Methods of atomic oxygen and ozone retrieval from observations of the O_2 dayglow emissions in the MLT region

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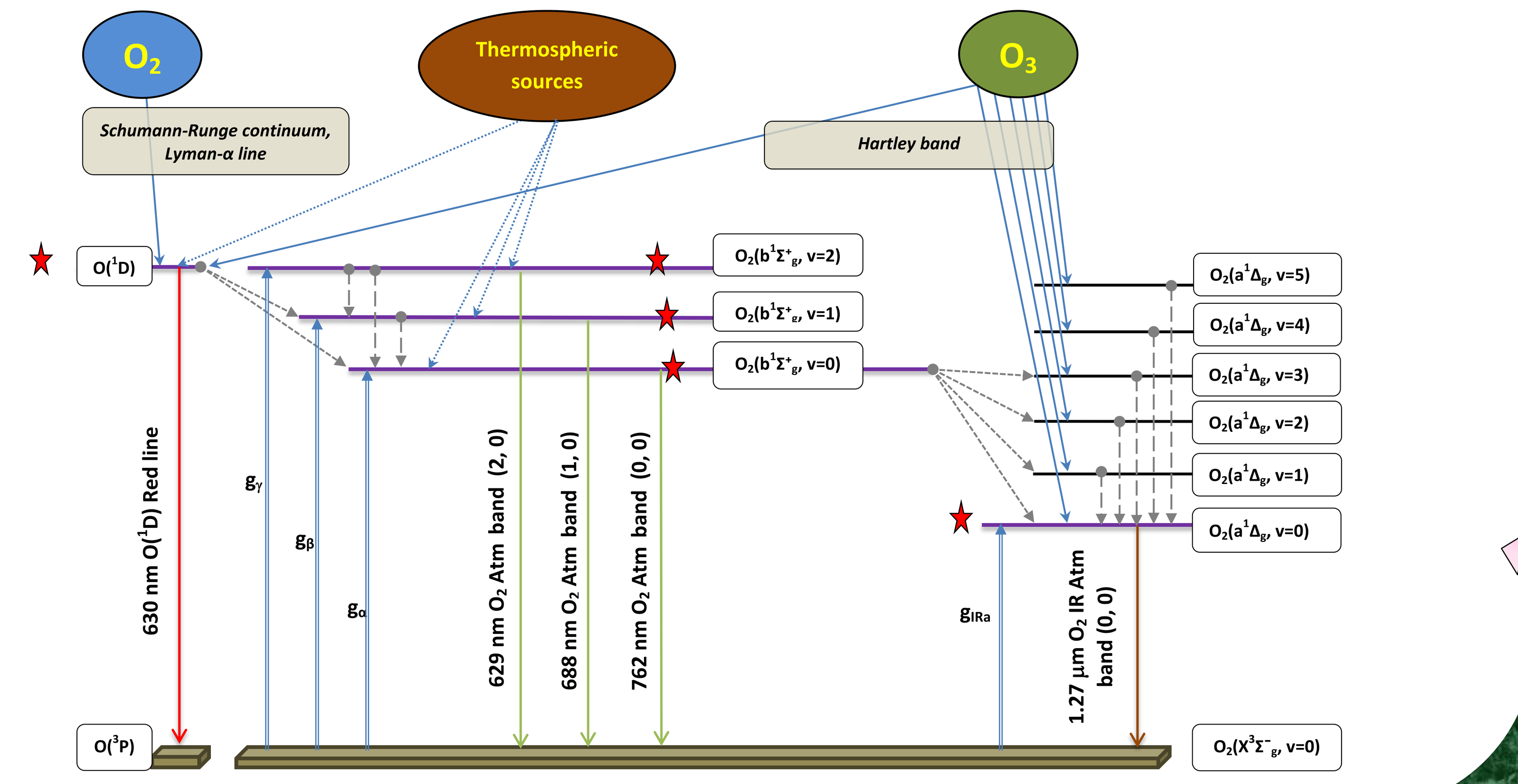
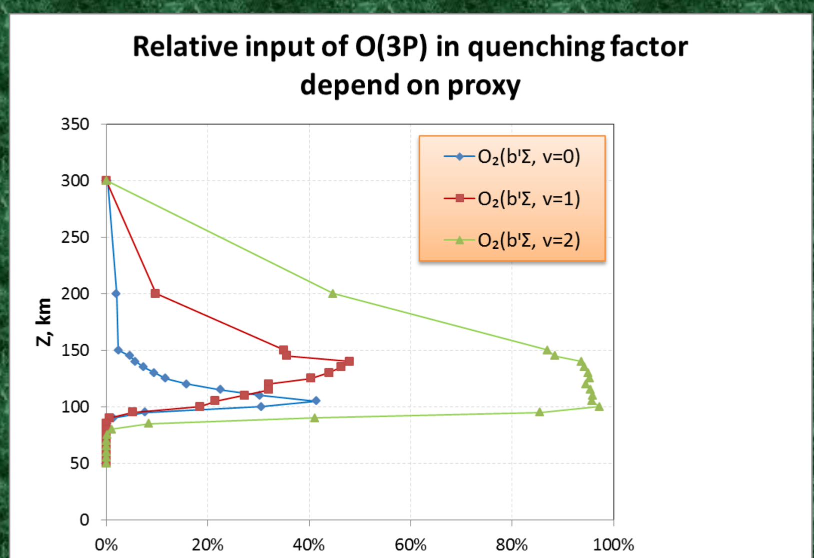
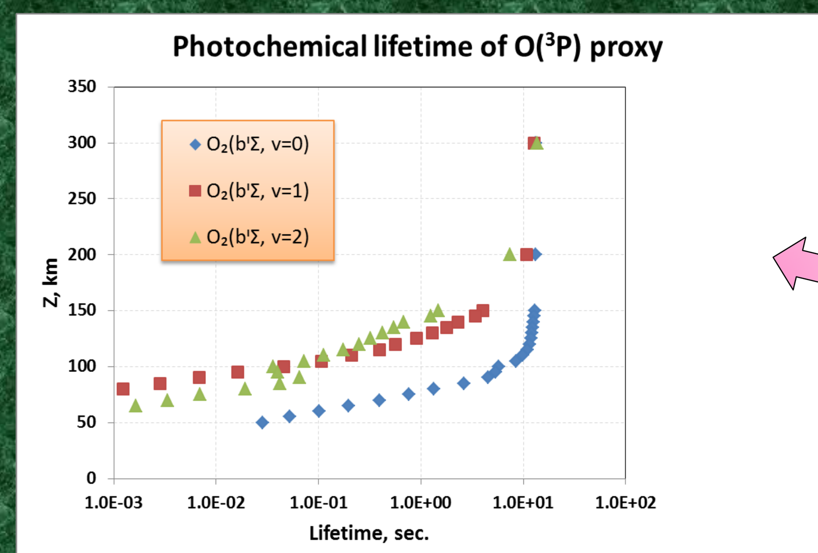
YM-2011 - model of electronic vibrational kinetics of excited products of O_3 and O_2 photolysis in MLT of the Earth







Sensitivity coefficient of proxy to variation parameter (after sign ;)	ξ	* - proxy type for retrieval of [O(³P)]				
		O(¹D)	$O_2(b^1\Sigma^+, v=2)$	$O_2(b^1\Sigma^+, v=1)$	$O_2(b^1\Sigma^+, v=0)$	$O_2(a^1\Delta, v=0)$
S(*;T_n)		++	+	++	+	+
S(*;K(O(¹D);O(³P)))	±0.27	+++	–	++	++	++
S(*;K(O(¹D);O_2))	±0.08	++	–	++	+++	++
S(*; F(O(¹D) → $O_2(b^1\Sigma^+)$))	±0.125	–	–	+++	++	++
S(*;K(O(¹D); N_2))	±0.10	+++	–	++	+++	++
S(*;K(O(¹D); O_3))	±0.20	+	–	+	+	+
S(*;K(O(¹D); CO_2))	±0.15	+	–	+	+	+
S(*;K(O_2(b, v=2); O(³P)))	±0.30	–	+++	+	+	+
S(*;K(O_2(b, v=2); O_2))	±0.07	–	+	+	+	+
S(*;K(O_2(b, v=2); N_2))	±0.40	–	+	+	+	+
S(*;K(O_2(b, v=2); O_3))	±0.40	–	+	+	+	++
S(*;K(O_2(b, v=2); CO_2))	±0.30	–	+	+	+	+
S(*;K(O_2(b, v=1); O(³P)))	+0.18/-0.29	–	–	++	++	+
S(*;K(O_2(b, v=1); O_2))	±0.04	–	–	++	+	+
S(*;K(O_2(b, v=1); N_2))	n/d	–	–	+	+	+
S(*;K(O_2(b, v=1); O_3))	n/d	–	–	+	+	+
S(*;K(O_2(b, v=1); CO_2))	n/d	–	–	+	+	+
S(*;K(O_2(b, v=0); O(³P)))	±4	–	–	–	+++	+++
S(*;K(O_2(b, v=0); O_2))	±0.50	–	–	–	+	+
S(*;K(O_2(b, v=0); N_2))	±0.11	–	–	–	+	+
S(*;K(O_2(b, v=0); O_3))	±0.15	–	–	–	+	+
S(*;K(O_2(b, v=0); CO_2))	±0.20	–	–	–	+	+
S(*;K(O_2(a, v≥2); O(³P)))	n/d	–	–	–	–	+
S(*;K(O_2(a, v≥2); O_2))	±0.11	–	–	–	–	+
S(*;K(O_2(a, v≥2); N_2))	±0.36	–	–	–	–	+
S(*;K(O_2(a, v≥2); O_3))	±0.43	–	–	–	–	+
S(*;K(O_2(a, v≥2); CO_2))	n/d	–	–	–	–	+
S(*;K(O_2(a, v=1); O(³P)))	n/d	–	–	–	–	+
S(*;K(O_2(a, v=1); O_2))	±0.45	–	–	–	–	+
S(*;K(O_2(a, v=1); N_2))	±0.36	–	–	–	–	+
S(*;K(O_2(a, v=1); O_3))	±0.43	–	–	–	–	+
S(*;K(O_2(a, v=1); CO_2))	n/d	–	–	–	–	+
S(*;K(O_2(a, v=0); O(³P)))	±2	–	–	–	–	++
S(*;K(O_2(a, v=0); O_2))	±0.20	–	–	–	–	+
S(*;K(O_2(a, v=0); N_2))	n/d	–	–	–	–	+
S(*;K(O_2(a, v=0); O_3))	±0.10	–	–	–	–	+
S(*;K(O_2(a, v=0); CO_2))	n/d	–	–	–	–	+

Table 1.

Influences of model parameters (temperature of neutral gas components, K(A; B) - rate constant, and F – quantum yield of products of aeronomical reactions A + B → C + D) in solving of inverse problem for retrieval of [O(³P)] from different types of proxies.

Scale of influence: "+++" – large than 30% of total result, "++" – from 3 to 30%, "+" – smaller than 3%; sign "—" means no influence. ξ - relative uncertainty of rate constant (or quantum yield) value for corresponding reaction, "n/d" – means absence of data.

Analogous Table with solution of inverse problem for retrieval of [O_3] is shown in Stand B119.

Abstract

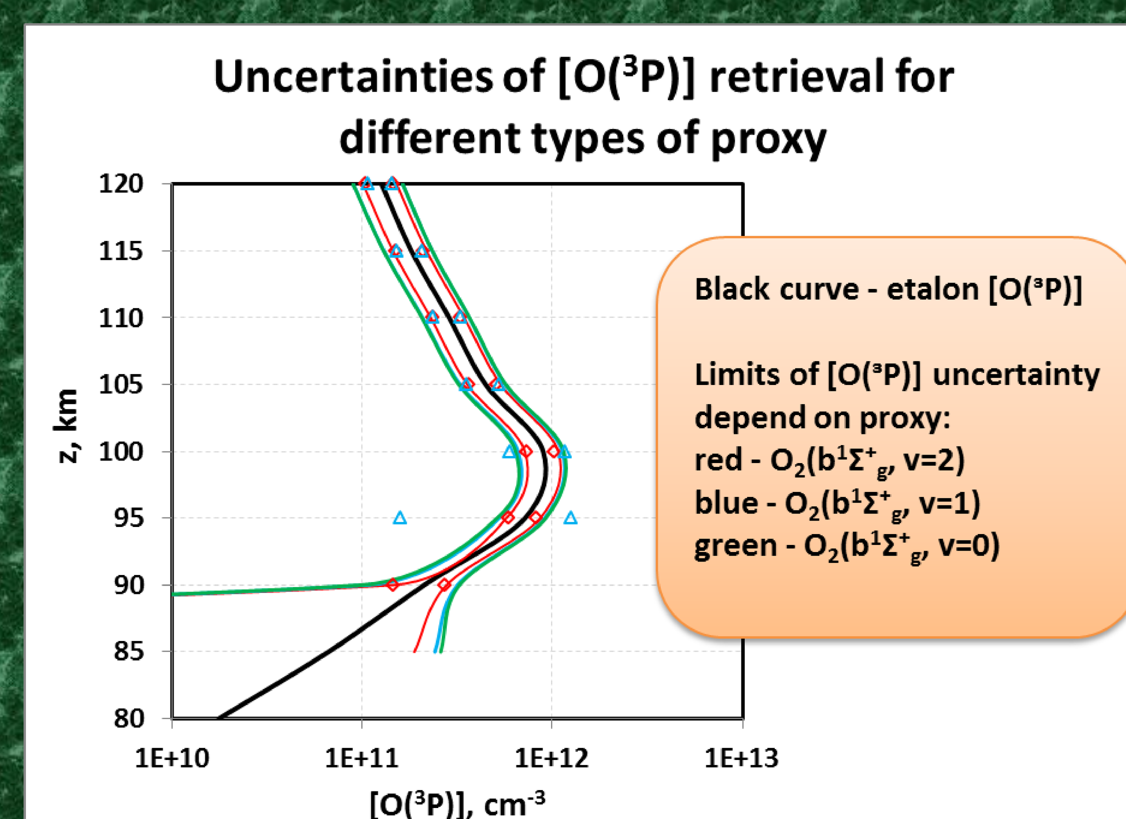
The problem of creating the new methods of remote sensing of altitude profile of the [O(³P)] and [O_3] in the daytime is actual for the mesosphere and lower thermosphere range. Currently there is no reliable method for remote sensing of altitude profile of the [O(³P)], but atomic oxygen is a key component in the mechanism of the atmosphere cooling by quenching of vibrationally excited CO2 molecules and also one of basic quencher of excited components in MLT region.

The airglow emission in 1.27 μm IR Atm(0 - 0) band from [$O_2(a^1\Delta_g$, v=0)] has been used as a proxy for [O_3] in MLT for over a decade. However, lifetime of $O_2(a^1\Delta_g$, v=0) is more than 1 hour, therefore this method is not suitable for detecting of relatively rapid [O3] variations which occur due to the variability of the solar spectrum in the UV range (120 - 320 nm) and other space factors. The aim of this study is revealing of proxies for retrievals of [O(³P)] and [O_3]. In the framework of developed model of electronic vibrational kinetics of excited products of O_3 and O_2 photolysis in MLT of the Earth (model YM-2011) [1] we consider the photolysis of O_2 in the Schumann–Runge continuum and Lyman-α H atom and of O_3 in Hartley band and for excited products of photolysis ($O_2(a^1\Delta_g$, v=0 - 5), $O_2(b^1\Sigma^+_g$, v=0, 1, 2) and excited oxygen atom O(¹D)) we took into account more than 60 aeronomical reactions of photoexcitation and deexcitation by energy transfer between the excited levels and of quenching of the levels in collisions with O(³P) O_2, N_2, O(³P), O_3, CO_2. The total system of kinetic equations for 10 components has been solved and altitude profiles of concentrations of O(¹D), $O_2(b^1\Sigma^+_g$, v=0, 1, 2), and $O_2(a^1\Delta_g$, v=0 – 5) have been calculated.

To compare characteristics of assumed proxies we used sensitivity analysis of the proxy concentrations altitude profiles to variations of [O_3] and [O(³P)] and have calculated the altitude profiles of: 1) photochemical lifetimes of excited states; 2) volume emission rates (VER) of these excited components; 3) the relative uncertainties values of [O(³P)] and [O3] retrieved from intensities of emissions formed by the corresponding radiative transitions (using Monte Carlo method (color symbols in Fig.) and Sensitivity study (color curves in Fig.)).

Conclusions

Based on this complex analysis we concluded that the optimal proxy for [O(³P)] retrieval are $O_2(b^1\Sigma^+_g$, v=0) and/or $O_2(b^1\Sigma^+_g$, v=2) at 90-150 km, and for [O_3] retrieval are $O_2(b^1\Sigma^+_g$, v=1) and/or $O_2(a^1\Delta_g$, v=0) at 40-97 km. It should be noted, that lifetimes of $O_2(b^1\Sigma^+_g$, v=0, 1, and 2) are not more than 10 s in MLT, what gave the opportunity to register the short-period [O(³P)] and [O_3] variations



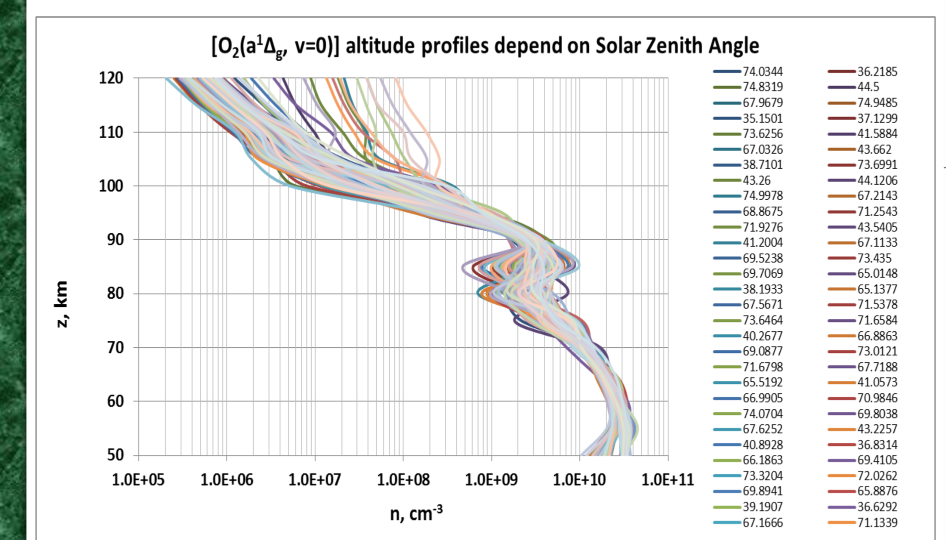
We tested 5 excited components, namely,

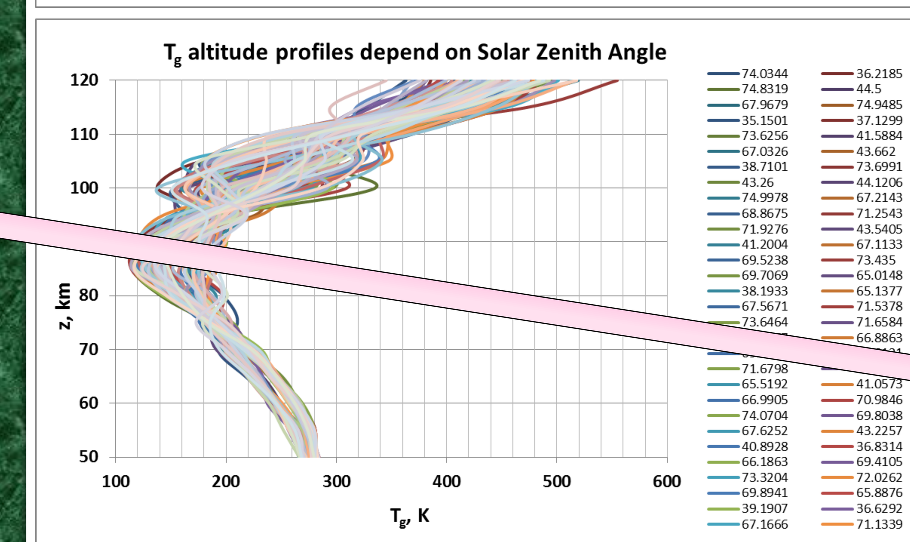
$O_2(b^1\Sigma^+_g$, v=0, 1, 2), $O_2(a^1\Delta_g$, v=0 – 5) and O(¹D)

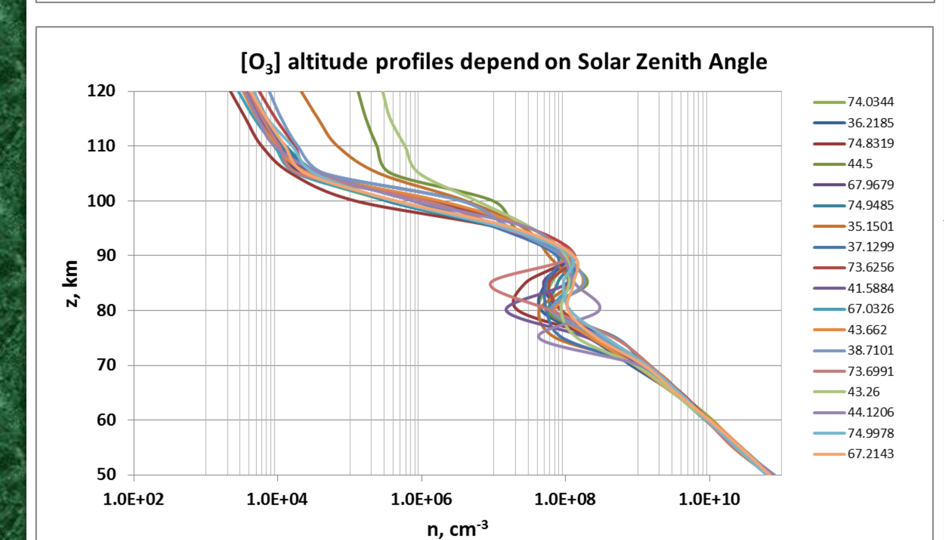
as the [O(³P)] and [O_3] proxies.

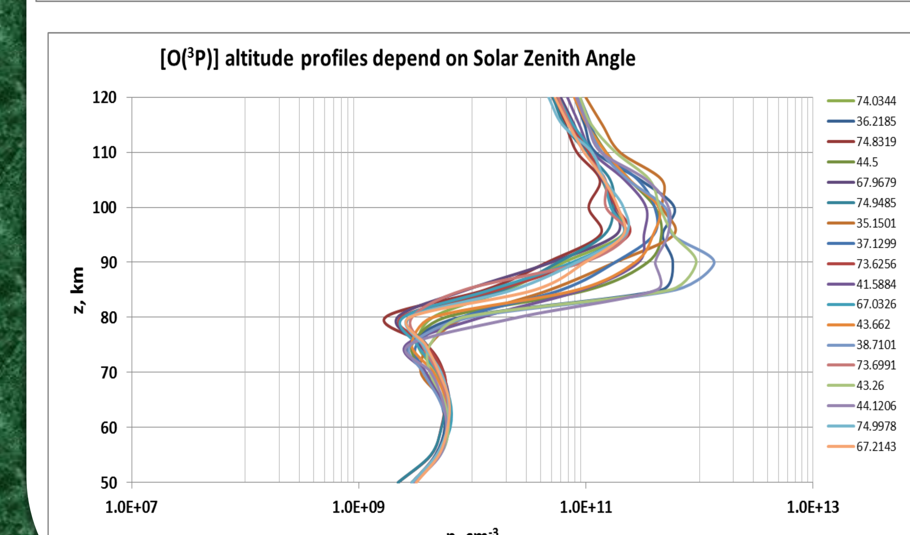
See ★ on scheme of YM-2011 model (at left and Table 1, below).

Reference Atmosphere from SABER data (Summer solstice, 2010)

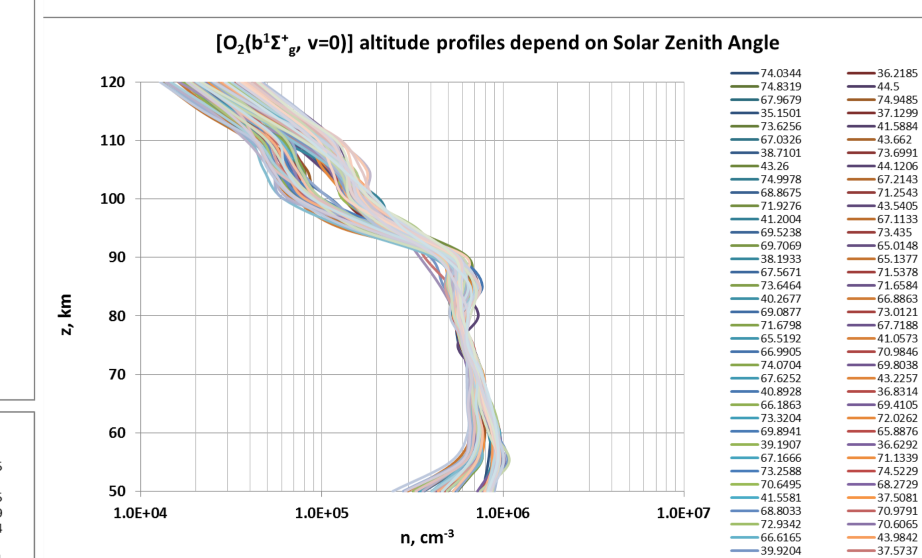


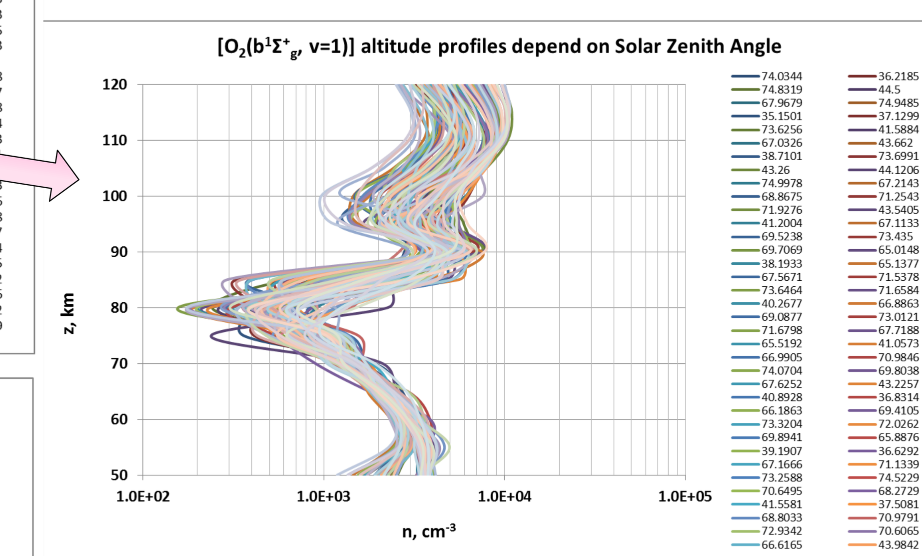


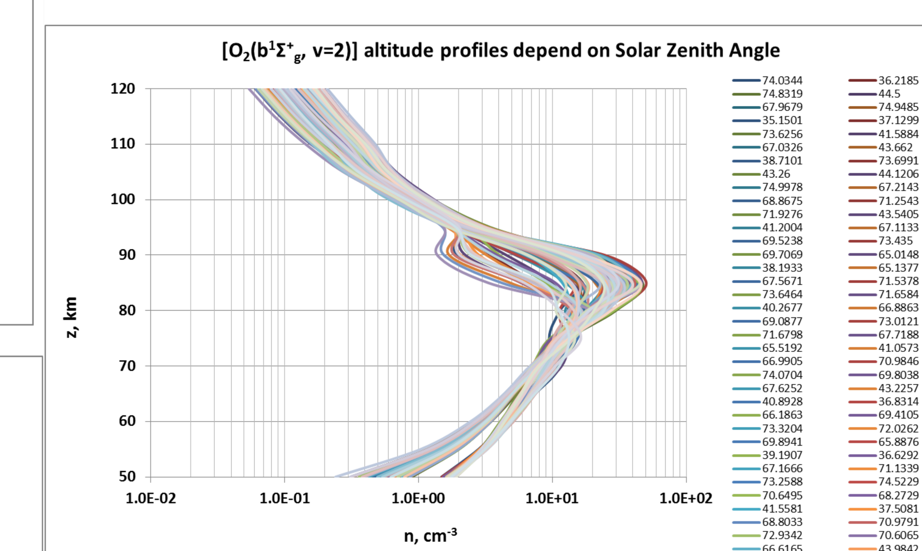




Results: calculations using YM-2011 model for conditions of Reference Atmosphere and synchronized solar irradiance







The values of Volume Emission Rate are calculated:

$$VER = [O_2(b^1\Sigma^+_g, v')] \cdot A(b, v' \to X, v''),$$

where $A(b, v' \to X, v'')$ - Einstein coefficient corresponding transition.