Global Climate Teleconnections & Extremes: Impact on the Risk of Animal and Human Vector-Borne Disease

National Forum on Climate and Pests (NFC&P)

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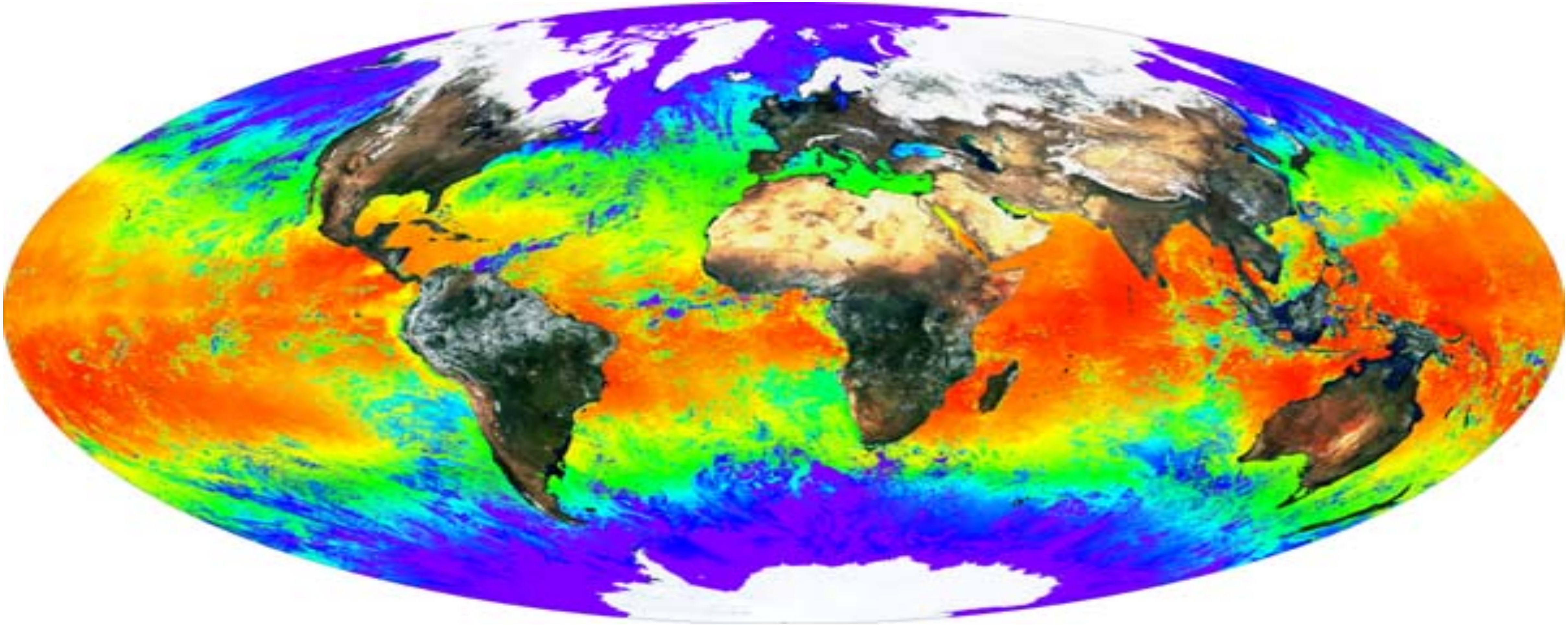
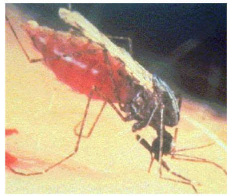
Earth's oceans serve as the engine of the earth's climate and they are closely linked with each other

Climate Change Increases Climate Variability & presents significant Challenges relative to Vector-Borne Disease



TOPICS

1. CLIMATE TELECONNECTIONS TO VECTOR BORNE DISEASES
2. FORECASTING RIFT VALLEY FEVER
3. NEAR FUTURE (2015-2016) POTENTIAL DISEASE RISKS
4. SUMMARY



1. Climate teleconnections to Vector-Borne Diseases (dengue, chikungunya, Rift Valley fever, and malaria)

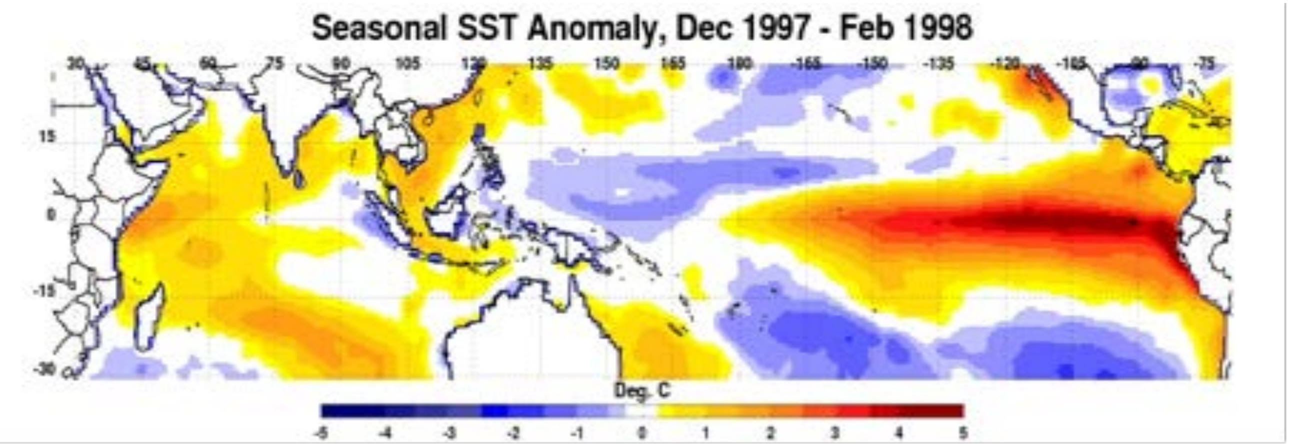
Vector-borne Disease – Climate Links

- **Building evidence suggests links between El Niño/ Southern Oscillation (ENSO) driven climate anomalies and infectious diseases, particularly those transmitted by arthropods:**
  - Murray Valley encephalitis (Nicholls 1986)
  - Bluetongue (Baylis et al. 1999)
  - **RVF (Linthicum et al. 1999)**
  - African Horse Sickness (Baylis et al 1999)
  - Ross River virus (Woodruff et al. 2002)
  - **Dengue (Linthicum et al. 2007 IOM publication)**
  - **Malaria (Bouma & Dye 1996)**
  - **Chikungunya (Chretien et al. 2006)**

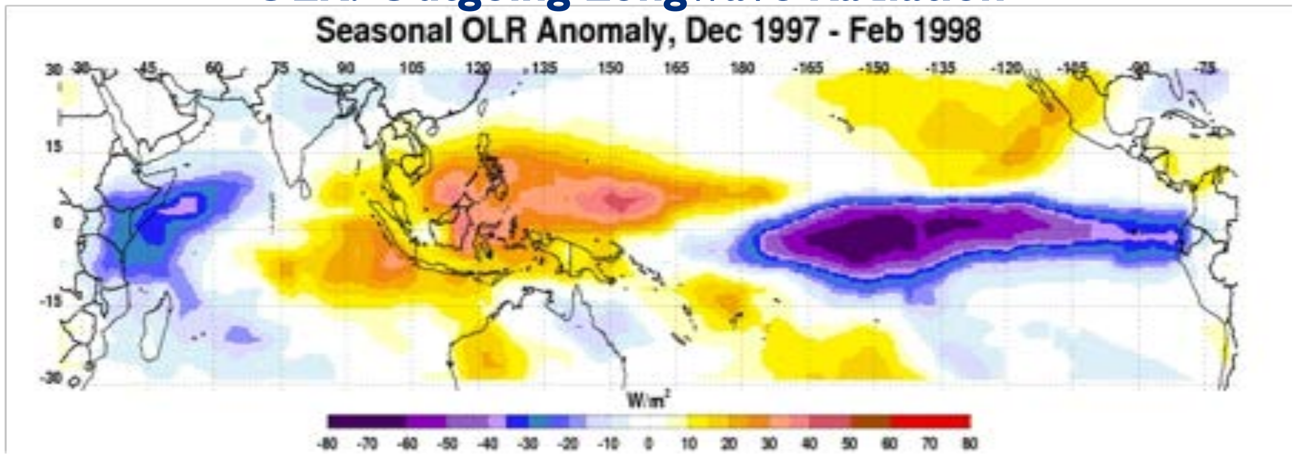
El Niño/ Southern Oscillation (ENSO)

- Influences the patterns of floods and drought on an interannual time scale.
- Extremes have an impact on the emergence, propagation and survival of disease vectors/pathogens
- Results in episodic patterns of disease outbreaks as they dance in tune with climate variability

SST: Sea Surface Temperature



OLR: Outgoing Longwave Radiation

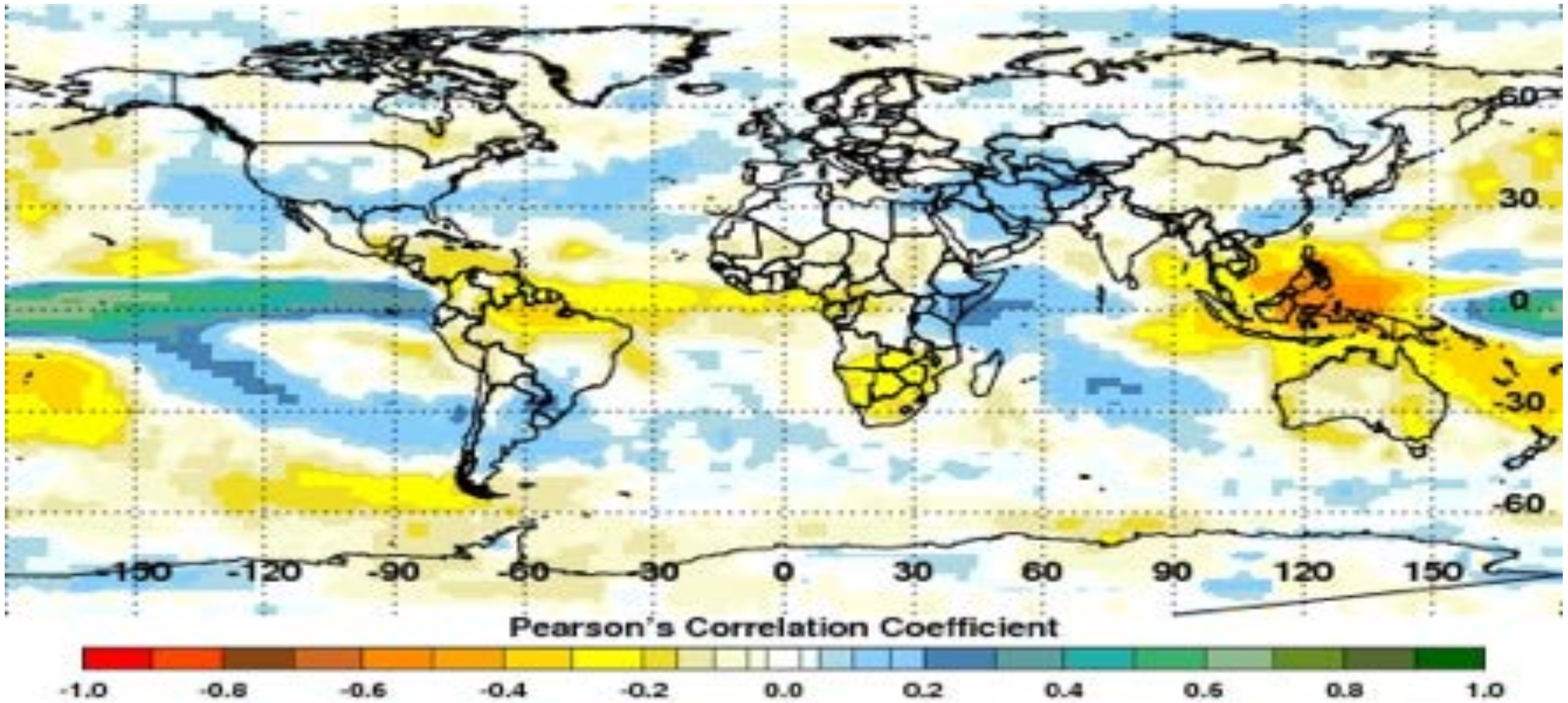


Red: Hotter/Warmer, Blue: Cold/Cooler than Normal

ENSO Teleconnections

- Differential impacts at specific regional locations around the world
- ENSO +| Floods and excess rainfall in EEA, E.E. Pacific, Southern Brazil/Argentina, Southern-tire US
- ENSO +| Drought and >+ temperatures (Southern Africa, SE Asia, NE Brazil, C Africa
- ENSO – [Largely reverse conditions)

through Global Precipitation



Green/Blue: +/Wetter Yellow/Red: -/Drier

From Anyamba et al. 2012 PLOS Neglected Tropical Diseases

Climate change/variability Impact on ecology of vectors/vector-borne diseases

A. **Temperature**

- Affect *on* ***Aedes aegypti*** **to transmit dengue** virus in Southeast Asia
- Affect on ***Ae. aegypti*** **&** ***Ae. Albopictus*** **/ chikungunya virus** in East Africa, Central Africa, South and Southeast Asia

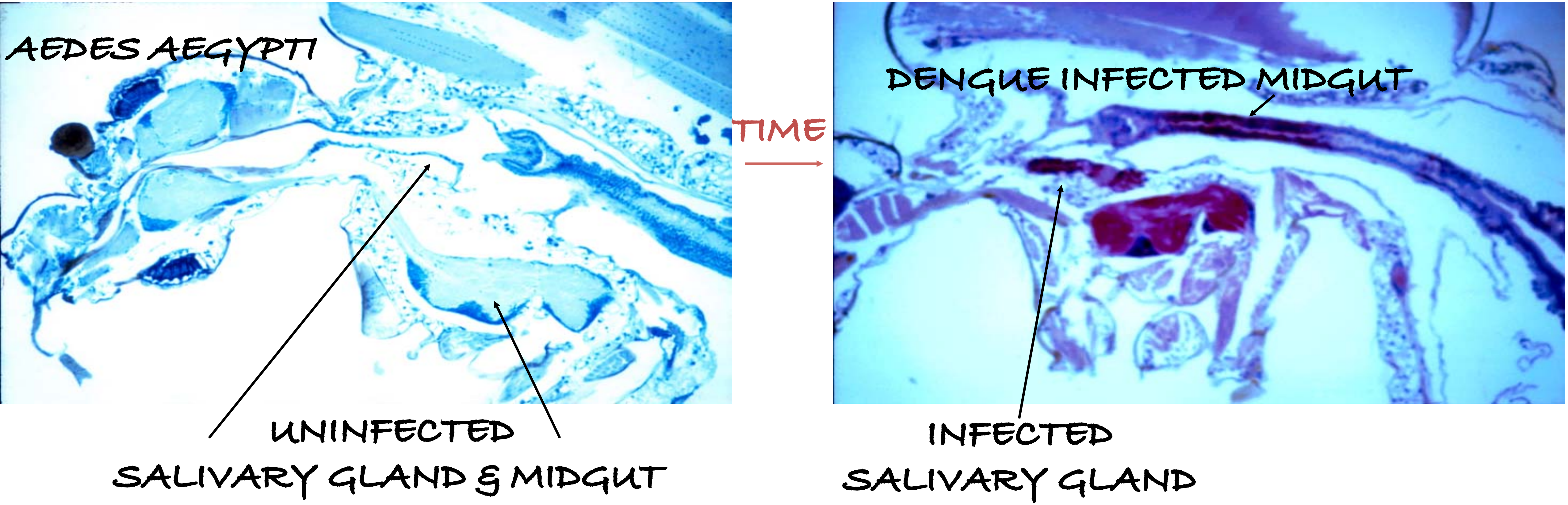
- Affect on ***Anopheles*** **species/** ***P. vivax*** malaria in Republic of Korea

B. **Rainfall**

- Affect on ***Aedes*** **and** ***Culex*** **to transmit Rift Valley fever** in sub-Saharan Africa

A. Temperature

- Vectorial competence is dependent upon the Extrinsic incubation (EI) period
- EI = time from virus ingestion to virus in Salivary Gland
- Shorter EI period (higher ambient temperature) = greater vectorial competence



Vectorial Capacity[1]

$$C = \frac{(HA)AP^N}{-\ln P}$$

HA = daily human-biting rate

A = daily rate of blood feeding

P = daily rate of survival

N = length of sporogonic cycle (extrinsic incubation cycle)

[1]GARRETT-JONES AND SHIDRAWI 1969

A. Temperature (dengue)

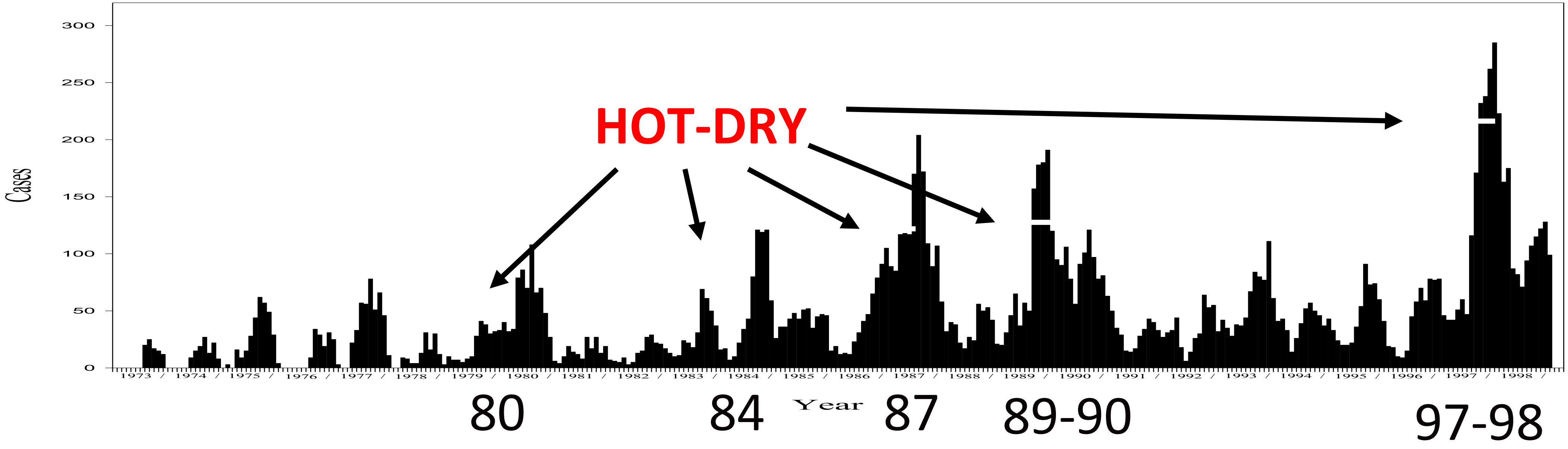
- *Aedes aegypti* mosquitoes transmit dengue virus

- Dengue virus infection produces classical dengue, DHF and DSS
- In Southeast Asia dengue is hyperendemic
- DHF is reported, classic dengue is not

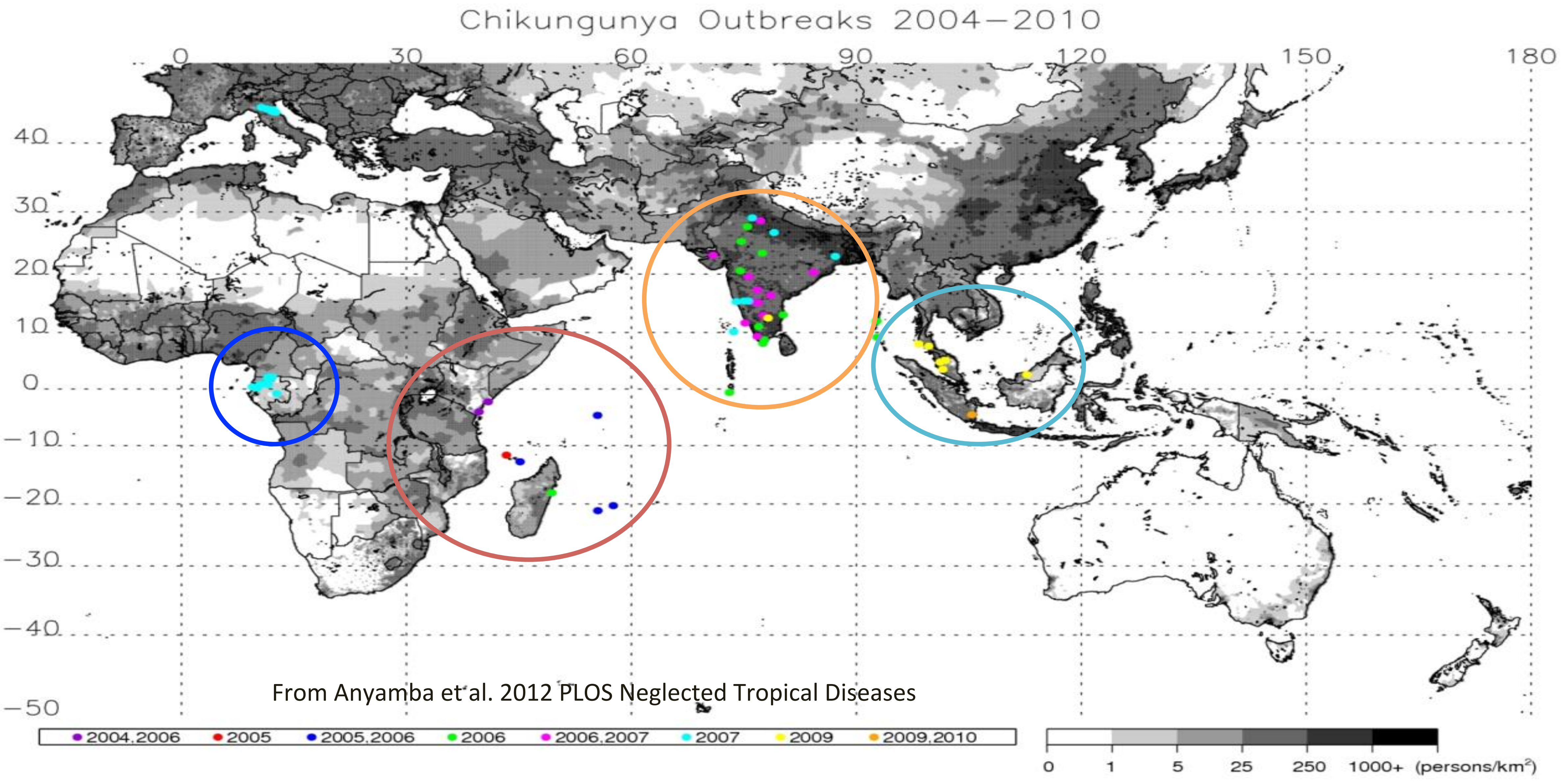
Dengue Summary

- Hot -dry periods precede elevated DHF
- Elevated DHF is likely the result of short Extrinsic Incubation period in mosquito

Figure Three: Seasonal Distribution of Serologically Confirmed Dengue Cases at Bangkok Children's Hospital from 1973-1998.

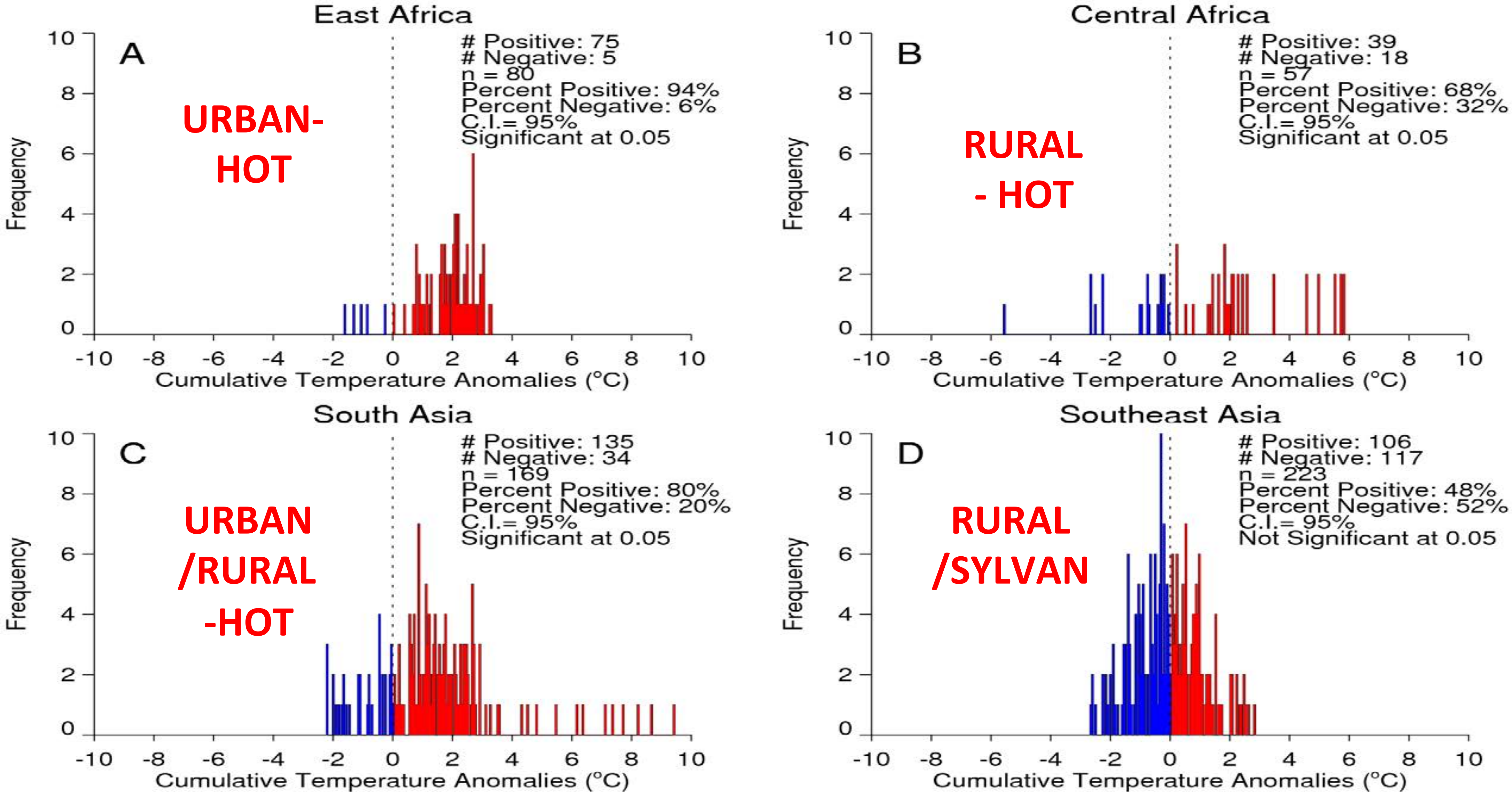


Recent chikungunya Outbreaks in Relation to Human Population Density

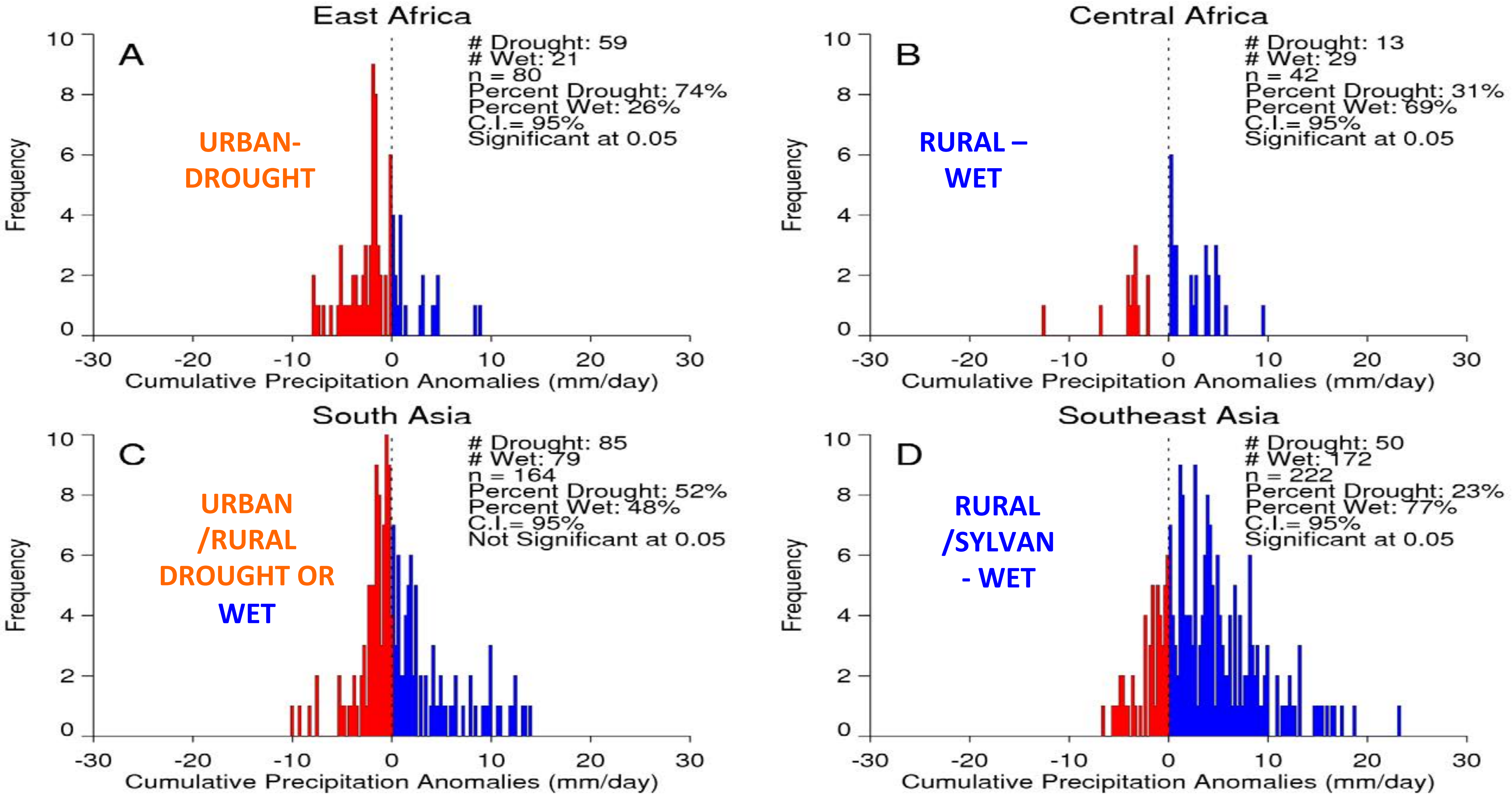


From Anyamba et al. 2012 PLOS Neglected Tropical Diseases

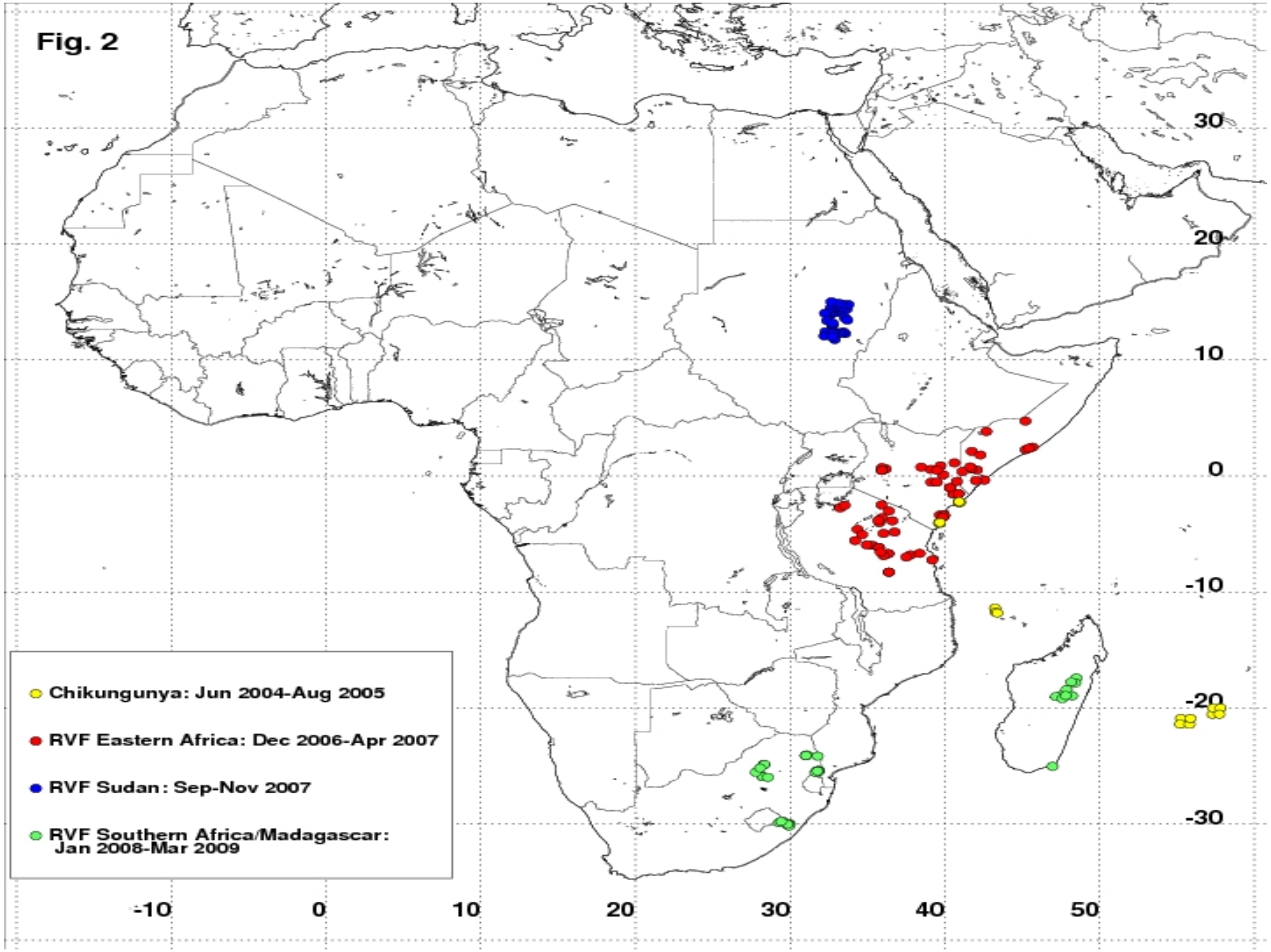
Impact of **Temperature** on Chikungunya Outbreaks (2004-2010)



Impact of **Drought** on Chikungunya Outbreaks (2004-2010)

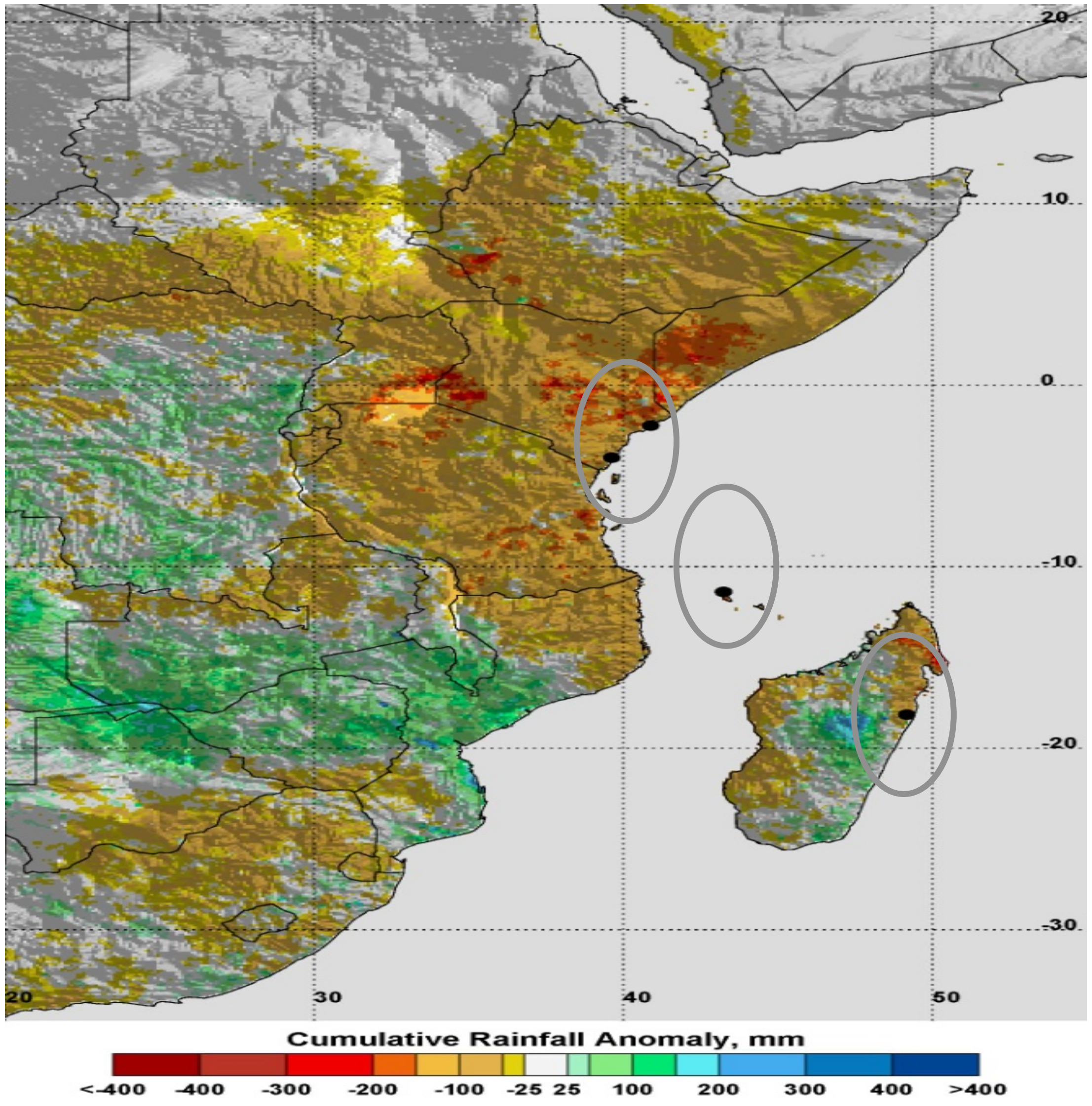


Geographic distribution of recent outbreak clusters of chikungunya (2004-2006) and Rift Valley fever (2006 – 2009) over Africa and the Indian Ocean islands



RAINFALL ANOMALIES: OCT-DEC 2005

Rainfall anomalies for Eastern Africa showing the large-scale regional drought during the period October – December 2005. Anomalies are calculated with reference to the 1995-2000 base mean period. Epicenters of **chikungunya** outbreaks during this period are shown by black dots



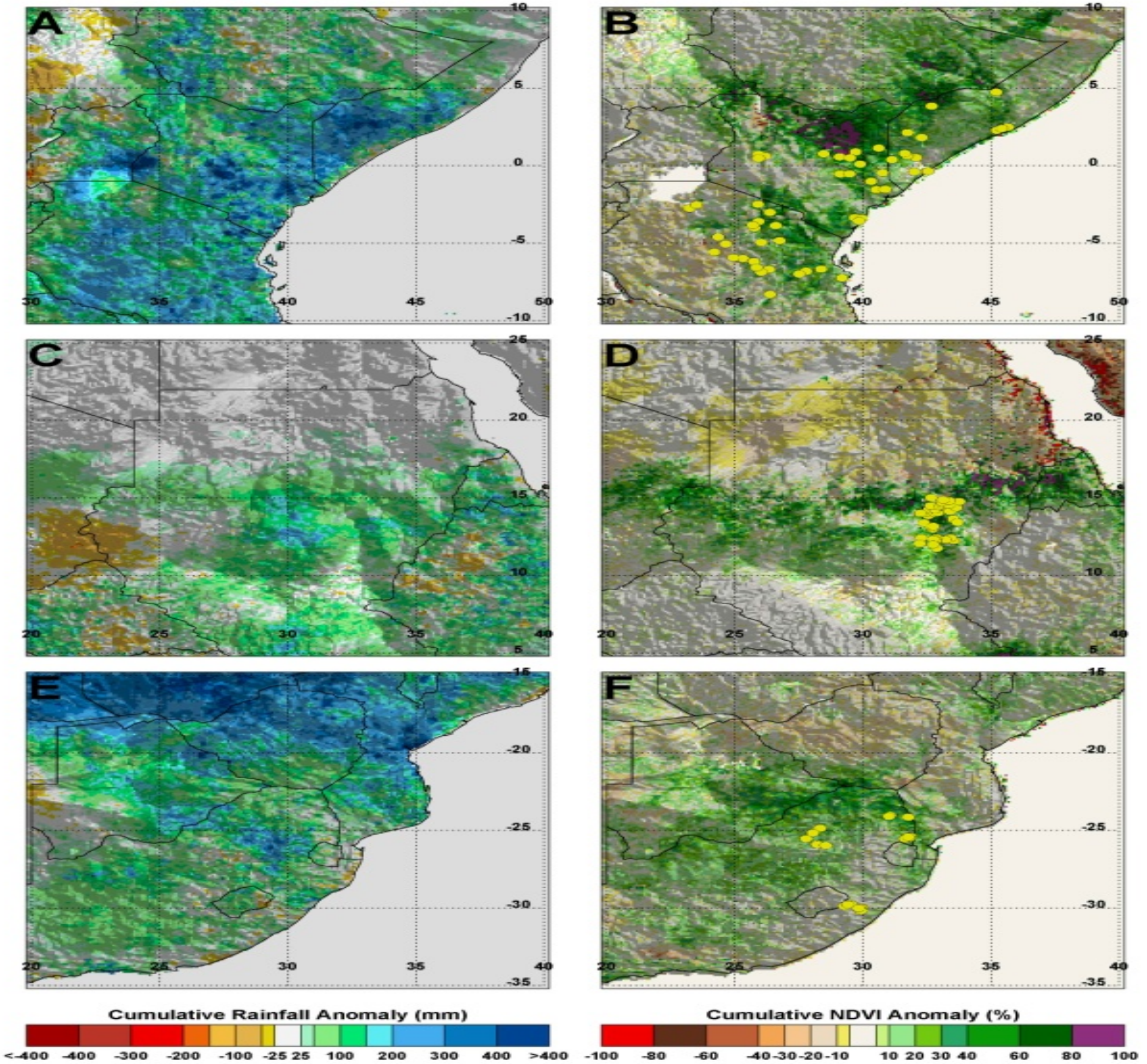
RAINFALL AND NDVI ANOMALIES: 2006-2008

EAST AFRICA

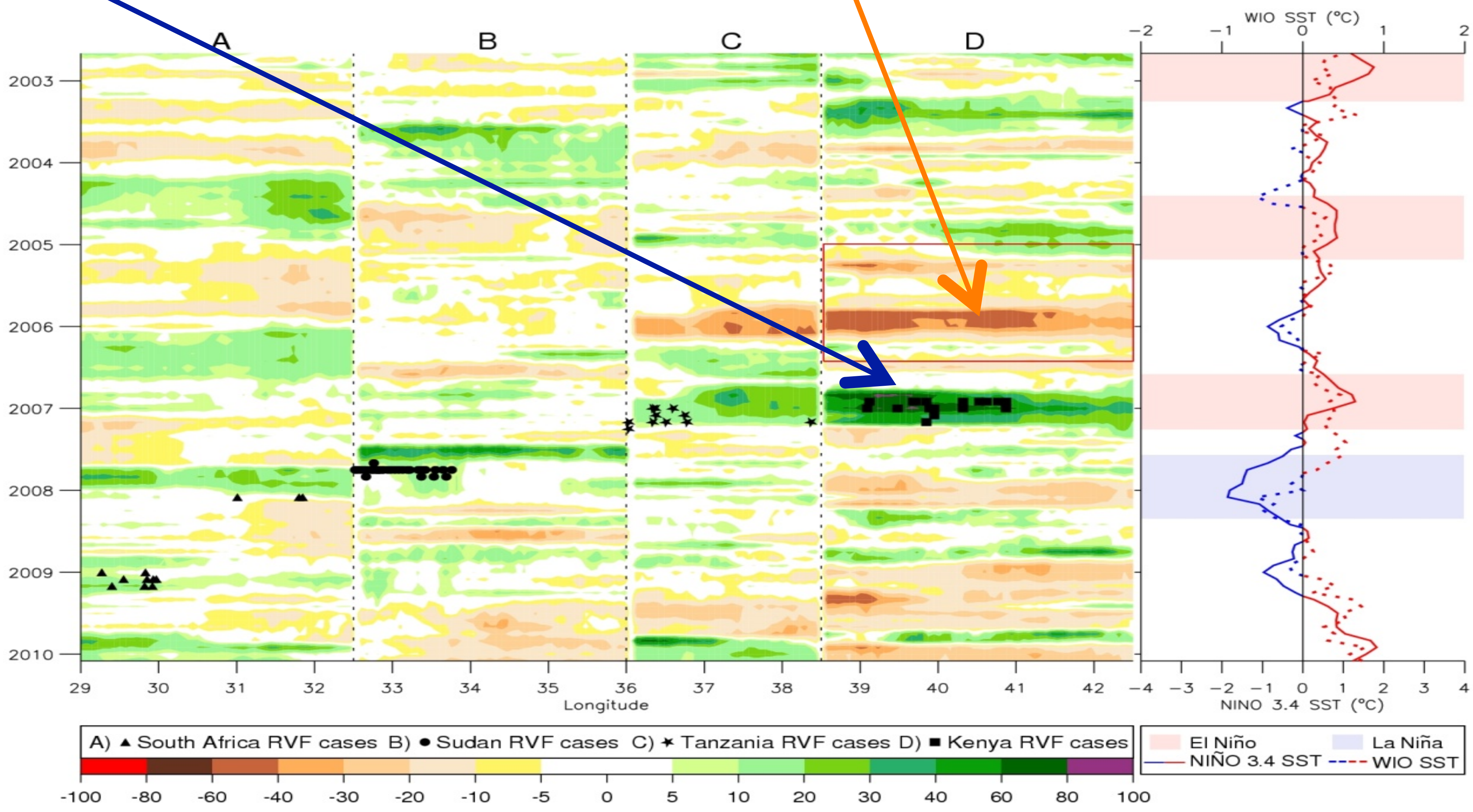
SUDA
N

SOUTHERN
AFRICA

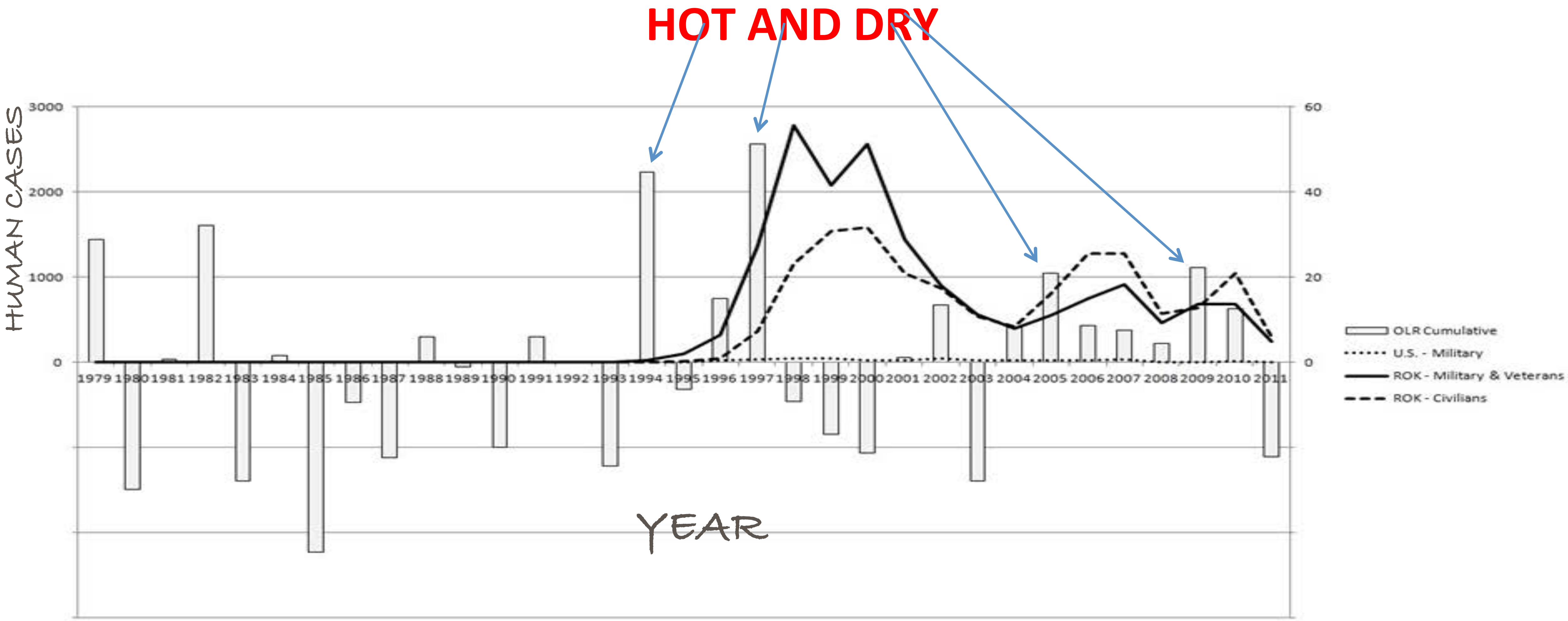
Cumulative rainfall anomaly and vegetation index anomalies patterns preceding outbreaks **of Rift Valley fever** in **East Africa:** September 2006 - December 2006; **Sudan**: June 2007 - September 2007, and **Southern Africa**: October 2007 - January 2008. Areas of Rift Valley fever outbreaks are marked by the yellow dots



RVF Relationship to **Wet** Conditions and Chikungunya Relationship to **Dry** Conditions

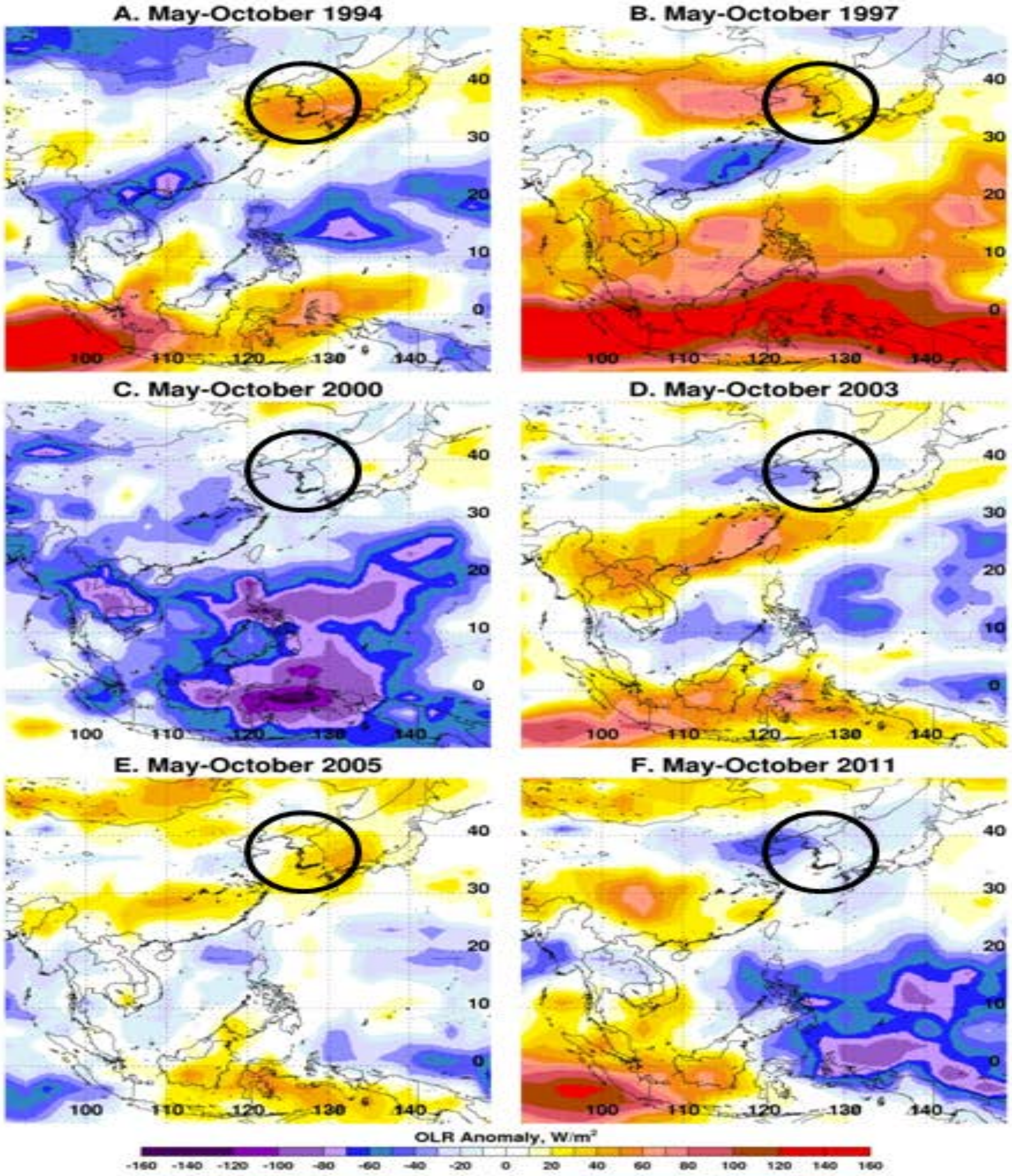


P. Vivax Malaria in Republic of Korea



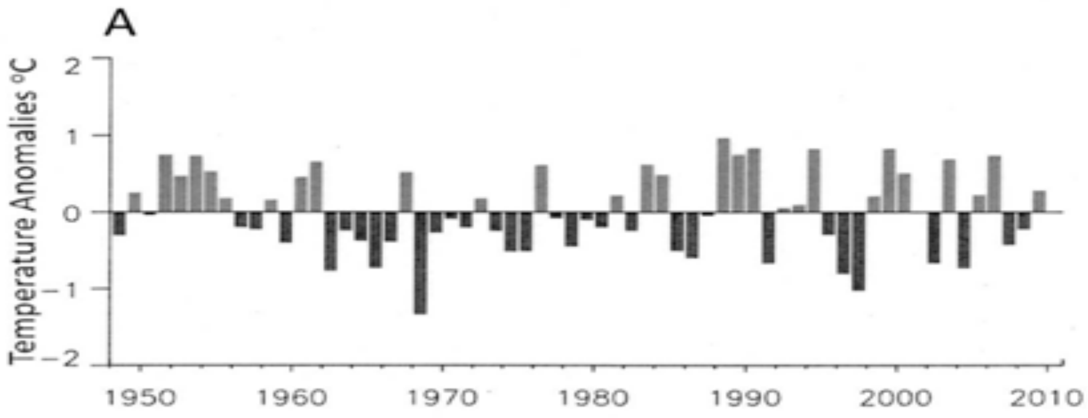
P. Vivax Malaria in ROK from 1979 – 2011 and Cumulative OLR Data

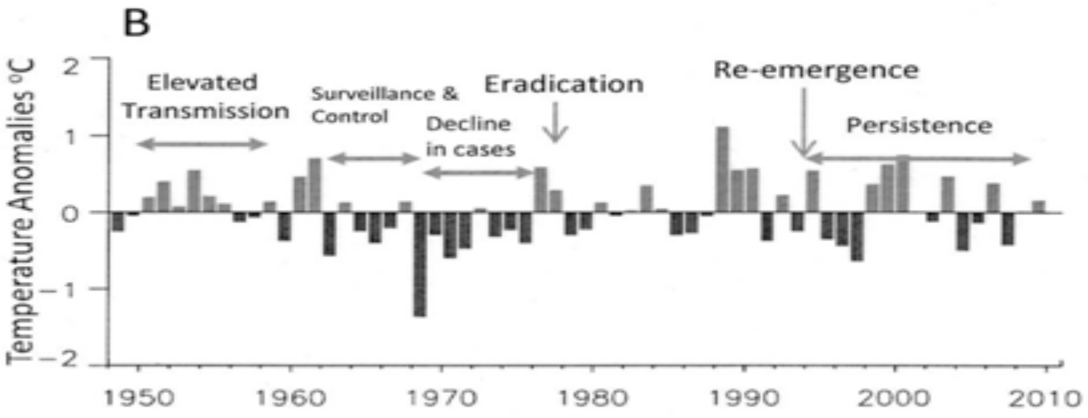
From Linthicum et al. 2014 Military Medicine


A. May-October 1994
B. May-October 1997
C. May-October 2000
D. May-October 2003
E. May-October 2005
F. May-October 2011
OLR Anomaly, W/m²
-160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160

NORTH KOREA (DPRK)

SOUTH KOREA (ROK)



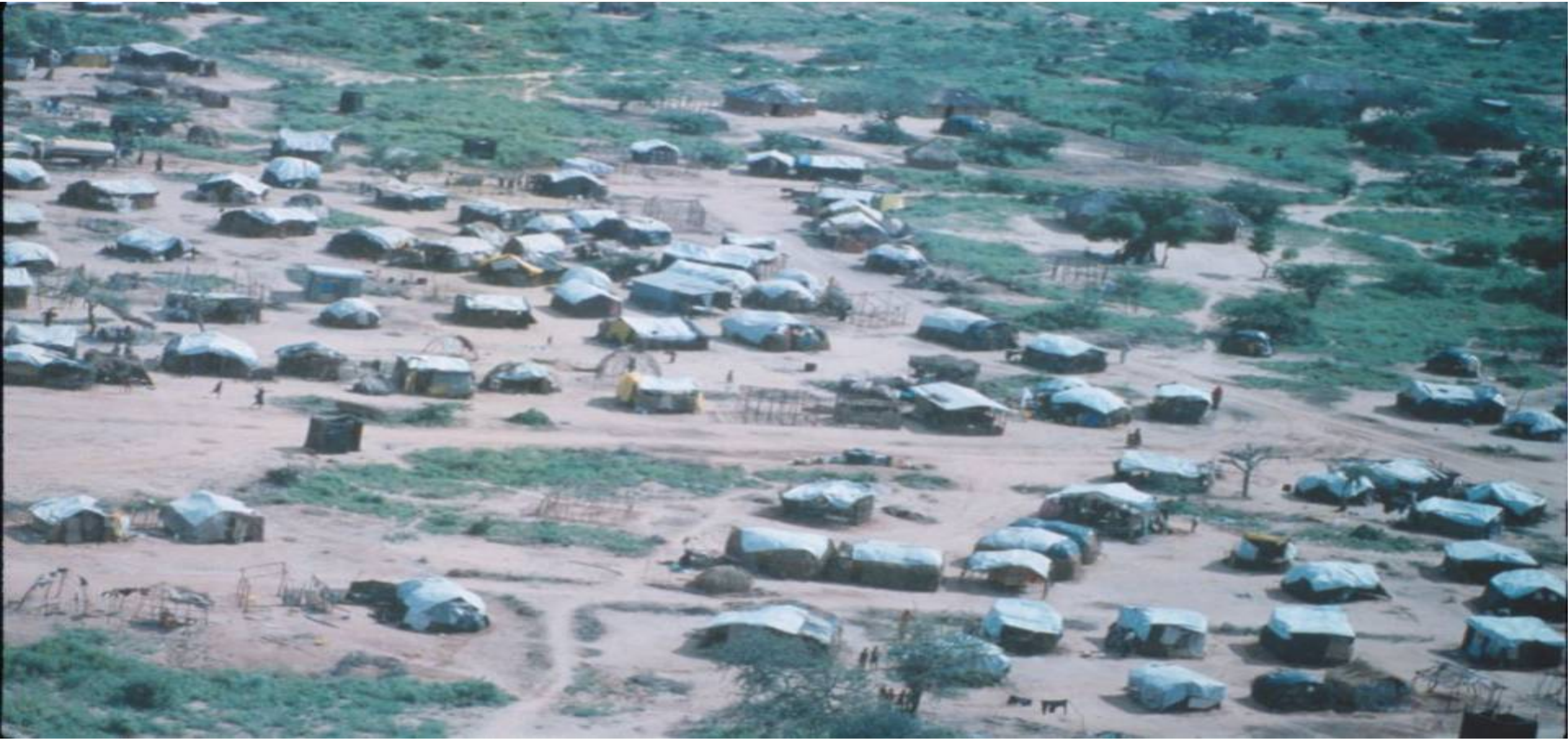


Temperature anomalies from 1950 - 2011

2. Rift Valley fever Risk Forecasting

Human Impact: Flooding near Garissa, Kenya, 1997

NOMADIC REFUGEES IN CAMP NEAR GARISSA, KENYA
1997




RIFT VALLEY FEVER
FLOODED DAMBO

Transmission







RIFT VALLEY FEVER

HERDERS LIVE ON RAW BLOOD & MILK

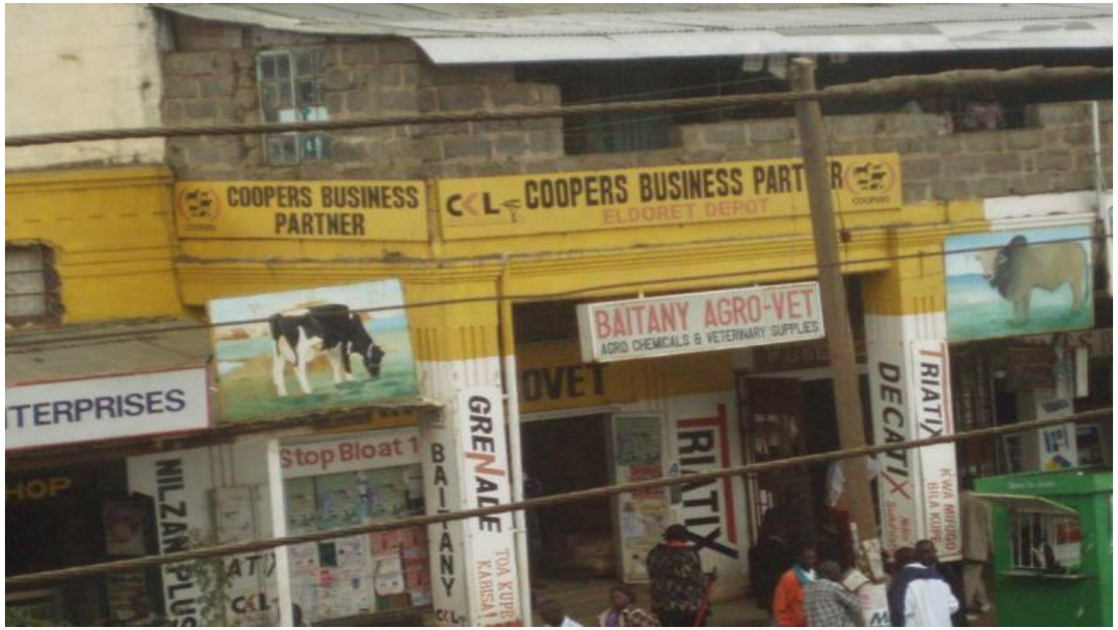
NAIVASHA, KENYA

REPORTED DISEASE ON BUFFALO FARM IN NAIVASHA

TRADE IN SHEEP PRODUCTS IMPORTANT INCOME SOURCE FOR THE RURAL COMMUNITIES.

RVF Manifestations

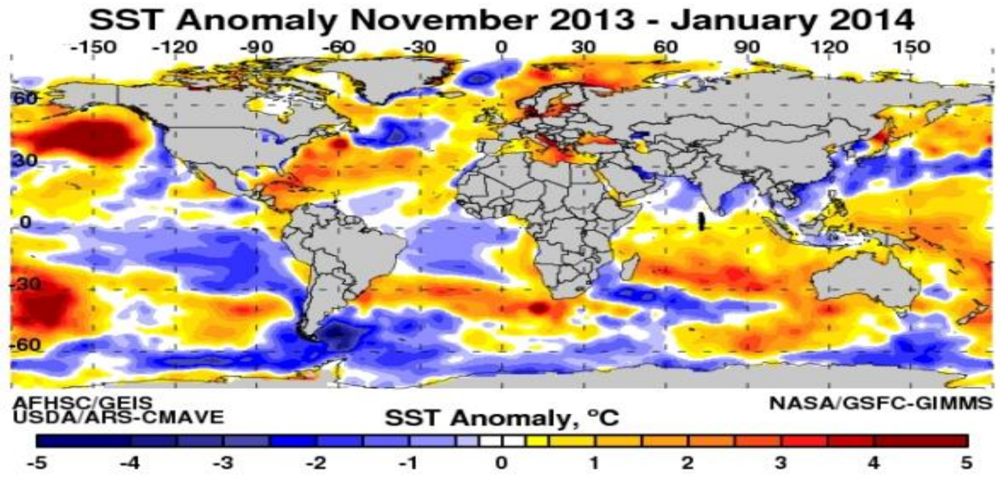
- ANOREXIA AND WEAKNESS
- LISTLESSNESS
- EVIDENT ABDOMINAL PAIN
- ABORTIONS AS HIGH AS 100% IN LAMBS
- CEREBRAL INFECTIONS
- OCULAR INFECTIONS
- HEMORRHAGIC FEVER WITH MARKED HEPATITIS AND BLEEDING MANIFESTATIONS
- COMMON BLEEDING MANIFESTATIONS INCLUDE GASTROINTESTINAL BLEEDING
- NEUROLOGIC SYMPTOMS INCLUDE CONFUSION, LETHARGY, TREMORS, ATAXIA, COMA, SEIZURES E.T.C

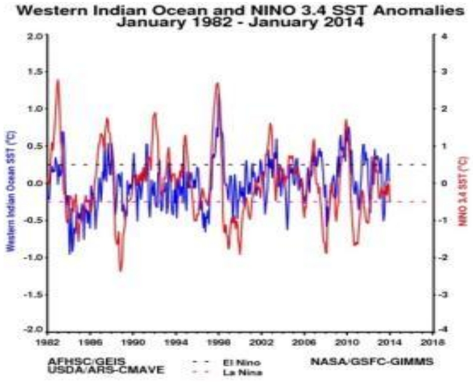



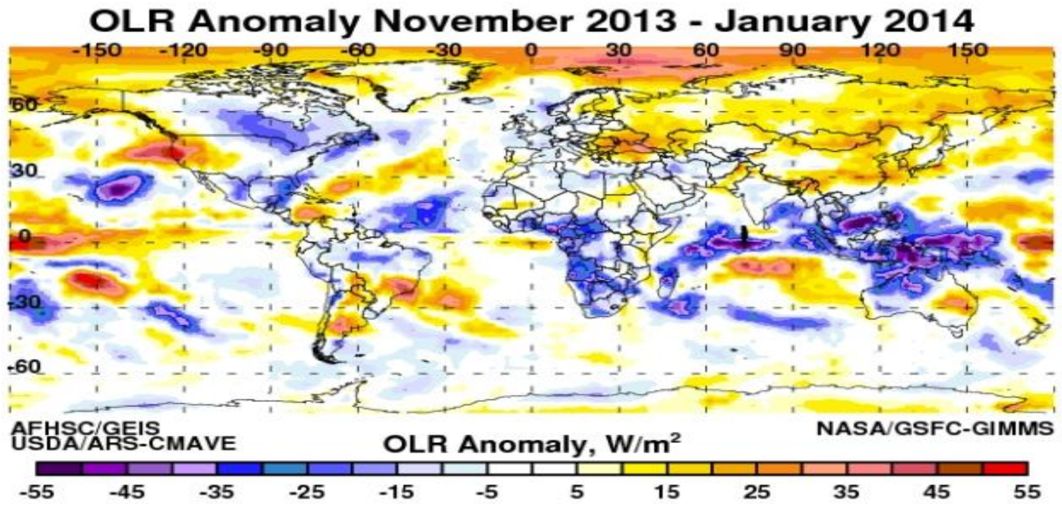
THE GREAT RIFT DIVIDE – BEEF CONSUMPTION IN WESTERN RIFT REGION NORMAL, BARN IMPOSED IN THE EASTERN RIFT REGION, REDUCED BEEF CONSUMPTION, PRICE INCREASE FOR CHICKEN, FISH. CERTIFIED BEEF AVAILABLE FOR CONSUMPTION ONLY FROM KENYA MEAT COMMISSION (KMC)

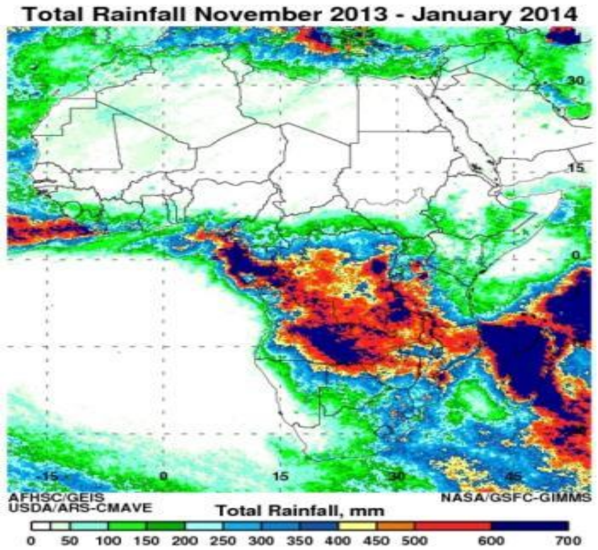
HTTP://WWW.ARS.USDA.GOV/BUSINESS/DOCS.HTM?DOCID=23464

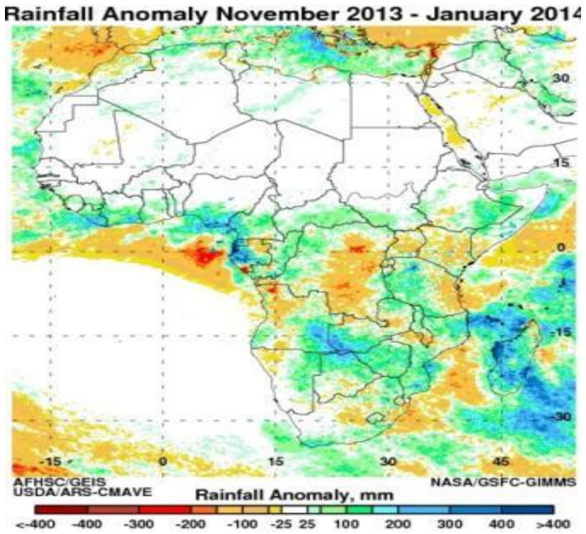
Rift Valley fever MONITOR

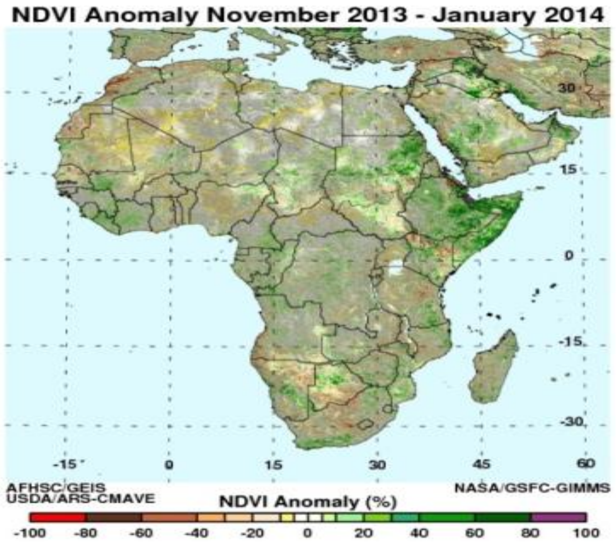


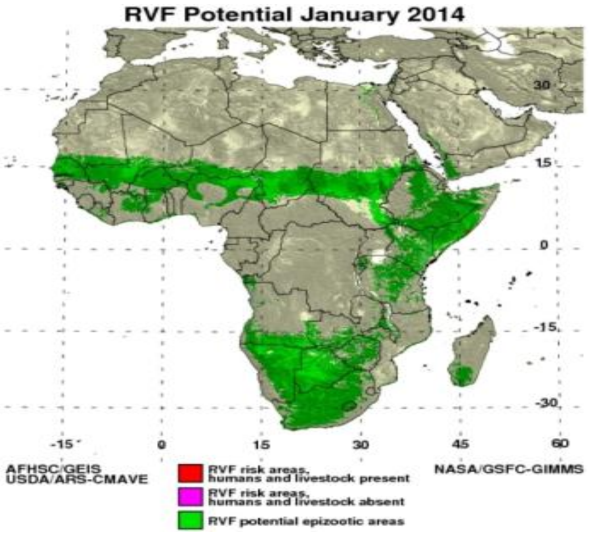




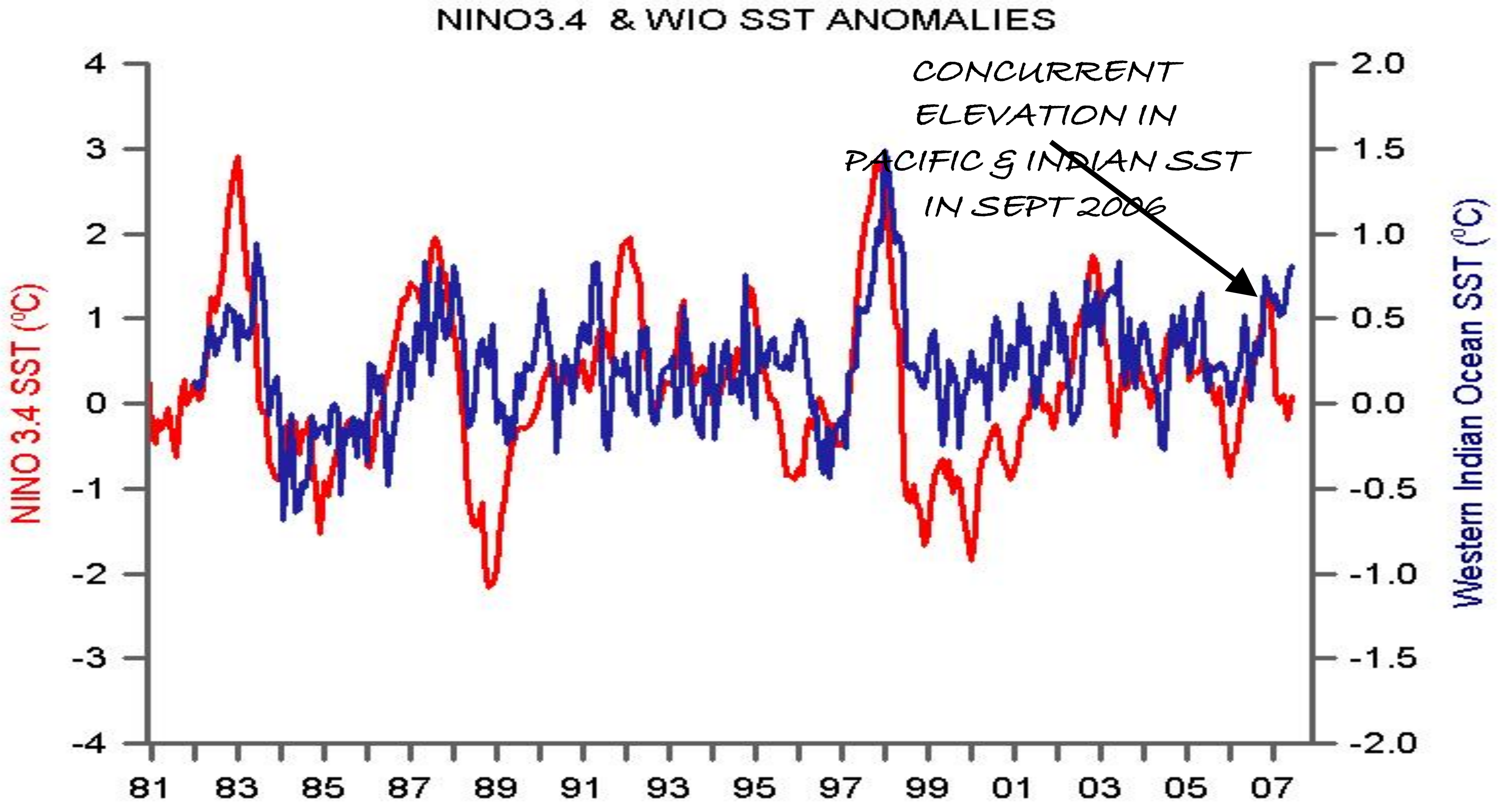




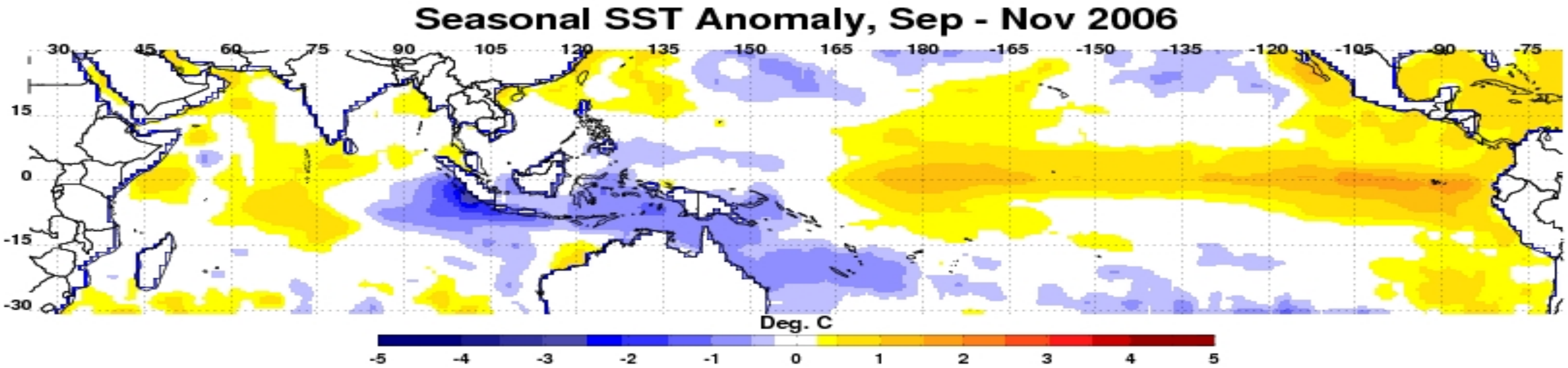


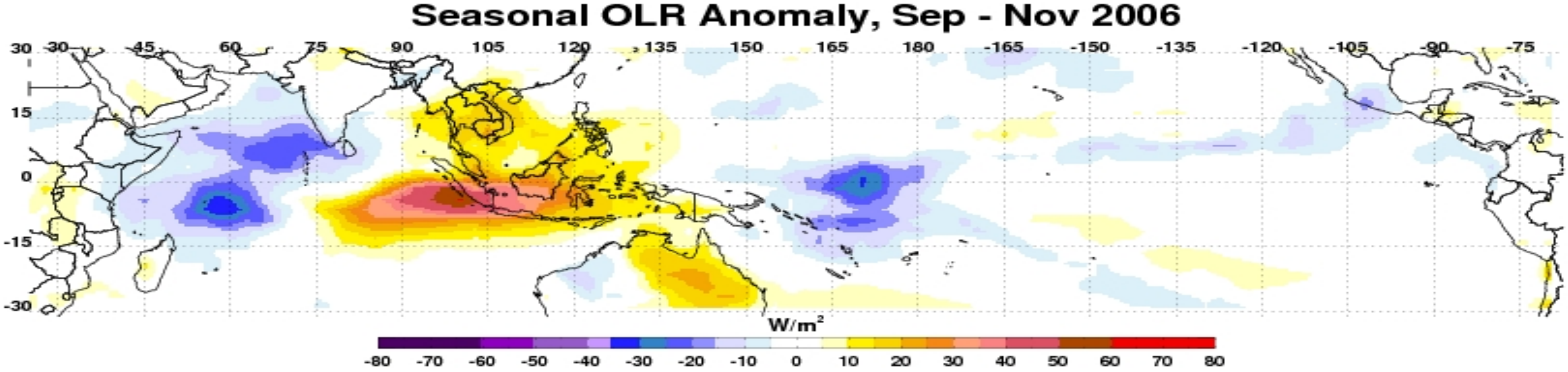


Prediction of Rift Valley fever
SST Time Series

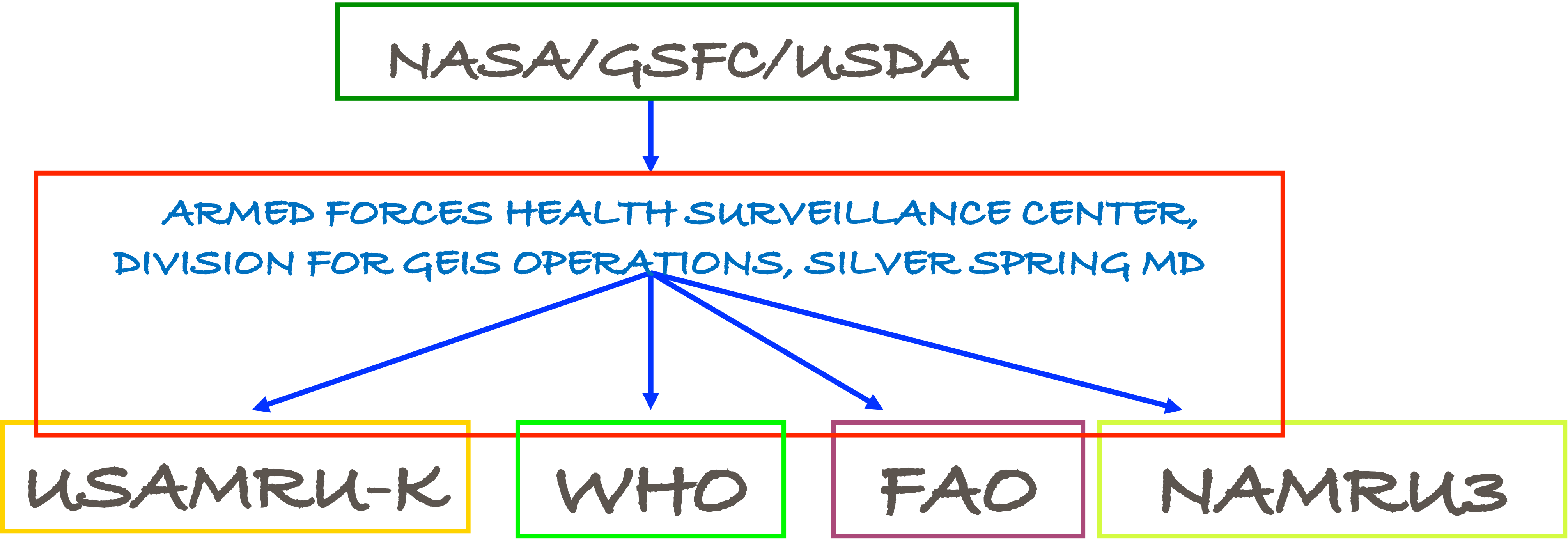


Successfully Used Remotely Sensed Satellite Global Climate Data to Predict 4 Rift Valley Fever Outbreaks in Livestock and Humans in Africa 2006-2009





INFORMATION DISSEMINATION INFRASTRUCTURE



REGIONS & COUNTRIES

EARLY WARNINGS – INCREMENTAL MONTHLY PUBLIC DOMAIN, ALERTS – CUSTOMIZED E.G. EMPRES

FAO Alerts: Emergency Prevention System (EMPRES) for Transboundary Animal and Plant Pests and Diseases

EMPRES WATCH

emergency prevention systems

Possible RVF activity in the Horn of Africa

1. Introduction

Rift Valley fever (RVF) is an arthropod-borne viral disease of ruminants, camels and humans. It is a significant zoonosis which may present itself from an uncomplicated influenza-like illness to a haemorrhagic disease with severe liver involvement and ocular or neurological lesions. In animals, RVF may be unapparent in non-pregnant adults, but outbreaks are characterised by the onset of abortions and high neonatal mortality. Transmission to humans may occur through close contact with infected material (slaughtering or manipulation of runts), but the virus (Phlebovirus) is transmitted in animals by various arthropods including 6 mosquito genus (*Aedes, Culex, Mansonia, Anopheles, Coquillettidia* and *Eretmapodites*) with more than 30 species of mosquitoes recorded as infected and some of them been proved to have a role as vectors. Most of these species get the infection by biting infected vertebrates, yet some of these (specifically *Aedes* species) transmit the virus to their eggs. These infected pools of eggs can survive through desiccation during months or years and restart the transmission after flooding, and then other species (*Culex* spp.) may be involved as secondary vectors.

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This vertical infection explains how the disease can persist between outbreaks.

RVF virus (RVFV) is recorded to occur from South Africa to Saudi Arabia including Madagascar, in varied bioclimatic ecotypes, ranging from wet and tropical countries such as the Gambia, irrigated regions such as the Senegal River Valley or the Nile Delta, to hot and arid areas such as Yemen or Chad. The occurrence of RVF can be endemic or epidemic, depending on the climatic and vegetation characteristics of different geographic regions. In the high rainfall forest zones in coastal and central African areas it is reported to occur in endemic cycles which are poorly understood. Currently available evidence suggests that this may happen annually after heavy rainfall, but at least every 2-3 years otherwise. In contrast, in the epidemic areas in East Africa, RVF epidemics appear at 5 to 15 year cycles. These areas are generally relatively high rainfall plateau grasslands, which may be natural or cleared from forests. In the much drier bushed Savannah grasslands and semi-arid zones, which are characteristic for the Horn of Africa, epidemic RVF has manifested itself only a few times in the past 40 years, in 1961-62, 1982-83, 1989 and in 1997-1998.

In addition the possibility exists that RVFV may spread outside traditionally endemic areas, or even out of the continent of Africa, mostly due to the large range of vectors capable of transmitting the virus and requires a level of viraemia in ruminants and humans that is sufficiently high to infect mosquitoes. Such a situation occurred following the unusual floods of 1997-1998 in the Horn of Africa countries, and subsequently the disease spread to the Arabian Peninsula in 2000.

2. Disease ecology and climatic drivers in the horn of Africa

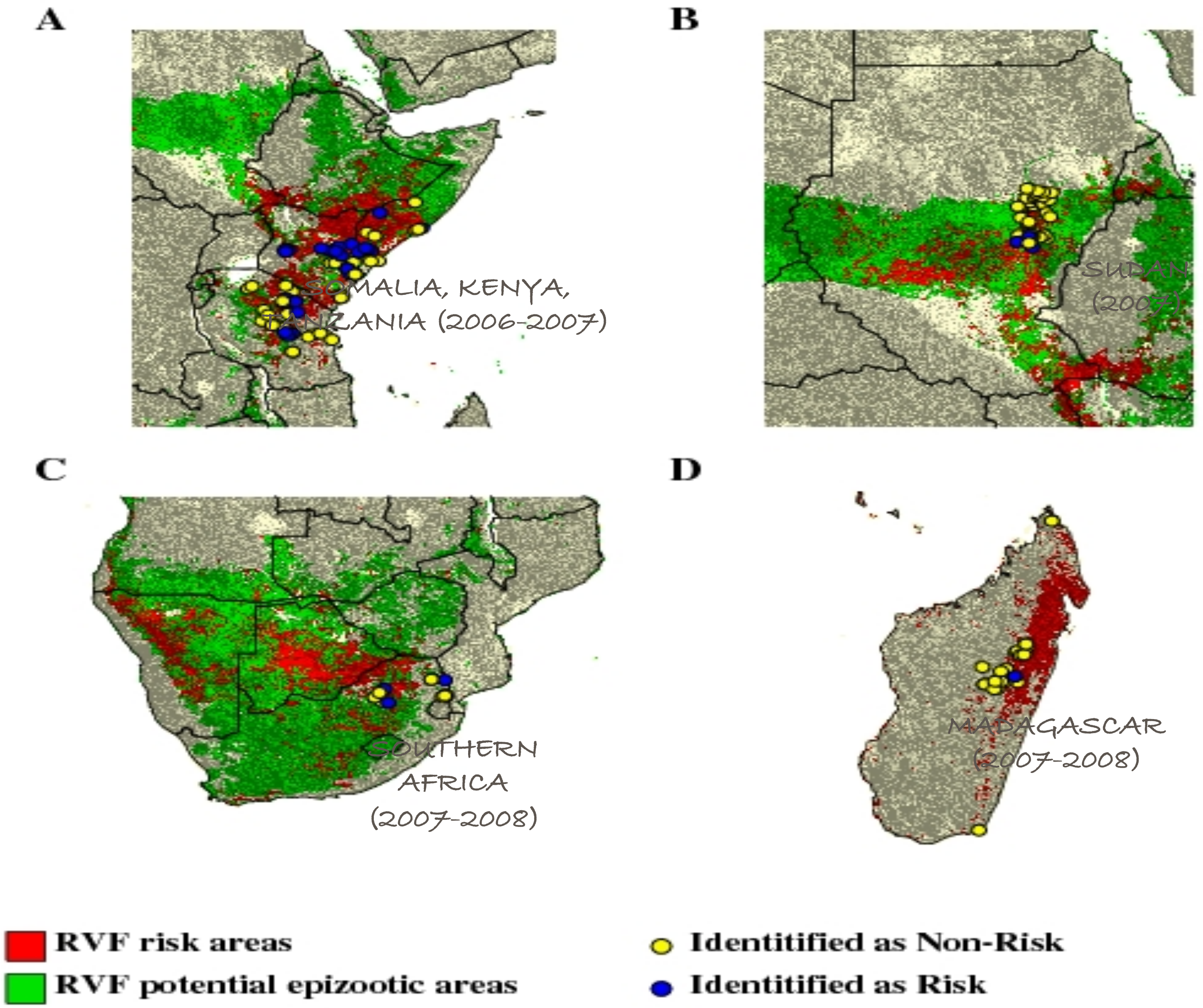
The ecology of RVF has been intensively explored in East Africa. Historical information has shown that pronounced periods of RVF virus activity in Africa have occurred during periods of heavy, widespread and persistent

HTTP://WWW.FAO.ORG/AG/AGAINFO/PROGRAMMES/EN/EMPRES/HOME.ASP

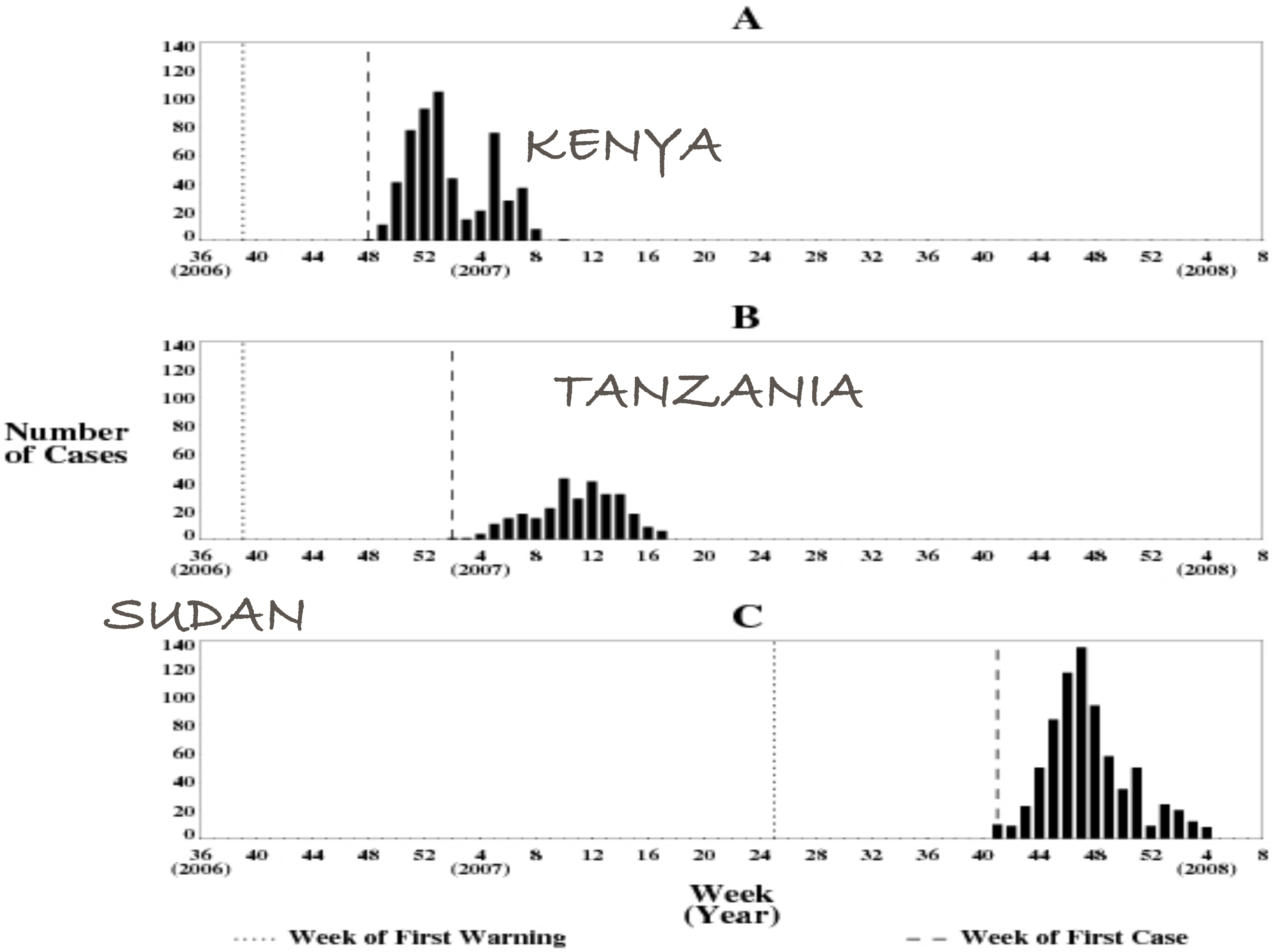
RVF Outbreaks: Human Case Data

Years	Countries	NB human cases estimates	NB human cases reported	Nb human deaths reported
2006 -07	Kenya	75,000	684	234
2006-07	Somalia	30,000	114	51
2006-07	Tanzania	40,000	264	109
2007-08	Sudan	75,000	738	230
2007-08	Madagascar	10,000	418	17
2007-09	South Africa		15	0
2008-09	Madagascar	2,500	233	4

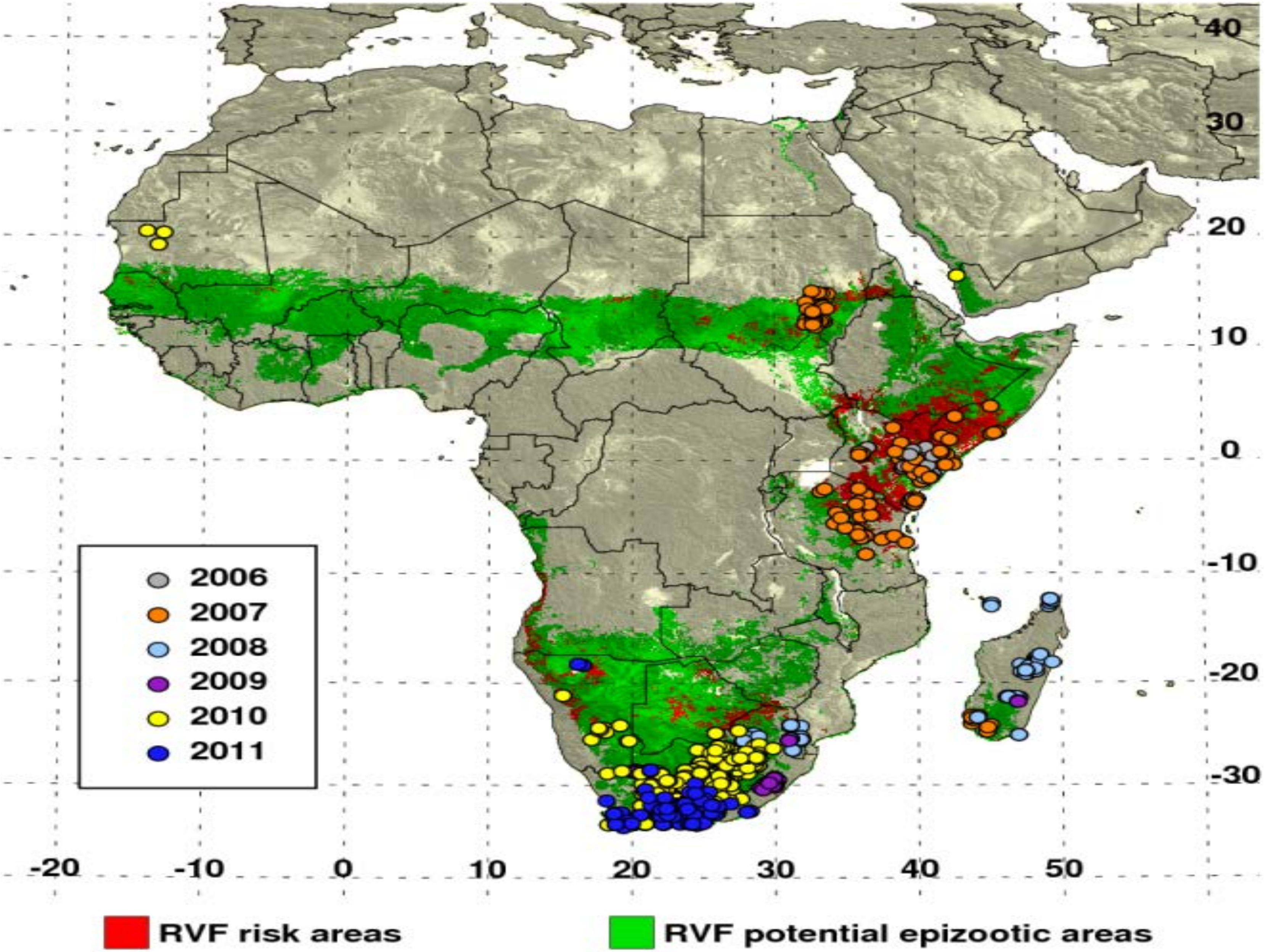
PREDICTED RIFT VALLEY FEVER RISK AREA (RED) AND ACTUAL HUMAN CASES (YELLOW AND BLUE DOTS)



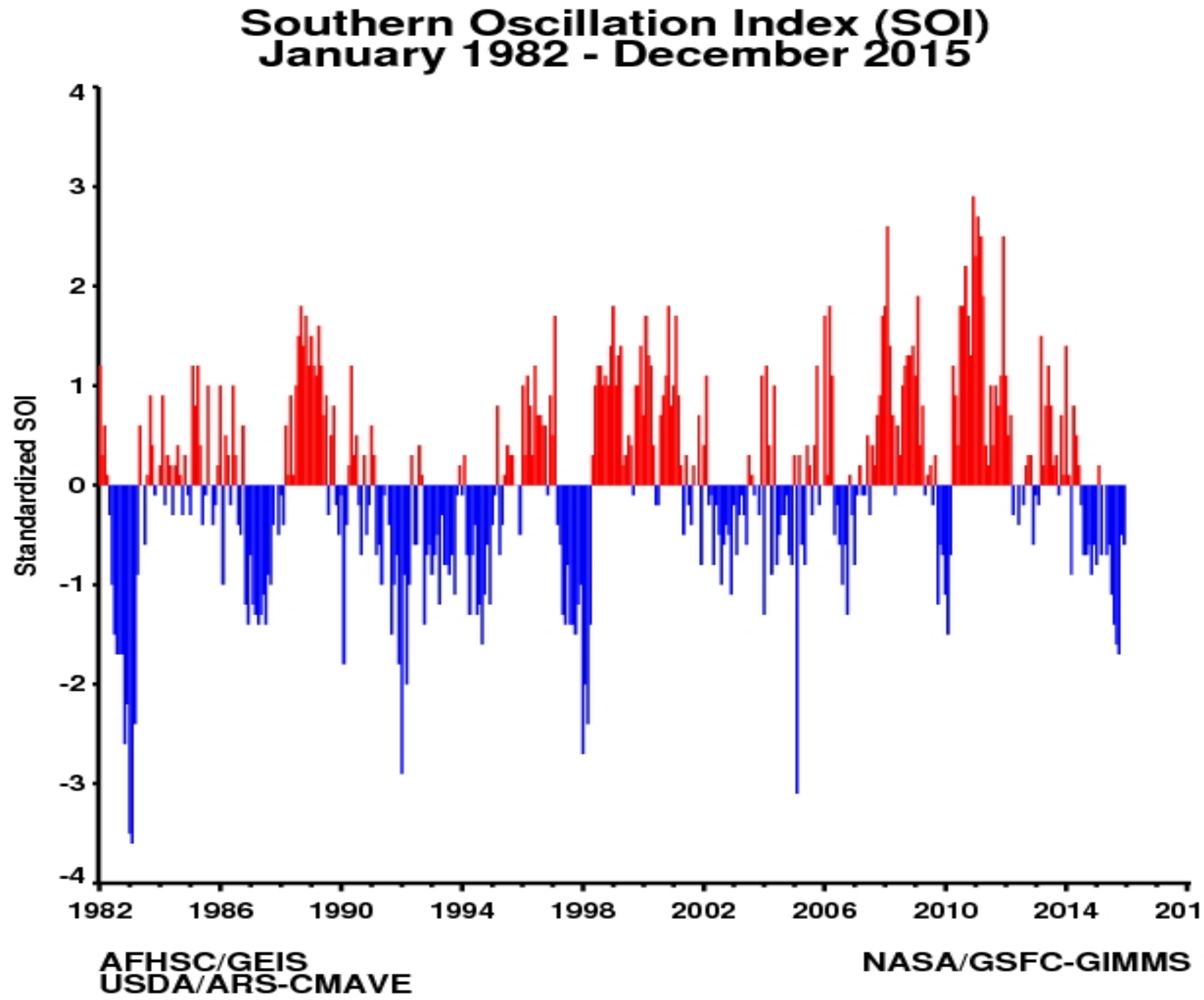
RIFT VALLEY FEVER WARNING (DOTTED LINE) 2.5-4.5 MONTHS PRIOR TO ONSET OF HUMAN CASES (DASHED LINE)

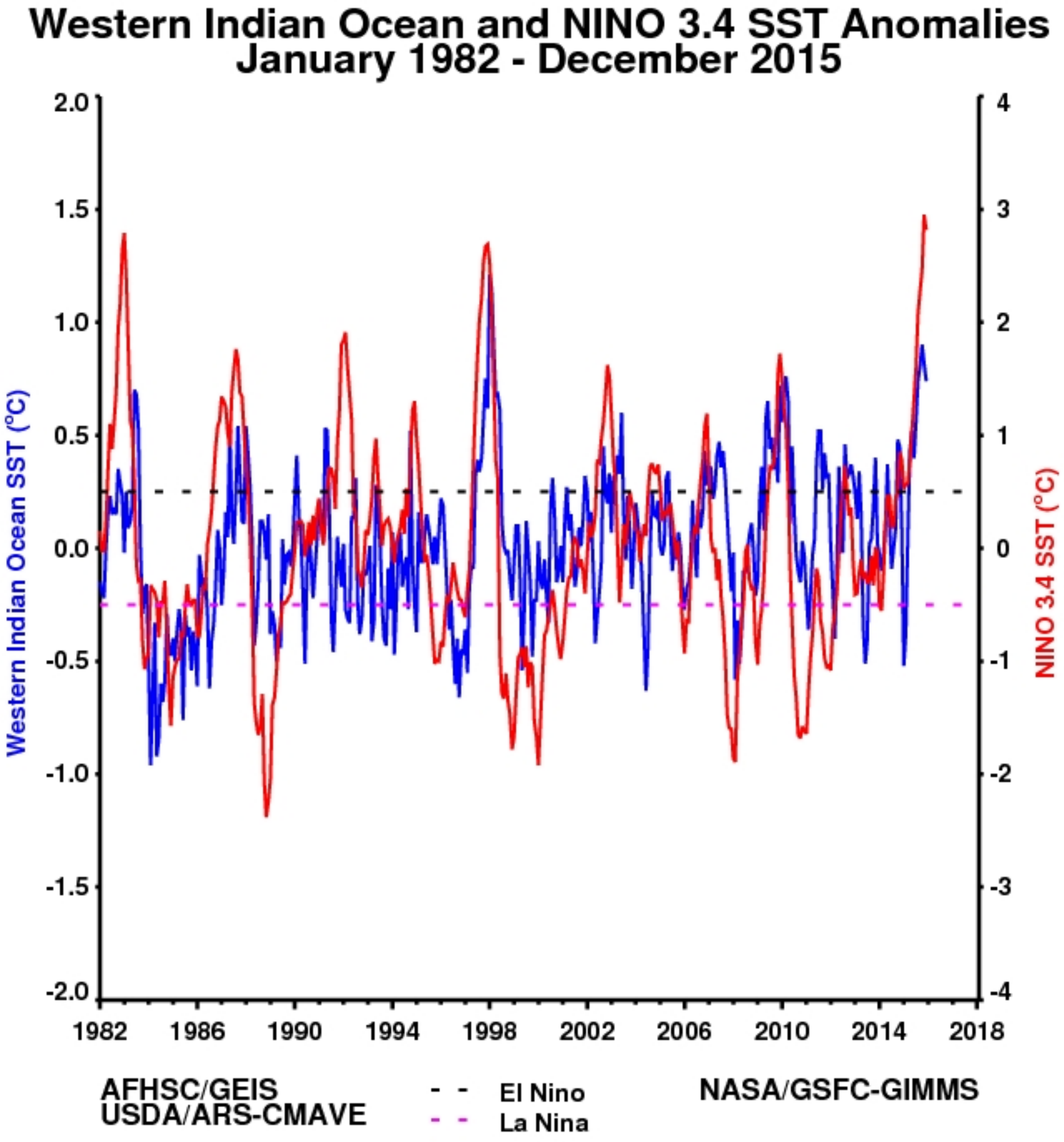


Geographic Distribution of Locations of Rift Valley fever epidemics/epizootics from 2006-2011.



3. Recent Past, Current and Near Future (2015-2016) Potential Disease Risks


Southern Oscillation Index (SOI)
January 1982 - December 2015
Standardized SOI
4
3
2
1
0
-1
-2
-3
-4
1982
1986
1990
1994
1998
2002
2006
2010
2014
2018
AFHSC/GEIS
USDA/ARS-CMAVE
NASA/GSFC-GIMMS


Western Indian Ocean and NINO 3.4 SST Anomalies
January 1982 - December 2015
Western Indian Ocean SST (°C)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
NINO 3.4 SST (°C)
4
3
2
1
0
-1
-2
-3
-4
1982
1986
1990
1994
1998
2002
2006
2010
2014
2018
AFHSC/GEIS
USDA/ARS-CMAVE
El Nino
La Nina
NASA/GSFC-GIMMS

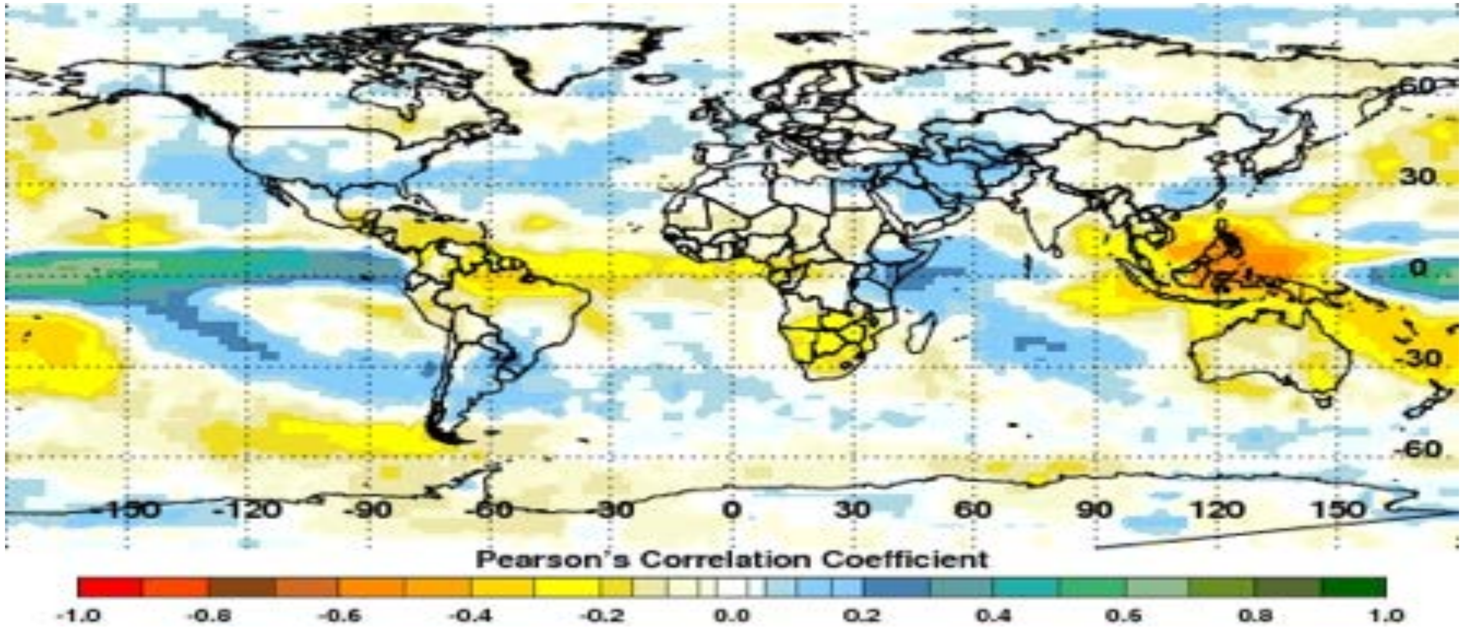
Month	**2006-2007**		**2014 - 2015**	
	WIO	**NINO3.4**	**WIO**	**NINO3.4**
April	**-0.05**	**-0.19**	**+0.10**	**-0.24**
May	**+0.21**	**+0.06**	**+0.37**	**+0.46**
June	**-0.01**	**+0.20**	**+0.10**	**+0.46**
July	-0.13	+0.13	-0.09	+0.18
August	+0.17	+0.40	-0.01	+0.20
September	+0.09	+0.62	+0.09	+0.45
October	+0.17	+0.78	+0.48	+0.49

Comparison of the evolution of Western Indian Ocean (WIO) and eastern Pacific Ocean region 3.4 (NINO3.4 SST) anomaly indices in degrees centigrade between 2006-2007 El Niño event and the currently developing 2014-2015 event. Chance of has decreased from 65% (winter to Spring 2015)

ENSO TELECONNECTIONS

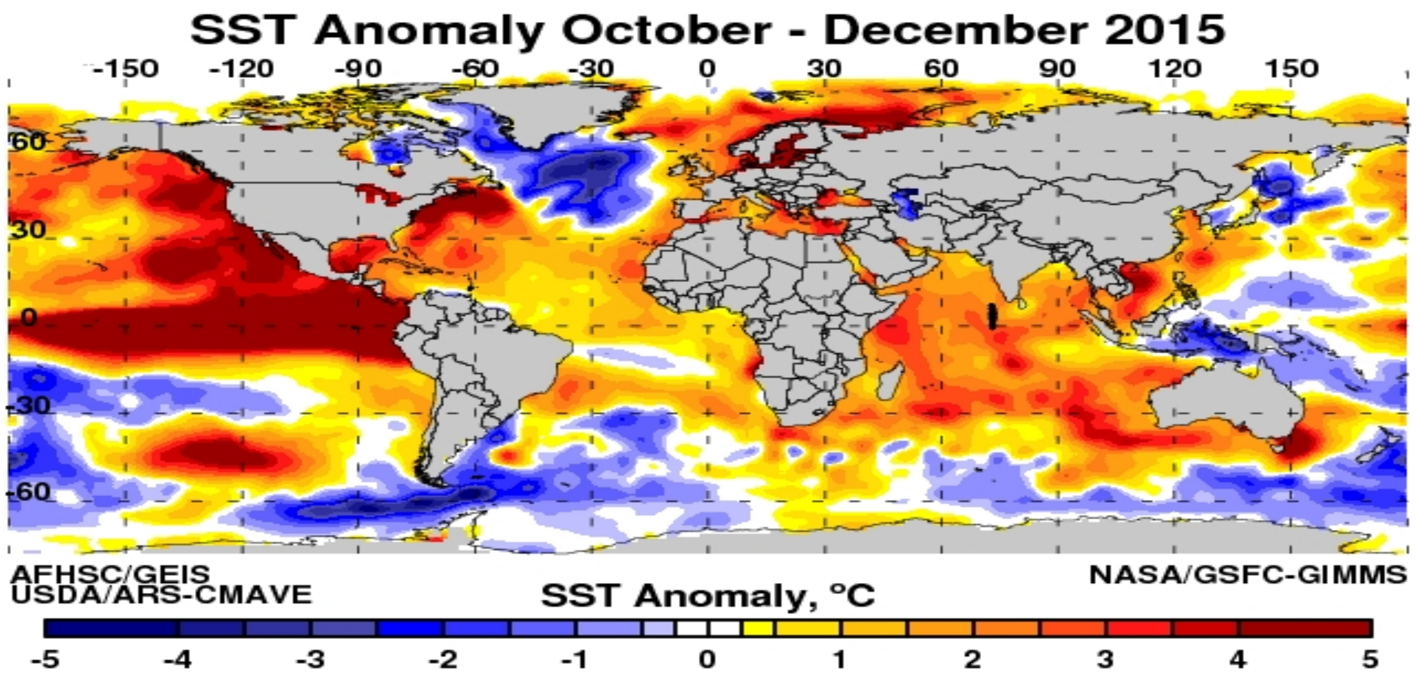
- Differential impacts at specific regional locations around the world
  - ENSO +| Floods and excess rainfall in EEA, E. E. Pacific, Southern Brazil/Argentina, Southern-tire US
  - ENSO +| Drought and >+ temperatures (Southern Africa, SE Asia, NE Brazil, C Africa
  - ENSO – [Largely reverse conditions)

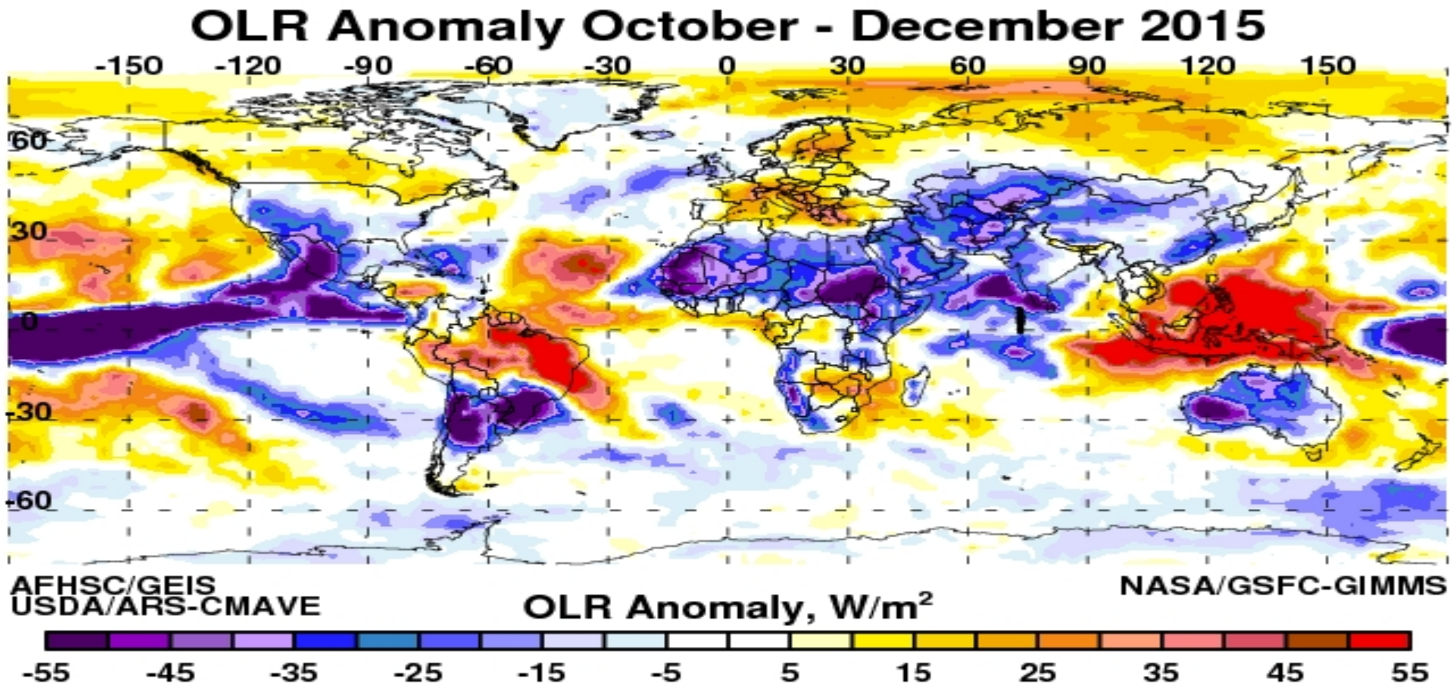
through Global Precipitation

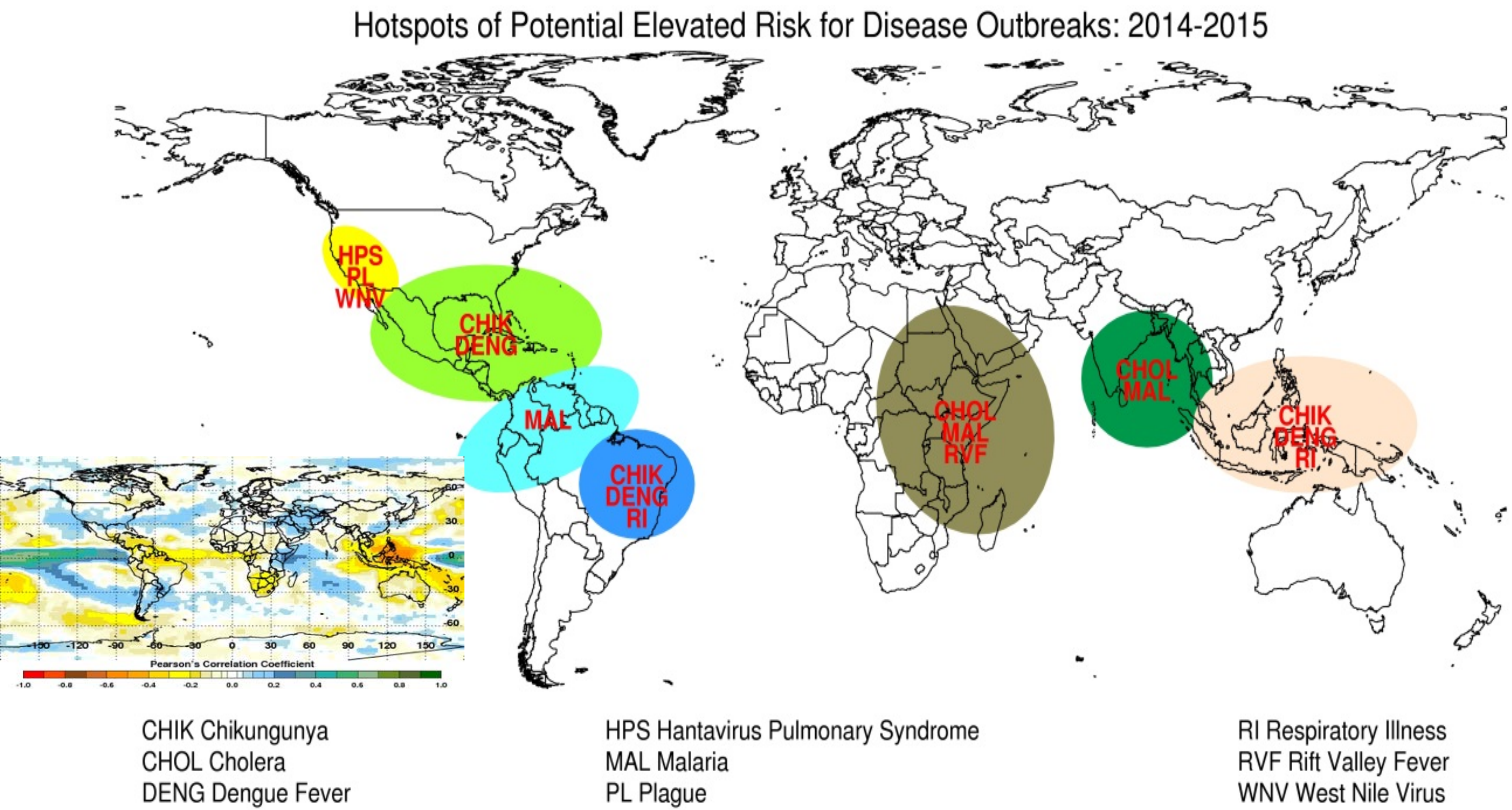


CORRELATION BETWEEN PACIFIC OCEAN (NINO 3.4) [*EL NIÑO*] SST AND RAINFALL ANOMALIES

Green/Blue: +/Wetter Yellow/Red: -/Drier


SST Anomaly October - December 2015
-150 -120 -90 -60 -30 0 30 60 90 120 150
60 30 0 -30 -60
AFHSC/GEIS
USDA/ARS-CMAVE
NASA/GSFC-GIMMS
SST Anomaly, °C
-5 -4 -3 -2 -1 0 1 2 3 4 5


OLR Anomaly October - December 2015
-150 -120 -90 -60 -30 0 30 60 90 120 150
60 30 0 -30 -60
AFHSC/GEIS
USDA/ARS-CMAVE
NASA/GSFC-GIMMS
OLR Anomaly, W/m²
-55 -45 -35 -25 -15 -5 5 15 25 35 45 55



CHRETIEN ET AL. 2015. PLOS CURRENT OUTBREAKS)

GLOBAL ASSESSMENT ASSUMING EL NIÑO OCCURS IN FALL 2015

1. Indonesia, Malaysia, Thailand and most of the Southeast Asia Islands: Increased risk for dengue and chikungunya transmission caused by drought conditions which (1) increase water storage around houses leading to elevated *Aedes aegypti* mosquito populations and (2) elevate ambient air temperatures which will reduce the extrinsic incubation period for the virus in vector *Aedes aegypti* and Aedes *albopictus* mosquitoes increasing vector capacity; respiratory illnesses due to haze from uncontrolled burning of tropical forests when extreme drought occurs.

2. Coastal Peru, Venezuela, Colombia: Malaria due to elevated *Anopheles* vector populations which will develop when various types of immature habitats are flooded after heavy rainfall.

3. Bangladesh, coastal India, Sri Lanka: Elevated risk for cholera and malaria outbreaks.

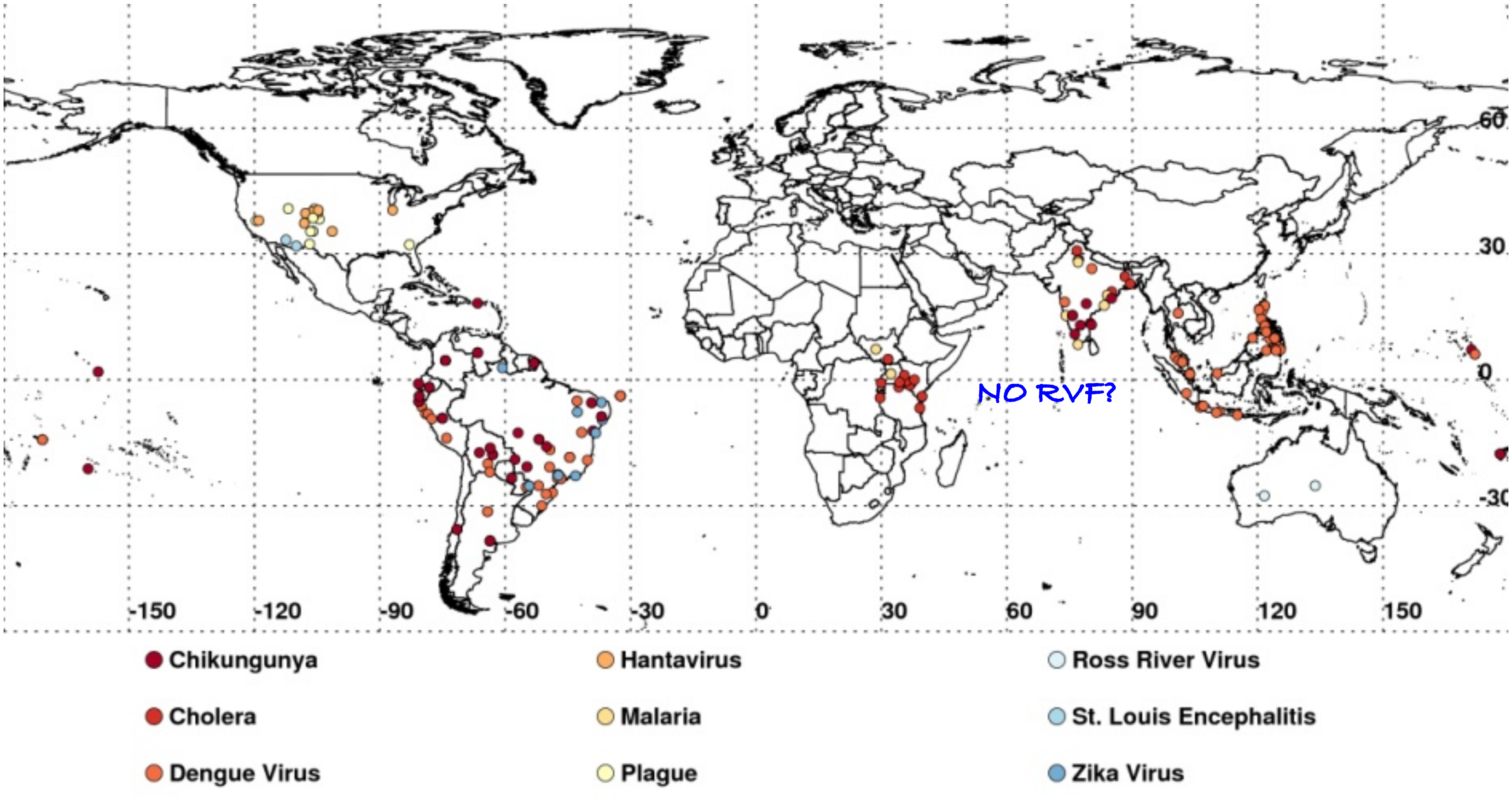
4. **East Africa (Kenya, Tanzania, Somalia, Uganda and Ethiopia)**: Increased risk for RVF and malaria resulting from elevated mosquito vector populations, and cholera caused by flooding due to heavy rainfall in dry land areas. We advise early surveillance of vector populations and disease control planning. Much will depend on how the El Niño plays out and the evolution of rainfall conditions in the September – November 2014 period.

5. South West USA (New Mexico, Arizona, Colorado, Utah, Texas, California): Hantavirus pulmonary syndrome and plague due to elevated rodent populations caused by heavy rainfall. Impact on new *Ae. aegypti* populations in central California and *Ae. albopictus* in southern California uncertain (has survived w/o rain).

6. Southern and Southeast USA, particularly along the Gulf Coast: Elevated rainfall conditions may increase *Aedes albopictus* and *Aedes aegypti* populations, potentially increasing the likelihood of local transmission of dengue and chikungunya virus following introduction from endemic regions in the Caribbean and/or Central/South America.

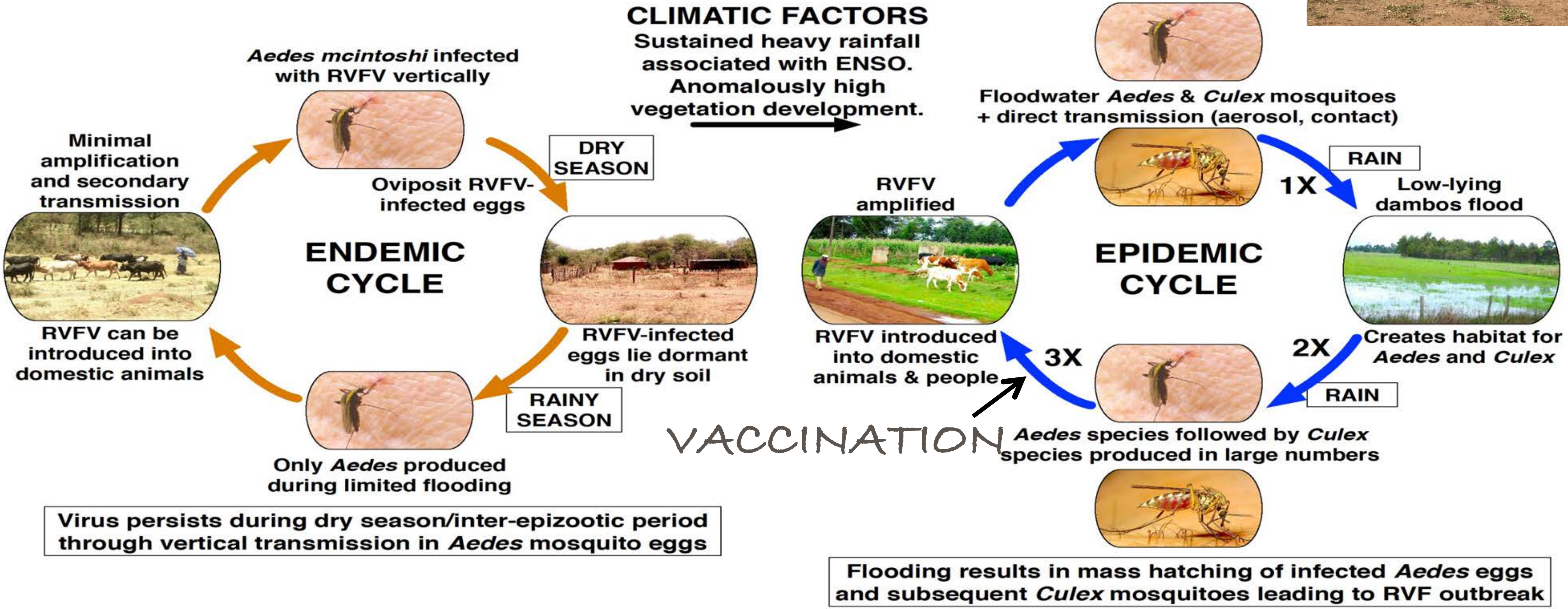
7. Northeast Brazil: Increased risk for dengue and respiratory illnesses due to drought conditions and large scale forest fires. Additionally, increased risk of chikungunya introduction from the Caribbean and/or Central/South America into Brazil.

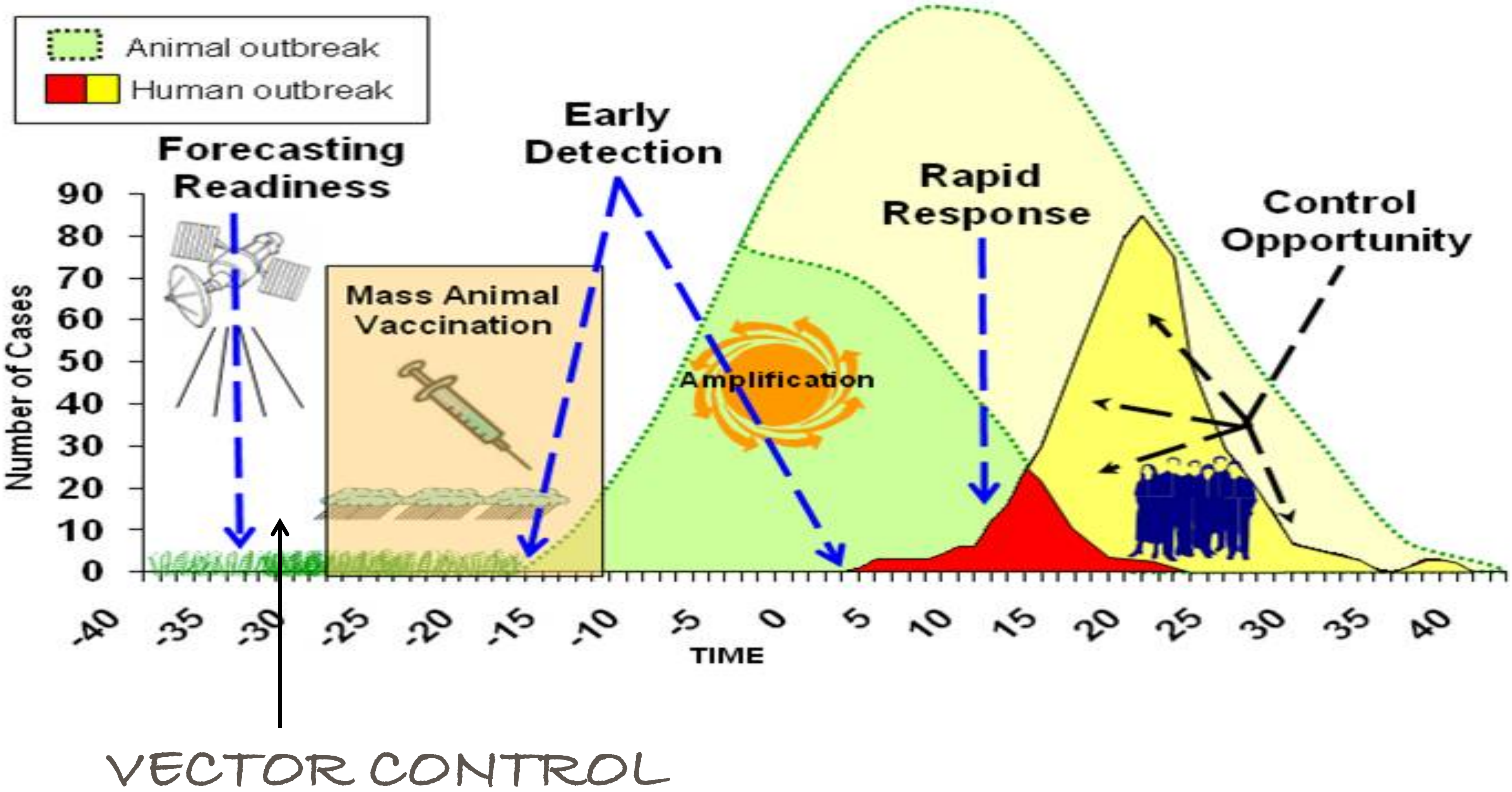
Some infectious disease risks, primarily mosquito-borne diseases that have been occurring in various parts of the world in 2015 and are likely to continue or increase in severity in 2016 (from Anyamba et. al. NASA-Goddard Space Flight Center/Global Precipitation Climatology Project. See also Chretien et al. 2015



Flood Mosquito Habitats

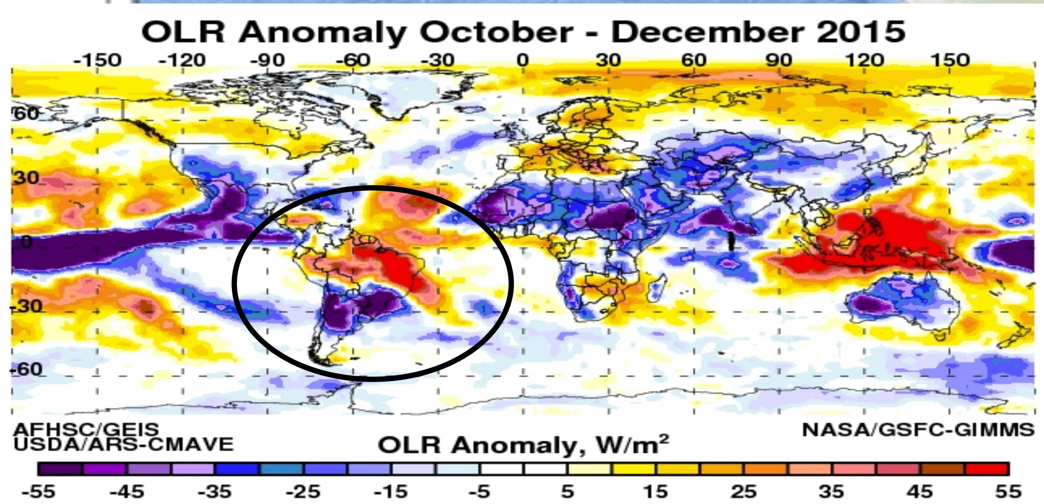
Rift Valley Fever Virus (RVFV) Life Cycle





Animal outbreak
Human outbreak
Forecasting Readiness
Early Detection
Rapid Response
Control Opportunity
Mass Animal Vaccination
Amplification
Number of Cases
90
80
70
60
50
40
30
20
10
0
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40
TIME
VECTOR CONTROL


Countries and territories with confirmed cases of Zika virus (autochthonous transmission) in the Americas, 2015-2016.
Pan American Health Organization
World Health Organization
Americas
Updated as of Epidemiological Week 4 (Jan 24-30, 2016)
Legend
Countries with confirmed cases of Zika virus
Presence
Contries with confirmed cases
Country limits
Mexico
Jamaica
Dominican Republic
Saint Martin
Puerto Rico
Guadeloupe
Martinique
Barbados
Guatemala
Honduras
El Salvador
Nicaragua
Costa Rica
Panama
Curacao
Venezuela
Colombia
Guyana
Suriname
French Guiana
Ecuador
Brazil
Bolivia
Paraguay
Puerto Rico
United States Virgin Islands
Saint Martin
Guadeloupe
Martinique
Barbados
Venezuela
Data Source:
Reported from the IHR National Focal Points and through the Ministry of Health websites.
Map Production:
PAHO-WHO AD CHA IR ARO


OLR Anomaly October - December 2015
-150 -120 -90 -60 -30 0 30 60 90 120 150
60
30
0
-30
-60
AFHSC/GEIS
USDA/ARS-CMAVE
OLR Anomaly, W/m²
NASA/GSFC-GIMMS
-55 -45 -35 -25 -15 -5 5 15 25 35 45 55

DENGUE FEVER HAWAII ISLAND OUTBREAK

Map Updated: 1/25/2016 at 1:00 pm

Potentially Infectious Individuals = 3

Cases No Longer Infectious = 234

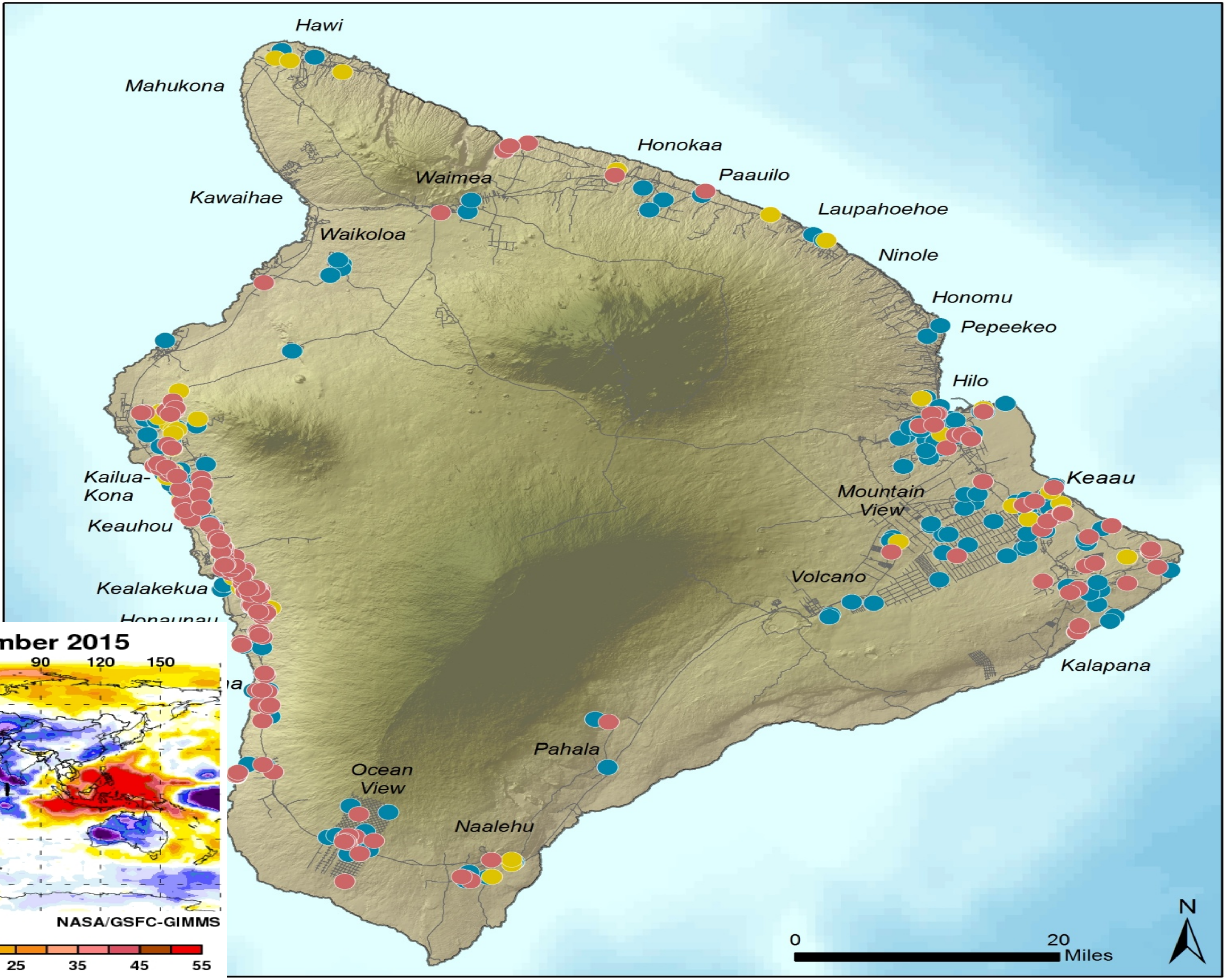
Total Confirmed Cases = 237

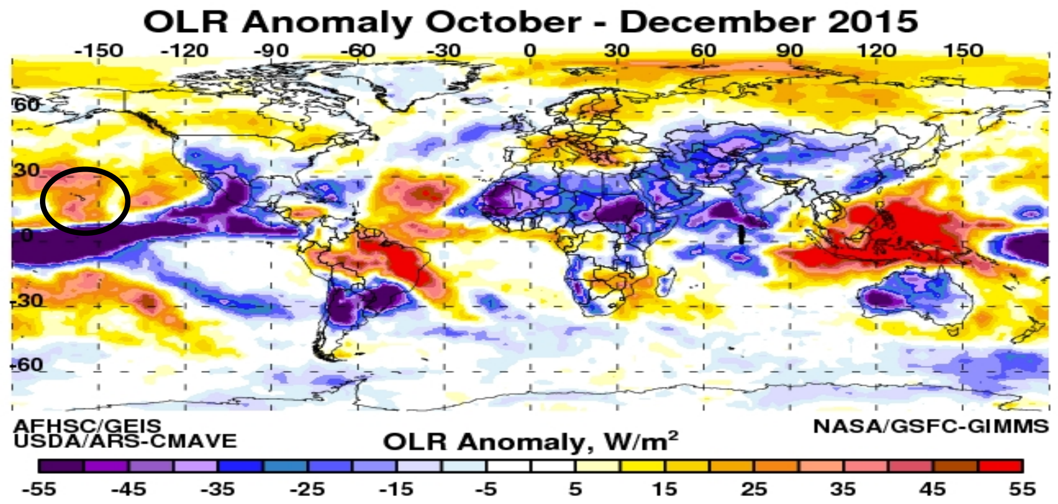
- Confirmed DOH Case Locations *(Tested and Confirmed Positive)*
- Suspect DOH Case Locations *(Under Investigation)*
- Negative DOH Case Locations *(Tested and Confirmed Negative)*

Potentially Infectious Individuals:
- Illness Onset 1/16/16 to 1/17/16

Cases No Longer Infectious
- Illness Onset 9/11/15 to 1/13/16

Confirmed Cases:
- 214 Hawaii Island Residents
- 23 Visitors
- 193 Adults

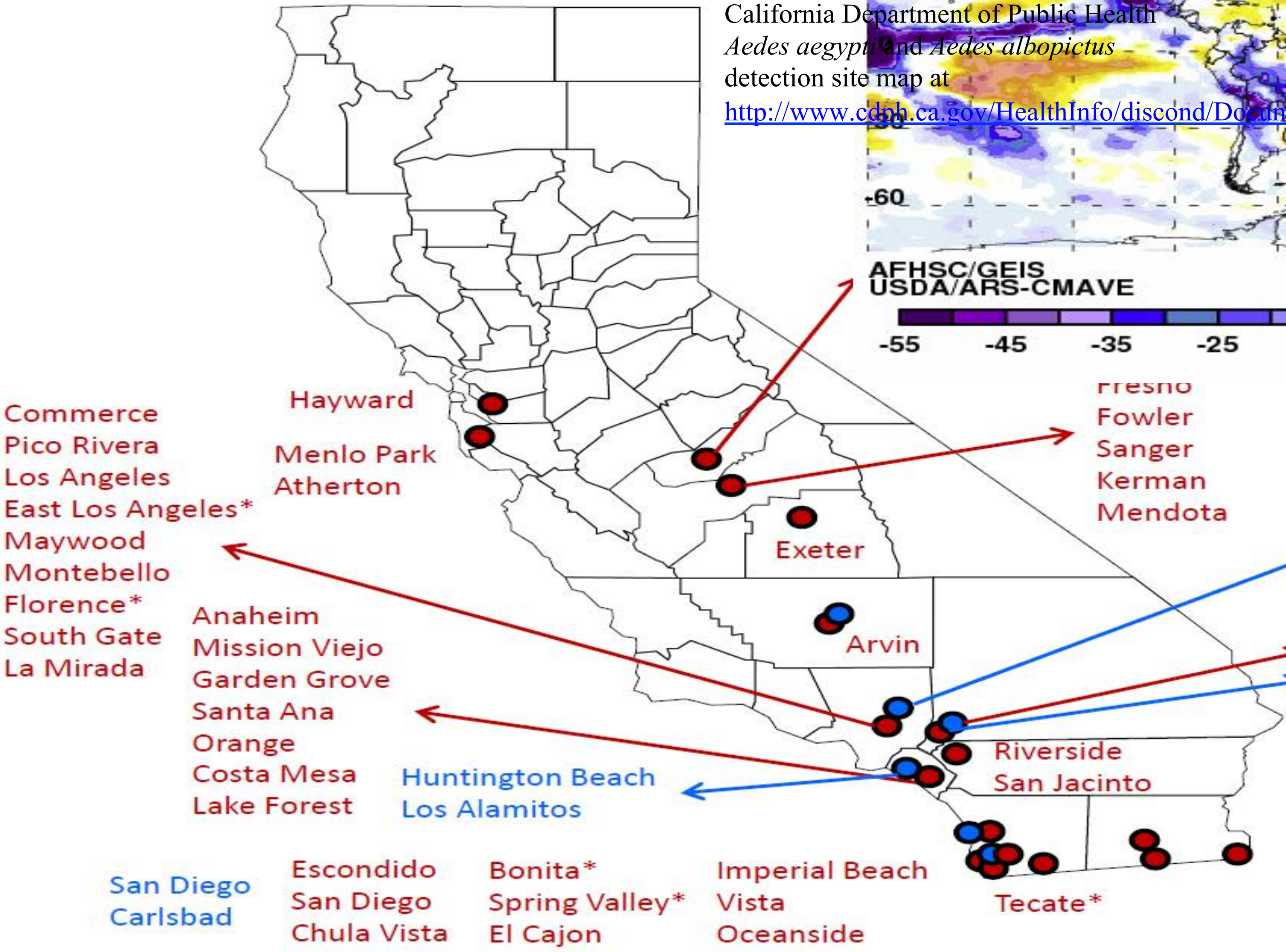


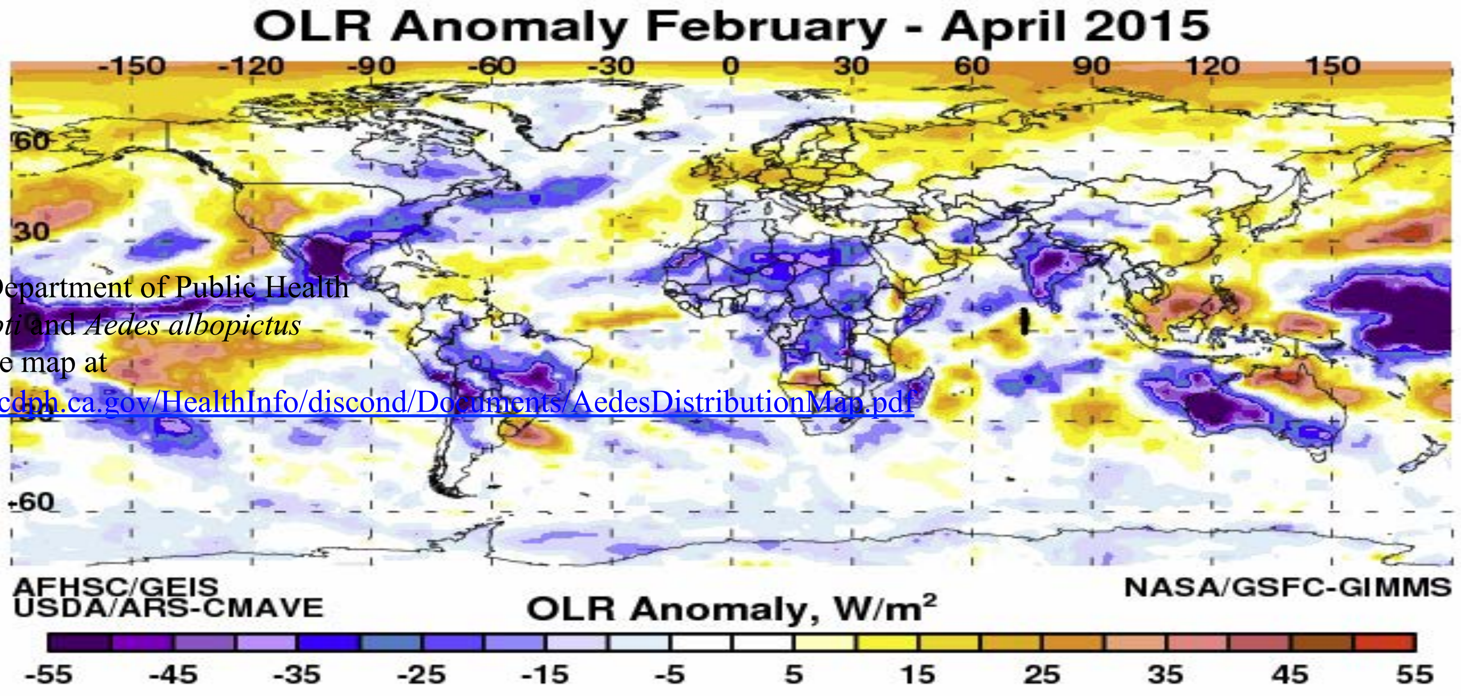


Aedes aegypti and A
Detection Sites

Updat

California Department of Public Health *Aedes aegypti* and *Aedes albopictus* detection site map at http://www.cdph.ca.gov/HealthInfo/discond/Documents/AedesDistributionMap.pdf





4. Summary

Conclusions

- Some vector-borne disease outbreaks can be predicted using Earth Observing Technologies
- **The development of El Niño/La Niña conditions and subsequent local weather have significant implications for global One Health**
- Threat from globalization of various vector-borne diseases like dengue, chikungunya, malaria and RVF, is real and ever present danger
- Prediction in endemic areas followed by mitigation can reduce threat from globalization

TP://WWW.ARS.USDA.GOV/BUSINESS/DOCS.HTM?DOCID=23464

Rift Valley fever MONITOR