

CNES Strategy, Satellite data and modeling for Public Health

***Murielle Lafaye
Environment-Climate-Health Program Responsible***

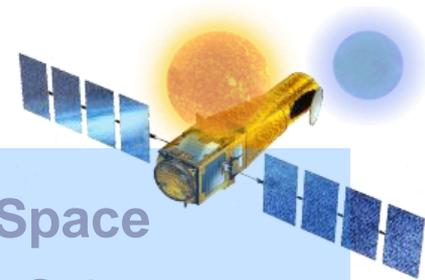
***Directorate Strategy and Program
Applications and Valorisation Departement***

CNES Strategic Action Domains

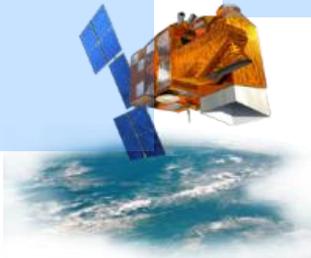
Civil applications



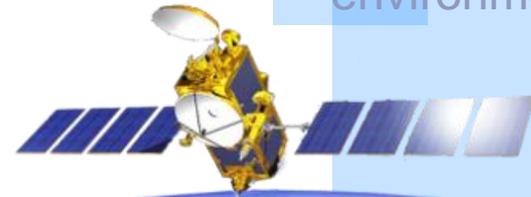
Space
Sciences



Security & Safety



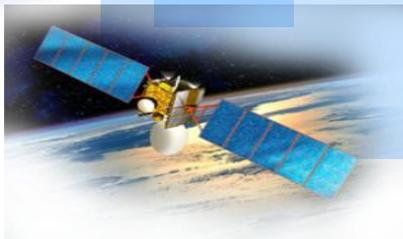
Earth
environment
climate



Access
to Space



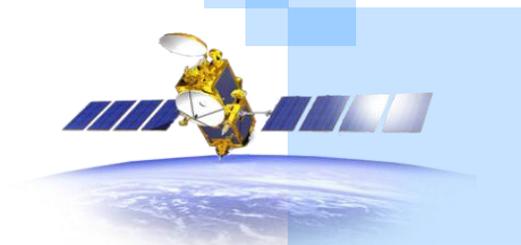
Civil applications



Security & Safety



Earth Environment Climate



- ✓ Ressources management
- ✓ Crisis & Natural hazards management
- ✓ Numeric Access & Services
- ✓ Transports
- ✓ Health

Telemedecine

Ease access to healthcare
In mobile or isolated areas

DIABSAT mobile van

French Guyana network

PSMA crisis facility

S2E epidemiological networks

EPIDEFENDER / IMOGENE

Tele-epidemiology

Characterize Environmental Risk for
air-borne, water-borne & vector-borne diseases

Gaz

algal bloom

malaria

Aerosols

vibrio/ cholera

dengue

Particules

bilharzia

Rift Valley

Asthma

cyanobacteria

West Nile...

La Télésanté

L'Espace au service de la santé

1 - Improving access to healthcare

Treating patients at remote and mobile sites

2 - Environment / Climate / Health

Monitor, predict and prevent epidemics

Tele-epidemiology consists in monitoring and studying the propagation of human and animal diseases (water, air and vector borne diseases) which are closely linked to climate and environmental changes, based on space technology. The French Spatial Agency (CNES) has thus developed a concept based on a deterministic approach of the climate-environment-health relationships and on an original and really adapted space offer.

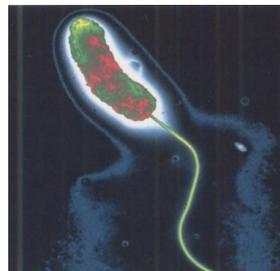
“Tele-epidemiology” Conceptual approach

Multidisciplinary approach linking disciplines

Environment
Climate



Social Sciences



Microbiology



Entomology



Veterinary

1- UNDERSTANDING the MECHANISMS favoring EMERGENCE and PROPAGATION

Diagnostic: extract and identify the main physical and biological mechanisms at stake

Observing strategy: monitoring and assembling multidisciplinary in-situ datasets

2- DEVELOPING well ADAPTED PRODUCTS integrating Space tools

Remote-sensing monitoring of environment, linking epidemics with confounding factors

Remote-sensing from space: use of products, fully adapted to spatio-temporal scales of variability

3- INNOVATIVE Risk Maps using SPACE TOOLS

ZPOM modeling as a contributor for EWS

cnes “Tele-epidemiology” Partnerships & Projects

- Conceptual approach currently applied to different infectious diseases :
 - MALARIA in URBAN Areas: Puerto Iguazu (Argentine) and Dakar (Senegal)
 - MALARIA in RURAL Areas: Burkina Faso and Paraguay
 - RIFT VALLEY FEVER in Senegal
 - BILHARZIA in China
 - VIBRIO related diseases (diarrhea, cholera) in the Mediterranean basin
 - DENGUE in Argentina
 - LEISHMANIASIS and MALARIA in Algeria
- Towards Early Warning System ⇒ Rift Valley Fever in Senegal



“Tele-epidemiology” & Rift Valley Fever in Senegal



CENTRE NATIONAL D'ÉTUDES SPATIALES

Météo France, France

Association Reflets, France

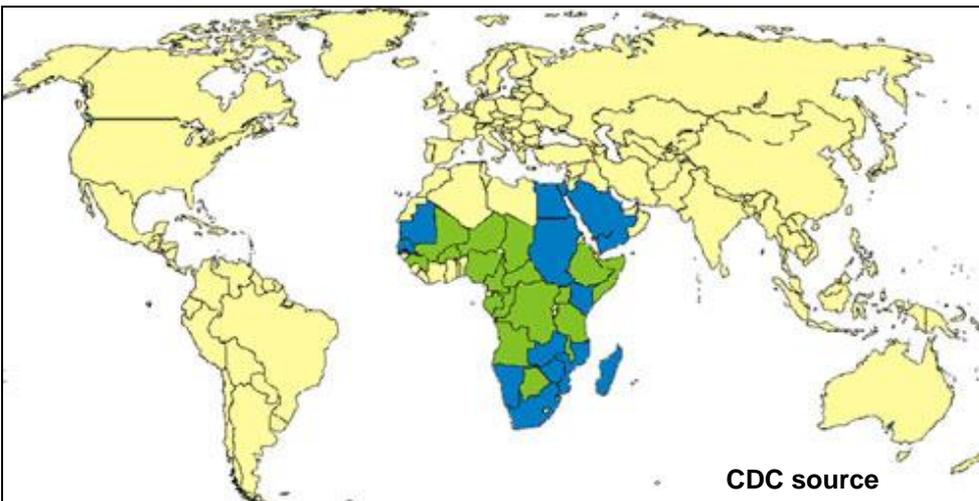
Direction des Services Vétérinaires, Senegal

Centre de Suivi Ecologique, Senegal

Institut Pasteur de Dakar, Senegal

- The Rift Valley Fever (RVF) is an arthropod-borne viral disease,
- Found essentially in Africa
- Primarily spread amongst domestic animals by the bites of infected mosquitoes, especially *Aedes vexans* and *Culex poicilipes* ⇒ The abundance of such RVF vectors is directly linked to **ponds' dynamics** and their vegetation cover and turbidity degree. The ponds' dynamics is associated with the **spatio-temporal variability of rainfall events**.
- RVF virus could also infect humans
- RVF is causing epizootics of spontaneous abortion and high mortality rate for domestic animals

⇒ **RVF can cause very serious economic losses in livestock.**



■ Countries with endemic disease and substantial outbreaks of RVF

Gambia, Senegal, Mauritania, Namibia, South Africa, Mozambique, Zimbabwe, Zambia, Kenya, Sudan, Egypt, Madagascar, Saudi Arabia, Yemen

■ Countries known to have some cases, periodic isolation of virus, or serologic evidence of RVF :

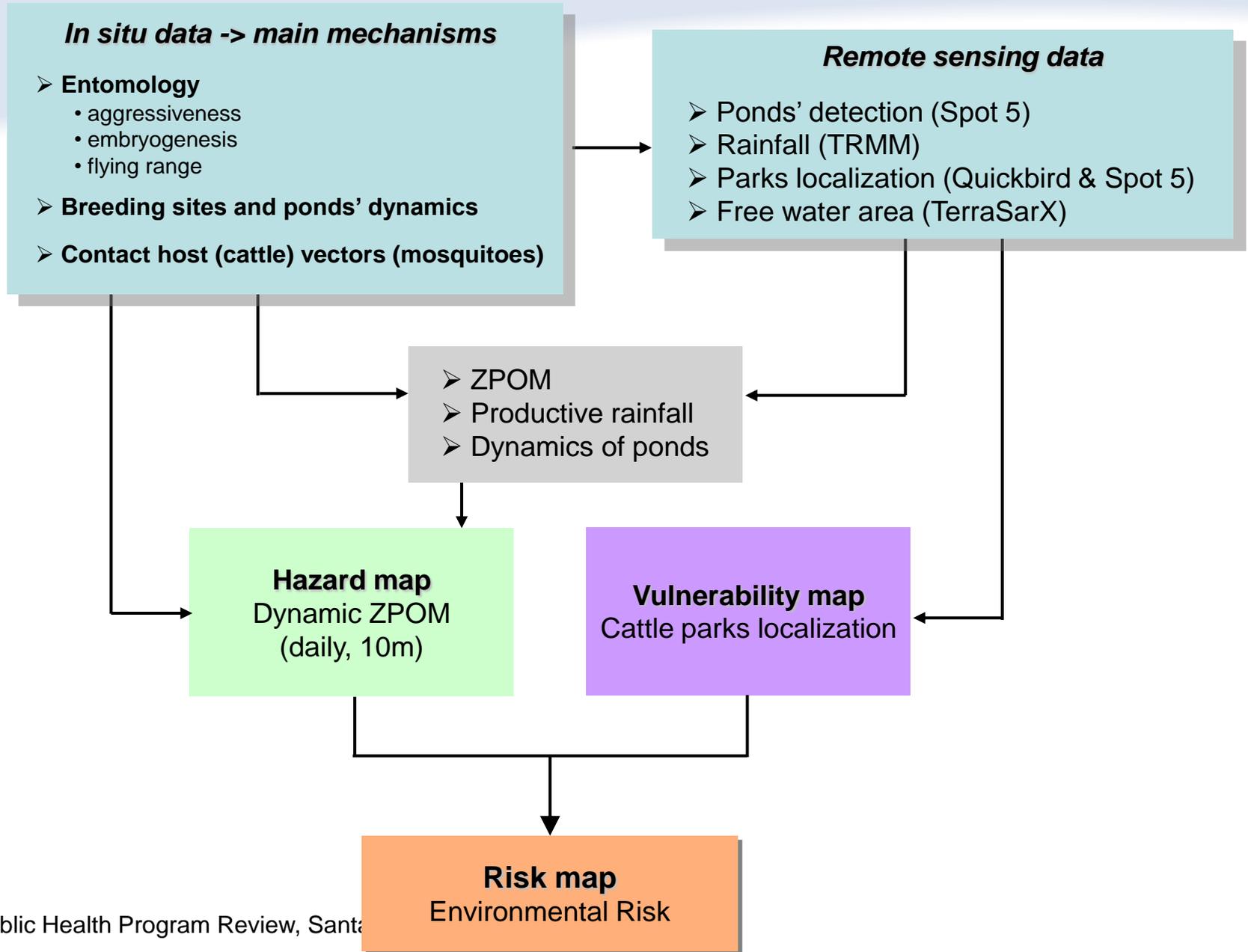
Botswana, Angola, Democratic Republic of the Congo, Gabon, Congo, Cameroon, Nigeria, Central African Republic, Chad, Niger, Burkina Faso, Mali, Guinea, Tanzania, Malawi, Uganda, Ethiopia, Somalia



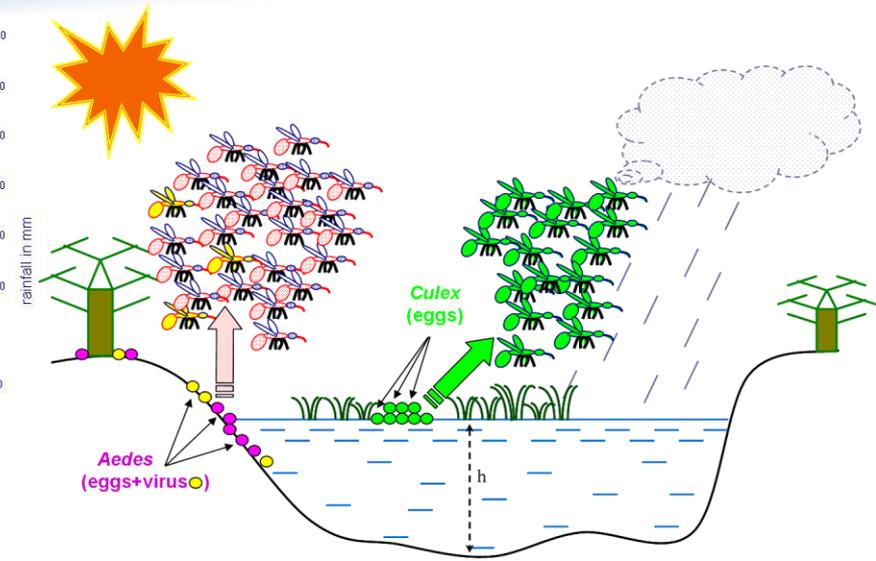
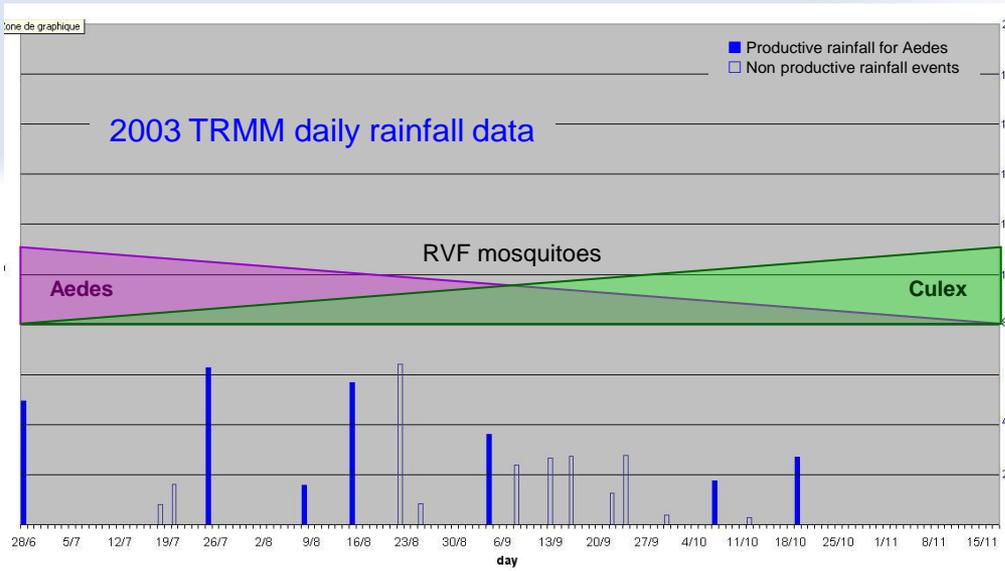
Studied area centered around Barkedji in the Ferlo region in Senegal

Sahelian Climate

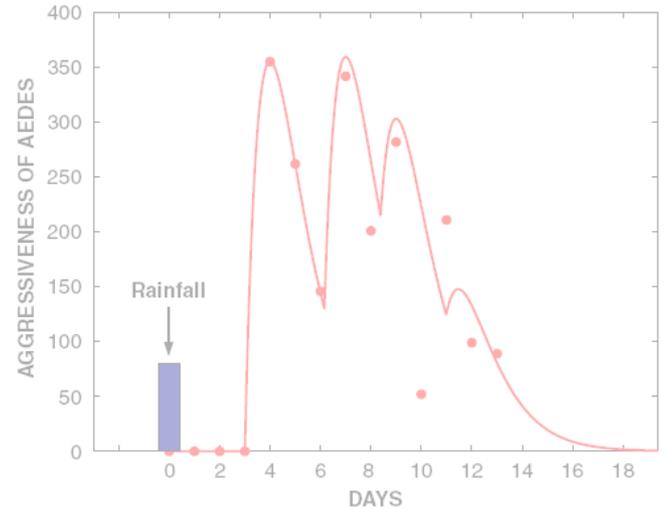
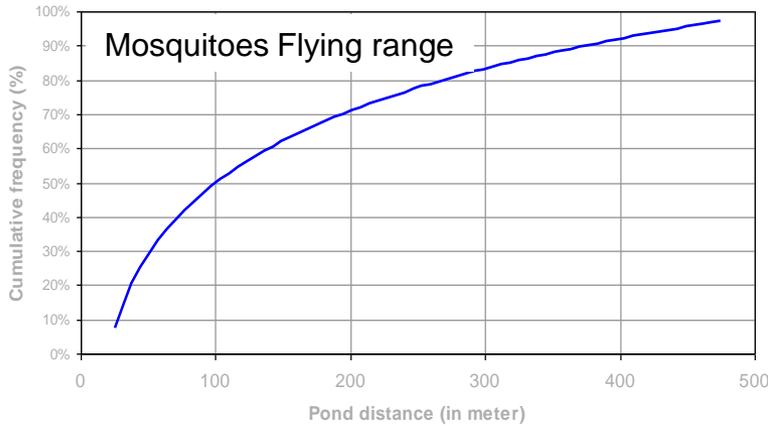
Rainfall 300 to 400 mm in 4 or 5 months (July to November)



From rainfall event to vectors' aggressiveness



Aedes vexans (%) versus pond distance (meter)



Ndiaye et al., 2006

2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

A Remote-sensing tool applied to Rift Valley Fever (RVF) Monitoring

Analyses and processing of high-spatial resolution satellite images (SPOT 5, 10m)



Computation of ponds' area, their vegetation cover and turbidity



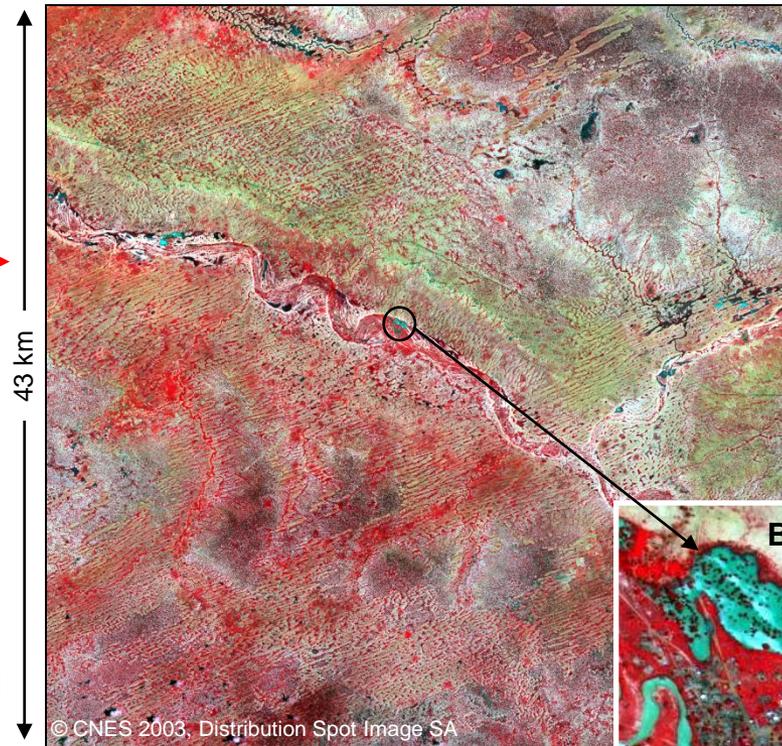
Evaluation of Zones Potentially Occupied by Mosquitoes (ZPOM)



Map of Senegal – African Atlas (Jaguar Edit.)

□ Studied area : Ferlo region in Senegal

Multi-spectral SPOT 5 Image (high-spatial resolution -10m)



On the 26/08/2003

Studied area: 198 337 ha

Number of ponds: 1354

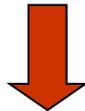
Ponds' area: 1703 ha

Ponds' percentage: 0.9%

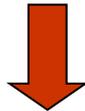


2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS A Remote-sensing tool applied to Rift Valley Fever (RVF) Monitoring

Detection of ponds and their characteristics



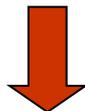
Developing brand-new indices by combining various wavelengths



Ponds detection



NDPI f(MIR, Green)



Ponds characteristics

┌ → % Vegetation
└ → % Turbidity

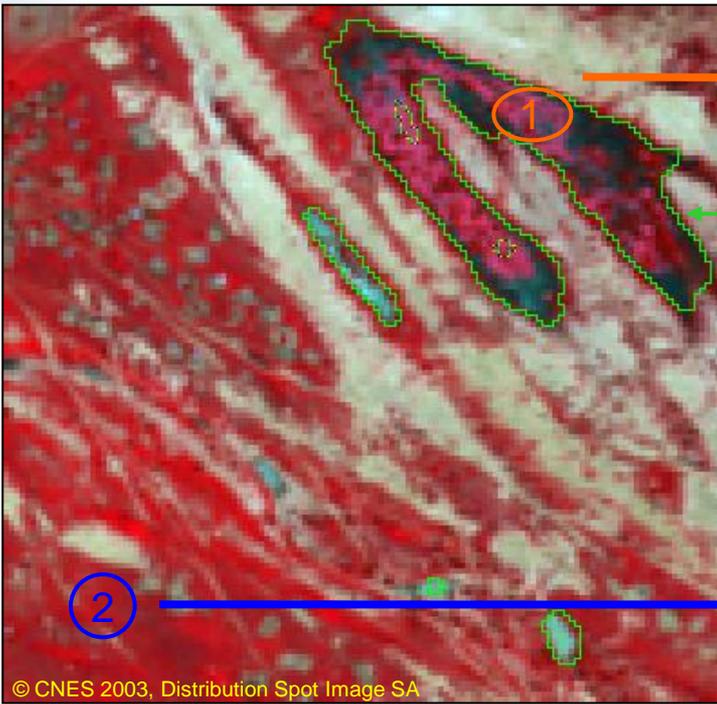


NDVI f(NIR, Red)



NDTI f(Red, Green)

Spot 5, multi-spectral high-spatial resolution (10-m)
 August 26th, 2003 (during the rainy season)



Pond south-west Barkedji
 15 ha (peak of rainy season)
 55% covers by vegetation
 45% free water



1- pond vegetation



2-sahelian savanna

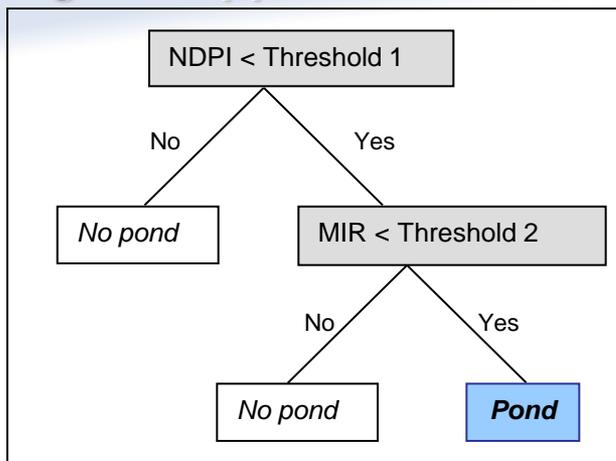
The new Normalized Difference Pond Index
 or:

$$NDPI = (MIR - Green) / (MIR + Green)$$

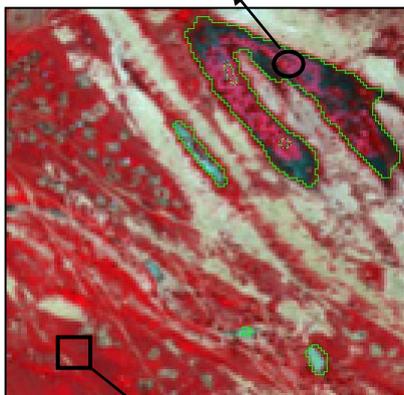
2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

A Remote-sensing tool applied to Rift Valley Fever (RVF) Monitoring

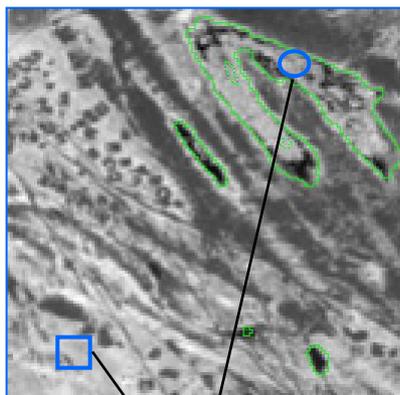
Detection of ponds by using a decision-tree conditional classifier based on the NDPI index



'Object' # 2: Vegetation within ponds

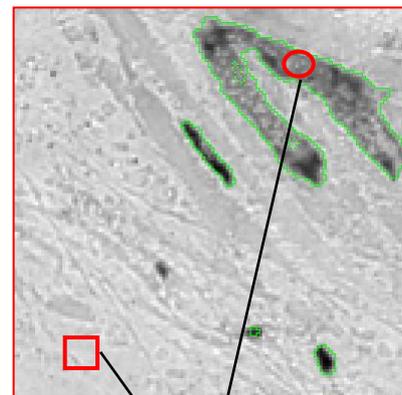


'Object' # 1: Vegetation outside ponds



Similar response

Cannot differentiate between 2 'objects'

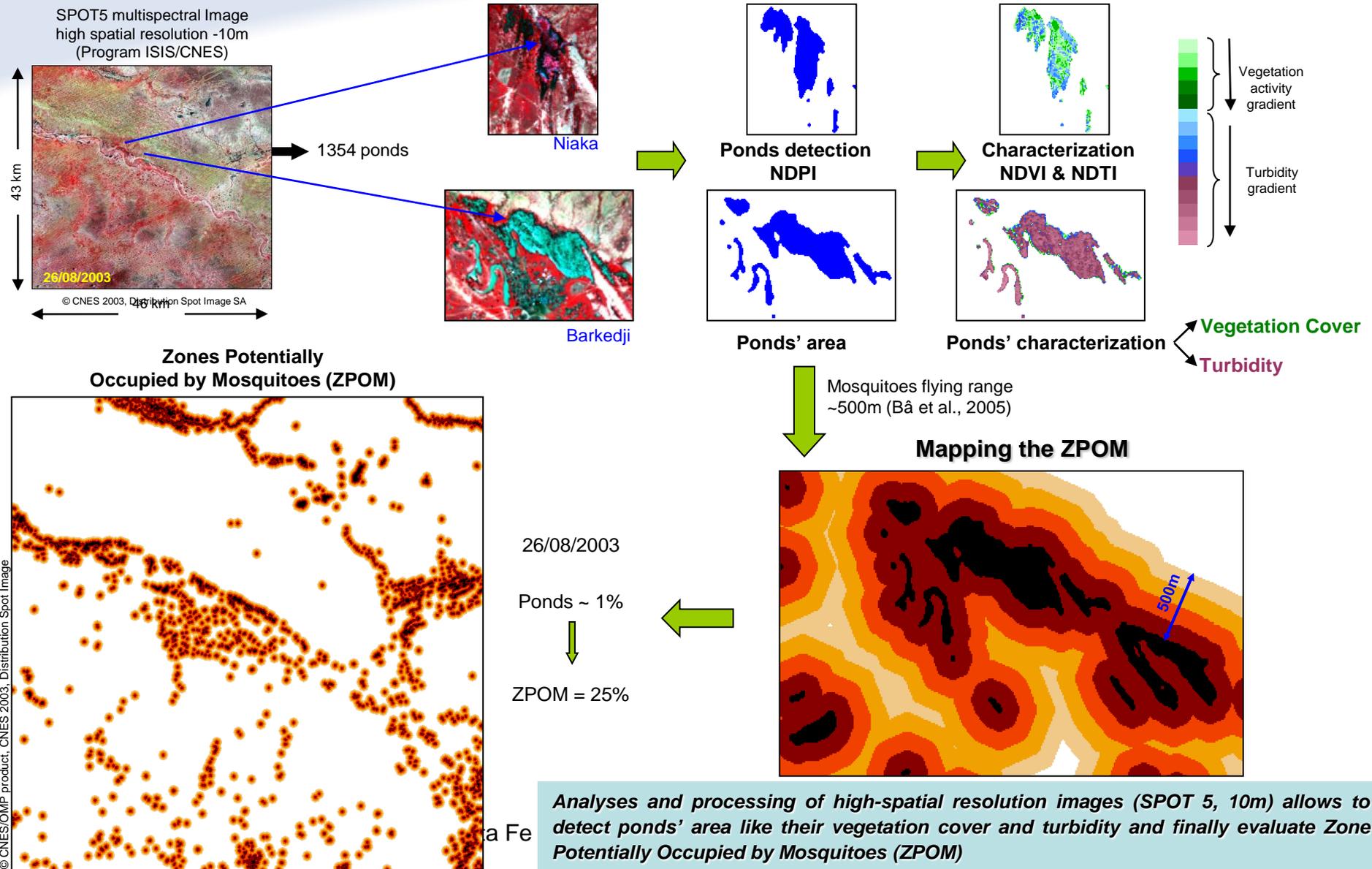


Different response

Two 'objects' are distinct

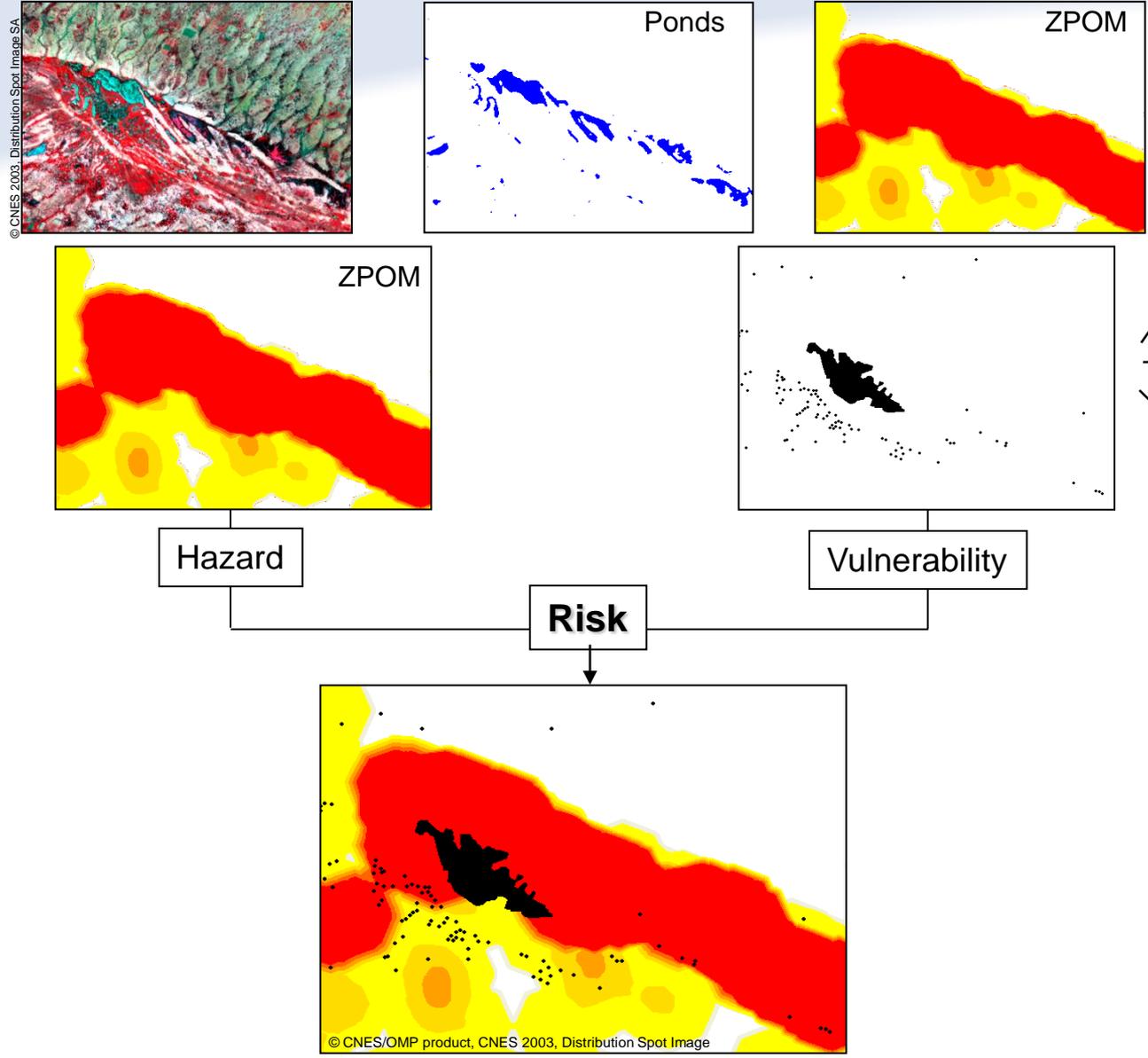
3 – Innovative RISK MAPS using SPACE TOOLS

Identify environmental factors of *Aedes* & *Culex* presence by remote sensing to obtain risk map



Analyses and processing of high-spatial resolution images (SPOT 5, 10m) allows to detect ponds' area like their vegetation cover and turbidity and finally evaluate Zone Potentially Occupied by Mosquitoes (ZPOM)

3 – Innovative RISK MAPS using SPACE TOOLS

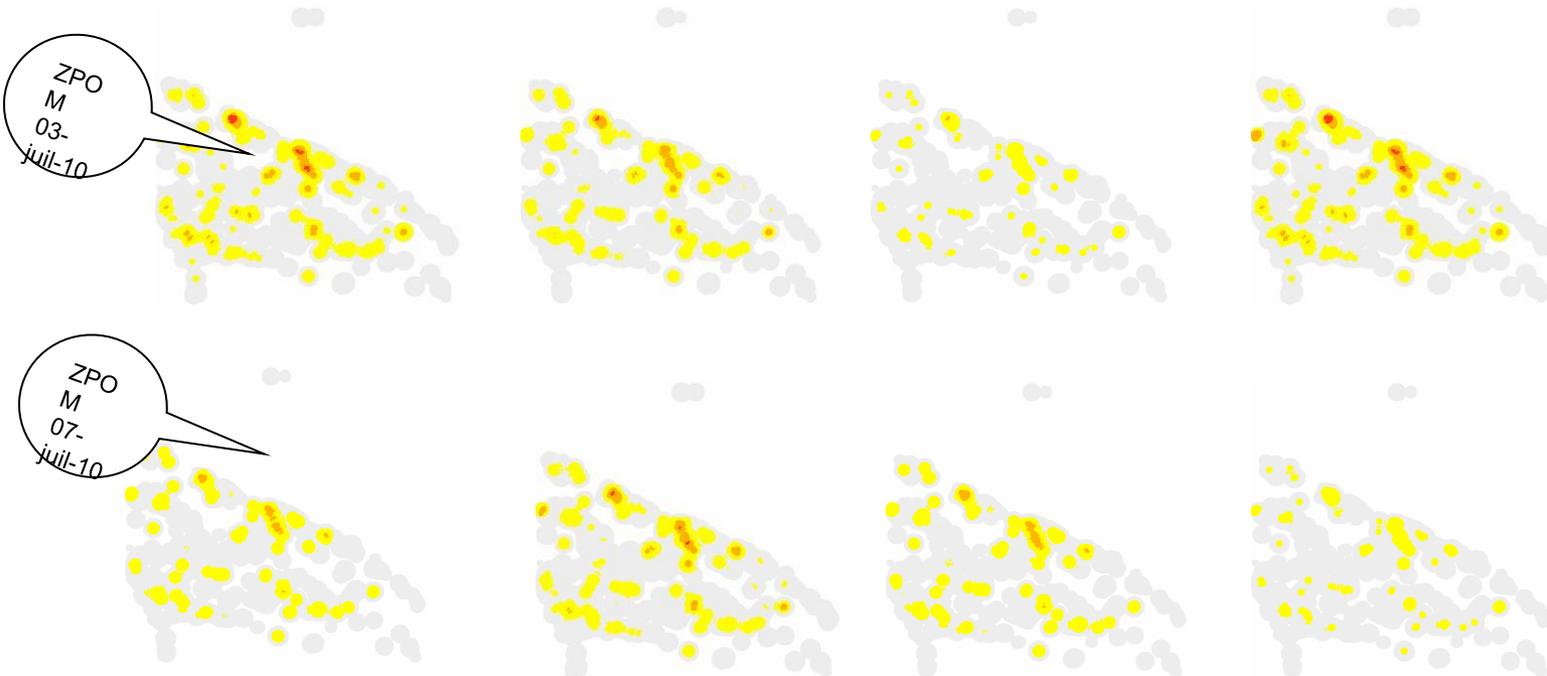


Some parks ...



3 – Innovative RISK MAPS using SPACE TOOLS

Vector related diseases : Rift Valley Fever Environmental Risk EWS



**Towards Service Project AdaptFVR
MEDDTL - GICC Program**

**CSE, DSV, Institut Pasteur Dakar,
Météo France, Reflets, CNES (coord.)**

“Tele-epidemiology” & Dengue in Argentina

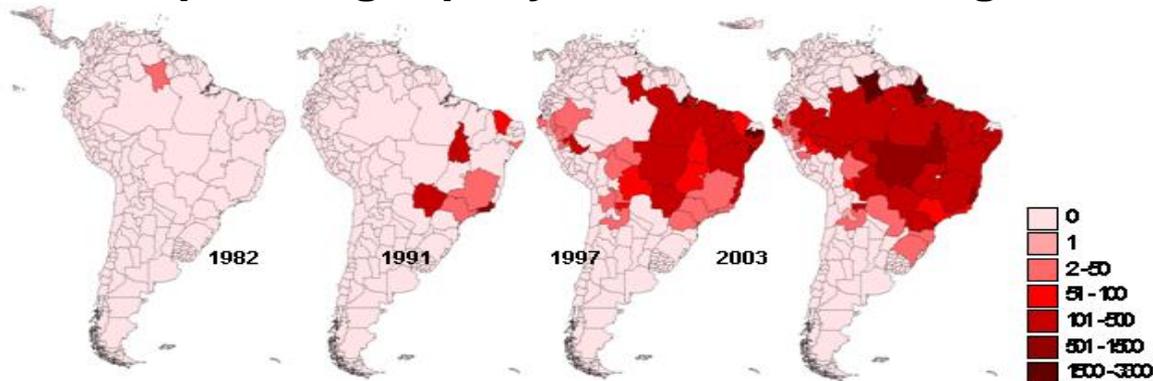


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***CONAE, Argentina
Ministry of Health, Argentina
Mondo Sano Foundation, Argentina
INRA/ENVL, France***

- Dengue Fever is transmitted by the bite of a *Aedes* mosquito (*Aedes aegyptis*, in South America), infected by one of the 4 dengue viruses; one of them is hemorrhagic fever
- It affects infants, young children and adults
- Dengue Fever represents more than 70% of the disease burden in South-East Asia and Middle Pacific areas; in the Americas and the Caribbean, the incidence and severity are increasing rapidly
- Ecology of the vector makes cans, tires and small reservoirs favorable as breeding sites; **vector's production** is linked to vegetation and urban types, and garden cleanliness.

⇒ **Dengue fever is spreading rapidly in non affected regions**

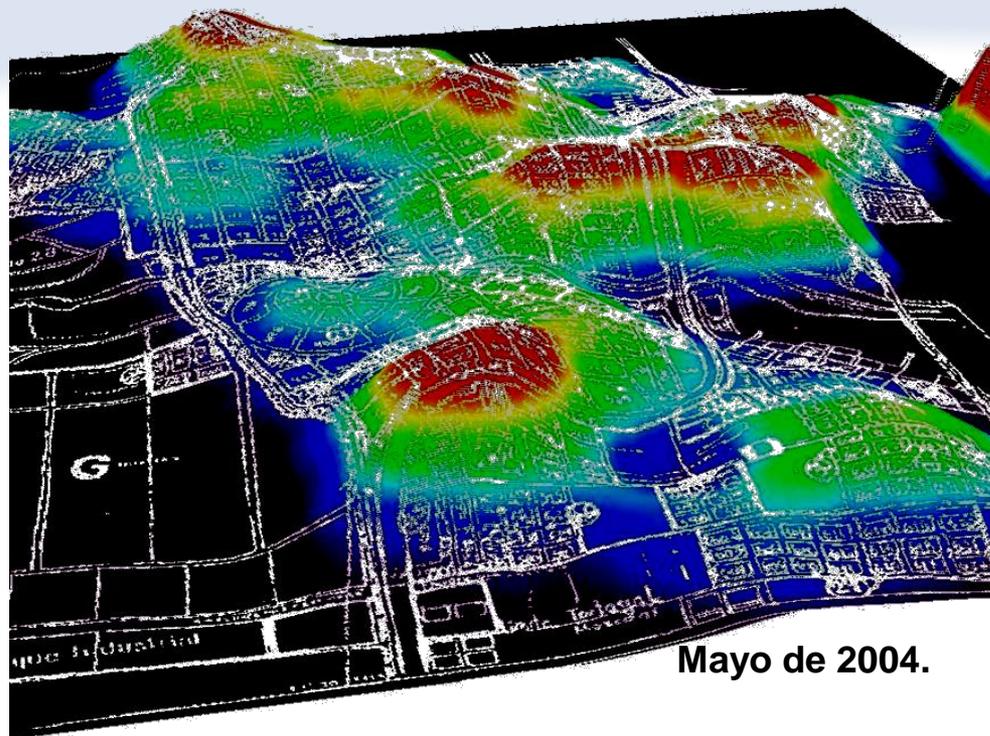


Dengue spreading in Argentina

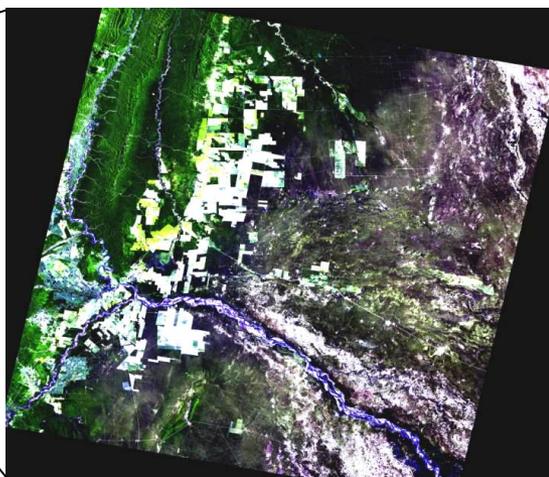


Aedes aegyptis breeding sites

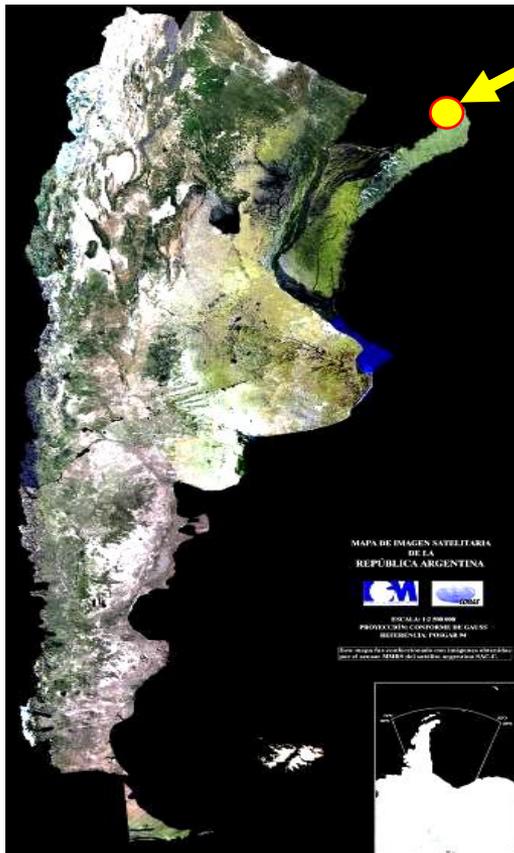




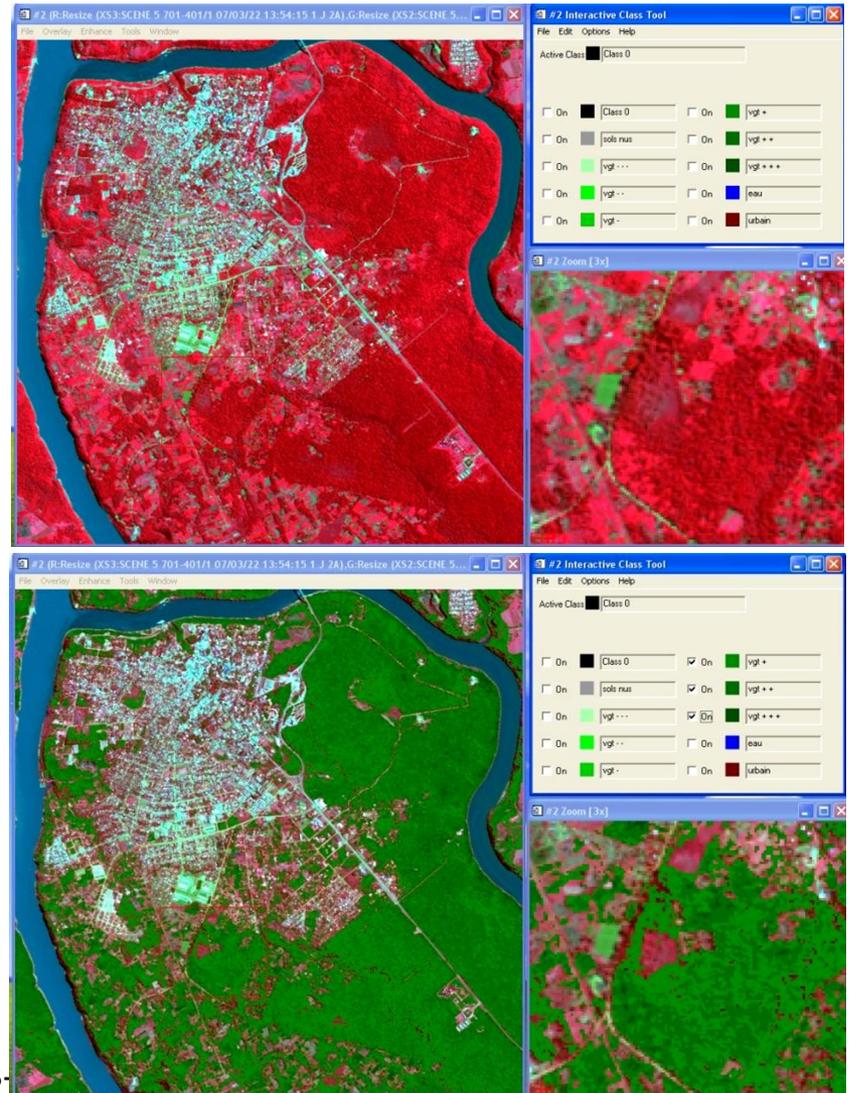
Epidemiological survey



2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS A Remote-sensing tool applied to Dengue Monitoring

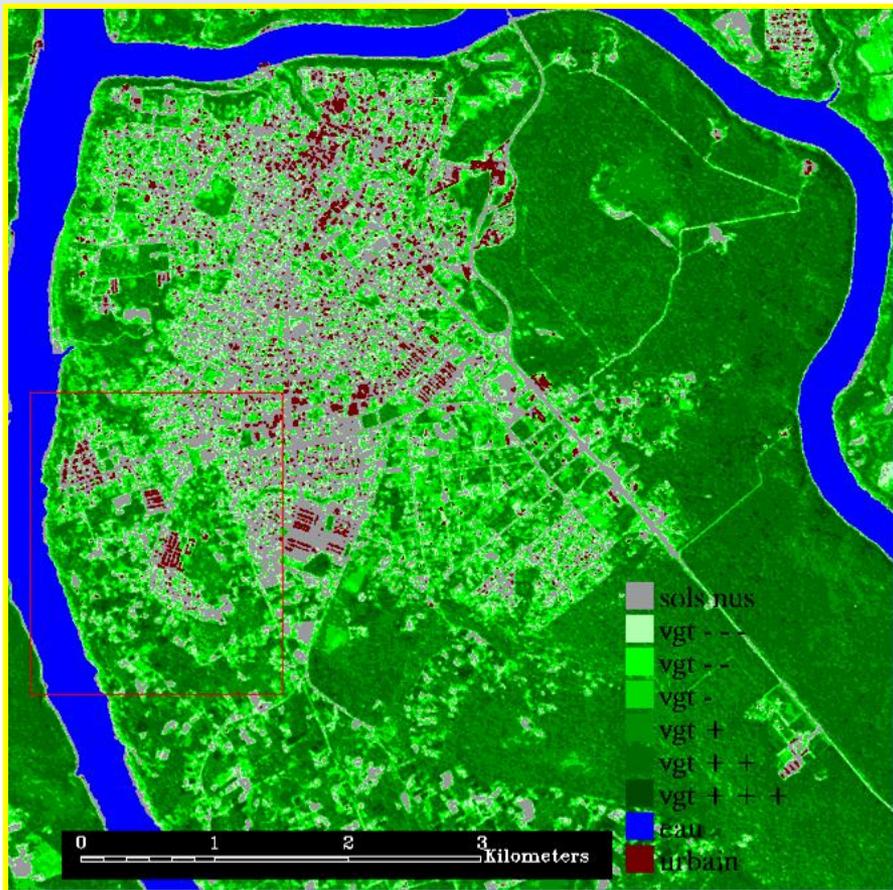


Puerto Iguazú

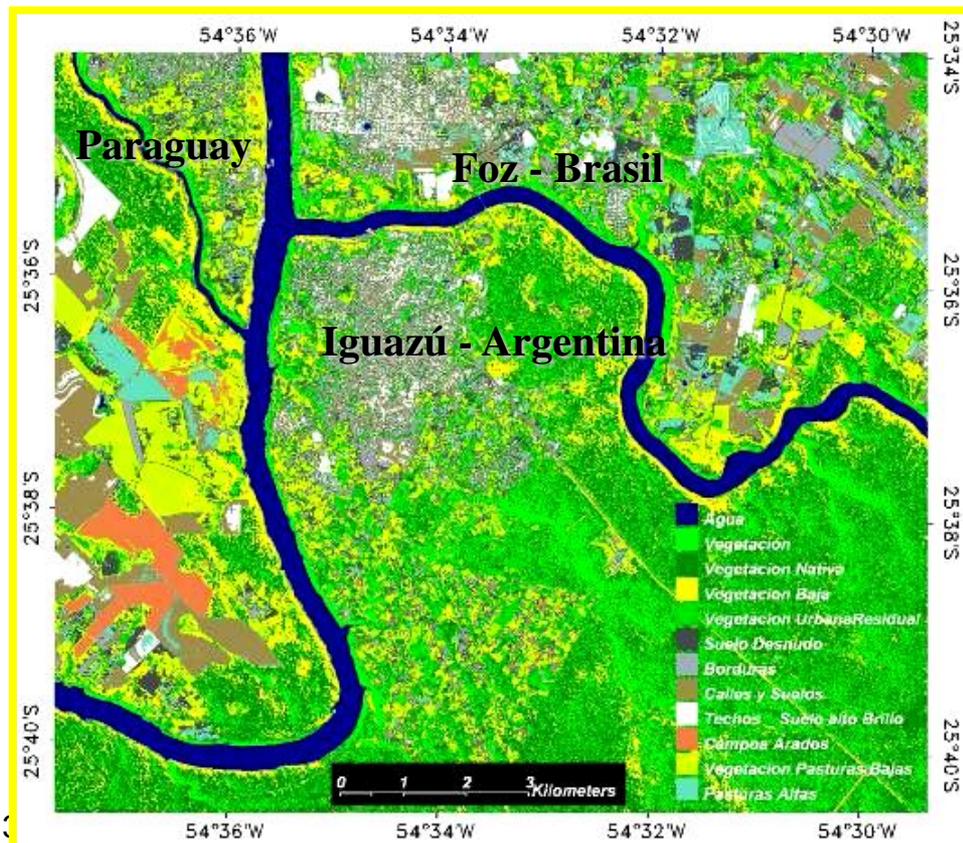


2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

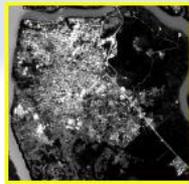
A Remote-sensing tool applied to Dengue Monitoring



Supervised classification



3 – Innovative RISK MAPS using SPACE TOOLS



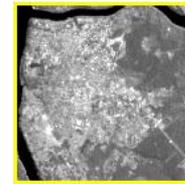
bande 1



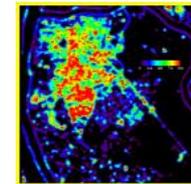
bande 2



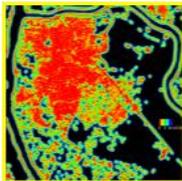
bande 3



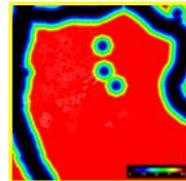
bande 4



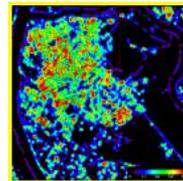
% Sol Nu



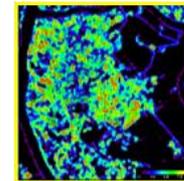
Buff. SolNu



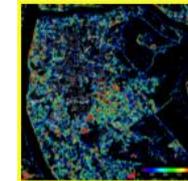
Buff. ClasEau



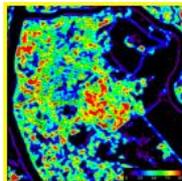
% végétB2



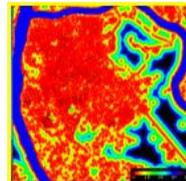
% végétB3



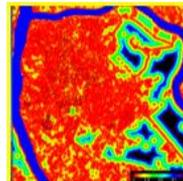
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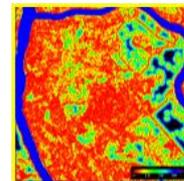
% végétBT



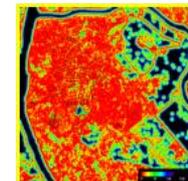
Buff. végétB1



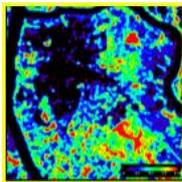
Buff. végétB2



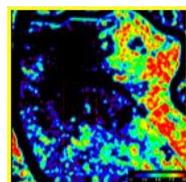
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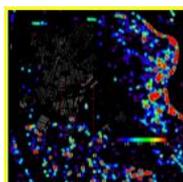
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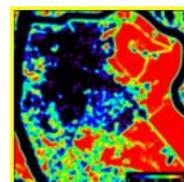
% végétA5



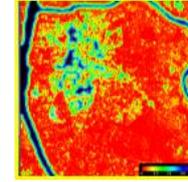
% végétA6



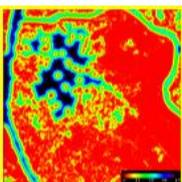
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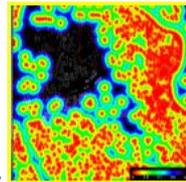
% végétAT



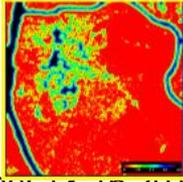
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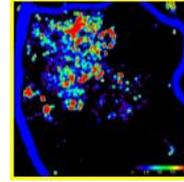
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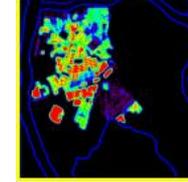
Buff. végétA7



Buff. végétAT



% UrbainClas



% Urbain.Shp

“Tele-epidemiology” & Urban Malaria in Dakar City, Senegal



IRBA, France

Observatoire Midi-Pyrénées – Laboratoire deAérologie, France

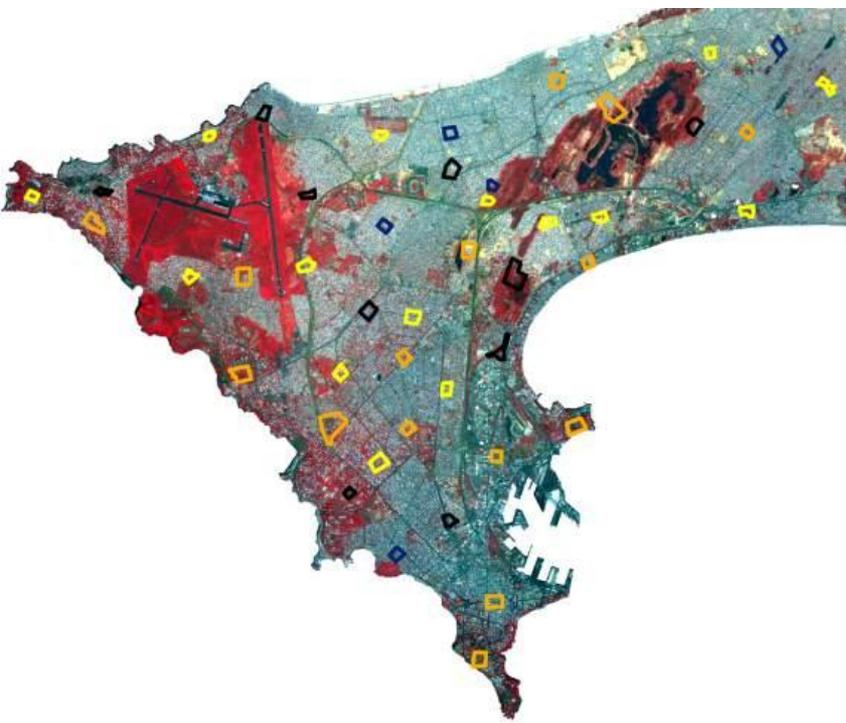
IRD Dakar, Senegal

Diversity of Anopheles Breeding sites

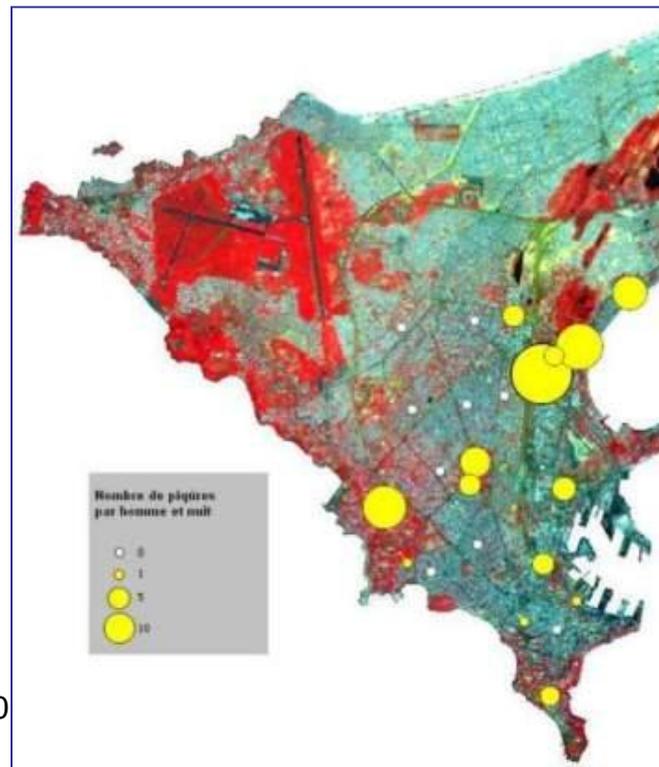


Urban Malaria in Dakar City, Senegal 1 - Understanding mechanisms at stake

Entomological data (2007-2010) on 45 sites
+ SPOT & radar images

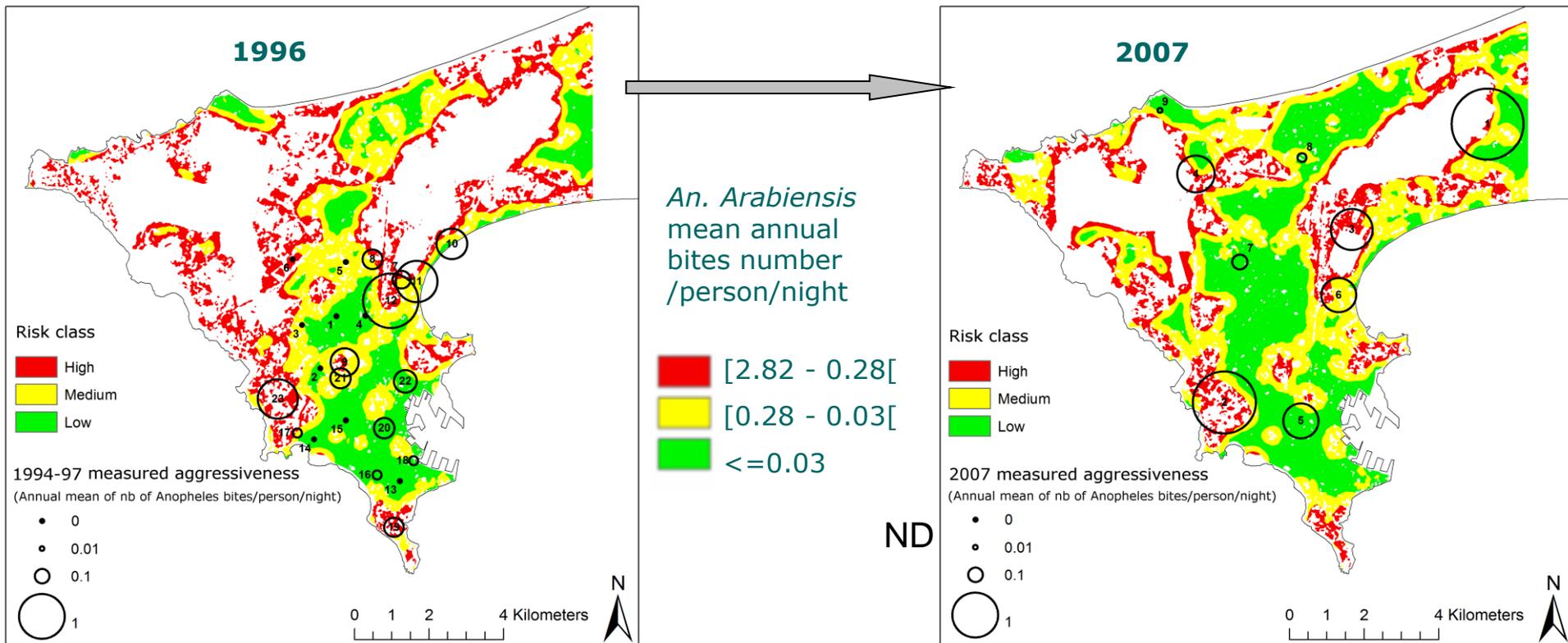


Anopheles human biting rate (nb bites/person/night)
Estimated Diallo et al, 1994-1997

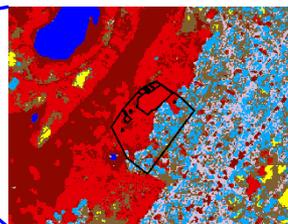
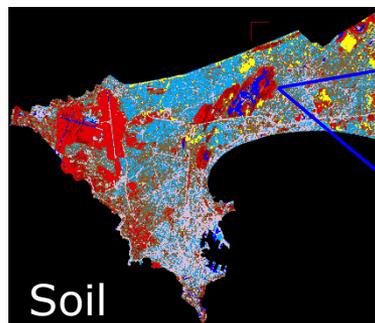
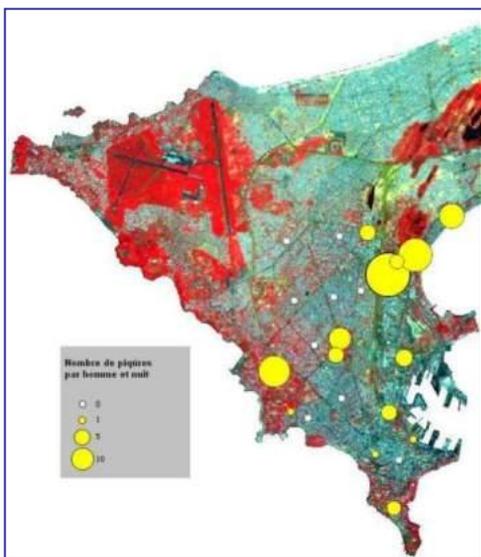


2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

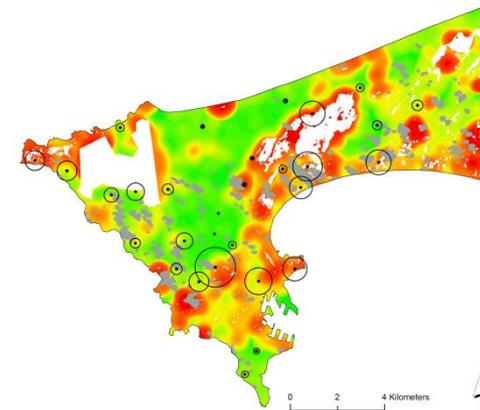
A Remote-sensing tool applied to Urban Malaria in Dakar city, Senegal



Thesis Vanessa Machault, funded by IRBA & CNES
with scientific support of Laboratoire d'aérodologie & IRD



Detecting breeding sites



Comparing predicted and measured Anopheles n° bites.person/night

Towards Service EEOS Malaria SIRS, SERTIT, IRBA



“Tele-epidemiology” & Rural Malaria in Nouna, Burkina Faso



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University of Heidelberg, Germany
CRSN Nouna, Burkina Faso
Météo France, France

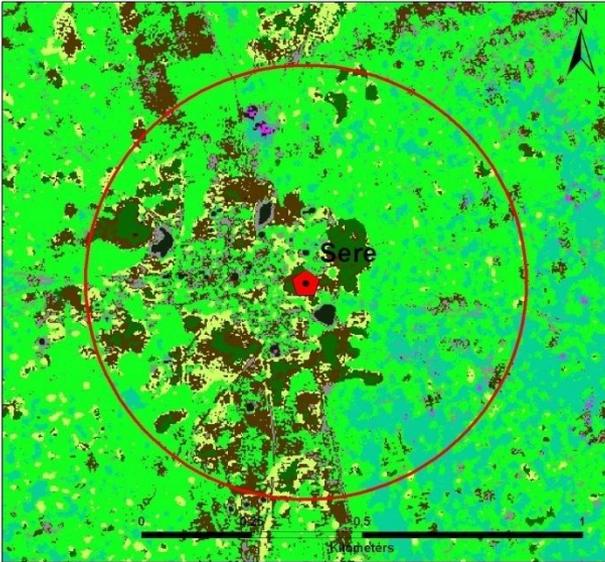
Rural Malaria in Nouna, Burkina Faso

1 - Understanding mechanisms at stake



2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

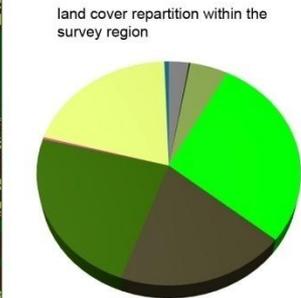
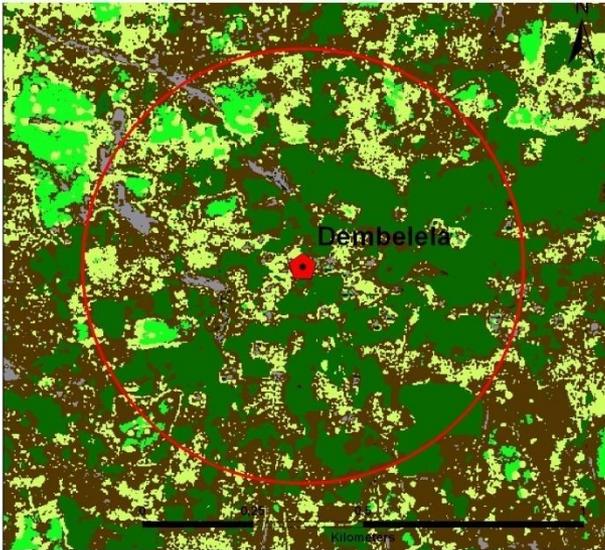
A Remote-sensing tool applied to Malaria in Nouna, Burkina Faso



Land cover repartition in 500m buffer zone around the villages of

Sere (highest risk) and Dembelela (lowest risk).

Land cover risk within the survey region (pie diagram, same legend).

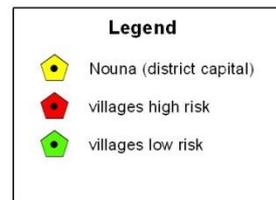
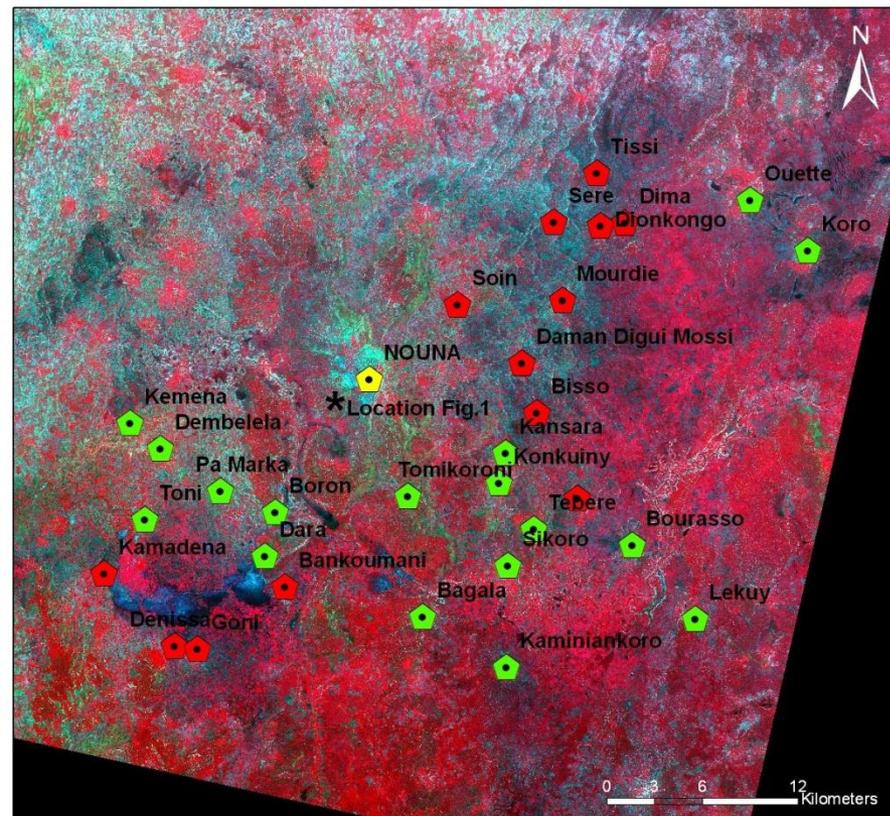
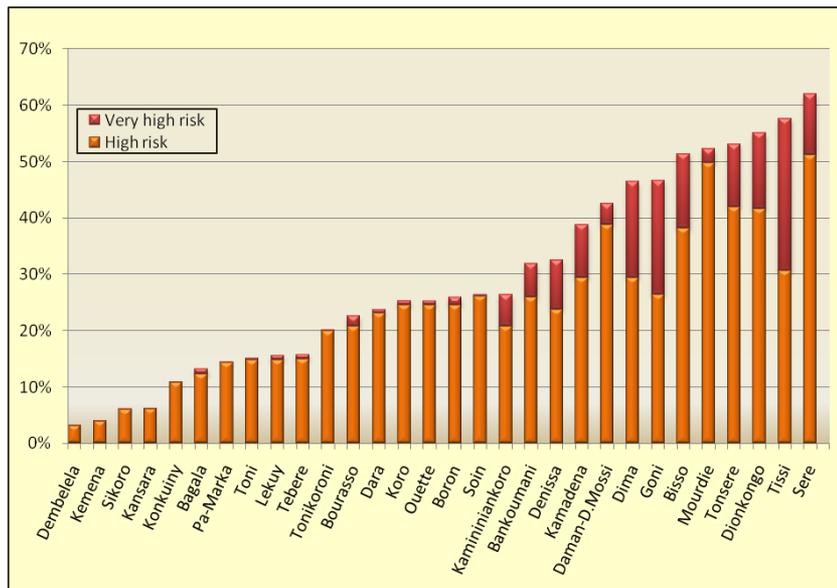


Relative repartition of land cover risk in 500 m buffer		
risk	Sere	Dembelela
low	31,41	58,10
medium	6,65	38,76
high	51,18	3,14
very high	10,76	0,00
sum total	100	100

		Malaria vector risk level
no.	land cover class	
1	sandy soil	Low
2	bare soil, laterite	Low
3	dry vegetation	Low
4	housings	Medium
5	wood-bush	Medium
6	crop field	High
7	water turbid	High
8	wet rice field	very high
9	herb-soil-submerged	very high
10	water with veg. Cover	very high

Rural Malaria in Nouna, Burkina Faso

3 – Innovative RISK MAPS using SPACE TOOLS



SPOT Image
2,5m res. 09.August 2008



Risk Map

“Tele-epidemiology” & Malaria in Caaguazu, Paraguay



CENTRE NATIONAL D'ÉTUDES SPATIALES

Observatoire Midi-Pyrénées – Laboratoire d'aérodologie, France

LEGOS, France

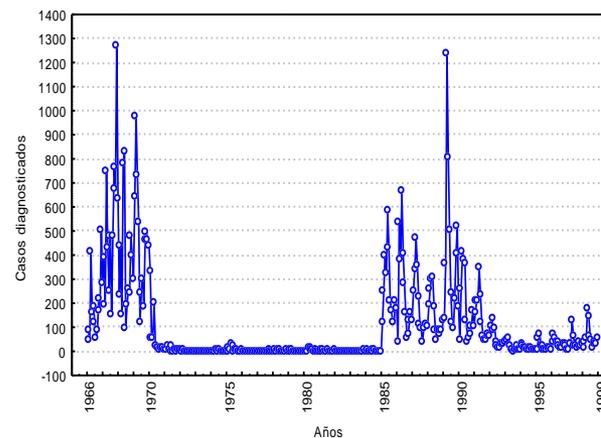
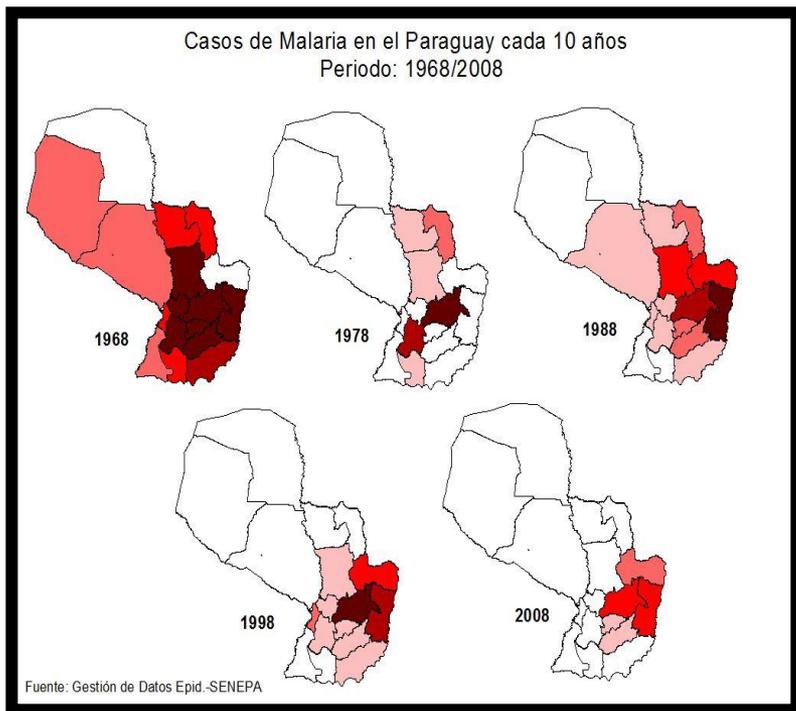
CONAE, Argentina

SENEPA, Paraguay

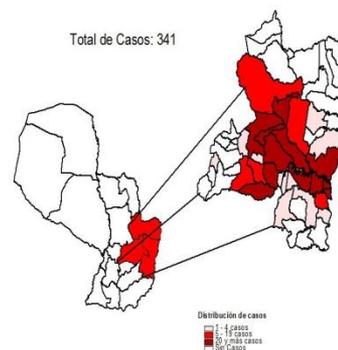
Rural Malaria in Caaguazú, Paraguay

1 - Understanding mechanisms at stake





MALARIA EN AREA ENDEMICA - AÑO 2008



Fuente: Gestión de Datos Epid.-SENEPA

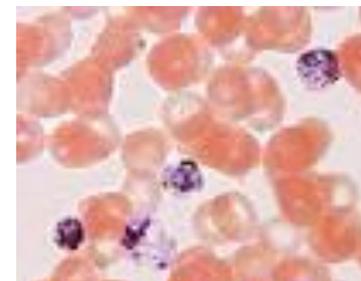
Rural population

Indians Guarani

No access to Health Centre



An. Darlingi



Plasmodium Vivax



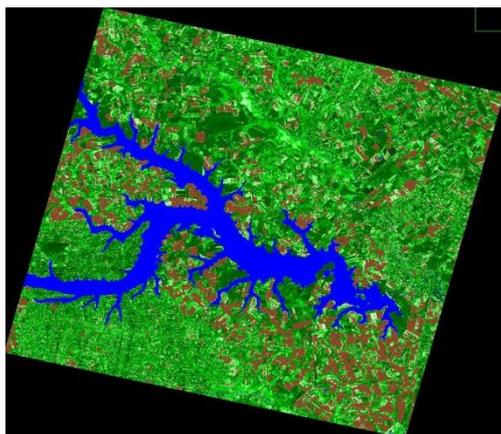
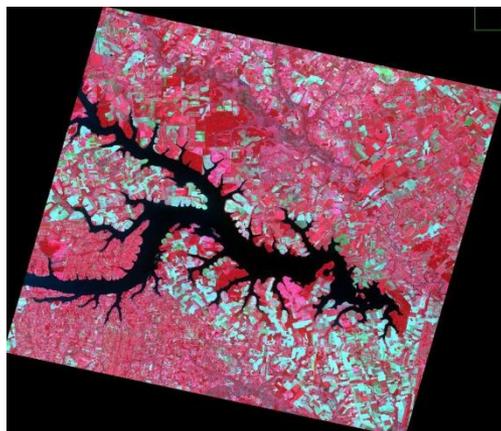


Anopheles Breeding sites

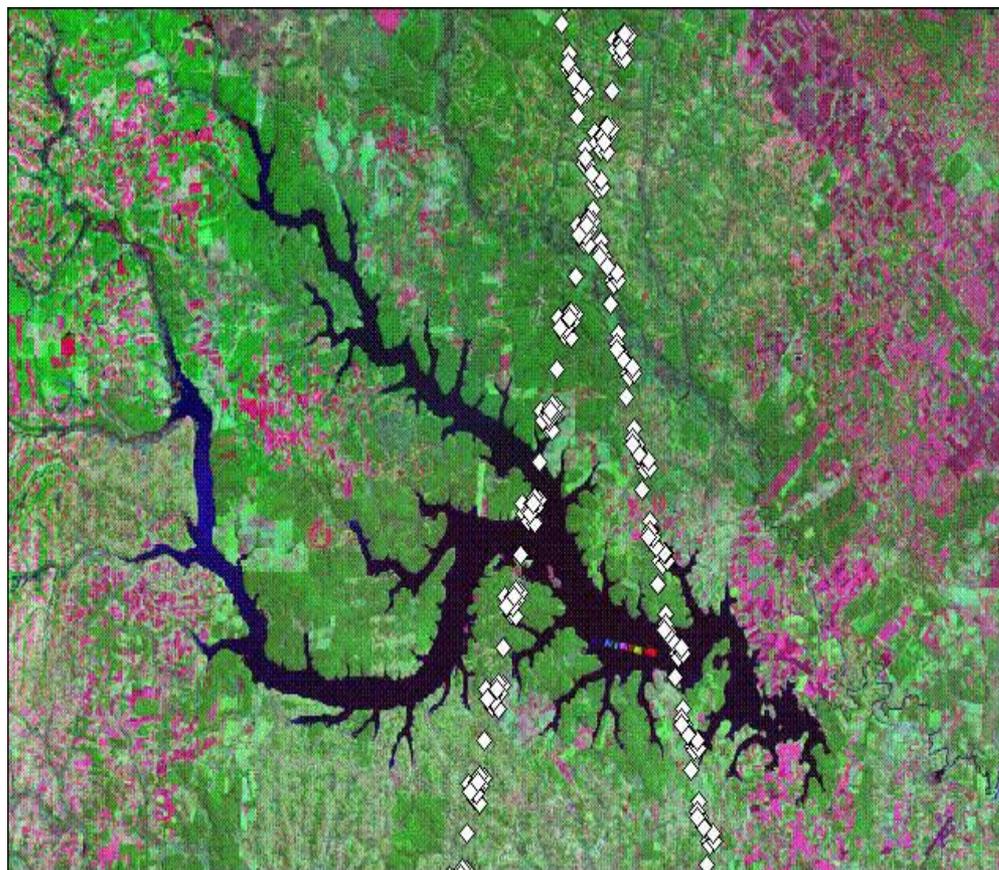
2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

Space tools applied to Malaria in Caaguazu, Paraguay

Remote sensing: free water detection



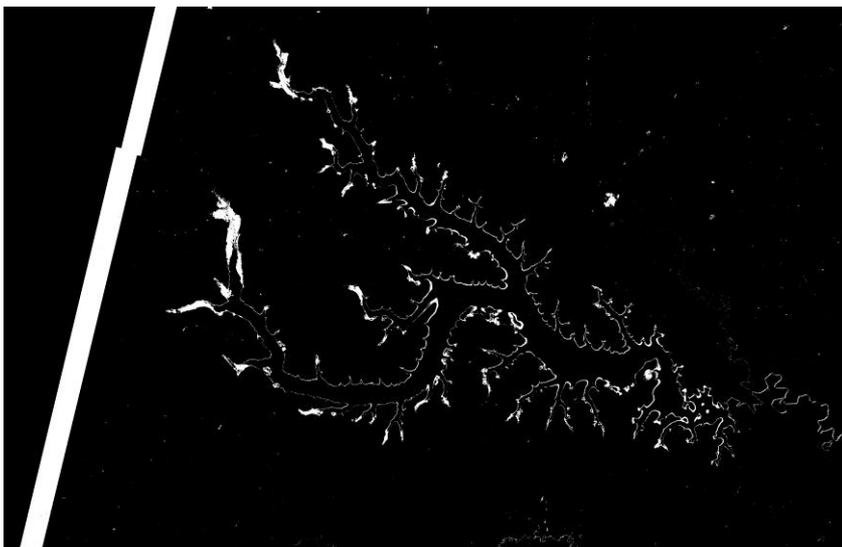
Altimetry from space: water level variation



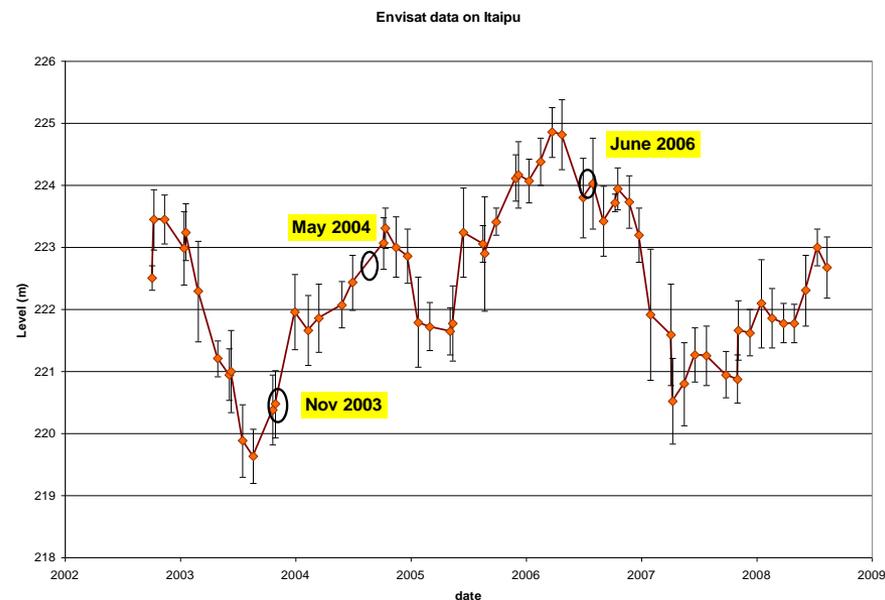
2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

Space tools applied to Malaria in Caaguazu, Paraguay

Free water, LANDSAT



Lake Itaipu level variation monitoring, ENVISAT



From J-F. Crétaux, 2009

“Tele-epidemiology” & Vibriion related diseases In Mediterranean Sea



CLS

University of Verona

University of Genova

IFREMER

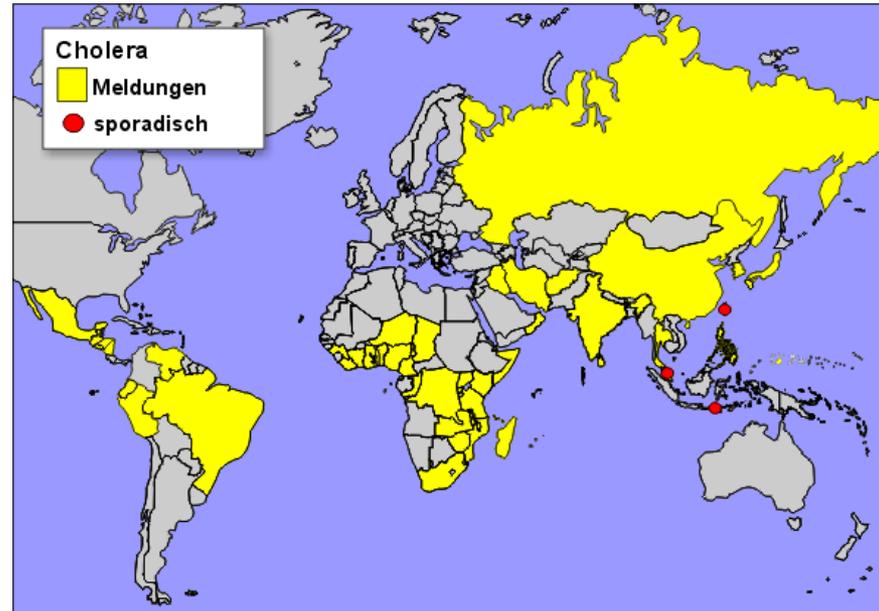
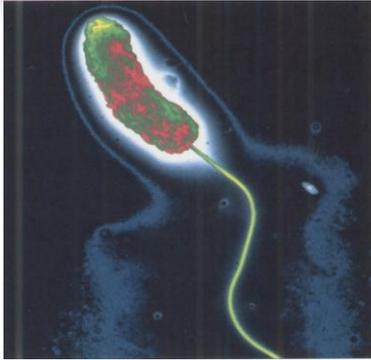
Institut Pasteur Paris – NRC Cholera

Institut Pasteur Algeria

Institut Pasteur Marocco

Veterinary Institute Hassan II Marocco

Institut Pasteur Tunisia



Ocean Surface Temperature → Plancton increasing → Vibron increasing

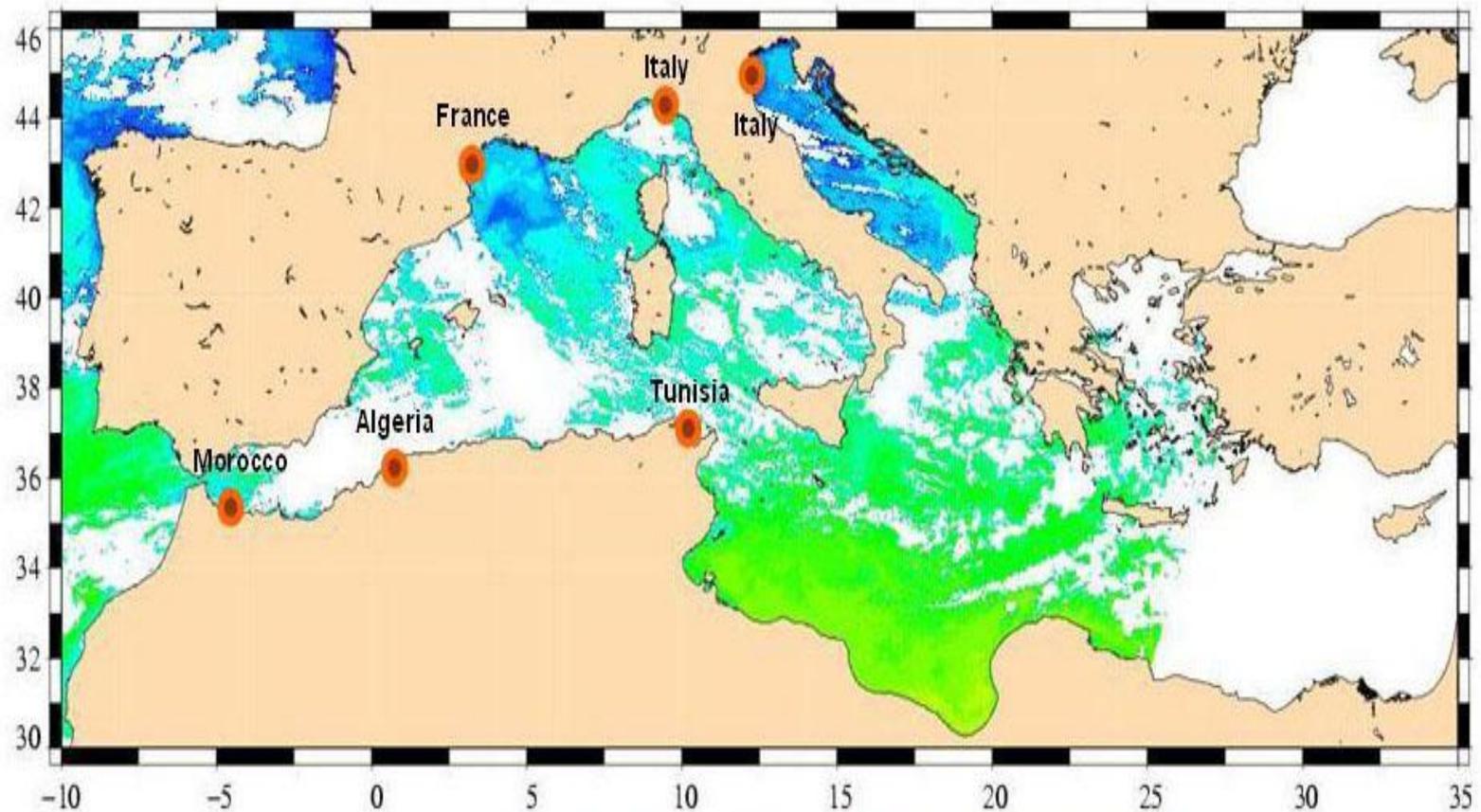
Altimetry from space → Sea level Elevation → Vibron move towards flooded and stagnant areas

↓
Possible contacts between host-vibrions

2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

Space tools applied to Vibriion surveilliance in Mediterranean Sea

Pilot sites



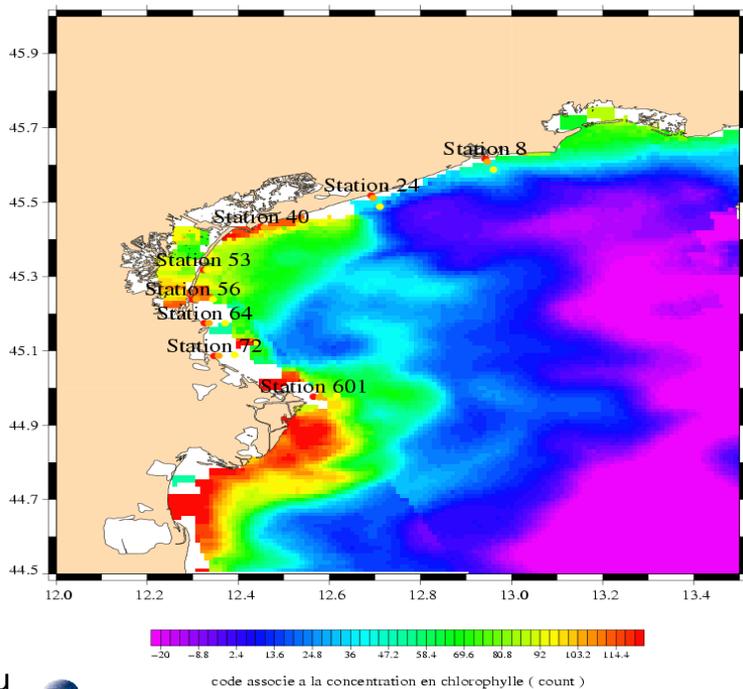
Remote sensing data
MODIS
MERIS

Environmental/climatic parameters to be monitored:

- Sea Surface Temperature (SST),
- chlorophyll A,
- salinity,
- turbidity

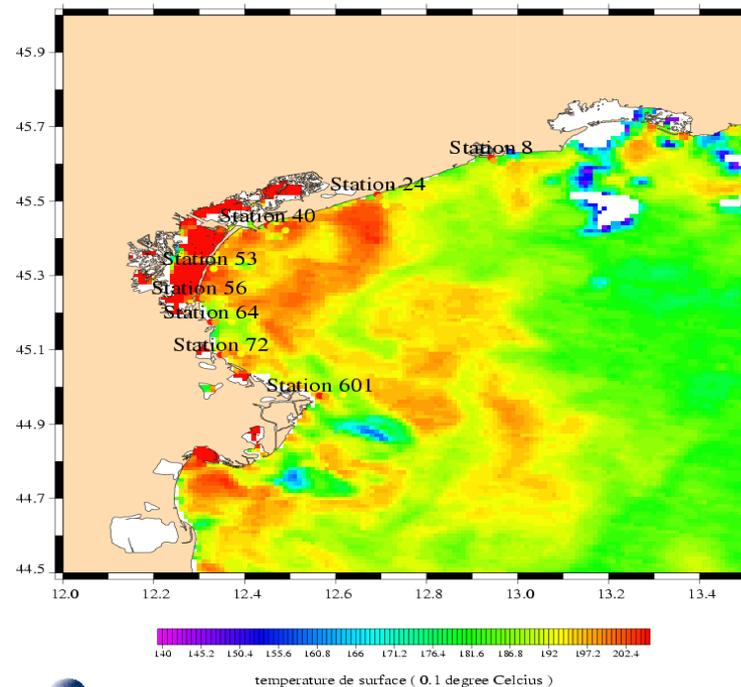
Chlorophyl A

Couleur de l'eau MODIS sur la zone Adriatic et donnees in situ



SST

Temperature MODIS sur la zone Adriatic et donnees in situ



“Tele-epidemiology” & Bilharzia around the Poyang lake in China



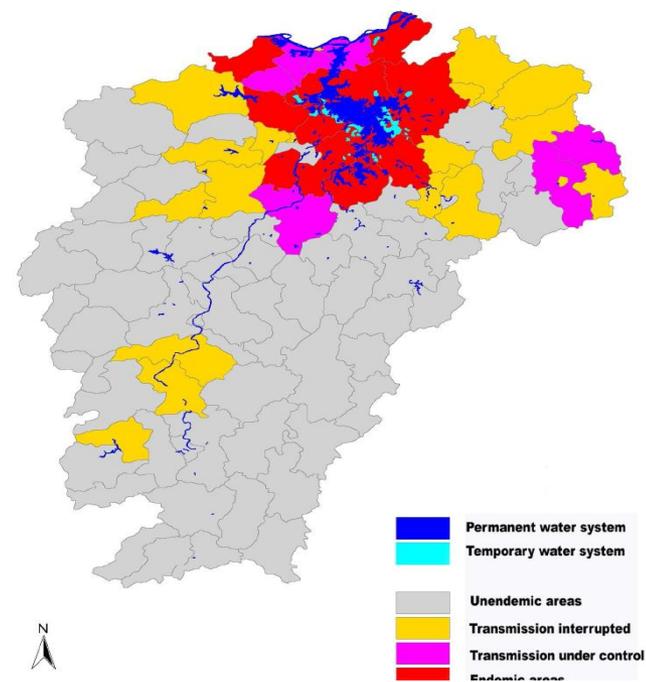
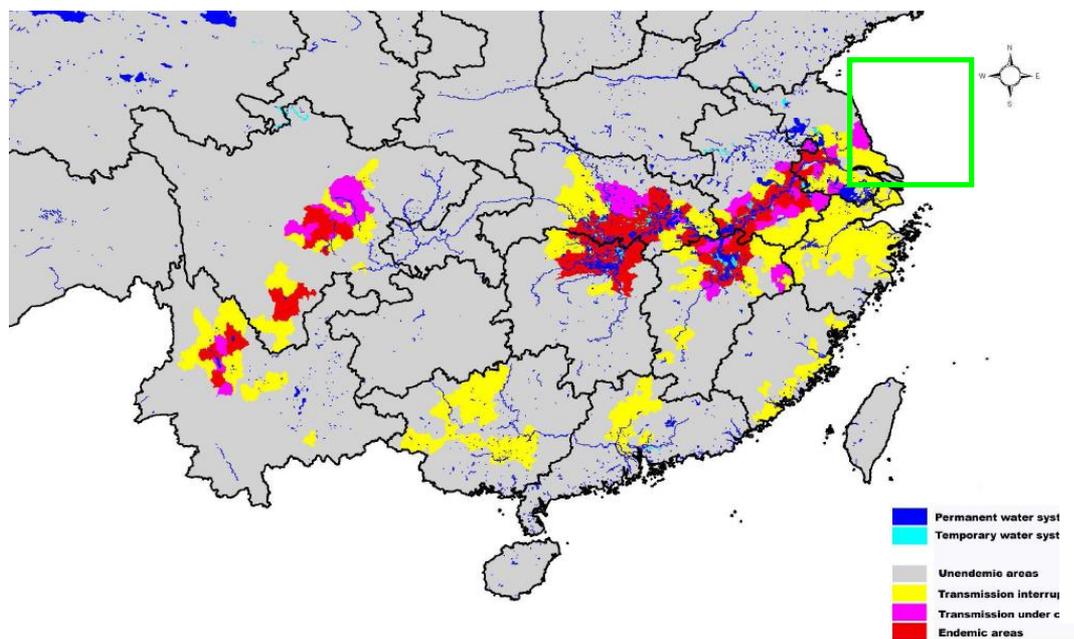
***SERTIT
NIPD Shanghai***

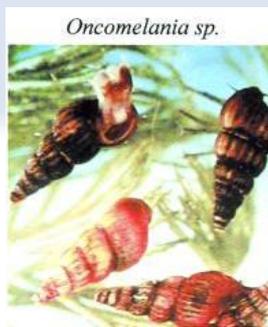
- **Biggest soft water lake in China**
- **Jiangxi Province:**
 - 43 million inhabitants
 - 250 inhab/km²
- **Mousson lake:**
 - Surface varies from 1000 km² to 4000 km²
 - Level varies up 10 to 18 m
- **Very rich biotope :**
 - Wetlands of international concern (RAMSAR)
 - Key wintering area for South-East Asia



Bilharzia is endemic along Yangtze

And in lake Poyang region, Jiangxi Province





Polygonum



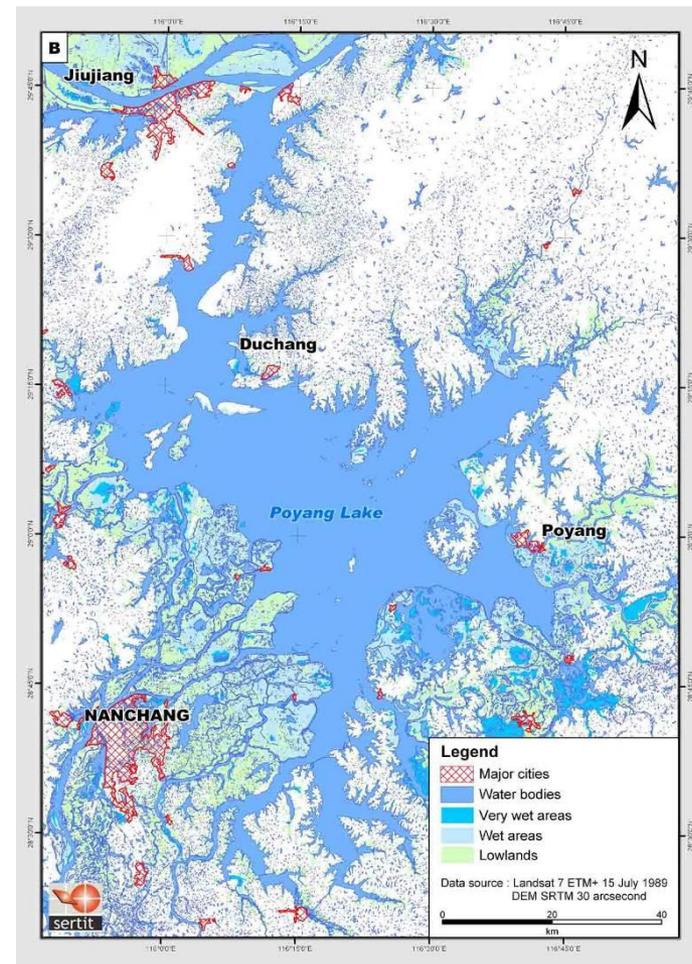
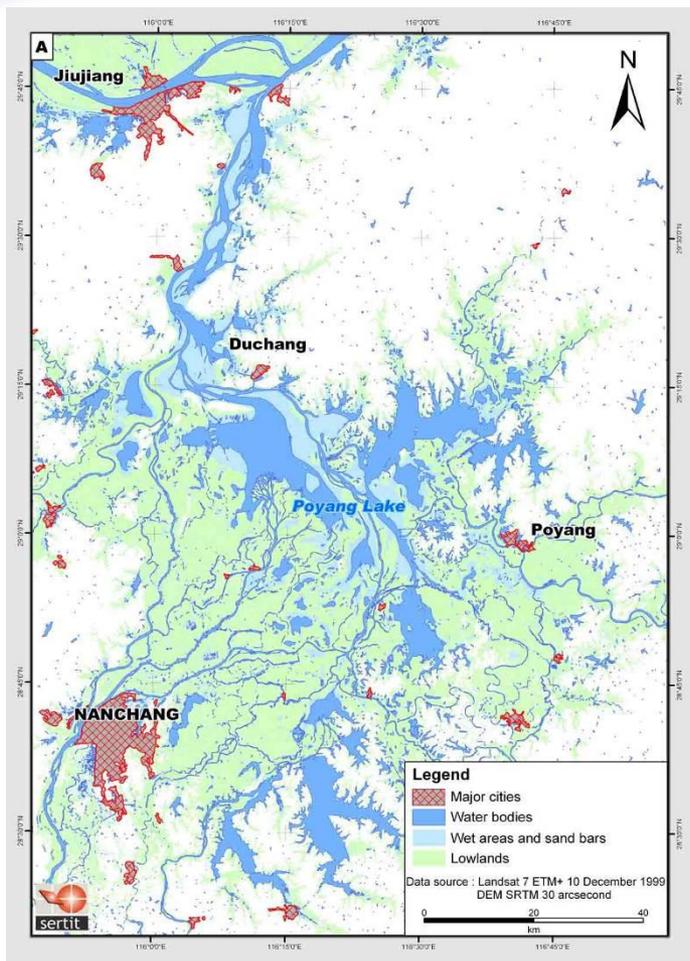
Carex



Understanding Ecology of the Vector

2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

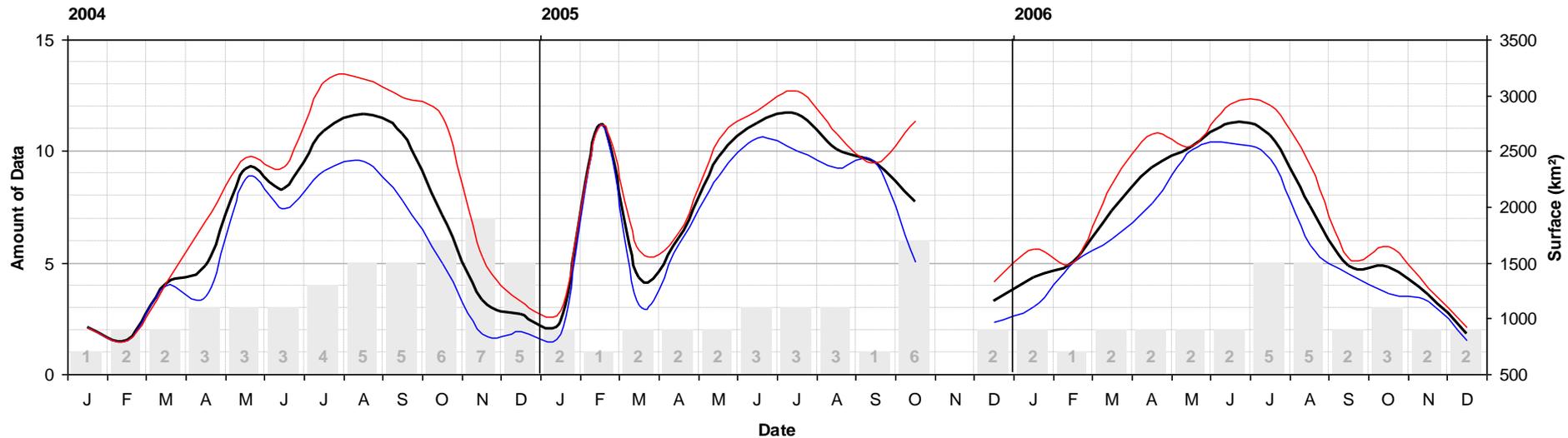
Space tools applied to Bilharzia monitoring around Poyang lake, China



Lake surface inter-annual variation monitoring

2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

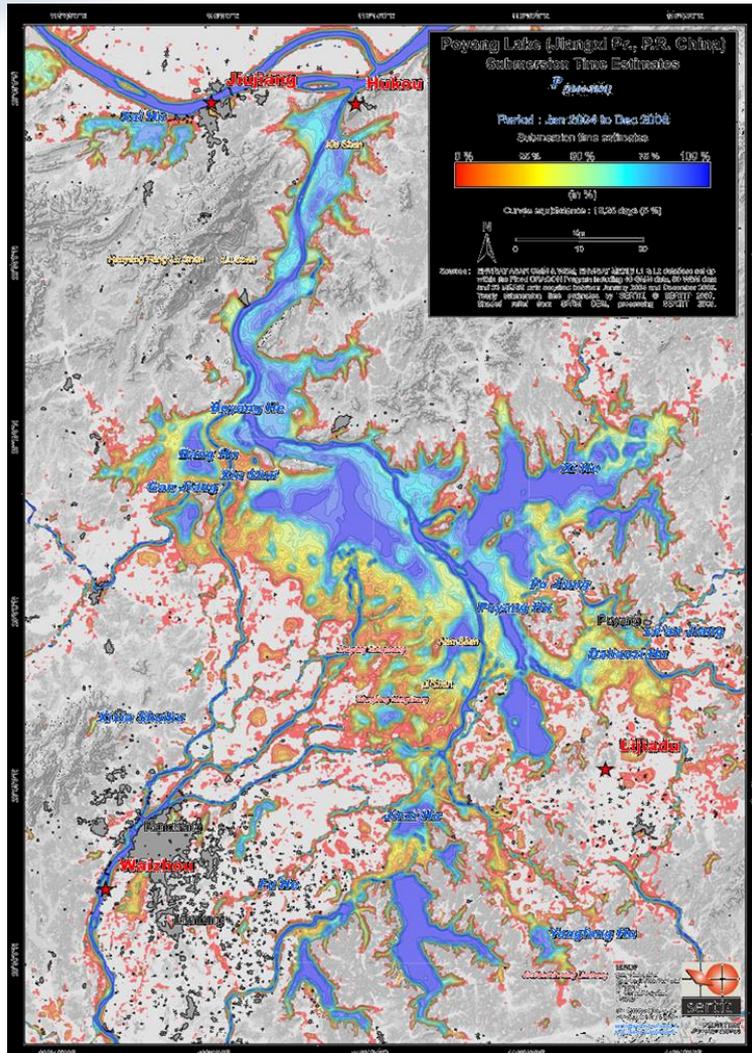
Space tools applied to Bilharzia monitoring around Poyang lake, China



Lake level variation monitoring, ENVISAT

2 – Developing ADAPTED PRODUCTS integrating SPACE TOOLS

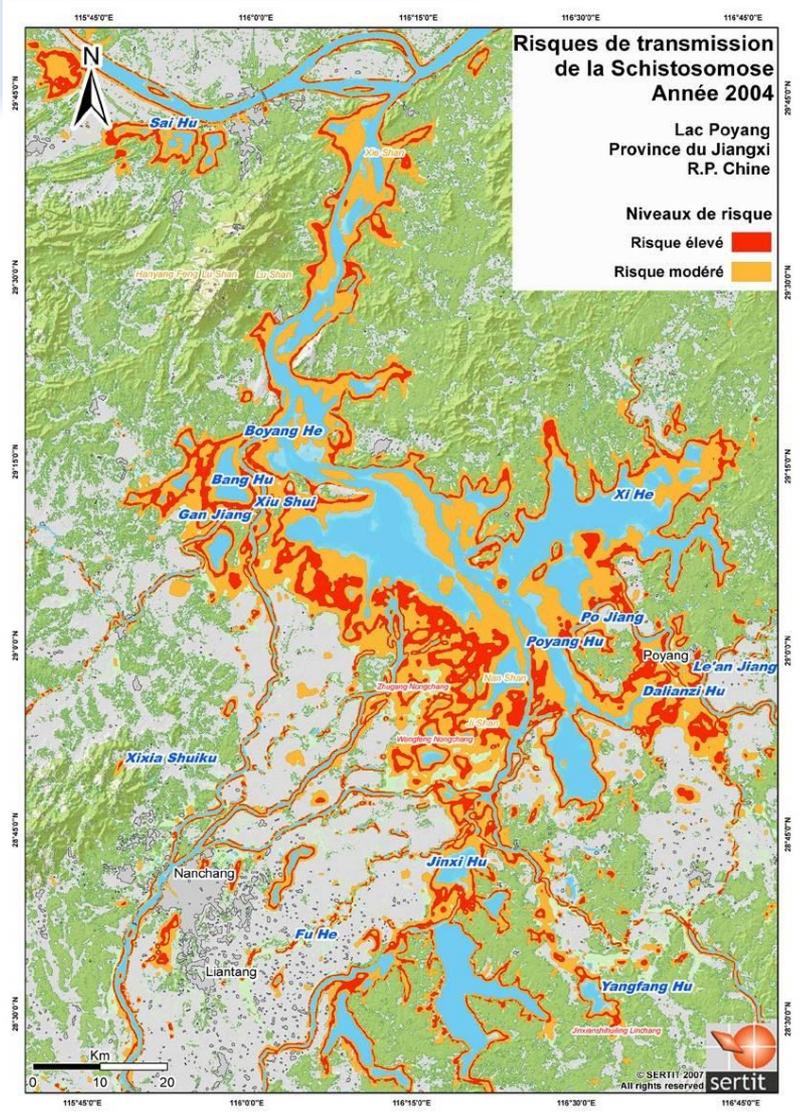
Space tools applied to Bilharzia monitoring around Poyang lake, China



- Annual submersion time estimate
- For various zones:
 - Flooding duration
 - Geographic positioning

Bilharzia around Poyang lake, China

3 – Innovative RISK MAPS using SPACE TOOLS



Risk Map: ZPOM
Zone potentially occupied by Mollusc



CNES strategy for developing the use of satellites in Societal Benefit Areas

At National level : developing business opportunities

Users community

Scientific community

Industrial partners – services providers

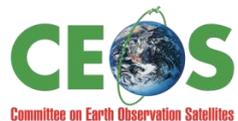
At International level : promoting the use of space for SBA & Health

GEO Workplan 2009-2011 + Workplan 2012-2015

Community of Practice “Health & Environment” co-leads CNES, WHO, ICMR



CEOS SBA Health (leader CNES)





CNES strategy for developing the use of satellites in Societal Benefit Areas



GEO SBA Health Workplan 2012-2015

HE-01 Tools and Information for Health Decision-Making

C1 Air-borne Diseases, Air Quality and Aeroallergens:

C2 Water-borne Diseases, Water Quality and Risk

C3 Vector-borne Diseases

C4 A Holistic Approach to Health: Transmission Dynamics, Urban Health Forecasting, Linkages and New Technologies

HE-02 Tracking Pollutants

C1 Global Mercury Observation System

C2 Global Monitoring of Persistent Organic Pollutants, Emerging Contaminants and Global Change Indicators

CNES strategy for developing the use of satellites in Societal Benefit Areas

COES SBA Health Tasks addressing GEO Workplan 2012-2015



HE-11-01_C1 EO contribution to Air-borne Diseases, Air Quality and Aeroallergens

HE-11-01_C2 EO contribution to Water-borne Diseases, Water Quality and Risk

HE-11-01_C2 EO contribution to C3 Vector-borne Diseases

- ✓ sharing experience between space organisms using remote sensing
- ✓ identify relevant EO information and indicators
- ✓ ease providing health users with really adapted products at pertinent scales (time and resolution)

NASA & CNES should extend their cooperation

TOPEX-POSEIDON

JASON

CALIPSO

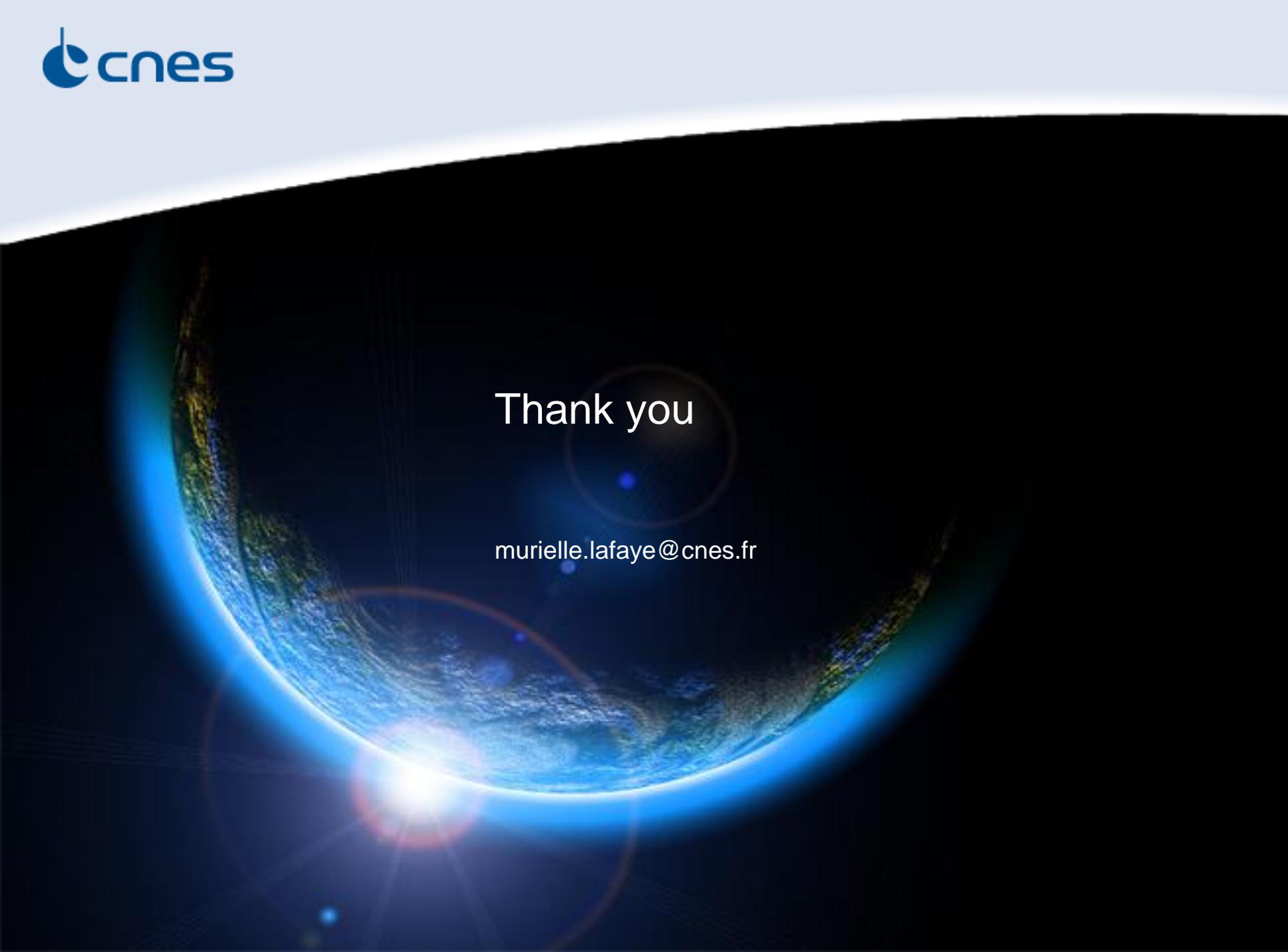
SWOT

....

What about a NASA-CNES joint Health Program ?

How to initiate it?

GEO, CEOS, bilateral cooperation...

The background of the slide is a photograph of Earth as seen from space. The planet is curved, showing blue oceans and green landmasses. A bright light source, likely the sun, is visible at the bottom left, creating a lens flare effect with multiple colored arcs and a bright white spot. The sky is a deep, dark blue/black.

Thank you

murielle.lafaye@cnes.fr