Improving epidemiological modelling using satellite derived soil moisture proxies
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**: quantitative 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

- Enzootic from sub-saharian Africa; first reports in Europe in 1957-1960 (Portugal & Spain), 1977 (Cyprus), Greece (1980).
- 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
EPIDEMOIST – project objectives

- Improve distribution maps through
  - Inclusion of additional predictor variables
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# Literature review:

<table>
<thead>
<tr>
<th>Satellite data</th>
<th>Meteorological data</th>
<th>Soil data</th>
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<tbody>
<tr>
<td>Land surface temperature</td>
<td>Temperature (annual mean, min, max)</td>
<td>Organic matter content</td>
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<tr>
<td>Air temperature</td>
<td>Precipitation (annual mean)</td>
<td>Soil texture (clay and sand content)</td>
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<td>Middle IR reflectance</td>
<td>Aridity index (P/PET)</td>
<td>Distance from fine textured soils</td>
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<td>NDVI = (NIR – RED)/(NIR+RED)</td>
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<td>Altitude (DEM), slope</td>
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<td>Land cover (distance from forest)</td>
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EPIDEMOIST – soil moisture proxies

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

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

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

<table>
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<tr>
<th>Decreasing wetness</th>
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<tr>
<td>Dry pixels</td>
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<tr>
<td>(evapotranspiration = low)</td>
</tr>
<tr>
<td>Wet pixels</td>
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<tr>
<td>(evapotranspiration = high)</td>
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</table>
EPIDEMOIST – soil moisture proxies

Derived from optical RS

- Thermal inertia \(\rightarrow\) 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 $\sim$ 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)
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
http://epidemoist.avia-gis.com

Thanks for listening!