Department
for Environment
Food & Rural Affairs

Met Office
Hadley Centre

Exploring the limitations of degree day models in assessing the potential development of transient pests: *Bemisia tabaci* in the UK and France

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Rationale for the study

1. To assess the potential for glasshouse pests to establish transient summer populations outdoors in areas with cold winters:
   - degree day models are often used to determine whether there is sufficient temperature to complete at least one generation outdoors
   - survival in cold weather is not usually taken into account because summers are warm and the species are assumed to die out each winter
2. The tobacco whitefly (*Bemisia tabaci*):
   - often causes outbreaks in UK and French glasshouses,
   - has ample opportunity to escape outdoors each summer
   - transmits so many viruses that it is assumed that even small outdoor populations would be readily detected
3. However, *Bemisia tabaci* is only found outdoors in the south of France despite degree day models showing it should have multiple generations in large areas of the UK, central and northern France
4. A large number of climatic indices were examined to try and account for this conundrum

Bemisia tabaci

- The tobacco whitefly (Hemiptera, Aleyrodidae)
- Worldwide pest of large numbers of outdoor and protected crops (host range > 1,000 species)
- Transmits more than 110 viruses
- Infestation levels may be very high but even low densities can be damaging due to virus transmission
- A plant health quarantine insect for many parts of the world
- "*Bemisia tabaci*" is a species complex:
    - Up to 28 morphologically indistinguishable putative species
    - MEAM1 (Biotype B) & MED (Biotype Q) most significant to UK

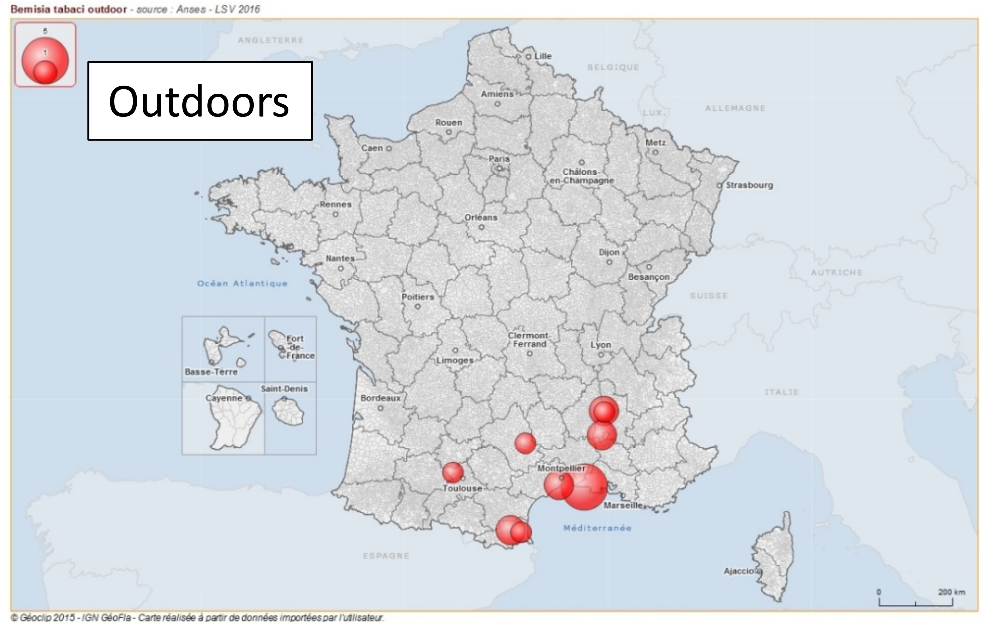


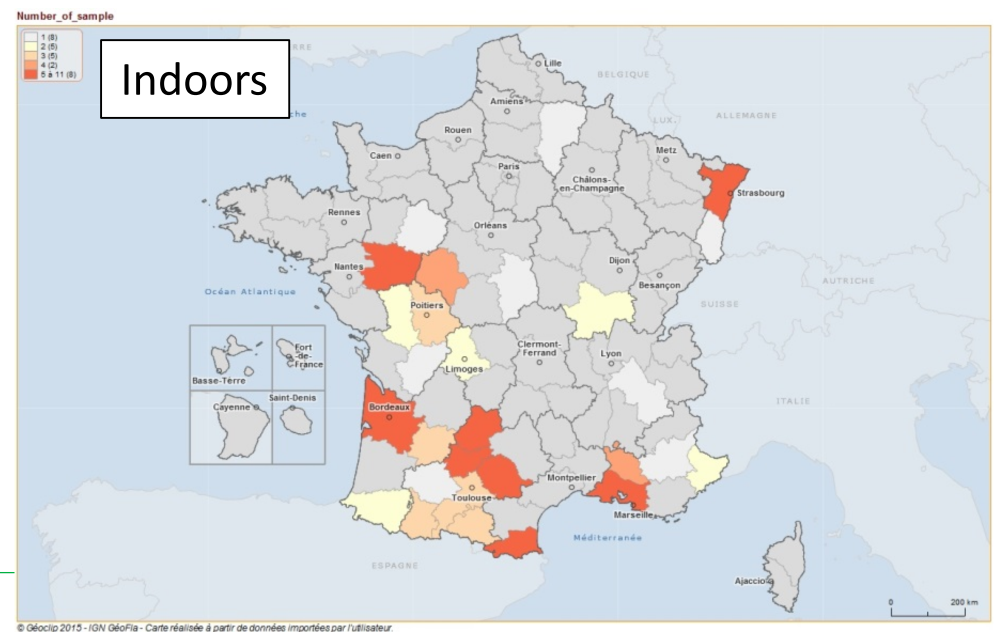
Bemisia tabaci distribution in France and the UK

France (1996-2016)

- Outdoors (top map)
- Under glass (bottom map)

Maps and data courtesy of ANSES – Philippe Reynaud



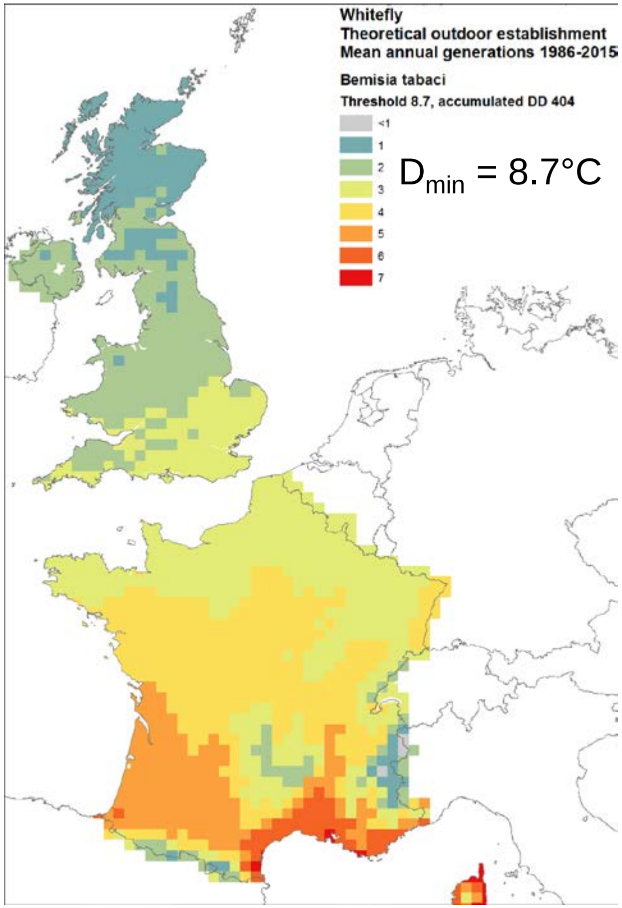


UK

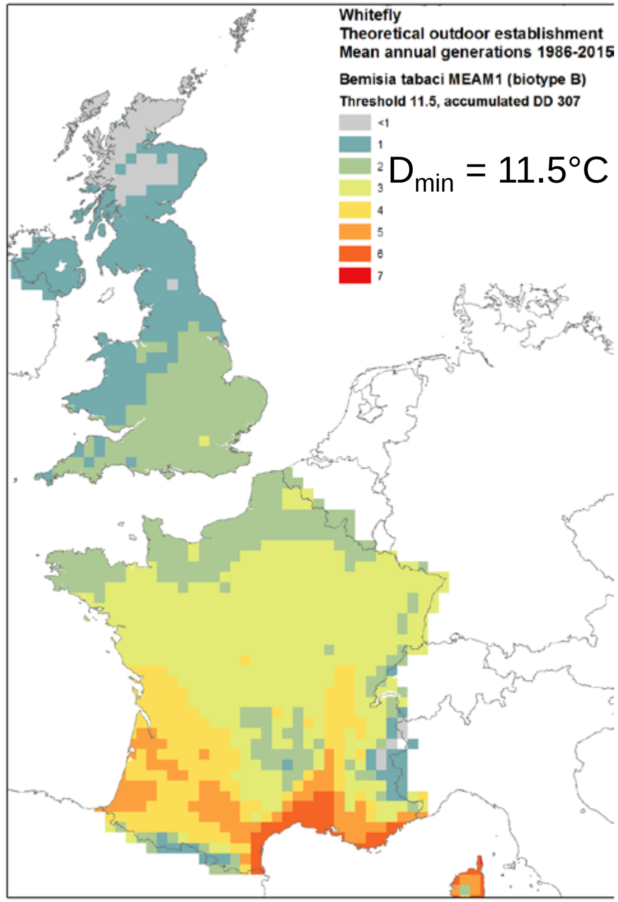
- Only transient populations under glass (average 20 outbreaks a year in 1998-2015)
  - Quarantine pest
  - Eradication whenever it is found

Potential number of generations per annum outdoors in UK and France based on three *B. tabaci* degree day models

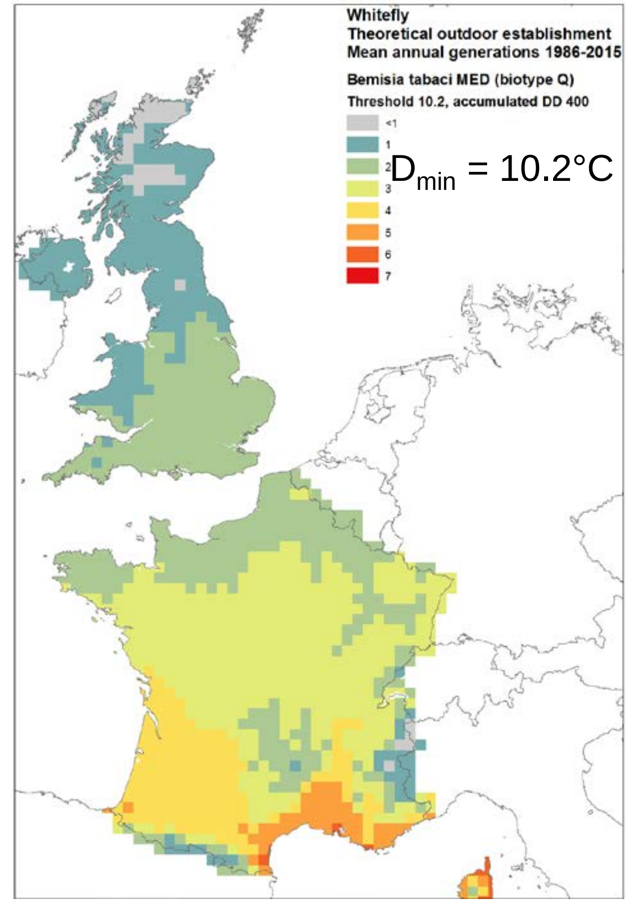
MEAM1 (Biotype B)
Muñiz (2000)



MEAM1 (Biotype B)
Bosco & Cagliari (1998)



MED (Biotype Q)
Bonato *et al*. (2007)



Estimates use the JRC-MARS 25km gridded temperature data, average for 1986-2015

Muñiz, M. 2000. Development of the B-biotype of *Bemisia tabaci* (Gennadius,1889) (Homoptera: Aleyrodidae) on three varieties of pepper at constant temperatures. Boletín de Sanidad Vegetal Plagas, 26, 605-618.
Bonato, O., Lurette, A., Vidal C. & Fargues, J. 2007. Modelling temperature-dependent bionomics of *Bemisia tabaci* (Q-biotype). Physiological Entomology, 32, 50-55.
Bosco, D., & Caciagli, P. 1998. Bionomics and ecology of *Bemisia tabaci* (Sternorrhyncha, Aleyrodidae) in Italy. European Journal of Entomology, 95, 519-527.

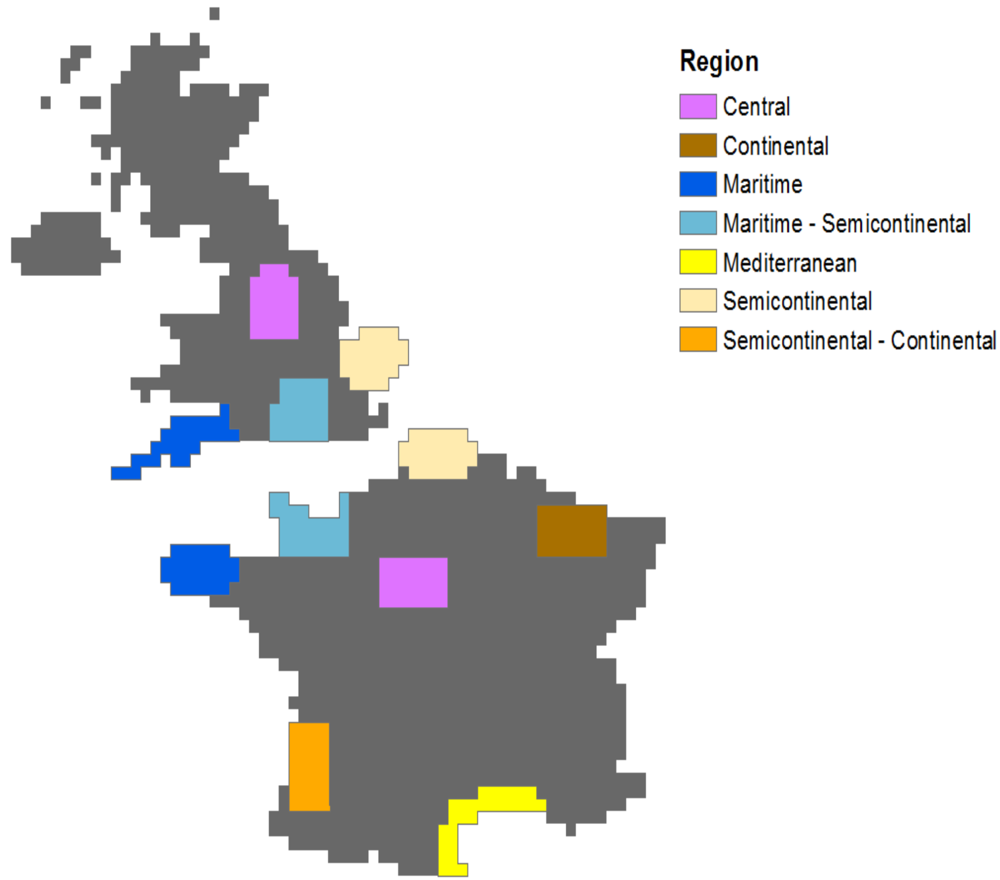
The climatic datasets and indices studied:

- Two freely available European climate datasets with daily data interpolated to ~25 km resolution for 1986-2015 were explored:
  - E-OBS from the EU ENSEMBLES Project
  - JRC-MARS
- 48 standard climate assessment indices were calculated:
  - Every month of the year studied separately
  - Maps for UK & France prepared
  - Seven climatic regions defined by continentality and oceanicity used for statistical comparisons
  - Focused on the three key summer months (June-August) and comparisons with the Mediterranean region where *B. tabaci* can survive outdoors

JOINT RESEARCH CENTRE
Agricultural Resources Data Portal

E-OBS gridded dataset

ENSEMBLES



Results: monthly maps for each index

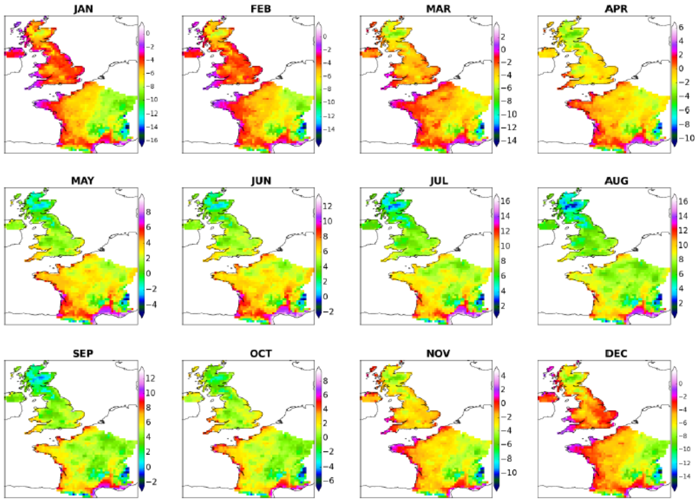


Figure 1: Minimum daily minimum temperature (°C)

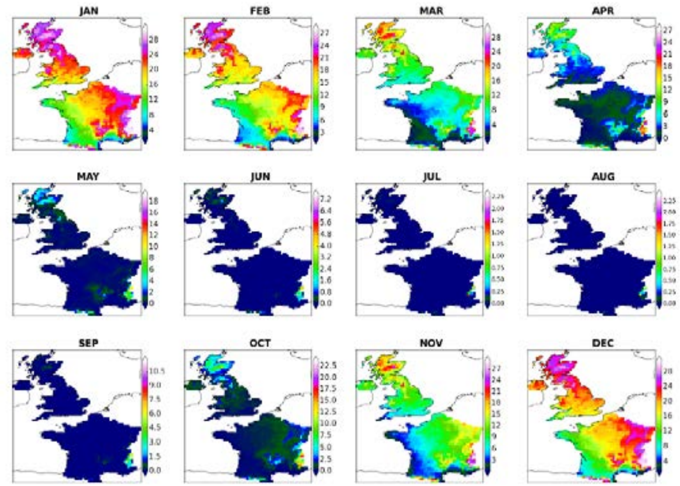


Figure 4: Number of days max temperature below 8.7°C

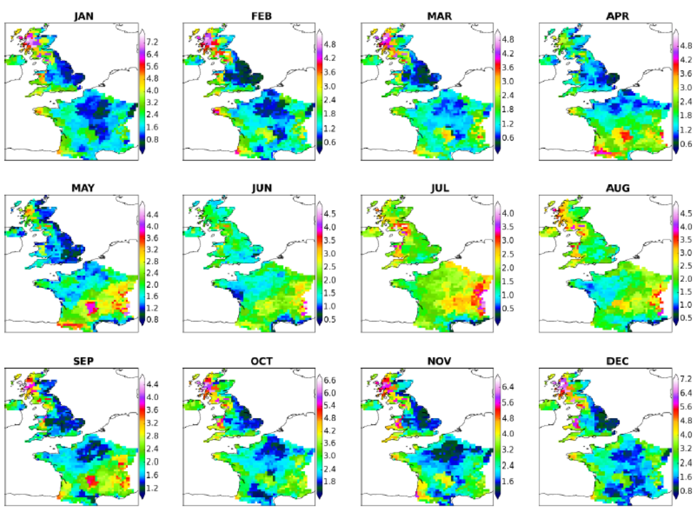


Figure 17: Number of heavy rain days

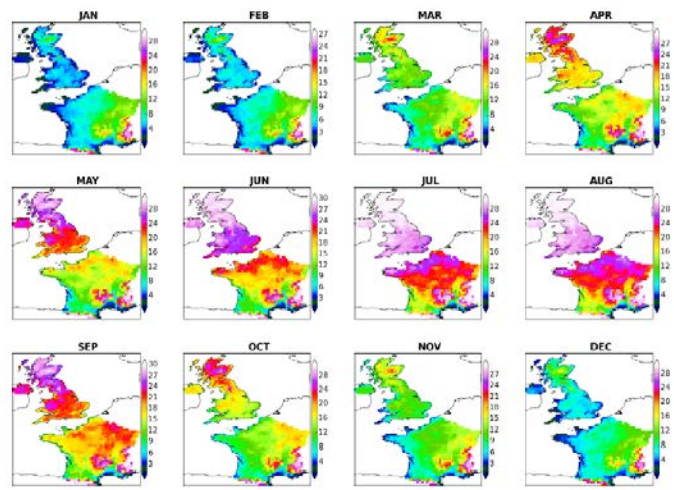


Figure 28: Number of cold nights relative to Mediterranean region

… Plus 42 other climatic indices

… Repeated for the second climatic dataset

Results: box plots for each index comparing the 7 regions

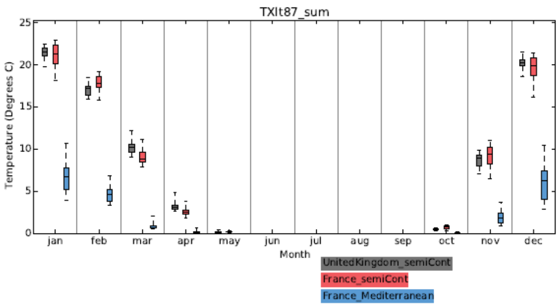


Figure 5: Number of days below 8.7°C

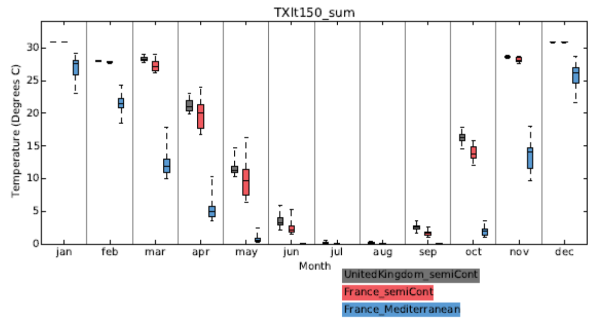


Figure 7: Number of days below 15°C

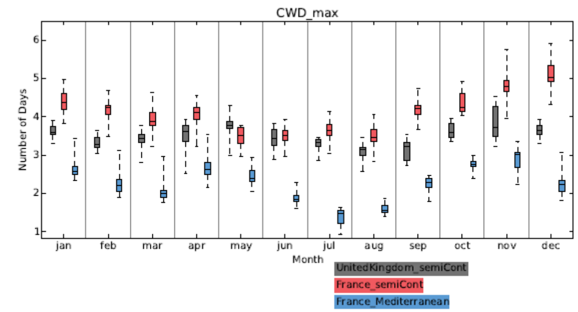


Figure 14: Number of consecutive wet days

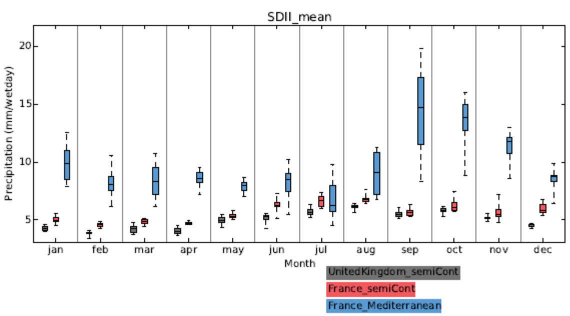


Figure 17: Mean wet day intensity (mm)

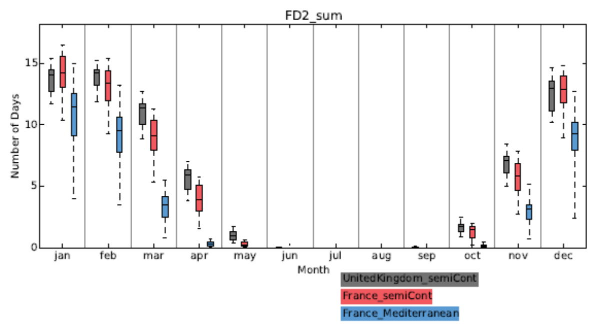


Figure 25: Number of frost days (<2°C)

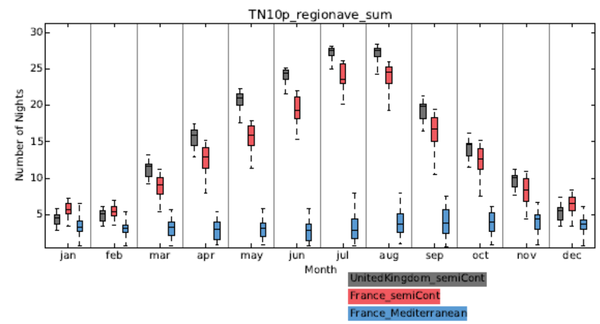


Figure 28: Number of cold nights relative to Mediterranean region

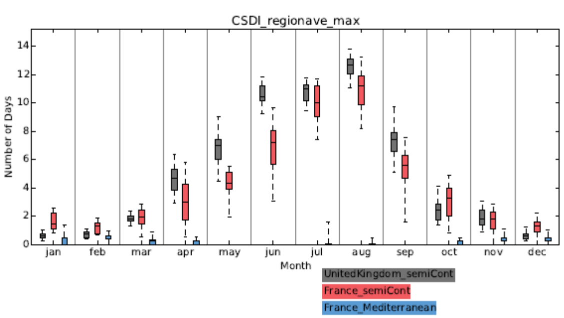


Figure 29: Cold spell duration relative to Mediterranean region (days)

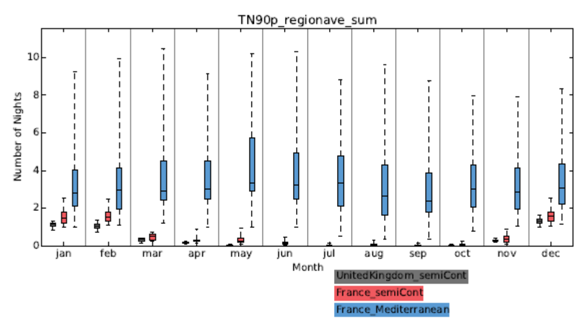


Figure 36: Number of warm nights relative to Mediterranean region

… Plus 38 other climatic indices
… Repeated for each of 5 regional comparisons
… Repeated for the second climatic dataset

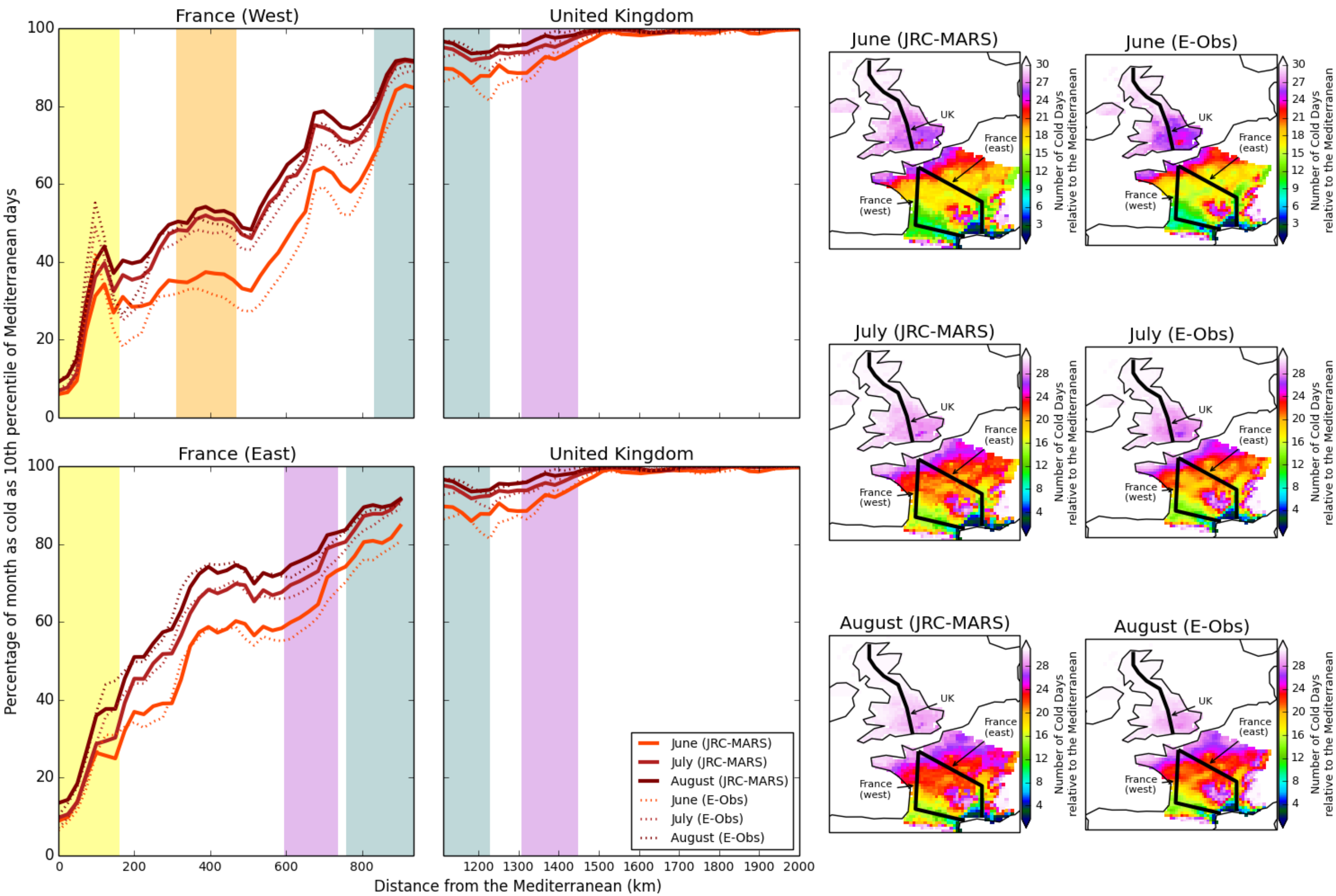
Results: Top 5 significantly different indices between the UK Regions and the Mediterranean in June, July and August
(JRC-MARS only – similar results for E-Obs)

UK Region	% indices different	Most different indices									
		1st		2nd		3rd		4th		5th	
		Index	t-stat	Index	t-stat	Index	t-stat	Index	t-stat	Index	t-stat
Maritime	73	TG10p (JUN)	49.6	SU (AUG)	46.3	TG10p (JUL)	46.1	TG10p (AUG)	44.8	TN10p (JUL)	39.6
Maritime/ Semicontinental	78	TN10p (JUL)	40.5	TG10p (JUN)	36.9	TN10p (AUG)	35.0	TG10p (JUL)	34.7	TN10p (JUN)	34.5
Semicontinental	80	TG10p (JUN)	39.1	TG10p (JUL)	37.0	TG10p (AUG)	36.1	TN10p (JUL)	33.5	TN10p (AUG)	32.5
Central	78	TN10p (JUL)	47.5	TG10p (JUN)	46.5	TG10p (AUG)	46.0	TN10p (JUN)	45.1	TN10p (AUG)	44.6

TN10p	**Cold Nights** - the minimum daily temperature is less than the 10th percentile mean temperature for a 5 day period centred on each calendar day in the Mediterranean Region
TG10p	**Cold Days** - the mean daily temperature is less than the 10th percentile mean temperature for a 5 day period centred on each calendar day in the Mediterranean Region
SU	**Summer Days** – the maximum daily temperature is greater than 25°C

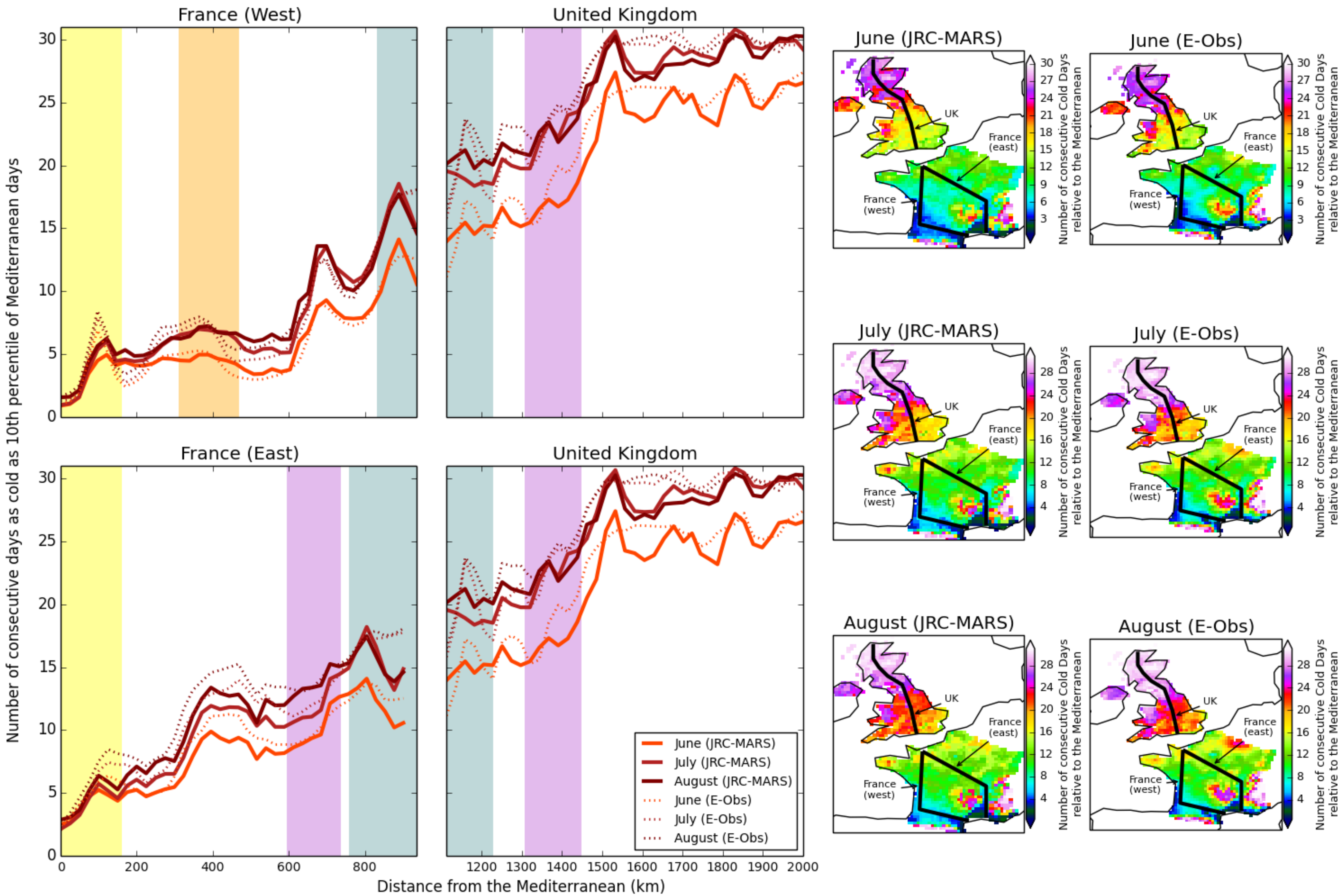
Results: North-south transects through Eastern and Western France and the UK – Cold Days

Percentage of the month as cold as the 10th percentile of cold days in the Mediterranean region



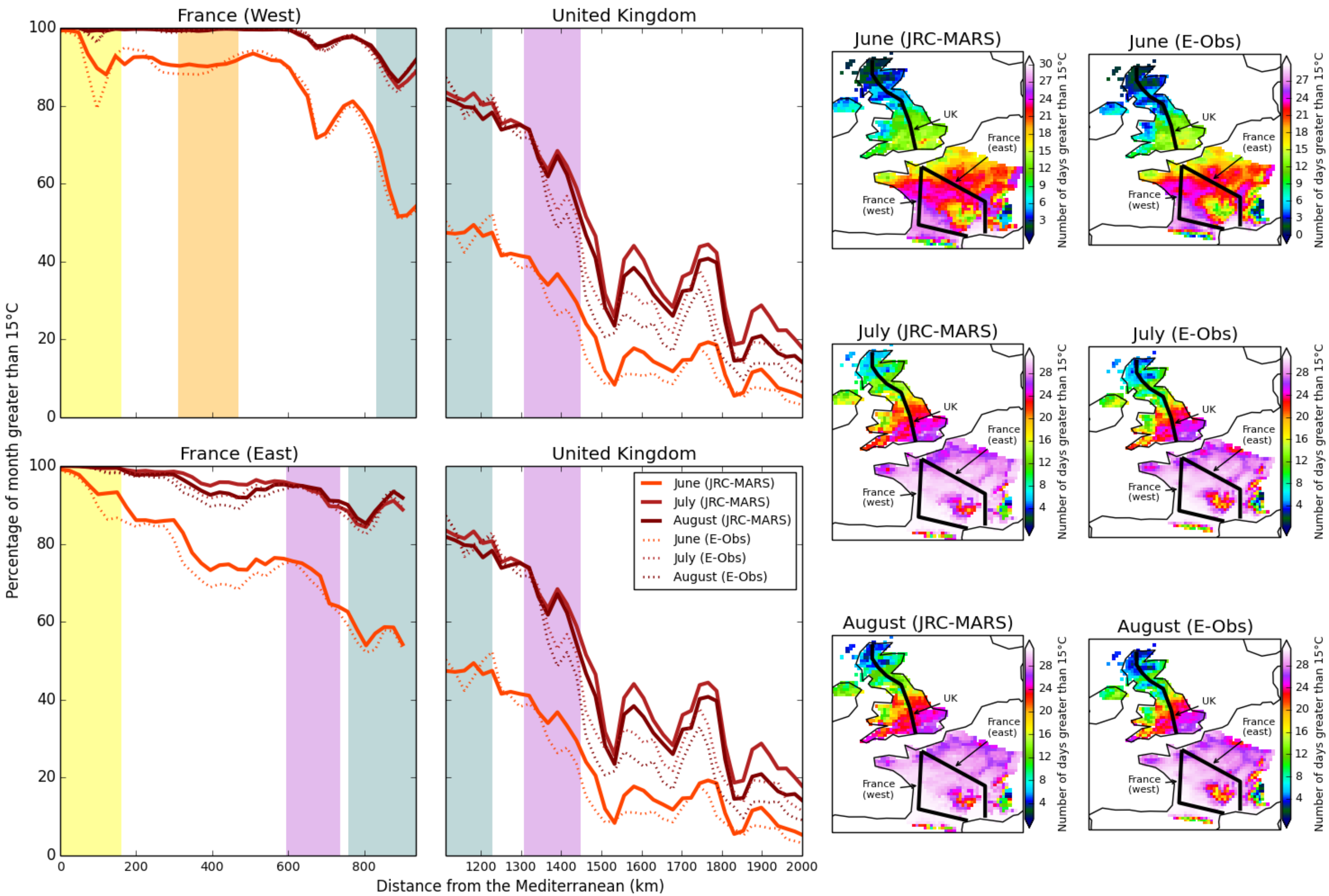
Results: North-south transects through Eastern and Western France and the UK – Consecutive Cold Days

Number of consecutive days as cold as the 10th percentile cold days in the Mediterranean region



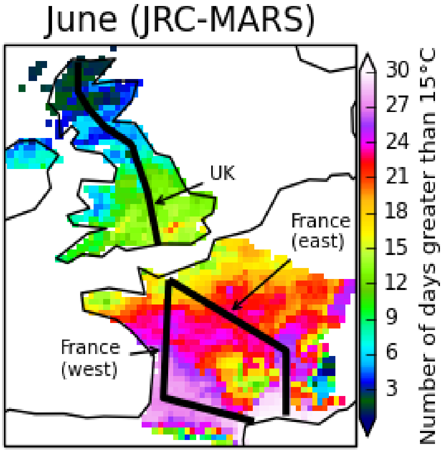
Results: North-south transects through Eastern and Western France and the UK – Summer Days

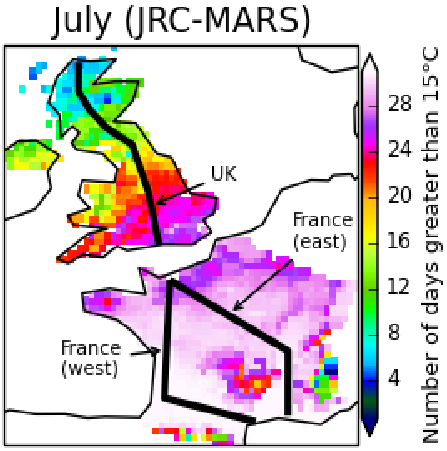
Percentage of the month greater than 25°C

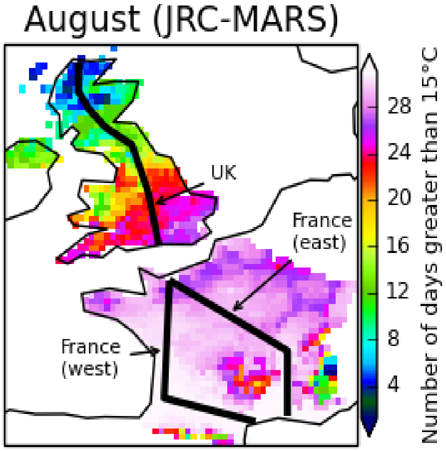


Summary of the Results

1. Three indices showed the greatest statistically significant difference between the four UK regions selected and the Mediterranean region:
    - Number of cold days
    - Number of cold nights
    - Number of summer days
2. A clear north-south gradient exists for both the number of cold days and cold nights and the number of consecutive cold days and cold nights
3. This north-south gradient also occurs in indices related to the degree days available for development such as the days that can be considered optimal for development: >=15°C







Conclusions

1. The absence of outdoor populations of *Bemisia tabaci* in latitudes to the north of southern France cannot be explained simply by degree day models.
2. The higher number of cold days and cold nights in summer that occur in central and northern France as well as the UK may induce chilling injury and cause mortality in pests such as *B. tabaci* that are unlikely to have the rapid cold hardening adaptation of organisms in temperate climates as they are found in protected cultivation where there are relatively high constant temperatures.
3. The gradient in climatic variables related to pest development and summer cold stress through eastern and western France, either side of the Massif Central, indicates that northwards pest movements and outdoor glasshouse populations in France can be used as an early warning of potential pest invasions in the UK.
4. Over-wintering remains the principal challenge for invertebrate pests in temperate climates but further work is also required to determine the role played by over-summering in limiting pest distributions, particularly in maritime climates.

Acknowledgements

We are very grateful to Phillipe Reynaud from ANSES, the French Agency for Food, Environmental and Occupational Health & Safety for providing data on *B. tabaci* in France.

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http://www.plantanswers.com/Articles/TomatoYellowLeafCurlVirus.asp