Monitoring Malaria from Operational Satellites

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OUTLINE

- Background
- Malaria and Environment
- AVHRR Sensor & Data
- Vegetation Health (VH) System
- Data Applications & Interpretation
- Callenges

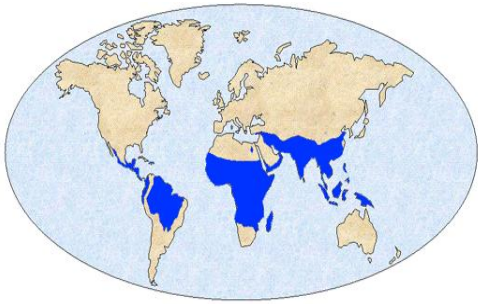
Global Burden of Infectious Diseases Caused by Arthropod Vector

Global Burden of Infectious Diseases Caused by Anthropod Vector

Diseases	Disease Burden (% from total)	Mortality (% from total)
Malaria	**78**	**89**
African trypanosomiasis	**3**	**3**
Lymphatic filariasis	**10**	**0**
Dengue fever	**1**	**2**
Leishmamiasis	**5**	**5**
Chaga disease	**1**	**1**
Onchocerciasis	**2**	**0**

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).

WORLD Malaria Facts



- **107 world countries are affected**
- **3.2 billion people (48% of the world) are at risk**
- **300–500 million annual malaria cases**
- **1.5-3 million people die annually (4-5% of global fatalities)**
- **Children (C) & Pregnant women (PW) vulnerable**
  (C): One million dies annually; (PW): 10% maternal death
- ***P. falciparum* and *P. vivax* cause of death (one million deaths caused by *P. falciparum* only)**
- **Area: Africa, Asia, Latin America, the Middle East & part of Europe**
- **Expenditure: 40% of Africa's health**
- **Sub-SAHARA Africa contributes: 60%** of global, **75%** of *P. falciparum* & **80%** of deaths cases; **Every 30 sec** a child dies

MALARIA & ENVIRONMENT

- **CLIMATE & LANDSCAPE determine**

  distribution of mosquito-borne diseases

- **WEATHER affects**

  timing, duration, area and intensity of outbreaks

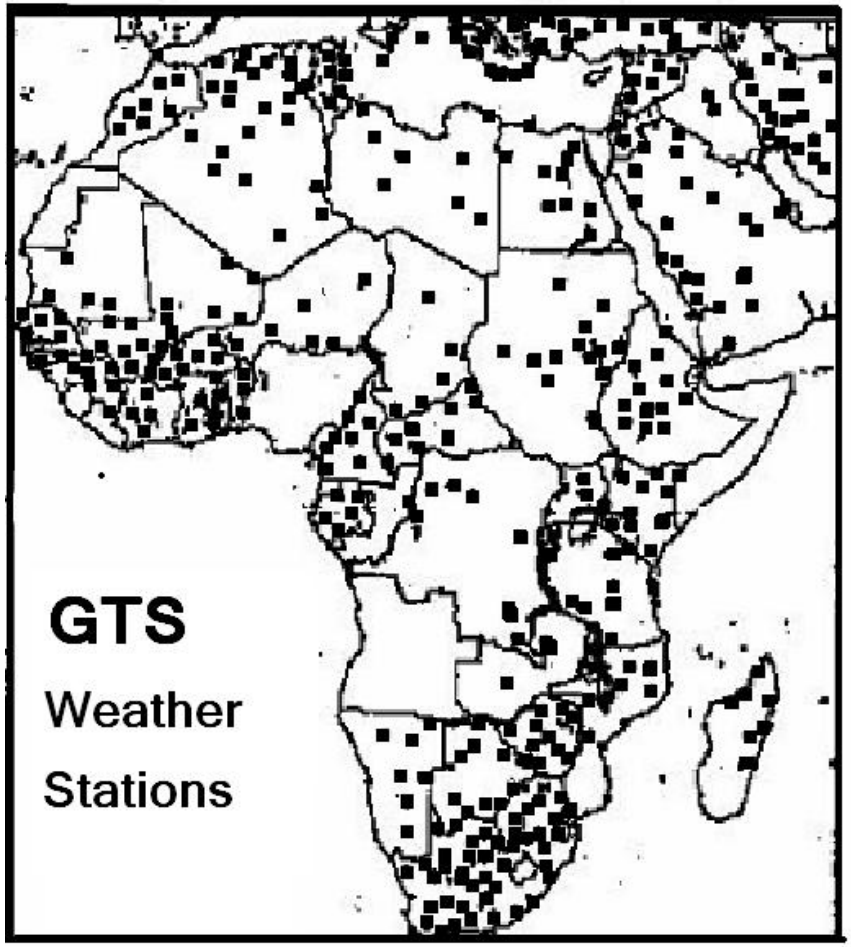
- **WARM & WET surface stimulates**

  mosquito's activities to carrying the disease to people

Correlation between malaria cases & weather data, **TANZANIA**, ***Hai District***

MONTH	Rains	Tmax	Tmin
May	0.24	0.45	0.45
Jun	0.38	0.36	0.29
Jul	0.41	0.29	0.30
Aug	0.29		0.42

AFRICA: GTS weather station network

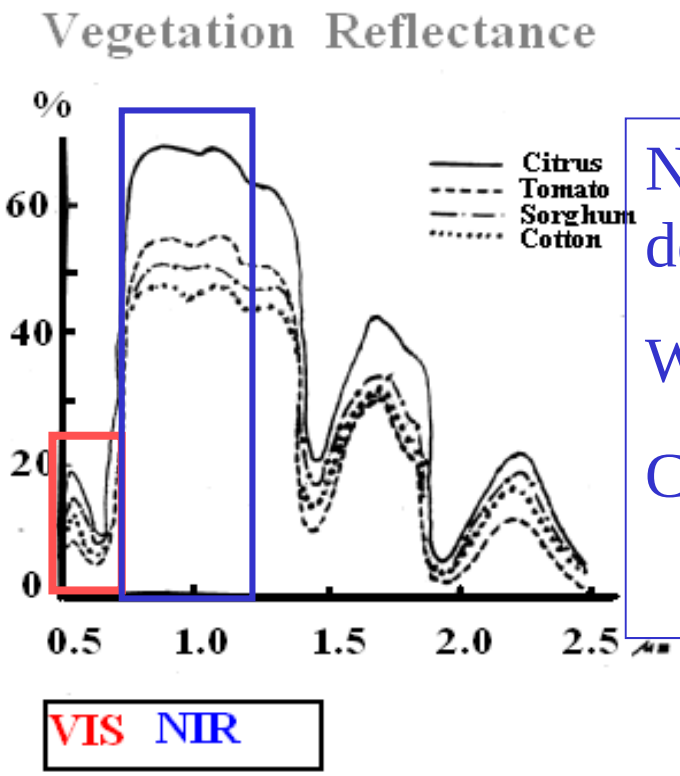


THEORY
Typical Vegetation Reflectance

VIS reflectance depends on

CHLOROPHYLL

CAROTENOID



NIR reflectance depends on

WATER CONTENT

CELL STRUCTURE

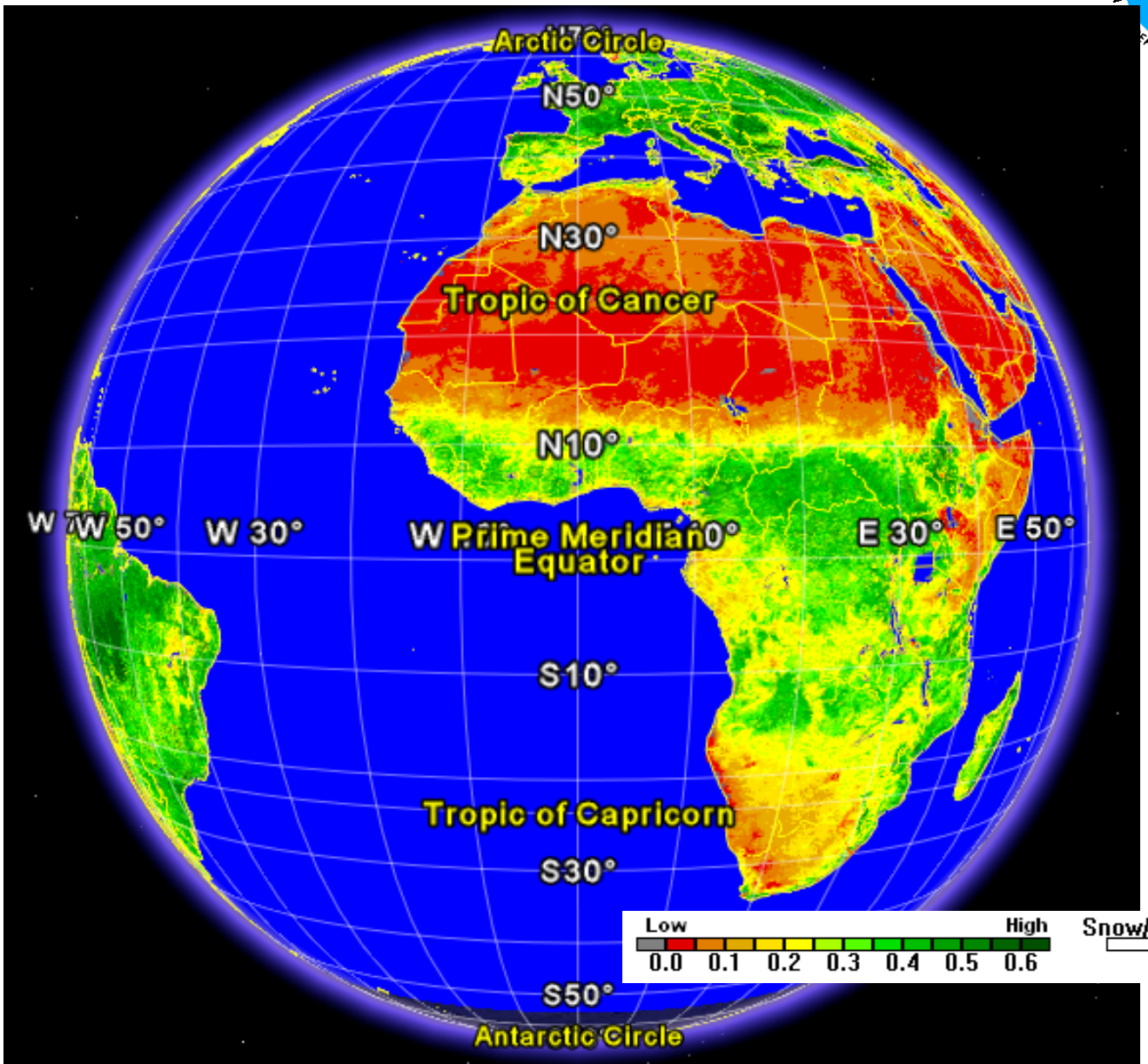
NDVI = (NIR-VIS)/(NIR+VIS)

NDVI & Reflectance

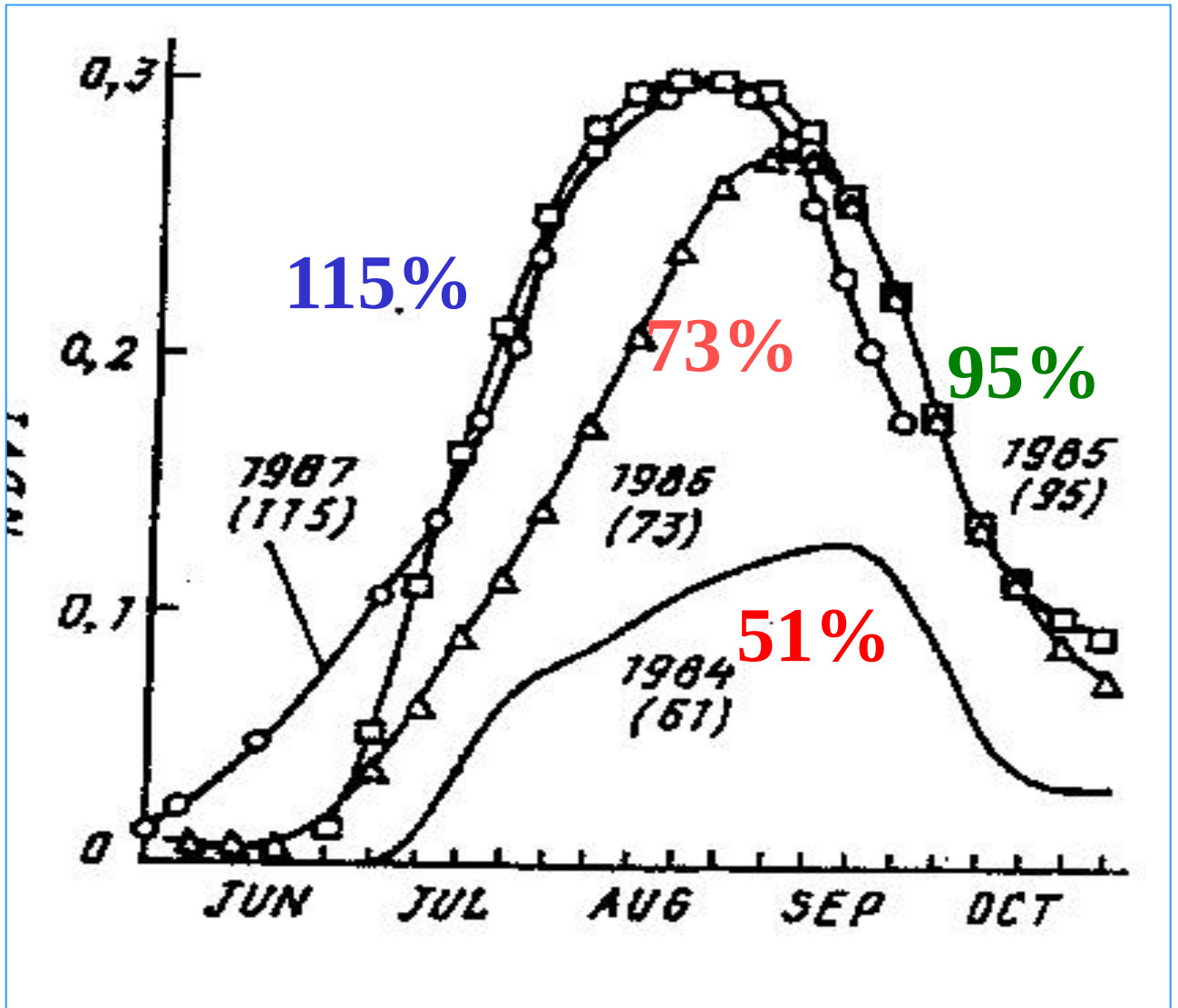
Cover Type	Ch1	Ch2	NDVI
Vegetation: Dense	.050	.150	**0.500**
Medium	.080	.110	**0.140**
Light	.100	.120	**0.090**
Bare Soil	.269	.283	**0.025**
Clouds	.227	.228	**0.002**
Water	.022	.013	**-0.26**

NDVI= (Ch2-Ch1)/(Ch2+Ch1)

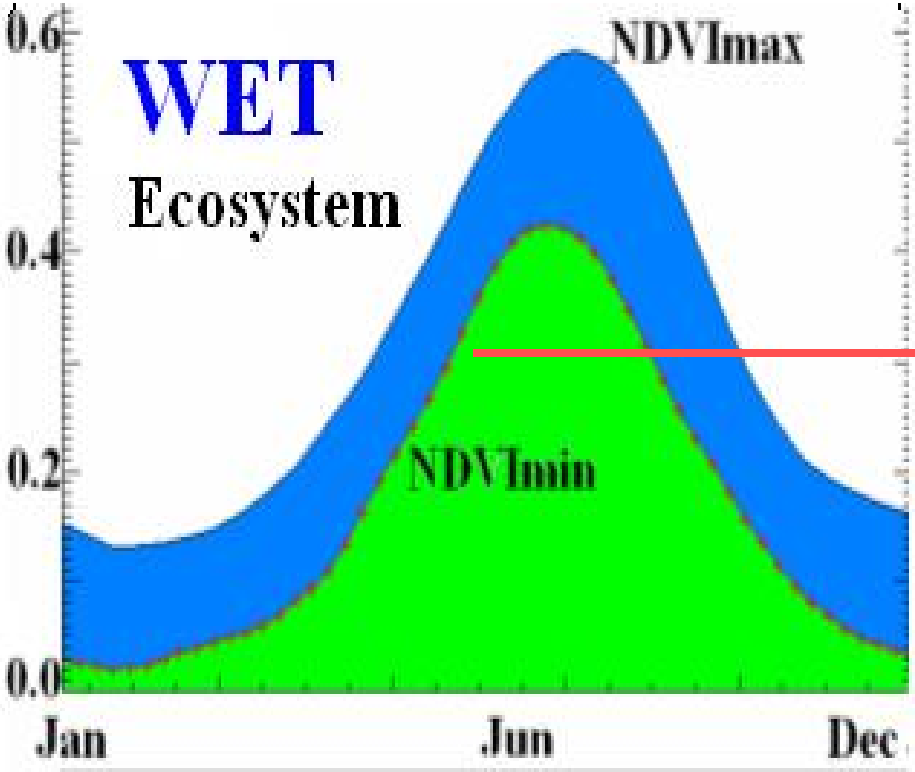
NDVI from MSG-2 SEVIRI
June 2007

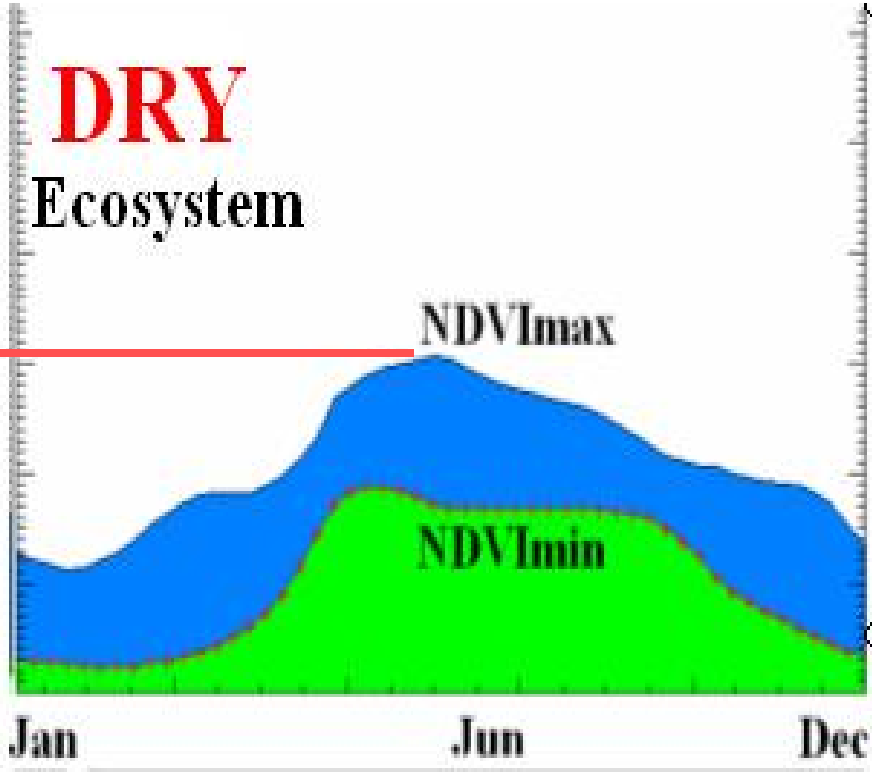


NDVI & Rainfall (% mean), SUDAN (1984-1987)



NDVI in Dry & Wet Ecosystems





NDVImax indicates **HEALTHY** vegetation

NDVImin indicates **UNHEALTHY** vegetation

AVHRR-based VH Indices

Vegetation condition index (VCI), values 0 - 100

VCI=(NDVI-NDVImin)/(NDVImax-NDVImin)

NDVImax, and NDVImin – climatology (1981-2000 maximum and minimum NDVI for a pixel;

MOISTURE

Temperature condition index (TCI), values 0 - 100

TCI=(BTmax-BTmin)/(BTmax-BTmin)

NDVImax, and NDVImin – climatology (1981-2000 maximum and minimum NDVI for a pixel

THERMAL

Vegetation Health Index (VHI), values 0 – 100

VHI=a*VCI+(1-a)*TCI

VEG. HEALTH

0 – indicates extreme stress

100 – indicates favorable conditions

Vegetation Health (VH) System

- **Satellites:** NOAA
- **Sensor:** AVHRR
- **Records:** 30-year
- **Characterize:** LAND SURFACE
  - GEENNESS (Chlorophyll)
  - MOISURE (Vigor)
  - THERMAL (Temperature)
- **Assess:**
  - VEGETATION HEALTH
  - CUMULATIVE impact "have memory"
  - from EXTREME STRESS to FAVOURABLE
- **Issued**
  - WEEKLY
  - 4 km PIXEL
  - ALL LANDSCAPE
- **Products:** VEGETATION HEALTH, MOISTURE (VCI), THERMAL (TCI) CONDITION

Vegetation Health Interpretation

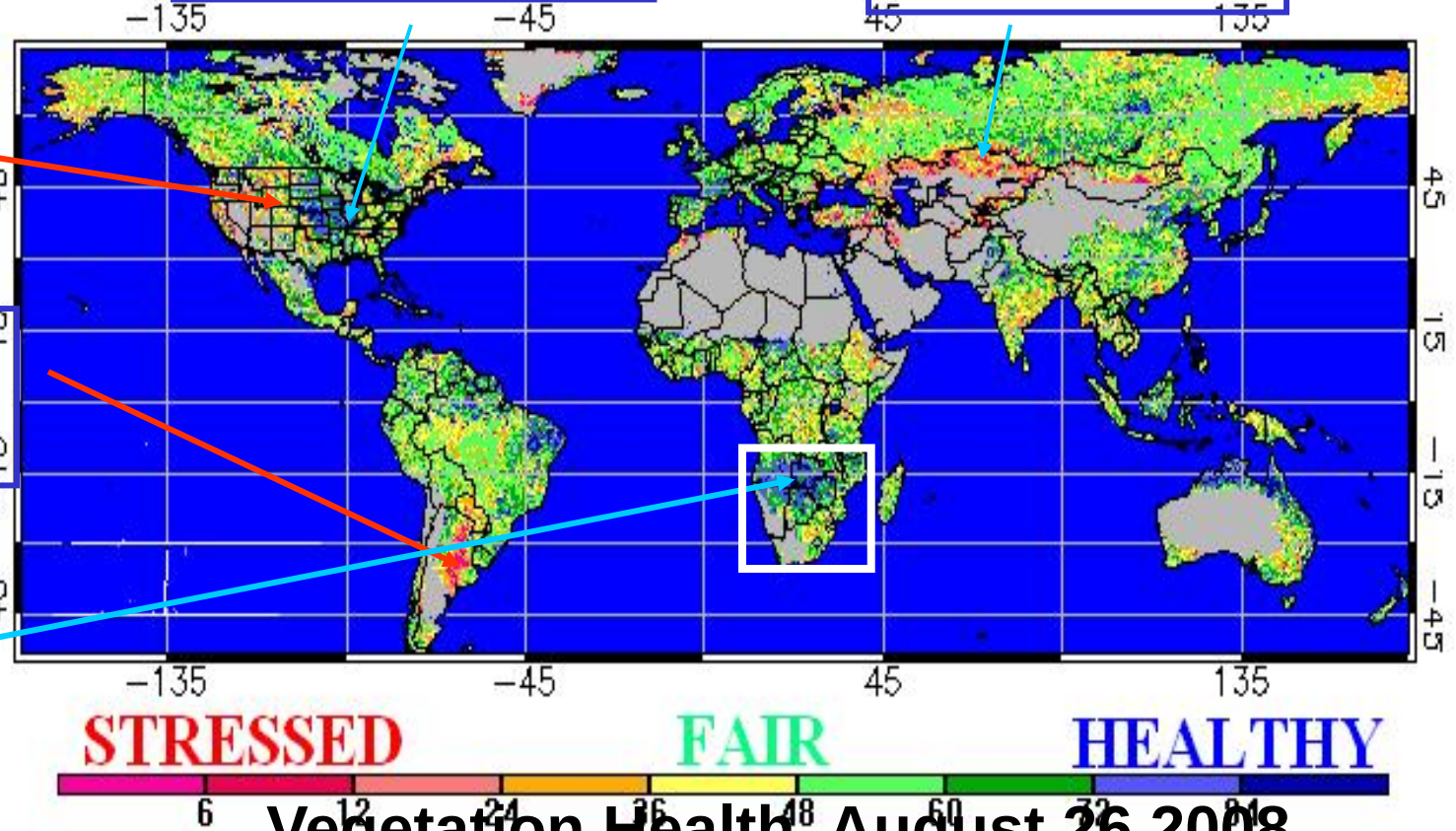
Central USA
Healthy vegetation
Impact: ***Good crops***

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

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

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

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



Vegetation Health, August 26 2008

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

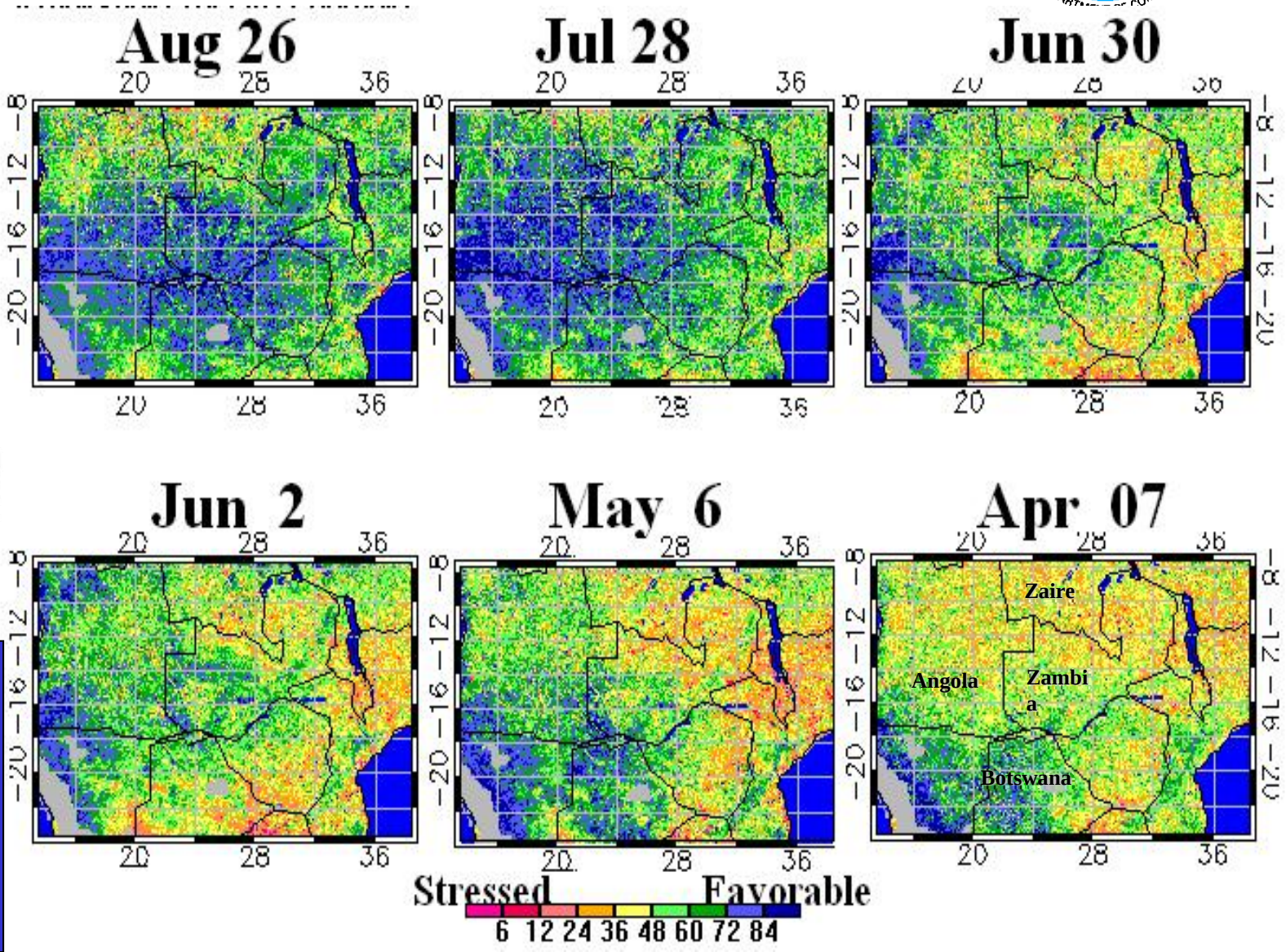
Project Lead: Felix Kogan

Sponsor: NOAA/NESDIS

2008 VH s-c AFRICA

Healthy condition

- Started in May
- Expanded in July & August

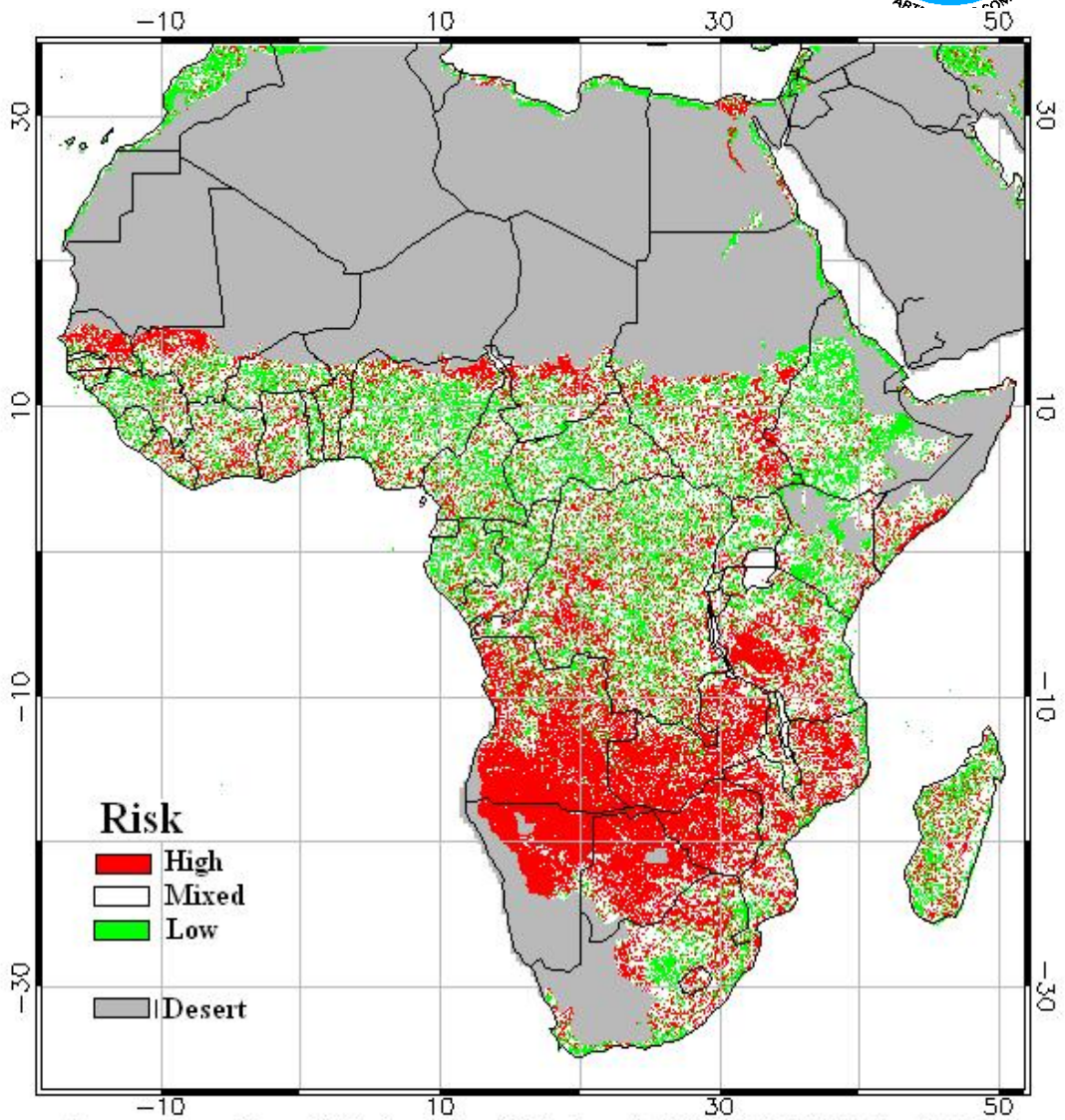


VH products
- Detect
- Diagnose
- Forecast

Strategy: MONITORING RISK AREA

AUGUST 26 2008

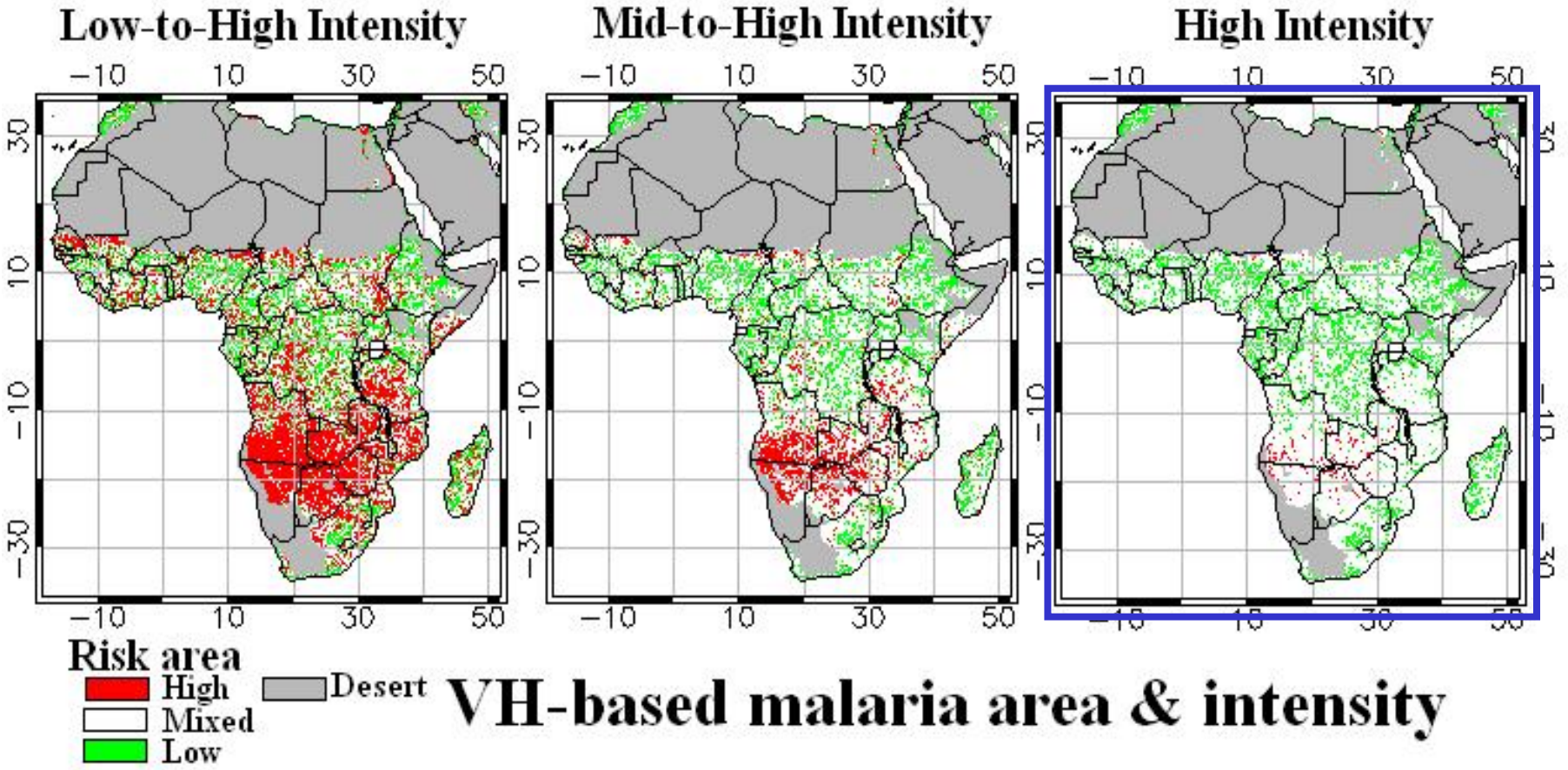
Malaria risk maps identify priority areas to fight epidemics



Area under Malaria Risk, AUGUST 26, 2008

Strategy: MONITORING RISK AREA & INTENSITY

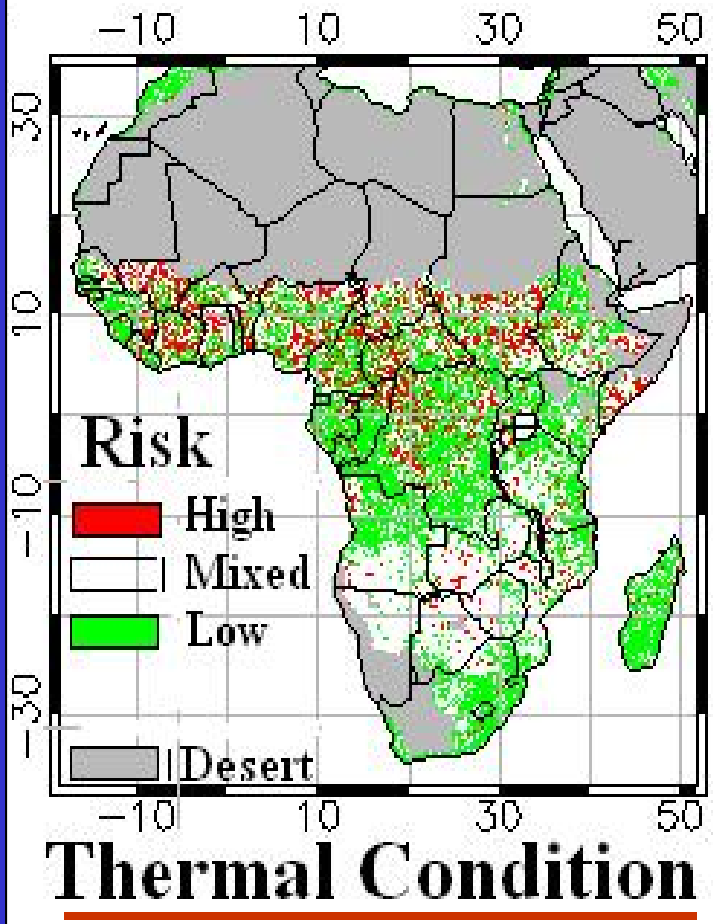
AUGUST 26, 2008



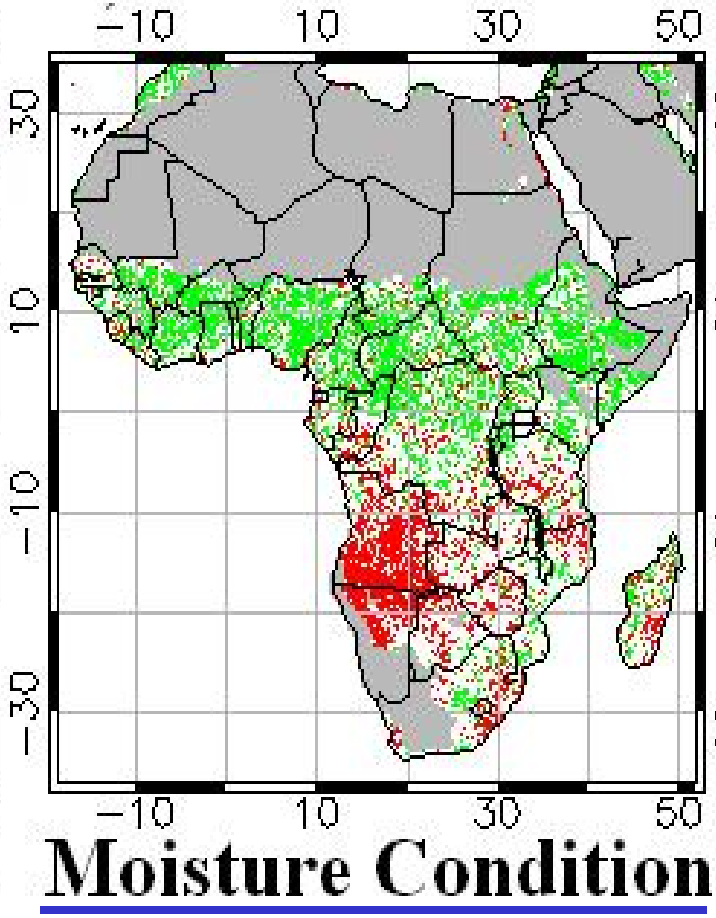
Malaria risk maps identify priority areas & additional resource distribution to fight epidemics effectively

Strategy: WEATHER PROXY
AUGUST 26, 2008

Malaria risk maps identify priority areas and additional resource needed to fight epidemics effectively



Thermal Condition



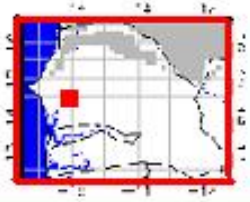
Moisture Condition

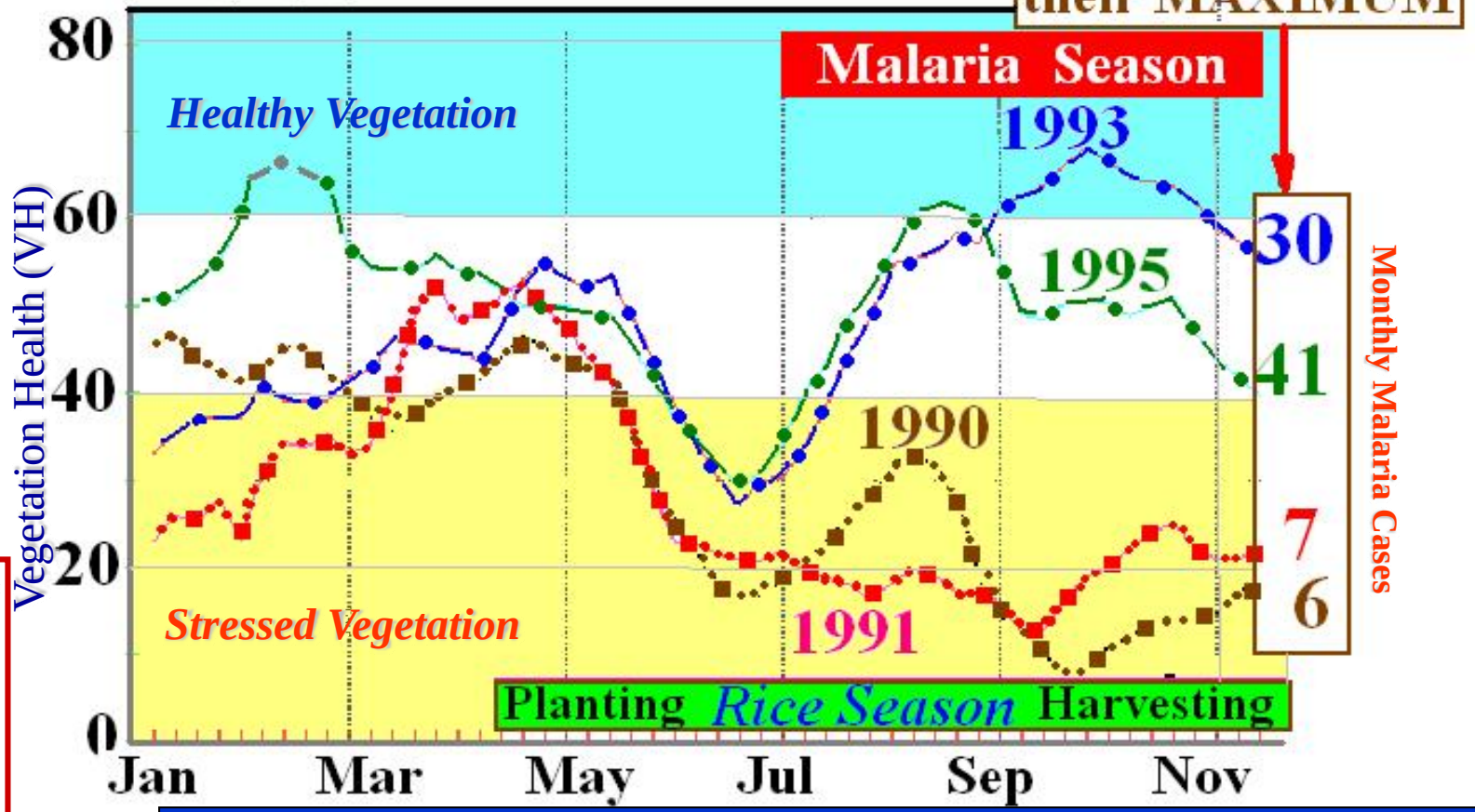
INTENSIVE MALARIA

VALIDATION: VH & Malaria
SENEGAL

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

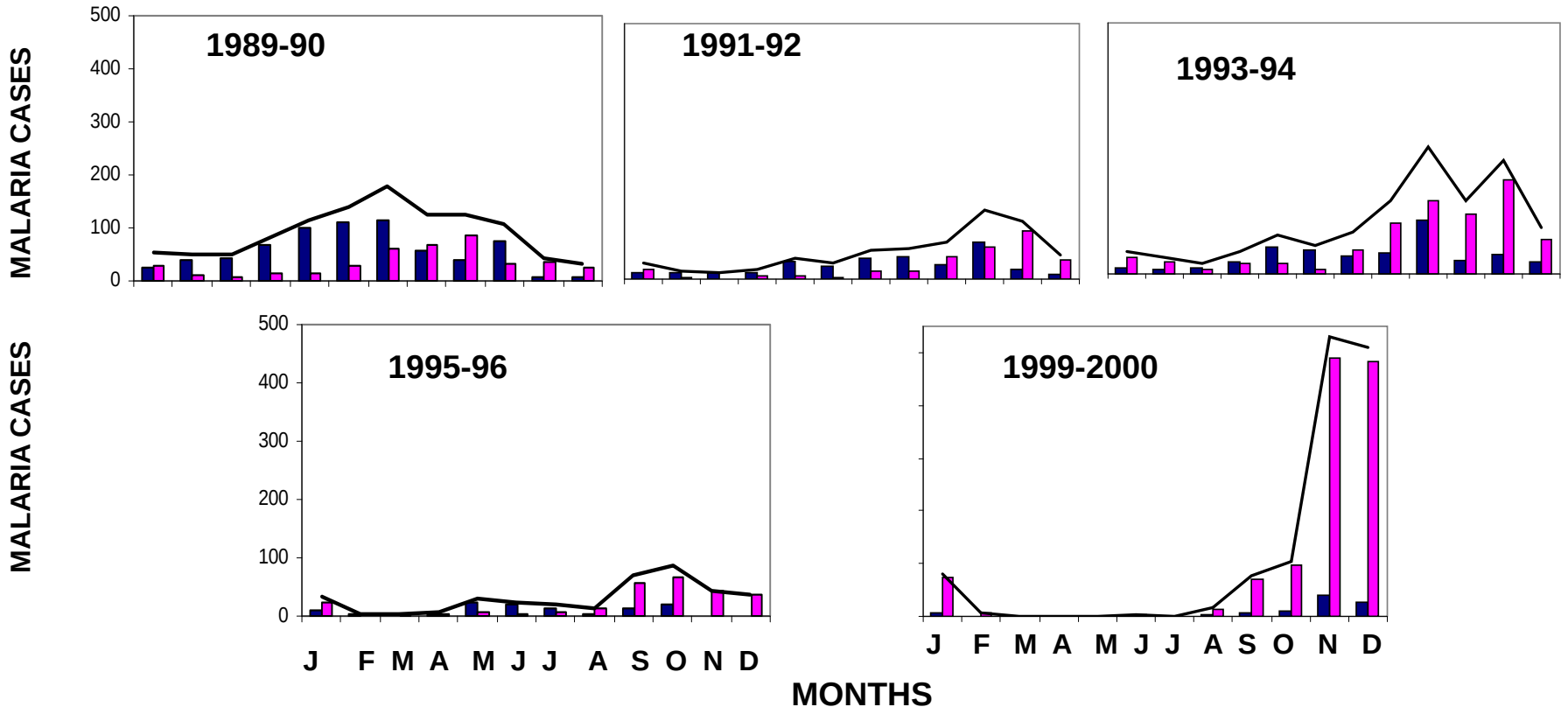
NO Malaria if dry condition in semi-arid climate





Climate controls selection of VH strategy

Plasmodium vivax & P. falciparum in village studies, INDIA



Month wise, year wise cases of Plasmodium vivax and P.falciparum recorded in study villages between 1989-2000.

Singh et al., 2004.Trop. Med. Int. Hlth

Breeding Sites

Labour Camp

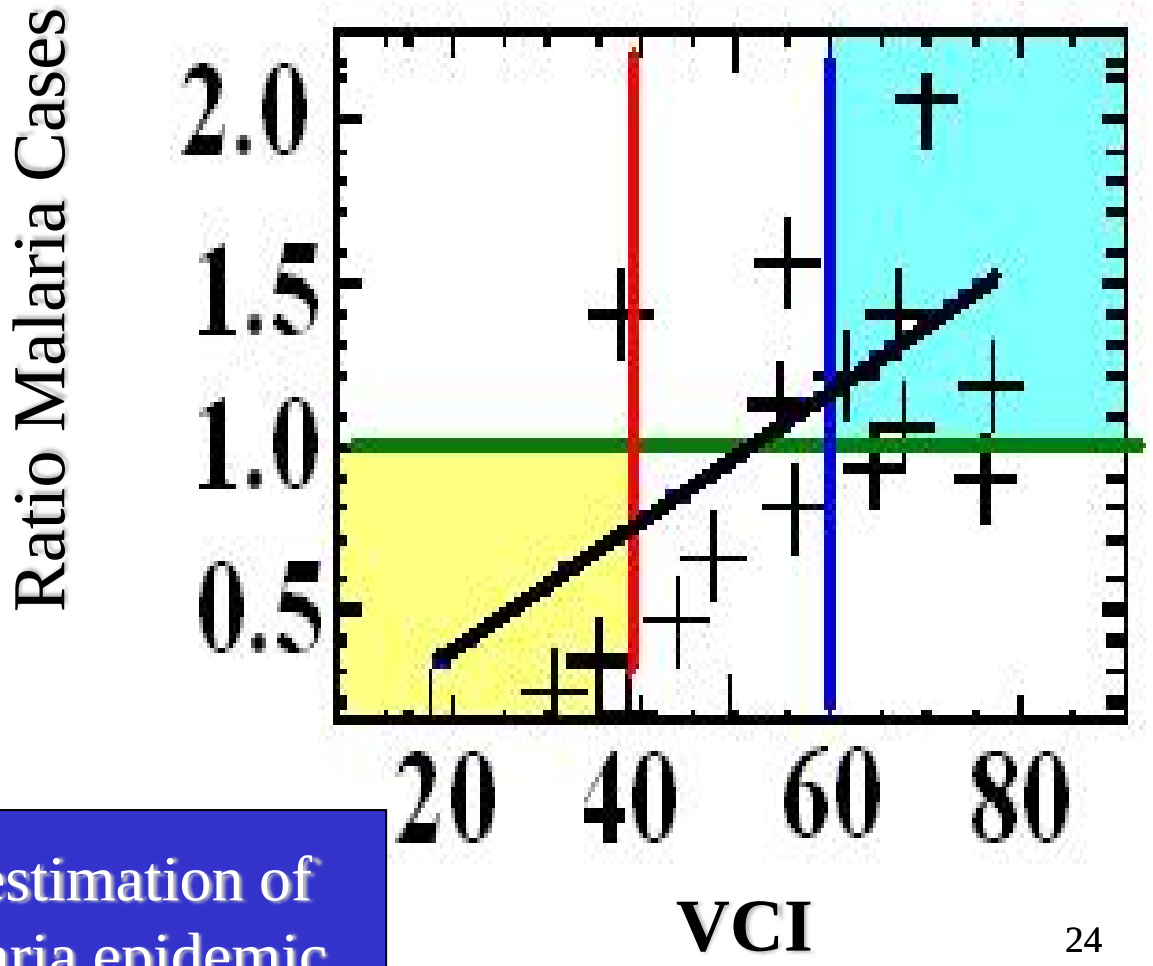
Treated Bed Nets Evaluation

Validation: VH & Malaria in INDIA
Karnataka, Raichur

(Correlation of Malaria Cases (Annual Malaria Incident (AMI)/Trend of AMI) with Moisture Index (VCI))

VCI < 40 (dry) – Lower AMI

VII > 60 (wet) – Larger AMI



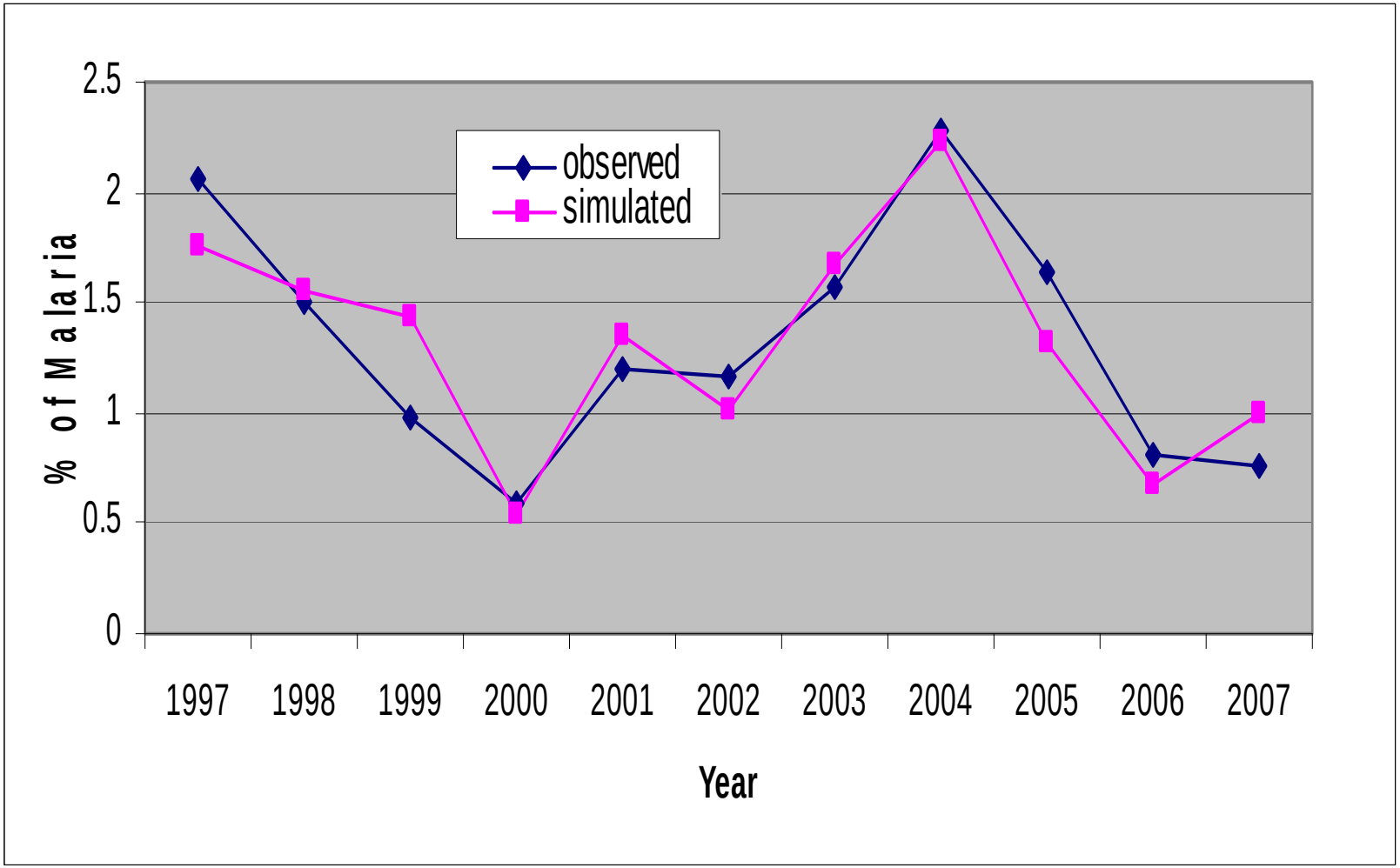
Rainfall 600 mm/year

VH is a good proxy for estimation of vegetation health & malaria epidemic

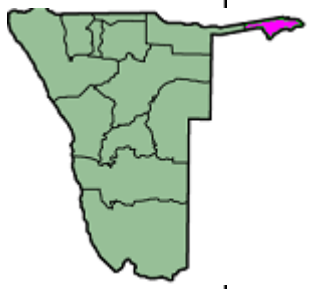
VALIDATION: Malaria (%)

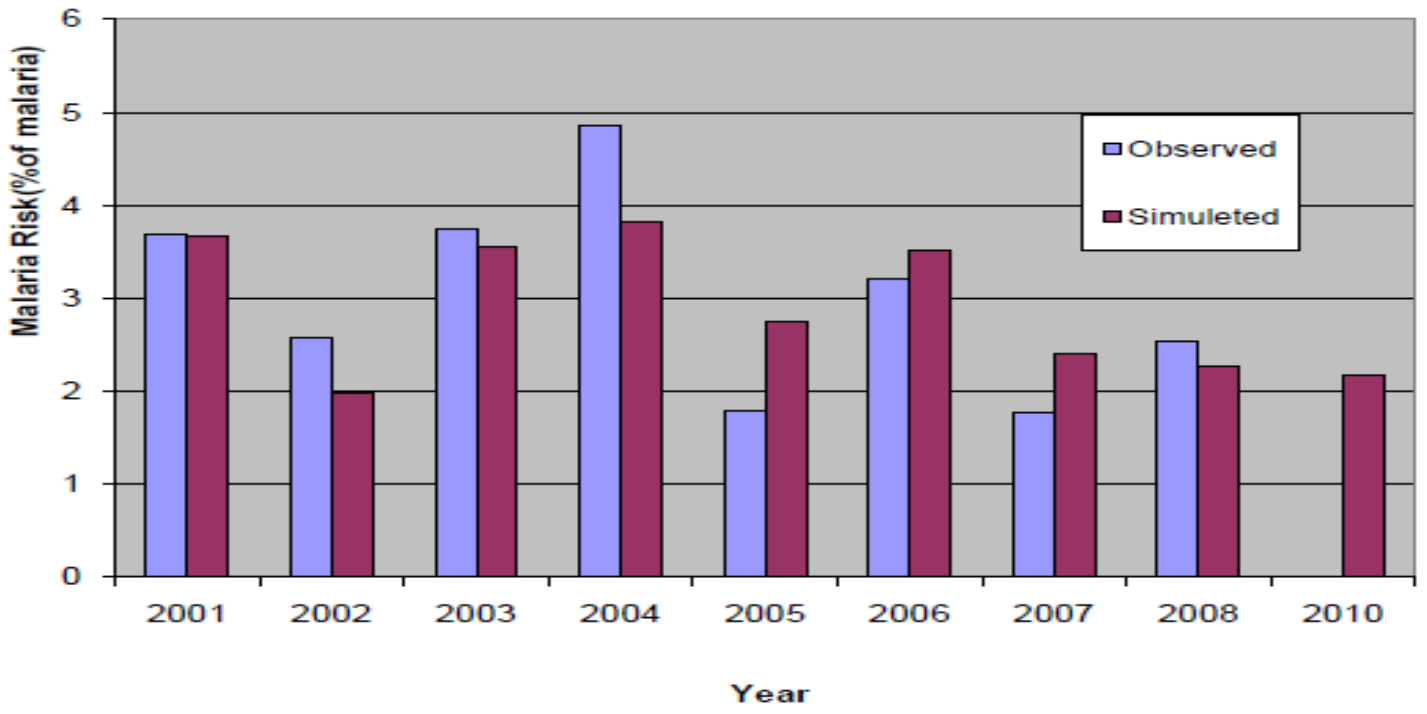
Observed vs. VH-Simulated

Gujarat INDIA



VALIDATION: Malaria observed vs. VH (TCI)-simulated Caprivi NAMIBIA

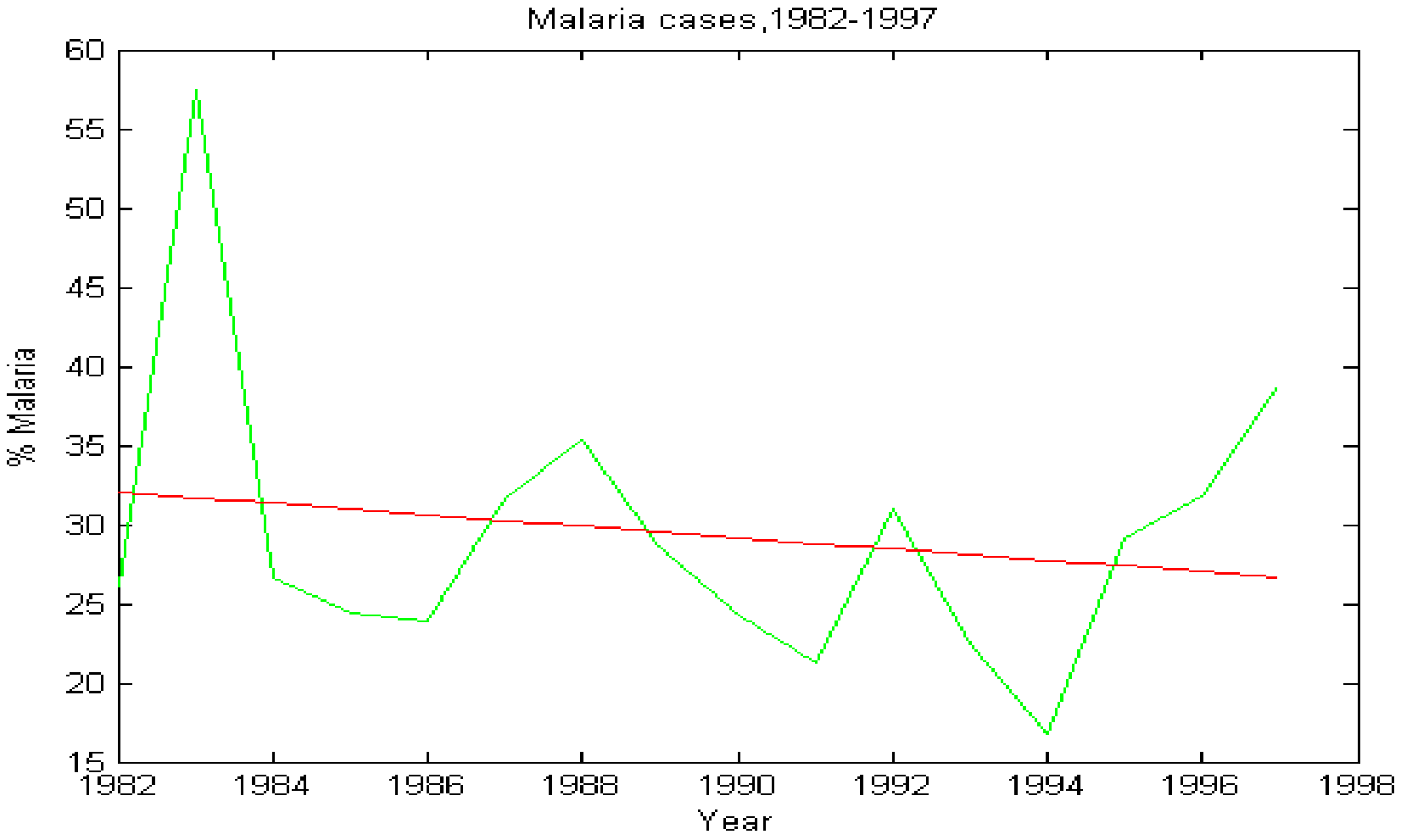




Lat 17.5-18.0 S; Long 21.5-22.10 E

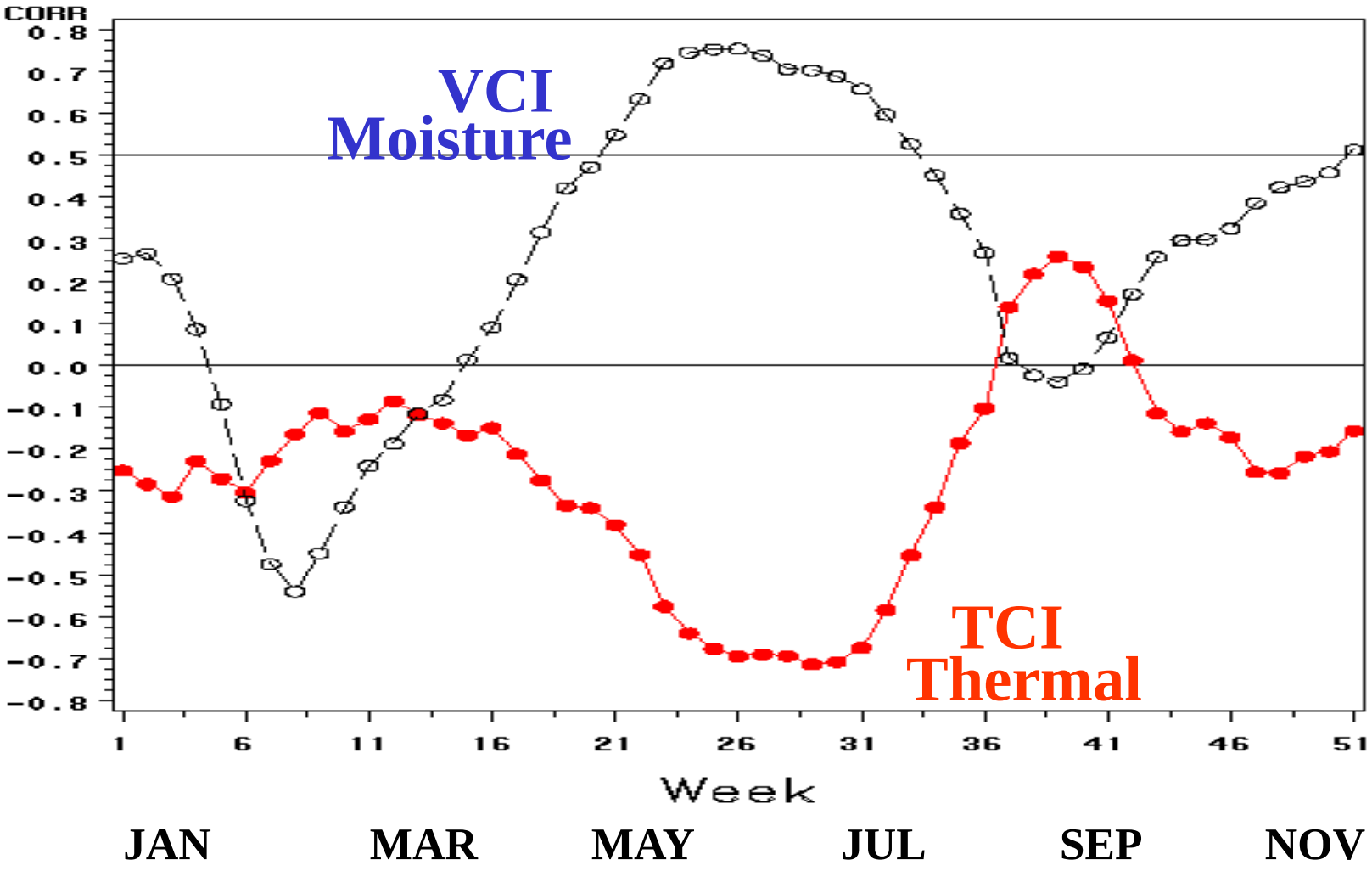
dY=60.26-0.34TCI49+0.34TCI50+0.65TCI51+0.08TCI52

Malaria Cases (%)
Choco COLOMBIA



Correlation: Malaria Cases (%) with VCI & TCI

Choco COLOMBIA



Strategy: PREDICTION

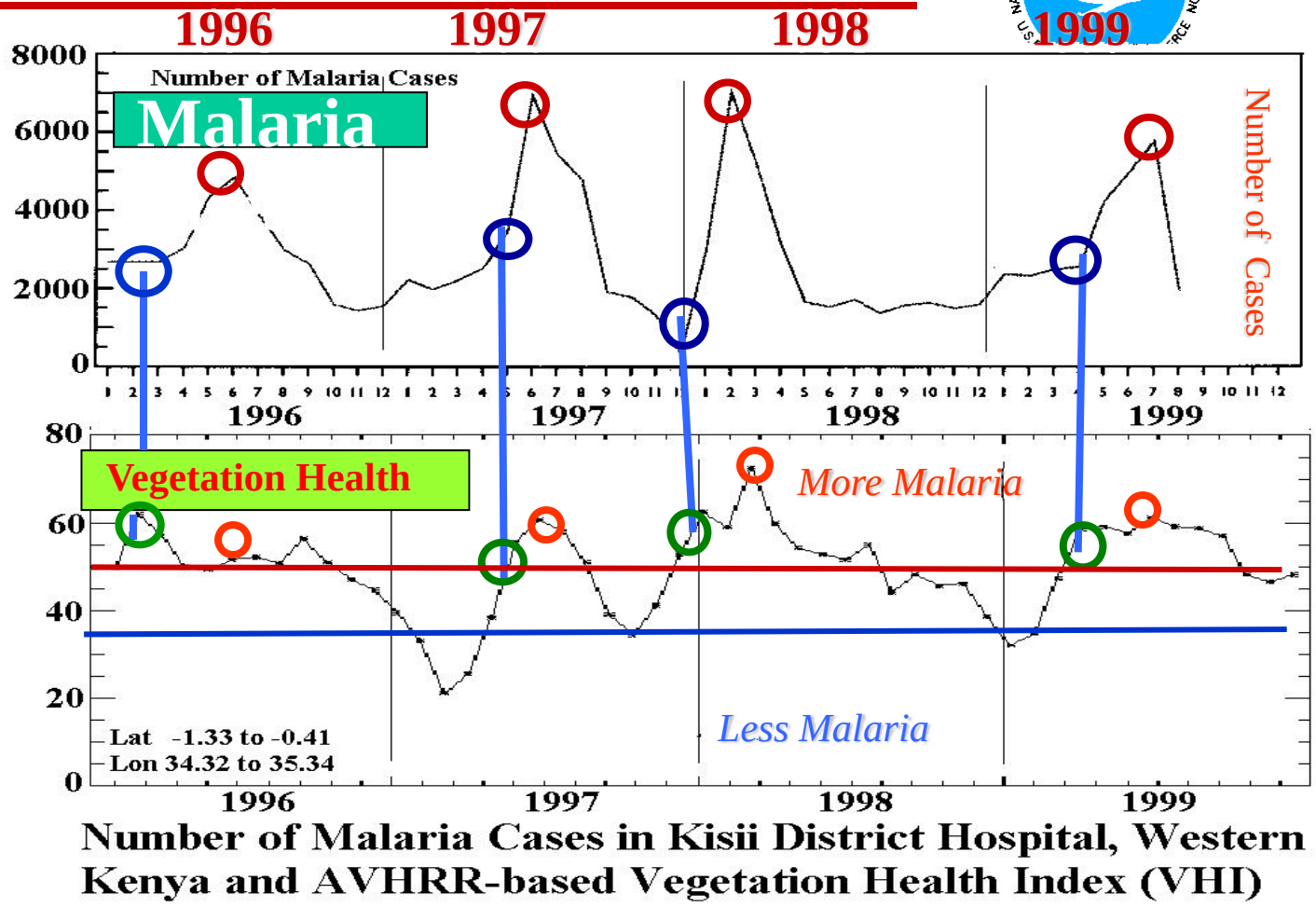
Kisii District Hospital KENYA

Malaria & VH

(1) High VH (green circle) occurs 1-4 months prior to the malaria peak (red circle)

(2) VH correlates with malaria cases & can be used as **epidemic predictor**

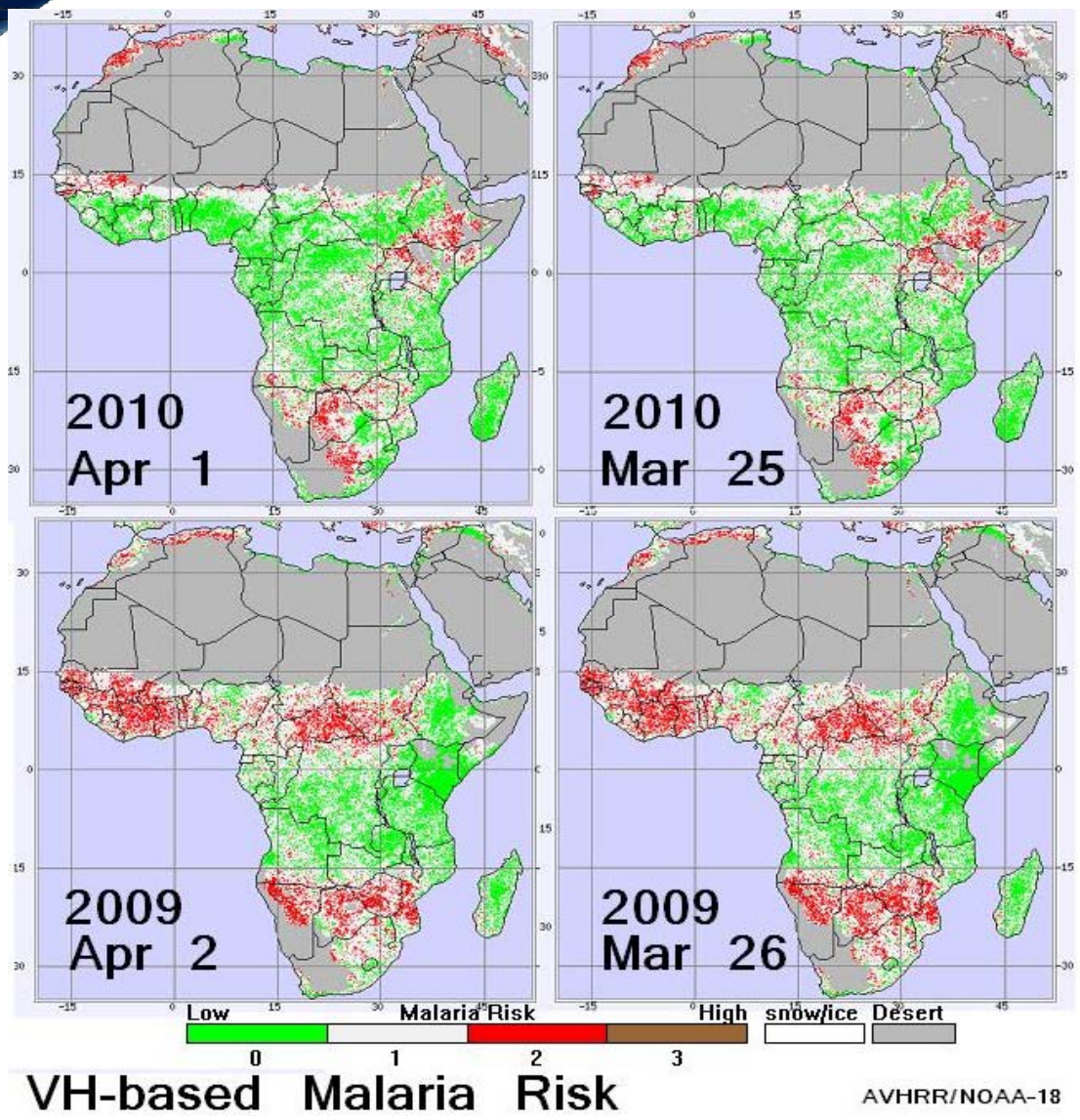
(3) In 1998, **malaria** peak shifted to spring - similarly VH



Number of Malaria Cases in Kisii District Hospital, Western Kenya and AVHRR-based Vegetation Health Index (VHI)

- VH provides up to 4 months advance malaria warnings
- The warnings must be area specific

VH-based Malaria Risk



2010

2009

http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_browse.php

Combat Malaria Programs

- UN Malaria Envoy
- Roll Back Malaria Partnership
- Global Fund to Fight Aids, TB & Malaria
- Presidential Malaria Initiative
- Melinda & Bill Gates Foundation
- US Congress (2009-2013)

PMI Program

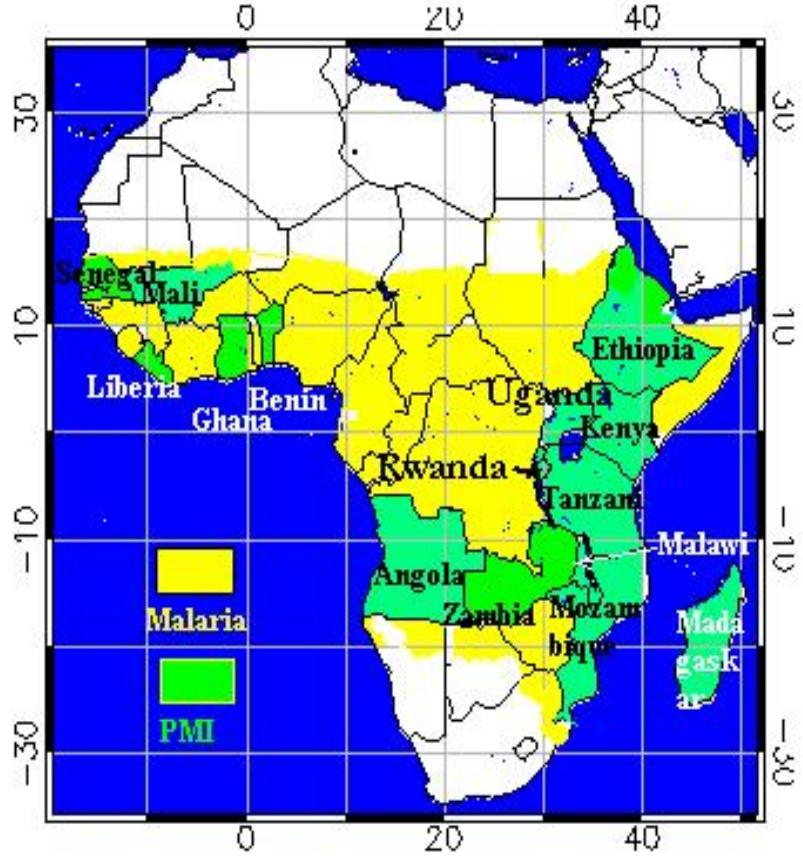
- Indoor Residual **Spraying** (IRS)
- Insecticide Treated **Nets** (ITN) incl. LLITN
- Artemisinin-based combination **therapy** (ATC)
- Intermittent preventive **treatment** for pregnant women (IPTp)
- Improving infrastructure and technology

Interview to RBM by Rear Admiral T.Ziemer (7/24.2008)

PMI: Goals & Countries

June 2005, President G.W. Bush announced a **$1.2 billion** aid package for AFRICA: Reduce 50% malaria death in 15 countries

SENEGAL
MALI
LIBERIA
GHANA
BENIN
ETHIOPIA
KENYA
UGANDA
RWANDA
MALAWI
TANZANIA
MOZAMBIQUE
ZAMBIA
ANGOLA
MADAGASCAR



Area – 3,243,000 sq. mi. People – 343,000,000

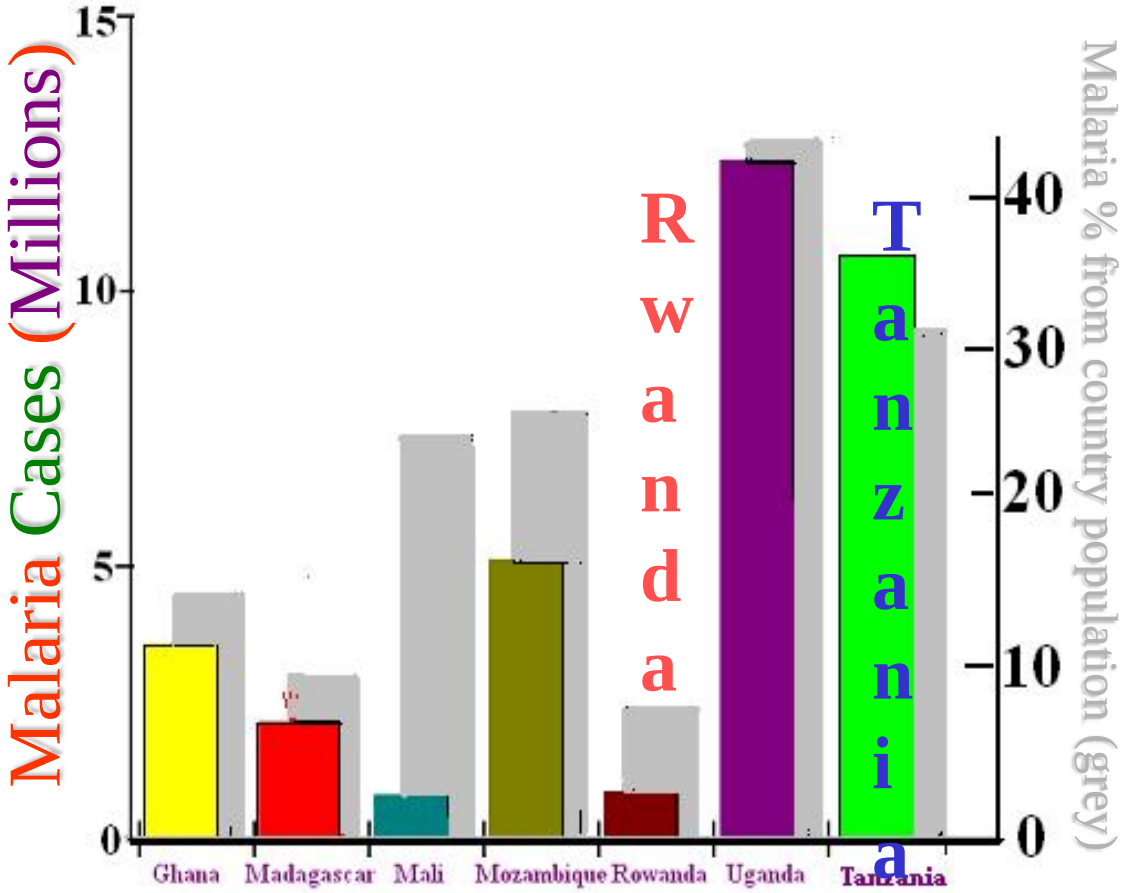
2003 Malaria PMI Countries

Endemic Area

POPULATION AFFECTED
- Rwanda 1.5 mil. (9% pop.)
- Uganda 13.0 mil. (41% pop.)

MALARIA CASES are SPECIFIC to
- Country
- Affected area
- Population
- Weather
- Climate
- Malaria Intensity

VH PROVIDES COMBINE ESTIMATION OF THESE CONDITIONS in ENDEMIC AREAS



http://www.wno.int

VH diagnoses malaria risk over a country & an area advising on cost-effective resource distribution

VH-Malaria Risk Area as a predictor, 2003

Endemic Area

TANZANIA

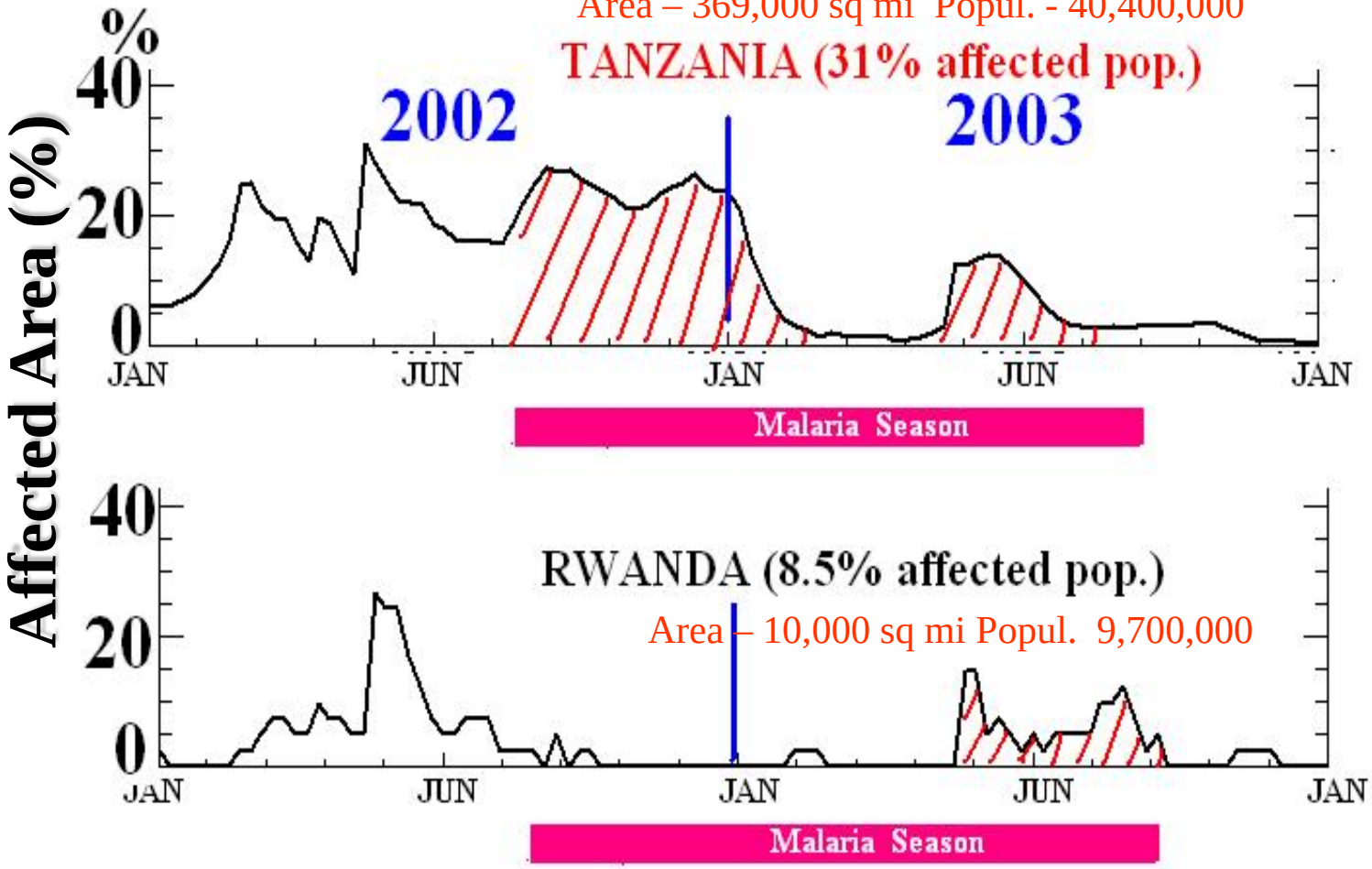
-25-30% malaria risk area, Sep-Jan

- 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

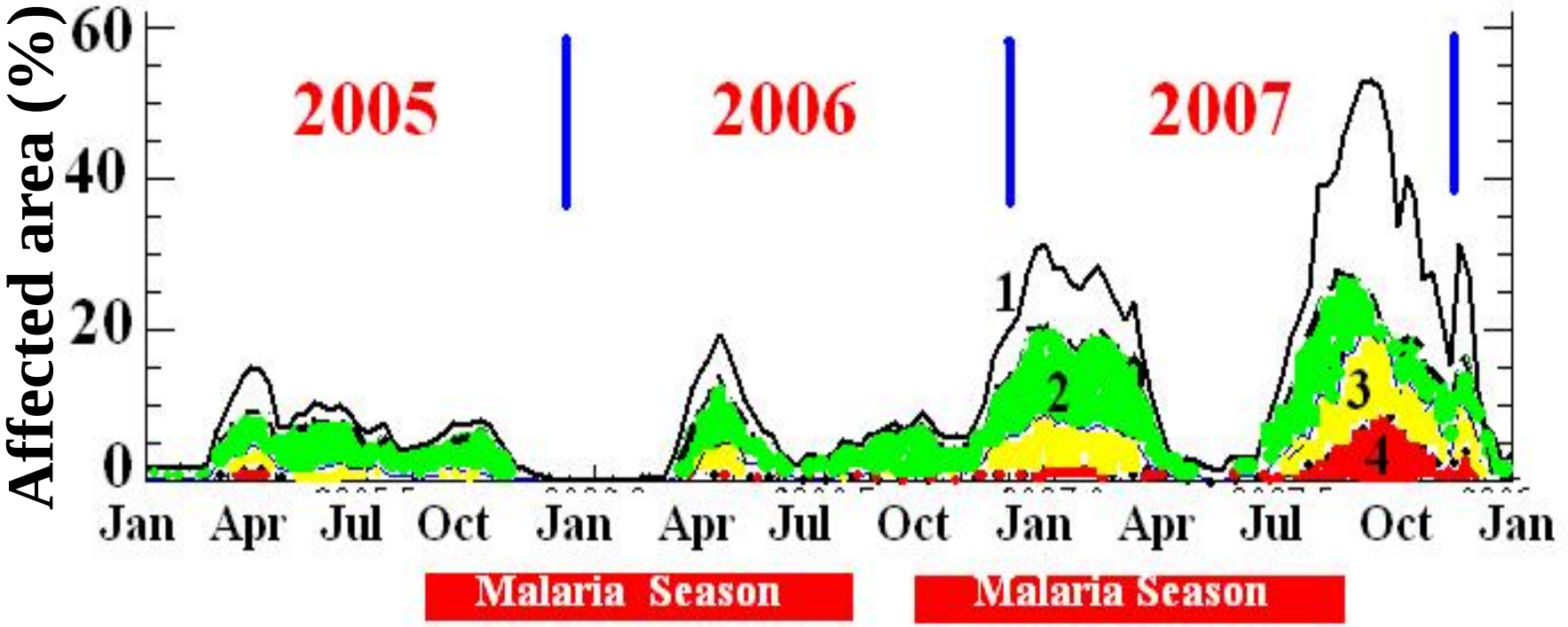


*** VH provides malaria risk area for an entire country**

*** Pre-season VH forecasts malaria epidemics**

VH Malaria Risk Area (%) by Intensity UGANDA

AREA - 94,000 sq mi. PEOPLE – 30,900,000



Malaria risk area: 1 - Low-to-High total; 2 - Low; 3 - Moderate; 4 - High

Percent (%) of UGANDA under malaria risk of different intensity

VH

(a) Provides risk area & epidemic intensity

(b) Validates effectiveness of fighting measures

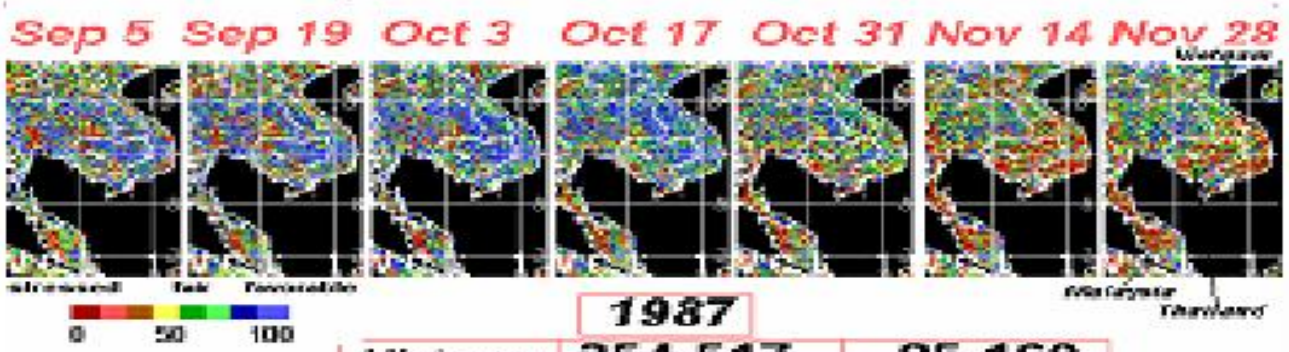
GOALS

- Early detection of environmental conditions conducive for mosquito development & spread of malaria using operational satellites
- Monitoring Malaria Start/End, Area, Intensity & Impacts

1987 & 1988 **Dengue Fever** & VH

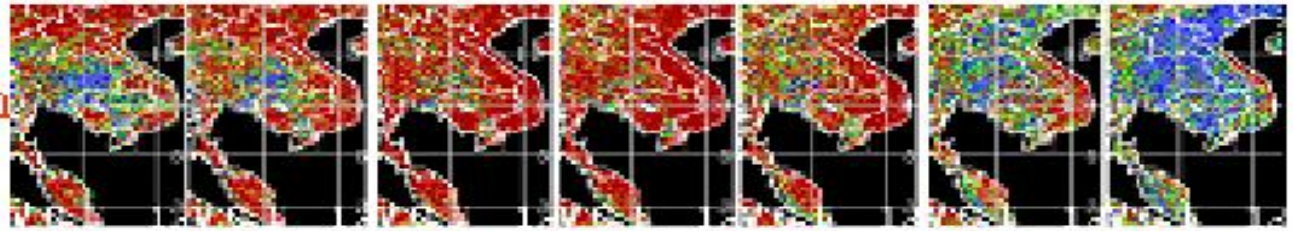
Vietnam, Thailand, Malaysia

Vegetation Health and Dengue Fever Disease



NUMBER of CASES

	1987	1988
Vietnam	354,517	85,160
Thailand	174,265	26,926
Malaysia	304	233



Vegetation Health & Dengue Hemorrhadic Fever Cases

Source NOAA-9 & WHO

NOAA Capabilities (Examples)

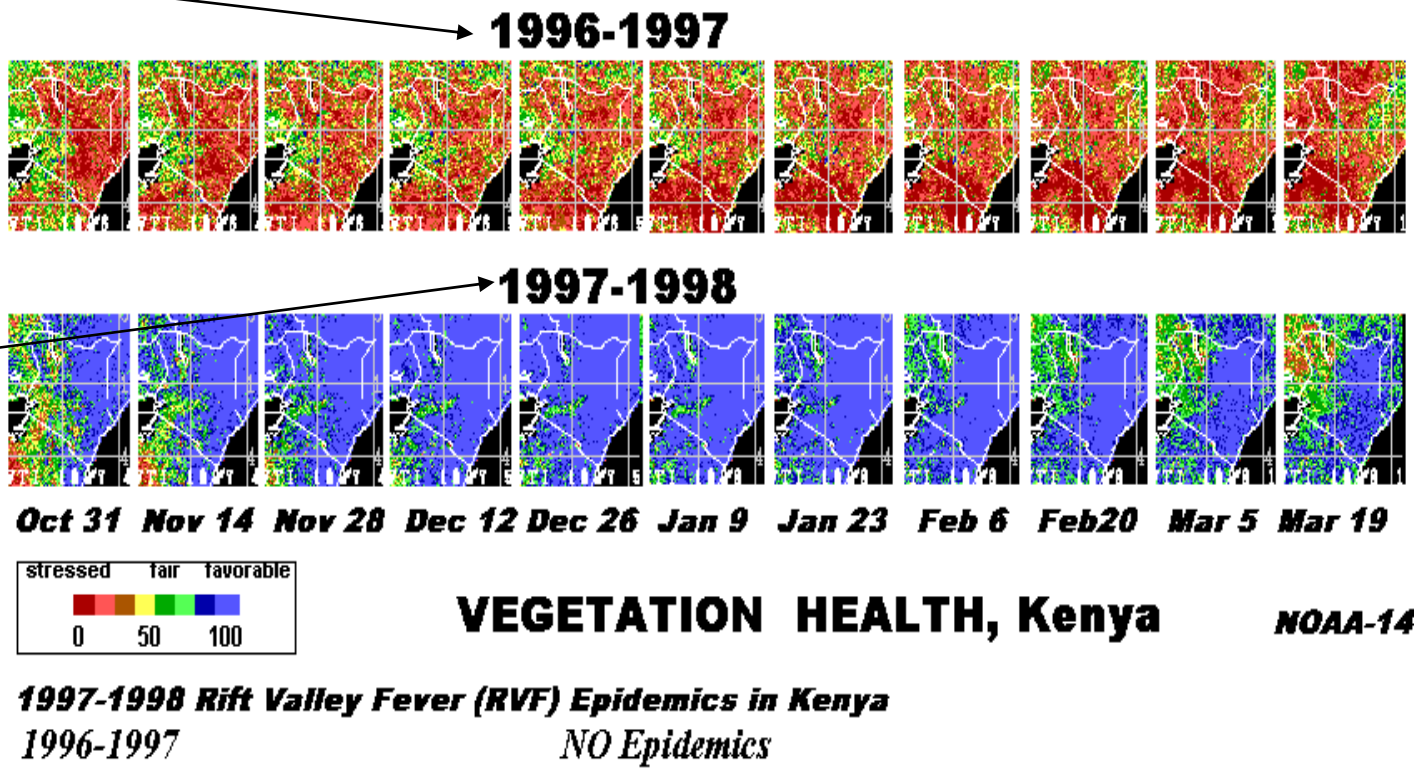
KENYA: RVF (Rift Valley Fever) & Vegetation Health (VH)

1996-97

VH<20 - Severe DROUGHT – NO RVF epidemics

1997-98

VH>80 - FAVORABLE condition – Intensive RVF epidemics

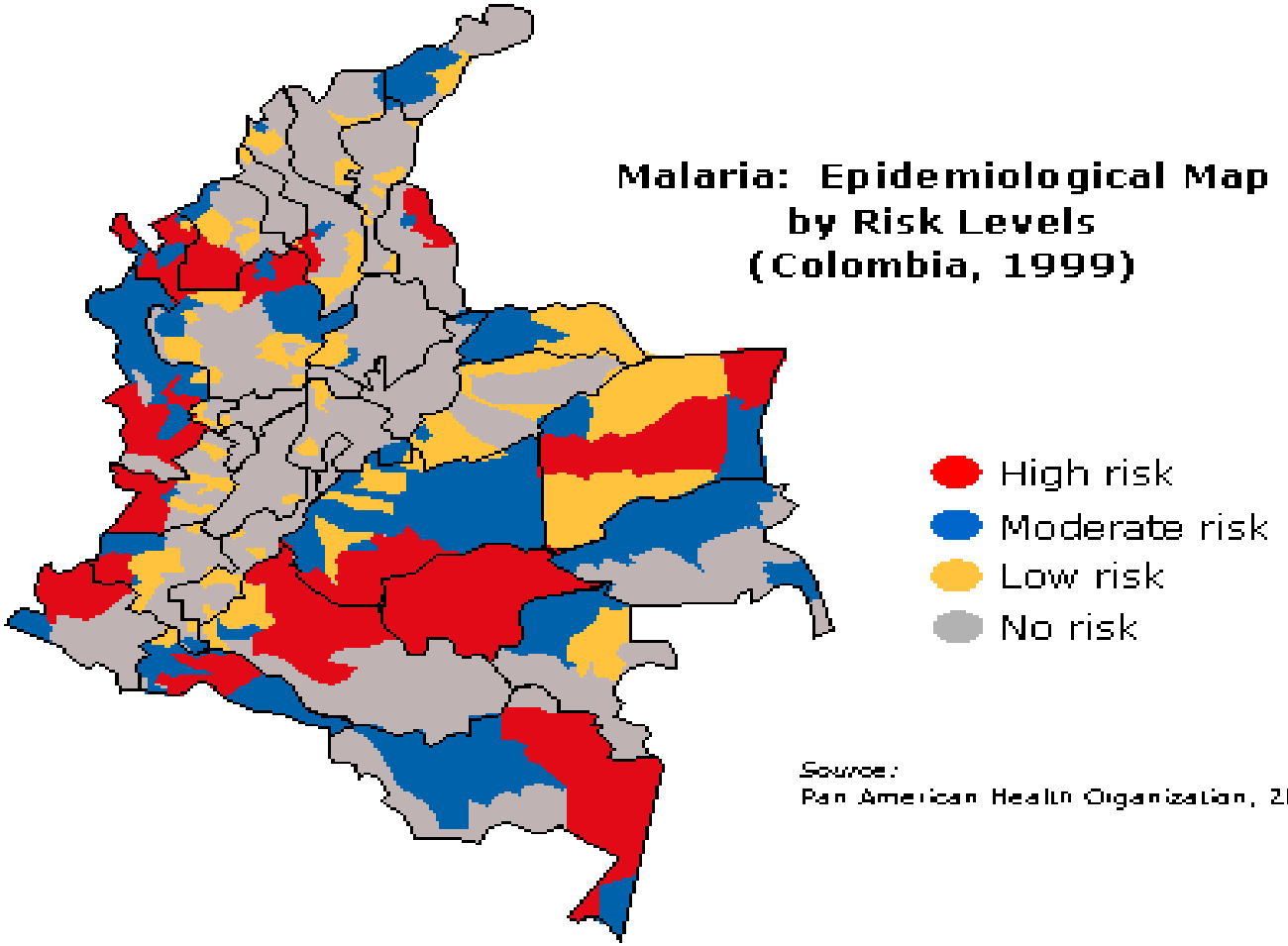


1997-1998 Rift Valley Fever (RVF) Epidemics in Kenya

1996-1997 *NO Epidemics*

NOAA has capability to identify & monitor other mosquito-born diseases

Challenges in Monitoring Malaria
COLOMBIA



Satellite data are proxy requiring calibration & validation

CHALLENGES in treatment

- Increasing mosquitoes resistance to insecticides
- Parasite resistance (undermine malaria control)
- Changes in mosquitoes behavior due to treatments
- Changes in ecology due to human activities
- Diminishing number of effective insecticides
- No alternatives for DDT and pyrethroids
- Limited evidence of the treatment impact

Web

http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/index.php

Thank You