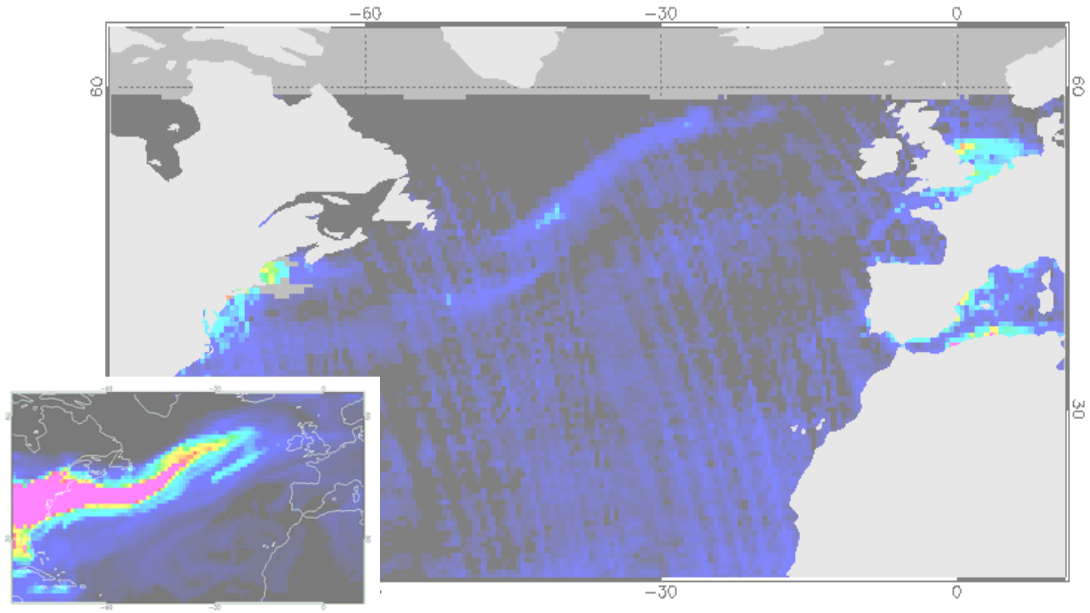
Satellite Data (OMI/NO_2) used in Hemispheric AQ Transport Modelling



Bart Dils
Bas Mijling
Ronald van der A
Ruud Dirksen
Jos van Geffen
Martine De Mazière
Michel van Roozendael

TEMIS

- The Tropospheric Emission Monitoring Internet Service (TEMIS) is part of the Data User Element (DUE) of the European Space Agency (ESA)

- Goal: Provide global concentrations of tropospheric trace gases, aerosol and UV products derived from observations of nadir-viewing satellite instruments such as GOME, SCIAMACHY, OMI and (A)ATSR.
  - **Air pollution monitoring**
  - UV radiation monitoring
  - Support to protocol monitoring
  - Support to aviation control monitoring

- The products are freely available at http://www.temis.nl

Support to Air Pollution Monitoring

- Air quality is a global issue:
  - Emissions on continent A can impact the air quality on continent B

- Monitor (in NRT) long range transport pollution events
  - Good temporal coverage
    - Transatlantic LRT events can take just a few days
  - Good spatial coverage
    - Gaps in the data should be avoided

The OMI instrument

- Ozone Monitoring Instrument
- Dutch-Finnish cooperation
- Launched by NASA on EOS-AURA (2004)

- OMI measures the complete spectrum in the UV/visible wavelength range with
  - ❖ a *high spatial resolution* (up to 13 km × 24 km)
  - ❖ a *daily global coverage* (2600 km wide viewing swath, using a 2D CCD)

The OMI LRT product

- Problem: Clouds!
  - Standard OMI NO_2 product rejects pixels which contain more than 50% clouds
  - This causes substantial datagaps
  - information on the outflow of pollution is lost

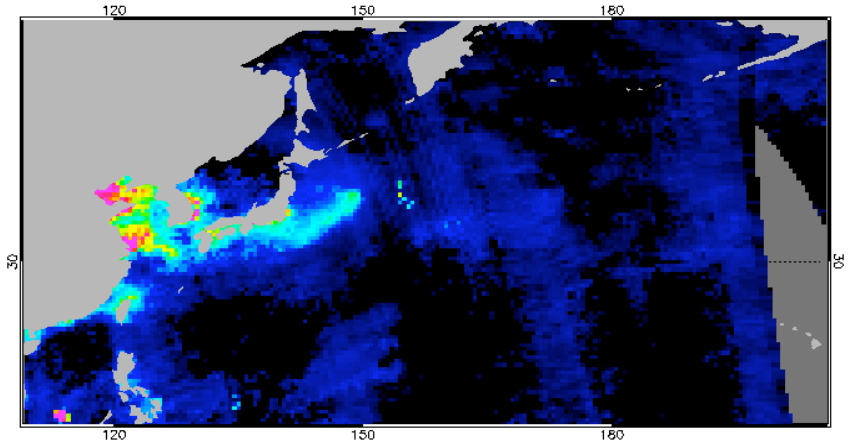
- Solution:
  - Include clouded pixels

- Molecule Criteria:
  - No strong sources near the surface
  - Sufficiently long lifetimes at high altitudes only

$\Rightarrow$ **NO_2!**

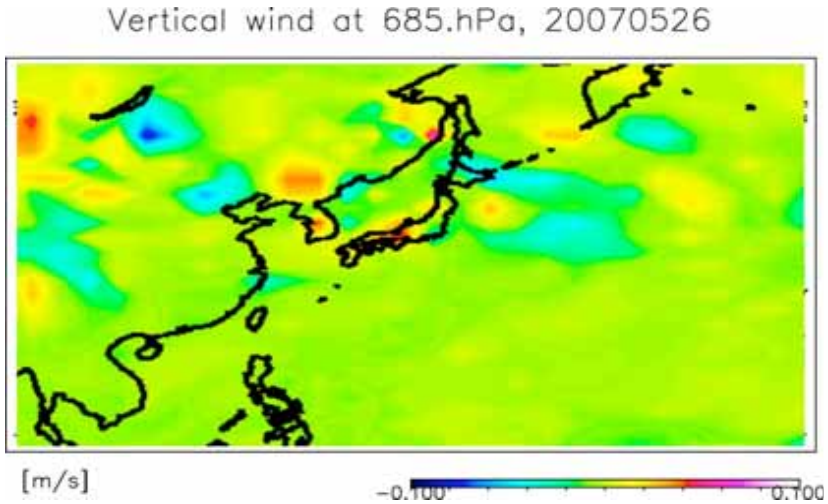
Monitored above oceans only

Basic mechanism of long range transport

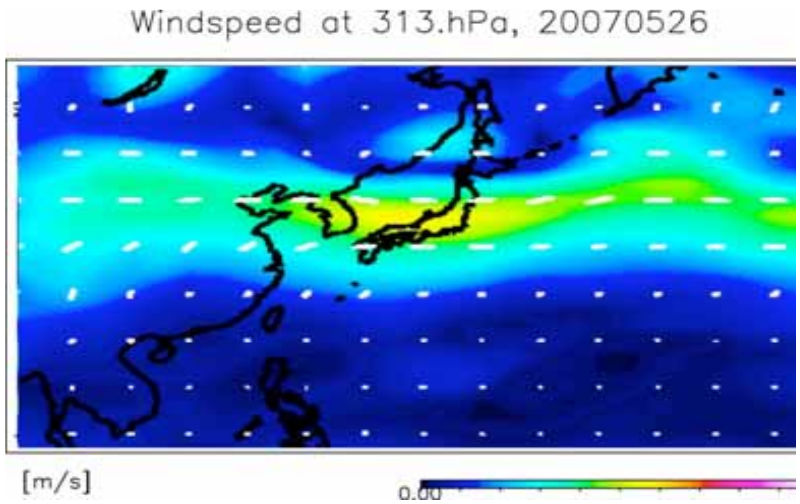


East Asian outflow of tropospheric NO_2 observed by OMI 26 May 2007

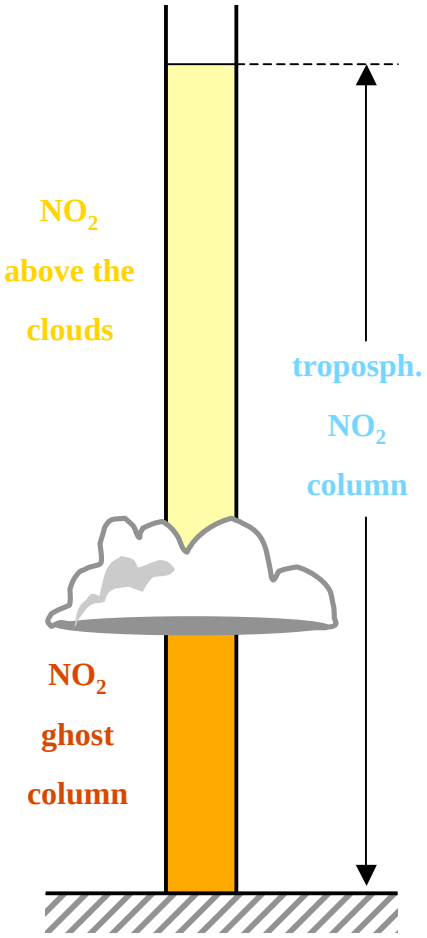
1. Rapid uplift



2. Fast horizontal transport



The OMI NO_2 LRT product



Standard NO_2 product uses assimilated TM4 model data to derive tropospheric slant column and the Air Mass Factor

$$N_v = \frac{N_{sl} - N^*_{sl,strat}}{AMF} \qquad AMF = \frac{N^*_{sl,trop}}{N^*_v}$$

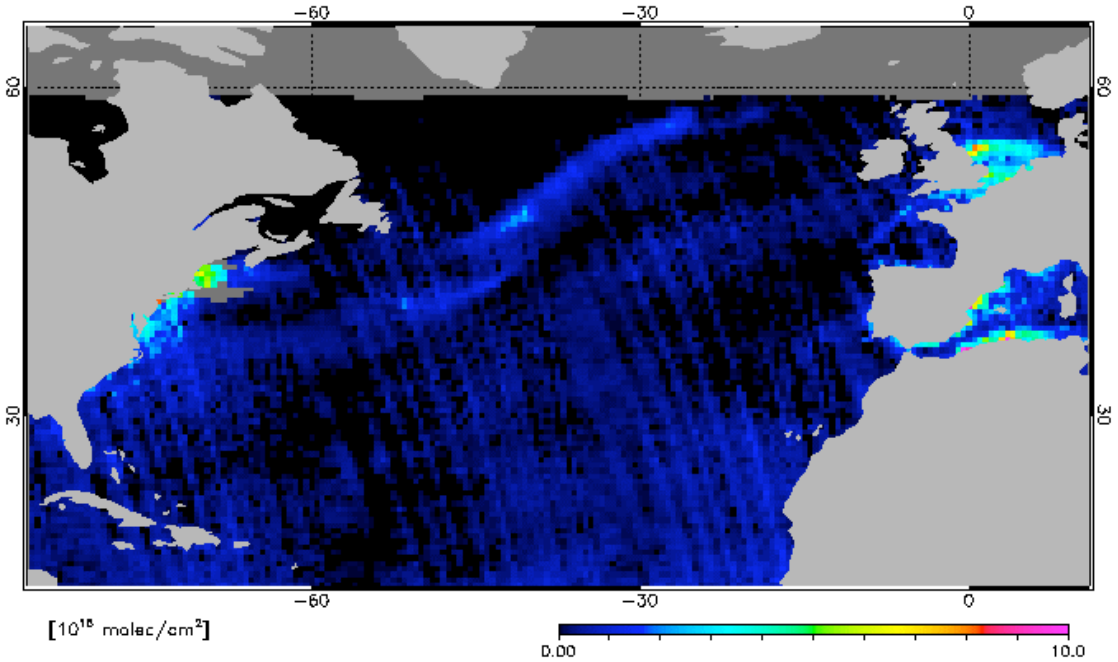
instead of the vertical column N_v, we now calculate the observable column N_{obs}

$$N^*_{obs} = w(N^*_v - N^*_{ghost}) + (1-w)N^*_v$$

$$N_{obs} = \frac{N_{sl,trop}}{AMF_{obs}} = \frac{N_{sl,trop}}{AMF}\left(1 - w\frac{N^*_{ghost}}{N^*_{trop}}\right)$$

Transport or not?

OMI, 14 Jan 2007



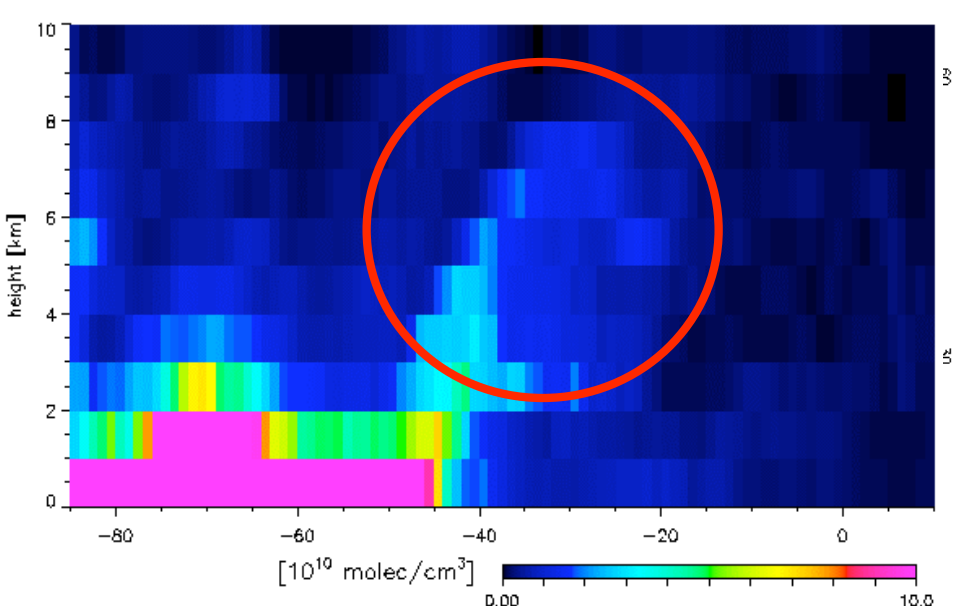
* Transport simulations can fill in the gaps & add value to the observations
* Focus on spatial distribution and source allocation
* Lagrangian particle distribution model FLEXPART
  developed by Andreas Stohl

FLEXPART:: Input & Output

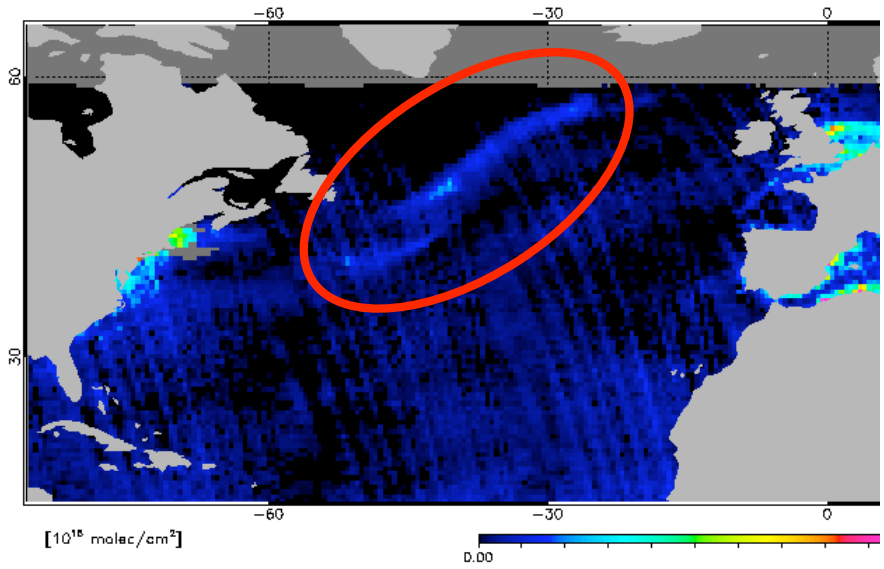
- In: Windfield data from ECMWF (1°x1°, 3hourly)
- In: NOx emission data from EDGAR 3.2 FT2000
  - Yearly mean 1°x1°, emission grids within 110°E to 50°E & 15°N to 65°N
- In: FLEXPART control parameters
  - Atmospheric half-lifetime = 2 days
- Out: 1°x1° lat-lon grid, 10 vertical levels (1km resolution)
- Out: 3h averages every 3 hours (15:00UT corresponds with the transatlantic overpass-time of OMI)

OMI observation / FLEXPART simulation

Flexpart, 14 Jan 2007



OMI, 14 Jan 2007



FLEXPART overestimates NO_2 in boundary layer

OMI less sensitive to NO_2 in lower troposphere

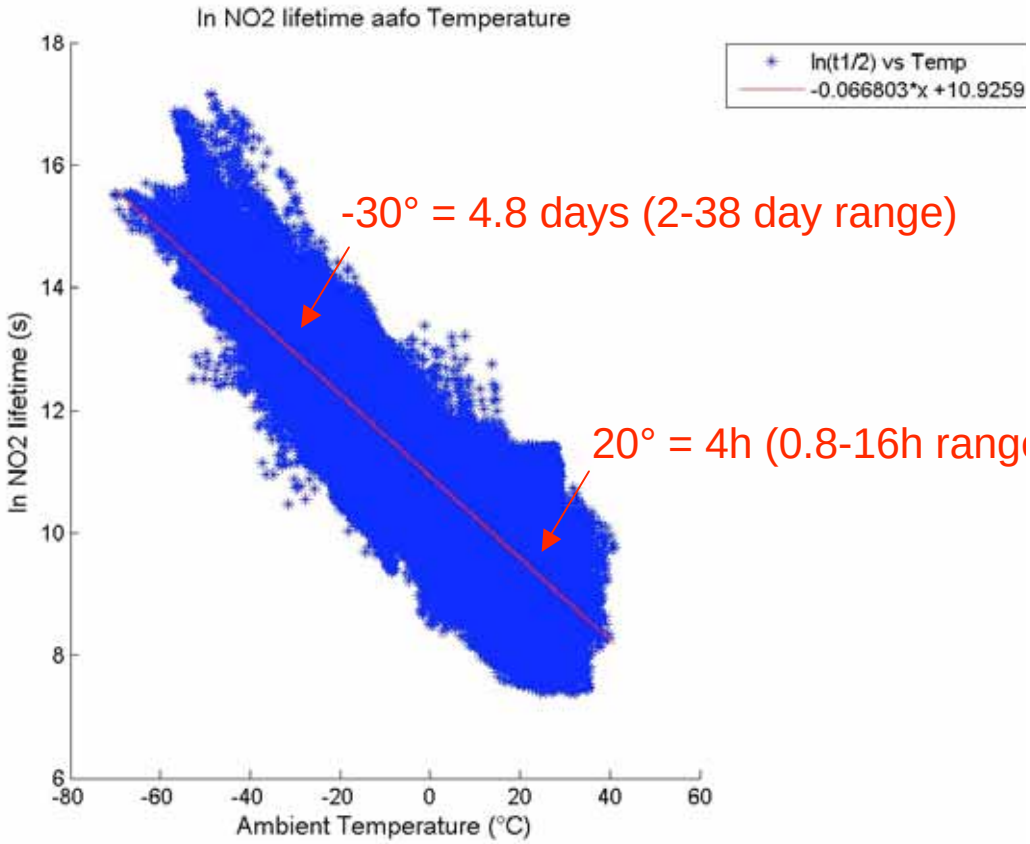
Added Temperature dependence on the NO_2 half life time!!

NO_2 lifetime aafo Temp

- $t_{1/2}(s)=55598*\exp(-0.066803*T(°C))$

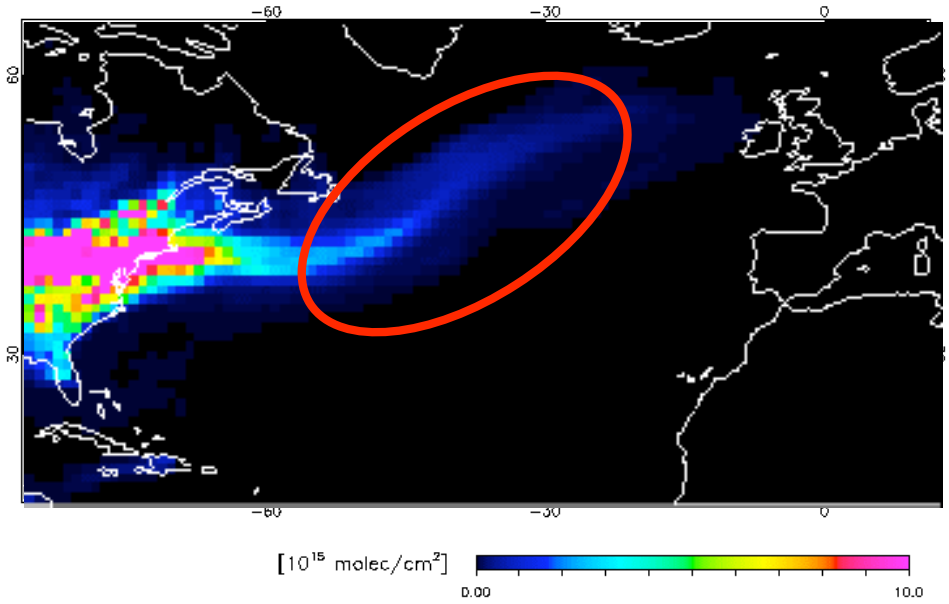
*Parameters have been obtained from the IMAGES model (Muller and Stavrakou, Atmos. Chem. Phys., 2005)

*Still significant variability, but a far better marker than the fixed lifetime of 2 days

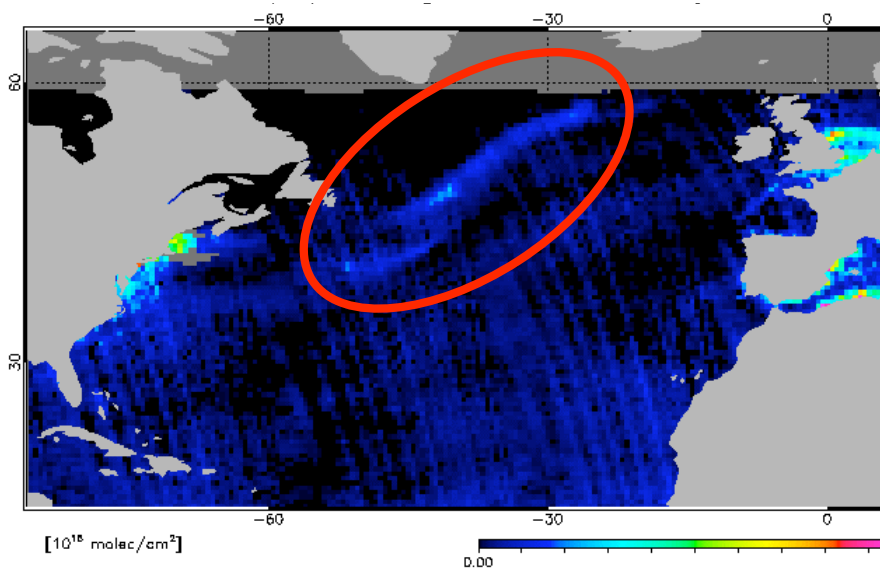


OMI observation / FLEXPART simulation

Flexpart, 14 Jan 2007



OMI, 14 Jan 2007



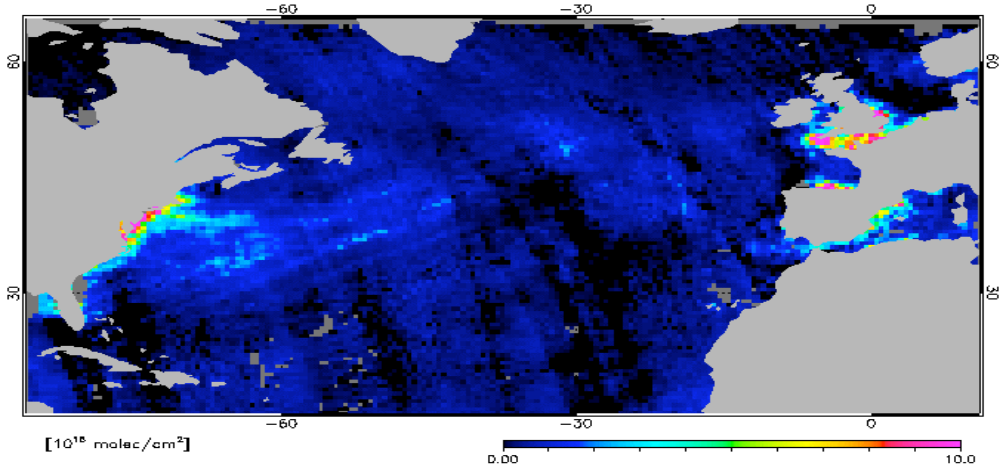
FLEXPART overestimates NO_2 in boundary layer

OMI less sensitive to NO_2 in lower troposphere

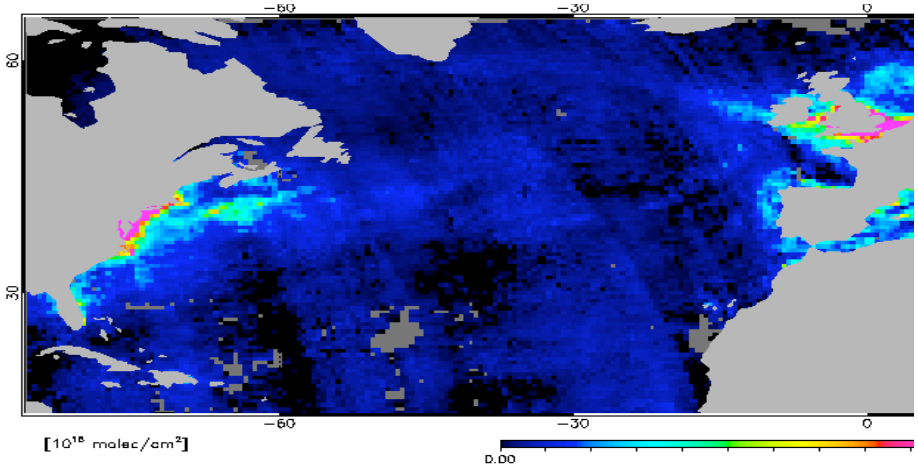
Added Temperature dependence on the NO_2 half life time!!

Example: Backflow from Europe

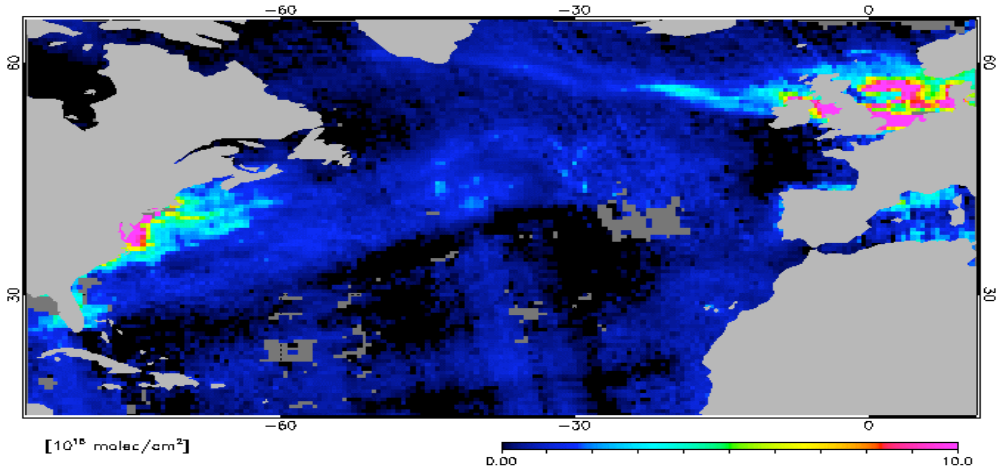
6-2-2007



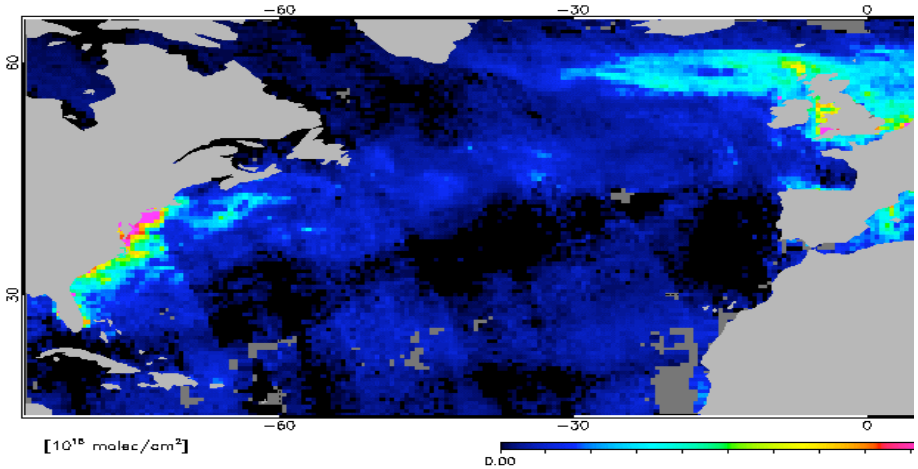
7-2-2007



8-2-2007

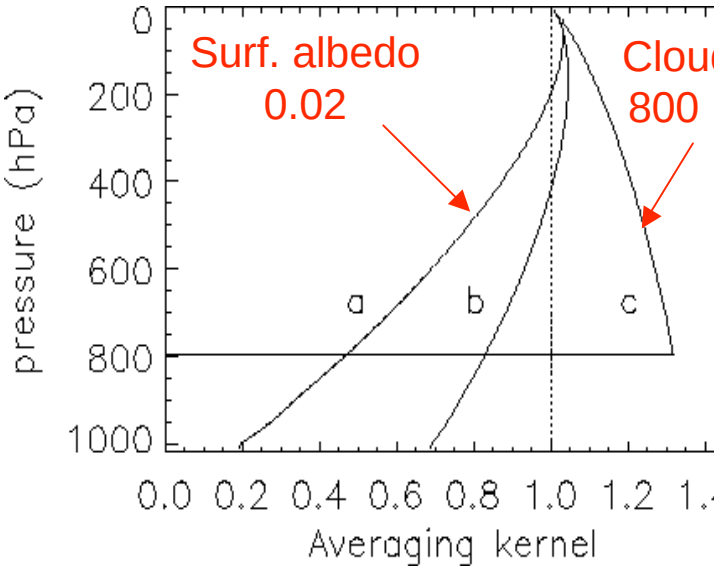


9-2-2007



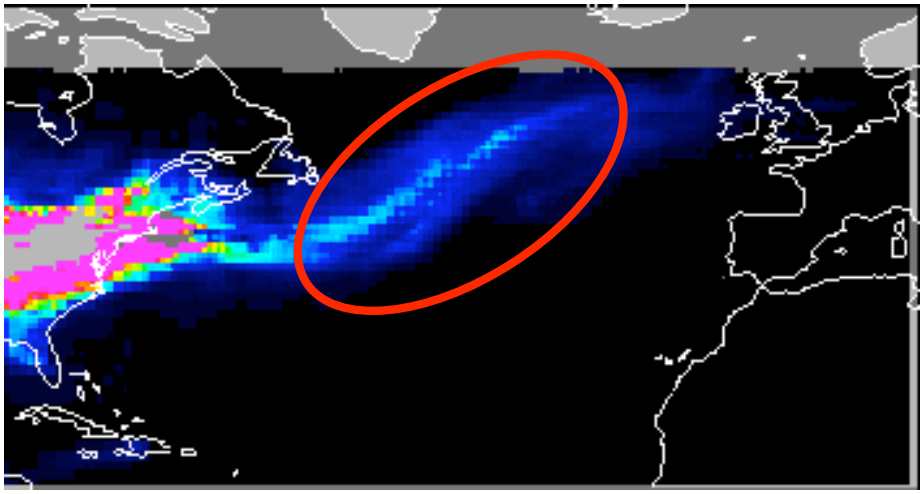
Comparison

- OMI data combines clouded and clear sky data:
  - Information content differs greatly from one pixel to the other
  - Include OMI NO2 Averaging Kernels to the TEMIS dataset
- For practical purposes we started the Flexpart-OMI comparison using the uncorrected OMI output but applying the a-priori and AVKs to the Flexpart data

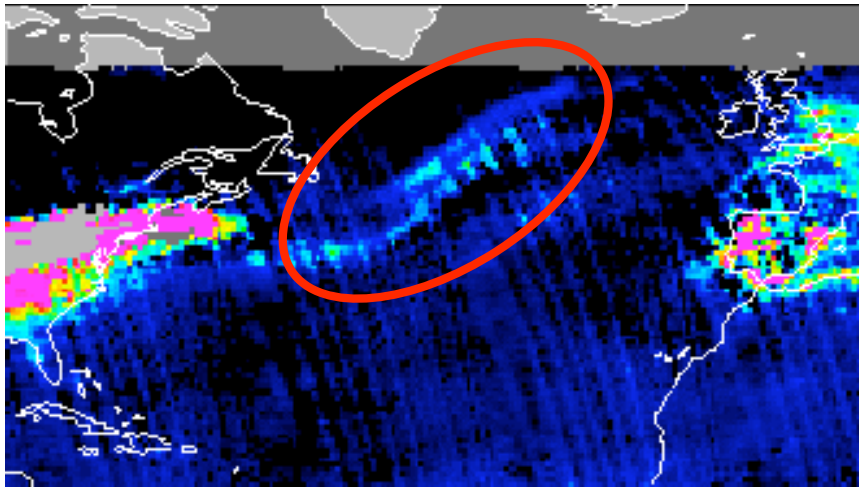


OMI observation / FLEXPART simulation

Flexpart, 14 Jan 2007

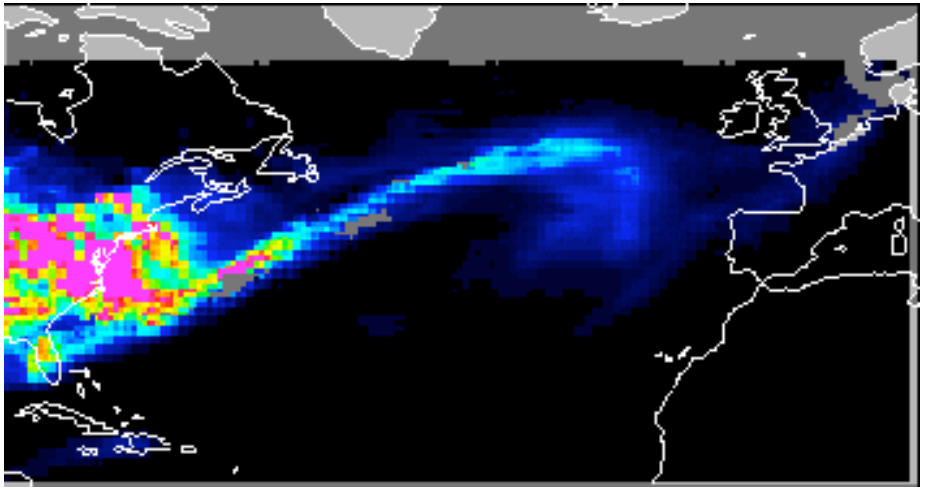


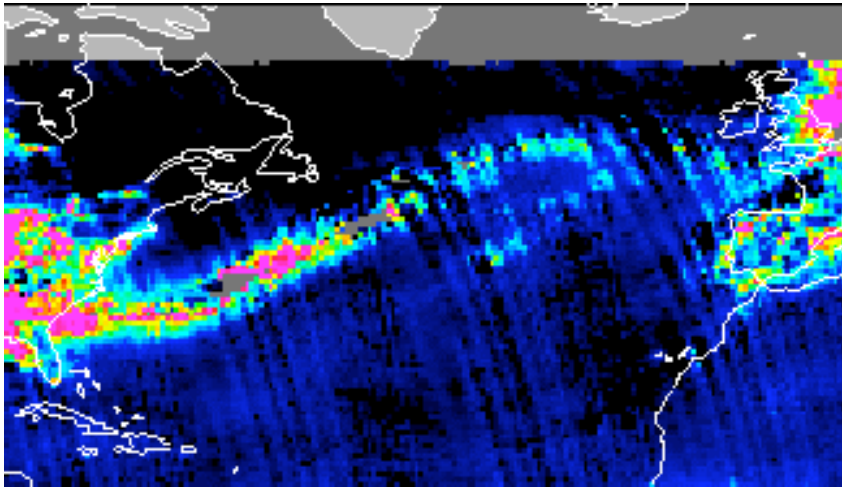
OMI, 14 Jan 2007



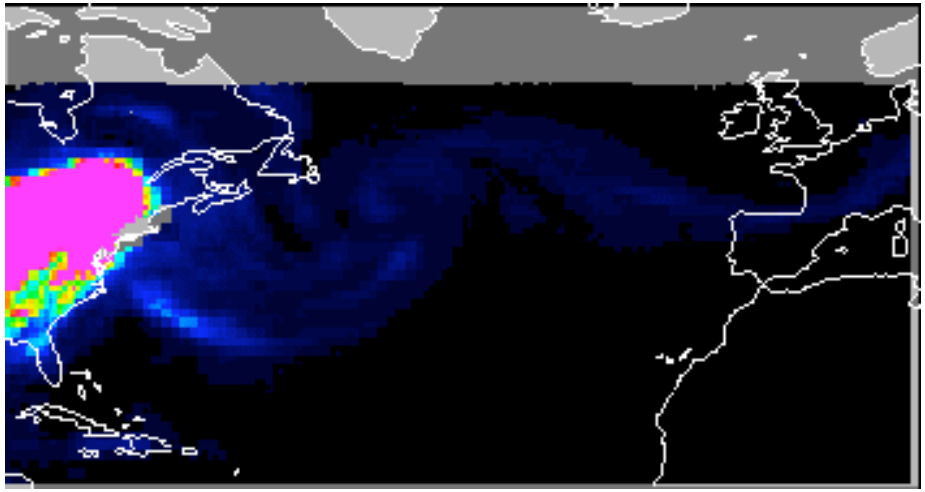
Application of OMI Averaging Kernels to the FLEXPART output

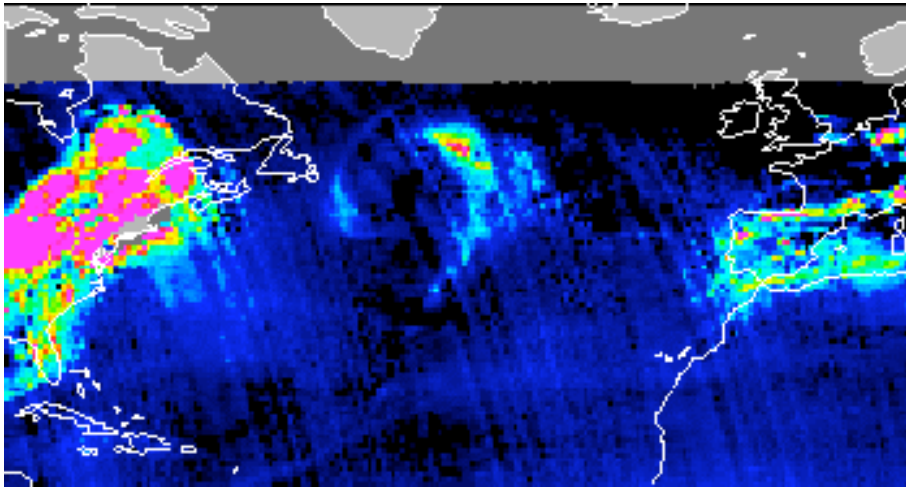
Other examples: 17-01-07



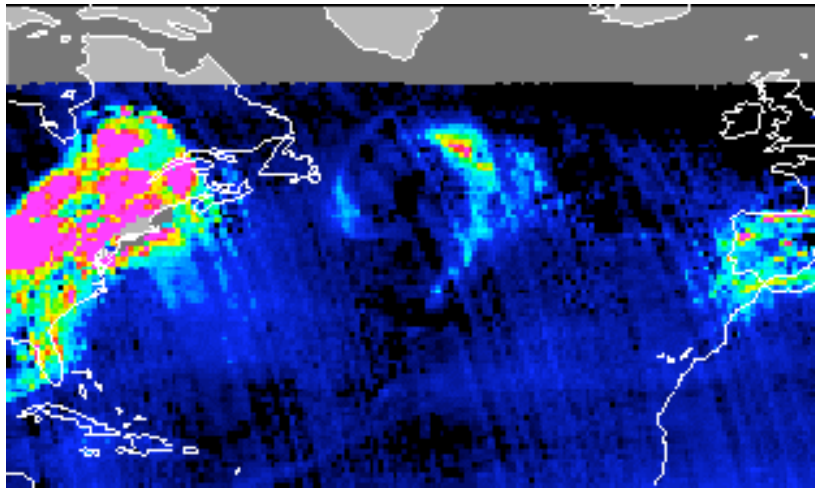


Other examples: 01-01-07





Other examples: 01-01-07



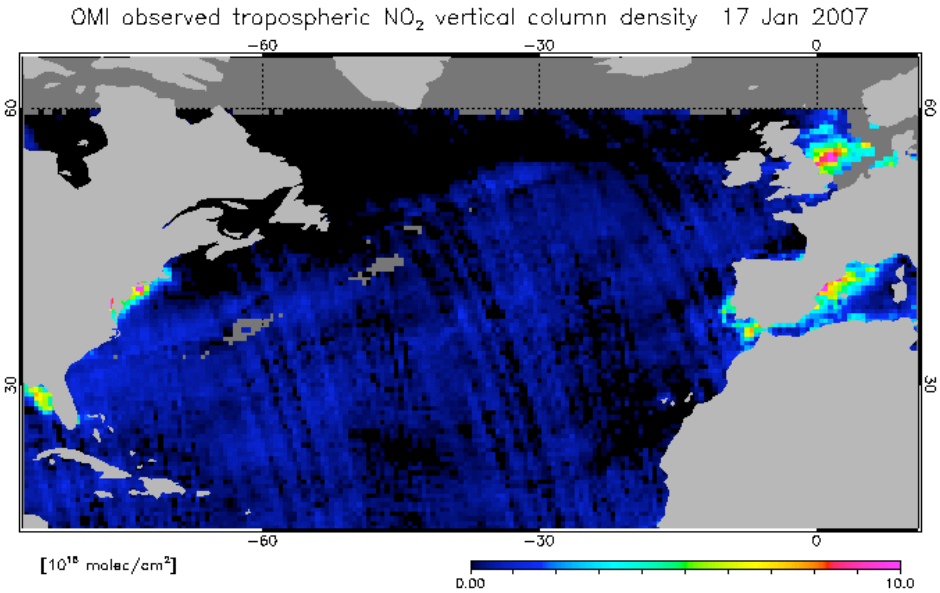
Lightning data from LIS (Lightning Imaging Sensor)

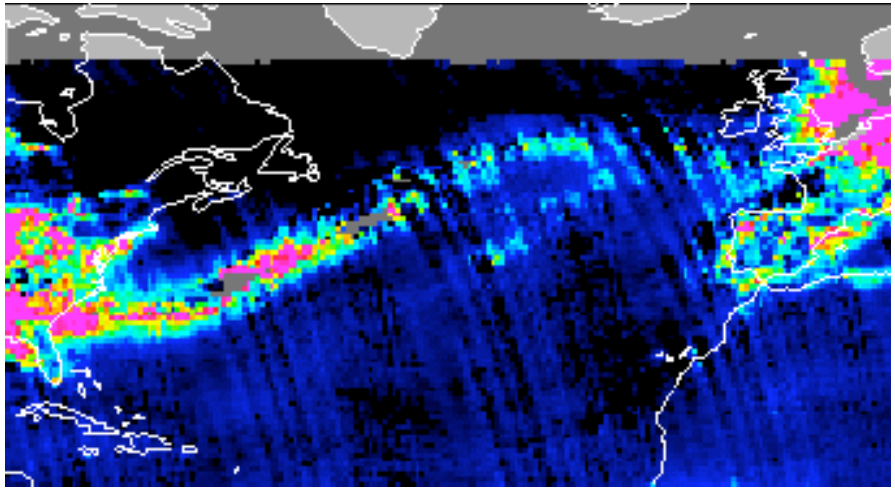
Alas no data above +39.5°N

Strong lightning spots visible at tail of our NO2 signature

Comparison

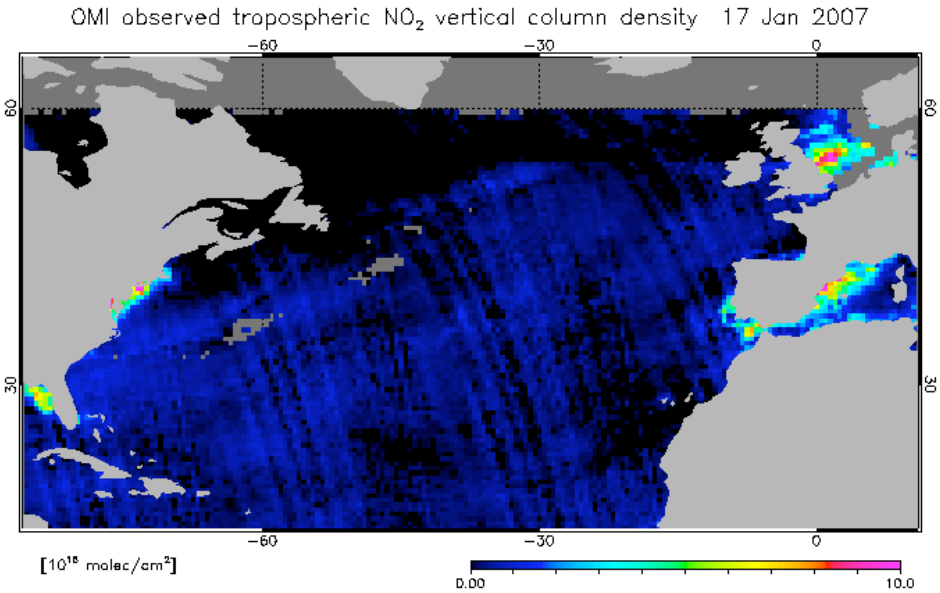
- A more quantitative analysis needs to follow but initial results are encouraging
- At some events large difference between AMF-corrected and standard OMI

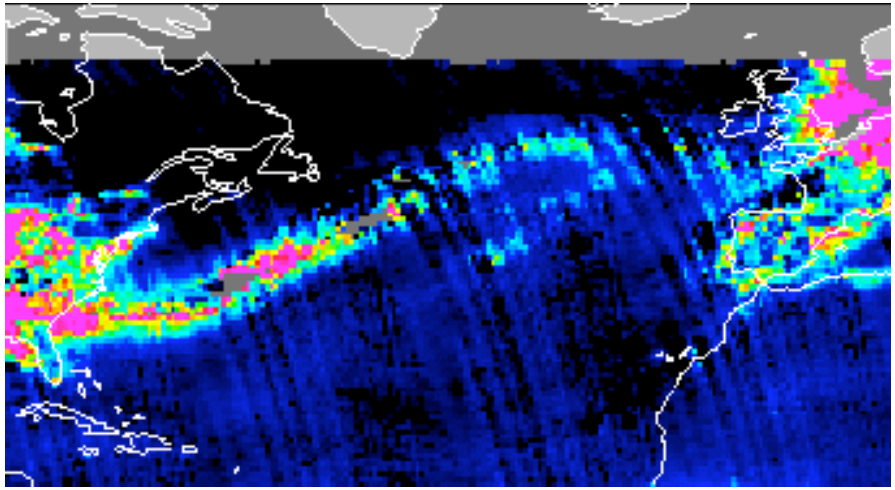




Comparison

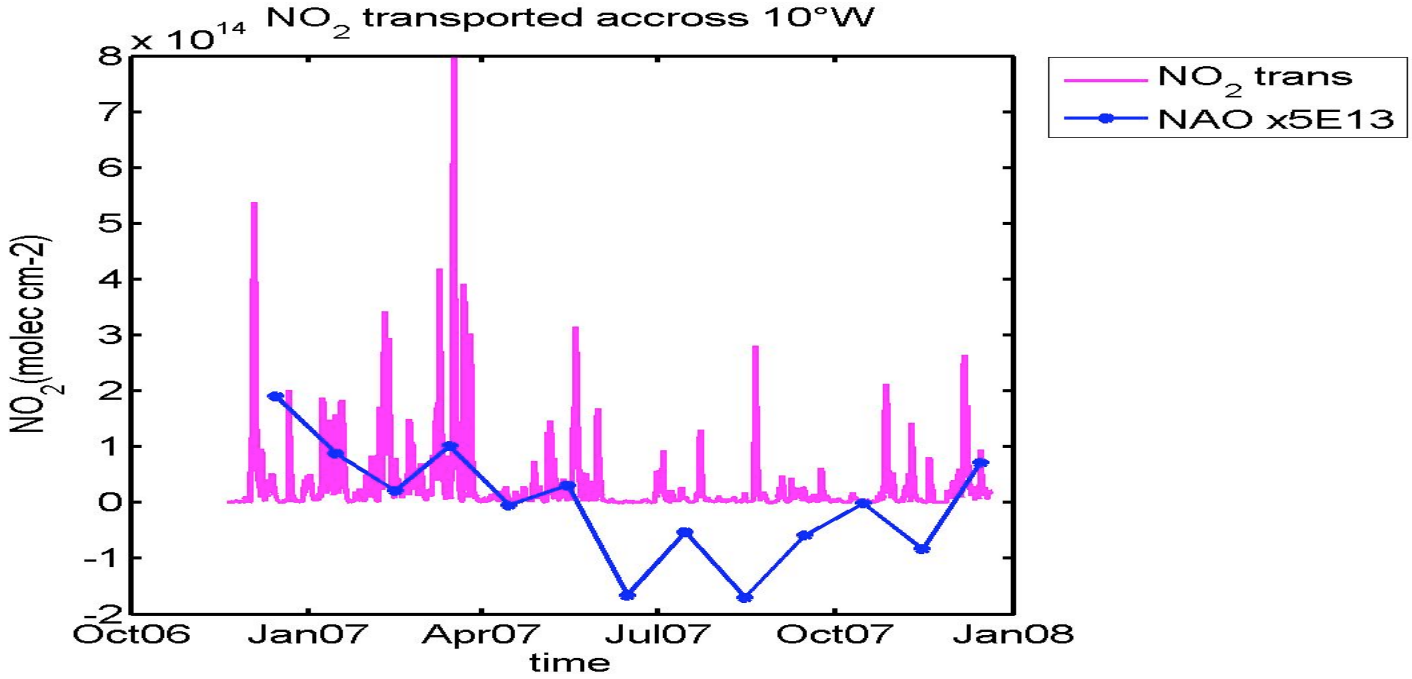
- Flexpart still shows NO2, below cloud altitudes. AMF correction too strict?
- Or is the uncorrected OMI output a pure cloud scene anomaly?





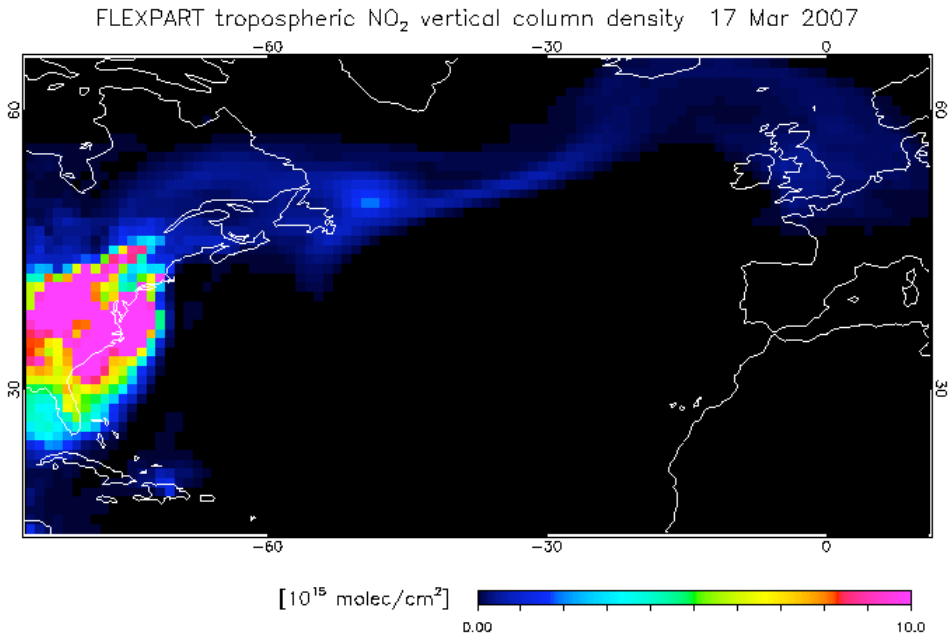
North Atlantic Oscillation

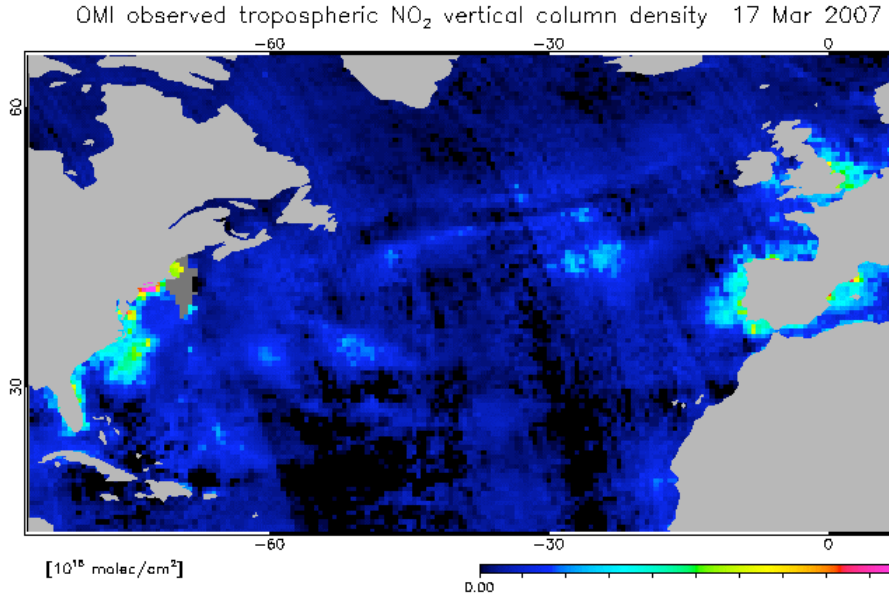
- Calculated the highest Flexpart total column East of 10°W
- North Atlantic Oscillation (NAO) is defined as the normalized pressure difference between a station on the Azores or Gibraltar and one on Iceland



Strongest transport event 2007 (17-03)

- Highest Flexpart total column value is only $8x10^{14}$ molec/cm^2!!



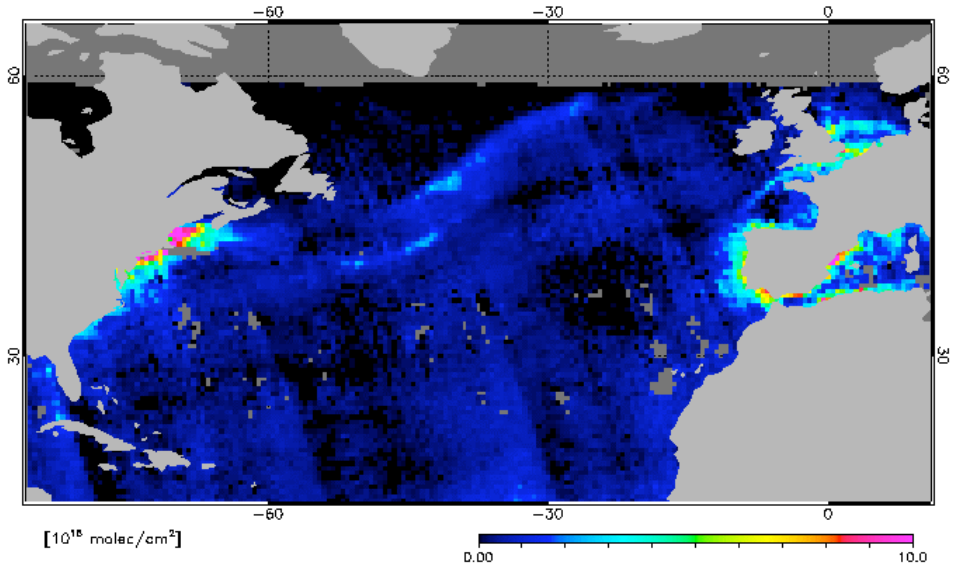


- Entire event is drowned in background noise (still collection 2 data)

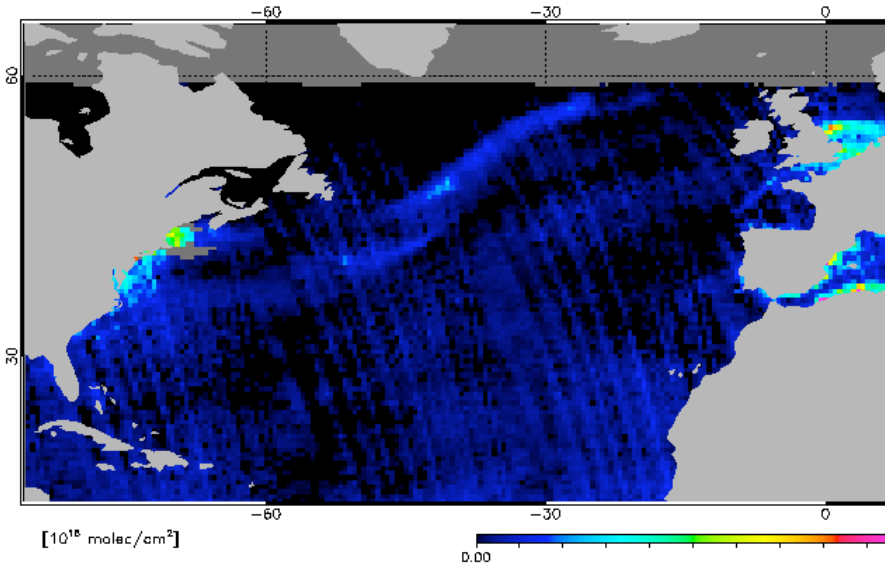
Other issues

- Destriping improved but not perfect

Collection 2



Collection 3



- Since June 25th, 2007: OMI suffers from an increasing number of row anomalies.

  Corrections for this effect are currently under investigation

To do/Wish list

- Further implementation+improvement of destriping filter
- Detailed OMI-Flexpart comparison taking into account the AVKs
- Make AVKs available

- Finding solution to row anomalies (feasible?)
- Other satellite instruments (GOME-2)
- Other areas (outflow from East Asia, South Africa, …)
- Other species

Flexpart improvements

- Implementation of Flexpart 8.0
  - Allows crude OH chemistry
- Flexpart NO_2 half lifetime improvements
  - Diurnal variability
- Improved emission fields
- Forecasting using NCEP-GFS data

Conclusions

- A NRT dataset dedicated to the trans-Atlantic transport of NO2 is up and running. http://www.temis.nl/lrt
- Agreement with Flexpart is encouraging

- Detection limit is probably insufficient to monitor a complete US to Europe event
- Striping and row anomalies
- Investigate if AMF correction is too strict

Other examples: 01-01-07