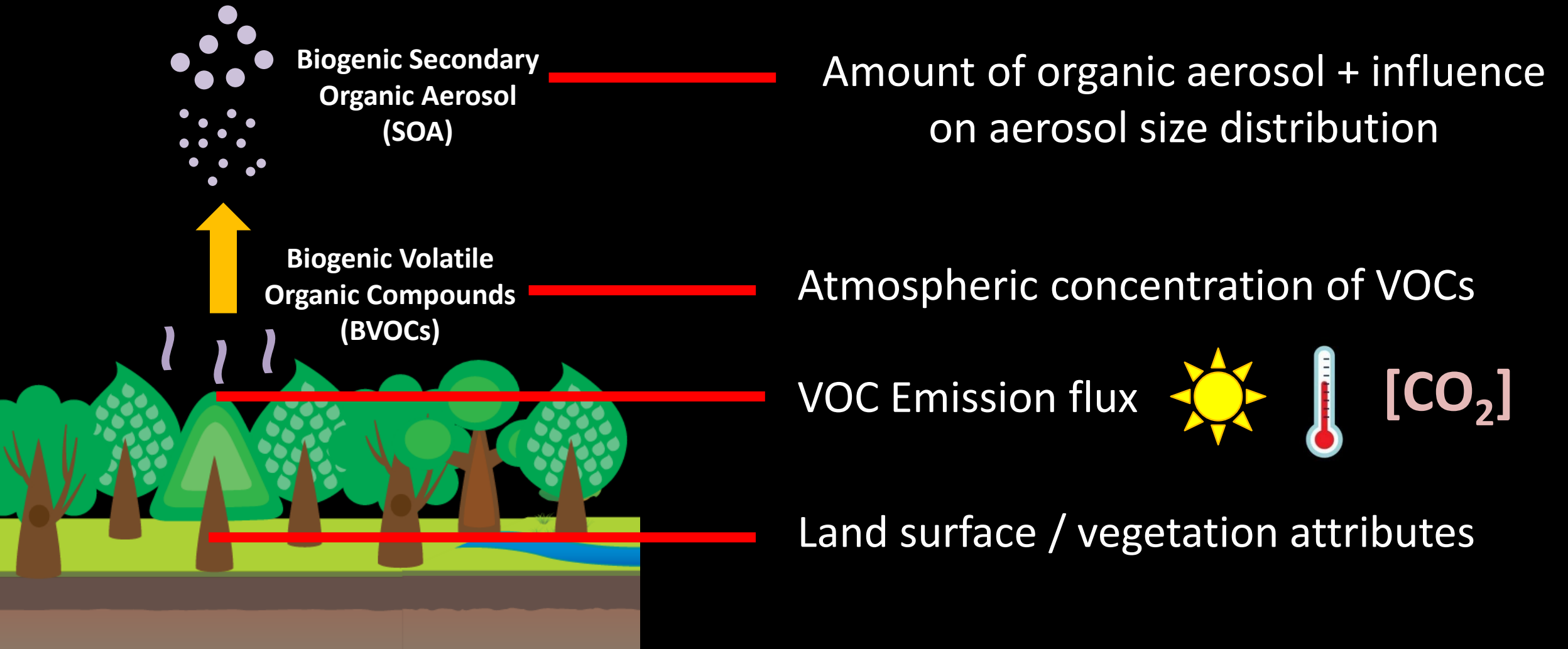


# How well do the latest Earth System Models capture the behaviour of biogenic secondary organic aerosol in the atmosphere?

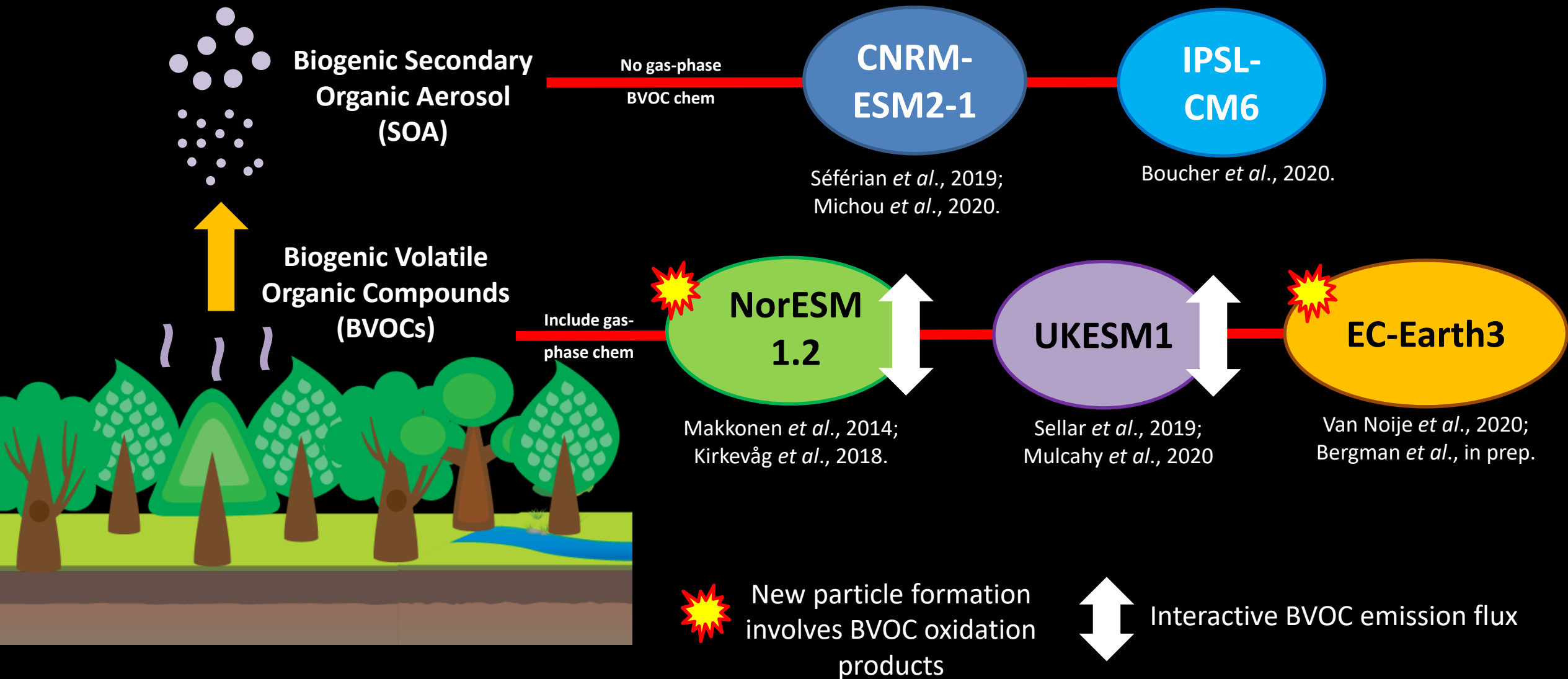
**Cat Scott, University of Leeds**

**Masaru Yoshioka, Chris Dearden, Ken Carslaw, Dominick Spracklen (University of Leeds, UK), Fiona O'Connor, Gerd Folberth, Mohit Dalvi, Jane Mulcahy (UK Met Office), Yves Balkanski, Ramiro Checa-Garcia (LSCE-IPSL), Dirk Olivie, Michael Schulz (MetNo), Martine Michou, Pierre Nabat (CNRM), Lars Nieradzic (Lund University), Twan van Noije, Philippe le Sager, Jason Williams (KNMI), Hannele Korhonen, Tommi Bergman, Declan O'Donnell, Antti-Illari Partanen (Finnish Meteorological Institute)**

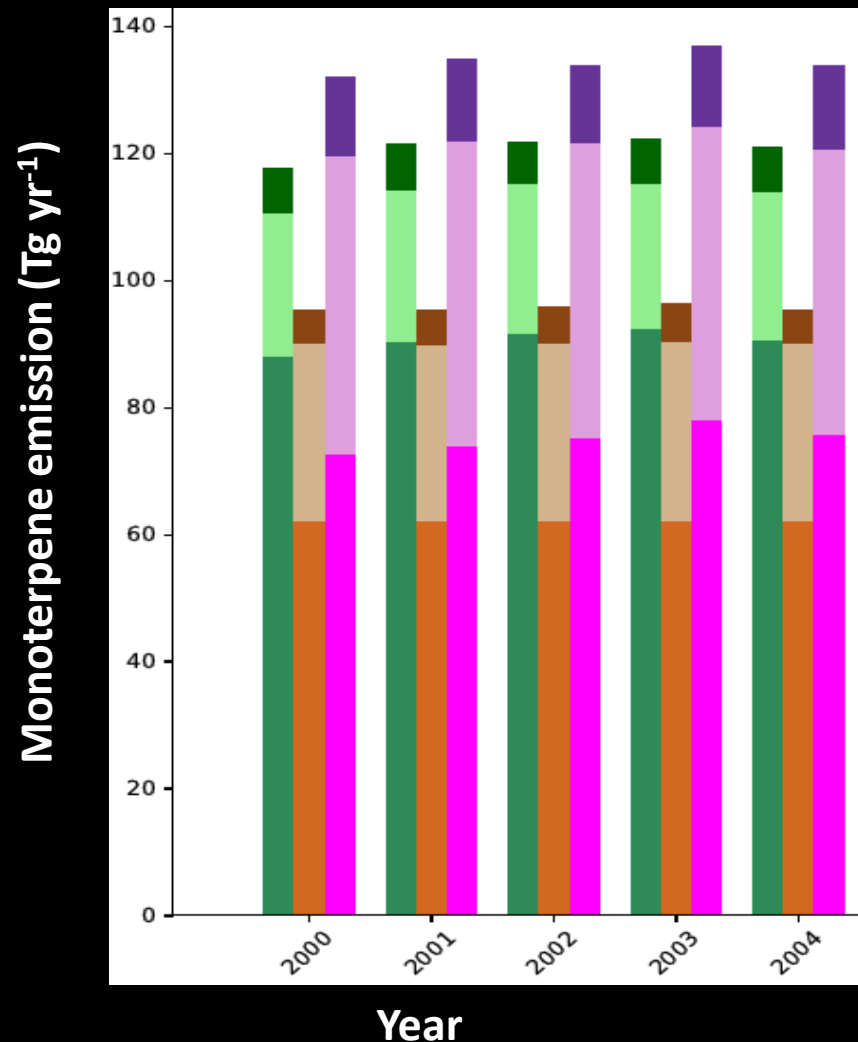




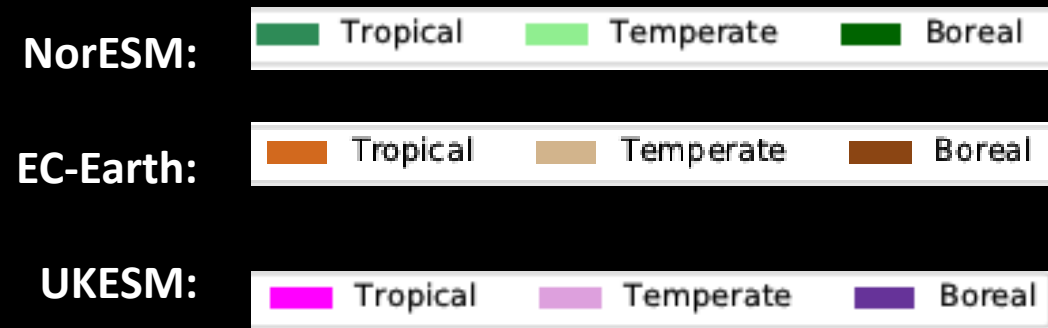
# Biogenic secondary organic aerosol in five Earth System Models



In NorESM & UKESM the emissions of BVOCs are calculated *interactively by the land-surface model* and will therefore respond to changes in climate. No interannual variation in EC-Earth emissions.



A greater proportion of the global total BVOC emissions originate from tropical latitudes in NorESM (by MEGANv2.1 in CLM4.5) than in UKESM (by iBVOC in JULES)



Literature values for annual monoterpene emissions span ~ 30 – 180 Tg yr<sup>-1</sup>

# Where can we see a strong contribution from SOA?

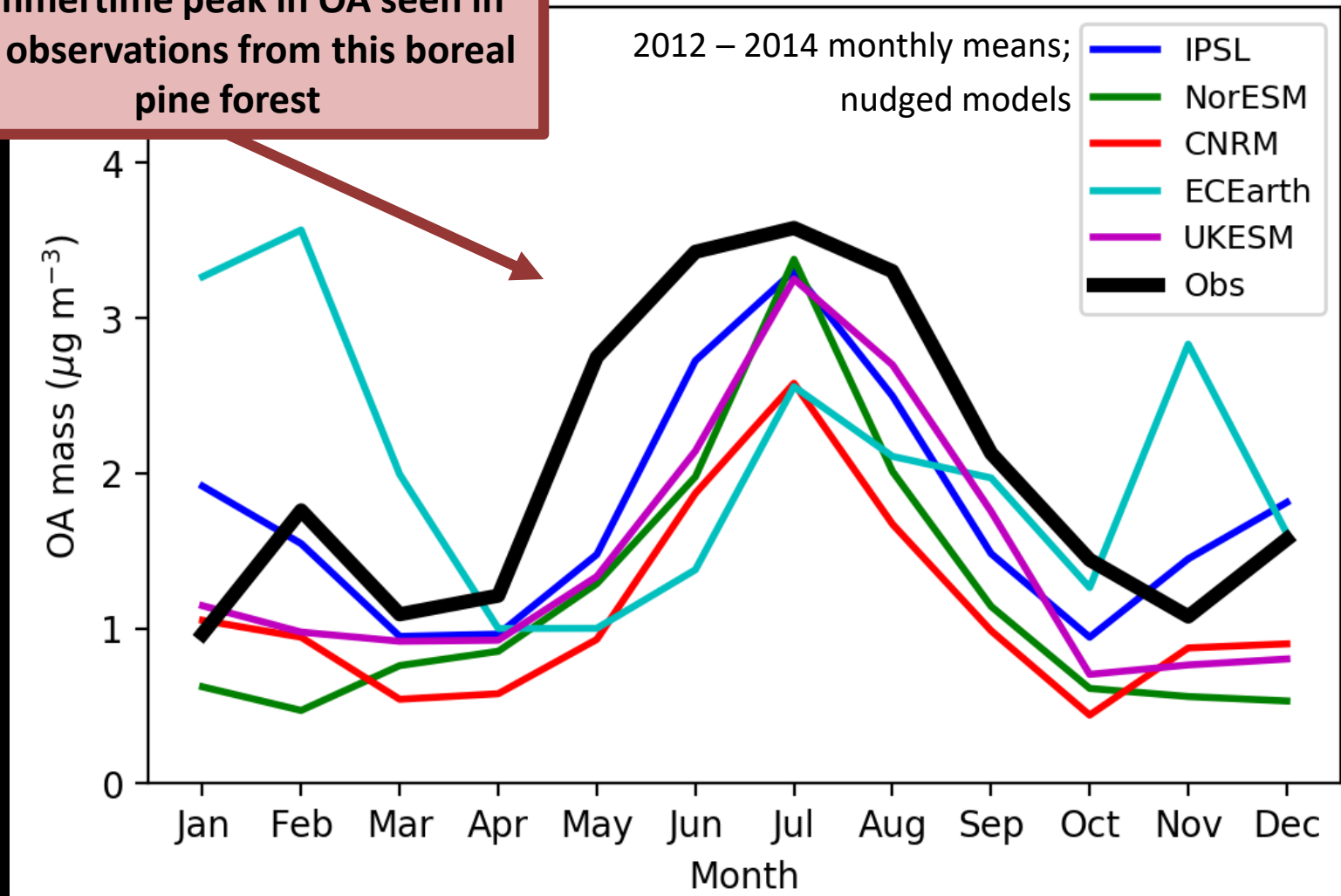


e.g. at Hyytiälä, Finland



Most models capture the summertime peak in OA seen in the observations from this boreal pine forest

Aerosol Chemical Speciation Monitor measurements (black line) from Heikkinen *et al.*, ACP, 2020 ([link](#)).



# Where can we see a strong contribution from SOA?

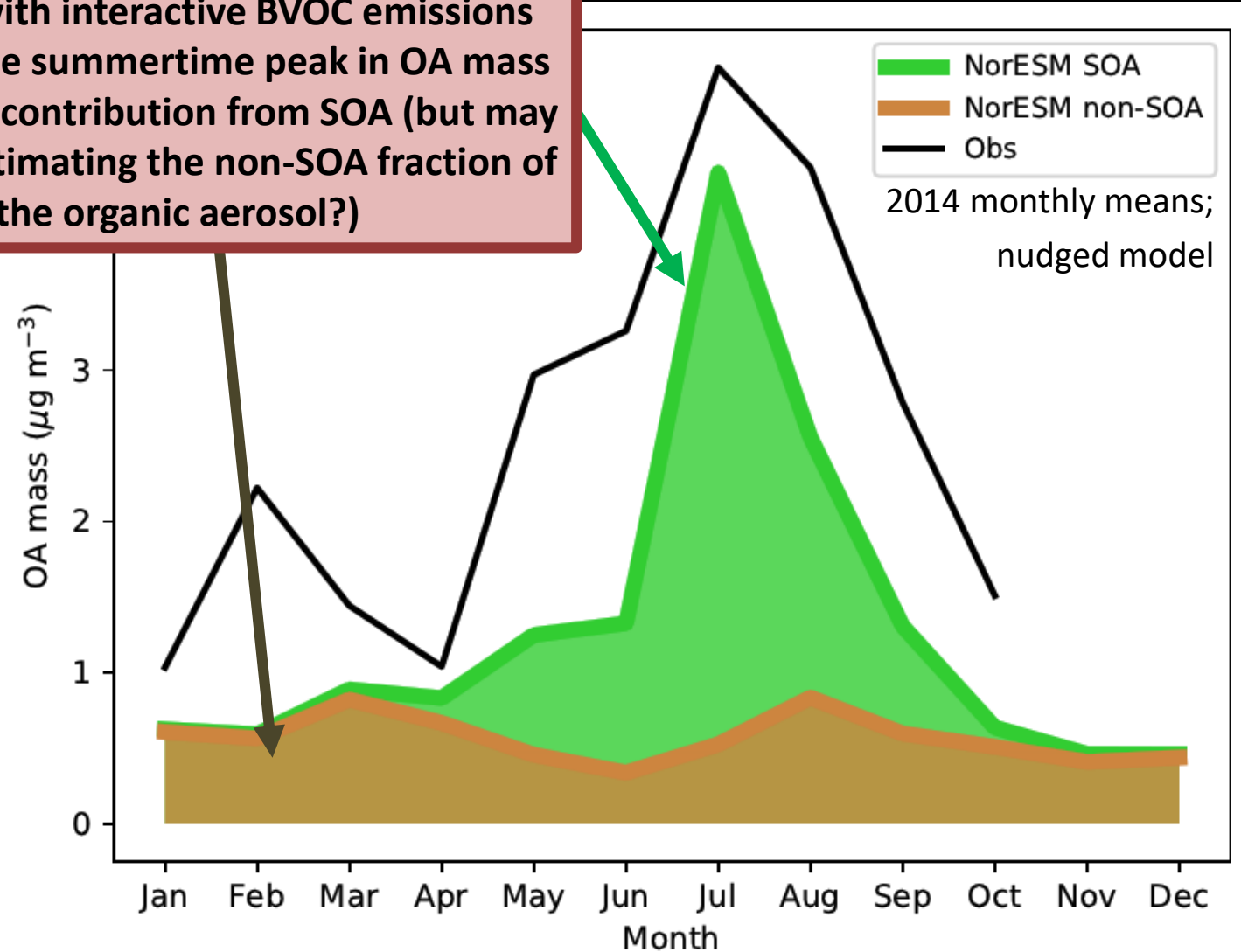


e.g. at Hyytiälä, Finland

NorESM with interactive BVOC emissions captures the summertime peak in OA mass well due to contribution from SOA (but may be underestimating the non-SOA fraction of the organic aerosol?)



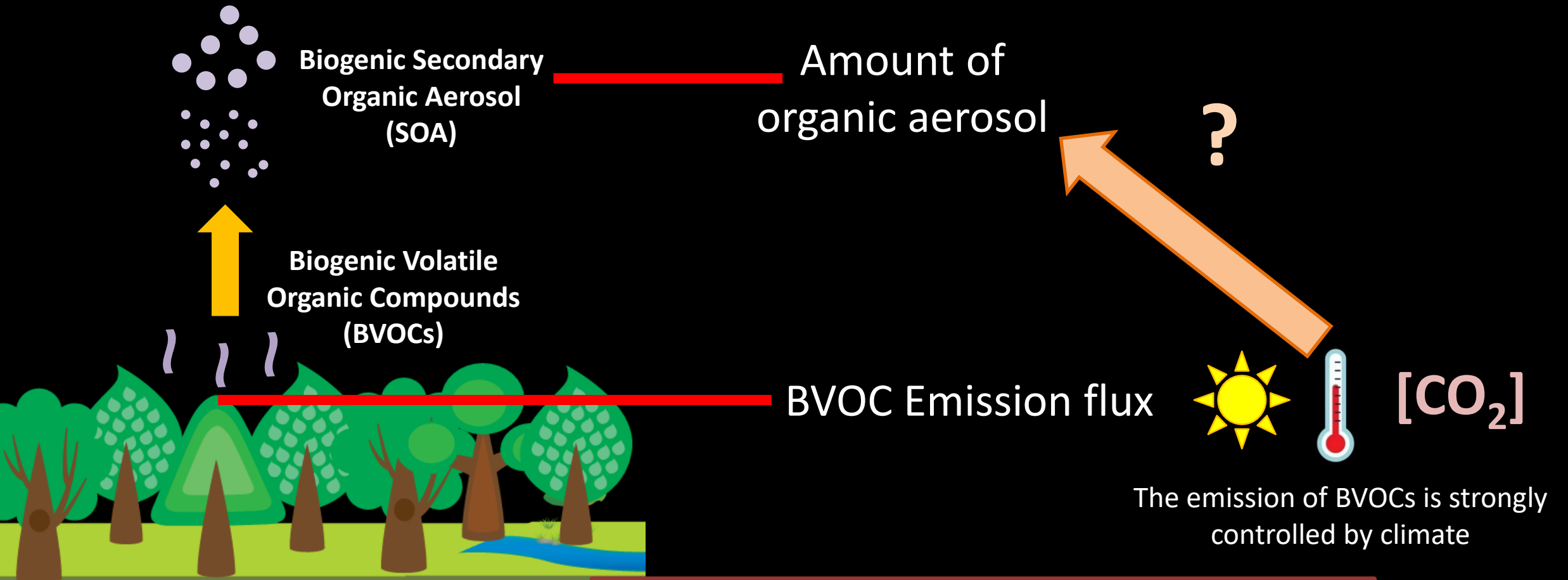
Aerosol Chemical Speciation Monitor measurements (black line) from Heikkinen *et al.*, ACP, 2020 ([link](#)).



# Can we expect these ESMs to capture climate driven changes in atmospheric composition?

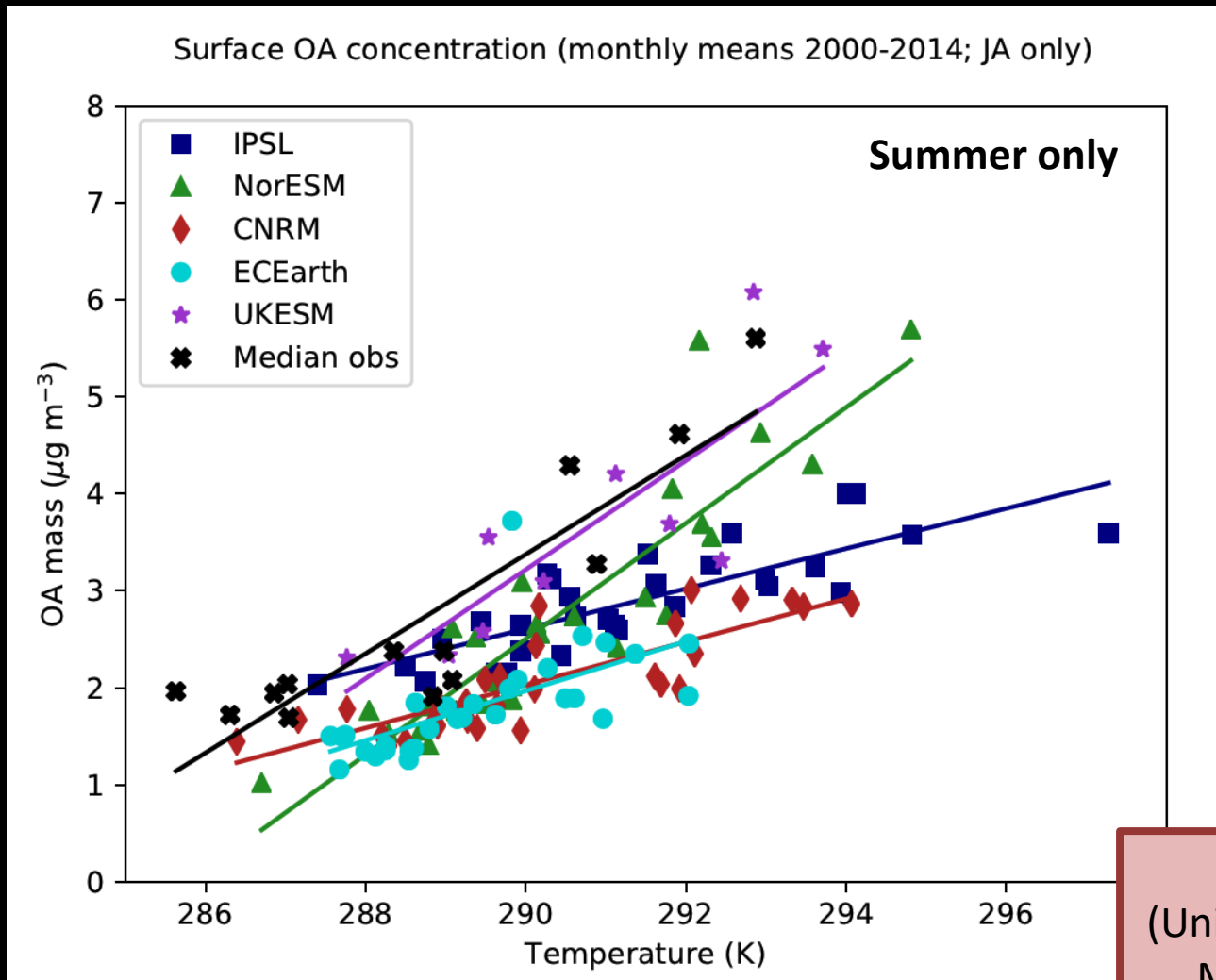


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In collaboration with: Annele Virtanen, Taina Yli-Juuti (University of Eastern Finland), Liine Heikkinen, Mikko Aijälä, Mikael Ehn, Tuukka Petäjä (University of Helsinki), Tero Mielonen, Harri Kokkola, Antti Arola, Antti Lipponen (FMI)

# Do our ESMs capture the observed relationship?



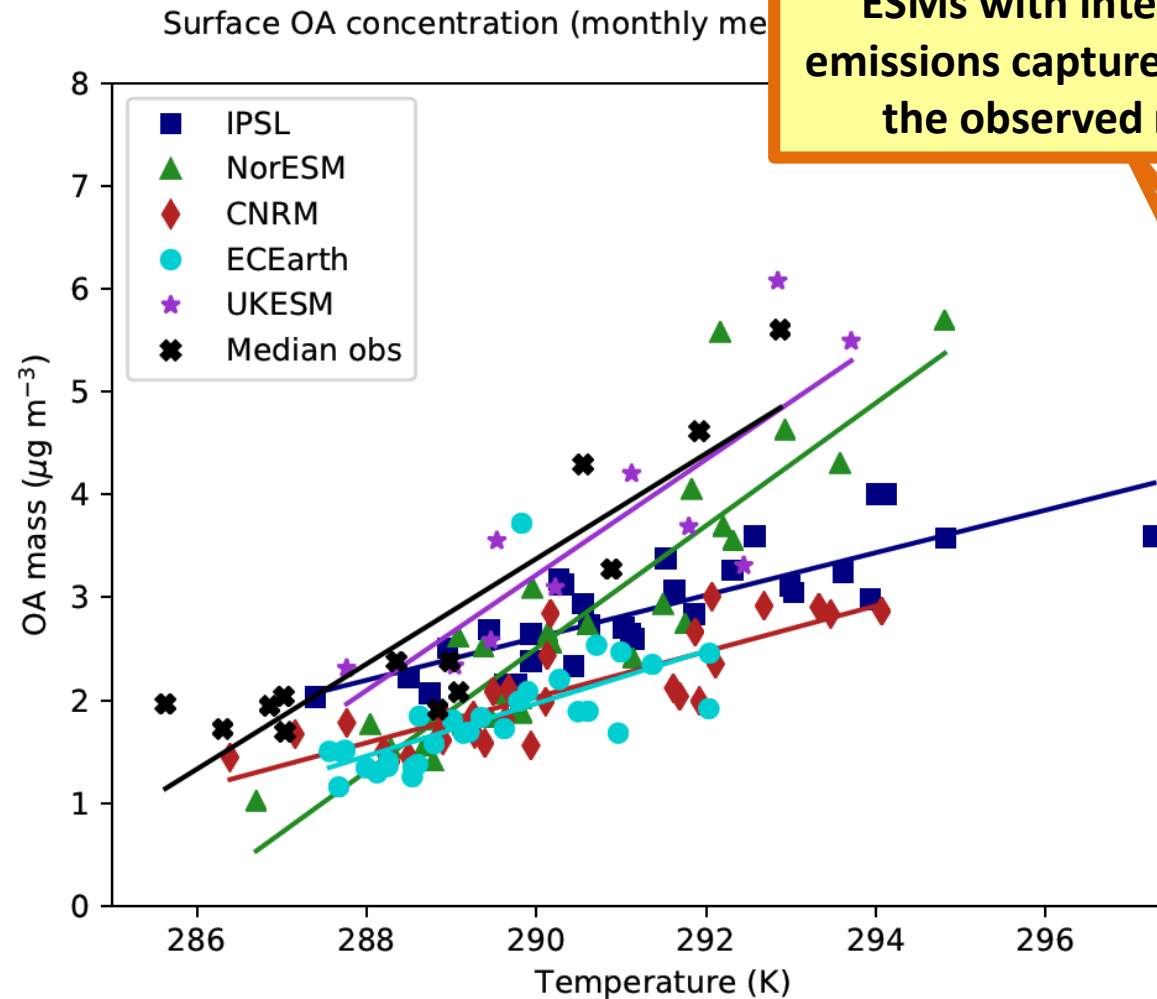
	Correlation coefficient (R)	Gradient ( $\mu\text{g m}^{-3} \text{K}^{-1}$ )
<b>Observations</b>	<b>0.90</b>	<b>0.51</b>
<b>IPSL</b>	<b>0.82</b>	<b>0.21</b>
<b>NorESM</b>	<b>0.90</b>	<b>0.60</b>
<b>CNRM</b>	<b>0.83</b>	<b>0.22</b>
<b>ECEarth</b>	<b>0.64</b>	<b>0.26</b>
<b>UKESM</b>	<b>0.83</b>	<b>0.56</b>

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Hyytiälä, Finland



# Do our ESMs capture the observed relationship?

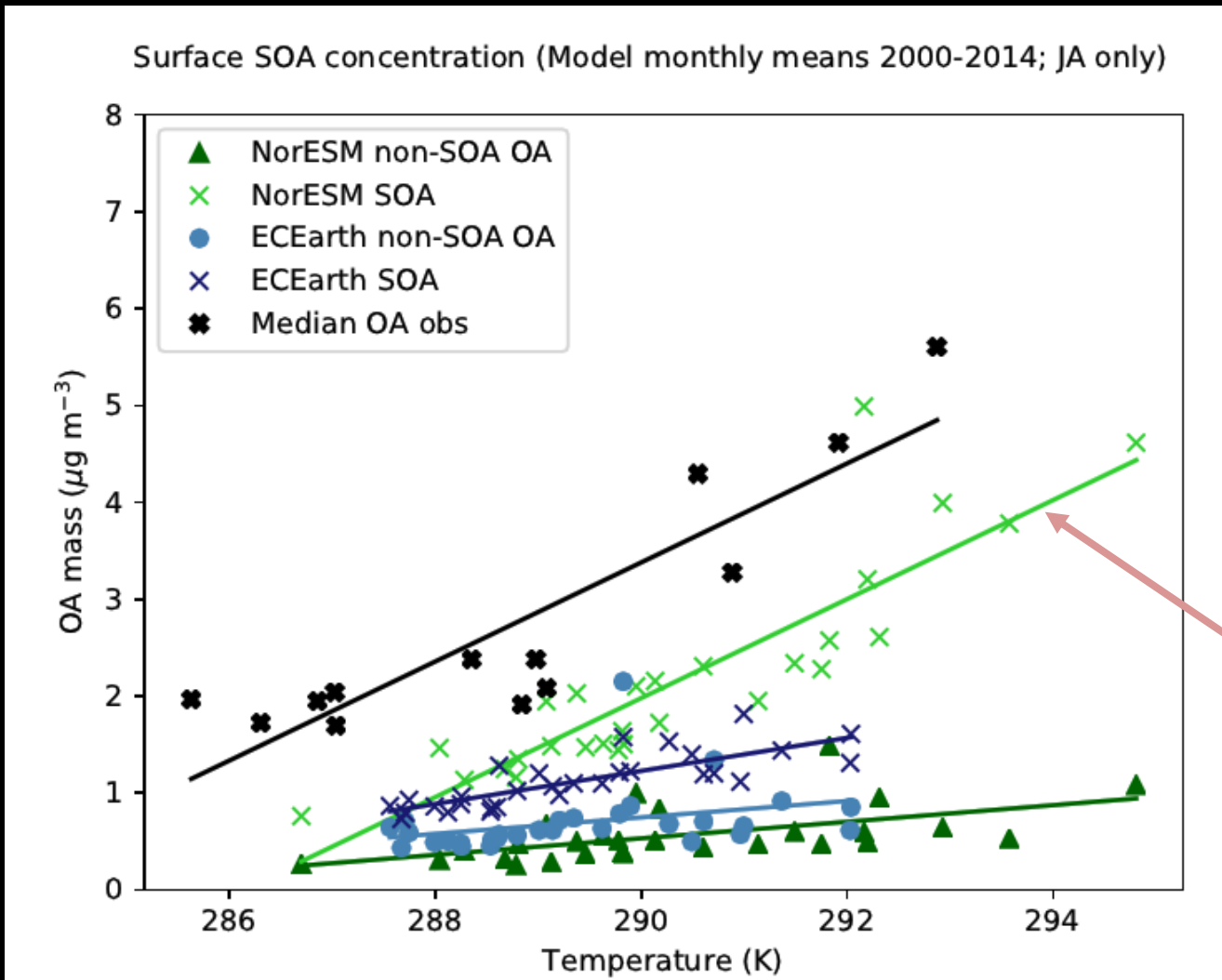


ESMs with interactive BVOC emissions capture the strength of the observed relationship

	Correlation coefficient (R)	Gradient ( $\mu\text{g m}^{-3} \text{K}^{-1}$ )
Observations	0.90	0.51
IPSL	0.82	0.21
NorESM	0.90	0.60
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# Which part of the OA correlates with temperature?



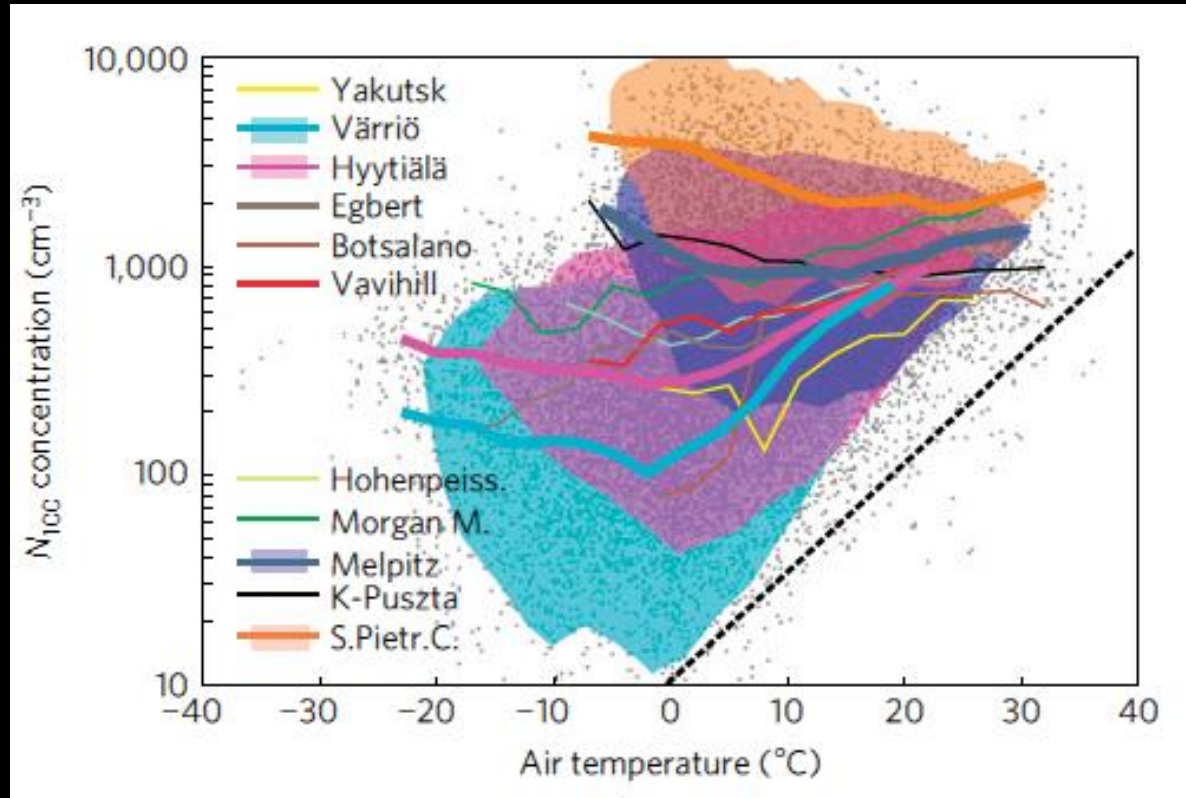
Model	Component	R	Gradient ( $\mu\text{g m}^{-3} \text{K}^{-1}$ )
NorESM	Non-SOA OA	0.56	0.09
	SOA	0.88	0.51
EC-Earth	Non-SOA OA	0.34	0.08
	SOA	0.80	0.17
Obs	Total OA	0.90	0.51

The SOA component in NorESM captures the strength of the observed OA v T relationship

Gradient in EC-Earth is weaker because emissions do not vary from year to year

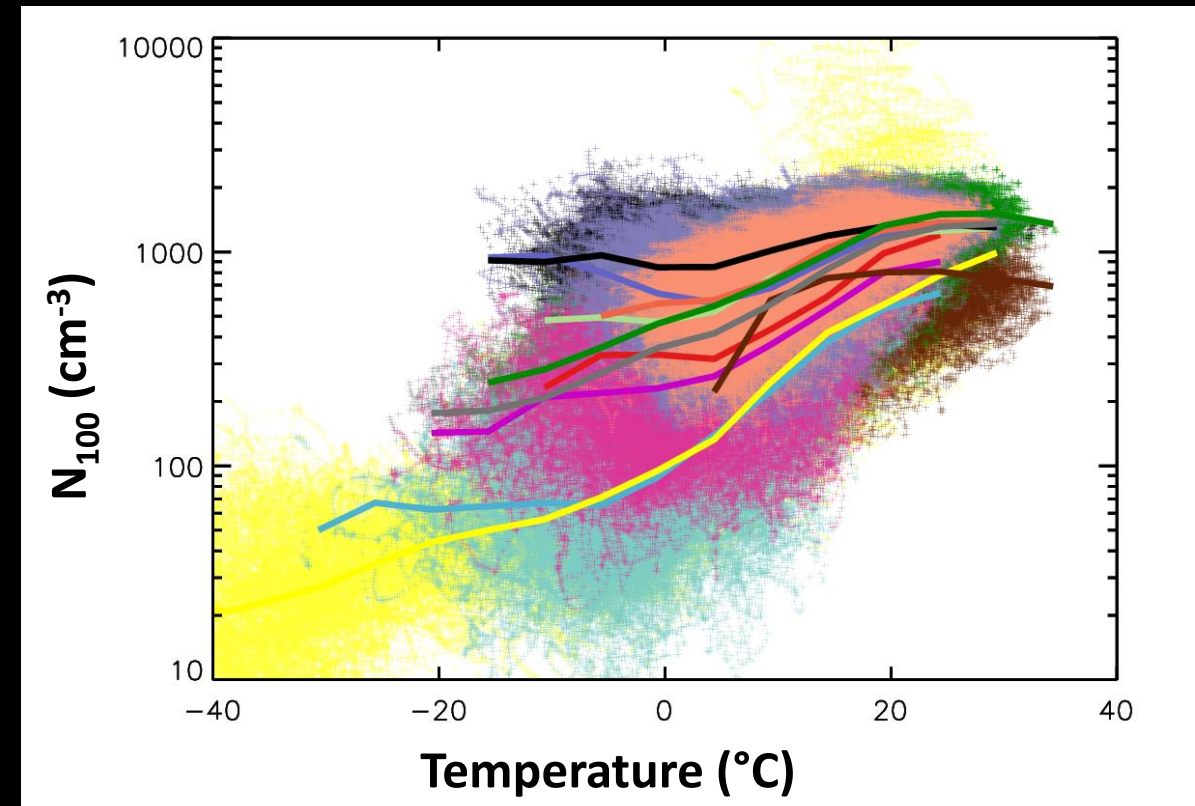
## Observations

Compiled by Paasonen *et al.*, 2013, *Nature Geoscience*.



## Model

From Scott *et al.*, 2018, *Nature Geoscience*

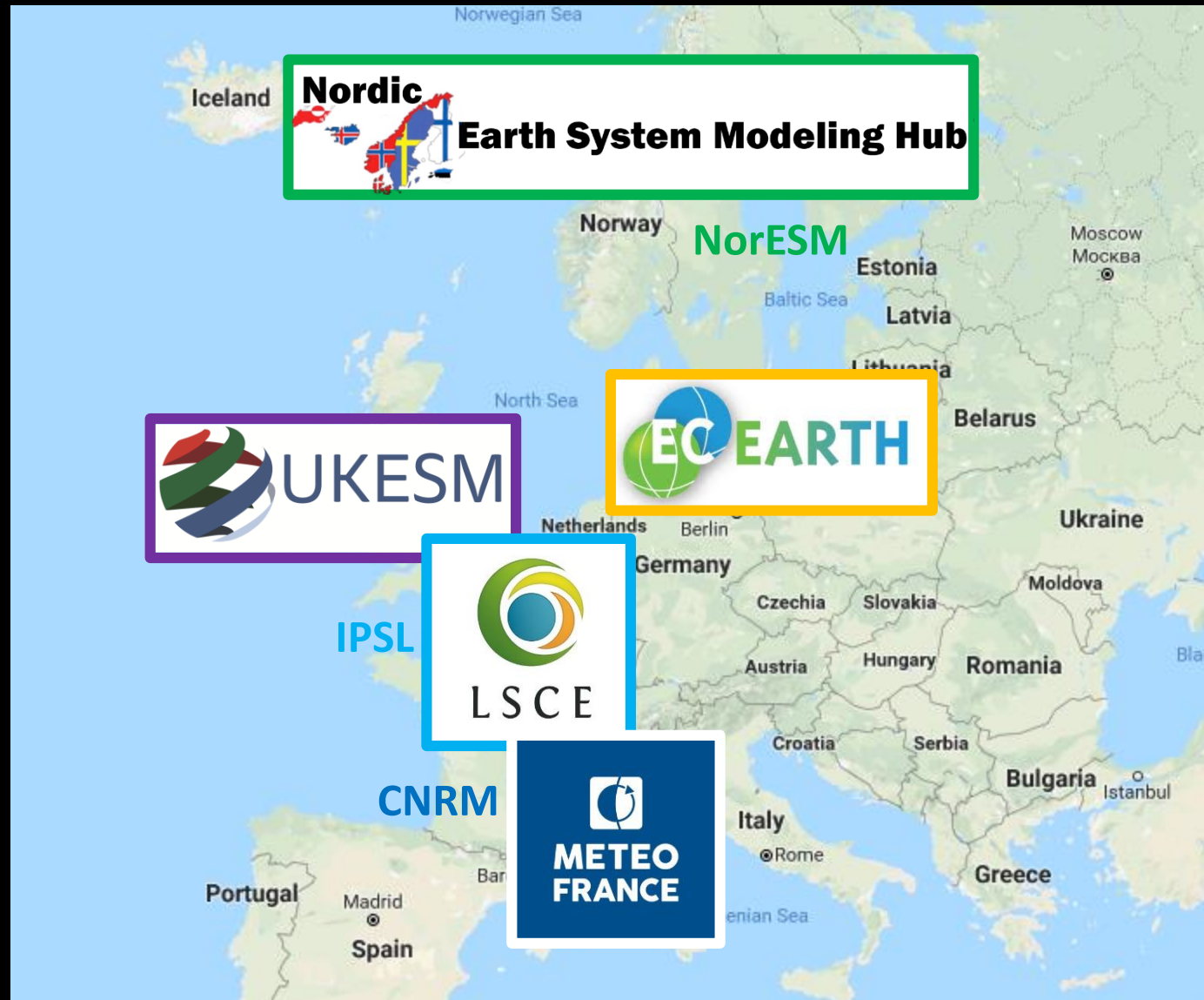


■ Hyytiälä    ■ Värriö    ■ Vavihill    ■ Hohenpeissenberg    ■ Melpitz  
■ K-pusztá    ■ Yakutsk    ■ San Pietro    ■ Botsalano    ■ Morgan Munroe    ■ Egbert

- The five ESMs reproduce seasonal cycle in organic aerosol (OA) at boreal forest site, but all overpredict wet season OA concentration over Amazon
- All models capture the positive relationship between temperature and OA concentration observed at boreal forest site -> strength of relationship only captured by models with interactive biogenic VOC emissions
- Still to explore: contribution of SOA to aerosol number and the aerosol size distribution!
- Get in touch: [c.e.scott@leeds.ac.uk](mailto:c.e.scott@leeds.ac.uk)



# Additional slides



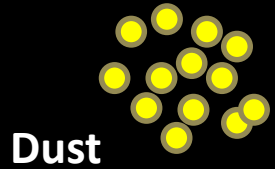
**Models  
being used  
for CMIP6  
(AerChemMIP)**



# Natural aerosols in the Earth System



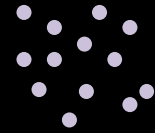
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Dust

Secondary Organic Aerosol

Aerosol

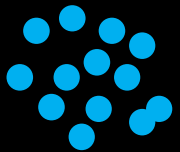


Biogenic Volatile Organic Compounds (BVOCs)

Fire

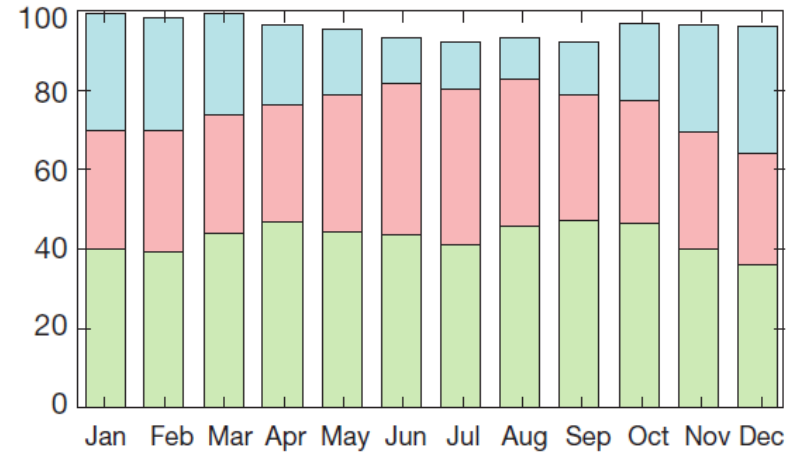


DMS



Sea-spray

% contribution to IRF variance

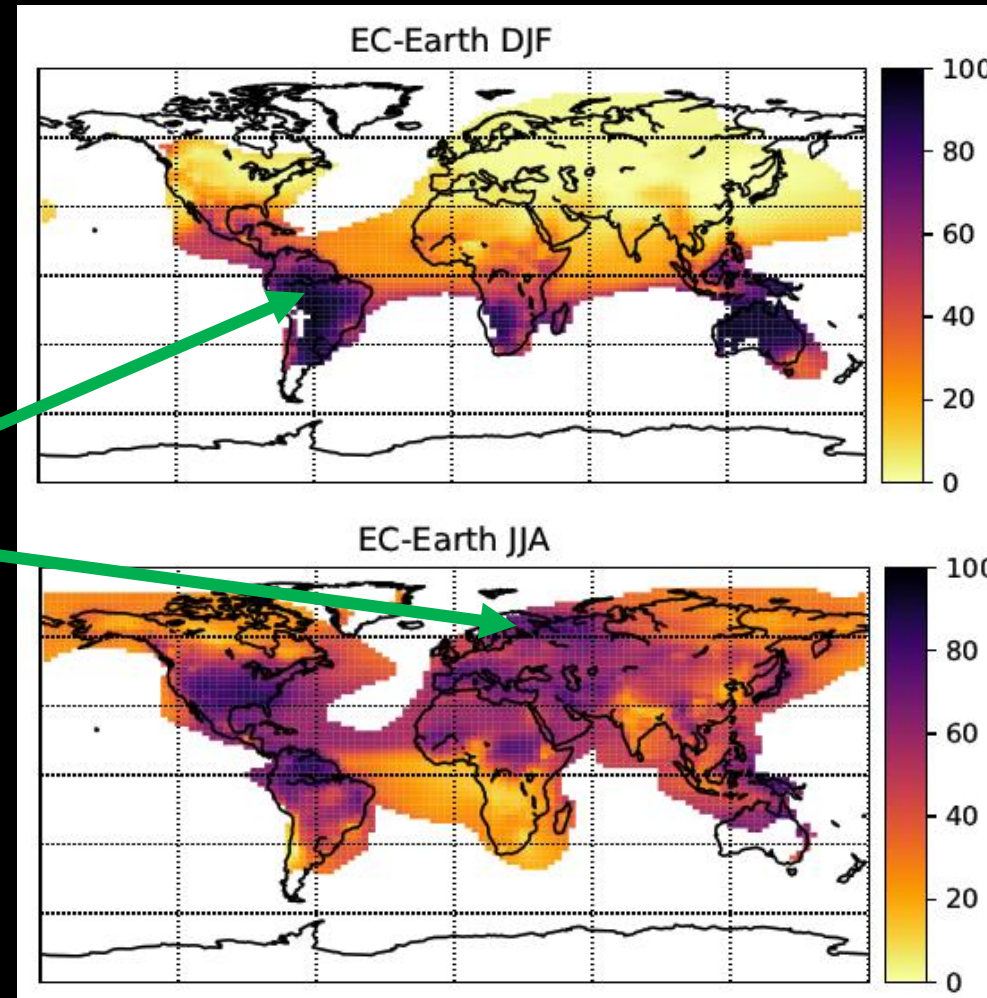


(Carslaw *et al.*, 2013)

# How much organic aerosol is SOA?



In EC-Earth, primary and secondary organic aerosol are tracked independently – allowing us to identify regions of the world where SOA makes up the majority of the (simulated) organic aerosol during different seasons



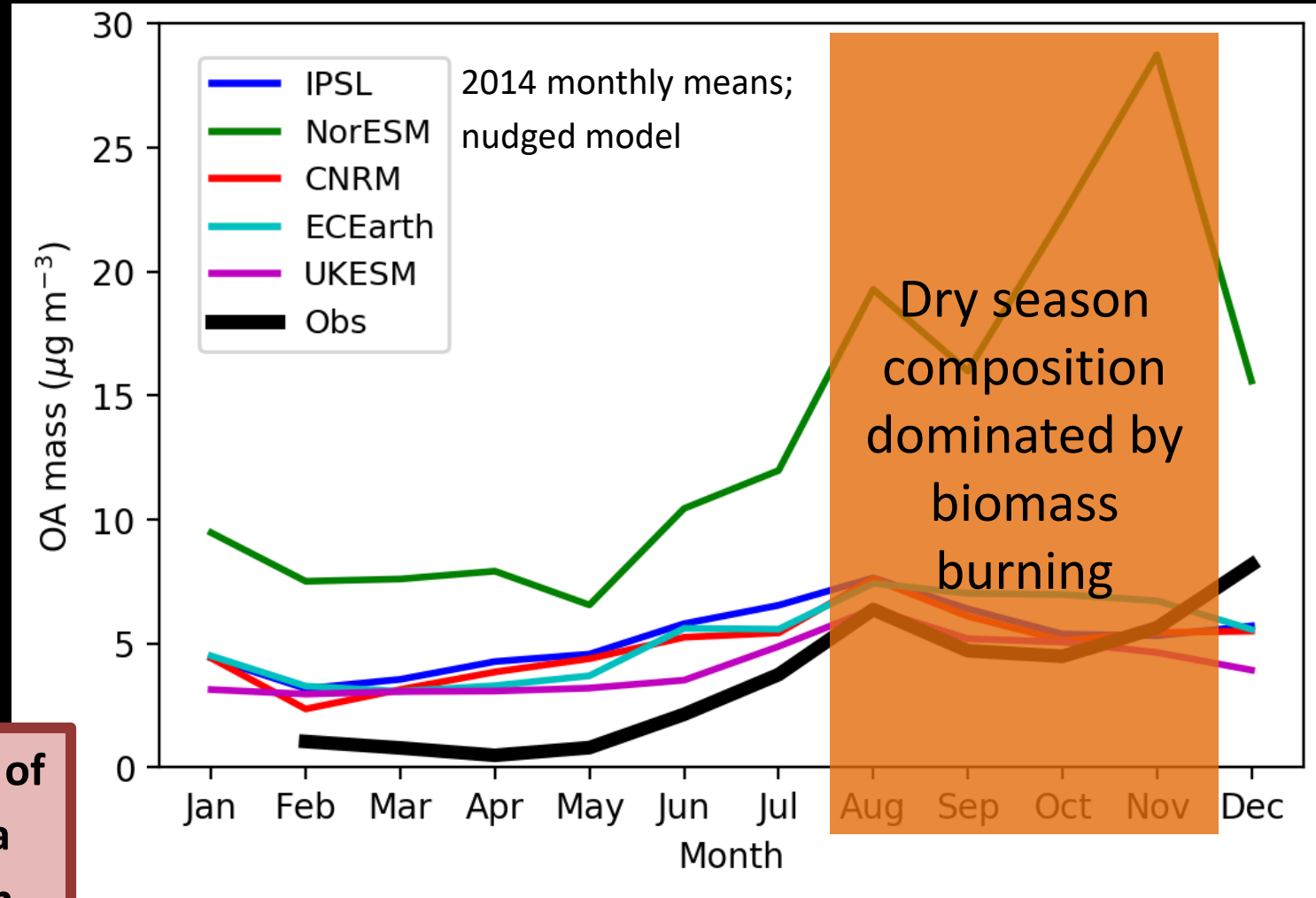
% of OA that is SOA



# Where can we see a strong contribution from SOA?



e.g. at ATTO tower, Brazil

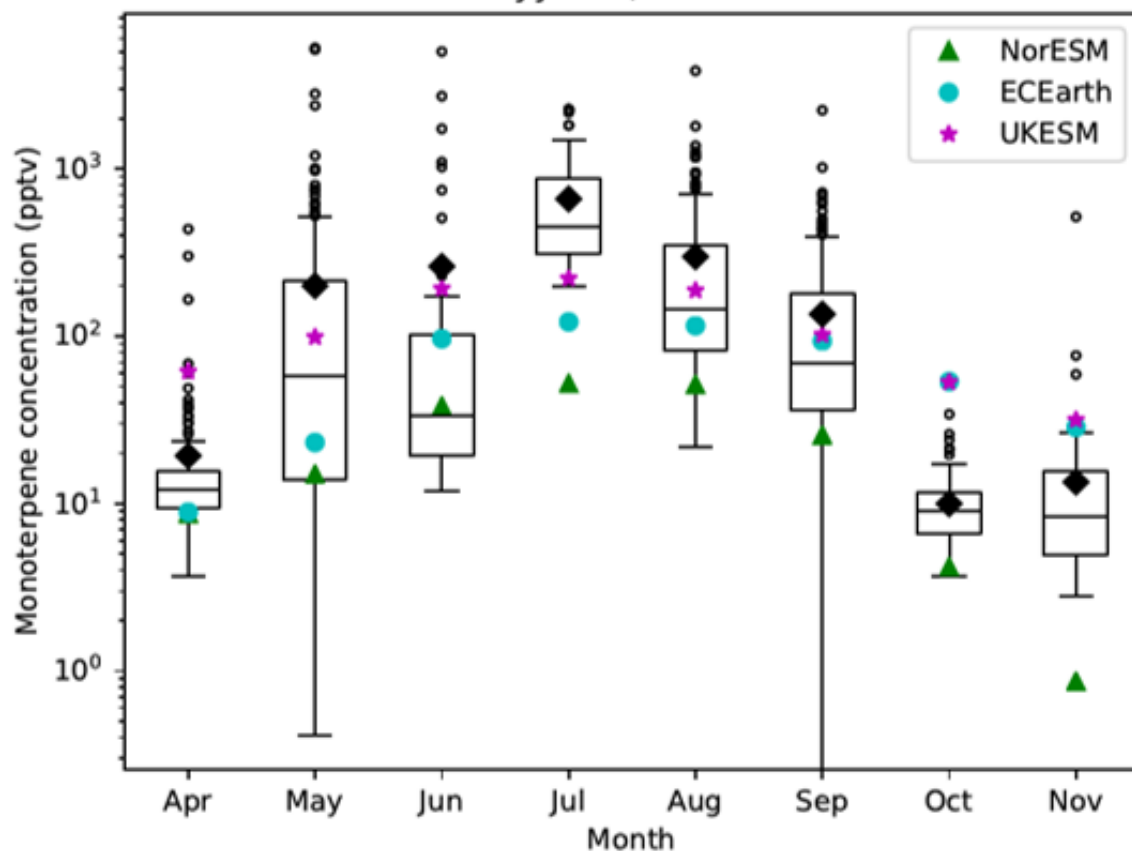


Observations courtesy of Paulo Artaxo, Samara Carbone + ATTO team

Monoterpenes: underpredicted

Isoprene: overpredicted

Hyytiala, Finland



Hyytiala, Finland

