# 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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|---|---|
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| **CIESIN:** | **S. Adamao (Co-PI), M. Levy, G. Yetman, SA** |
| **GISS:** | **J. Perlwitz, R. Miller** |
| **JPL:** | **O. Kalashnikova** |



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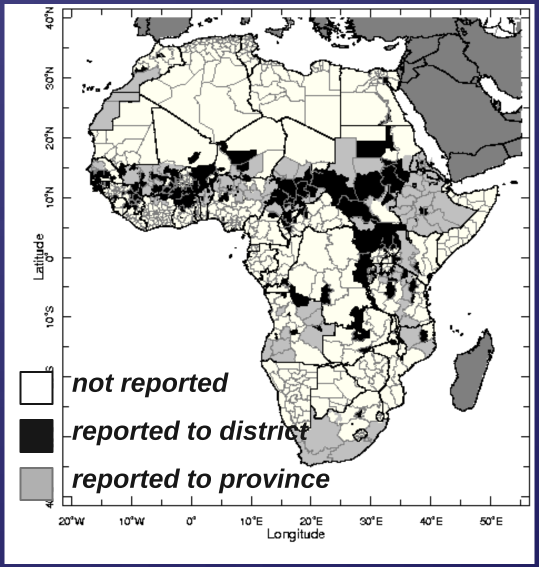
Goddard Institute for Space Studies

CIESIN Columbia Universit

The International Research Institute for Climate and Society

# 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 sequeals
- **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




*Observed Meningitis Epidemics Distribution 1841-1999. (Molesworth et al. 2003)*

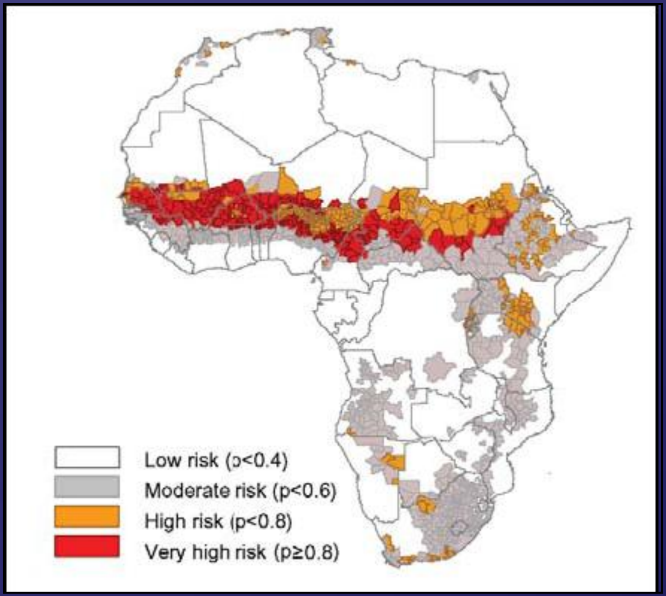
# Meningococcal Meningitis - few facts (cont.)

## 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*)

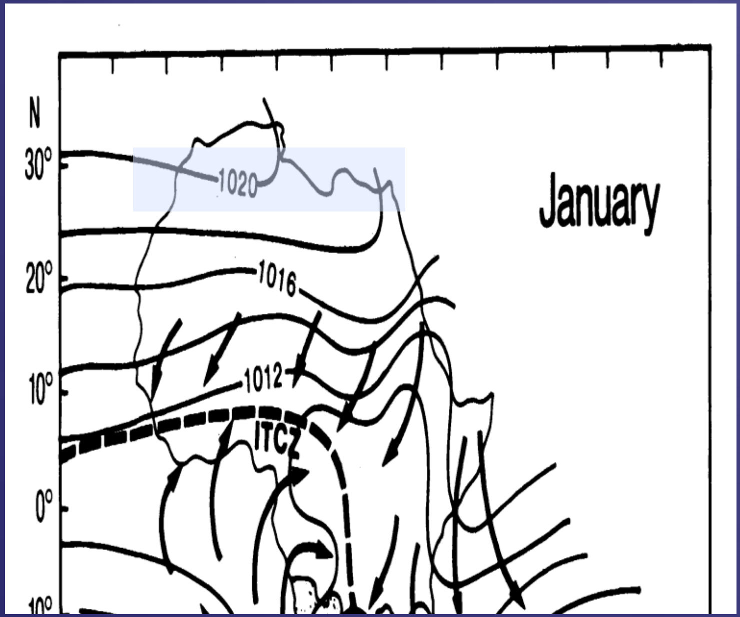
## Other determinants

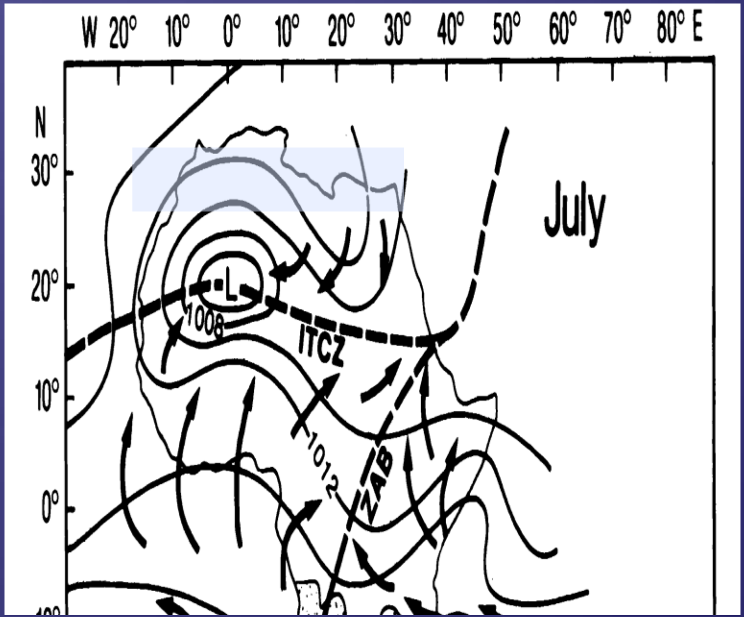
- **herd immunity (after epidemics, vaccination, lack of immunity due to migration)**
- **population density (indoors crowding, gatherings)**
- **age groups**




***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

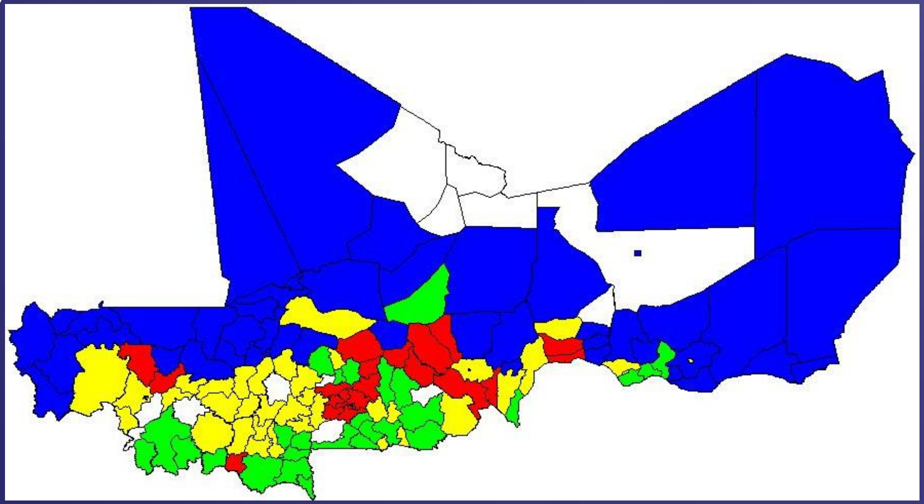
- rainy season in the Sahel
- NEasterly winds (Harmattan) retreat to the north and are replaced by moist and dust –free SWesterly monsoon flow
- meningitis stops in high humidity conditions

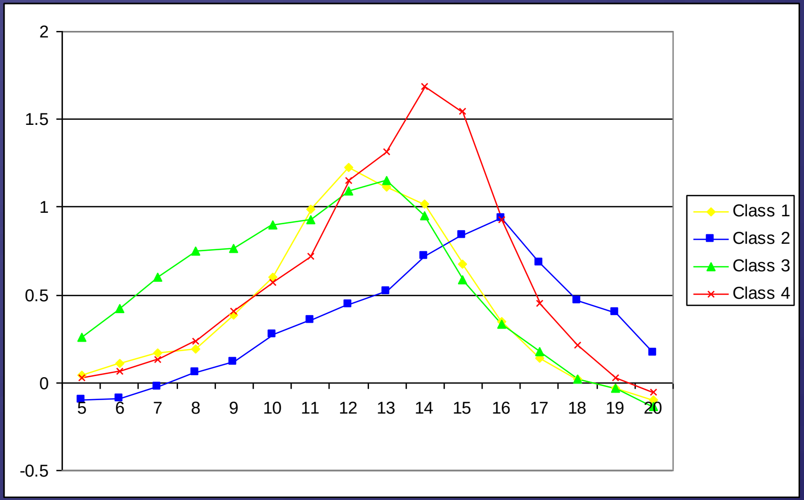
## Seasonal Cycle:

- the whole system migrates N & S
- rainy season shorter in the N than in the south

# Meningitis Mean Seasonal Cycle

- Cluster Analysis: weekly incidence at district level in Burkina Faso, Mali, Niger






Weeks 5-20, standardized, 4 classes

**Earlier** onset and termination of meningitis season in **southern** districts

- Northward progression of the epidemic season
- Population density effect?

# 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 con 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 Sa**

# 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

ROSES-2008 **Public Health: Environmental factors and population dynamics as determinants of meningococcal meningitis epidemics in the Sahel: an investigation of NASA and NOAA products. (PI Sylwia Trzaska)**

## Earth System Models

**Model name, type, predictive capabilities, assimilations, other info**

- GISS dust model embeded in GISS ModelE
- IRI seasonal forecast outputs (ECHSM 4.5 GCM)
- NCEP Reanalysis

## 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

## 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

**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

## Observations, Parameters & Products

## Decision Support Systems, Assessments, Management Actions

•WHO meningitis Early Warning System

•WHO reactive meningitis vaccination

•Meningitis Vaccine Project

**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***

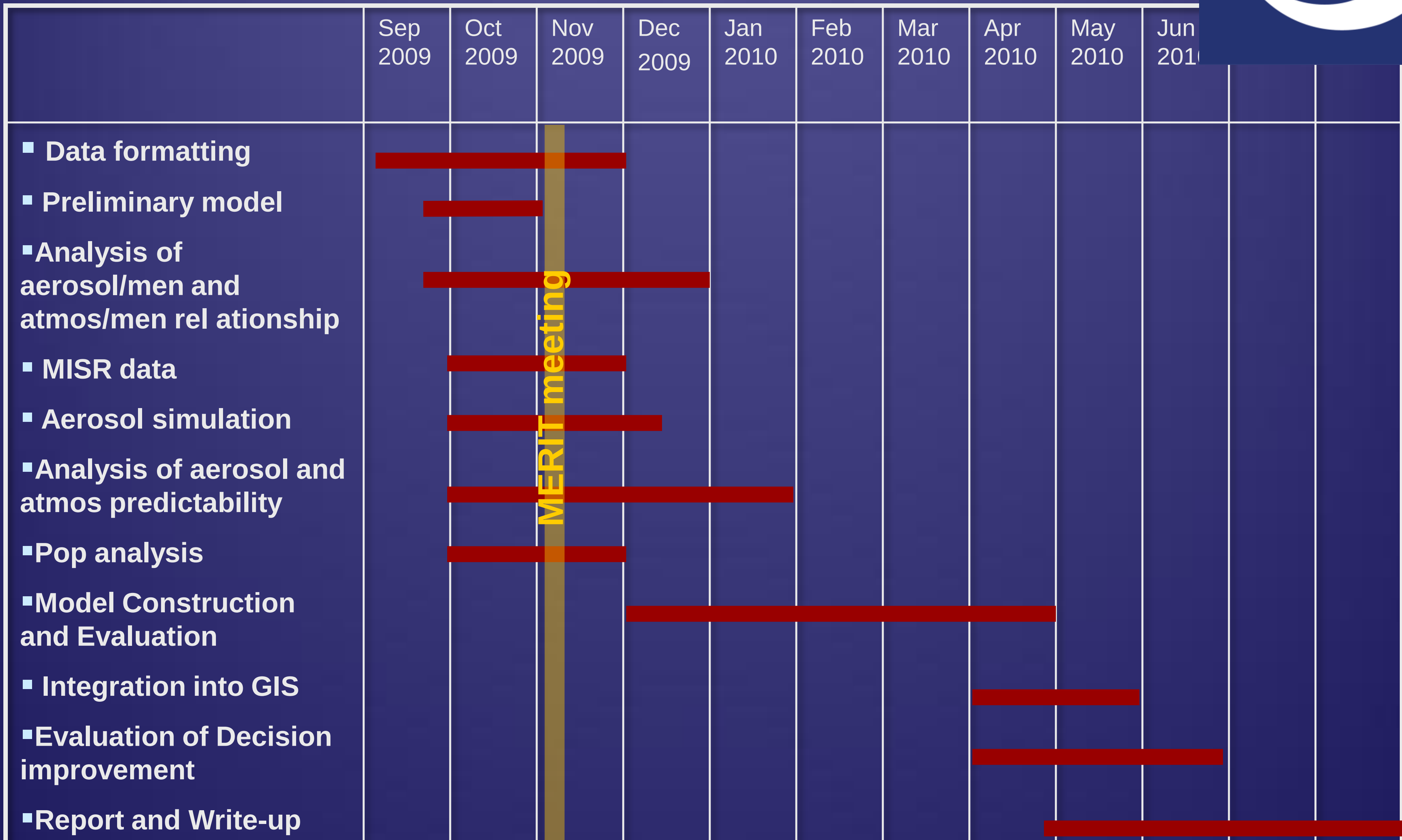
***(actual, expected, estimated)***

- 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, georefernced 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

# Timeline


Sep 2009
Oct 2009
Nov 2009
Dec 2009
Jan 2010
Feb 2010
Mar 2010
Apr 2010
May 2010
Data formatting
Preliminary model
Analysis of aerosol/men and atmos/men rel ationship
MISR data
Aerosol simulation
Analysis of aerosol and atmos predictability
Pop analysis
Model Construction and Evaluation
Integration into GIS
Evaluation of Decision improvement
Report and Write-up
MERIT meeting