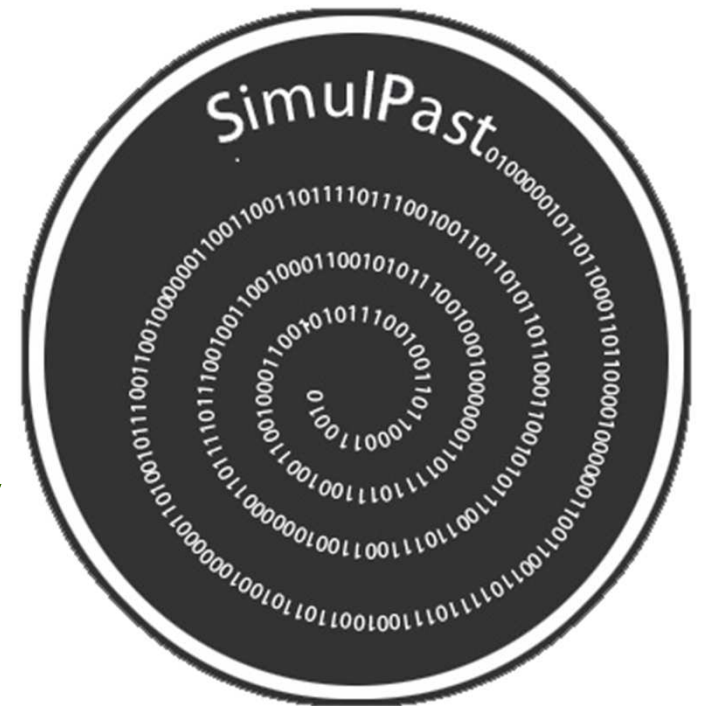
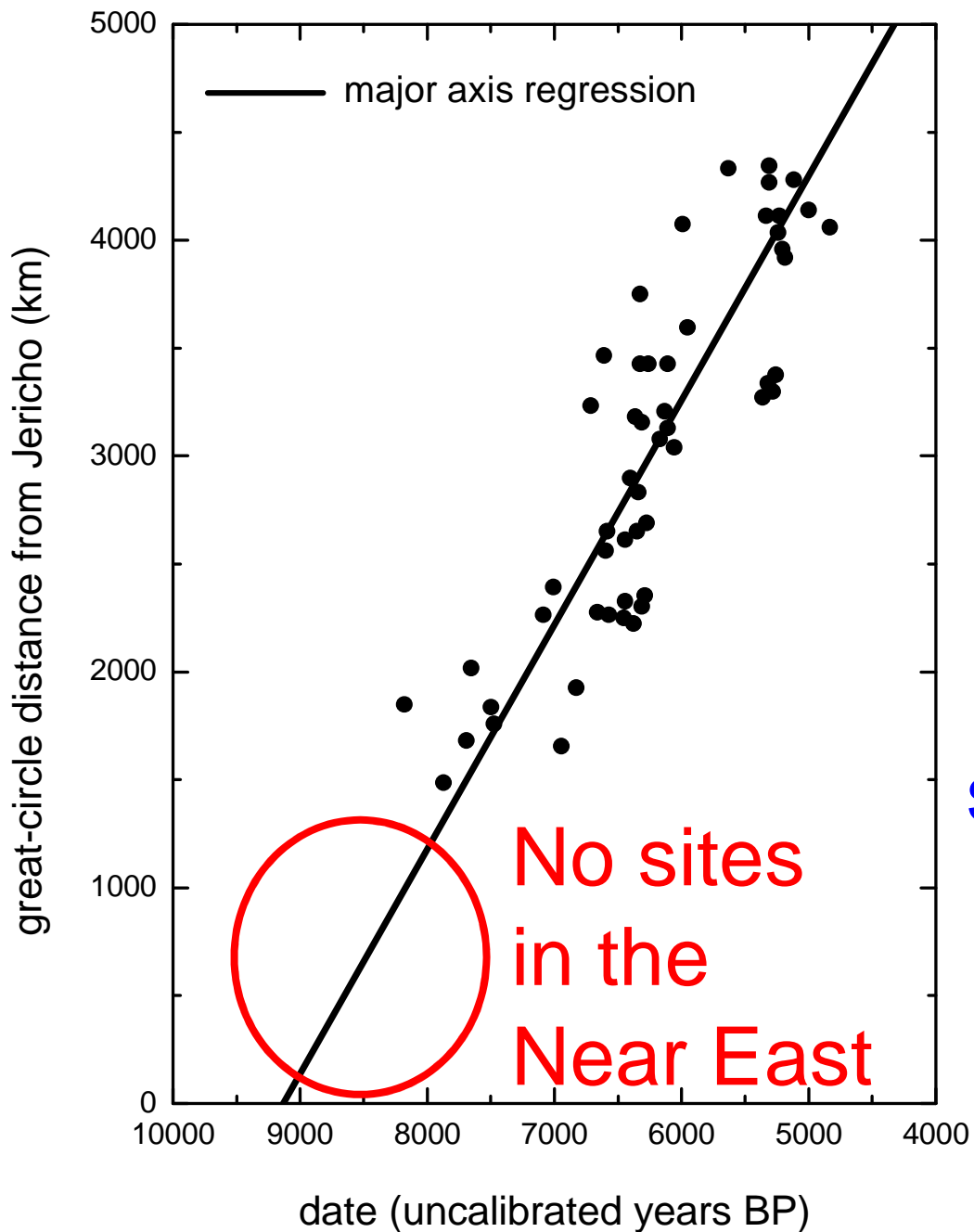


# Population spread and cultural transmission in Neolithic transitions

Joaquim Fort (UdG)  
Antonieta Jerardino (UPF)  
Neus Isern (UAB)  
Bernardo Rondelli (UPF)

Simulation the Past to Understand Human History  
Social Simulation Conference  
UAB, September 3<sup>rd</sup> 2014



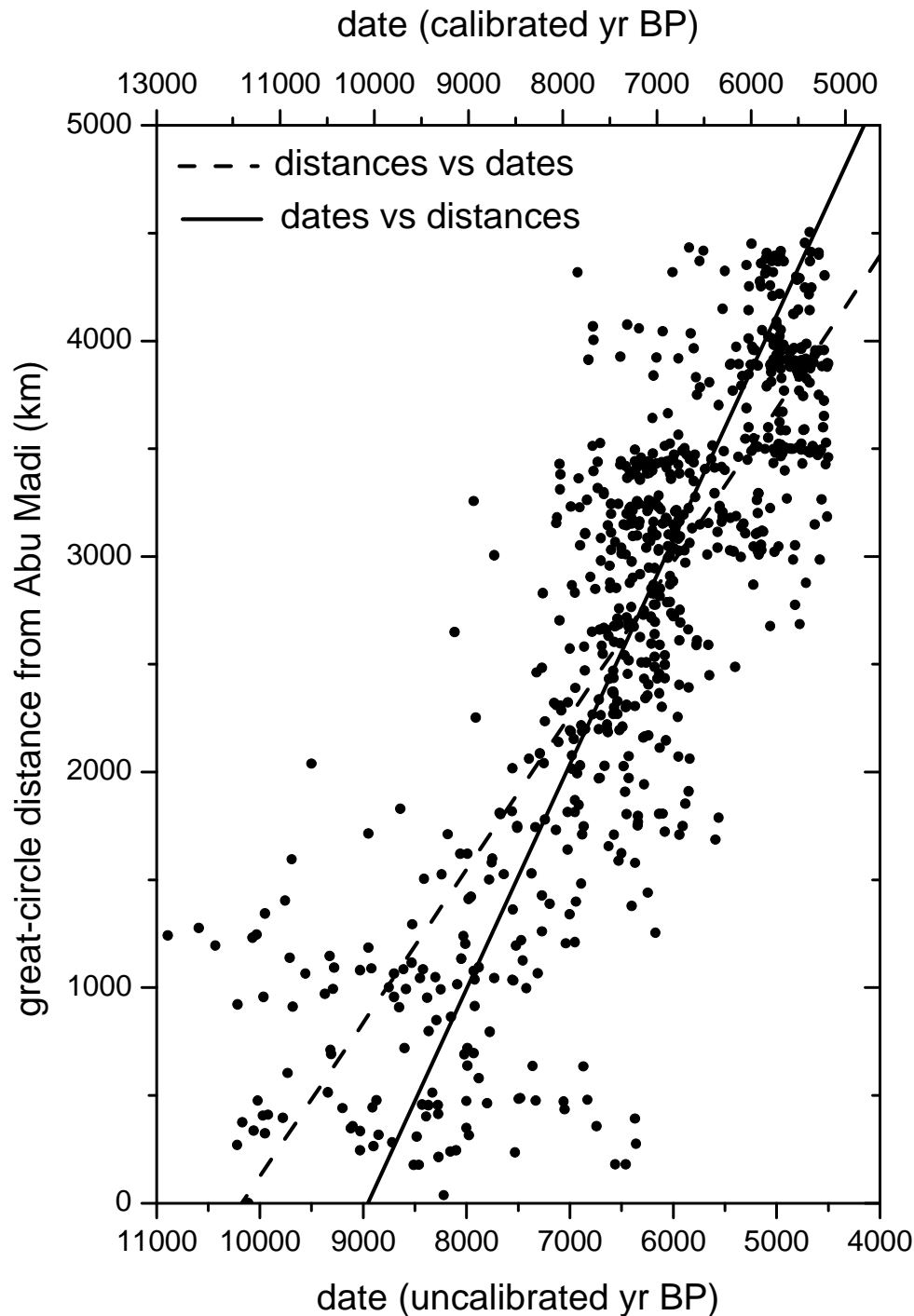


Ammerman &  
Cavalli-Sforza  
(1971)

53 sites in Europe

speed =  $1.0 \pm 0.2$  km/yr

$r = 0.89$  (Jericho,  
highest- $r$  origin)



Pinhasi, Fort &  
Ammerman,  
*PLoS Biol.* (2005)

735 sites in Europe & the  
Near East

speed =  $1.0 \pm 0.4$  km/yr

$r = 0.83$  (highest- $r$   
origins for great circles &  
shortest paths)

# Models of Neolithic transitions

**1. Demic model:** it assumes that they were mainly driven by the spread of farming populations.

**2. Cultural model:** it assumes that they were mainly a spread of ideas (transmission of domestic plants, animals and knowledge from farmers to hunter-gatherers).

Can a demic and/or cultural model describe the archaeological data?



# Ammerman & Cavalli-Sforza (1973)

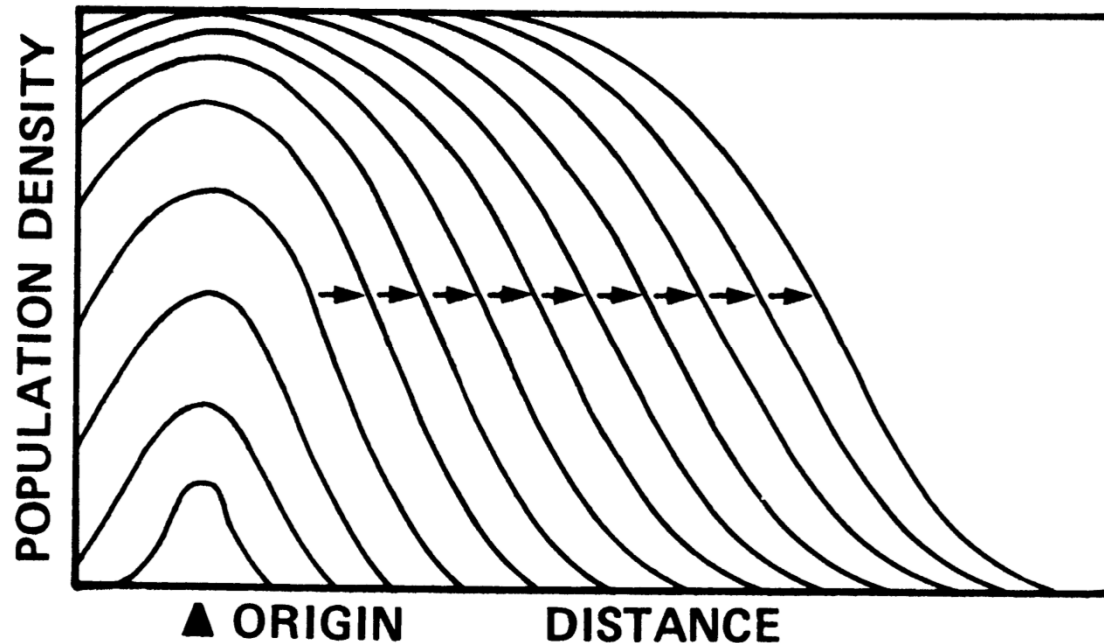


FIGURE 5.2. Fisher's model of a population wave of advance. This graphic representation shows the rise in local population density expected with increasing distance

Quantitative  
demic  
model

speed:

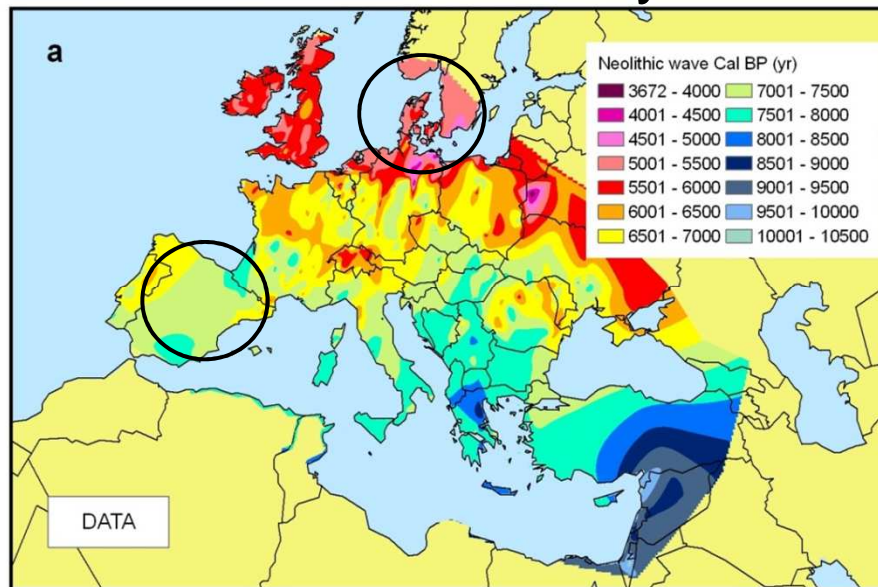
$$v_{Fisher} = \sqrt{\frac{r m}{T}}$$

Preindustrial farmers :

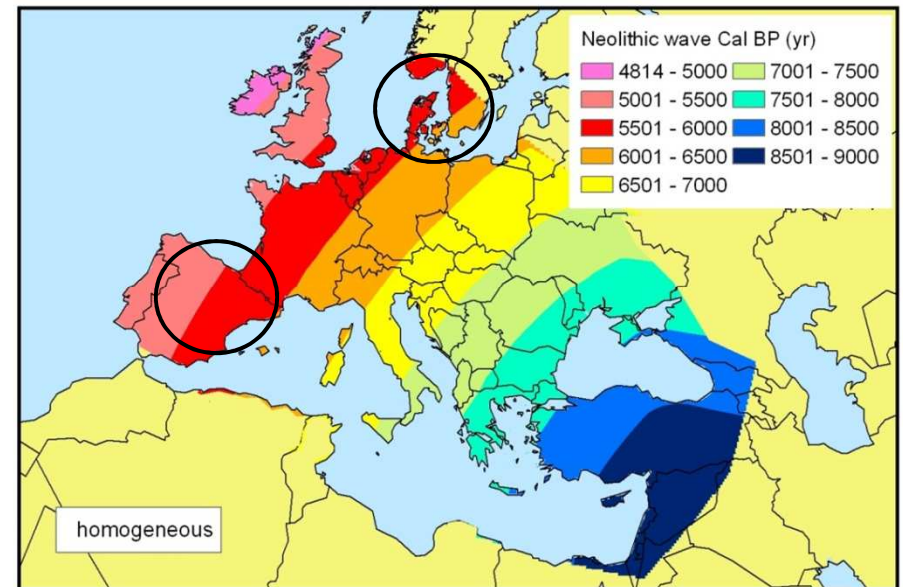
$$\left. \begin{array}{l} \text{Reproduction : } r = 0.032 \text{ yr}^{-1} \\ \text{Mobility : } m = 1544 \text{ km}^2 \\ \text{Generation time : } T = 25 \text{ yr} \end{array} \right\} \rightarrow v_{Fisher} = 1.4 \text{ km/yr}$$



DATA → 1 km/yr



HOMOGENEOUS MODEL → 1 km/yr



The homogeneous model agrees with the average observed speed but not with local features (circles).

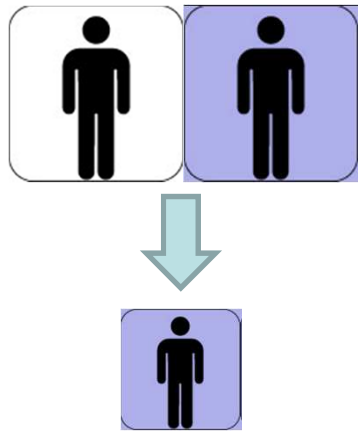
Non-homogeneous models  
(not explained in this talk)  
can improve the agreement

Fort, Pujol & vander Linden, *Amer. Antiq.* 2012

Isern, Fort & vander Linden, *PLoS One* 2012

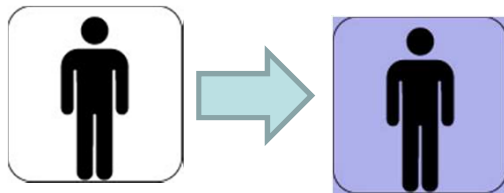
# Cultural models

Cultural transmission takes 2 forms



1) Vertical transmission is due to interbreeding between farmers and hunter-gatherers

Small effect (Fort, *Phys. Rev. E* 2011)



2) Horizontal/oblique transmission is due to acculturation (copying)

We focus on this case

# Acculturation

Cavalli-Sforza & Feldman (*book* 1979)

Boyd & Richerson (*book* 1985)

Fort (*PNAS* 2012)

Population numbers after ( $P'$ ) and before ( $P$ )  
cultural transmission (during 1 generation):

$$\left\{ \begin{array}{l} \text{farmers (F): } P'_F = P_F + f \frac{P_F P_H}{P_F + \gamma P_H} \\ \text{hunter - gatherers (H): } P'_H = P_H - f \frac{P_F P_H}{P_F + \gamma P_H} \end{array} \right.$$

$f$  = intensity of cultural transmission

$\gamma$  = preference of  $H$ s to copy  $F$ s rather than  $H$ s (if  $\gamma < 1$ )

Lotka-Volterra eqs. ( $P'_F = P_F + \eta P_F P_H$ ) are not realistic as:

- they are not derived from cultural transmission theory

- they yield, e.g.: if  $P_H \rightarrow \infty$ , then  $\frac{P'_F - P_F}{P_F} \rightarrow \infty$  !!



Fort (PNAS 2012)

$$\begin{cases} P'_F = P_F + f \frac{P_F P_H}{P_F + \gamma P_H} \approx P_F + C P_F \\ P'_H = P_H - f \frac{P_F P_H}{P_F + \gamma P_H} \approx P_H - C P_F \end{cases}$$

$$C = \frac{f}{\gamma}$$

if  $P_H \gg P_F$ , then

$\frac{P'_F - P_F}{P_F} = C$  is the number of  $H$ s converted by farmer  
 $\frac{P'_F - P_F}{P_F}$  is not  $\infty$ , in contrast to Lotka-Volterra eqs.

The front speed does not depend on  $f$  and  $\gamma$  separately, but only on  $C = \frac{f}{\gamma}$ .

# Demic-cultural models

Fort (*PNAS* 2012)

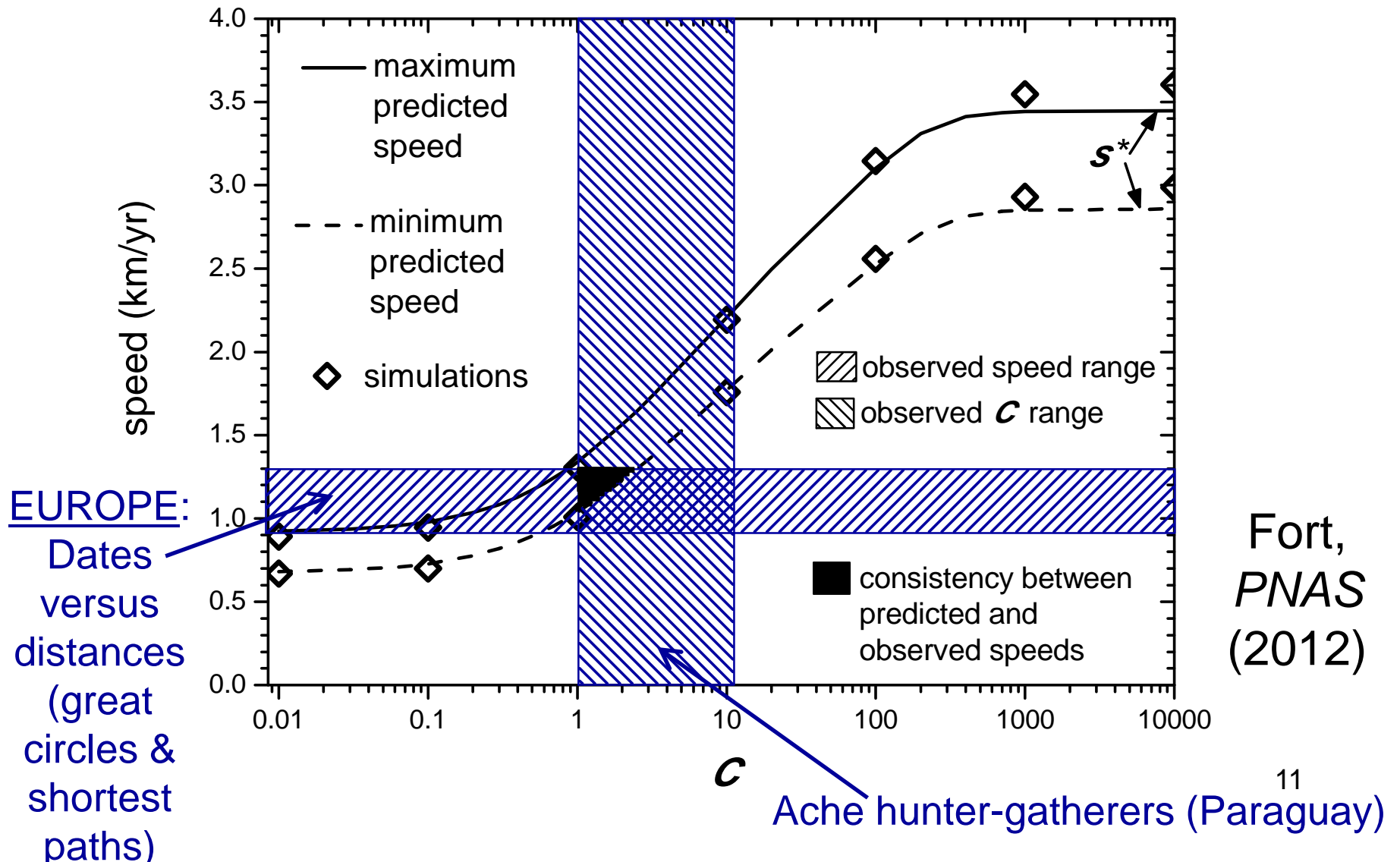
## Steps:

1. reproduction (logistic)
2. cultural transmission (horizontal/oblique)
3. dispersal (distance kernel)

The order of events does not change the speed

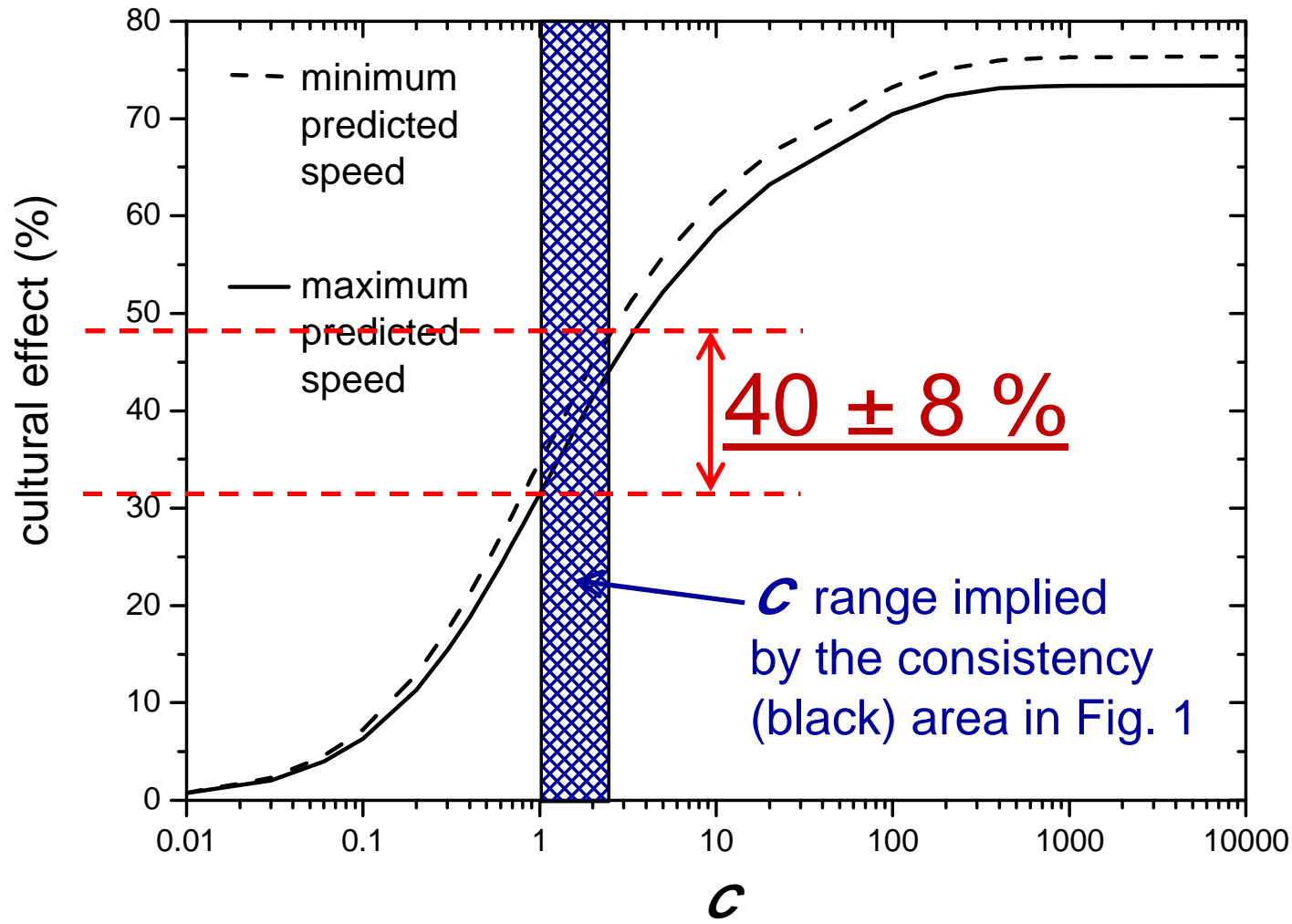
This cycle is repeated many times (once per generation)

# Effect of acculturation intensity $C$ on the front speed in Europe



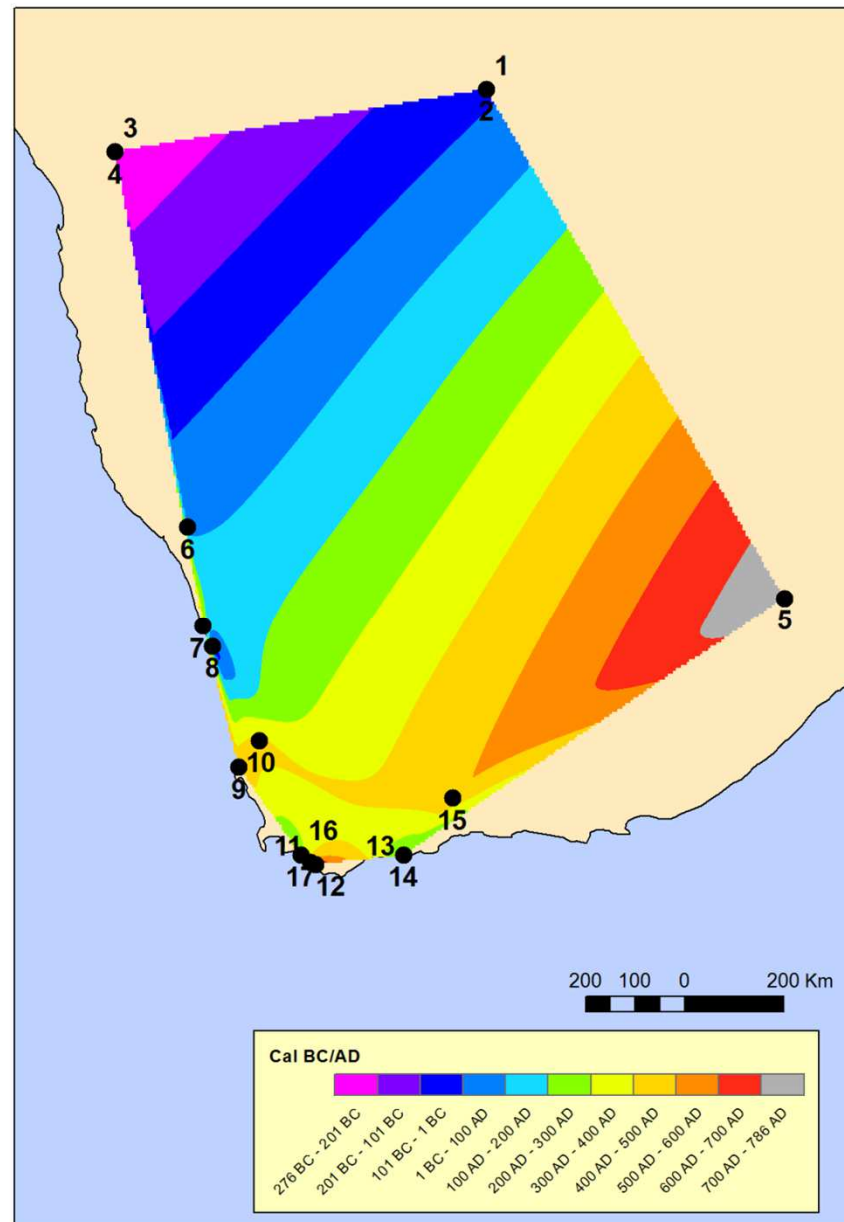
# Effect of cultural diffusion in Europe

$$\text{Effect (\%)} = (\text{speed} - \text{demic speed}) / \text{speed} \cdot 100$$



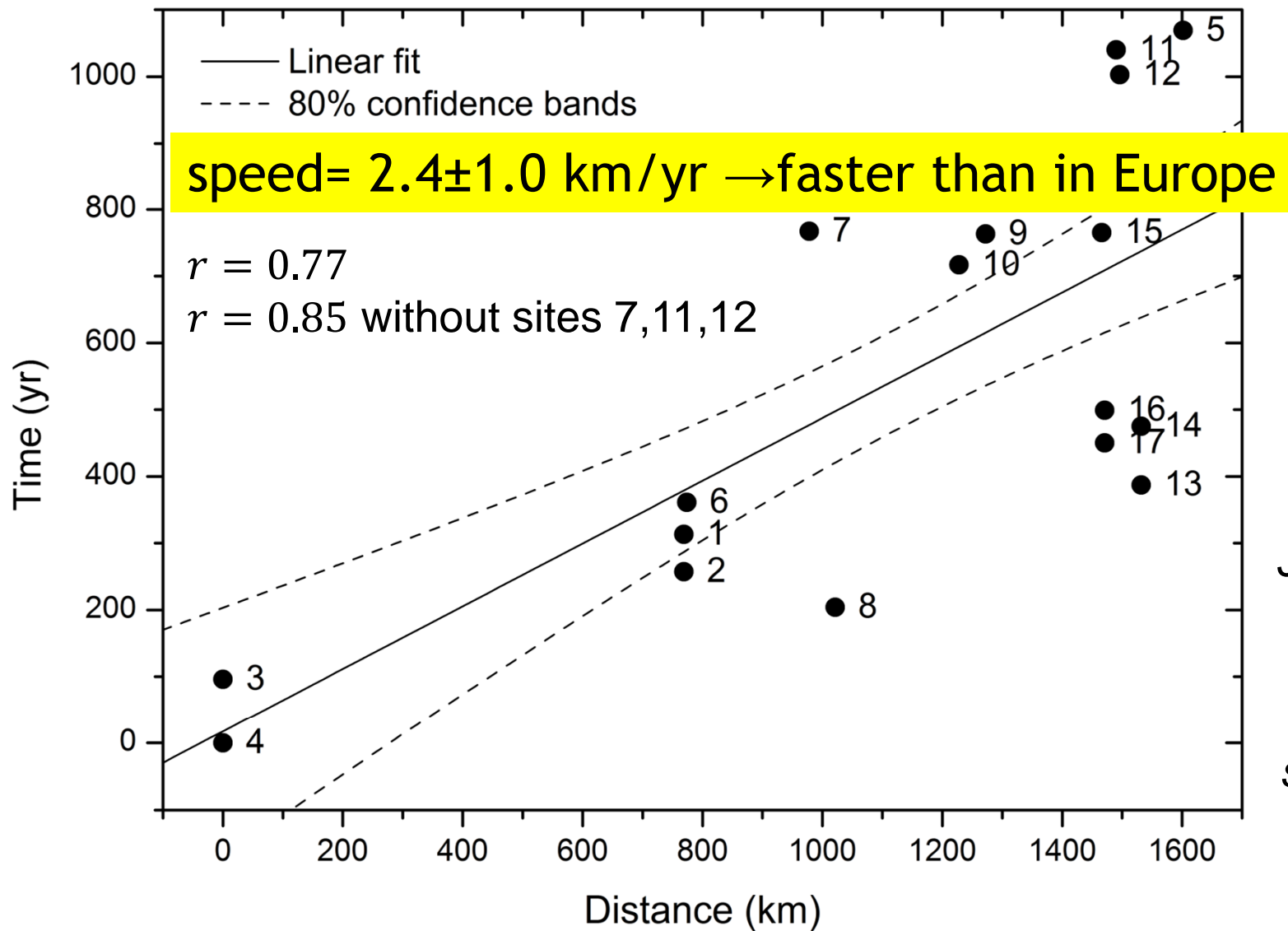
Fort,  
*PNAS*  
(2012)

# The Neolithic transition in southern Africa



Jerardino,  
Fort,  
Isern,  
Rondelli,  
*submitted*  
(2014)

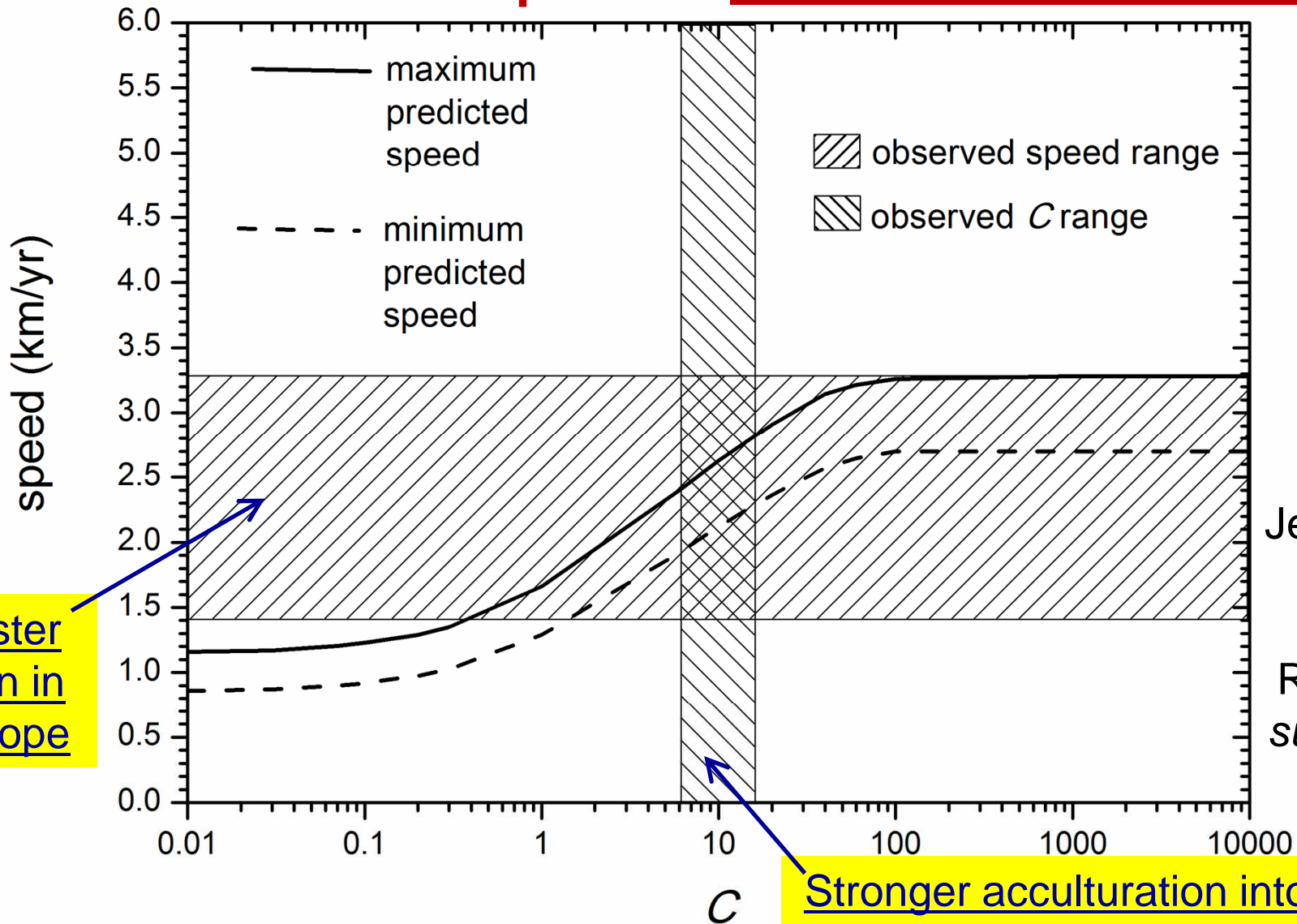
# The Neolithic transition in southern Africa



Jerardino,  
Fort,  
Isern,  
Rondelli,  
*submitted*  
(2014)



# Effect of acculturation intensity $C$ on the front speed in southern Africa



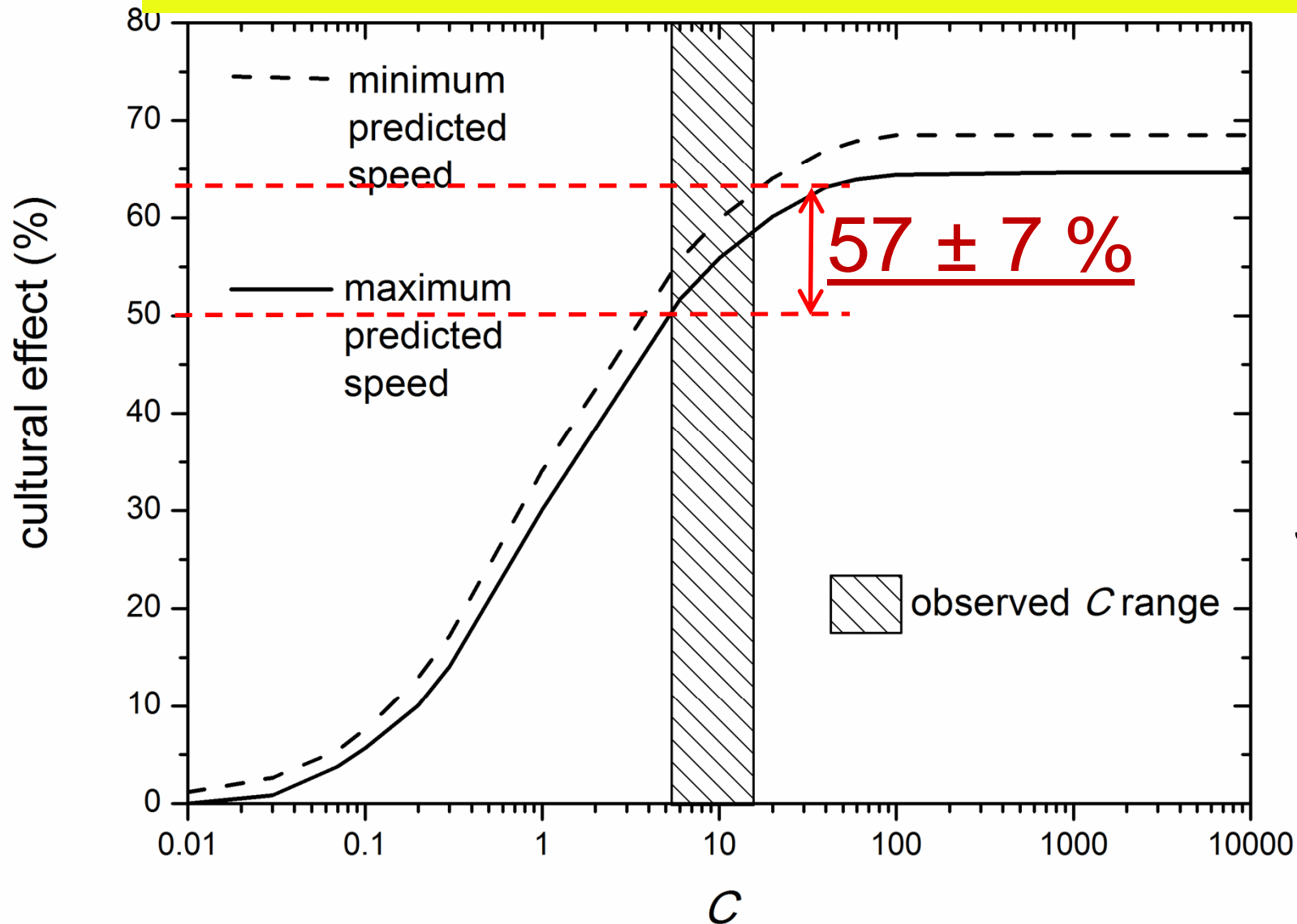
Faster than in Europe

Stronger acculturation into herding than into farming

Jerardino, Fort, Isern, Rondelli, submitted (2014)

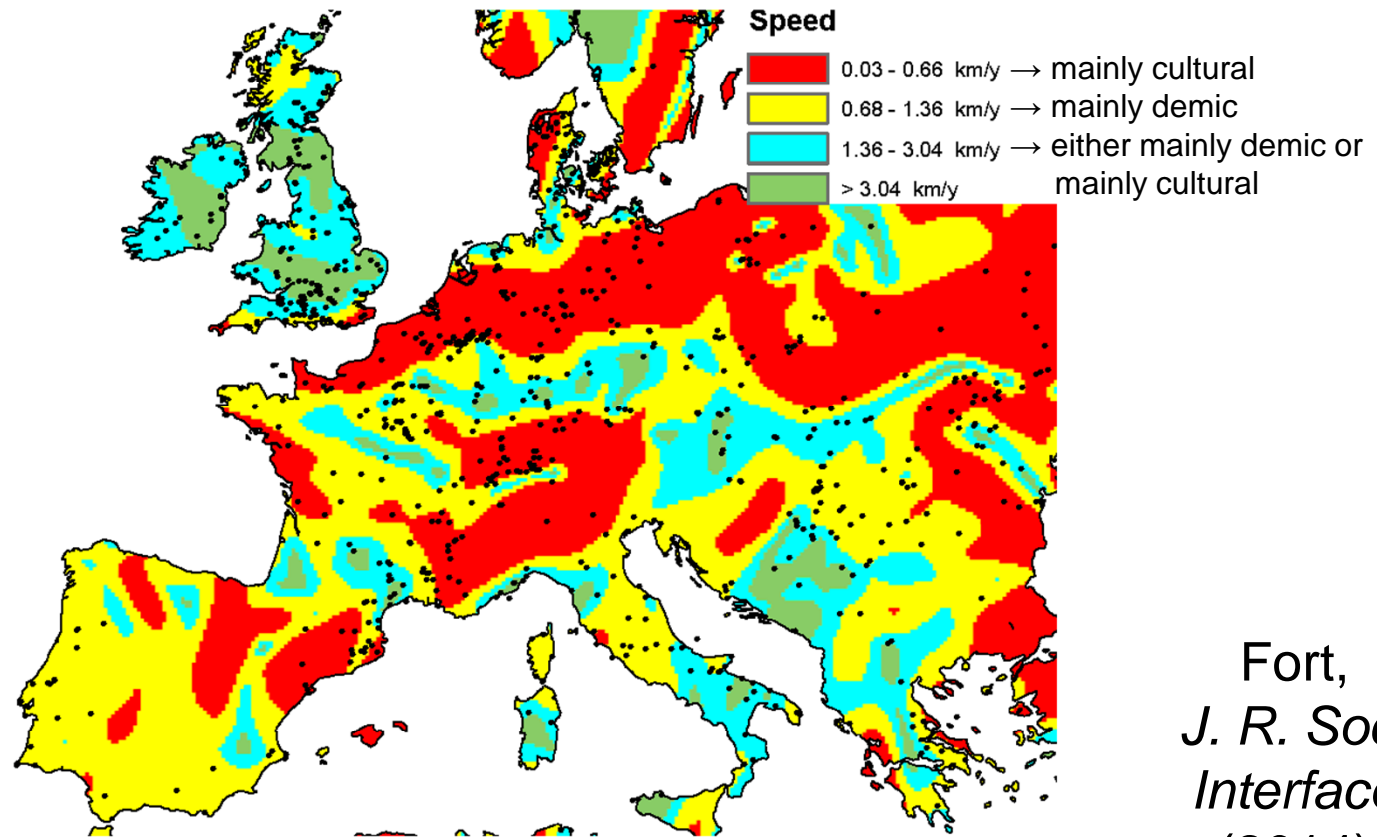
# Effect of cultural diffusion in southern Africa

$$\text{Effect (\%)} = (\text{speed} - \text{demic speed}) / \text{speed} \cdot 100$$



Jerardino,  
Fort,  
Isern,  
Rondelli,  
*submitted*  
(2014)

# Local features in Europe



Fort,  
*J. R. Soc.  
Interface*  
(2014)

It would help a lot to measure prehistoric dispersal kernels, if possible (Genetics?)