CREATE: Aviation impact on atmosphere and climate using SILAM CTM.

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and the other members of the SILAM-team.
Finnish Meteorological Institute
CREATE Final Exploitation Event, September 13, 2022, Naples, Italy

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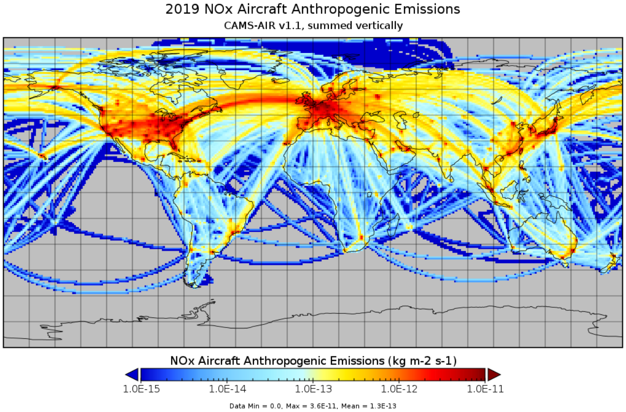
Global aviation emissions

See e.g.: D.S. Lee, *et al.* (2021), The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018, Atm. Env., Vol 244, 117834, and references therein.

- 2.5% of global CO_2 emissions
- 1.9% of global GHG emissions
- NO_x: $\sim$ 2 Tg/year (lightning $\sim$ 5 Tg/year)
- Water contrails (net warming)
- Aerosols (cooling)



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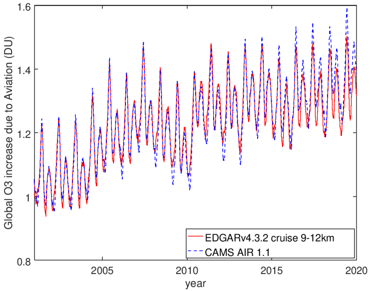
SILAM System for Integrated modeLling of Atmospheric coMposition

SILAM v.5.7 CTM using CBM05 chemistry including stratosphere:

- Various emissions from different inventories:
  - Antropogenic emissions (e.g. CAMS-GLOB-2.1/4.2)
  - Lightnings (GEIA)
  - Aviation (EDGAR4.3.2 / CAMS-AIR-1.1)
  - Biogenic (MEGAN-MACC, CAMS-BIO-3.1)
  - N_2O, CFCs, CH_3Cl and CH_3Br *etc.*
- Secondary Organic Aerosols:
  - Based on volatility bin approach (e.g. Woody *et al.* ACP201
- Sea-salt emissions including its bromine factor:
  - Based on combined Monahan-Martensson method.
- Wind-blown dust source.
- DMS from seas.



Performed global simulations with and without aviation for 2000–2019 (WP2) and European region for 2010 including also the effect of LTO emissions (WP3).

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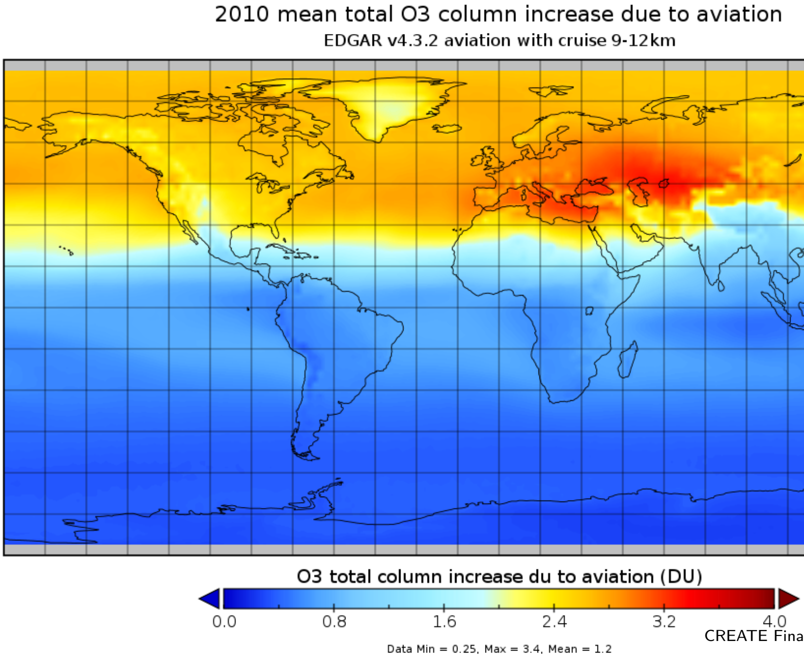
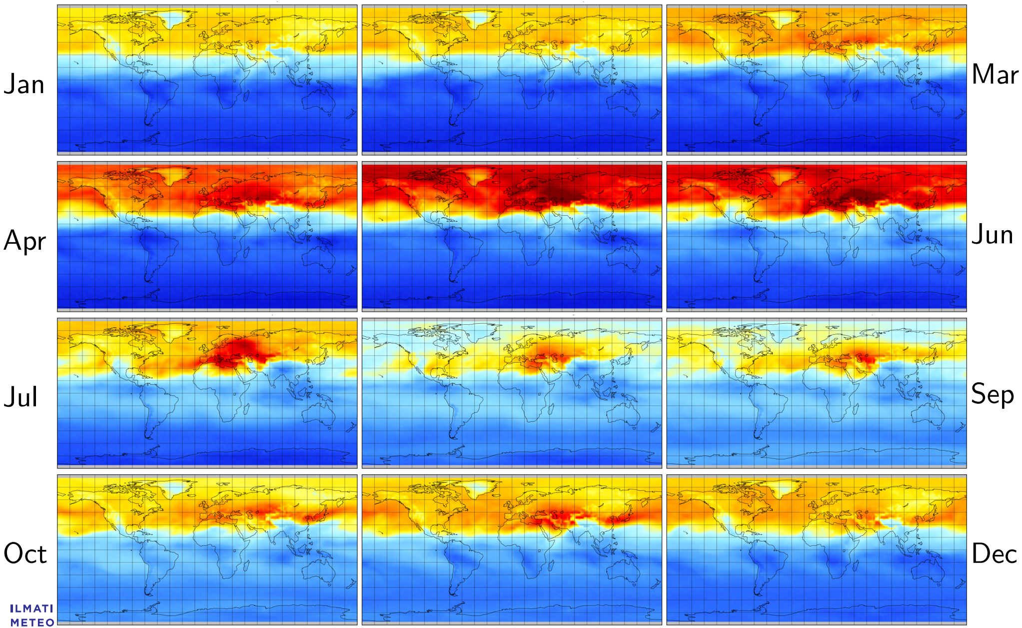
2010 annual total ozone column change due to aviation

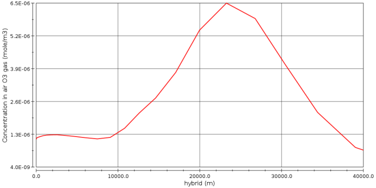


2010 monthly total ozone column change due to aviation

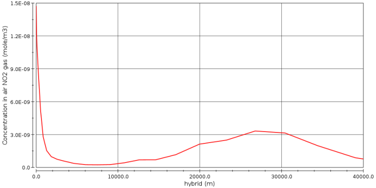


2010 global mean and aviation change for O_3, NO_2, and $PM_{2.5}$

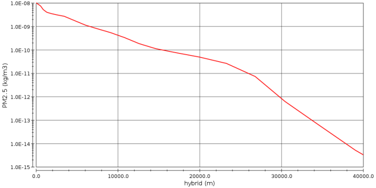
Without aviation: O_3



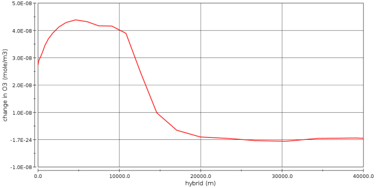
NO_2

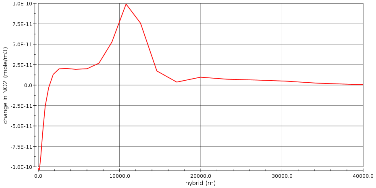


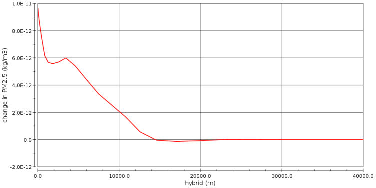
$PM_{2.5}$



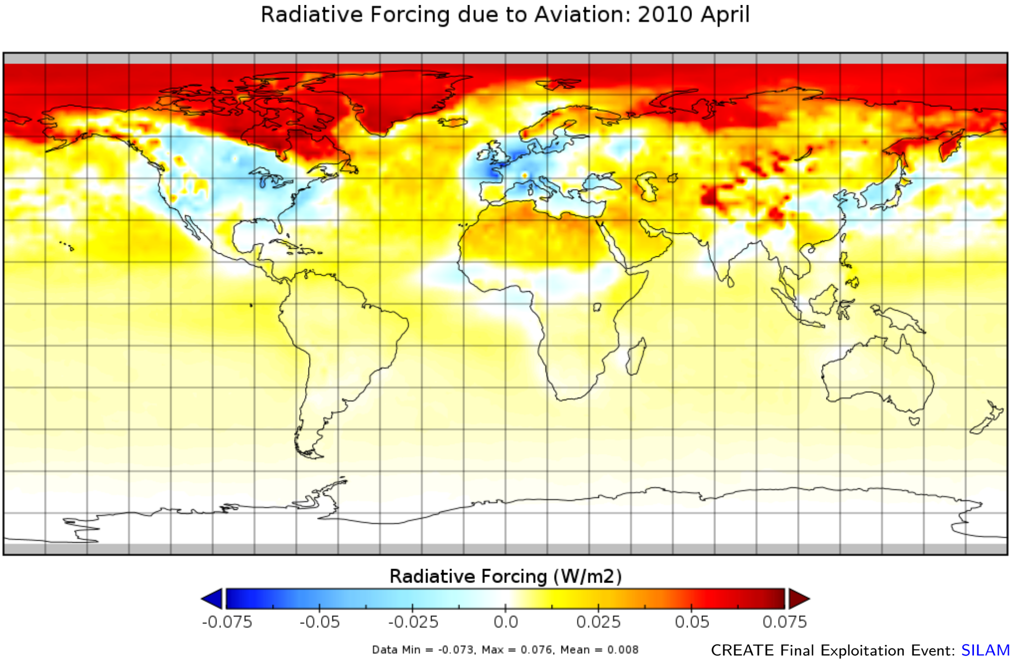
Change due to aviation:



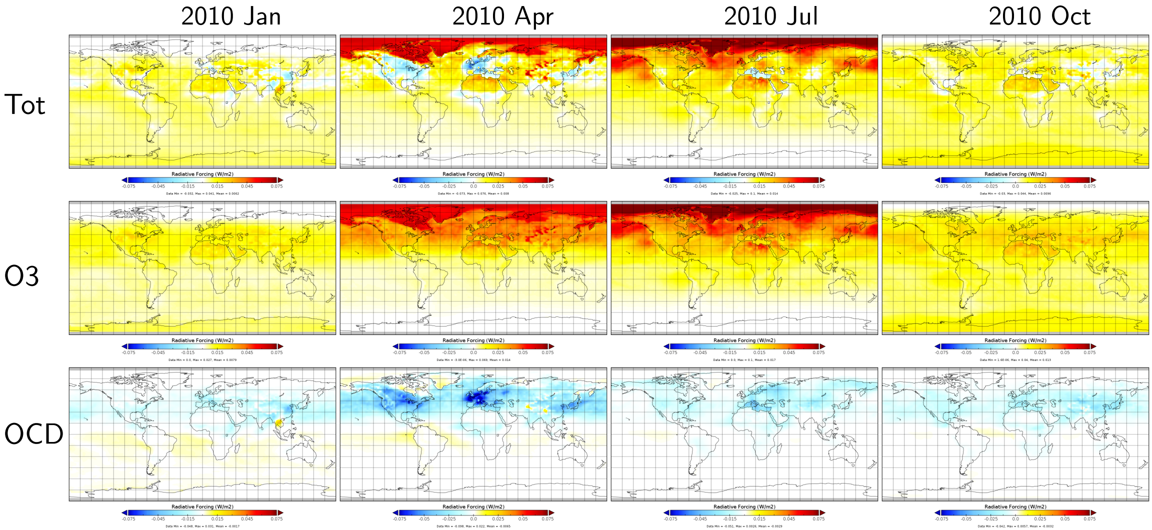




Radiative forcing using libRatran (RF due to changes in O3 and OCD)



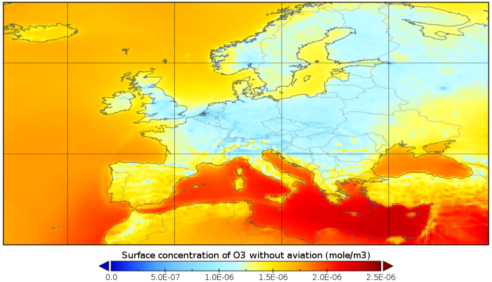
Radiative forcing using libRatran



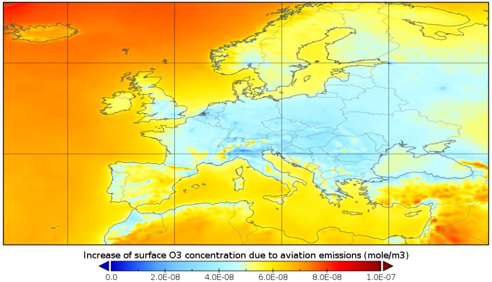
Summary from global runs

- Analyzed globally the aviation emissions with SILAM:
  - Global 2-degree run for years 2000–2019 with and without aviation.
- Change in total O_3:
  - Aviation brings globally about 1 DU increase in ozone.
  - Concentrated in Northern Hemisphere.
  - Maximum monthly mean increase around 4…5 DU above Europe in May.
  - Main increase in troposphere.
- Change in NO_2:
  - Largest increase at the cruise level.
  - At surface the NO_2 concentrations slightly drop (global and yearly mean)
  - Decrease is due to the reaction $NO_2 + O_3 \rightarrow NO_3 + O_2$ and due to increase in O_3 that originates from high altitude emissions (mainly NO_x).
- Estimated the Radiative Forcing due to O_3 & aerosols (direct effect/change in OCD):
  - Ozone tend to warm the climate, RF $\sim +13$ mW/m^2.
  - Direct aerosol effect is cooling, on average, RF $\sim$ -4 mW/m^2.
  - Effects seem to be smaller than the warming due to contrail formation and CO_2 emissions.

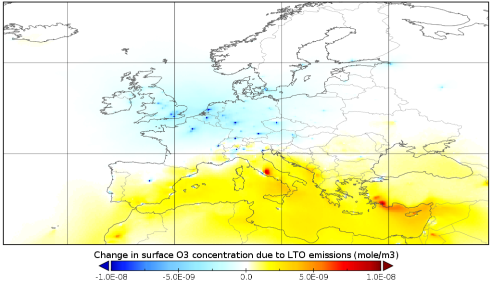
Europe: Surface O_3 (2010 mean)



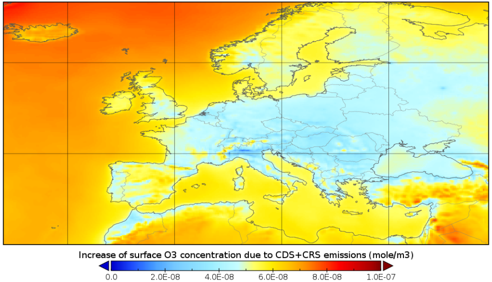
Surface concentration of O3 without aviation (mole/m3)



Increase of surface O3 concentration due to aviation emissions (mole/m3)



Change in surface O3 concentration due to LTO emissions (mole/m3)



Increase of surface O3 concentration due to CDS+CRS emissions (mole/m3)

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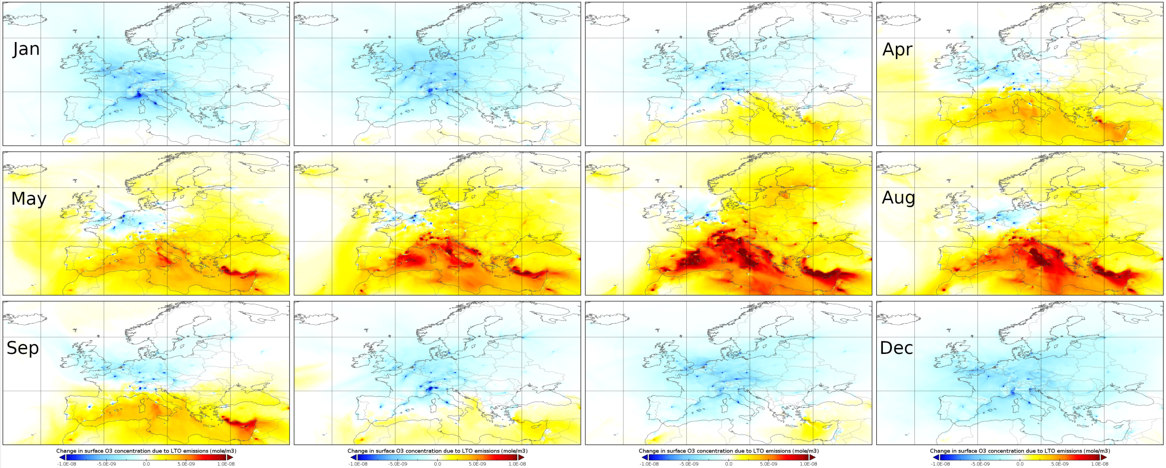
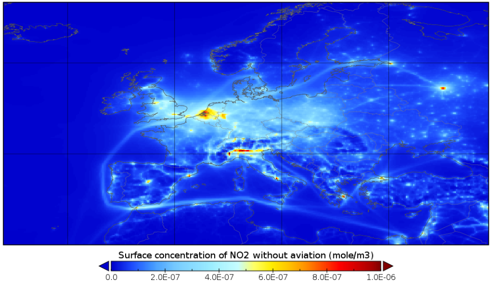
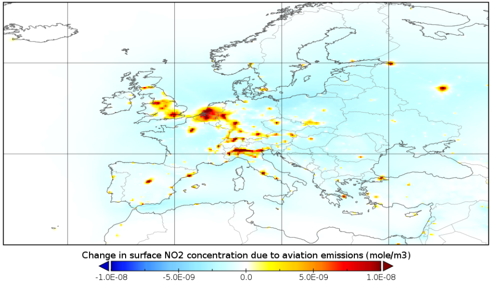
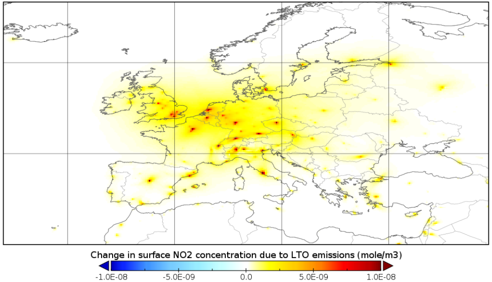
Europe: Surface O_3 due to LTO emissions (monthly for 2010)

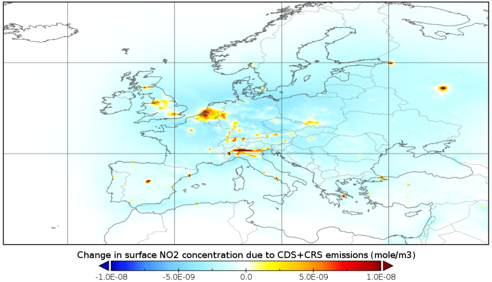


Europe: Surface NO_2 (2010 mean)



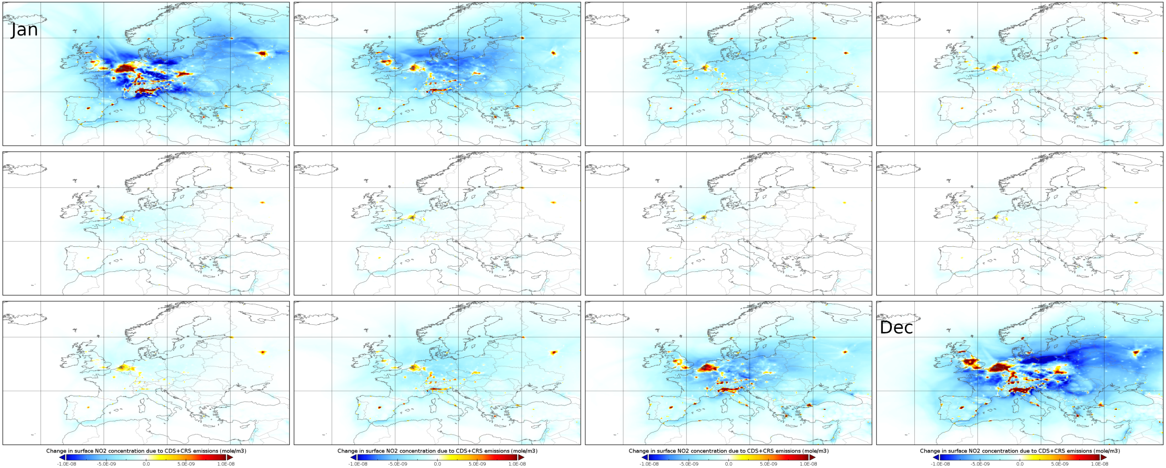






Decrease is due to reaction $NO_2 + O_3 \rightarrow NO_3 + O_2$

Europe: Surface NO_2 due to CDS+CRS (monthly for 2010)



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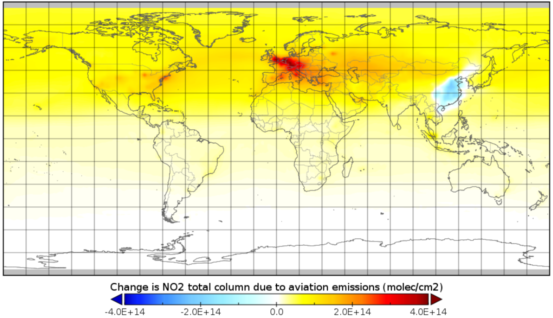
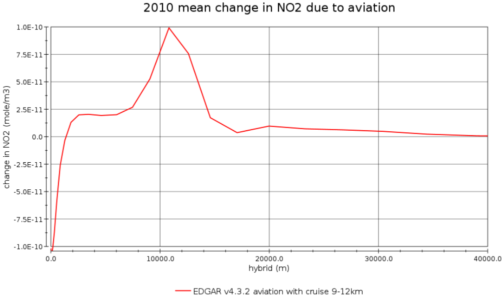
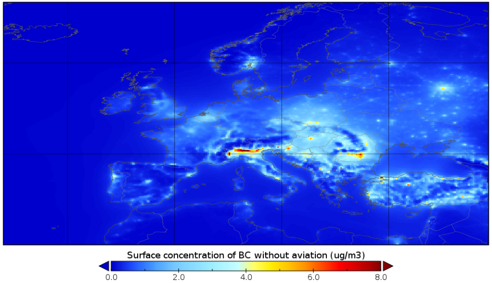
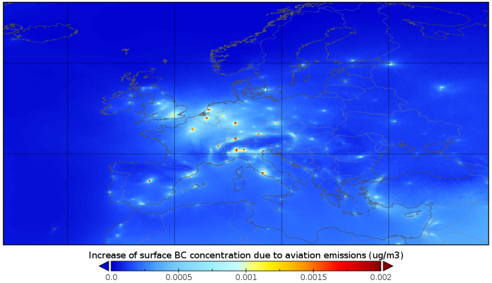
Global: NO_2 column change due to aviation (2010 mean)

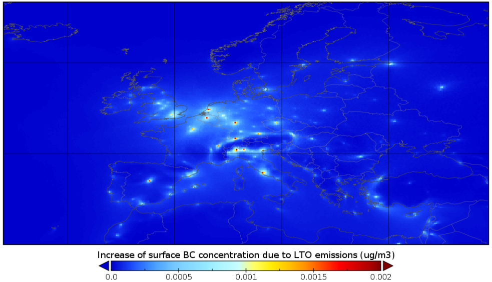


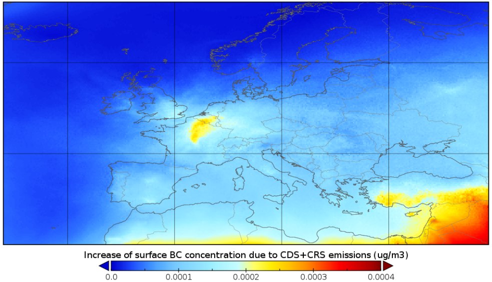


Europe: Surface BC (part of $PM_{2.5}$)









European summary

- Analyzed aviation emissions in Europe with SILAM:
  - Most effects at the surface are due to NO_x emissions.
- Change in surface O_3:
  - Total effect of aviation is to increase surface O_3.
  - LTO emissions tend to decrease O_3 locally (titration).
  - Far away from the airports even the LTO emissions tend increase surface O_3.
  - Strong seasonality in the effect of LTO emissions.
- Change in surface NO_2:
  - Can be positive or negative!
  - Increase is mainly due to local NO_x emissions near aiports.
  - Decrease is due to the reaction $NO_2 + O_3 \rightarrow NO_3 + O_2$ and due to increase in O_3 that originates from high altitude emissions (mainly NO_x).
- Change in surface BC:
  - Positive but small, concentrated near the airports.
  - Only due to LTO emissions.