Annexes

Annexe 1 : Carte présentant la dispersion du nuage de téphra de l'éruption de Santorin obtenue par krigeage (Athanassas et al., 2017).

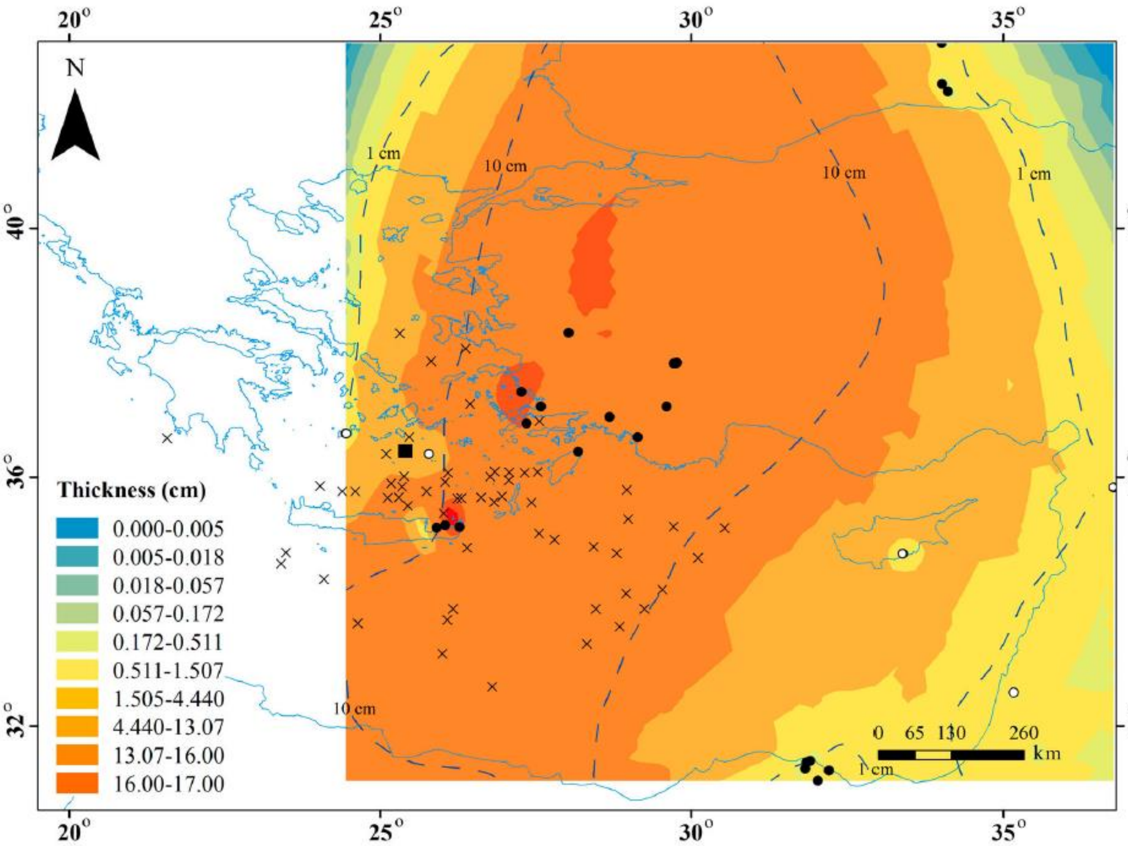


Figure 0.1 : Geostatistical prediction map for the dispersion of Minoan tephra over the Eastern Mediterranean, as derived from ordinary kriging. Predicted tephra thicknesses are shown as filled color-graded contours. Coordinate system is WGS84. Filled circles correspond to sites where Minoan tephra has been identified on land, while empty circles correspond to 'absence' sites. '×' marks the marine spots. Santorini is marked by the solid rectangle. Dashed lines correspond to isopachs of 1 and 10 cm, respectively (Athanassas et al., 2017).

Annexe 2 : Modélisation d'isopaques pour une éruption plinienne, coignimbrite et la combinaison des deux, en été et au printemps (Johnston et al., 2012) et isopaques présentés dans des études antérieures.

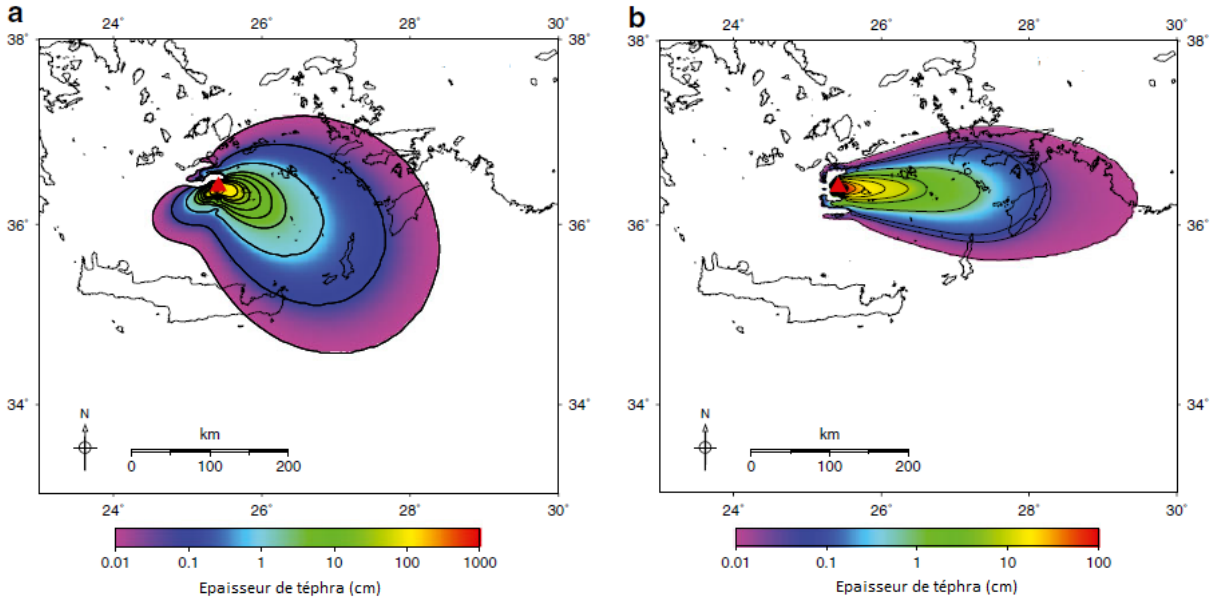


Figure 0.2 : Isopaques modélisées de la dispersion du téphra produit pour (a) une éruption plinienne en été et (b) une éruption plinienne au printemps (Johnston et al., 2012).

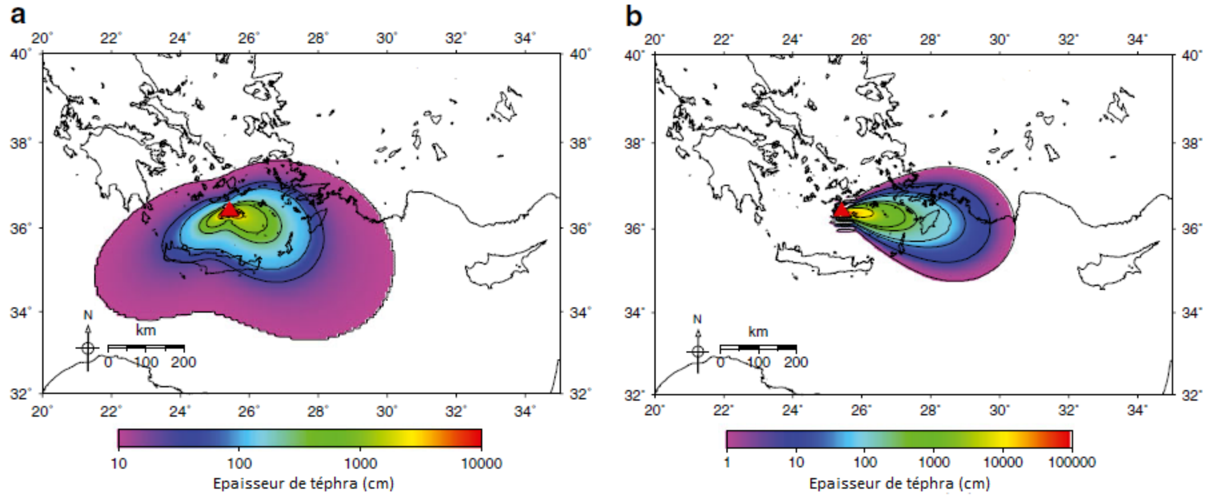


Figure 0.3 : Isopaques modélisées de la dispersion du téphra produit pour (a) une éruption coignimbrite en été et (b) une éruption coignimbrite au printemps (Johnston et al., 2012).

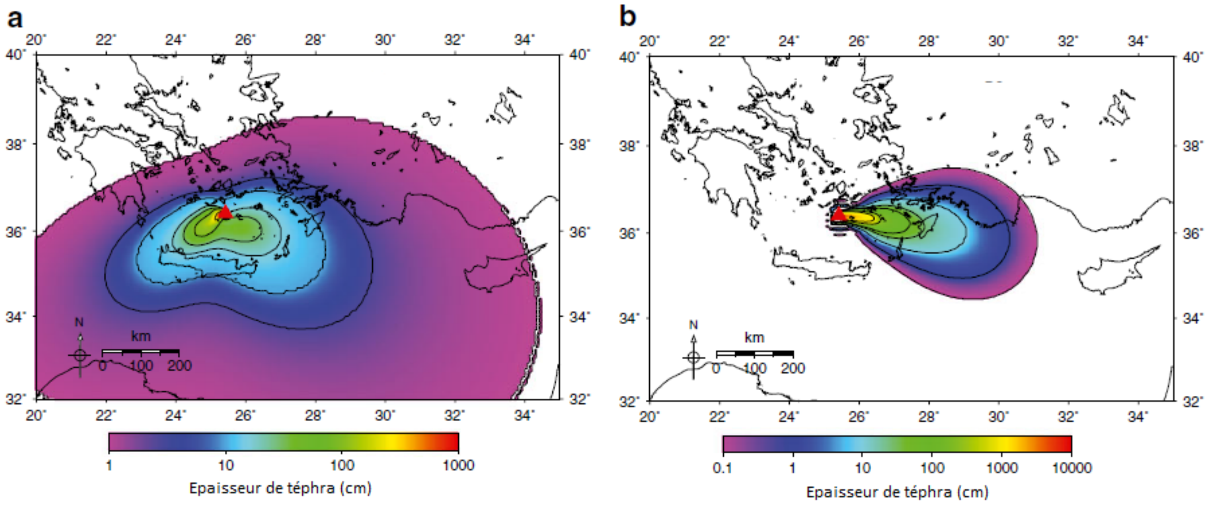


Figure 0.4 : Isopaques modélisées de la dispersion du téphra produit pour (a) une éruption en été et (b) une éruption au printemps, sur base des données de dépôts marins (Johnston et al., 2012).

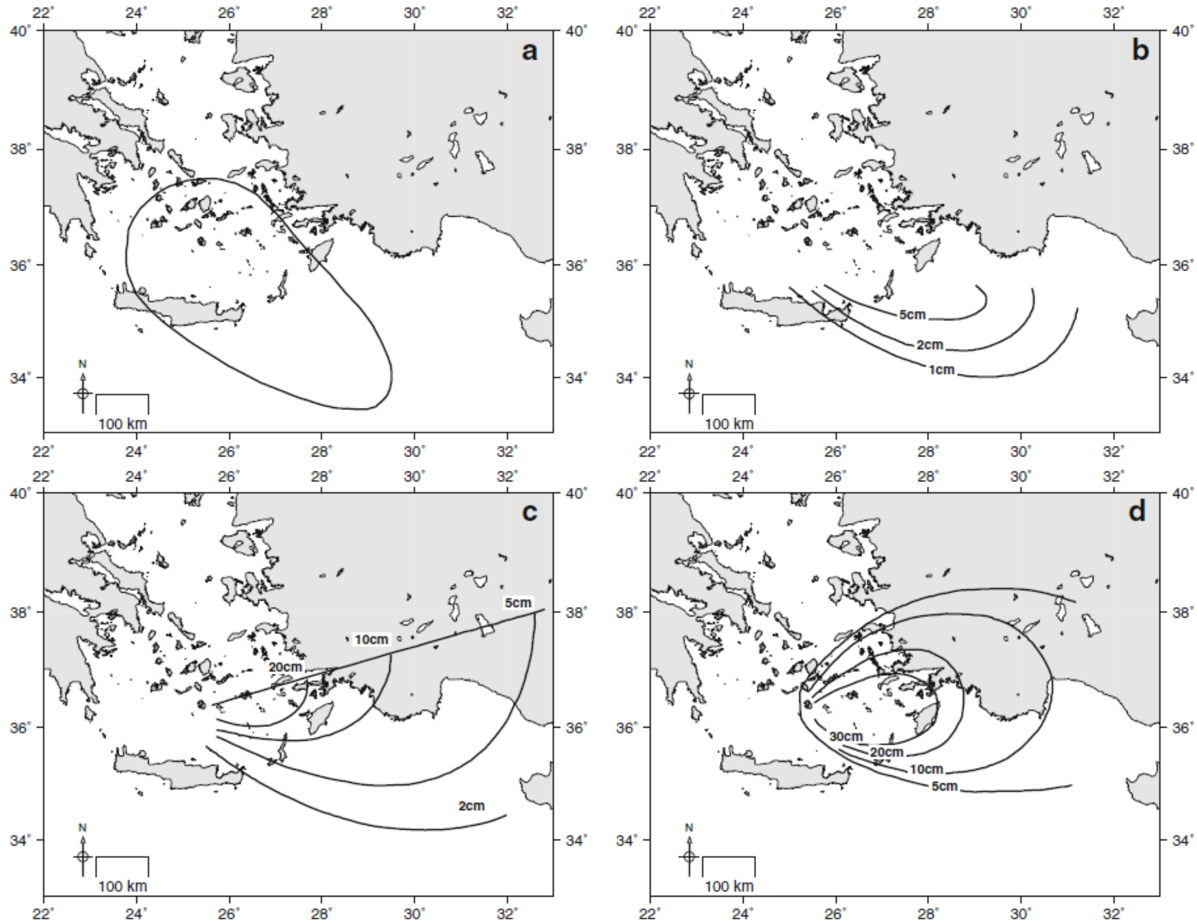


Figure 0.5 : Cartes d'isopaques publiées (en cm) : (a) Ninkovich and Heezen (1965), (b) Watkins et al. (1978), (c) Sigurdsson et al (1990), (d) Pyle (1990). La figure 8.5(a) ne montre que la distribution générale du téphra, la publication originale ne contenant pas de valeur d'isopaque (Johnston et al., 2012).

Annexe 3 : Tableaux reprenant la nature et l'ampleur des dégâts (1%, 20% et 90% de pertes) causés par le dépôt de différentes épaisseurs de téphra sur les secteurs agricoles de la production de bétail (bœuf et moutons), les biens agricoles (par exemple, le matériel, les terres…) et les cultures (aussi bien la diminution de production que les dégâts causés aux plantes) d'après Wilson et al., 2007.

Tableau 0.1 : Ratios et justification des dégâts dus au téphra sur la production de bœufs.

Dr	**Ash Depth (mm, dry)**	**Effects (Damage)**
0.01	1	Some increase in supplementary feed consumption as animals are put off pasture. Risk of chemical poisoning from aerosols (e.g. fluorosis).
0.2	10	Pasture covered, cattle put off feeding, animal health impacts, increased chance of aerosol poisoning, increased supplementary feed required as pastures are increasingly covered. This additional stress on the beef cows lowers their weight gaining potential. Ash takes longer to be shed from pastures (Neild et al., 1998).
0.9	100 (low)	All pasture will be coated with ash regardless of length, potentially stopping animals eating it. Pastures may be destroyed so will need to be rehabilitated as quickly as possible. Similar impacts as to dairy farms.
	175 (average)	
	300 (high)	

Tableau 0.2 : Ratios et justification des dégâts dus au téphra sur la production de moutons et de gibier (cervidés).

Dr	**Ash Depth (mm, dry)**	**Effects (Damage)**
0.01	1	lowest possible value – any ashfall is likely to impact production
0.2	7	Pasture will be mostly covered, stock put off eating, increased use of supplementary feed. Less resilient than beef as graze closer to ground level – higher level of volcanic ash ingestion (increased animal health impacts, e.g. teeth abrasion, aerosol poisoning, etc.).
0.9	90 (low)	Similar vulnerabilities to beef and dairy farms, with pasture rehabilitation likely to be required at this point.
	150 (average)	
	250 (*high*)	

Tableau 0.3 : Ratios et justification des dégâts dus au téphra sur les biens agricoles.

Dr	Ash Depth (mm, dry)	Effects (Damage)
0.01	5 mm	Possible damage to gutters on farm buildings, corrosion of metal roofs and fences, damage to cooling systems (condensers), farm machinery if operating in ashy conditions (Neild et al., 1998; Blong, 1984; Johnston, 1997)
0.2	70 mm	Damage to pastures creating a possible need to cultivate (plough under) ash layer, additional fertiliser inputs, potential long term loss of soil fertility. If the ash becomes wet and has not been cleared from roofs, then collapse may be possible (Spence et al., 2005). Animal deaths are likely to occur through lack of clean feed (dependant on supplementary feed reserves) and health problems.
0.9	200 mm (low)	Inability to plough ash into soil (Neild et al., 1998), possibly resulting in the need to consider land use change (e.g. to forestry). 300 mm of wet ash is a 6 kPa load, creating a 96% probability (P) roof collapse for weak roof; 70% P roof collapse for strong roof (Spence et al. 2005). It is likely the farm will suffer near complete loss of livestock herd, either through lack of feed, culling or health problems.
	300 mm (average)	
	400 mm (high).	

Tableau 0.4 : Ratios et justification des dégâts dus au téphra sur les légumes à feuilles.

Dr	Ash Depth (mm, dry)	Effects (Damage)
0.01	1	Some abrasion and chemical impacts.
0.2	2	Ash abrasion and chemical impacts on plants. Increased difficulty removing volcanic ash from crops to a satisfactory level for sale. Careful hand washing techniques may be necessary to remove ash from leaves and crevices at bases of leaves (Wilson et al., 2007).
0.9	5 (low)	Ninety percent of crop is likely to be un-saleable as volcanic ash coverage is of sufficient amounts to either destroy crops, or make ash removal so expensive as to make harvesting un economical (Barnard, 2003).
	10 (average)	
	30 (high)	

Tableau 0.5 : Ratios et justification des dégâts au téphra sur les fruits.

Dr	Ash Depth (mm, dry)	Effects (Damage)
0.01	1	Some abrasion and chemical damage
0.2	3	Some of crop destroyed from abrasion of fruit by ash and absorption of ash similar into skins, similar to tree crops but more severe as closer proximity to the ground (secondary deposition, wind abrasion, thicker bunches of leaves on stalks)
0.9	5 (low)	Very small amount of crop can be successfully harvested and sold after intense washing and ash removal efforts during cleanup.
	10 (average)	
	20 *(high)*	

Tableau 0.6 : Ratios et justification des dégâts dus au téphra sur les légumes racines.

Dr	Ash Depth (mm, dry)	Effects (Damage)
0.01	5	Some abrasion and chemical damage to leaves. Most of the crop value retained as the valuable root remains unaffected and the relatively small thickness of ash may be washed from leaves over time either manually or naturally.
0.2	30	Increased impacts to above ground leaves, possibly causing smothering or acidification damage.
0.9	50 (low)	Crop lost due to higher amounts of ash accumulating and overwhelming leafy vegetable stalks near to the ground, which might decimate the portions of the plants above ground, but allows for removal of below ground (valuable) portions with some difficulty.
	100 (average)	
	150 (high):	

Tableau 0.7 : Ratios et justification des dégâts dus au téphra sur la production des arbres fruitiers.

Dr	Ash Depth (mm, dry)	Effects (Damage)
0.01	1	Losses expected due to pitting of fruit skin and absorption of ash into the fruits (Barnard, 2003). Some impact to harvesting operations.
0.2	3	Higher frequency of occurrence of losses due to pitting and skin damage, also harvesting operations more severely affected.
0.9	10 (low)	Severe impact to fruit, possible breakage of tree branches. Very small amount of crop can be successfully harvested and sold, even after intense washing and ash removal efforts.
	20 (average)	
	50 (high)	

Tableau 0.8 : Ratios et justification des dégâts dus au téphra sur la production des vignes.

Dr	Ash Depth (mm, dry)	Effects (Damage)
0.01	1	Some abrasion and chemical impacts to grapes. Some impact to harvesting operations.
0.2	2	Intensive steps necessary to save fruit (hand washing). Costs to recover grapes by removing ash begin to equal value of crop.
0.9	1 (low)	Grapes nearly all destroyed by volcanic ash – near total loss of crop.
	5 (average)	
	20 (high)	

Tableau 0.9 : Ratios et justification des dégâts dus au téphra sur les biens liés aux plantes annuelles.

Dr	Ash Depth (mm, dry)	Effects (Damage)
0.01	5	impacts to gutters on farm buildings, corrosion of metal roofs, fences, damage to cooling system (condensers), farm machinery if operating in ashy conditions
0.2	100	impact to soils, need to cultivate (plough under) ash layer, additional fertiliser inputs, potential long term loss of soil fertility. Wet ash – roof collapse (Spence et al., 2005). Specialist harvesting equipment may be damaged if operated in ashy conditions.
0.9	200 (low)	Inability to plough ash into soil – land use change to forestry may be required.
	300 (average)	
	400 (high).	

Tableau 0.10 : Ratios et justification des dégâts dus au téphra sur les biens liés aux plantes pérennes.

Dr	Ash Depth (mm, dry)	Effects (Damage)
0.01	3	Few trees and plants destroyed, some damage to farm infrastructure
0.2	75	Trees and plants breaking under ash load, minor damage to farm infrastructure
0.9	250 (low)	Widespread damage to trees and plants, high risk of building and equipment damage (as mentioned within seasonal crops).
	350 (average)	
	100 (high)	

Tableau 0.11 : Ratios et justification des dégâts dus au téphra sur les vignes

Dr	Ash Depth (mm, dry)	Effects (Damage)
0.01	10	Some damage to grape vines from load of ash on leaves, physical abrasion and chemical damage
0.2	50	Moderate damage to grape vines from load of ash on leaves, physical abrasion and chemical damage. Minor damage to vineyard
0.9	100 (low)	Widespread damage to vines, high risk of building and equipment damage.
	250 (average)	
	400 (high)	

Annexe 4 : Présentation des sites utilisés pour la modélisation, et itérations de la modélisation du réseau de commerce en mer Egée avant l'éruption de Santorin, immédiatement après, et à long terme, de Knappett et al. (2011).

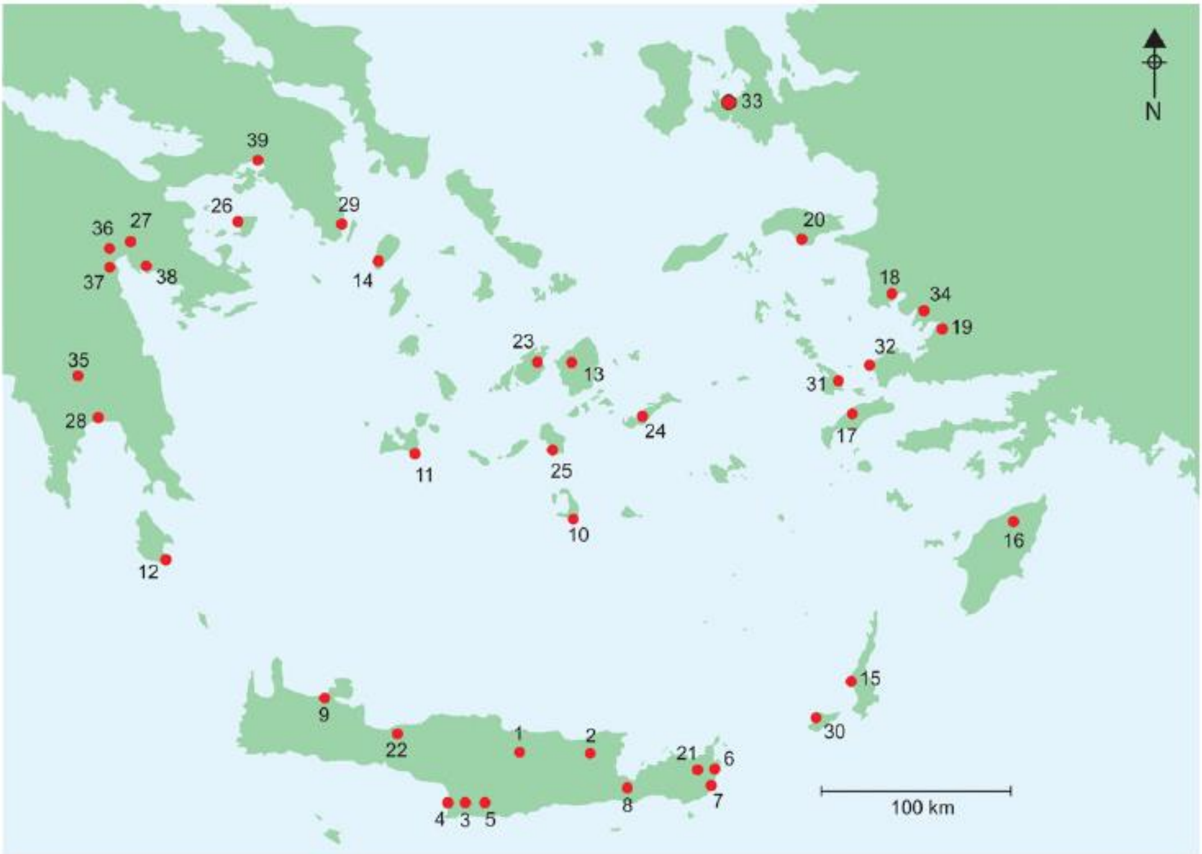


Figure 0.6 : La mer Egée, avec les 39 sites sélectionnés pour la génération du réseau de commerce maritime : 1. Knossos, 2. Malia, 3. Phaistos, 4. Kommos, 5. Ayia Triadha, 6. Palaikastro, 7. Zarkos, 8. Gournia, 9. Chania, 10. Thera, 11. Phylakopi, 12. Kastri, 13. Naxos, 14. Kea, 15. Karpathos, 16. Rhodes, 17. Kos, 18. Miletus, 19. Iasos, 20. Samos, 21. Petras, 22. Rethymnon, 23. Paroikia, 24. Amorgos, 25. Ios, 26. Aegina, 27. Mycenae, 28. Ayios Stephanos, 29. Lavrion, 30. Kasos, 31. Kalymnos, 32. Myndus, 33. Cesme, 34 Akbuk, 35. Menelaion, 36. Argos, 37. Lerna, 38. Asine, 39. Eleusis.

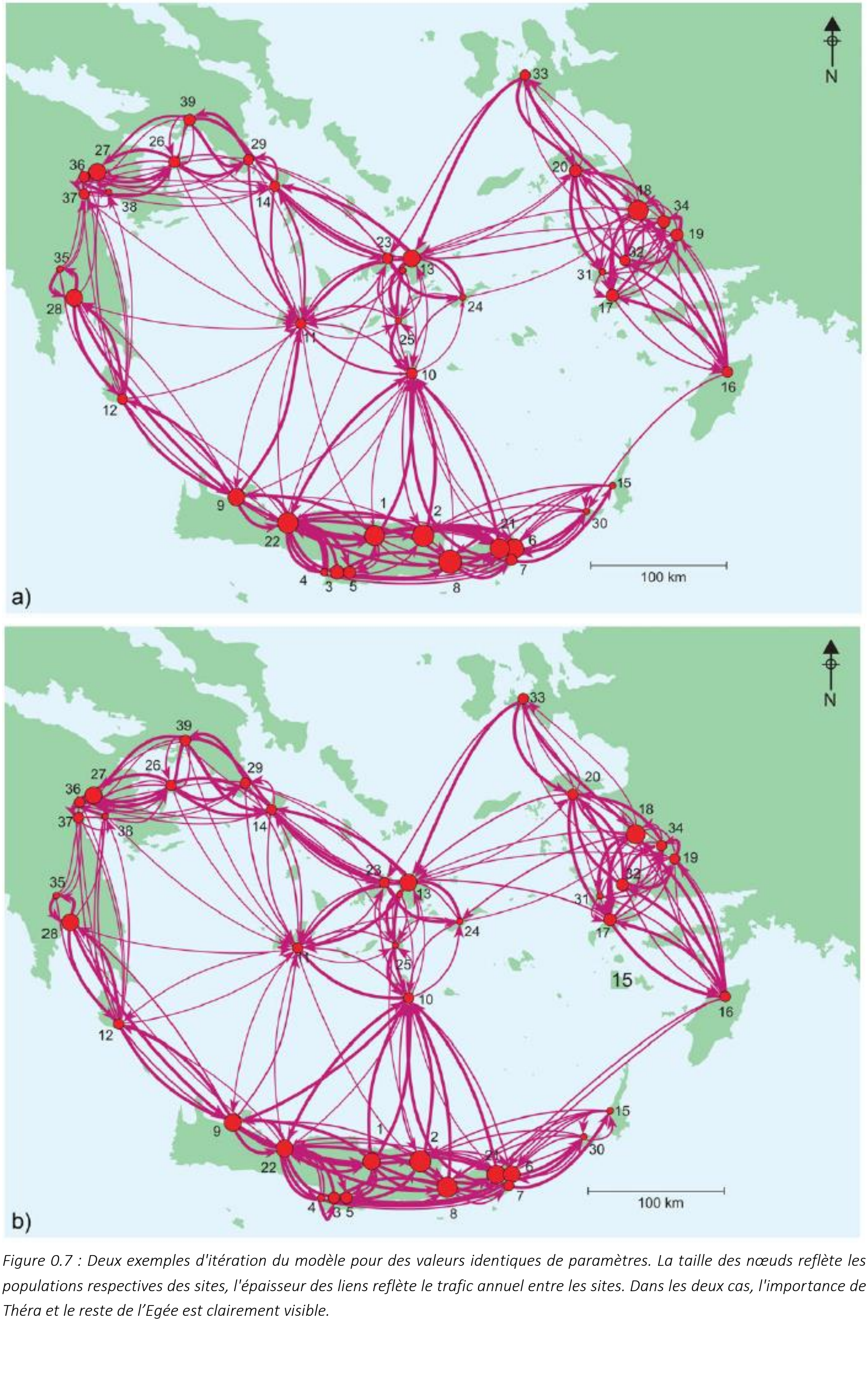


Figure 0.7 : Deux exemples d'itération du modèle pour des valeurs identiques de paramètres. La taille des nœuds reflète les populations respectives des sites, l'épaisseur des liens reflète le trafic annuel entre les sites. Dans les deux cas, l'importance de Théra et le reste de l'Egée est clairement visible.

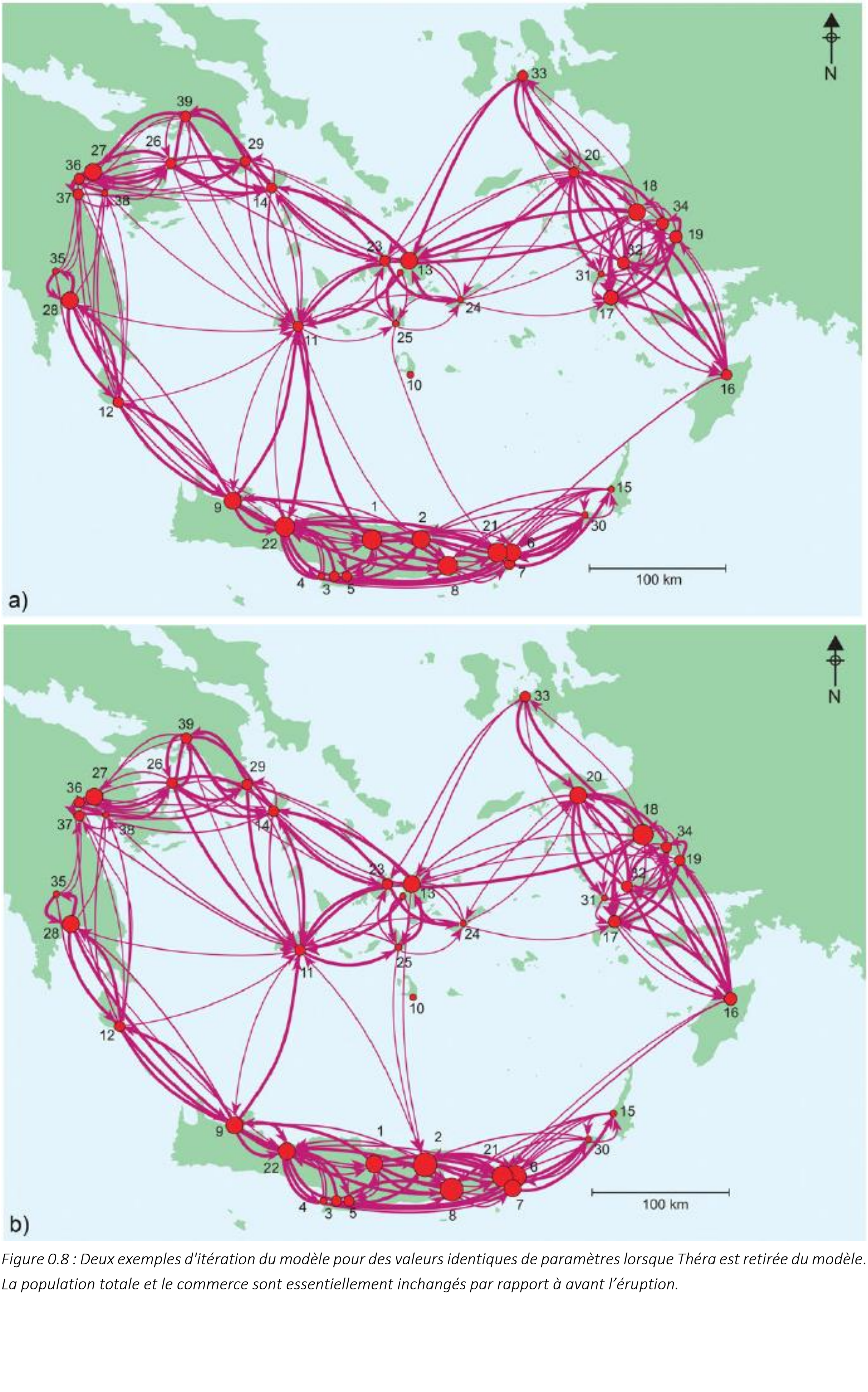
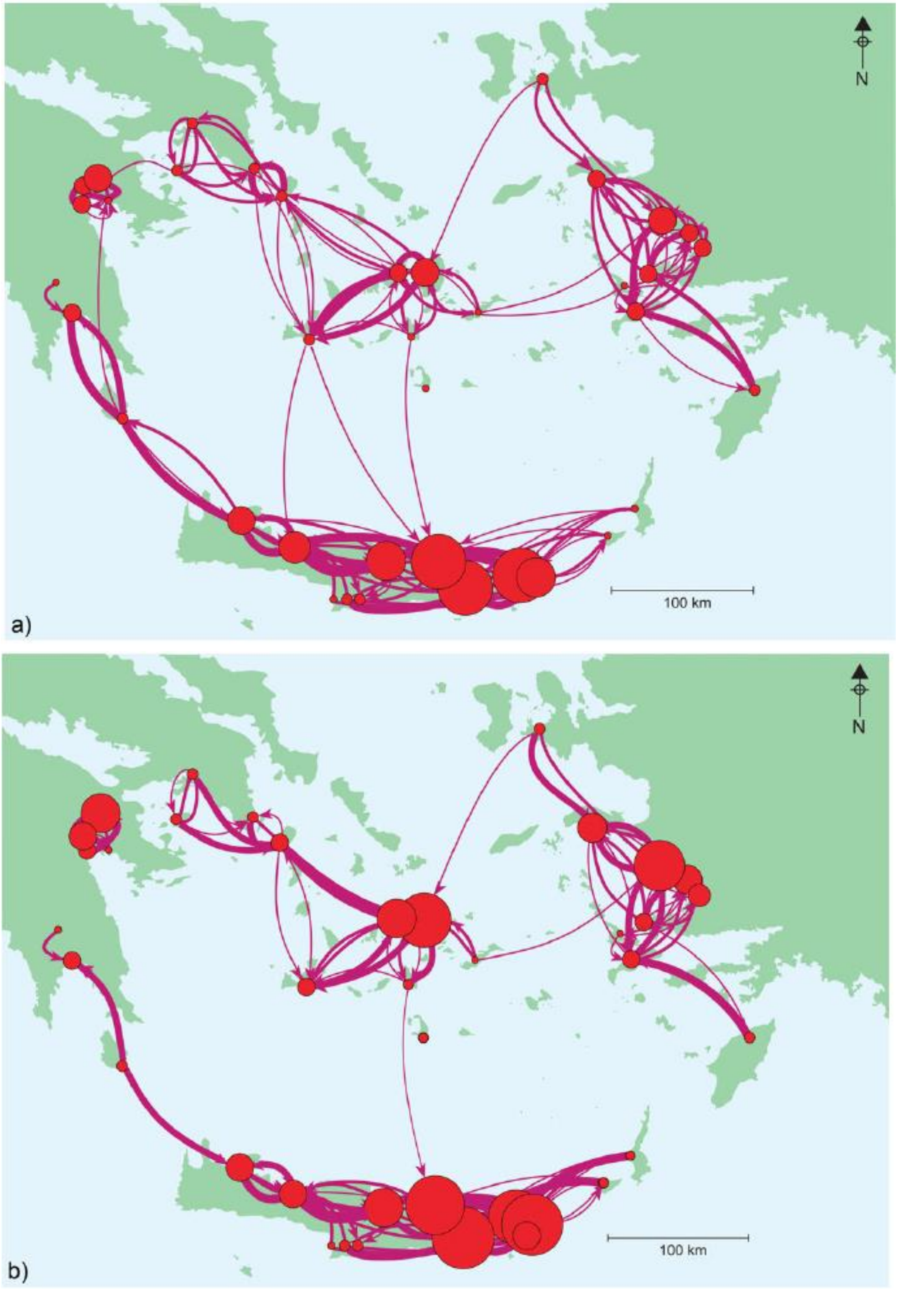


Figure 0.8 : Deux exemples d'itération du modèle pour des valeurs identiques de paramètres lorsque Théra est retirée du modèle. La population totale et le commerce sont essentiellement inchangés par rapport à avant l'éruption.


N
100 km
a)
N
100 km
b)

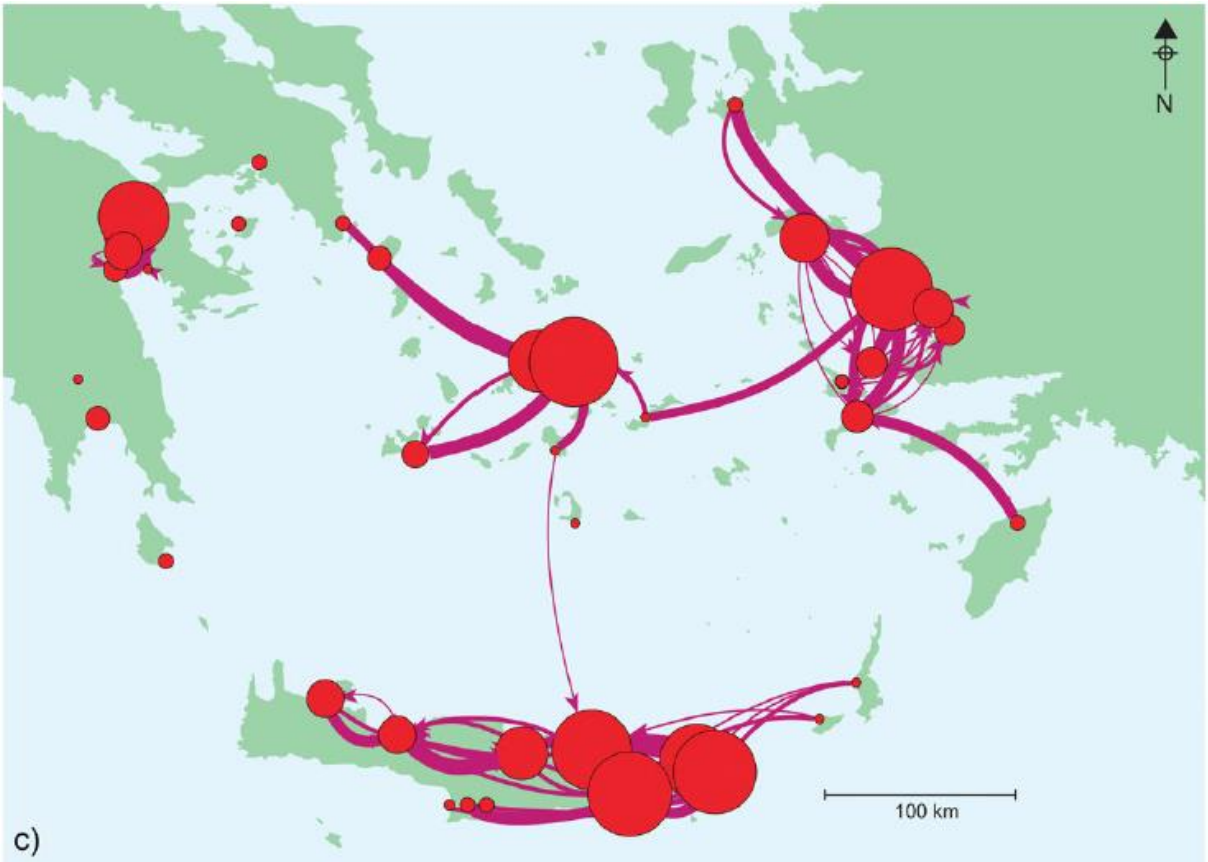


Figure 0.9 : Trois exemples d'itération du modèle dans lesquels, en commençant avec les valeurs des paramètres de la Figure 8.8, les coûts de maintien des liens sont augmentés.