Modeling past vulnerability to Mediterranean climate change:

The AMENOPHYS project for dynamically coupling behavioral, erosion, and agroecosystem models under variable climatic conditions

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AMENOPHYS – Adaptation of Mediterranean Economies of the Past to Hydroclimatic Changes

Focus:

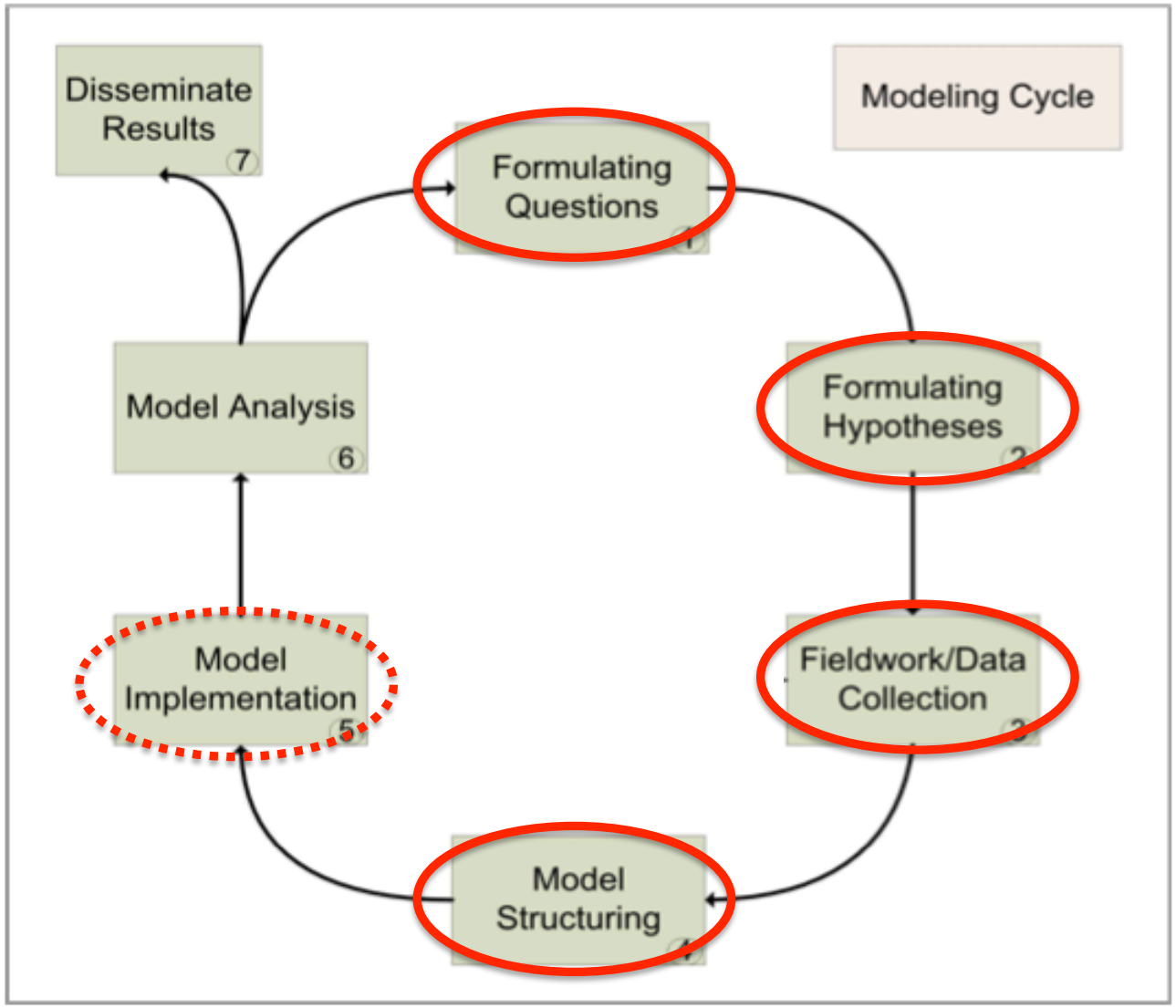
- adaptation of past societies to climatic/environmental change in the Mediterranean

Goals:

- integrate expertise of project members from distinct disciplines (archaeology, paleoclimatology, economics, ecology)
- explore an agent-based modeling approach grounded in empirical archaeological and paleoclimatological evidence
- develop arguments about *how* climatic changes stimulate sociopolitical change (or why they don't)
- identify characteristics that enhance or reduce vulnerability/resilience

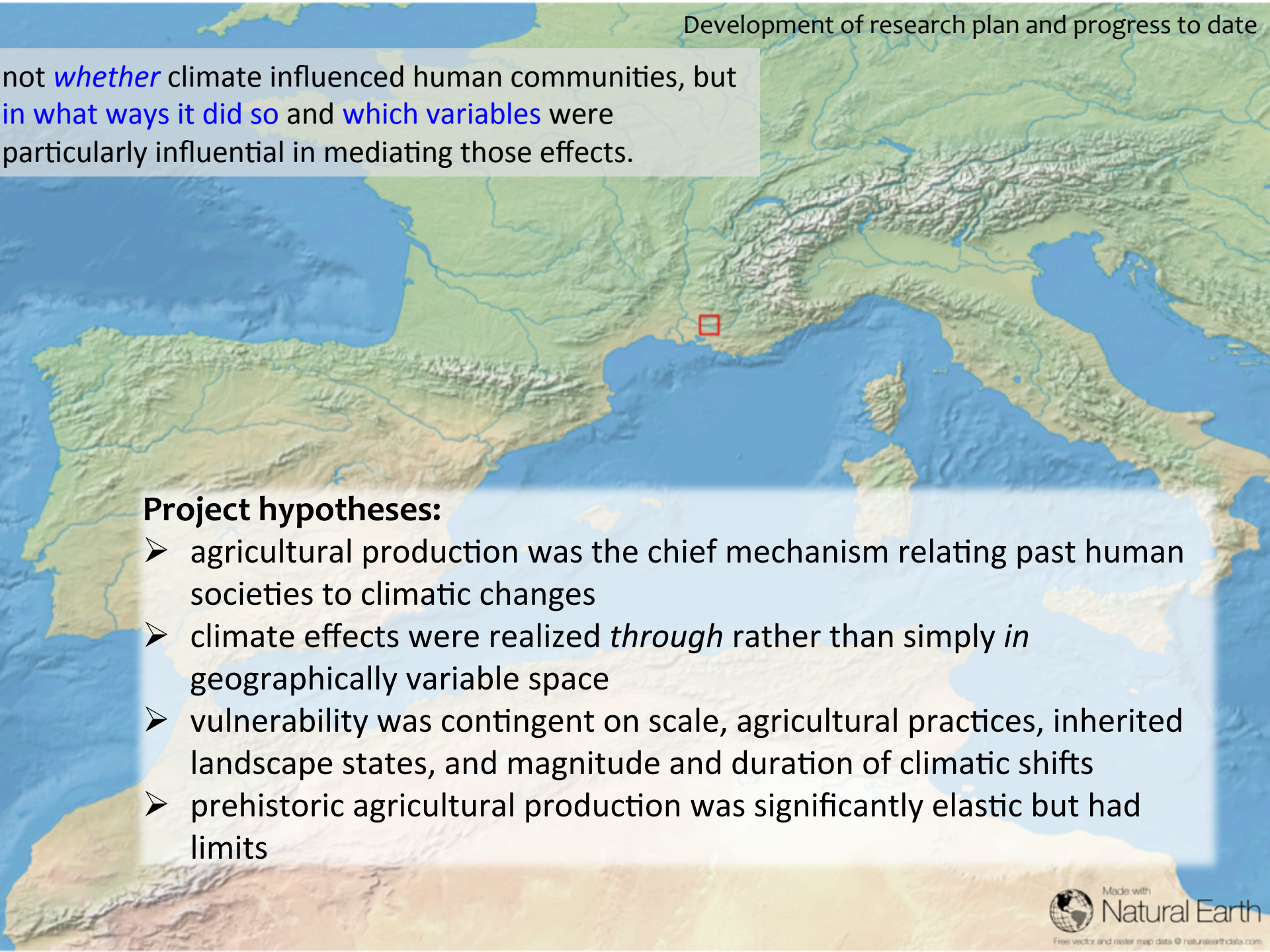
Main tasks so far:

1) formulation of (manageable) problem,
2) creation of testable hypotheses, and
3) integration of interdisciplinary project members
4) data collection
5) structuring of model
6) early stages of model implementation



modified from Altaweel, Mark R, Lilian N Alessa, Andrew Kliskey, and Chris Bone. 2010. A Framework to Structure Agent-Based Modeling Data for Social-Ecological Systems. *Structure and Dynamics* 4(1): 1–20.

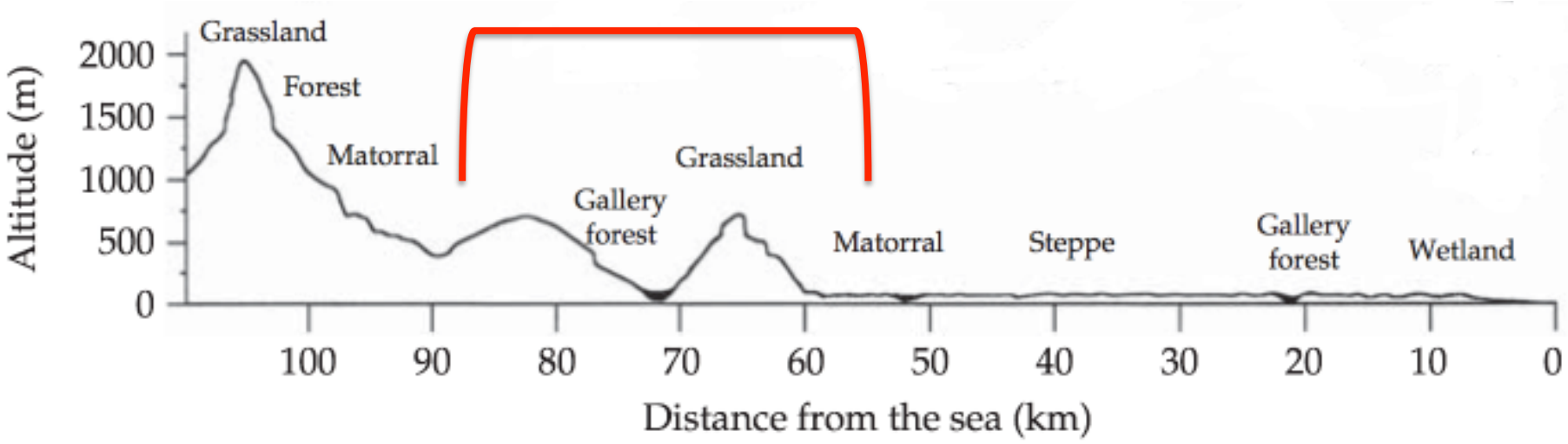
not *whether* climate influenced human communities, but in what ways it did so and which variables were particularly influential in mediating those effects.



Project hypotheses:

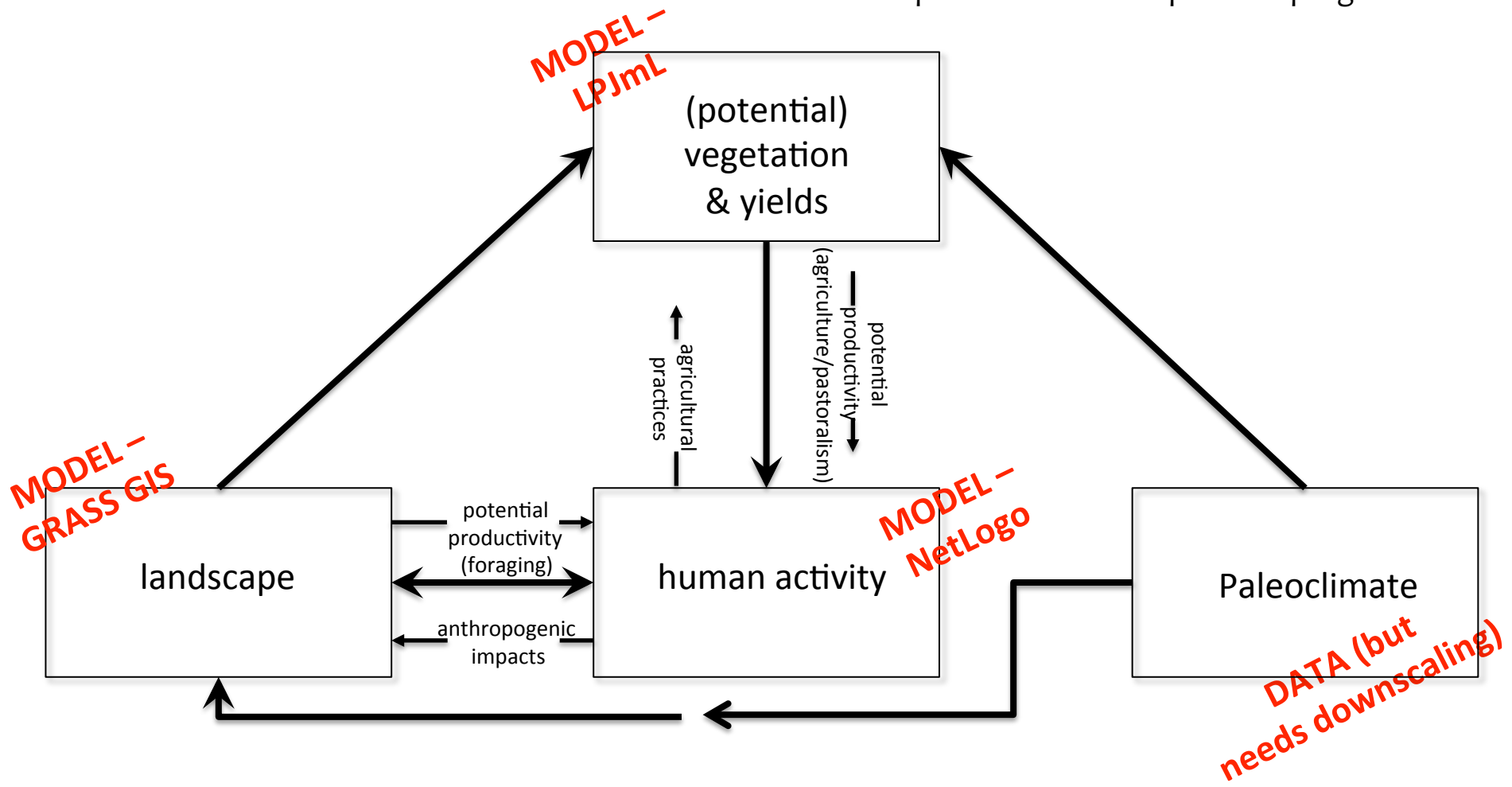
- agricultural production was the chief mechanism relating past human societies to climatic changes
- climate effects were realized *through* rather than simply *in* geographically variable space
- vulnerability was contingent on scale, agricultural practices, inherited landscape states, and magnitude and duration of climatic shifts
- prehistoric agricultural production was significantly elastic but had limits

- study area captures the majority of local bioclimatic zones
- ±50 km^2, with resolution of 30m pixel
- available database of relevant archaeological information (**ArkeoGIS**)



from Blondel et al 2010:Fig.5.4

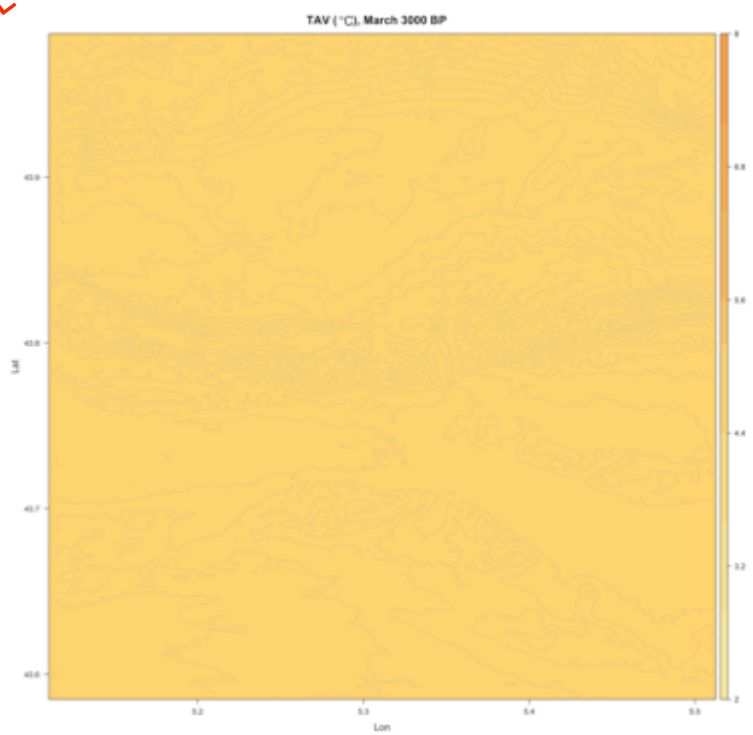
Figure 5.4 Transect through Provence, from the Camargue to Mont-Ventoux, showing bioclimatic zones…

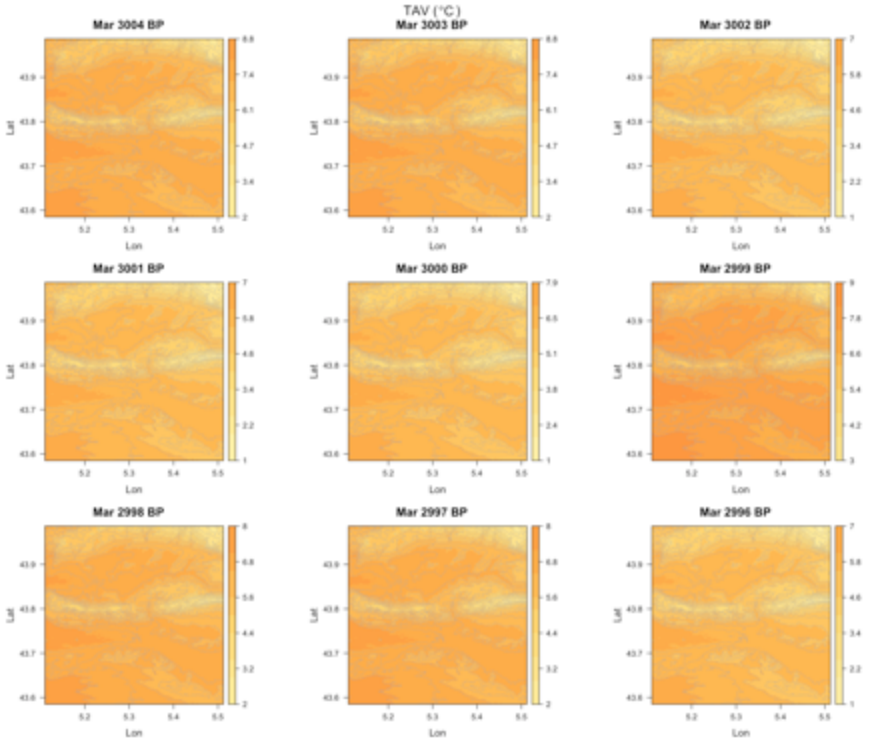


- LPJmL: agricultural productivity
- Landscape (r.landscape.evol): topography + soils + landcover
- Paleoclimate: temperature and precipitation
- Agent-Based Model (NetLogo): food production + social organization

PALEOCLIMATE DATA

Downscaling and simulating paleoclimate data for the study area





Single TAV value for 40km pixel, March 3000 BP

Geographically-weighted regression based on environmental variables + modern climate data

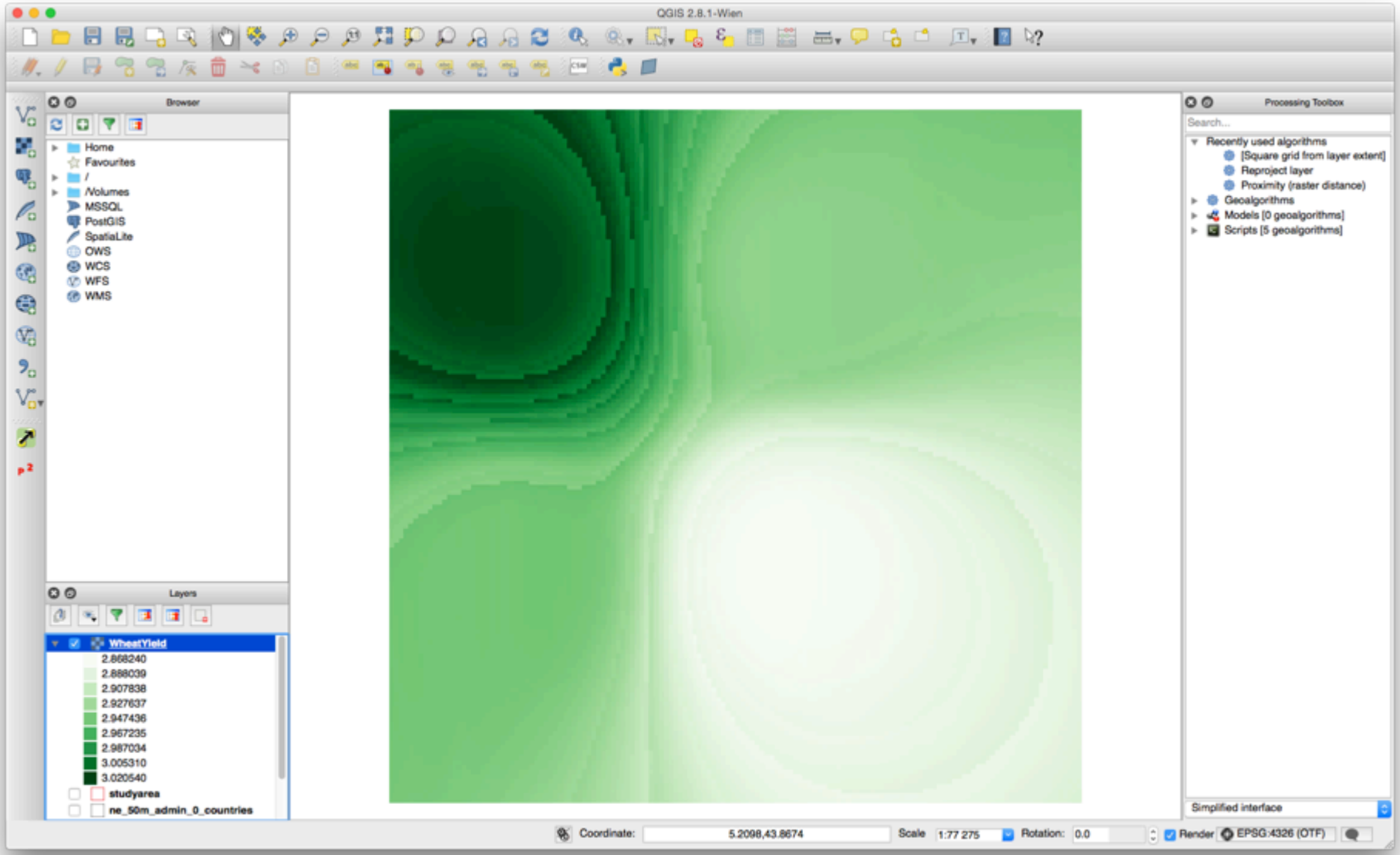
+

Monthly simulation based on interannual variability and seasonal amplitude of modern climate data

TAV values at 300m pixel resultion for each March from 3004 BP – 2996 BP

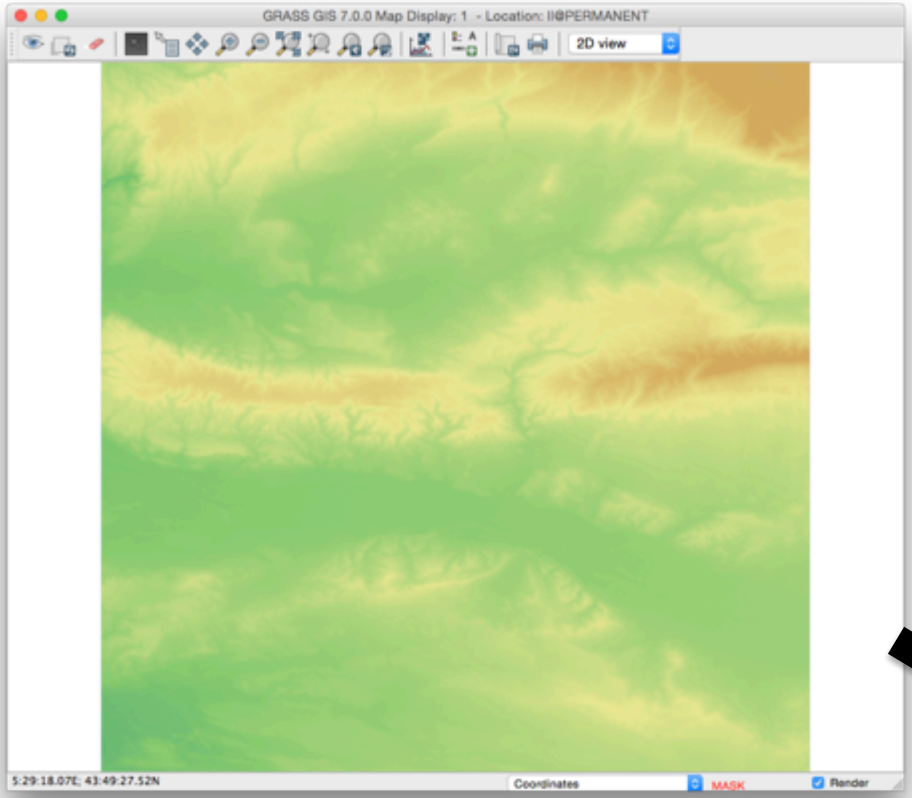
AGROECOSYSTEM MODEL

LPJmL – agroecosystem model
(fantasy kg/ha data – but spatially variable)

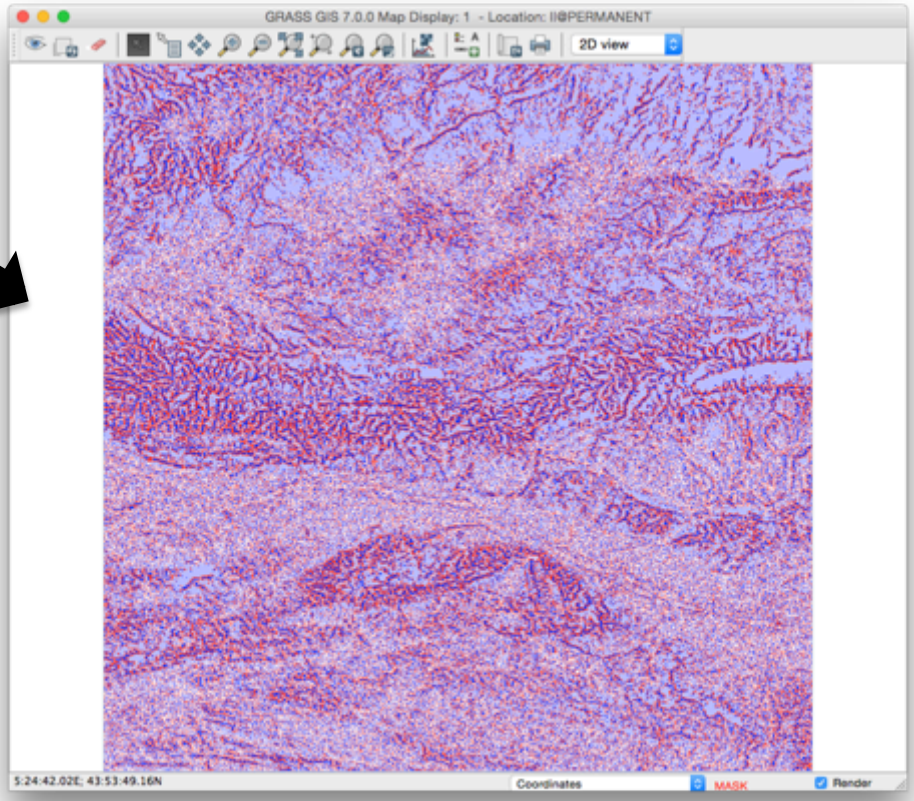


EROSION MODEL

DEM



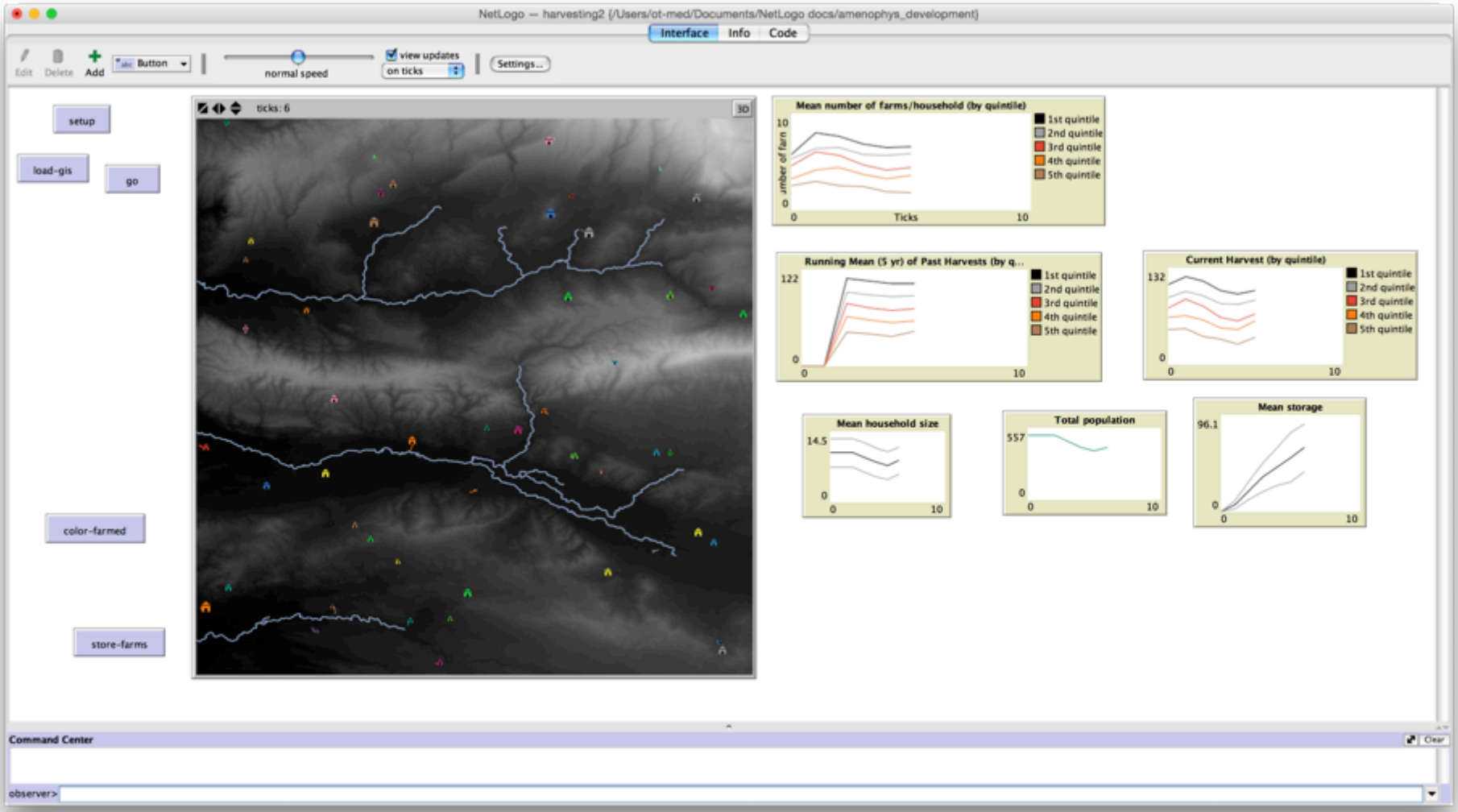
Δ elevation (m)



GRASS GIS - r.landscape.evol

BEHAVIORAL MODEL

Agent-based modeling in **Netlogo**



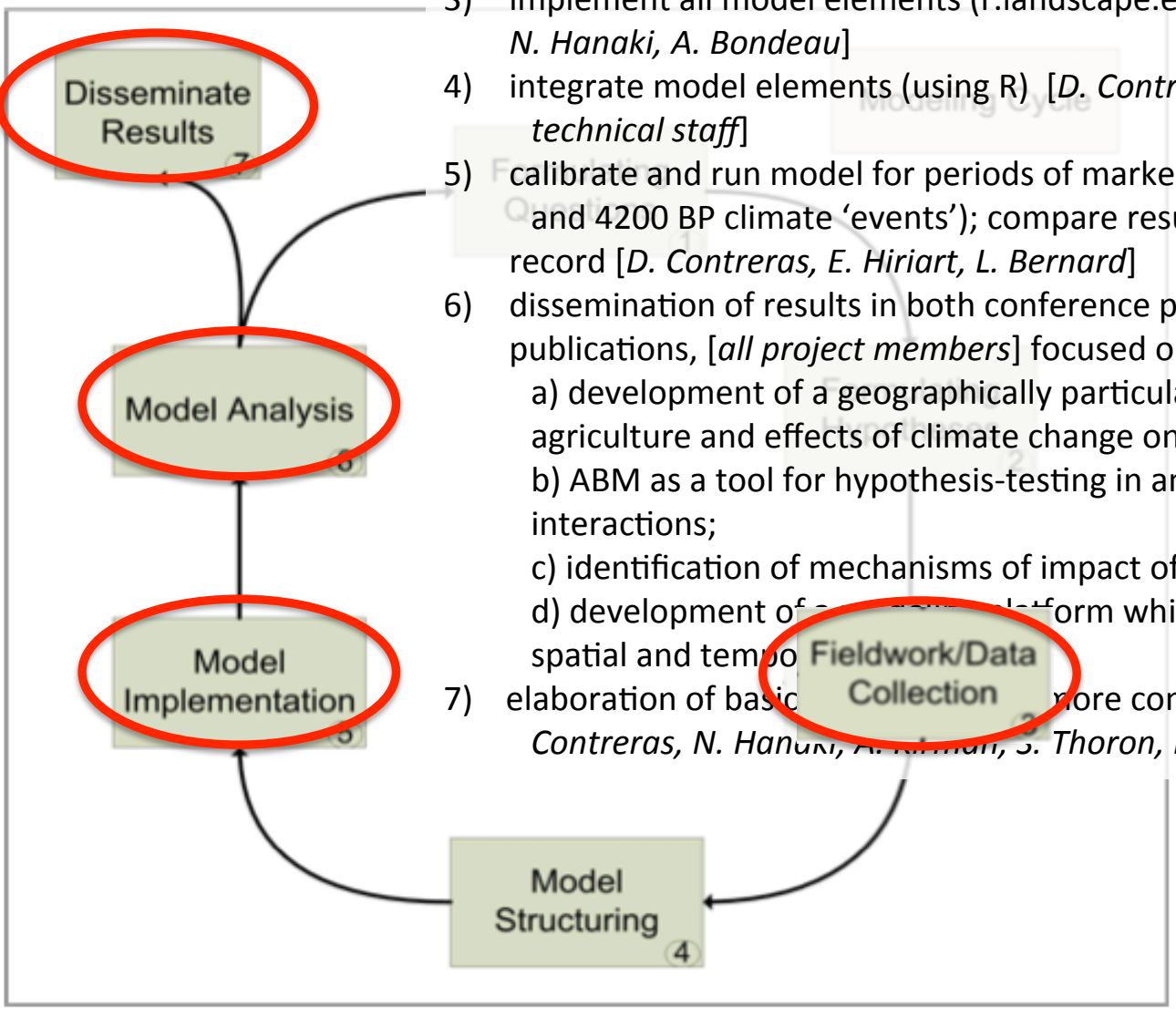
NetLogo — harvesting2 {/Users/ot-med/Documents/NetLogo docs/amenophys_development}

Interface | Info | Code

Find... | Check | Procedures | Indent automatically

```
extensions [ gis ]

turtles-own [ considering locHome potFarms closefarms farming lastFarming thisharvest harvests yields currentharvest pastharvests pastharvests2 availLabor laborcost householdsiz
patches-own [locations livable farmable potLive occupied farmed farmedpatches patchharvests perpatchyields patchyields pastyields thispatchyield yieldsperpatch wet elev slop soi
globals[distanceFarm numPick elevation potYields_wheat slope soil streams sortedlist totalfarms1 totalfarms2 totalfarms3 totalfarms4 totalfarms5 harvests1 harvests2 harvests3 ha

to setup
    clear-all
    create-turtles 50
    ask turtles[
      setxy random-xcor random-ycor
        set locHome patch-here
        set householdsize round (random-normal 10 3) ; then target farms and targetharvests should be a function of size
        set size householdsize / 2
        set shape "house"
        set farming no-patches
        set lastFarming no-patches
        separateHH
    ]


  ask patches [
   set livable list (random 10) (random 10) ; this is arbitrary - to be replaced w/ criteria for household location
   set farmable list (random 10) (random 10) ; replace with wheatyields
   set occupied turtles-here
]
   reset-ticks
end


to separateHH
  ; avoid two household at the same place at initialization
 if any? other turtles-here[
   set xcor xcor + 1
   set ycor ycor + 1
   separateHH
  ]
end

to load-gis
  set elevation gis:load-dataset "srtm30_provencestudyarea.asc" ; projection?
  gis:set-world-envelope-ds gis:envelope-of elevation
  gis:paint elevation 50
  gis:apply-raster  elevation elev
  set slope gis:load-dataset "srtm30_slope.asc"
  gis:apply-raster  slope slop ; irritating to have to keep these variables as both globals and patches-own, with different names for the same thing - but unavoidable?
  set soil gis:load-dataset "soildepths.asc"
  gis:apply-raster  soil soildepth
```

Plans for the remainder of Year 1 and for Year 2



With the model architecture designed and the elements defined, the next steps are:

1) make defensible estimates for empirically-derived model parameters [*E. Hiriart, D. Contreras*]
2) collate and downsample paleoclimate data [*J. Guiot, D. Contreras*]
3) implement all model elements (r.landscape.evol, LPJmL, NetLogo) [*D. Contreras, N. Hanaki, A. Bondeau*]
4) integrate model elements (using R) [*D. Contreras w/ support from OT-Med technical staff*]
5) calibrate and run model for periods of marked climate change (e.g., around 8200 and 4200 BP climate 'events'); compare results to empirical archaeological record [*D. Contreras, E. Hiriart, L. Bernard*]
6) dissemination of results in both conference papers and peer-reviewed publications, [*all project members*] focused on:
   a) development of a geographically particular ABM that can simulate past agriculture and effects of climate change on it;
   b) ABM as a tool for hypothesis-testing in analysing human-environment interactions;
   c) identification of mechanisms of impact of climate 'events' in the past; and
   d) development of a [illegible] platform which can be easily adapted to other spatial and tempo[illegible]
7) elaboration of basic [illegible] more complex sociopolitical formations [*D. Contreras, N. Hanaki, A. [illegible], S. Thoron, L. Bernard*]

Acknowledgements/Core Project Members:

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