Demic and cultural models of Neolithisation

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22nd Neolithic seminar: Modelling the process of Neolithisation
Univ. of Ljubljana
November 6th, 2015

SimulPast

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Models of Neolithic transitions

- Demic diffusion = spread of farming populations = dispersal + net reproduction

- Cultural diffusion = spread of ideas = transmission of plants, animals and knowledge from farmers to hunter-gatherers (acculturation).

- Demic-cultural models

Cultural models

Population numbers after *(P′)* and before *(P)* cultural transmission (during 1 generation):

$$
\begin{cases}
\text{farmers } (F): & P_F' = P_F + f \dfrac{P_F P_H}{P_F + \gamma P_H} \\[2em]
\text{hunter} - \text{gatherers } (H): & P_H' = P_H - f \dfrac{P_F P_H}{P_F + \gamma P_H}
\end{cases}
$$

The wave-of-advance speeds depends only on $C = f/\gamma$. This is not surprising since when the first farmers arrive:

$$P_F \approx 0 \rightarrow P_F' \approx P_F + C P_F$$

C = number of hunter-gatherers becoming farmers per generation. We call C the acculturation intensity.
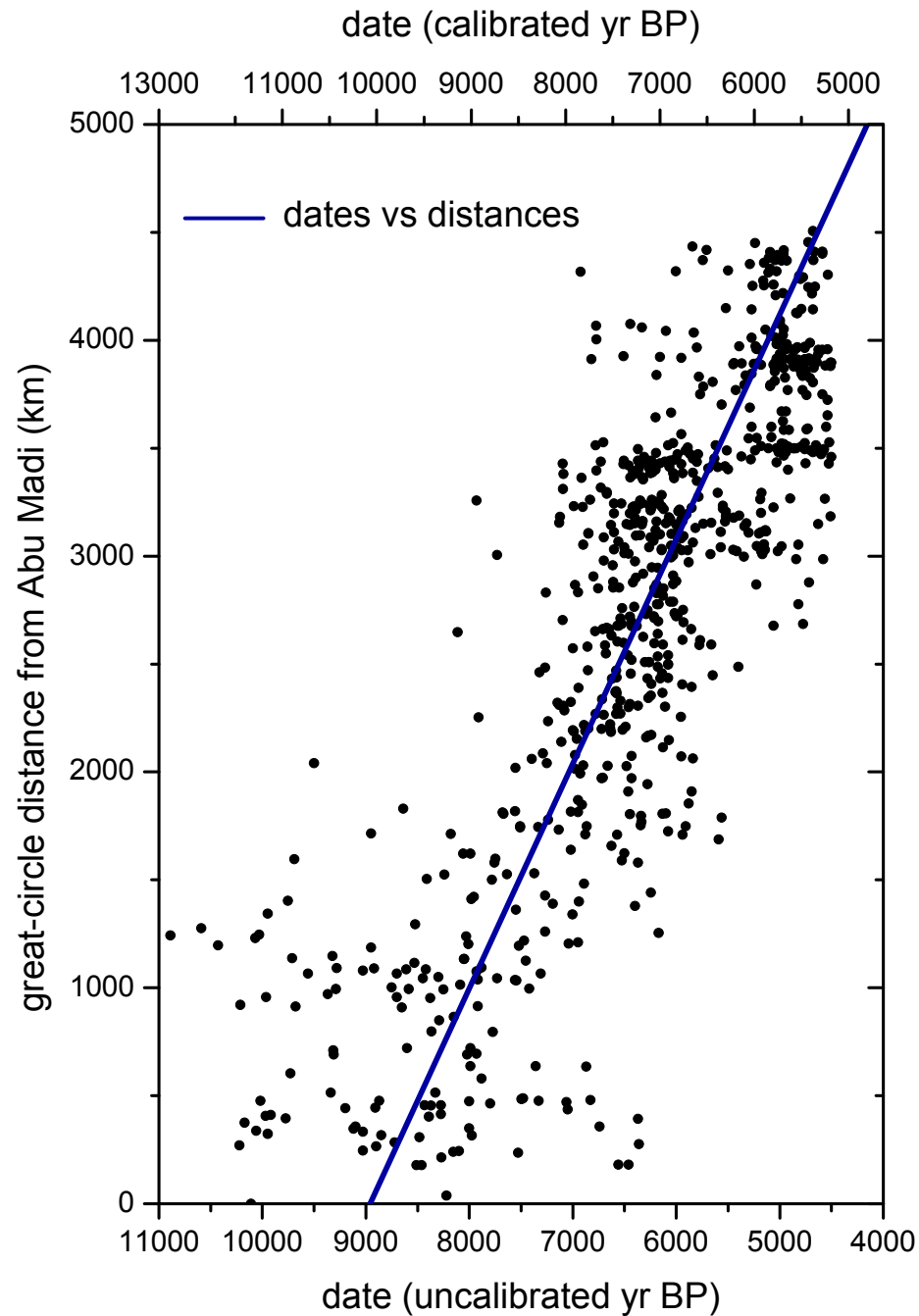
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Demic-cultural models

Steps:

1. reproduction (logistic)
2. cultural transmission (acculturation)
3. dispersal (distance kernel)

The order of steps does not change the speed

This cycle is repeated many times (once per generation)

Up to now we have discussed models.
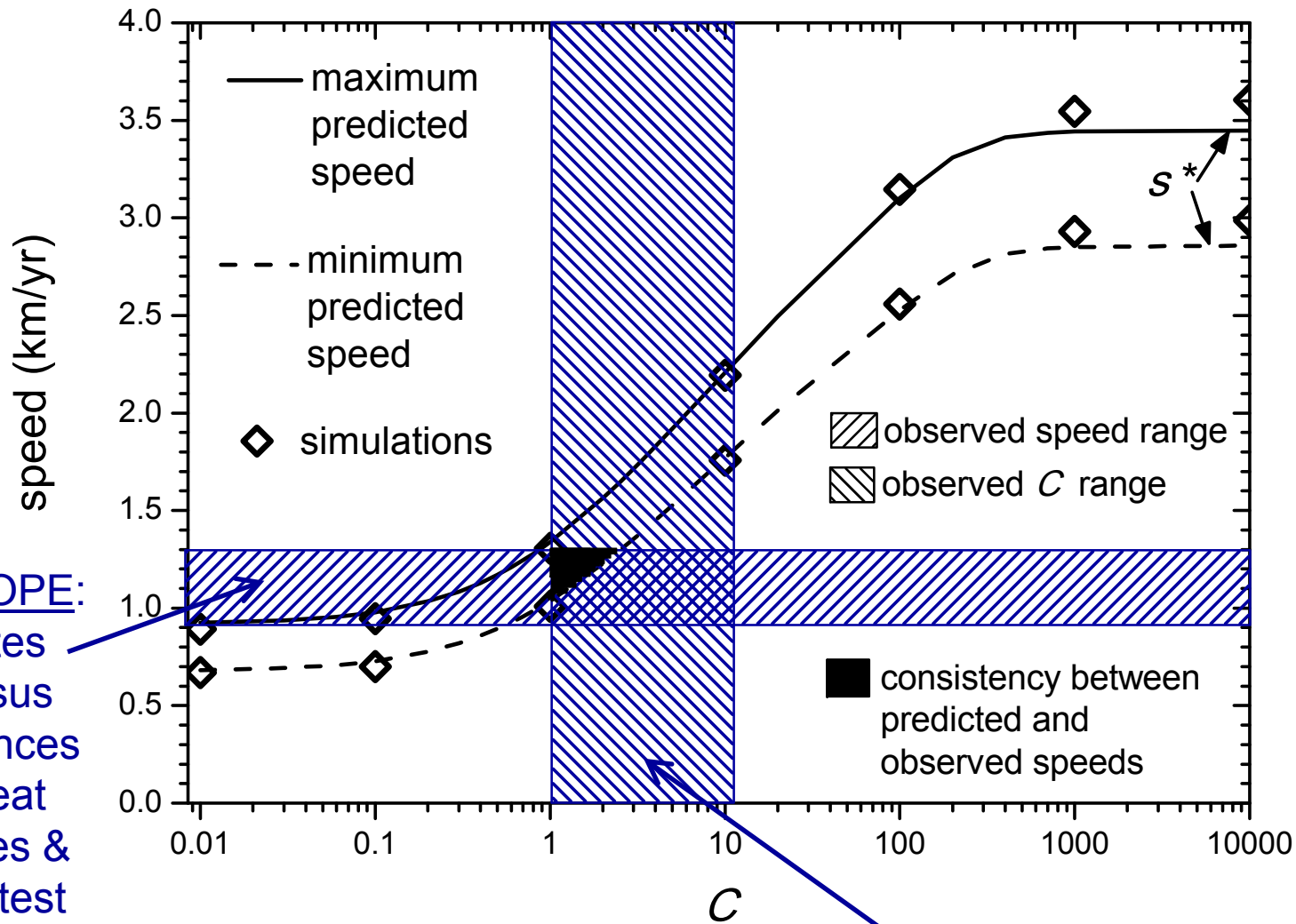
What is the observed speed?

0.9-1.3 km/yr

735 sites in Europe & Near East

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

Pinhasi, Fort & Ammerman,

PLoS Biol. (2005)

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Effect of acculturation intensity *C* on the front speed <u>in Europe</u>
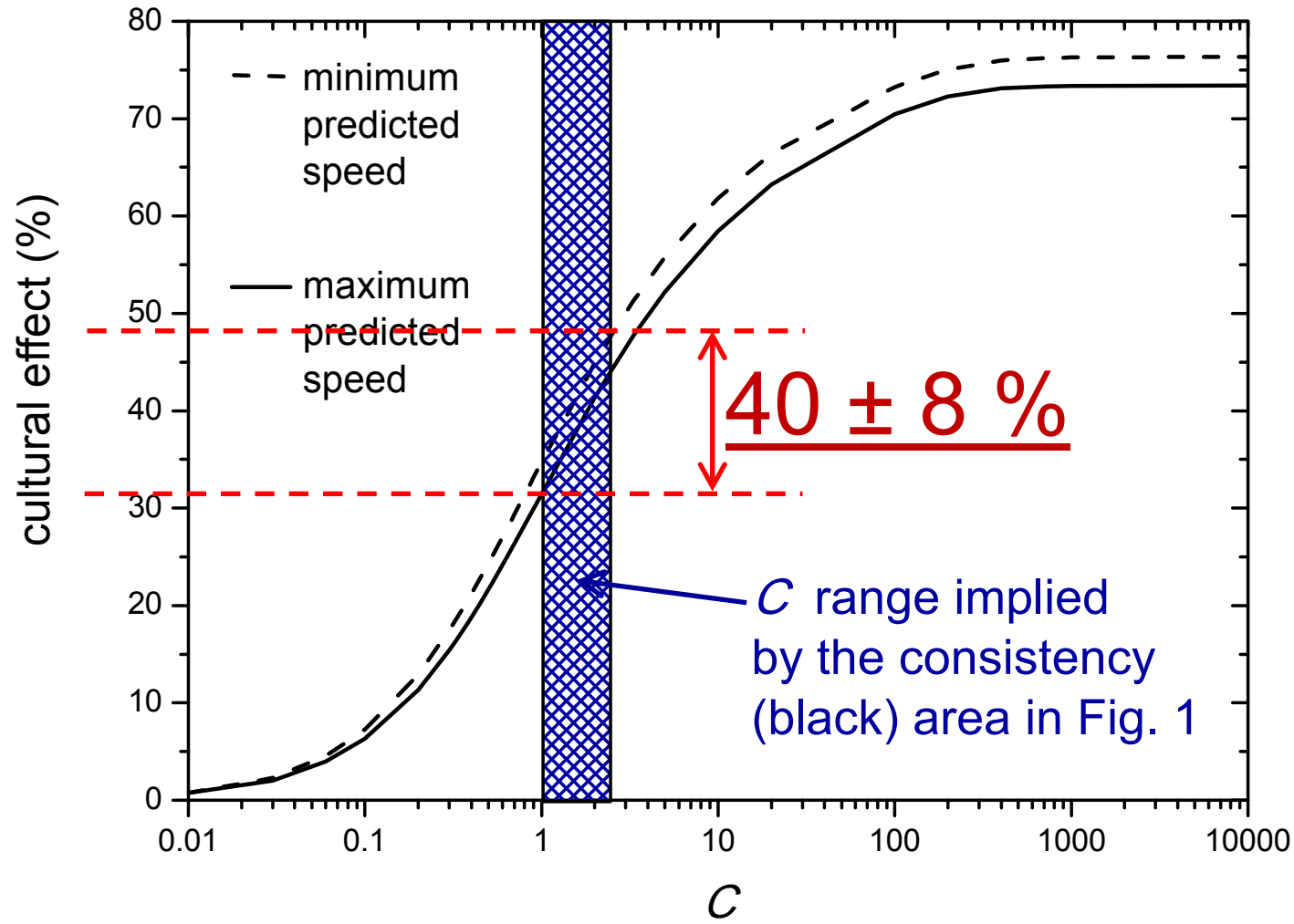

EUROPE: Dates versus distances (great circles & shortest paths)

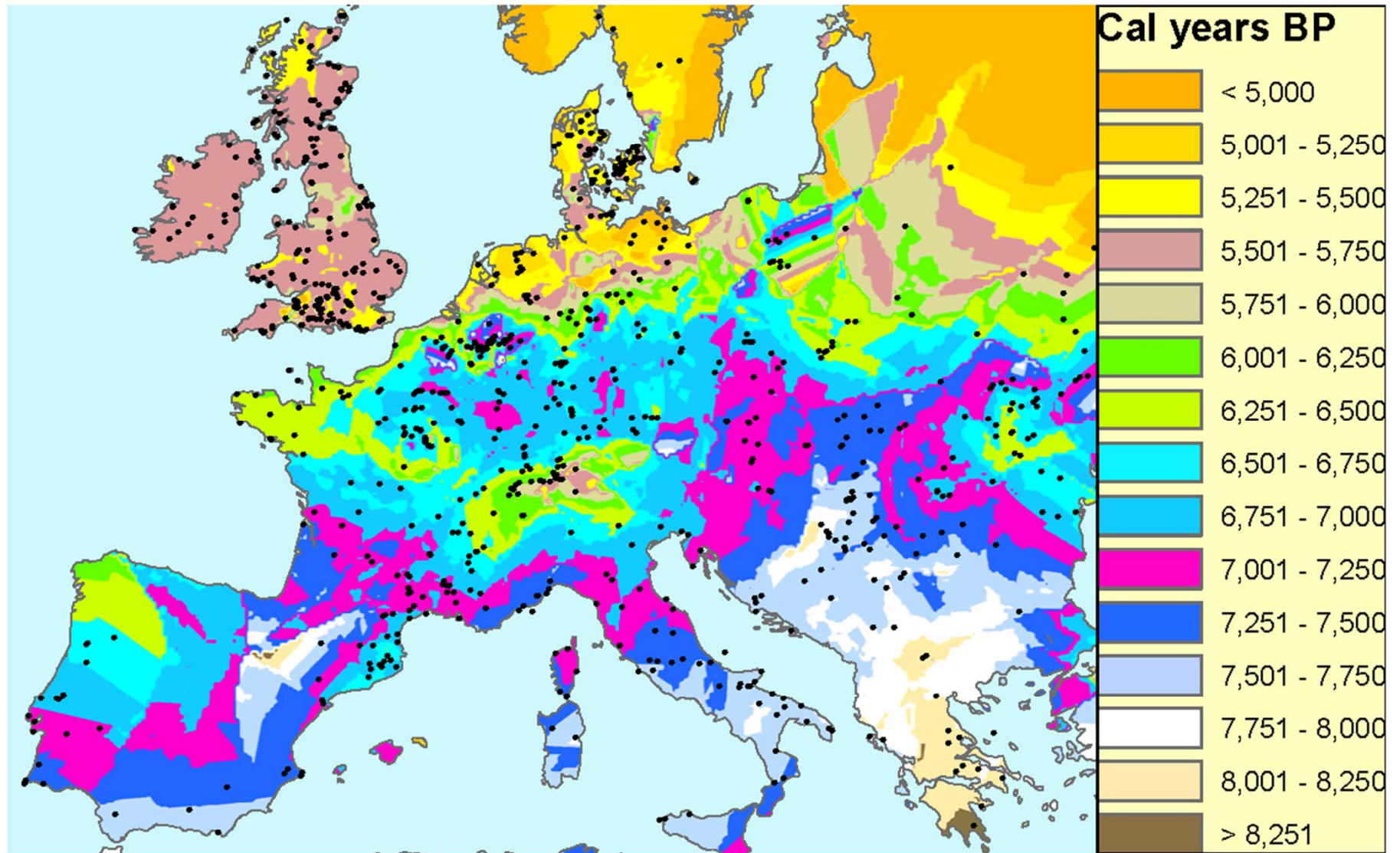Ache hunter-gatherers (Paraguay)

Fort, *PNAS* (2012)

Effect of cultural diffusion in Europe

Effect (%) = (speed – demic speed) /speed · 100

cultural effect (%)

- - - minimum predicted speed

—— maximum predicted speed

40 ± 8 %

C range implied by the consistency (black) area in Fig. 1

C

Fort, *PNAS* (2012)

Local features in Europe

Fort, *J. R. Soc. Interface* (2015)

Speed

- 0.03 - 0.66 km/y
- 0.68 - 1.36 km/y
- 1.36 - 3.04 km/y
- > 3.04 km/y

Fort,
*J. R. Soc.
Interface*
(2015)

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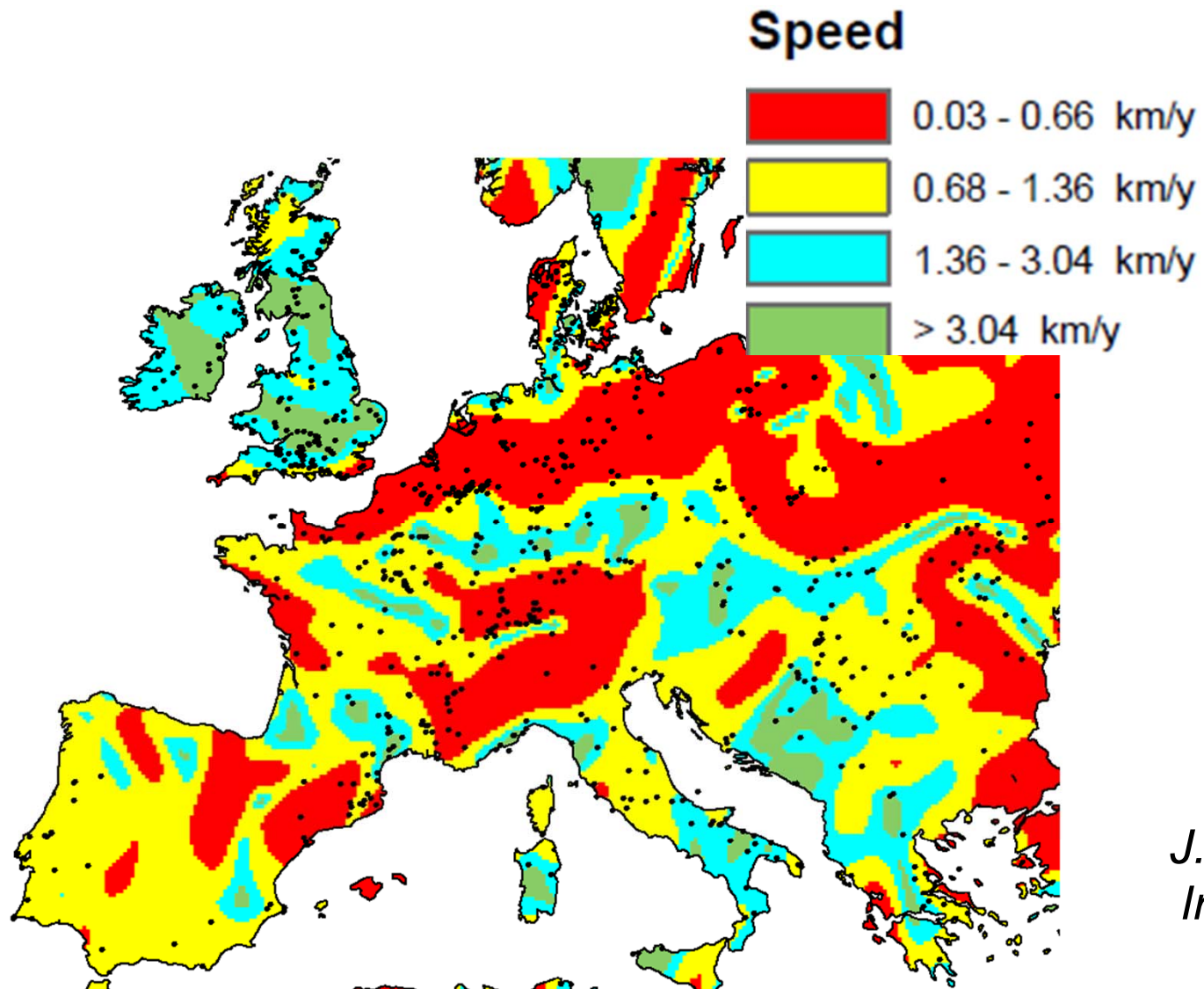
The previous maps show <u>observed</u> speeds.

What are the speeds from the models?

1. Purely cultural model

2. Purely demic model

3. Demic-cultural model

Purely cultural model

· Population 1 (Mbuti, band I): $\{P_k\}=\{0.59, 0.37, 0.04\}$, $\{R_k\}=\{2.5, 7.5, 12.5\}$km $\rightarrow$ 0.17-0.36 km/y.

· Population 2 (Mbuti, band II): $\{P_k\}=\{0.12, 0.30, 0.43, 0.15\}$, $\{R_k\}=\{2.5, 7.5, 12.5, 17.5\}$km $\rightarrow$ 0.30-0.57 km/y.

· Population 3 (Mbuti, band III): $\{P_k\}=\{0.20, 0.41, 0.26, 0.08, 0.05\}$, $\{R_k\}=\{2.5, 7.5, 12.5, 17.5, 22.5\}$km $\rightarrow$ 0.32-**0.66 km/y**. **MAX**

· Population 4 (Aka): $\{P_k\}=\{0.12, 0.25, 0.11, 0.04, 0.03, 0.16, 0.05,$ $0.05, 0.05, 0.14\}$, $\{R_k\}=\{0.05, 0.1, 0.2, 0.25, 0.3, 0.4, 2,3,5,6\}$km $\rightarrow$ 0.09-0.19 km/y.

· Population 5 (Baka): $\{P_k\}=\{0.48, 0.04, 0.13, 0.14, 0.18, 0.03\}$, $\{R_k\}=\{0, 0.5, 0.8, 1.5, 1.7, 2.7\}$km $\rightarrow$ **0.03**-0.07 **km/y. MIN**

Overall range: **0.03-0.66 km/y** (cultural model)

Interpretation of the observed speeds

Fig. 3
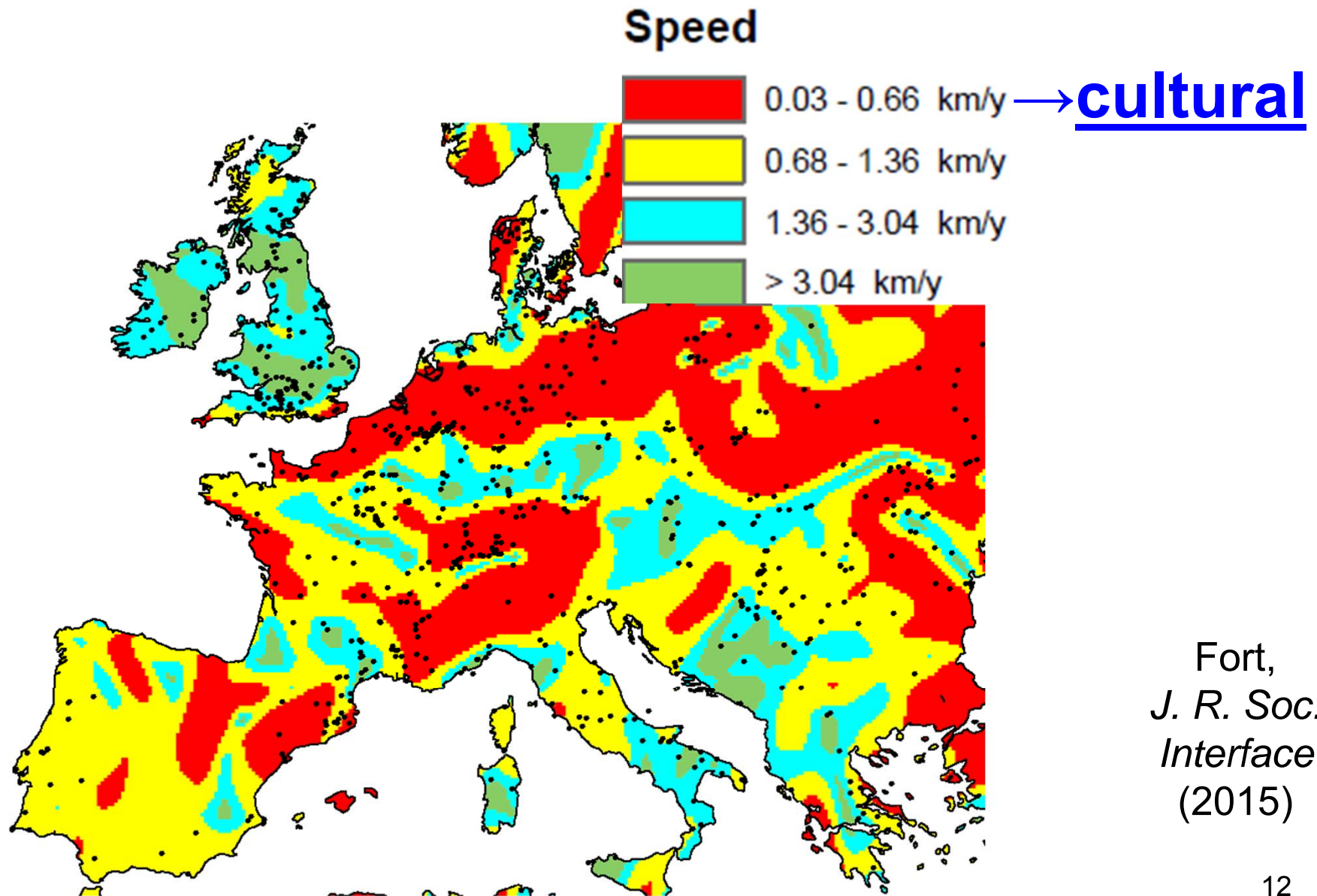
Purely demic model

· <u>Population A</u> (Gilishi 15): $\{p_j\}=\{0.54, 0.17, 0.04, 0.25\}$,
$\{r_j\}=\{2.4; 14.5, 36.3, 60.4\}$km → 0.87-1.15 km/y.

· <u>Population B</u> (Gilishi 25): $\{p_j\}=\{0.40, 0.17, 0.17, 0.26\}$,
$\{r_j\}=\{2.4; 14.5, 36.3, 60.4\}$km → 0.92-1.21 km/y.

· <u>Population C</u> (Shiri 15): $\{p_j\}=\{0.19, 0.07, 0.22, 0.52\}$,
$\{r_j\}=\{2.4; 14.5, 36.2, 60.4\}$km → 1.14-**1.48 km/y**. **MAX**

· <u>Population D</u> (Yanomano): $\{p_j\}=\{0.19, 0.54, 0.17, 0.04, 0.04, 0.02\}$,
$\{r_j\}=\{5, 30, 50, 70, 90, 110\}$km → 1.12-1.48 km/y.

· <u>Population E</u>(Issongos):$\{p_j\}=\{0.42; 0.23; 0.16; 0.08; 0.07; 0.02; 0.01; 0.01\}$,
$\{r_j\}=\{2.3, 7.3, 15, 25, 35, 45, 55, 100\}$km → **0.68**-0.92 **km/y**. **MIN**

Overall range: **0.68 -1.48 km/y** (purely demic model)

For 0.68 km/y, obviously 0% cultural.
But for 0.7, 0.8, 0.9, ... km/y, what is the cultural %?

$$s_{obs} = \text{observed speed}$$

$$s_D = \text{speed predicted by the purely demic model}$$

Cultural effect (in %) = $E = \dfrac{s_{obs} - s_D}{s_{obs}} 100$

$$s_{D\,min} = 0.68 \text{ km/y} \rightarrow E_{max} = \left(1 - \dfrac{0.68}{s_{obs}}\right)100 \rightarrow$$

$E_{max} < 50\%$ if $s_{obs} \underline{<1.36 \text{ km/y}}$: <u>mainly demic regions</u> (yellow in the map)

Interpretation of the observed speeds

Speed

▮ (red)	0.03 - 0.66 km/y → cultural
▮ (yellow)	0.68 - 1.36 km/y → **_mainly demic_**
▮ (cyan)	1.36 - 3.04 km/y → either mainly demic or mainly cultural
▮ (green)	> 3.04 km/y	
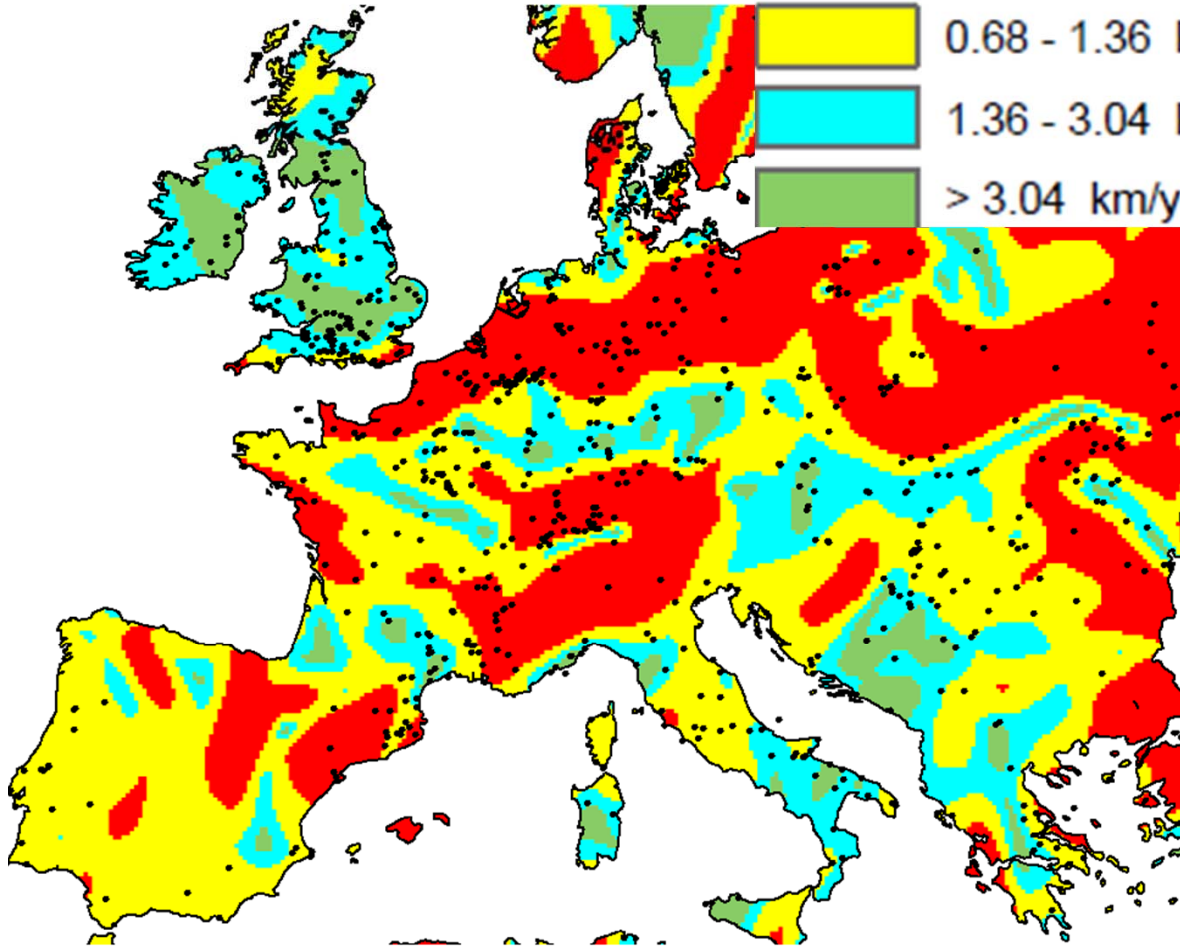
↕ due to uncertainty in the parameter values

Fort, *J. R. Soc. Interface* (2015)

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Interpretation of the observed speeds

·Mainly demic diffusion (<u>yellow regions</u>) was fast (speeds above 0.68 km/y). Areas: Greece, Italy, the Balkans, Hungary, Slovakia, Czechia and central Germany. This includes a substantial part of the Linearbandkermic (LBK) culture in Central Europe*.
It agrees with Bogucki (2003) and Shennan & Edinborough (2007).

·Cultural diffusion (<u>red regions</u>) was slow (speeds below 0.66 km/y). Areas: Northern Europe, the Alps and West of the Black Sea. This agrees, respectively, with Bogucki (1996), Clark (1990) and Anthony (2007).

*Kaczanowska M, Kozlowski JK (2003), Fig. 12.7
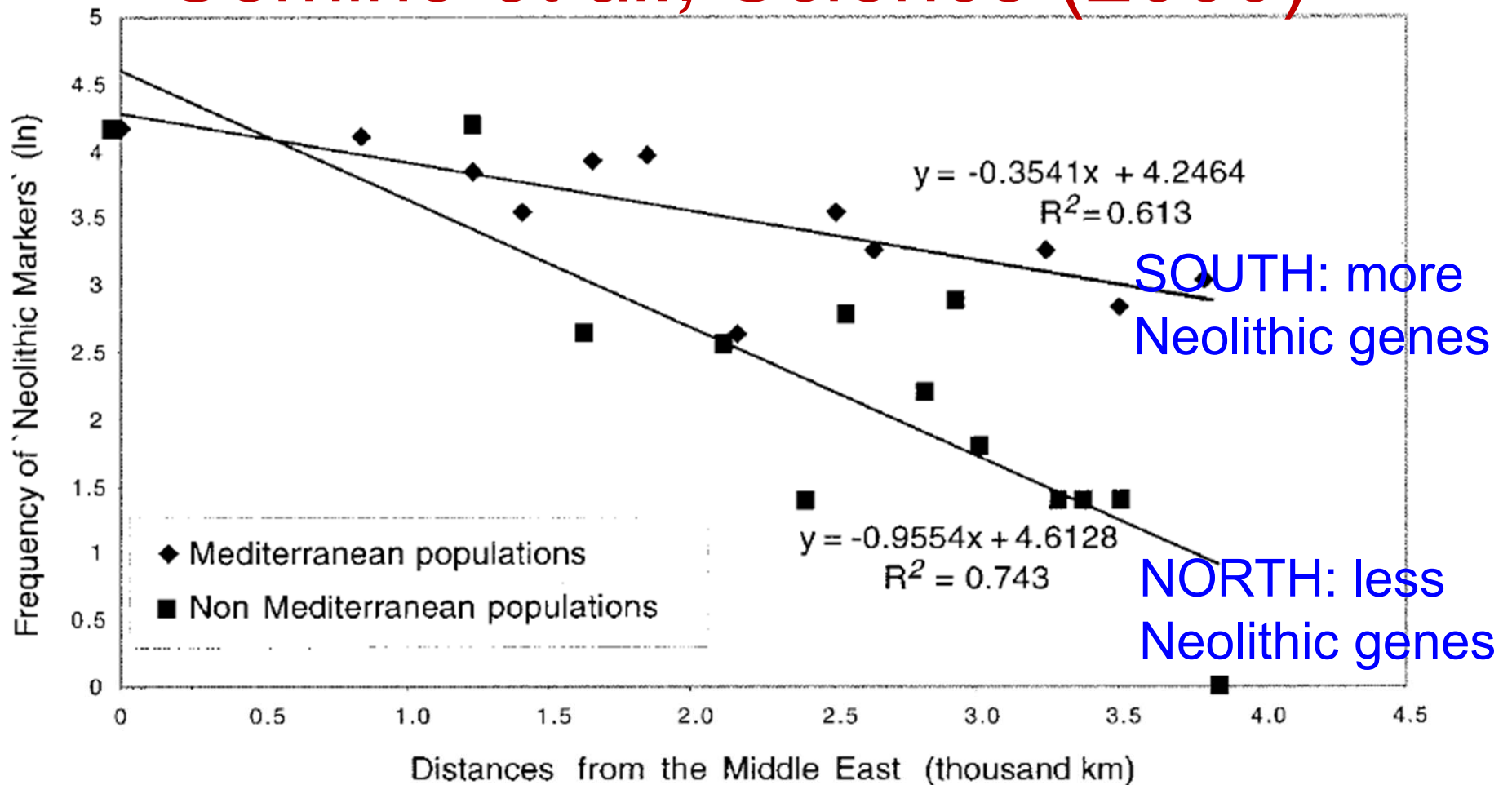
Semino *et al.,* Science (2000)

Fig. 2. Abscissa: distances in thousands of kilometers of each population from the average of the two Middle Eastern populations (Lebanese and Syrians). Ordinate: logarithm of relative frequencies of Neolithic markers (sum of Eu4, Eu9, Eu10, and Eu11) in the Mediterranean and non-Mediterranean populations. The Middle Eastern point ($X = 0$) was considered for both series of points. The two regression lines are significantly different ($P < 0.01$).

Open problem

These results use parameter values which
are not fitted but estimated from independent data.
But are the parameter values used realistic?

It would help a lot to measure <u>prehistoric</u>
dispersal kernels, if possible:
· Strontium isotope: not accurate distances
· Genetics: identification of parent-child pairs?

Until we have accurate parameter values,
the models can be useful but the
conclusions are preliminary.