Performance of the JULES land surface model for UK Biogenic VOC emissions

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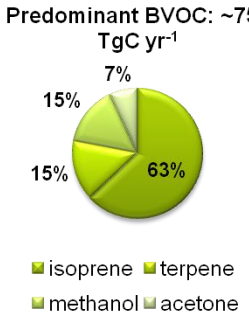
Contents and Acknowledgements

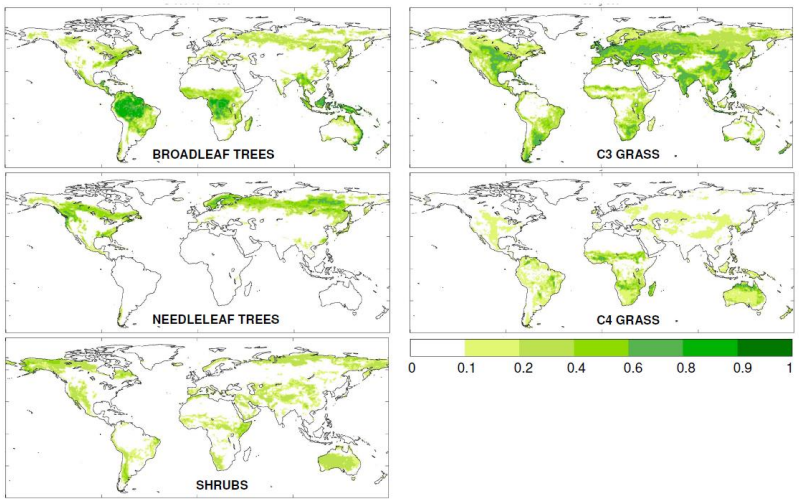
- JULES land surface model and Biogenic VOC emissions
- Comparison against site measurements
- Comparison against emission estimates from the EMEP4UK model
- UK emission estimates

JULES: Biogenic VOCs

- Process-based model of the carbon, energy and water exchange between the land surface and atmosphere

- Standard configuration uses 5 PFTs with emissions of four biogenic VOC species





- Isoprene scheme (Pacifico et al., 2011). Based on approach of Arneth et al., 2007 and Niinemets et al., 1999

$$I = IEF\,\frac{A_{canopy} + R_{Dcanopy}}{A_{st} + R_{D_{st}}}\,f_T \cdot f_{CO_2}$$

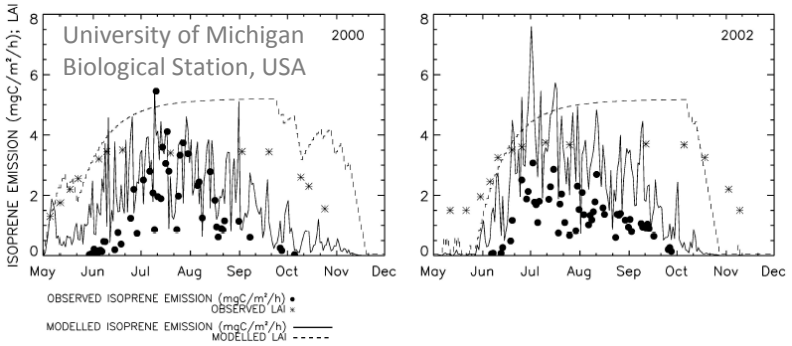
- Semi-empirical approach for the other species

JULES PFT	Base Emission Factor (μg C g dry weight^{-1} h^{-1})	
	Isoprene	Terpene
Trees: Broadleaf	35	0.4
Trees: Needle Leaf	12	2.4
Grass: C3	16	0.8
Grass: C4 tropical	8	0.8
Shrubs	20	0.8

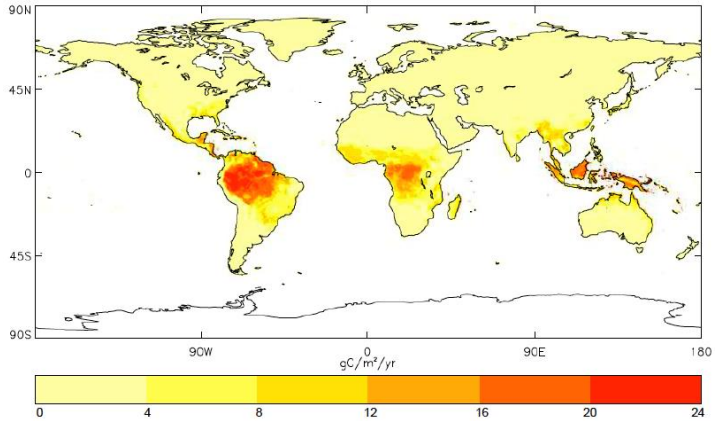
Evaluation of the Isoprene Emission scheme (Pacifico et al.)

JULES captures the diurnal, day-to-day and seasonal variability at most of the above-canopy isoprene flux measurement sites.

JULES overestimates observed emissions at most sites, partly because isoprene loss through the canopy is not included, but it is also linked with the large uncertainty on pft-dependent Isoprene Emission Factors used (Guenther et al., 1996, J. Geophys. Res.).

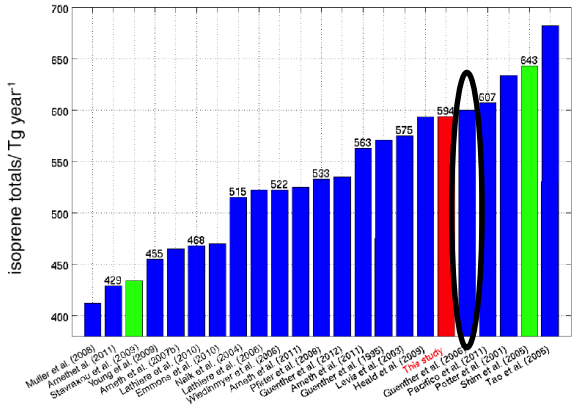


Present-day (1990s) global estimate of isoprene emissions simulated with JULES is 535 Tg C yr^{-1}



Pacifico et al., 2011, ACP

In agreement with other published estimates (400-600 Tg C yr^{-1}, Arneth et al., 2008, ACP; Sindelarova et al., 2014).



Scaled to 600 Tg yr^{-1}
Sindelarova et al., 2014

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Biogenic VOC flux measurements

Alice Holt, UK
July 2005

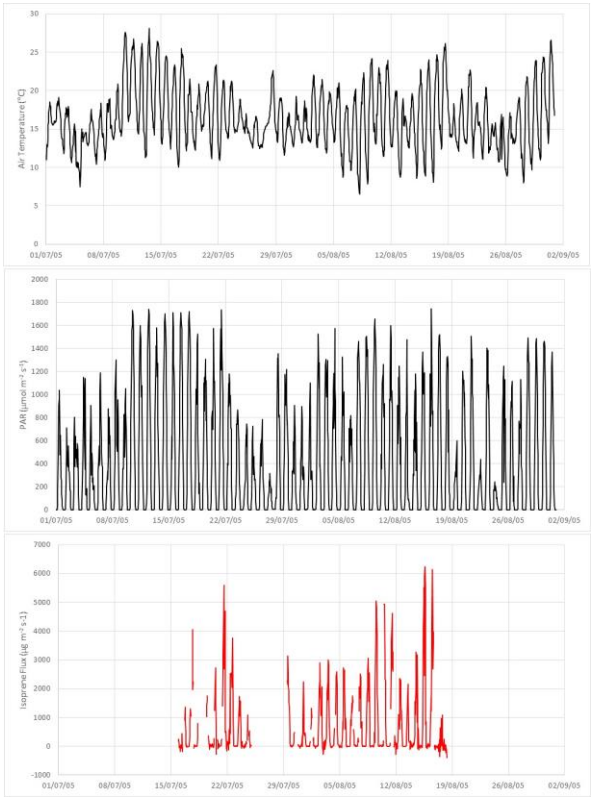
- Forest site in S. England
- 90% oak interspersed with 10% Ash
- Fluxes & concentrations of isoprene
- Langford et al.

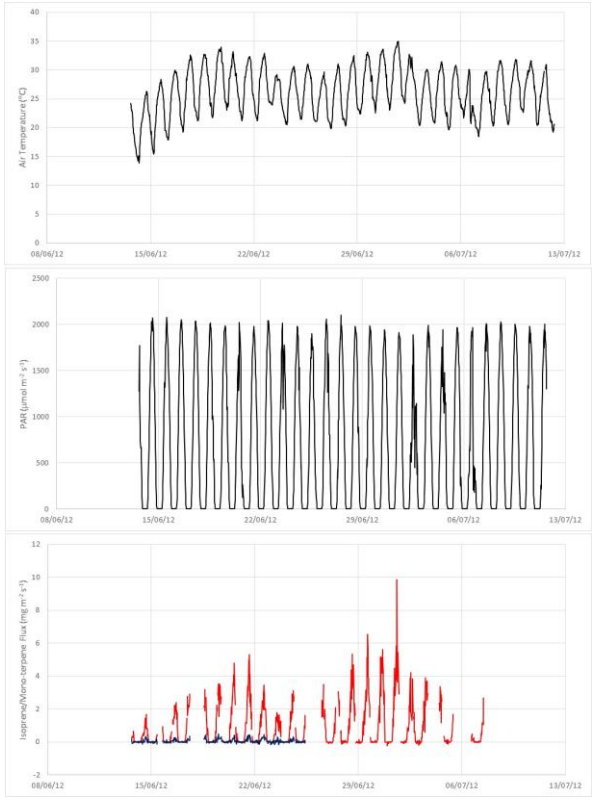
Bosco Fontana, Italy
June/July 2012

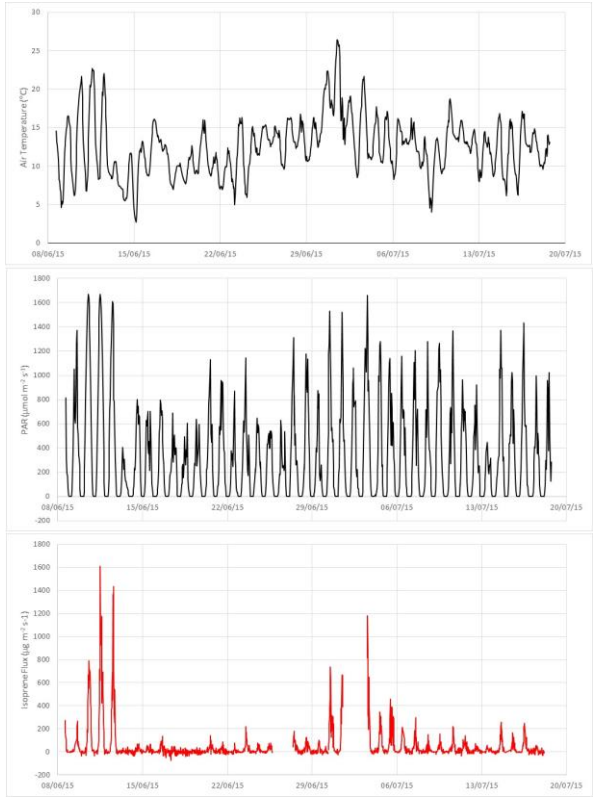
- Semi-natural woodland, comprising a mix of oak and hornbeam
- Fluxes & concentrations of isoprene, terpenes, …
- Acton et al., 2016, ACP

Auchencorth Moss, UK
July/August 2015

- Ombrotrophic peatland
- Fluxes & concentrations of isoprene
- Langford et al., 2017, in prep

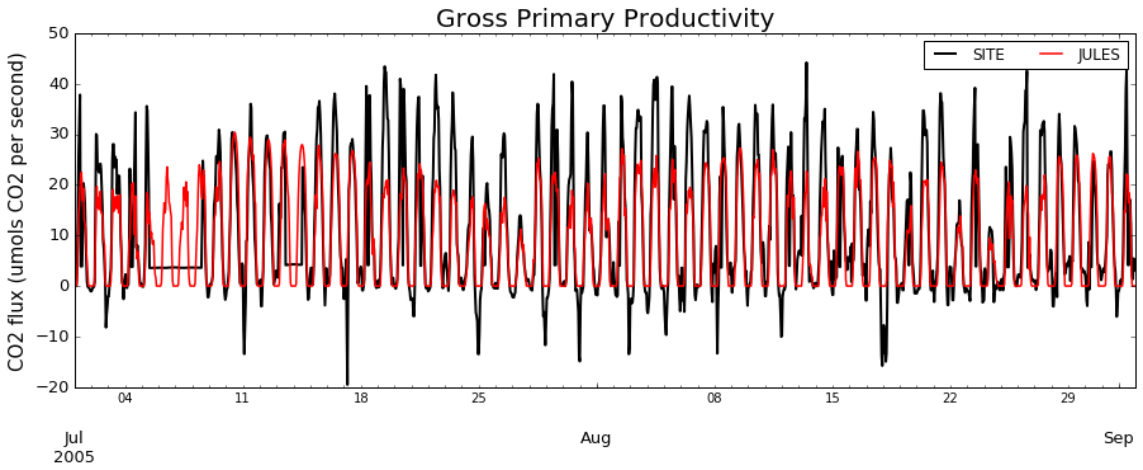






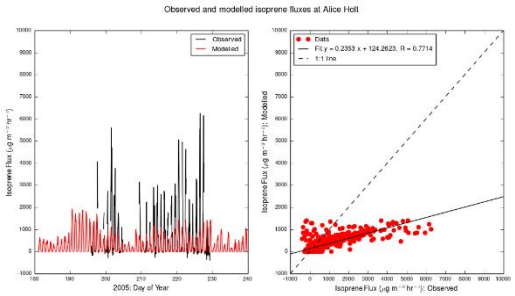
Comparison against Alice Holt measurements

- JULES runs with site-specific met and other parameters
- Comparison with observations of GPP and isoprene fluxes
- Strong sensitivity to isoprene emission factors

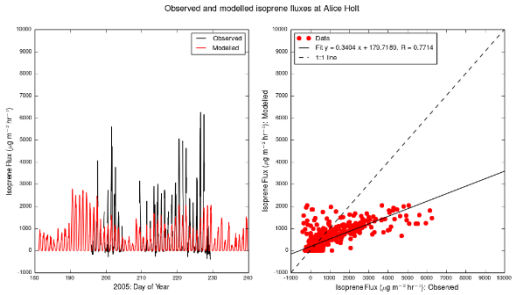


Plant functional types	Isoprene Base Emission Factor (µg C g dry weight^{-1} h^{-1})		
	EMEP4UK	JULES	MEGAN
Trees: Broadleaf	24.2	35	96.0
Trees: Needle Leaf	2.77	12	7.2
Grass: C3	0.1	16	12.8
Grass: C4 tropical	0.1	8	1.6
Shrubs	8.0	20	26.7

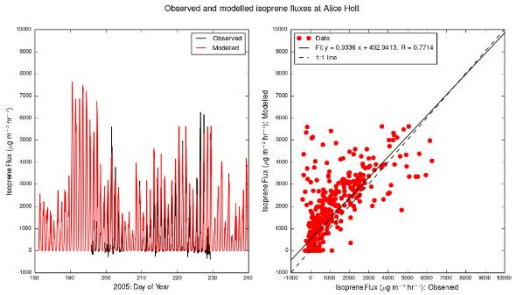
EMEP4UK isoprene emission factor



JULES isoprene emission factor



MEGAN isoprene emission factor



Comparison against site measurements

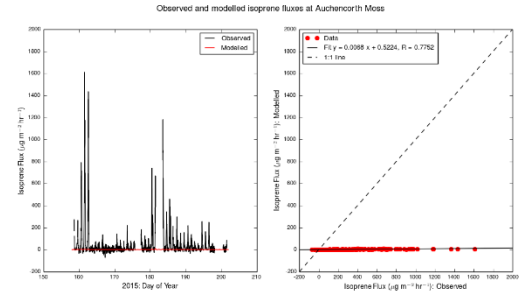
JULES runs with site-specific met and other parameters

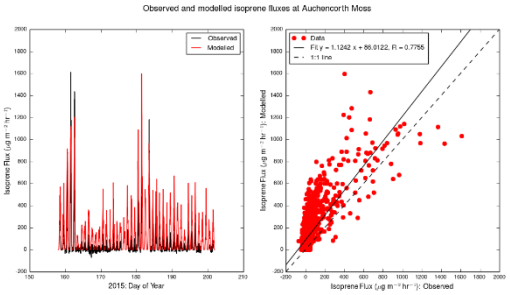
EMEP4UK isoprene emission factor

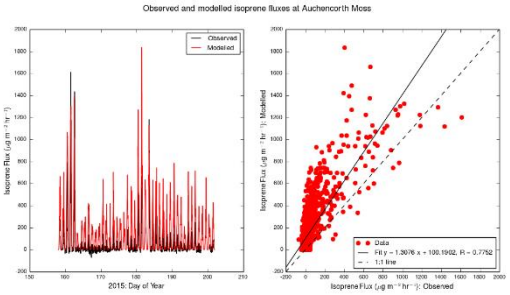
JULES isoprene emission factor

MEGAN isoprene emission factor

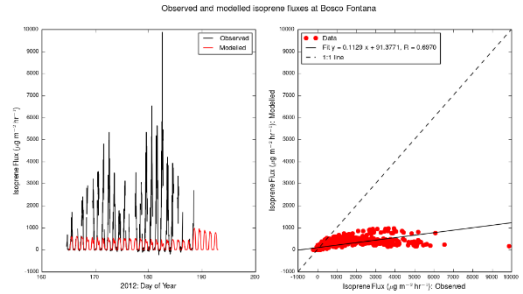
Auchencorth Moss Isoprene

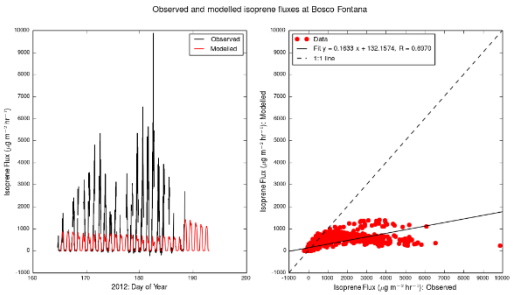


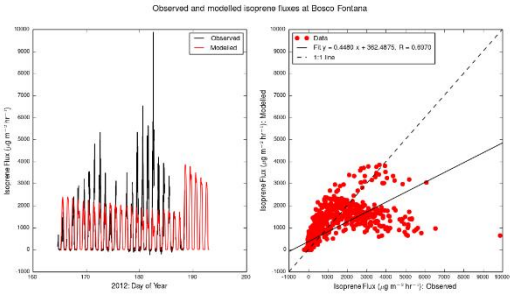




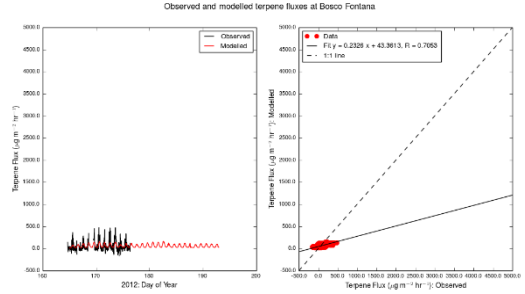
Bosco Fontana Isoprene

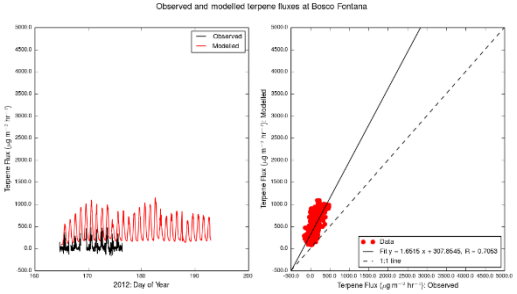


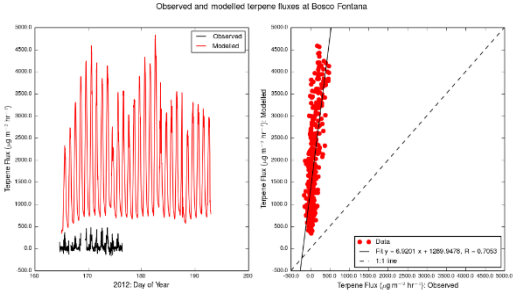




Bosco Fontana Terpene

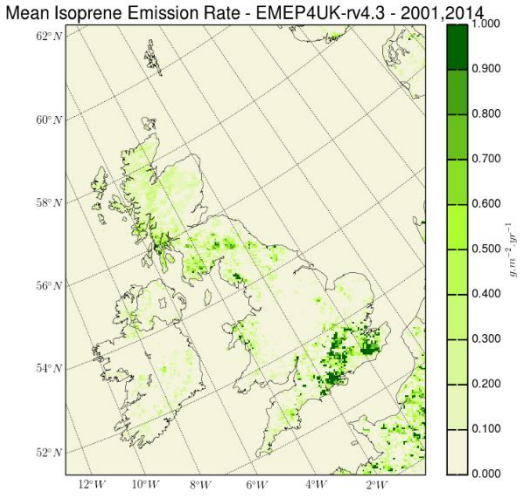






UK Biogenic VOC fluxes: Comparison against EMEP4UK

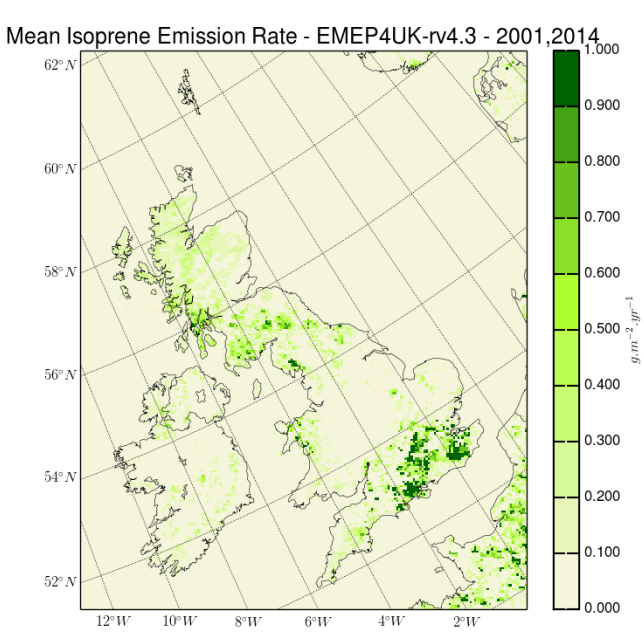
- EMEP4UK (r4.3)
  - High resolution version of EMEP chemical transport model over the UK (5 km x 5 km)
  - WRF as met driving data
  - Model run from 2001-2014
  - Vieno et al., 2010, ACP

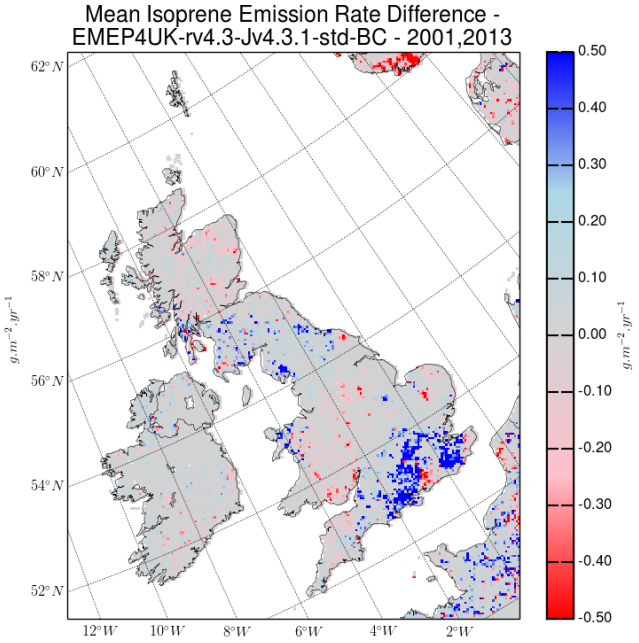


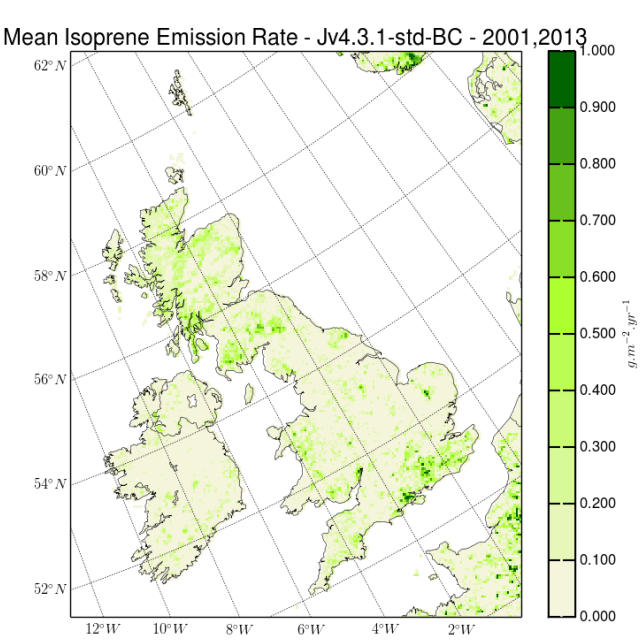
- JULES set-up
  - Uses same model grid and driving met data as EMEP4UK
  - Created JULES ancillary files on EMEP4UK grid
  - Additional pft's added to match those used in EMEP4UK
  - JULES run for 2001 to 2014

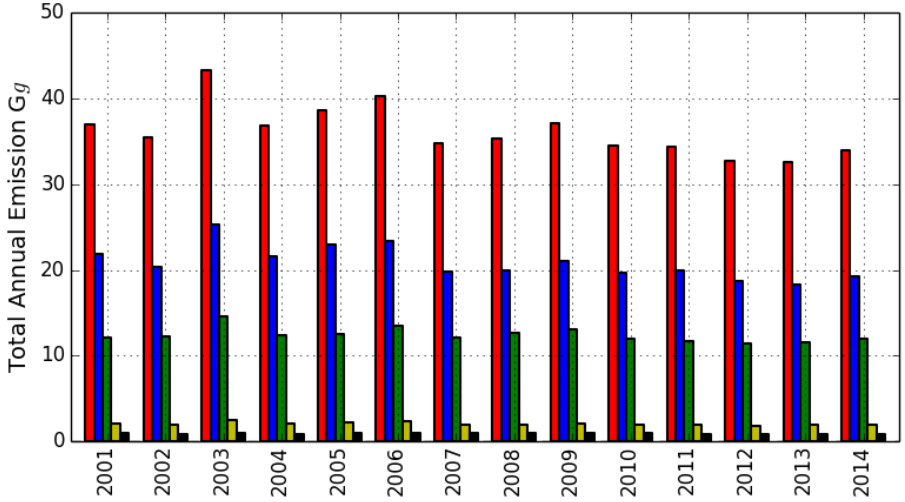
EMEP vegetation types	Foliar Biomass Density ($g\ m^{-2}$)	Base Emission Factor ($\mu g\ g\ dry\ weight^{-1}\ h^{-1}$)		
		Isoprene	Terpene (light/ temperature	Terpene (temperature)
Trees: Temperate/Boreal Coniferous	1000	(1)	(0.5)	(2)
Trees: Temperate/Boreal Deciduous	320	(15)	(2)	(2)
Trees: Mediterranean Needle Leaf	500	(4)	(0.2)	(4)
Trees: Mediterranean Broadleaf	300	(0.1)	(10)	(0.2)
Crops: Temperate/Boreal	700	0.1	0.2	0.2
Crops: Mediterranean	700	0.1	0.2	0.2
Crops: Root	700	0.1	0.2	0.2
Moorland	200	5	0.5	0.5
Grass	400	0.1	0.5	0.5
Scrub: Mediterranean	150	8	0.5	2
Wetlands	150	2	0.5	0.5
Tundra	200	5	0.5	0.5

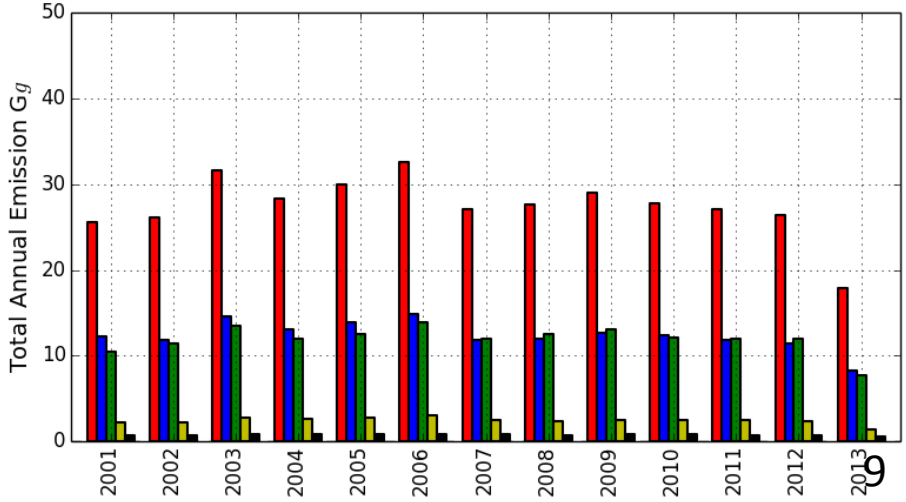
Comparison of isoprene fluxes

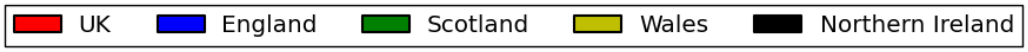




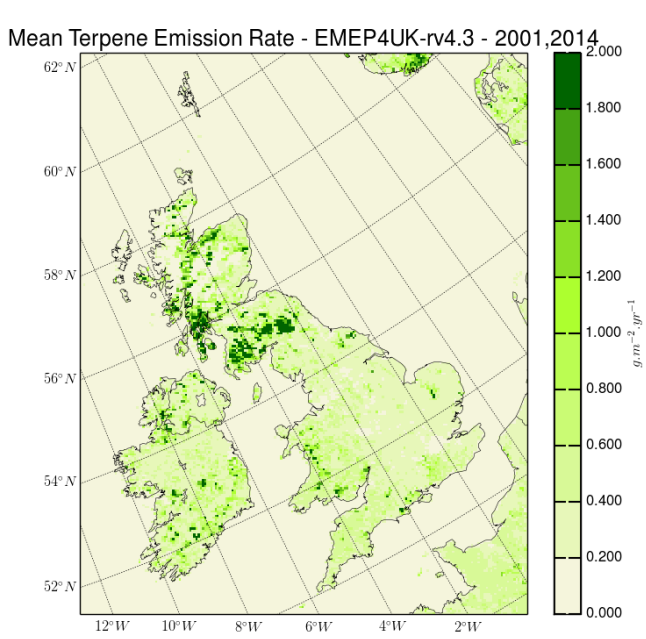


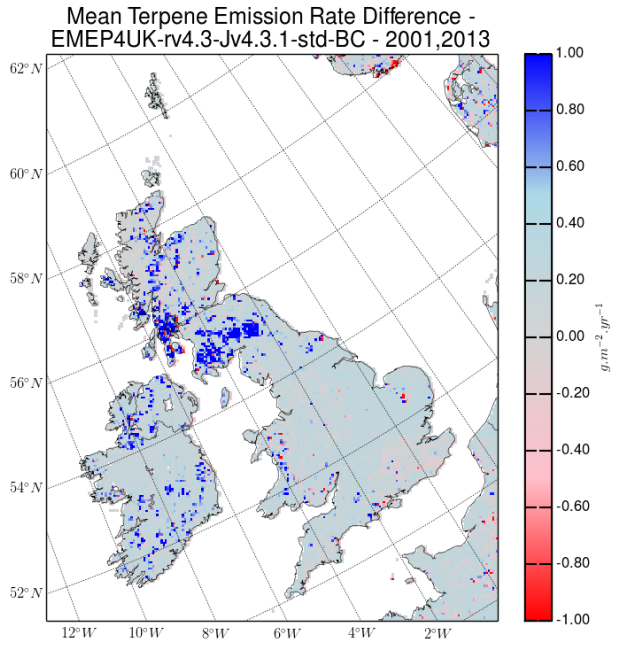


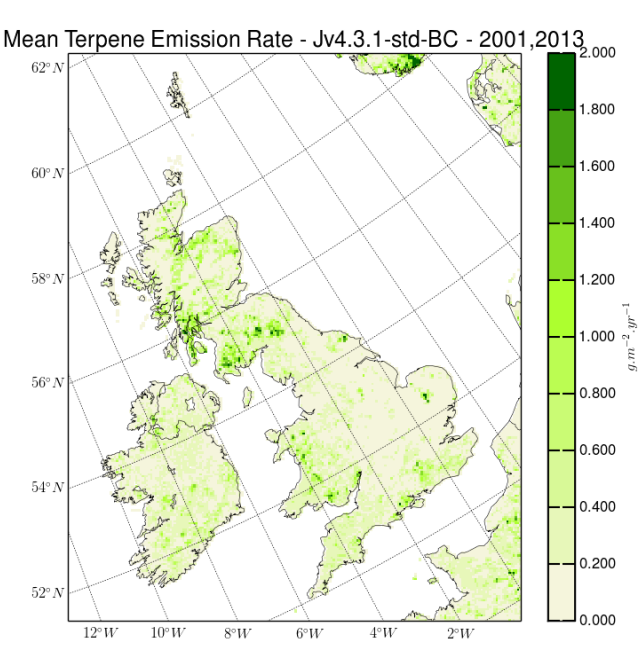


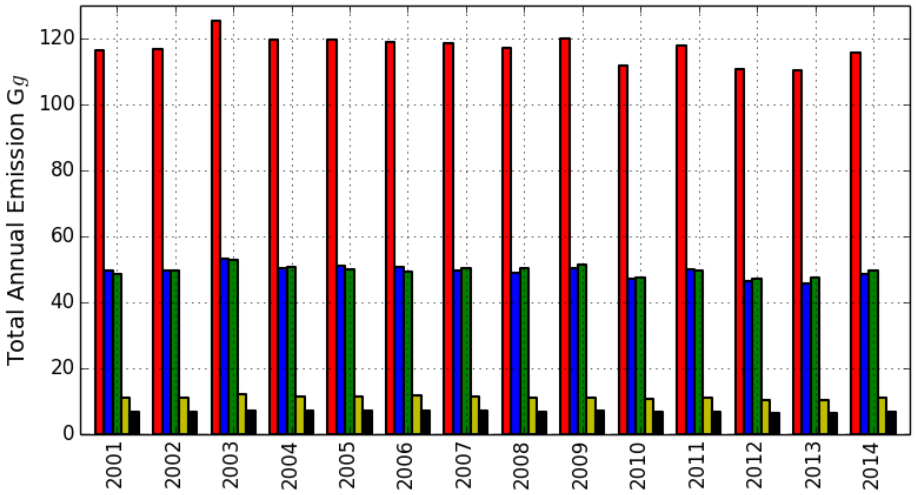


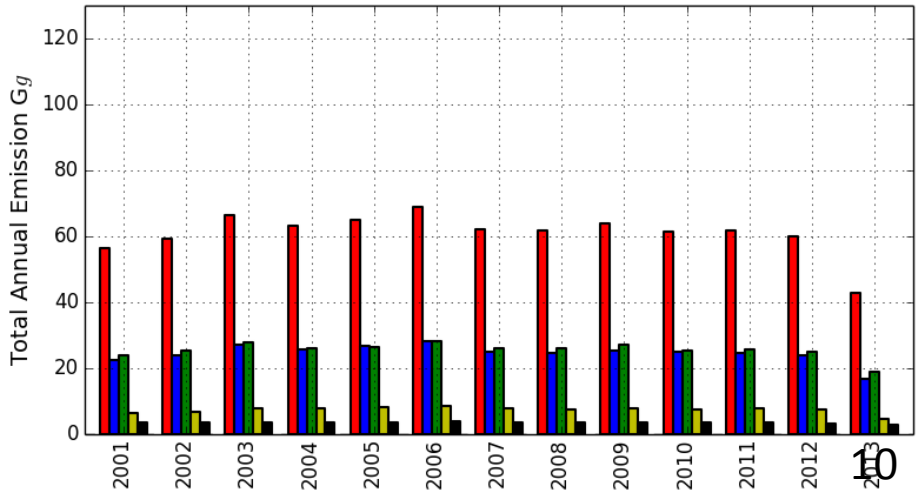
Comparison of terpene fluxes

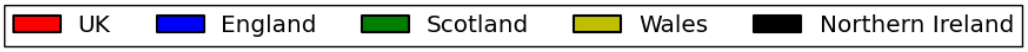








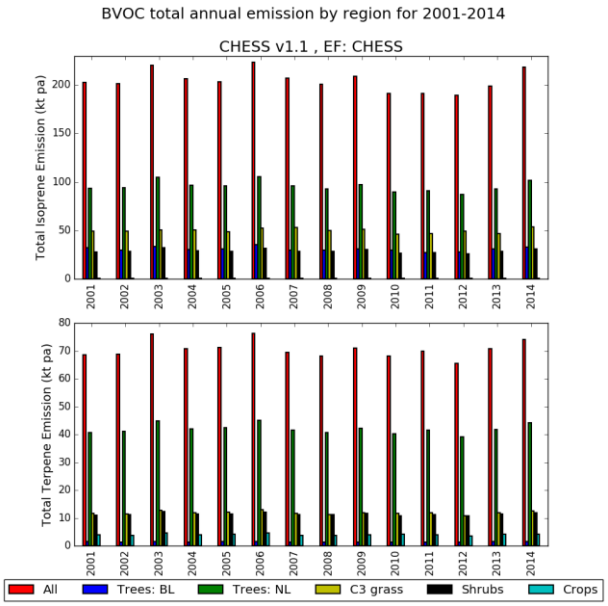


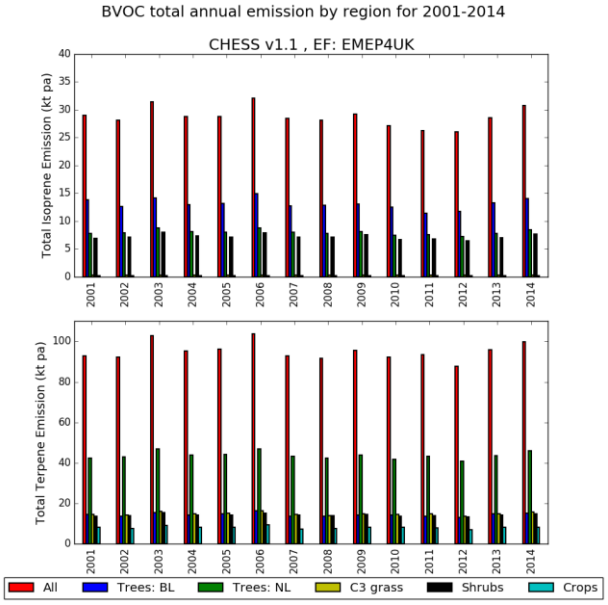


UK Biogenic VOC fluxes: Sensitivity

- JULES CHESS Configuration
  - 1 km x 1km grid over Great Britain
  - CHESS met driving dataset
  - CEH land cover
  - JULES & EMEP emission factors

UK Annual Isoprene Emissions (kT pa)				
Model	EFs	Mean (2001-2013)	Min	Max
EMEP4UK	EMEP4UK	36.6	32.7	43.6
JULES	EMEP4UK	32.3	20.9	37.8
CHESS	EMEP4UK	28.6	26.0	32.1
JULES	JULES	189.9	121.9	220.6
CHESS	JULES	234.4	218.0	255.0
UK Annual Terpene Emissions (kT pa)				
Model	EFs	Mean (2001-2013)	Min	Max
EMEP4UK	EMEP4UK	116.9	110.1	124.9
JULES	EMEP4UK	63.9	44.6	71.3
CHESS	EMEP4UK	94.8	87.7	103.9
JULES	JULES	58.3	40.9	65.0
CHESS	JULES	82.5	76.2	90.2





- Isoprene emission factor for C3 grass

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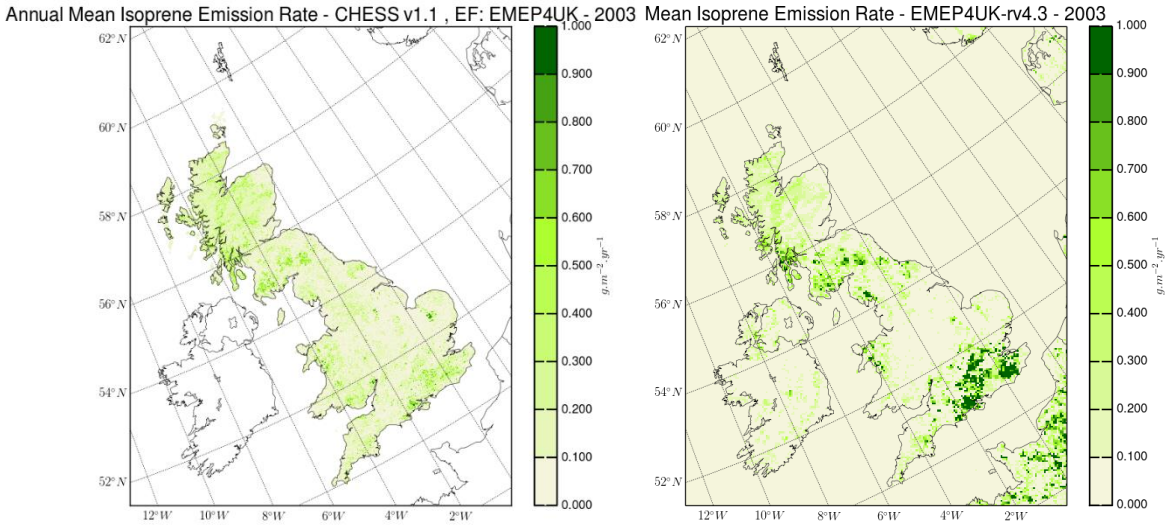
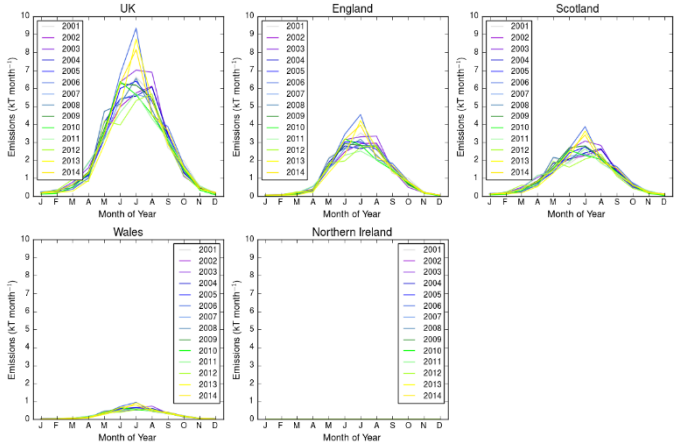
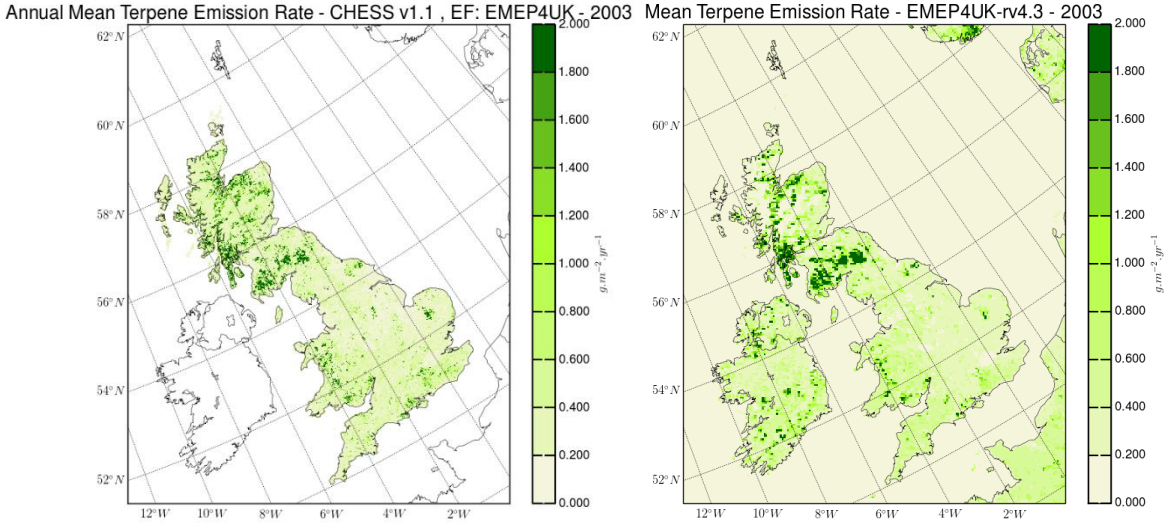
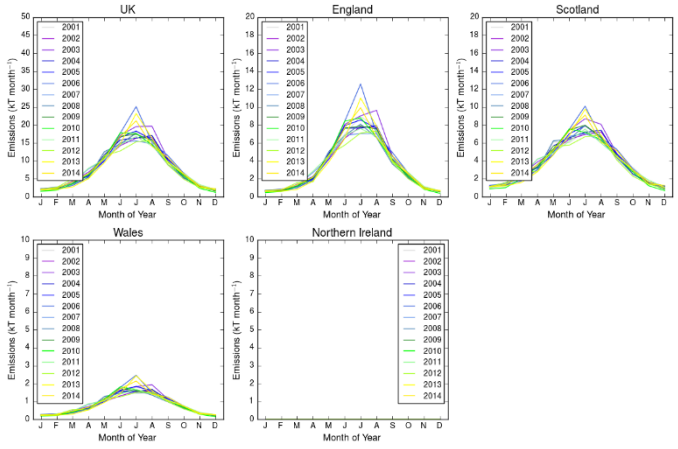
UK Biogenic VOC fluxes: Sensitivity









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Comparison with other UK emission estimates

Study	Annual Emissions (ktonne per annum)				Year(s)
	Isoprene	Terpenes	Others	Total	
Anastasi et al. (1991)	115			211	
Hewitt and Street (1992)				50-100	
Simpson et al. (1995a)	22.7		29.4		
Simpson et al. (1999)					
• Forests	38	25	15	77	
• Grasslands/Pasture	20	5	48	73	
• Other			27	27	
• All				177	
PELCOM (Winiwarter et al., 2001)				67	
Stewart et al. (2003)	8	83			1998
Karl et al. (2009)					
• Agriculture				113	2005
• Forests				41	
• Other Land Use				65	
• All				219	
Steinbrecher et al. (2009)				281	2003
Hayman et al. (2010)					
• Forests	7.1	51.7	36.7	95.5	2003
EMEP/CORINAIR (2002, 2016)	53	39	27	119	
NAEI (inventory years to 2002)	58	31	89	178	
NAEI (inventory years from 2003)	8	83			
This work					
• EMEP4UK	32.7-43.6	110.1-124.9			2001-2013
• JULES	20.9-37.8	44.6-71.3			
• CHESS	26.0-32.1	87.7-103.9			

Summary

- JULES biogenic VOC emission fluxes compared to site measurements and EMEP4UK model
- Strong sensitivity to choice of base emission factors
- Need for UK-specific emission factors
- Need for more flux measurements (and over longer periods)