Climate and Public Health - The MERIT initiative: a climate and health partnership to inform public health decision makers.

Abstract

Many human diseases are climate-sensitive: climate acting as an important driver of spatial and seasonal patterns, year-to-year variations (including epidemics), and longer-term trends. Although climate is only one of the many drivers of both infectious and non-infectious disease, public health policy makers and practitioners are increasingly concerned about the potential impact of climate change on the health of populations. Noticeable changes in average climate are already being observed (and are therefore likely to affect the spatial distribution of some diseases, such as malaria). It is also expected that extreme events that can have devastating socioeconomic, environmental, and health impacts (e.g., floods, droughts, and heat waves) are more likely to occur. Furthermore, where rain-fed agriculture predominates climate is a key driver of food insecurity and thereby under-nutrition; a major contributor to poor health. Climate also impacts on agricultural/livestock pests and diseases providing a further avenue for its impact on food security, food safety and socio-economic development. In this paper we seek to strengthen the discourse between the broad public health and climate research and practitioner communities to identify opportunities for improved public health outcomes created through targeted research focused on the development and use of tailored climate information for decision-making.

The MERIT initiative was launched in 2007 as a multi-sectoral partnership 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. The main objective of the initiative was to address meningococcal meningitis epidemics in Africa in the context of perceived environmental, biological, economic and demographic influences. The effort was designed to create knew knowledge that can be used to improve the current, (reactive) and future (proactive) vaccination strategies.

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Introduction

With increasing recognition of the importance of climate as a driver of many infectious disease occurrences and the potential for climate change to exacerbate global health concerns (61st World Health Assembly, Agenda Item 11.11, Climate Change and Health WHA61.19, May 19-24, 2008) there is growing interest from the climate and environmental communities to contribute knowledge and resources towards improving climate sensitive health outcomes. The scientific literature on the impact of climate on infectious diseases transmission dynamics (including parasitic, viral and bacterial pathogens such as malaria, leishmaniasis, schistosomiasis, dengue rotavirus, meningococcal meningitis, etc) indicates significant research interest in this area (Kelly-Hope & Thomson, 2008). However the public health community lags behind others in the use of climate and environmental information for climate-sensitive decision-making. Recent developments in climate science and, more recently, climate services, along with new technologies for data management, analysis and sharing provide unprecedented opportunities for rapidly advancing this area. However, new developments must be responsive to the real needs of the global health decision-making community and empower their associated research communities if this potential is to be fully realized.

Use of climate information in health decision-making

Opportunities for the use of climate information in public health decision-making are as follows:

1. **Mechanisms:** Improved understanding of the mechanisms of disease transmission which can help identify new opportunities for intervention
2. **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.
3. **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.
4. **Trends in risk:** Understanding long term drivers of disease occurrence (including climate changes) can help plan long term prevention and response strategies.
5. **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

In recent years, health and climate scientists and practitioners have identified major challenges in moving from new research discoveries linking climate and health, to actual products and services that improve human health and well-being. This challenge mimics a well understood gap between research and action which is often termed “The Valley of Death.” This chasm contains numerous obstacles that can keep new knowledge from reaching its full societal value. The “Valley of Death” is so strewn with institutional and marketplace barriers, that experts believe we need to make changes in the support structure for translational research[1]. As anyone attempting translational research will testify, basic scientists have few incentives to move outside their comfort zone. It means getting involved with

[1] Traversing the Valley of Death: A Guide to Assessing Prospects for Translational Success

complex political processes, capacity building and regulatory - issues with many personal but few career rewards.

Climate and sectoral scientists, essential to the development of quality climate information, are often astonished by the time taken in discussing the various policy issues and are dismayed when their hard won research outputs are dismissed as 'academic' when it comes to health practitioner decision-making. On the other hand, those seeking to use knowledge of the climate in improved health decision-making wonder "why does it take so long and why are the available products still so far from what we need".

Central to the use of new (in this case climate) information in health decision-making is the role of evidence (both of the link between climate and health outcomes and the utility of climate information in improving those outcomes) and much effort is now given to strengthening the evidence base for effective health policies as a key step in translating research into policy and practice.

Getting Evidence into Policy and Practice

It has been suggested (1) that there are four key requirements that are necessary if evidence is to have a greater impact on policy and practice. They are presented here in sequence for convenience rather than because of strong prior beliefs that the sequencing reflects either necessary temporal positioning or relative importance. These key requirements are:

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

Here we argue that these requirements must also be met to establish an effective climate and health research and operational agenda if the outcomes are to influence policy and practice. Significant challenges arise when different communities seek to fulfill these requirements as each community has its own perspectives on each requirement.

The recently established WMO Global Framework for Climate Services (GFCS) could significantly improve matters with an increased focus on delivering climate research results into products tailored for specific decision-making communities (ref). One of the 4 major GFCS components is the creation of a user interface platform for supporting different societal areas, including health and bridging the gap between climate information providers and users. GFCS is envisaged in the health sector as a system to support academic and operational interactions between the health and the weather/climate communities.

In this paper we explore the key issues and present attempts to address them through an innovative operational research consortium focused on the prevention and control of epidemic meningitis in Africa.

Problem Identification – Epidemic meningitis in the African Sahel

Epidemic bacterial meningitis (causal agent *Neisseria meningitides, Nm*) devastates the lives of individuals and communities across the 'Meningitis Belt' of Africa, an eco-epidemiological zone first described by Lapeyssonnie in 1963 (2). This bacterial disease is transmitted through respiratory droplets throughout the year but disease is largely restricted to dry season(3). The mechanism by which environmental and climatic factors may influence meningitis epidemic occurrence remains unclear; the most common explanation for this role is that physical damage to the epithelial cells lining the nose and throat in hot, dry and dusty conditions permits the easy passage of the bacteria (found here frequently in a benign form) into the blood stream causing invasive disease (4). It has often been noted that meningitis epidemics are preceded by viral infections which may also break down the normal barrier provided by the mucous surfaces (5). Viral infections may, in part, be associated with specific climatic conditions and mineralogical properties of dust aerosol. Many non-climatic factors have also been associated with invasive disease, these include new bacterial strains, overcrowding, etc.

The disease has severe social and economic consequences at the individual, household and community level (6)and is widely feared because of its rapid onset, high mortality rate and frequent long term sequelae (4). The need for rapid vaccination in response to epidemics means that health staff are diverted from other important service activities creating an additional burden to the health sector(7).

Current and emerging control strategies

Meningitis control activities currently largely rely on the early identification of epidemics followed by a rapid deployment of polysaccharide vaccines (8). Although much debate has been dedicated to the efficacy of these interventions (9), it is widely recognized that there is only a short lead-time for vaccination once an epidemic is underway and the impact of the vaccination response largely depends on the quality and timeliness of the surveillance system. Finally, the characteristics of the polysaccharide vaccine (short duration of the immunity, absence of herd immunity) and its limited availability precludes its use for truly preventive vaccination campaigns (10) .

As a consequence of the limitations of the current vaccine a new strategy involving a conjugate A vaccine has been developed. This vaccine (which protects against infections caused by *Neisseria meningitidis* serogroup A which is responsible for the vast majority of the outbreaks) offers great potential to eliminate large meningitis outbreaks as a public health problem(11). Almost 10 years after the initiation of its development by the Meningitis Vaccine Project (MVP, http://www.meningvax.org/), the conjugate A vaccine was successfully introduced during the last quarter of 2010 in Burkina Faso, Mali and Niger. A further 5 to 10 years are now required to immunize individuals at highest risk living in the 25 countries targeted by the project. In the meantime, tight epidemiological and microbiological surveillance and forecasting systems which can help identify populations at risk remain a public health priority to detect and respond to meningitis outbreaks (whether due to Nm serogroup A or other that A, such as W135 or X) and to evaluate the impact of the vaccine (12).

Climate, environment and the risk of epidemics

There is substantive evidence that climatic and environmental factors describe the overall spatial distribution of the disease in the Meningitis Belt of Africa (from Senegal in the West to Ethiopia in the East) (2) and the indication that climate controls the seasonality of the disease is also widely accepted (3); outbreaks start in the latter half of the Sahelian dry season when the weather is dry and dusty and subside at the onset of the rains. Much is still unclear about why they occur but it is likely that a combination of environmental, demographic, and behavioural factors as well as those relating to the hosts' susceptibility to disease will determine the occurrence of epidemic meningitis. In particular, the fact that the disease incidence tends to fall off rapidly once the moist pre-monsoon air arrives is seen as indicative of an important climatic control to disease occurrence. For a number of years research focused on the relationship of environmental and climatic variables to meningitis incidence produced tantalizing results suggesting a significant interaction (13-19). However limitations in the data sets and modeling frameworks used precluded a definitive answer (20).

Key decision-maker concerns are set out below:

- **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)

Thus a key identified need was for better data collection and research that could contribute robust estimates of the environmental contribution (alongside other factors such as carriage and immunity) to spatial and seasonal risk, year to year variation and longer term trends in meningitis epidemic occurrence and intensity.

The MERIT Initiative

Converging interests from the health and climate communities around the problem of epidemic meningitis were explored at a meeting hosted by the Group on Earth Observations (GEO) Secretariat in Geneva (26-27 September 2007). Here a multidisciplinary group of participants (practitioners and researchers from both public health and climate communities) led by the World Health Organization (including the WMO, GEO, IFRC, IRI, HCF, AEMET and IFRC) agreed to the formation of the Meningitis Environmental Risk Information Technologies (MERIT, http://merit.hc-foundation.org) project.

MERIT Objectives

The original objectives of MERIT were clearly expressed in the purpose statement for the 1st MERIT meeting (which took place at the John Knox Centre in Geneva on 26-27 September, 2007) as a) partnership b) new knowledge and c) improved decision-making. This purpose stemmed from expressed interests of the public health community to:

1. find a common platform between relevant communities to address meningococcal meningitis epidemics in Africa in the context of perceived environmental, biological, economic and demographic influences;
2. gain a greater understanding of the current knowledge and active research surrounding the epidemic risk indicators; and
3. communicate the information needs of the public health community to the research community to enhance epidemic meningitis control strategies in Africa.

The MERIT Initiative was designed to encourage greater cross-disciplinary interactions, connect research more directly to the needs of public health practitioners and provide a unique model for building effective health-climate partnerships within the framework of improving health outcomes. In June 2008 a Steering Committee was formed with the specific objective of charting the course of the MERIT consortium throughout its expected lifetime of a decade. The consortium aims to extend current capabilities to more effectively combine environmental information with knowledge of epidemic meningococcal meningitis through analysis of the spatial and temporal distribution of cases, populations, environmental and climatic conditions, vaccination status and strain characteristics. Ultimately, this research seeks to inform three operational areas:

i) the reactive vaccination strategy (improve the impact of the reactive mass vaccination campaigns, prepare for the following epidemic season, refine the response strategy for outbreaks due to serogroups other than A, assess the risk of Nm A outbreak in areas previously vaccinated with the conjugate A vaccine);
ii) the preventive vaccination campaigns with the conjugate A vaccine (guide the introduction of the conjugate A vaccine and estimate the impact of the conjugate A vaccine); and
iii) 5 to 10 years time-horizon forecasting to gather information on the possible vaccine needs in the medium and long term.

Key to the MERIT concept was that research needs would be demand led, ie. identified by those that were responsible for solving the health problem.

While the development and refinement of research questions are guided by the public health needs, the momentum of the MERIT Initiative is in large part sustained by long-term research grants which support specific research questions, often over a period of several years. The challenge that has arisen is to determine how to maintain a degree of flexibility in the research arena which enables the research projects to stay in line with a changing public health strategy.

Summary table of analysis scale and research needs identified by WHO

Research need	Spatial scale	Time scale	Comments

To improve the impact of the reactive mass vaccination campaigns	District	Forecast the weekly attack rate several weeks ahead of time	
To prepare for the following epidemic season	Region, country	Forecast the magnitude of an epidemic (yearly cumulative rate) one year ahead of time	
To refine the response strategy for outbreaks due to serogroups other than A (NmW135, NmX)	District	Forecast the weekly attack rate several weeks ahead of time	Describe the dynamic of the outbreaks Estimate impact of reactive vaccination campaign
To assess the risk of NmA outbreak in an area previously vaccinated with the conjugate A vaccine	District	Forecast the weekly attack rate several weeks ahead of time	Estimate decay in immunity after vaccination campaigns Estimate level of coverage required to prevent outbreak
To guide the introduction of the conjugate A vaccine	Region, country, district	Seasonal risk and historical trends	
To estimate the impact of the conjugate A vaccine	Region, country, district	Predict the number and magnitude of epidemics one/several year(s) ahead of time	Impact of preventive vaccination
To gather information on the possible vaccine needs in the medium and long term	Region, country	Predict changes in the meningitis belt (number of outbreaks and cumulative attack rate) 5-10 years ahead of time	

MERIT Research Networking Capabilities

In its initial phase the MERIT consortium has focused on core countries of the Meningitis Belt (including Niger, Burkina Faso, Ethiopia, Ghana and Nigeria). Four international technical meetings have been held in Geneva (2007), Ethiopia (2008 and 2010) and Niger (2009), gathering over 30 research and practice groups from the public health and environmental sectors, governments, regional and international organizations as well as research institutions. Smaller 'Mini MERIT' meetings have been held in New York, Montpellier, Lancaster and Boulder Colorado and have focused on specific research modeling questions. In total over 100 research papers have been presented in oral or poster format. Presentations and MERIT meeting reports have been made available on the web via http://merit.hc-foundation.org. MERIT members are in the process of publishing their results in peer review journals.

Research groups from Europe, the USA and Africa have attended each of the technical meetings. Despite these meetings occurring in Ethiopia and Niger, participation by African research groups has been limited; at least in part because funding for MERIT has been largely based on 'contributions in kind' to MERIT participants and the bringing together of ongoing research efforts. However, African, European and American scientists and decision-makers involved in MERIT have benefited from participation in the IRI Summer Institute 'Climate Information for Public Health'.

Summary of Research projects performed under the MERIT umbrella or relevant for MERIT

As a research consortium without core funds MERIT achievements are in reality the achievements of MERIT members some of which have developed and implemented specific MERIT related research projects, others of which have contributed research efforts developed under another umbrella to the

overall MERIT initiative. Research outputs are ongoing and will be formally reviewed at the forthcoming International Technical meeting to be held in Geneva in November 2011.

WHO Global Alert and Response Department . Central to the work of MERIT and guiding the research projects are the operational activities of WHO country, regional and international teams.

At all levels, WHO provides technical assistance and support to Ministries of Health to help improve the prevention and control of meningitis epidemics in the region. The WHO office in Geneva works closely with the WHO African Regional Office Intercountry Support Team based in Ouagadougou, Burkina Faso to strengthen data management and surveillance of meningitis across the Meningitis Belt countries. As seen in recent years, the unpredictable nature of the extent and intensity of meningitis epidemics and the changing influence of meningococcal strains from one year to the next, emphasize the importance of robust meningitis surveillance across the Meningitis Belt. Furthermore, in its role as Secretariat of the International Coordinating Group (ICG) for Meningitis Vaccine Provision, WHO is responsible for the management of the GAVI-funded emergency vaccine stockpile and works closely with ICG partners (UNICEF, MSF, IFRC and WHO), vaccine manufacturers and Member States to ensure a rapid response to meningitis outbreaks.

In the MERIT context, WHO is not directly leading MERIT-related research activities but has helped guide the design of research projects with a view to integrating the increasing understanding of environmental influences on meningitis epidemics into the meningitis control strategy. Ultimately, WHO would like to synthesize research outcomes from various MERIT projects in such a way as to support its activities in the field and strengthen the decision algorithm which determines the timing and distribution of vaccines to countries during an epidemic season.

The engagement of WHO with MERIT partners has reached into several new areas of activity, including:

1. Chairing the MERIT Steering Committee and facilitating the interactions between MERIT partners through **annual technical meetings**. Since 2007, these international meetings have been held in Geneva, Addis Ababa and Niamey. Smaller 'mini-MERIT' meetings have been held on an ad hoc basis in order to engage public health specialists with research groups to present outcomes and review the direction of specific research projects.

2. WHO has recently led the development of a **district prioritization tool (DPT)** to support the roll-out of the new conjugate A vaccine in countries and districts across the Meningitis Belt. This tool is at the heart of the current public health vaccination strategy and integrates factors such as vaccine availability, current epidemiology, country capacities for implementation and surveillance, and political situations. While the DPT tool is not a result of the MERIT project, there is potential for results from MERIT research activities to feed into the tool and inform more broadly the introduction of the conjugate A vaccine. (*Stephane, Katya to check ….)*

3. 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 (see below).

The CHICAS[2] 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. The project has advanced through collaboration between Lancaster University and Columbia University's International Research Institute for Climate and Society (IRI). Combining weekly epidemiological data from Niger (1986-2007) with gridded reanalysis climate data for the region aggregated to the national level including humidity, temperature and wind, the preliminary results suggest that climate data is of limited value for short-term (subseasonal) forecasting but would add value to longer-term forecasting of the meningitis season ahead. While plans to field-test the model in Niger in early 2011 were abandoned due to the political situation at the time, the group hopes to test the model before the start of the next epidemic season.

UCAR Project: The University Corporation for Atmospheric Research (UCAR) in Boulder, Colorado USA received funding from Google to research methodologies for short-term forecasting during the meningitis season, with initial emphasis on the end of the meningitis season. Working with the Navrongo Health Research Centre in Ghana, North Carolina State University, Regional Maritime University in Ghana and the IRI, the project aims to help increase the understanding of environmental variables which may influence the epidemic status of a district, and use that information to better respond to epidemics already in progress or about to start. Using a differential-equation based model of disease transmission, physical insight into meningitis transmission, 10 years of regional data and 2 years of data from across the belt, the team was able to show that humidity, NE winds and heat all show positive correlations with future cases, as compared to historical persistence. Additional test with a generalized additive model confirmed that the temperature, humidity, and carbon monoxide concentration (as a proxy for burning) were the variables most persistently related to meningitis. These two models, along with current epidemiological data and weather forecasts, provide the basis for weekly predictions of meningitis cases that can help guide vaccination. Other areas of research include determining the economic benefits of the forecast, surveying to document the knowledge, attitudes and practices of area residents, identifying the impacts of these predictions and other public health interventions, and, most importantly, developing an information system for surveillance, data collection, and disease management.

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. In collaboration with other research groups both within Columbia University (CEISIN and Mailman School of Public Health) and internationally, the IRI has received funding from NOAA, NIEHS, NASA Roses and Google to help improve the application of available information and knowledge on the factors which influence meningitis epidemics, with a view to improving decision-

[2] CHICAS: Combining Health Information, Computation and Statistics, Lancaster University

making in meningitis control. The IRI has also contributed to the MERIT initiative through its innovative Summer Institute 'Climate information for Public Health'.

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. The initial areas of focus of the group under the MERIT framework will be on carriage studies and the integration of climate and environment data, and to explore linkages between the onset and size of epidemics with climatic and environmental conditions at the scale of the health center. Partners of the MAMEMA consortium include researchers from CNRS IRD - France, University of Bourgogne, University of Bristol, AMP, Lancaster University, and Ecole des Hautes Etudes en Santé Publique.

MACC - Monitoring Atmospheric Composition and Climate - is the current pre-operational atmospheric service of the European GMES programme (http://www.gmes-atmosphere.eu/). MACC provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead. MACC WP 3.1 (funded by the EU and NSF Spain) "Meningitis linked to mineral dust transport in the Sahel" has provided detailed validation of the dust model in the Sahel and elsewhere (22)

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:

MERIT partners in disease endemic countries have formed local consortiums with an aim to apply MERIT research outputs into operational decision making at the country level.

Ethiopia

Following the 2nd MERIT Technical Meeting in Addis Ababa in 2009, the 'MERIT Ethiopia' project was established to help apply MERIT research across four key operational areas: 1) socio-economic impact of the disease, 2) determinants and risk factors of meningitis outbreaks, 3) education and training, and 4) disease surveillance. The MERIT-Ethiopia project was expected to benefit from and leverage the high level political momentum which had been generated by the formalization of collaborative framework between the health and climate sectors under the title 'Climate and Health Working Group'. Despite this initial optimism however, the engagement of donors to support the country-led activities has not been actively pursued at the country level or by the MERIT Steering Committee, and as such the potential results have not yet been realized.

Nigeria

In Nigeria, a state MERIT committee was established in Katsina State bordering Niger in northern Nigeria. With an initial level of financial support provided by the State Focal Office on MDGs in the Governor's Office, the 'MERIT Katsina' project aims to: 1) fully realize current meningitis research and development initiatives, 2) build capacity within health and climate community to improve health

outcomes in the state, and 3) identify gaps and accelerate new warning and intervention strategies for meningitis. The MERIT Katsina group plans to establish a strong collaboration with a European-based mini-MERIT consortium, MAMEMA**.**

Burkina Faso

In Burkina Faso the National Meteorological Services has run an "Environment and Bioclimatology" desk for the last ten years in order to a) promote research on the relationship between climate - environment and diseases distribution – emergence, b) to use observations forecasts and information on environment and climate to predict diseases outbreak and spatial distribution and c) to contribute to elaboration of an integrate early warning system for prediction of climate sensitive diseases and promotion of suitable public health policies.

Among others activities, every year, at the beginning of the meningitis epidemic season, a common bulletin from National Met and Health Services on prediction of meningococcal meningitis yearly incidence trend in Burkina Faso and Niger is produced by integrating climate, environment and health data and information. At the end of the year, a common evaluation is done. This information are jointly transmitted to national, regional and international organization and research centers working in medical and climate sectors as a contribution to help mitigate the diverse consequences of meningococcal meningitis epidemics. Using reanalysis data from the National Centers for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR) reanalysis project (with an up-to-date version of the Medium Range Forecast model) [17] a statistical analysis of annual incidence of meningococcal meningitis and climatic variables for Niger indicated that 25% of the disease variance from year-to-year in this country can be explained by the winter climate; a similar analysis failed to represent accurately the disease dynamics in Burkina Faso (19).

Regional

"Following the Season "

4. Following the 3rd MERIT meeting held in Niamey, Niger in November 2009, **a cross-sectoral monitoring of the 2010 meningitis epidemic season was initiated.** Throughout the 2010 meningitis epidemic season, WHO participated in an exploratory exercise with the IRI and ACMAD to follow the meteorological and epidemiological developments of a meningitis season. Between December 2009 and April 2010, WHO (Geneva), ACMAD (Niamey, Niger) and the IRI (New York) met via teleconference on a 10-daily basis to share information on 1) the developments of epidemic outbreaks in districts and areas of alert across the Meningitis Belt, and 2) the climatic, meteorological and air quality observations and forecasts at the global and regional level. Climate information discussed global Sea Surface Temperature anomalies (known to influence atmospheric circulation on seasonal time-scales), large scale atmospheric circulation indices such as NAO (past and projected conditions) relevant for dust bearing circulation patterns, information on recent wind and humidity conditions including the location of the Inter-tropical Discontinuity (IITD-a region of convergence between the dry and dusty air from the Sahara and moist and dust-free air from the Atlantic) as well as on dust (past conditions and 8-day forecasts).

In total, 12 teleconference calls were held over the 4- month period, and while anecdotal feedback has been recorded a formal assessment of the exercise is yet to be finalized.

Throughout the season observed climate showed conditions not favoring meningitis outbreaks with frequent higher than usual humidity, lower wind and dustiness conditions, consistent with a relatively quiet meningitis season until mid March.

Retrospective analysis of 2010 vs 2009 seasons showed that, while epidemic conditions differed substantially between those years with larger number of districts across the belt reaching epidemic level in 2009 and the epidemic regions confined to Burkina Faso and Tchad in 2010, climatic conditions averaged over the entire season did not exhibit such substantial differences. While demographic and immunological factors certainly play a role in inter-annual variations, differences in sub-seasonal climatic characteristics were found: in 2010 higher variations in low level wind and humidity patterns brought moist and dust-free air to the region more often than in 2009, except in Burkina Faso, where the higher sub-seasonal variability in wind patterns translated in higher occurrence of dry and dusty episodes in 2010 as compared to 2009. This points to the potential importance of sub-seasonal characteristics of the season in MM outbreaks, but needs to be further documented.

A summary of the exchanges reported at the MERIT International Technical Meetings to date is given below.

	MERIT 1	**MERIT 2**	**MERIT 3**	**MERIT 4**
	2007	2008	2009	2010
Overview of MERIT MVP and MenAfricar	(23, 24)		(25-27)	(28-30)
Recent and Current situation in the belt			(31)	(32, 33)
Overview of topic	(34-39)	(40, 41)	(42-45)	(46-50)
Overview related projects	(51-56)	(57-59)	(60-65)	(66-72)
Overview ongoing projects	(73-77)	(78-81)	(6, 81-87)	(88-94)
Project results	(18, 95, 96)	(97-99)	(87, 100-105)	(106, 107)

Overview of related and proposed tools	(108)	(9)	(40, 81, 109-111)	
New tools available				(112)
Overview related and proposed data sources	(39)	(80, 113, 114)		
New Data sources available				(114)

Bringing it all together

Through the MERIT initiative a much broader understanding by natural scientists of the problem of epidemic meningitis in the Sahel has been achieved. GEO has played a significant role in ensuring that policy makers in the environmental community are aware of MERIT and has sought their support through its network of high level partnerships.

Disparate data sets have been enhanced and brought together for analysis. These include epidemiological data sets from national surveillance systems facilitated through WHO, population data from the Global Rural-Urban Mapping Project (GRUMP), and a wide range of environmental and climatic variables now made available via open access portals such as the IRI Data Library. The challenge of integrating these disparate datasets should not be underestimated. Combined with practical knowledge of the data sources and their constraints a raft of modeling exercises have been undertaken by the different research teams. More recently models which can incorporate both extrinsic (e.g climate/environmental) drivers and instrinsic (e.g. immunity) have been explored. This modeling effort has been combined with detailed field studies, such as those at Navrongo, Northern Ghana led by UCAR.

Of particular relevance to the project has been the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) which was developed to study, among other questions, the impacts of dust aerosol on health, including the possible link of dust with meningitis and other diseases. The initial premis being that the prediction of dust events can help to better understand the hypothesized role of mineral dust and dry hot air in outbreaks of meningitis across the Sahel's "meningitis belt." Under the SDS-WAS umbrella there are several activities and studies of relevance for MERIT; some have been specifically undertaken to support the MERIT initiative. These include:

A SDS-WAS regional centre for Northern Africa, Middle East and Europe has established in 2010 a portal – "one-stop-shop" http://sds-was.aemet.es/. It is delivering near-real-time observations and short-medium range forecasts of dust-related parameters, but also forecasts of associated meteorological conditions. Observations include:

- ground observations:
- satellite products:
- Dust forecast products for periods of several days ahead are available from several organizations running dust modelling systems.
- Parameters of potential importance for MERIT include
    - columnar dust amount,
    - surface concentration,
    - wet and dry deposition.

Very significantly since the dust concentration component in numerical models is driven by the atmospheric model, meteorological values such as temperature, air moisture, wind and precipitation are available simultaneously with the dust-related parameters(115). All data mentioned above are available on a daily basis for the Meningitis Belt and beyond and can now be accessed via the IRI Data Library (iridl.**ldeo**.columbia.edu/) as well as from their original source.

Research outcomes to date

Possible role of dust mineral composition in meningitis epidemics

The mechanism by which dust may cause meningitis epidemics remains unclear. A common explanation is that physical damage to the nose and throat epithelial cells by dust particles permits invasion of bacteria into the blood stream. It is hypothesised that the activation of the meningococcal bacteria is fostered with high iron content in Fe-rich minerals in dust (Thompson, 2008). Current dust models are not capable of simulating/predicting in details the mineral fractions and trace metals such as Fe in dust concentration. However, recently developed global high-resolution (1-km) datasets on soil mineralogical composition,(116, 117) if used as input in dust models could help better understand of possible links between meningitis and iron fraction in dust.

Limitations of current modelling studies and environmental products

Most of the products relevant for MERIT are publicly available. However, short term forecasts have limited value for MERIT because, in case of operational dust modelling, forecasts are valid for 3-5 days in advance which is too short period to be of practical use for planning vaccination actions in the field. On the other hand, re-analyses made for multi-decadal periods can help understanding if and how meningitis outbreaks depend on environmental conditions and their seasonality.

However medium range subseasonal forecasts may prove relevant. There are promising opportunities for designing such concepts; namely several operational centers (ECMWF, UK Met Office JMA, NCEP, Environment Canada, Bureau of Meteorology – Australia) are already providing global experimental sub-seasonal/seasonal weather forecasts, and several other organizations working on predictions for the same time scales but using regional modelling facilities such as UCAR. Following interest for such forecasts over extended periods, WMO (as a joint WCRP and WWRP initiative) is just launching the new project “Sub-seasonal to Seasonal Prediction”. With added dust components in such systems, it will be possible to explore the value of longer term dust forecasts for the needs of the MERIT health users.

Contributions from the MERIT climate community to the assessment of the links between weather/climate and meningitis occurrence

A number of significant modelling results are emerging from different research teams as a result of the creation of new sources of weather, climate and environmental data tailored to MERIT needs. For example a series of analyses have resulted through the development of the dust-modelling activities of the SDS-WAS.

In a study based on a 30-year simulation model (1979-2010) recently developed with a 0.5º x 0.5º resolution (NASA/GISS , IRI, BSC) (118) the relation between meningitis outbreaks in sub-Saharan Africa and simulated dust aerosol concentrations over the Meningitis Belt has been examined (Perez 2008). The study concludes that there is a certain level of correlation between dust and climate variability parameters, such as NAO index. This result forms a basis to use climate indices as first-approximation indicators on favorable conditions for meningitis outbreaks.

Using the same simulation model (NASA/GISS, IRI, BSC, Lancaster University) the relation between meningitis outbreaks in sub-Saharan Africa and simulated dust aerosol concentrations over the Meningitis Belt has been examined (Perez et al., 2010). The outputs of the simulations have been validated at the daily, seasonal, annual, inter-annual and trend scales using in situ and satellite dust data (119). They are also being used to perform a seasonal and weekly analysis of meningitis epidemic outbreaks at national and district levels in Niger (120, 121). Preliminary results show that climate parameters (including wind and dust) and early season meningitis cases explain about a quarter of the epidemic year-to-year variability at national and district level. However, at district level the results are heterogeneous and suggest that other co-factors such as susceptibility, viral infections, new strains or previous vaccinations have a critical role on the dynamics of the disease.

The non-linear interaction of different co-factors, many of them not known, partly hampers the assessment of the impact of climate and dust upon epidemics. This problem is even more critical at the weekly scale. In a recent study using the regional dust and climate database (Stanton et al., 2011), at the national scale, zonal wind and dust concentration made modest improvements in meningitis incidence forecasting ability, but the majority of temporal variation could be explained using a seasonal trend and previous incidence. At the district level, the inclusion of climate variables made no real difference to the models' forecasting performance and the majority of temporal variation could be explained using a seasonal cycle and previous incidence (121).

These results all point to a significant contribution of climate and environmental variables to the temporal distribution of meningitis cases in West Africa at the seasonal scale – accounting for about 25% of the variance in cases from one year to another. When combined with a simple model accounting for immunity the predictability of year to year variability in meningitis cases in Niger increased to approximately 50% (Carlos Perez pers. comm).

Data Policy challenges and opportunities

The MERIT Steering committee has sought to create a data policy designed to achieve maximum research opportunities and outcomes while promoting open use by Health practitioners and decision makers for the public benefit. However no single solution has been found to the diverse types of data involved and the diverse needs of the MERIT community since different data and products carry different access and dissemination conditions (eg restrictions due to privacy) and intellectual property rights. As a consequence the MERIT Steering Committee is actively discussing data sharing through the WHO information platform OpenHealth, the IRI Data Library and the GEO WebPortal (http://www.earthobservations.org).

The 4th MERIT Technical Meeting in Addis Ababa extensively discussed the issue of data sharing, interoperability and developments of tools, including a proposal of a central MERIT information system. While so far the MERIT information systems are a combination of independently developed information systems, the community is continuing to explore technical options in order to realize the MERIT goals.

Meningitis Maproom

The Meningitis Map Room, situated in the IRI Data Library, makes Meningitis-related environmental, demographic, and epidemiological data available for visualization, integration, analysis, and download (http://iridl.ldeo.columbia.edu/maproom/.Health/.Regional/.Africa/.Meningitis/). The data are web-accessible through a set of easy-to-use map pages and links to datasets. The spatial extent of the area of interest is controlled by click and drag cursor controls. First and second order administrative boundaries are used to calculate time varying spatial averages of gridded environmental data. These environmental time series can be correlated with time series of epidemiological data or downloaded to the user's desktop. New datasets are added when the spatial resolution or quality of the data is an improvement upon existing map room datasets.

The environmental data include rainfall, temperature, relative humidity, visibility, and wind speed. There are environmental quantities from a regional dust model run that spans 1979-2008. The demographic data is the CIESIN Gridded Population of the World Version 3 (GPW3).

The Fifth MERIT Technical Meeting planned for Geneva in November 2011 is fast approaching. At this meeting the achievements of MERIT todate will be evaluated by an independent set of experts and a new chart for MERIT activities will be developed based on the changing needs of the meningitis control community.

Impact on Policy and Practice – preliminary results

Emily Firth 27/10/11 19:20
Comment [1]: Maybe good to bring this earlier in the paper .. seems to be key

i) agreement as to the nature of evidence

a. 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.

ii) a strategic approach to the creation of evidence, together with the development of a cumulative knowledge base.

a. Multi-sectoral steering committee led by WHO has enabled new communities to be bought together
b. MERIT international meetings a platform for research innovation and scientific knowledge sharing
c. Engagement with national research and health decision-making partners

iii) effective dissemination of knowledge; together with development of effective means of access to knowledge

a. in development

iv) initiatives to increase the uptake of evidence in both policy and practice.

a. Challenge of single disease approach – possible move to a multi-disease approach
b. Challenge of changes in policy environment – move from reactive to proactive
c. Creation of training opportunities such as the IRI summer Institute.

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