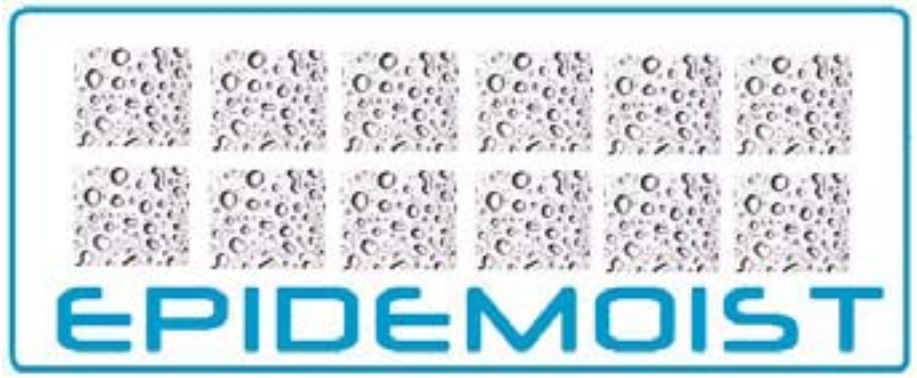
Improving epidemiological modelling using satellite derived soil moisture proxies



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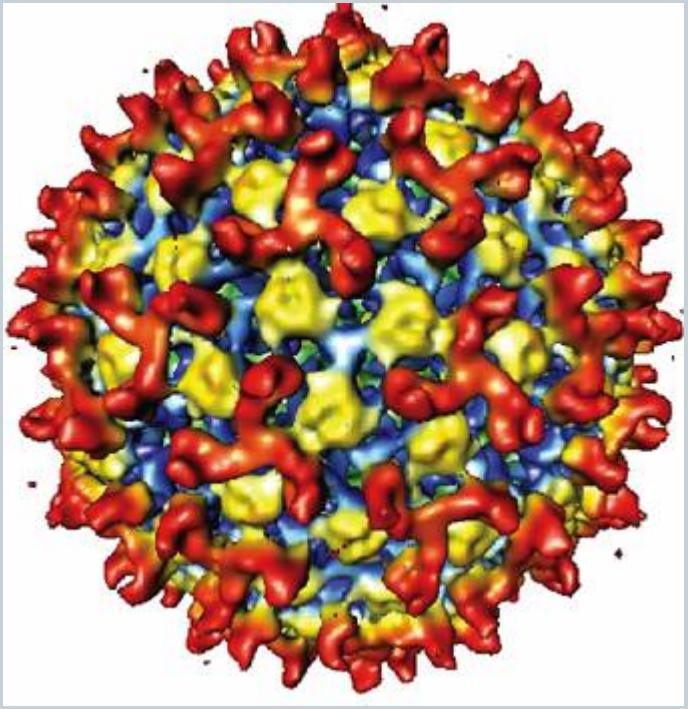
Epidemiology

- Epidemiology :
  - study of factors affecting the health and illness of populations
  - foundation to make interventions in the interest of public health and preventive care

- Epidemiologic modelling : quantitive studies on different epidemiological aspects, such as
  - analysis of factors that influence and control invasion, persistence and variability of disease
  - spatial and temporal dynamics of epidemics at a range of spatial scales
    - improved understanding of space-time dynamics of disease transmission
    - increased effectiveness disease control strategies
    - prevent disease outbreaks
    - prevent disease spread

Bluetongue – the disease

- A severe *viral* disease of *ruminants*, affecting sheep, cattle, goats, ...
- The virus is transmitted by biting midges of the genus *Culicoides* (Diptera: Ceratopogonidae).
- No public health issue.
- Economic losses (worldwide 3 billion USD/year).

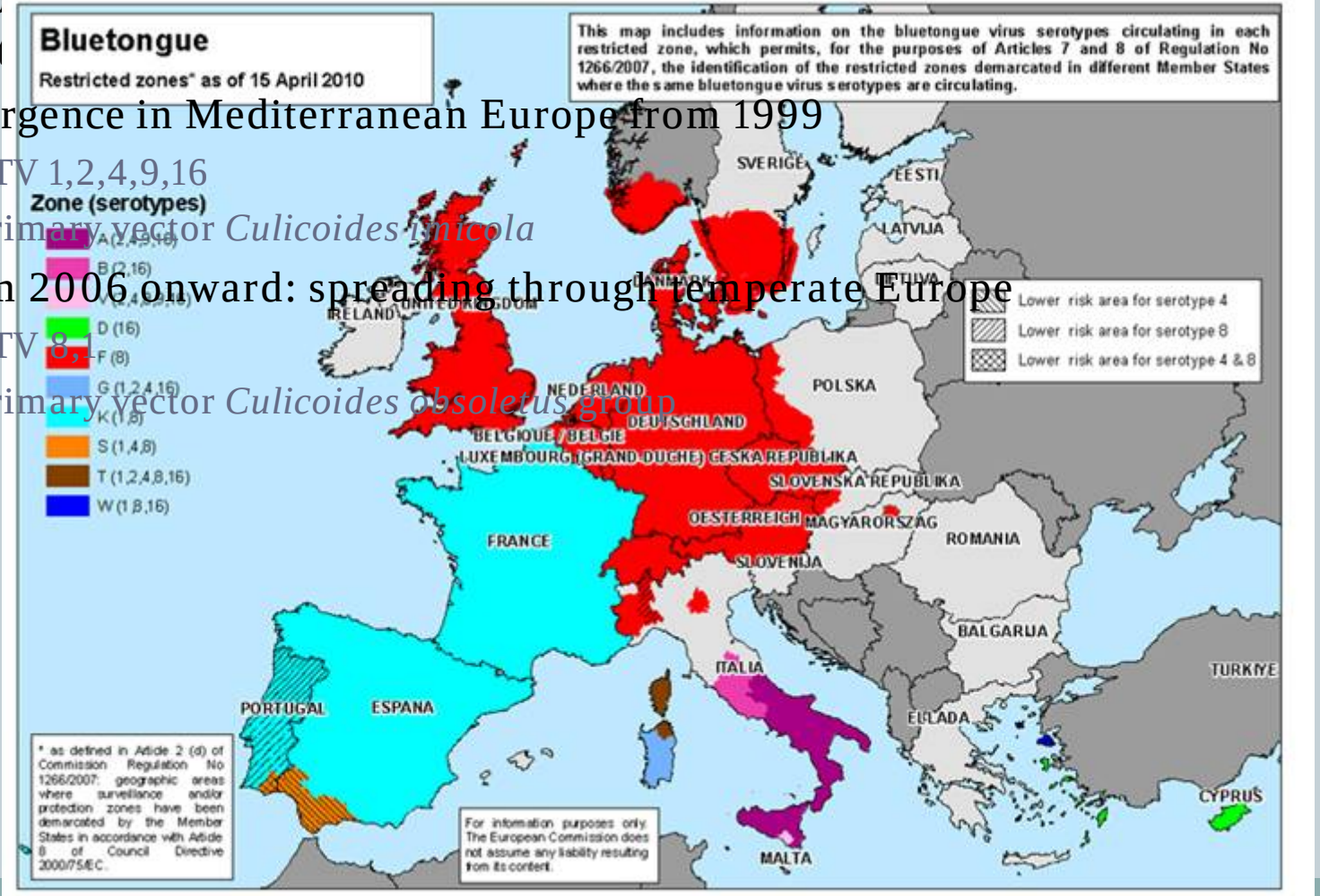


Bluetongue - symptoms

- Fever
- Swelling of the head and neck
- Lameness
- Inflammation of the mucous membrane of the mouth, nose and eyes
- Drooling
- Respiratory problems
- Discoloration and swelling of the tongue
- High mortality rate

Bluetongue - history

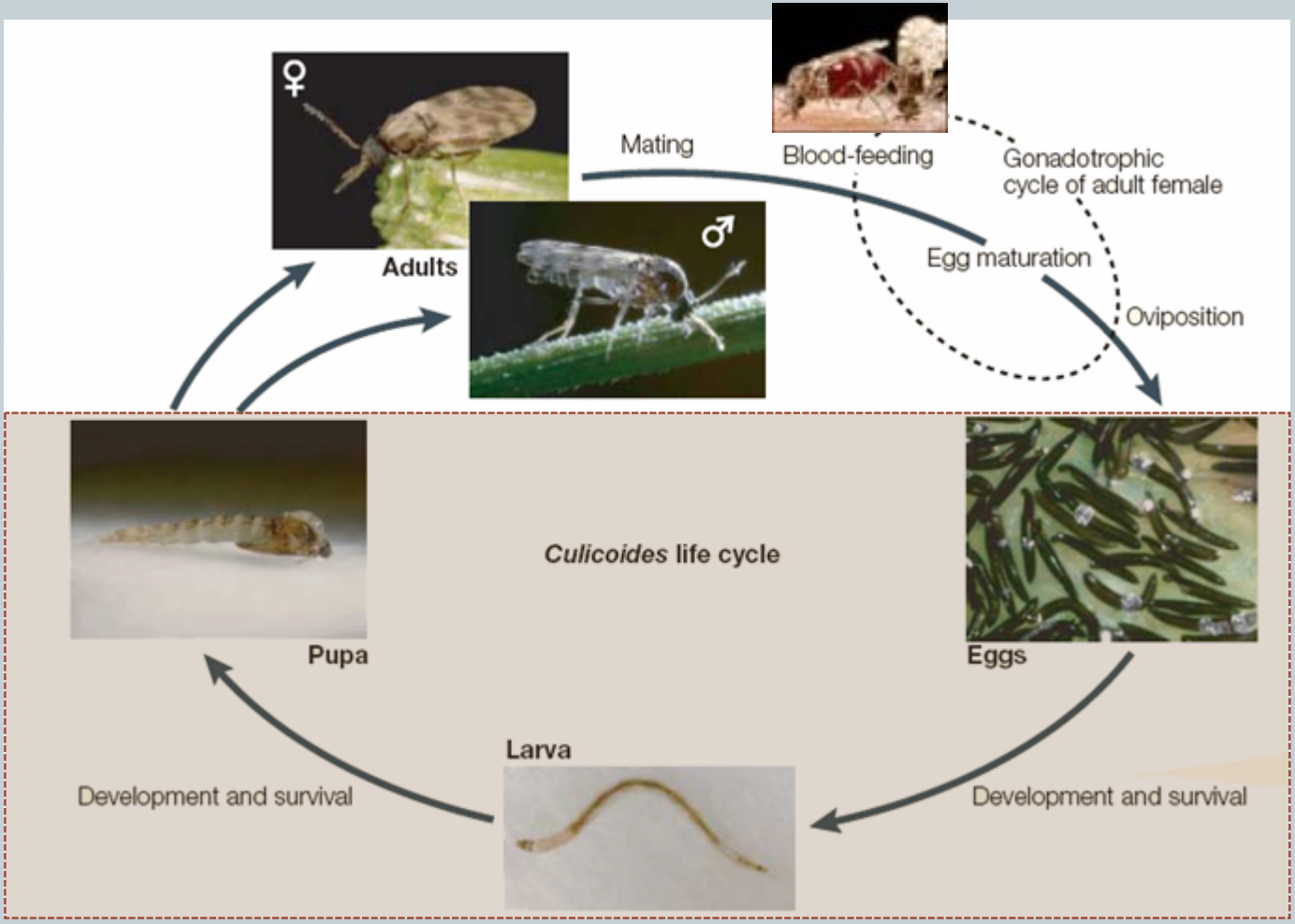
- Enzo
  (Port
- Emergence in Mediterranean Europe from 1999
  - BTV 1,2,4,9,16
  - Primary vector *Culicoides imicola*
- From 2006 onward: spreading through temperate Europe
  - BTV 8,1
  - Primary vector *Culicoides obsoletus* group



Culicoides – What are they?

- Genus of biting midges
- The large majority of *Culicoides* species are blood-feeding insects
- Over 120 species in Europe
- Only a very low fraction of those species are known to vector pathogens, including BTV, African Horse Sickness
- Very diverse habitats and ecologies; some species are common, some have very specific habitats
- Complex taxonomy

Culicoides – life cycle



In the topsoil

Culicoides – distribution model

- Model geographical distribution of *Culicoides* using (a)biotic predictor variables
  - Meteorological data (weather stations, remote sensing)
  - Land Use/ Land Cover
  - Elevation, aspect
- Several studies in Mediterranean basin (*C. imicola*)
- Good model performances on a national scale

EPIDEMOIST – project objectives

- Improve distribution maps through
  - Inclusion of additional predictor variables
  - Application of State-of-the-Art modelling techniques

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EPIDEMOIST – common predictors

Literature review :

Satellite data

Land surface temperature
Air temperature
Middle IR reflectance
NDVI = (NIR – RED)/(NIR+RED)
Altitude (DEM), slope
Land cover (distance from forest)

Meteorological data

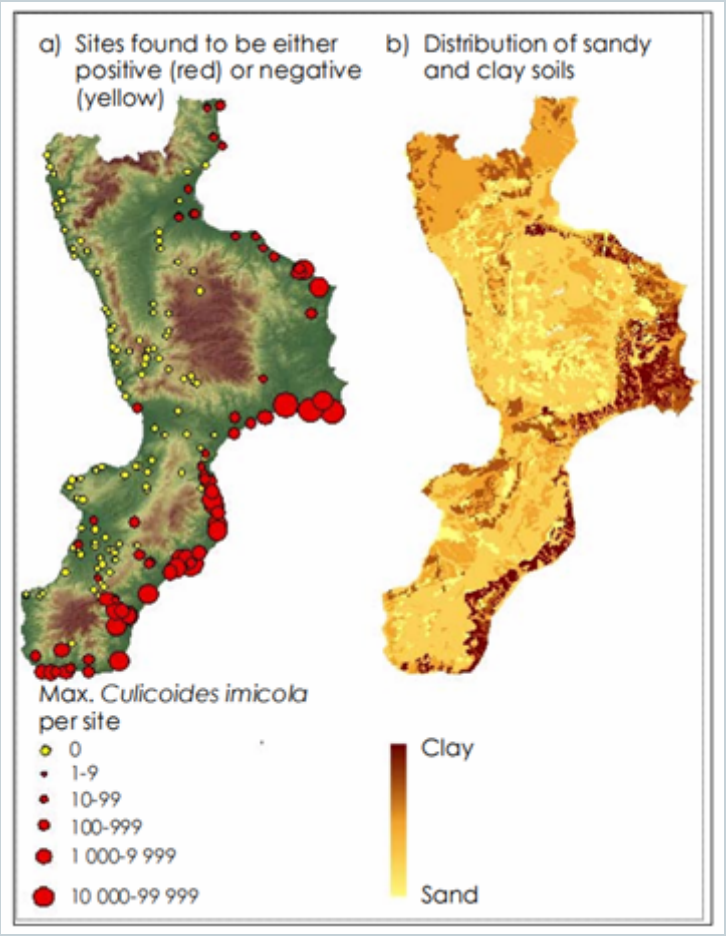
Temperature (annual mean, min, max)
Precipitation (annual mean)
Aridity index (P/PET)

Soil data

Organic matter content
Soil texture (clay and sand content)
Distance from fine textured soils

EPIDEMOIST – soil moisture proxies

- Link with *C. imicola* life cycle (larvae, pupae)
- Relation suggested by Conte *et al.* (2007)



Conte *et al.* 2007, Vet. Ital. 43 (3), 571-580.

EPIDEMOIST – soil moisture proxies

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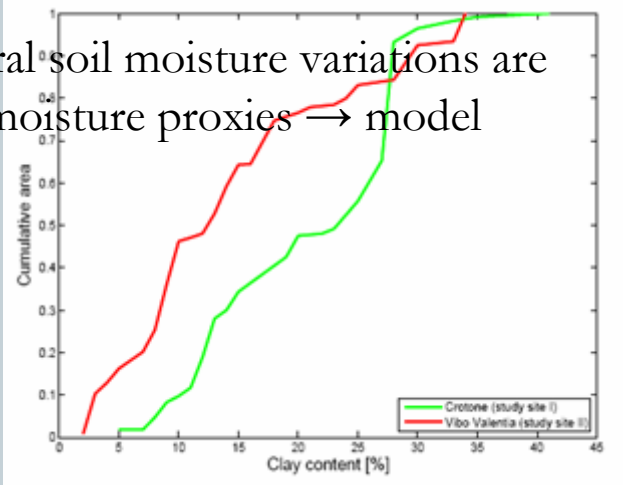
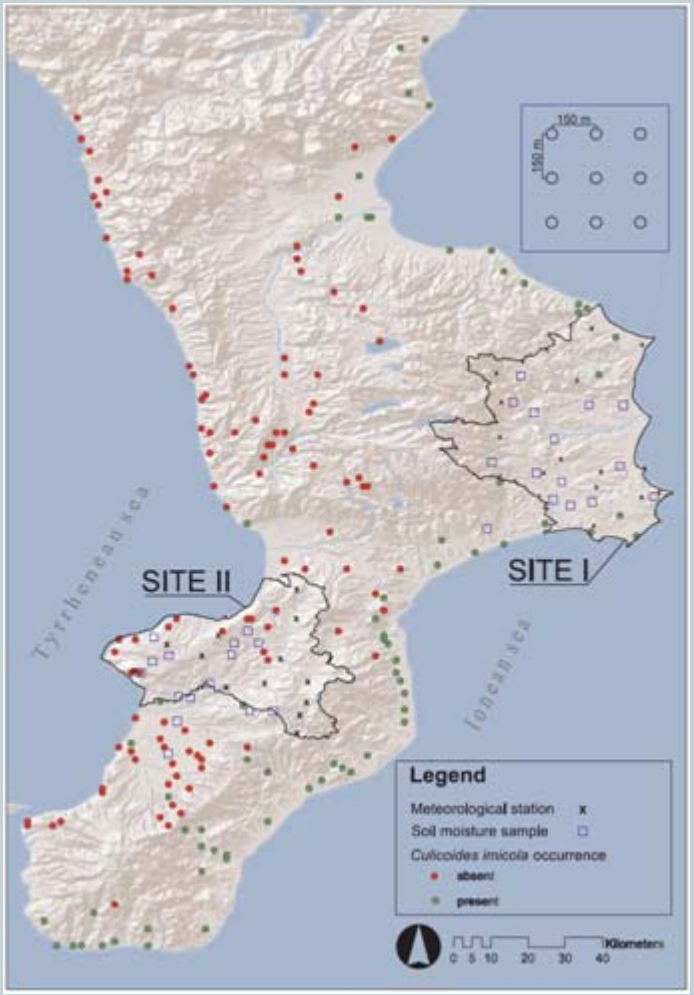
Spatial and temporal soil moisture variations are addressed by soil moisture proxies → model predictors





EPIDEMOIST – soil moisture proxies

- Predictor requirements
  - Related to top 5cm soil moisture content
  - From remote sensing data only
  - Applicable over heterogeneous landscape
  - Spatial resolution: 10m – 1km
  - Temporal resolution: days – weeks
- Derived from RS
  - Optical sensor: MODIS
  - Radar sensor: ASAR

EPIDEMOIST – soil moisture proxies

Derived from optical RS

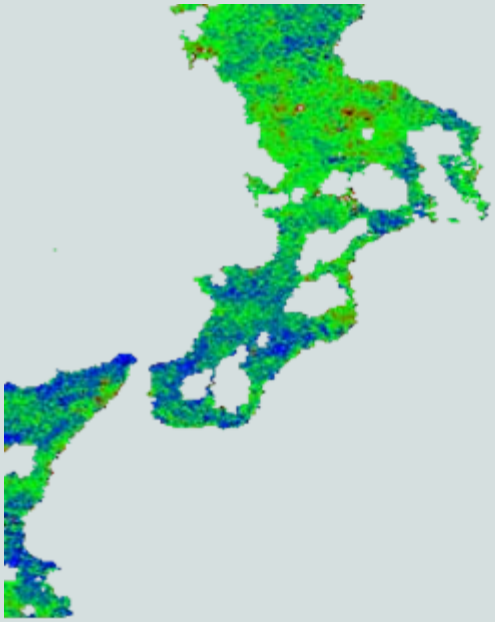
- Response of vegetation to water stress
- Indices from VIS, NIR and MIR

Normalized Difference Water Index (NDWI)
Normalized Difference Vegetation Index (NDVI)

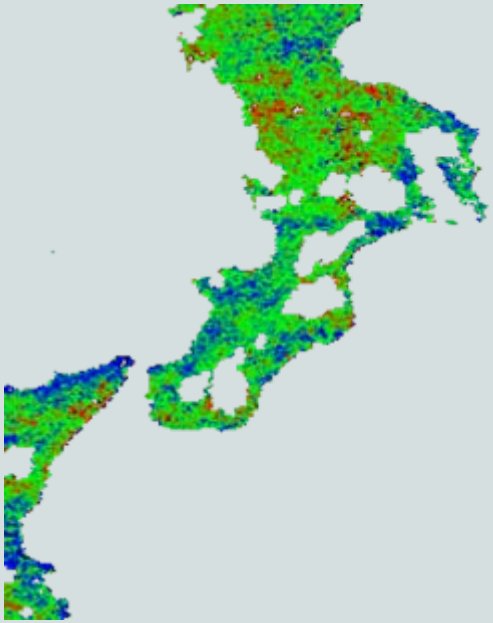
Deseasoned to eliminate the effects of the yearly phenological cycle

EPIDEMOIST – soil moisture proxies

Derived from optical RS



Deseasoned NDVI 8/10/2009



Deseasoned NDWI 8/10/2009

Wetter than average

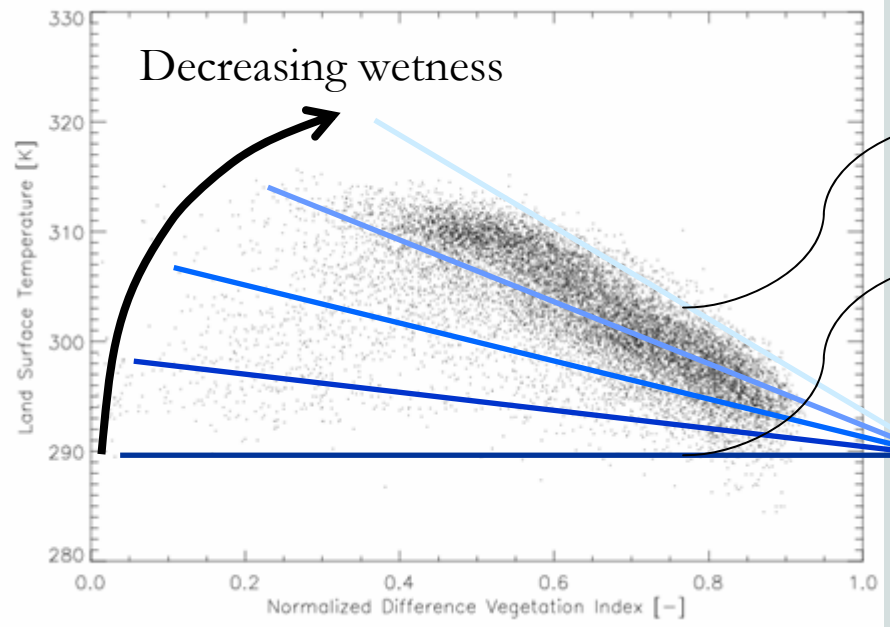
Average moisture

Dryer than average

EPIDEMOIST – soil moisture proxies

Derived from optical RS

- "Triangle method" → combinations of VIS, NIR and TIR
- Evapotranspirative cooling at higher moisture levels



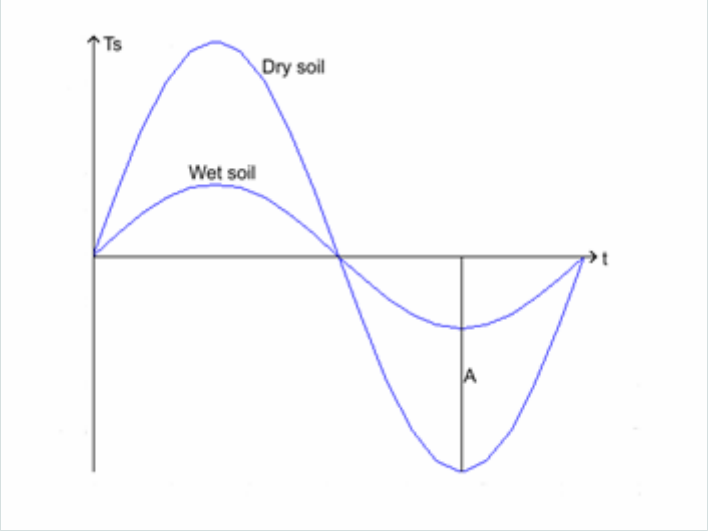
Dry pixels
(evapotranspiration = low)

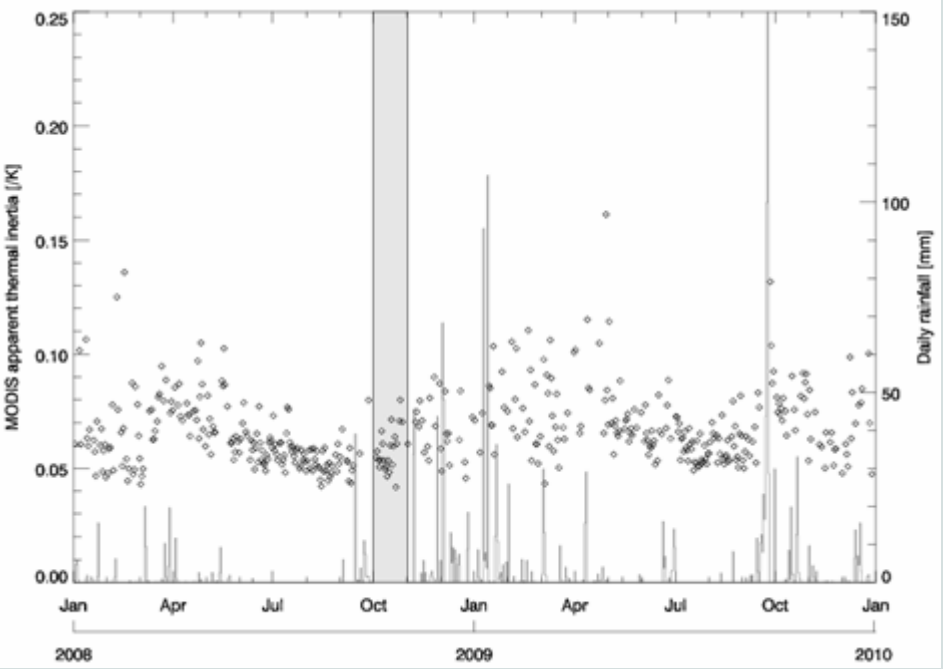
Wet pixels
(evapotranspiration = high)

EPIDEMOIST – soil moisture proxies

Derived from optical RS

- Thermal inertia → combinations of VIS, NIR and TIR
- Day-night temperature difference decreases with increasing soil moisture





EPIDEMOIST – soil moisture proxies

Derived from radar RS

- Radar backscatter function of
  - Soil moisture
  - Soil roughness
  - Vegetation cover
- Change detection
  - Variation in soil moisture at shorter timescales than variation in roughness and vegetation
  - Change backscatter ~ change soil moisture
- Principal Components Analysis

  Influences on backscatter separated or grouped

EPIDEMOIST – soil moisture proxies

- Validation of proxies
  - In-situ soil moisture measurements
    - Gravimetric (soil sample)
    - Volumetric (TDR)
  - Rainfall (meteorological data)

EPIDEMOIST – Conclusions

Soil moisture proxies

- Currently applied soil moisture proxies are too noisy
- Their inclusion into the C. imicola distribution model is not yet satisfactory
  - Further testing on a study area in Spain
  - Introduce state-of-the-art speckle reducing algorithms

EPIDEMOIST

http://epidemoist.avia-gis.com