

Ozone in the eastern Mediterranean free troposphere during MINOS

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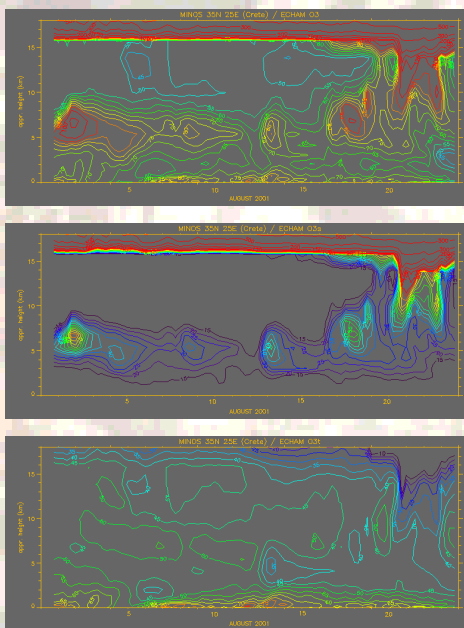
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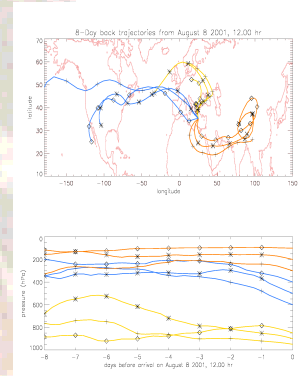
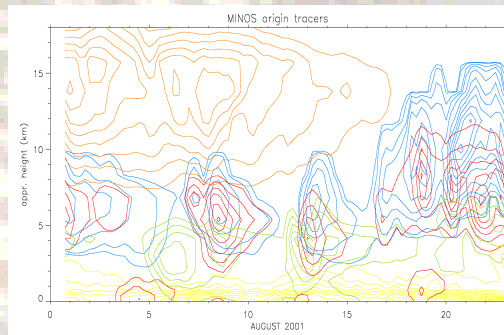


Introduction. The MINOS measurement campaign (Mediterranean Intensive Oxidant Study) was conducted in the Mediterranean region during July/August 2001, based on Crete (35°N, 25°E). The purpose of MINOS was to observe and understand the chemical composition of tropospheric air in the Mediterranean region in terms of atmospheric transport and chemistry. MINOS made use of ground-based and an aircraft-based measurement platforms for observation of atmospheric ozone, CO, higher hydrocarbons, nitrogen oxides and aerosol. This model study focusses on the distribution of tropospheric ozone in the eastern Mediterranean region during MINOS.

Model description. We use the general circulation model ECHAM4, with a tropospheric chemistry scheme with CBM4 [Roelofs and Lelieveld, JGR, 105, 22697-22712, 2000]. The model simulates the meteorology for summer 2001 by nudging with ECMWF reanalyzed data. A separate chemical tracer, O_{3s}, is used for ozone from stratospheric origin, the residual between ozone and O_{3s} reflects ozone photochemically produced in the troposphere.



Time-altitude plots of simulated ozone for August 1-23, 2001, Crete (top panel), and the contributions from ozone from stratospheric origin (O_{3s}; middle panel) and from photochemical formation in the troposphere (O_{3t}; lower panel). Before August 20, the upper troposphere is characterized by ozone levels between 45 and 55 ppbv. The model simulates an ozone maximum between 3 and 9 km altitude. The middle panel (O_{3s}) shows that the mid-tropospheric ozone maximum is mainly associated with ozone from stratospheric origin. This generally contributes more than 30% and sometimes even 60% to total ozone in this layer. Peaks at August 1, 8 and 13 relate to transports associated with synoptic disturbances. The lower panel (O_{3t}) shows ozone from photochemical formation in the free troposphere.

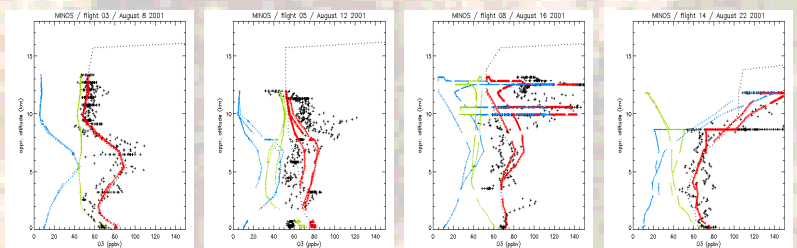


Time-altitude distribution at Crete of ideal tracer concentrations (left), and backward trajectory analysis (right) illustrate general air mass transports between source regions and the Mediterranean region during summer.

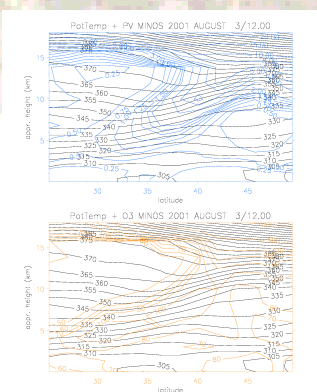
Orange: between ~9 km altitude and the tropopause, ~17 km altitude, air originates from the South-East (SE) Asian boundary layer. It is transported upward by convection in the ITCZ and then enters the upper tropospheric anti-cyclone centered over the Tibetan plateau that is associated with the summer monsoon. The influence of the anti-cyclone temporarily decreases after August 15.

Blue: between ~4 and 9 km altitude, air advected from the west originates from upper troposphere/lower stratosphere. The presence of the upper tropospheric anti-cyclone over the eastern Mediterranean funnels this air south- and downward. Transports associated with synoptic disturbances add air from the North-American (red) and Atlantic (green) lower troposphere to this layer.

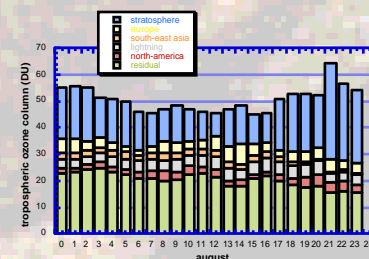
Yellow: between the surface and ~4 km altitude, air originates from the boundary layer over eastern Europe.



Observed (black) and simulated (red) ozone profiles for measurement flights 3, 5, 8 and 14. Blue and green symbols denote the contribution to total simulated ozone by ozone from stratospheric and tropospheric photochemical origin, respectively. Ozone measurements were performed by the DLR using a modified TE 49 instrument.



Latitudinal distribution of modeled potential temperature (black), potential vorticity (blue, top panel) and ozone (orange, lower panel). A relatively stable layer of air lies in between the boundary layer and the relatively unstable anticyclonic air in the upper troposphere. This layer enables efficient transport from the extra-tropical UT to the sub-tropical lower troposphere.



Simulated tropospheric ozone column (between the surface and ~17 km altitude) for August 1-23, 2001, at 35°N, 25°E (Crete), subdivided in contributions from the stratosphere, from lightning emissions and from precursor emissions in several regions (left). These contributions reflect recently produced ozone, ~1 month old. The residual reflects the background tropospheric ozone column during summer at mid-latitudes. The table (right) lists the average contributions between August 1 and 15.

source region	column (DU)
stratosphere	14.0 ± 3.2
India, Southeast Asia	2.3 ± 0.2
North America	2.4 ± 0.6
Europe	4.0 ± 1.5
lightning	4.2 ± 0.5
residual	21.6 ± 2.0
total ozone column	48.4 ± 3.2