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Potential habitat of the tiger mosquito *Aedes albopictus* in Northern Italy derived from reconstructed MODIS Land Surface Temperature maps

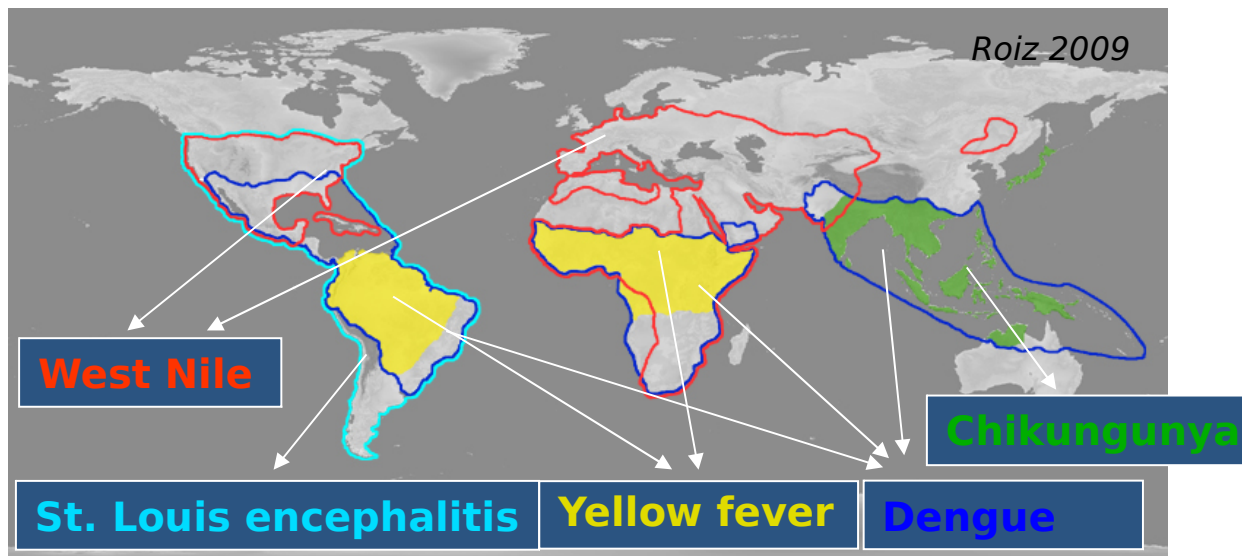
FOSS4G 2010 Barcelona, 6-9 Sep 2010



Introduction

Increasing spread of the Asian Tiger Mosquito (*Ae. albopictus*):

- Disease vector, continuous spread in Europa and elsewhere
- Egg depositing in small vessels filled with rain water, used tyres and Lucky Bamboo plants (*Dracaena sanderiana*)
- Northern Italy 2007: >200 Chikungunya cases transmitted through India traveller



Diseases transmitted by *Aedes albopictus*



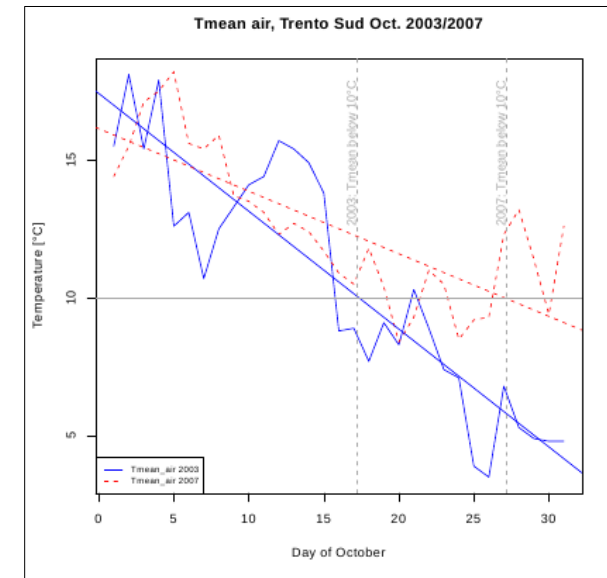
Small vessels in a garden (Trento)

Introduction

Temperature as important environmental variable

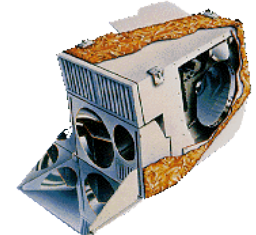
In research and elsewhere

- Use of **directly measured values**, or resp.
- **derived, aggregated data**, such as:
 - Weekly or monthly aggregations,
 - Threshold maps, e.g. to identify unusual hot or cold seasons,
 - Temperature gradients in spring or autumn



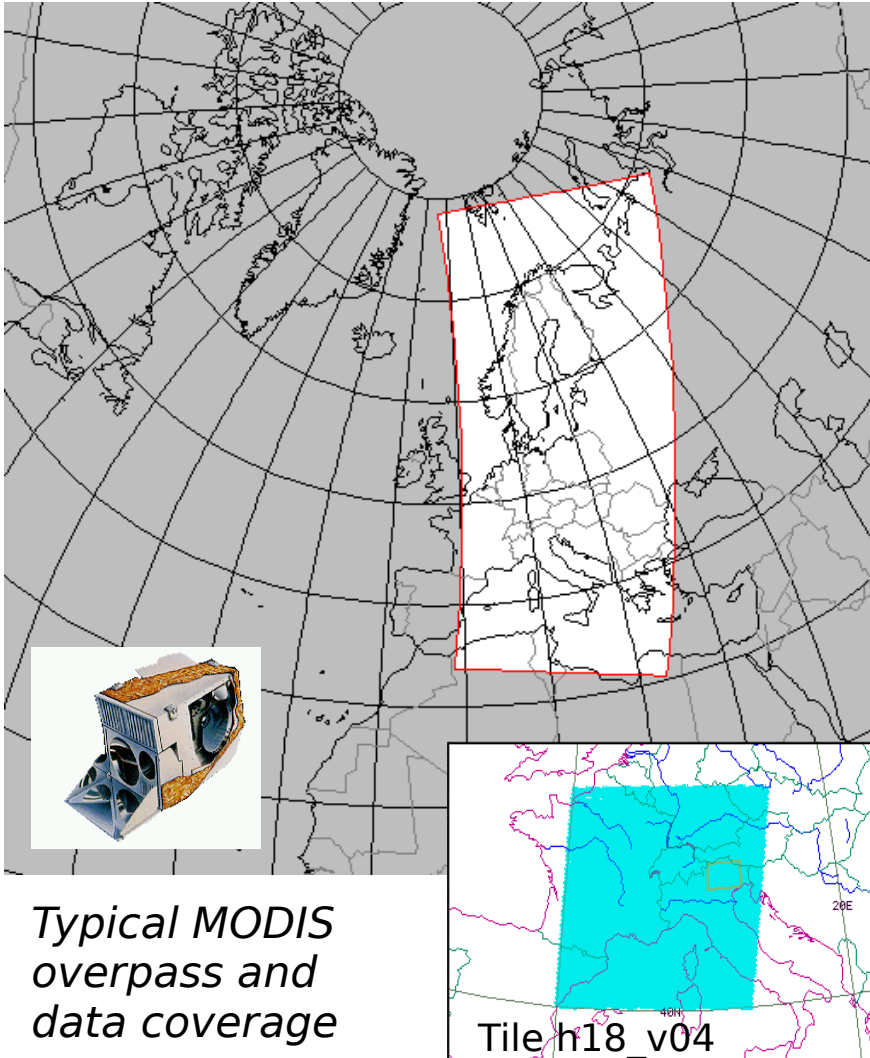
Potential data sources (Aim: high temporal resolution)

- Temperature measurements from meteo-stations; then interpolation
- Satellite data:
 - Landsat, ASTER
 - Meteosat
 - NOAA/AVHRR LST, Terra/MODIS and Aqua/MODIS LST



The MODIS Sensor

The MODIS sensor on board of Terra and Aqua satellites



- Sensor with 36 channels in the range of optical light, near and thermal infrared
- Delivers data at 250 m, 500 m and 1000 m pixel resolution
- LST error rate: $< 1 \text{ K} \pm 0.7 \text{ K}$

MODIS/Terra (EOS-AM):

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

MODIS/Aqua (EOS-PM):

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

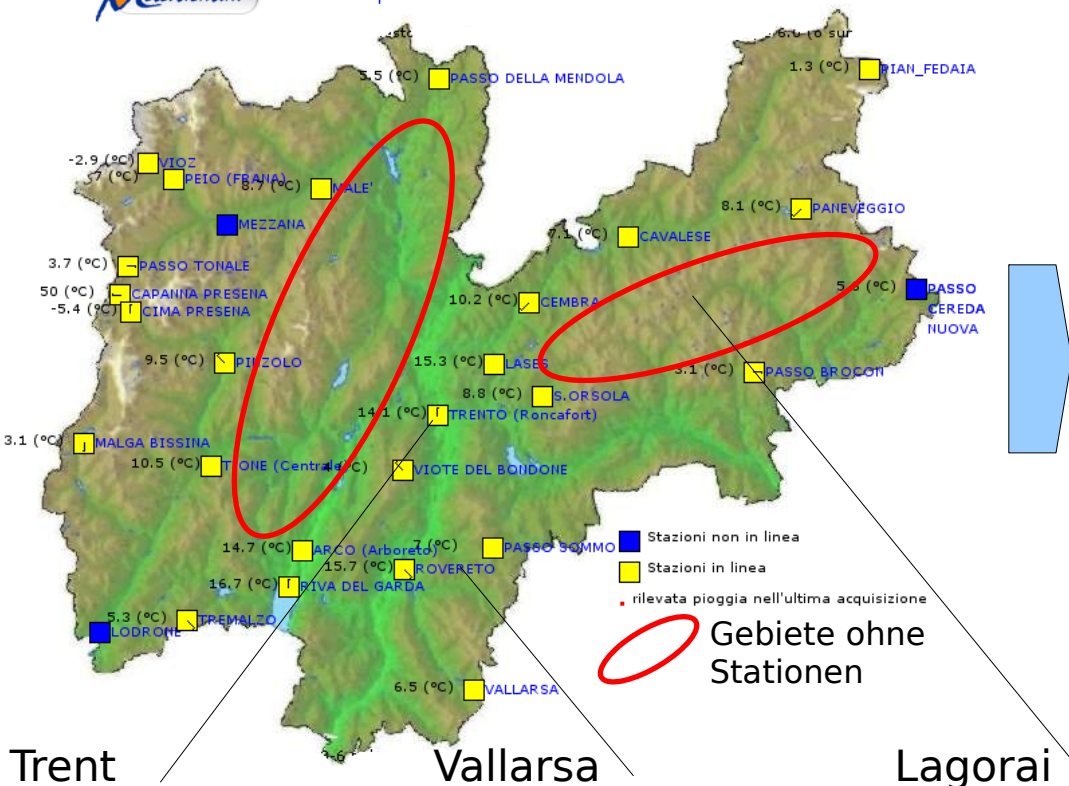
- ➔ **4 overpasses in 24h**
- ➔ **data availability after ~72h**

Study area and data quality

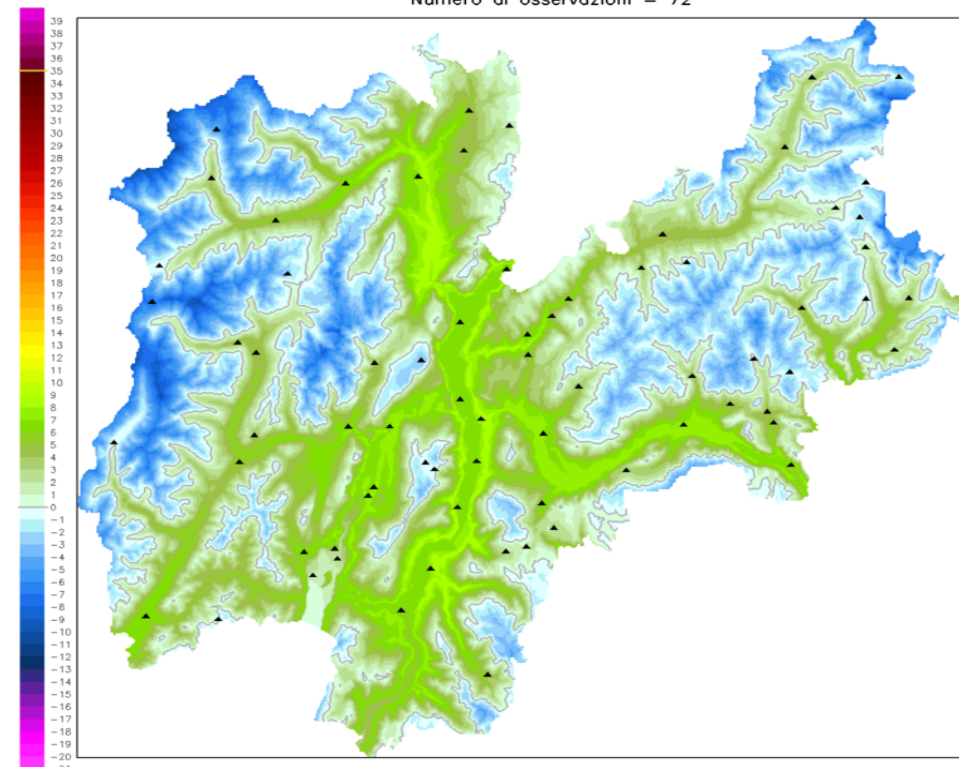
Scarce meteo-stations or dense MODIS LST maps?

*Interpolation of meteo data likely complicated due to complex alpine relief:
Data density and micro-climatic effects*

Meteotrentino Dati rilevati presso le stazioni meteo

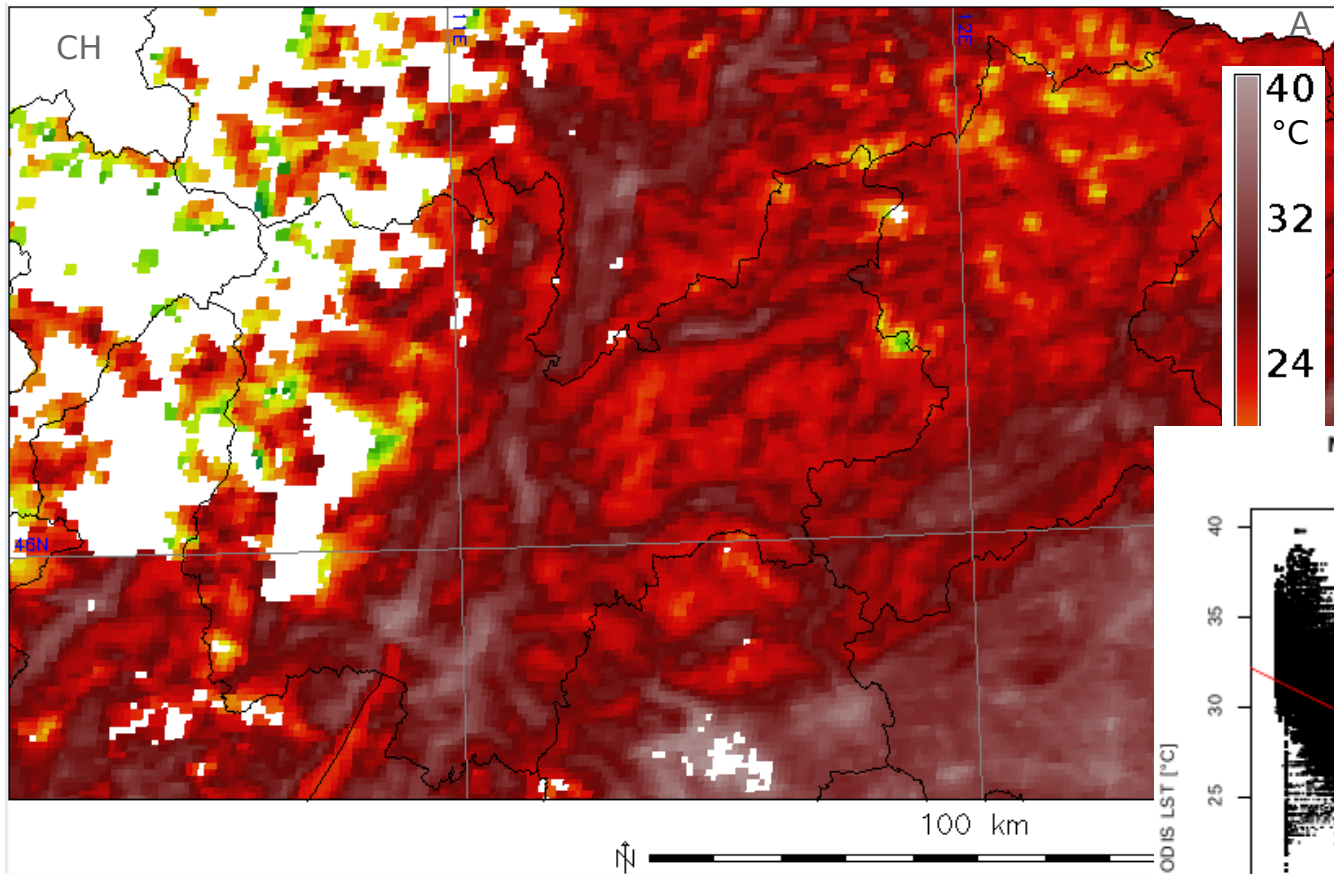


Temperatura [°C] 19.04.2010 ore 00:00 UTC+1
Numero di osservazioni = 72



Official temperature map from meteo model (number of stations variable, data access limited)

Problem of optical/thermal remote sensing: clouds



MODIS LST/Terra, 24 June 2003, 10:30 solar time

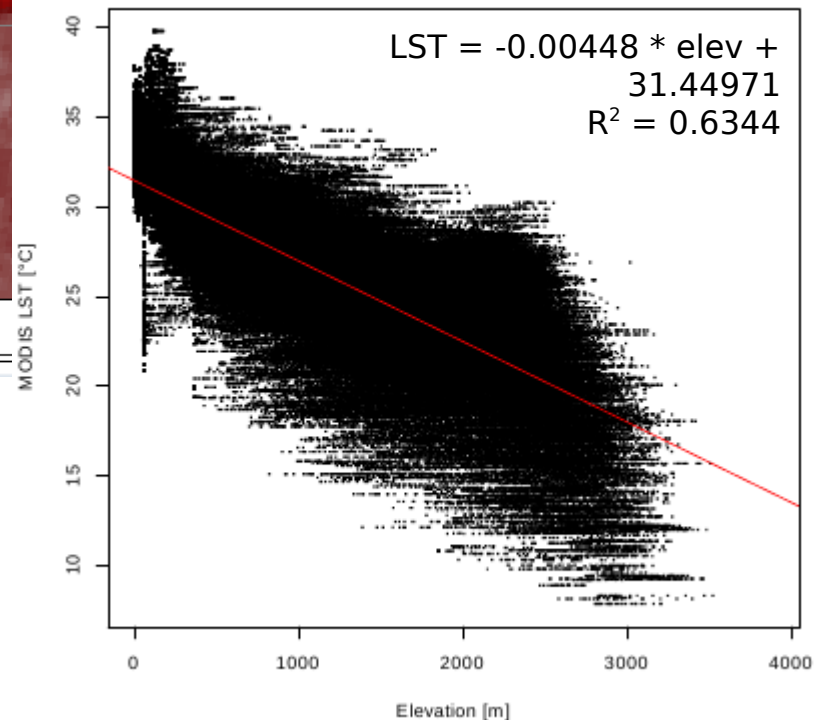
Missing pixels due to clouds, aerosol, haze, ...

Approach:

Relationship temperature - elevation: gradient method

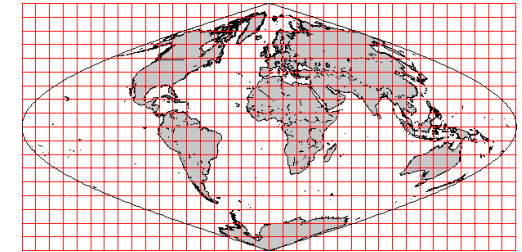
Elevation model \rightarrow LST

MODIS LST: Temperature-Elevation relationship
24 June 2003, 10:30

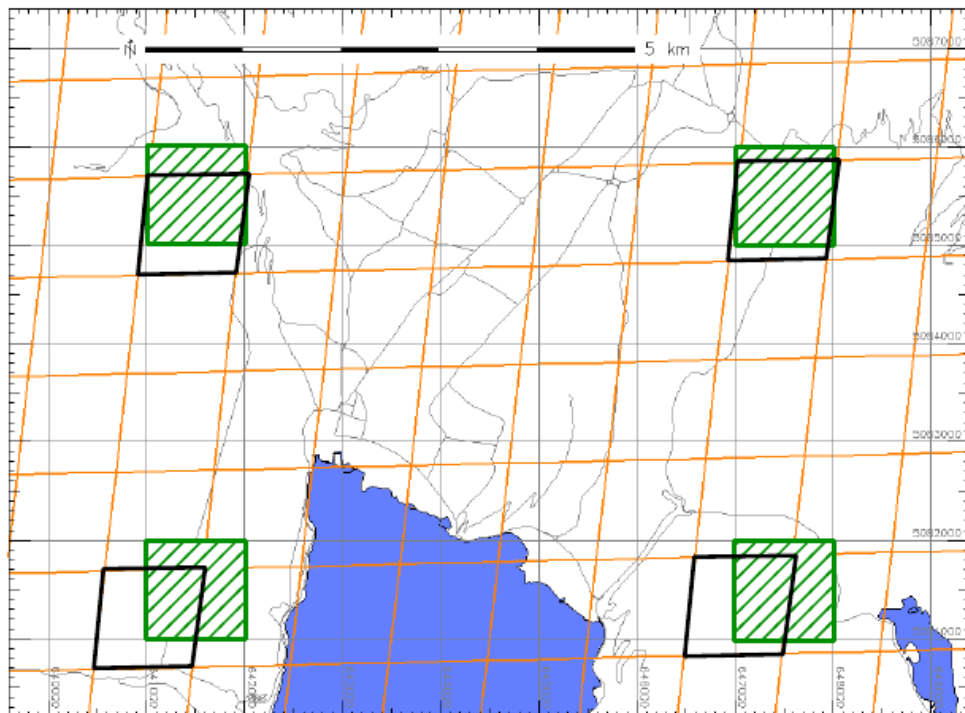


Reconstruction of MODIS LST maps

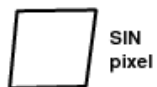
Minimization of artefacts in reprojection step from MODIS-Sinusoidal → UTM32N:
Resolution increment from 1000 m to 200 m



MODIS-Sinusoidal projection



1000 m

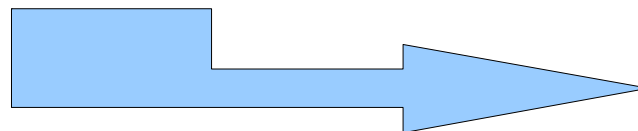


SIN pixel



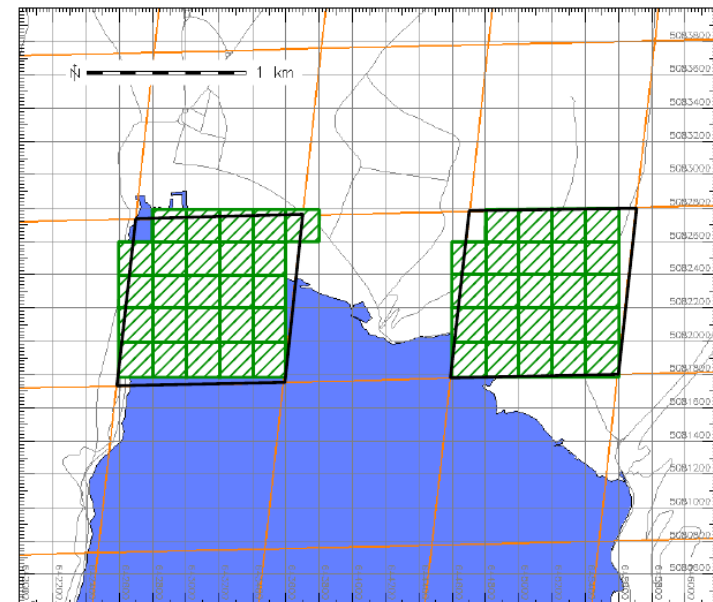
UTM 32N pixel

Reprojection with Nearest Neighbor resampling



Resampling with Nearest-Neighbors, since

- cubic convolution: spikes at cloud fringes in MRT software
- bilinear: too much generalisation (micro-climatic effects)

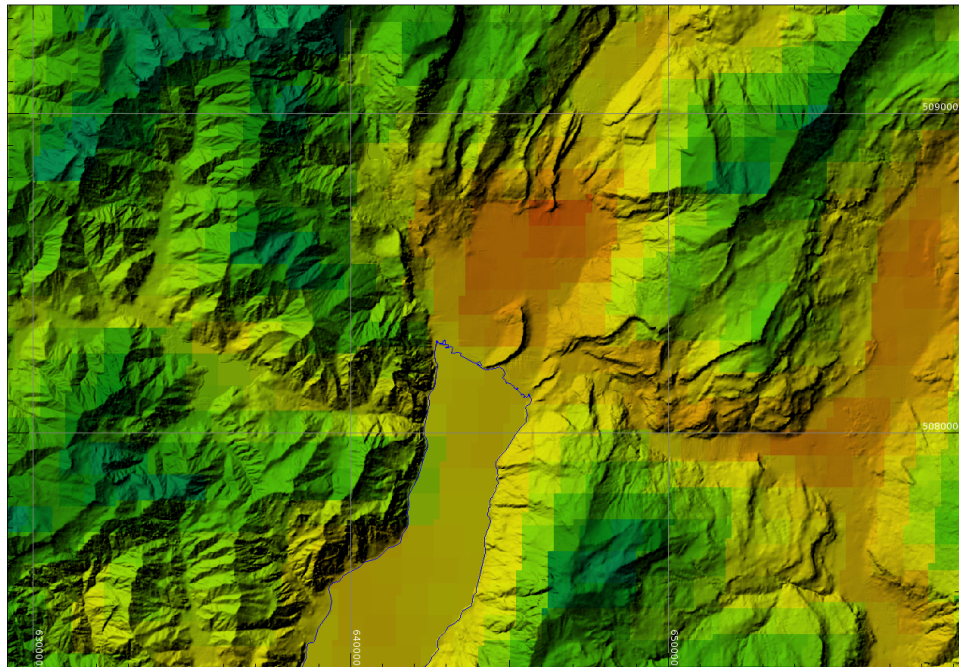


200 m

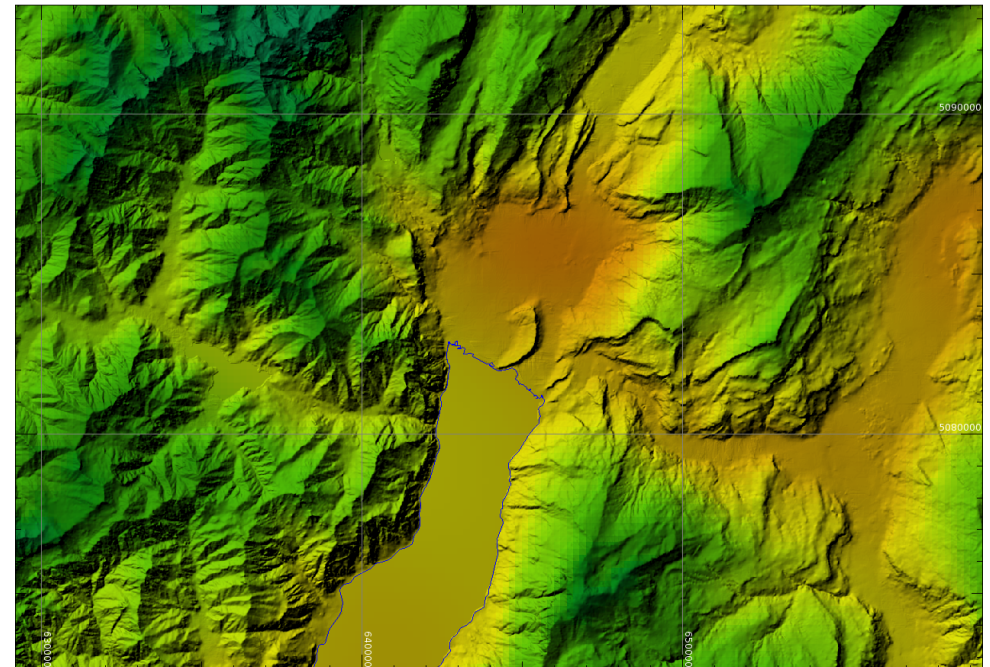
Reconstruction of MODIS LST maps

Example for a filtered, complete MODIS LST map: „raw“ and reconstructed

TERRA at 2001-Nov-1 10:30 (raw data)



TERRA at 2001-Nov-1 10:30 (RST reconstructed)



-15 -6 2 11 20 [°C]

-15 -6 2 11 20 [°C]

1000 m x 1000 m original
pixel size resampled to
200 m x 200 m

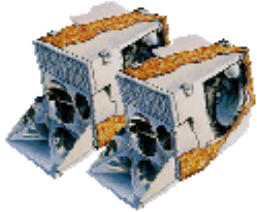
200 m x 200 m
final pixel size

Cloud free map

Area: Riva del Garda
1:25.000

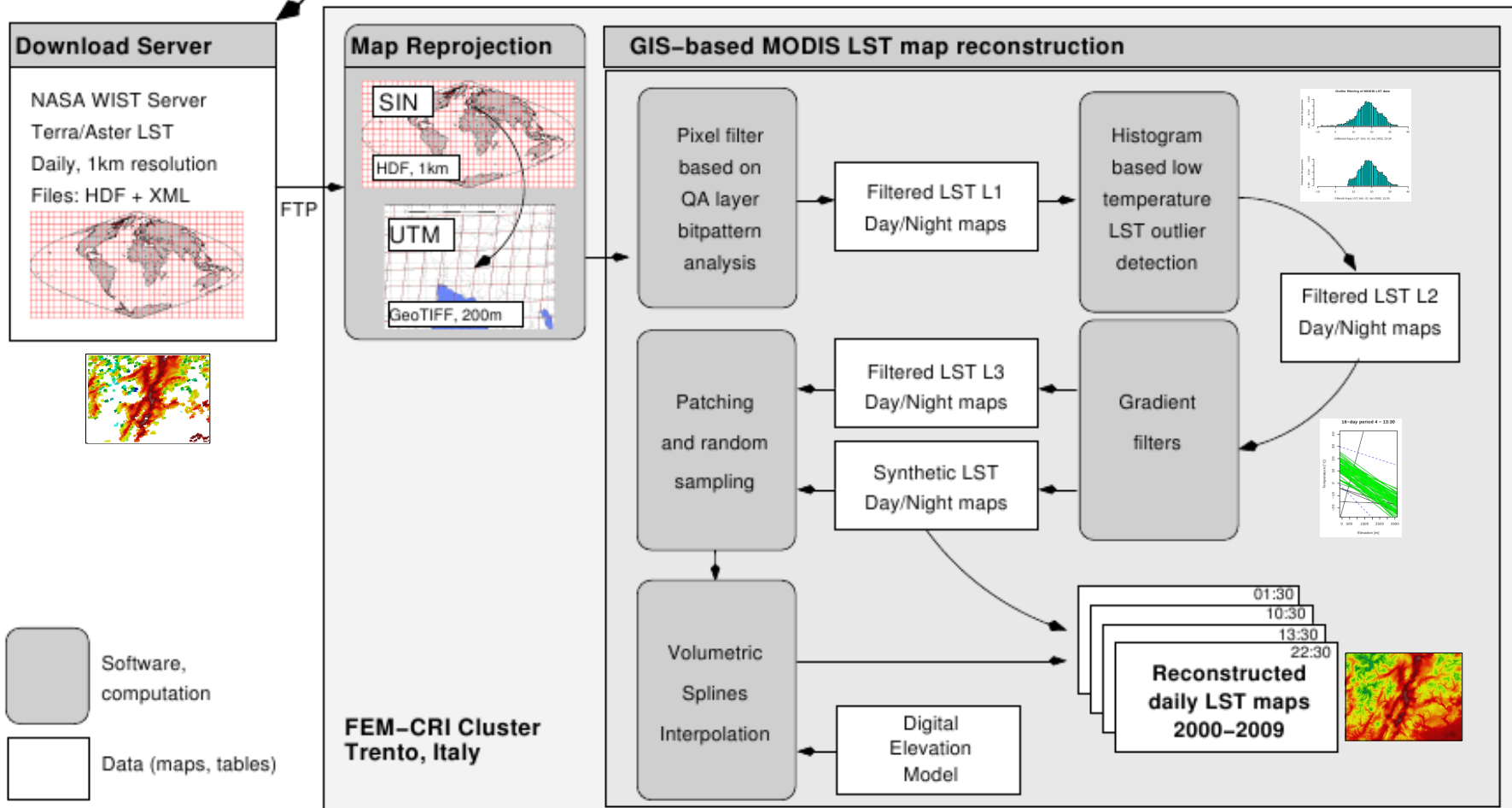
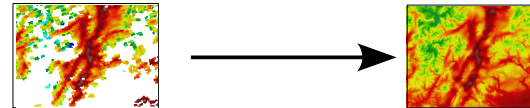
Reconstruction of MODIS LST maps

MODIS/Terra



MODIS/Aqua

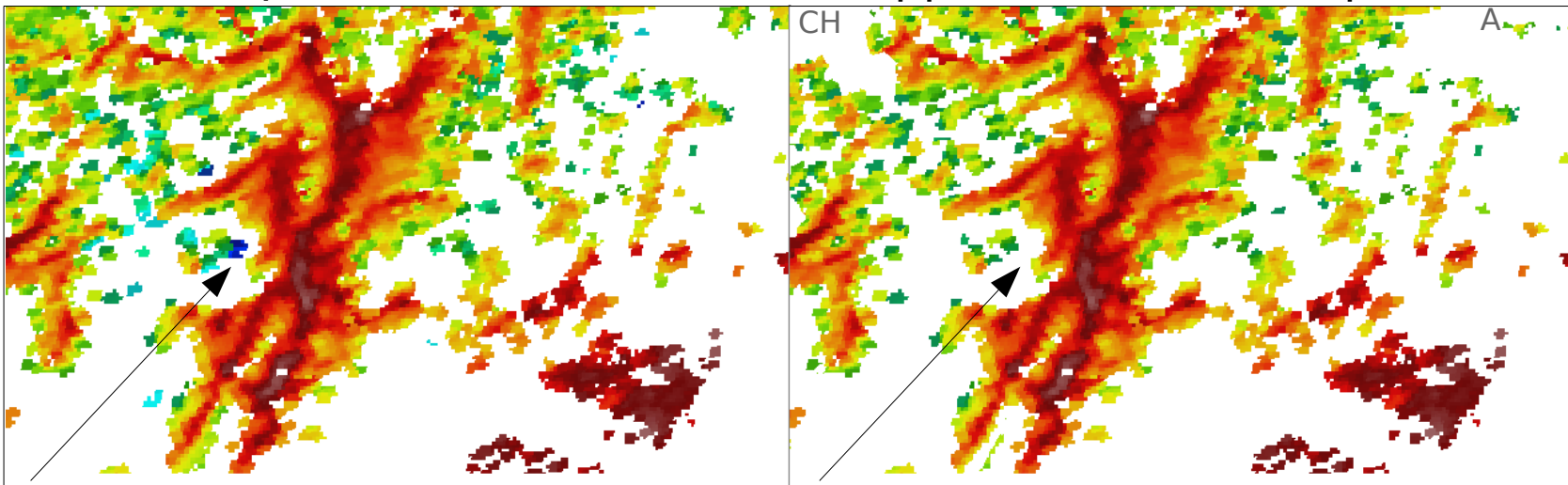
Simplified workflow of developed method



Results of MODIS LST reconstruction

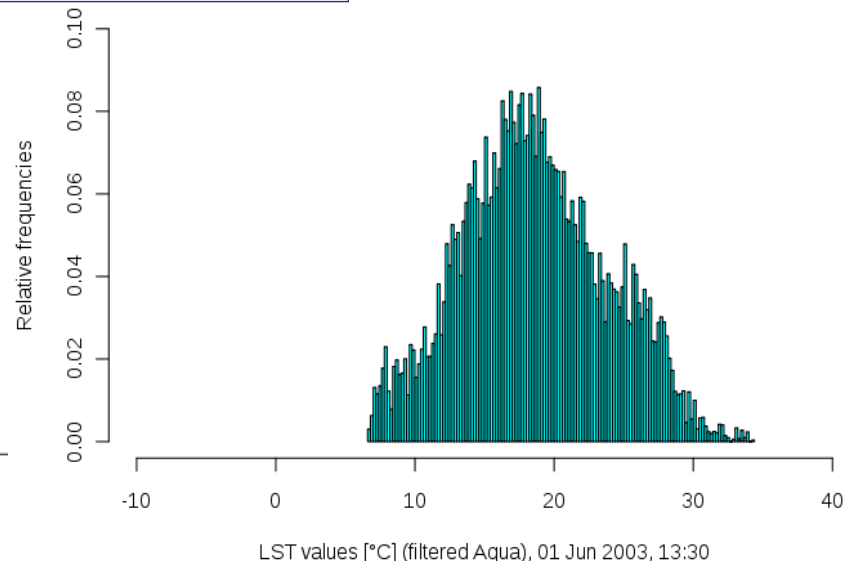
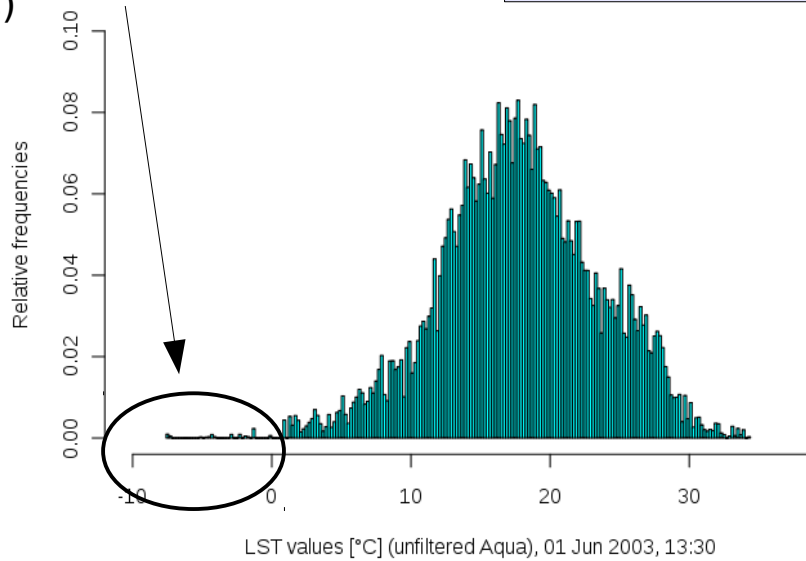
Original MODIS LST map,
QA map used as filter

Second and third filter step
applied to MODIS map



By NASA algorithm
undiscovered outliers
(clouds)

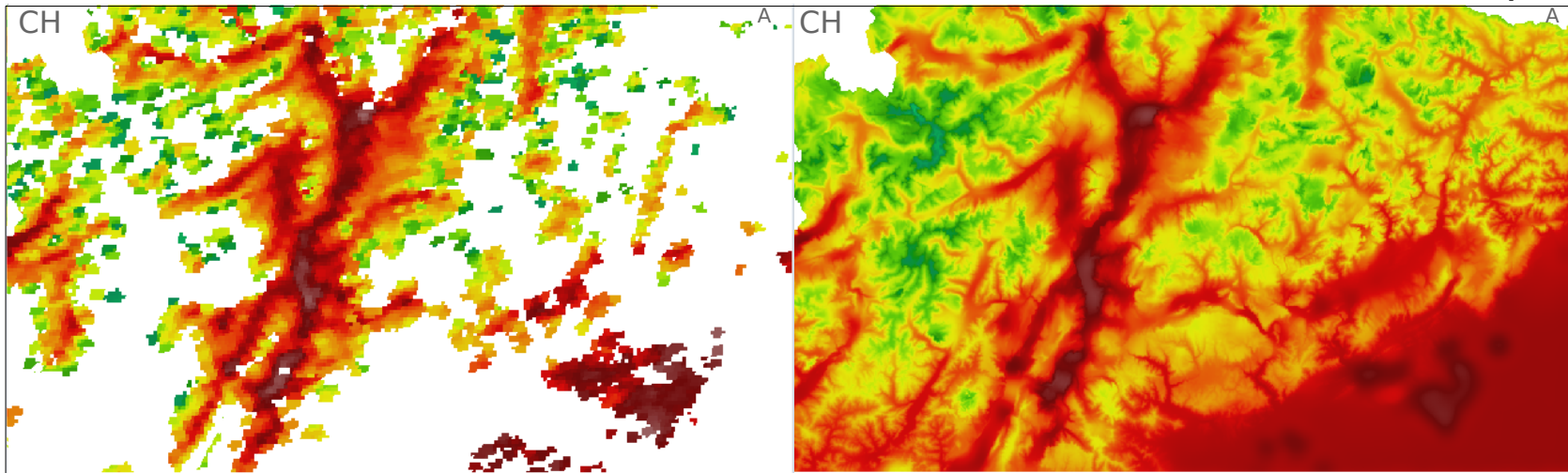
MODIS LST (Aqua satellite)
1. June 2003, 13:30 solar time



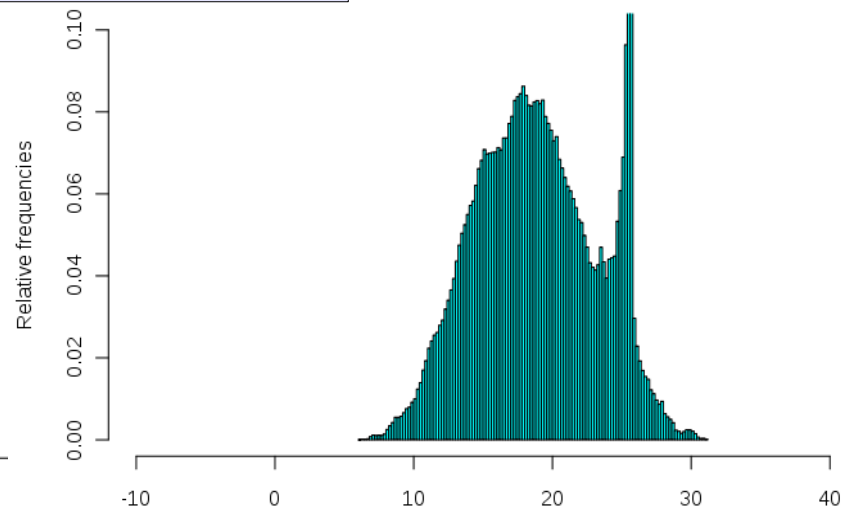
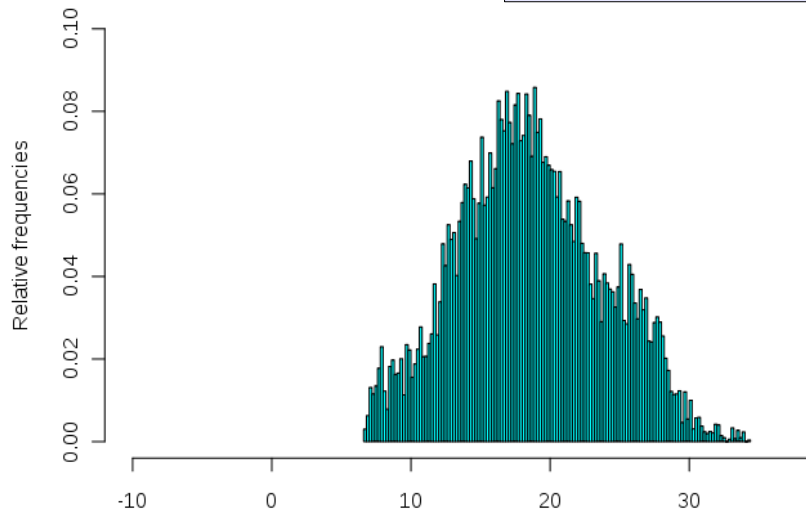
Results of MODIS LST reconstruction

Second and third filter step
applied to MODIS map

Reconstructed MODIS LST map



MODIS LST (Aqua satellite)
1. June 2003, 13:30 solar time



LST values [°C] (filtered Aqua), 01 Jun 2003, 13:30

LST values [°C] (reconstructed Aqua), 01 Jun 2003, 13:30

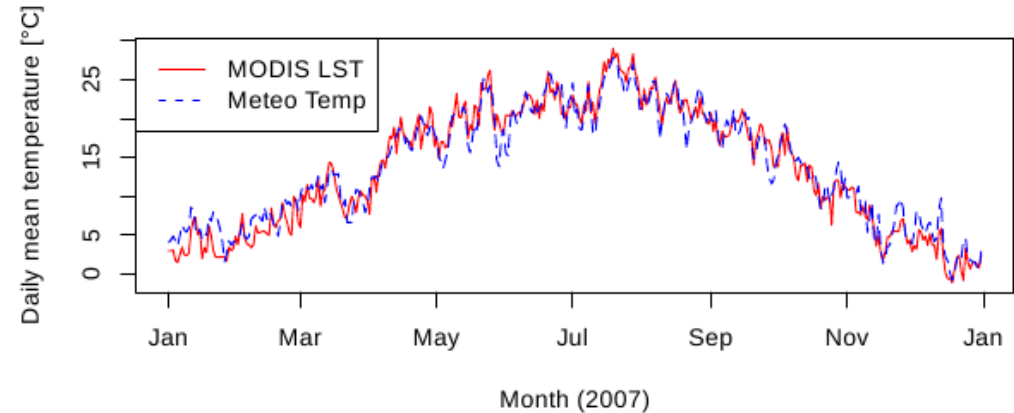
Reconstructed MODIS LST vs Meteo data

Comparison of

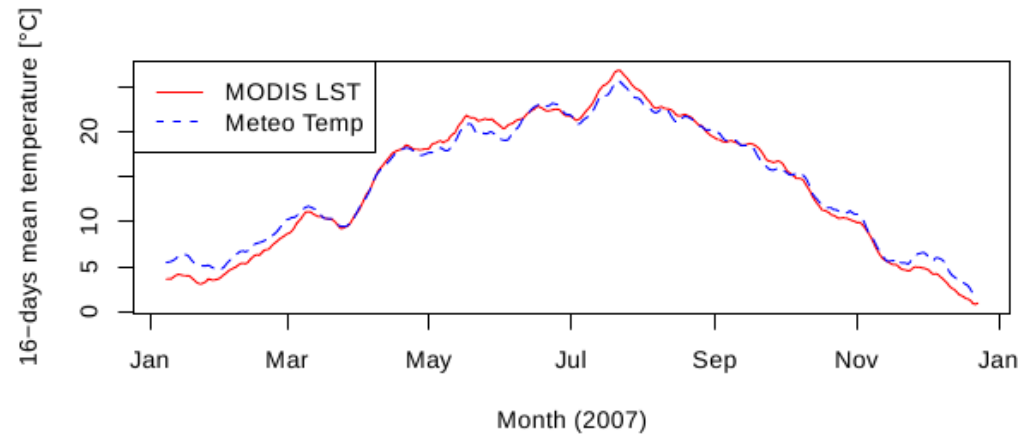
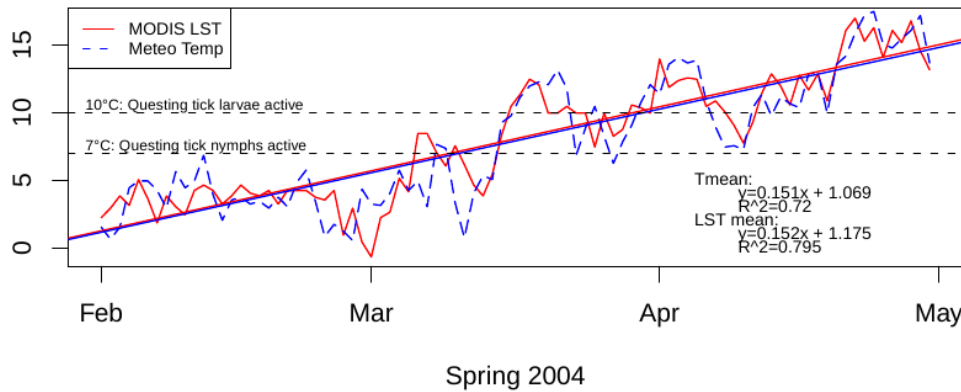
- Daily mean temperatures
- To 16-days aggregated mean values
- linear regression for trend analysis

LST (soil surface) and meteo temperature data (2m/soil) are two independent data sets

Temperatures 2007 Arco, Italy: daily and 16-days means



Spring warming 2004, Trento Sud
daily means from MODIS LST versus Meteo station



Parallelised GIS Processing

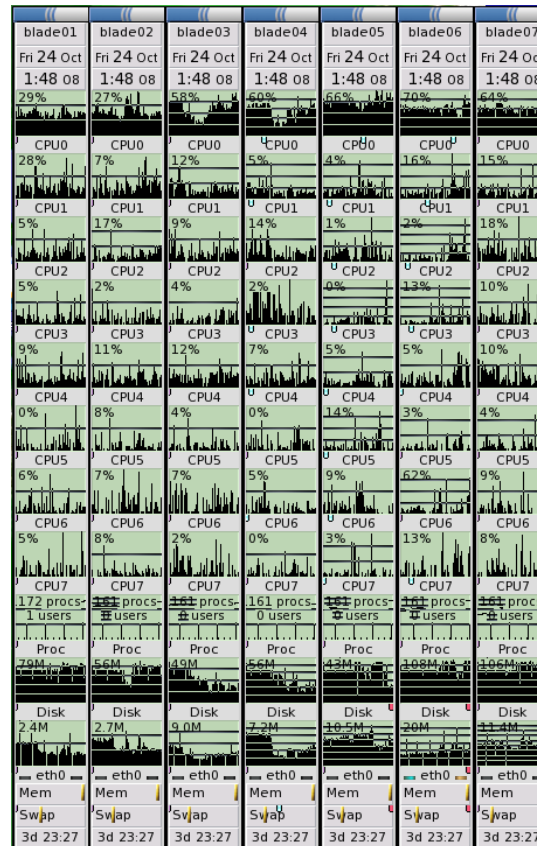
Infrastructure: FEM-GIS Cluster

- 12 single-blades and 2 double-blades
- In total 128 nodes with 400 Gb RAM
- Circa 1.7 Tflops/s
- Linux operating system, blades headless

- **GRASS GIS and R-stats**

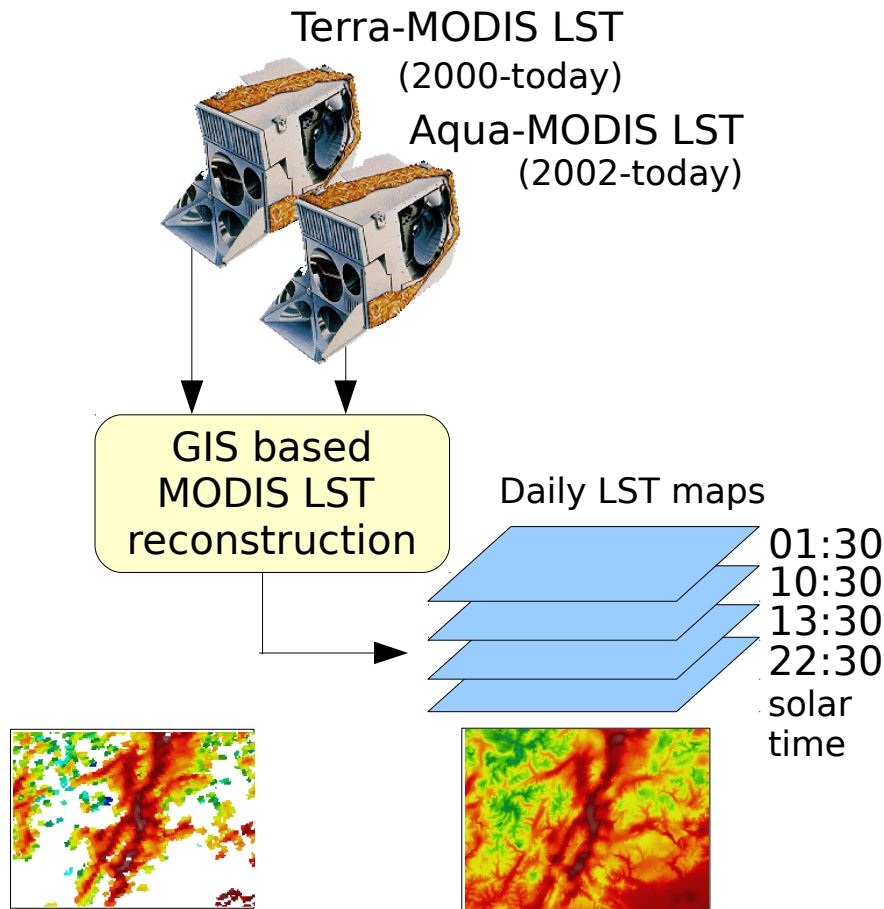
- Queue system for job management (Grid Engine)

- Processing of all 11,000 maps in parallel: one map per node
- Computational time: 3 weeks



LST Applications: Tiger mosquito survival

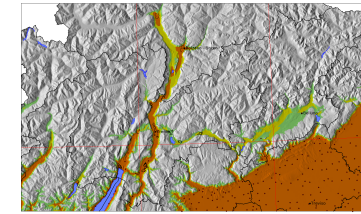
***Aedes albopictus* survival maps from reconstructed Daily MODIS Land Surface Temperature maps**



GIS based map elaboration

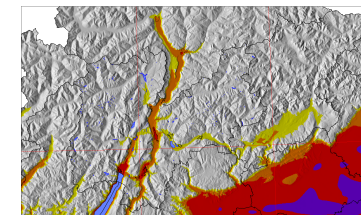
Egg winter survival

January temperature thresholds (2001-2009)



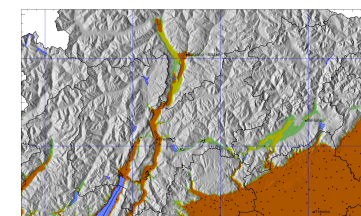
Adult annual survival

Annual temp. thresholds (2001..2009)



Life stages development

**1350 Growing Degree Days/
autumnal threshold
of 10°C (2003..2009)**



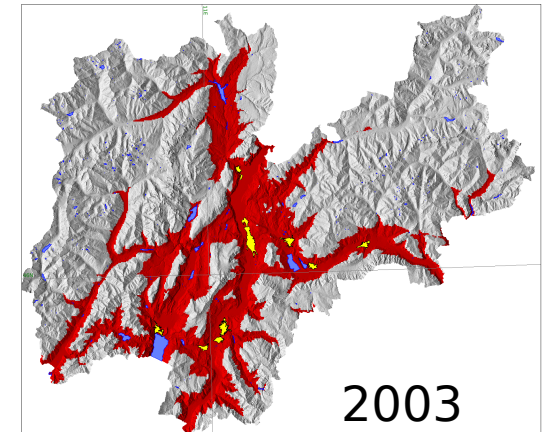
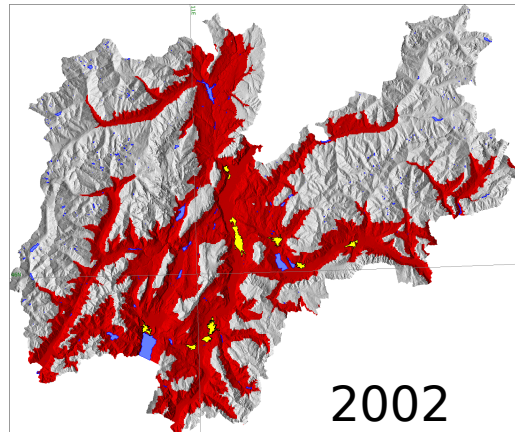
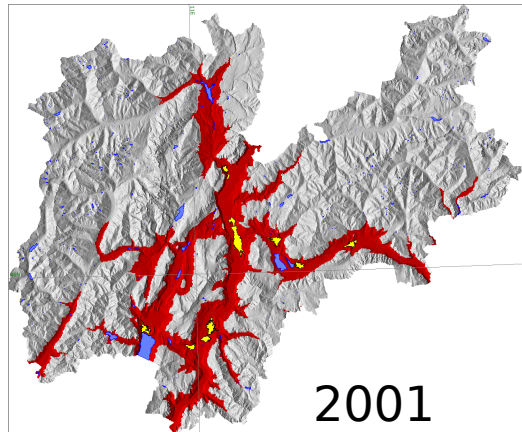
Classification

- 0-49%: unsuitable,
- 50-69%: marginally suitable,
- 70-89% moderately suitable,
- 90-100% highly suitable

Neteler, Roiz, Castellani,
in prep.

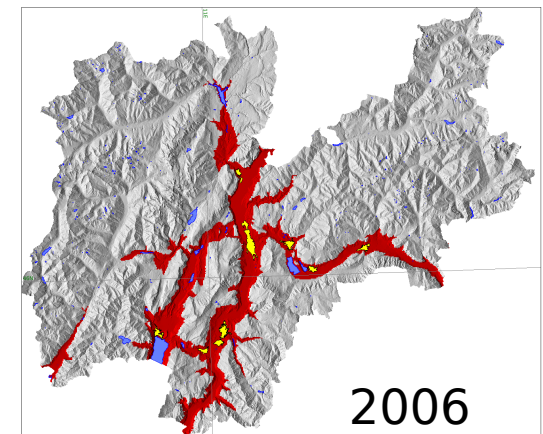
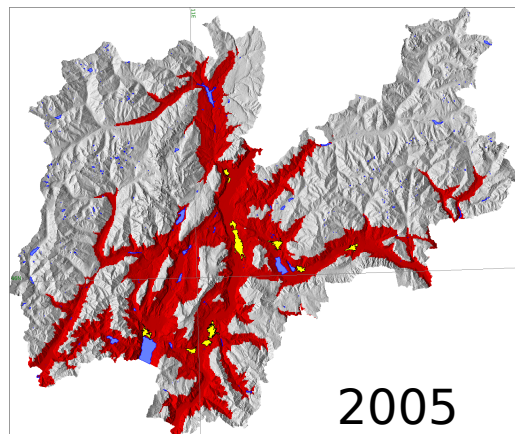
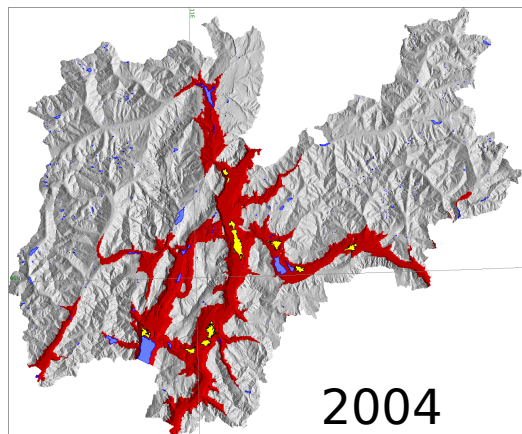
LST Applications: egg winter survival

Example: January temperature $\geq 0^{\circ}\text{C}$ threshold



 Cities
 LST $> 0^{\circ}\text{C}$

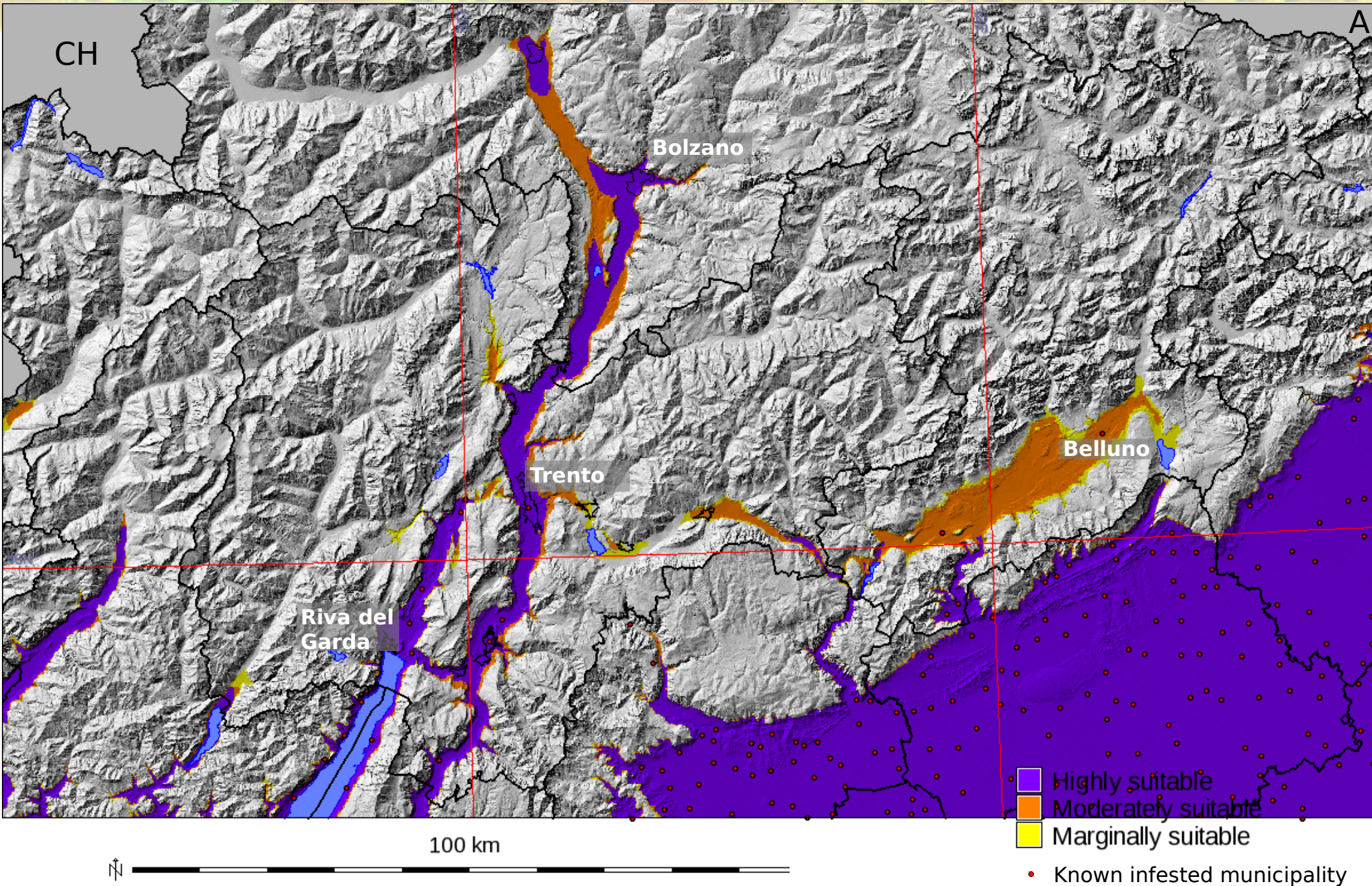
Aut. Prov.
of Trento



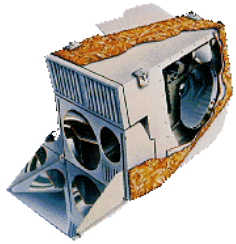
**Spatio-temporal heterogeneity of the areas optimal
for *Aedes albopictus* egg winter survival**



Result: Tiger mosquito survival map

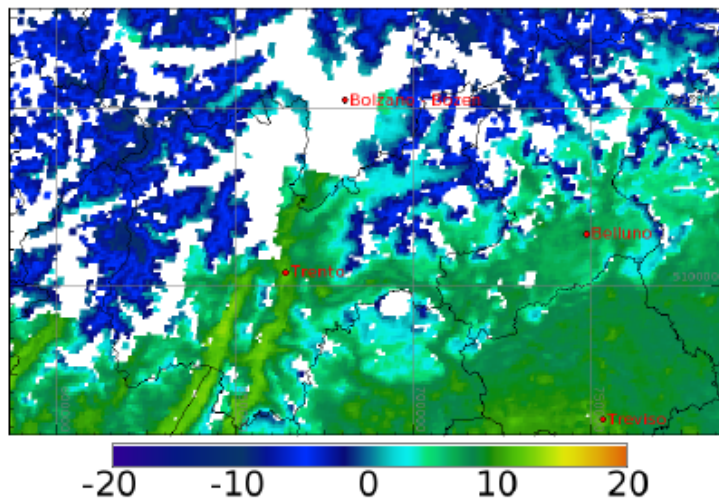


Conclusions

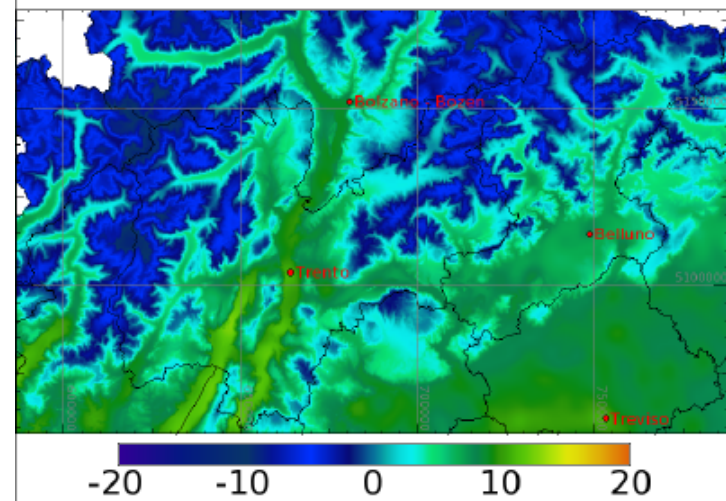


- New data set: > 11,000 reconstructed MODIS LST maps as time series (4 maps/day)
- Successfully applied to disease vector distribution assessment
- Generally usable in agriculture, epidemiology etc.
- Each pixel can be considered as „virtual meteo station“
- New batch job capabilities integrated in GRASS 6.4

TERRA at 2008-Apr-25 22:30 (raw data)

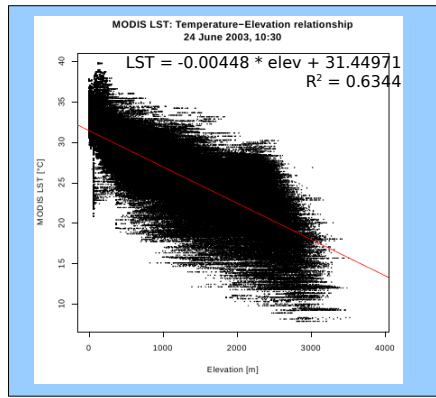
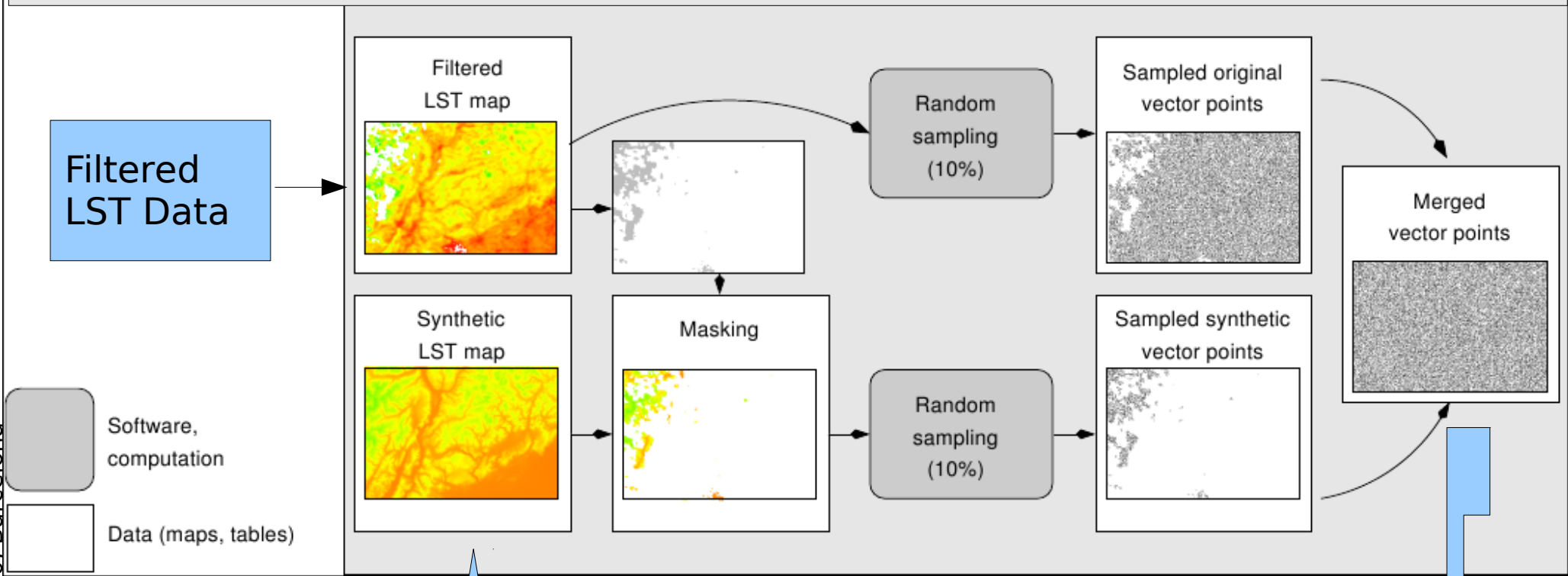


TERRA at 2008-Apr-25 22:30 (RST reconstructed)



Reconstruction of MODIS LST maps

Support of volumetric splines interpolation (3D-RST) by synthetic maps; random sampling to minimize artefacts



Generation of synthetic map from filtered temperature gradients Based on map statistics

3D Splines Interpolation