Freie Software und infektiöse Krankheiten: Von Rohdaten zu ökologischen Indikatoren

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FOSSGIS Konferenz

20-22 März 2012

Fondazione Edmund Mach, Trento, Italy

- **Founded 1874** as IASMA - Istituto Agrario San Michele all'Adige (north of Trento, IT)
- Research Centre, Tech. Transfer Center and highschool, 720 staff
- ... of those **300 staff in research** (Environmental research, Agro-Genetic research, Food safety)

http://cri.fmach.eu/

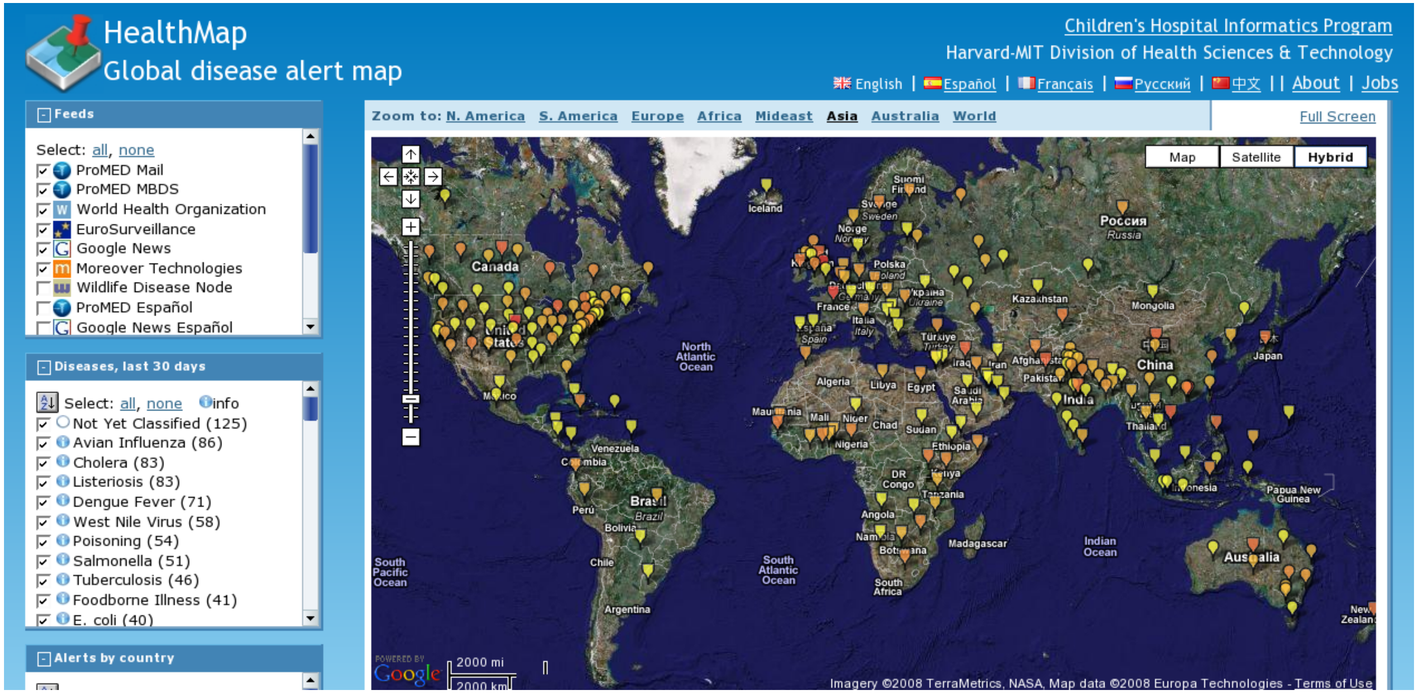
The problem: Emerging infectious diseases in Europe and elsewhere

Focus on **zoonotic diseases**

- They are able to be transmitted from animals to humans, usually by a **vector** (e.g., ticks, mosquitoes)
- Both **wildlife** (e.g., roe and red deer, rodents) and **domestic animals** are reservoir hosts
- Zoonoses involve all types of **agents** (bacteria, parasites, viruses and others)

Zoonotic diseases cause **major health problems** in many countries.

They are driven by environmental and pathogen **changes** as well as political and cultural changes.



EDENext

Biology and control of vector-borne infections in Europe

SEVENTH FRAMEWORK PROGRAMME

http://www.edenext.eu

EDENext (FP7, 2011-2014) aims at generating knowledge on vectors and their biology relevant to human and veterinary diseases.” (ticks, rodents, mosquitoes) addresses research questions to improve our understanding of:

1. **Emergence and spread** of vector borne diseases (VBD)
2. **Intervention and control** of VBD

Example Finland

Viral disease transmitted by rodents: haemorrhagic fever with renal syndrome (HFRS – Hantavirus)

Climate change effects:

- milder winters than in the past,
- less snow and more rain
- rodents take more refuge in houses and man made shelters: increase of human infection risk
- record epidemic peak during the winter of 2008-2009, with 3500 cases of HFRS for a total population of just over 5 million

EuroWestNile

European West Nile R&D collaborative project

http://eurowestnile.isciii.es/ewn/

SEVENTH FRAMEWORK PROGRAMME

West Nile virus (WNV) is a flavivirus with potentially serious disease (but approx. 80% of WNV infections in humans without symptoms). Usually transmitted by mosquito bites.

EuroWestNile: Selected goals

- Biobanks of West Nile like viruses, development of animal models for WNV research on pathogenicity, treatment and vaccine development
- **Landscape** primary data in different scenarios for WNV transmission
- Integrated data in **mathematical models**

Objectives PGIS and Ecohealth units @ FEM for 2012/2013

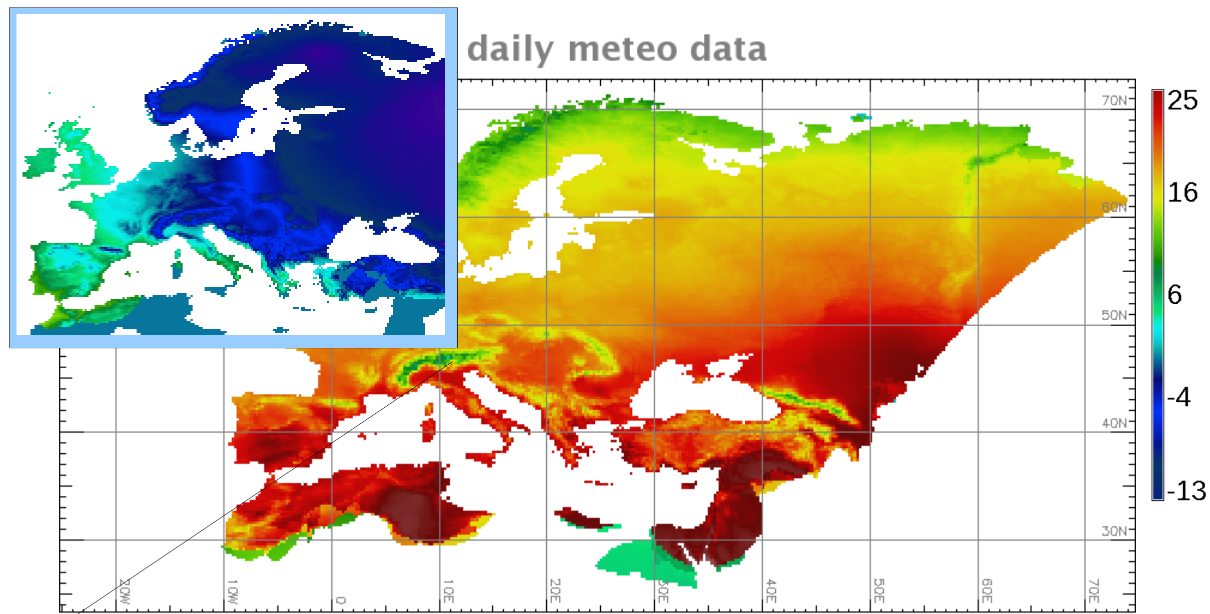
- Evaluate the **effect of temperature** on WNV transmission potential and the emergence of new foci
- Perform analysis of relationship between **spring temperatures** at European scale and following WNV appearance as a measure to identify disease risk ahead of WNV appearance.

GIS and Clima: Ecological variables from spatialized meteo data times series

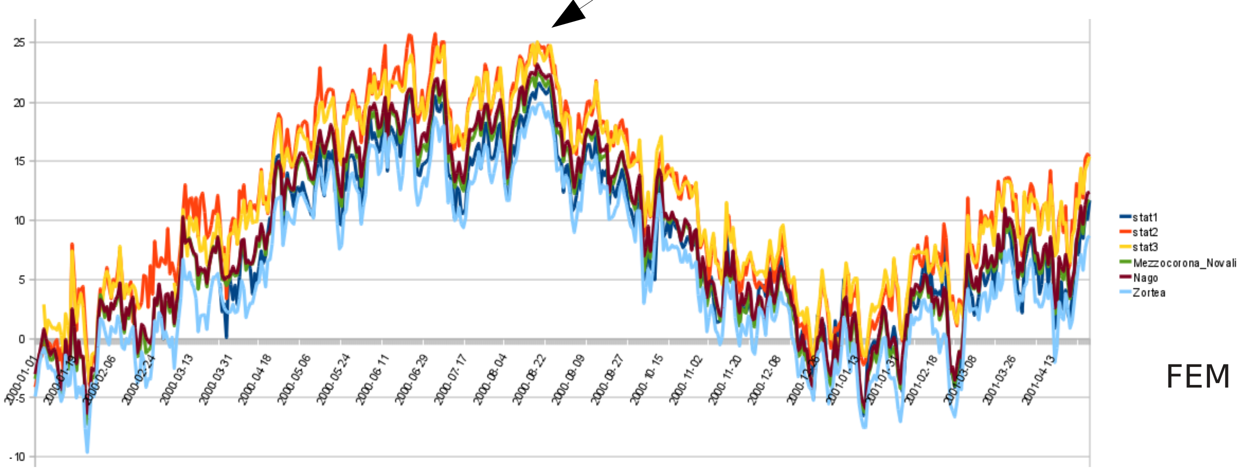
Monthly Tmean: 1950-2010
(derived from EU Ensemble Gridded data ECAD)

Climatic variable	Coefficients[§]	Value	Std. Error	t value	Pr (>|t|)
Annual total precipitation	All	−3.814	1.226	−3.112	**
	Pos	−1.477	2.027	−0.729	0.467
	Neg	−2.129	1.600	−1.331	0.185
	Diff.Pos.Neg	0.652	2.568	0.254	0.800
Annual min temperature	All	0.019	0.006	3.424	***
	Pos	0.005	0.010	0.535	0.593
	Neg	0.018	0.006	3.032	**
	Diff.Pos.Neg	−0.013	0.011	−1.134	0.257
Annual max temperature	All	0.034	0.005	7.524	***
	Pos	0.037	0.008	4.448	***
	Neg	0.028	0.005	5.499	***
	Diff.Pos.Neg	0.009	0.009	0.938	0.349

[§]All, slope for all provinces pooling data; Pos, slope for positive provinces; Neg, slope for negative provinces; Diff.Pos.Neg, difference in slopes between positive and negative provinces.
**P≤0.01.
***P≤0.001.
doi:10.1371/journal.pone.0004336.t003



http://eca.knmi.nl/



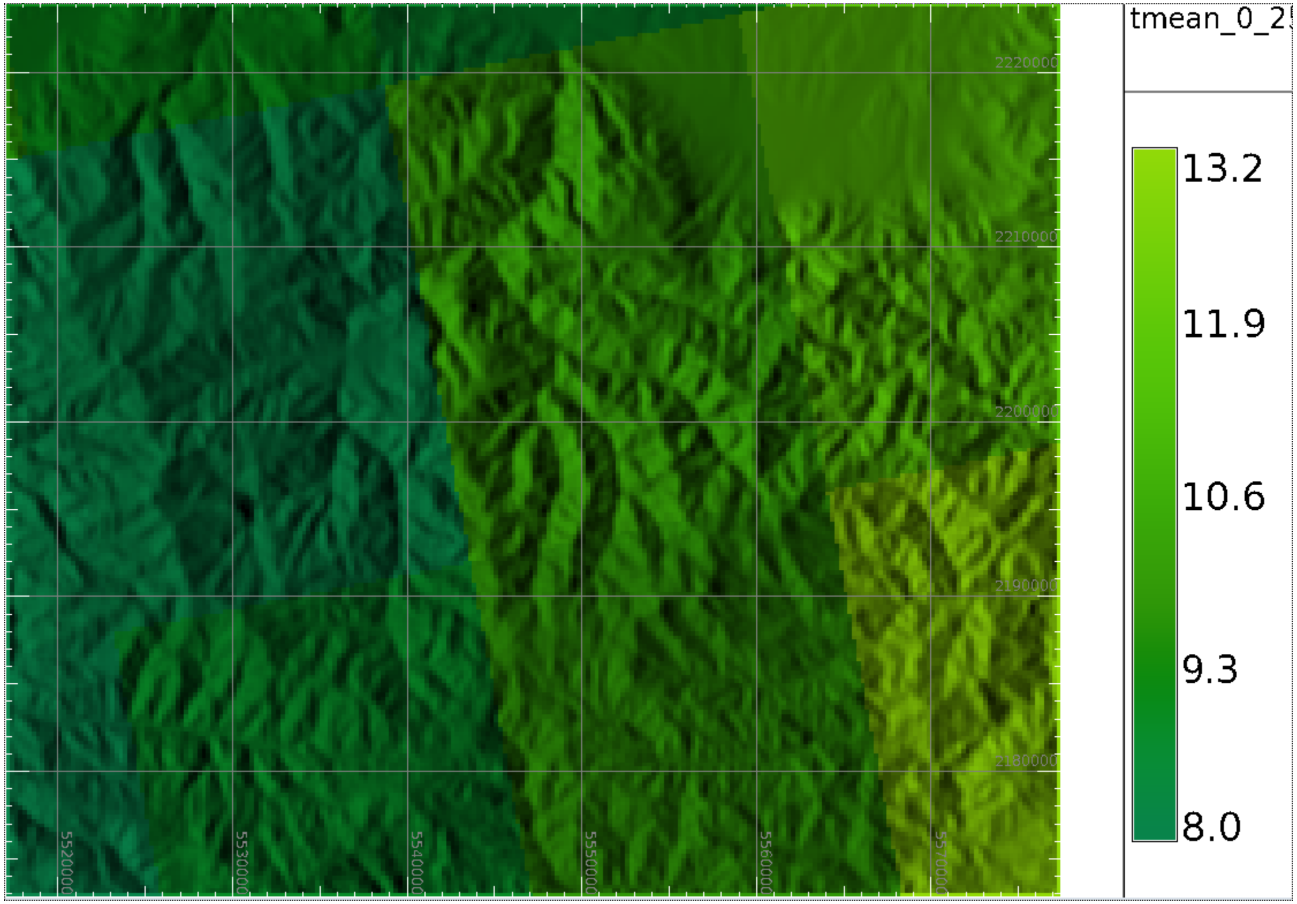
FEM meteo vs ECAD

ECAD Temperature data at regional scale

ECAD - European Climate Assessment & Dataset
(http://eca.knmi.nl)

Resolution: 0.25 arcsec, 1950-2011 daily

T_mean map: 1 Jan 2010, Turkey subregion



ECAD:

- *Advantages*:
  long time series, daily
- *Disadvantage*:
  Low resolution for mountainous areas

Alternative datasets:

- CRU (0.5°, 1901-2006, monthly)
- Worldclim (30 arcsec, 1950-2000, monthly)
- others

Klein Tank, A.M.G. and Coauthors, 2002. *Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment*. Int. J. of Climatol., 22, 1441-1453.

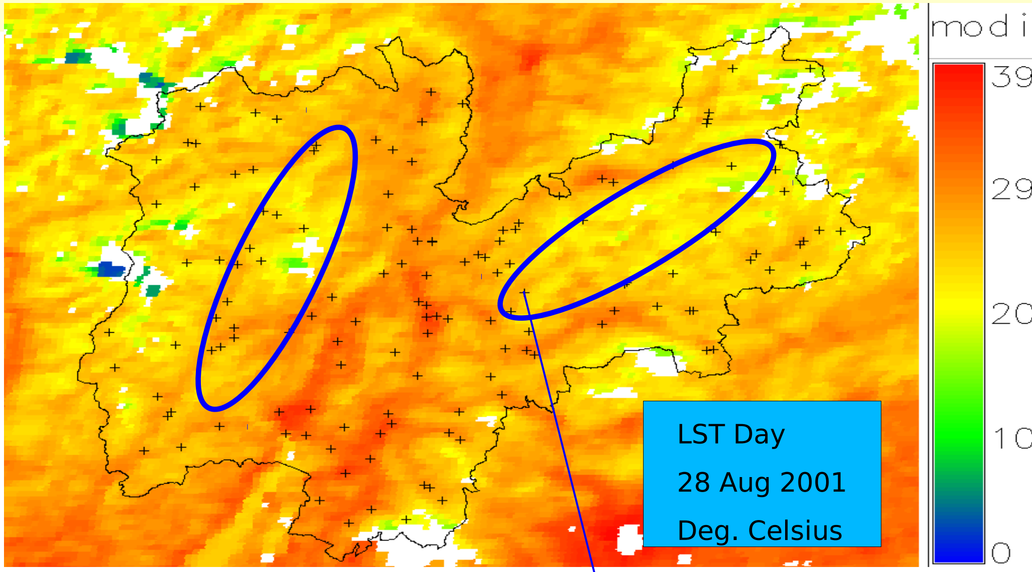
PGIS unit @ FEM, Trento

Batch processing of massive geodata

PGIS Linux cluster: 300 nodes, 34 TB raw space, GDAL + GRASS etc.

LAND SURFACE TEMPERATURE (LST)

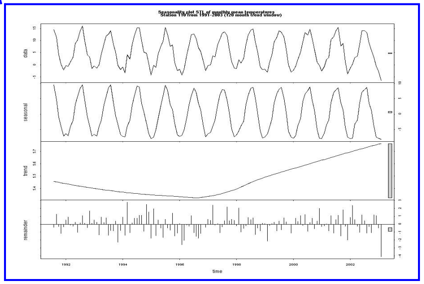
Data enhancements in complex Alpine terrain



+ Provincial meteo stations

Temperature trends

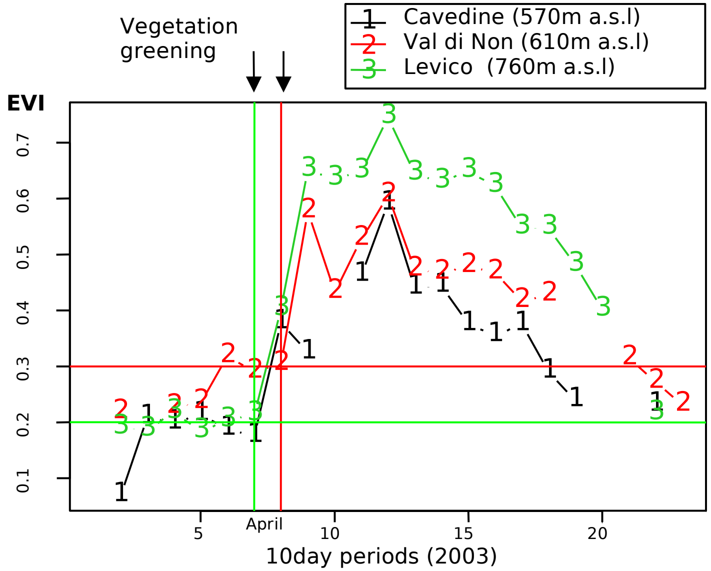
from meteo station

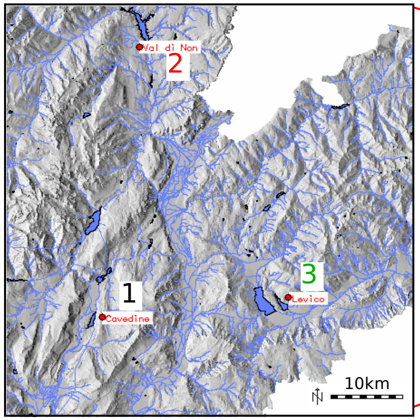


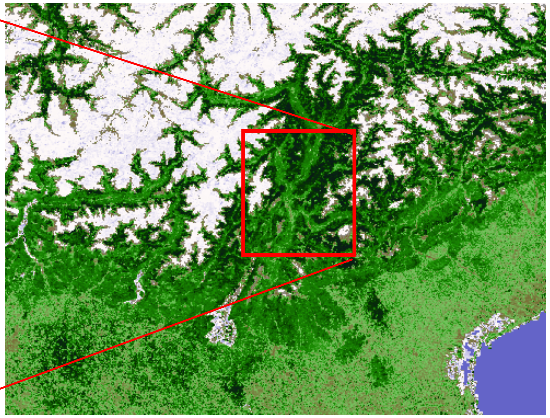
Enhanced Vegetation Index (EVI)

"Spring detection" example: Trentino 2003

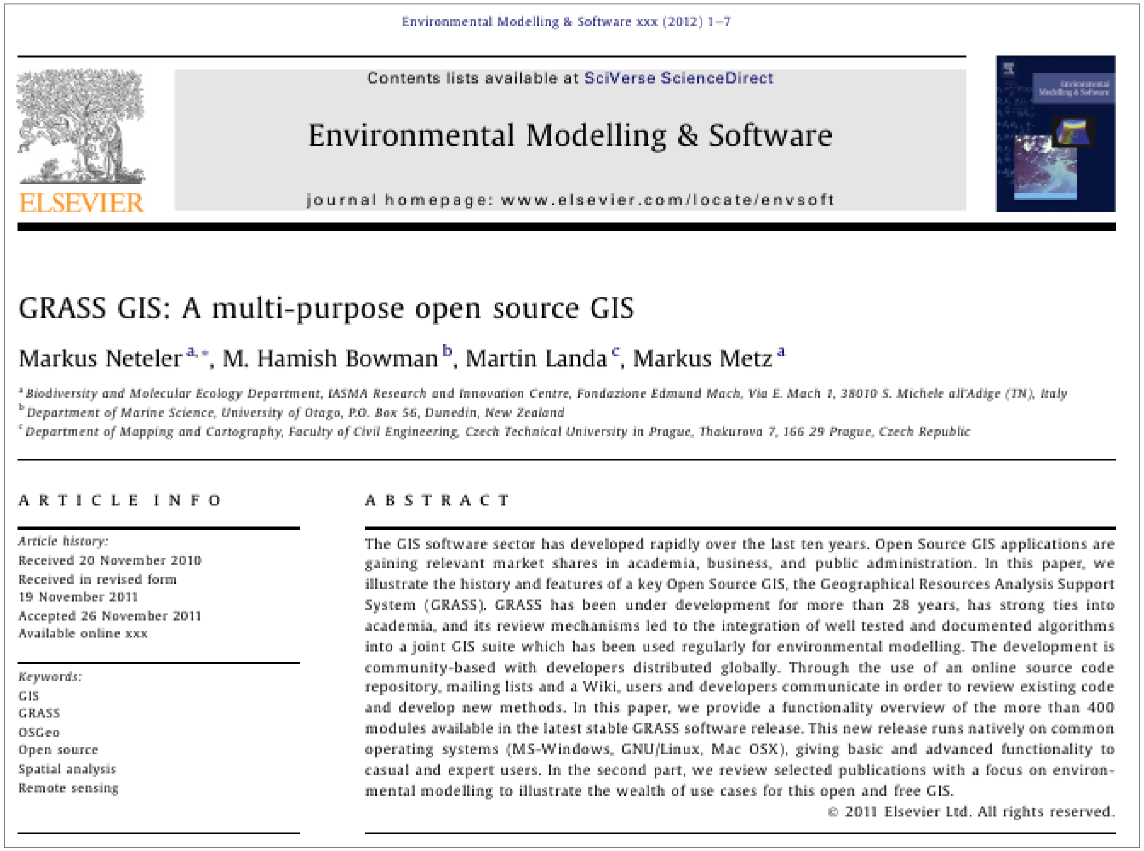
Effect of valley orientation and exposition







Desktop GIS & massive data analysis: GRASS GIS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ELSEVIER

GRASS GIS: A multi-purpose open source GIS

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ABSTRACT

The GIS software sector has developed rapidly over the last ten years. Open Source GIS applications are gaining relevant market shares in academia, business, and public administration. In this paper, we illustrate the history and features of a key Open Source GIS, the Geographical Resources Analysis Support System (GRASS). GRASS has been under development for more than 28 years, has strong ties into academia, and its review mechanisms led to the integration of well tested and documented algorithms into a joint GIS suite which has been used regularly for environmental modelling. The development is community-based with developers distributed globally. Through the use of an online source code repository, mailing lists and a Wiki, users and developers communicate in order to review existing code and develop new methods. In this paper, we provide a functionality overview of the more than 400 modules available in the latest stable GRASS software release. This new release runs natively on common operating systems (MS-Windows, GNU/Linux, Mac OSX), giving basic and advanced functionality to casual and expert users. In the second part, we review selected publications with a focus on environmental modelling to illustrate the wealth of use cases for this open and free GIS.

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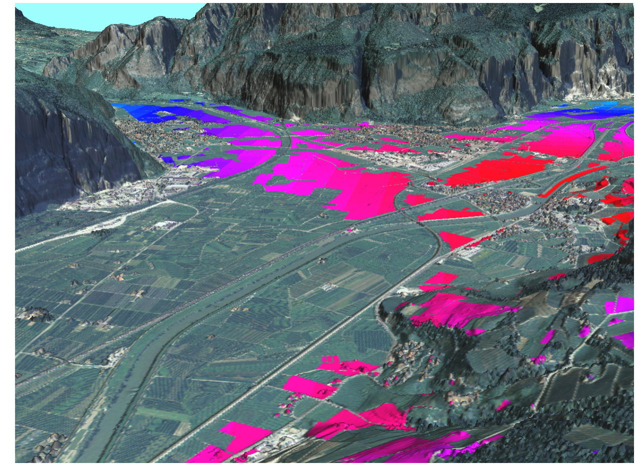
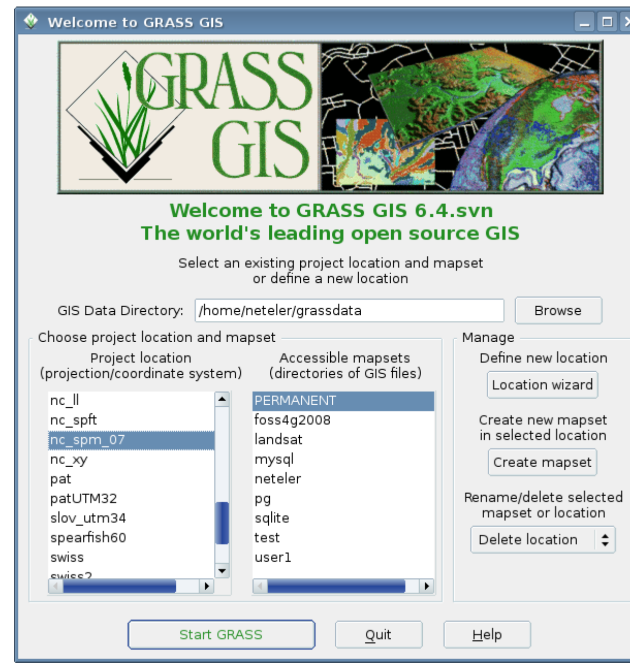
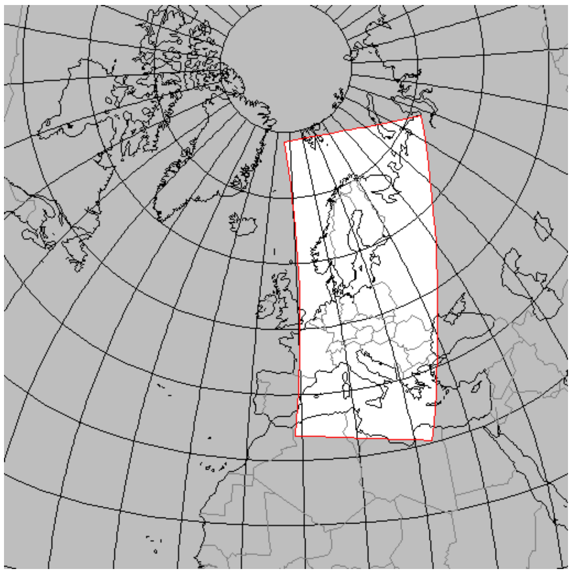


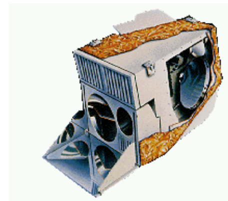


http://grass.osgeo.org
http://www.grassbook.org

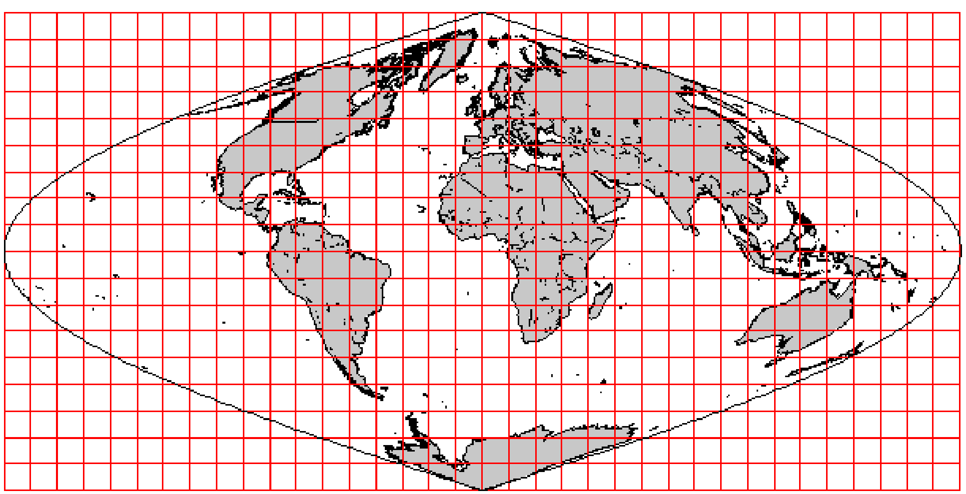
The MODIS Sensor: 11 years of data

The MODIS sensor on board of Terra and Aqua satellites





Typical MODIS overpass and data coverage (map tiles)



- Sensor with 36 channels in the range of optical light, near and thermal infrared: **Vegetation state, snow, temperature, fire detection ...**
- Delivers data at 250 m, 500 m and 1000 m pixel resolution
- LST error rate: < 1 K ± 0.7 K

MODIS/Terra satellite (EOS-AM):

- startet in Dec. 1999
- overpasses at circa 10:30 + 22:30 solar local time

MODIS/Aqua satellite (EOS-PM):

- startet in May 2002
- overpasses at circa 13:30 + 01:30 solar local time

→ **4 overpasses in 24h**

→ **data availability after ~72h**

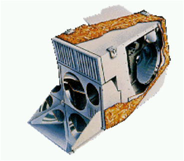
Ecological Indicators from satellite data: Temperature

Base product: Land surface temperature (LST)

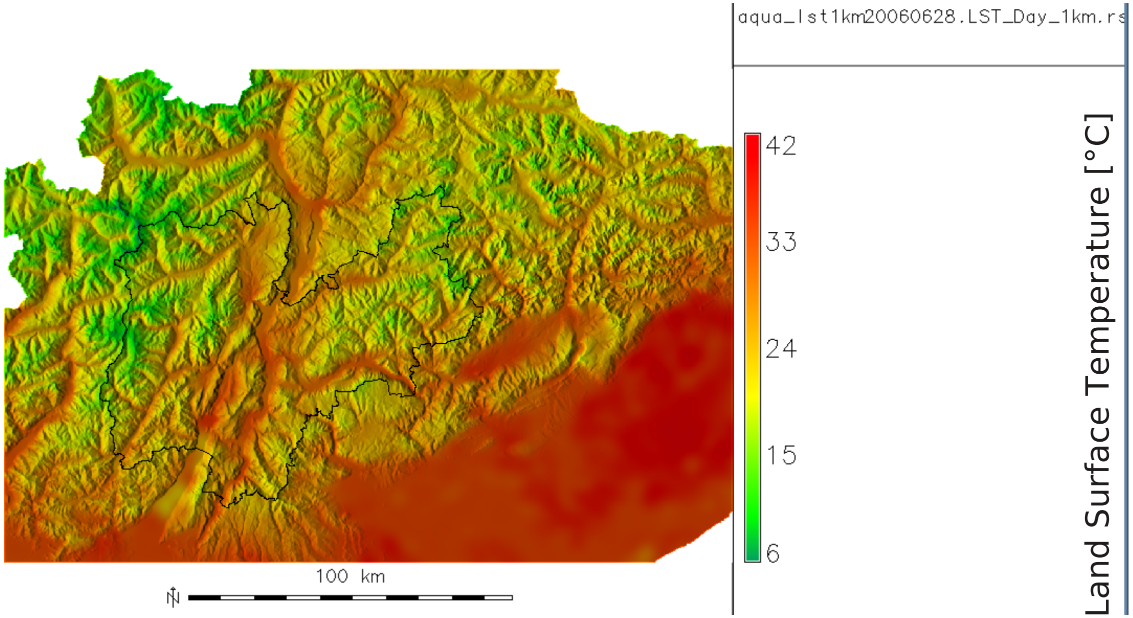
LST derived indices relevant for disease monitoring and risk modeling: (through time series analysis in GIS)

- **late frost periods**: relevant for masting of trees and seed production
- **growing degree days** (GDD) for phenological status

- **hot/cold summers** through mean temperature differences
- **autumnal temperature decrease, spring warming gradient**
- annual/monthly **temperature minima/maxima**



Trentino LST map
28 June 2006
from Aqua satellite
at ~13:30 local time
(Deg. Celsius)

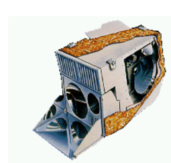


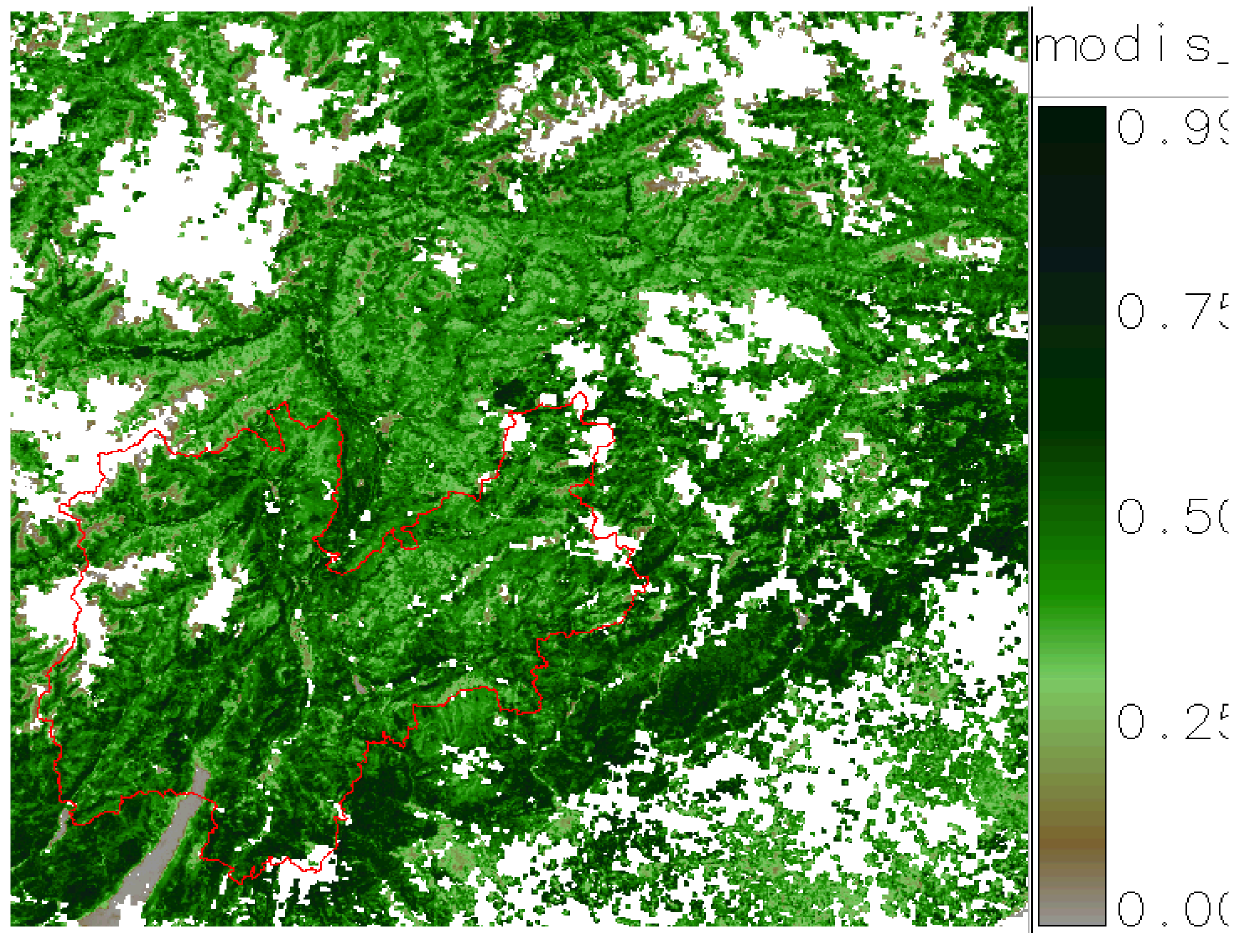
Ecological Indicators from satellite data: Phenology

Enhanced Vegetation Index (EVI)

EVI tends to perform better than Norm. Differences Veg. Index (NDVI):
- less prone to saturation
- less sensitive to haze

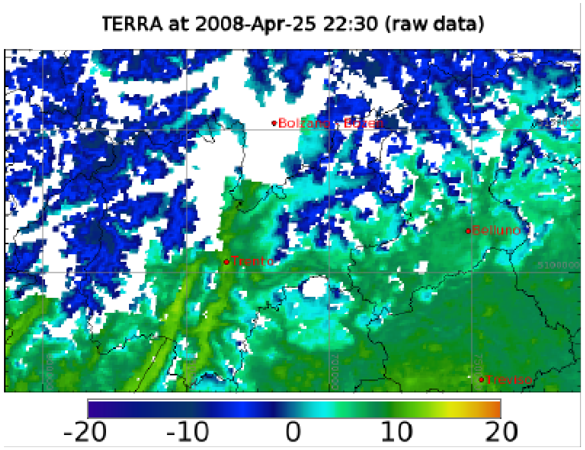
Derived indices:
- **seasonal differences** by simple pixel-wise map substraction
- in a localized way:
  - spring/autumn detection
  - length of growing season

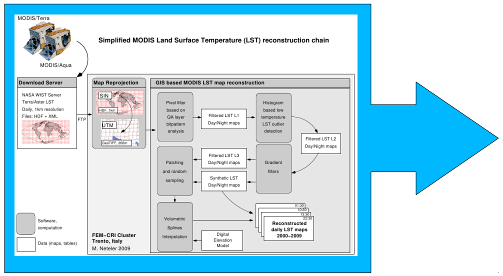


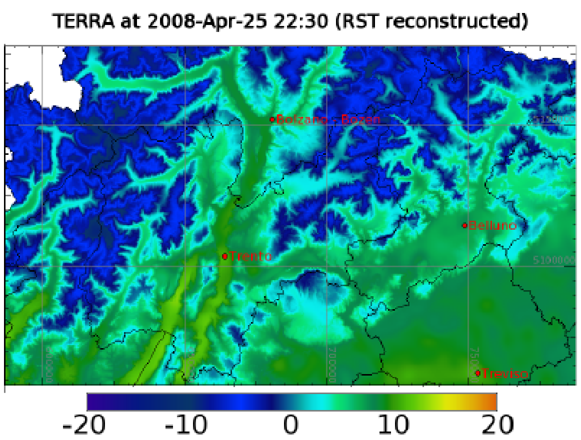


Satellite based land surface temperature (LST) map reconstruction: MODIS LST maps

Missing data due to clouds etc.



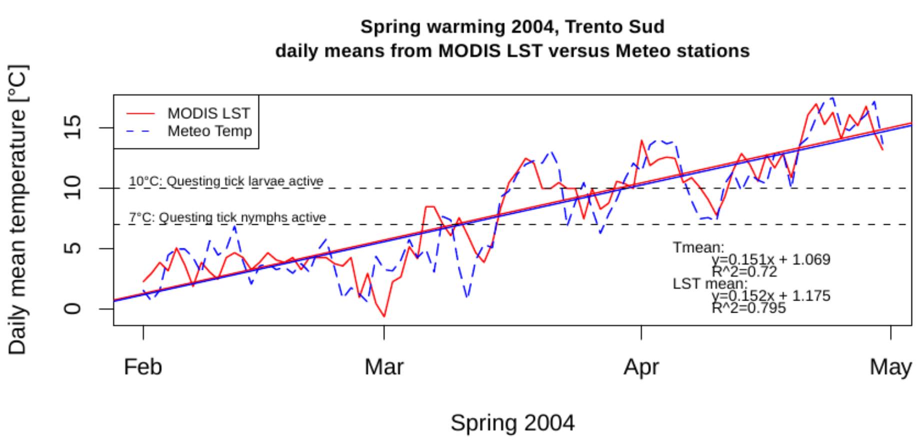


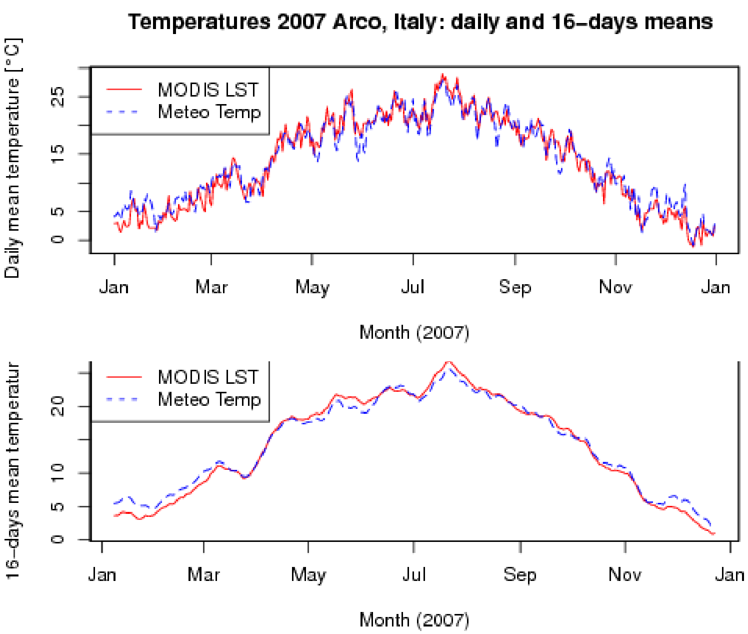


Available now: > **13000 LST maps (4/day)**

Examples for

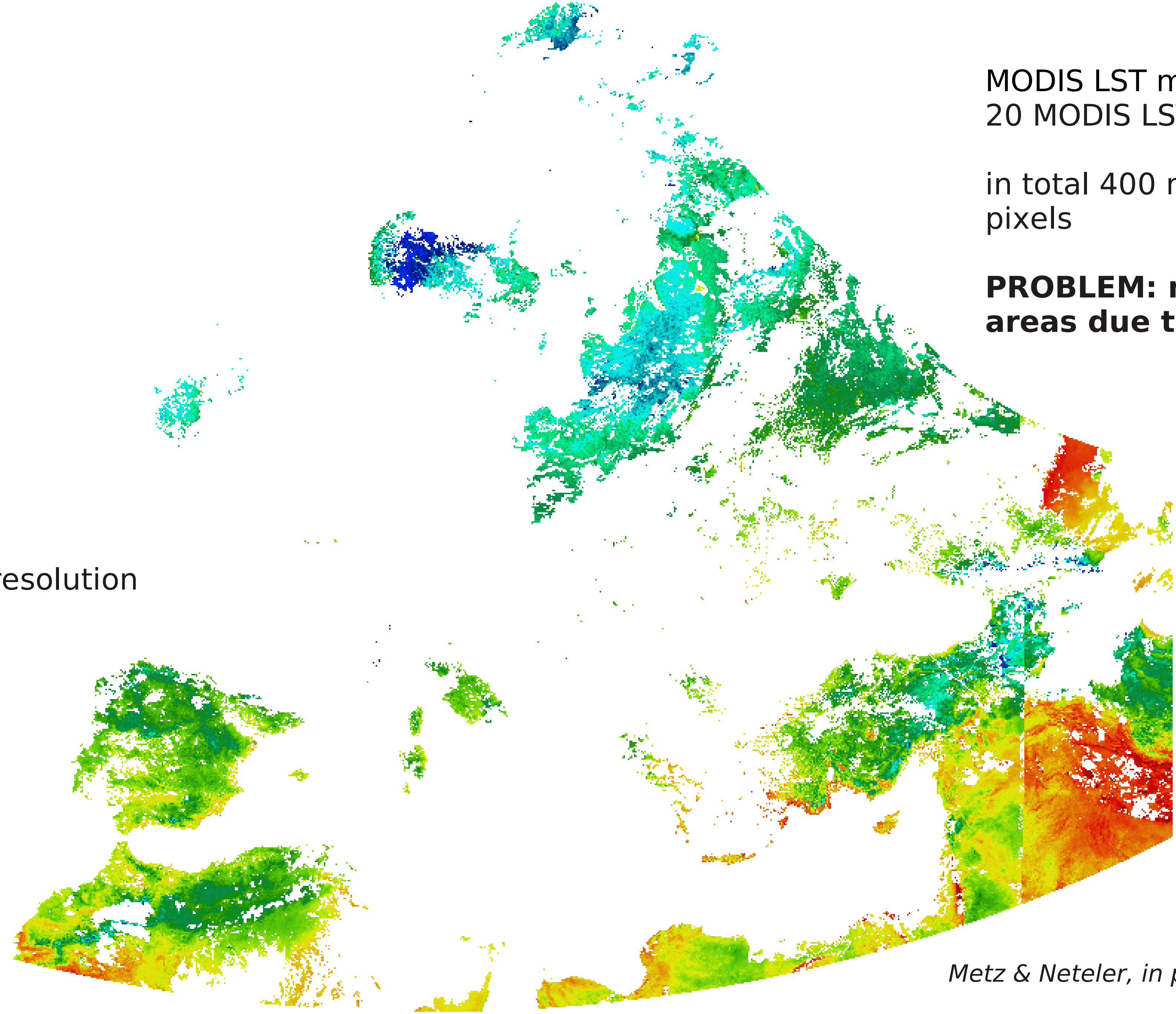
- Daily mean data
- 16-day period aggregated means
- Linear regression for trend analysis





Neteler, M., 2010: *Estimating daily Land Surface Temperatures in mountainous environments by reconstructed MODIS LST data*. Remote Sensing 2(1), 333-351 [PDF]

MODIS LST at European scale (filtered mosaic)



MODIS LST mosaic of 20 MODIS LST tiles,

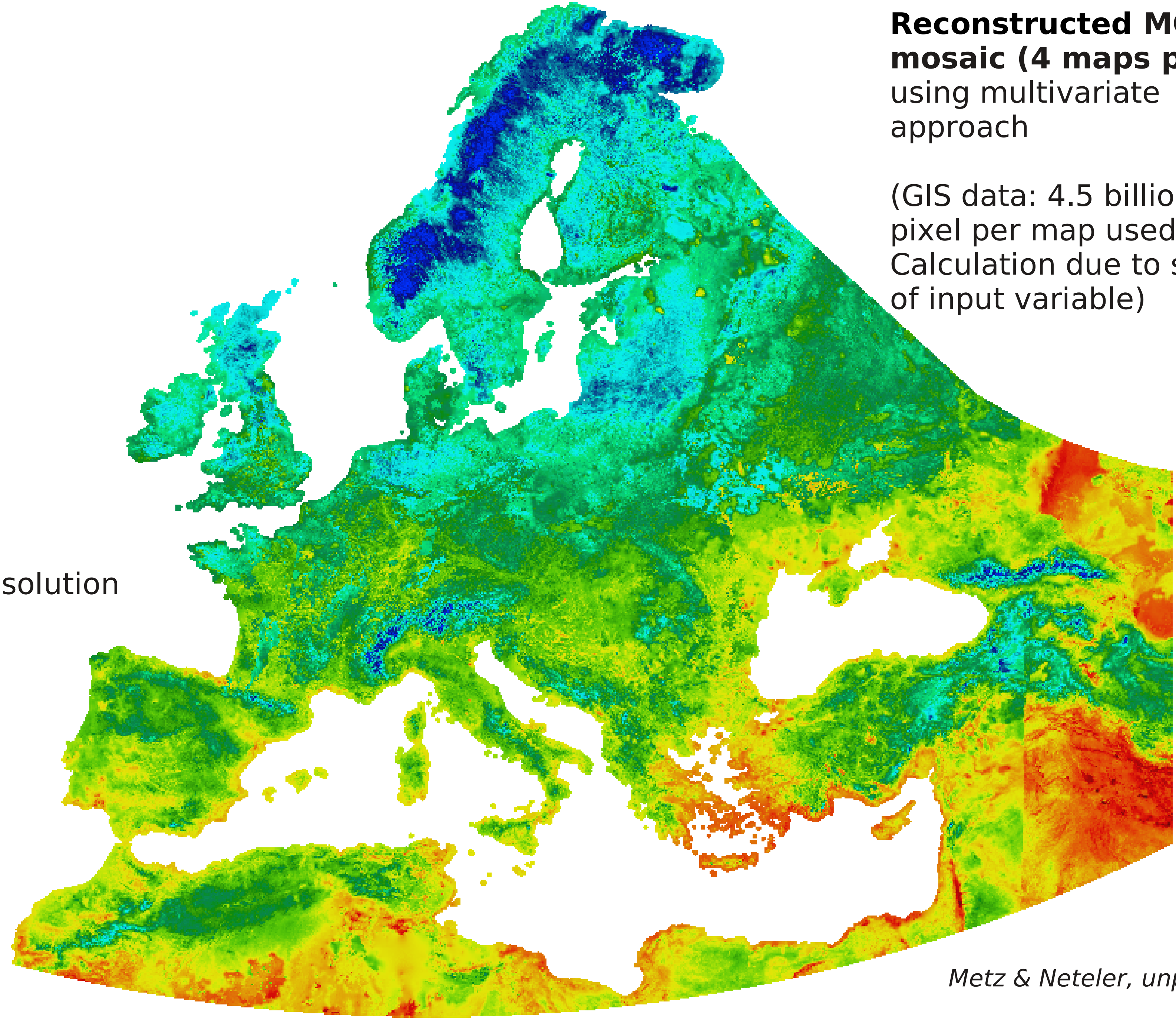
in total 400 million pixels

PROBLEM: no data areas due to clouds

1000m resolution

Metz & Neteler, in prep.

MODIS LST at European scale (reconstructed)



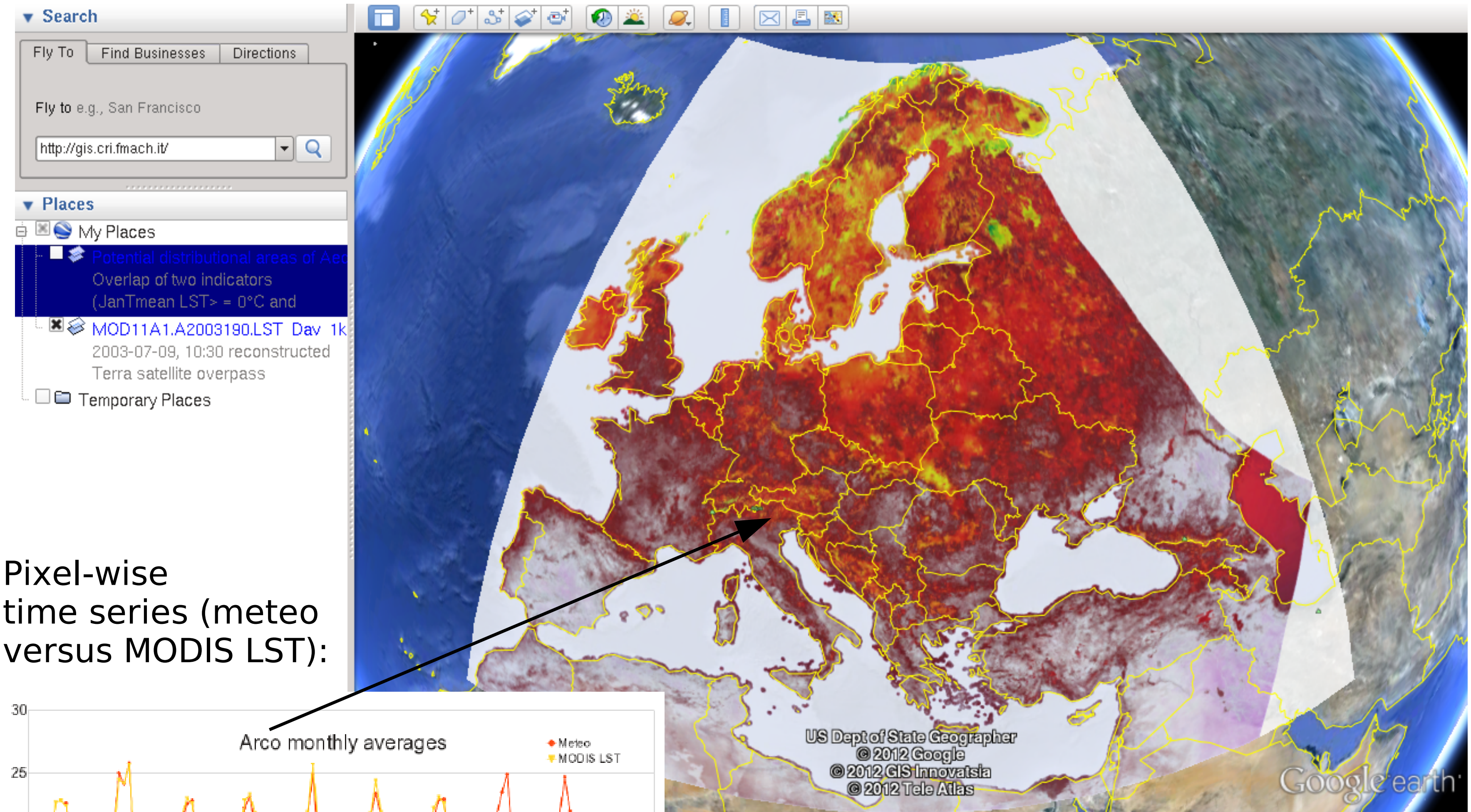
Reconstructed MODIS LST mosaic (4 maps per day) using multivariate approach

(GIS data: 4.5 billion pixel per map used in Calculation due to series of input variable)

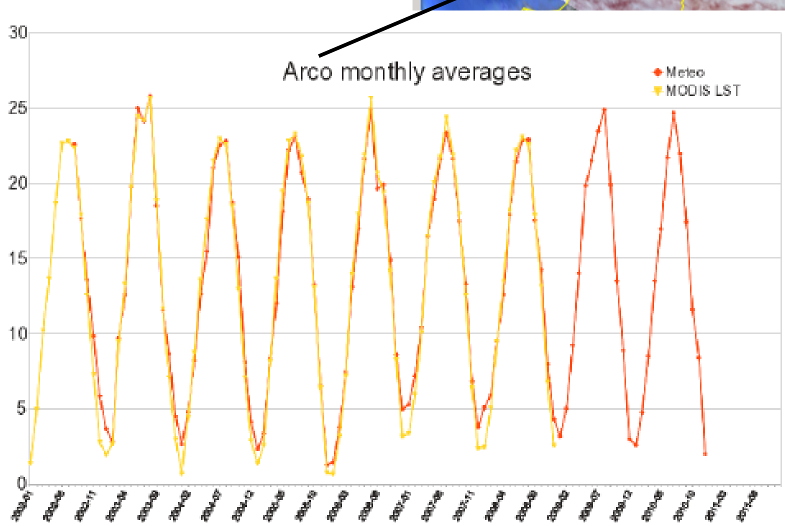
250m resolution

Metz & Neteler, unpublished

The new European daily MODIS LST time series



Pixel-wise
time series (meteo
versus MODIS LST):

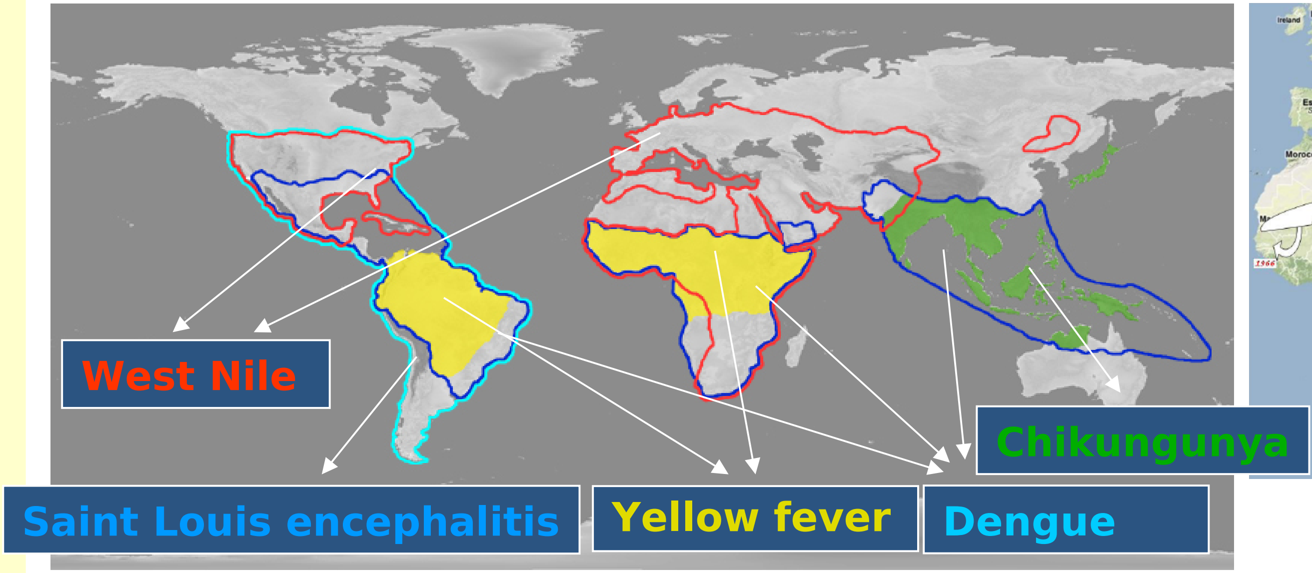


European
MODIS LST mosaic
reconstructed with
multivariate approach

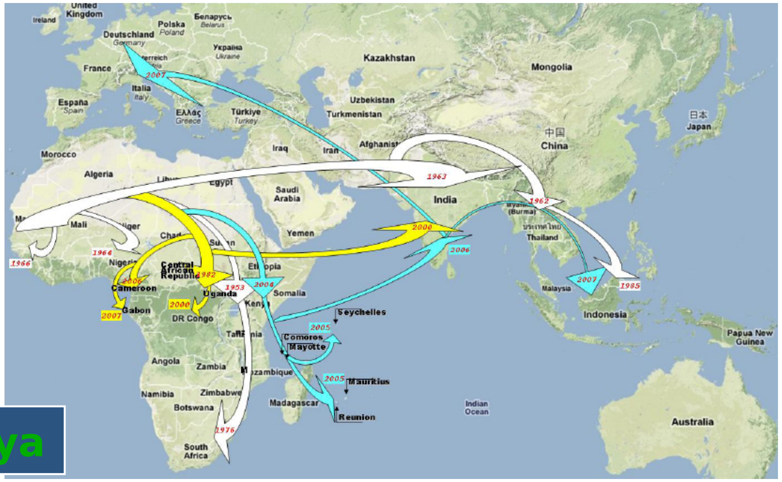
Metz & Neteler, in prep.

250m resolution
4 maps per **day**
data since 2000

Spread of the tiger mosquito (*Aedes albopictus*): infectious disease vector



Roiz 2009



De Llamballerie et al., 2008: Chikungunya

- Tiger mosquito: Disease vector
- Spreads in Europe and elsewhere
- Breeding and transport: In small containers, used tires and lucky bamboo plants
- >200 cases of Chikungunya in northern Italy in 2007 (CHIKv imported by India traveler and was then spread by *Ae. albopictus*)

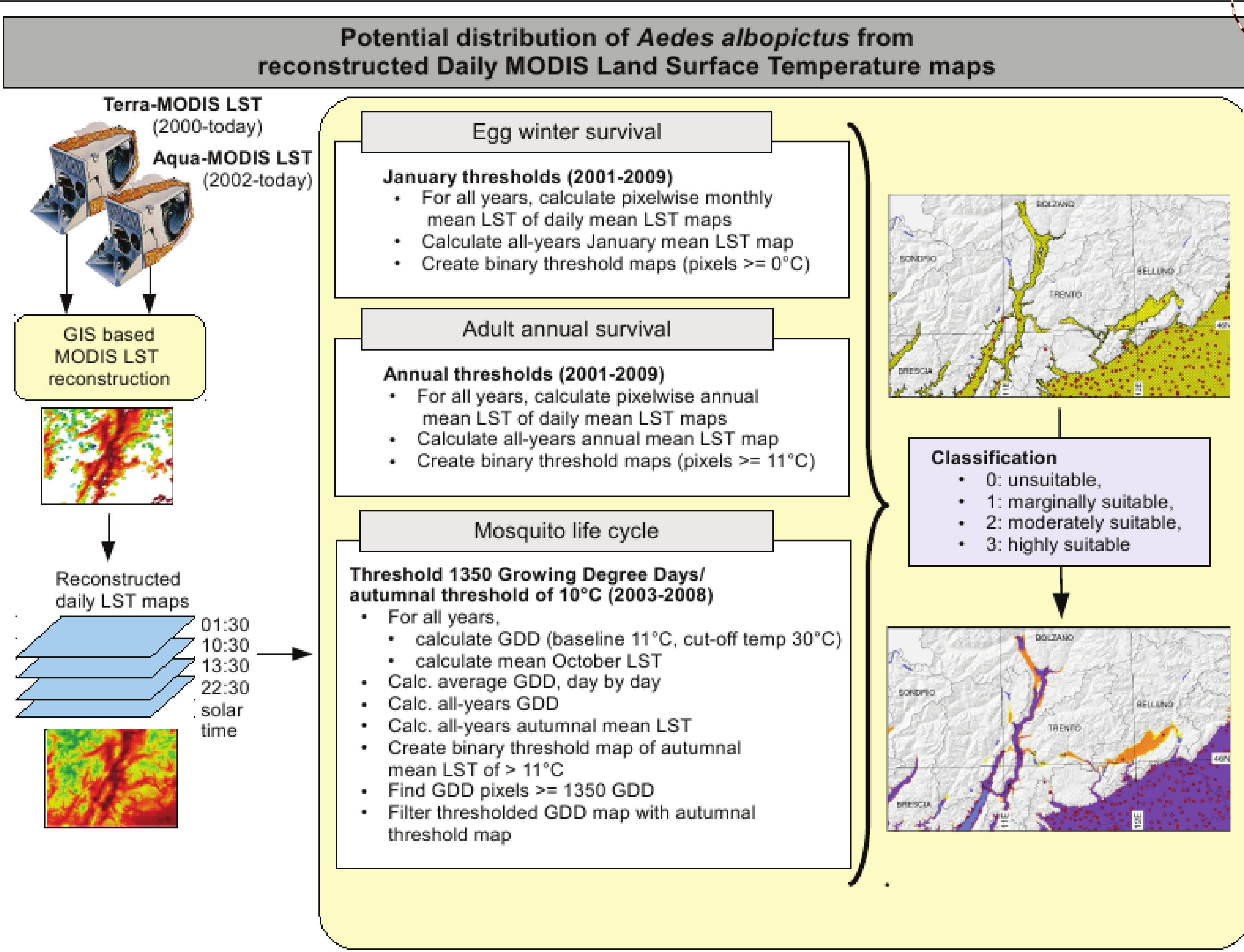
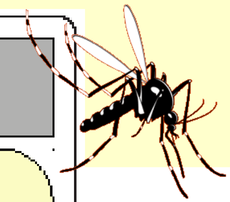
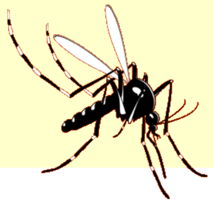


Figure 1 Workflow of aggregating MODIS LST into ecological indicators for the potential distribution of *Ae. albopictus*. The original daily MODIS LST data are reconstructed mapwise and then aggregated into three different ecological indicators used as proxies to predict the potential distribution of *Ae. albopictus*.



Neteler et al., 2011: Int J Health Geogr, 10:49, http://www.ij-healthgeographics.com/content/10/1/49
*Roiz, D., Neteler, M., et al., 2011: Climatic factors ... tiger mosquito. **Plos ONE**, 6(4): e14800*

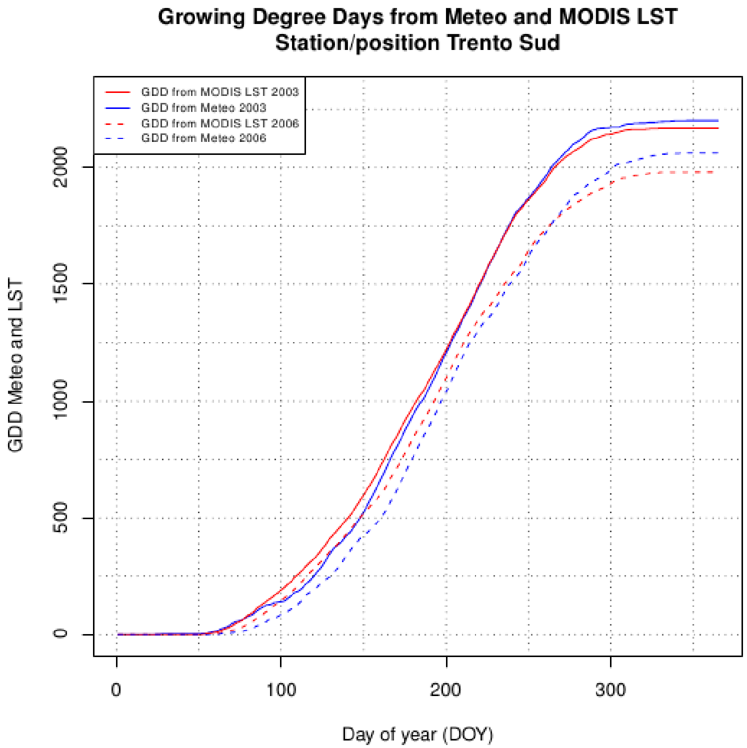
Life-cycle: MODIS LST and GDD

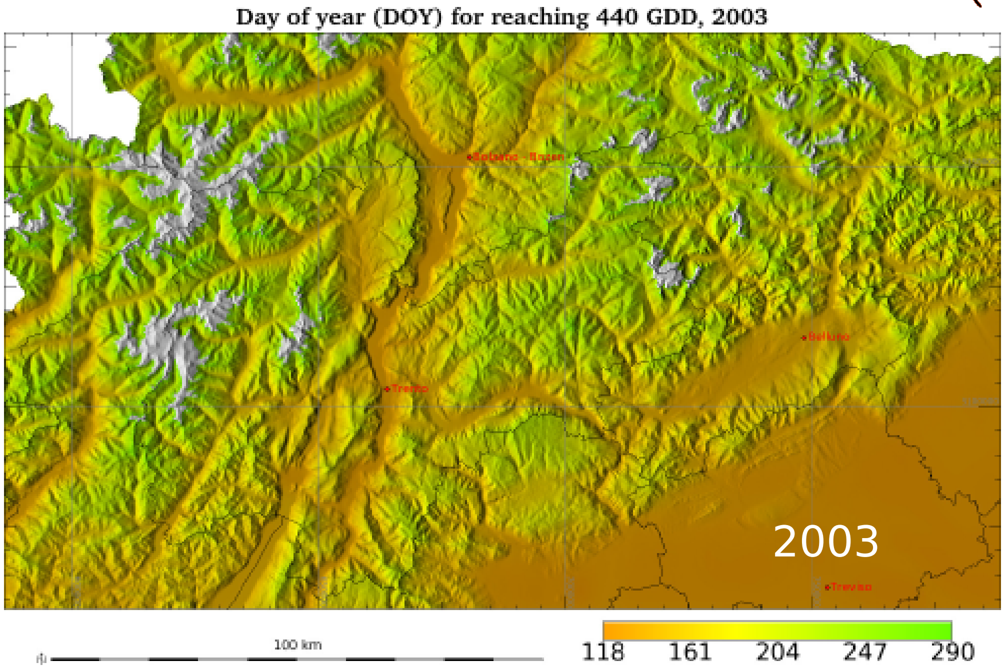


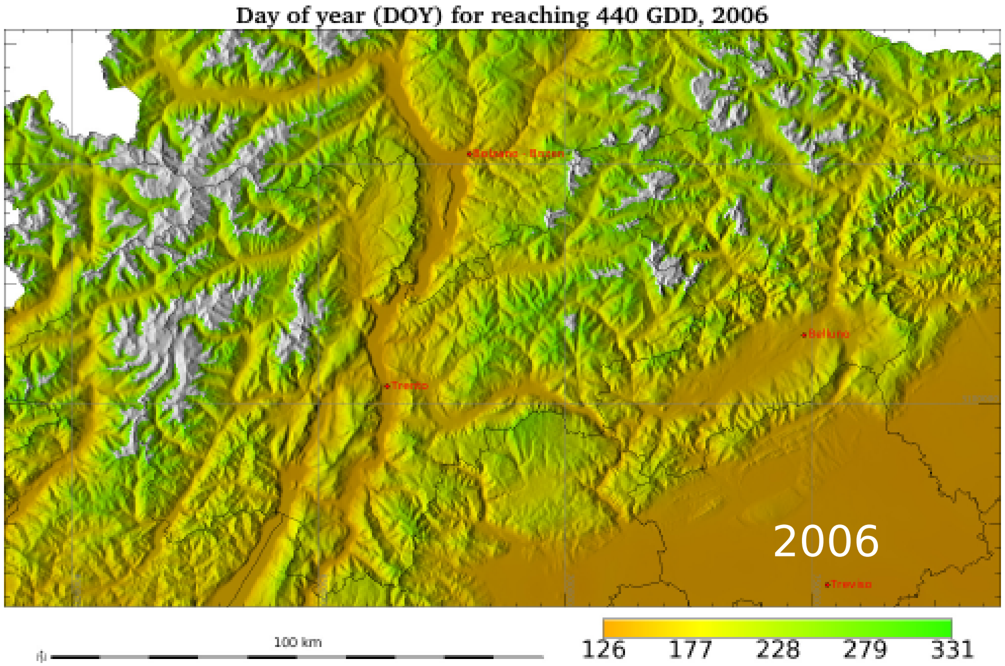
Growing Degree Days
(used for plant or insect growth assessment)

Number of Day-Of-Year (**DOY**) to reach **440** accumulated growing degree days (GDD) in the years 2003 and 2006:

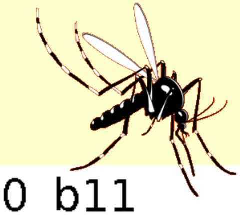
- proxy for life-stage survival analysis of insect
- satellite-derived GDD are delivered as map

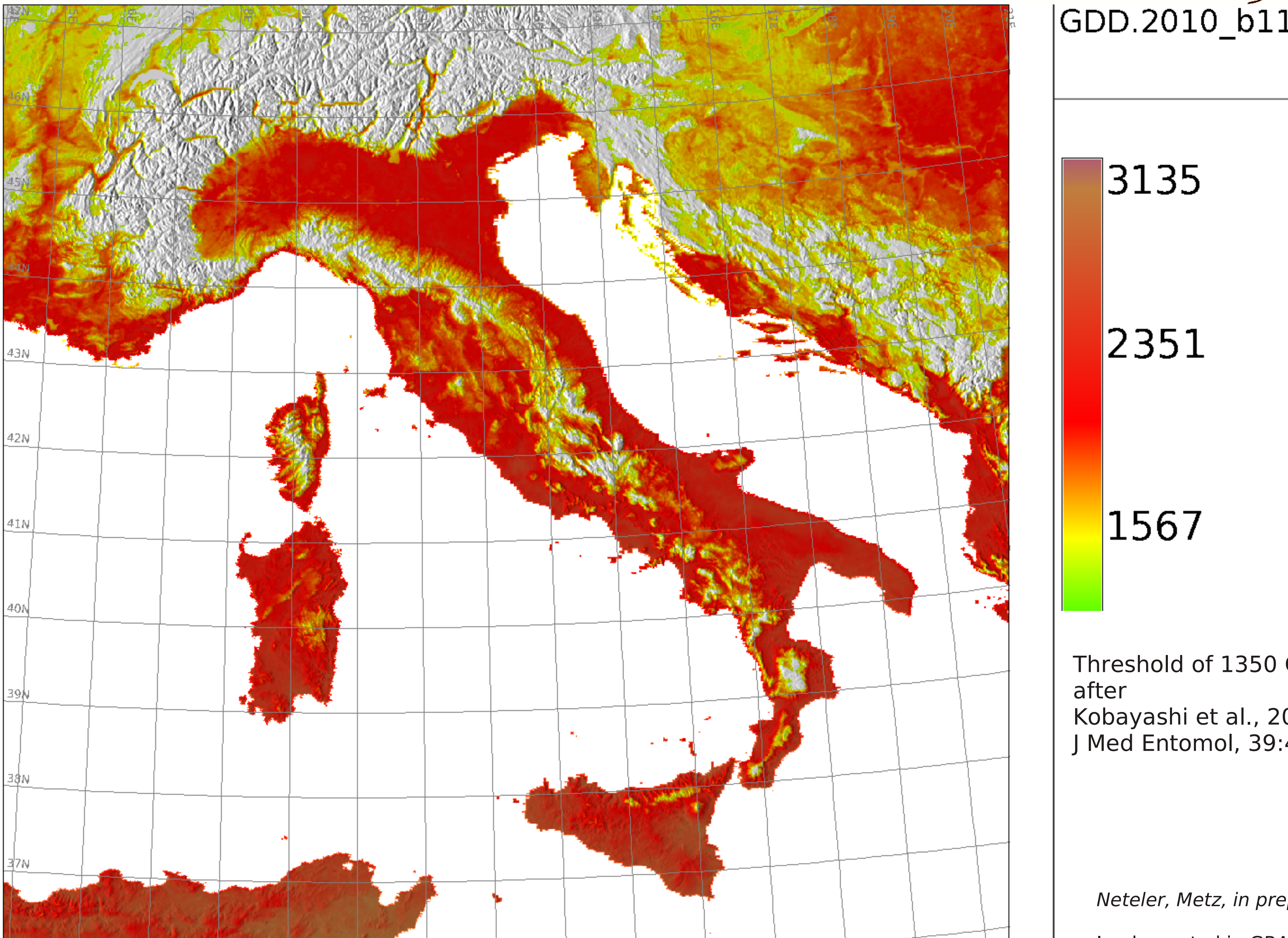






Threshold map >1350 GDD from MODIS LST





Threshold of 1350 GDD after
Kobayashi et al., 2002.
J Med Entomol, 39:4-11.

Neteler, Metz, in prep.

Implemented in GRASS GIS

Winter survival from MODIS LST
Microhabitat distinction

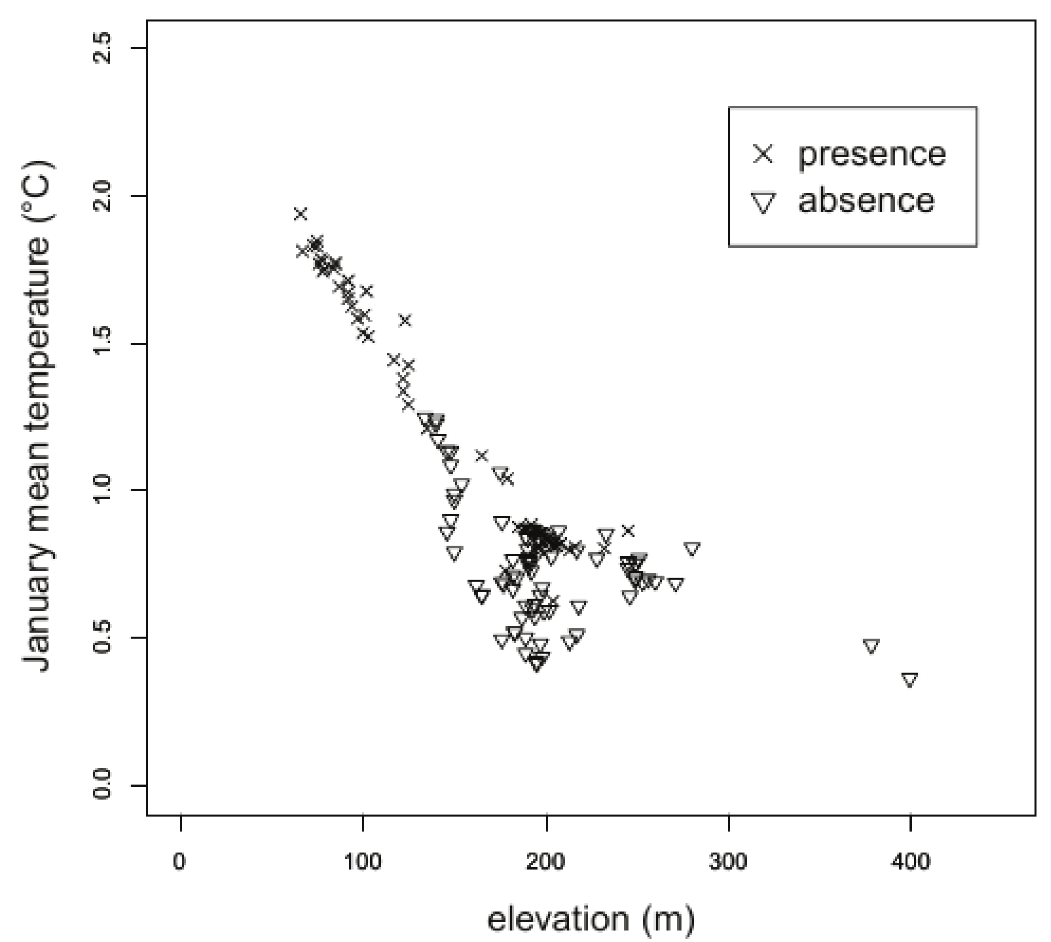
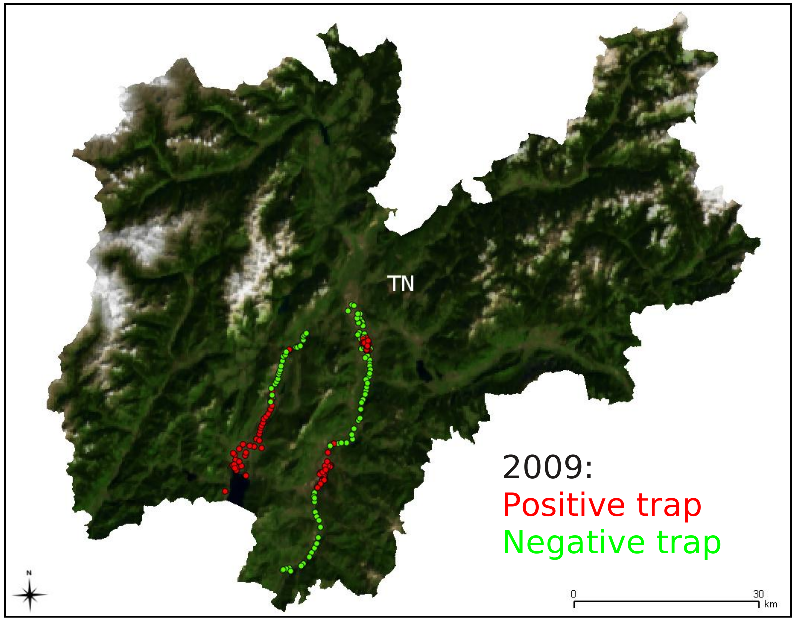


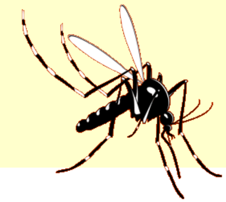
Figure 7 Relationship between the altitude, JanT^{mean} and the current distribution of *Ae. albopictus*. The absence/presence data and elevations were obtained from traps. The complete data set for this figure is included with the manuscript as additional file 1.



Microhabitat detection from MODIS LST (not possible with ECAD and not easily with interpolated meteorological data)

Neteler et al., 2011: Int J Health Geogr, 10:49, http://www.ij-healthgeographics.com/content/10/1/49

Current and potential distribution *Ae. alb.*



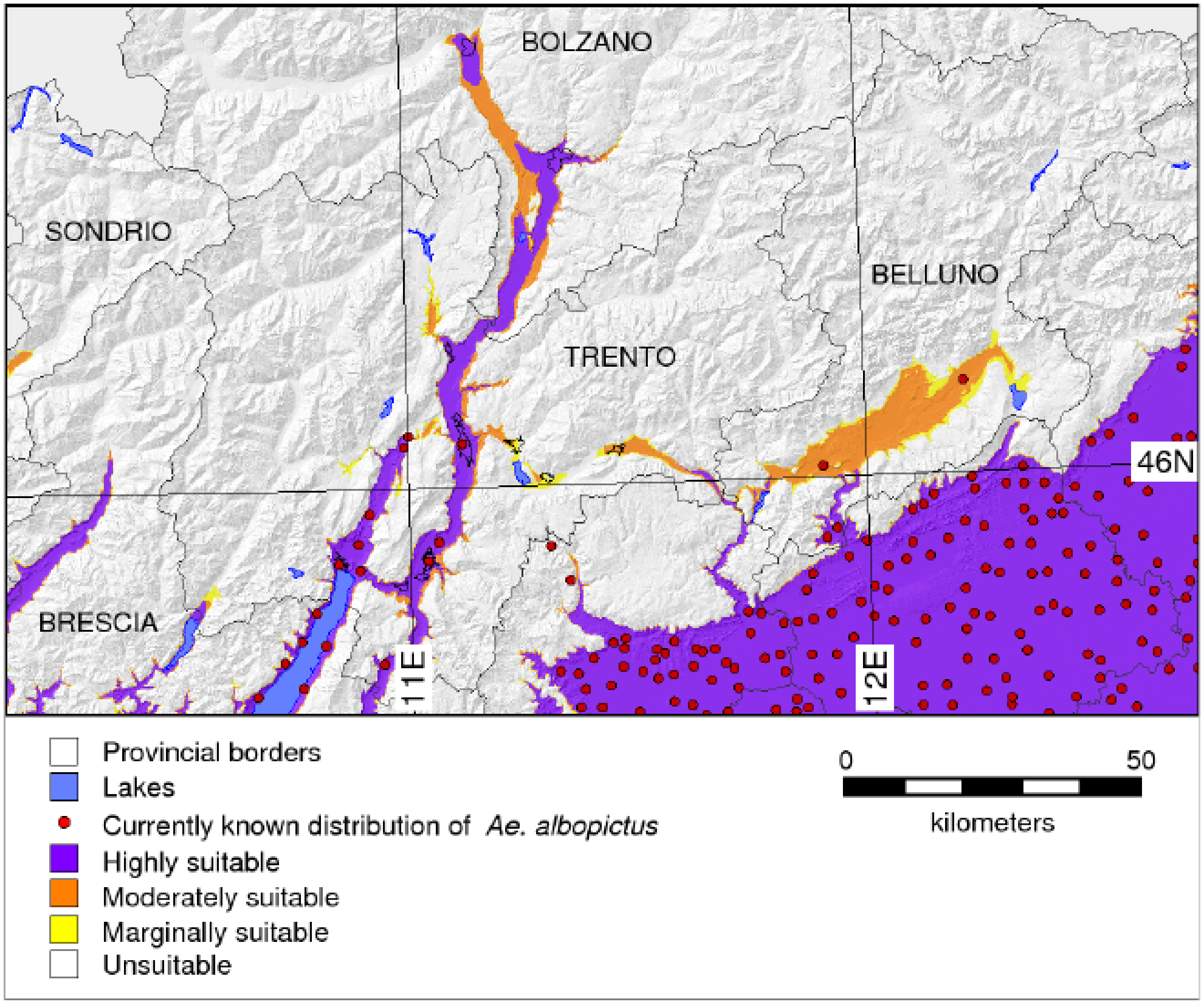
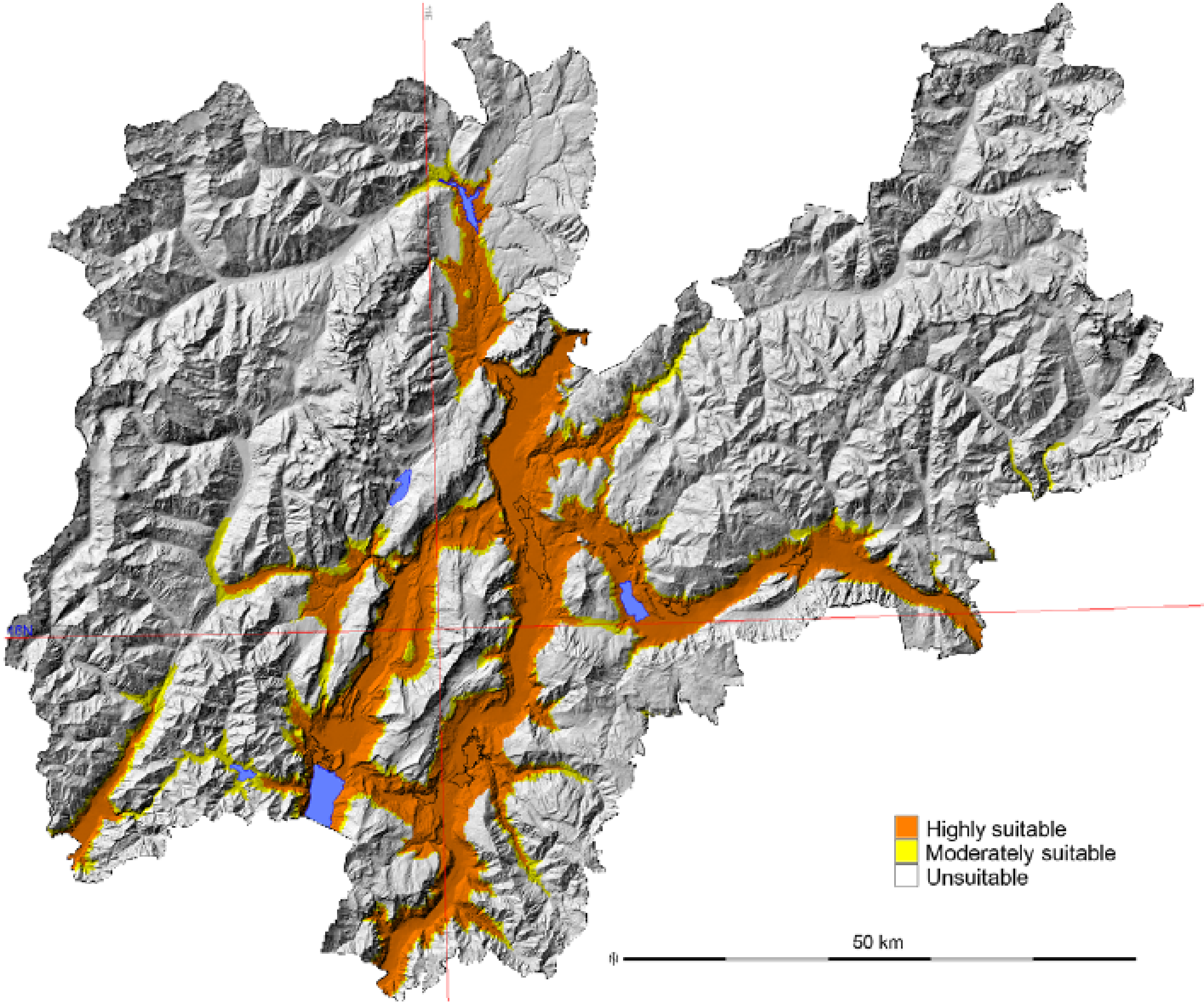


Figure 3 Habitat suitability map of *Ae. albopictus* in north-eastern Italy. The map is based on classified summary of egg winter survival, annual adult survival, and the areas of successful life cycle completion (see also explanations for Figure 2).

Neteler et al., 2011

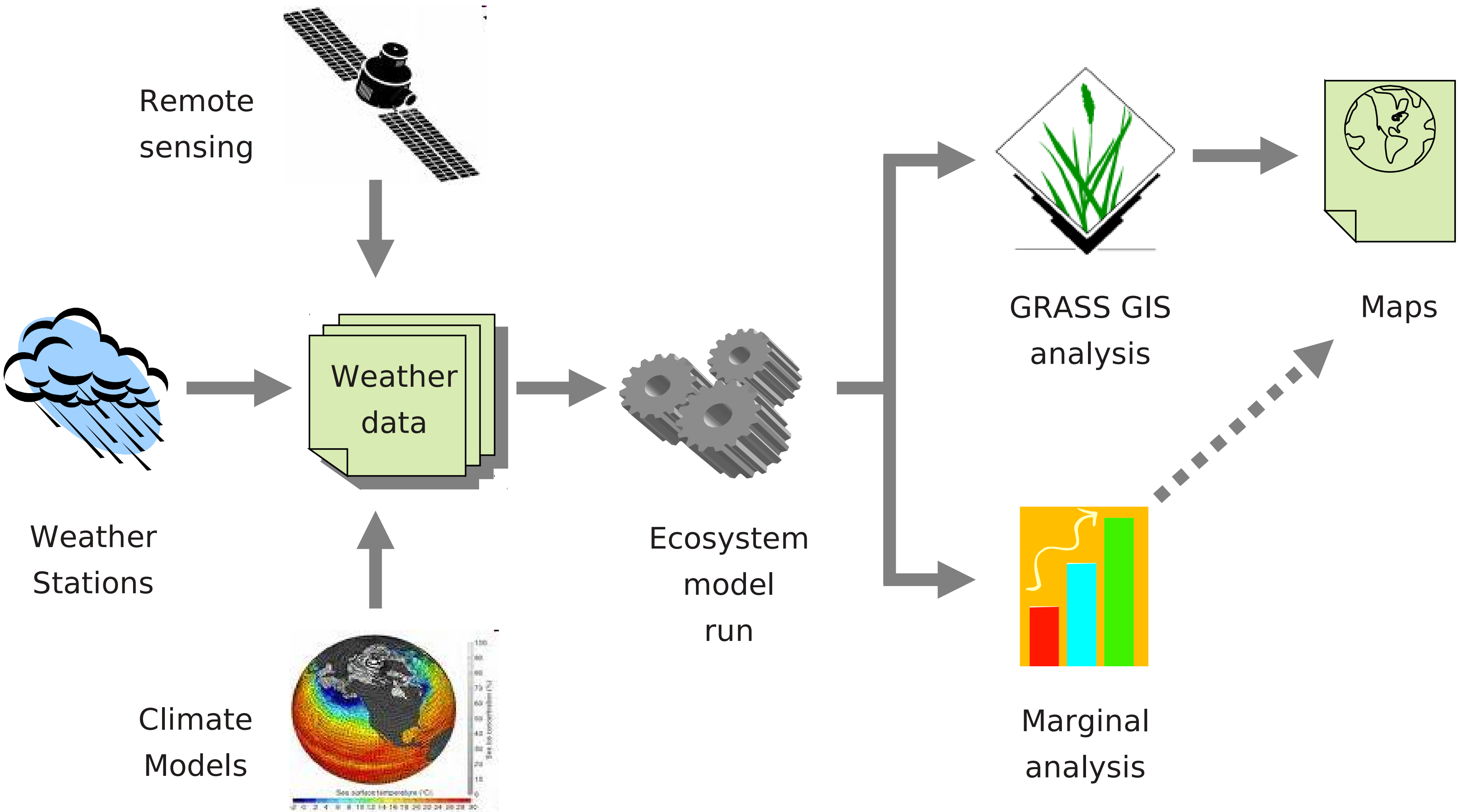
Future distribution *Ae. alb.*: 2050 Scenario A2



Potential distribution of *Ae. albopictus* in an A2 scenario for 2050 (IPCC, Eccel et al., 2011, Cafarra et al., 2010). Overlap of both indicators (January mean LST +1,5 °C and Annual mean LST +1 °C) were plotted for the study period and integrated in a final map with 3 categories. (Roiz et al., 2011)

Ecosystem analysis uses site-specific weather, GIS maps and marginal analysis

By Luigi Ponti, ENEA, Italy

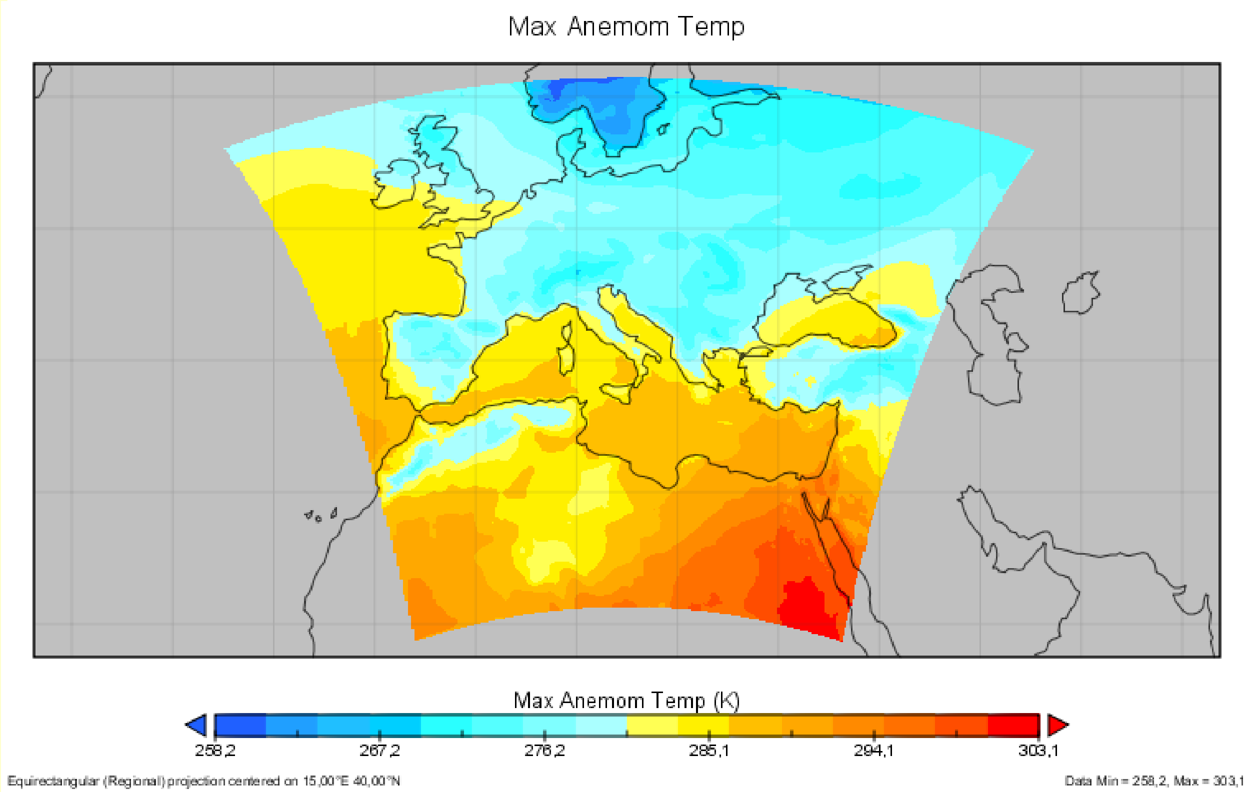


Gutierrez et al. 2010

The GlobalChangeBiology project
Climate change & Mediterranean agroecosystems
http://sites.google.com/site/globalchangebiology/

Analysis of Mediterranean olive systems using the PROTHEUS present climate data

By Luigi Ponti, ENEA, Italy



ERA-40 reanalysis climate data for 1958-2000

↓

PROTHEUS: Regional climate model RegCM3 coupled to MIT ocean model

↓

Down-scaling of climate data for the Mediterranean region

Artale et al. 2010

The GlobalChangeBiology project
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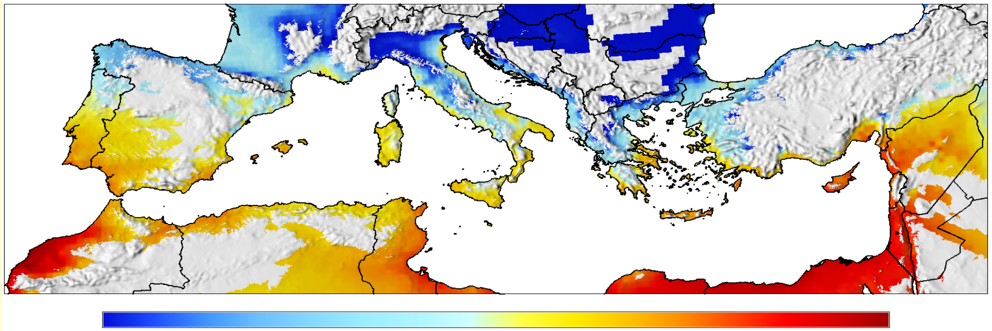
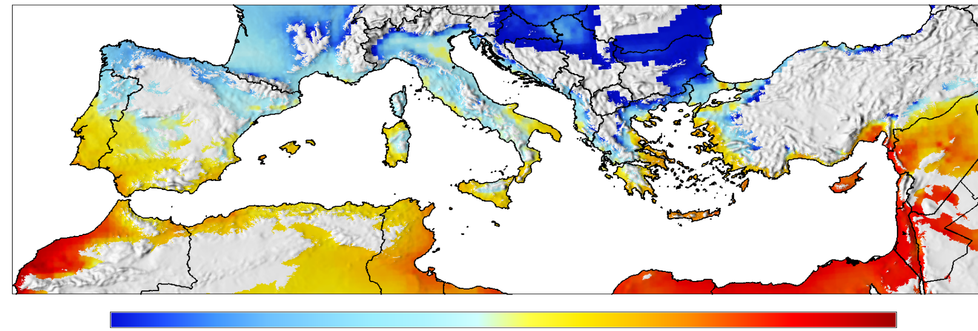
Multitrophic interactions of olive and olive fly mapped across the Mediterranean

By Luigi Ponti, ENEA, Italy

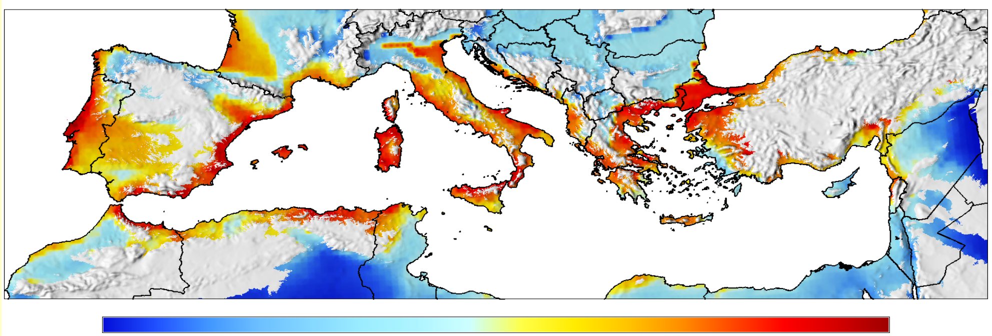
Average olive yield (kg), 1958-1967



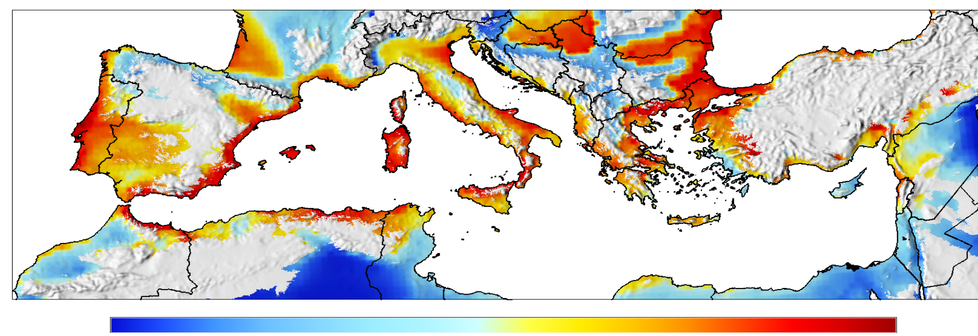
Average olive yield (kg), 1988-1997



% fruit attacked by olive fly, 1958-1967



% fruit attacked by olive fly, 1988-1997



Ponti et al. 2009

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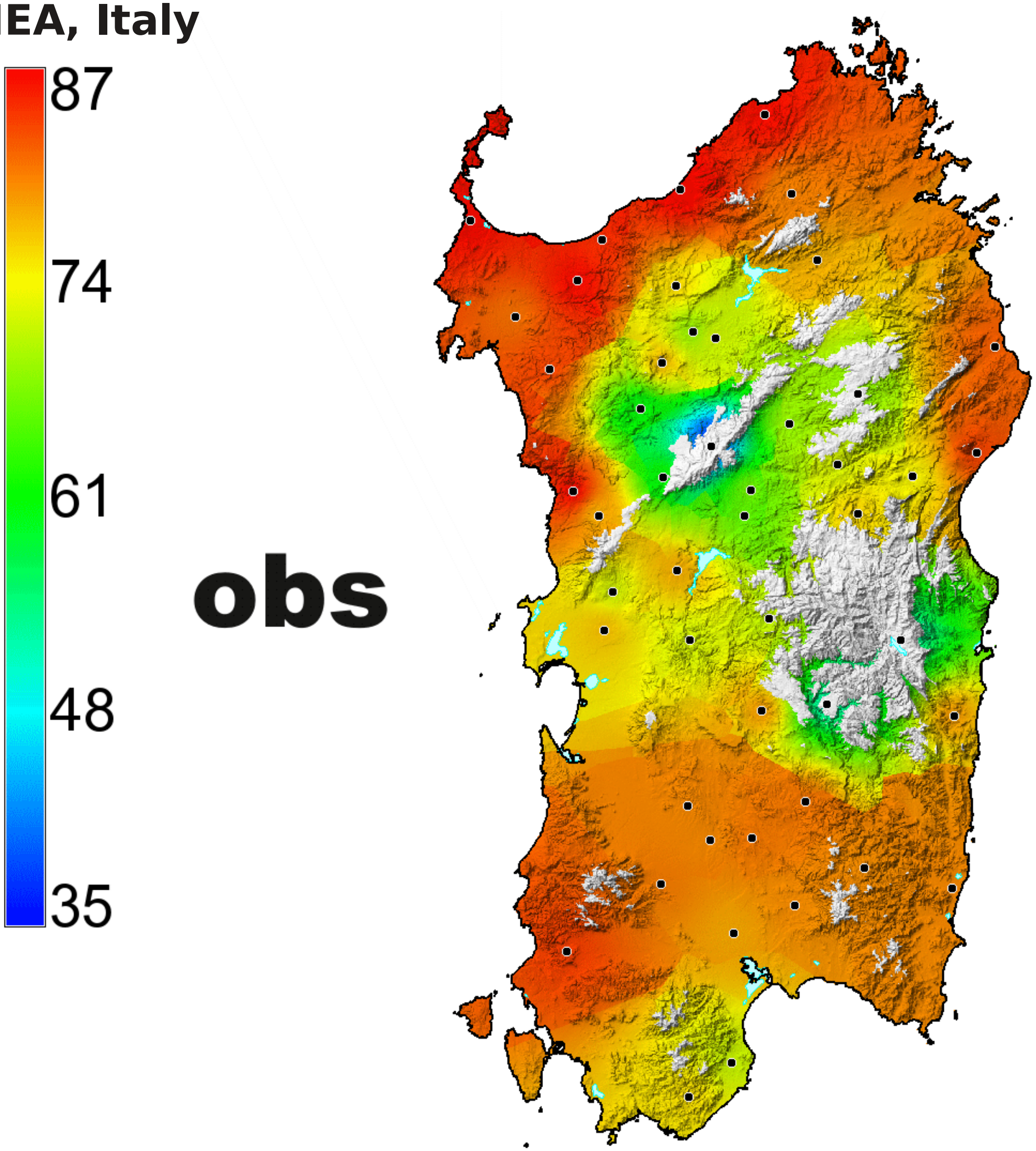
http://sites.google.com/site/globalchangebiology/

Olive fly infestation % in Sardinia under climate warming

By Luigi Ponti, ENEA, Italy



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http://sites.google.com/site/globalchangebiology/

Ponti et al. 2009

Conclusions

- **Emerging diseases** need to be considered among the “emerging themes” to be covered by integrated research strategies because of their dramatic impact on well being and economy
- **Current and potential distribution of disease vectors** (like *Ae. Albopictus*) can be modelled at high resolution
- **Reconstructed daily MODIS LST** data provide high accuracy with temporally 4 map per day and spatially 250 m x 250 m pixel resolution
- **Almost unlimited possibilities** with GRASS and other FOSS4G software thanks to rich interfaces
- User levels: **from newcomers to power users**
- **Software Quality: peer reviewed code**, often with academic background

PGIS unit: remote sensing and diseases/vectors

Neteler *et al. International Journal of Health Geographics* 2011, **10**:49
http://www.ij-healthgeographics.com/content/10/1/49

INTERNATIONAL JOURNAL OF HEALTH GEOGRAPHICS

RESEARCH Open Access

Terra and Aqua satellites track tiger mosquito invasion: modelling the potential distribution of *Aedes albopictus* in north-eastern Italy

Markus Neteler[1*†], David Roiz[2†], Duccio Rocchini[1], Cristina Castellani[1] and Annapaola Rizzoli[1]

Abstract

Background: The continuing spread of the Asian tiger mosquito *Aedes albopictus* in Europe is of increasing public health concern due to the potential risk of new outbreaks of exotic vector-borne diseases that this species can transmit as competent vector. We predicted the most favorable areas for a short term invasion of *Ae. albopictus* in north-eastern Italy using reconstructed daily satellite data time series (MODIS Land Surface Temperature maps, LST). We reconstructed

Remote Sens. **2010**, *2*, 333-351; doi:10.3390/rs1020333

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Article

Estimating Daily Land Surface Temperatures in Mountainous Environments by Reconstructed MODIS LST Data

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Climatic Factors Driving Invasion of the Tiger Mosquito (*Aedes albopictus*) into New Areas of Trentino, Northern Italy

David Roiz[1,2*¶], Markus Neteler[1¶], Cristina Castellani[1], Daniele Arnoldi[1], Annapaola Rizzoli[1]

1 Department of Biodiversity and Molecular Ecology, Fondazione Edmund Mach, Research and Innovation Centre, S. Michele all' Adige, Italy, 2 Wetland Ecology Department, Doñana Biological Station (CSIC), Seville, Spain

Abstract

Background: The tiger mosquito (*Aedes albopictus*), vector of several emerging diseases, is expanding into more northerly latitudes as well as into higher altitudes in northern Italy. Changes in the pattern of distribution of the tiger mosquito may affect the potential spread of infectious diseases transmitted by this species in Europe. Therefore, predicting suitable areas of future establishment and spread is essential for planning early prevention and control strategies.

Methodology/Principal Findings: To identify the areas currently most suitable for the occurrence of the tiger mosquito in the Province of Trento, we combined field entomological observations with analyses of satellite temperature data (MODIS Land Surface Temperature: LST) and human population data. We determine threshold conditions for the survival of overwintering eggs and for adult survival using both January mean temperatures and annual mean temperatures. We show that the 0°C LST threshold for January mean temperatures and the 11°C threshold for annual mean temperatures provide the best predictors for identifying the areas that could potentially support populations of this mosquito. In fact, human population density and distance to human settlements appear to be less important variables affecting mosquito distribution in this area. Finally, we evaluated the future establishment and spread of this species in relation to predicted climate warming by considering the A2 scenario for 2050 statistically downscaled at regional level in which winter and annual temperatures increase by 1.5 and 1°C, respectively.

REVIEW ARTICLES

Lyme borreliosis in Europe

A Rizzoli (annapaola.rizzoli@iasma.it)[1,2], H C Hauffe[1,2], G Carpi[1], G I Vourc'h[3], M Neteler[1], R Rosà[1]

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2. Both authors contributed equally to this work.
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Citation style for this article:
izzoli A, Hauffe HC, Carpi G, Vourc'h GI, Neteler M, Rosà R. Lyme borreliosis in Europe.
Euro Surveill. 2011;16(27):pii=19906. Available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=19906

Article published on 7 July 2011

Despite improvements in prevention, diagnosis and treatment, Lyme borreliosis (LB) is still the most common arthropod-borne disease in temperate regions of the northern hemisphere, with risk of infection associated with occupation (e.g. forestry work) and certain outdoor recreational activities (e.g. mushroom collect-

is unknown (see [3] for a review). Less controversial is the fact that the geographical distribution of LB is still expanding, especially towards higher altitudes and latitudes ([3] and references therein). Moreover, LB is likely to become an increasingly relevant health risk in the near future due to complex interactions between

http://gis.cri.fmach.it/publications/

FEM GIS and Remote sensing unit:
Spatial modelling of disease vectors, biodiversity and beyond

http://gis.cri.fmach.it

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Page 1 of 6 > >>

New paper: Climatic Factors Driving Invasion of the Tiger Mosquito (Aedes albopictus)...
Roiz D., **Neteler M.**, Castellani C., Arnoldi D., Rizzoli A., 2011: *Climatic Factors Driving Invasion of the Tiger Mosquito (Aedes albopictus) into New Areas of Trentino, Northern Italy*. **PLoS ONE**. 6(4): e14800

[More]

New paper: Benefits of hyperspectral remote sensing for tracking plant invasions
He, K.S., **Rocchini, D.**, **Neteler, M.**, Nagendra, H. (2011). Benefits of hyperspectral remote sensing for tracking plant invasions. ***Diversity and Distributions***, 17: 381-392.

[More]

GIS and Remote Sensing Unit at Fondazione Edmund Mach

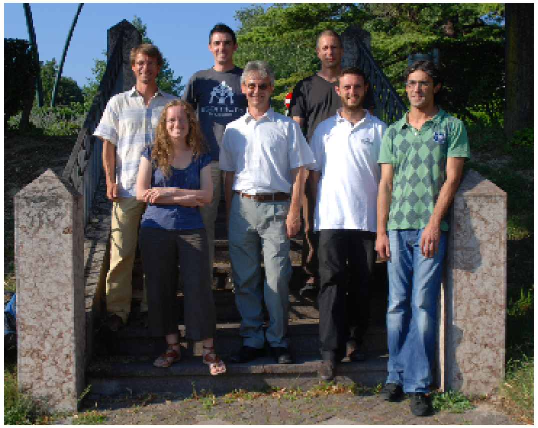
The mission of the GIS and Remote Sensing unit (*Piattaforma GIS & Remote Sensing*) is to develop and provide multi-scale approaches for the description of 2-, 3- and 4-dimensional biological systems and processes. Core activities are the acquisition, processing and validation of geographical data, the support for the scientific analysis and management of physical, ecological and geographical data, collected within research projects or monitoring activities. The Geographic Information System (GIS) approach allows the description of continental down to landscape scale systems such as including the 3D-reconstruction of small sampling sites. We focus on the geostatistical analysis of such information layers, the creation and processing of indicators, and the production of ecological, landscape genetics, eco-epidemiological and physiological models. The group pursues actively the development of innovative methods and their implementation in a GIS framework including the analysis of proximal and remote sensing data and time-series.
The Edmund Mach Foundation (FEM) is a private research foundation established by the government of the Autonomous Province of Trento which continues and improves the activities of the former Istituto Agrario di S. Michele all'Adige (IASMA) and the former Centro di Ecologia Alpina (CEA). The GIS and Remote Sensing group is part of the Research and Innovation Centre (FEM-CRI).

Foundation at S. Michele rendered from Lidar data and Orthophoto

People

The GIS and Remote Sensing Unit team:

- Luca Delucchi (GIS technician)
- Anne Ghisla (PhD student)
- Dr. Markus Metz (Post-Doc)
- Dr. Markus Neteler (head)
- Dr. Duccio Rocchini (Researcher)
- Dr. Roberto Zorer (Researcher)



PGIS group as of June 2011 (with Javier as guest)

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