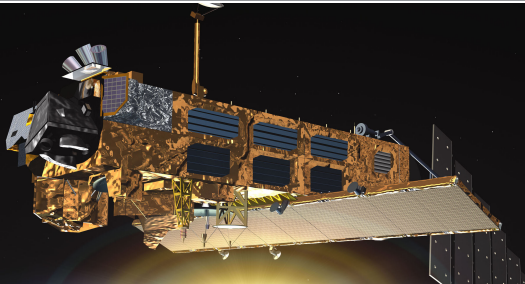


Nitric oxide observations 2008/2009 with SCIAMACHY

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nominal mode

data from 2003 until 04/2012

- limb scans $\sim -3 \dots 93$ km
- continuous measurements with few outages

MLT mode

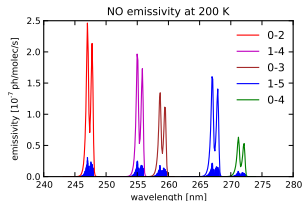
from 07/2008 until 04/2012:

mesosphere and lower thermosphere (MLT) mode

- limb scans $\sim 50 \dots 150$ km
- 15 orbits every 2 weeks
- in coordination with MIPAS upper atmosphere (UA) mode
approx. once every 30 days

NO gamma bands (UV)

- electronic transition
 $A^2\Sigma^+ \rightarrow X^2\Pi$
- also used by SNOE
(1998–2003)
→ NOEM model



resonant transitions

- excitation and emission at the same energy
- ⇒ possible re-excitation
- self-absorption
- examples ($v' \rightarrow v''$):
 $1 \rightarrow 0, 2 \rightarrow 0$

non-resonant transitions

- excitation and emission at different energies
- no re-excitation
- self-absorption negligible
- examples ($v' \rightarrow v''$):
 $0 \rightarrow 1, 0 \rightarrow 2, 1 \rightarrow 4$

radiative transfer equation

$$I_\nu = \int_{\text{LOS}} \left(x(s) \gamma_\nu(s) F_\nu(s) + \underbrace{\sigma_R \rho_{\text{air}}}_{\text{bg fit}} \right) e^{-\tau_\nu} ds \approx \gamma F \underbrace{\int_{\text{LOS}} x(s) ds}_{\text{scd}}$$

slant column densities (scd) \rightarrow number density

- γ : emissivities (calculated, cf. Stevens et al.)
- F : solar irradiance, SAO 2010 reference spectrum
- x : number density

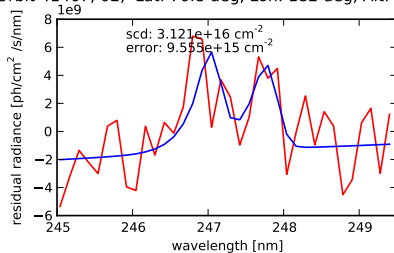
transitions and wavelengths

- $0 \rightarrow 2$: excitation ~ 225 nm, emission ~ 247 nm
- $1 \rightarrow 4$: excitation ~ 214 nm, emission ~ 255 nm
- $1 \rightarrow 5$: excitation ~ 214 nm, emission ~ 267 nm

radiative transfer equation

$$I_V = \int_{\text{LOS}} \left(x(s) \gamma_V(s) F_V(s) + \underbrace{\sigma_{RQ_{\text{air}}}}_{\text{bg fit}} \right) e^{-\tau_V} ds \approx \gamma F \underbrace{\int_{\text{LOS}} x(s) ds}_{\text{scd}}$$

Orbit 41467, 02, Lat: 70.8 deg, Lon: 182 deg, Alt: 106 km.



regularisations

- **2d-retrieval** of orbit
- 3d ray tracing
- ozone and air absorption correction
- regularisation:
 - vertical – $\lambda_{\text{alt}}, \mathbf{R}_{\text{alt}}$
 - horizontal – $\lambda_{\text{lat}}, \mathbf{R}_{\text{lat}}$
- empirically tuned for resolution

⇒ minimise:

$$\|\mathbf{K}\mathbf{x} - \mathbf{y}\|_{\mathbf{S}_y^{-1}}^2 + \|\mathbf{x} - \mathbf{x}_a\|_{\mathbf{S}_a^{-1}}^2 + \lambda_{\text{alt}} \|\mathbf{R}_{\text{alt}}(\mathbf{x} - \mathbf{x}_a)\|^2 + \lambda_{\text{lat}} \|\mathbf{R}_{\text{lat}}(\mathbf{x} - \mathbf{x}_a)\|^2$$

a priori input

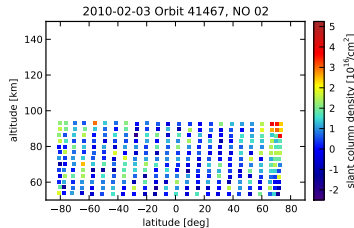
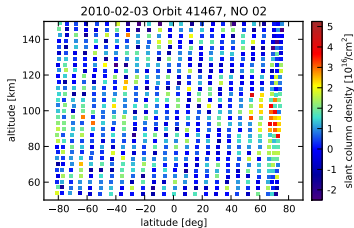
- NOEM model, based on SNOE data (1998–2003),
only from 100 km to 150 km
- null a priori
- covariance $\mathbf{S}_a = \lambda_a \mathbb{I}$

iterative solution

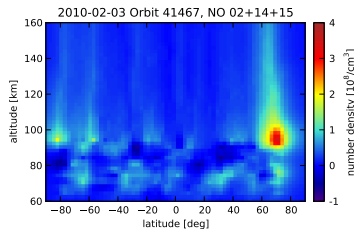
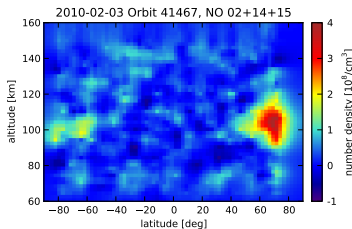
$$\mathbf{R} := \mathbf{S}_a^{-1} + \lambda_{\text{alt}} \mathbf{R}_{\text{alt}}^T \mathbf{R}_{\text{alt}} + \lambda_{\text{lat}} \mathbf{R}_{\text{lat}}^T \mathbf{R}_{\text{lat}}$$
$$\mathbf{x}_{i+1} = \mathbf{x}_i + \left(\mathbf{K}^T \mathbf{S}_y^{-1} \mathbf{K} + \mathbf{R} \right)^{-1} \cdot \left[\mathbf{K}^T \mathbf{S}_y^{-1} (\mathbf{y} - \mathbf{y}_i(\mathbf{x}_i)) + \mathbf{R}(\mathbf{x}_a - \mathbf{x}_i) \right]$$

MLT NO number density

slant column densities



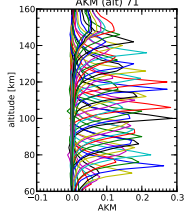
number densities



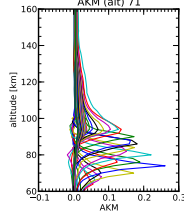
MLT vertical resolution

averaging kernel matrix elements

20100203: Orbit 41467, NO 02+14+15
AKM (alt) 71

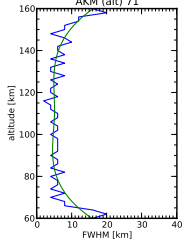


20100203: Orbit 41467, NO 02+14+15
AKM (alt) 71

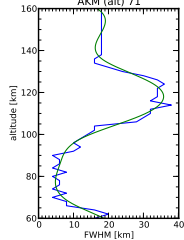


vertical resolution

20100203: Orbit 41467, NO 02+14+15
AKM (alt) 71

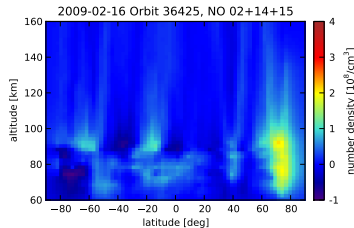
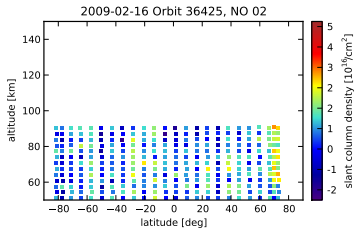


20100203: Orbit 41467, NO 02+14+15
AKM (alt) 71



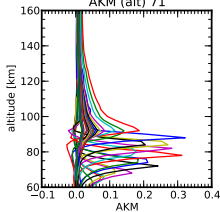
Nominal mode NO number density

densities

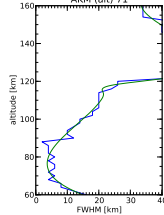


resolution

20090216: Orbit 36425, NO 02+14+15
AKM (alt) 71

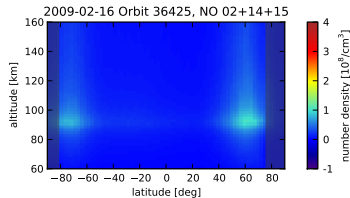
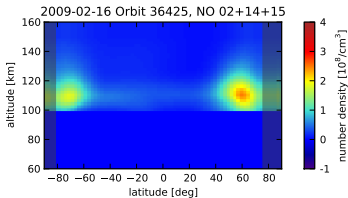


20090216: Orbit 36425, NO 02+14+15
AKM (alt) 71

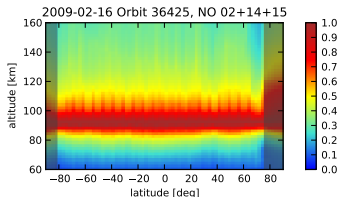


Thermospheric column

AKM mapped a priori



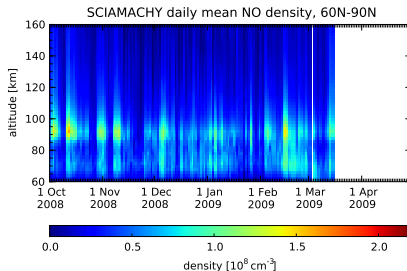
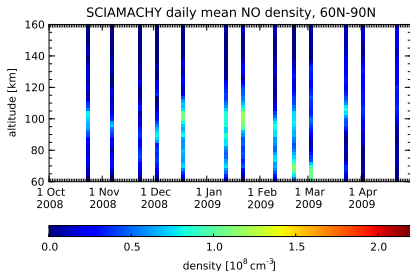
correction factor $n_{\text{NO}}(\text{lat}) / \max(n_{\text{NO}}(\text{lat}))$



NO time series 2008/2009

daily means 60°N–90°N

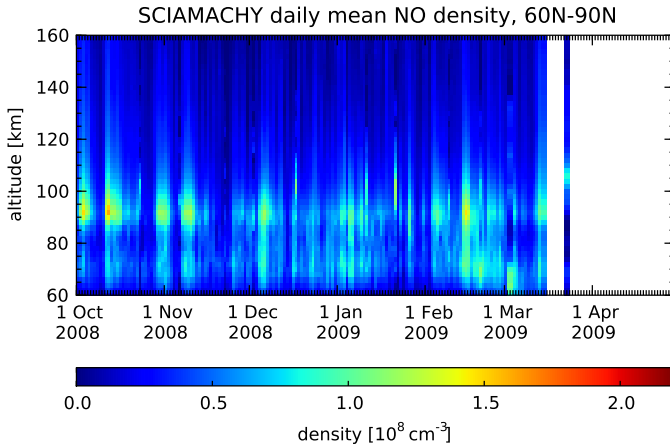
SCIAMACHY MLT mode vs nominal mode number density



NO time series 2008/2009

daily means 60°N–90°N

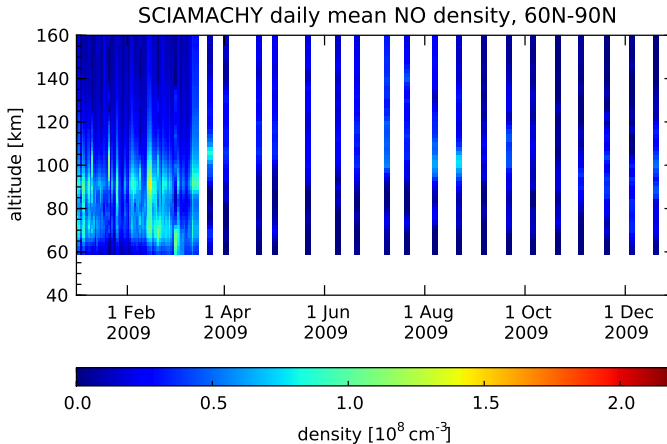
SCIAMACHY MLT + nominal combined



NO density 2009

daily means 60°N–90°N

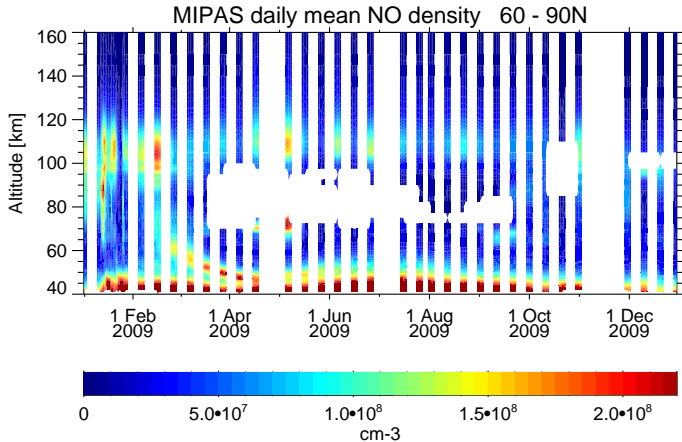
SCIAMACHY MLT + nominal combined



NO density 2009

daily means 60°N–90°N

MIPAS UA data (courtesy of the MIPAS collaboration)



Conclusion

- NO retrieval from SCIAMACHY limb scans
 - MLT mode 60... 160 km
 - nominal mode (useful 60... 90 km)
- vertical resolution 5... 10 km
 - MLT: 70... 140 km
 - nominal: 70... 90 km
- time series for winter 2008/2009: NO enhancement below 80 km

Outlook

- SCIAMACHY nominal mode retrieval \Rightarrow daily data 2002–2012
- dis-entangle local production from downward transport
- correlation with solar indices ($f_{10.7}$, A_p , K_p , $L-\alpha$, ...)