SATELLITE-BASED REAL TIME & EARLY WARNING SYSTEM for MONITORING VECTOR BORNE DISEASES

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2011
Global Burden of Infectious Diseases Caused by Arthropod Vector

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Disease Burden (% from total)</th>
<th>Mortality (% from total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td>78</td>
<td>89</td>
</tr>
<tr>
<td>African trypanosomiasis</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Lymphatic filariasis</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Dengue fever</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Leishmamiasis</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Chaga disease</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Onchocerciasis</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Based on Disability Adjusted Life Years (DAILY) – the number of healthy years of life lost due to premature death and disability (World Health Organization 2002, The World Health Report, Geneva).
Malaria Facts: WORLD

- **109** world countries are affected by malaria
- **3.2 billion people** (48% of the world’s population) are at risk
- **350–500 million** clinical malaria cases occur annually
- **1.5-3 million people** die from malaria annually (account 4-5% of global fatalities)
- **Children & Pregnant women vulnerable**
  One million children dies annually
- **Areas**: Africa, Asia, Latin America, the Middle East & part of Europe
IMPORTANT GOALS

• Early detection of environmental conditions conducive for mosquito development & spread of malaria
• Monitoring Malaria Start/End, Area, Intensity & Impacts
MALARIA & ENVIRONMENT

- CLIMATE & LANDSCAPE determine distribution of mosquito-borne diseases
- WEATHER affects timing, duration, and intensity of outbreaks
- WARM & WET surface stimulates mosquito’s activities to carrying the disease to people
AFRICA: GTS (WMO-based) weather station network

On the average

One weather station Covers 23,000 sq. km

NOAA satellites cover 16 sq. km
The Space Based Global Observing System, 2000
A Combination of Geostationary and Polar Orbiting Satellites

GOES-e

GOES-W

METEOR (Russian Federation)

DMSR

NOAA
Can satellite data identify WARM & WET surfaces?

WARM & WET surface stimulates mosquito’s activities to carrying the disease to people

Vegetation Health Indices (VH)

- VH are proxy providing cumulative estimation of vegetation condition (health) from AVHRR surface reflectance in VIS, NIR & IR wavelengths

- VH characterize land surface Temperature (IR) and Moisture from vegetation greenness & vigor (VIS & NIR)

- VH is represented by
  
  Vegetation Condition Index (VCI) - MOISTURE
  Temperature Condition Index (TCI) - TEMPERATURE
  Vegetation Health Index (VHI) - HEALTH

  \[ VCI = \frac{ND - ND_{min}}{ND_{max} - ND_{min}} \]
  \[ TCI = \frac{B_{tmax} - BT}{B_{tmax} - B_{tmin}} \]
  \[ VHI = a \times VCI + (1-a) \times TCI \]
AVHRR-derived Vegetation Health
A combination of **Temperature** and **Moisture** Characteristics

**Central USA**
Healthy vegetation
*Impact: Good crops*

**Kazakhstan**
Vegetation stress
*Impact: Bad crops*

**Western USA**
Vegetation stress
*Impact: Fire*

**Argentina**
Vegetation Stress
*Impact: Drought*

**Southern Africa**
Healthy Vegetation
*Impact: Malaria*

Significance: Vegetation Health estimates vegetation condition – a proxy for drought, crop & pasture production, fire, malaria;  [http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH](http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH)

Project Lead: Felix Kogan
Sponsor: NOAA/NESDIS
NDVI & Vegetation Health (VH)

**NDVI represents**
- Ecosystems
- Weather

**VH represents**
- Weather

August 12, 2010
Malaria risk maps identify priority areas to fight epidemics based on AVHRR-estimated weather condition.
Malaria risk map identify priority areas & additional resource needed to fight epidemics effectively
WEATHER CONDITIONS Triggering INTENSIVE Malaria
AUGUST 26, 2008

Malaria risk map identify priority areas and additional resource needed to fight epidemics effectively.
S. AMERICA: Modeling malaria incidents vs VCI & TCI

Malaria cases (MC) - % from total number of tested people per year
MC deviation from trend (DY) per year

Correlation of annual DY with VCI and TCI

More cases – Hot & Moist
Less Cases – Cool & Dry
ASIA: Malaria Cases (%) vs. VH, INDIA

% Malaria Cases

Karnataka, Raichur

GUJARAT: Observed & VH simulated % malaria cases
AFRICA: Malaria observed and simulated (%) from VH (TCI) data in Caprivi NAMIBIA

Malaria Simulation for Caprivi, NAMIBIA

Lat 17.5-18.0 S; Long 21.5-22.10 E
dY=60.26-0.34TCI49+0.34TCI50+0.65TCI51+0.08TCI52
AFRICA: VH & Malaria in DRY CLIMATE
SENEGAL

Healthy Vegetation (1993, 1995)
4-5 times more malaria cases then stressed vegetation

NO Malaria if dry condition in semi-arid climate

Climate controls selection of VH strategy

Malaria Cases in a month of their MAXIMUM

Healthy Vegetation

Stressed Vegetation

Monthly Malaria Cases

Planting Rice Season Harvesting
AFRICA: VH-Malaria Risk Area, 2002-2003
Endemic Area – TANZANIA, RWANDA

**TANZANIA**
- 25-30% malaria risk area, Sep-Jan
- April-June provided 3-4 months advance malaria indication

**RWANDA**
- <5% malaria risk area, Sep-May
- Pre-season malaria risk area was low indicating no malaria risk

* VH provides malaria risk area for an entire country
* Pre-season VH forecasts malaria epidemics
NOAA Capabilities (Examples)
KENYA: RVF (Rift Valley Fever) & Vegetation Health (VH)

1996-97
VH<20 - Severe DROUGHT – NO RVF epidemics

1997-98
VH>80 - FAVORABLE condition – Intensive RVF epidemics

NOAA has capability to identify & monitor other mosquito-born diseases
1987 & 1988 Dengue Fever & VH
Vietnam, Thailand, Malaysia

Vegetation Health and
Dengue Fever Disease

No Stress

NUMBER of CASES

Vegetation Stress

Vegetation Health & Dengue Hemorrhagic Fever Cases

Source: NOAA-9 & WHO
Vegetation Health Web

http://www.orbit.nesdis.noaa.gov/smcd/emb/vci
VH-based Moisture & Thermal Conditions
PUBLICATIONS

2011

F. Kogan, Alfred Powell and Oleg Fedorov (Editors), 2011: Use of Satellite and In-Situ Data to Improve Sustainability. Springer, 314 pp.


2010


2002


CONCLUSIONS

Vegetation Health (VH) provide

• Malaria risk predictions, diagnostics & assessments
• Malaria start and end
• Zones of enhanced mosquitoes activities and a risk of malaria transmission
• Malaria intensity
• Up to four months warning
• Validation of malaria treatments
• Other mosquitoes-born diseases (dengue, RVF etc.)
BACK UP
AVHRR Data for Land Use

Sensor: Advanced Very High Resolution Radiometer (AVHRR)

Satellites: NOAA-7, 9, 11, 14, 16, 18, 19

Data Resolution: Spatial - 4 km (GAC), 8 & 16 km; Temporal - 7-day composite

Period: 31 years (1981-2011)

Coverage: World (75 N to 55 S)

Channels: VIS (ch1), NIR (ch2), Thermal (ch4, ch5)