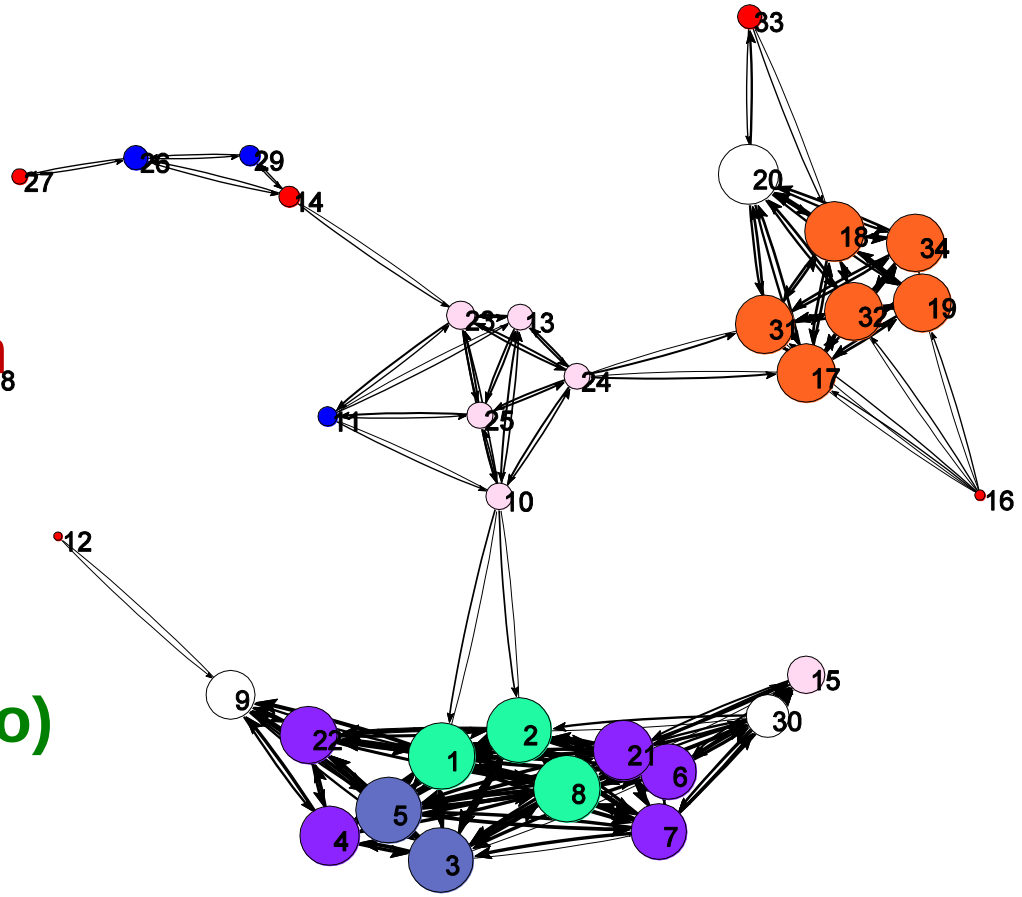
Imperial College London

Articulating scales in sea-based social Networks:

A transdisciplinary approach



Ray Rivers (Physics, IC)

Carl Knappett (Art, Toronto)

Tim Evans (Physics, IC)

Focus: Middle Bronze Age (MBA) Aegean

-c.2000 BC
Distinct Minoan culture starts

-c.1500 BC
End of Minoan cultural dominance

Roughly self-contained in space and time

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Sail supercedes oar – direct interactions possible over long distances

Minoanisation:

Spread of Minoan culture from N. Crete

Pottery as a proxy for more general cultural, political and social transmission

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Pottery as a proxy for more general cultural, political and social transmission

Example:

Volcanic eruption in c.1600 BC of Thera/Santorini left a good record in pottery

Minoanisation manifested in imports e.g. Akrotiri phase C

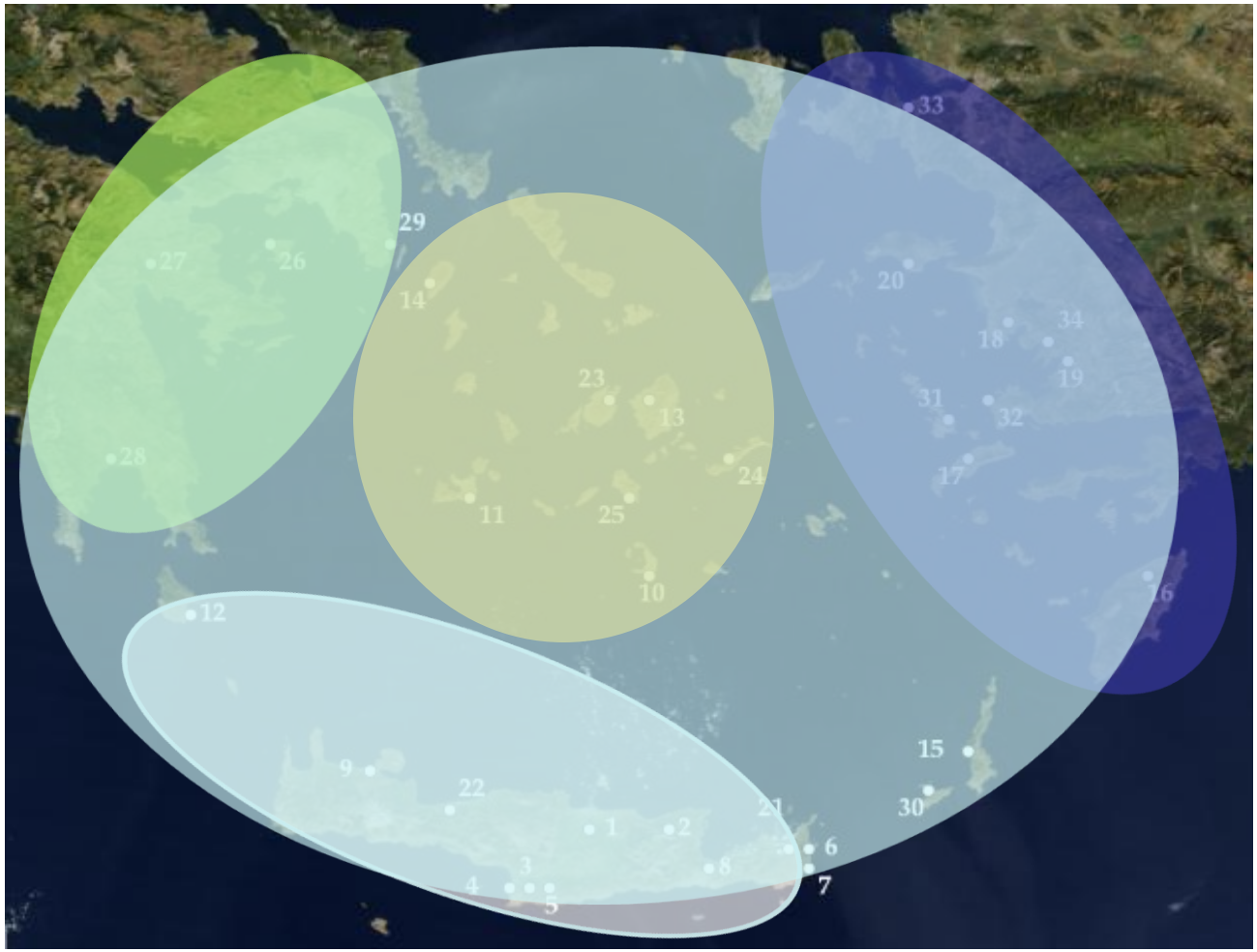
Minoanisation also reflected in local imitations

Two extreme approaches to Minoanisation:

1. Regional level: Integration of regions that have internal social connections

We have chosen 34 key sites

4 regional groupings



BUT

Heterogeneous

Discontinuous

Crosscutting links

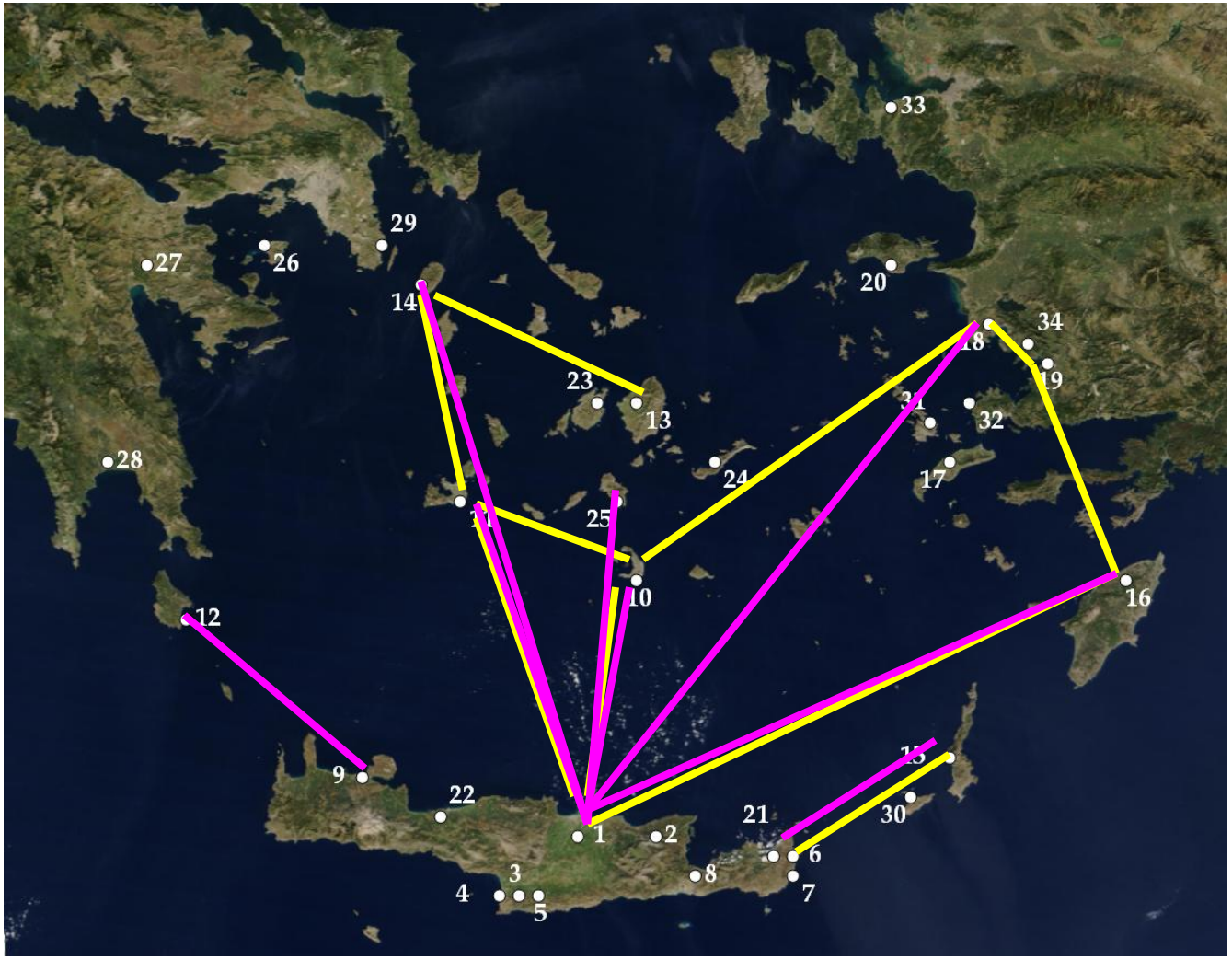
Two extreme approaches to Minoanisation:

2. Local level: Use the pots to join the dots (e.g. C.1700 BC)

Simple Network of nodes and links

= ‘contact’

= ‘colony’



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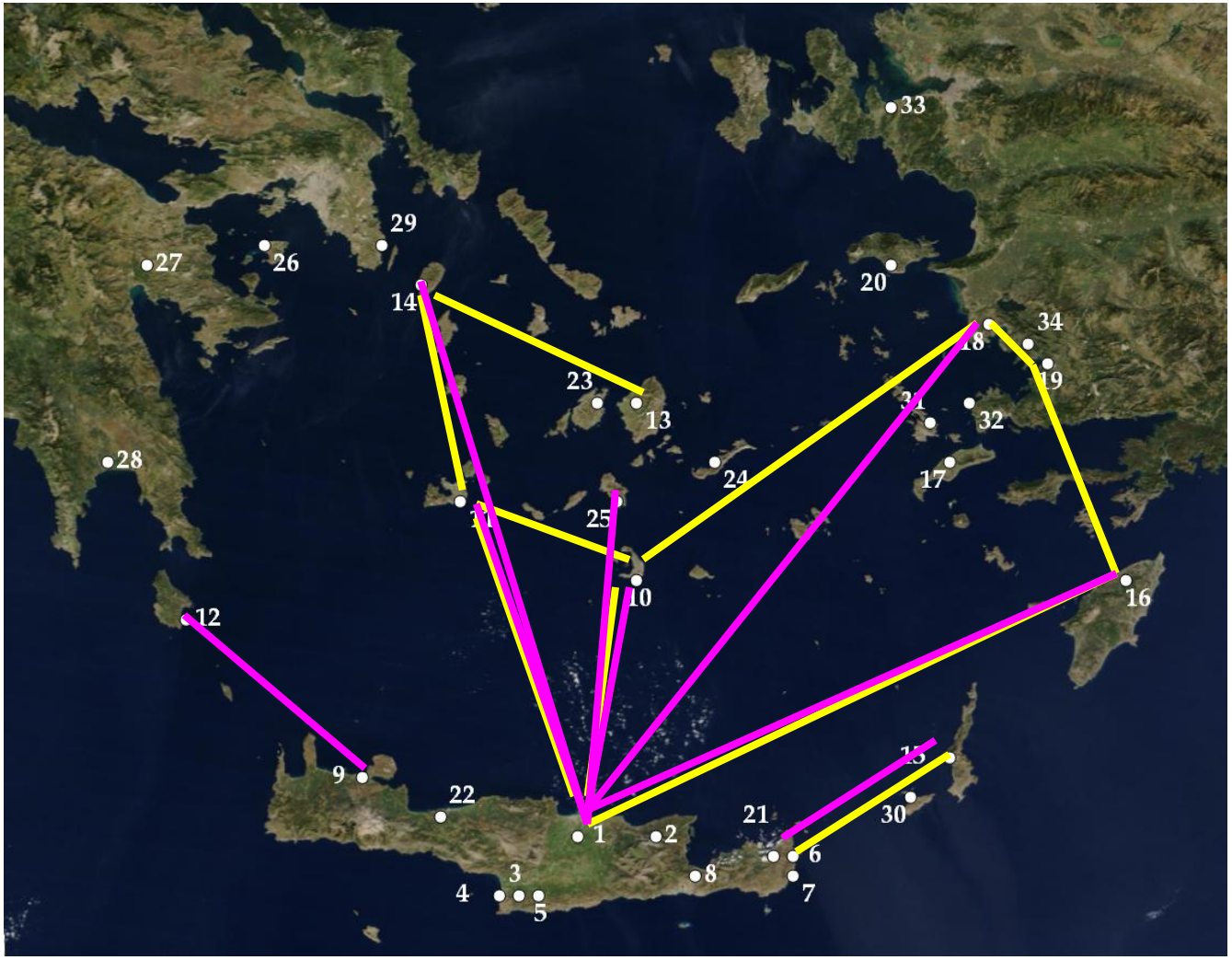

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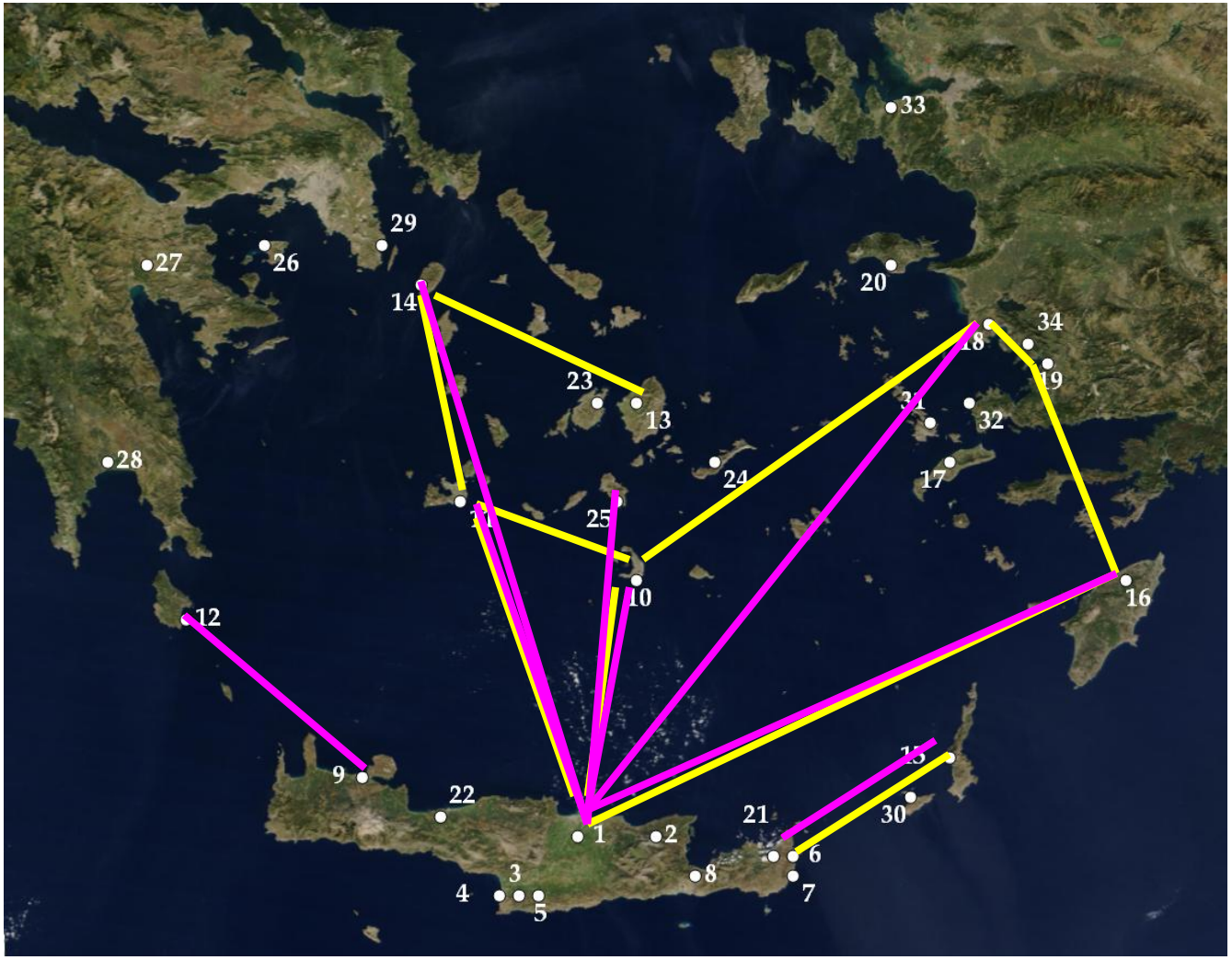

BUT

At this level

Too granular To show regional behaviour

Question:

What is the connection between macro-scale development of regional networks and emergence of primary centres?

More concretely:

How does

- Social organisation
- Geography
- Marine technology

lead to

- population distribution
- local link strengths
- site importance
- ‘cultural transmission’

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Social Organisation: Many different levels

- Global (Minoanisation)
- Regional (e.g. Cycladic)
- Local;

a) Macroscopic (whole islands)

b) Mesoscopic (communities on islands)

- Microscopic - Household/individual

Increased complexity

How to accommodate these different scales?

Emergence:

We would like the global properties of networks to emerge from local properties, from as bottom-up as possible

Agency:

Most extreme approach:

Multi-Agent System (MAS) modelling: (e.g. BA Mesopotamia)

Individuals upwards

Too difficult – too many different levels of aggregation

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We begin at ‘local’ level, but in same spirit

Our agency: Imperfect' rational choice

- Rational choice :

  'Optimisation' of a cost/benefit function /'social 'potential' that reflects the costs and benefits of local resources and links that enable the population to sustain global interactions

- Imperfect'

  We find networks which are only *approximately* optimal using standard statistical methods (> 10^{1000} possibilities)

  i.e. start off with some network and keep on trying to improve it until you can get no further

  Introduce volatility' (e.g. weather)

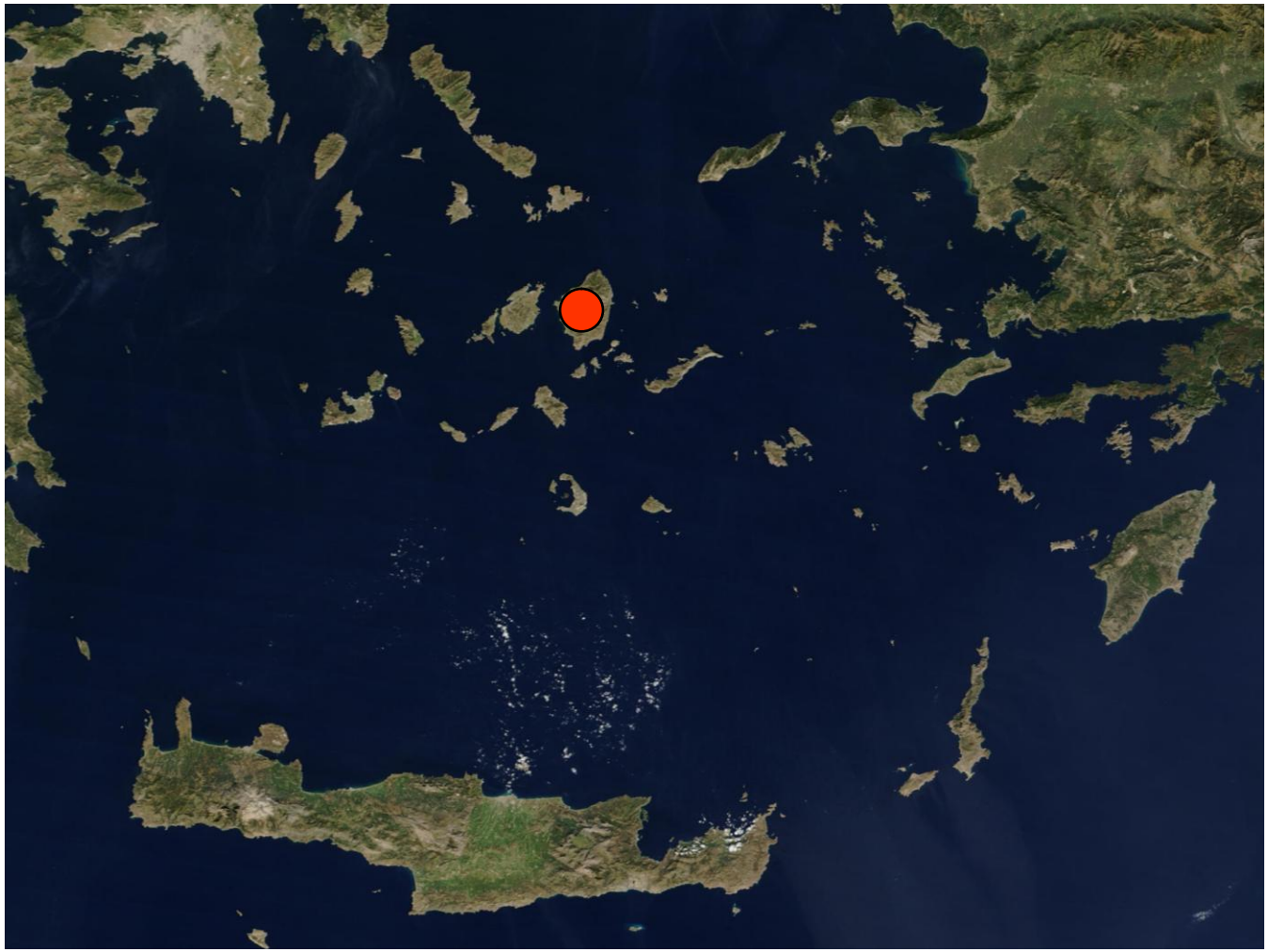
Outcome: Model is Non-deterministic

- We never find exactly the same network twice on looking for the optimal solution
- Usually networks are similar , but sometimes may find very different networks - harbinger of instability ?
- Look for consistent statistical patterns

  e.g. N. Crete dominant 4 times out of 5, Dodecanese once in 40 times, indicates why Crete is important

Local scales::

Assume meso-scale can be subsumed into the macro-scale



Sail (harbours?) suggests island-to-island interaction rather than hamlet-to-hamlet interaction

'Gravity' Model !

Main Implications:

- Homophily: - ‘Similarity breeds connection’

  Large connects to large

- We minimise the effects of our ignorance of archaeological record

  e.g. if a major site is discovered we do not have to include it, since island-wide output can be distributed as we wish

  Desirable since archaeological record is very patchy

Question:

What is the connection between macro-scale development of regional networks and emergence of primary centres?

More concretely:

How, in the MBA Aegean, does

- Social organisation
- **Geography**
- **Marine technology**

lead to

- population distribution
- local link strengths
- site importance
- ‘cultural transmission’

Inputs: Geography/marine technology

Not physical geography per se, but the ability to travel between sites that is the important input

- In particular, how easy is it to travel in the sea/landscape between two sites in essentially one trip – this determines 'island hopping';

Encodes
- physical distance (sea/land)
- tides/winds

- distance scale for sail travel

100km – Knossos-Akrotiri

- Geography reappears in the carrying capacity of the sites (availability of resources) needed as input - although their distribution within an island not important

Inputs: Social interactions

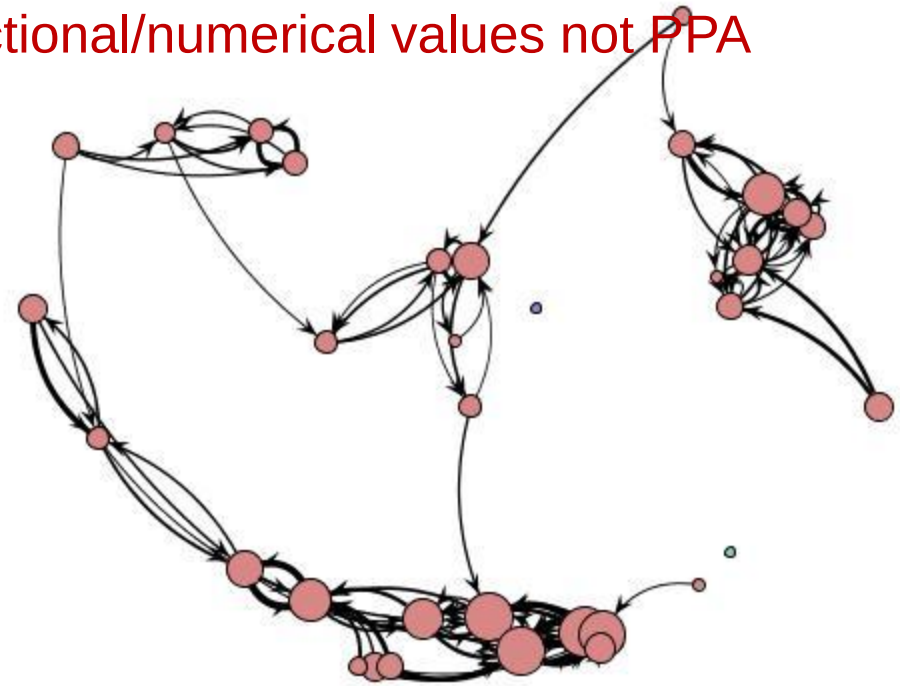
- Benefits in establishing links; Gravity/Homophily
- Benefits from local resources, penalties for overuse of resources
- Costs in supporting links, supporting population

Typical outputs:

Four regional clusters joined by ‘weak’ links to ‘primary‘ centres/gateway sites

Geography still plays an important part

- but pop. density varies and links carry directional/numerical values not PPA



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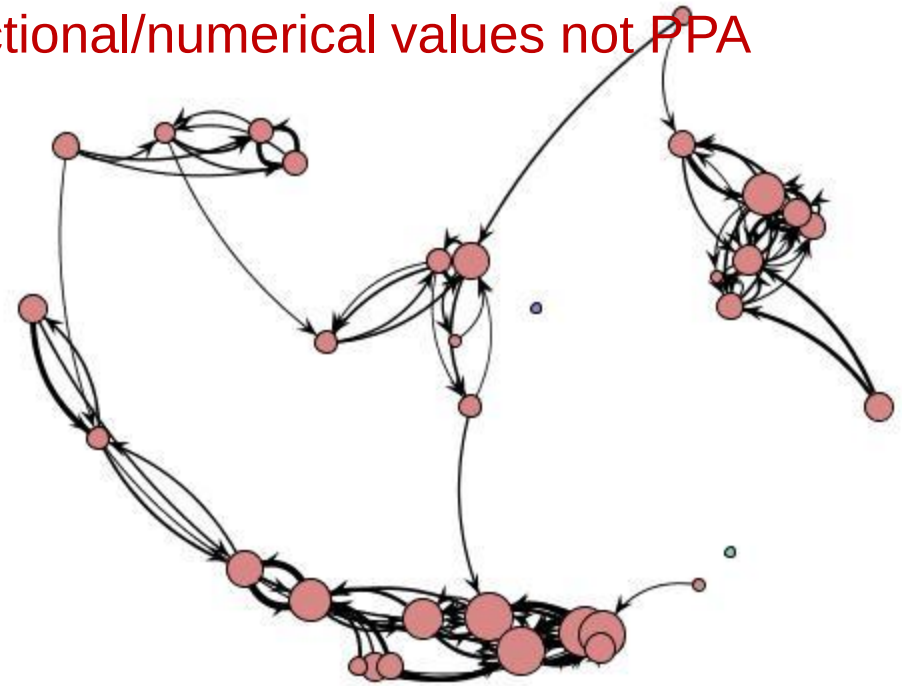

Gateway sites
Important for innovation

‘The strength of weak ties’

- Granovetter

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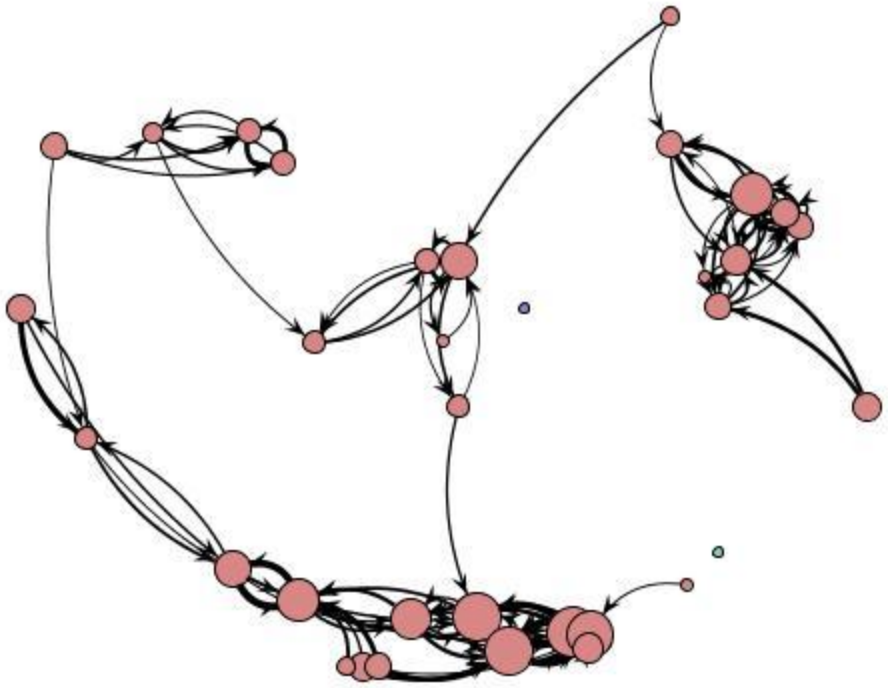
Increasing benefit of ‘trade’ ⟹ increasing variation in size



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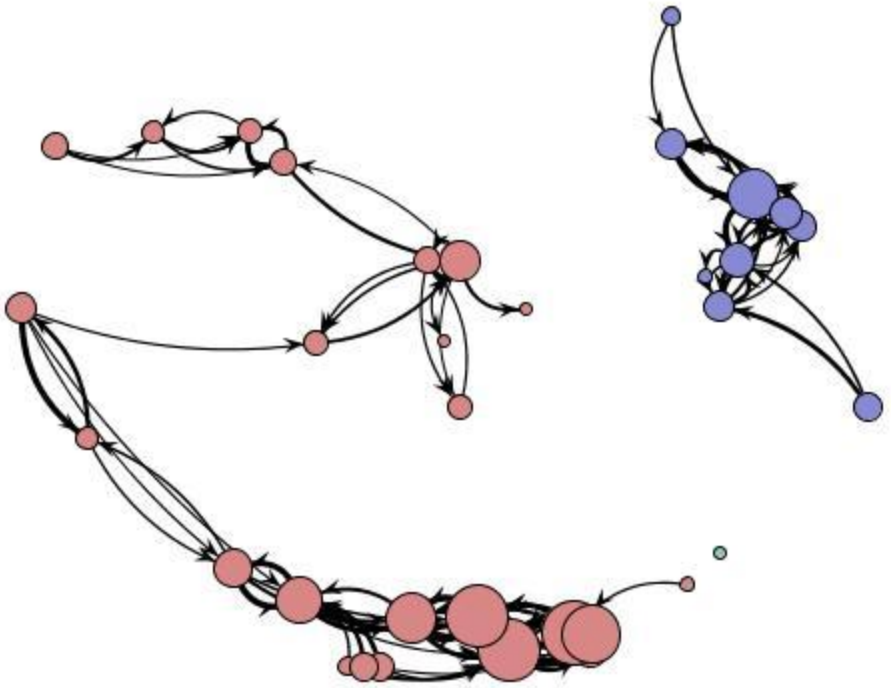
$(j,\mu,\kappa,\lambda)=(-1,0,1,2.5)$
slider 8%
0.69 (1.26 – 0.27) site weights

Increasing benefit of ‘trade’ ⟹ increasing variation in size



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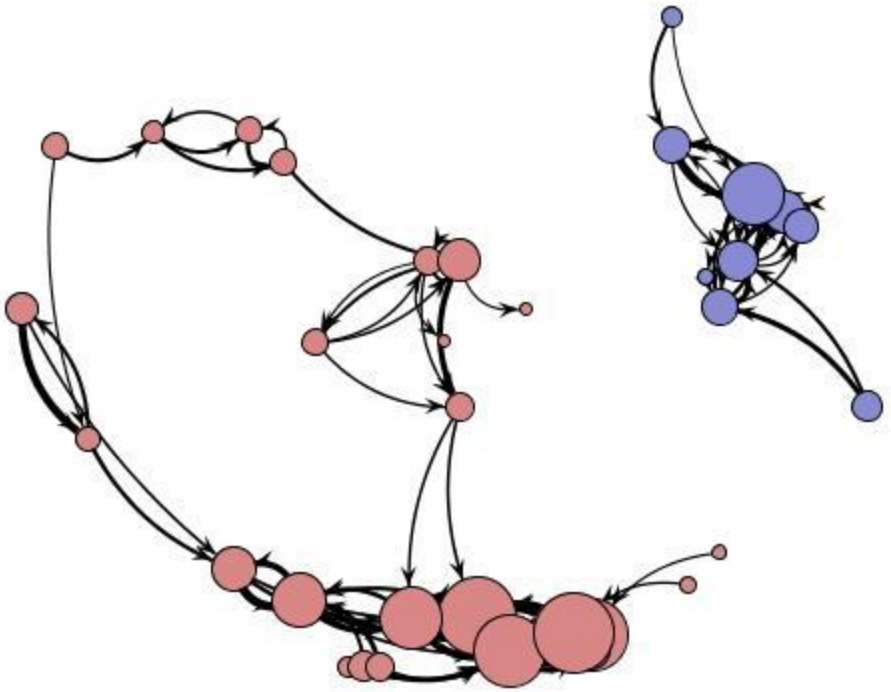
$(j,\mu,\kappa,\lambda)=(-1,0,1,3)$
slider 8%
0.79 (1.6 – 0.28) site weights

Increasing benefit of ‘trade’ ⟹ increasing variation in size



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$(j,\mu,\kappa,\lambda)=(-1,0,1,3.5)$
slider 8%
0.9 (1.99 – 0.3) site weights

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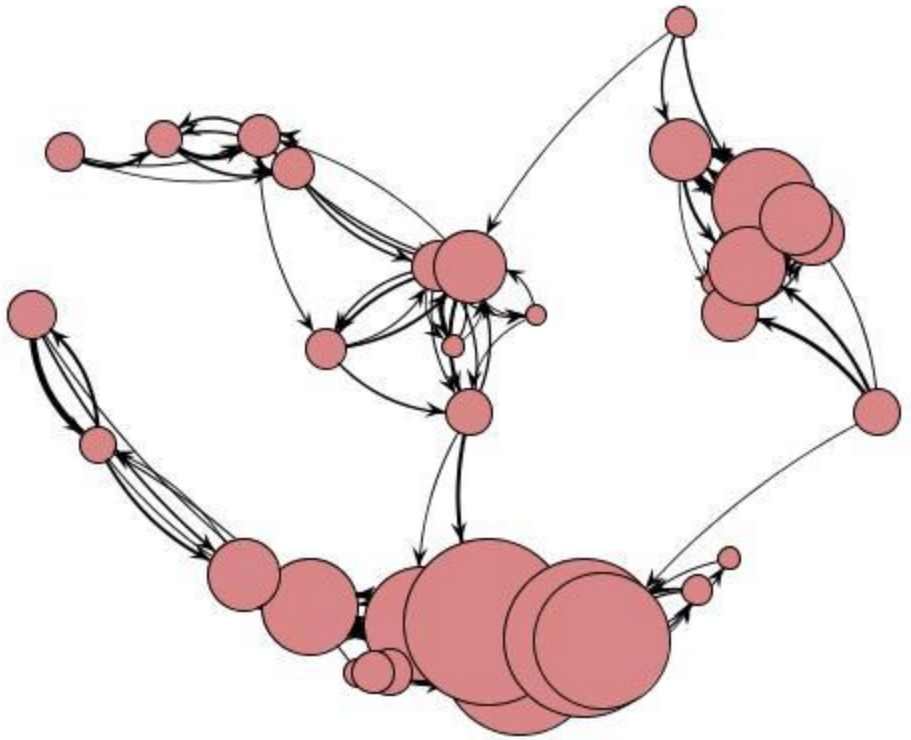

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Size differentiation unique to ‘gravity’ models

Rerunning the model will give slightly different results

$(j,\mu,\kappa,\lambda)=(-1,0,1,4)$
slider 8%
0.88 (2.42 – 0.0) site weights

Other properties of sites; transfer of people/things

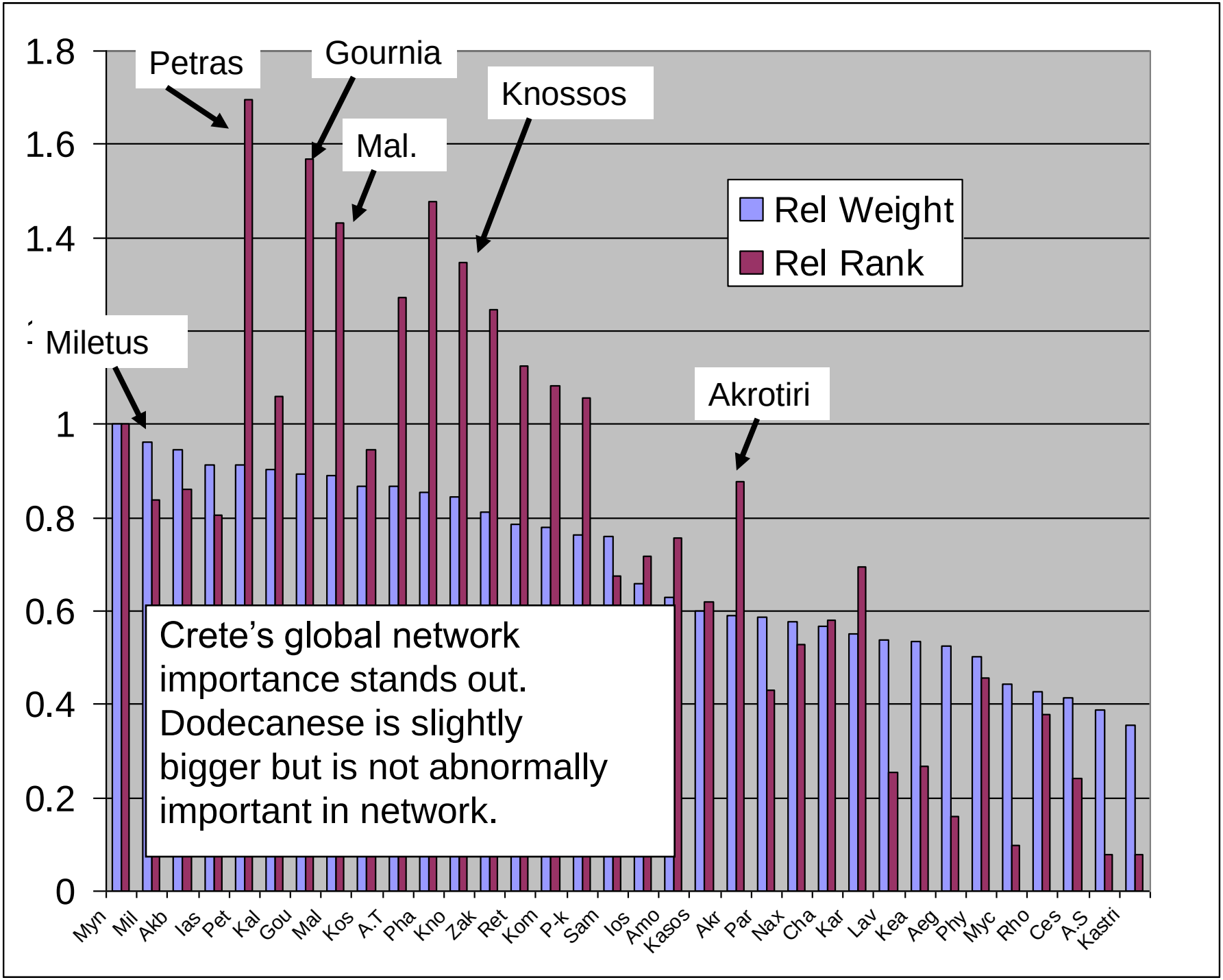
1. Influence = measure of how many people arrive at a site (ever) if each one only does a limited amount of travelling

2. Rank = measure of how many people pass through a site in a given time,

   c.f. Hage & Harary 1991 (Kula Ring), Google PageRank

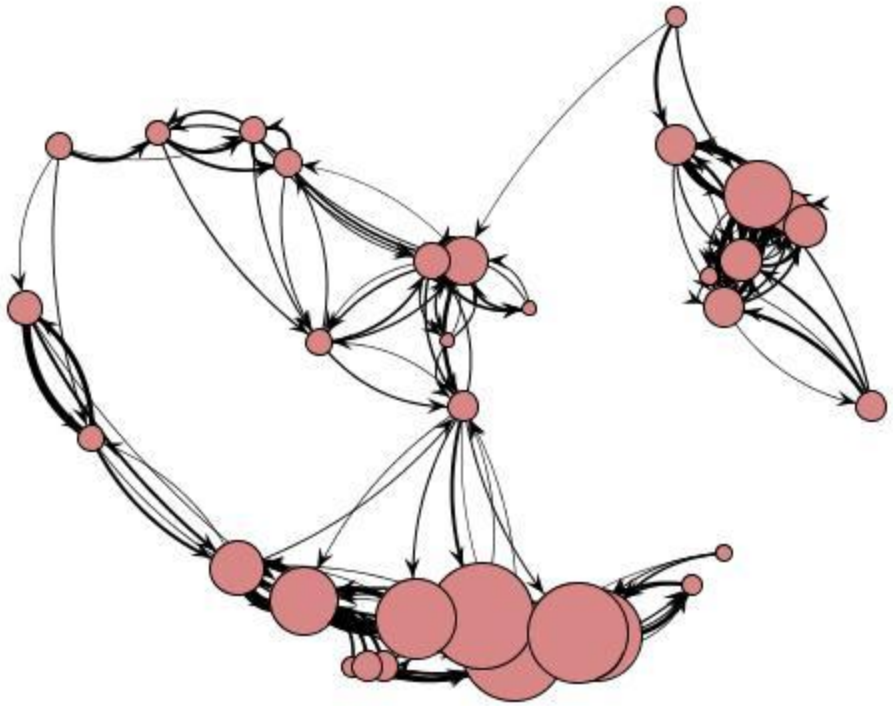
'Global 'rather than 'local '– conditioned but not determined by local geography even though they are attributes of site

Look for sites which go against general trends


1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Petras
Gournia
Knossos
Mal.
Miletus
Akrotiri
Rel Weight
Rel Rank
Crete's global network importance stands out. Dodecanese is slightly bigger but is not abnormally important in network.
Myn
Mil
Akb
Ias
Pet
Kal
Gou
Mal
Kos
A.T
Pha
Kno
Zak
Ret
Kom
P-k
Sam
Ios
Amo
Kasos
Akr
Par
Nax
Cha
Kar
Lav
Kea
Aeg
Phy
Myc
Rho
Ces
A.S
Kastri

Resilience: Eruption of Thera/Santorini (c. 1600 BC)

Before Eruption



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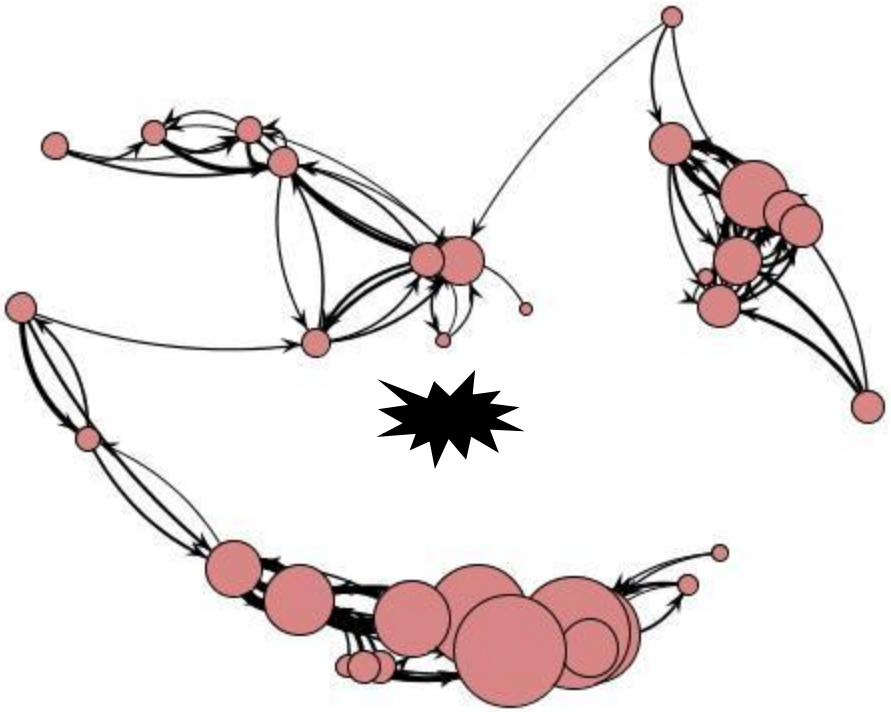
$(j,\mu,\kappa,\lambda)=(-1,0,1,4)$
slider 5%
Just connected
1.07 (0.37-2.67) site weights

Resilience: Eruption of Thera/Santorini (c. 1600 BC)

After Eruption



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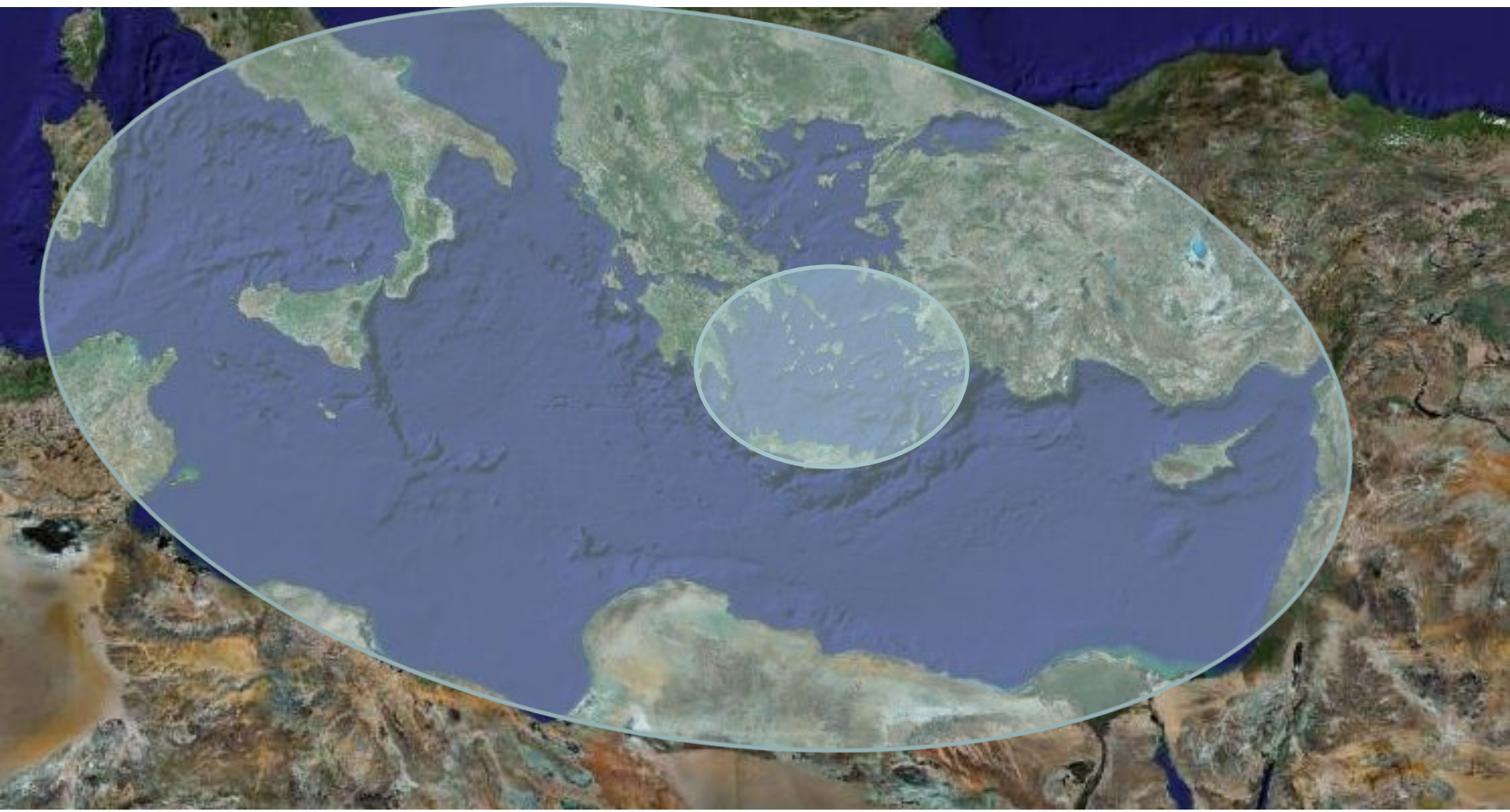
$(j,\mu,\kappa,\lambda)=(-1,0,1,4)$
slider 8%
Just connected
1.07 (0.37-2.67) site weights

Future work …



- Extending spatial scale of networks
- Late Bronze Age ‘international’ trade and political collapse

Warning: Do not expect a larger version of MBA Aegean

Some generic behaviour but

- particular shift in sailing technology
- assumptions about social organisation (gravity model)
- geography of network (heterogeneous)

specific to MBA Aegean

Cf. Broodbank's PPA approach to homogeneous EBA Cyclades

Anti-gravity model based on rowing technology