Satellite observed sensitivity of malaria to ENSO and AVHRR based vegetation health for short and long term forecasting in Bangladesh and India

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Vector-Borne Diseases

- Malaria
- Dengue
- Dog heartworm
- Yellow fever

Malaria Parasite

- Plasmodium falciparum
- Plasmodium vivax
- Plasmodium malaria
- Plasmodium ovale

Malaria Vector

- Aedes
- Anopheles
- Culex
- Psorophora

Environmental factors for malaria

- Temperature (16-20^0 C)
- Humidity (60%)
- Rainfall (50 mm monthly)

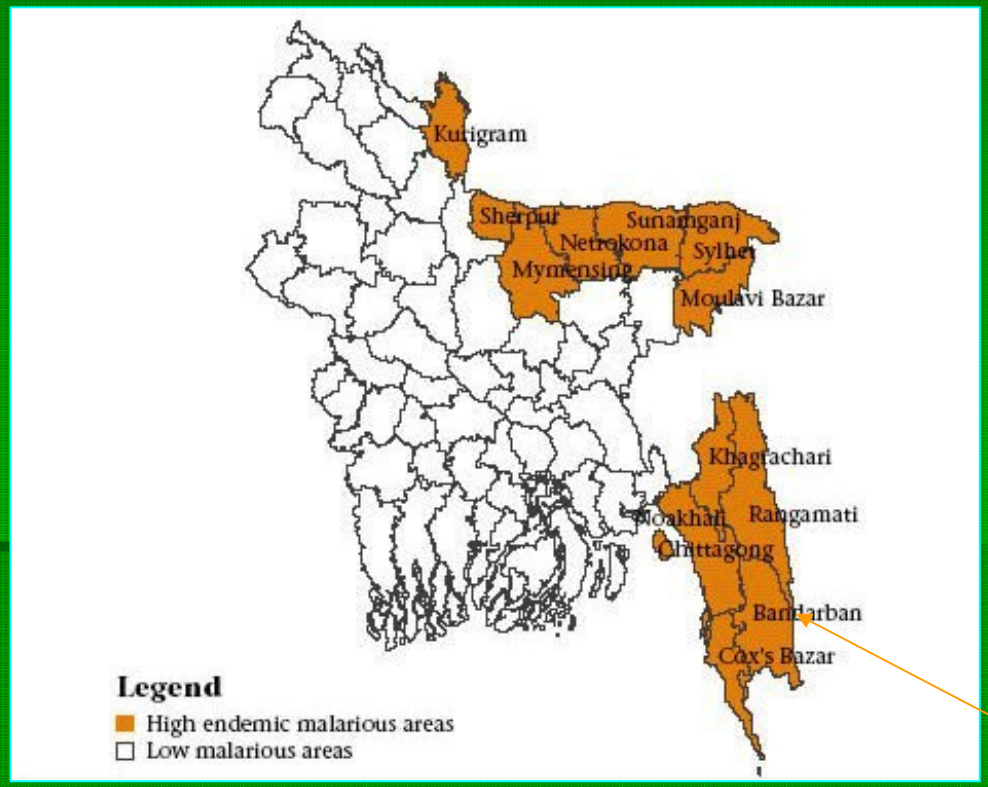
Impact of Malaria Bangladesh

- Growth penalty 1.3%
- Deter investments
- Poverty
- Loss of work

Goal of early detection and monitoring of malaria

- Use vegetation health indices to predict epidemics
- To assist governments
- To reduce the malaria risk
- Boosting economy

Malaria endemic districts of Bangladesh



Bandarban

Climate of Bangladesh

- Wet hot -April to October
- Cool dry –November to February
- Hot dry –February to April

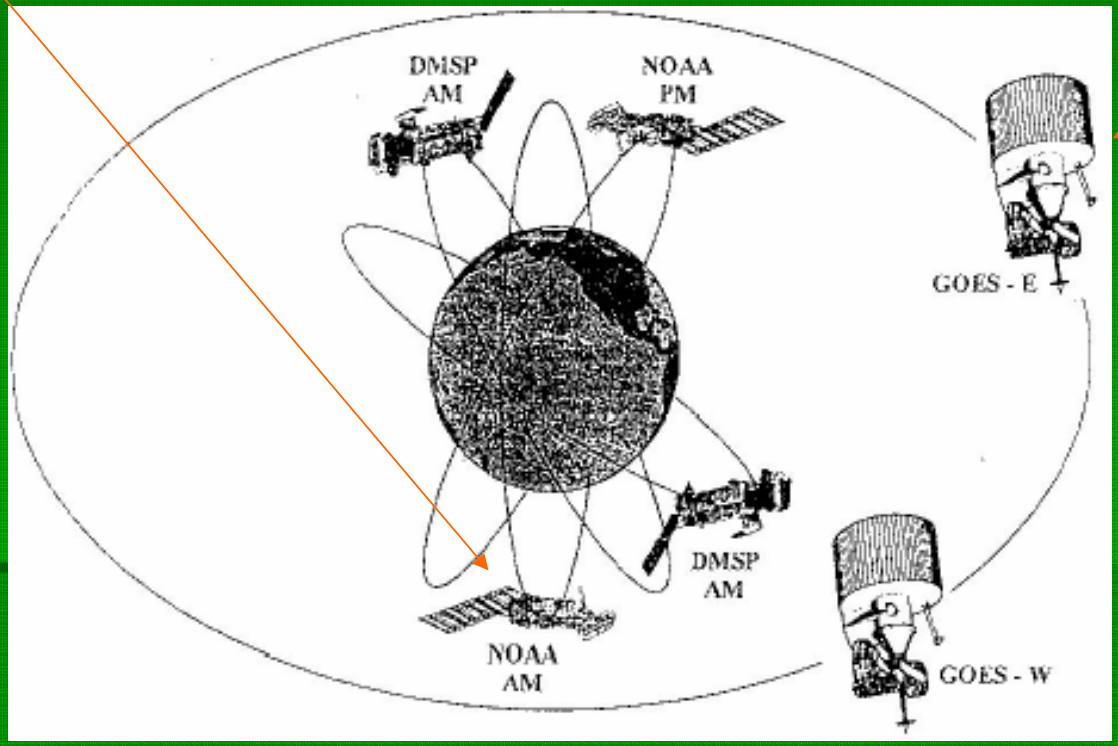
DATA

- Malaria statistics
- Satellite data

NOAA Operational Environmental Satellites

polar orbiting satellites

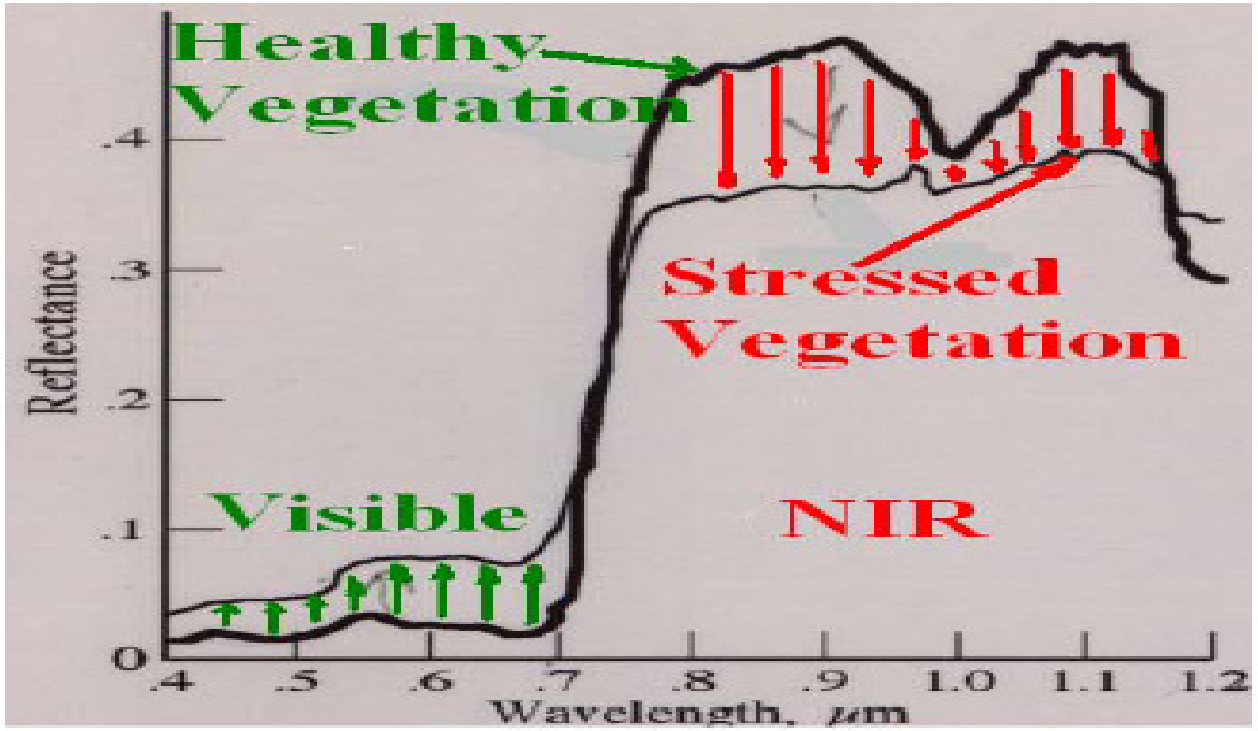
Geostationary **satellites**



Satellite Data

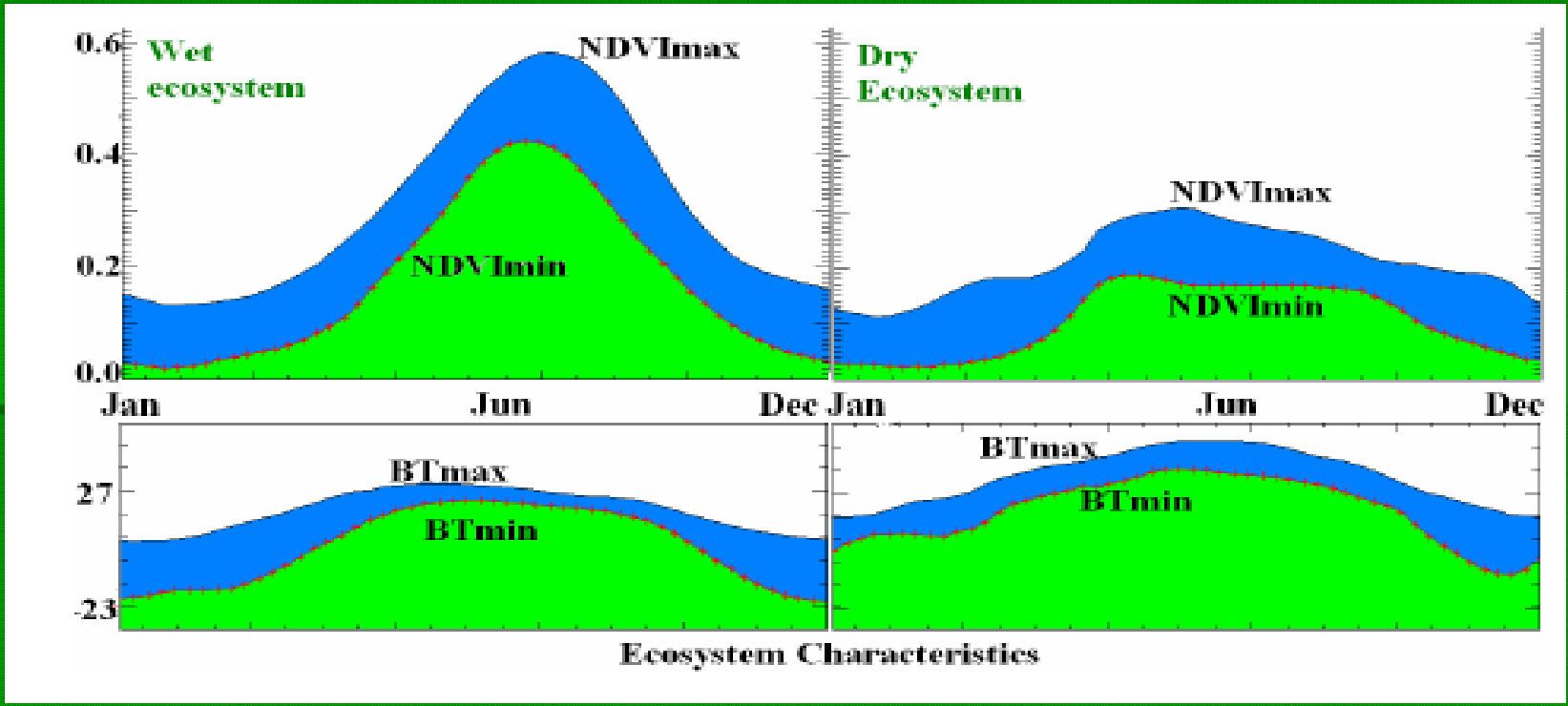
- NOAA afternoon polar orbiting satellites
- NOAA/NESDIS Global Vegetation Index (GVI) data set from 1992 through 2005
- Spatial resolution of 4 km (sampled to 16 km)
- Daily temporal resolution sampled to 7-day composite.

AVHRR Reflectance



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

Weather and Ecosystem Components in NDVI & BT



Vegetation Health Indices

- Normalized Difference Vegetation Index

  NDVI= (CH2- CH1)/(CH2+CH1)

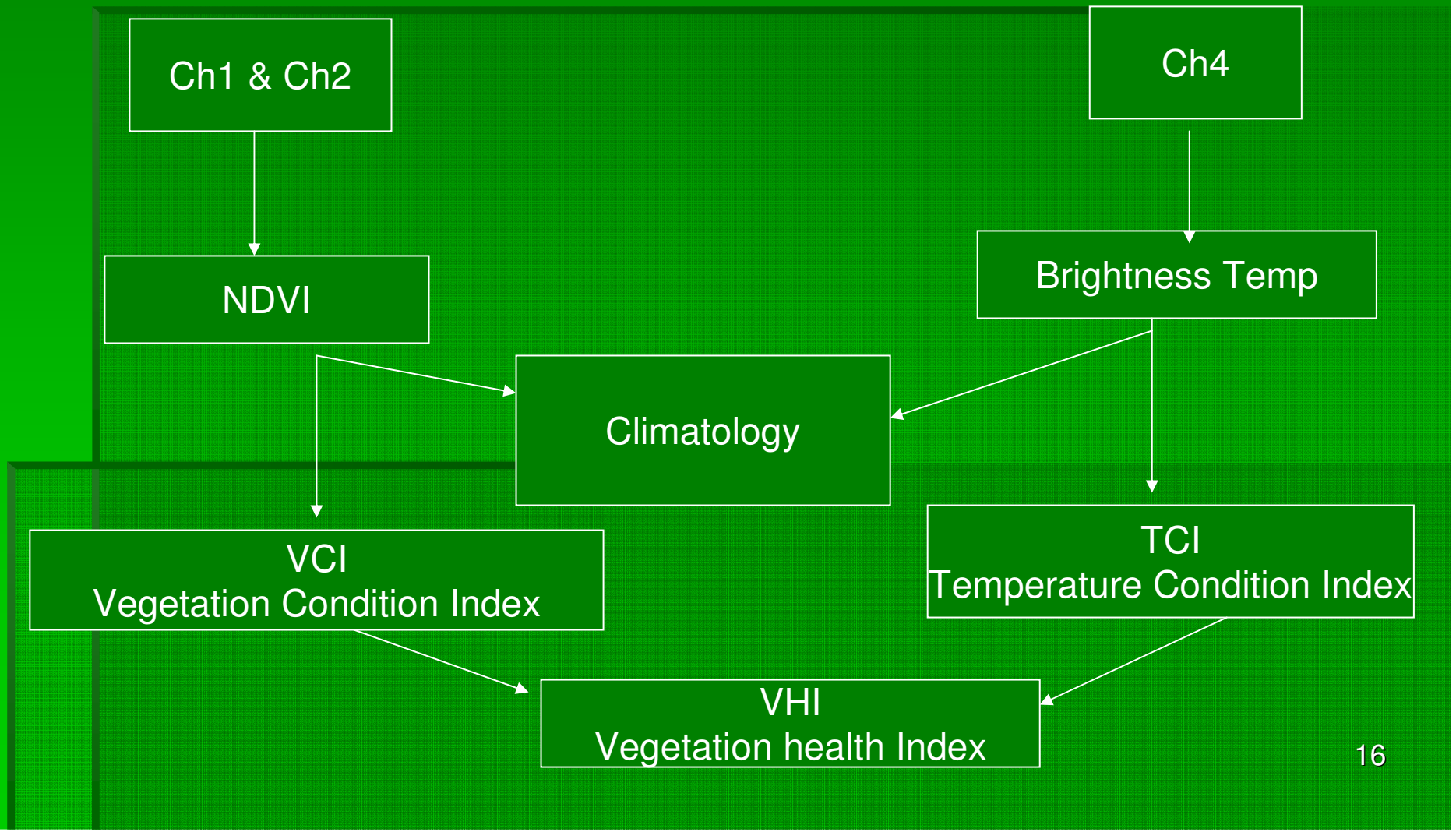
- Vegetation Condition Index (VCI)

  VCI=100*(NDVI – NDVI min)/ (NDVImax – NDVImin)

- **Temperature Condition Index (TCI)**

  TCI=100*(BTmax – BT)/ (BTmax – BTmin)

Vegetation Health Indices Algorithm



Use Vegetation Health Indices to Assess

- Moisture Condition (VCI)
- Thermal Condition (TCI)
- Vegetation Health (VHI)

Malaria in Bandarban

- Malaria Parasite
  - Plasmodium falciparum (95%)
  - Plasmodium vivax (5%)
- Female Anopheles Vectors
  - An Dirus
  - An minimus

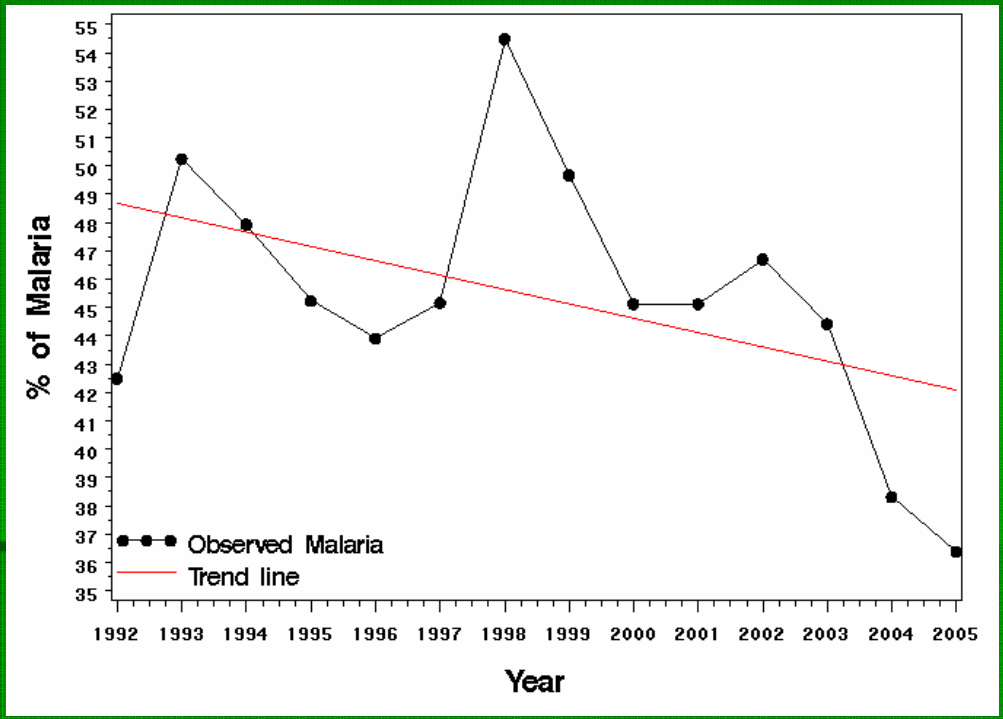
Tools and Method

- Mat Lab
- SAS
- Trend Analysis
- Correlation Analysis
- Regression Analysis
- Principal Component Analysis

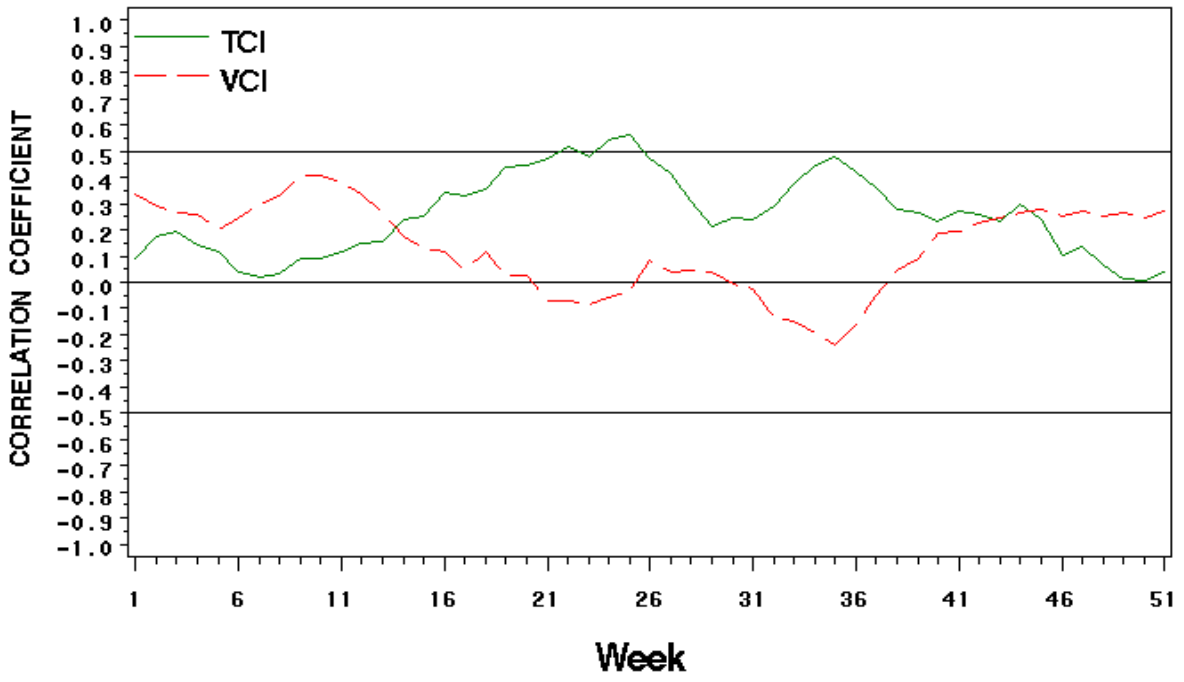
Annual malaria cases, and trend line 1992-2005

$Y_{trend} = 1059.95 - 0.506^{*}$ Year

$DY = (Y / Y_{trend})^{*}100$



Correlation dynamics of DY versus TCI and VCI



Regression Analysis

$$DY=b_0 + b_1TCI_{32} +b_2TCI_{33} + b_3TCI_{34} + b_4TCI_{35} + b_5TCI_{36}$$

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Tolerance	Variance Inflation
Intercept	1	86.226	3.11859	27.65	<.0001	.	0
TCI32	1	-1.1168	0.59254	-1.88	0.0962	0.01203	83.12697
TCI33	1	-0.00702	1.19173	-0.01	0.9954	0.00307	326.03281
TCI34	1	0.22426	1.27245	0.18	0.8645	0.00254	393.64865
TCI35	1	2.33509	0.81987	2.85	0.0215	0.00617	162.00663
TCI36	1	-1.26114	0.61886	-2.04	0.0759	0.01051	95.18932

R^2=0.88, RMSE= 4.8

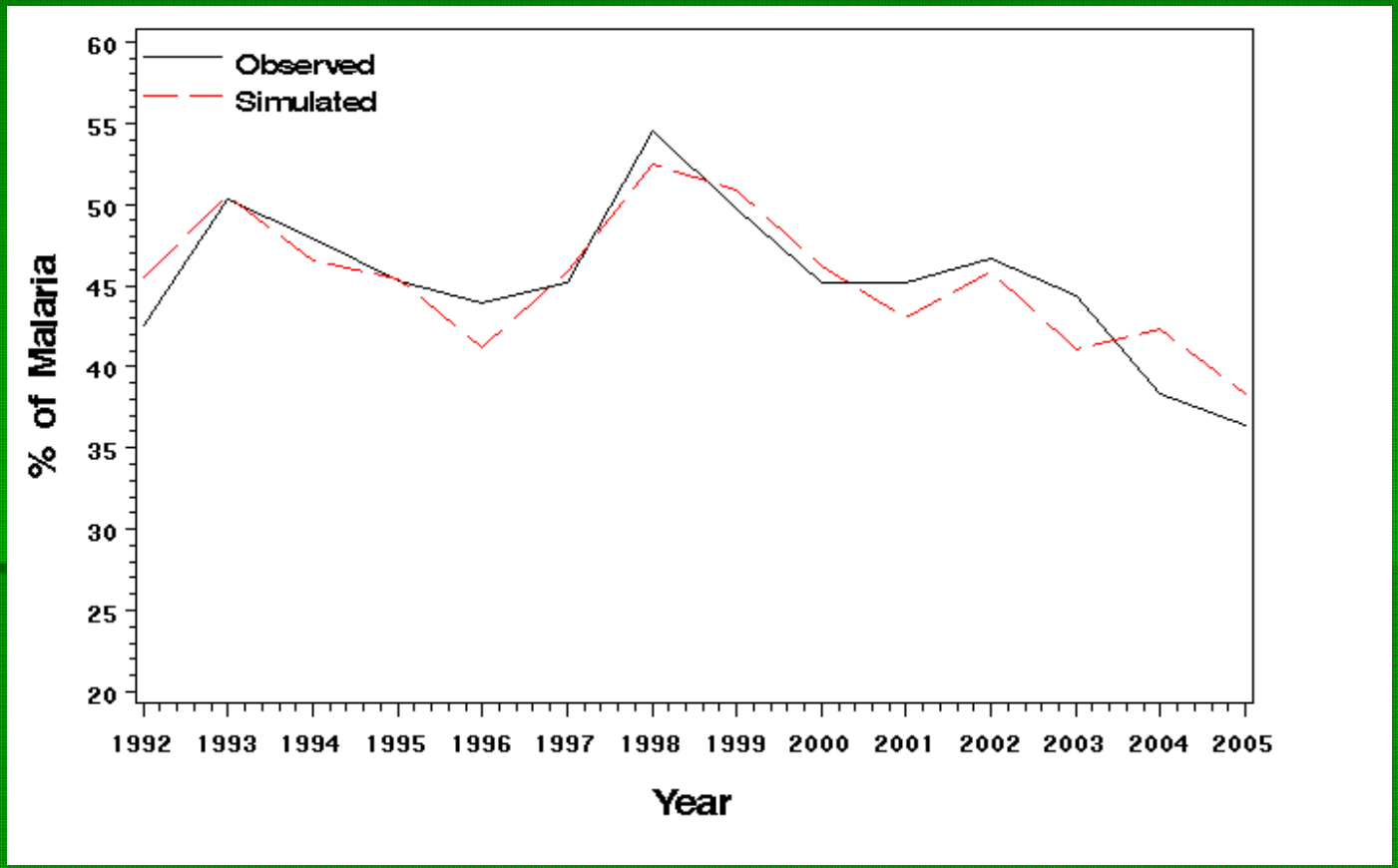
Principal component analysis

- DY= 86.48- 0.98 TCl_{32}-0.36 TCl_{33}+0.61 TCl_{34}+ 2.20TCl_{35}-1.31TCl_{36}

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	99.9894	1.23302	81.09	<.0001
Prin1	1	1.64897	0.57579	2.86	0.0187
Prin2	1	-28.26484	6.11437	-4.62	0.0012
Prin3	1	-28.75508	11.9657	-2.4	0.0397
Prin4	1	43.6613	18.32133	2.38	0.041

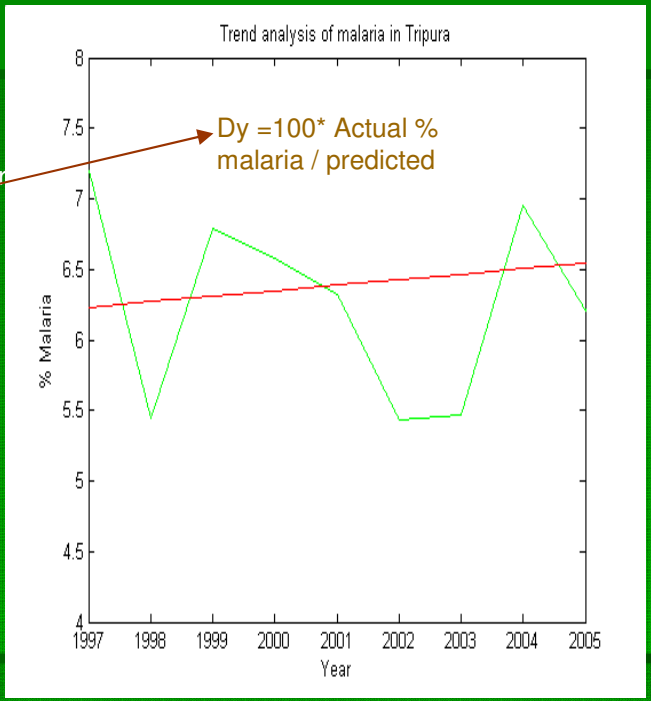
(R^2=0.84)

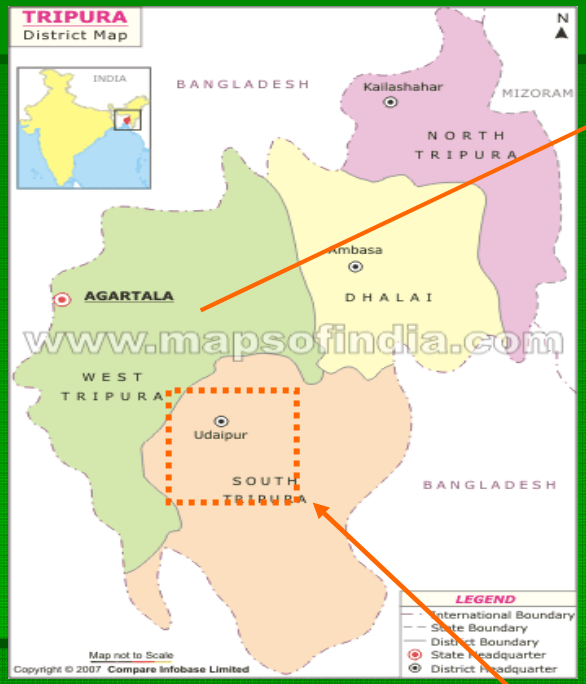
Simulated and observed malaria

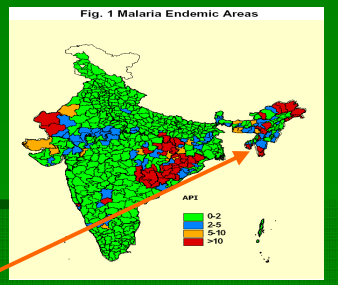


Annual malaria cases and trend Tripura State India

Malaria cases departur
from the climatology







%of malaria =100* (# of positive cases) / (# of Blood slide examined)

Satellite data collection

Correlation Dynamics of DY versus Vegetation Health Indices (Tripura)

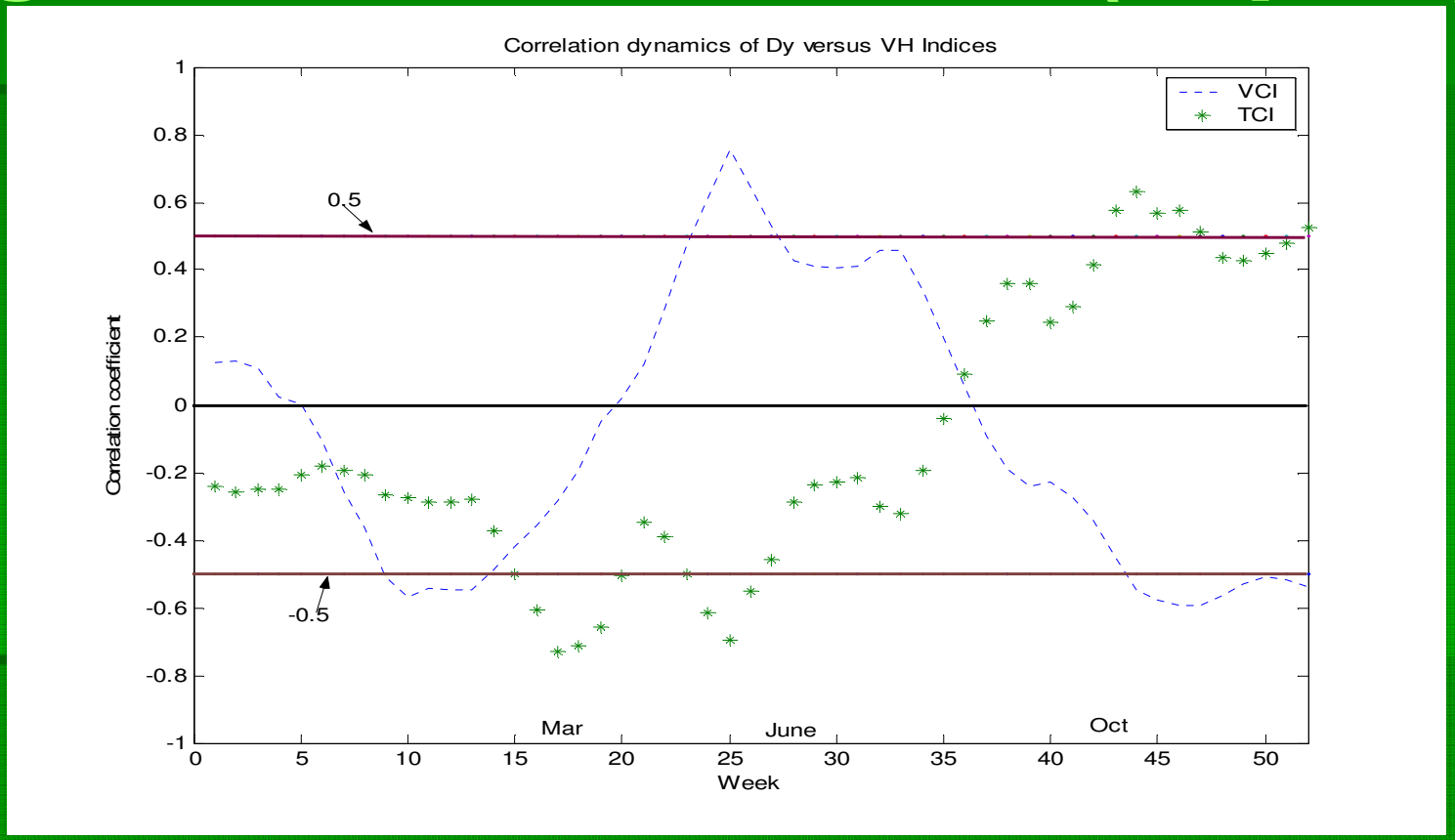
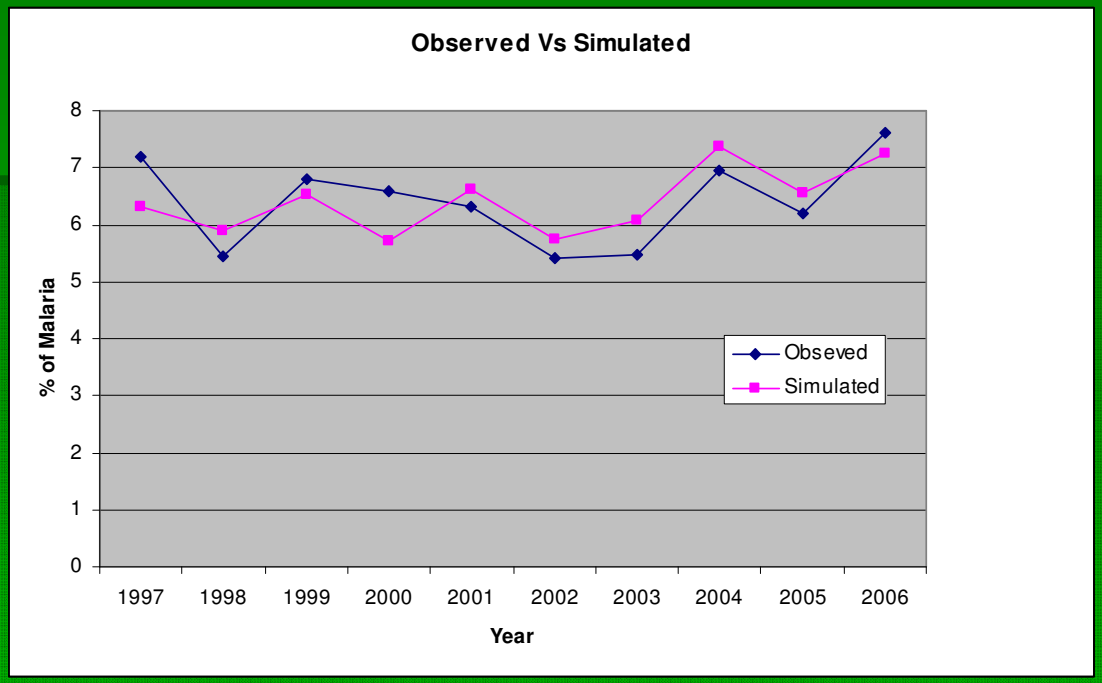


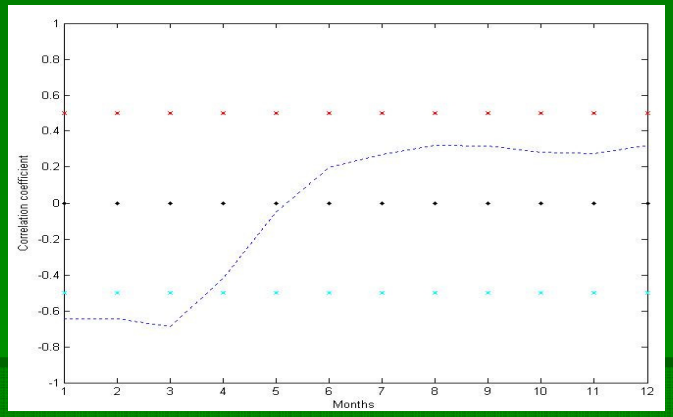
Table 4: Observed and simulated values of Malaria in Tripura

Year	observed	Simulated
1997	7.19404	6.30258
1998	5.44091	5.88717
1999	6.79443	6.51759
2000	6.57792	5.72703
2001	6.32706	6.61496
2002	5.42733	5.74369
2003	5.47161	6.06909
2004	6.94934	7.35645
2005	6.2023	6.54456
2006	7.60217	7.25593

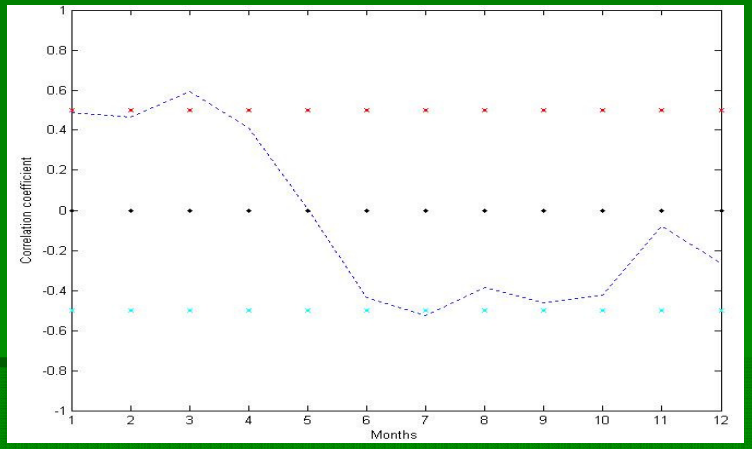


Independently simulated and observed percent of malaria Tripura (R^2 =.86).

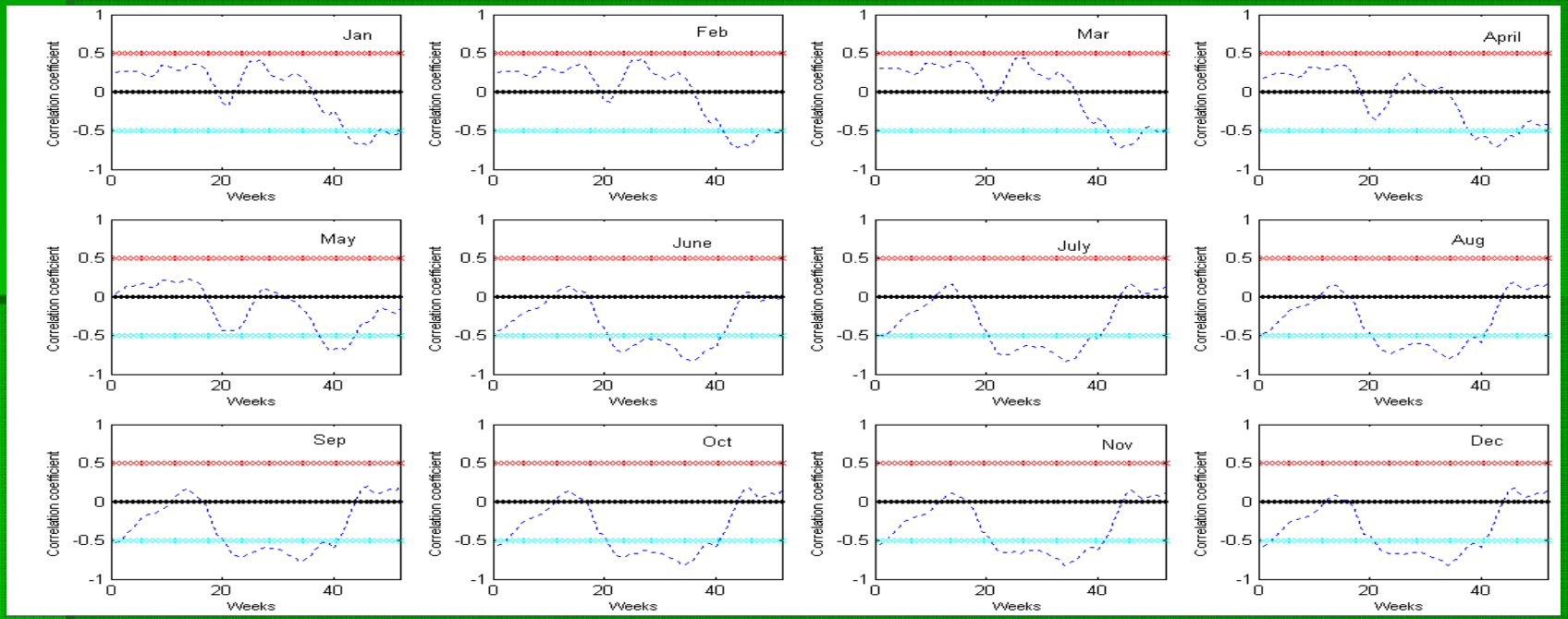
$$DY=129.7 - 0.07\ TCI_{15} - 0.08\ TCI_{16} - 0.08\ TCI_{17} - 0.09\ TCI_{18} - 0.09\ TCI_{19} - 0.12 TCI_{20}$$



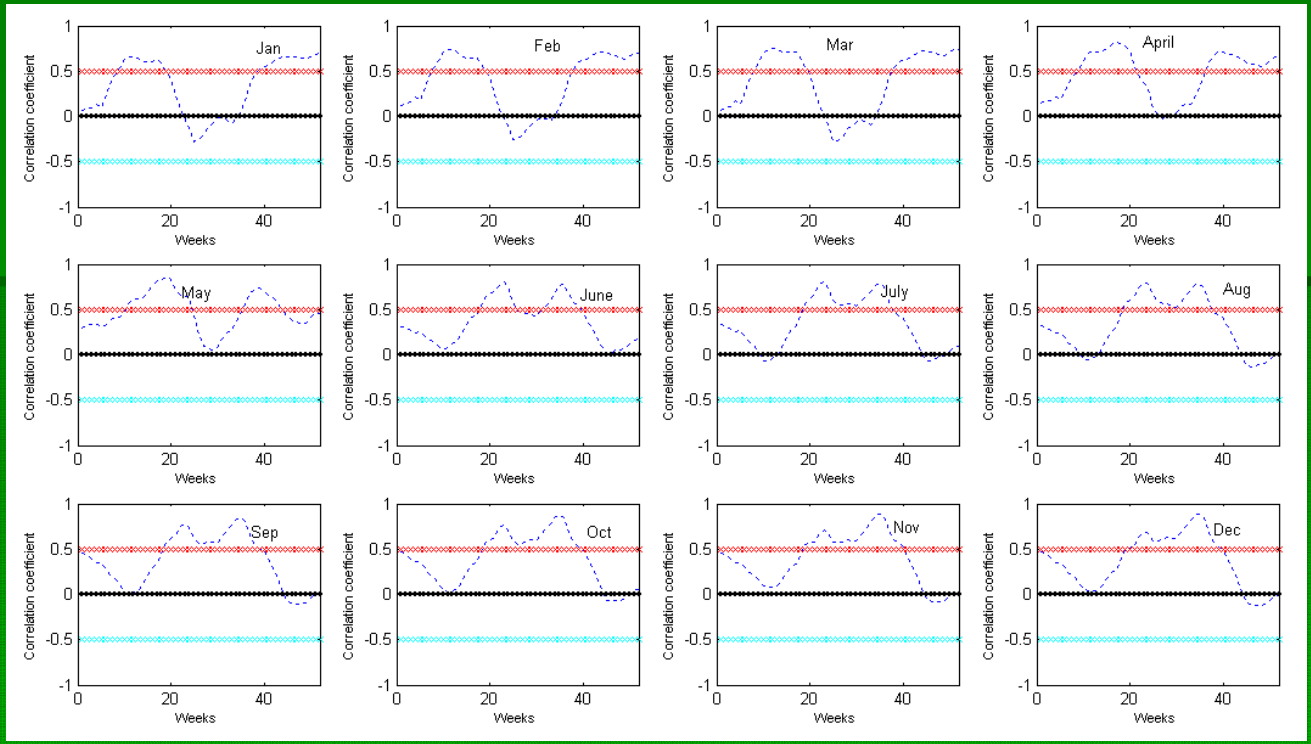
Correlation coefficient dynamics of the percent deviation of malaria from trend versus monthly SST anomaly at ENSO zone 3.4



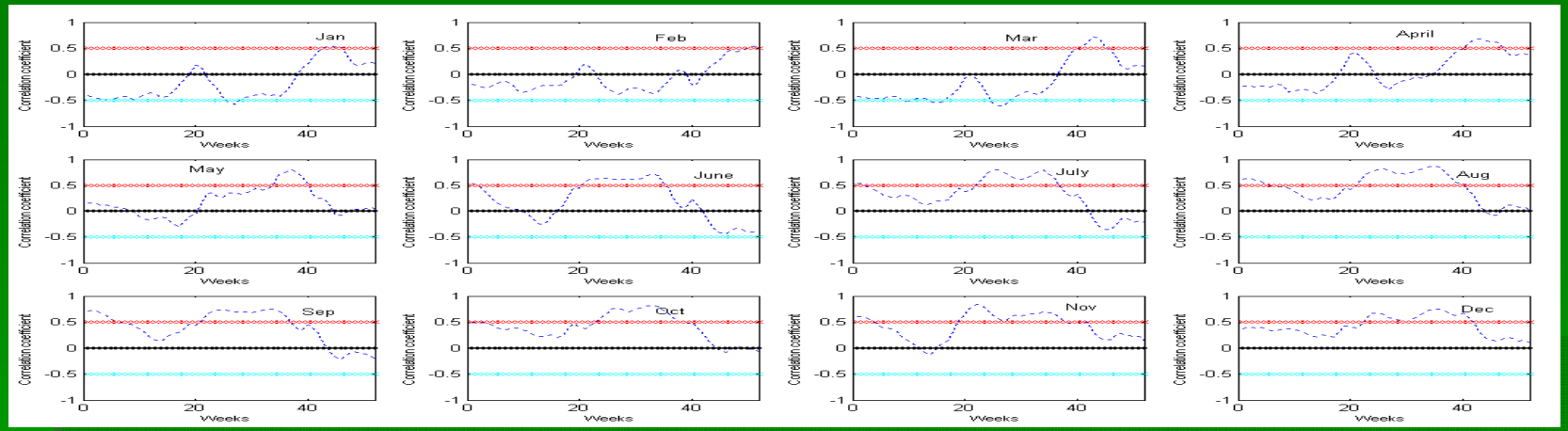
Correlation coefficient dynamics of the percent deviation of malaria from trend versus monthly SOI anomaly



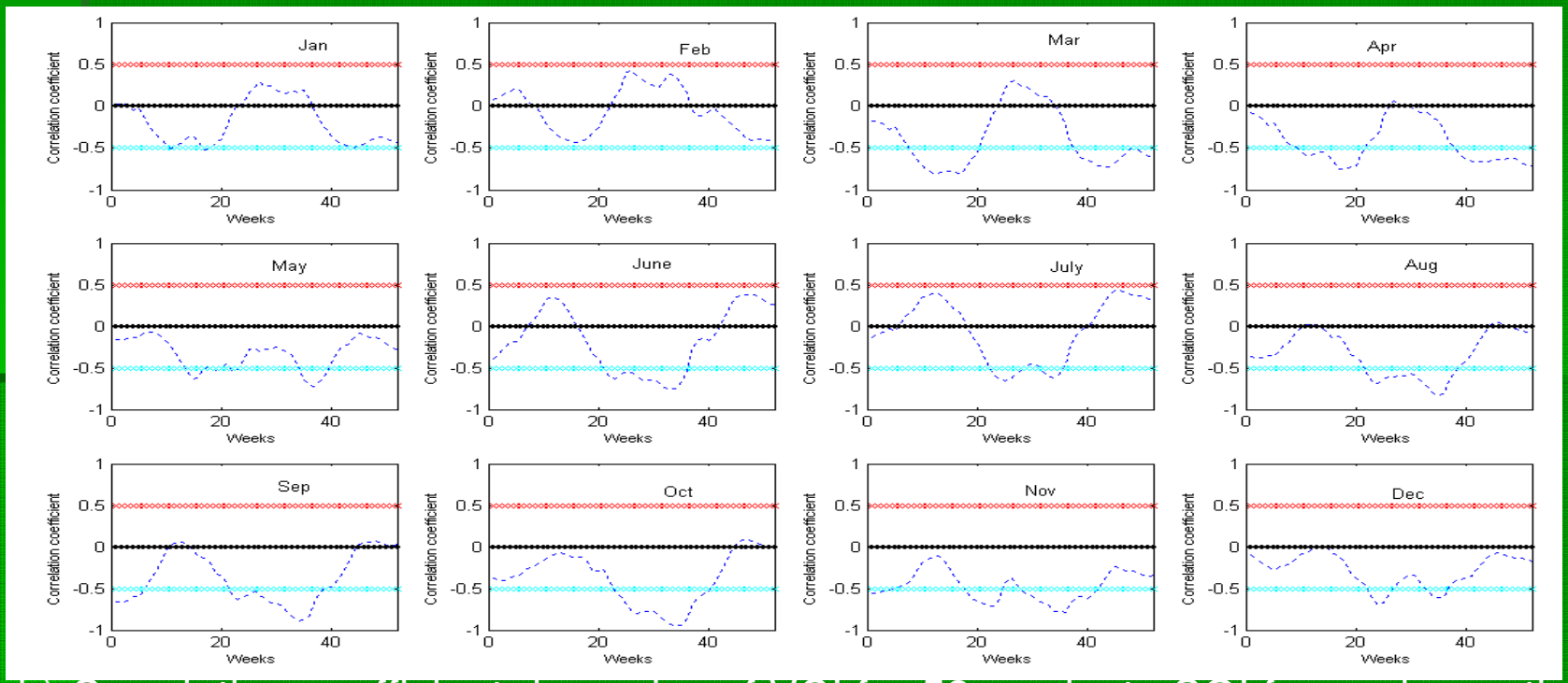
(a) Correlation coefficient dynamics of TCI for 52 weeks to SST(3.4) for each month TCI-SST



b) Correlation coefficient dynamics of VCI for 52 weeks to SST for each month



(a) Correlation coefficient dynamics of TCI for 52 weeks to SOI (southern oscillation index) for each month



b) Correlation coefficient dynamics of VCI for 52 weeks to SOI for each month

Conclusions

- Uses TCI and VCI for malaria prediction
- Model will allow to predict epidemics 1-2 months ahead (short term forecasting)
- ENSO can be used for long term forecasting malaria (six month ahead)
- Government will be able to plan ahead to fight epidemics

THANK YOU