

G8: Universitat de Girona – Department of Physics
CS6: Origin and spread of agriculture in prehistoric Europe

Origin and spread of agriculture in Europa... and beyond

J. Fort, N. Isern, J. Pérez-Losada,
T. Pujol, B. Comas, V. L. de Rioja

Universitat de Girona

Simulpast Workshop
Where we are,
where we want to go

Barcelona, 11 March 2015

Outline

- **The Case Study**
- **Interactions between groups**
- **What has been done**
- **Plans for the last leg of the project**
- **Meta-research questions: Possible areas of overlapping**

Where we started

The Case Study



CS6: Origin and spread of agriculture in prehistoric Europe

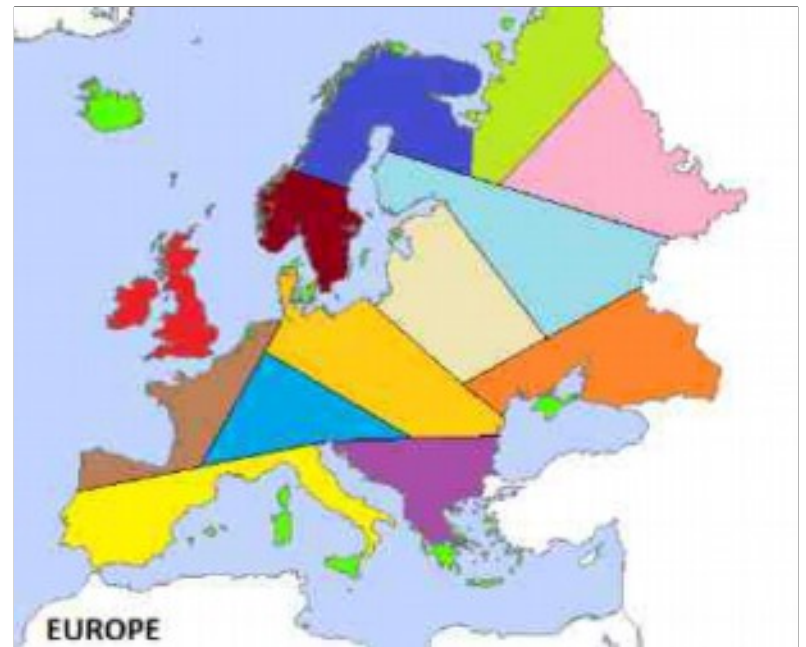
- Aim: "... formulate solutions that can explain some of the local variability at the expanding front of the Neolithic transition..."



Random non-meaningful divisions

Factors of local variability

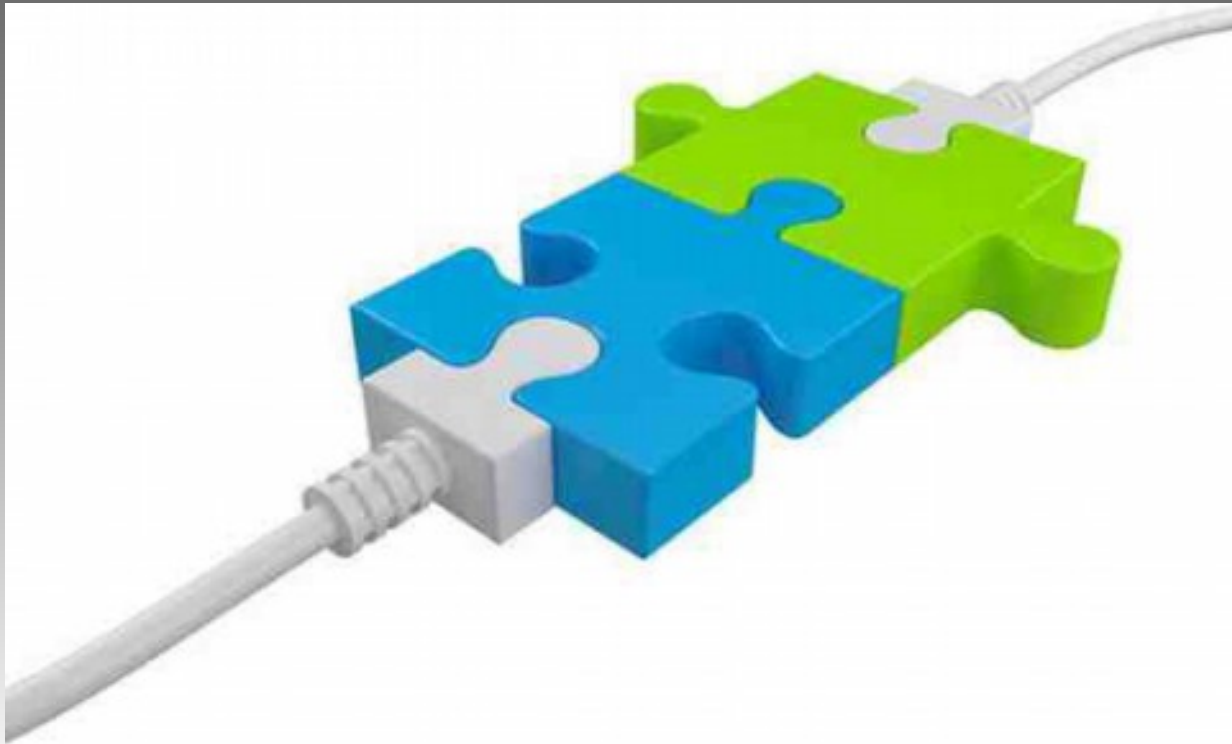
- Geographical factors?
- Mesolithic interaction?
- Cultural diffusion?
- ...



Random non-meaningful divisions

Work connections

Interactions between groups



Interactions with other groups

- G3-G8: Neolithic in the Iberian Peninsula
 - Validation of the reasonability of the hypothesis of a dual entrance in Iberia, one from the north and one from Africa
- G1-G8: Neolithic expansion in southern Africa
 - Data analysis supporting a mostly cultural spread of the Neolithic in southern Africa
- G1-G8: Neolithic expansion in Asia
 - *Work in progress*

Where we are

What has been done so far



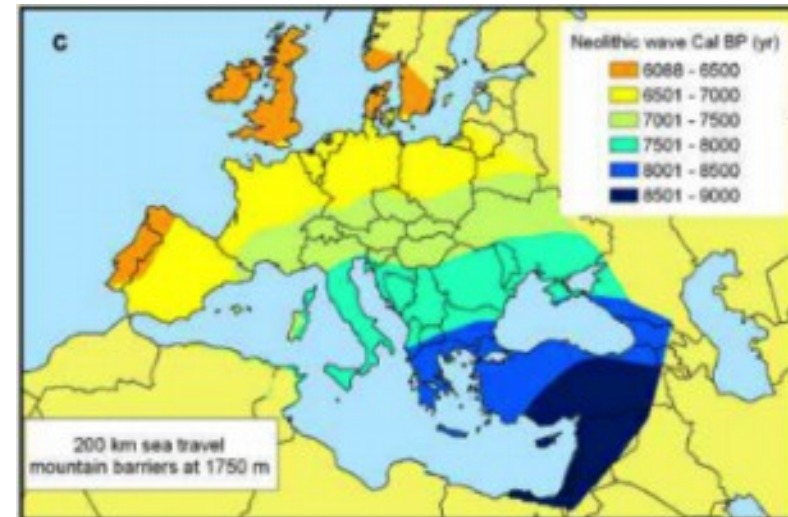
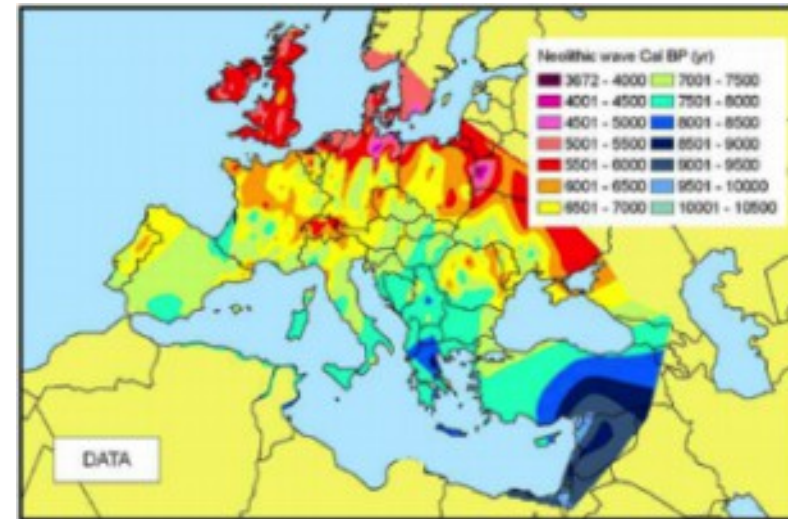
Geographical Factors

- J Fort, T Pujol, M Vander Linden (2012) Modelling the Neolithic transition in the Near East and Europe, 203-219. In *American Antiquity* 77 (2).
- N Isern, J Fort, A F Carvalho, J F Gibaja, J J Ibañez (2014) [The Neolithic Transition in the Iberian Peninsula: Data Analysis and Modeling](#), 447-460. In *Journal of Archaeological Method and Theory* 21 (2).

Origin and spread in Europe

J Fort, T Pujol, M Vander Linden (2012).
American Antiquity 77 (2) 203-219.

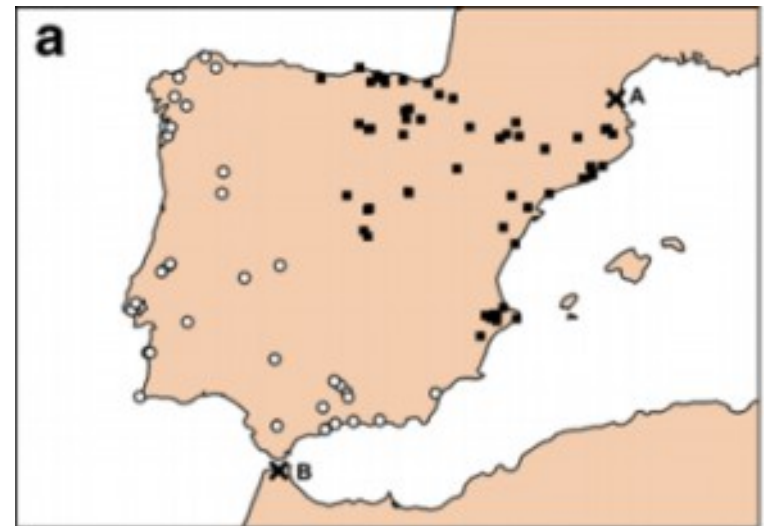
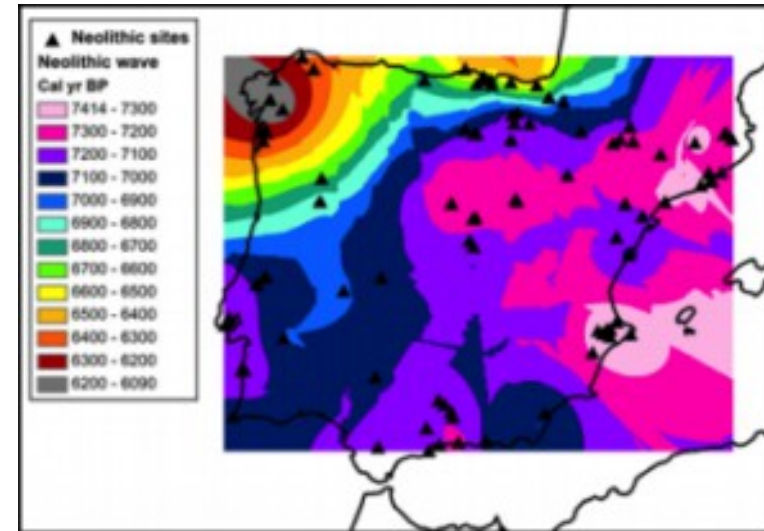
- Development of a computational model.
- Origin of the spread: PPNB/C
- Sea travels are essential (best results 150km).
- Mountains as barriers are negligible.



Entrance paths in Iberia

N Isern, J Fort, AF Carvalho, JF Gibaja, JJ Ibañez (2014). *Journal of Archaeological Method and Theory* 21 (2) 447-460.

- *Collaboration with G3*
- Database compilation
- GIS analysis, statistical analysis, and computational approach
- Data agrees with the viability of a dual entrance in Iberia



Mesolithic Interaction

- N Isern, J Fort (2010)
Anisotropic dispersion, space competition and the slowdown of the Neolithic transition
, 123002. In *New Journal of Physics*.
- N Isern, J Fort (2011)
Cohabitation effect on the slowdown of the Neolithic expansion,
58002. In *EPL (Europhysics Letters)* 96 (5).
- N Isern, J Fort (2012)
Modelling the effect of Mesolithic populations on the slowdown of the Neolithic transition
, 3671-3676. In *Journal of Archaeological Science* 39 (12).
- N Isern, J Fort, M Vander Linden (2012)
Space competition and time delays in human range expansions [Appl](#)

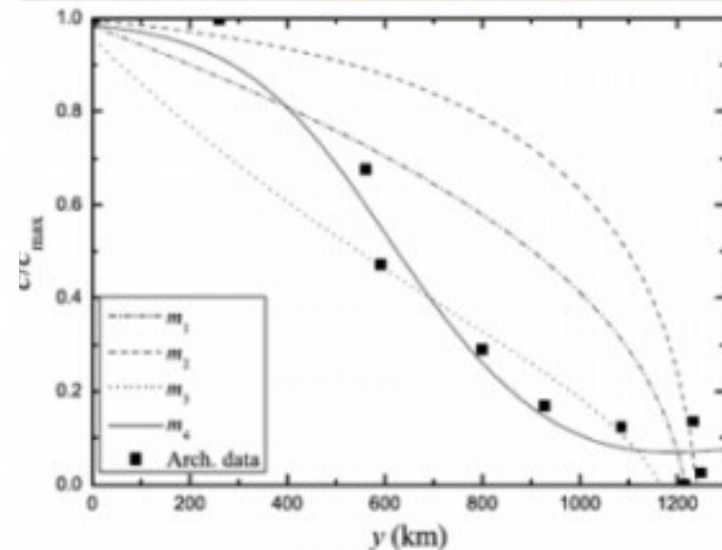
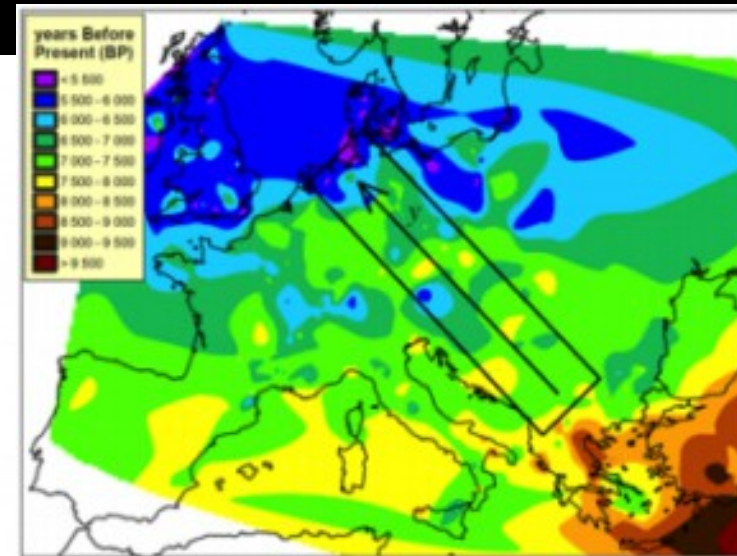
Competition for space and resources

- Slowdown of the Neolithic expansion → Competition?
- Development of reaction-diffusion models
- Competition reduces reproduction

$$F = aN \left(1 - \frac{N}{N_{max}} - \frac{M}{M_{max}} \right)$$

- Competition hinders dispersion

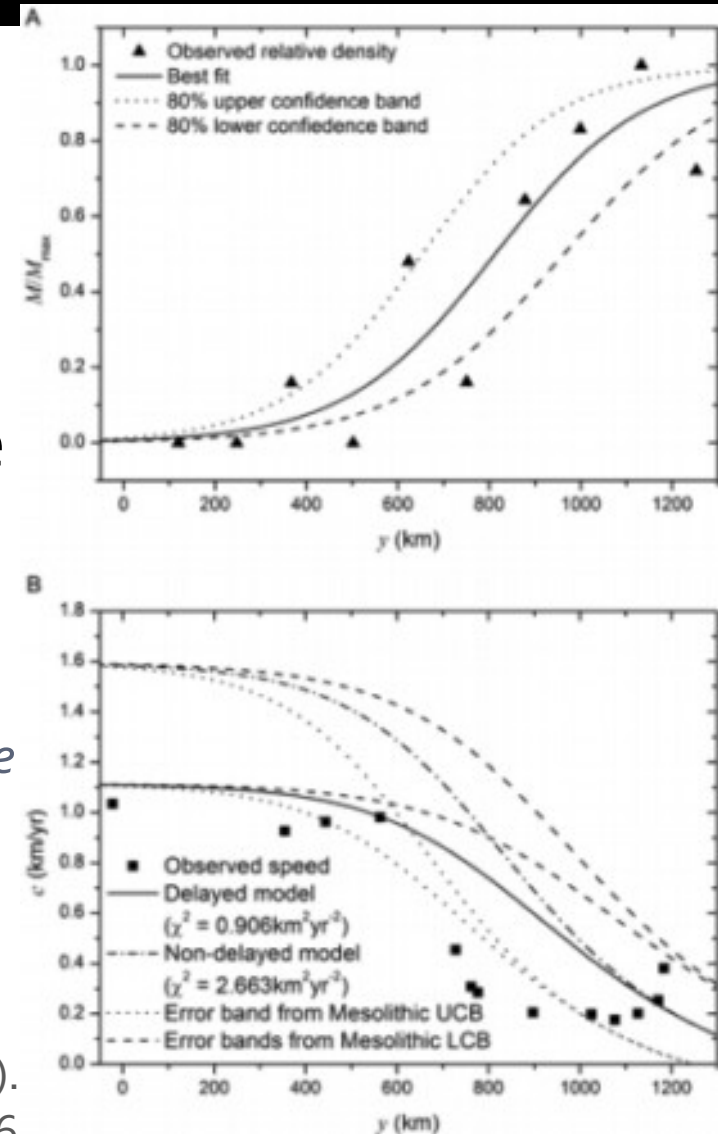
$$\phi = \frac{1}{2\pi} \left[1 - \frac{\partial M / \partial y}{M - M_{max}} \Delta \sin \theta \right] \psi(\Delta)$$



Slowdown of the Neolithic expansion

- Available Mesolithic data agrees with assumption and yields consistent results. *EPL, PLoS One*
- The effect on reproduction is more important. *J Archaeol Sci*
- Cohabitation and time-delay effects must be considered. *PLoS One*
- *The slowdown can be explained as a result of population competition.*

N Isern, J Fort & M vander Linden (2012).
PLoS One, 7 (12) e51106.



Time-delayed Models

- Daniel R. Amor, Joaquim Fort (2013)
Lag-driven motion in front propagation, 4946-4955. In *Physica A: Statistical Mechanics and its Applications* 392 (20).
 - Time-delayed models can describe different systems (e.g., human dispersals, virus infections)
 - One can obtain a general approximate speed expression

$$c = \sqrt{2D/T}$$

- Neolithic predictions are consistent

Spatial Cultural Drift

- J Pérez-Losada, J Fort (2011)
Spatial dimensions increase the effect of cultural drift, 1294-1299. In *Journal of Archaeological Science* 38 (6).
 - Reduction of crop diversity with Neolithic expansion → LBK expansion
 - Cannot be explained by climatic factors
 - Adding spatial dimension to cultural drift models can explain the observations
 - Computational modelling approach with culture as a binary string

Cultural Diffusion

- J Fort (2011) [Vertical cultural transmission effects on demic front propagation: Theory and application to the Neolithic transition in Europe](#), 056124. In *Physical Review E* 83 (5).
- Joaquim Fort (2012) [Synthesis between demic and cultural diffusion in the Neolithic transition in Europe, 18669-18673](#). In *Proceedings of the National Academy of Sciences* 109 (46).
- A Jerardino, J Fort, N Isern, B Rondelli (2014) [Cultural diffusion was the main driving mechanism of the neolithic transition in southern Africa.](#), e113672. In *PloS one* 9 (12).

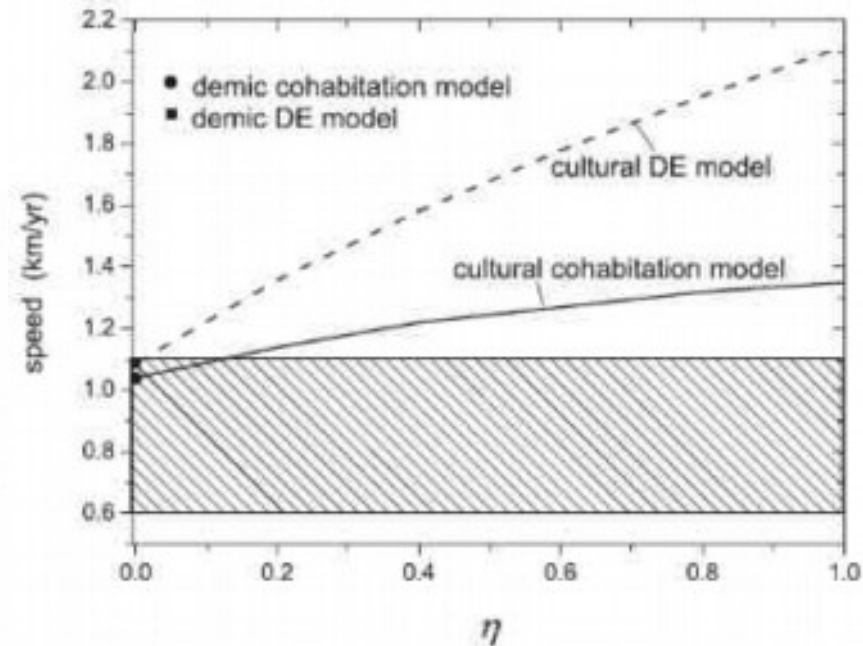
Vertical cultural transmission

J Fort (2011). *Physical Review E* 83 (5) 056124.

- VCT \leftrightarrow interbreeding
- Lotka-Volterra terms ($I_N = \Gamma p_N p_P$, $I_P = -\Gamma p_N p_P$) are inadequate
- New transmission terms: (limited by the smaller population)

$$I_N = R_{0N} \eta \frac{p_N p_P}{p_N + p_P}$$

$$I_P = -R_{0P} \eta \frac{p_N p_P}{p_N + p_P}$$



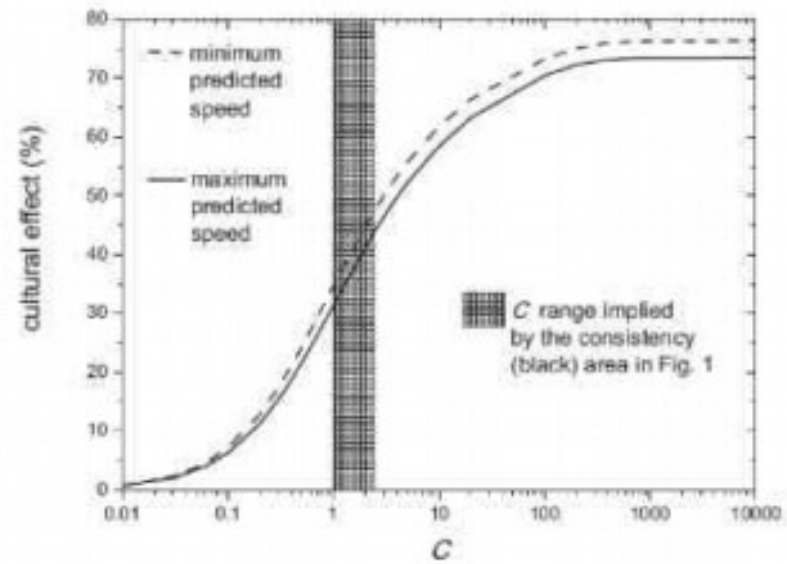
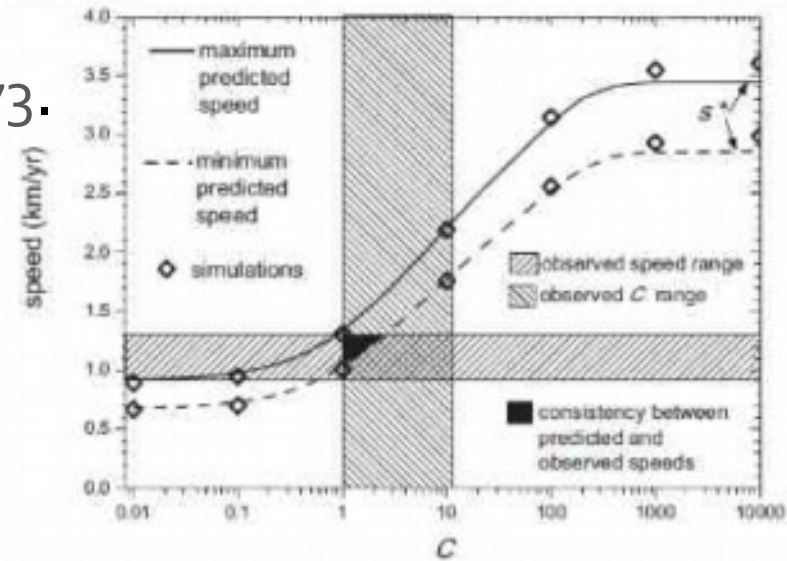
Horizontal cultural diffusion

J Fort (2012). *PNAS* 109 (46) 18669-18673.

- Interaction term

$$I = f \frac{p_N p_P}{p_N + \gamma p_P}$$

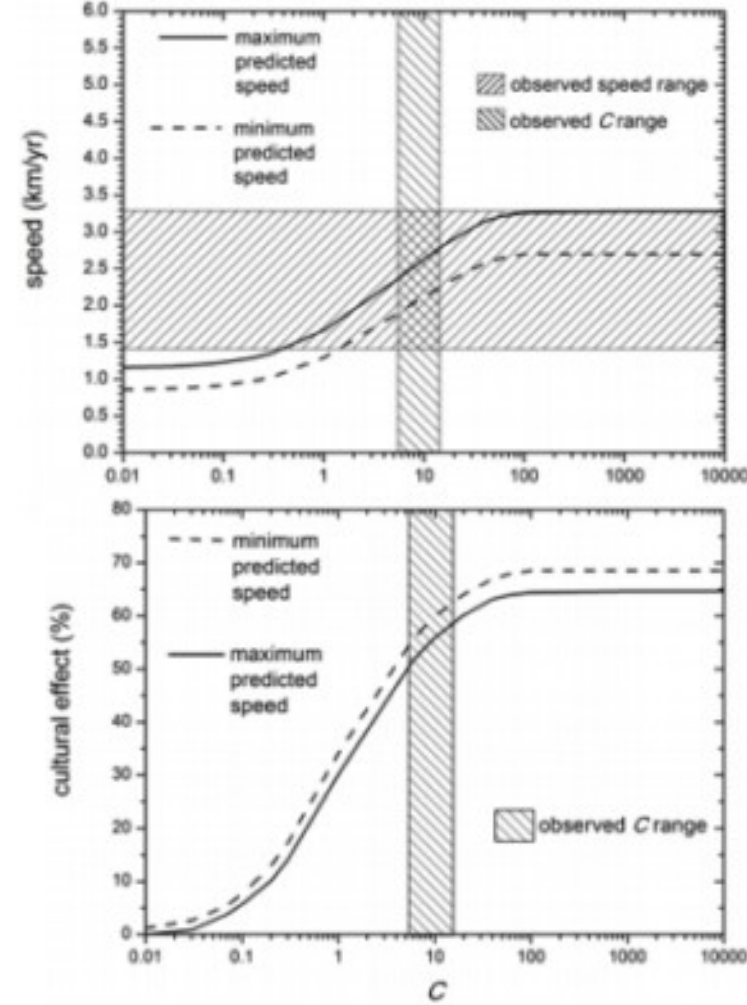
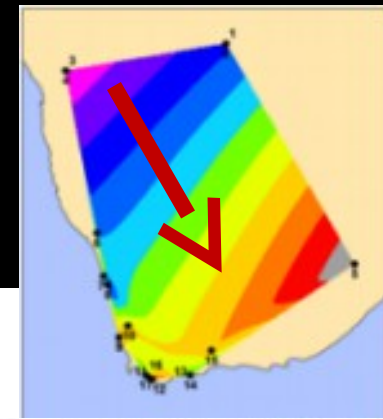
- If $p_N \ll p_P$, $I = C p_N$
- C : number of hunter gatherers converted per farmer.
- Cultural diffusion explains about 40% of the rate of spread of the Neolithic in Europe.



Cultural diffusion in southern Africa

A Jerardino, J Fort, N Isern, B Rondelli (2014).
PloS One 9 (12) e113672.

- Early Neolithic database
- GIS and statistical analysis: speed estimates
- Applying previous model: Cultural diffusion explains about 60% of the rate of spread of the Neolithic in southern Africa.
- Possible easier adoption of herding/pastoralism



Spin-off: Linguistics

- Joaquim Fort, Joaquim Pérez-Losada (2012) Front Speed of Language Replacement, 755-772. In *Human Biology* 84 (6).
- N. Isern, J. Fort (2014) Language extinction and linguistic fronts, 20140028-20140028. In *Journal of The Royal Society Interface* 11 (94).

Language competition and replacement speeds

■ Fort & Pérez-Losada, *Hum Biol* 84 (6) 755-772 (2012)

- Spatial dimension for language competition.
- Language competition by Abrams & Strogatz, *Nature* 2003.

$$\dot{p}_A = \gamma(sp_A^\alpha p_B - (1-s)p_A p_B^\alpha)$$

■ Isern & Fort, *J Roy Soc Interface* 11 20140028 (2014)

- Alternative language competition model.

$$\dot{p}_A = \gamma p_A^\alpha p_B^\beta$$

- Predicts consistent front speeds for modern Welsh-English retreating border.

Where we want to go

Plans for the last leg of the project



Planned lines of work

- **J Fort**

Cultural diffusion / Demic diffusion

- **J Pérez-Losada**

Linguistic drift

- **N Isern**

Neolithic in Western Mediterranean

- **B Comas**

Neolithic expansion in Asia

Meta-research questions: Possible areas of overlapping



Meta-research questions

- **Concepts developed and to be developed**
 - Demic / Demic-cultural spread
 - Cultural drift / Phonetic drift
 - Competition
 - Maritime colonization demic model
- **Theoretical framework**
 - Front propagation theory
 - Neolithic waves of advance
- **Methodological approach**
 - Integrodifference equations
 - Simulations (Fortran); output visualization with GIS

A word cloud featuring the phrase "thank you" in multiple languages. The words are arranged in a roughly heart-like shape, with "thank you" being the largest and most prominent. Other visible words include: "danke", "謝謝", "ngiyabonga", "teşekkür ederim", "gracias", "moichakkeram", "go raibh maith agat", "sukriya", "kop khum krap", "arigato", "lakk", "dakujem", "mercii", "merci", "спасибо", "dziękuje", "obrigado", "sagolun", "kop khum krap", "arigato", "lakk", "dakujem", "mercii", "merci", "감사합니다", "mochchakkeram", "teşekkür ederim", "ngiyabonga", "danke", "謝謝", "gracias", "moichakkeram", "go raibh maith agat", "sukriya", "kop khum krap", "arigato", "lakk", "dakujem", "mercii", "merci", "спасибо", "dziękuje", "obrigado", "sagolun", "kop khum krap", "arigato", "lakk", "dakujem", "mercii", "merci", "감사합니다".