Comparison of NO_2 long-range transport events in GOME-2 observations and CTM simulations

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Introduction

- NO_2 is emitted in combustion processes, is toxic and affects the ozone budget
- upon uplift into the free troposphere, the lifetime can amount to multiple days
- NO_2 long-range transport (LRT) can transport pollution from emission regions to remote, otherwise pristine areas
- to assess the impact of LRT, statistical studies on satellite and model data are needed
- NO_2 LRTs are frequent and need to be studied using automatization
- we present an algorithm to find and verify such events and assess their properties

Detection algorithm

Data preparation

- create 2D global maps of NO_2 troposhperic vertical column density (VCD)
- generate ±6 days sliding mean (μ) and standard deviation (σ) for each day, excluding the day of observation itself, and mask continents

Plume detection

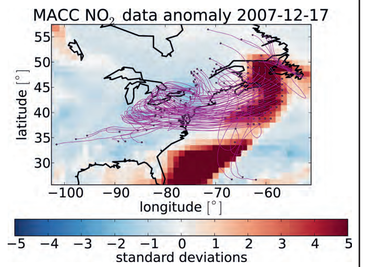
- find seeds where $\mathrm{data} \geq \mu + n_{\mathrm{seed}} \cdot \sigma$
- expand seeds to adjecent observations where $\mathrm{data} \geq \mu + n_{\mathrm{member}} \cdot \sigma$
- the resulting plumes are the candidates which deviate significantly from what is normal in this region
- sensitivity can be adjusted by selecting n_{seed} and n_{member} appropriately

Lagrangian backtracing

- insert all pixel centers of a candidate into HYSPLIT at multiple altitudes
- get trajectories for 72 hours back in time

Verification

- find the most likely trajectory by scoring, favoring:
  - small dispersion
  - high NO_2 observations hitting high EDGAR emissions within boundary layer
- discard plumes not showing a sufficient ratio of EDGAR emissivity / NO_2 content



Sample detected plume with selected HYSPLIT backtrajectory in magenta. Colormap gives the number of standard deviations from the ±6 days moving average NO_2 VCD. Estimated plume age is 2 days.

Statistical Comparison

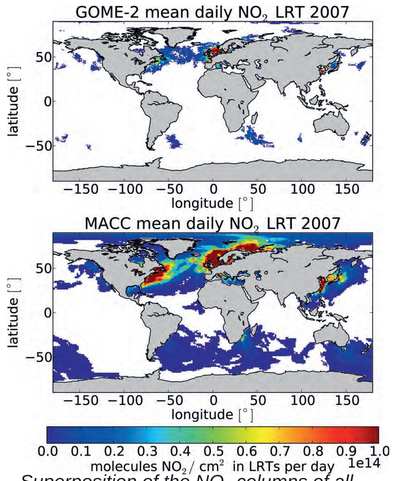
Data acquisition

- algorithm is used to extract NO_2 LRT plumes for 2007 in 2 data sets
  - GOME-2 satellite data
  - MACC reanalysis model data
- stronger constraints on MACC data to account for smoothness

data	n_{seed}	n_{member}	min size [molecules]	n_{plumes}
GOME-2	3	2	0	282
MACC	5	2	$5 \cdot 10^{30}$	540

Routes

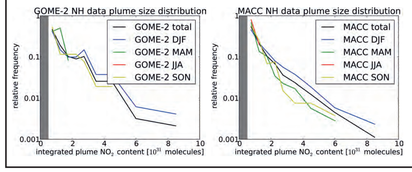
- LRTs occur on typical routes around emission regions:
  - East coast of the US, Europe, South Africa and China are most prominent
  - Australia and South America show smaller impact
  - Southern Hemisphere has less LRTs than Northern Hemisphere
  - no transport in the tropics
  - strong seasonality can be seen
    - due to more emission, longer lifetime and more favorable meteorology in winter
- GOME-2 and MACC agree on shape
- MACC yields 91% more LRTs
  - 57% more raw observations (2007)
  - leads to higher amplitude
  - probably due to smoothness of the model

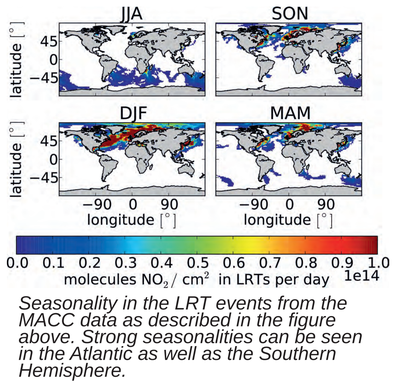


Superposition of the NO_2 columns of all plumes extracted from the GOME-2 (top) and MACC (bottom) data, divided by the number of observations, giving the average NO_2 VCD as seen in LRT per day.

Plume sizes

- biggest plumes occur in winter and autumn
- size distribution in MACC and GOME-2 match



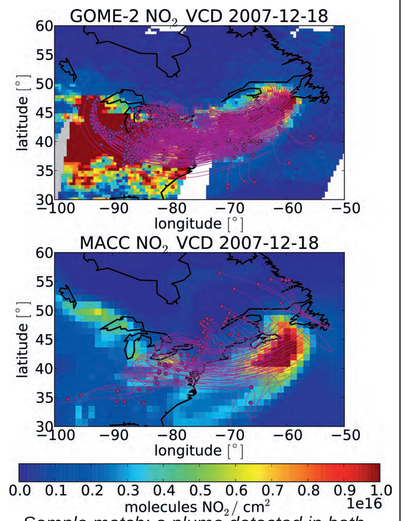


Seasonality in the LRT events from the MACC data as described in the figure above. Strong seasonalities can be seen in the Atlantic as well as the Southern Hemisphere.

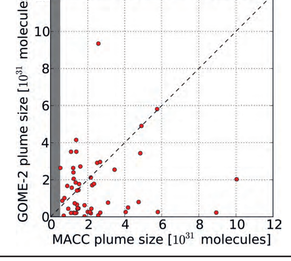
Individual Comparison

Plume matching

- out of 163 plumes in the GOME-2 data, only 52 are found in the MACC data
  - within 5° distance (center-to-center)
  - on the same date
- visual inspection of the matches
  - shape and extent roughly reproduced
  - estimated NO_2 content and location differ significantly
  - suspected origins may be far apart
- NO_2 content of matches is hardly correlated (r = 0.12)
  - influence of clouds, misappropriation by algorithm or model discrepancy



Sample match: a plume detected in both GOME-2 (top) and MACC data (bottom) with trajectories. Discrepancies come from differences in resolution and a different detected altitude.



NO2 content of matched LRT plumes for 2007. NO2 content is estimated from the vertical column density in the data and the spatial extent of the plume.

Selected References

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