28 October Denver Colorado

Session A6 Theme A6: Translating Scientific Understanding of Climate system into Climate Information for Decision Makers (Chair: L. Goddard)

Climate and Public Health

Madeleine C. Thomson,

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

The MERIT initiative: a climate and health partnerships to inform public health decision makers

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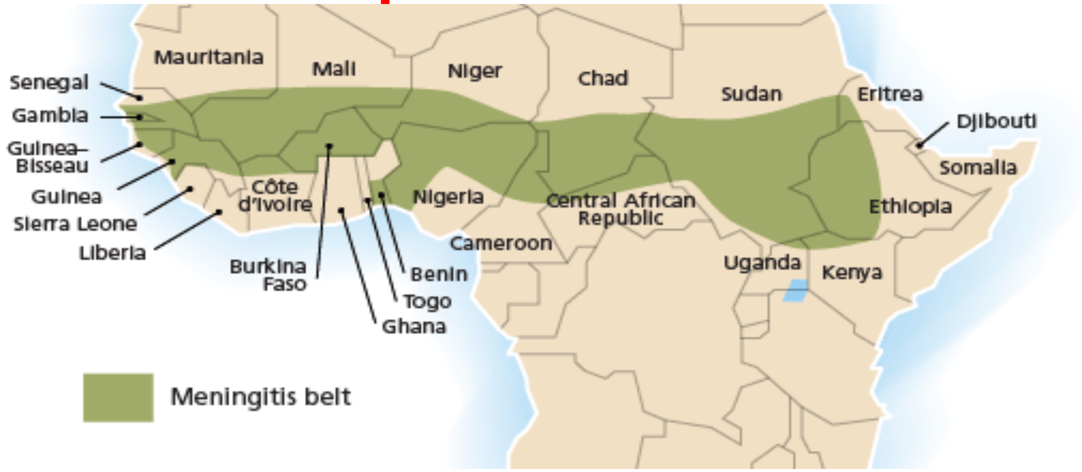
3 Health and Climate Foundation, Geneva, Switzerland
4 Climate and Health Working Group, Ethiopia
5 Group on Earth Observations, Geneva Switzerland
6 World Meteorological Organization, Geneva Switzerland

Meningitis Environmental Risk Information Technologies:

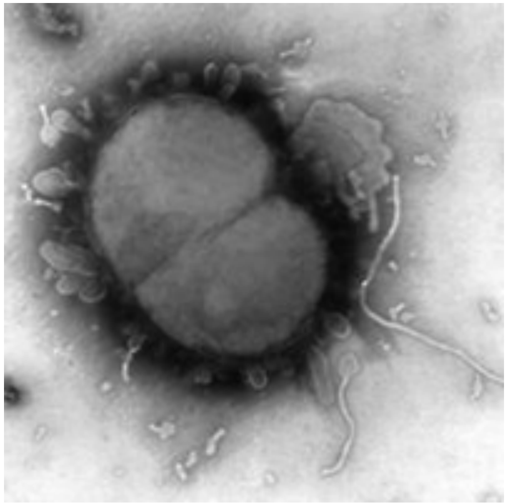
The MERIT initiative was launched in 2007 as a multi-sectoral partnership led by WHO to provide a platform for enabling health specialists (public health specialists, epidemiologists, immunologists, microbiologists, demographers, etc.) and climate and environment specialists to work together to help solve a pressing health problem.

Epidemic Meningitis in Africa: the problem



Source: Control of epidemic meningococcal disease, WHO practical guidelines, World Health Organization, 1998, 2nd edition, WHO/EMC/BAC/98.3
Extracted from http://www.meningvax.org/epidemics-africa.php

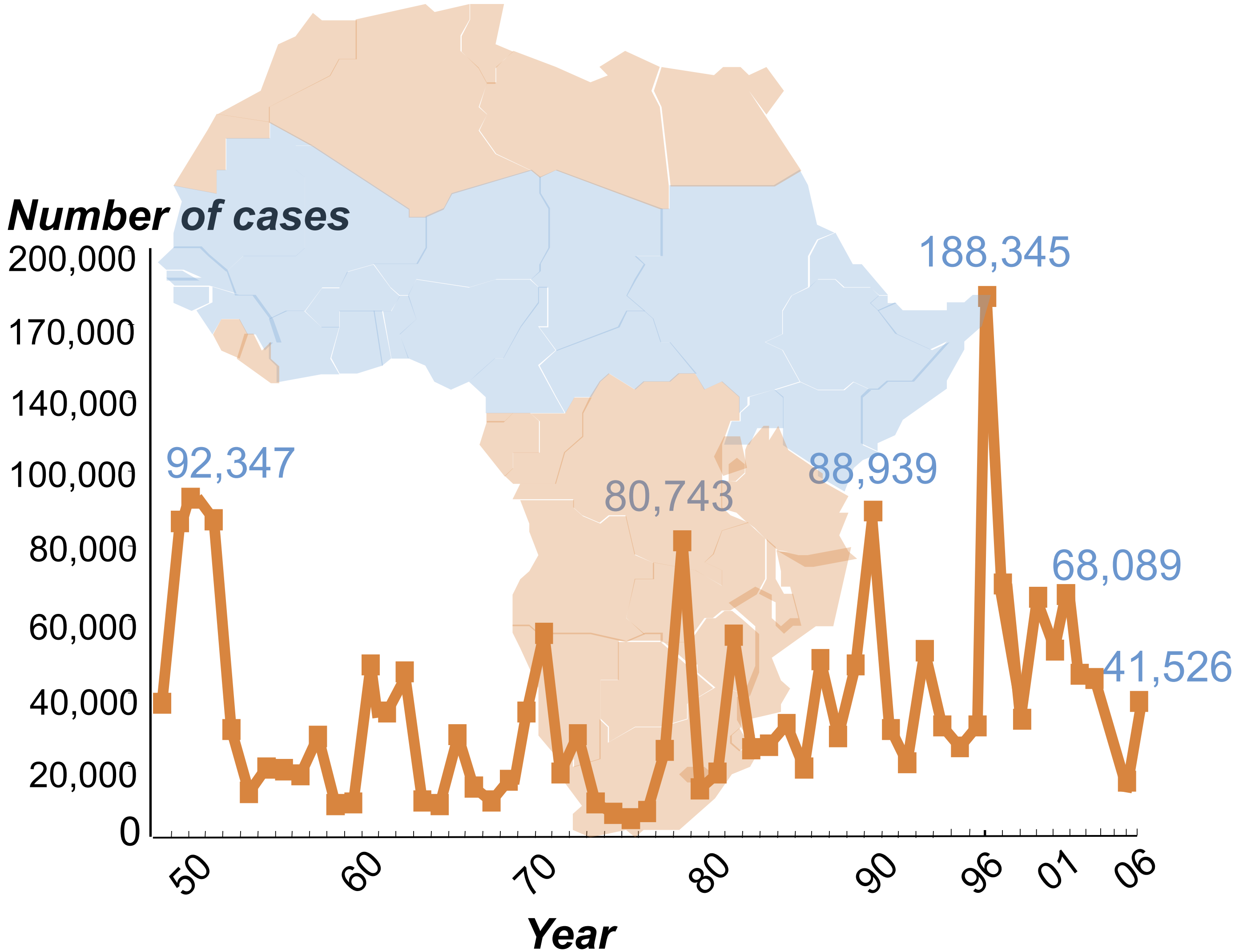
- Meningococal Meningitis, bacterial form of meningitis
- Direct transmission, person to person, respiratory droplets
- 12 serogroups. 4 in Africa: A, C, W135, X
- Serious infection of the thin lining that surrounds the brain and spinal cord
- Belt stretches from Senegal in the west to Ethiopia in the east (80 % of the global burden)
- 430 million people at risk, 1 million cases since 1998
- 10-50 % fatality rates, 10-20 % of survivors suffer permanent brain damage



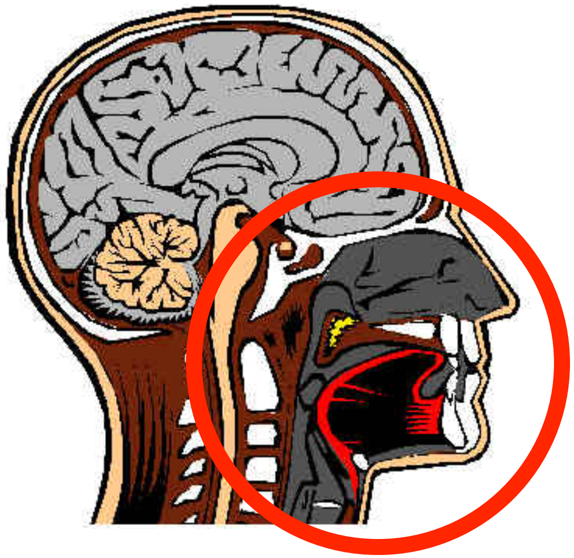
Epidemic meningitis in Africa

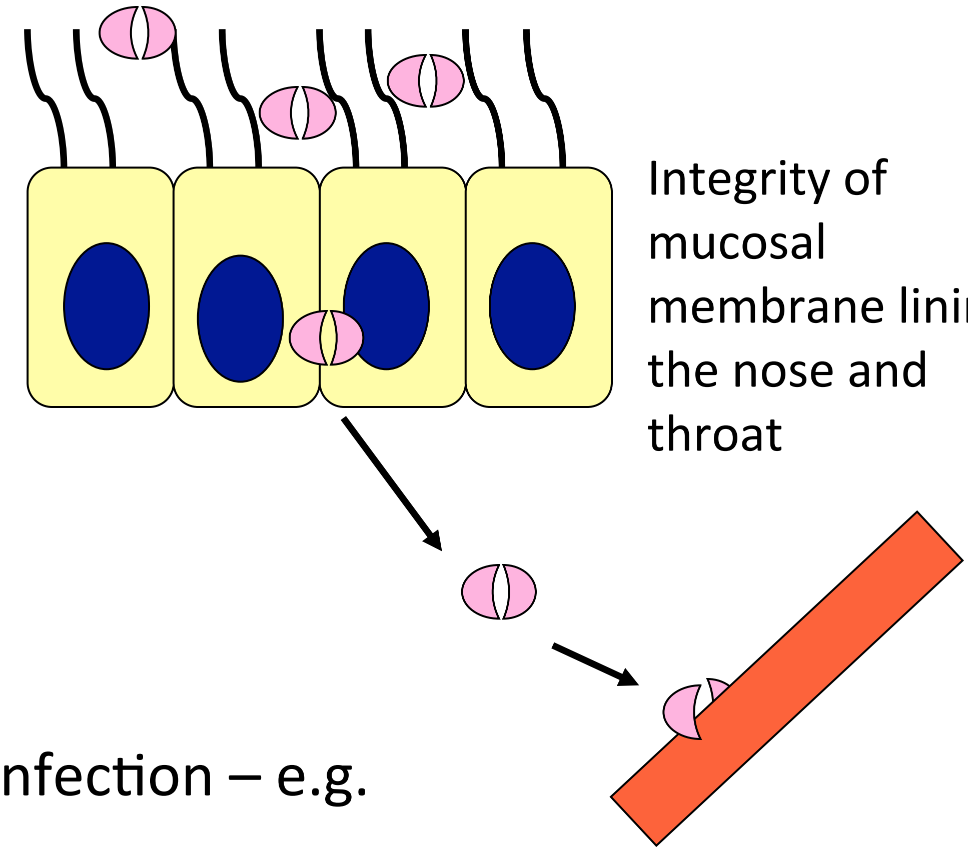
Meningitis belt: from Sudan in the east to Senegal The Gambia and Mali in the west: Sudan, Ethiopia, Chad, Niger, Benin, Northern Nigeria, Northern Ghana, Burkina Faso, Mali,The Gambia,Senegal

•1905: first documented epidemic, Northern Nigeria
•1919-1924: second great wave; over 45,000 deaths in Northern Nigeria
•1935-1937: third great wave: Chad 1,326 deaths; Nigeria 6,456 deaths
•1951-60: 340,000 cases with 53,000 deaths
•1996-1997: 300,000 cases with 30,000 deaths



Carriage and disease





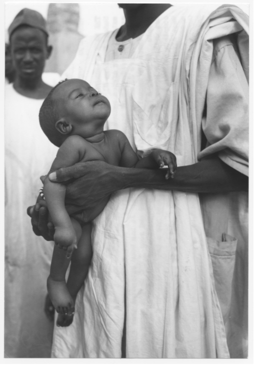
Integrity lost through:

- microbial damage from other infection – e.g. flu
- physical damage from low absolute humidity and dust

Courtesy Brian Greenwood

Characteristics

Impact on the individual

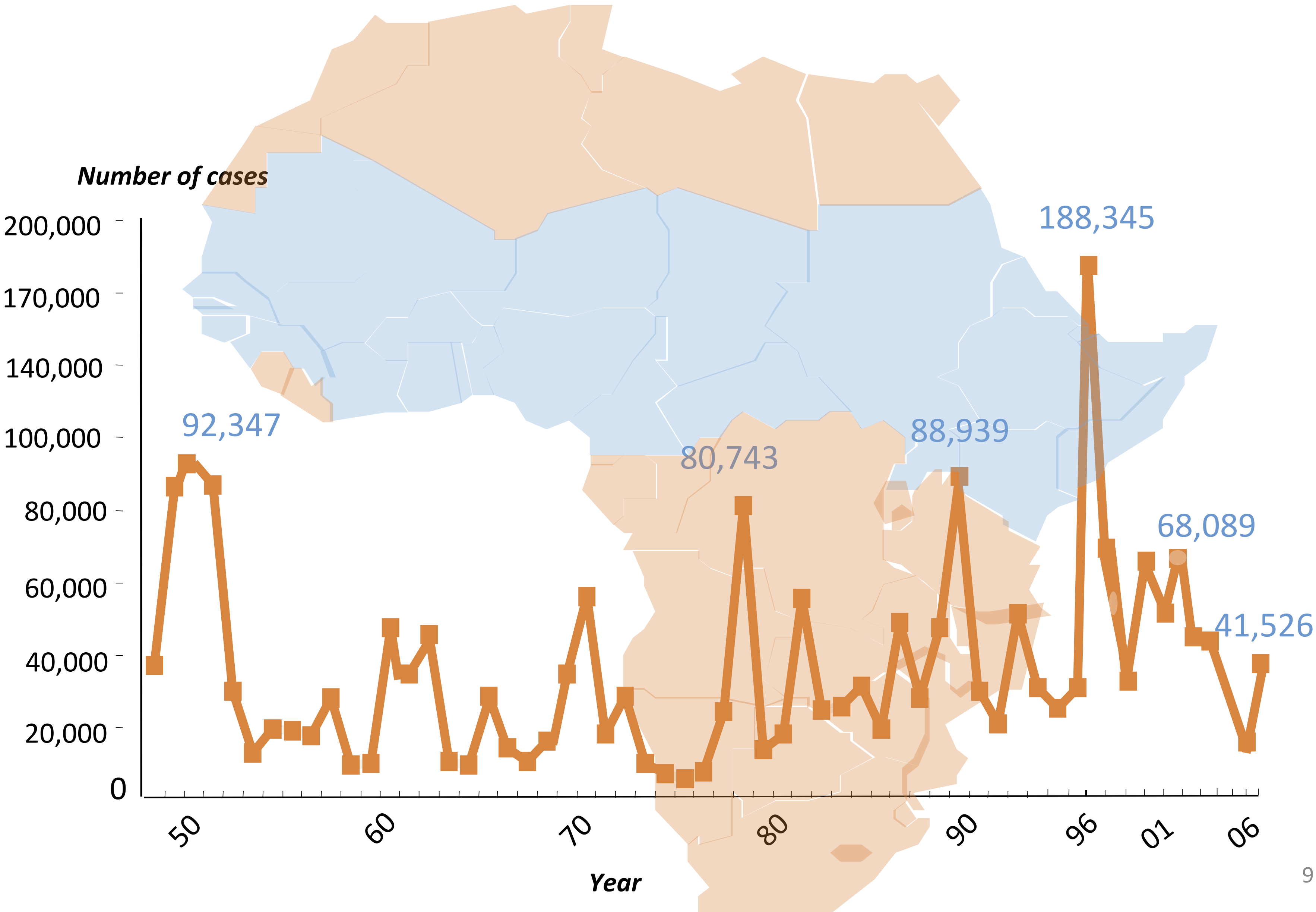


- Stiff neck
- High fever
- Headaches
- Vomiting
- Seizure, coma
- Rash
- 10% case fatality rate
- 10-20% of survivors suffer permenent brain damage

Impact on the community

Health facilities overwhelmed, household costs
-430 million people at risk, 1 million cases since 1998
-widely feared because of its rapid onset and devastating impact

Epidemic meningitis in Africa



Meningococcal Meningitis A Prevention and Control strategies

Old

- Reactive - polysaccharide vaccine – used in response to epidemic (A, C, X etc)

New

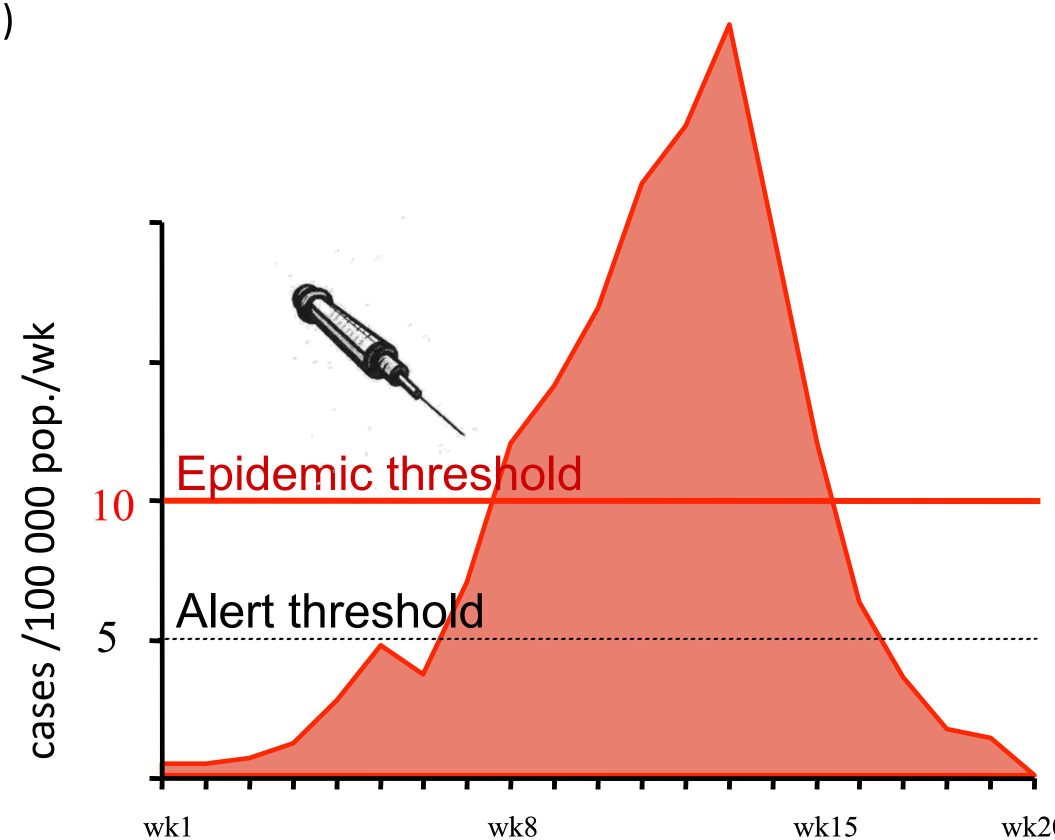
- Proactive – Conjugate vaccine – used to prevent epidemics of Meningococcal Meningitis A.

Control: polysaccharide reactive vaccination

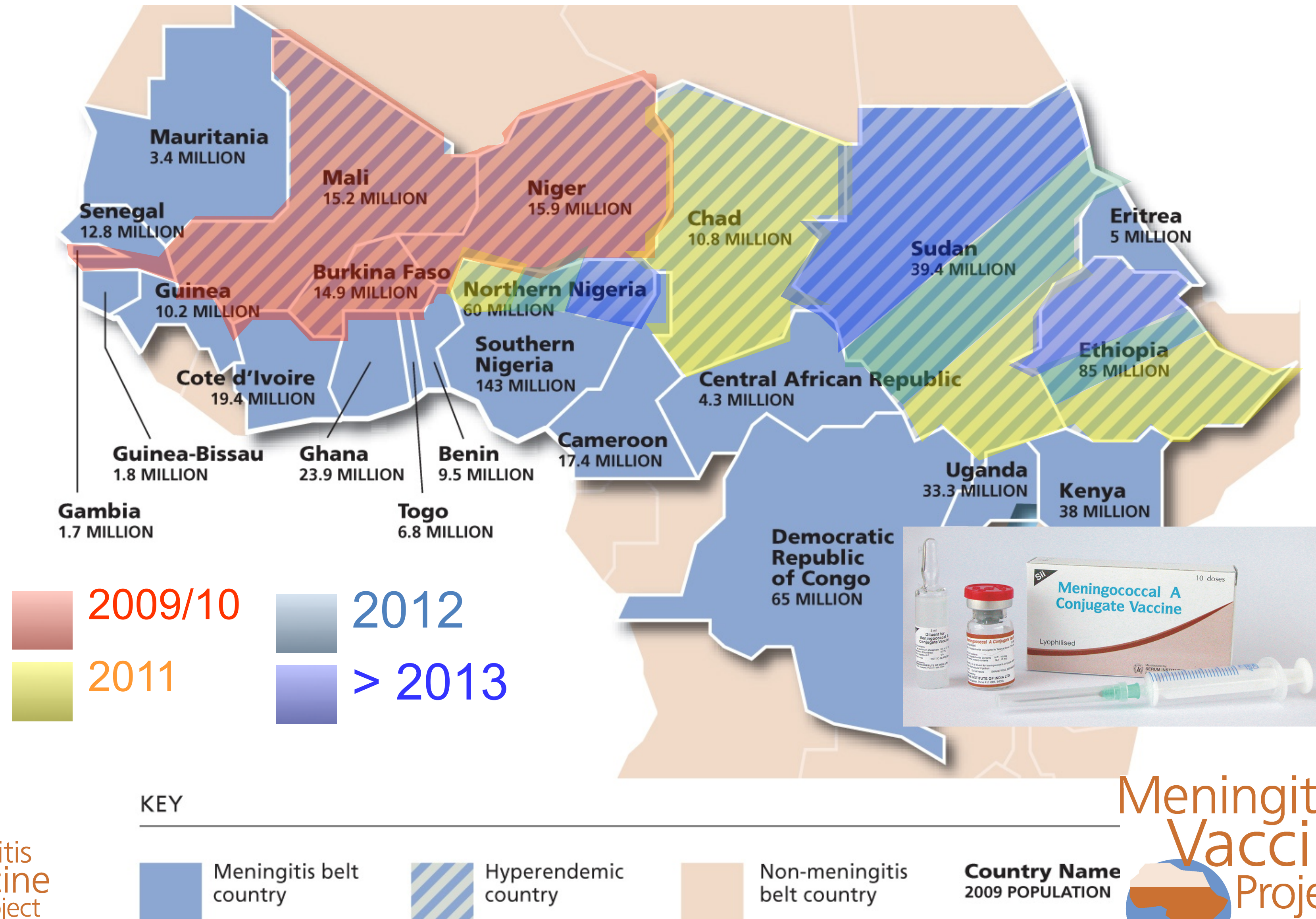
- District level
- Based on incidence thresholds (enhanced weekly surveillance)

- Does not prevent all cases

***CHALLENGE*: timely vaccination to optimize the control of the epidemics**

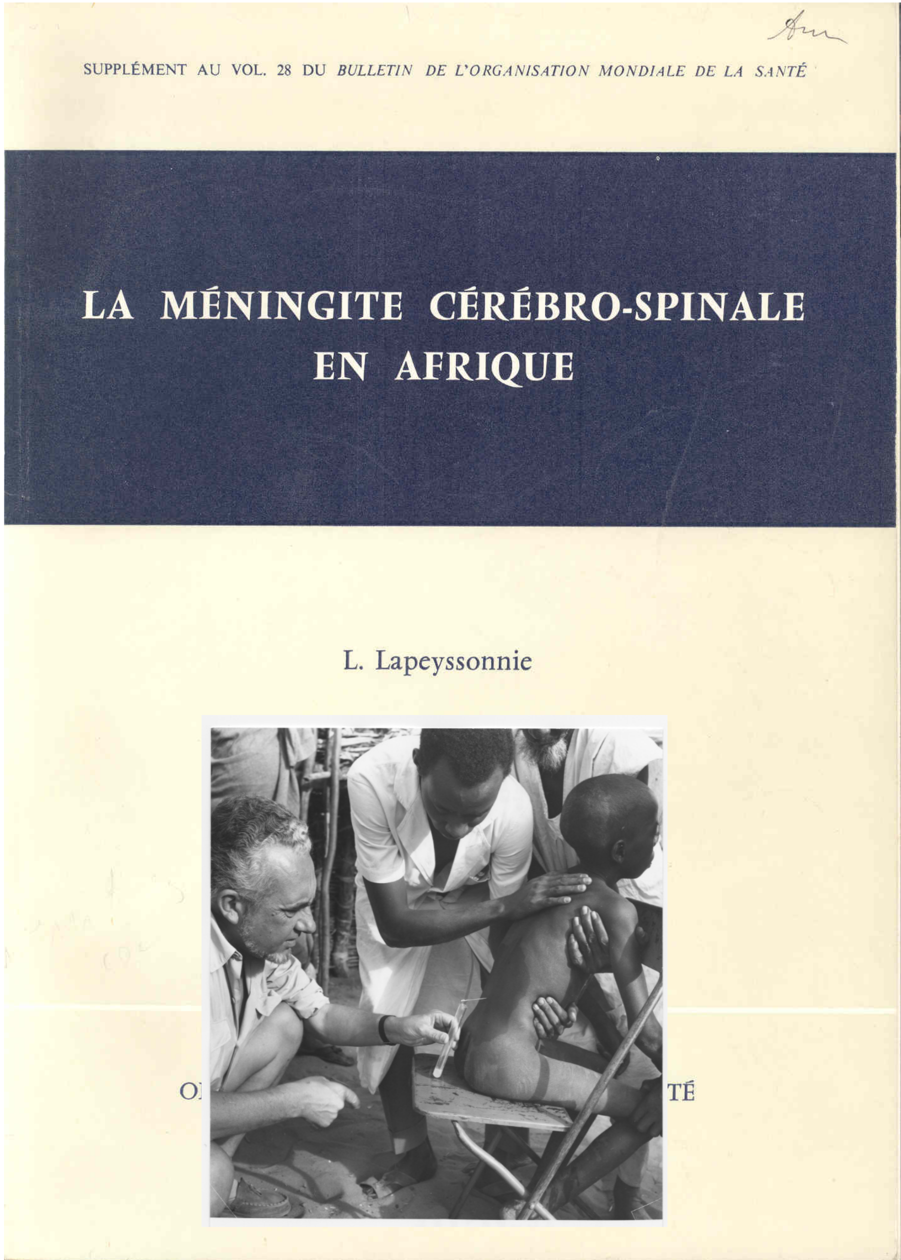


MenA conjugate vaccine introduction

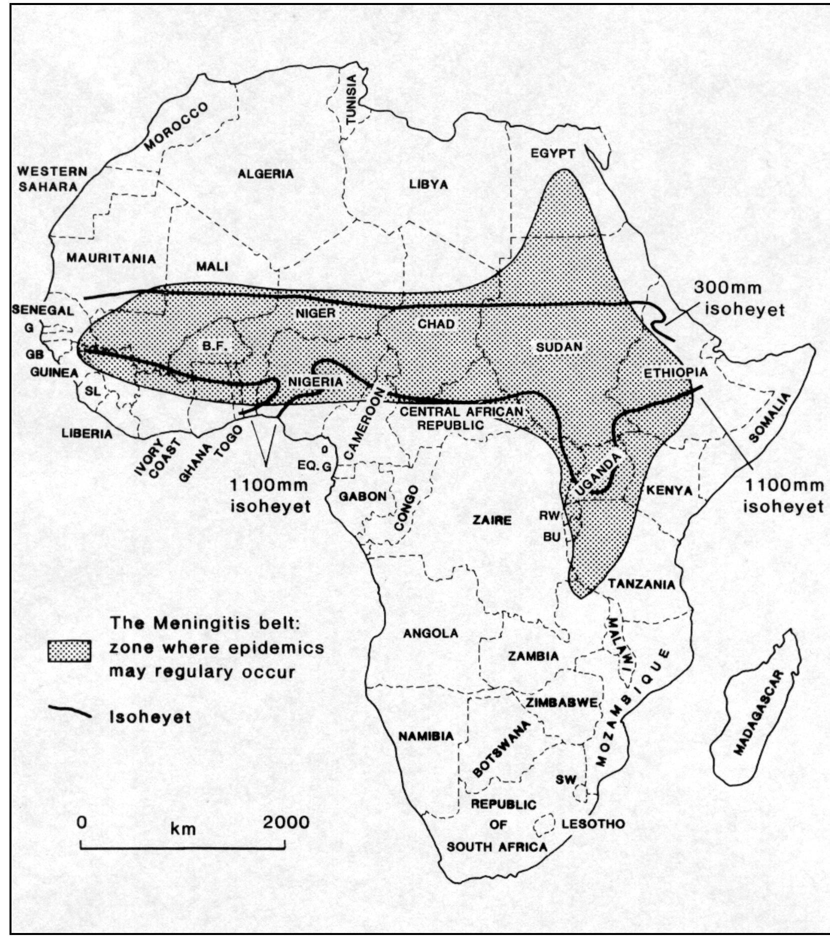


Challenge: changes in the strucuture of the Belt in the next 10 years

The natural history of the disease: still many question marks…



Defined the 'Meningitis Belt'



Cheesbrough JS, Morse AP, Green SDR. Meningococcal meningitis and carriage in western Zaire: a hypoendemic zone related to climate? *Epidemiology and Infection* 1995: **114;** 75-92

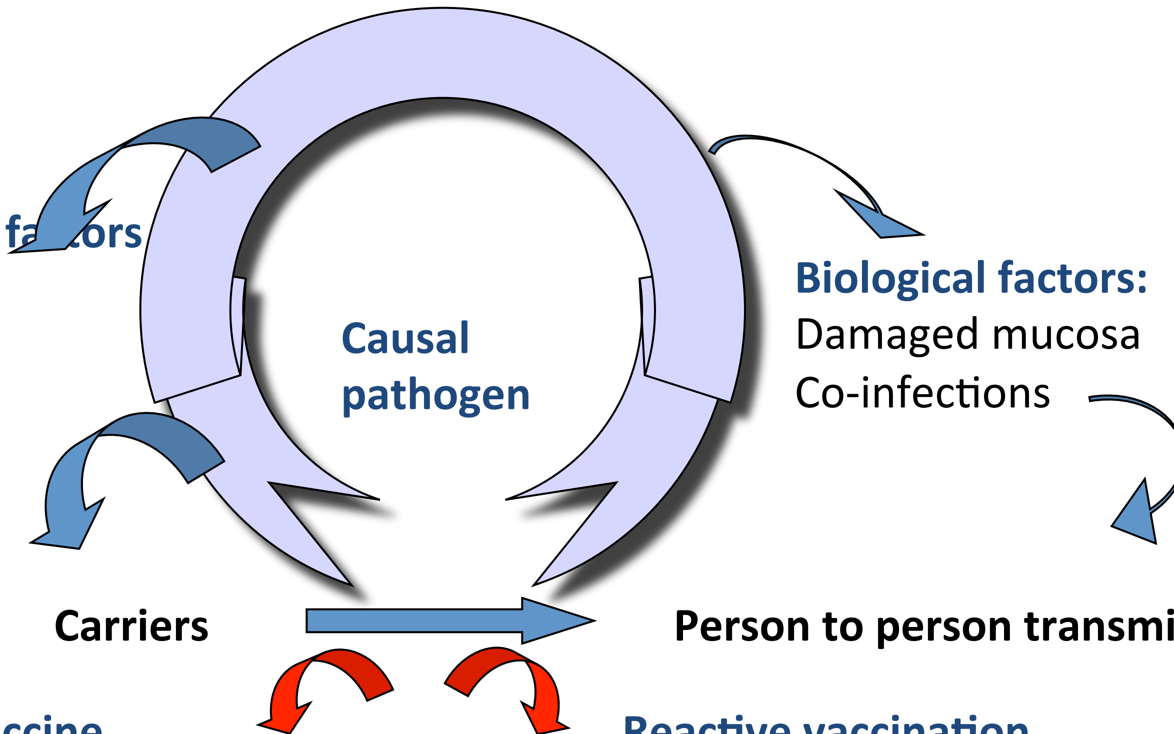
Epidemiological risks: A changing pattern

Climate factors:

Humidity, dust, winds, temperature

Dry season

December to June



Social & behavioural factors
Crowded housing
Displacements
Social gathering

Biological factors:
Damaged mucosa
Co-infections

Carriers → **Person to person transmission**

Preventive vaccine

Reactive vaccination

Seasonal annual epidemic pattern → **Major cyclic outbreaks every 8-12 Y**

Decision-maker concerns

- **Response to outbreaks**
    - Reducing time between outbreaks onset and reactive vaccination
    - Setting criteria for ending response to outbreaks
    - Forecasting: vaccine production and procurement
- **Introduction of a new conjugate vaccine**
    - Coverage scaling up: where first?
    - Protection effectiveness over time?
    - Coverage level required to prevent outbreaks ?
    - Risk assessment of non A meningitis outbreaks ?(Alert and Attack rates)
    - Long term changes in the Belt

How might climate information help?

- **Mechanisms:** Improved understanding of the mechanisms of disease transmission which can help identify new opportunities for intervention.
- **Spatial Risk and seasonal risk:** Understanding the geographic locations of populations at risk along with the timing of risk in an average year can improve timing of interventions.
- **Sub-seasonal and Year to Year changes in risk:** Understanding when changes in epidemic risk are likely to occur can help initiate appropriate prevention and response strategies.
- **Trends in risk:** Understanding long term drivers of disease occurrence (including climate changes) can help plan long term prevention and response strategies.
- **Assessment of the impacts of interventions:** As part of prudent impact assessment exercise climate can be factored in as it enables or limits disease transmission

Meningitis and environment

At the time MERIT was formed climatic and environmental factors were understood to effect

- Geographic occurrence of severe epidemics (the Meningitis Belt – confined to the semi-arid Sahel)
- Seasonality of disease (confined to the hot, dry and dusty dry season)

Also - Widespread acceptance of the importance of immunity, bacterial strains and population characteristics (including density)

- Tantelizing hints that climate variability might be important in the timing and intensity of disease occurrence – but research lacked quality climate, environmental and epidemiological data and robust analysis.
- Speculations on the mechanism(s) by which climate/environmental factors impact on meningococcal meningitis transmision and conversion from carriage to envasive disease – but little concrete evidence.

Climate information in public health decision-making: **Mechanism**

- Malaria

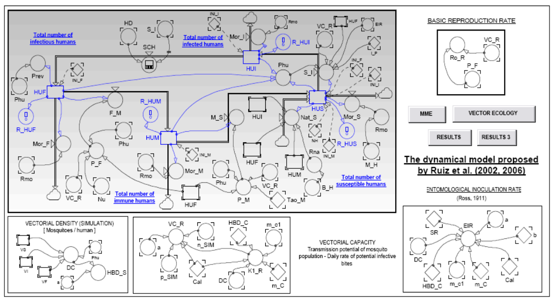
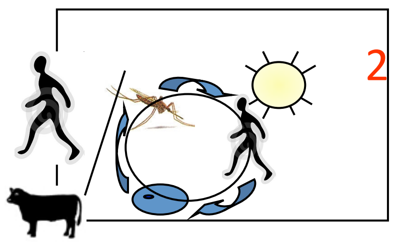


Figure 1.13. Stock-flow model of the human host component of the mathematical tool proposed by Ruiz *et al.* (2006)

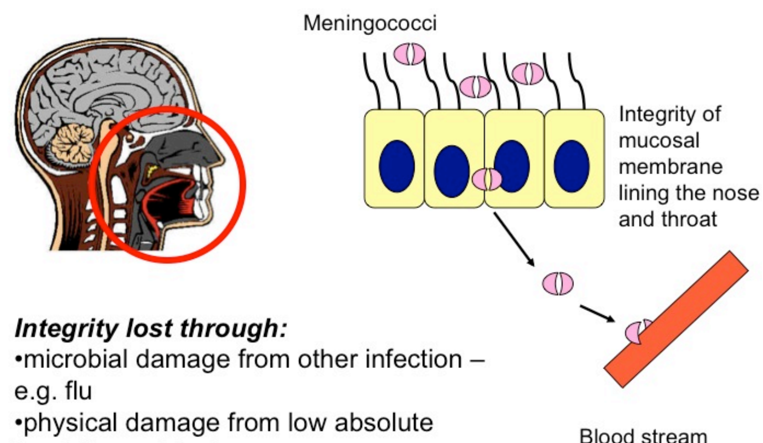
a^2 = proportion of vector feeding on human host (human biting index / length of feeding cycle in days)



Ruiz, D., Connor, S.J., and **Thomson, M.C.** (2008) A Multi-Malaria-Model Ensemble Framework in Support of Malaria Early Warning and Control. In Seasonal Forecasts, Climatic Change and Human Health. (Advances in Global Change Research) Eds M.C. Thomson, R.G Herrera and M. Beniston, Springer, 101-126

- Meningococcal meningitis ?

Mechanism – from carriage to disease

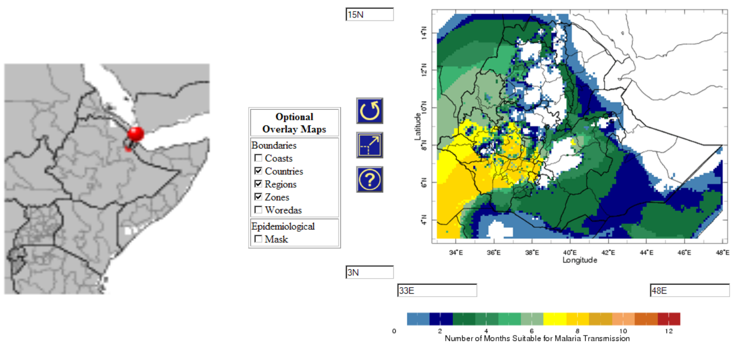


Integrity lost through:
•microbial damage from other infection – e.g. flu
•physical damage from low absolute humidity and dust

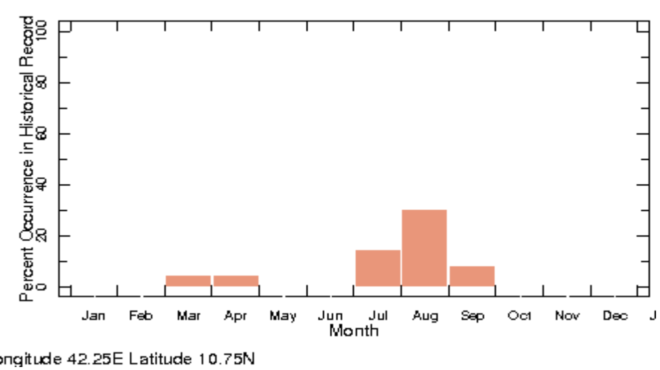
Courtesy Brian Greenwood

Climate information in public health decision-making: **Spatial Risk and seasonal risk:**

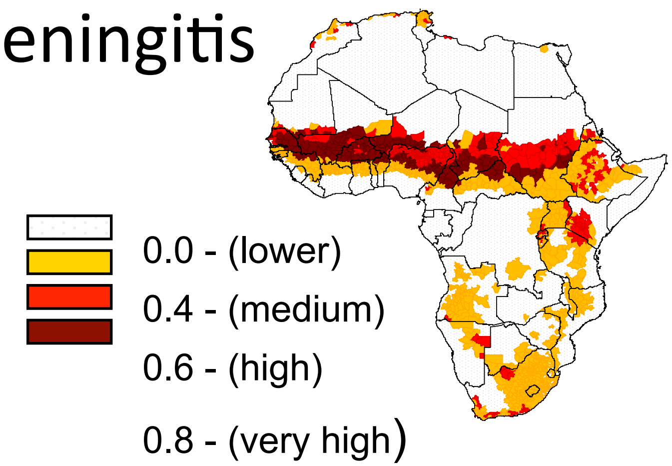
- Malaria

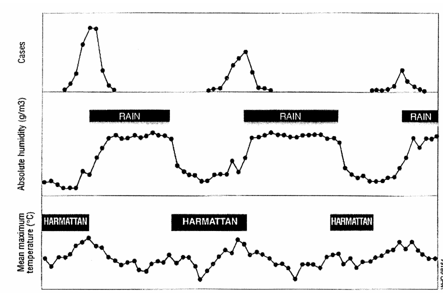


Percent Occurrence of Climate Conditions Suitable for Malaria Transmission



- Meningococcal meningitis





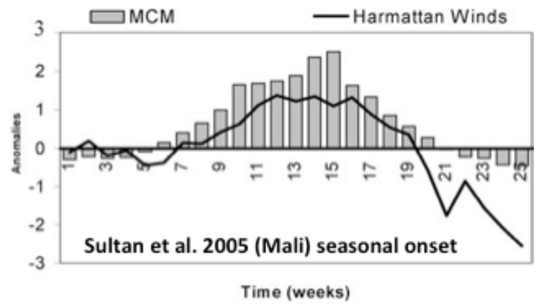
Climate information in public health decision-making: **Sub-seasonal and Year to Year changes in risk**

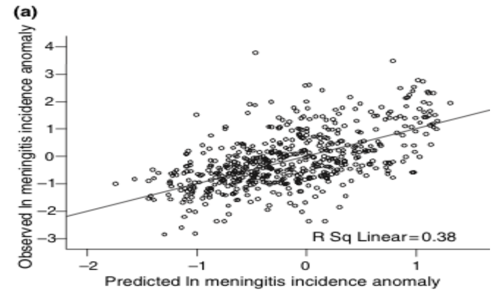
- Malaria

(DaSilva, et al. MJ 2004).(Thomson, et al. AJTMH 2005) (Thomson, et al. Nature 2006).

(Worrall, et al. *TMIH* 2007; Worrall, et al. 2008)

- Meningococcal meningitis



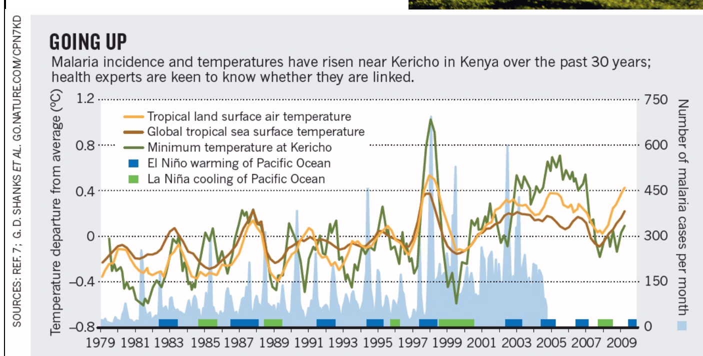


Thomson at al. (2006) exploratory attempt to capture the inter-annual variation of meningitis cases through anomalous climate-related environmental factors.

Climate information in public health decision-making: **Trends in risk:**

- Malaria

Judith A Omumbo, **Bradfield Lyon**, **Samuel M Waweru**, **Stephen J Connor** and **Madeleine C Thomson (2011) Raised temperatures over the Kericho tea estates: revisiting the climate in the East African highlands malaria debate** *Malaria Journal* 2011, **10**:12 doi: 10.1186/1475-2875-10-12

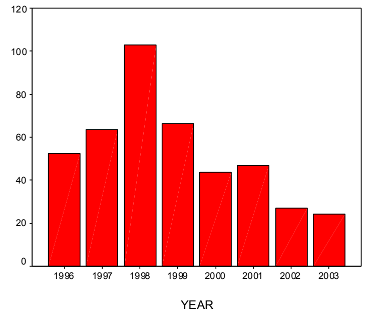


- Meningococcal meningitis

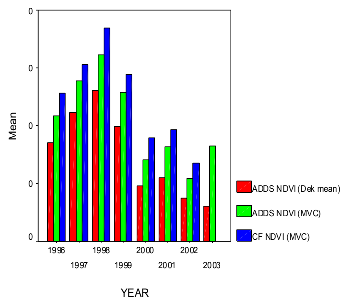
?

Climate information in public health decision-making: **Assessment of the impacts of interventions:**

- Malaria



Eritrea: 63% decline in Malaria in Eritrea 1999-2003



Eritrea: NDVI Vegetation Index also decreased

Graves, P.M., Osgood, D.E., Thomson, M.C., Sereke, K., Araia, A., WeldeMicael, A., Zerom, M., Ceccato, P., Bell, M., del Corral, J., Ghebreselassie, S., Brantly, E.P., and Ghebremeskel. T.(2008) Effectiveness of malaria control in Eritrea, 1998 to 2003. Tropical Medicine and International Health 13, (2) 218-228

- Meningococcal meningitis

?

MERIT members include:

- **WHO** Chairing the MERIT Steering Committee and facilitating the interactions between MERIT partners through **annual technical meetings**. Since 2007. WHO participated in Cross-sectoral monitoring of the 2010 meningitis epidemic season along with the African Centre for Meteorological applications in development and the IRI.

- **The CHICAS research group** at Lancaster University has invested in the development of a spatio-temporal model designed to support national- and district-level short-term forecasting of meningitis epidemics.

- **UCAR Project:** The University Corporation for Atmospheric Research (UCAR) in Boulder, Colorado USA received funding from Google to research methodologies for short-term forecasting of the end of the meningitis season.

- **International Research Institute for Climate and Society (IRI), Columbia University:** The IRI is leading several research projects under the MERIT framework to advance the understanding of the environmental factors (climate and aerosols) and population dynamics as determinants of meningitis epidemics in the Meningitis Belt.

- **MAMEMA - Multidisciplinary Approach for Meningitis Epidemiology and Modeling in Africa:** a consortium of MERIT partners mostly based in Europe was formed in 2010 to help increase the sharing of information between research groups on projects related to meningitis dynamics in the Meningitis Belt.

- **MACC** (Meningitis linked to mineral dust transport in the Sahel), funded by the EU and conducted by Spain NFS-funded Project. This is linked to the project - **Integrated Geophysical Modeling for Regional Climate Studies** (Global distribution of minerals in arid soils as lower boundary condition in dust models), conducted by Serbia AC.

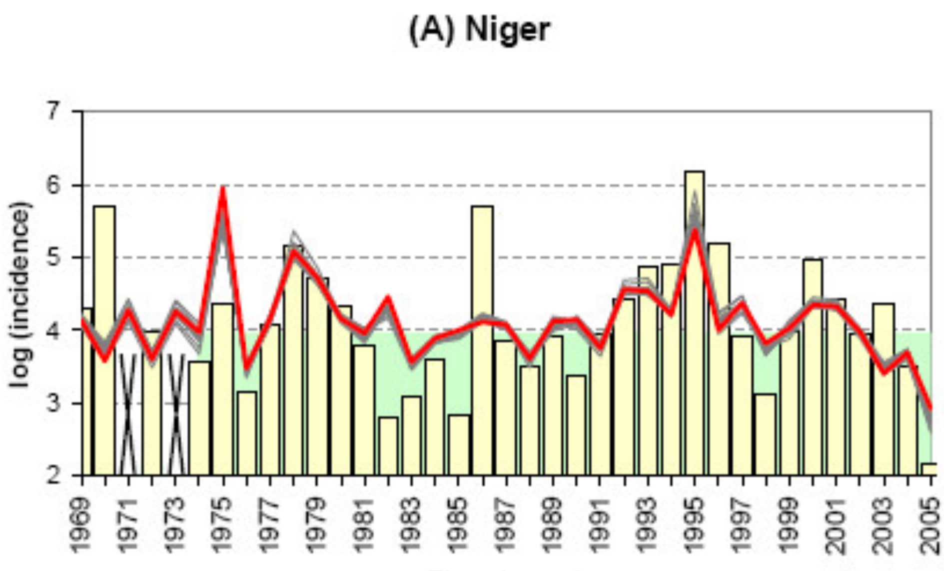
Country-led MERIT initiatives

- Ethiopia – MoH, Climate and Health Working Group
- Niger – Ministry of Health, CERMES
- Burkina Faso – National Met Service. MoH, MDSC
- Nigeria – Katsina State – MDG centre.

Research results

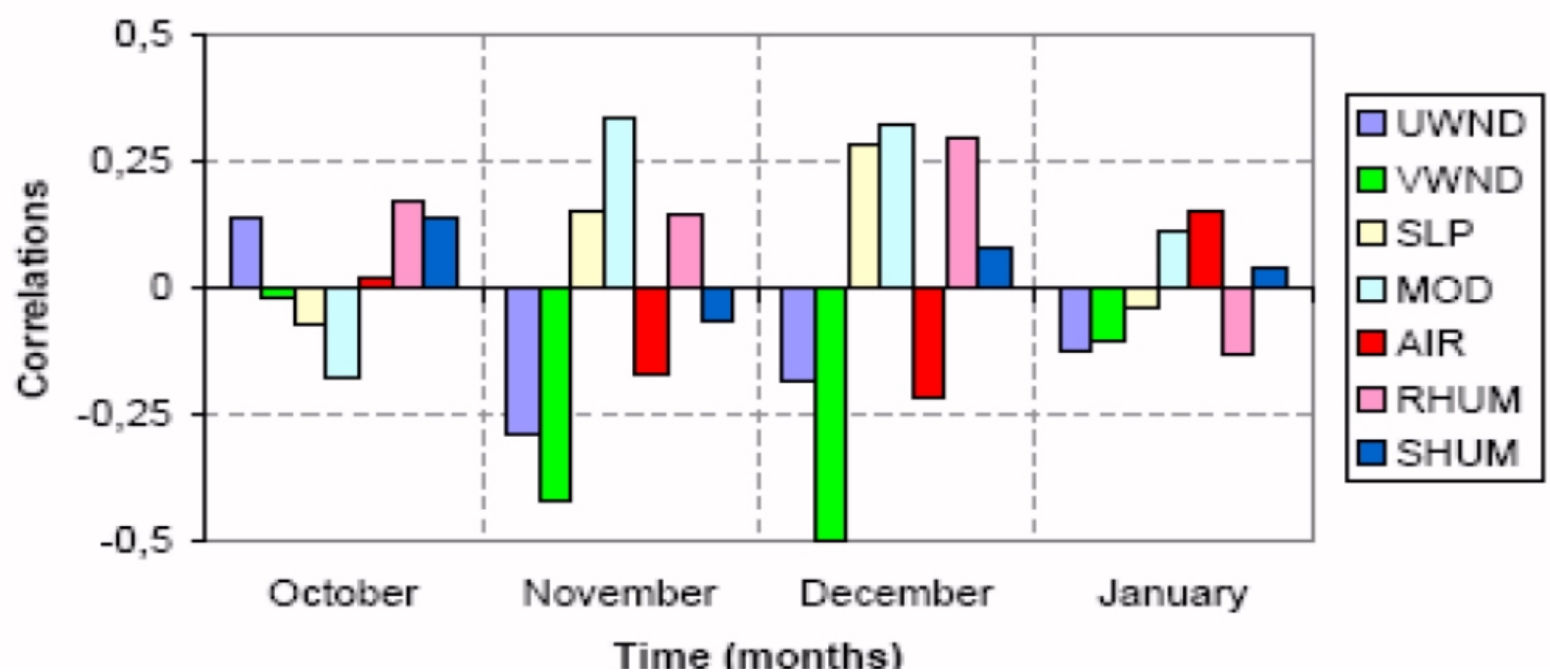
- 1. Climate + meningitis – Niger
- 2. Climate + immunity + meningitis – Niger
- 3. Climate + environment + meningitis - Ghana

USING CLIMATE ALONE as the PREDICTAND



(A) Predictions of meningitis outbreaks in Niger. Observed (yellow) meningococcal meningitis annual log-incidence time series and cross-validated forecast (red) for Niger (A) from 1968 to 2005. The grey lines represent each individual forecast produced during the cross-validation process. The crosses depict missing values.

Yaka, P., Sultan, B., Broutin, H., Janicot, S., Philippoin, S., Fourquet, & N.. Relationships between climate and year-to-year variability in meningitis outbreaks: A case study in Burkina Faso and Niger. *International Journal of Health Geographics* 2008 7:34



Skill Score for Niger meningitis model	Climate Based Model	Persistence Model	Desirable
Cross Validated Correlations	0.83	0.67	1
Hit Rate	0.47	0.41	1
False Alarm Rate	0.68	0.63	0
Hanssen & Kuipers score	0.68	0.63	>0.5

The environmental variables used in the study obtained from NCEP reanalysis were 1) Zonal wind (m/s) UWIND, **2) Meridional wind (m/s) VWIND**, 3) Wind speed (m/s) MOD, 4) Sea level pressure SLP, 5) Surface temperature (°C) AIR, 6) Surface relative humidity (%) RHUM, 7) Surface specific humidity (kg/kg) SHUM. Yaka *et al. International Journal of Health Geographics* 2008 **7**:34

THE EARTH INSTITUTE
COLUMBIA UNIVERSITY

A 30-year High-Resolution Model Reanalysis of Dust and Climate for the Meningitis Belt

Carlos Pérez García-Pando

Earth Institute - NASA GISS - IRI

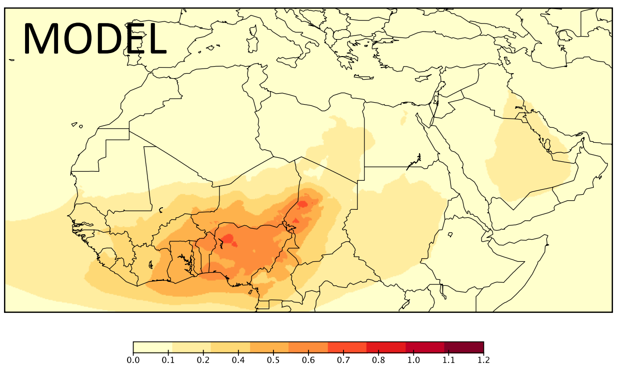
Collaborators:
S. Trzaska, M. C.Thomson, P. Ceccato (IRI), M. Stanton, P. Diggle (CHICAS, U. of Lancaster), R.L. Miller, J. Perlwitz (GISS), S. Adamo, G. Yetman (CIESIN), K. Haustein, J.M. Baldasano (BSC-Spain), E. Cuevas, C. Camino (AEMET-Spain)

Regional simulations of dust and climate for the Meningitis Belt
NMMb/BSC-Dust model

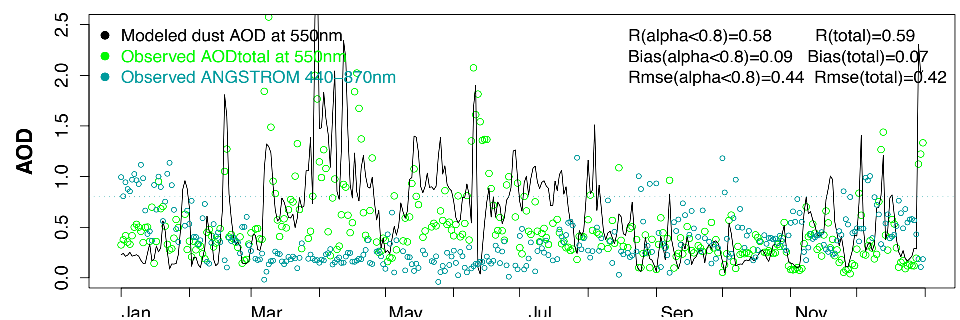
(Pérez, C., K. Haustein, Z. Janjic, O. Jorba, N. Huneeus, J.M. Baldasano, T. Black, S. Basart, S. Nickovic, R.L. Miller, J.P. Perlwitz, M. Schulz, and M. Thomson, (2011 Atm. Chem. Phys.,Disc (accepted))

AERONET vs MODEL

JAN-FEB-MARCH Modeled Dust Optical Depth at 550 nm

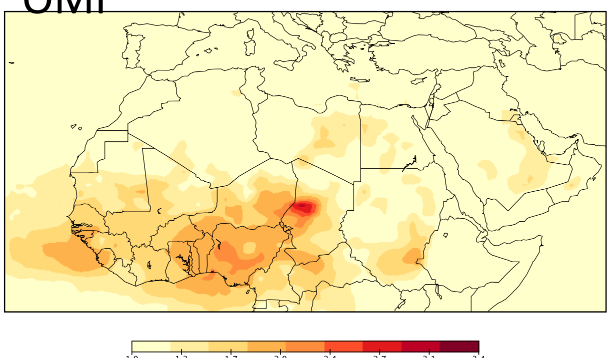


Banizoumbou

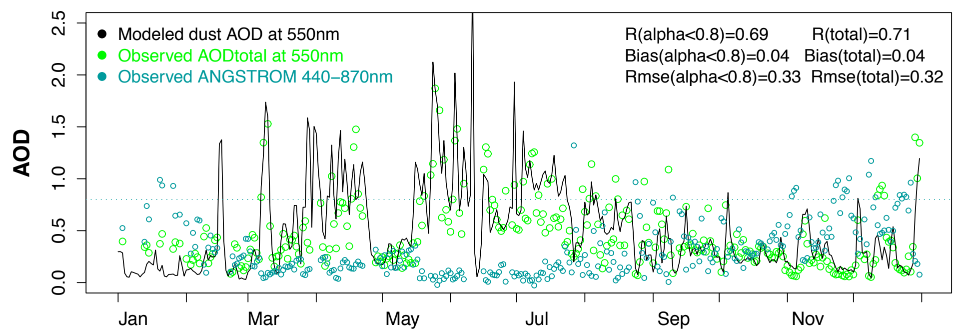


OMI

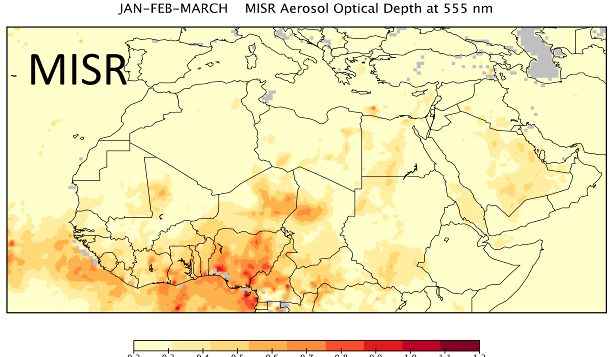
JAN-FEB-MARCH OMI Aerosol Index



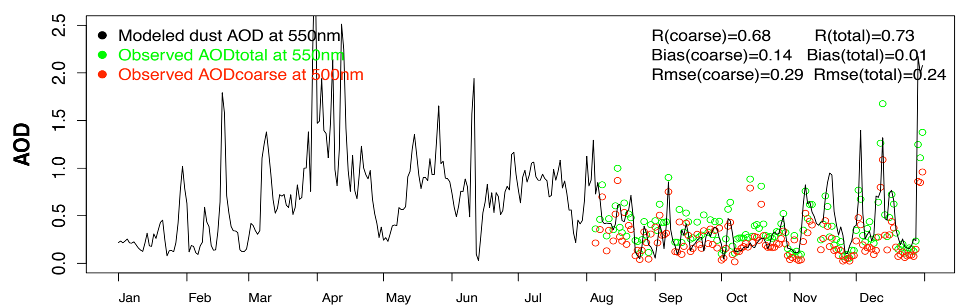
Agoufou



JAN-FEB-MARCH MISR Aerosol Optical Depth at 555 nm



Niamey

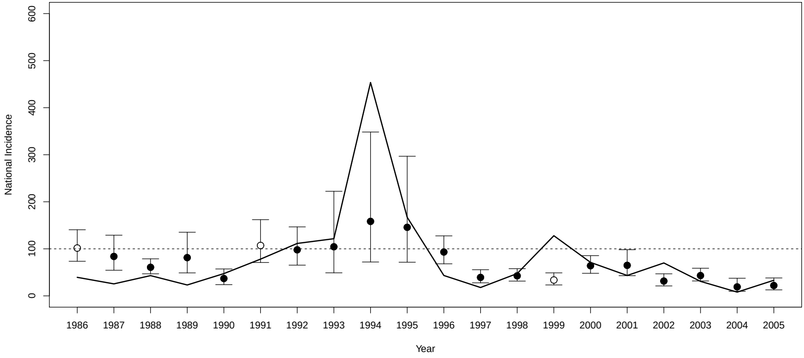


Summary of National Analysis

- We fitted a negative binomial model to *January-May* meningitis count data
- Variables in the model included
  - December Incidence (proxy for susceptibility/immunity)
  - Climate variables
  - December Incidence + Climate variables
- Climate variables for consideration in these models were
  - Specific Humidity (*Feb 2m, Feb 925hPa*)
  - Temperature (*Sep-Dec 2m, Sep-Dec 925hPa*)
  - Meridional wind (*Nov-Dec 10m, Nov-Dec 925hPa*)
  - Zonal wind (*Nov-Jan 10m, Nov-Jan 925hPa*)
  - Wind speed (*Nov-Dec 10m, Dec 10m*)
  - Dust Concentration (*Sep-Dec, Oct-Dec*)
- The final climate models contained Nov-Dec meridional wind (925hPa) only
- Both Climate and December incidence assist in explaining the temporal variation in national meningitis counts
- In comparing the predictions to those obtained under the assumption that the incidence in year t is equal to that observed in $t-1$ (persistence), the Climate + December model is better at identifying high incidence years.

Summary of National Analysis

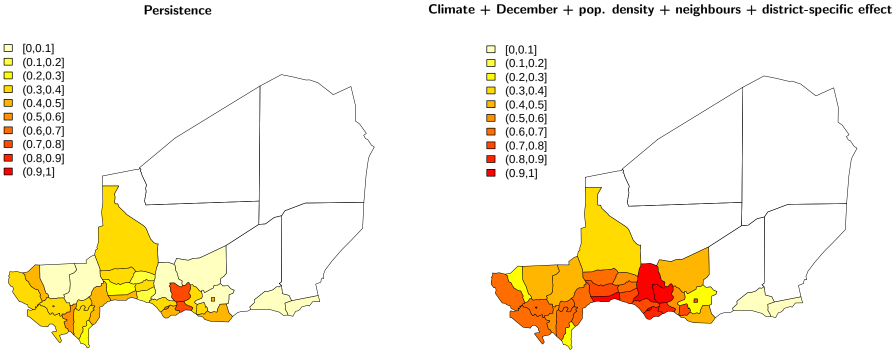
December incidence + Nov-Dec Meridional Wind (925hPa)



Summary of District-level Analysis

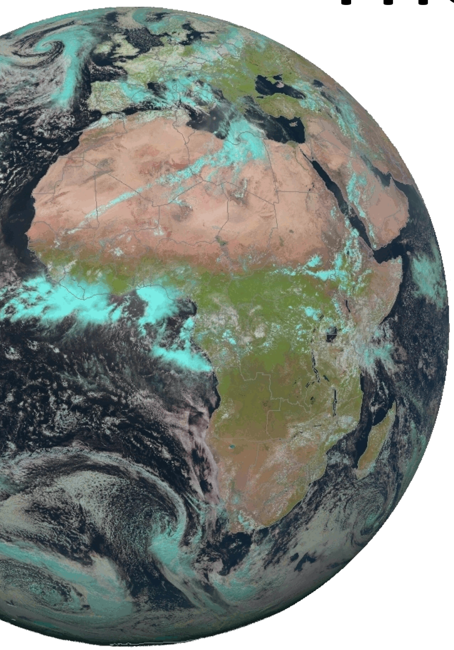
- We extended the negative binomial model to the district-level
- Additional covariates under consideration included
  - Both national and district-level effects of December incidence and climate
  - Average December incidence of neighbouring districts
  - Population density
  - Latitude
  - Urban/rural indicator
- As with the national model, both climate and December incidence assist in explaining the temporal variation in the disease
- District-level climate and December incidence information were significant
- Climate variables in the final model were Nov-Dec meridional wind (925hPa), Nov-Dec wind speed and Oct-Dec dust concentration
- The inclusion of population density and latitude assisted in explaining between the districts which cannot be accounted for by climate and December incidence, but these variables did not explain the differences fully.
- This model performs better than the persistence model at identifying high incidence years

Summary of District-level Analysis



Sensitivity of our predictions with respect to whether we correctly predict that the district-level incidence will exceed 100 cases per 100,000.

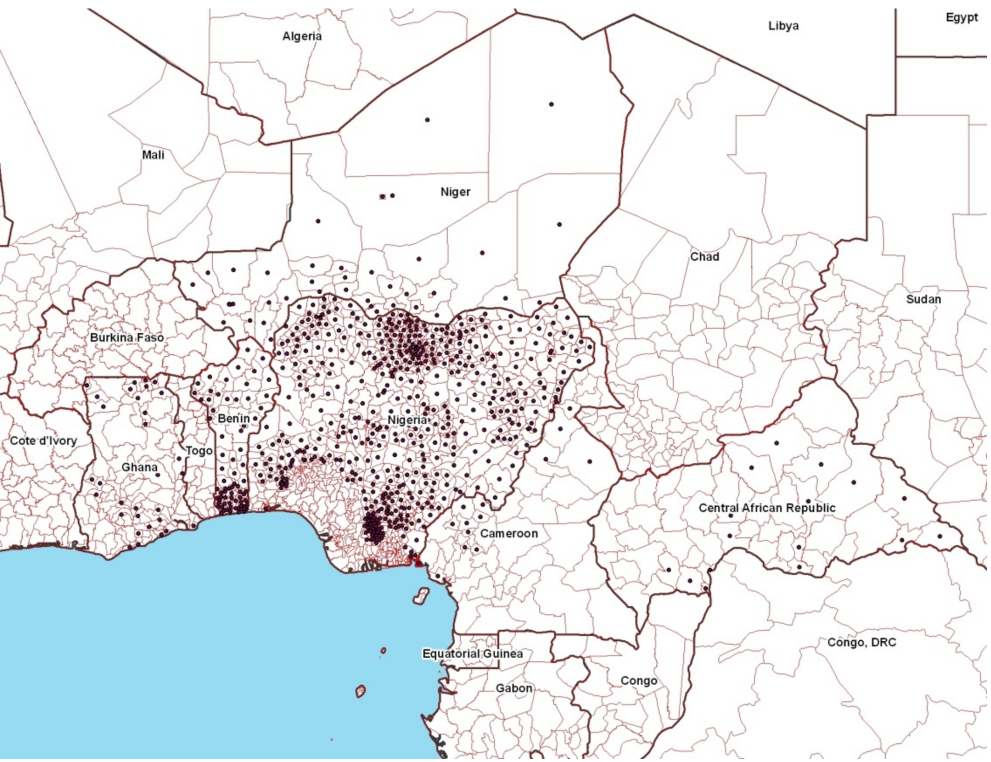
The Google-funded project

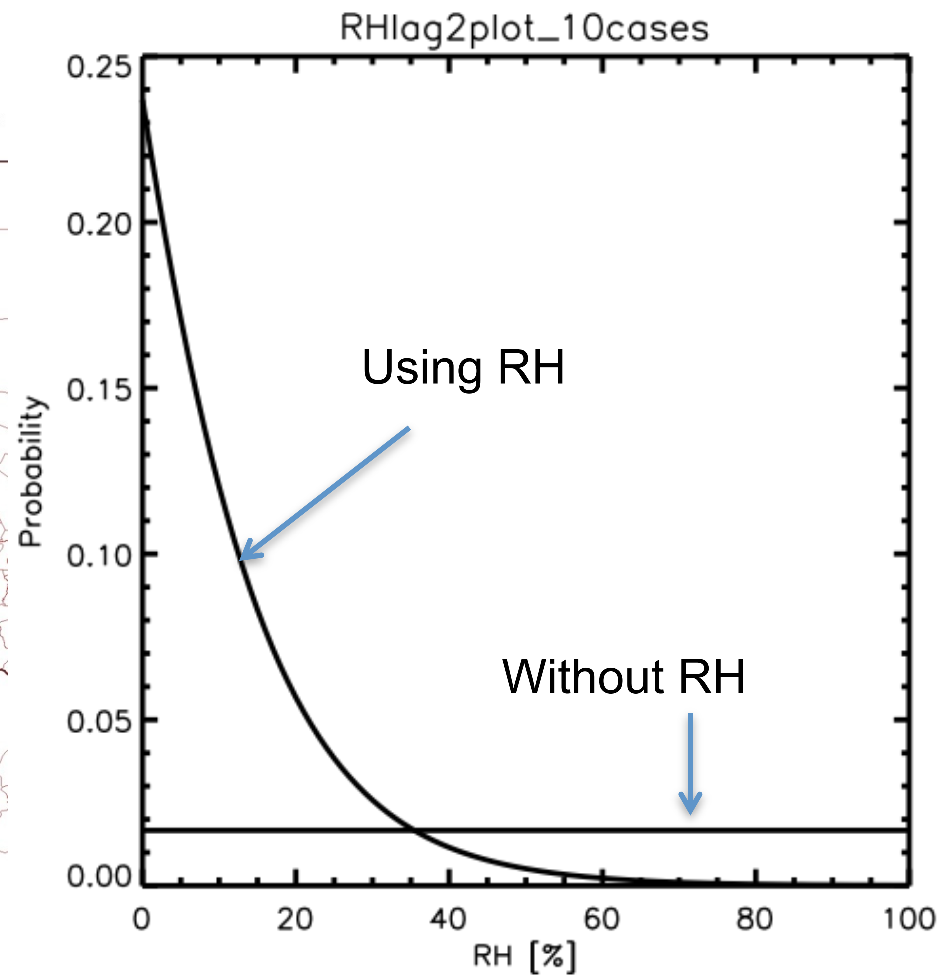


- Project goal:
  - Reduce risk of meningitis through understanding weather-disease link
- Project objectives:
  - Use meteorological forecasts to inform vaccination campaigns
    - Leverage TIGGE ensembles
  - Characterize environmental and other risk factors
    - 222 households surveys of knowledge, attitudes and practices
    - Disease models tested against atmospheric, demographic, and epidemiological data
  - Characterize the economic impact
    - 74 households surveyed

Abudulai Adams-Forgor, Patricia Akweongo, Anaïs Columbini, Vanja Dukic, Mary Hayden, Abraham Hodgson, Thomas Hopson, Benjamin Lamptey, Jeff Lazo, Roberto Mera, Raj Pandya, Jennie Rice, Fred Semazzi, Madeleine Thomson, Sylwia Trazka, Tom Warner, Tom Yoksas

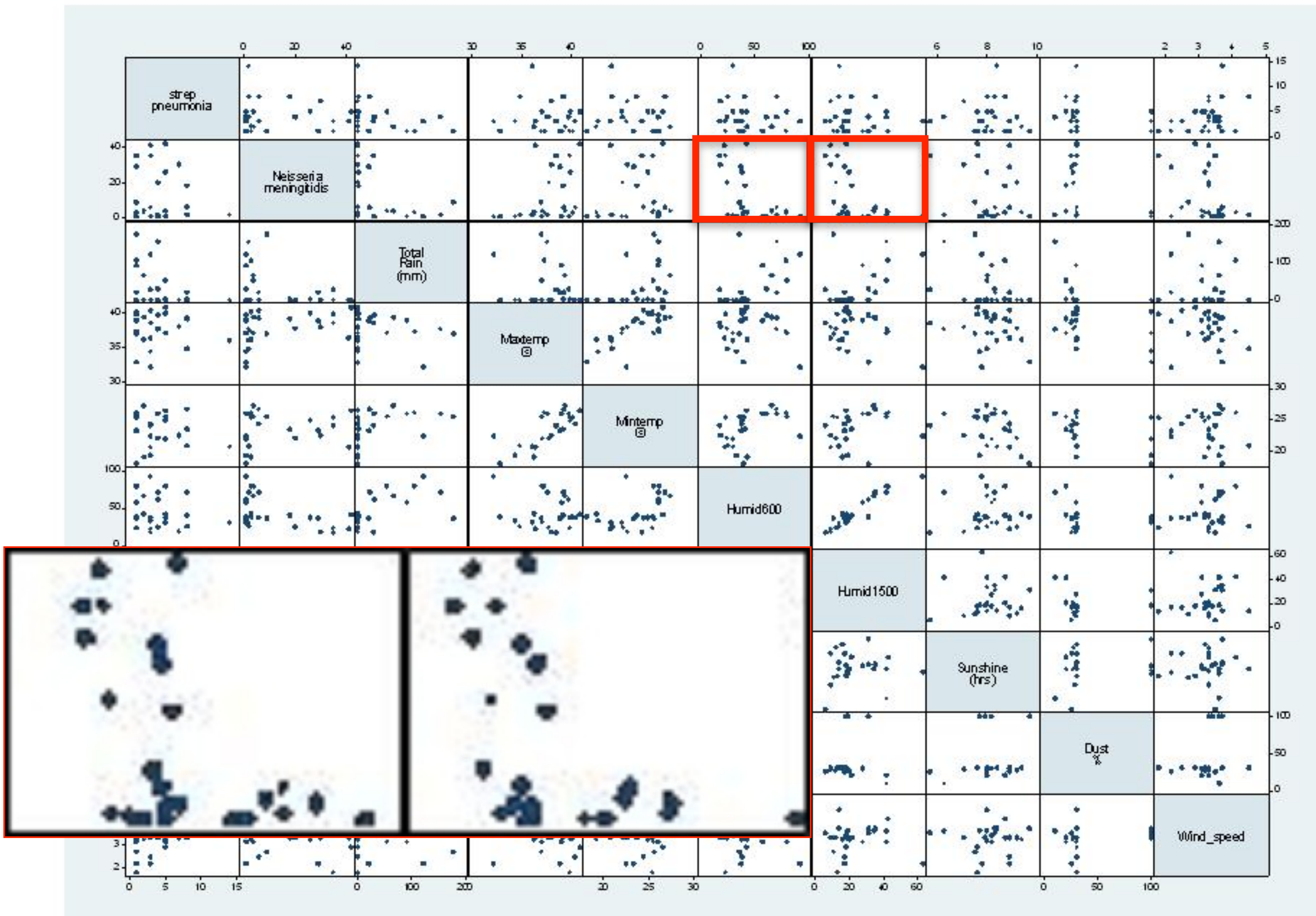
REGIONAL SCALE
Probability of an Epidemic versus Relative Humidity over Africa's Meningitis Belt





LOCAL SCALE

Pairwise correlations between meteorological and health variables January 1998 - December 2008 for months that reported at least one case of meningitis.



Preliminary Results

- Meningitis is demonstrably linked to humidity (and wind, heat, and CO)
- Using current global weather models, we can anticipate the growth and decay of a meningitis epidemic
- In northern Ghana, a case of meningitis costs, on average, more than a year's wages
- Seasonal migration can protect from meningitis
- Early meningitis symptoms are often misidentified, delaying treatment – suggests an intervention
- Airborne matter (especially from local and regional burning) may increase risk

In summary – achievements to date

- **Health- Climate alliance:** WHO initiative, established at a GEO hosted meeting in 2007 Geneva:

- **Scientific platform**
  - 4 Internaional technical meetings.
  - Operational research: monitoring in near real time environmental conditions and epidemics, modelling and forecast testing
  - Research subgroups.
  - Country and regional settings
  - Global partnerships

- **Information and knowledge** dissemination; database development

- **Training**

Getting Evidence into Policy and Practice

Four key requirements have been identified as necessary if evidence is to have a greater impact on policy and practice*. These are:

- agreement as to the nature of evidence.
- a strategic approach to the creation of evidence, together with the development of a cumulative knowledge base.
- effective dissemination of knowledge; together with development of effective means of access to knowledge.
- initiatives to increase the uptake of evidence in both policy and practice.

* Nutley S, Davies HTO. Making a reality of evidence-based practice: Some lessons from the diffusion of innovations. Public Money & Management 2000;20(4):35-42.

Where are we now?

- **agreement as to the nature of evidence**
  - Meningitis – Climate linkages established taking into account the natural history of the disease, non climatic factors and verified and relevant climate and environmental information – but inhibited by lack of understanding of the mechanisms and the interaction of infection, disease and immunity.

- **a strategic approach to the creation of evidence, together with the development of a cumulative knowledge base.**
  - Multi-sectoral steering committee led by WHO has enabled new communities to be bought together
  - MERIT international meetings a platform for research innovation and scientific knowledge sharing
  - Engagement with national research and health decision-making partners

- **effective dissemination of knowledge; together with development of effective means of access to knowledge**
  - in development – IRI Data Library

- **initiatives to increase the uptake of evidence in both policy and practice.**
  - Challenge of single disease approach – possible move to a multi-disease approach
  - Challenge of changes in policy environment – move from reactive to proactive
  - Creation of training opportunities such as the IRI summer Institute.

- *Independent review Geneva November 2011.*

Climate and health in Africa:
From Bamako 1999…..

CLIMATE AND HEALTH IN AFRICA 10 Years On WORKSHOP

To Addis ababa 4-7 April 2011

http://conference2011.wcrp-climate.org/documents/ThomsonM_A6.pdf

http://merit.hc-foundation.org

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

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