Pesticide fate and climate: how are they linked?

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Enviresearch

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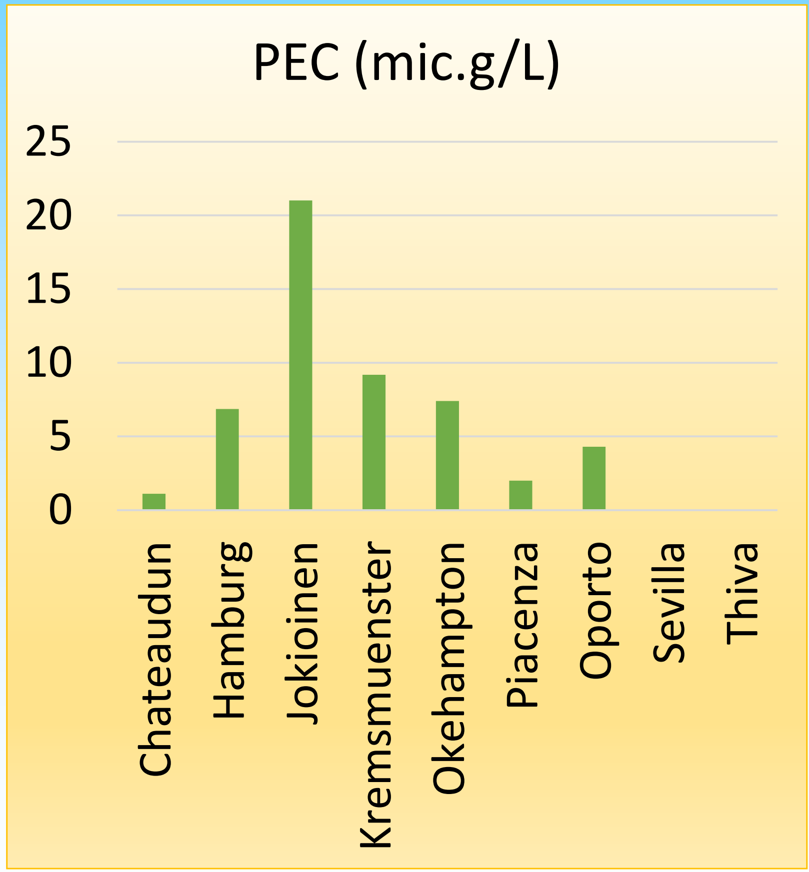
Outline

- What is fate?
- What is climate?
- Basic processes
- Indirect effects
- Modelling the link
- What really matters

FOCUS leaching scenarios

- Substance: FOCUS A
  - Koc = 103 L/kg
  - DT_{50} = 60 d
- Crop: winter wheat
- App date: 1 April
- Soil: Okehampton



Scope

Image to left by By Chafer Machinery - Flickr, CC BY 2.0,
https://commons.wikimedia.org/w/index.php?curid=47583182.
Image to right by Christian Fischer, CC BY-SA 3.0,
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Weather or climate

Weather

- Rain this year
- Rainstorm today
- Barbeque summer
- Weather here or there

Climate

- Annual average rain
- Distribution of storm events
- Likelihood of a barbeque summer
- Weather patterns across the world

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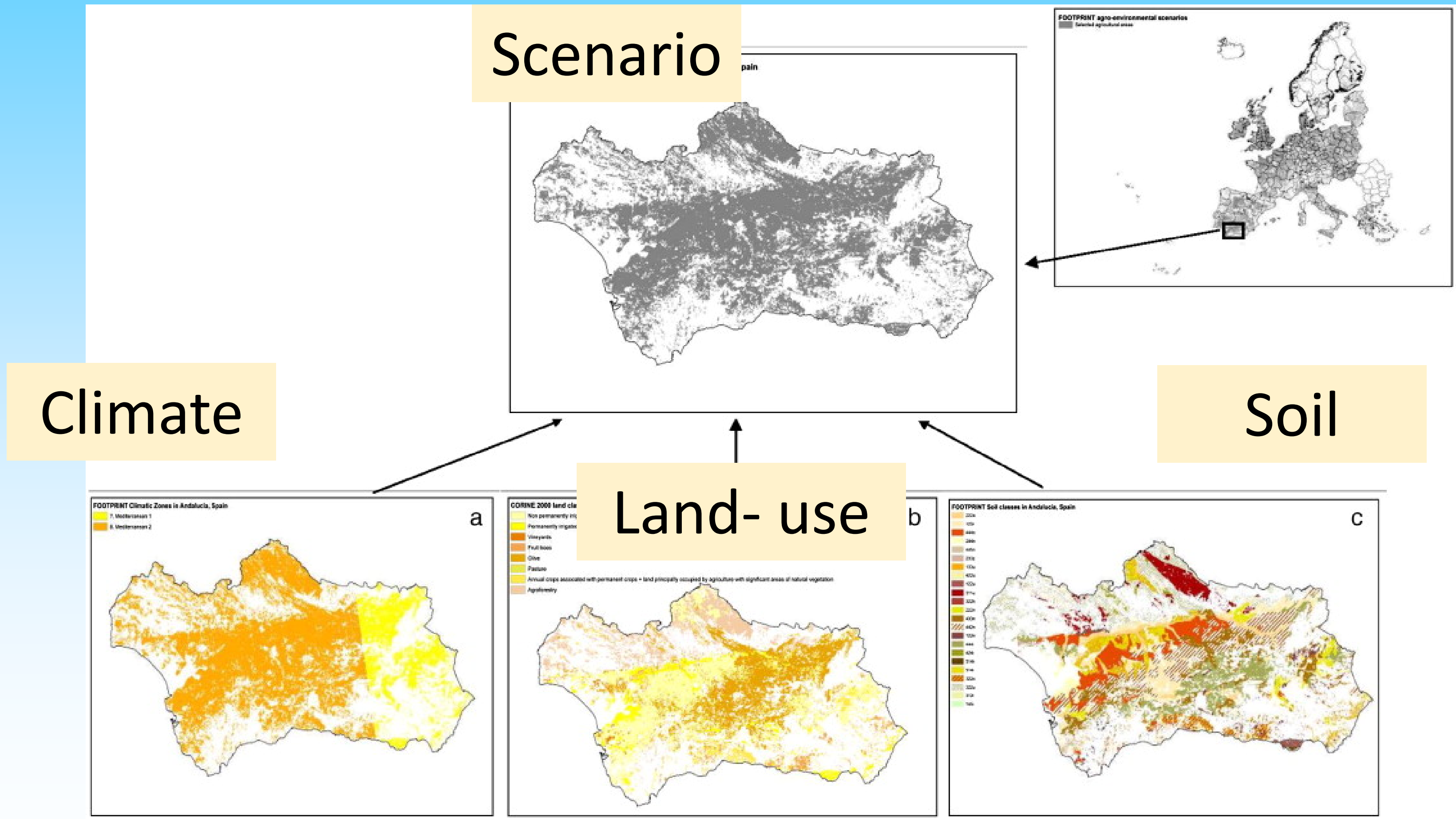
Climate in the context of agroecology

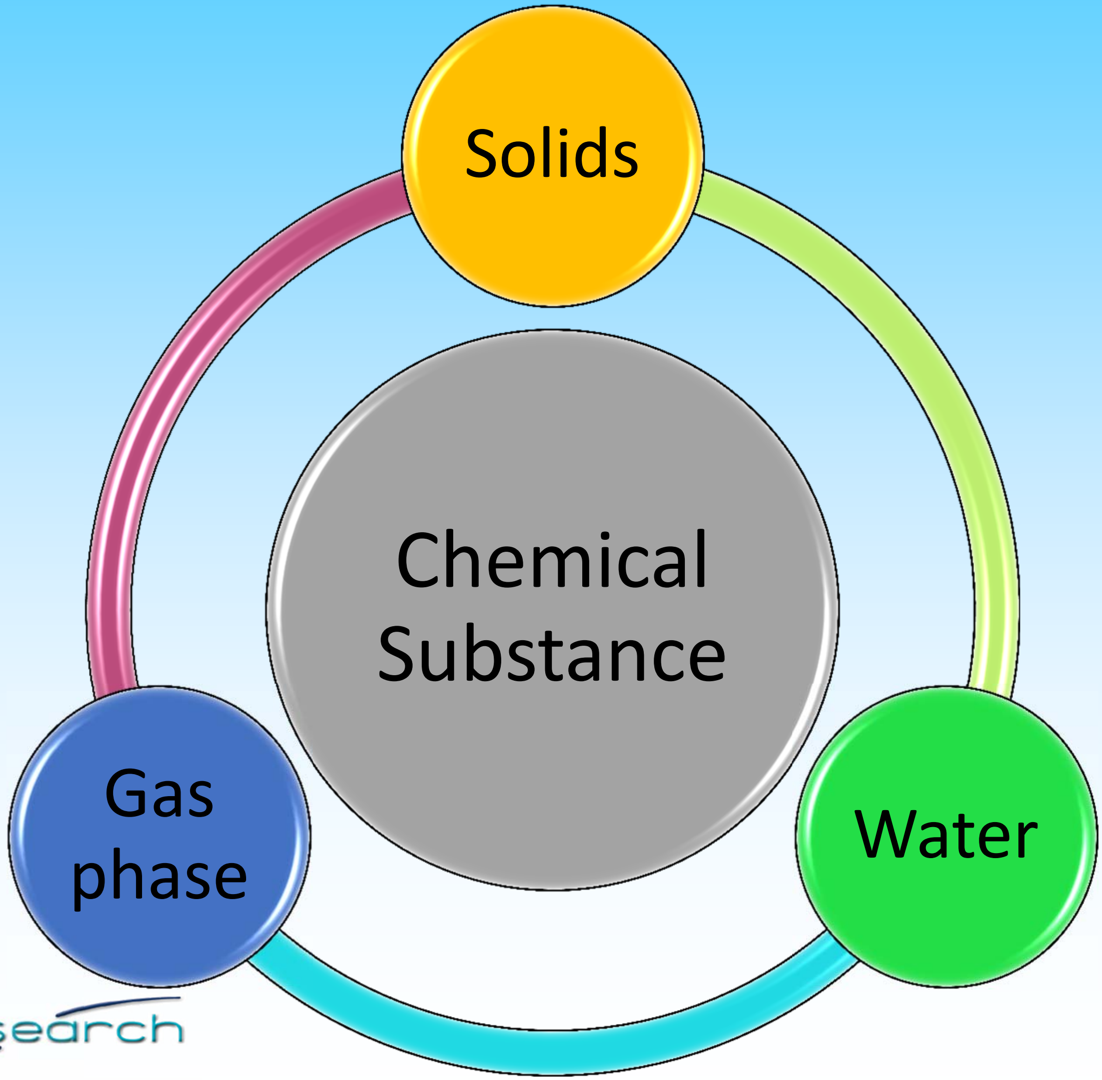


Centofanti *et al.*, 2008. Science of The Total Environment, Volume 407, Issue 1, 2008, 574–588

Basic processes

- Partitioning
- Chemical transformation
- Flow

Partitioning



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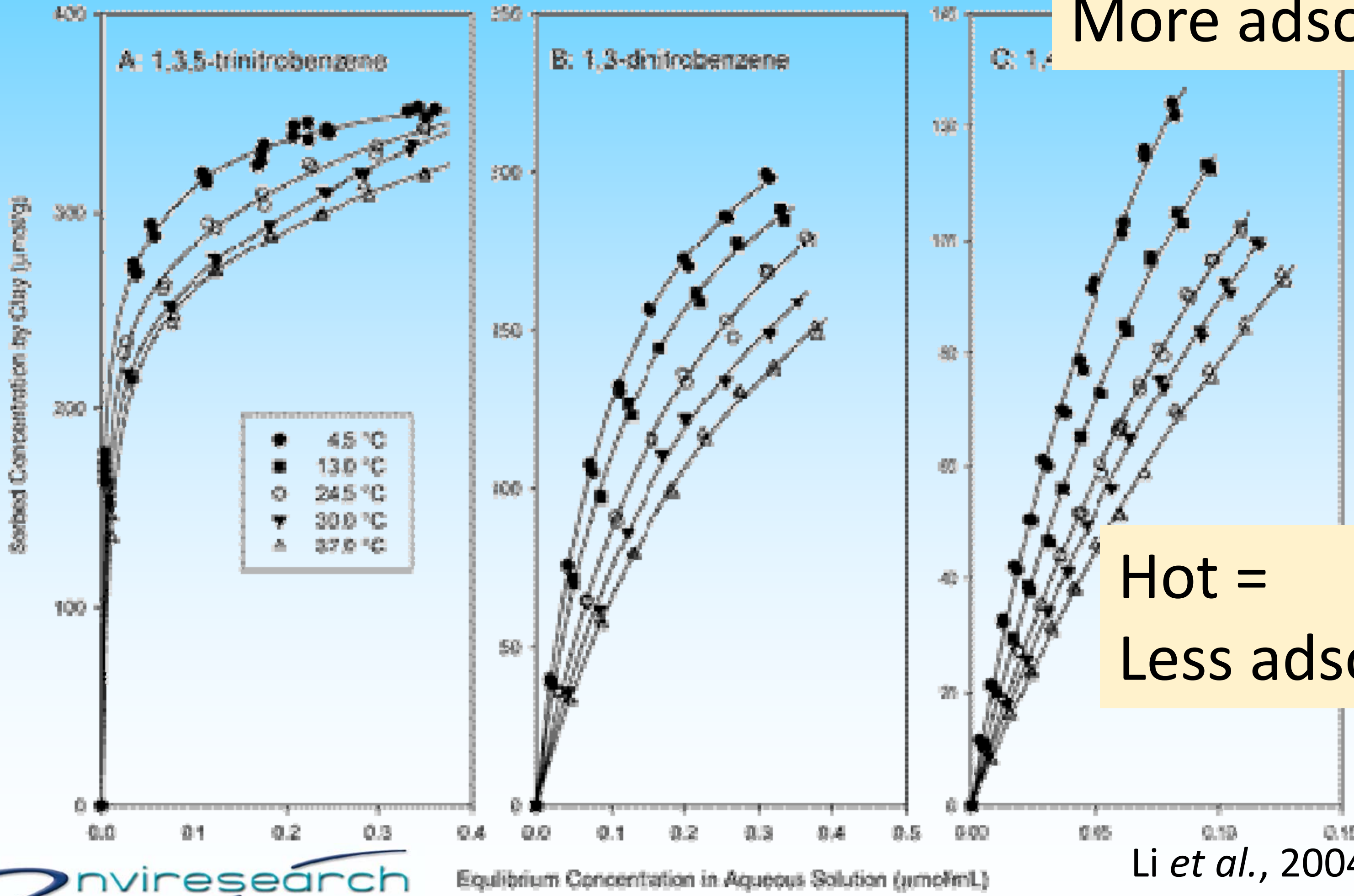
Temperature effects on solid-liquid partitioning

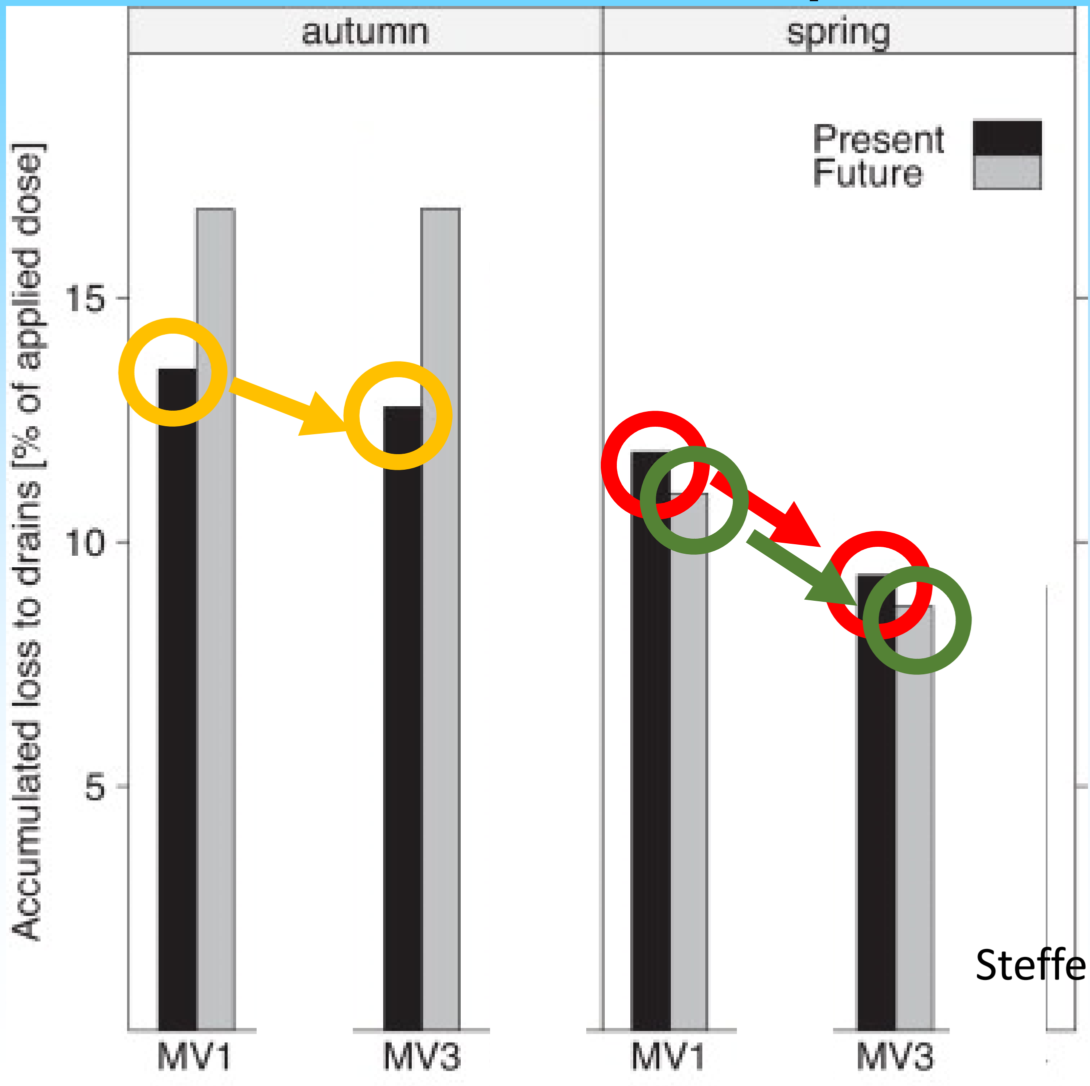
Cold =
More adsorption



Hot =
Less adsorption

Li *et al.*, 2004. Environ. Sci. Technol., 38 (20), pp. 5433–5442

Sorption and leaching and temperature



- 4 pairs of simulations
  - MV1 = baseline
  - MV3 = temperature-dependent sorption

- 3 show that inclusion of temperature – sorption gives lower leaching losses

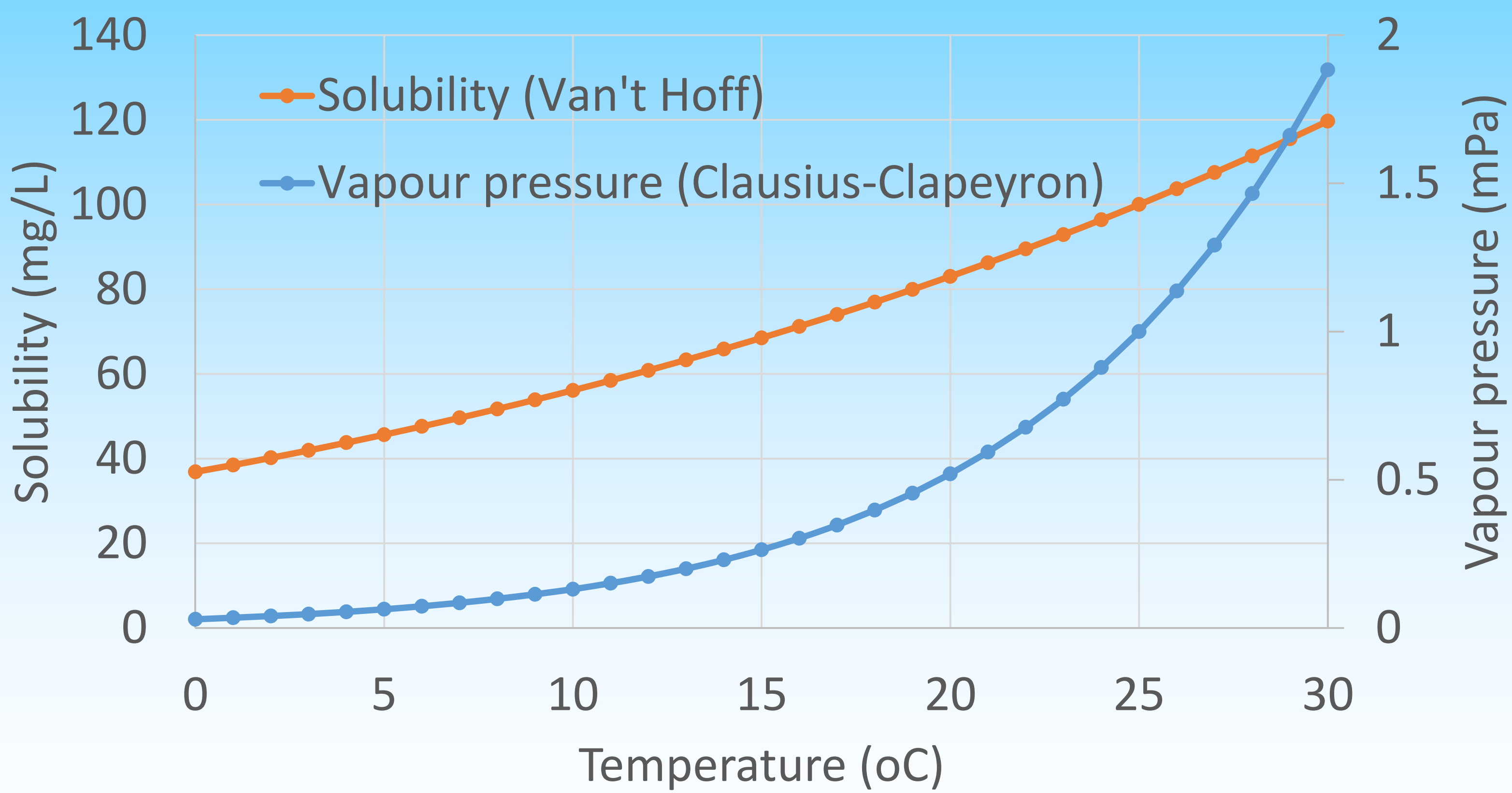
Steffens *et al.*, 2013. Agriculture, Ecosystems and Environment 172, pp. 24-34

Percentage of pesticides in phases of soil

Substance	Air	Liquid	Solid
Ethylene dibromide	0.66	28.4	70.9
Dichlobenil	0.0013	4.6	95.4
Simazine	1.3×10^{-7}	9.5	90.5
Lindane	4.1×10^{-5}	0.8	99.2
DDT	1.2×10^{-6}	4×10^{-4}	~100

Hartley, Graham-Bryce, 1980. Physical Principles of Pesticide Behaviour Vol 1, p. 242. Academic Press.,

The effect of temperature on solubility and vapour pressure



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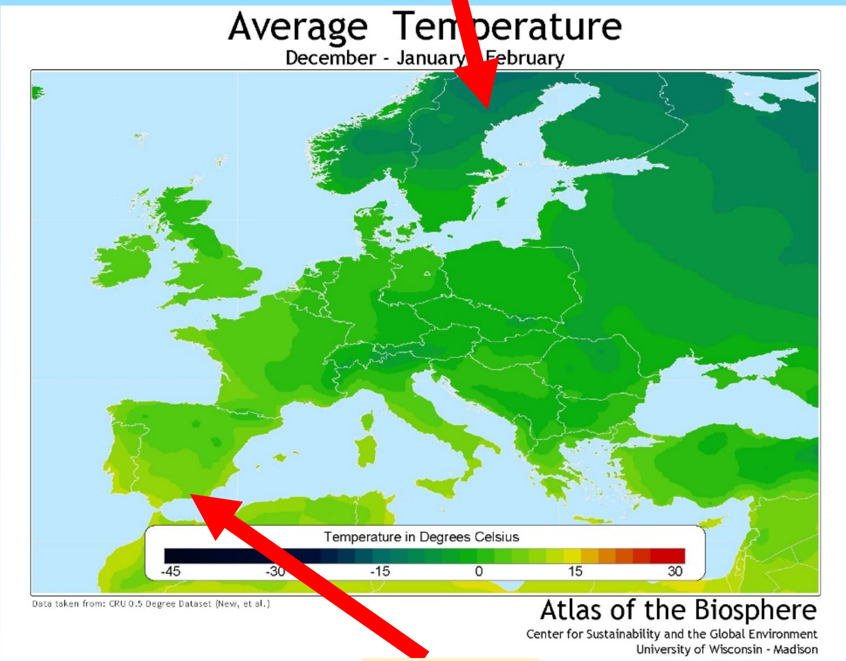
Summer and winter temperature in Europe

Winter

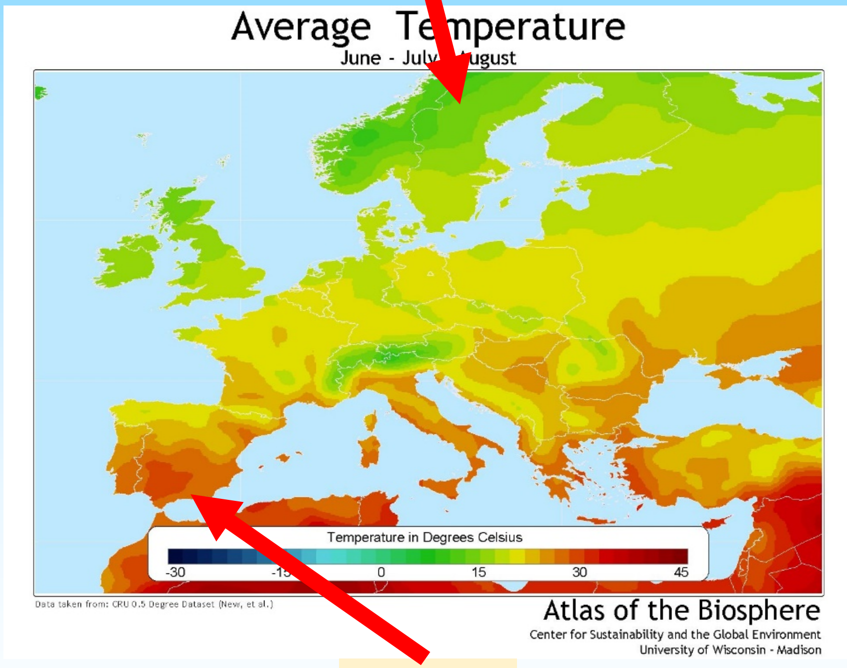
~ -15^{o}C



~ 10^{o}C

Summer

~ 8^{o}C



~ 30^{o}C

Climate Research Unit, Univ. of East Anglia.

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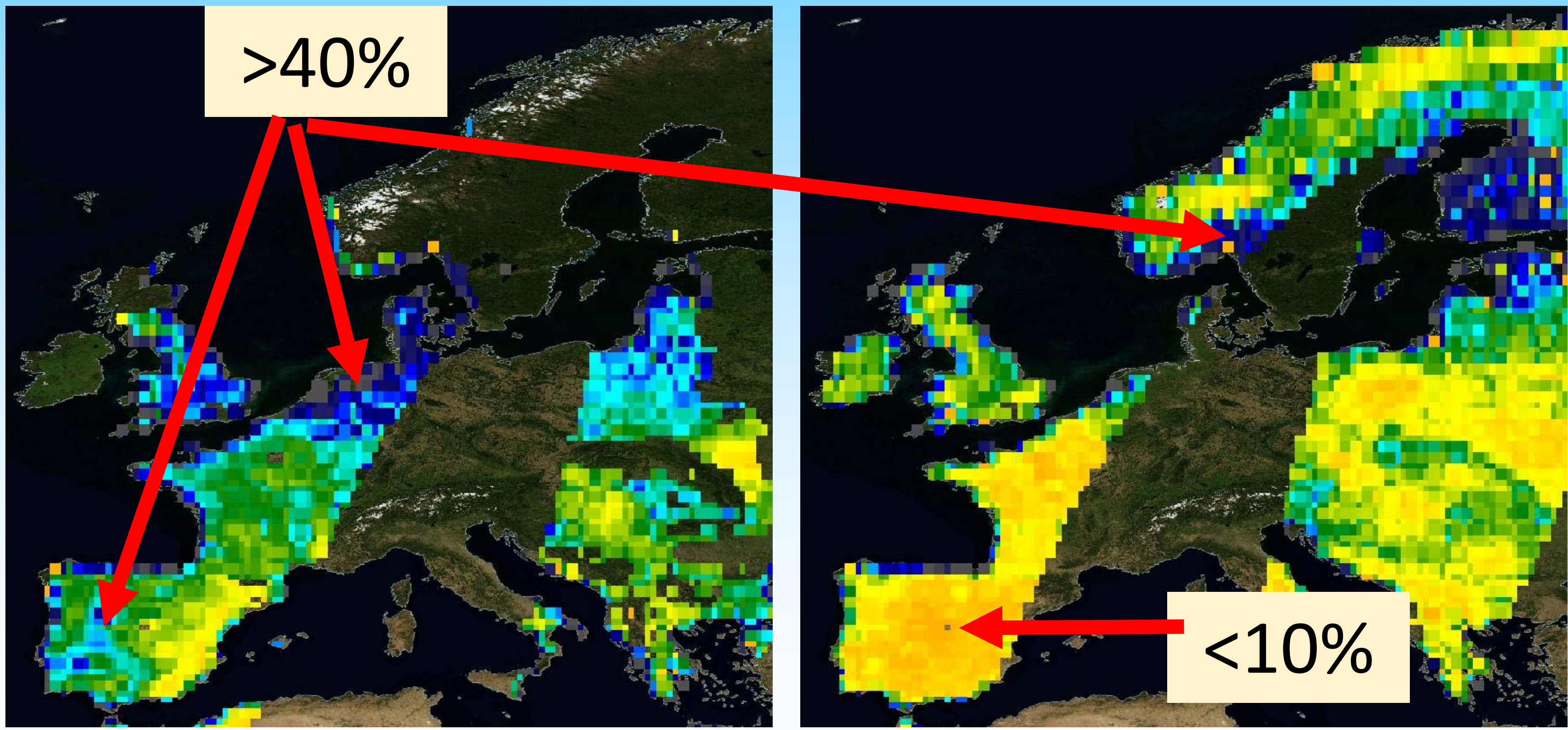
Soil moisture status across Europe

30 January 2016 **28 August 2016**



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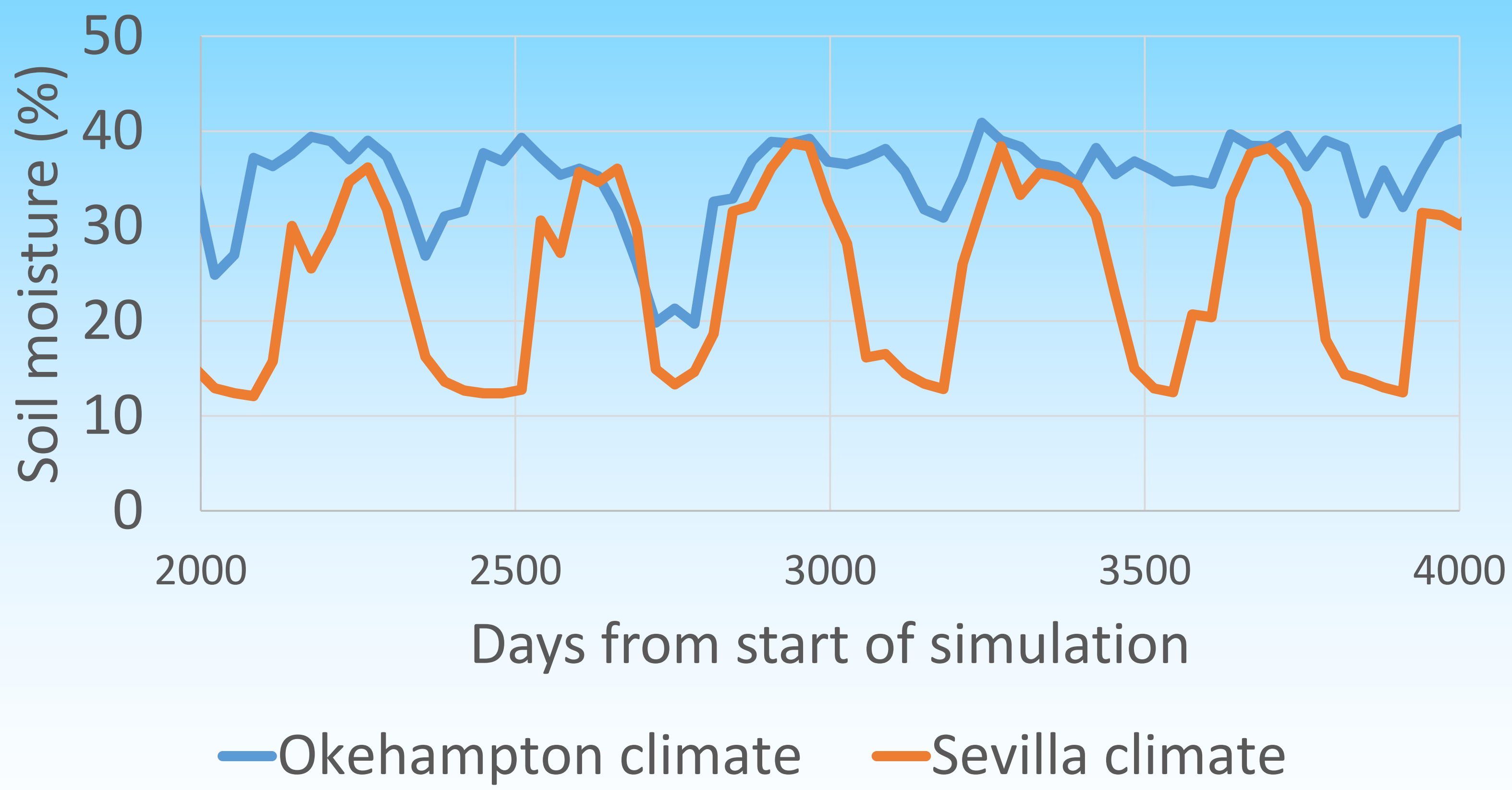
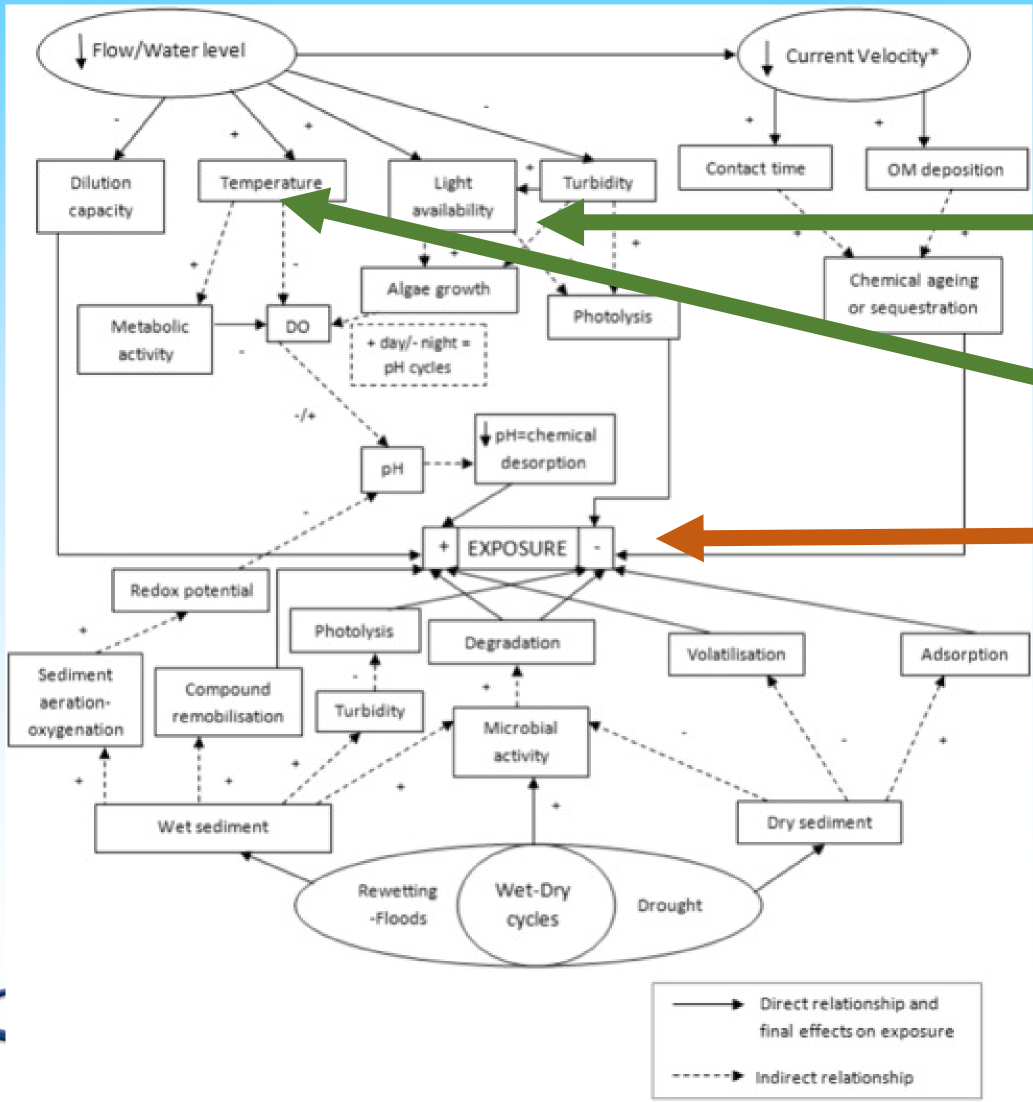
NASA Worldview (SMAP L-Band Radiometer)

Soil moisture at 10 cm depth in Okehampton soil



Factors affecting chemical transformation in surface water



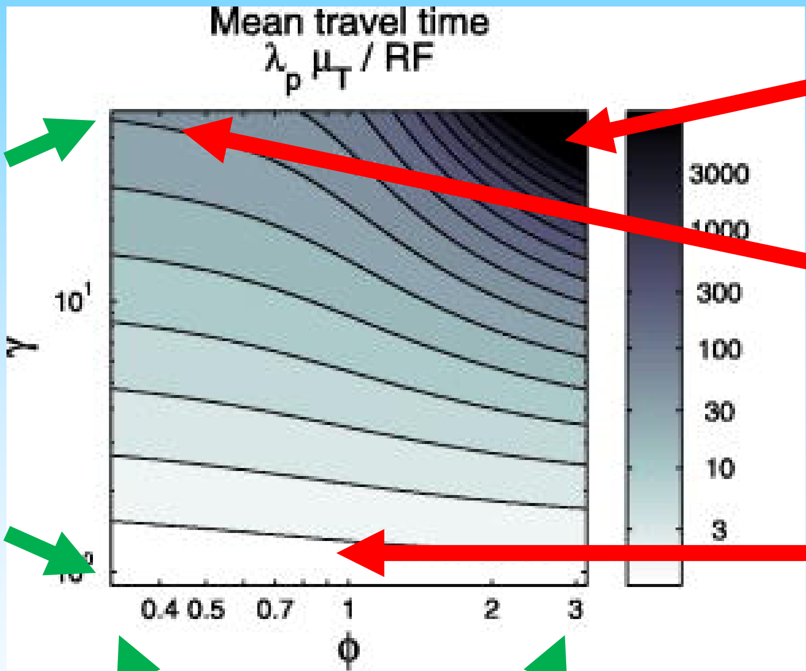
light

temperature

EXPOSURE

Arenas-Sanchez *et al.*, 2016. Science of The Total Environment 572, pp. 390–403

Contaminant travel time as a function of aridity and storminess



Rainfall pattern: Constant – Stormy

Aridity: Wet – Dry

Slow and variable

Medium speed and reliable

Fast and moderately reliable

Harman *et al.*, 2011. Water Resources Research 47, W00J13, doi:10.1029/2010WR010194.

Key climatic variables as determined by MACRO simulations

Mean April to June temperature (^{o}C)
Mean September to November temperature (^{o}C)
Mean October to March precipitation (mm)
Mean annual precipitation (mm)
Number of days (April to June) where total precipitation > 2 mm
Number of days (April to June) where total precipitation > 20 mm
Number of days (April to June) where total precipitation > 50 mm
Number of days (September to November) where total precipitation > 20 mm

Nolan *et al*., 2008. Pest Management Science 64. pp. 933-944

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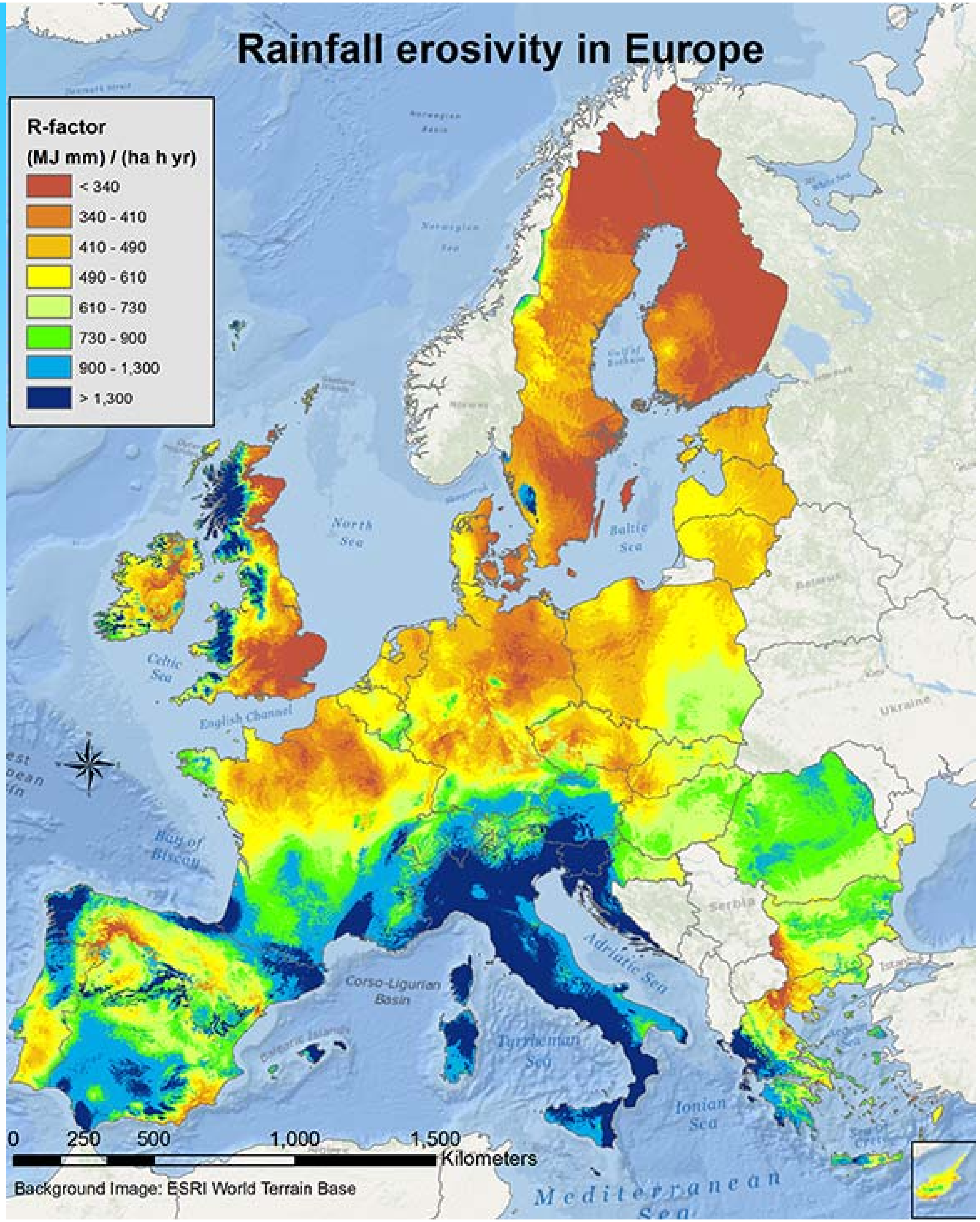
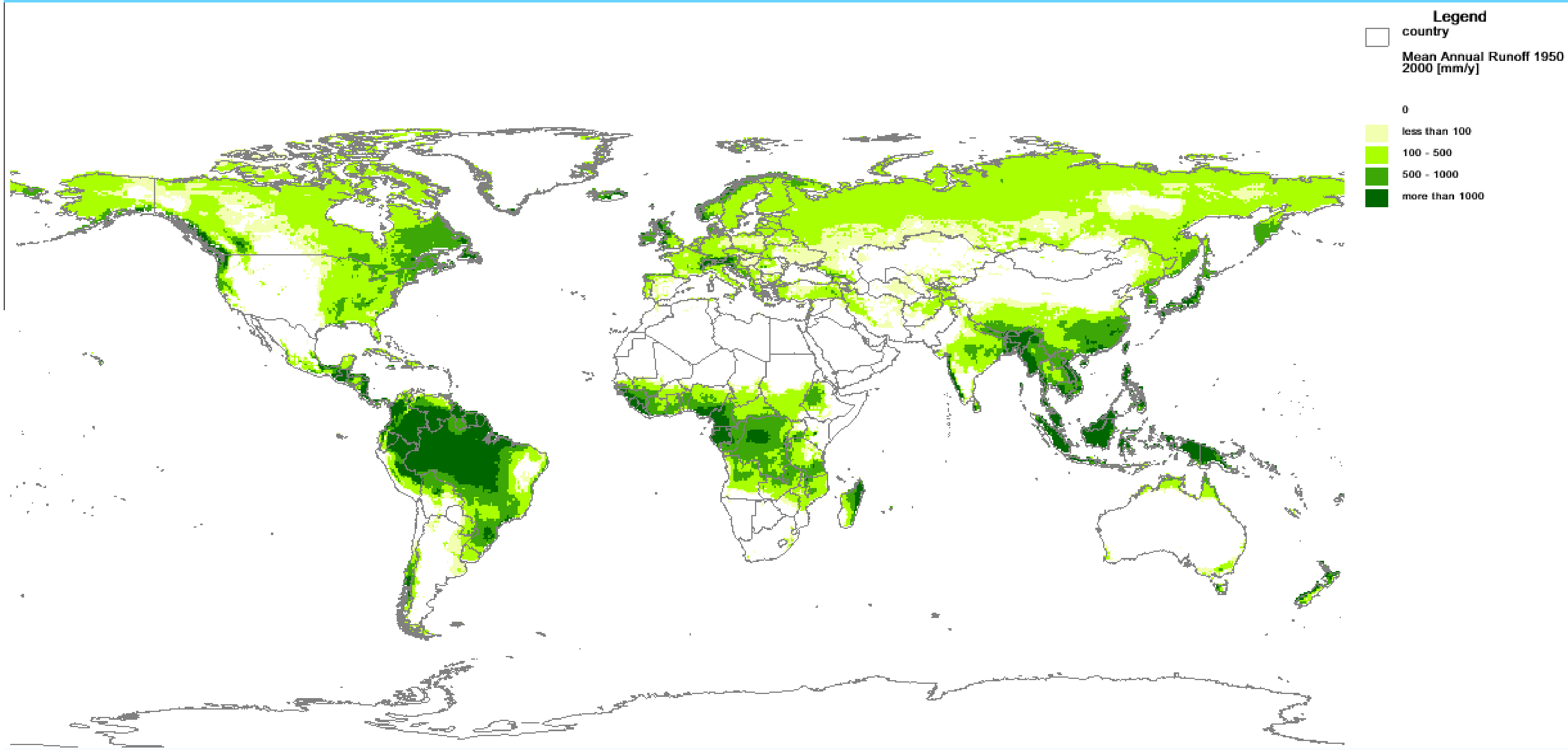
Rainfall R-factors across Europe

Panagos *et al.*, 2015. Science of The Total Environment 511, pp. 801–814

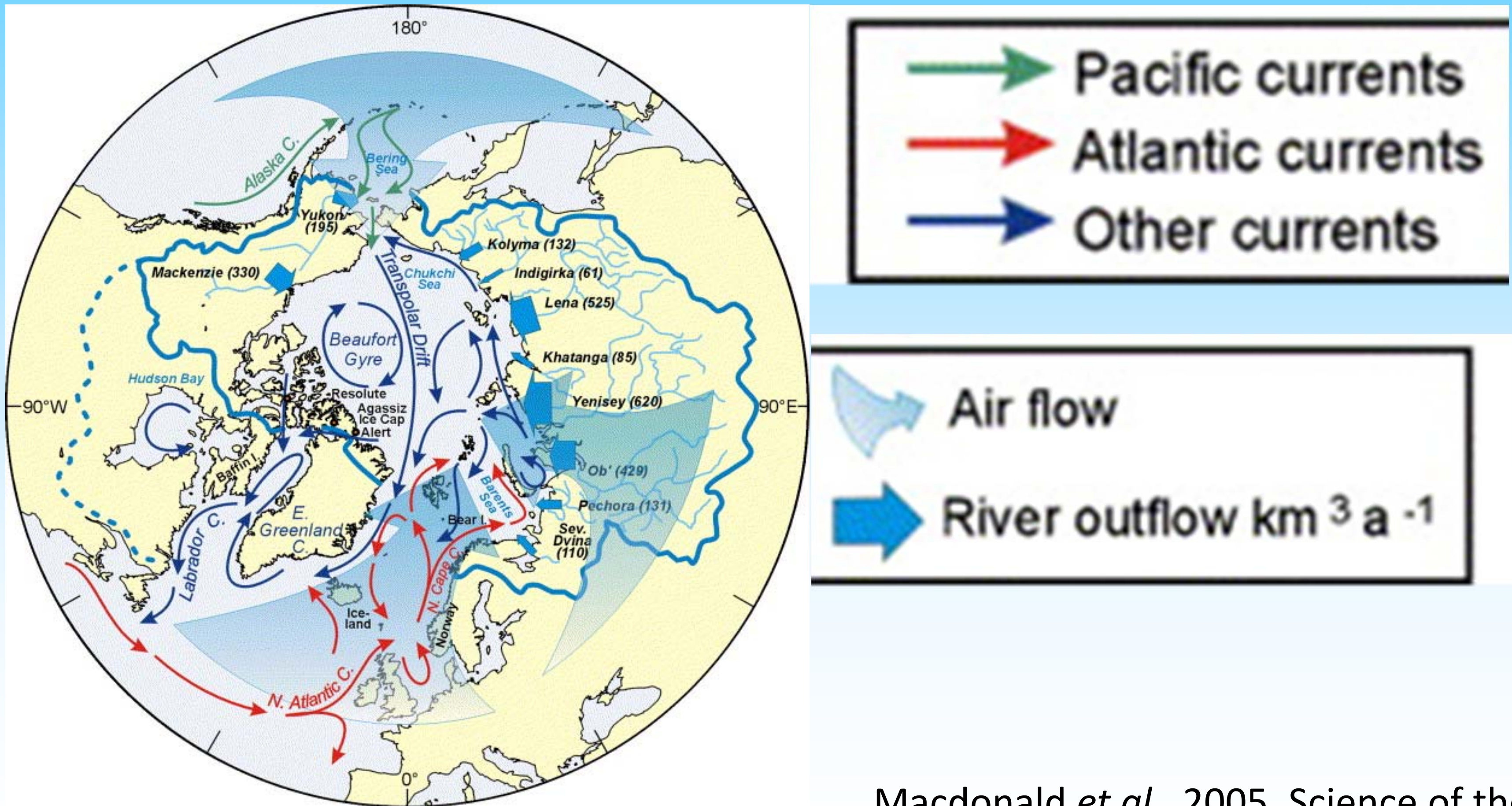


Global runoff



GWSP Digital Water Atlas (2008). Map 38: Mean Annual Surface Runoff 1950 - 2000 (V1.0). Available online at http://atlas.gwsp.org

Major physical pathways (wind, rivers and ocean currents) that transport contaminants to the Arctic



Macdonald *et al*., 2005. Science of the Total Environment 342, pp. 5-86

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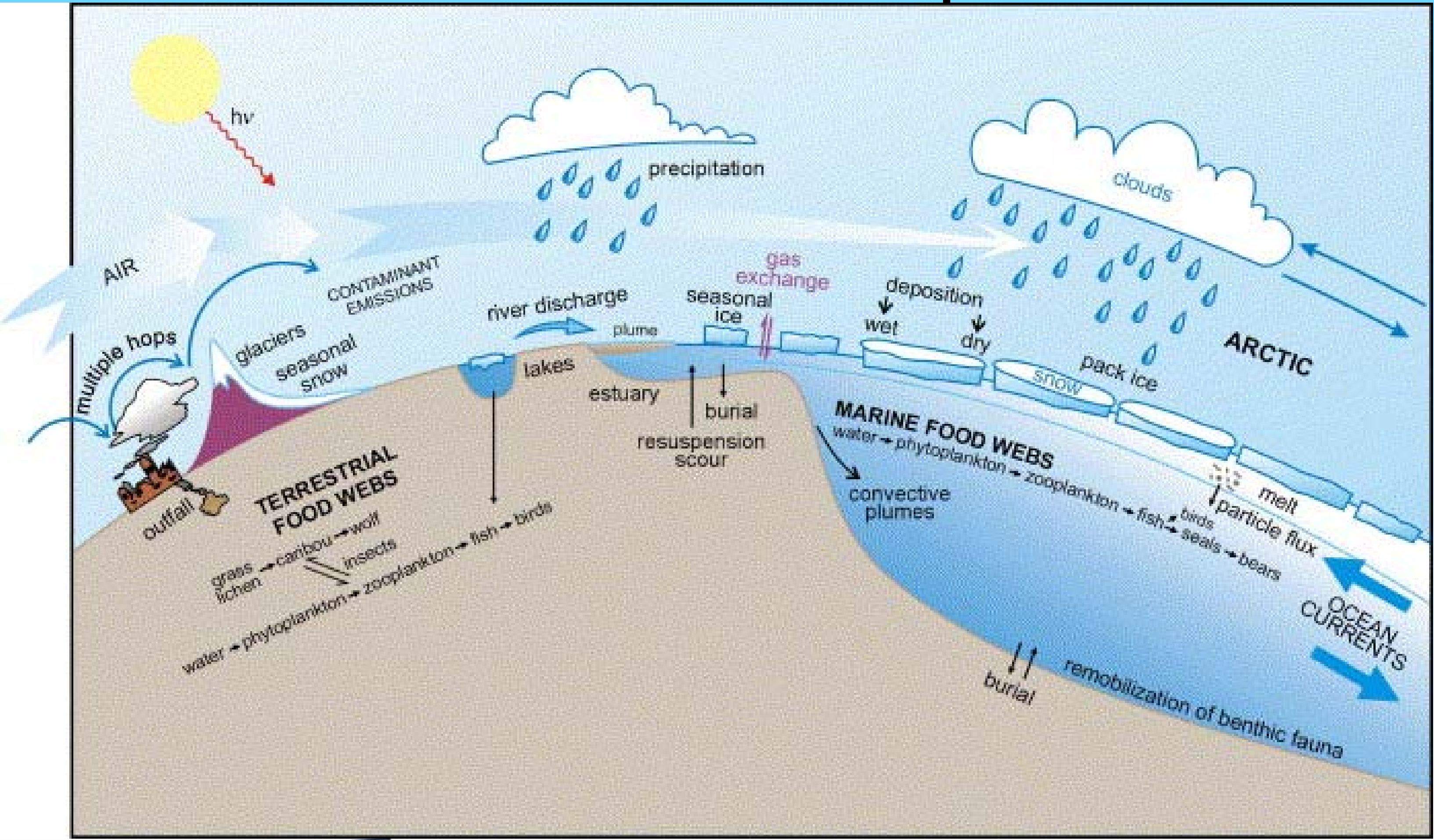
Delivery routes of contaminants to the arctic and subsequent fate



Macdonald *et al*., 2005. Science of the Total Environment 342, pp. 5-86

Indirect impacts of climate

Main impacts

- The decision to cultivate a piece of land
- The crop species
- The cultivar
- Irrigation
- Selection of pesticide
- Rate, timing and frequency of pesticide use.

A collection of references

- Chen & McCarl, 2001
- Bloomfield *et al.*, 2006
- Boxall *et al.*, 2009
- Noyes *et al.*, 2009
- Tu, 2009
- Kattwinkel *et al.*, 2011
- Wilson & Weng, 2011
- Visser *et al.*, 2012
- Delcour *et al.*, 2015
- Gagnon *et al.*, 2015
- Steffens *et al.*, 2015

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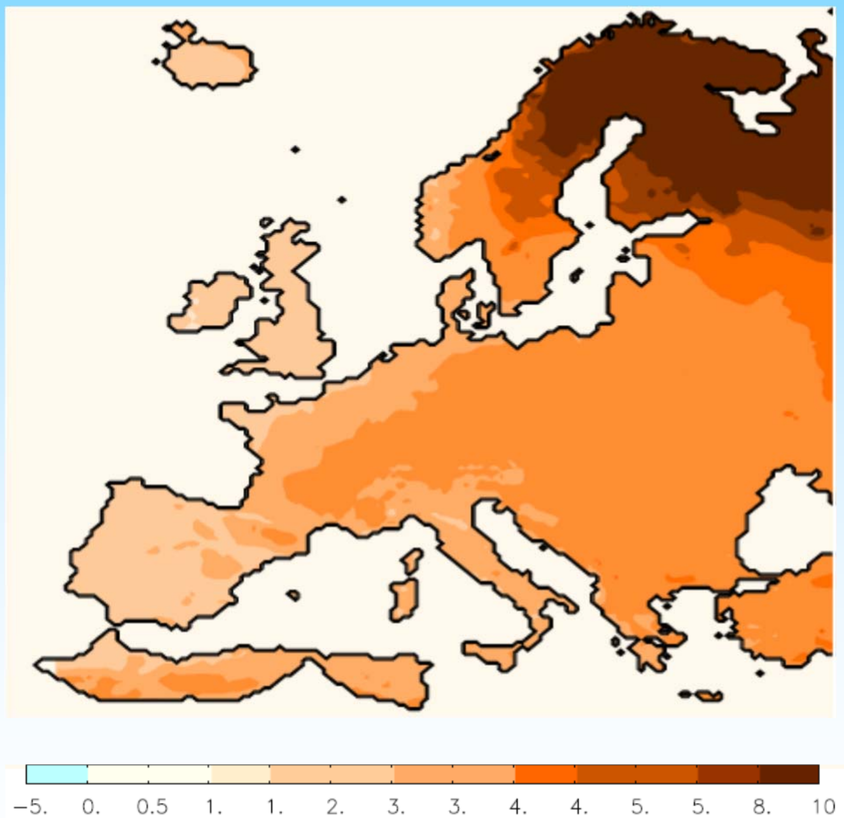
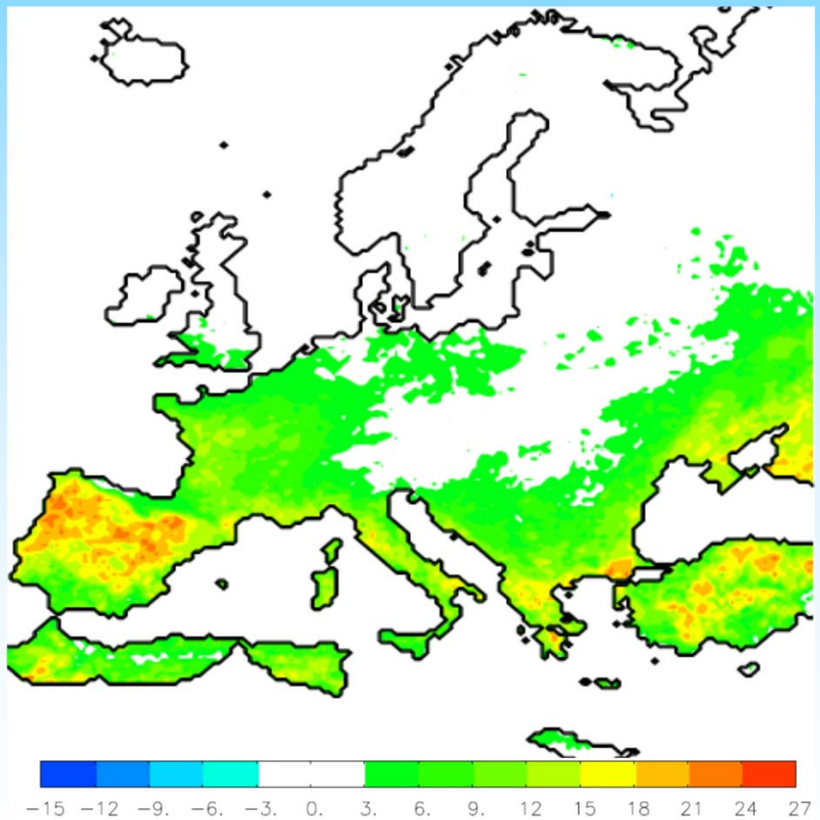
Climate change

Projected change in winter temperature (°C)



Projected change in consecutive summer dry days (d)



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Ciscar *et al*., 2014. Climate Impacts in Europe. The JRC PESETA II Project. JRC Scientific and Policy Reports, EUR 26586EN.

Impact of climate change on pesticide fate

- Partitioning
  - Lower sorption
  - More volatilisation
- Chemical transformation
  - Faster reactions due to high temperature
  - Slower reactions due to dry soils
  - More phototransformation
- Flow
  - More leaching
  - Faster contaminant movement in rivers
  - More pesticide runoff, erosion and macropore flow
  - More atmospheric transport
  - Changing oceanic pattern of global redistribution
- Indirect effects
  - Increased arable area will mean pesticides will be used in new areas
  - Higher pest pressure will lead to an increase of pesticide use overall
  - Regulatory and technological change: effects uncertain

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Conclusion:
What is important?

"In the long-term, land-use change driven by changes in climate may have a more significant effect on pesticides in the environment than the direct impacts of climate change on specific pesticide fate and transport processes."

Bloomfield *et al.*, 2006. Science of the Total Environment 369, pp. 163-177