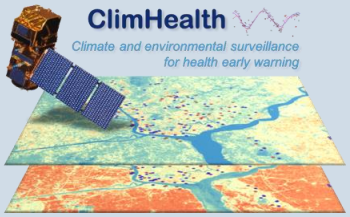


ClimHealth

Climate and environmental monitoring for health surveillance

Vincent HERBRETEAU (vincent.herbreteau@ird.fr)

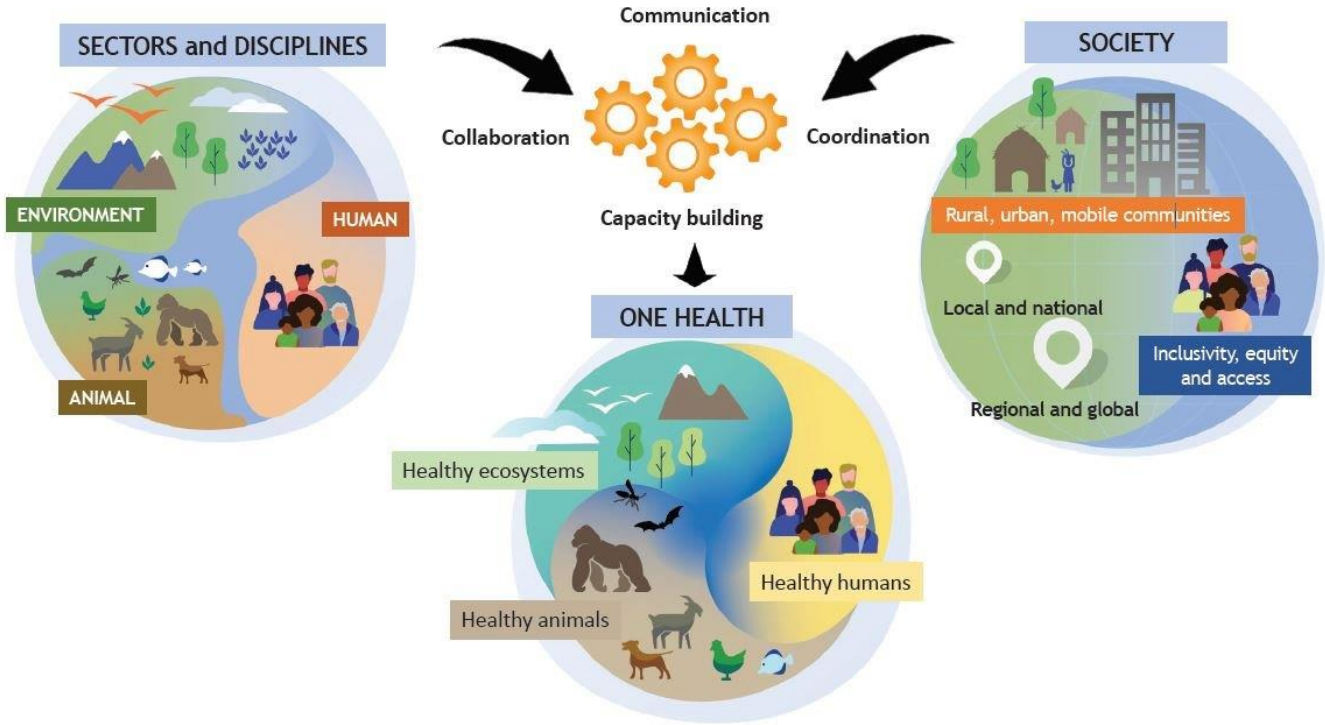
French National Research Institute for Sustainable Development (**IRD**) Espace-Dev,
Khmer Earth Observation Lab (**KHEOBS**) at the Institute of Technology of Cambodia (**ITC**)

GEO Health Community of Practice Telecon, 6th February 2024

Climate and environmental monitoring for health surveillance

- Some diseases and health situations are impacted by environmental, meteorological and climate dynamics
- Possibility to use environmental and meteorological information in real-time to inform disease surveillance

➢ But still no such data accessible in near realtime in health information systems



https://www.who.int/news/item/01-12-2021-tripartite-and-unep-support-ohhlep-s-definition-of-one-health

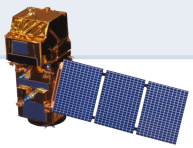
Climate and environmental monitoring for health surveillance

- Some diseases and health situations are impacted by environmental, meteorological and climate dynamics
- Possibility to use environmental and meteorological information in real-time to inform disease surveillance

➢ But still no such data accessible in near realtime in health information systems

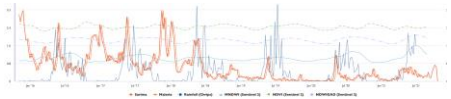
1- Monitoring environment and climate:

- Earth observation
- In situ measurements
- Local knowledge



2- Production of environmental and health indicators in realtime

3- Inform Health Surveillance Systems in realtime



https://www.who.int/news/item/01-12-2021-tripartite-and-unep-support-ohhlep-s-definition-of-one-health

Sentinel-2: satellite images designed for environmental monitoring

- **ESA (European Space Agency) Copernicus Project**
- 2 satellites:
  - Sentinel-2A launched in June 2015
  - Sentinel-2B launched in March 2017
- Lifetime: 7 years (extendable to 12 years)

- 13 spectral bands (visible, near and far InfraRed)
- **Spatial resolutions: 10m** / 20m / 60m

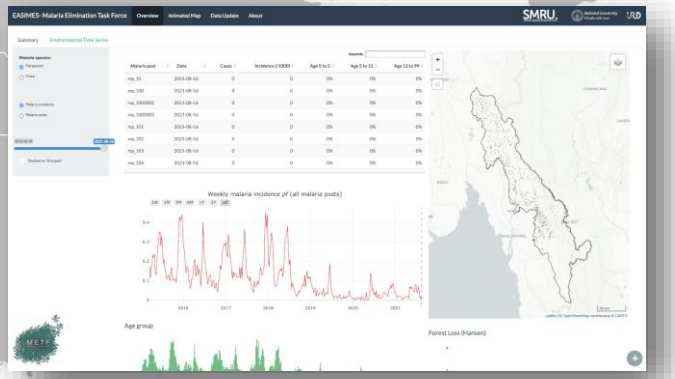
- Tile coverage: 290 km

- **Time between 2 revisits : 5 days** at the Equator (with the 2 satellites - without taking clouds into account)

Free and easily accessible data

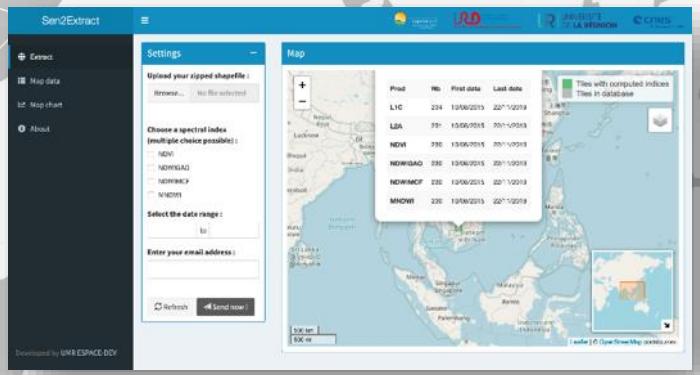
Sen2Chain: production of environmental indices

Projects: S2-Malaria (2017-2020, CNES) & ClimHealth (2020-2022, SCO-CNES)



4- Integration into Health Information Systems

1- **Sen2Chain**: Automated Sentinel-2 image acquisition and processing



3- Modelling of time series of environmental indices

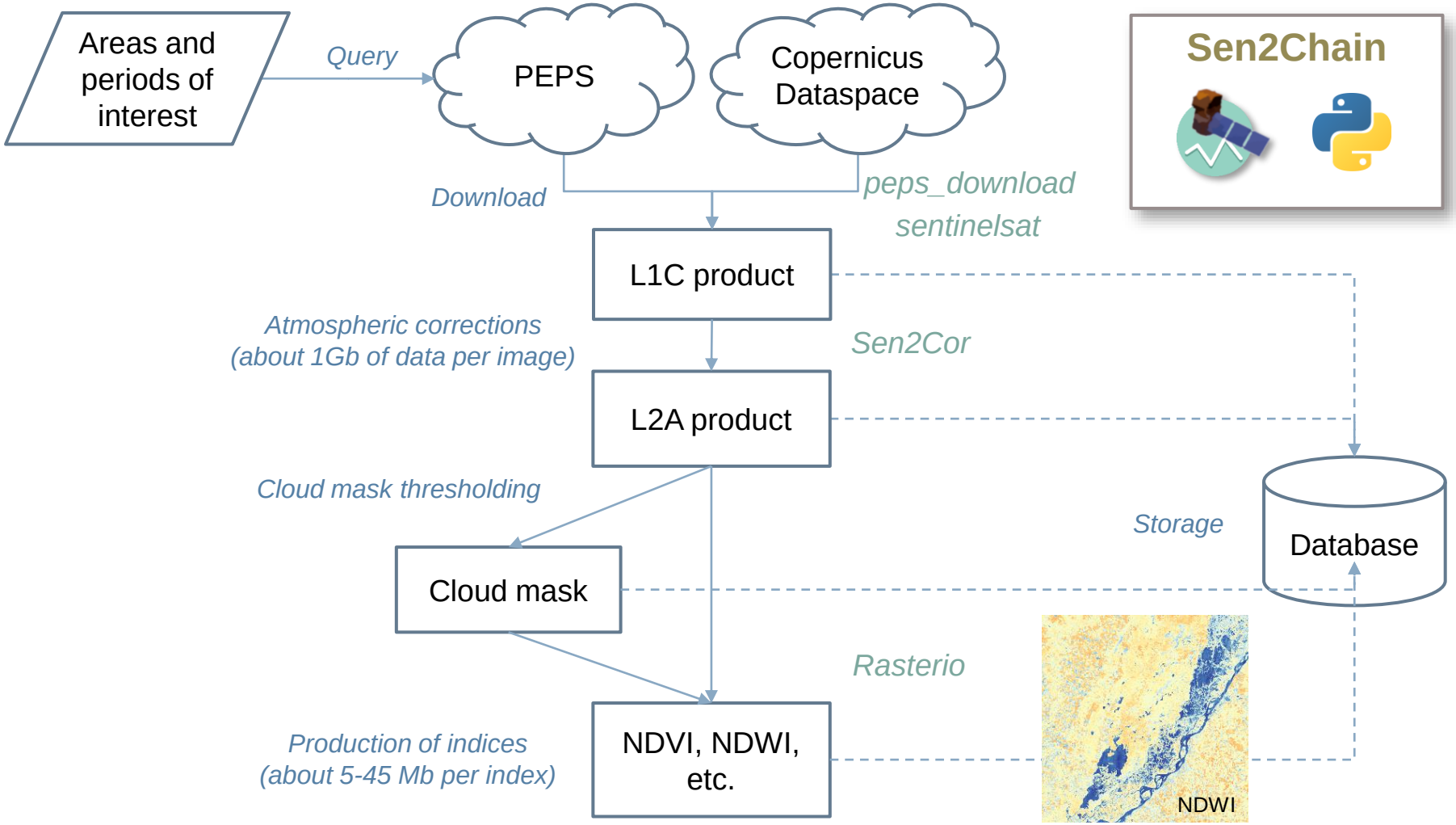
2- **Sen2Extract**: web interface facilitating the generation of time series

https://web.seas-oi.org/sen2extract/

Open source: https://framagit.org/espace-dev

Sen2Chain: production of environmental indices

Sen2Chain: aims at producing environmental indices from Sentinel-2 images as soon as these images are made available, to optimize near-real time monitoring.



Production of time series of environmental indices

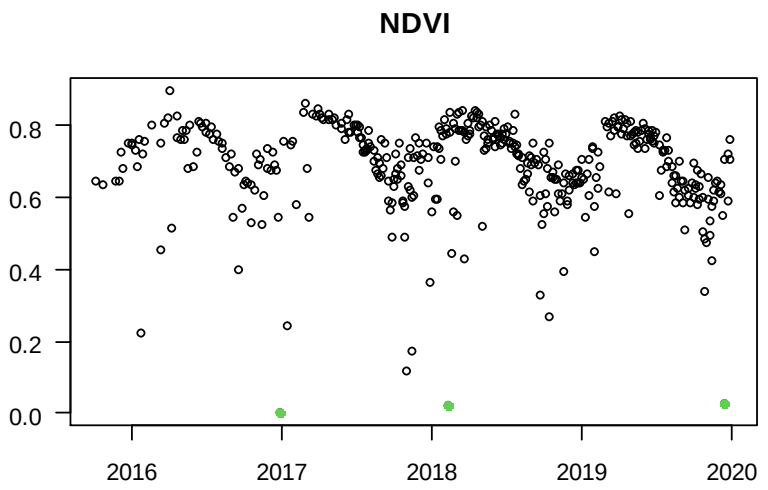
Objective: Link epidemiological dynamics with environmental dynamics

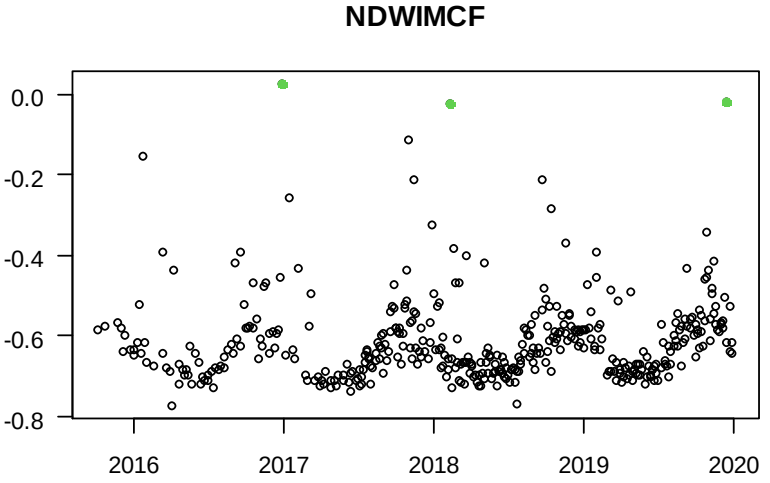
Constraints:

- Different observation dates
- Calculation of indices depending on cloud cover
- Missing dates
- Difficulties in detecting clouds

Solution: smoothing of time series

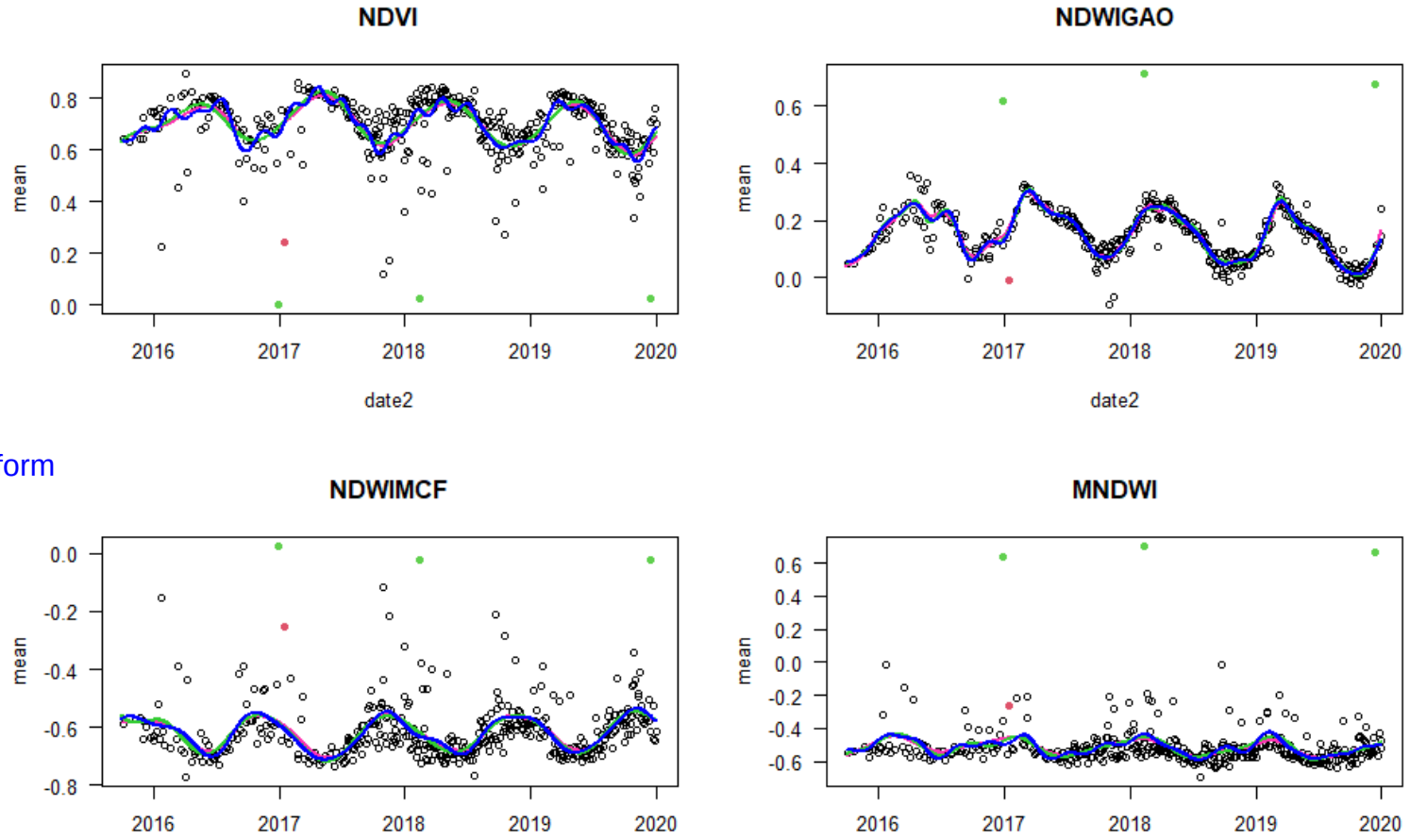
=> Estimated average index / day





Production of time series of environmental indices

- Temporal modelling of environmental indices



- ➢ Similar trends between the 3 methods, especially between Fourier and B-spline
- ➢ Best estimates on Cubic spline

Production of time series of environmental indices

Automated production on sites under surveillance (by polygon), before integration in the Health Information System

Yangoon – Latest indice extraction and smoothing in spatio-temporal polygons (daily updated)

```
.
├── [8.6M Sep  5 15:16]  Modele_de_prediction_SVM_500m.rds
├── [290M Feb  2 15:28]  Yangon_hexasurv_named_MNDWI_current.csv
├── [ 69M Feb  2 15:28]  Yangon_hexasurv_named_MNDWI_current.csv.gz
├── [ 81M Feb  2 15:53]  Yangon_hexasurv_named_MNDWI_smooth_current.rds
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├── [283M Feb  2 15:28]  Yangon_hexasurv_named_NDVI_current.csv
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├── [289M Feb  2 15:28]  Yangon_hexasurv_named_NDWIGAO_current.csv
├── [ 69M Feb  2 15:28]  Yangon_hexasurv_named_NDWIGAO_current.csv.gz
├── [ 83M Feb  2 15:53]  Yangon_hexasurv_named_NDWIGAO_smooth_current.rds
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├── [152K Feb  2 16:28]  lissage_hexa_temp.log
├── [ 84K Feb  2 16:46]  lissage_v5_temp.log
└── [7.3K Feb  2 16:49]  prediction_sur_500m.log
```
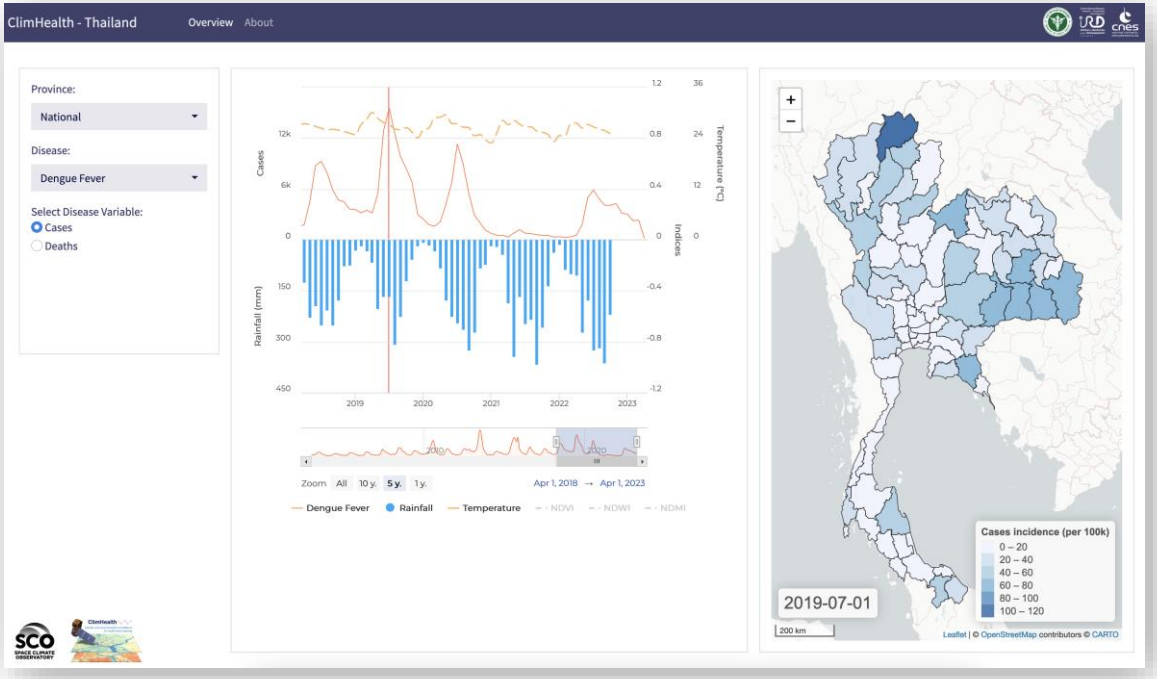

Integration of satellite information in health surveillance systems

National scale: monitoring of climate and environmental dynamics for health surveillance

ClimHealth, Space Climate Observatory (SCO) CNES 2020-2022: Climate and environmental monitoring for health early warning



ClimHealth Platform *developed to visualize the relations between climate, environment and epidemiological information*

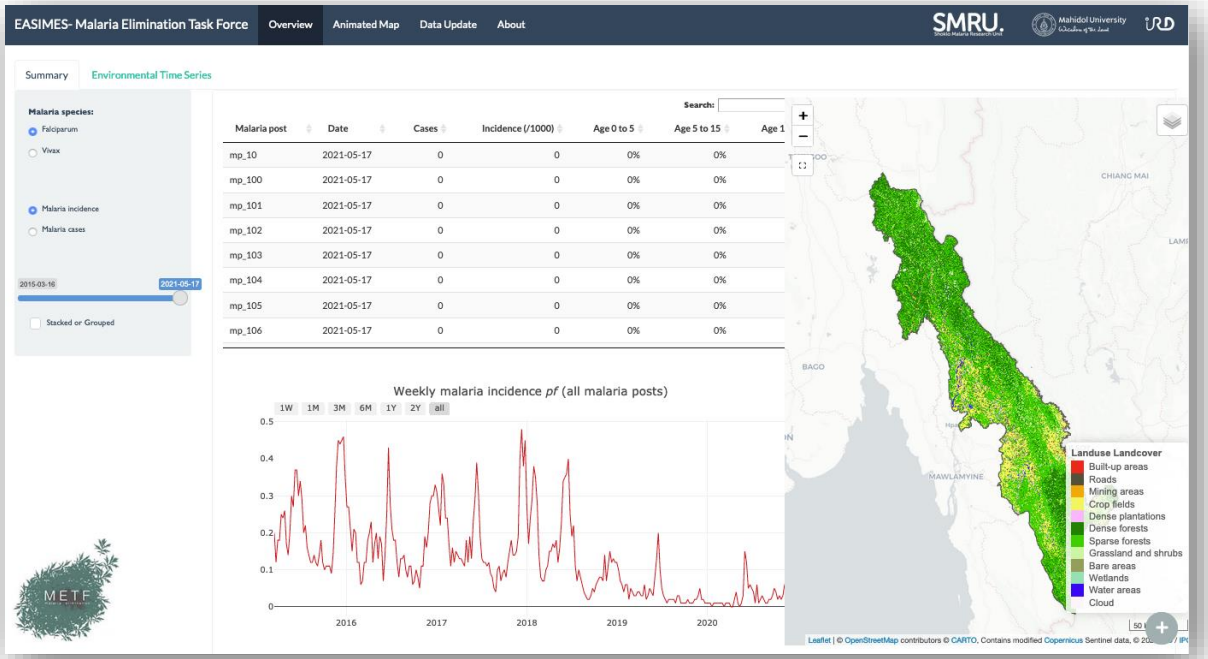
Integration of satellite information in health surveillance systems

National scale: monitoring of climate and environmental dynamics for health surveillance

Subnational scale: malaria surveillance system surveillance system for SMRU-METF

EASIMES, Global Fund (RAI2E) 2019-2021: Environment Analysis and Surveillance to Improve Malaria
Elimination Strategy in Myanmar

-> C19RM (2021-2023)



Integration of satellite information in health surveillance systems

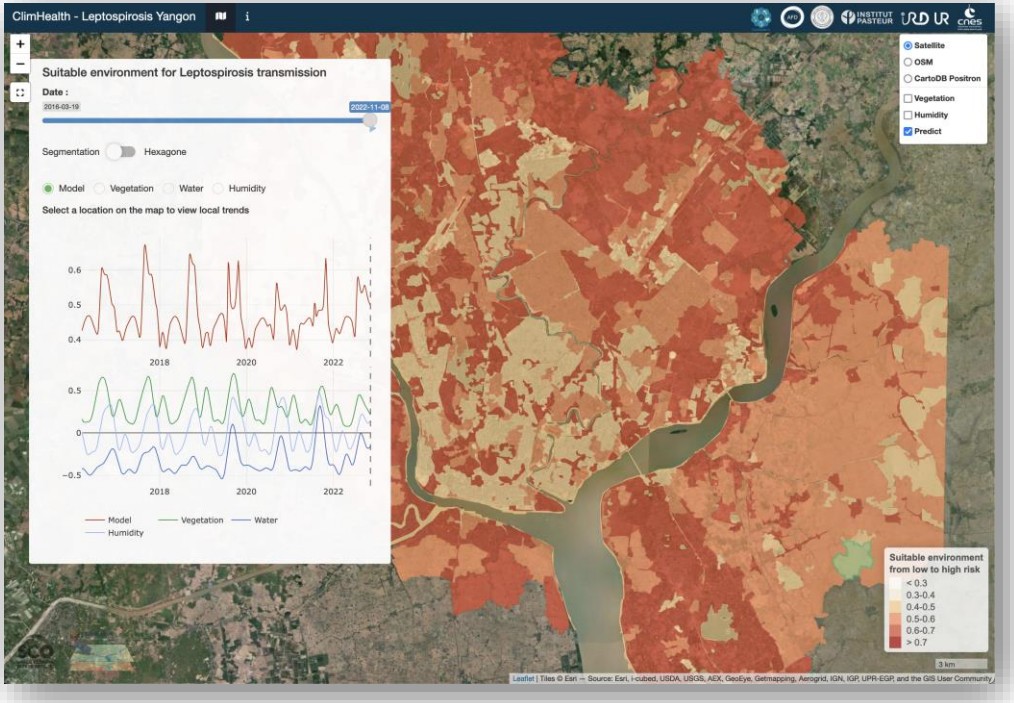
National scale: monitoring of climate and environmental dynamics for health surveillance

Subnational scale: malaria surveillance system surveillance system for SMRU-METF

Local scale: monitoring of suitable environments for disease transmission

ECOMORE II WP Myanmar + ClimHealth, 2021 : Lepto Yangon

https://leptoyangon.geohealthresearch.org/



Application for Leptospirosis surveillance of suitable habitats

This approach considers 2 facets of leptospirosis:

- **Leptospirosis remains a neglected disease:**
  - Leptospirosis affects vulnerable populations with limited resources, especially in tropical countries, in urban slums or rural areas.
  - It has a significant health burden worldwide: estimation of 1.03 million cases annually (Costa *et al.*, 2015), *i.e.* a total of approximately 2.90 million Disability Adjusted Life Years (DALY) (Torgerson *et al.*, 2015):
  - Rarely diagnosed in many countries.

  => A need to raise awareness, help inform public health systems

- **Leptospirosis is an environmental disease, water-borne, seasonal (associated to the rainy season in tropical countries):**

  => Potential to use ecological approaches to describe its distribution

  => Potential to use regular remotely-sensed information to monitor and predict its dynamics

  => Proposal to use Earth observation satellites

Figure summarizing the hypothetical mechanisms of Leptospira environmental survival and dispersion upon heavy rainfall (In: Bierque et al., 2020)

Application for Leptospirosis surveillance of suitable habitats

- **Part of the ECOMORE 2 Project** (funded by AFD, 2018-2022), WP Myanmar by National Health Laboratory in Yangon, Institut Pasteur du Cambodge (IPC) and Institut Pasteur de Nouvelle Calédonie (IPNC)

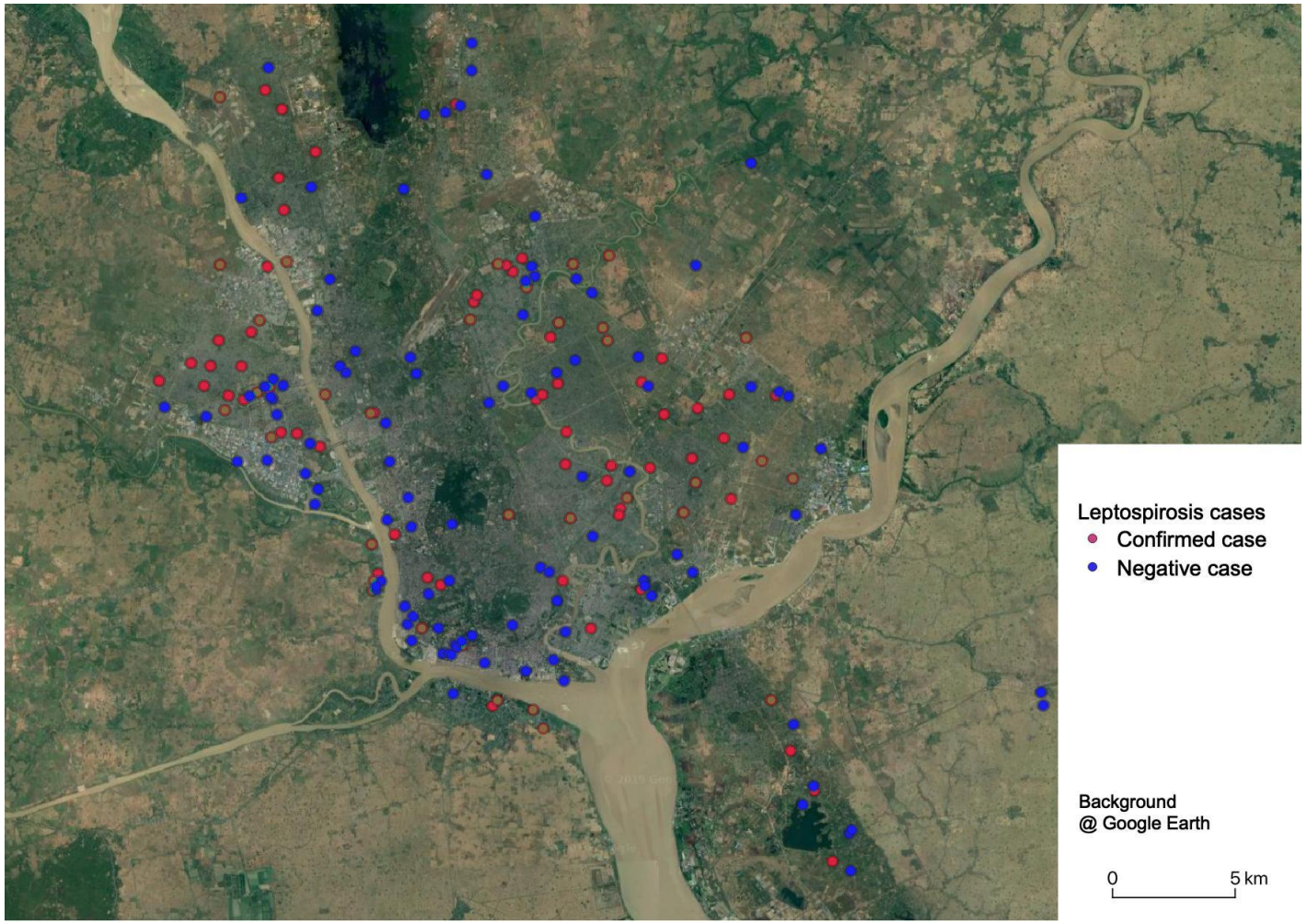
- **A multicenter hospital-based case-control study of leptospirosis in 10 public hospitals across the Yangon region, in Myanmar:**
  - Laboratory confirmed human cases: PCR and ELISA done at the National Health Laboratory (NHL, Yangon)
    - MAT analyses were recently done by IPNC
  - Patients located to their residence
  - 309 patients included from May 2019 to September 2020:
    - 139 positive cases: 87 confirmed cases and 52 probable cases
    - 170 negative cases

- **Development of an operational surveillance system**, under the SCO ClimHealth project (funded by CNES)

Application for Leptospirosis surveillance of suitable habitats

Acquisition of Sentinel-2 images

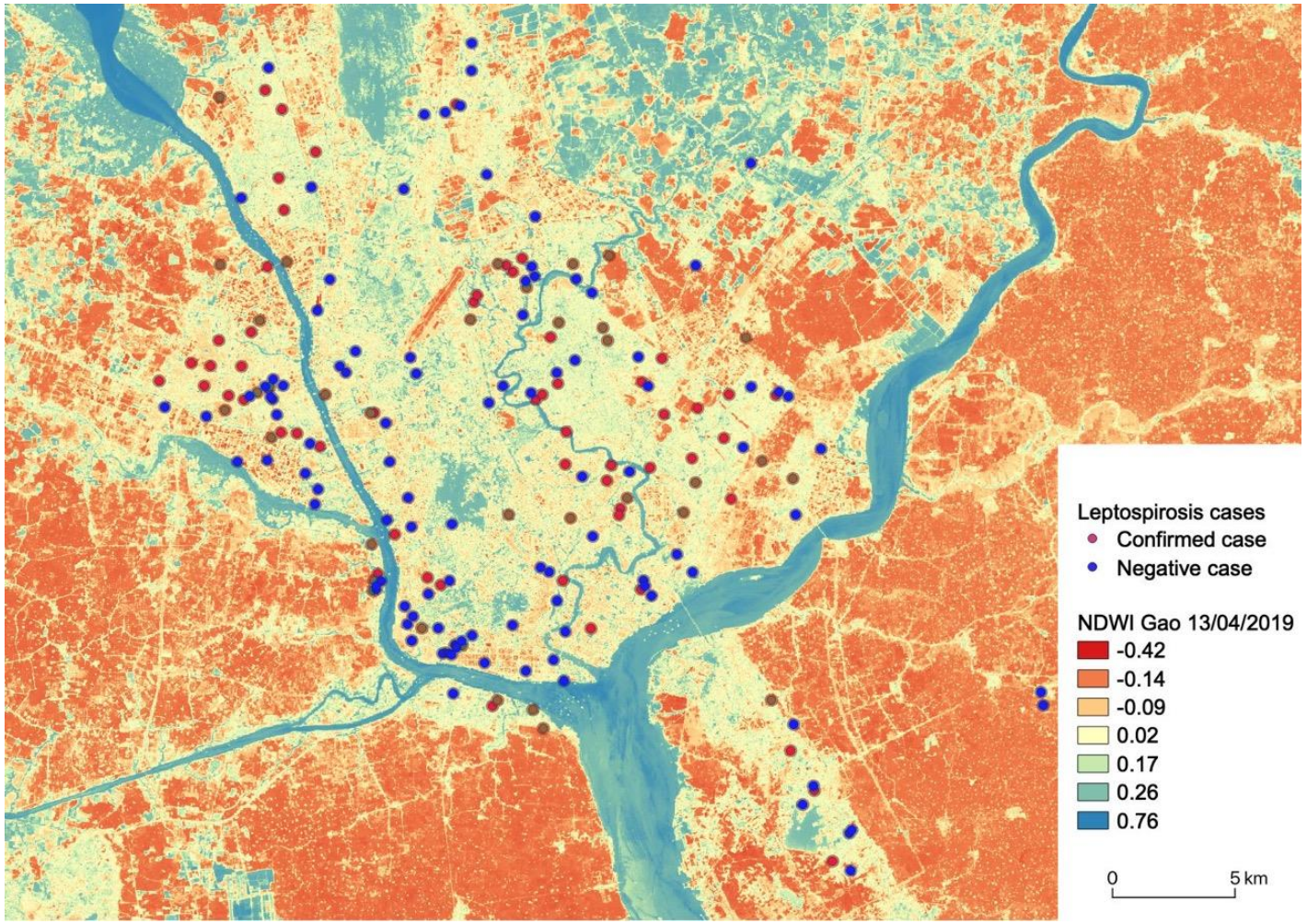
- 381 images from 09/01/2016 to 11/06/2022



Application for Leptospirosis surveillance of suitable habitats

Production of vegetation and water satellite indices (NDVI, NDWI Gao and MNDWI)

Calculation of indices around each sampling site (in 250 meters radius buffers)



Sentinel-2, NDWI Gao, 13/04/2019

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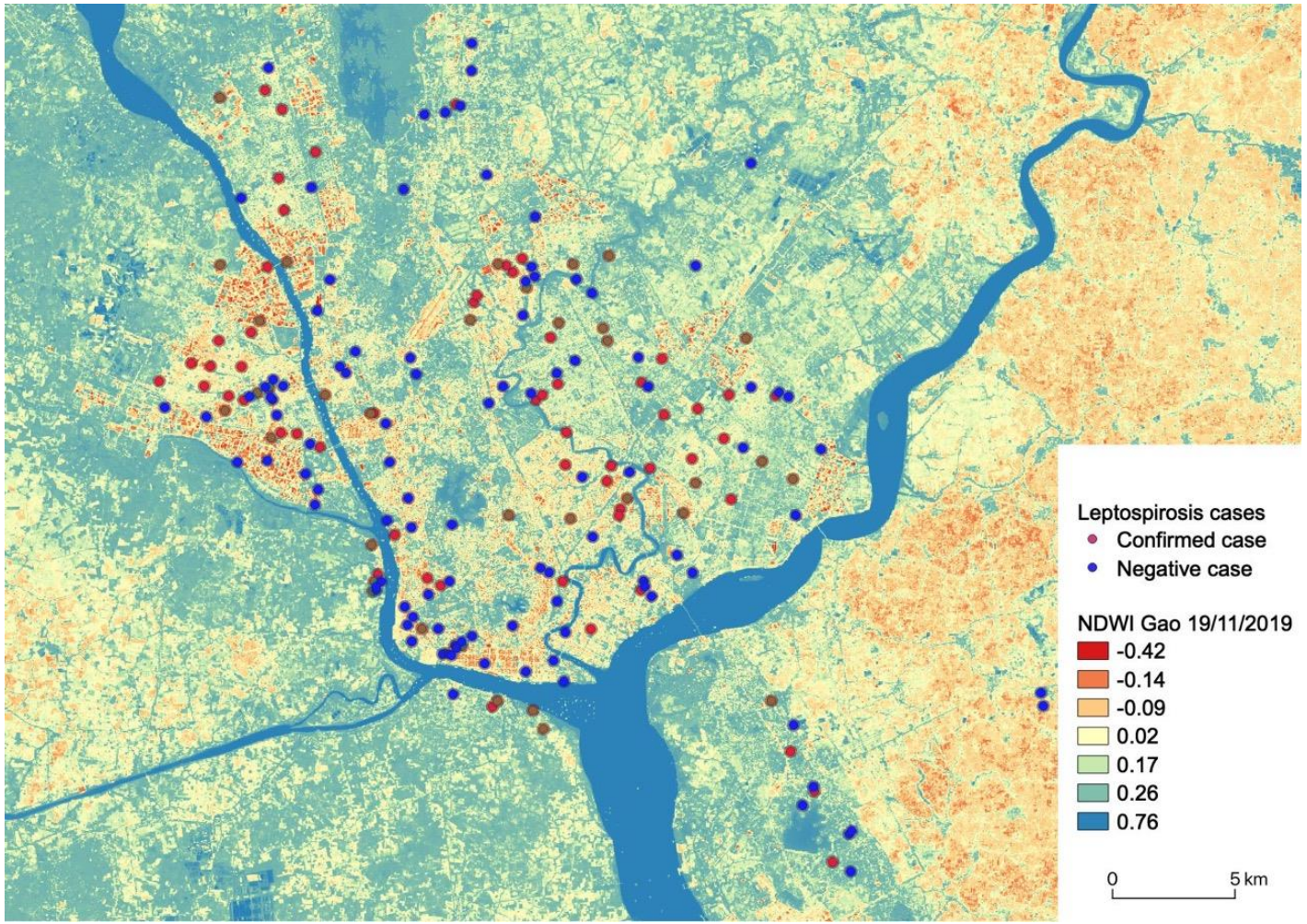
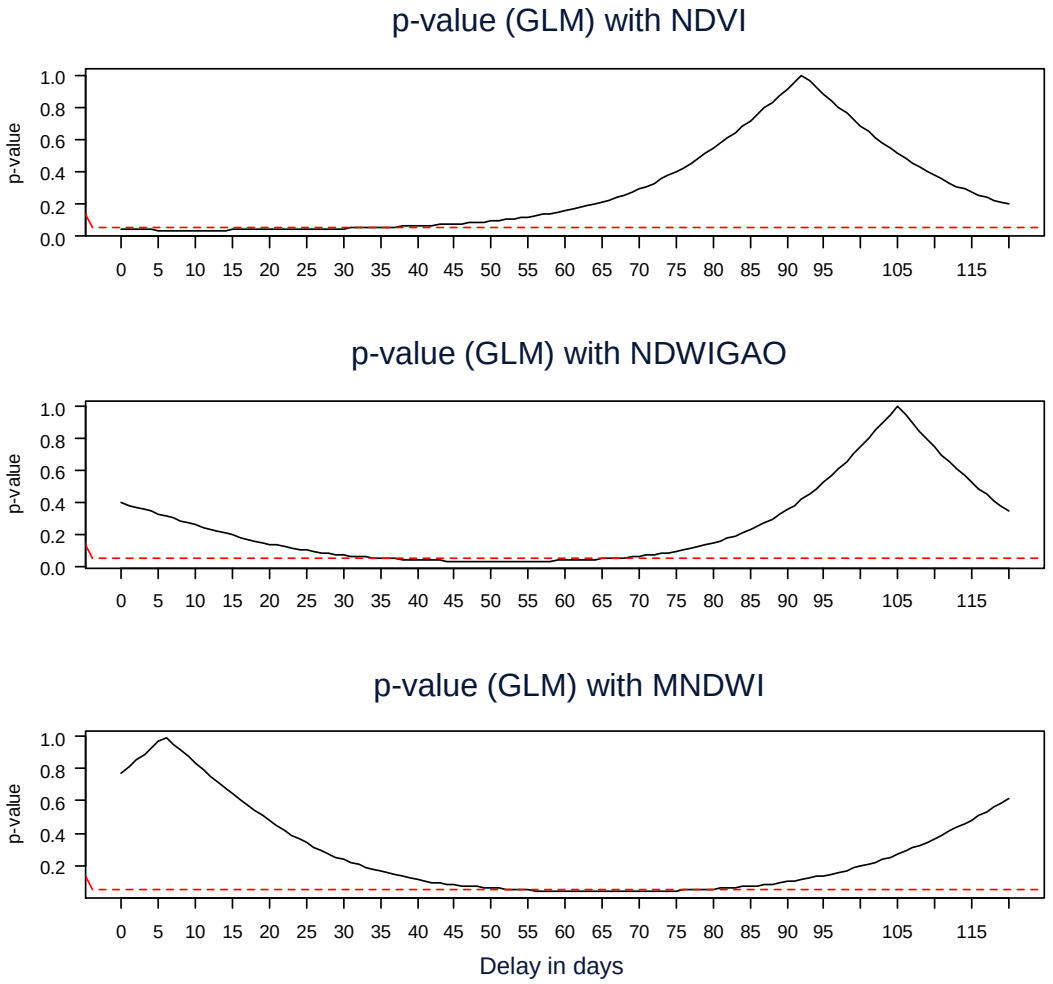


Sentinel-2, NDWI Gao, 13/04/2019

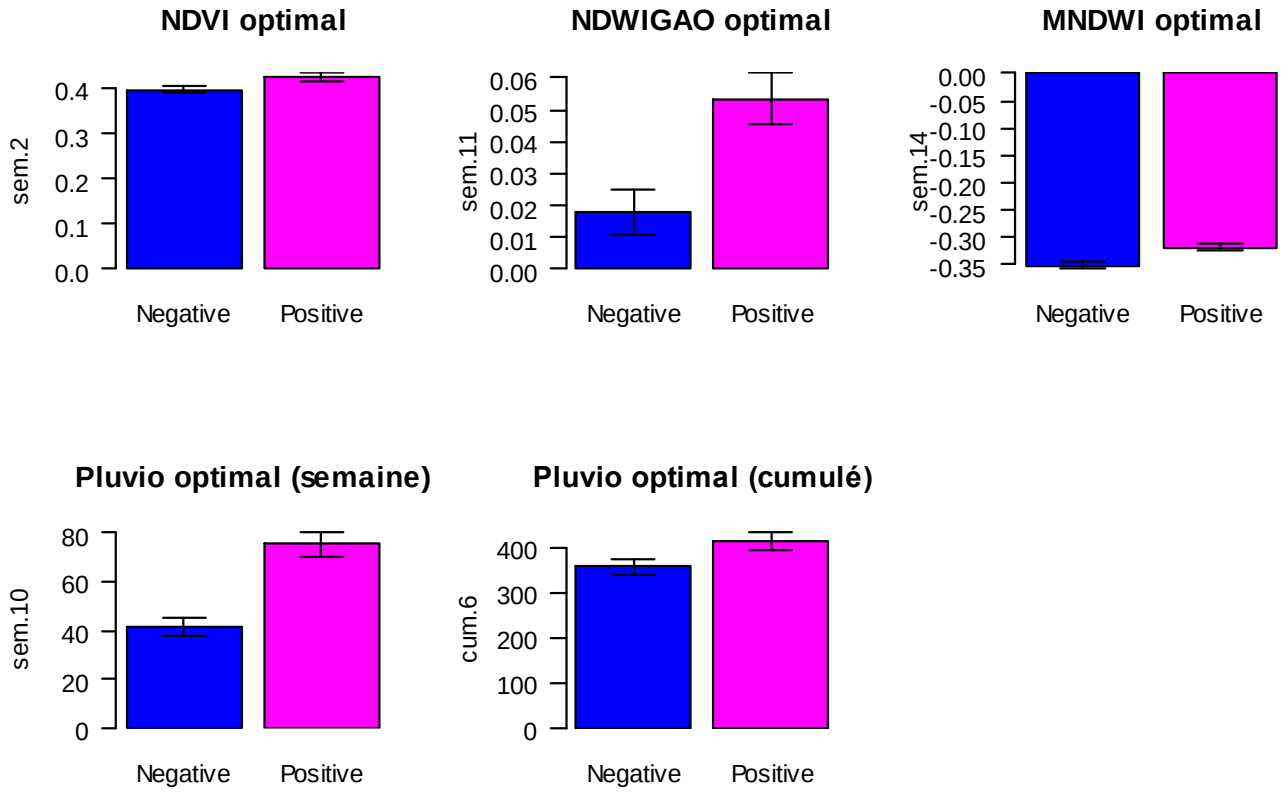
Application for Leptospirosis surveillance of suitable habitats

Calculation of the optimal delay between the case onset and daily environmental indices to discriminate positive vs negative patients:

- GLM on each variable, cross-validation k-fold repeated 5 times
- Optimal dates for indices:
  - NDVI at t - 10 days
  - NDWIGAO at t - 51 days
  - MNDWI at t - 66 days



Average optimal indices according to patient groups



Groups negatives vs *positives*

Application for Leptospirosis surveillance of suitable habitats

Model performance on training and test datasets:

- Multivariate analysis performed on the data with a 5-day lag and with the same training and test datasets, as well as a repeated k-fold cross-validation.
- **5 models performed:** Logistic regression with Stepwise method (GLM), Conditional Random Forest (RFc), Support Vector Machine with Radial Gaussian kernel (SVM), Regularized Discriminant Regression (RDA) and Gradiant Boosting (GBM).

	Min	Q25	Médiane	Moyenne	Q75	Max
GLM	0,4348	0,5652	0,6087	0,6065	0,6522	0,7917
RFc	0,4167	0,5652	0,5833	0,5956	0,6250	0,7826
SVM	0,4583	0,5697	0,6087	0,6203	0,6667	0,8333
RDA	0,4583	0,5652	0,6087	0,6186	0,6667	0,7917
GBM	0,4348	0,5652	0,6087	0,6116	0,6667	0,8750

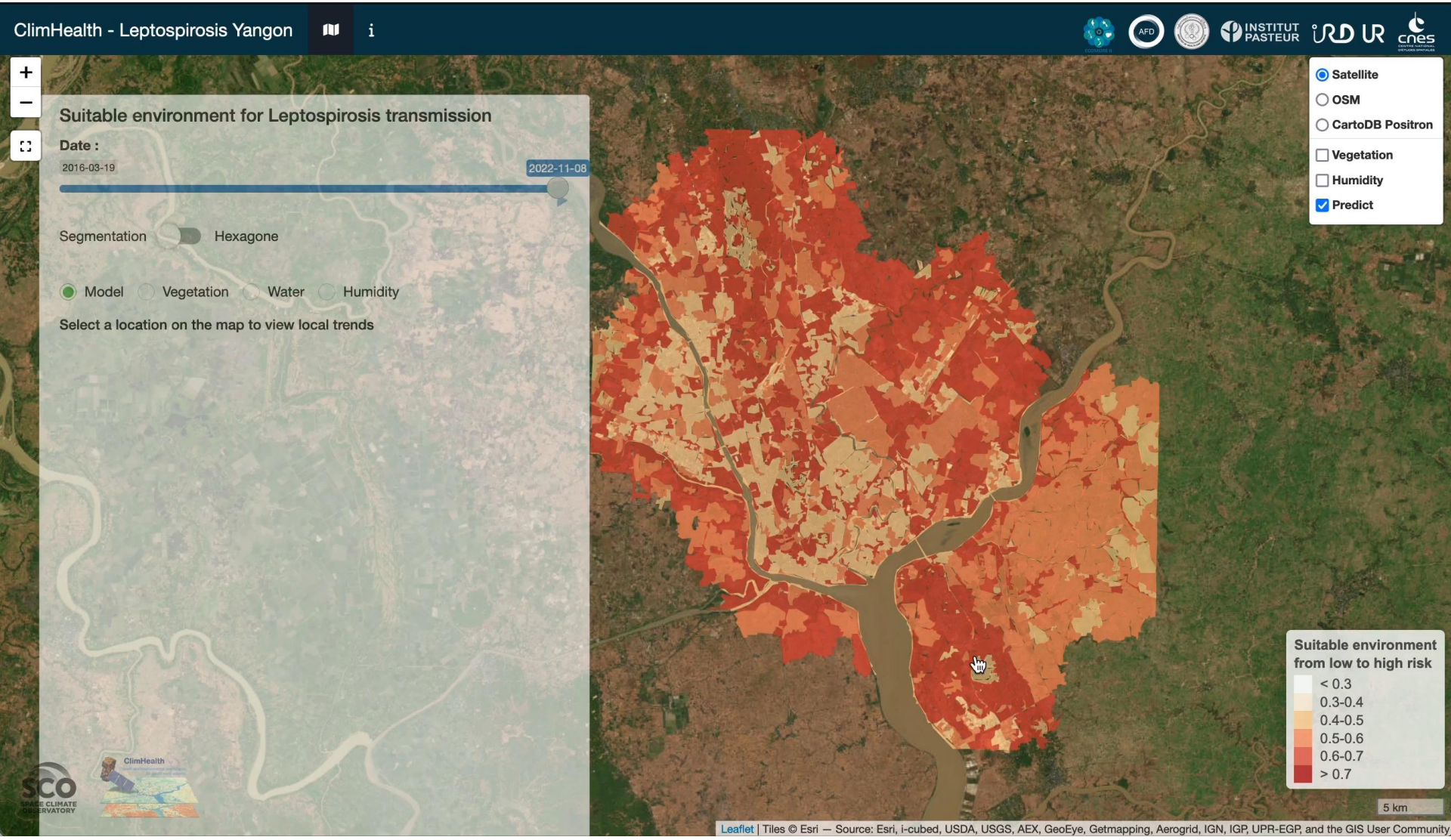
Application for Leptospirosis surveillance of suitable habitats

Definition of areas to apply the model:

- Areas based on the land cover: segmentation of temporal syntheses of Sentinel-2 images, based on:
  - NDVI
  - MNDWI

Application for Leptospirosis surveillance of suitable habitats

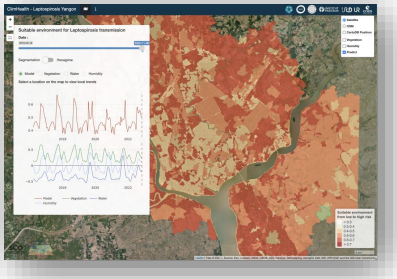
https://leptoyangon.geohealthresearch.org/



Application for Leptospirosis surveillance of suitable habitats

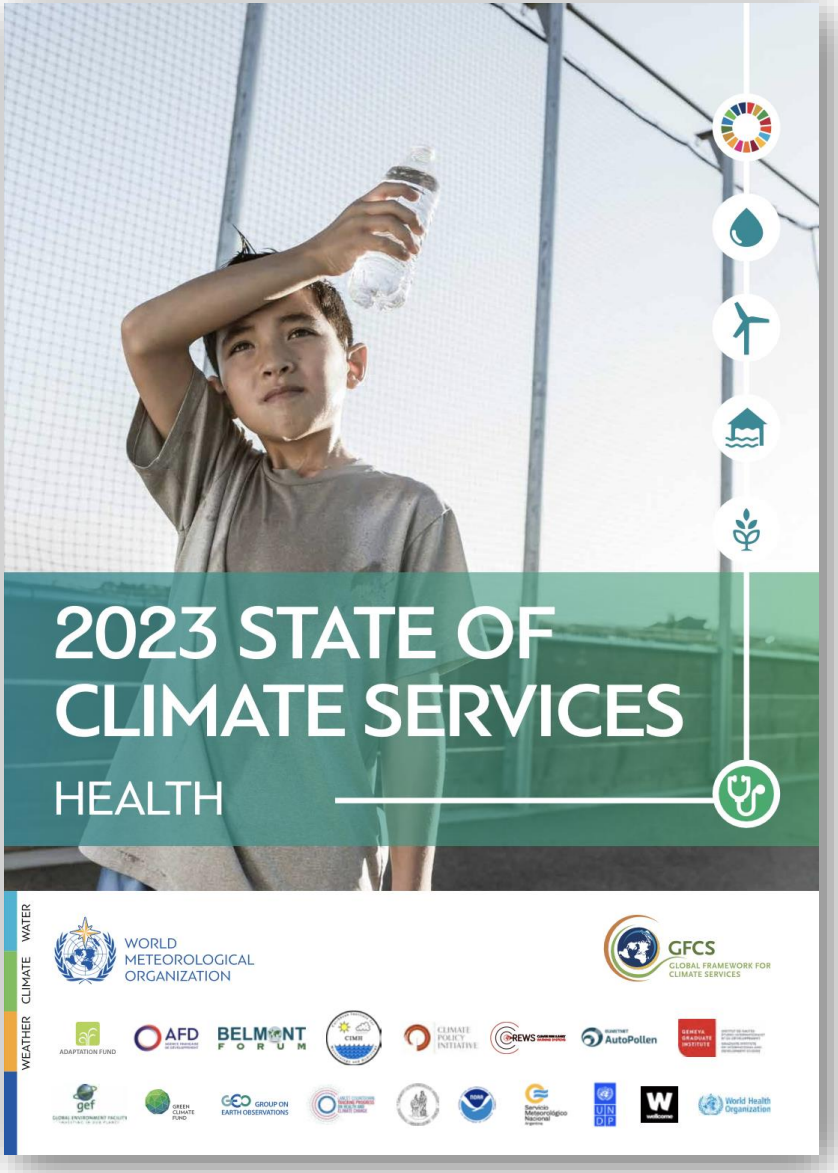
LeptoYangon, selected as a case study in the WMO 2023 State of Climate Services for Health report

https://library.wmo.int/records/item/68500-2023-state-of-climate-services-health



https://leptoyangon.geohealthresearch.org/

"There is huge potential for enhancing the benefits of climate science and climate services for health. Despite examples of success, data shows that the health sector is underutilizing available climate knowledge and tools. At the same time, climate services need to be further enhanced to fully satisfy the health sector requirements."



Conclusion

⇒ There are **still major development needs** for the operational use of Earth observation data for health surveillance

- **Interest for remote sensing data:**
  - increasingly free and accessible raw data and products,
  - available in near real time to build early-warning systems,
  - available at any place, esp. when meteorological data is not available
  - available at different scales : 10m / 5d (Sentinel-2) *vs.* 1km / hour (climate data)

- **Needs to:**
  - **further investigate** ecological and climate indicators and modelling of health signals (outbreaks, dynamics),
  - develop tools at different scales (Sen2Chain adapted to local scales), technical difficulty to scale-up
  - **develop pipelines** to process satellite data and export to Health information systems,
  - **train** and **develop local capacities,** in collaboration with space agencies, universities, research institutions
    - ⇒ Focus in Cambodia of the Khmer Earth Observation Laboratory (KHEOBS), at the Institute of Technology of Cambodia (ITC)
      - ⇒ Develop expertise and infrastructure (servers, storage)

KHEOBS
Khmer Earth Observation Laboratory

Teams involved and funders

Cambodia:

- Vincent Herbreteau, Sokeang Hoeun, George Ge, Chamroeun Yorngsok, Lucas Longour, Léa Douchet, Sylvaine Jégo (IRD Espace-Dev)
- Florian Girond, CDC-MoH Cambodia, Institut Pasteur du Cambodge (IPC)
- Vannak Ann, Institute of Technology of Cambodia (ITC)

France, Montpellier (IRD Espace-Dev):

- Benjamin Sultan, Thibault Catry, Renaud Hostache, Aneta Afelt

France, La Réunion (IRD, Université de La Réunion (UR), SEAS-OI):

- Pascal Mouquet, Christophe Révillion, Thomas Germain, Didier Bouche

Collaboration with: Institute of Technology of Cambodia (ITC), Institut Pasteur du Cambodge (IPC), CDC-MoH Cambodia, SMRU, Mahidol University, DDC MoPH Thailand

Funders: IRD, AFD, Global Fund, CNES