CAMAERA

TOWARDS A REPRESENTATION OF FUNGAL SPORES IN EMEP AND IFS-COMPO

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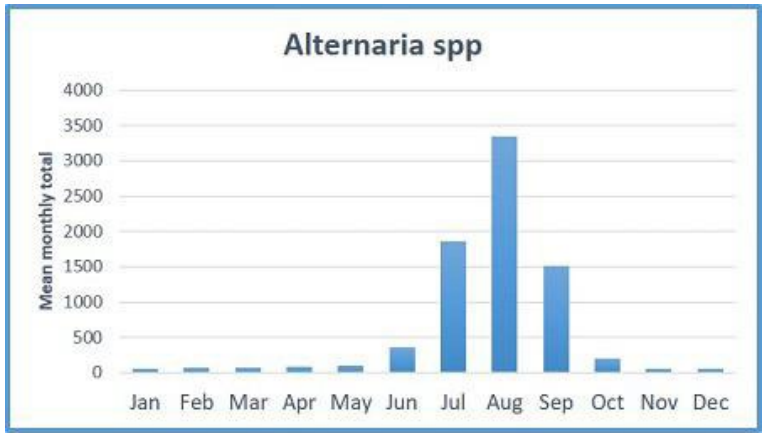
Whare fungal spores?

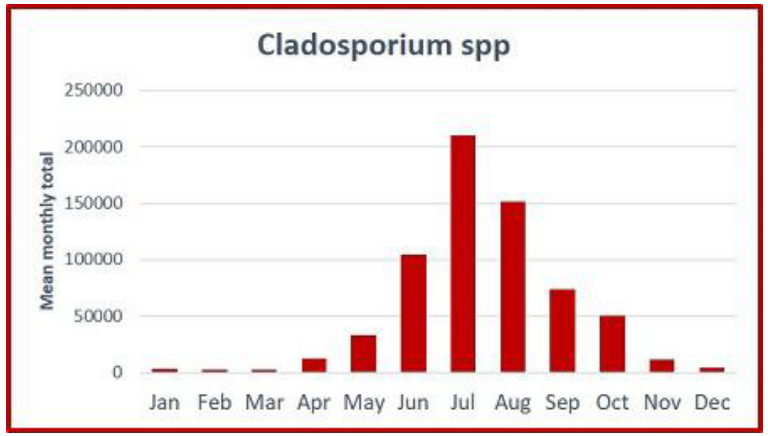
- Fungal spores are microscopic biological particles that allow fungi to be reproduced, serving a similar purpose to that of seeds in the plant world,
- Many fungal spores contain allergens which can trigger a range of respiratory symptoms in those susceptible,
- It is estimated that around 3-4% of the general population get allergy symptoms from fungal spores, including the majority of asthma sufferers,
- Fungi come in a wide range of types and sizes. Fungal spores are all microscopic. Most fungi require warmth and humidity to grow, reproduce and release their spores into the environment,
- In summer time and in affected places, fungal spores represent a significant fraction of observed PM10

Fungal spores. Coloured scanning electron micrograph (SEM) of the spores of a fungus. Steve Gschmeissner/Science photo library

Implementation of fungal spores in EMEP and IFS-COMPO

- Single tracer that represents all fungal spores : lumped approach which is a very big simplification
- Assumed mean diameter of 3 micron, density of 1000 kg/m3
- Three emission schemes as a function of temperature, humidity, wind speed and leaf area index (LAI) are being tested





Mean monthly counts of fungal spores from different species at Worcester (UK), as collected by the University of Worcester

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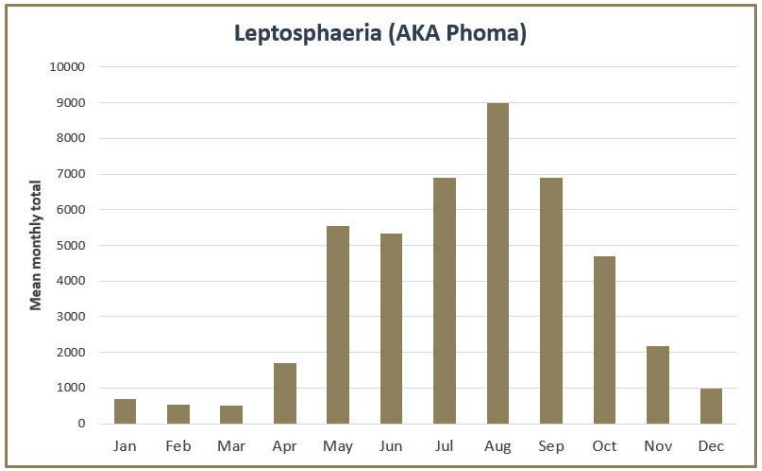

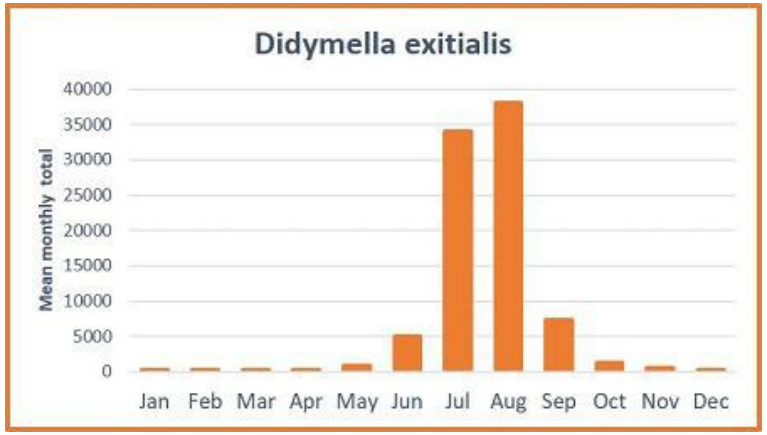

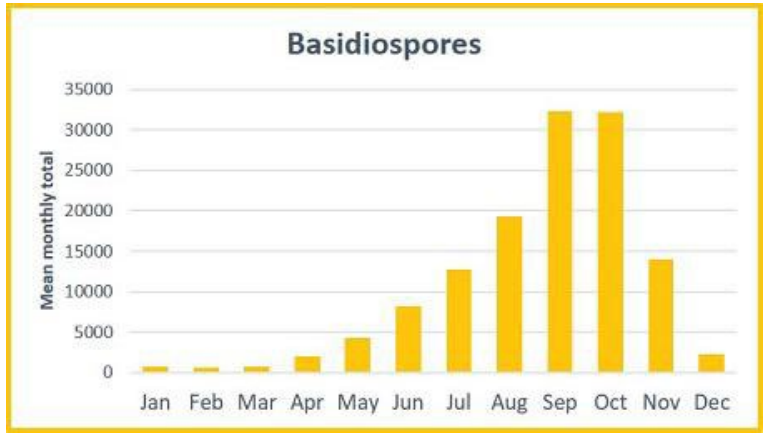

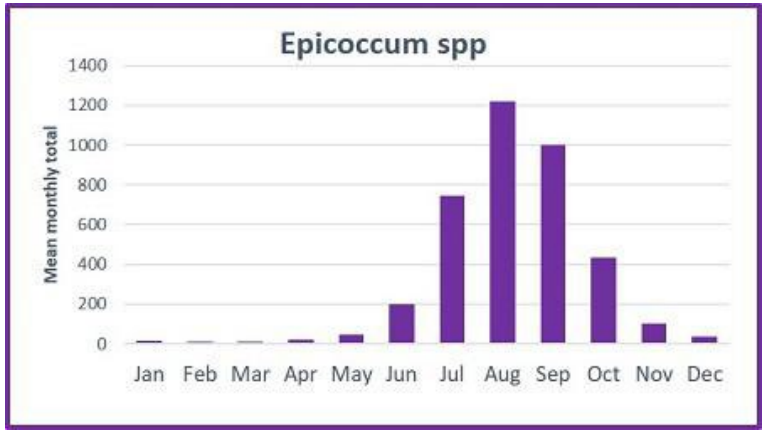

Mean monthly counts of fungal spores from different species at Worcester (UK), as collected by the University of Worcester

Fungal spores emission schemes

- Emission schemes tested:

$$F_{\mathrm{Js}} = 2.63 \times 10^{-5} + 6.1 \times 10^{3} \times \underbrace{q}_{\text{Specific humidity [kg/kg]}} + 46.7 \times \underbrace{\mathrm{LAI}}_{\text{Leaf-area index [m}^2\text{/m}^2\text{]}} + 59.0 \times \underbrace{u^*}_{\text{Friction velocity [m/s]}} \quad [\text{Ref. 1}]$$

$$F_{\mathrm{H\&S}} = c \times \frac{\overbrace{q}^{\text{Specific humidity [kg/kg]}}}{7.5 \cdot 10^{-2}} \times \overbrace{\mathrm{LAI}}^{\text{Leaf-area index [m}^2\text{/m}^2\text{]}}, \quad c = \begin{cases} 2315\ \mathrm{m^{-2}\ s^{-1}} & d = 3\ \mu\mathrm{m} \quad [\text{Ref. 2}] \\ 500\ \mathrm{m^{-2}\ s^{-1}} & d = 5\ \mu\mathrm{m} \quad [\text{Ref. 3}] \end{cases}$$

$$F_{\mathrm{Hm}} = 20.426 \times (\underbrace{T}_{\text{Temperature [}^{\circ}\text{C]}} - 275.82) + 3.93 \times 10^{4} \times \underbrace{q}_{\text{Specific humidity [kg/kg]}} \times \underbrace{\mathrm{LAI}}_{\text{Leaf-area index [m}^2\text{/m}^2\text{]}} \quad [\text{Ref. 4}]$$

- EMEP and CHIMERE used HS09
- IFS-COMPO tested all parameterizations

Heald, C. L., and D. V. Spracklen*: Atmospheric budget of primary biological aerosol particles from fungal spores, Geophys. Res. Lett., 36, 2009*

Hummel et al *: Regional-scale simulations of fungal spore aerosols using an emission parameterization adapted to local measurements of fluorescent biological aerosol particles, Atmos. Chem. Phys., 15, 6127–6146, https://doi.org/10.5194/acp-15-6127-2015, 2015.*

Janssen et al*: Drivers of the fungal spore bioaerosol budget: observational analysis and global modeling, Atmos. Chem. Phys., 21, 4381–4401, 2021.*

Fungal spores emission schemes

Additionally, a temperature threshold of 5° for fungal spores emissions has been tested in IFS-COMPO and EMEP

Plot from J21 Supplement

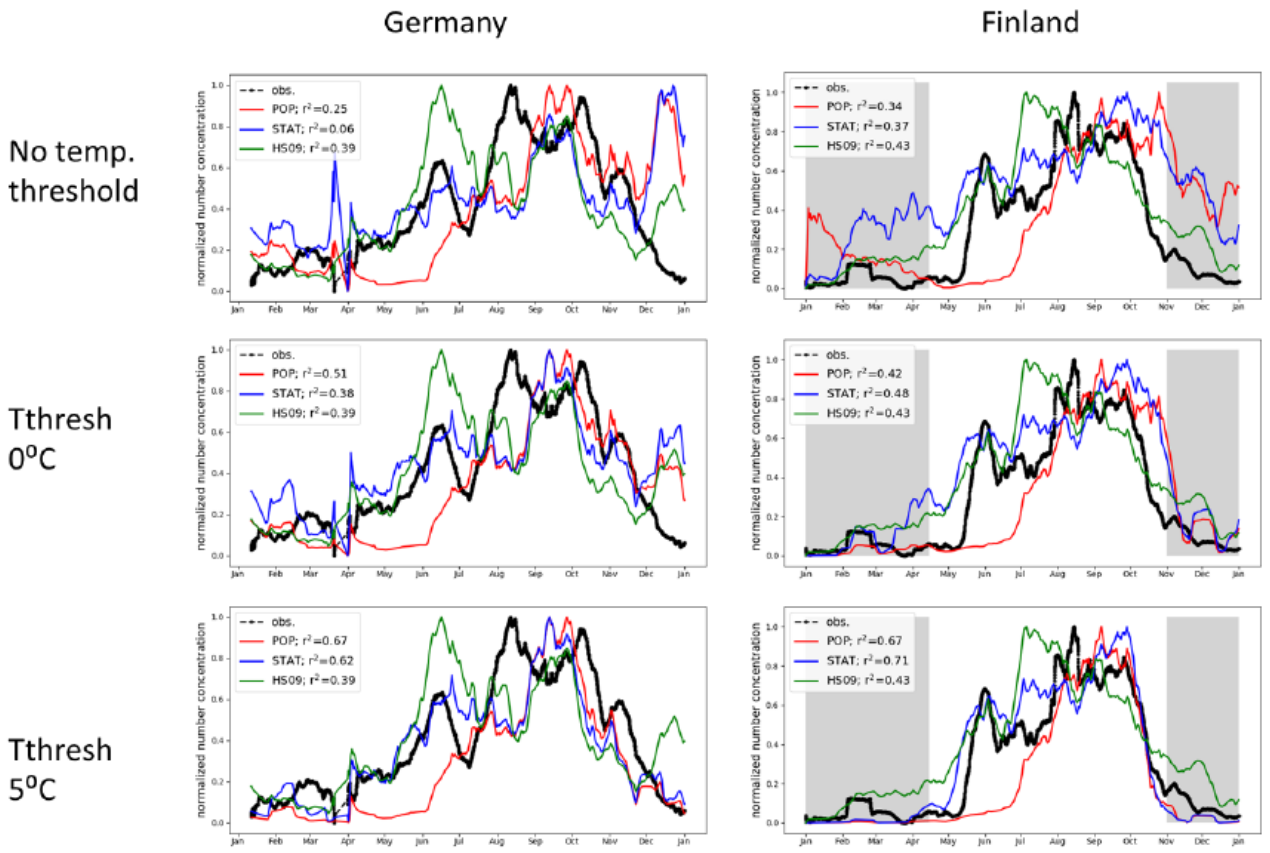

Figure S5: sensitivity to chosen temperature threshold of modeled spore concentrations at the sites in Germany and Finland. No temperature threshold (top), threshold of 0°C (middle) and threshold of 5°C (bottom)

Fungal spores emission schemes

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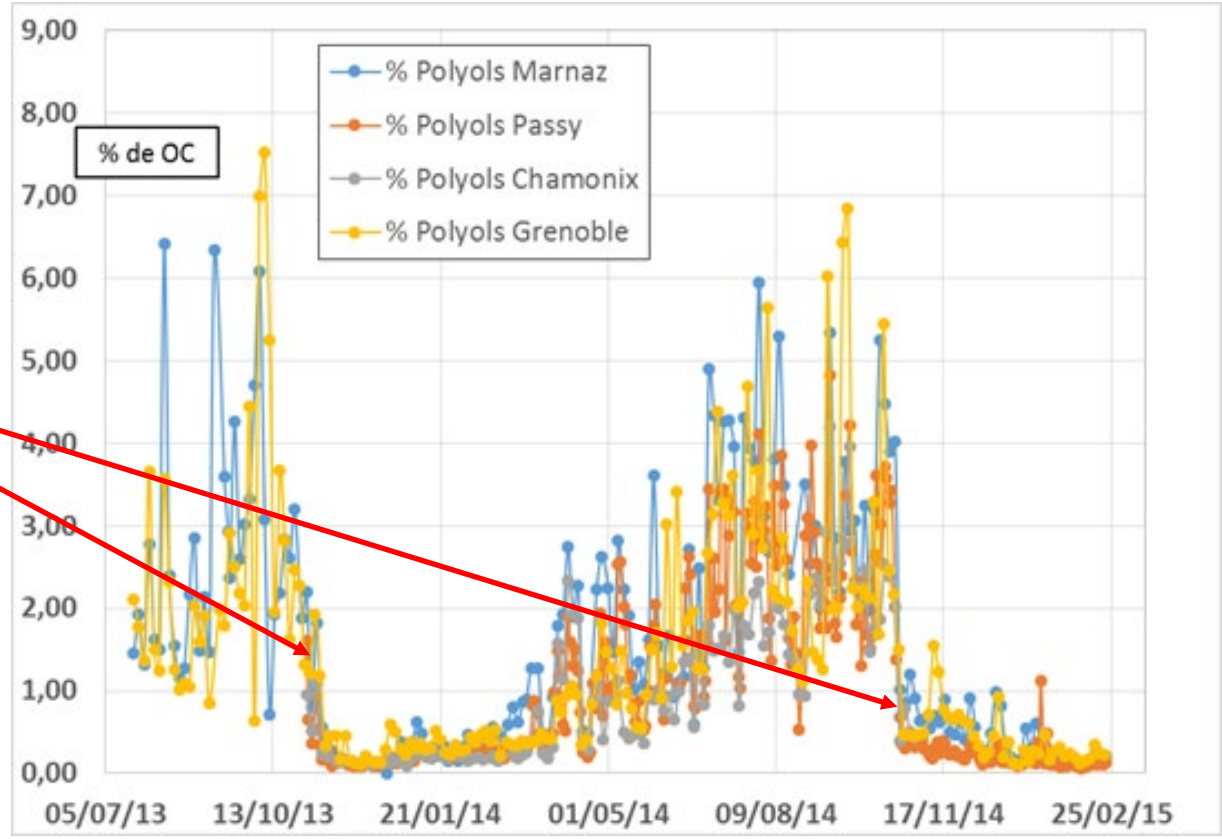
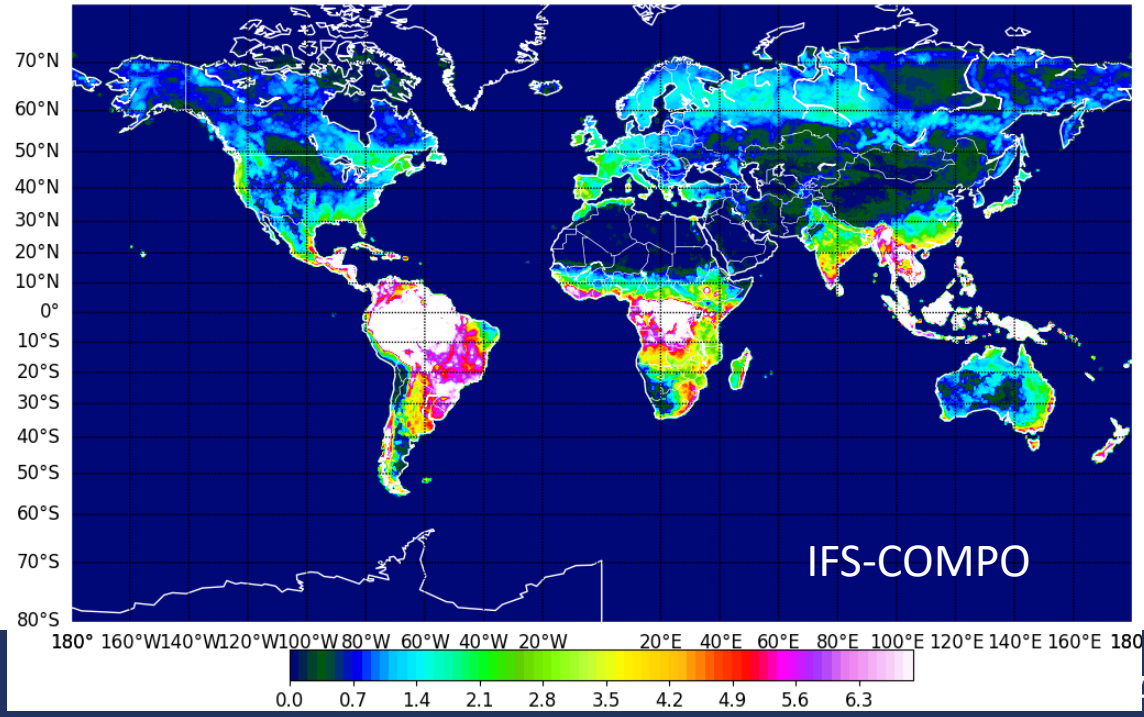
Abrupt decrease in fall when night-time temperature drops below 5°c

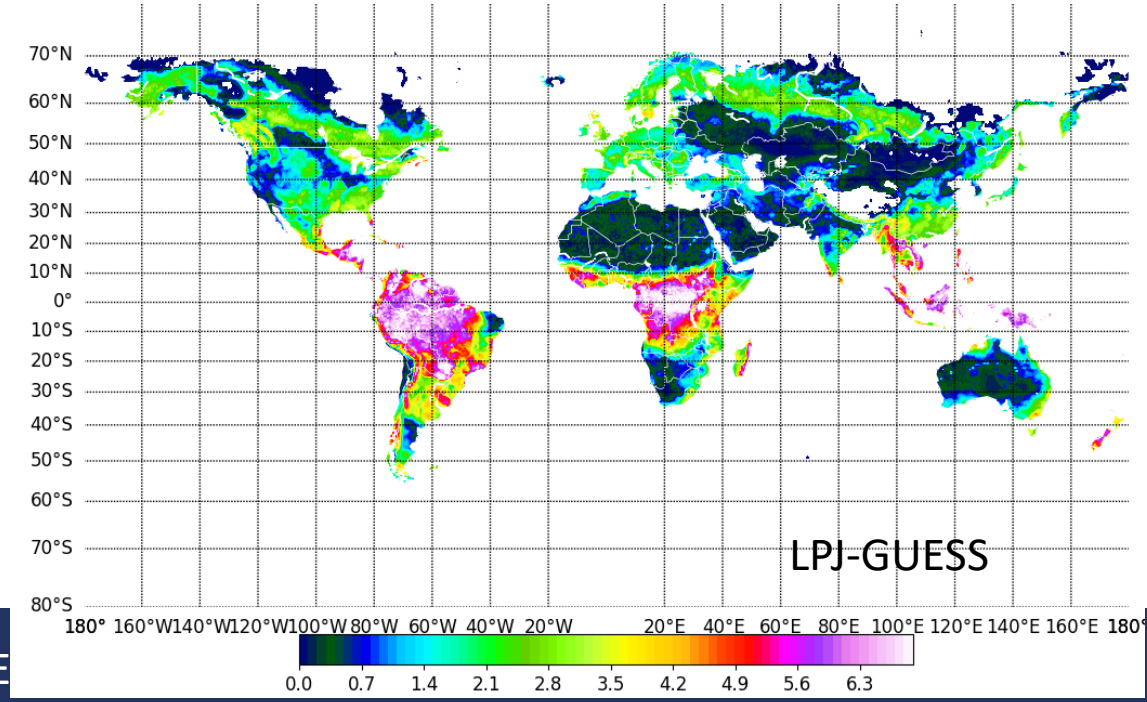
Plot from JL Jaffrezo



Fungal spores emission schemes

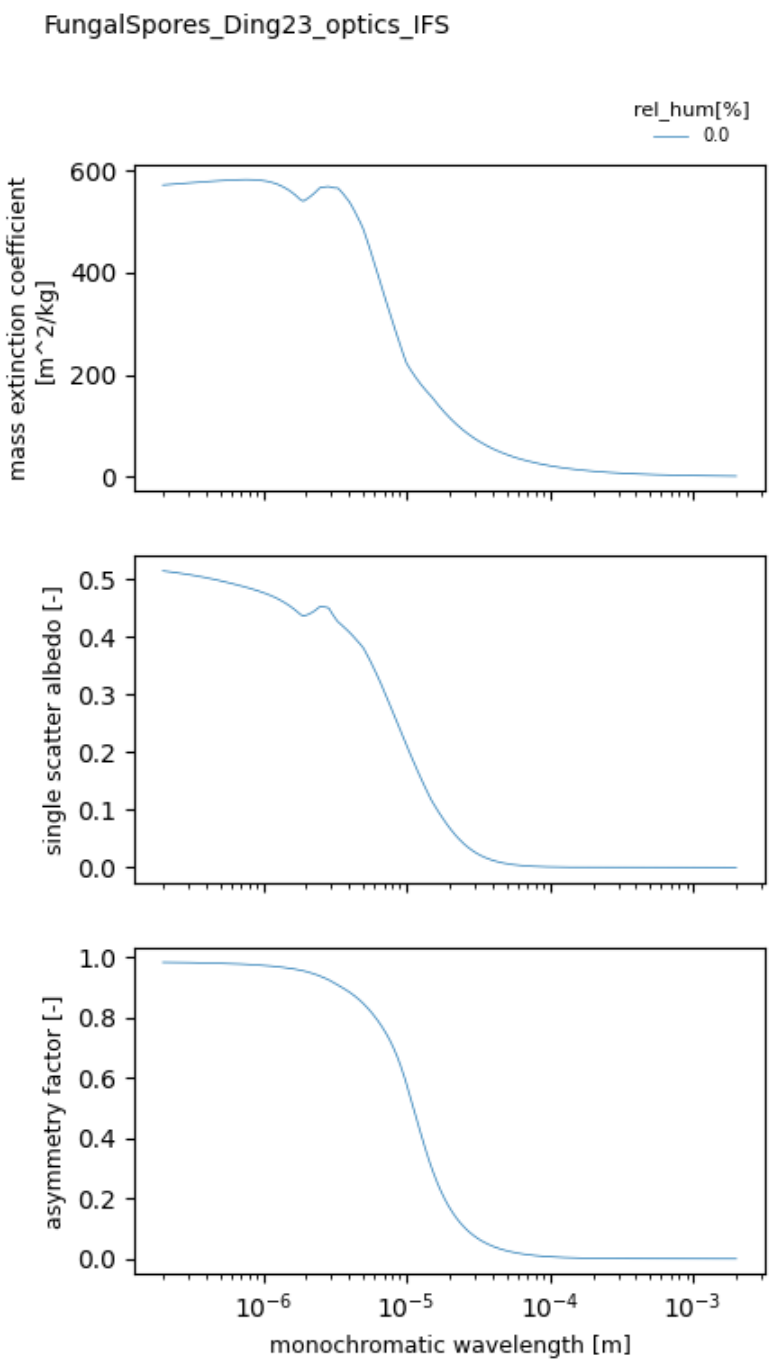
- All schemes rely a lot on LAI, but this is quite an uncertain quantity. In IFS cycle 49R1, LAI is from a climatology from Copernicus global land
- Comparison of IFS-COMPO LAI (sum of low veg + high veg) with LAI from the LPJ-GUESS ecosystem model (https://web.nateko.lu.se/lpj-guess/) for December 2016
- Significant differences, in equatorial forests IFS-COMPO LAI reaches values of 10-12 against 5-6 for LPJ-GUESS





Fungal spores optical properties

- In the EMEP implementation, fungal spores are transparent
- In IFS-COMPO, optical properties (mass extinction, SSA, asymmetry parameter, lidar ratio) of fungal spores have been computed using refractive indexes from Ding et al (2023). Main features:
  - Low mass extinction -> small impact expected on simulated AOD
  - Low SSA -> fungal spores are quite absorbing and could impact simulated AAOD/SSA



Wanying Ding, Youlin Gu, Yihua Hu, Hao Cao, Guolong Chen, and Haihao He, "Quantitative determination of microbial materials activity based on infrared extinction properties," Opt. Express 31, 31486-31503 (2023)

Fungal spores global budgets (IFS-COMPO)

- The H15 and J21 emissions have been adjusted in a second round of simulations

Model name	Emissions (Tg/Yr)	Dry deposition + Sedimentation (Tg/Yr)	Wet deposition (Tg/Yr)	Burden (Tg)	Lifetime (days)
HS09 (3 micron)	47.2	29.4	17.8	0.19	1.47
HS09 (5 micron)	63	42.3	20.7	0.21	1.21
H15 (native)	142.3	91.2	51.1	0.57	1.46
H15 (adjusted)	37.2	23.7	13.5	0.16	1.57
J21 (native)	65.7	47.4	18.3	0.22	1.22
J21 (adjusted)	38	25.5	12.5	0.14	1.34

Fungal spores global budgets – comparison with J21

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Emission scheme	Emission (Tg yr^{-1})	Burden (Gg)	Lifetime (d)	Lifetime dry dep. (d)	Lifetime wet dep. (d)
Population model	3.4	20.0	2.1	54	1.5
Statistical model	3.7	15.3	1.4	64	2.1
HS09	31	130	1.1–2.6	21–48	1.1–2.7

Fungal spores global budgets – comparison with J21

- Much higher values with HS09 in IFS-COMPO as compared to:
  - GEOS-CHEM (J21)
  - EMEP and CHIMERE as well

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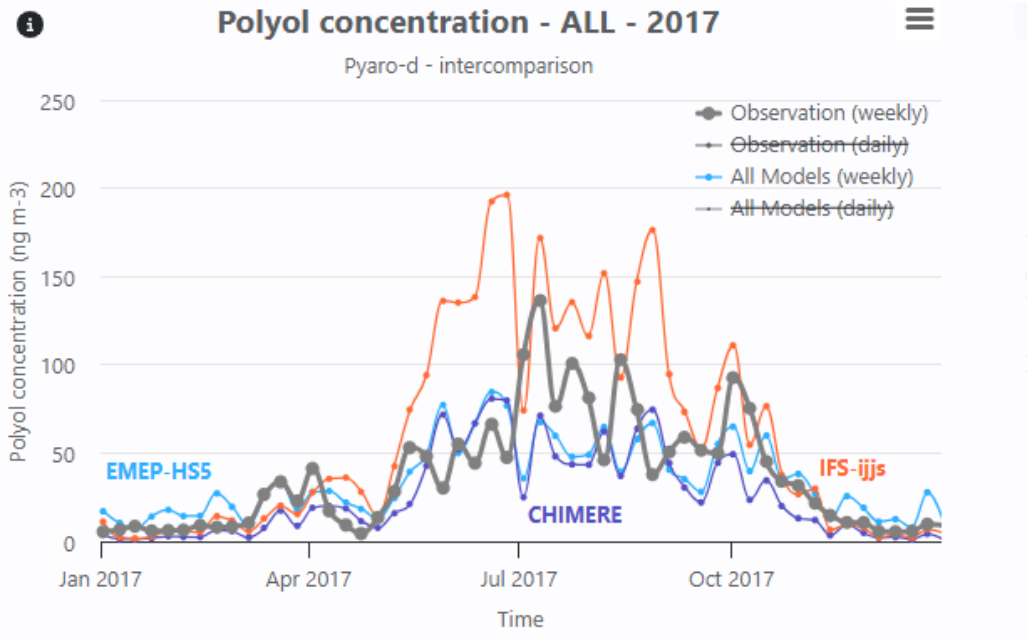

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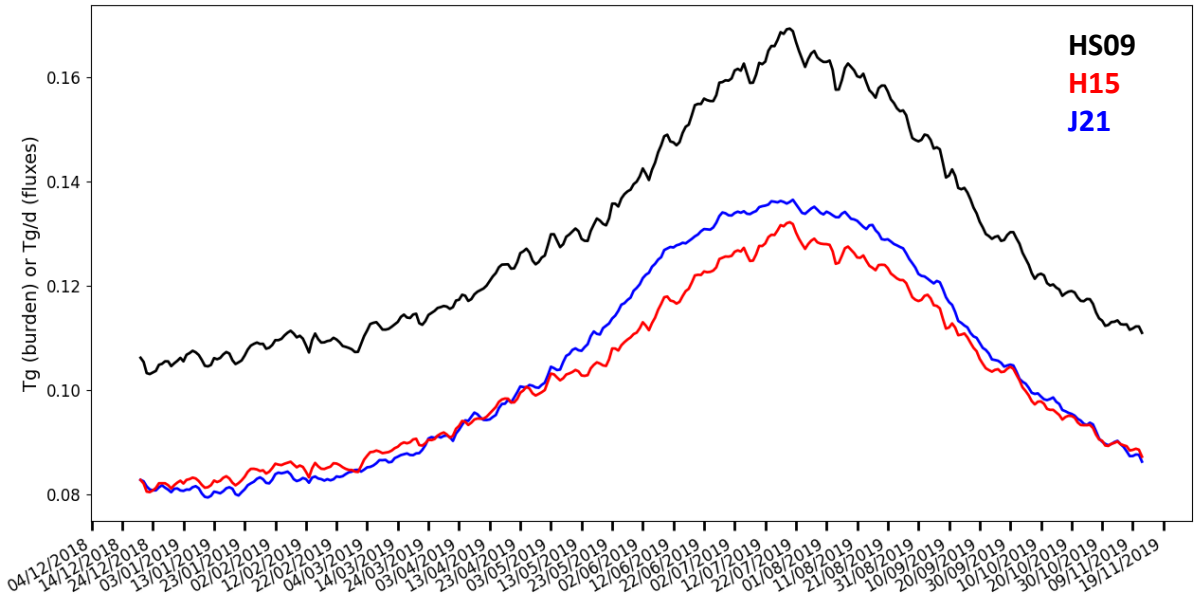
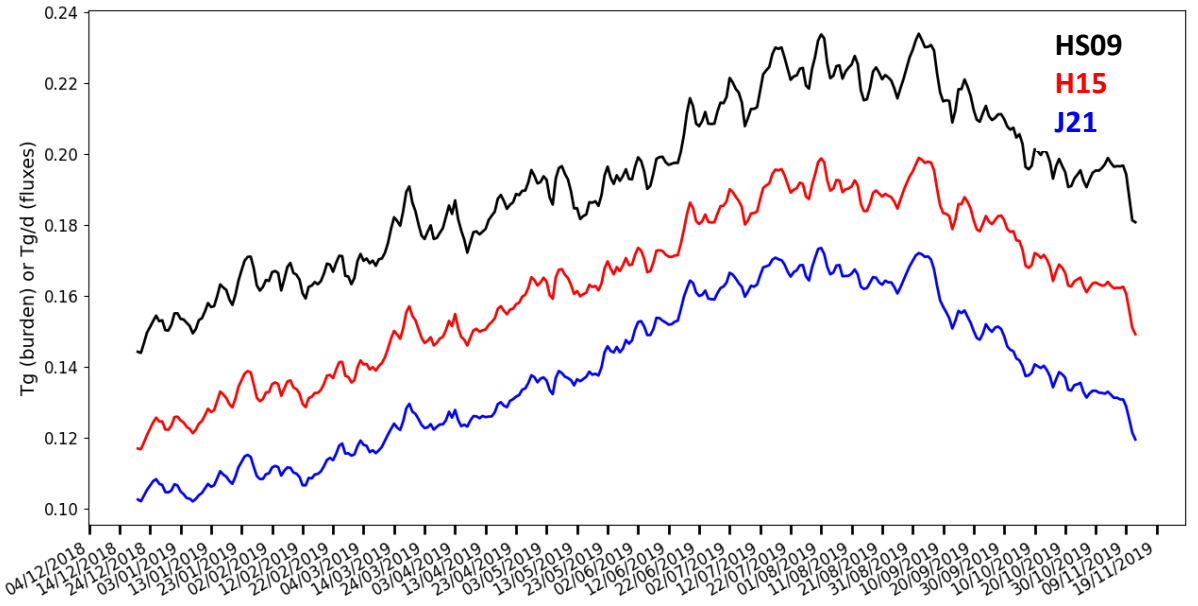
Global emissions (Tg/d)

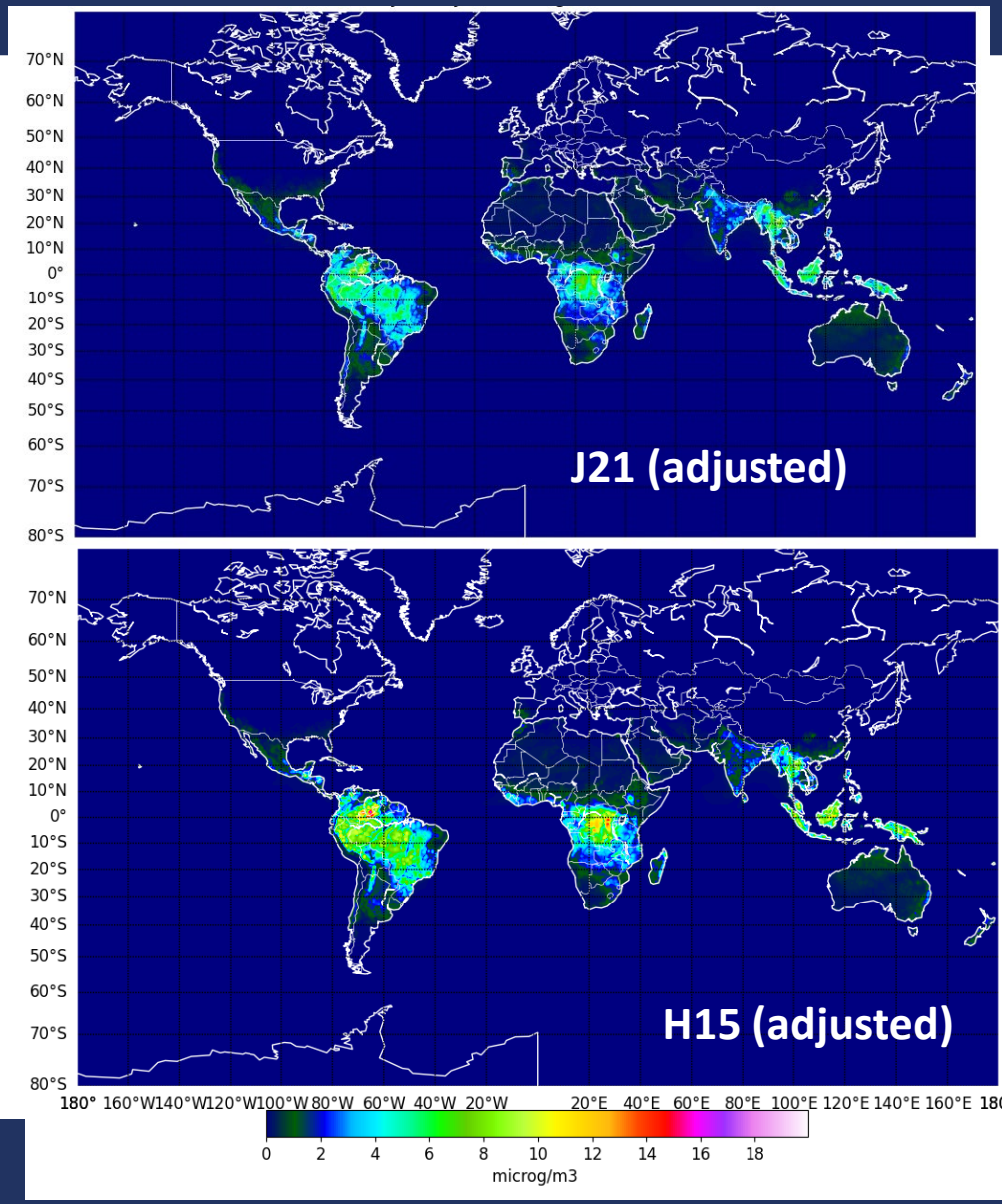


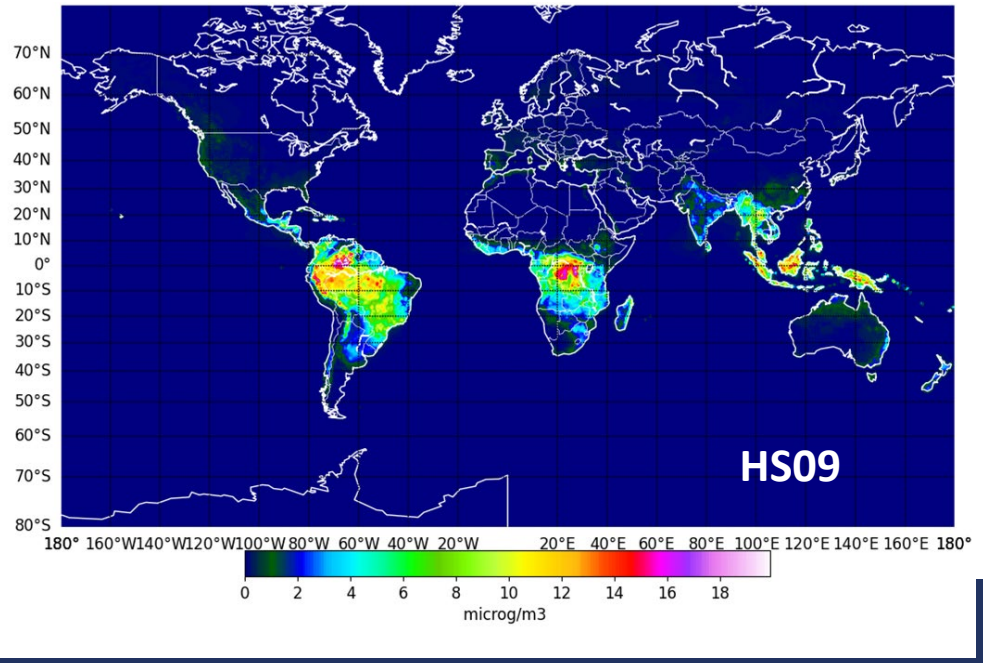
Burden (Tg)



Simulated fungal spores surface concentration

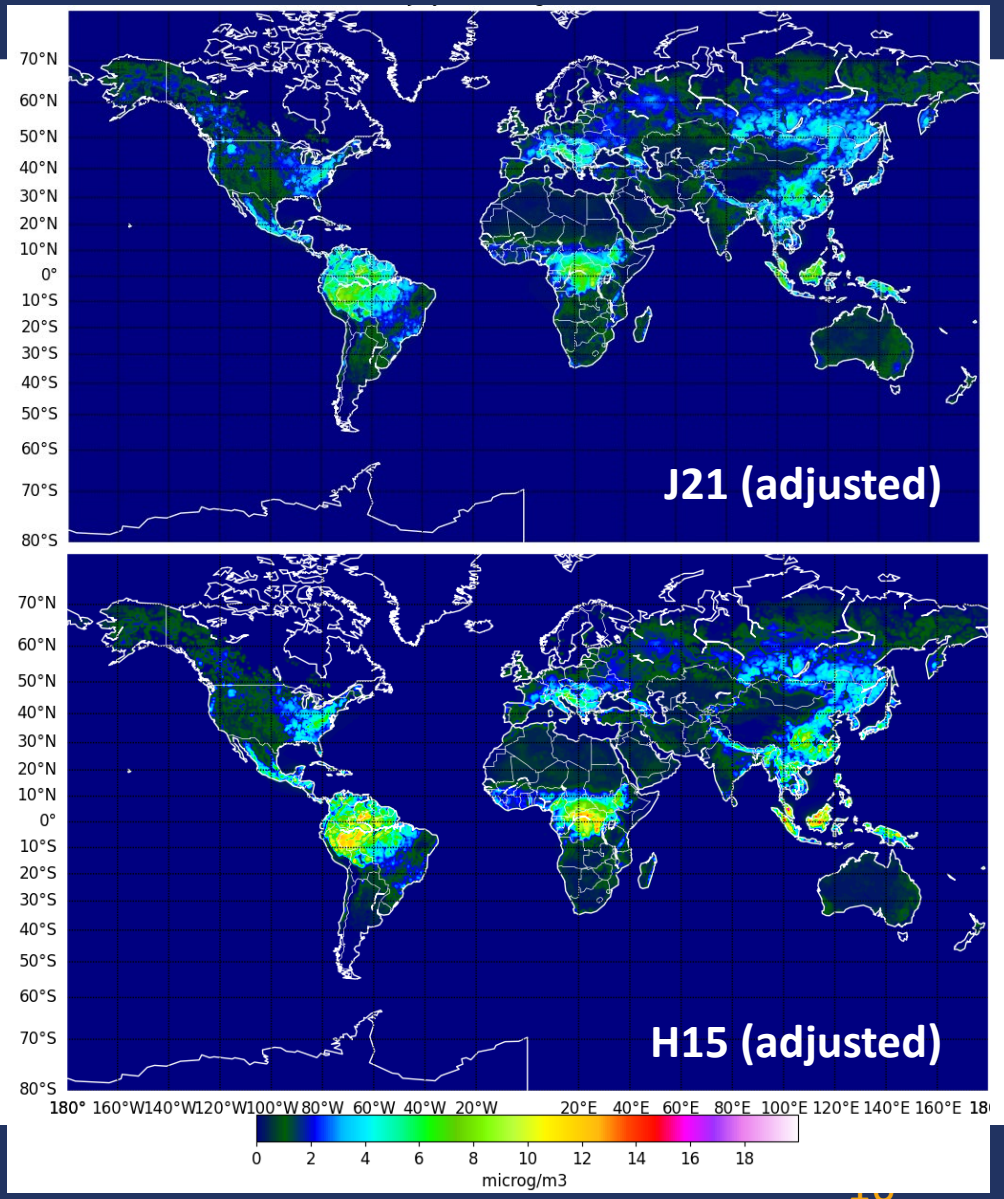
IFS-COMPO simulation without data assimilation, January 2019 average of fungal spores surface concentration

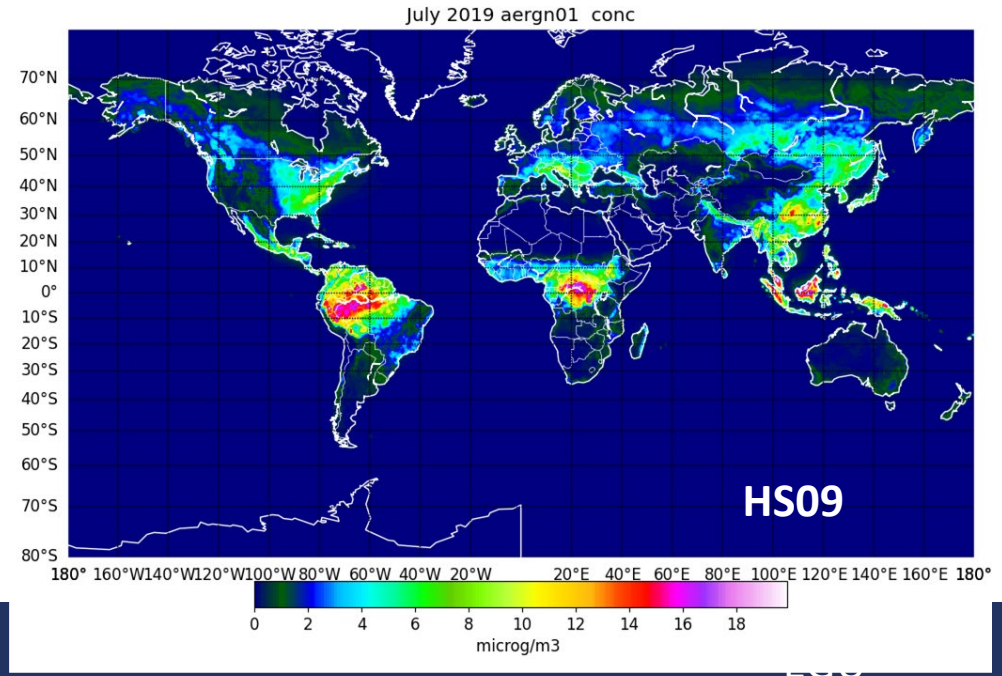




Simulated fungal spores surface concentration

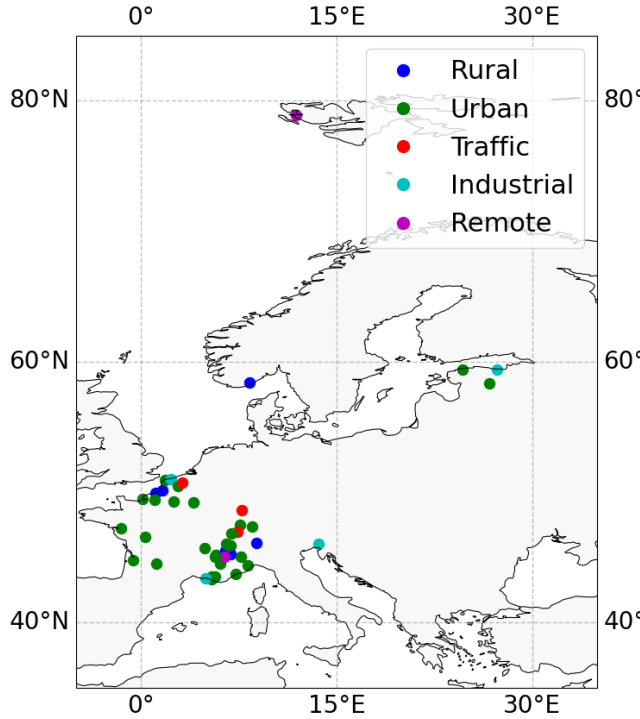
IFS-COMPO simulation without data assimilation, July 2019 average of fungal spores surface concentration



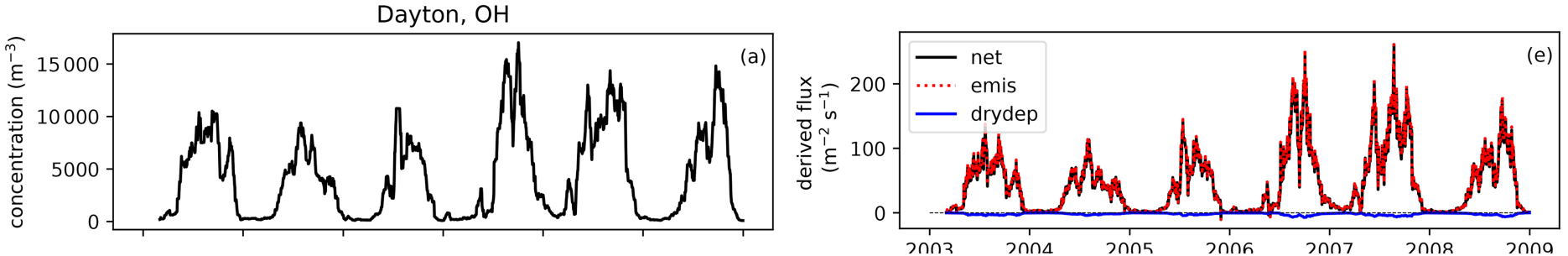


Evaluation strategy

- Fungal spores (and pollen) observations are often not open/free
- PM10 has been used to evaluate the impact of fungal spores over Europe, US, East Asia and Brazil
- A large dataset of observational datasets has been gathered for validation:
  - Arabitol/Mannitol concentration from IGE/IRD and from EBAS – polyols are a good proxy for fungal spores
  - Fungal spores emissions derived from ground observations of spores counts over the U.S. from Janssen et al (2021)
  - Fungal spores counts over Hyytiälä (Finland)
  - DNA abundance of fungal spores over 47 stations worldwide
  - In the future, possibly, fungal spores counts from the European Aeroallergen Network (EAN)



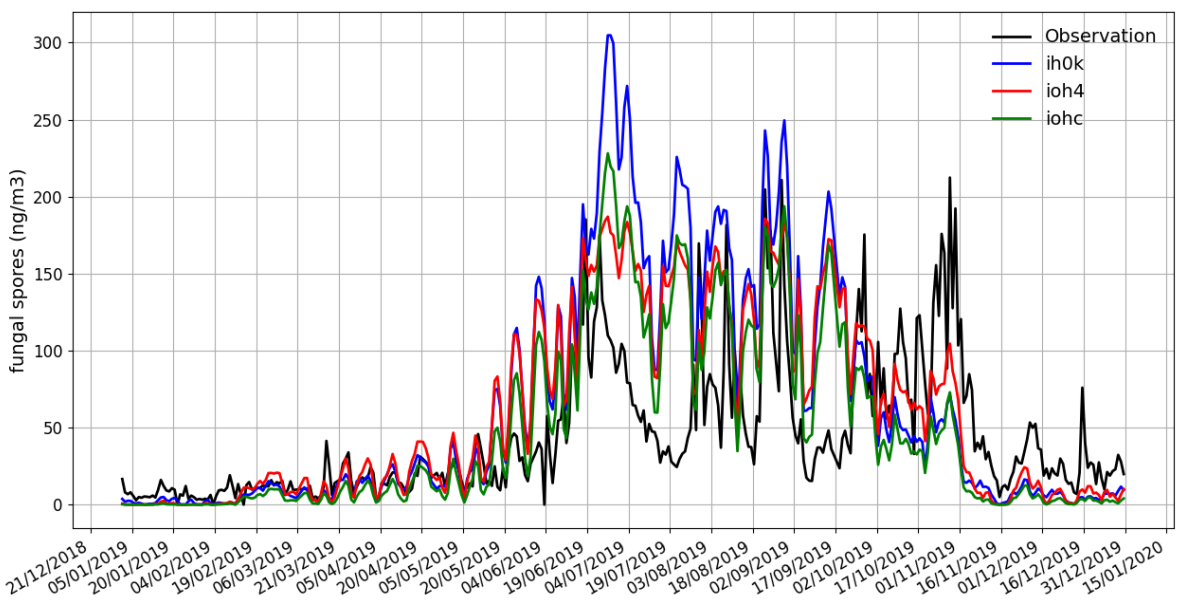
Stations with some polyol data available 2012-2021

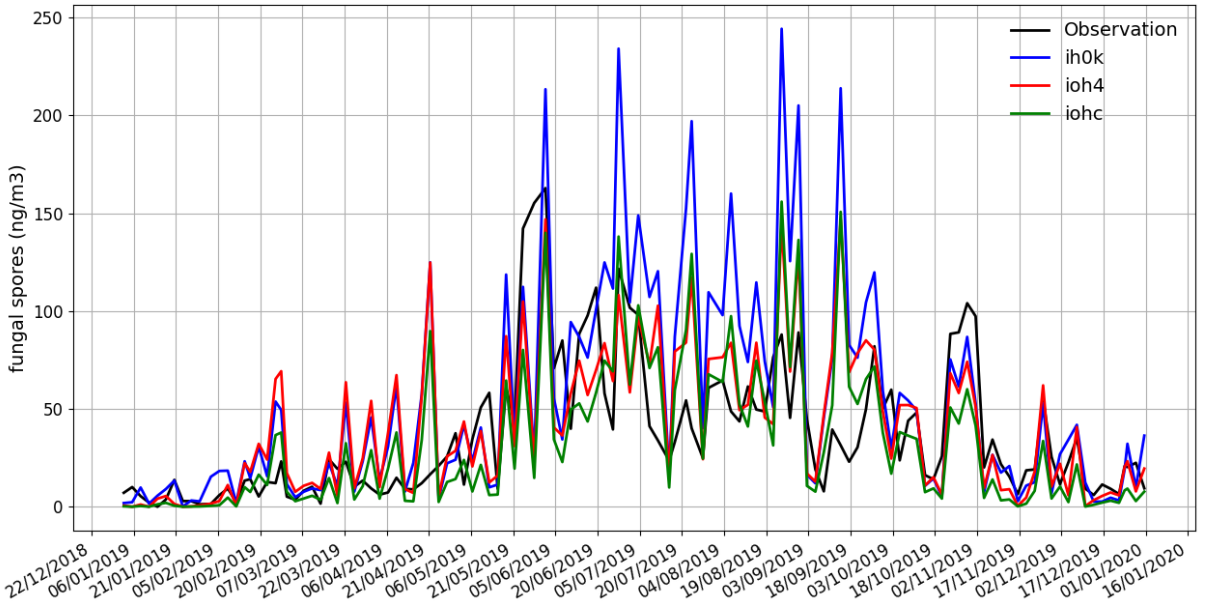


From Janssen et al (ACP, 2021) : left, observed spore counts at Dayton (OH, USA); right, derived fungal spores emission and dry deposition fluxes.

Evaluation versus observational datasets

- Comparison against fungal spores concentration derived from polyol observations from IGE-IRD, available at https://aeroval-test.met.no/danielh/pages/evaluation/?project=Fungal-Spores
- The seasonal cycle is relatively well represented with some exceptions





*Observed (**black**) and simulated (**blue=HS09**, **green=H15 adjusted**, **red=J21 adjusted**) surface concentration of fungal spores at Grenoble (left) and Lyon (right)*

Evaluation versus observational datasets

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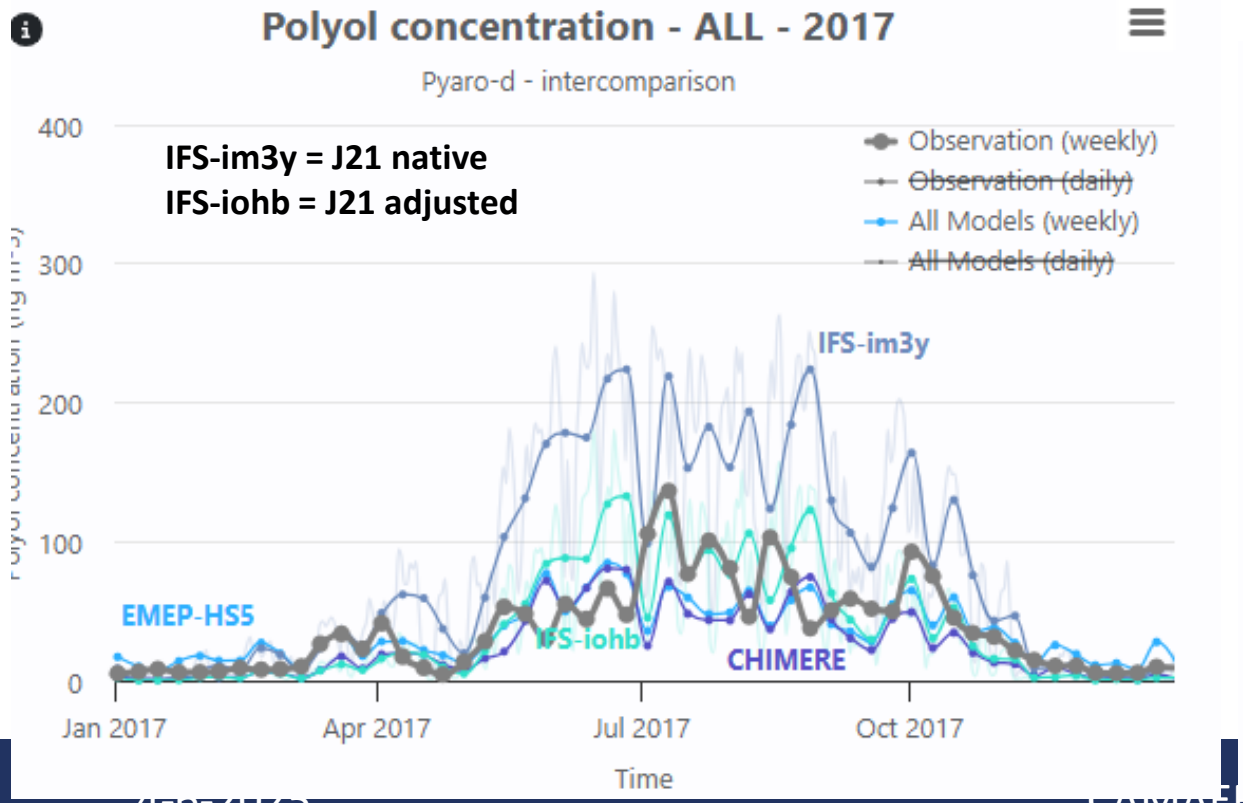
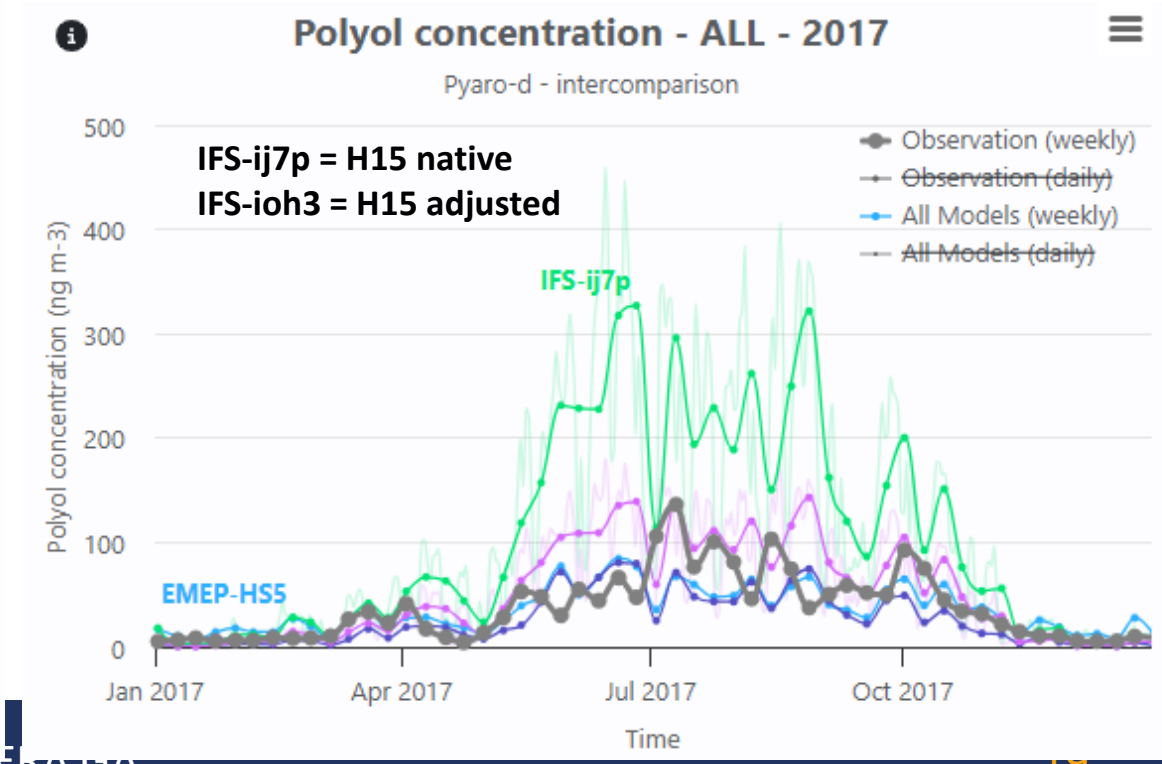
- Comparison of H15 native and adjusted, J21 native and adjusted





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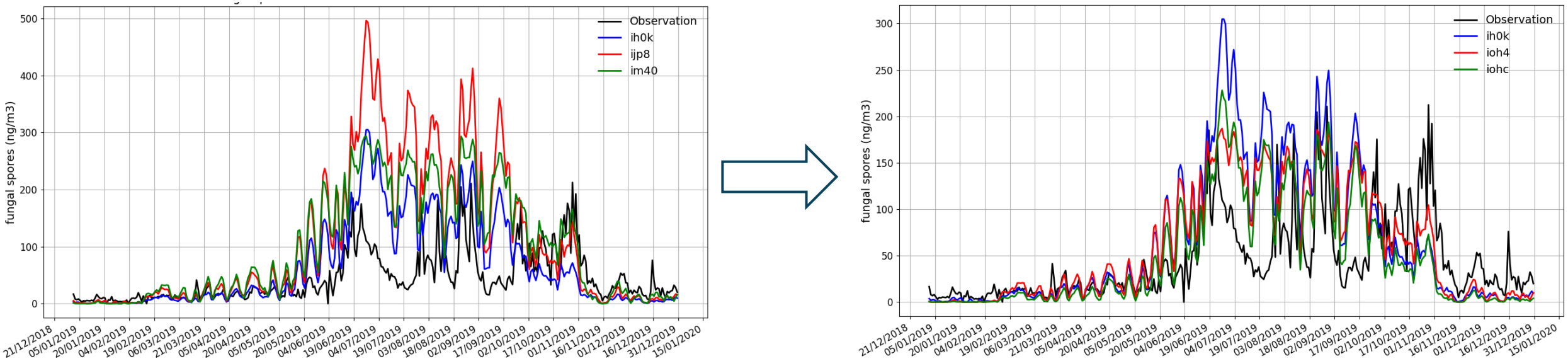

*Observed (**black**) and simulated (**blue=HS09**, **green=J21/J21 adjusted**, **red=H15/H15 adjusted**) surface concentration of fungal spores at Grenoble*

Evaluation versus observational datasets

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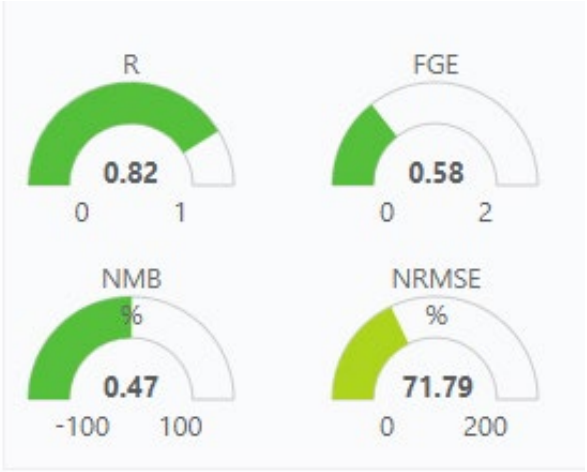
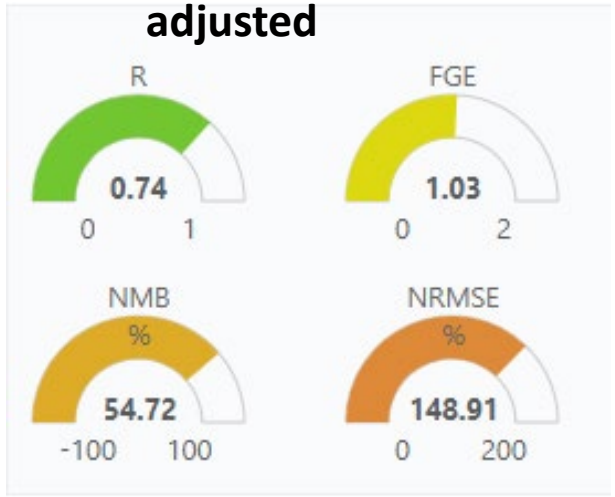
Skill scores

EMEP

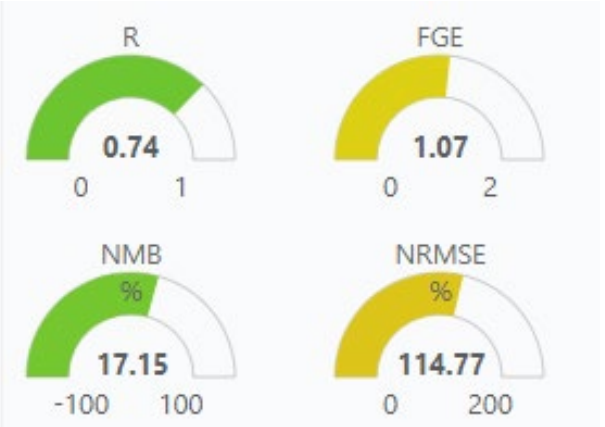


CHIMERE

IFS-COMPO H15 adjusted



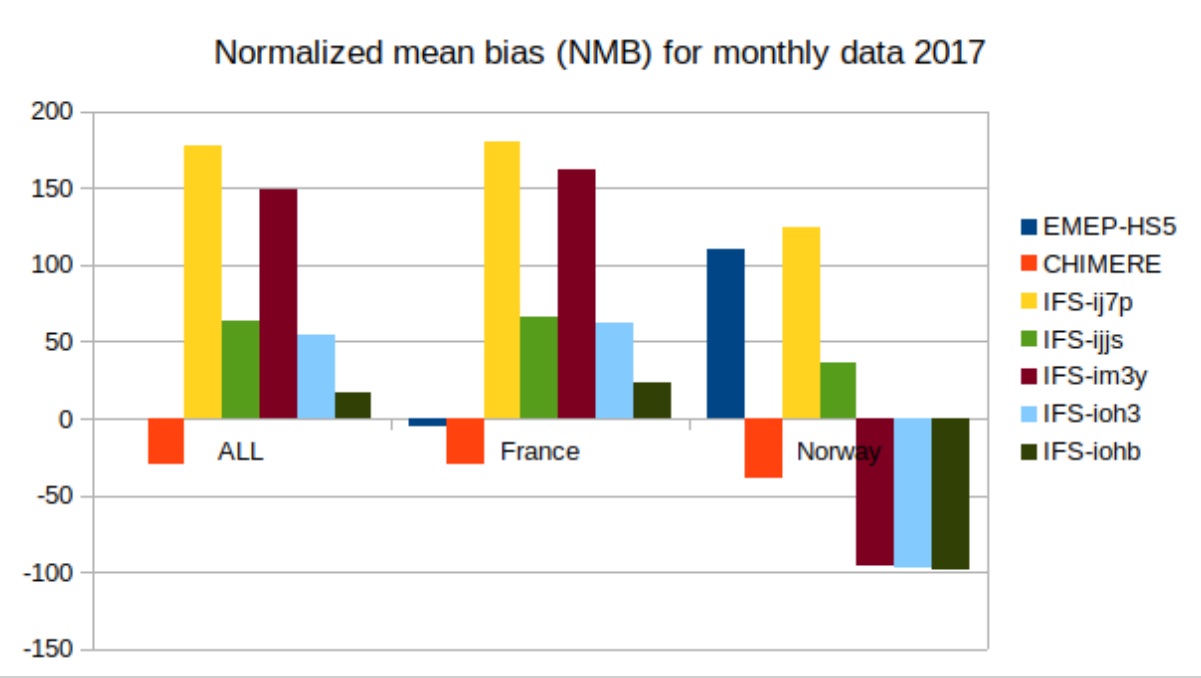
IFS-COMPO J21 adjusted

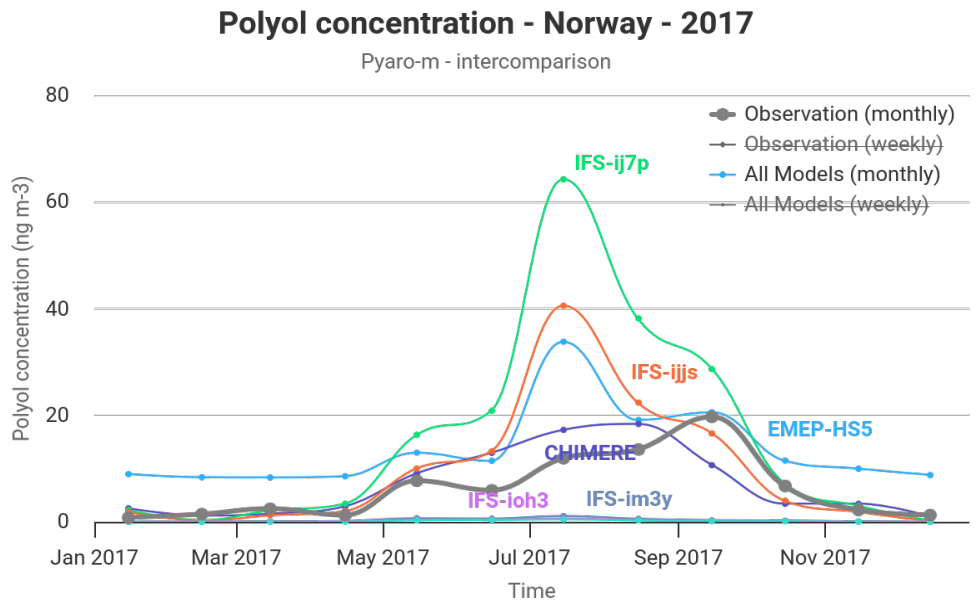


Evaluation versus observational datasets

Comparison against fungal spores concentration derived from polyol observations from IGE-IRD, available at https://aeroval-test.met.no/danielh/pages/evaluation/?project=Fungal-Spores

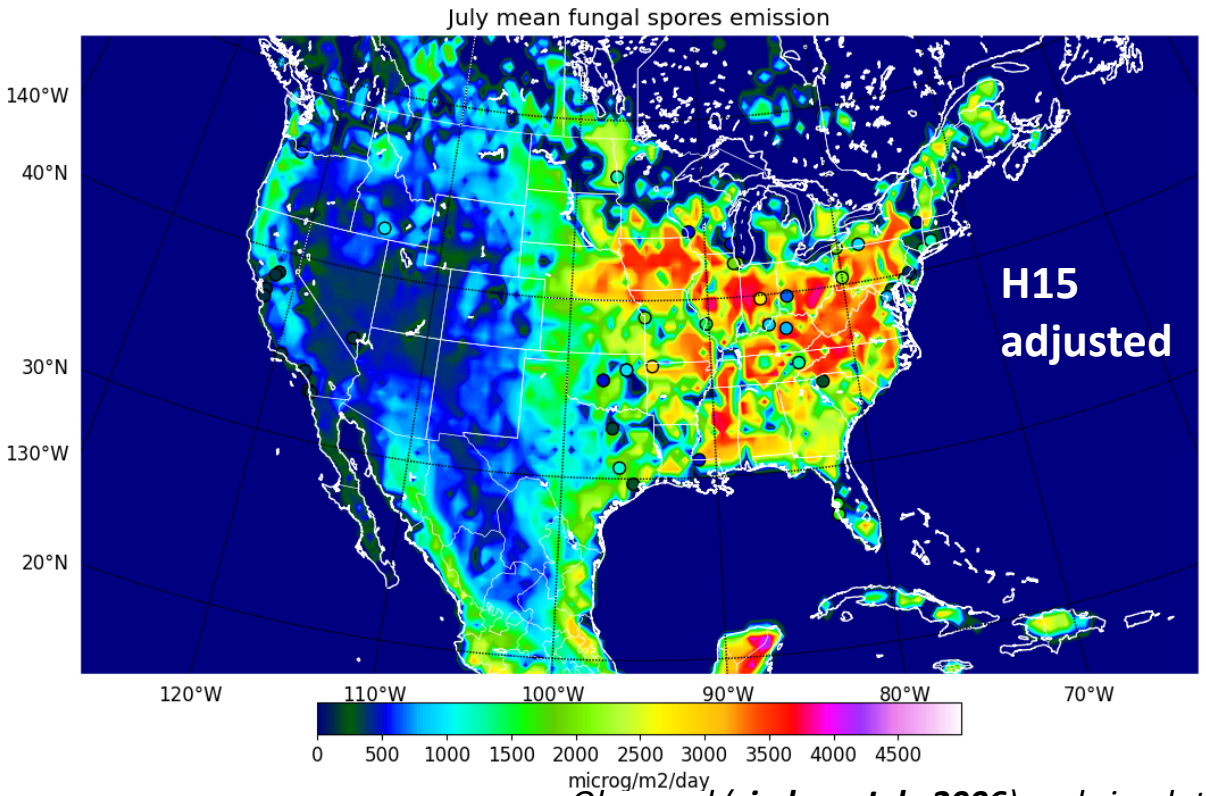
Issue over Norway with IFS-COMPO J21, J21 adjusted and H15 adjusted : possibly land-sea mask issue

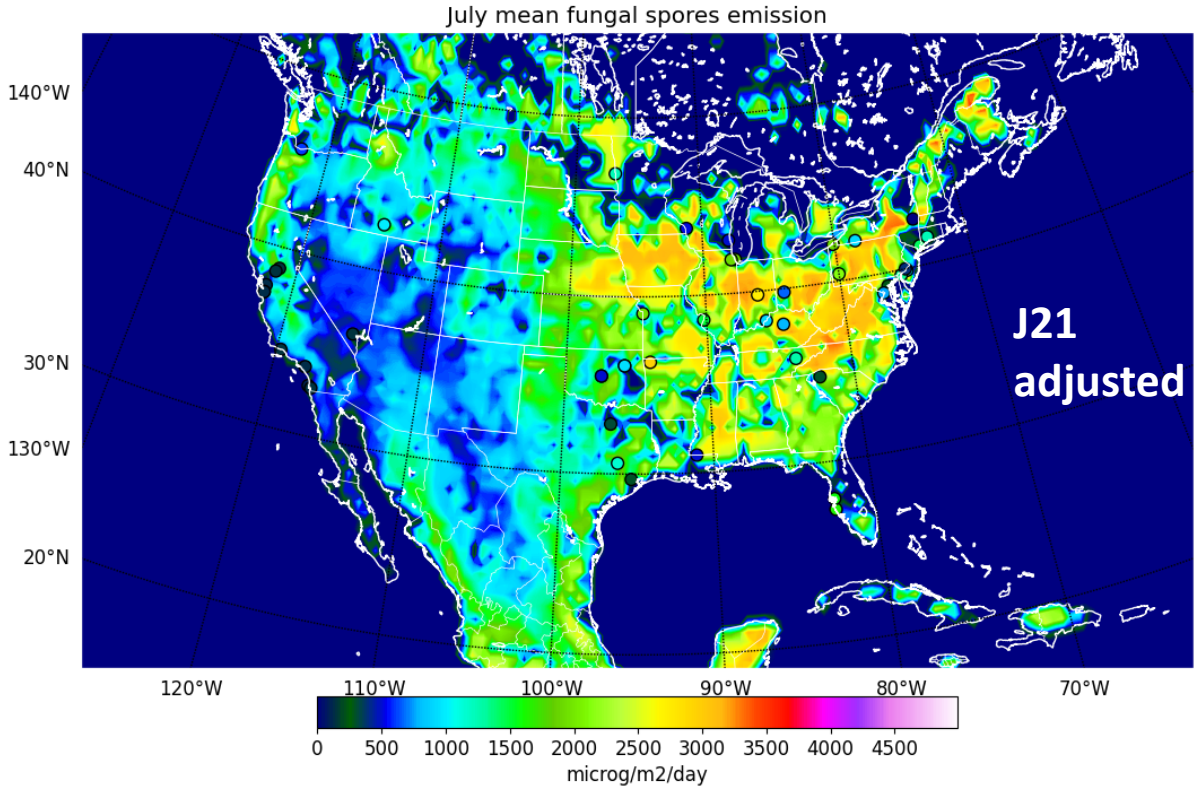




Evaluation versus observational datasets

- Comparison against fungal spores emissions derived from surface concentration observations from Janssen et al (2021)
- Simulated values often too high with H15 and HS09

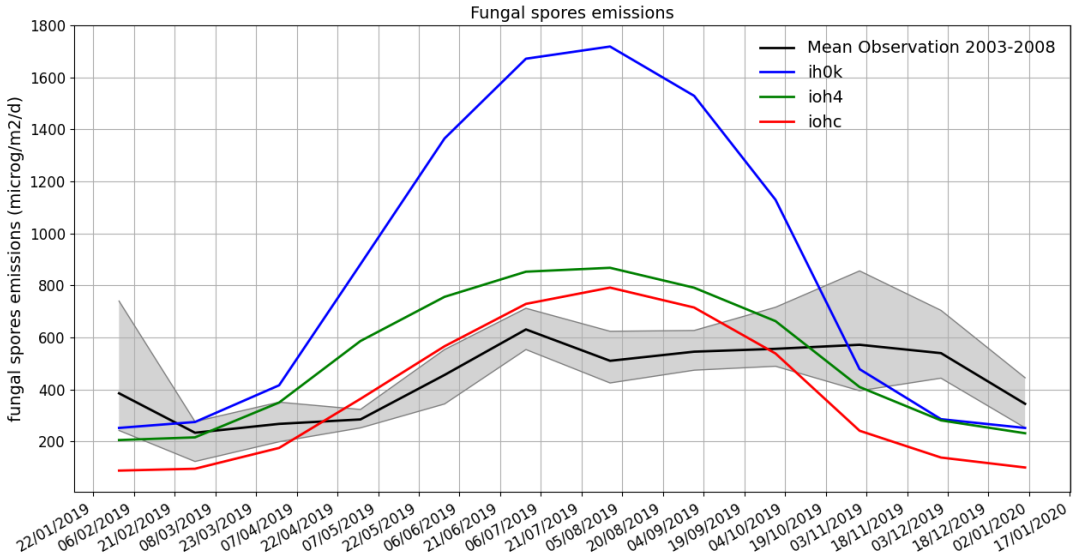


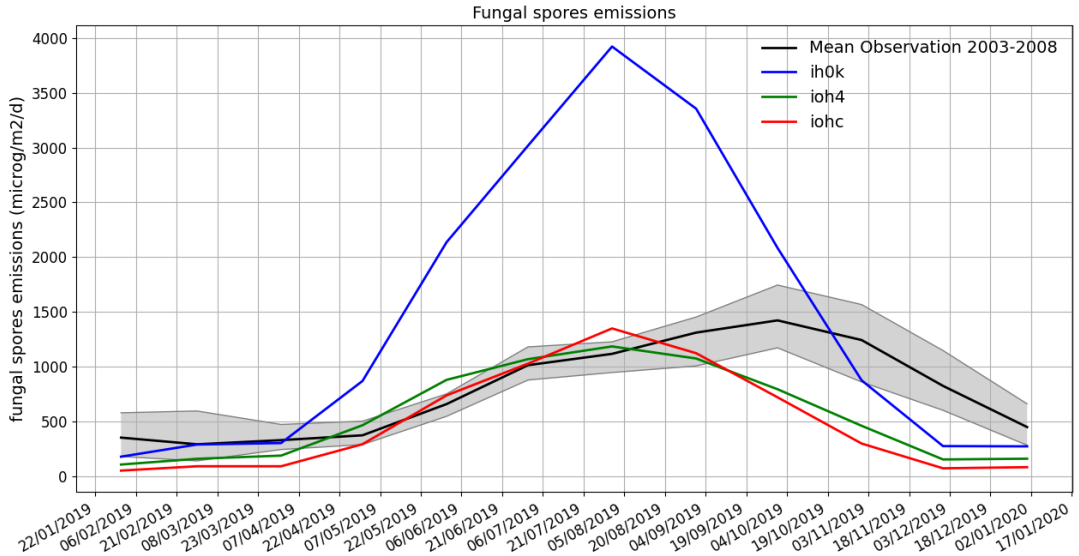


*Observed (**circles – July 2006**) and simulated (July 2019) mean fungal spores emissions*

Evaluation versus observational datasets

- Comparison against fungal spores emissions derived from surface concentration observations from Janssen et al (2021)
- Autumn peak not well represented; H09 much too high.

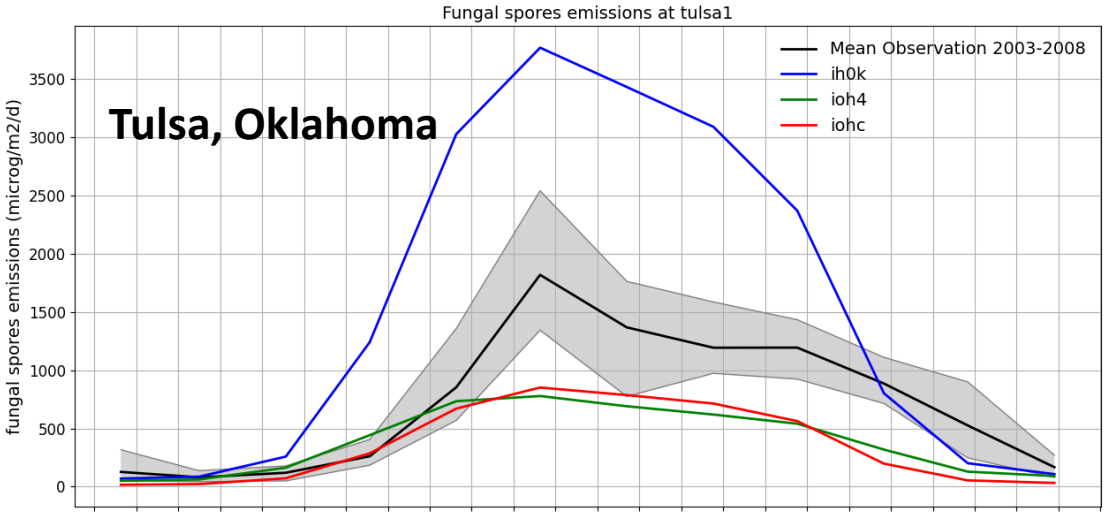


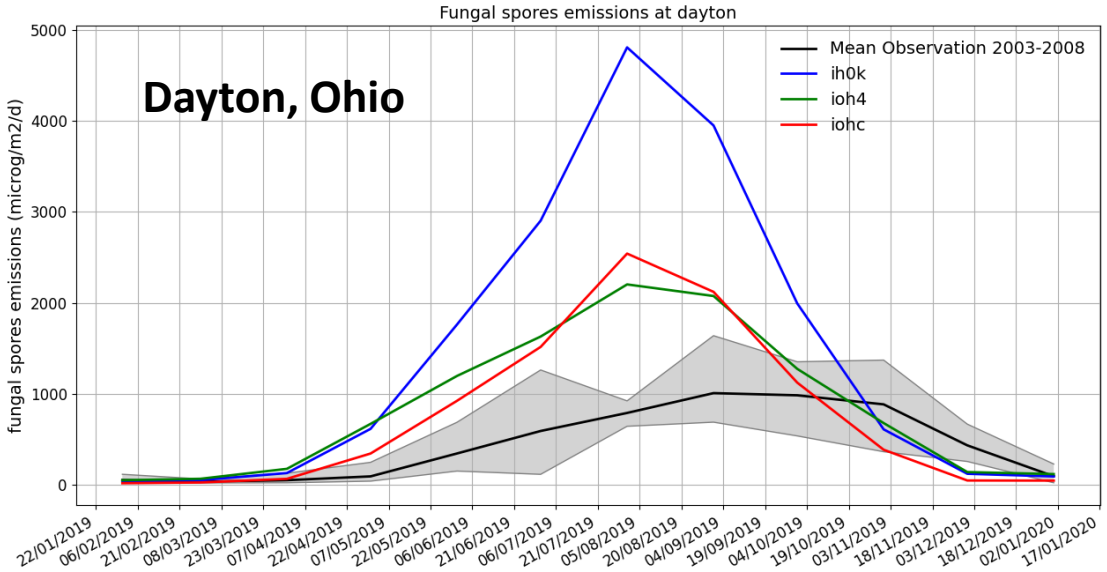


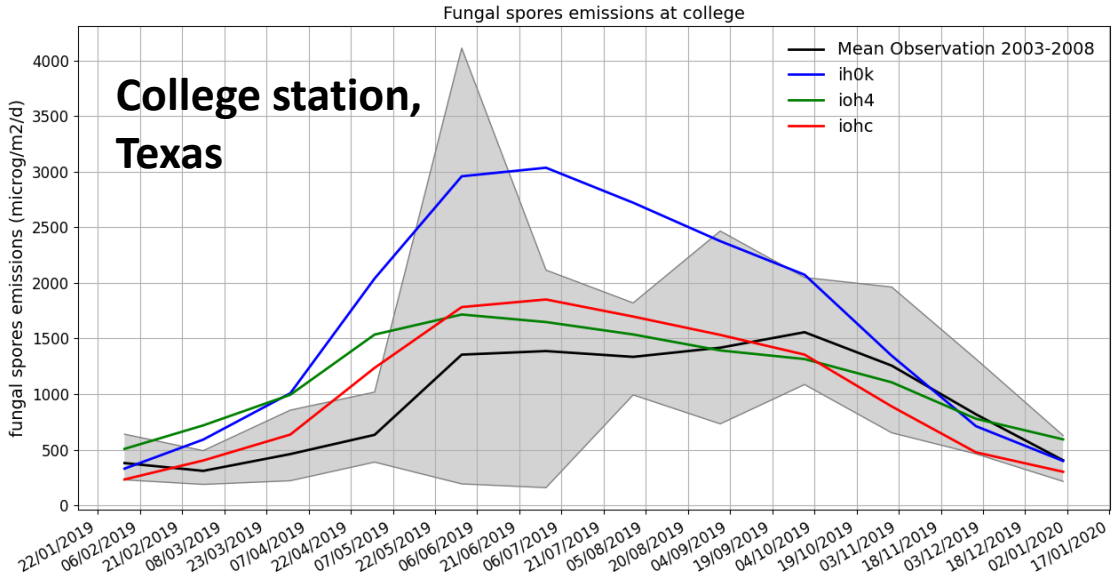
*Observed (**black, mean, and gray, 2003-2008 envelope**) and simulated (**blue=HS09**, **green=J21 adjusted**, **red=H15 adjusted**) fungal spores emissions over West US (left) and East US (right)*

Evaluation versus observatio

- Comparison against fungal spores emissions derived from surface concentration observations from Janssen et al (2021) – station plots



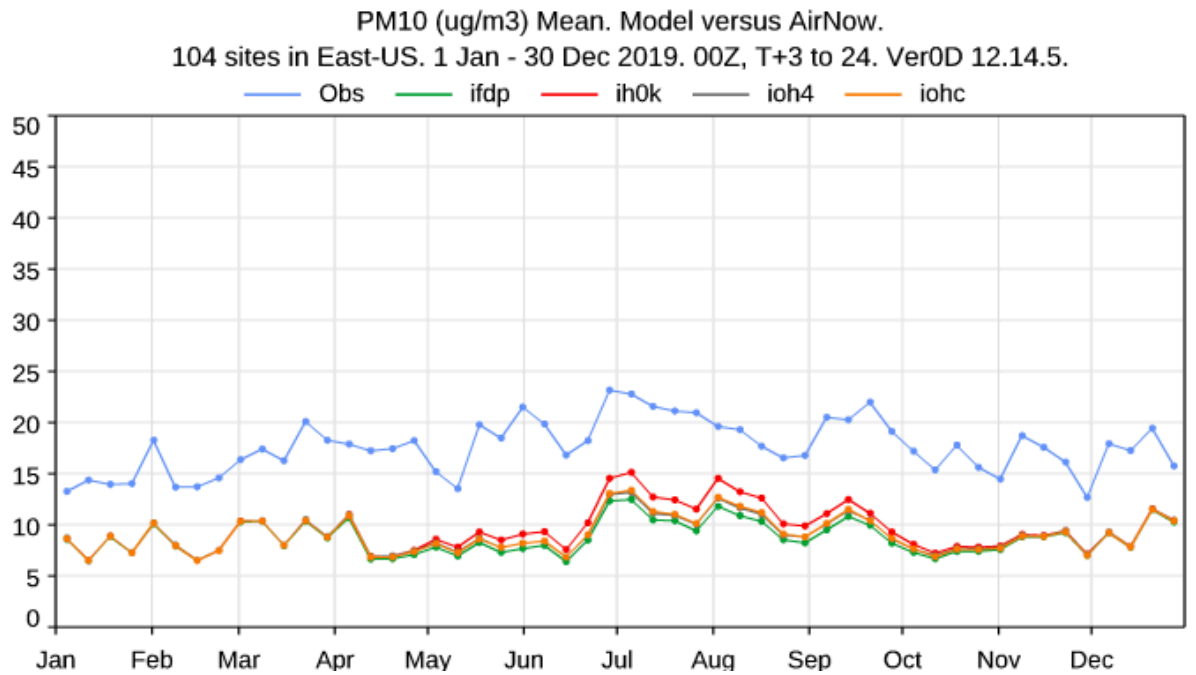


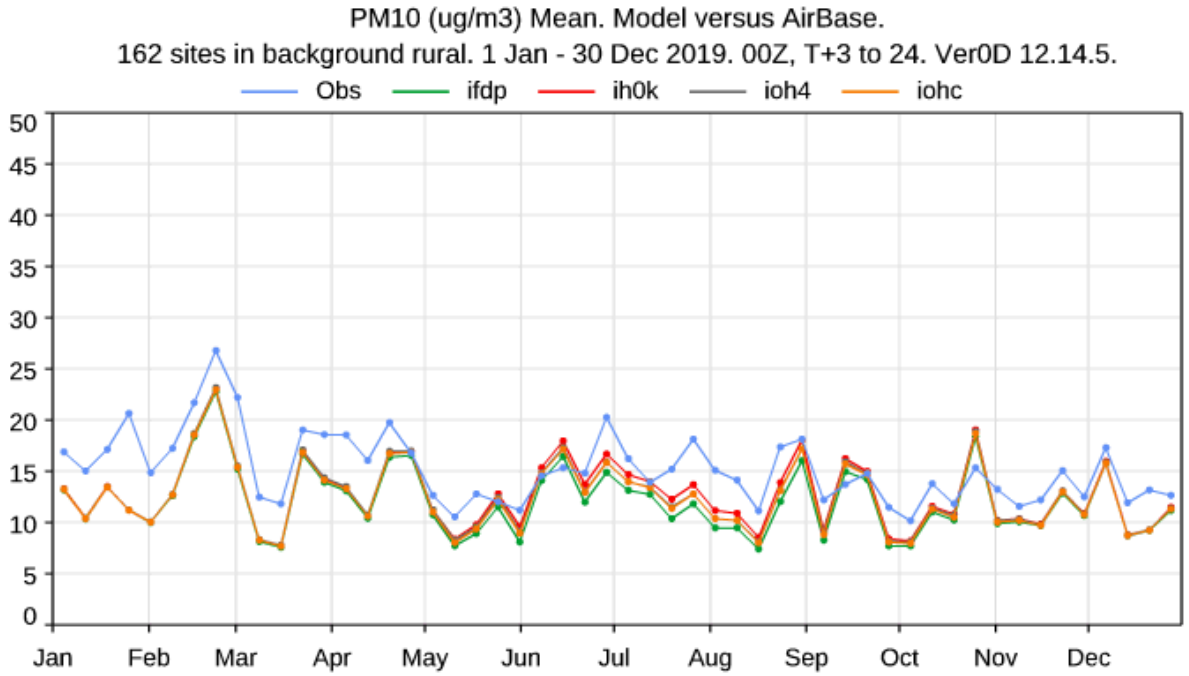


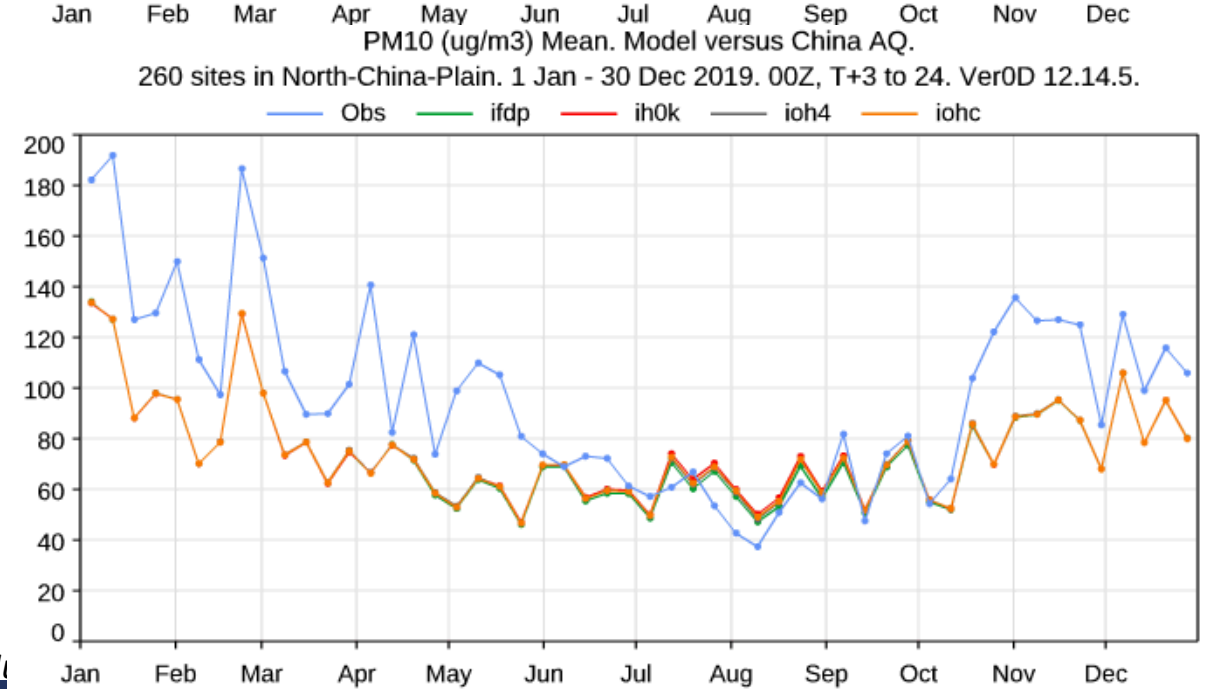
*Observed (**black, mean, and gray, 2003-2008 envelope**) and simulated (**blue=HS09**, **green=J21 adjusted**, **red=H15 adjusted**) fungal spores emissions over West US (left) and East US (right)*

Impact on simulated PM10

- Comparison of weekly observed and simulated PM10



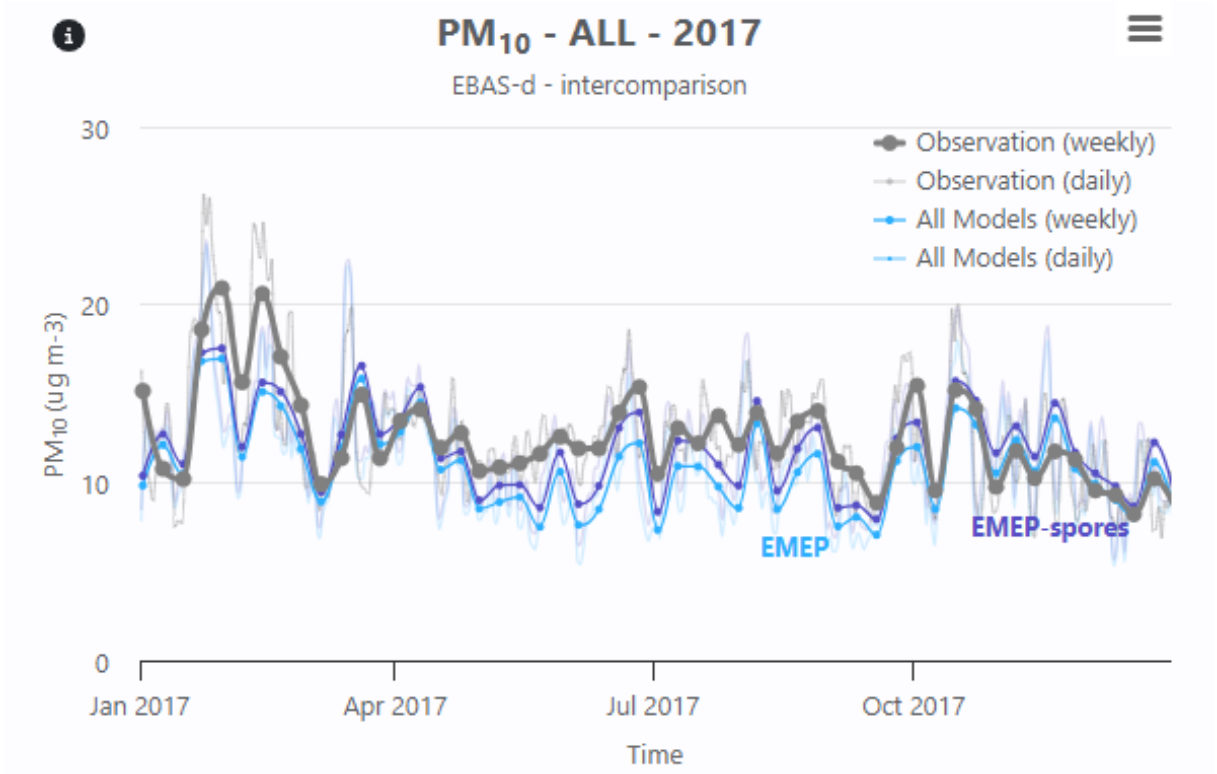


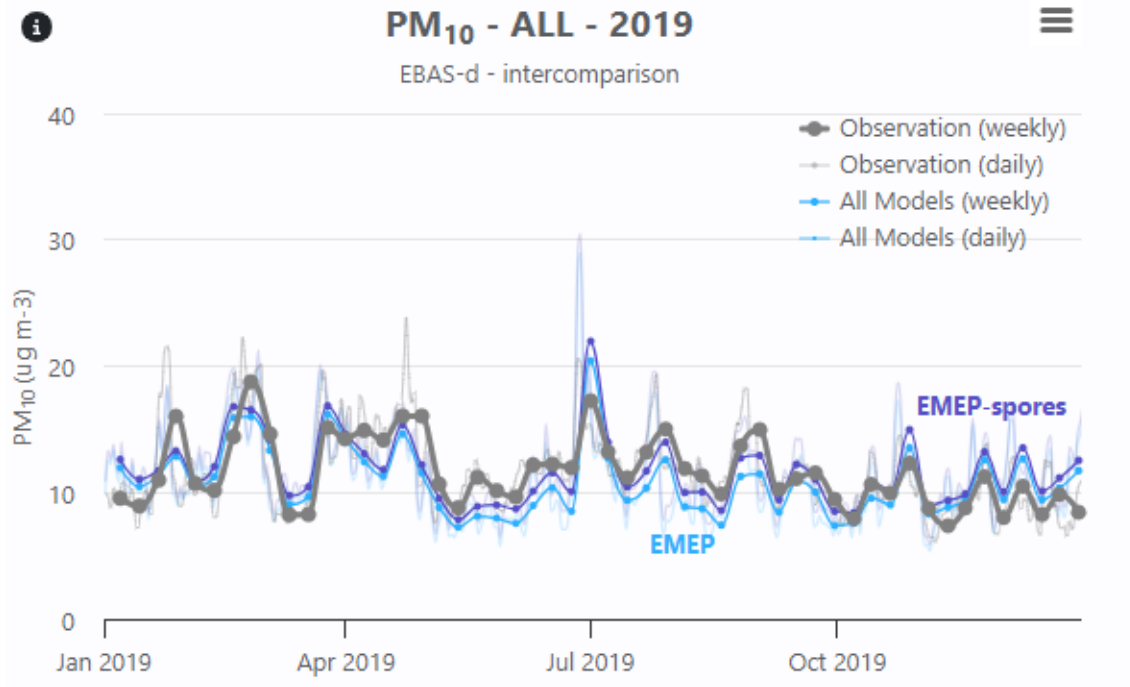


*Observed (**blue**) and simulated (**green=no fungal spores**, **red=HS09**, **orange=H15 adj**, **gray=J21 adj**) PM10 over different regions*

Impact on simulated PM10

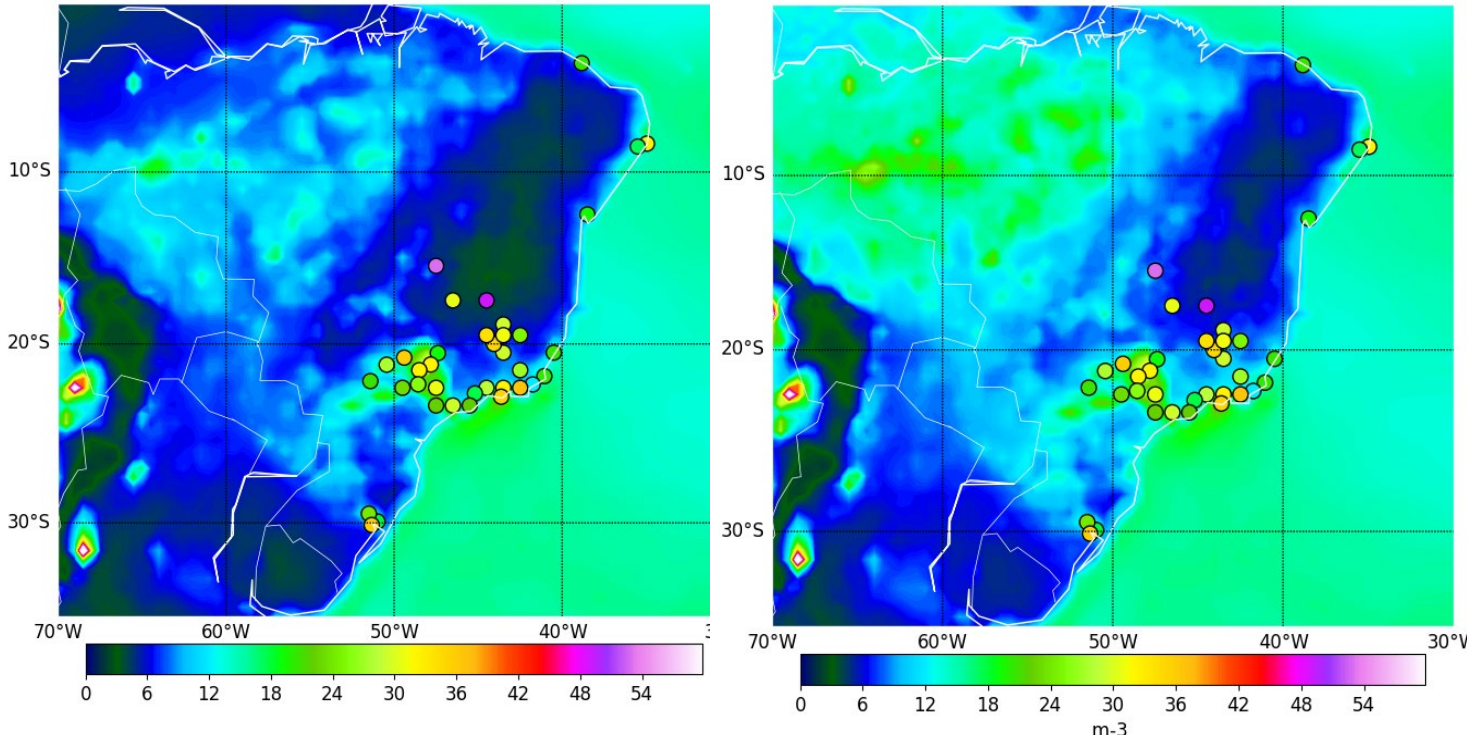
- Comparison of observed and simulated PM10 for EMEP



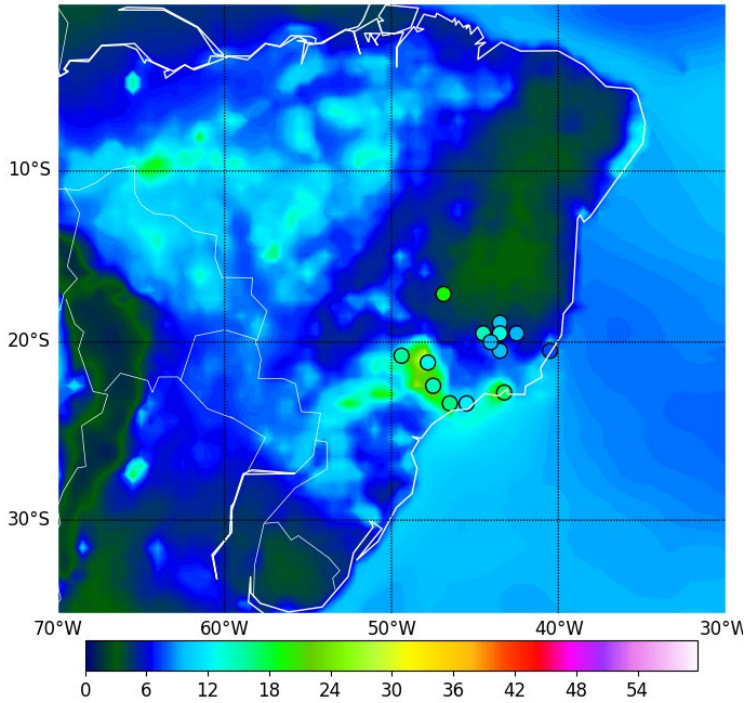


Impact on simulated PM10 over Brazil

- Comparison of observed and simulated PM10 over Brazil show a strong signal from fungal spores in the simulations



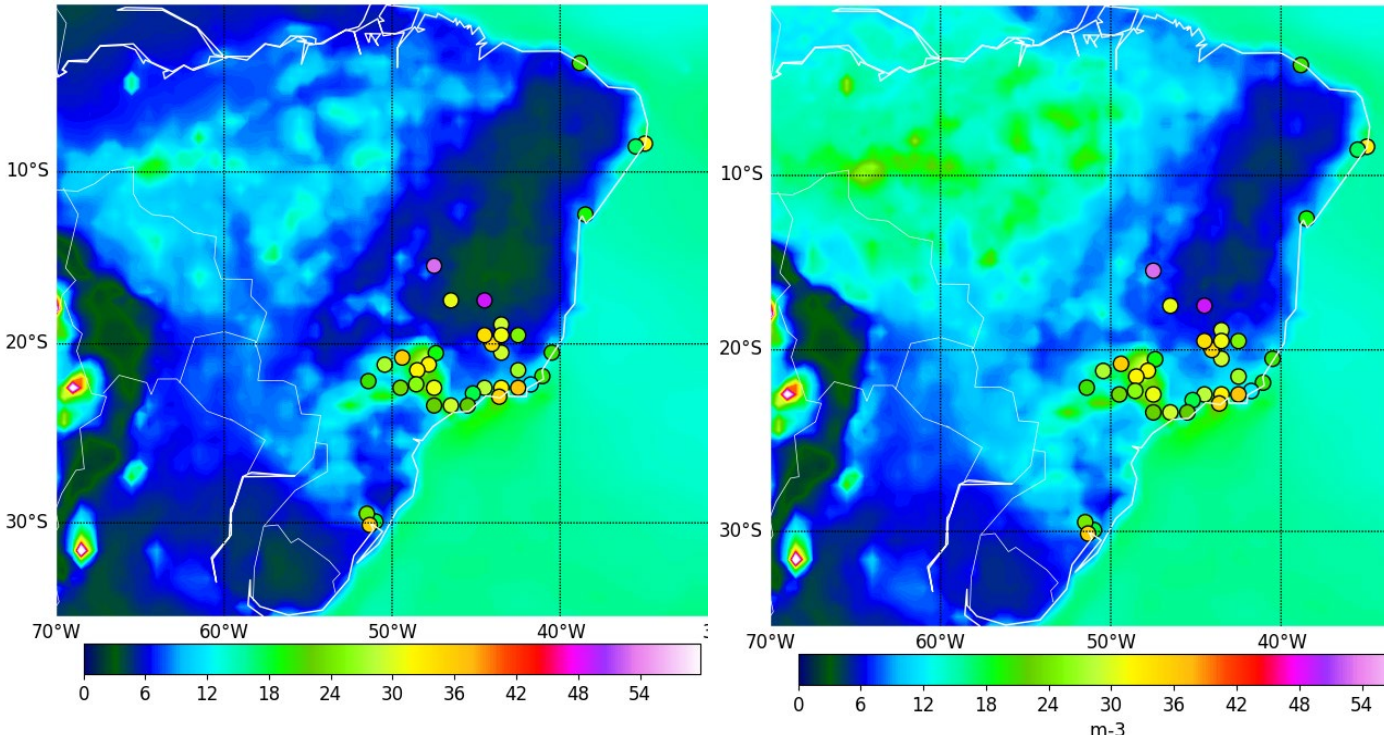
2017 mean observed (circles) and simulated PM10; left, without fungal spores, right, with fungal spores (HS09 emissions)



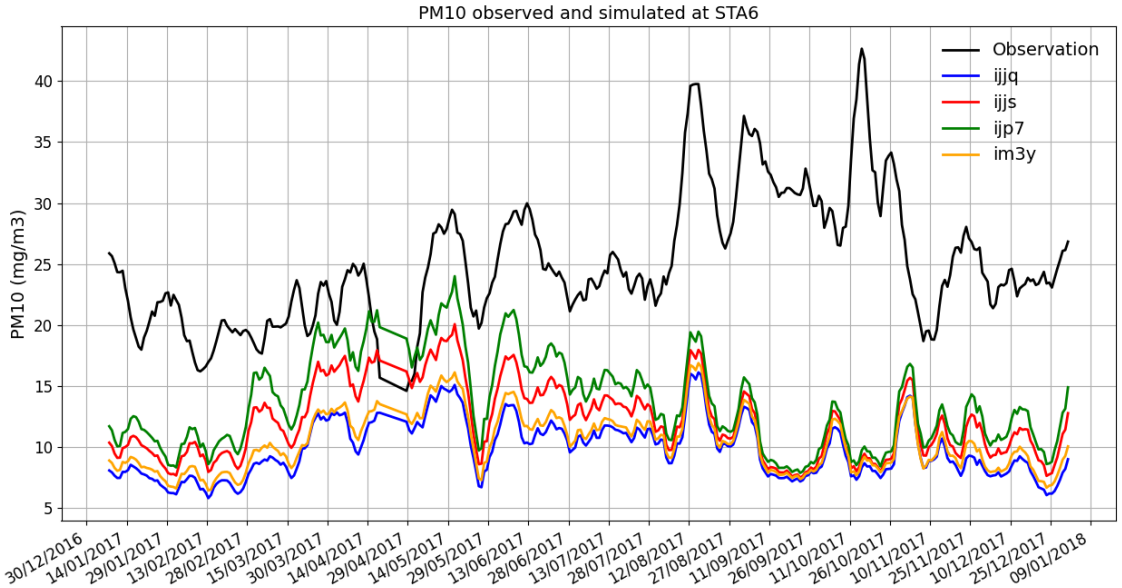
2017 mean observed (circles) and simulated PM2.5, without fungal spores.

Impact on simulated PM10 over Brazil

- Comparison of observed and simulated PM10 over Brazil show a strong signal from fungal spores in the simulations



2017 mean observed (circles) and simulated PM10; left, without fungal spores, right, with fungal spores (HS09 emissions)



*Observed (**black**) and simulated (**blue=no fungal spores**, **red=HS09**, **orange=J21**, **green=H15**) PM10 over a single station in Brazil*

Conclusions

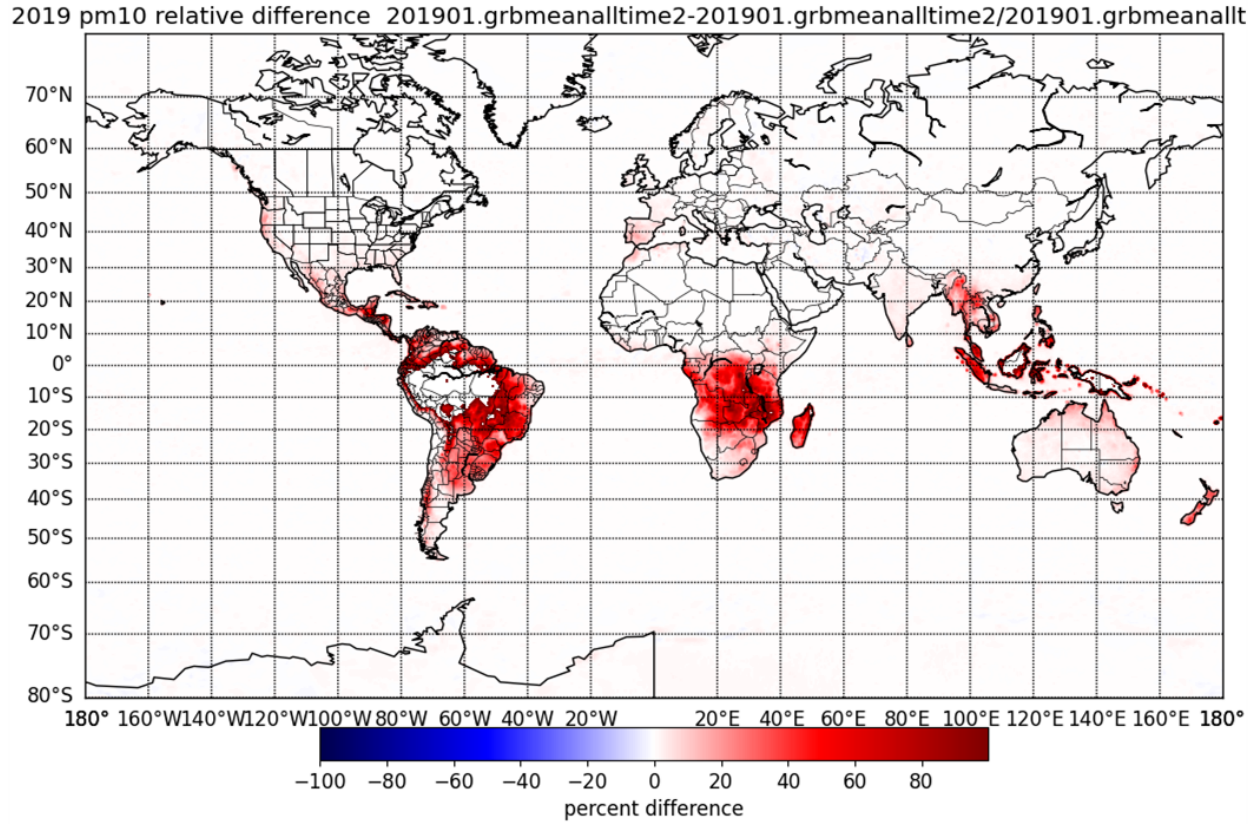
- A first implementation of fungal spores in IFS-COMPO and EMEP have been carried out, with different emission schemes, using a simplified approach.
- Direct evaluation is hard because of sparse observations – at first order, the seasonal cycle and general features of fungal spores surface concentration seem to be broadly represented.
- More complex features (peaks in Autumn, etc.) are not well represented – probably because of the use of a single tracer to represent many species
- The impact on simulated PM10 is generally positive in summertime
- All parameterizations rely heavily on LAI – test with IFS-COMPO using LPJ-GUESS LAI for fungal spores emissions?

Acknowledgements

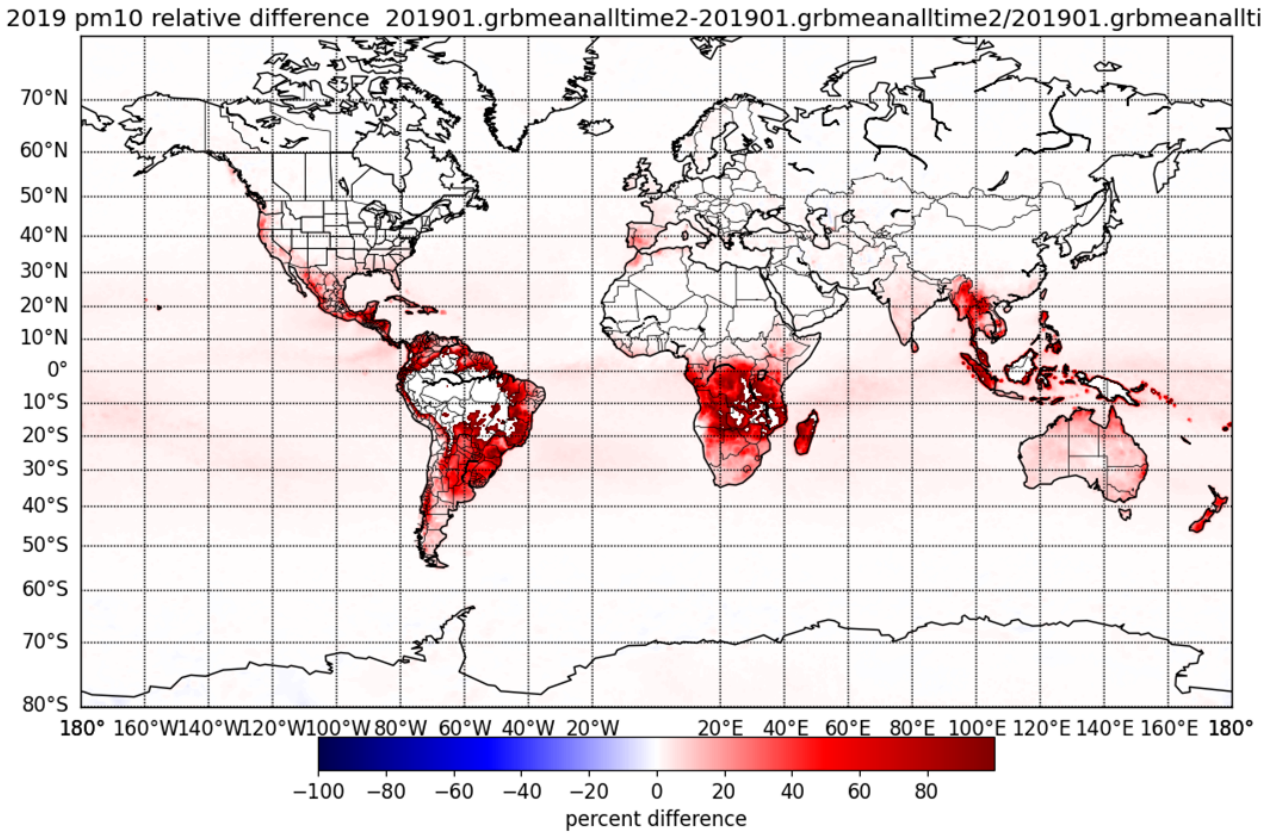
- Data in France are coming from many different programs conducted at IGE in collaboration with INERIS / LCSQA and many AASQA.
- Chemical analyses of the samples were conducted on the Air O Sol plateau at IGE.
- Many thanks to R. Janssen, J-L Jaffrezo and G. Uzu for providing the much needed observational datasets.

Simulated PM10 fraction composed of fungal spores, January 2019:

H&S (EMEP)

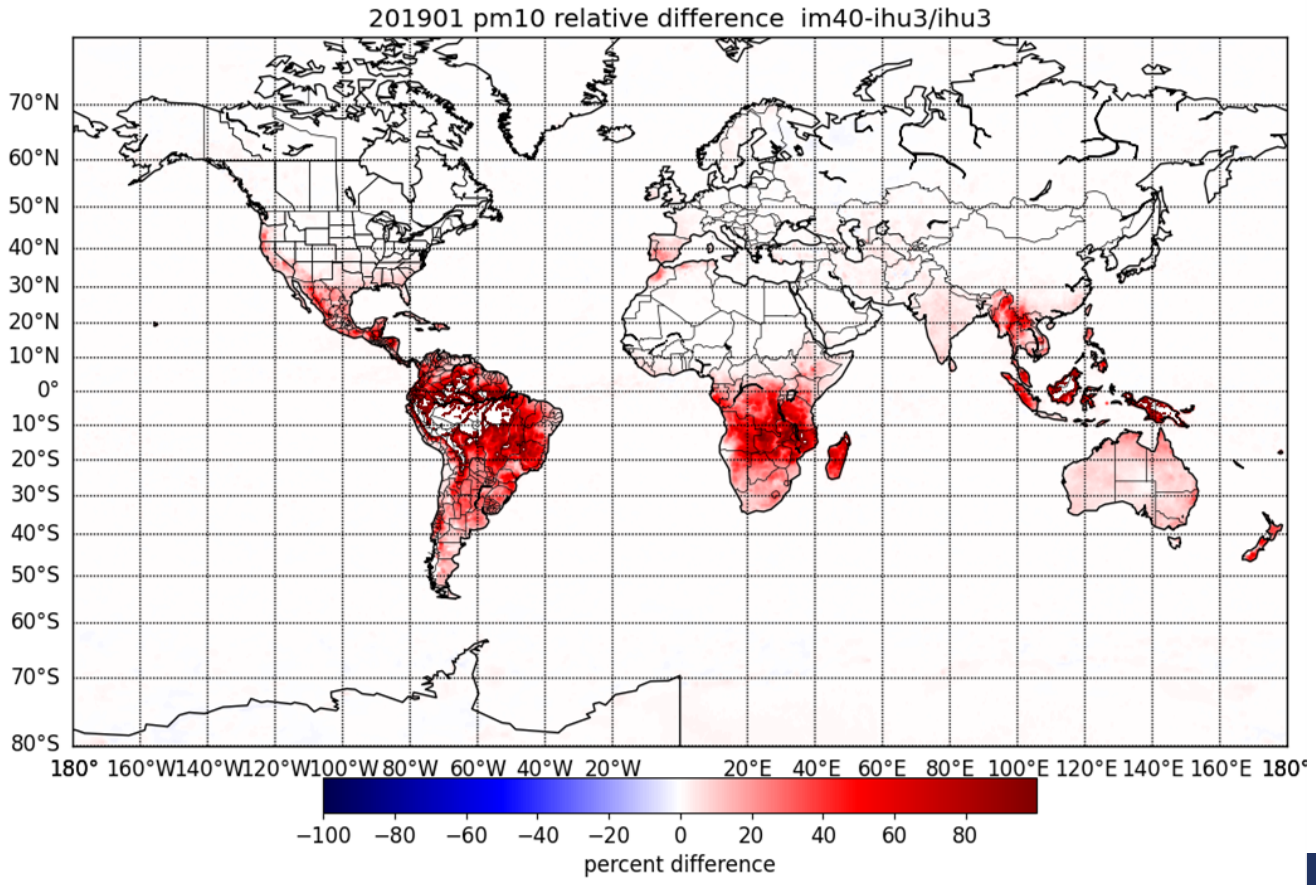


Hummel14



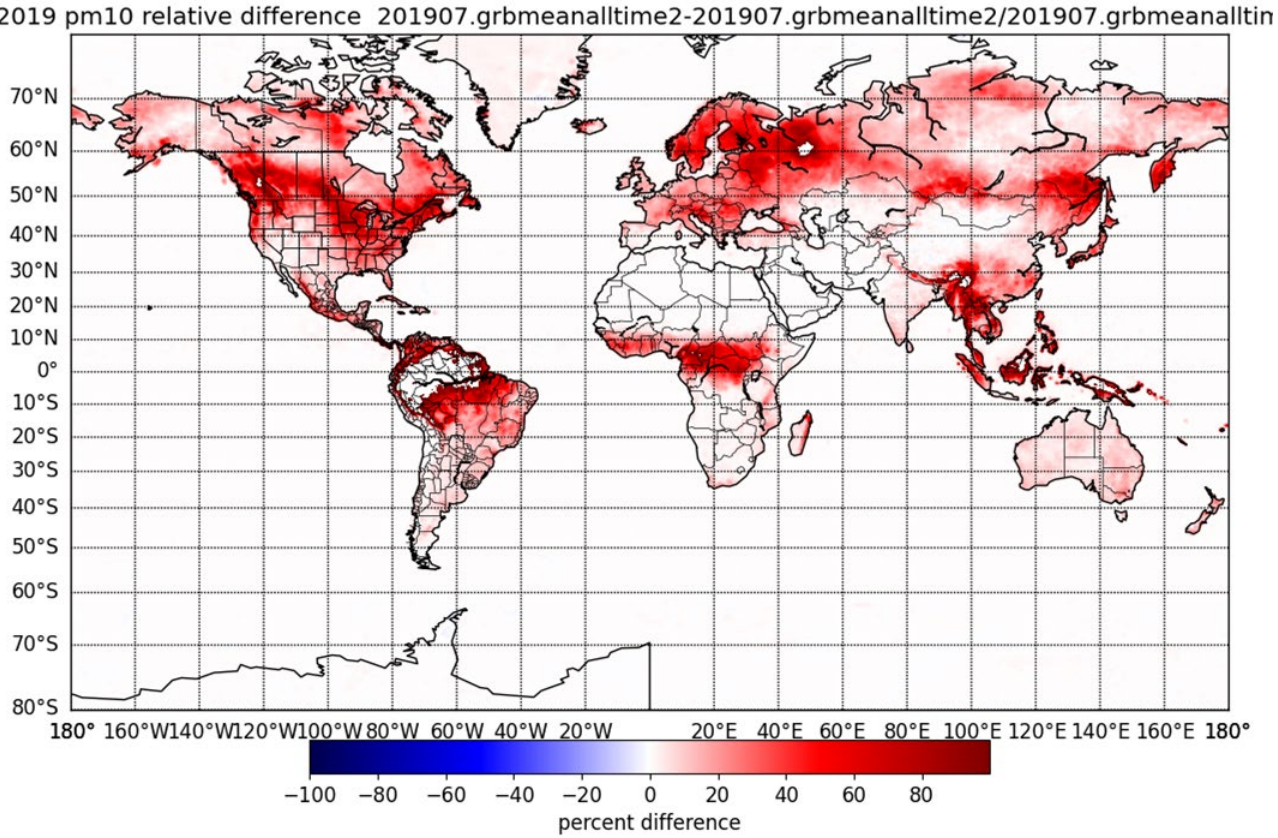
Simulated PM10 fraction composed of fungal spores, January 2019:

J01 - stat

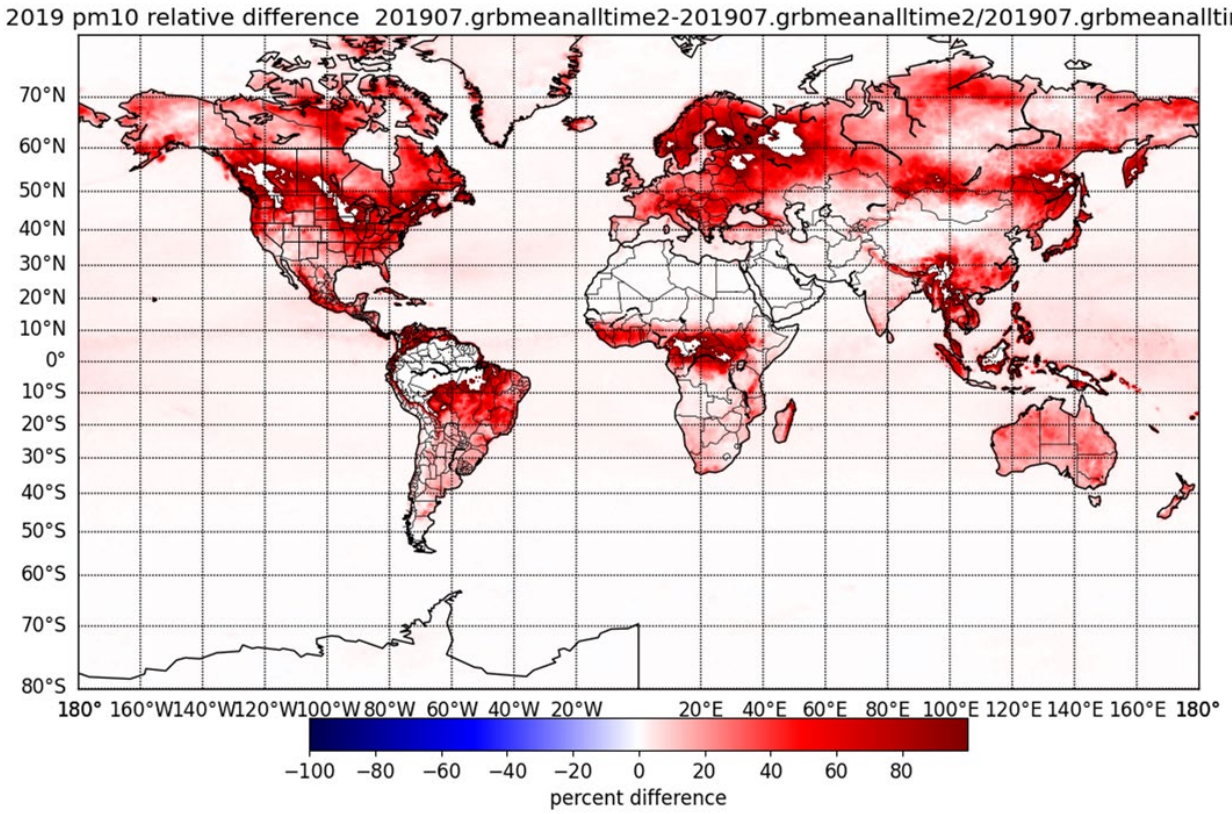


Simulated PM10 fraction composed of fungal spores, July 2019:

H&S (EMEP)

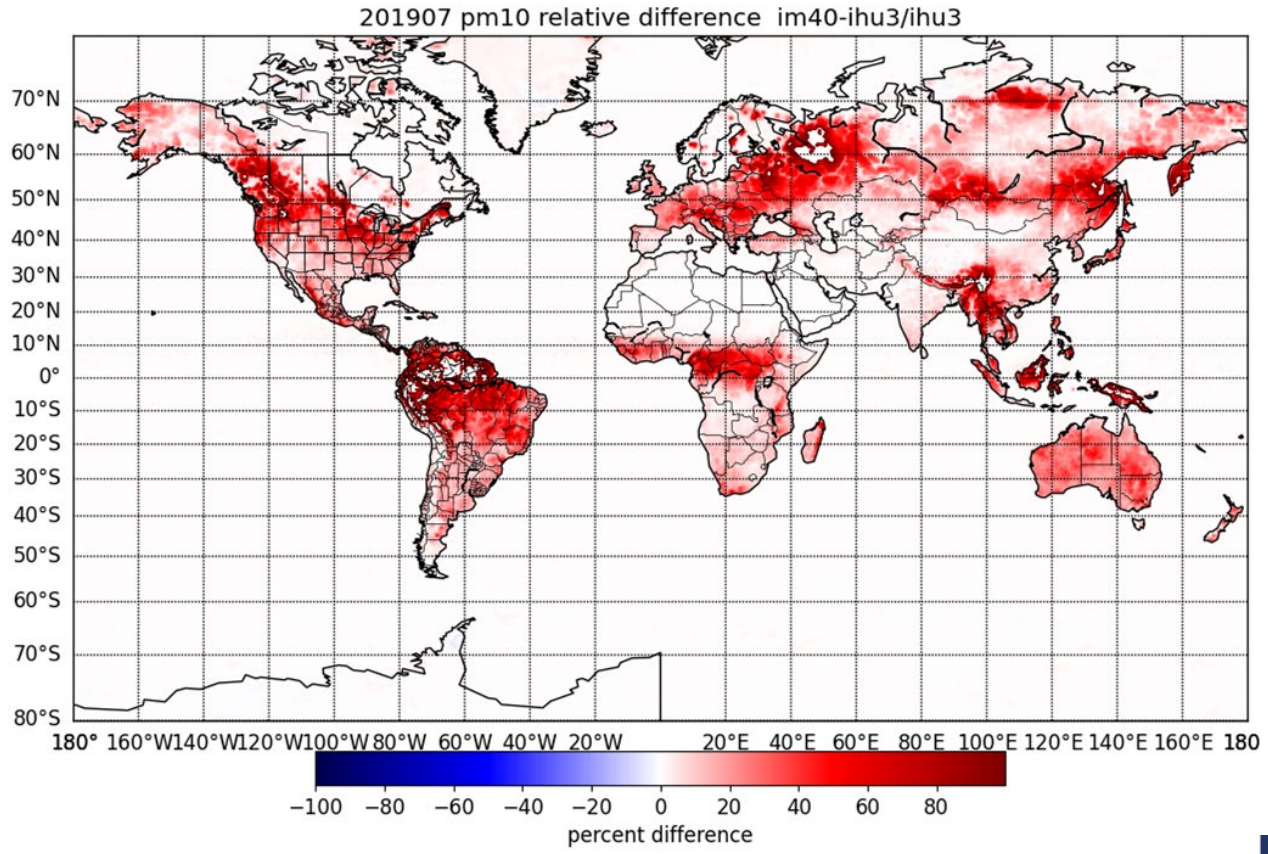


Hummel14



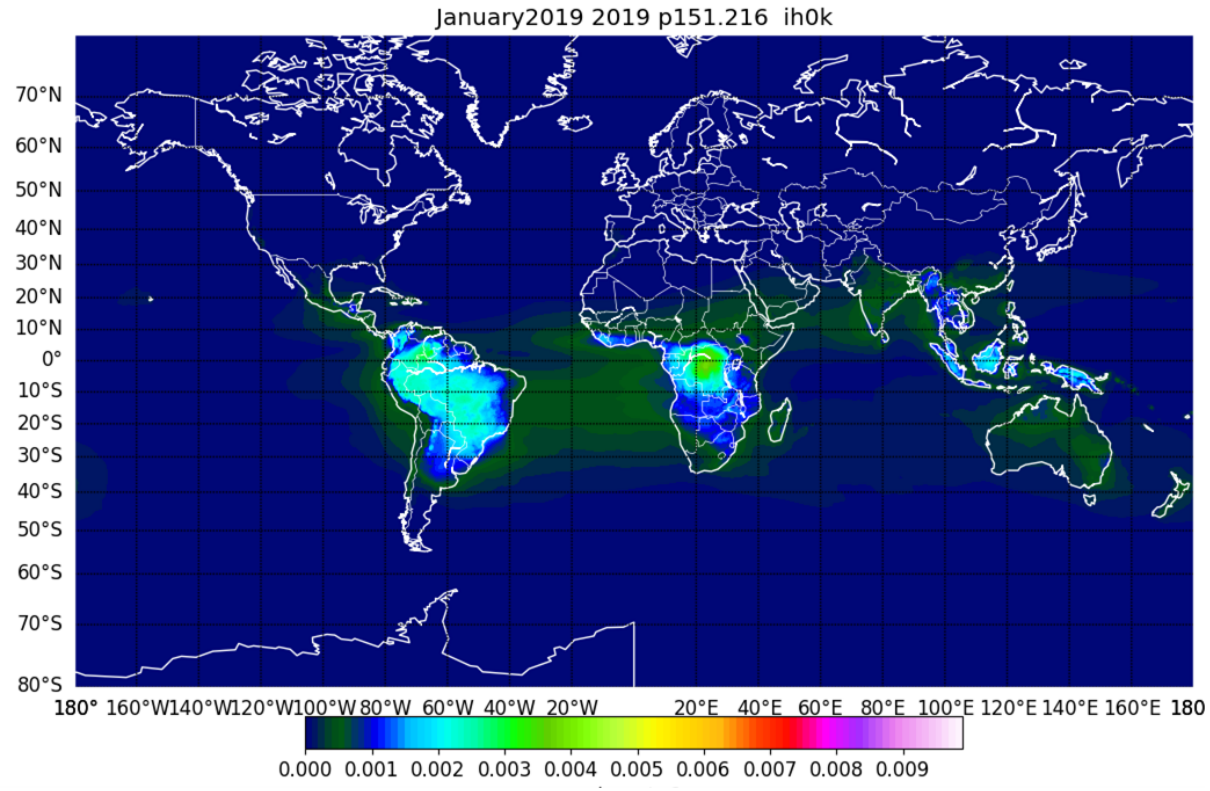
Simulated PM10 fraction composed of fungal spores, July 2019:

J01 - stat

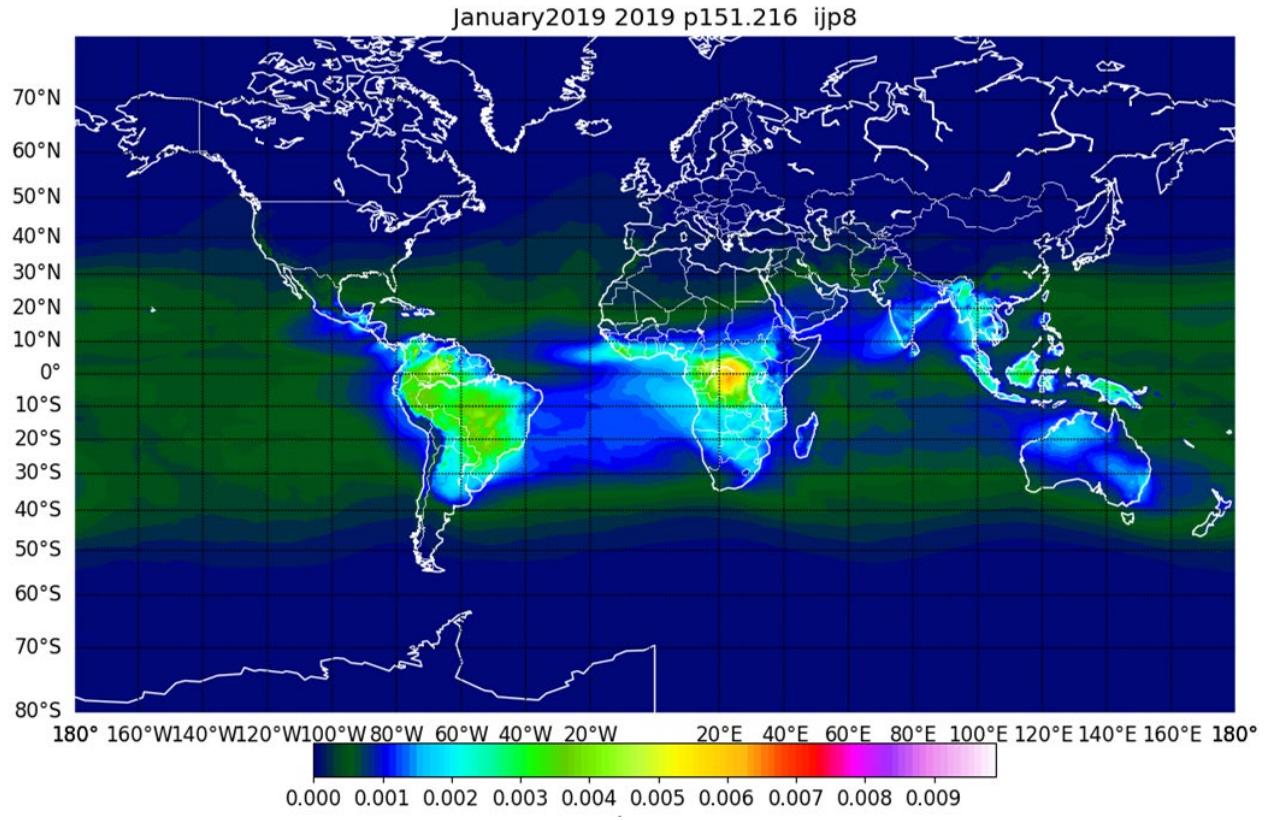


Simulated AOD at 550nm, January 2019:

H&S (EMEP)

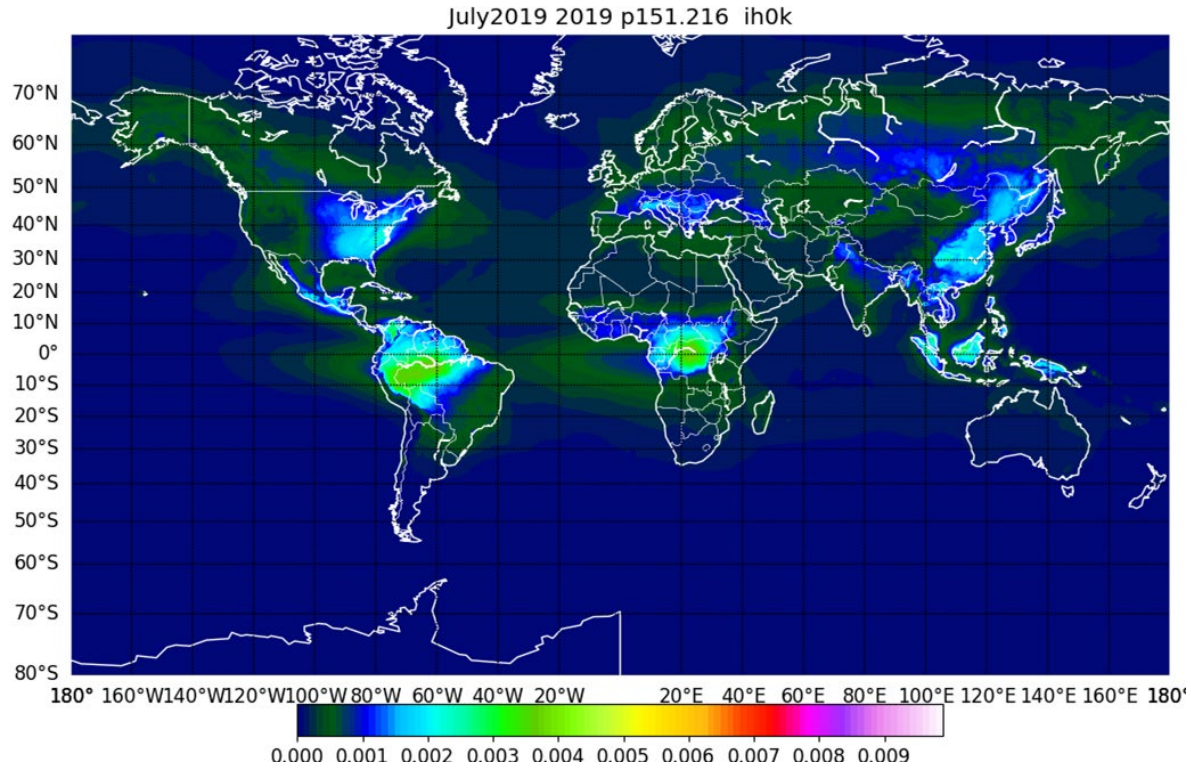


Hummel14

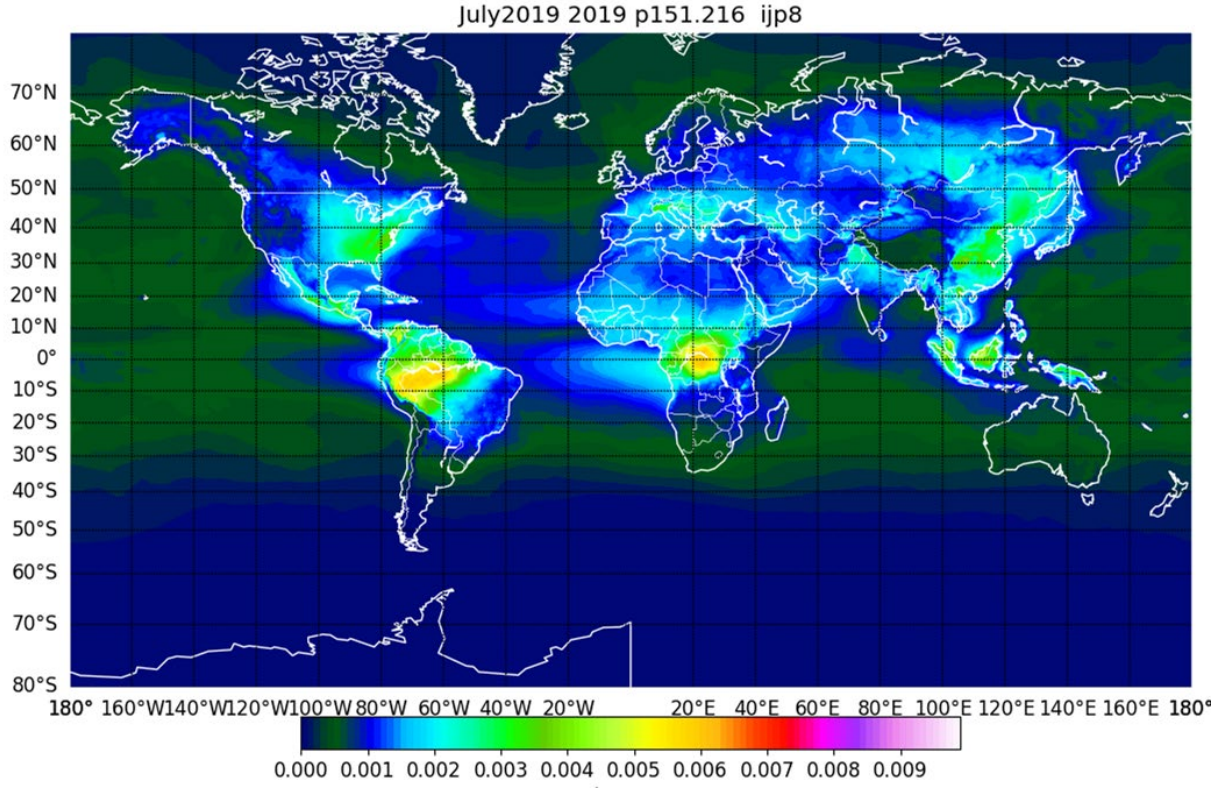


Simulated AOD at 550nm, July 2019:

H&S (EMEP)



Hummel14



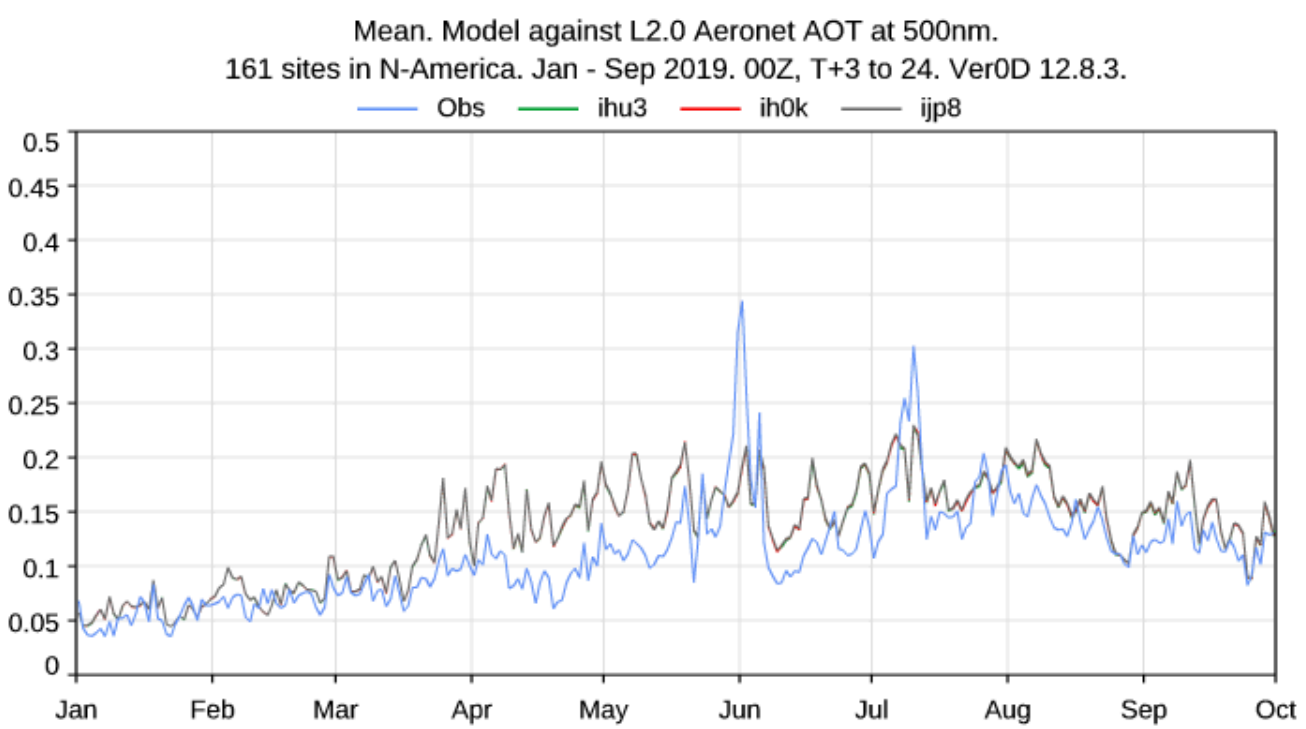
Evaluation of simulated AOD at 500nm versus AERONET

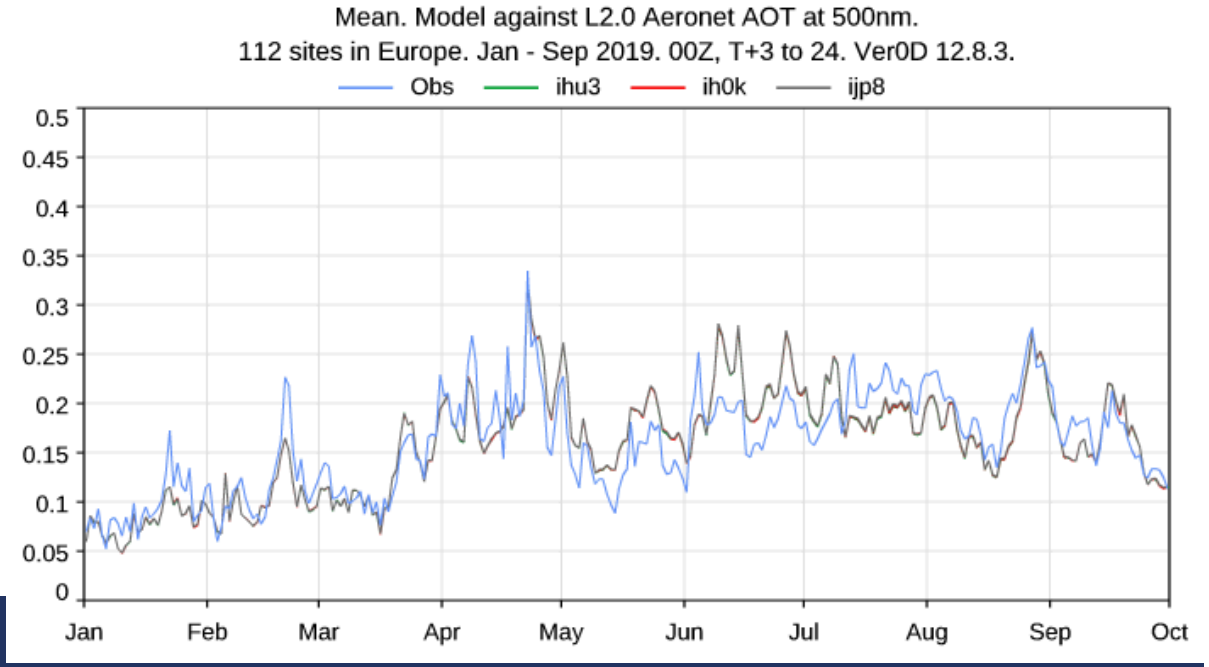
blue=observations

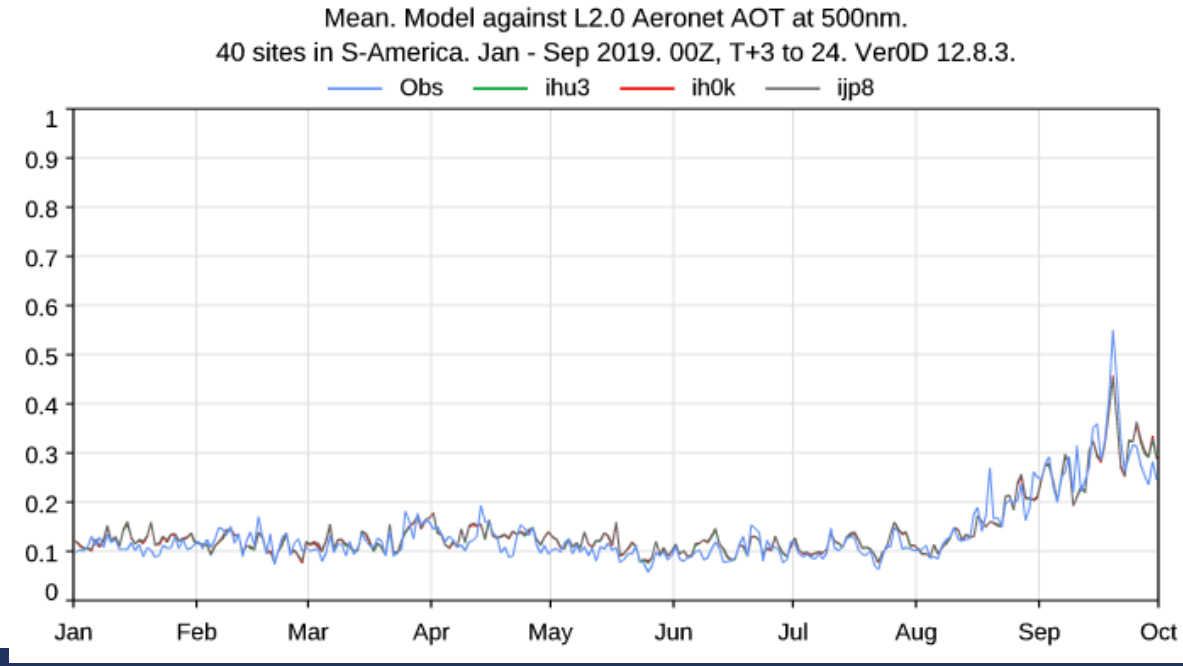
green=no fungal spores

red=H&S (EMEP)

gray=Hummel14







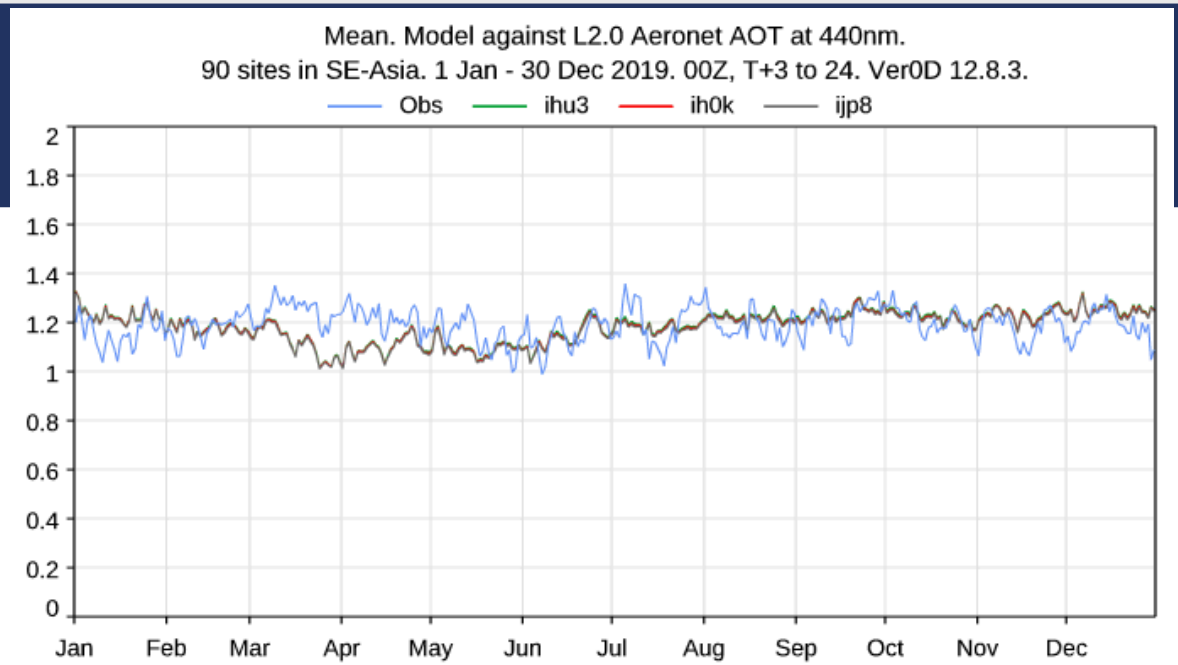
Evaluation of simulated Angstrom exponent versus AERONET

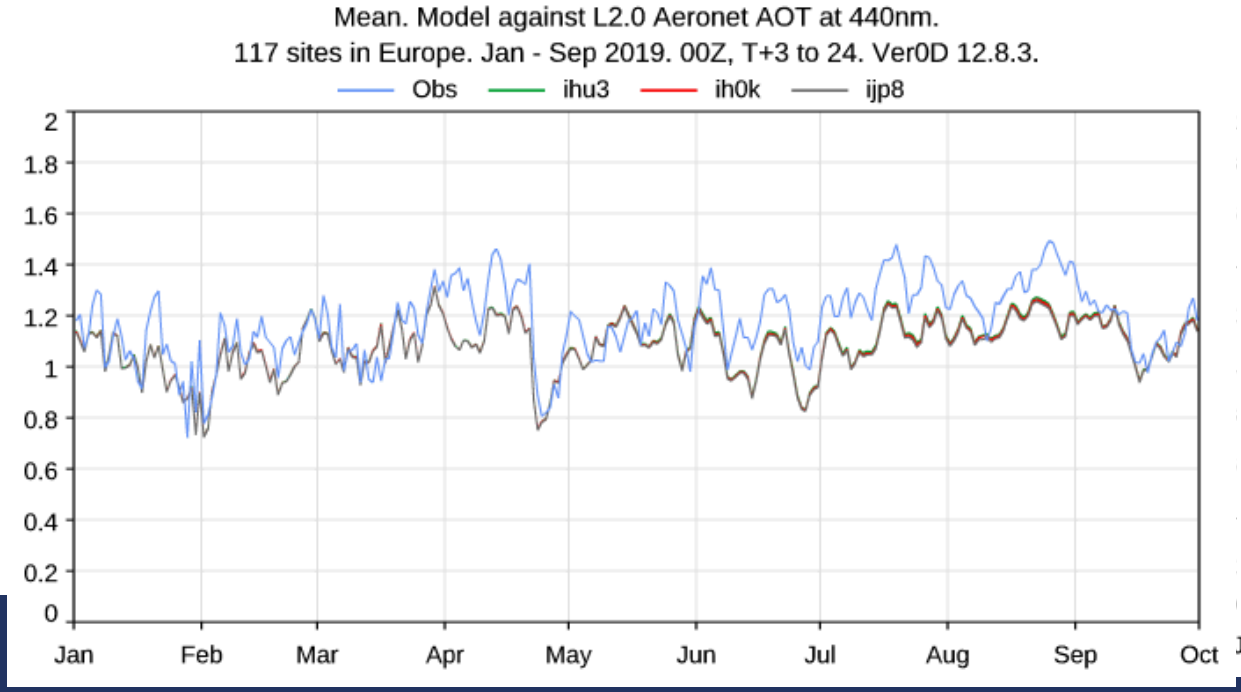
blue=observations

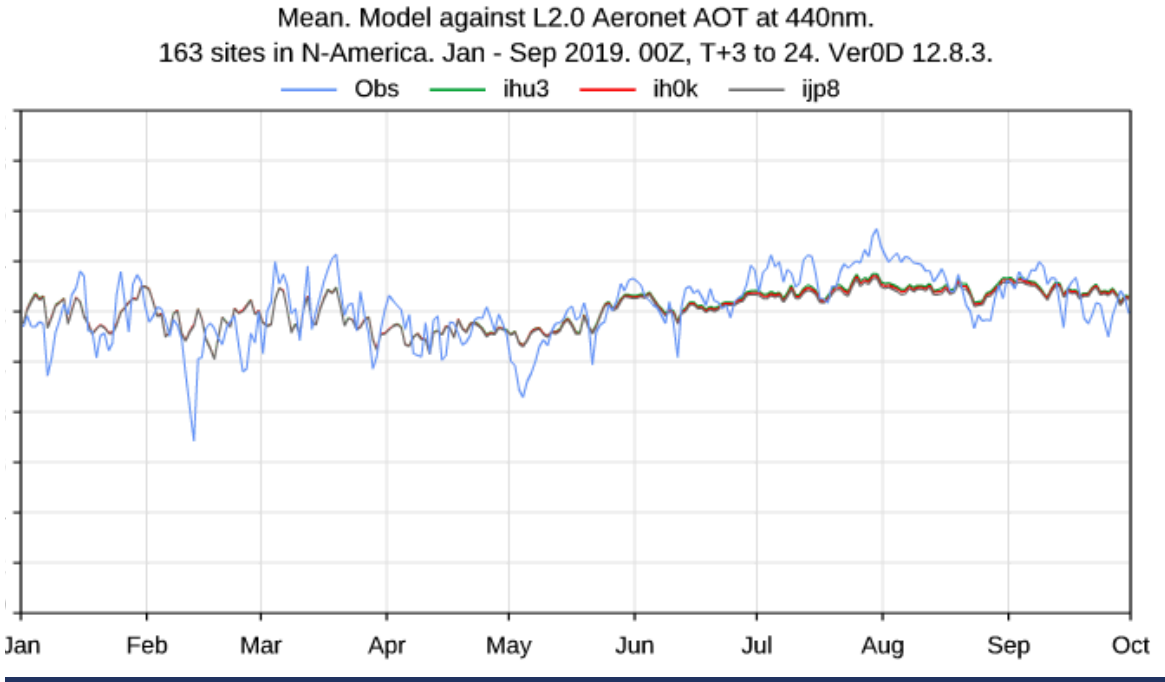
green=no fungal spores

red=H&S (EMEP)

gray=Hummel14







Evaluation of simulated Angstrom exponent versus AERONET

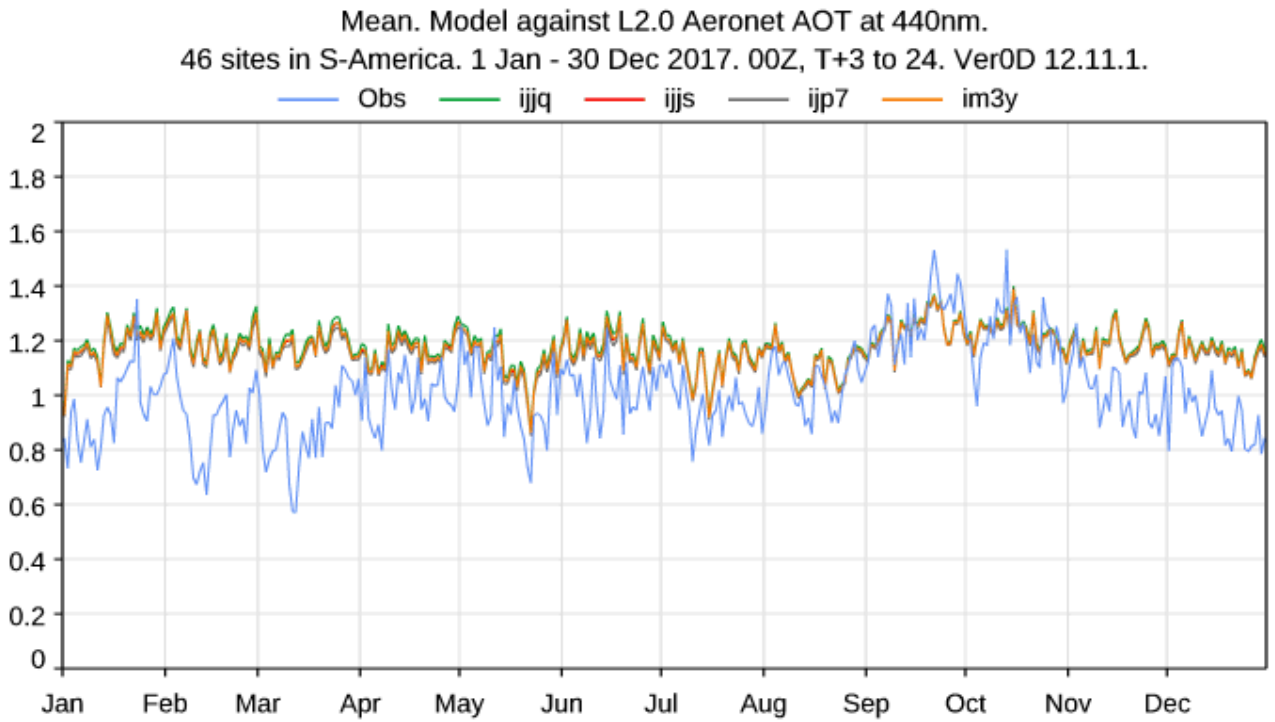
blue=observations

green=no fungal spores

red=H&S (EMEP)

gray=Hummel14

orange = J01 (stat)



Evaluation of simulated Angstrom exponent/AOD versus AERONET at Alta Floresta

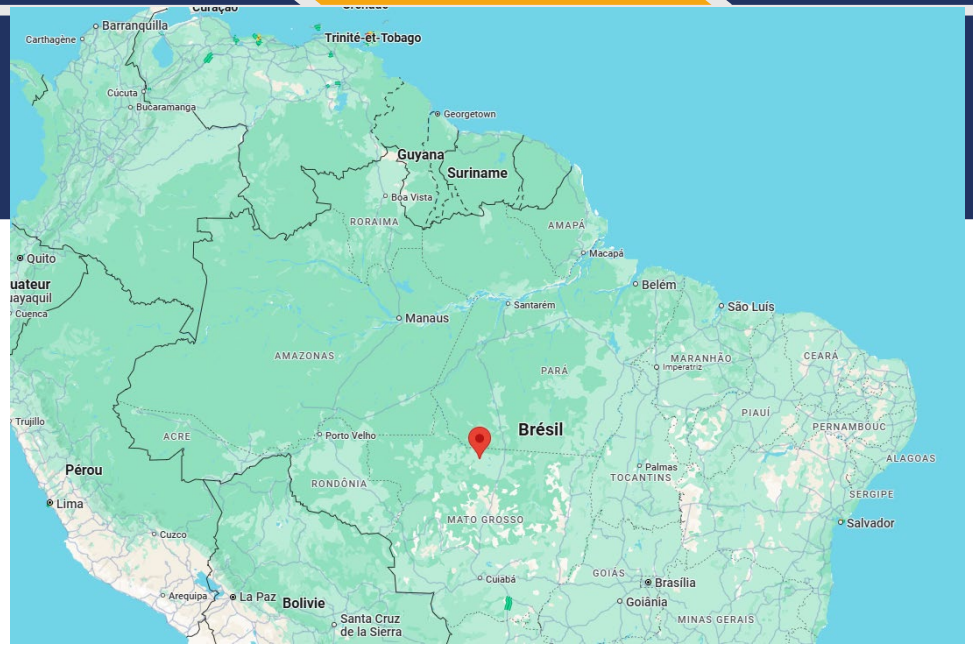
blue=observations

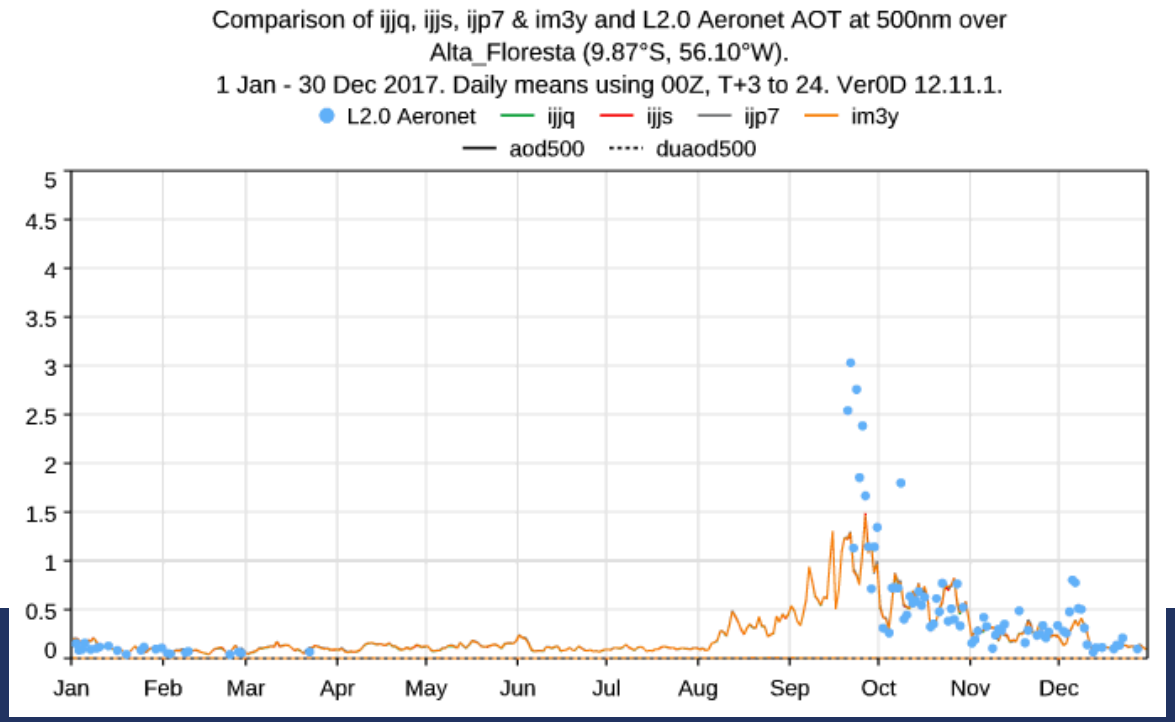
green=no fungal spores

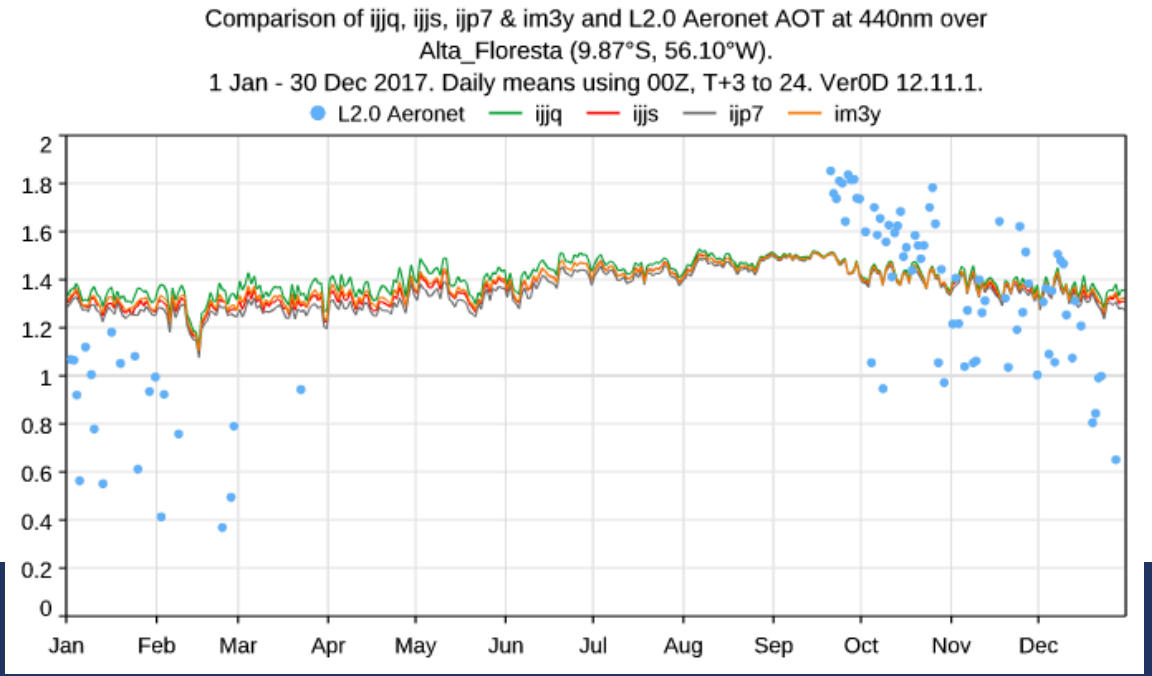
red=H&S (EMEP)

gray=Hummel14

orange = J01 (stat)







Evaluation of simulated Angstrom exponent/AOD versus AERONET at ATTO

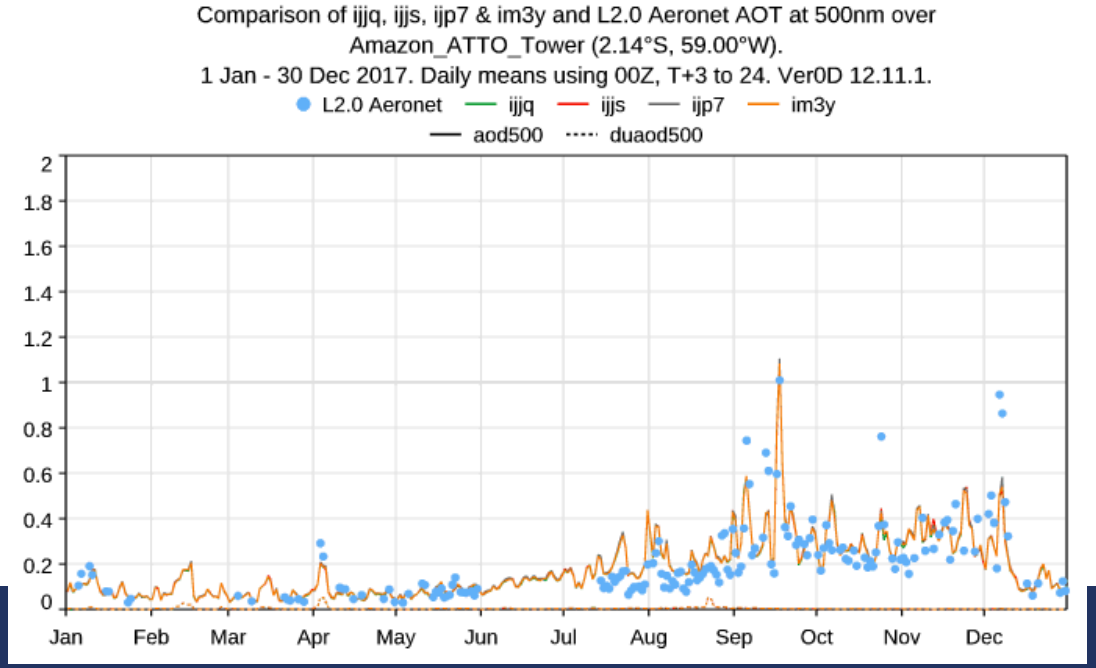
blue=observations

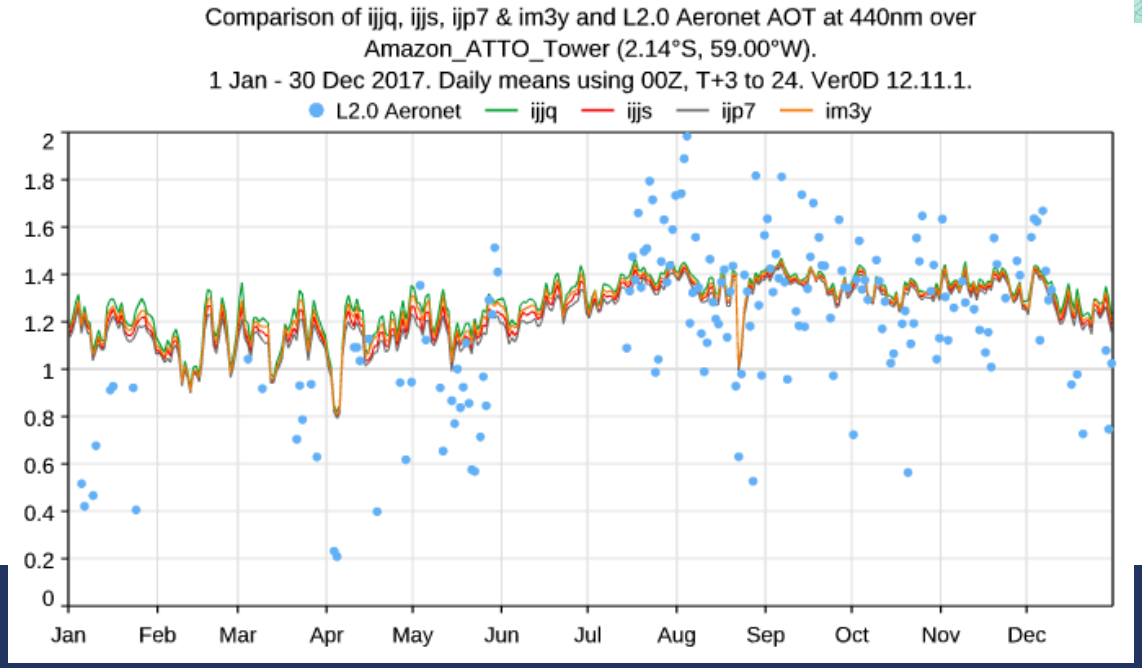
green=no fungal spores

red=H&S (EMEP)

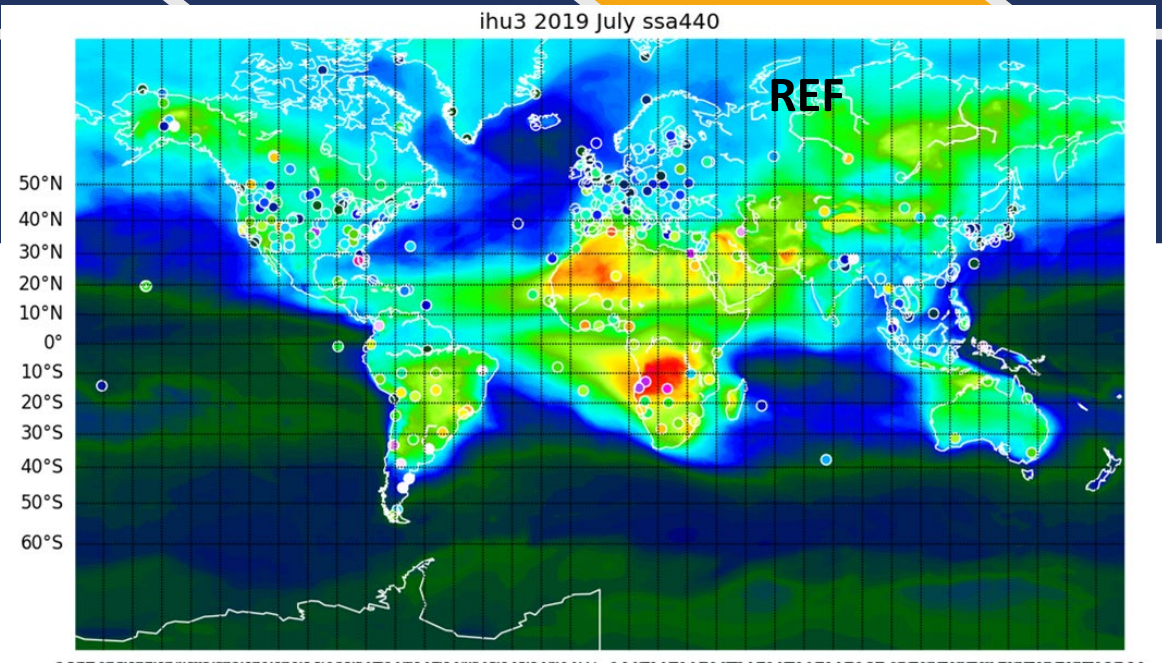
gray=Hummel14

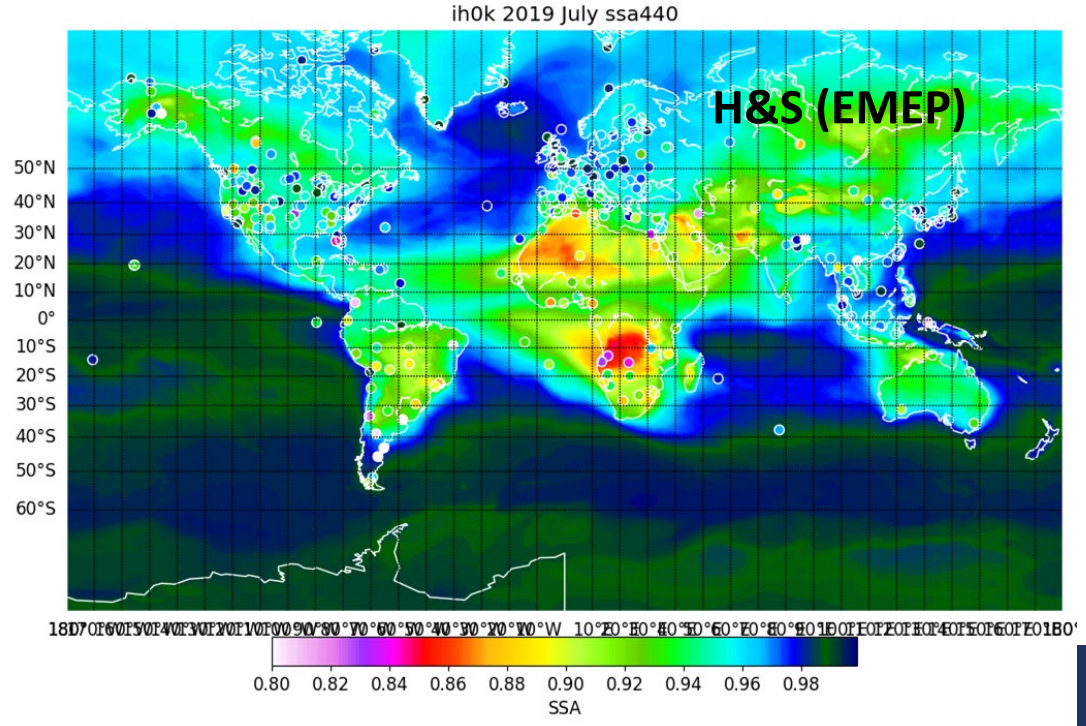
orange = J01 (stat)

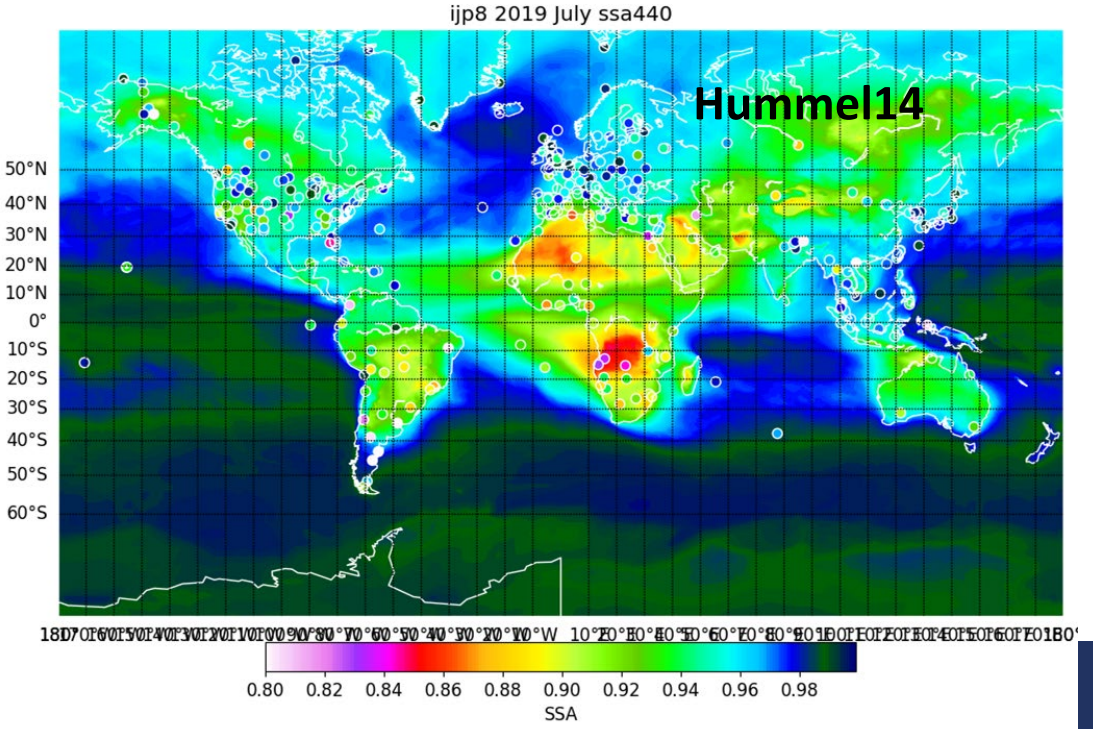




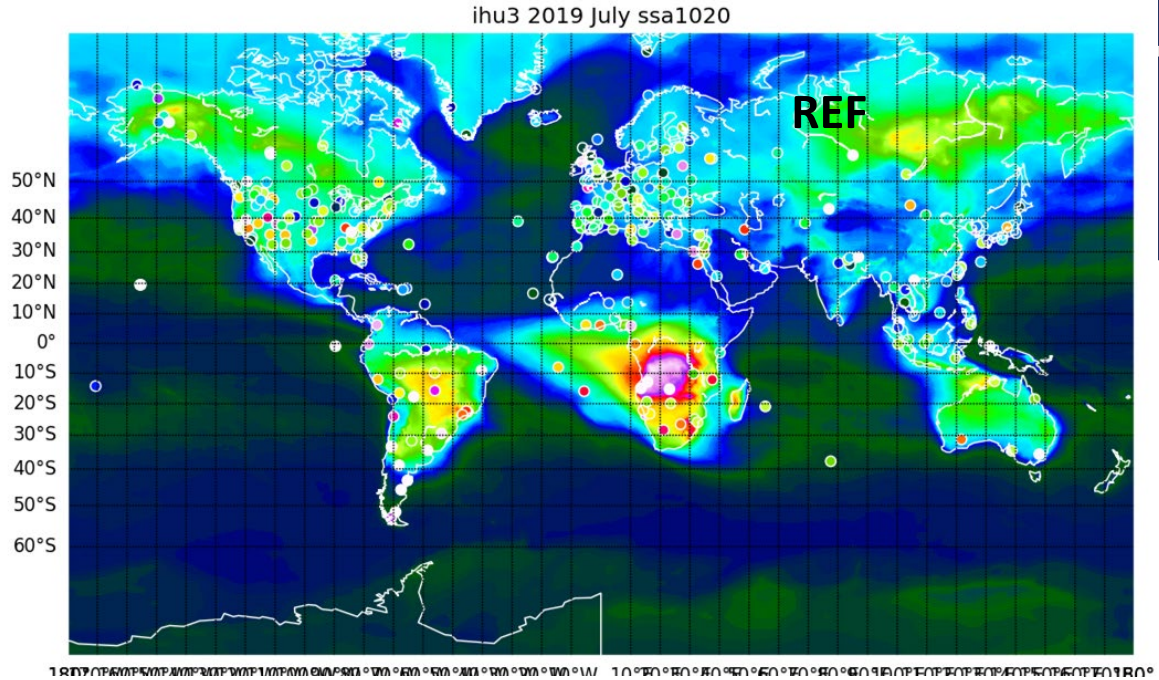
Evaluation of simulated SSA at 440nm in July 2019

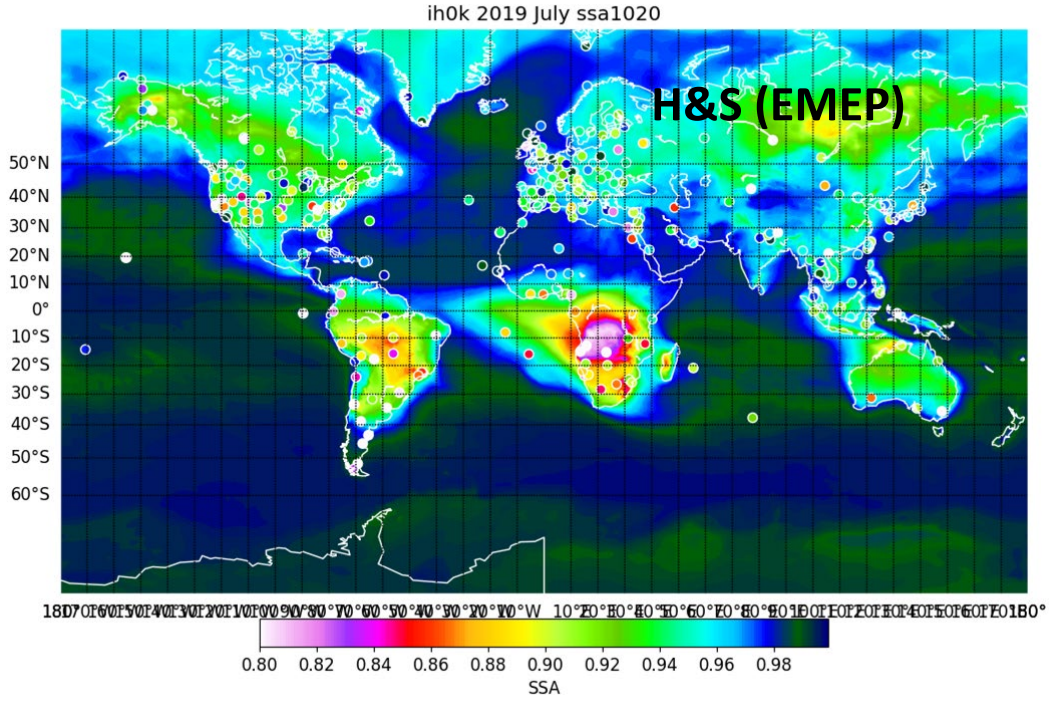


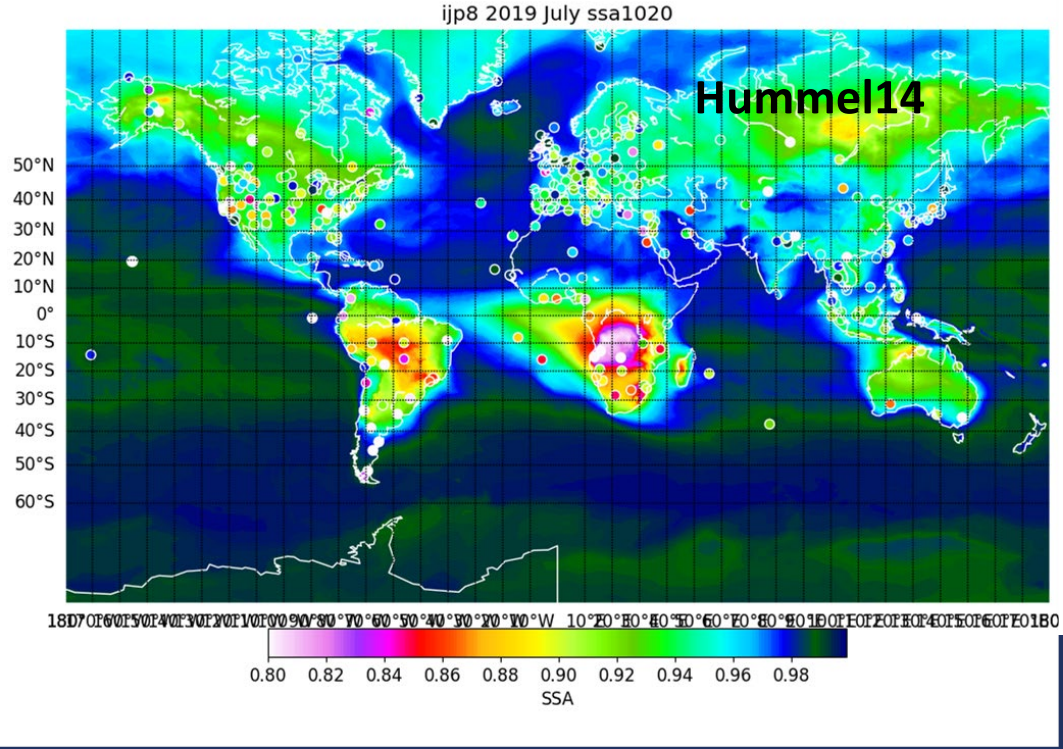




Evaluation of simulated SSA at 1020nm in July 2019







Evaluation of simulated SSA at 1020nm in July 2019