meningitis stops in high humidity conditions

- **Seasonal Cycle:**
  - the whole system migrates N & S
  - rainy season shorter in the N than in the south
Cluster Analysis: weekly incidence at district level in Burkina Faso, Mali, Niger

- Earlier onset and termination of meningitis season in southern districts
- Northward progression of the epidemic season
- Population density effect?

Weeks 5-20, standardized, 4 classes
Project Context

- EARTH SCIENCE APPLICATIONS FEASIBILITY STUDIES

- TARGETED DECISION SYSTEMS
  - WHO operating procedures for Men control in Africa
  - Planned mass preventive MenA vaccine (Meningitis Vaccine Project)

- IRI - PAHO/WHO Collaborating Centre on early warning systems for malaria and other climate sensitive diseases

- MERIT (Meningitis Environmental Risk Information Technologies Project)
  - joint effort of the World Health Organization (WHO) and partners to
    - utilize more effectively existing knowledge of the epidemiology of meningococcal meningitis to improve current control strategies;
    - to improve the understanding of the relationship between bacterial meningitis and environmental parameters;
    - to use this understanding to provide more timely warnings of the onset of meningitis epidemics;
    - and to use this knowledge to improve the efficacy of meningitis prevention and control strategies.

Endorsed by GEOSS
3rd Annual Meeting, Niamey, Niger, Nov. 9-11, 2009
Project Objectives

- GIS-based risk mapping system *integrating* epidemiological, demographic and environmental factors for planning preventive and curative actions.

- Demonstration for 42 districts in Niger
  - Weekly case data 1986-current, quality controlled

- Specific Earth Science results: Explore the potential of satellite and model data as inputs to meningitis risk mapping.

- Epidemiological factors:
  - Immunological state of the population

- Population factors:
  - Population surface by age and sex based on GRUMP
  - Population mobility

- Environmental factors:
  - Mineral dust: in situ (AERONET), satellite (NASA MISR)
  - Sporadic rain episodes: in situ, TRMM
  - Predictability of atmospheric circulations and mineral dust over the S
Project Objectives (cont.)

Statistical model forecasting the likelihood of epidemic threshold to be crossed (or not) at a given district at different time leads (before, at the beginning and during the season)

- Detect the optimal combination of predictors at different time lags
- Evaluate model’s skill (capacity to predict past epidemics and their timing)
- Demonstrate that different decisions can be made based on the available forecasts
Earth System Models
- GISS dust model embedded in GISS ModelE
- IRI seasonal forecast outputs (ECHSM 4.5 GCM)
- NCEP Reanalysis

Predictions/Forecasts
Specific products or types of predictions from the models
- Climate conditions in West Africa:
  - Probability of sporadic rainfall events
  - Seasonal cycle of low level circulations and its interannual variations
  - Simulated aerosol load
- Population:
  - Time series of population surfaces by age and sex
  - Estimation of migration flows and scenarios
Specific interoperability, data fusion, and other information technology to support integration
Merging climate, population, and immunological data via generalized linear model
GIS-based risk mapping

Earth Observations
(e.g., satellite, in situ)
- MISR (2000-2008)
- AERONET (1995-2008)
- Rain gauges (1995-2008)
- TRMM (1998-2008)
- Potentially in the future GPM - Global Precipitation Measurement

Observations, Parameters & Products
Specific observations products or parameters feeding the DSS
- Aerosol monitoring
- Rainfall monitoring
- GPW3; GRUMP; Migration data (several sources); population by age and sex
- Past epidemics and vaccination campaigns

Decision Support Systems, Assessments, Management Actions
Specific analyses to support the decision making
Maps of level of risk of meningitis in Niger based on:
- Monitoring of meteorological and aerosol conditions
- Predicting seasonal characteristics of aerosols and climate conditions
- Estimation of more-at-risk population groups
- Monitoring immunological state of the population
Specific Decisions / Actions
- WHO issuing Alerts and Warnings
- Management of Vaccine stockpiles including resource mobilization
- Planning of preventive vaccinations

Value & Benefits to Society
Improvements in the decision-making, decisions, and actions (actual, expected, estimated)
- Improved spatial risk mapping
- Improved lead time for alerts and warning leading to enhanced preparedness
- Better management of vaccine stockpiles and optimization of vaccine allocation
- Better surveillance targeted to regions at highest risk

Quantitative and qualitative benefits from the improved decisions (actual, expected, estimated)
- Enhanced lead-time for decision
- Improved preparedness at international and national levels
- More targeted allocation of country public health resources
- Estimated better protection of population with reduced economic losses
- Better management of vaccine (stockpiles, vaccination campaigns)
Project Participants and Their Responsibilities

**IRI:**
- analysis of relationships between atmospheric conditions & dust and meningitis, analysis of their predictability; construction and evaluation of the model - S. Trzaska, L. Cibrelus, M. Thomson (adv.)
- exploration of the potential of satellite data - P. Ceccato, T. Dinku
- evaluation of decision improvement potential - M. Madajewicz

**CIESIN:**
- population mapping by age structure, urban/rural distribution, population mobility, georeferenced datasets, construction of predictive model - S. Adamo, G. Yetman
- data integration and model construction – M. Levy

**GISS:**
- aerosols simulations – J. Perwitz
- validation and interpretation of model results – R. Miller (adv.)

**JPL:**
- MISR data and related technical expertise: O. Kalashnikova
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