ANALYSIS OF LANDSCAPE, WEATHER AND MOSQUITO VECTOR ECOLOGY FOR PREDICTING ARBOVIRUS DISEASE SPREAD

Irene Bosch
Magaly Koch
Anthony Guimaraes
Mauricio Nogueira
Vanessa Melandri

Jeronimo Alencar
Elena Naumova

Objectives of the study

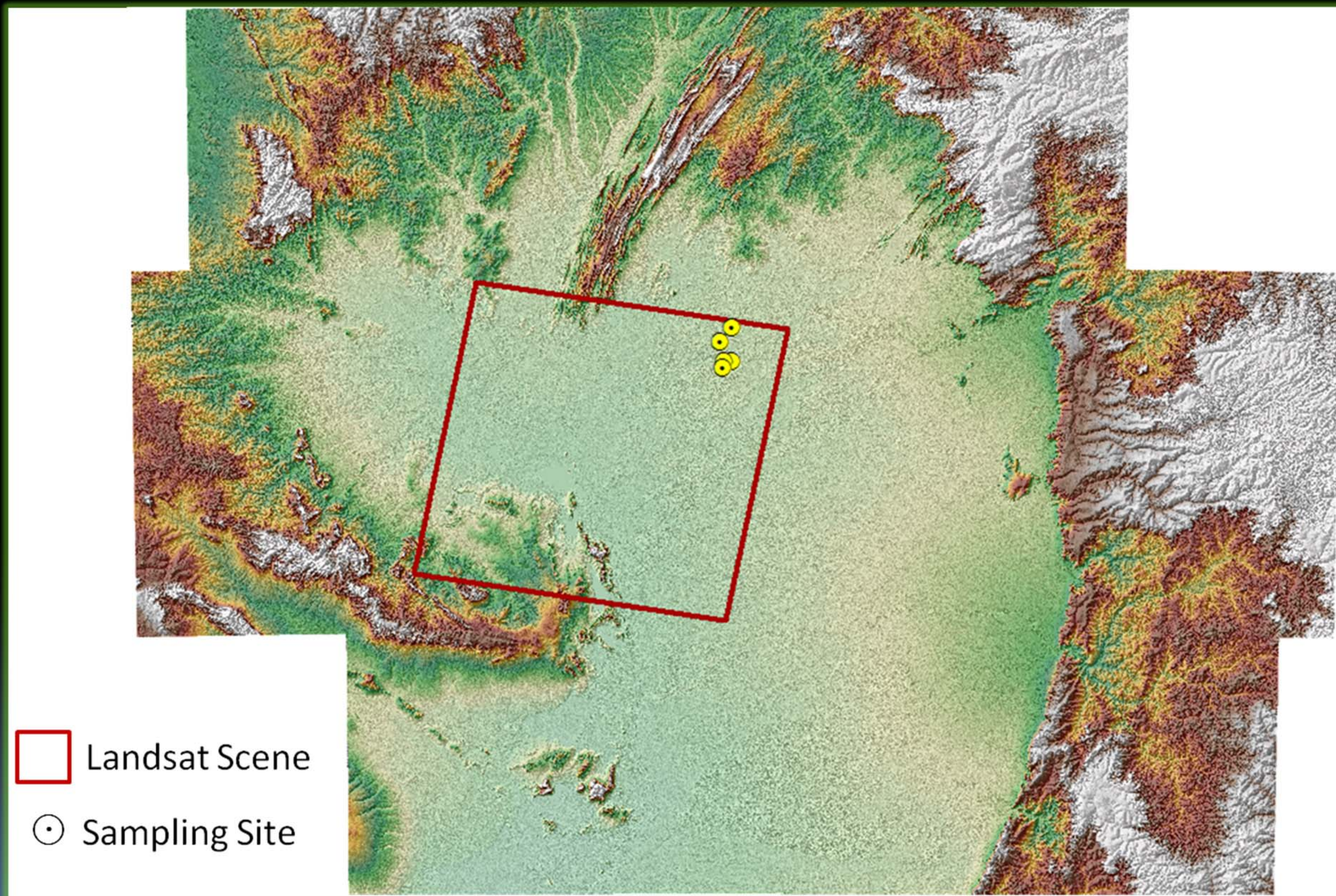
- Pantanal National Park is a protected wetland with restricted human and domestic animal presence
- Determine environmental parameters that affect vector habitat & disease spread
- Monitor arbovirus disease in the wildlife

- Describe the mosquito vector ecology
- Determine relationships between environmental factors and populations of specific mosquito species
- Determine presence of arboviruses and document history of disease exposure in susceptible hosts

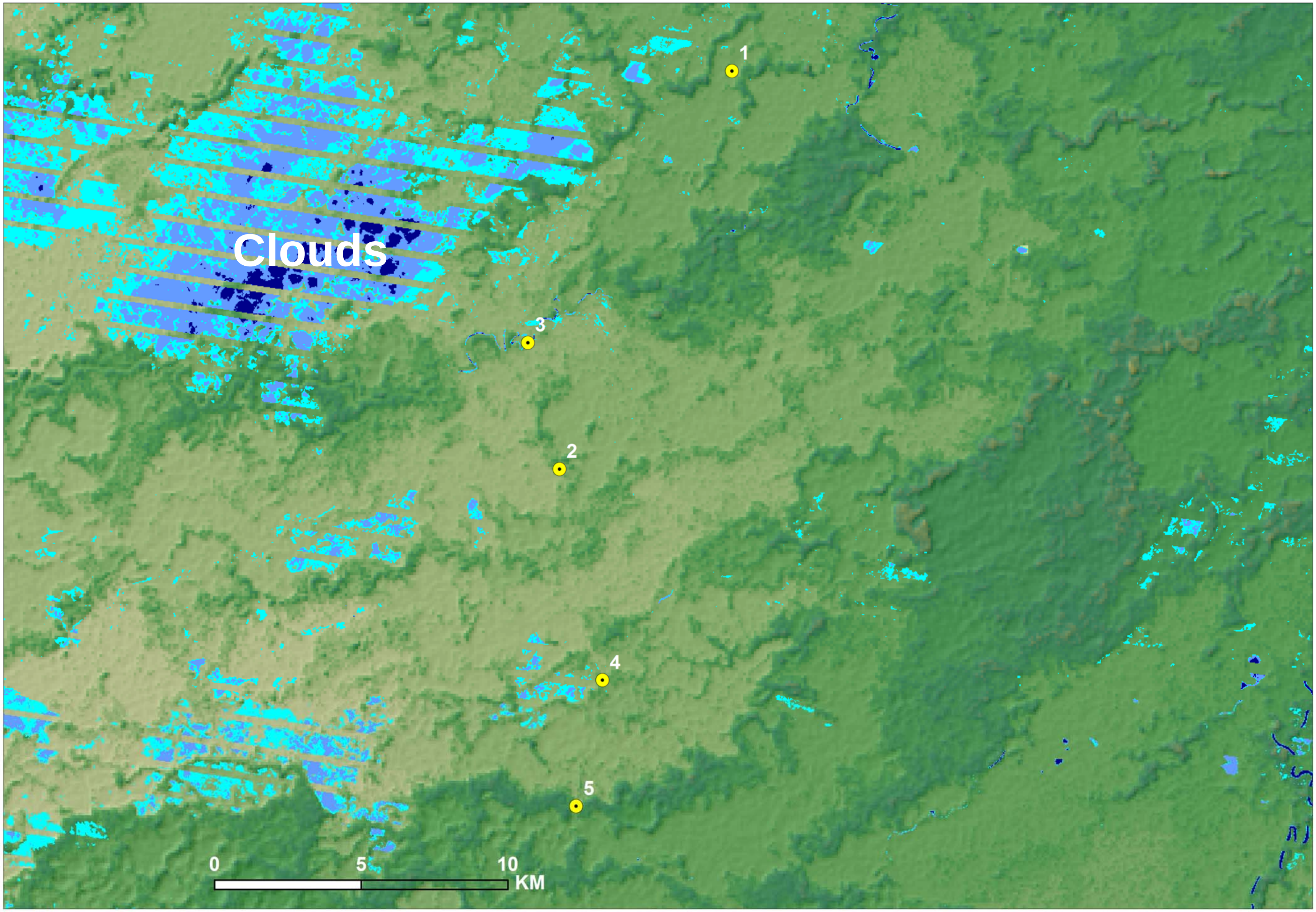
Location of Study Area in Pantanal, Brazil

1
3
4
5
© 2009 MapLink/Tele Atlas
© 2009 Cnes/Spot Image
Image © 2009 DigitalGlobe
© 2009 Google
lat -16.894762° lon -56.838851° elev 116 m
Eye alt 1.74 km
©2009 Google

Digital Elevation Model of Pantanal Wetland



November 2010



Specific landscape characteristics in each collection area (point 1)

Point 3- Hotel

Points 4 and 5

Arboviruses in the Americas is associated with animal and human diseases

- Togaviridae

  Mayaro, VEEV, EEEV, WEEV

- Flaviviridae

  CACI, DENV, ROCV, SLE, YFV, Ilheus, WNV

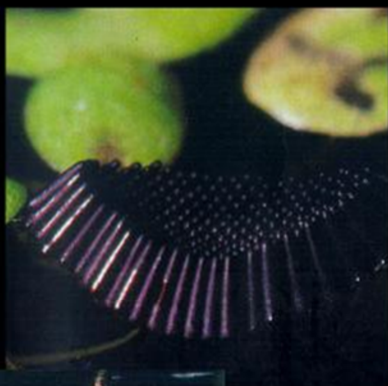
- Bunyaviridae

  OROV, LAC

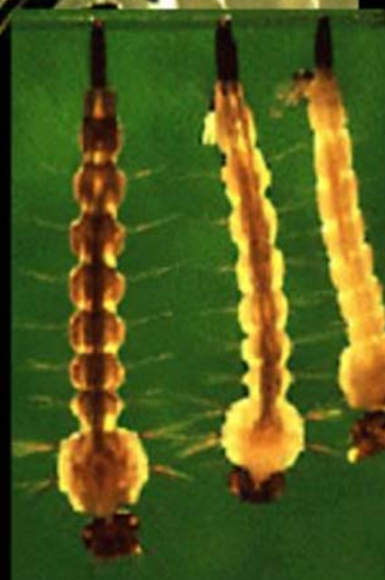
DIPTERA

There are over 2500 different species of mosquitoes throughout the world

Culex quiquefasciatus



Aedes aegypti



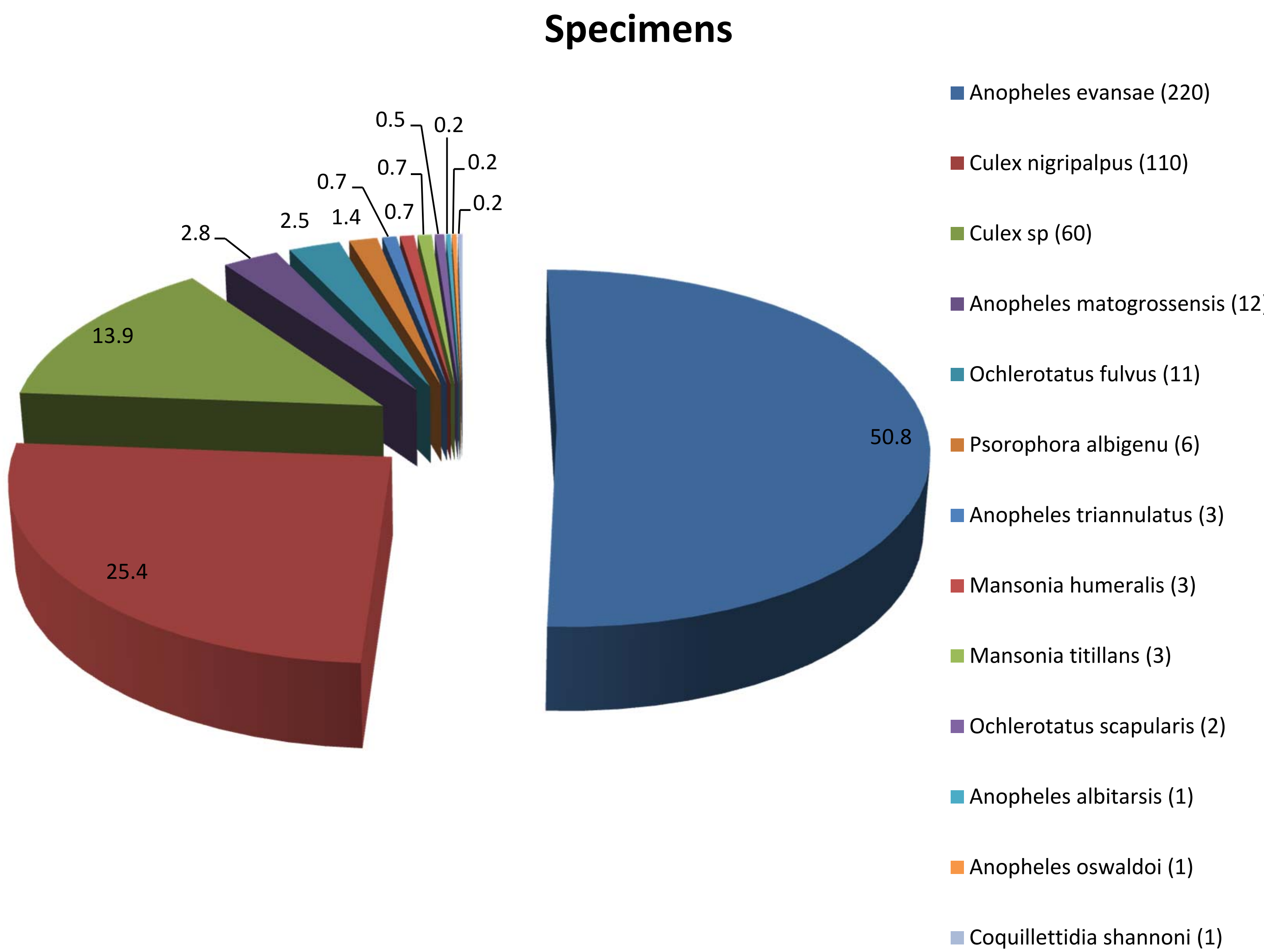
Aedes aegypti

Culex quiquefasciatus

Vectors of viral diseases

Vírus / Mosquitos	Aedes	Psorophora	Culex	Haemagogus	Sabethes	Anopheles
Dengue (DEN)	+++	-	-	-	-	-
Febre Amarela (YF)	+++	-	-	+++	++	-
Encefalite de São Luís (ESL)	-	-	+++	-	-	-
Encefalite Eqüina Oeste (EEO)	+	+	+++	-	-	-
Encefalite Eqüina Leste (EEL)	+	-	+++	-	-	-
Encefalite Eqüina Venezuelana (EEV)	+	-	+++	-	-	-
Encefalite Rocio (ROC)	+++	+++	-	-	-	-
Guamá (GUA)	-	-	+++	-	-	-
Guaroa (GRO)	-	-	-	-	-	+++
Ilhéus (ILH)	+++	+++	-	++	-	-
Mayaro (MAY)	+	-	-	+++	-	-
Melao (MEL)	+++	-	-	-	-	-
Oropouche (ORO)	+++	-	-	-	-	-
Serra do Navio (SDN)	+++	-	-	-	-	-
Tacaiuma (TCM)	-	-	+++	+	-	-

Pantanal, number of mosquitos/trap/night (one year summary-2010)



Anopheles sp.

In Pantanal may be vectors for Malaria (Xavier and Rebello, 1999): *An. evansae, An. matogrossensis, An. albitaris, An. oswaldoi*

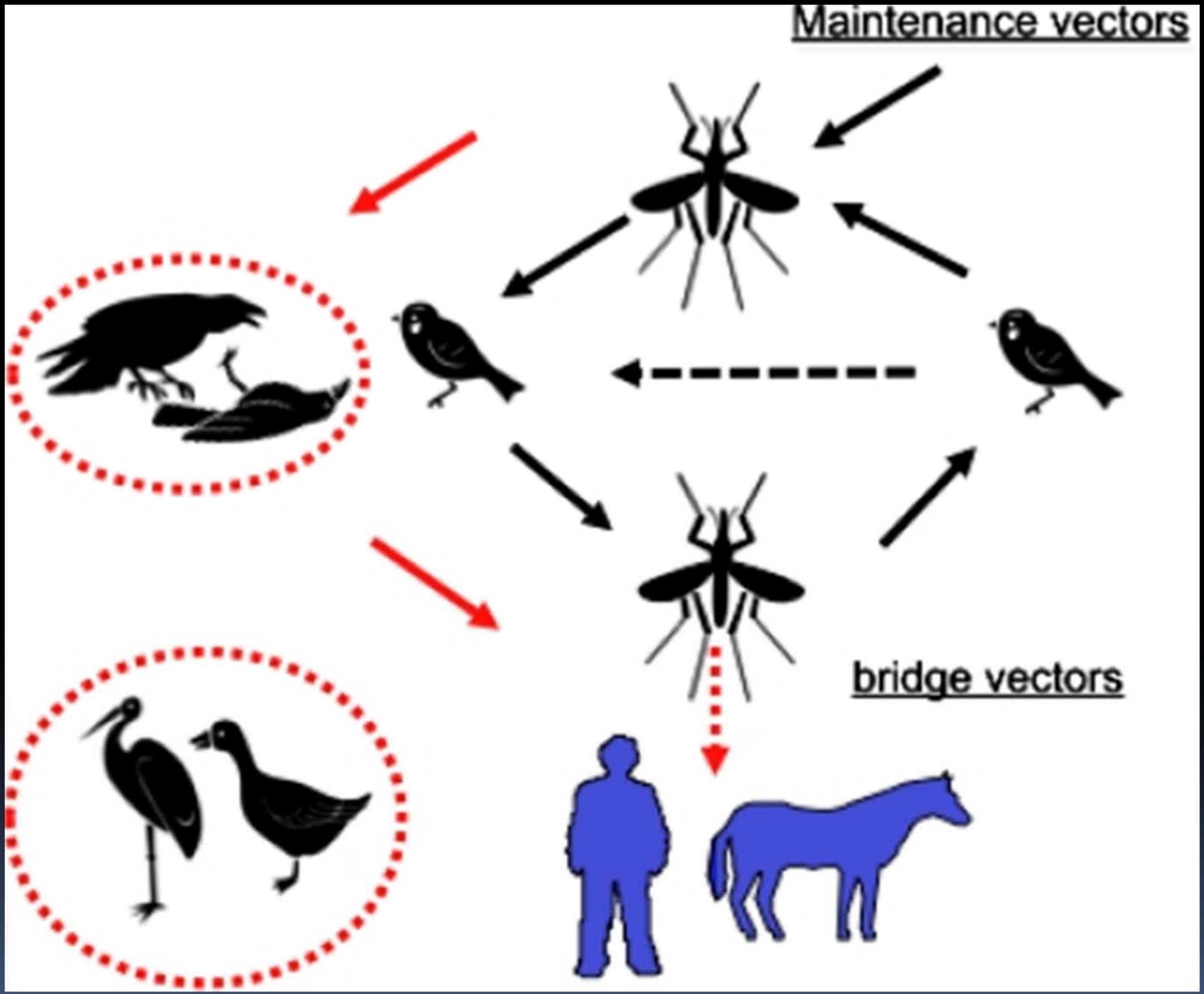
Culex sp.

WNV, SLEV, JEV

the second most abundant species found in Pantanal is related to the transmission of SLEV *(Culex nigripalpus)*

Source: http://www.fiocruz.br/~ccs/arquivosite/estetica/malaria.htm

West Nile Virus Life Cycle



Coquillettidia sp.

Related to the transmission of arboviruses; OROV *(Coquillettidia shannoni)*

Psorophora sp.

Related to the transmission of equine encephalitis; ILHV and WEEV *(Psorophora albigenu)*

Source: http://www.arbovirus.health.nsw.gov.au/areas/[illegible]tm

Mosquito traps: CDC-CO2 and human bate

Summary Statistics for total abundance, AN & CX by location

	1		3		4		5		All	
	Mean	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**	**Mean**	**Std Dev.**
Total	258.7	118.2	117.3	94.8	214.5	339.7	341.0	77.1	232.9	93.2
AN	30.9	19.4	36.8	38.9	51.3	82.5	175.5	32.5	73.6	68.5
CX	167.8	60.4	42.5	44.8	100.7	159.7	100.0	20.4	102.7	51.2

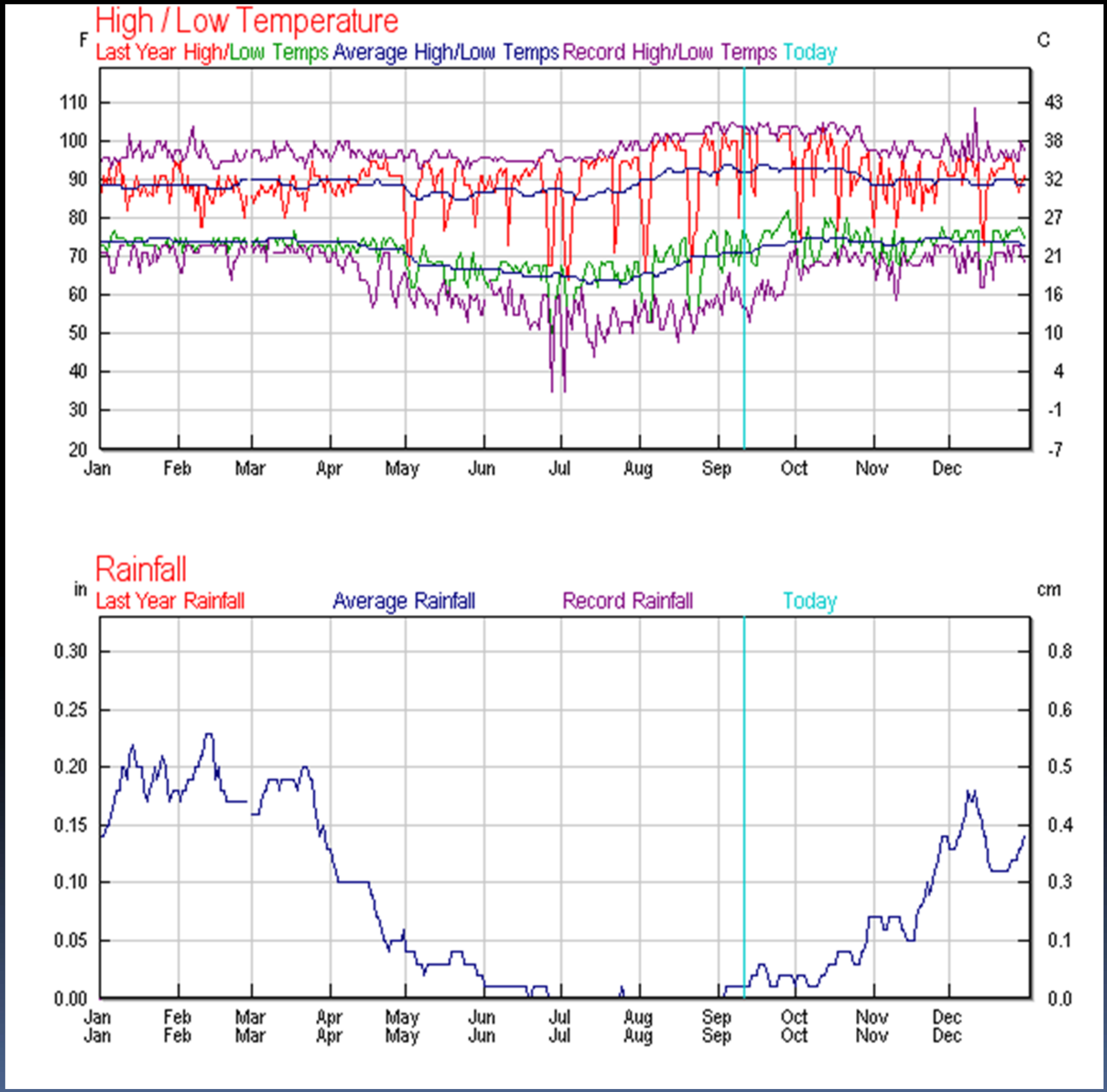
Summary Statistics for total abundance, AN & CX by month

	TOTAL M		AN		CX	
Month	average	st.dev	average	st.dev	average	st.dev
January	178.0	109.8	7.5	7.5	44.8	41.0
March	628.0	541.1	243.8	375.7	320.1	319.3
May	255.7	228.5	105.0	68.5	83.6	75.1
July	142.6	29.8	45.4	16.8	57.8	12.9
September	114.3	149.6	6.4	6.5	85.0	120.8
November	29.2	18.9	0.9	1.6	14.6	13.1

Average Proportions for AN and CX by month and location

	AN					CX				
	1	3	4	5	all	1	3	4	5	all
January	0.07	0.01	0.01	0.04	**0.04**	0.03	0.22	0.54	0.28	**0.25**
March	0.07	0.27	0.41	0.67	**0.39**	0.78	0.50	0.44	0.30	**0.51**
May	0.43	0.61	0.34	0.49	**0.41**	0.51	0.14	0.31	0.37	**0.33**
July	0.22	0.31	0.42		**0.32**	0.59	0.34	0.33		**0.41**
September	0.01	0.03	0.04	0.32	**0.06**	0.89	0.80	0.78	0.09	**0.74**
November	0.00	0.00	0.02	0.07	**0.03**	0.85	0.65	0.46	0.21	**0.50**
TOTALS	**0.12**	**0.32**	**0.24**	**0.53**	**0.31**	**0.64**	**0.36**	**0.47**	**0.30**	**0.45**

Cuiabá
Brazil



Field collected water temperatures (C) 2009-2010

(pools / inside tree holes)

January: 30C/ 23C

March: 26C/23C

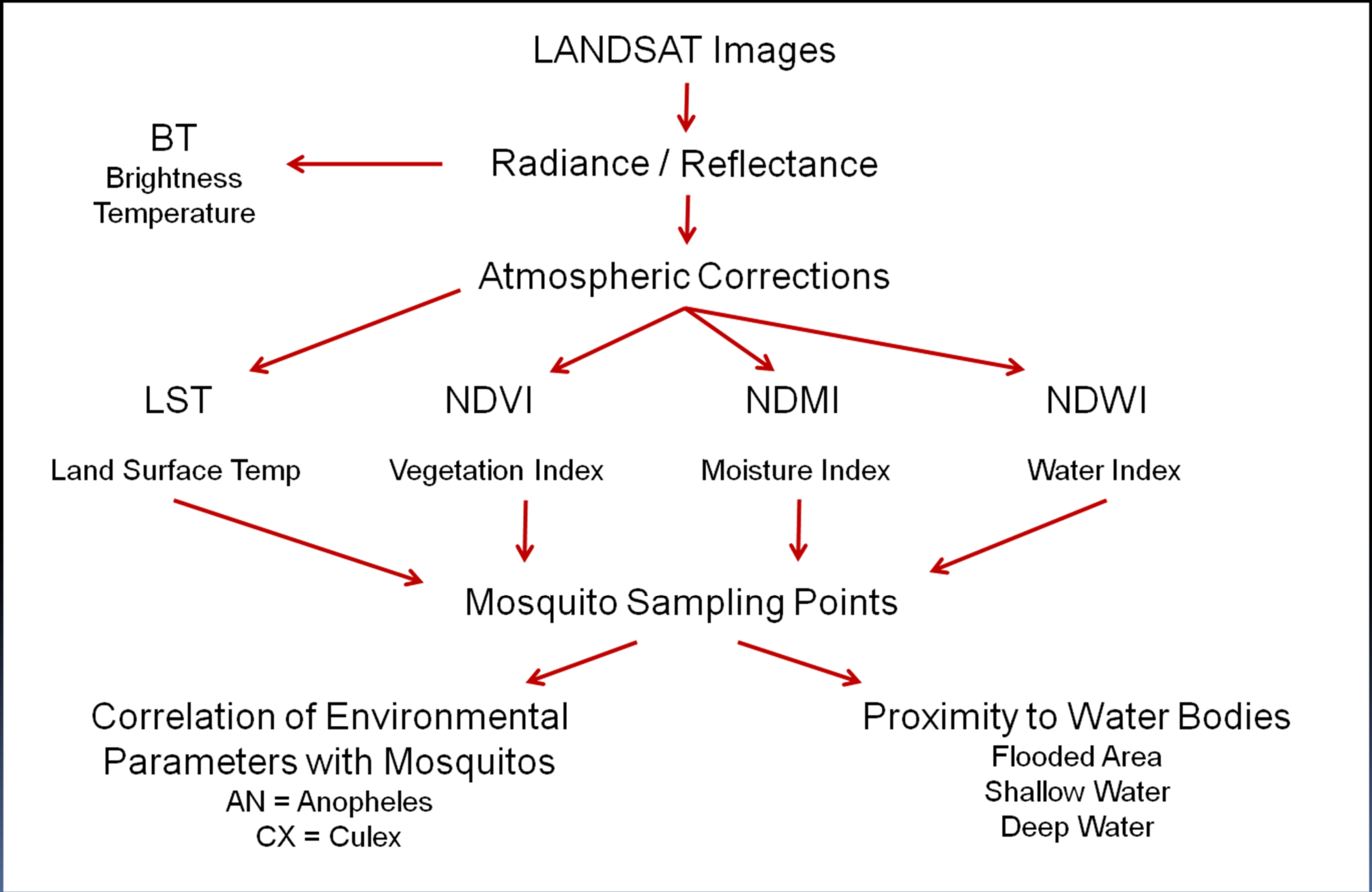
May: 27C/23C

July:24C/22C

September: 29C/21C

November: 29C/24C

IMAGE PROCESSING & METHODOLOGY



MOISTURE & WATER INDICES

Normalized Difference Moisture Index (also called **Infrared Index**) uses near infrared and mid-infrared bands, and is very sensitive to changes in plant biomass and water stress (Hardisky et al., 1983; Wilson et al., 2002); very useful in wetland studies:

$$NDMI = \frac{NIR_{TM\,4} - MIR_{TM\,5}}{NIR_{TM\,4} + MIR_{TM\,5}}$$

Normalized Difference Water Index (NDMI) is useful for delineating open water (McFeeters,1996)**:**

$$NDWI = \frac{GREEN_{TM\,2} - NIR_{TM\,4}}{GREEN_{TM\,2} + NIR_{TM\,4}}$$

BRIGHTNESS TEMPERATURE CALCULATION

T_B are retrieved by converting spectral radiance to at top of the atmosphere (TOA) brightness temperature using the formula:

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L\lambda} + 1\right)}$$

T_B = effective at satellite brightness temperature (K)
L_λ = spectral reflectance
K_1 and K_2 = thermal band calibration constants (units respectively in $Wm^{-2}sr^{-1}\mu m^{-1}$ and Kelvin)

LAND SURFACE TEMPERATURE CALCULATION

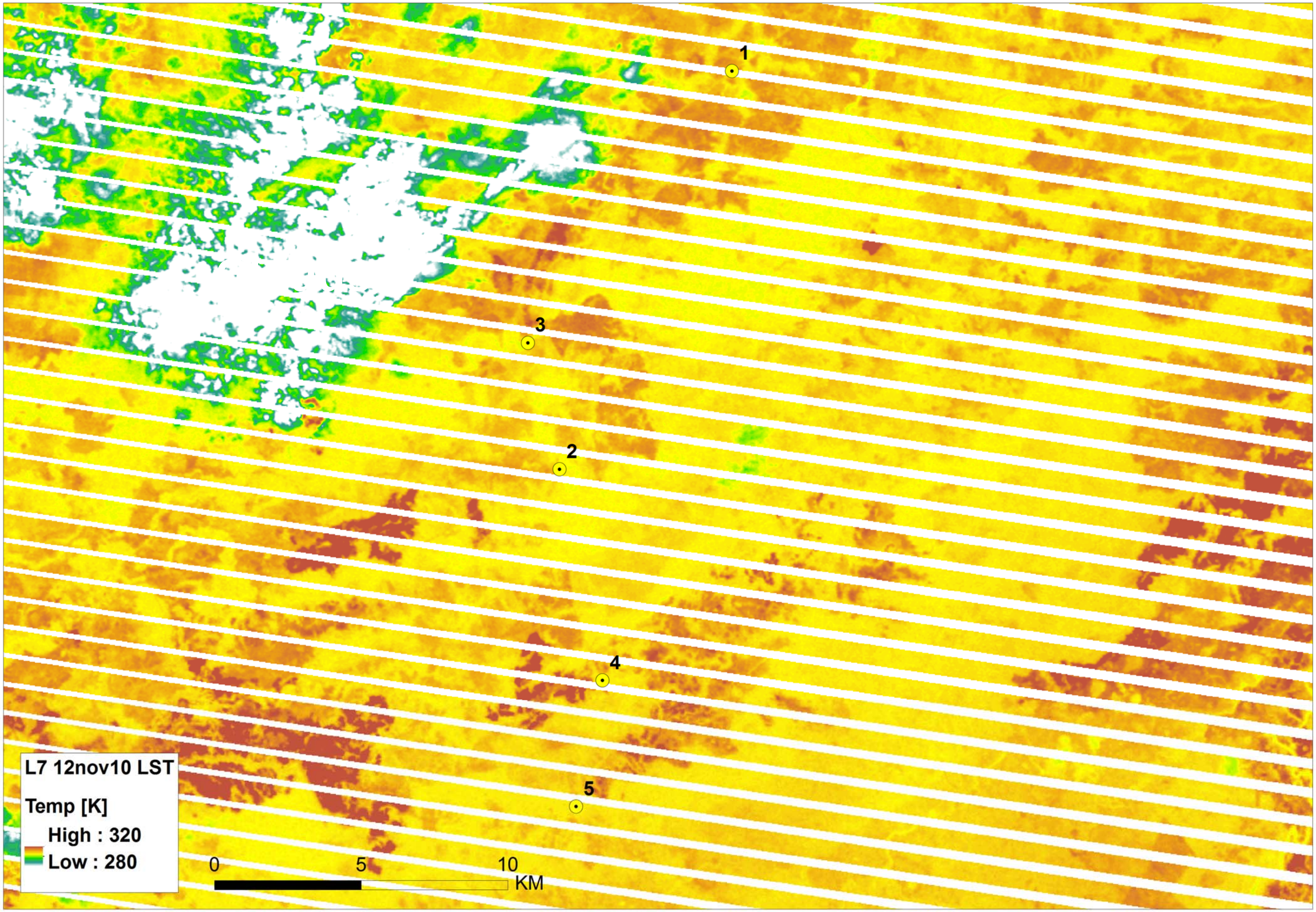
For retrieval of Land Surface Temperature (LST) atmospheric profiles of temperature and water vapor measured concurrently with satellite acquisition are necessary as inputs of a radiative transfer code, together with surface-emissivity data. A Web-based ACT (http://atmcorr.gsfc.nasa.gov) was used to obtain such parameters.

$$LST = \frac{L_{sen} - L^{\uparrow}}{\varepsilon \tau} - \frac{1-\varepsilon}{\varepsilon} L_{\downarrow}$$

LST = surface temperature
L_{sen} = at sensor radiance
$L^{\uparrow}$ = upwelling radiance
$L_{\downarrow}$ = downwelling radiance
τ = atmospheric transmittance
ε = emissivity of surface material

Coll et al. (2010) note that small overestimation between 0.15 and 0.3 K in the derived LST are possible.

November 2010



Culex sp proportion is highest in March and September

Anopheles sp peak in March and May and drop in September

Months/Locations	1	3	4	5
January	NDVI HIGH HOT MOIST	NDVI HIGH HOT MOIST	NDVI HIGH HOT MOIST	NDVI HIGH HOT MOIST
March	NDVI LOW HOT MOIST	NDVI MOD TEMP MOD MOIST	NDVI HIGH TEMP MOD MOIST	NDVI HIGH TEMP MOD MOIST
May	COLD/DRY	COLD/DRY	COLD/MOD DRY	COLD/MOD DRY
July	COLD NDVI LOW DRY	COLD NDVI LOW DRY	COLD NDVI LOW DRY	COLD NDVI LOW DRY
September	HOT/DRY	HOT/DRY	HOT/DRY	MOD HOT/DRY
November	HOT NDVI HIGH MOIST	HOT DVI HIGH MOIST	HOT NDVI HIGH MOIST	HOT NDVI HIGH MOIST

Migration of birds to the Northern Hemisphere

Migration of birds from Northern Hemisphere

Conclusions

- High incidence of Anopheles in colder/higher NDVI habitats. Peaks from March to May. Does not survive dry season (June-September)
- Incidence for Culex sp peaks twice a year: March and September ; and survives dry season
- West Nile virus could be transmitted in March (from local birds to migratory birds) and September (from migratory birds to local birds) perpetuating transmission of WNV in the whole Continent

Conclusions

- Satellite time series with good temporal & spatial resolution are essential for monitoring environmental factors favoring vector habitats and disease spread.
- Limited access to high quality satellite data are due to cloud cover and problems with older satellite systems (LANDSAT 7 , ASTER, ALOS)
- Time series of temperature, vegetation, soil moisture and open water bodies are useful for characterizing and monitoring the ecosystem of mosquito disease vectors

Acknowledgments

- Instituto Oswaldo Cruz. Diptera Laboratory, Rio de Janeiro, Brazil
- Panthera Inc, NY, USA
- Mount Sinai School of Medicine, NY, USA
- Boston University Center for Remote Sensing
- Tufts University, MA, USA
- Massachusetts Institute of Technology, MA, USA