TELE-EPIDEMIOLOGY

WHICH CONTRIBUTION FOR EARTH OBSERVATION SATELLITE DATA?

CNES ACTIVITIES IN TELE-EPIDEMIOLOGY

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TELE-EPIDEMIOLOGY

WHICH CONTRIBUTION FOR EARTH OBSERVATION SATELLITE DATA?

CNES ACTIVITIES IN TELE-EPIDEMIOLOGY

- ***Context***
- ***Telehealth activities***
- ***Tele-epidemiology concept***
- ***The example of the Rift Valley Fever in Senegal***
- ***The CNES strategy***

Context 1/2

Infectious diseases have been known since the dawn of time.
If science has made it possible to control them better, recent changes in human societies have changed their modes of diffusion and transmission

Some key figures to illustrate the increasing risks of epidemics, pandemics, and diseases re-emergence

- Infectious diseases are responsible for **14 million deaths** every year worldwide
- **More than 90% of these deaths occur in the South**, where infectious diseases account for 43% of all causes of death compared with 1% in industrialized countries
- Most emerging infectious diseases come from the animal world
- **335 new infectious diseases** were discovered between 1940 and 2004. **60% are zoonosis from 72% of wildlife**
- Malaria, dengue, cholera ....involve 3 to 4 billions people each year
- Infectious diseases represent serious **economic barriers**:

  Example of Malaria: main infectious disease transmitted by mosquitoes: ~ 50% of the world population exposed, 214 million cases per year reported causing 438 000 deaths per year (WHO 2015), estimated costs in Africa ~10 billion euros per year and reduce gross domestic product (GDP) growth by 1.3 per cent each year (OECD).

Context 2/2

Facing a world in transition ⇨rapid environmental changes fosters pathogens and their dispersal

Evolution of the main factors or variables that boost the emergence of infectious diseases

- **Increase of the world human population**: exceeds 6.5 billion men and women and will reach 9 billion by 2050, now concentrated in megalopolises where human-to-human transmissions are easier
- **Changes in agricultural practices** (deforestation, intensive livestock farming, movements of animals between forests and cities) that change ecosystems and bring men closer to wildlife
- **Globalization of trade** in goods and animals: contributes to the spread of disease vectors, for example, with maritime trade or certain trafficking in foodstuffs
- **Growth of air transport** which accelerates the **movement of people** in risk areas and weakens the "naïve" populations (tourists or businessmen for example)
- **Displacement of populations** (people live outside the country where they were born as a result of natural disasters, scarcity of water resources, famine or wars) and confronting them with new diseases and transporting them in new geographical areas
- **Climate change**, which favors the multiplication of certain vectors (mosquitoes, ticks ...), which have led to the appearance of new diseases (Lyme, dengue, chikungunya ...) previously unknown in temperate regions
- **Precarious health conditions** in some countries
- **Evolution of pathogens** (resistance to antibiotics, increase in virulence…)

Urging needs to improve our knowledge on the relationships between Environment/Climate and Health

Telehealth activities

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 studying human and animal diseases (transmitted by water, air or vectors) which are closely linked to climate and environment, by using space technology*

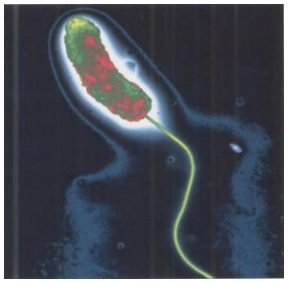
The French Space Agency (CNES) has thus developed, with its partners, a concept based on a deterministic/statistical approach of the climate-environment-health relationships and on an adapted space offer

Provide to public health actors additional tools/services helping them in diseases surveillance and in the implementation of strategies to diseases control

The tele-epidemiology conceptual approach

Multidisciplinary approach based upon the study of the key mechanisms favoring emergence and propagation of infectious diseases linking disciplines

Environment Climate



Microbiology

Entomology

Social Sciences

Veterinary

1- Experimental design mainly field studies

- *Observing strategy: monitoring and assembling multidisciplinary in-situ datasets*
- *Diagnostic: extract and identify the main physical and biological mechanisms at stake*

2- Obtaining well adapted products from Space

- *Remote-sensing monitoring of environment,*
- *Remote-sensing from space: use of products, fully adapted to the various spatio-temporal scales of variability*

3- Dedicating modeling for risk mapping

- *Built predictive models by combining in-situ data and remote sensing product derived from Earth Observation satellites, geographic data and meteorological data to produce* ***dynamic high spatio-temporal resolution risk maps***

Tele-epidemiological conceptual approach applied to Rift Valley Fever (RVF) Monitoring in Senegal

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Toujours un temps d'avance

RFV case study

Rationale

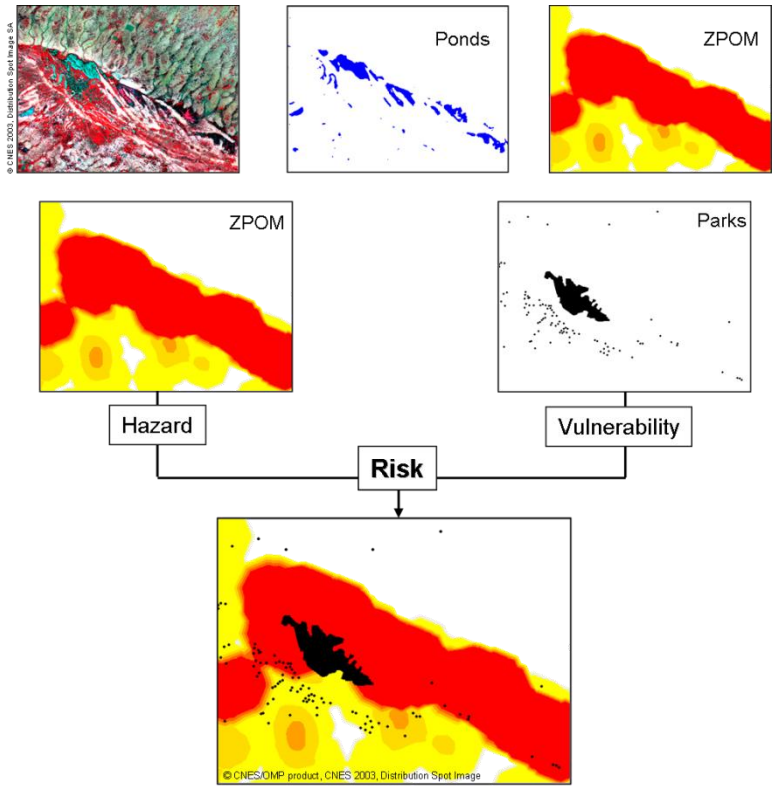
- *Viral disease found essentially in Africa*
- *Causes very serious economic losses in livestock*
- *Necessary condition for RVF epidemics ⇨ presence of the mosquitoes Aedes vexans and Culex poicilipes, the main vectors of the RVF virus in the Sahelian region of Senegal*
- *Abundance of such RVF vectors directly linked to ponds' dynamics*
- *Ponds' dynamics associated with the spatio-temporal variability of rainfall events*

Methods

- *Brand-new index for detecting of small and temporary ponds has been set-up using high-spatial SPOT-5 images (10-m)*
- *Modelling dynamic of zones potentially occupied by mosquitoes (ZPOM) combining mechanisms linking rainfall variability, dynamic of ponds and density of aggressive vectors.*
- *Crossing dynamic ZPOM (vector hazard) and cattle park localization (hosts vulnerability) ⇨ evaluation of the **environmental risk** (i.e risk for being exposed to vector bites)*

Results

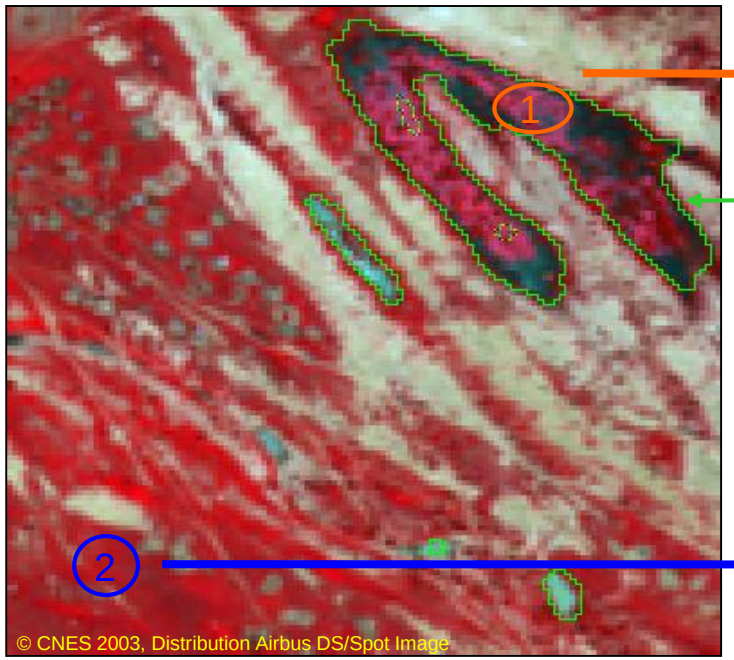
Based on space technology, design for local users such as health authorities brand new satellite-based decision-aid tools for a better management of animal health with the aim of a better adaptive strategy



After Tourre et al, 2009

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

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



False color composite

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

1- pond vegetation

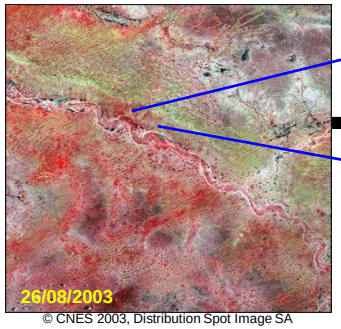
2-sahelian savanna

The Normalized Difference Pond Index or:
NDPI = (SWIR-Green) / (SWIR+Green)

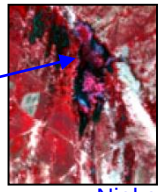
A Remote-sensing tool applied to Rift Valley Fever (RVF) Monitoring

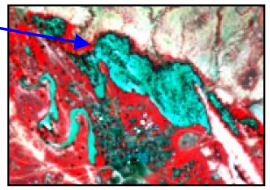
Identify environmental factors of A. vexans & C. poicilipes presence by remote sensing to obtain risk map

SPOT5 multispectral Image
high spatial resolution -10m
(Program ISIS/CNES)

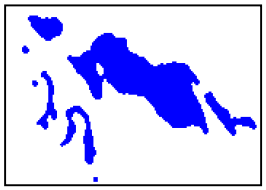


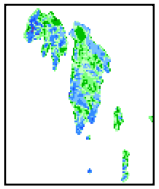
1354 ponds

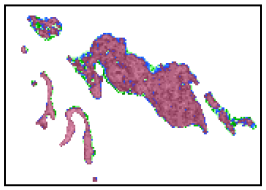

Niaka

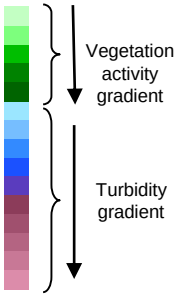

Barkedji


Ponds detection NDPI


Ponds' area


Characterization NDVI & NDTI


Ponds' characterization

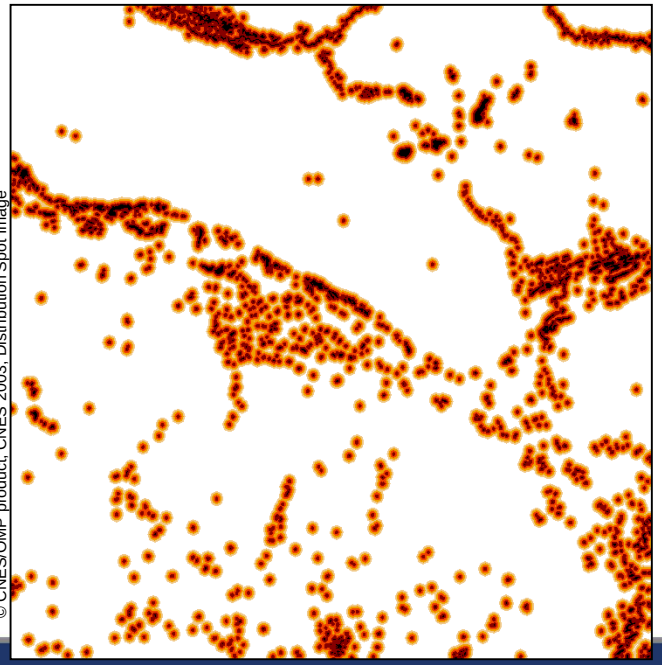


Vegetation Cover

Turbidity

Mosquitoes flying range
~500m (Bâ et al., 2005)

Zones Potentially Occupied by Mosquitoes (ZPOM)



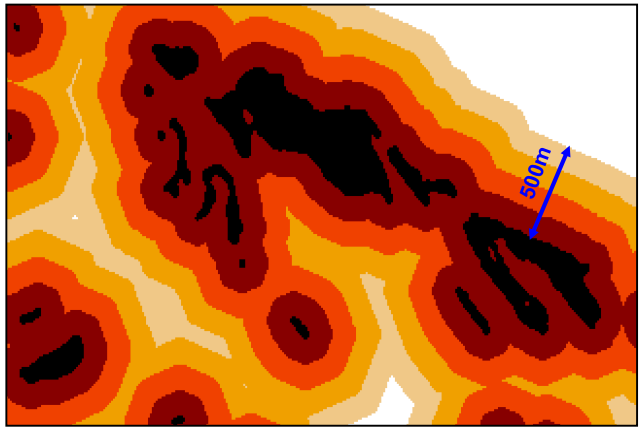
© CNES/OMP product, CNES 2003, Distribution Spot Image

26/08/2003

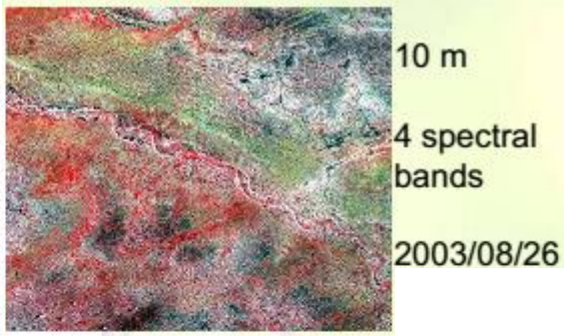
Ponds ~ 1%

ZPOM = 25%

Mapping the ZPOM



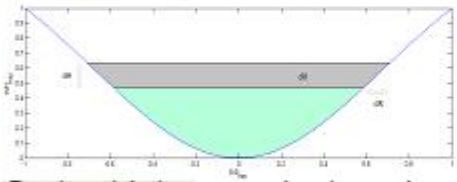
A Remote-sensing tool applied to Rift Valley Fever (RVF) Monitoring



© CNES 2003, distribution AIRBUS Defence & Space/Spot Image

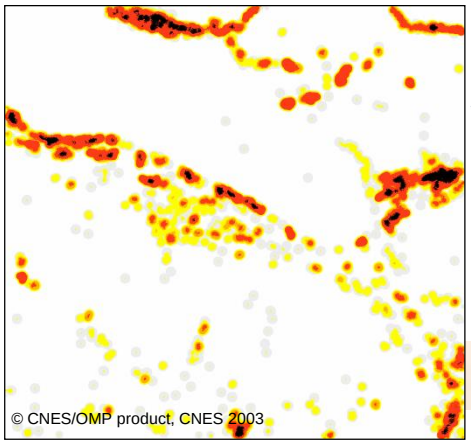
Rain gauge, Satellite products → Rainfall data → Correction → Corrected rainfall data

SPOT image → Ponds detection NDVI/NDPI → Ponds locations and maximum surfaces



Pond modeled as a gaussian depression

Ponds simple model → Ponds surface dynamic → Entomological model → Vectors agressiveness, risk maps



Aggressiveness (Number of bites of Aedes vexans per host, per night) for July 2, 2003

ZPOM Model : modelling of the risk of aggressiveness of mosquitoes, vectors of Rift Valley fever

Assessment & Perspectives

- Based on in situ entomological and meteorological data, on environmental data from the analysis of EO satellite images at appropriate resolution and on adequate modelling, it has been possible to draw up high spatio-temporal resolution environmental risk mapping
- If regularly updated and drawn at appropriate scales, risk maps could provide valuable information to optimize prevention and control strategies: targeted vector control and selective allocation of resources

helping health actors to know *where* and *when* to intervene

The Directorate of Veterinary Services (DSV) is then able to integrate this information into its adaptation strategy for animal health management. It includes

- parking livestock away from risk areas
- organizing vector control and vaccination
- a communication strategy towards the affected population

The contribution of Earth Observation satellite

*In the light of these challenges, an **integrated and multidisciplinary research** is being developed to investigate the close yet complex relationship between environment, ecosystems and pathogens responsible for **diseases** in human, animal and plant populations focusing on the « One Health » concept. This research needs to **clarify the mechanisms at stake and identify factors** that foster the emergence, spread and persistence of diseases. These **factors** may be **environmental**, **climatic**, **demographic**, **socio-economic** or **behavioral**. Some may be identified from **Space** but this requires developing efficient methods to turn remote sensing into a tool a tool capable of characterizing, mapping, monitoring and predicting these risk factors*

***Earth Observation satellites** data do not provide information directly related to pathogens causing the diseases but on their environment (geographical, meteorological, hydrological…). Therefore, the contribution of **EO satellite images** and remote sensing is to allow the measurement of the suitable (or not) environmental determinants of these diseases*

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

At CNES: creation of the directorate for Innovation Applications and Science

To promote, encourage and facilitate all initiatives for developing applications using space data

At National level : developing R&D activities and business opportunities

Users community
Scientific community
Industrial partners – services providers

At International level : promoting the use of space, R&D activities

- ***Bilateral/multilateral collaborations***
- ***Expert Group on Space and Global Health of the STSC of the COPUOS***
- ***Community of Practice "Health & Environment"***
- ***CEOS Societal Benefit Area on Health***

CNES activities related to the HE-01-C3* task :
Study on needs and expectations for the use of EO satellites in healthcare monitoring for France, Brazil and US
Vector control policies, users needs and EO performances have been instigated

*HE-01:Tools and Information for Health Decision-Making
C3 component: vector-borne diseases

The RedGems Information System

Re-Emergent Diseases & Global Environment Monitoring from Space

An Innovant and Multidisciplinary Health Information System

Highlight linkages between climate, environment and infectious diseases, using remote sensing data

THANK YOU FOR YOUR ATTENTION

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