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Fast emission estimates of NO_x constrained by satellite observations

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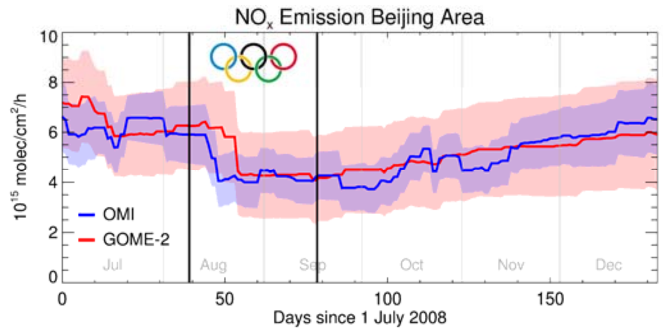
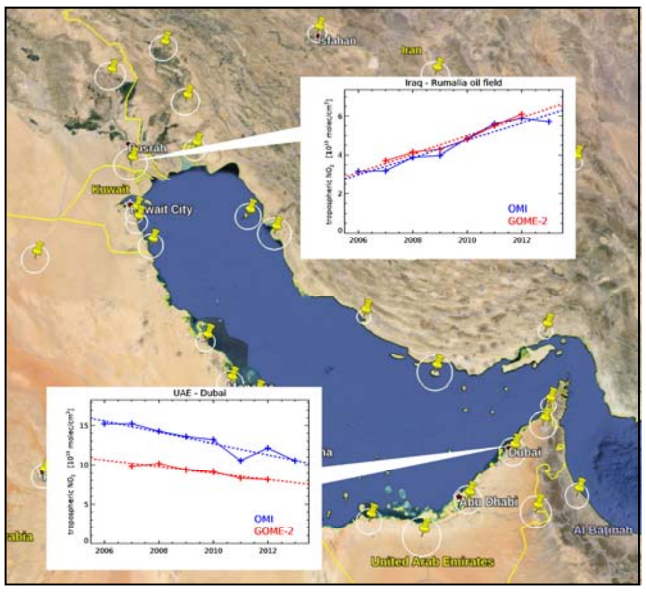
Up-to-date emission inventories of air pollutants are crucial information for policy makers and are important input data for air quality models. Anthropogenic emissions can change rapidly due to changing economic activity. Where current emission bottom-up inventories are inaccurate or outdated, satellite observations can provide valuable complementary information. We present the results of a new algorithm, specifically designed to use daily satellite observations of column concentrations for fast updates of emission estimates of short-lived atmospheric constituents on a mesoscopic scale (~25 km).





Satellites detect strong tropospheric NO_2 concentration trends for hot spots in e.g. the Middle East

The DECSO algorithm

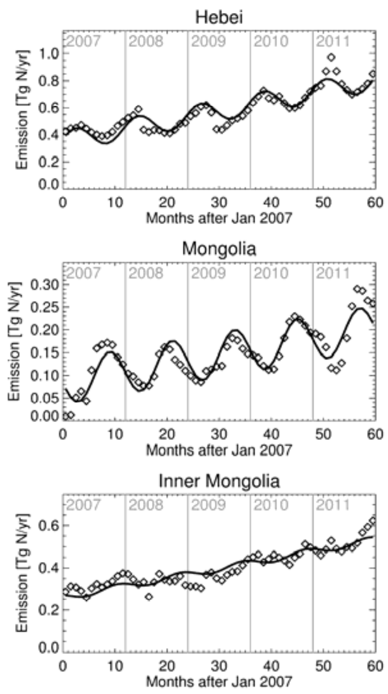
The DECSO algorithm is **fast** because only one forward chemical transport model (CTM) run is needed. It enables **high resolution** estimates by taking transport into account. It updates emissions by addition instead of scaling, enabling **detection of new hotspots** and relocation of existing sources.

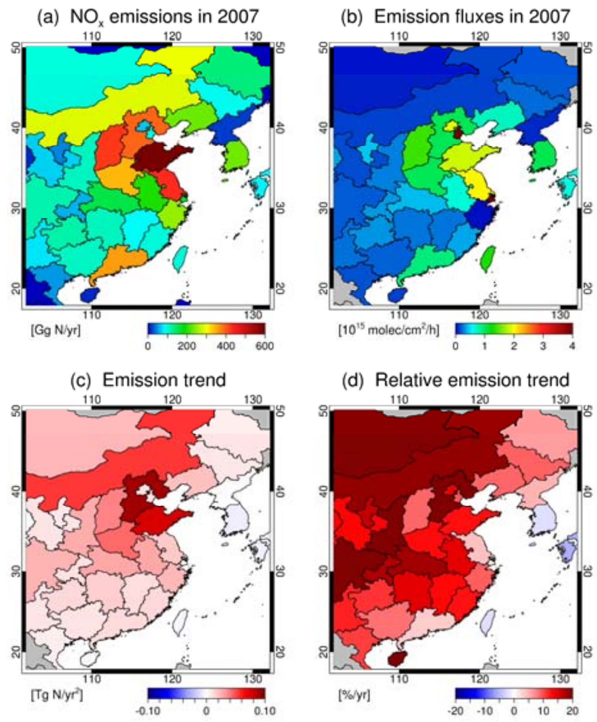
Central in DECSO is the approximation of how NO_2 column concentrations *c* in grid cell *i* depends on emission changes Δ*e* in grid cell *j*:

$$\mathbf{H}_{ij} = \frac{\partial c_i^{NO2}}{\partial e_j^{NOx}} = \gamma_i \frac{a_j}{a_i} \int_0^T \exp(-(T-t)/\tau_j)\Omega_{ij}(t) f_j(t) dt$$

The integral is taken over a time window [0,*T*] between two satellite overpasses (24h). Ω_{ij} describes the transport of NO_x from cell *j* to *i* during [*t*,*T*], based on trajectory analysis. After emission, NO_x is decayed with an effective lifetime τ_j. Modulation factor *f*(*t*) relates the time-dependent emissions *e*(*t*) to the daily averaged emission *e*: *e*(*t*)=*f*(*t*)*e*. The factor a_j/a_i accounts for the difference in grid cell area, and γ_j represents the NO_2/NO_x ratio. Lifetime τ_j is found by minimizing the difference at *t*=*T* between the NO_x columns of the CTM and the NO_x columns calculated with the transport kernel **Ω**. The sensitivities **H** are interpolated to the satellite footprints and are corrected for by the averaging kernel of the retrieval method. For short lived species **H** is a sparse matrix, facilitating a fast calculation of the inversion by a Kalman filter.

NO_x emission trends in East Asia

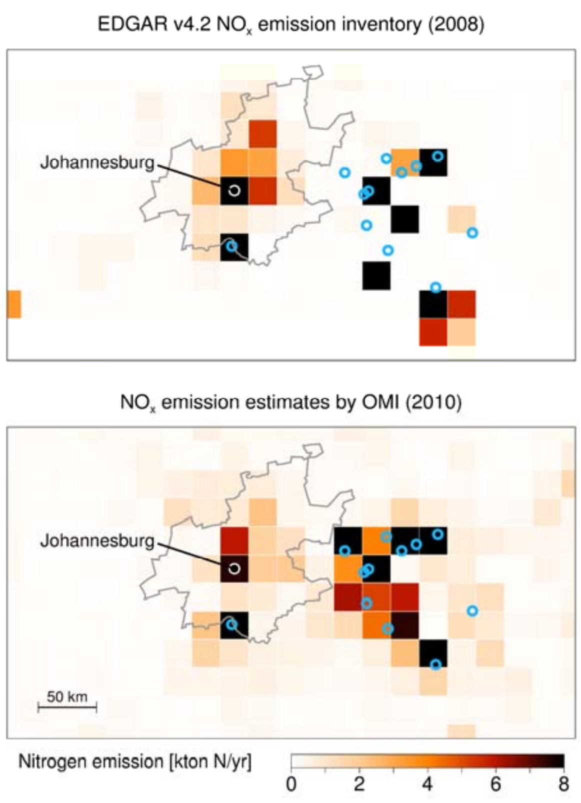




The DECSO algorithm has been implemented with the regional chemical transport model CHIMERE on a 0.25° resolution and ECMWF meteorology. Daily emission estimates based on OMI and GOME-2 both detect the emission drop during the Beijing Olympic Games in 2008, and the steady increase afterwards. Monthly emission series for 2007-2011 reveal strong positive trends in all Chinese provinces, some even over 20% yr^{-1}. Negative trends are found in South Korea, Taiwan and Japan. Seasonal emission peaks in industrialized provinces are found during winter. Natural NO_x emissions dominate in Mongolia; here the emission peak corresponds with the rainy season in summer.

Improvement of emission locations

DECSO is also used to study the emission in the industrialized Highveld in South Africa. The densely populated Gauteng province, containing Johannesburg and Pretoria, is indicated with a grey outline. Blue circles indicate the location of coal-fired power stations, dominating hot spots



of NO_x emissions. The upper panel shows the bottom-up NO_x emission inventory from EDGAR v4.2 for 2008. The lower panel shows the emission estimates from the OMI instrument for 2010. Using satellite data improves the relocation of the emission hot spots.

Conclusion and outlook

DECSO is a new algorithm for fast updates of emissions of short-lived species, taking transport from the source into account. It has been successfully applied to improve the NO_x emission inventory of China and South Africa. It will be applied to other regions (e.g. India and Middle East) and other species (e.g. SO_2).

More information

This work is part of the GlobEmission project, funded by the European Space Agency. DECSO data sets can be found at www.globemission.eu. For more information, please contact Bas Mijling (mijling@knmi.nl) or Ronald van der A (avander@knmi.nl).

References

B. Mijling and R.J. van der A (2012), JGR , Using daily satellite observations to estimate emissions of short-lived air pollutants on a mesoscopic scale

B. Mijling et al. (2013), ACP, Regional nitrogen oxides emission trends in East Asia observed from space