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3D simulations of atmospheric response caused by precipitating electrons and solar protons at both polar regions induced by geomagnetic storms

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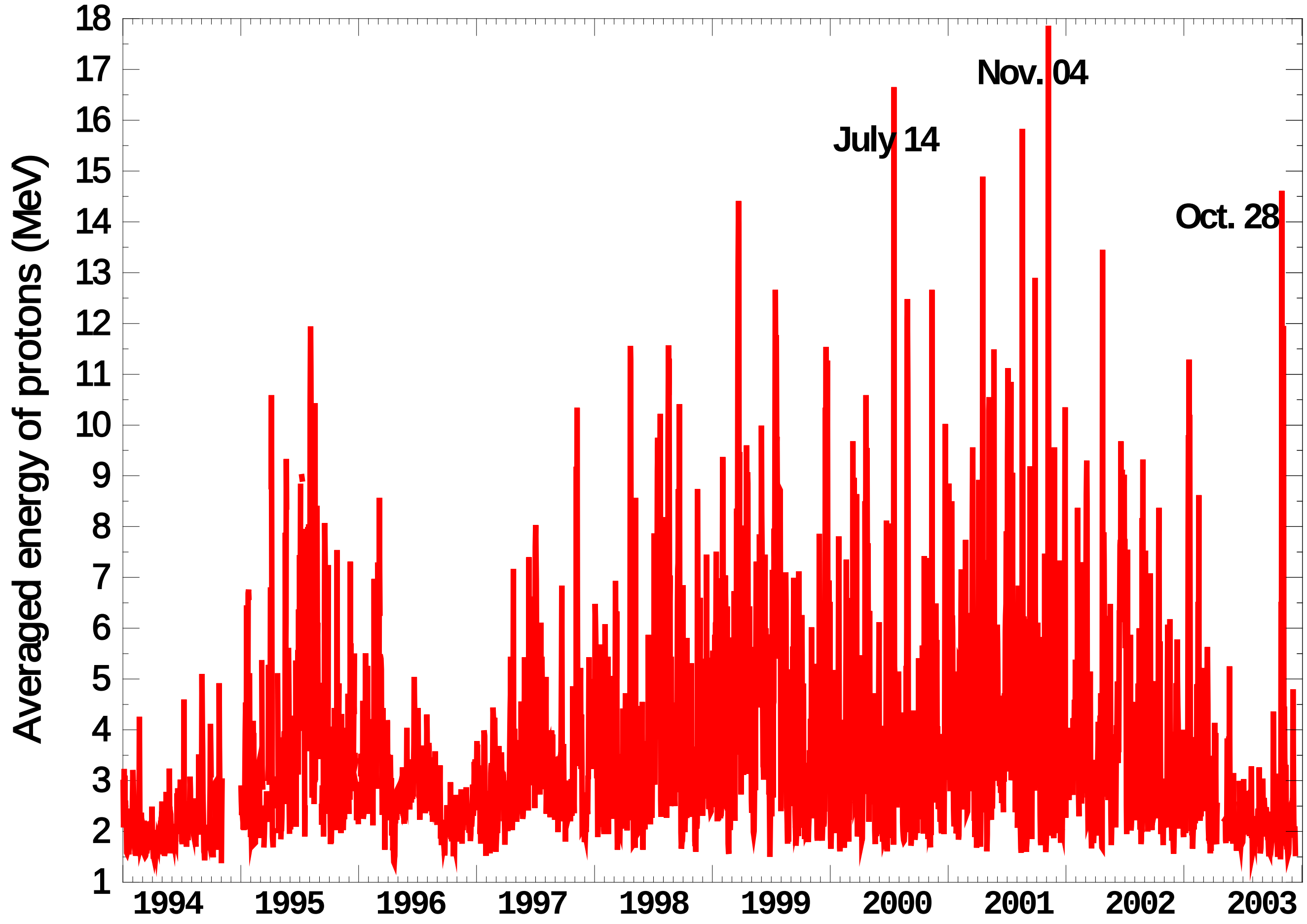
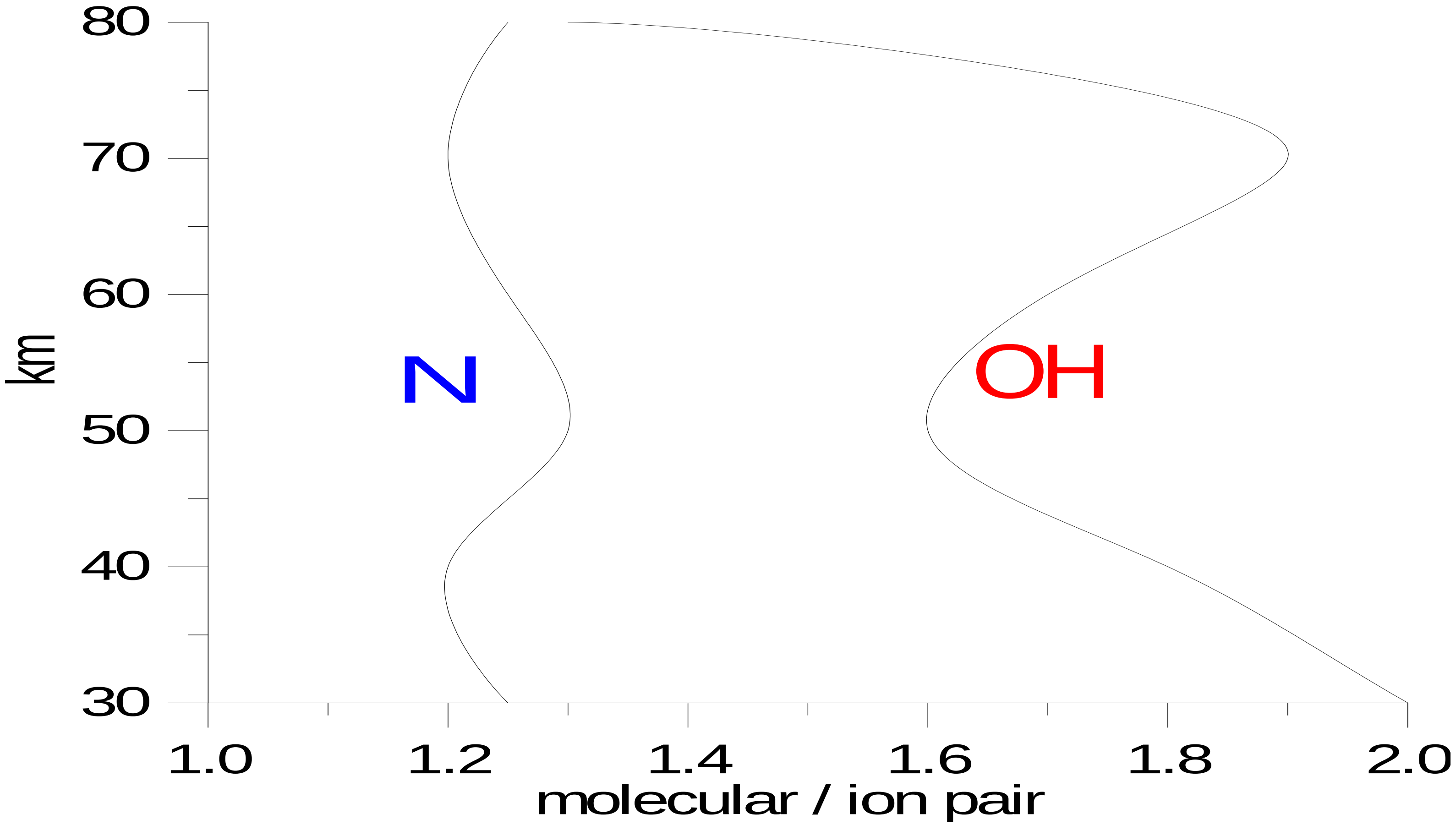
Outline

1. Particles-Ionization-Chemistry mechanism.
2. Ionization rates caused by the particles (October-November, 2003; HEPPA).
3. Models description
4. Particle effects in composition
5. Particle effects in temperature and dynamics
6. Conclusions

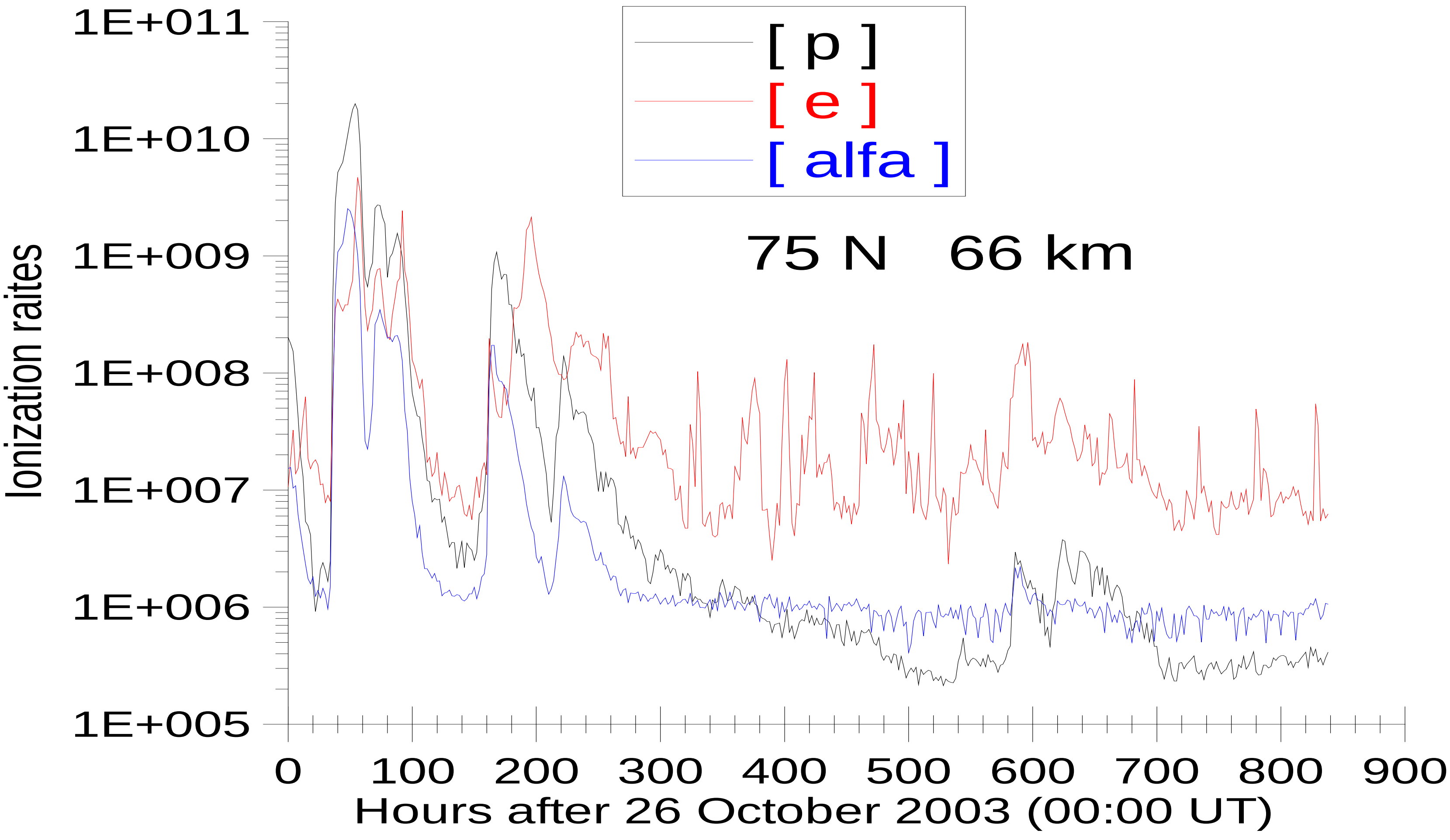
Daily averaged energy values of solar protons during 1994-2003 (1-100 MeV, GOES data)



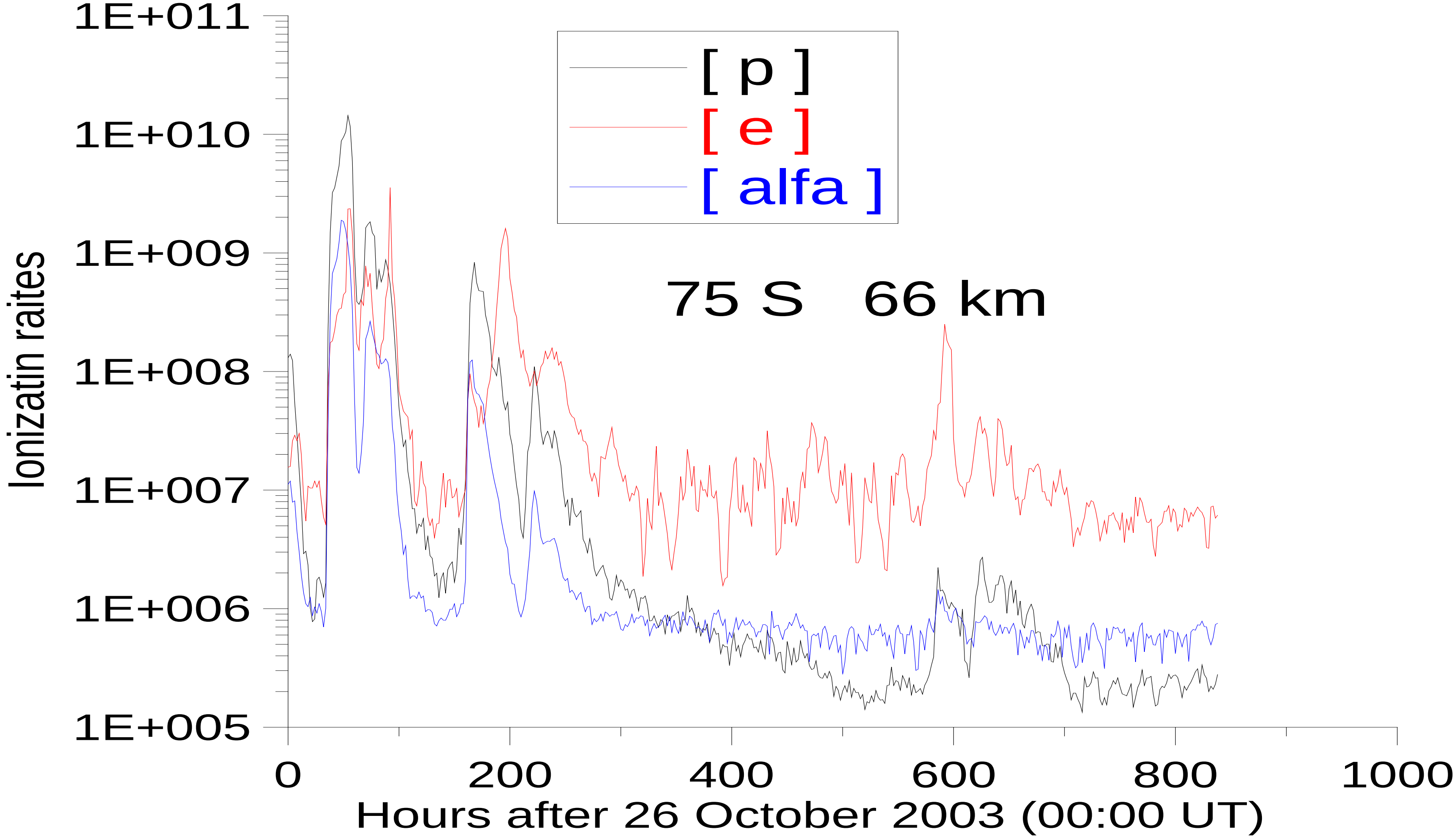
N and **OH** production caused by cosmic rays (Jackman et al., 1976; Heaps, 1978; Solomon and Crutzen, 1981)



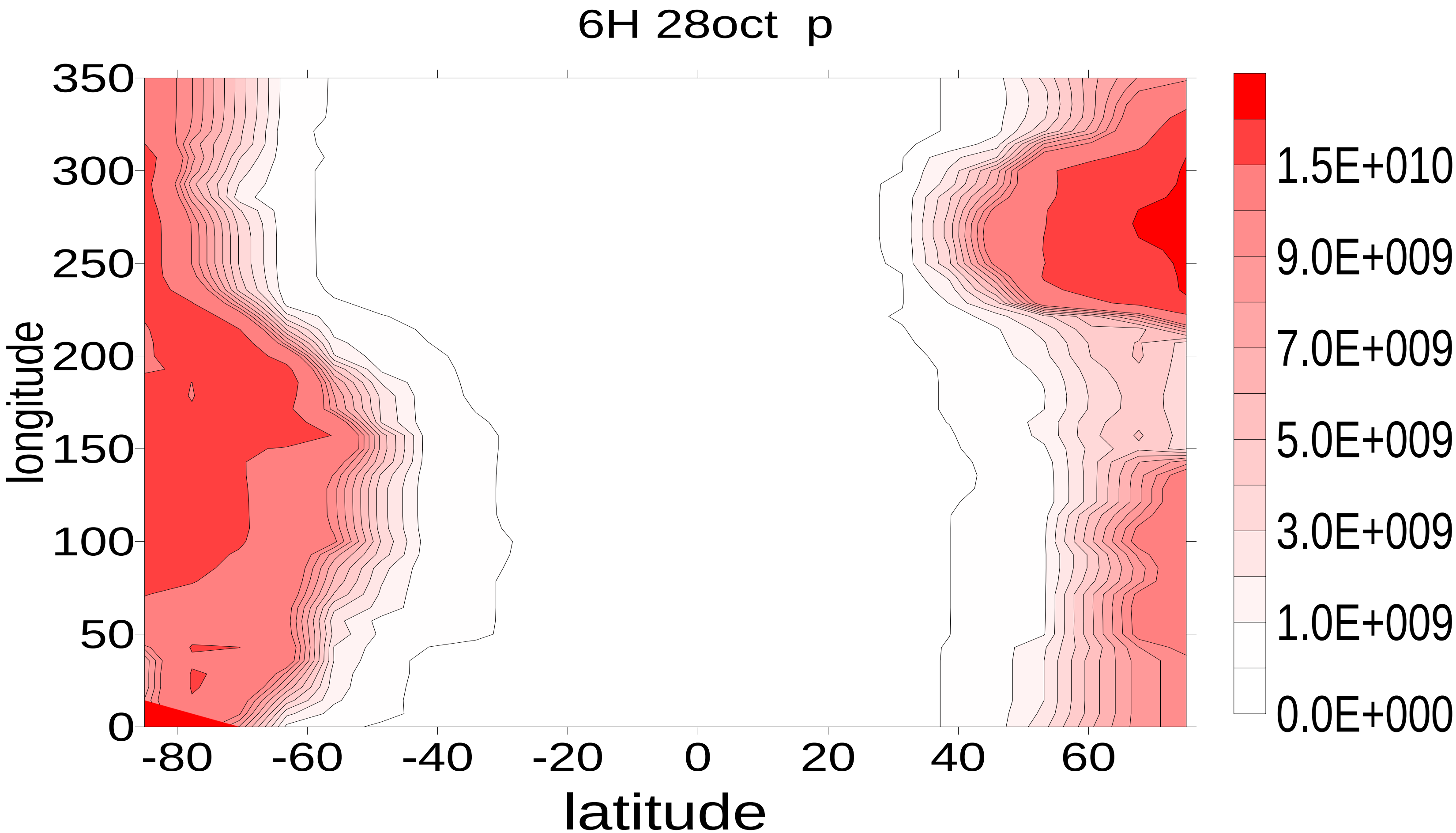
Ionization rates 75^0 N (66 km) caused by energetic particles during October-November 2003 (calculated by Maik Wissing)



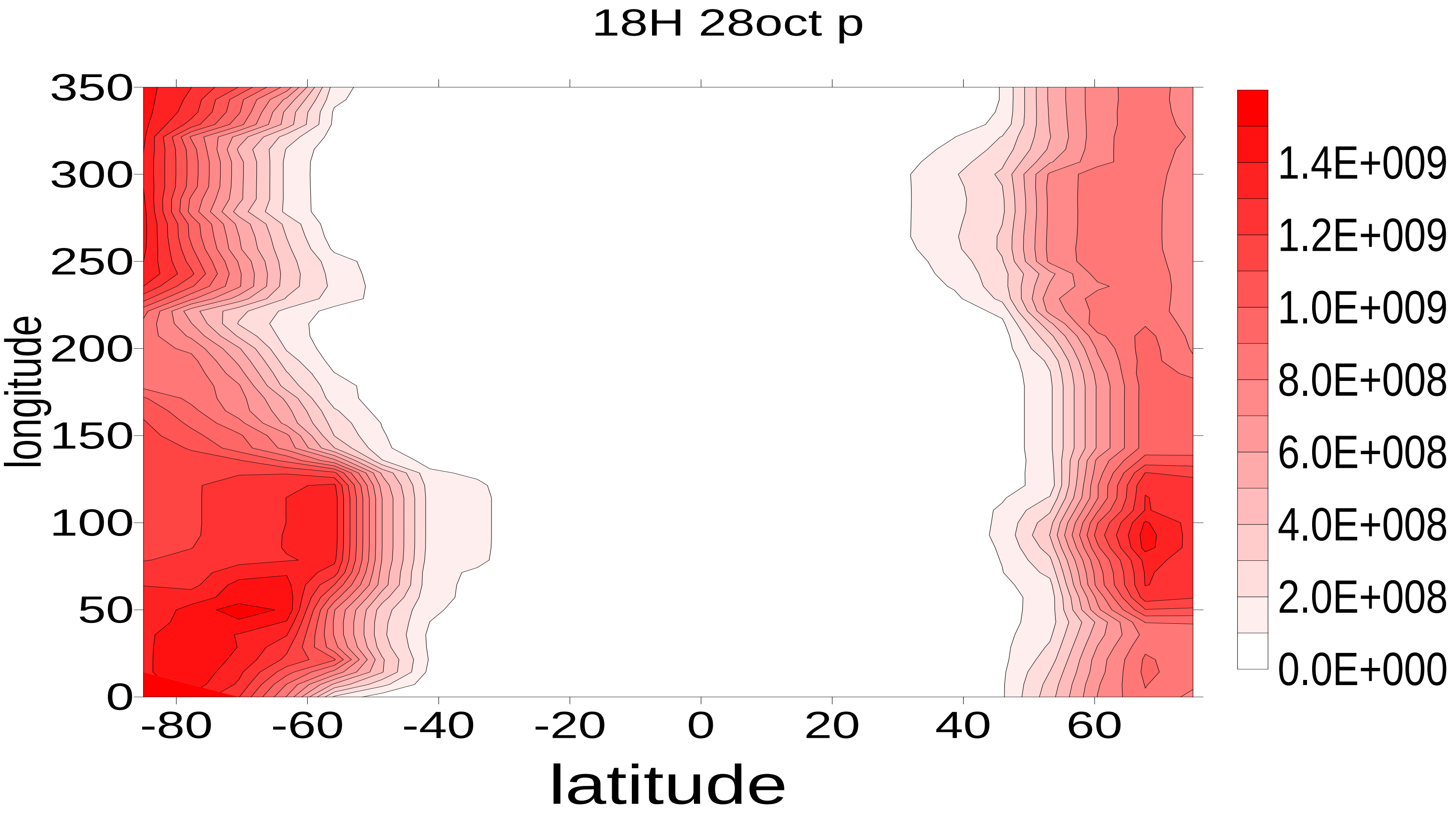
Ionization rates caused at 75^0 S (66 km) by energetic particles during October-November 2003 (calculated by Maik Wissing)



Calculated Ionization rates caused by solar protons at 66 km
(6 AM 28 October 2003)

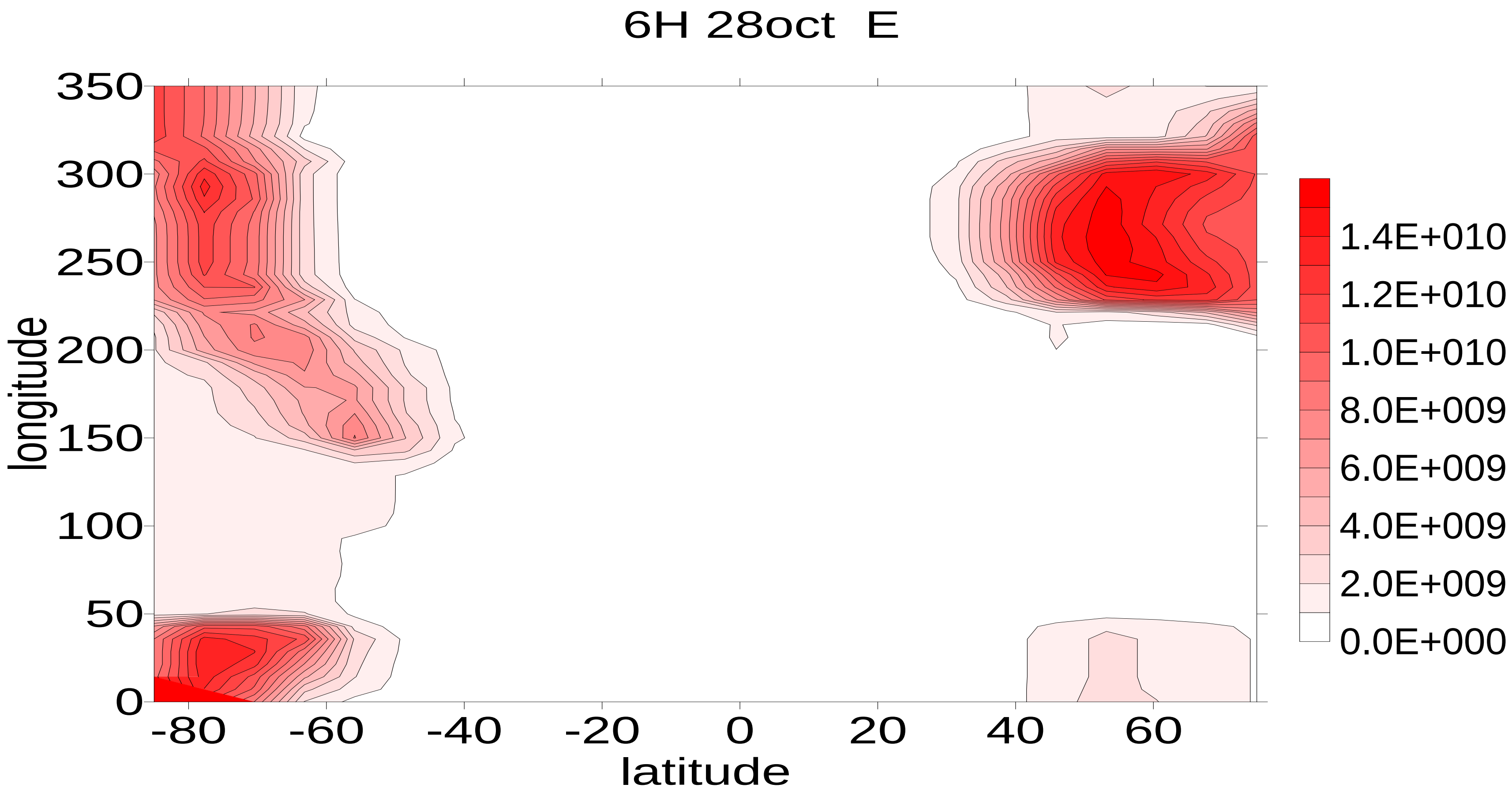


Calculated Ionization rates caused by solar protons at 66 km (6 PM 28 October 2003)

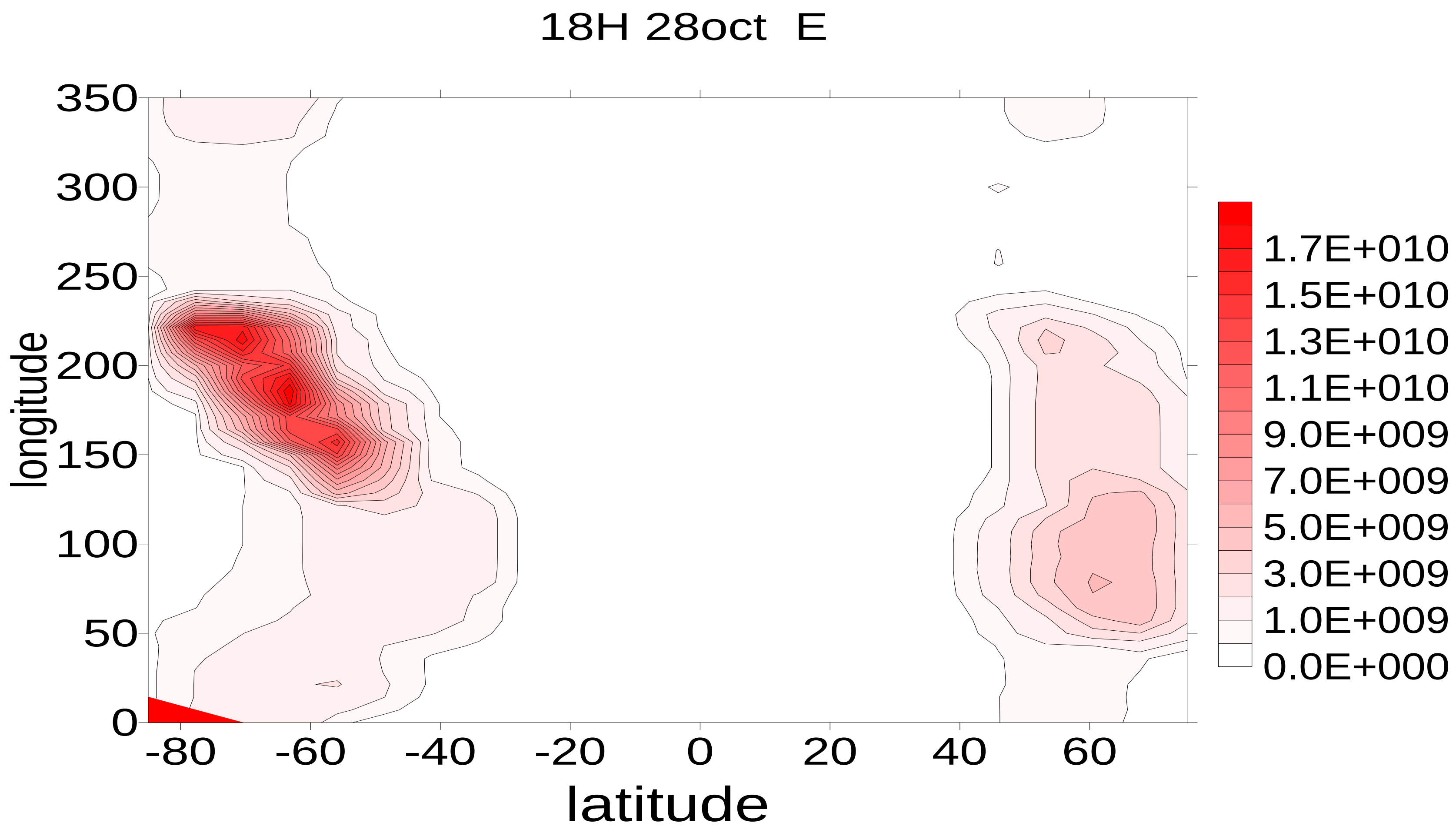


Calculated Ionization rates caused by relativistic electrons at 66 km

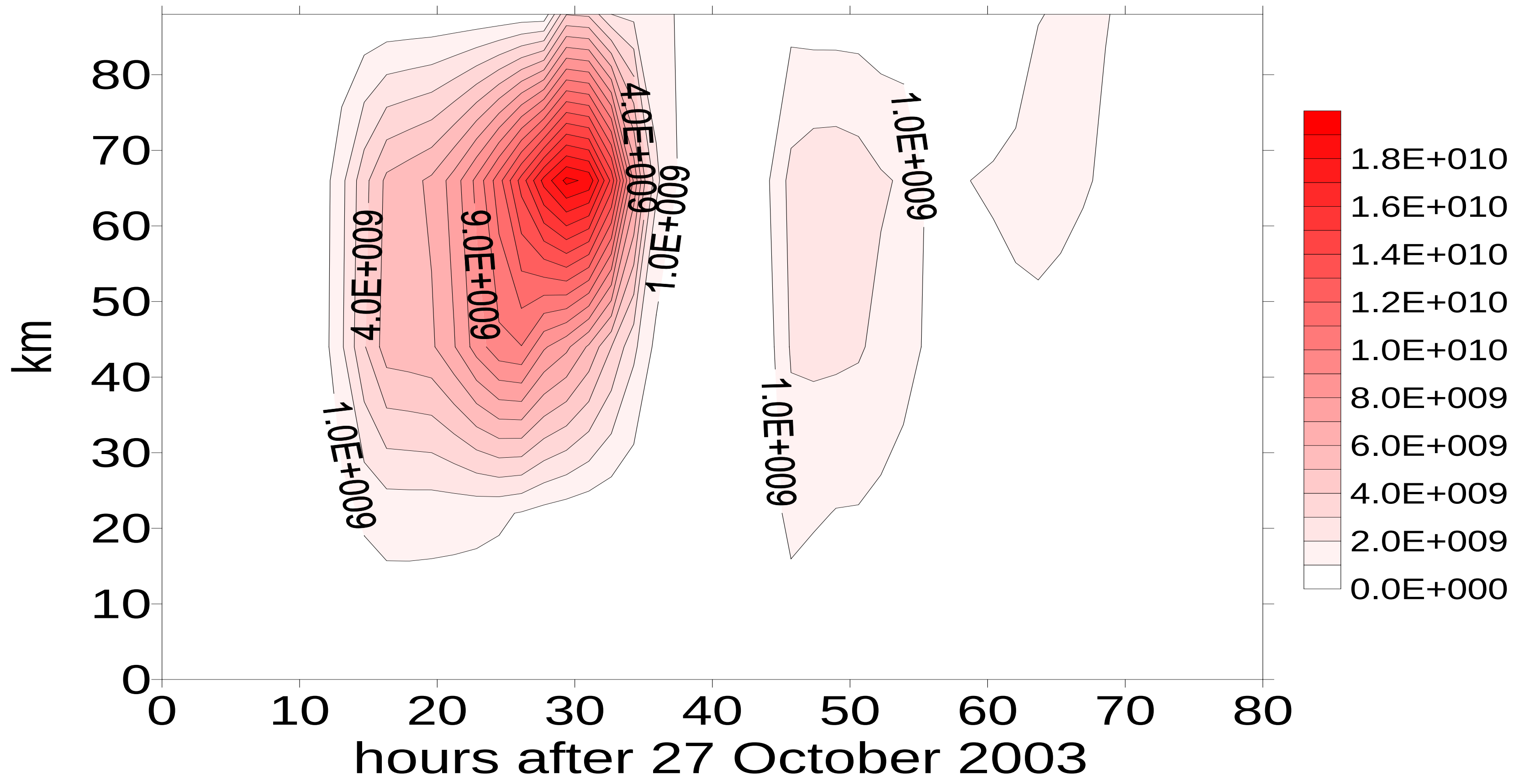
(6 AM 28 October 2003)



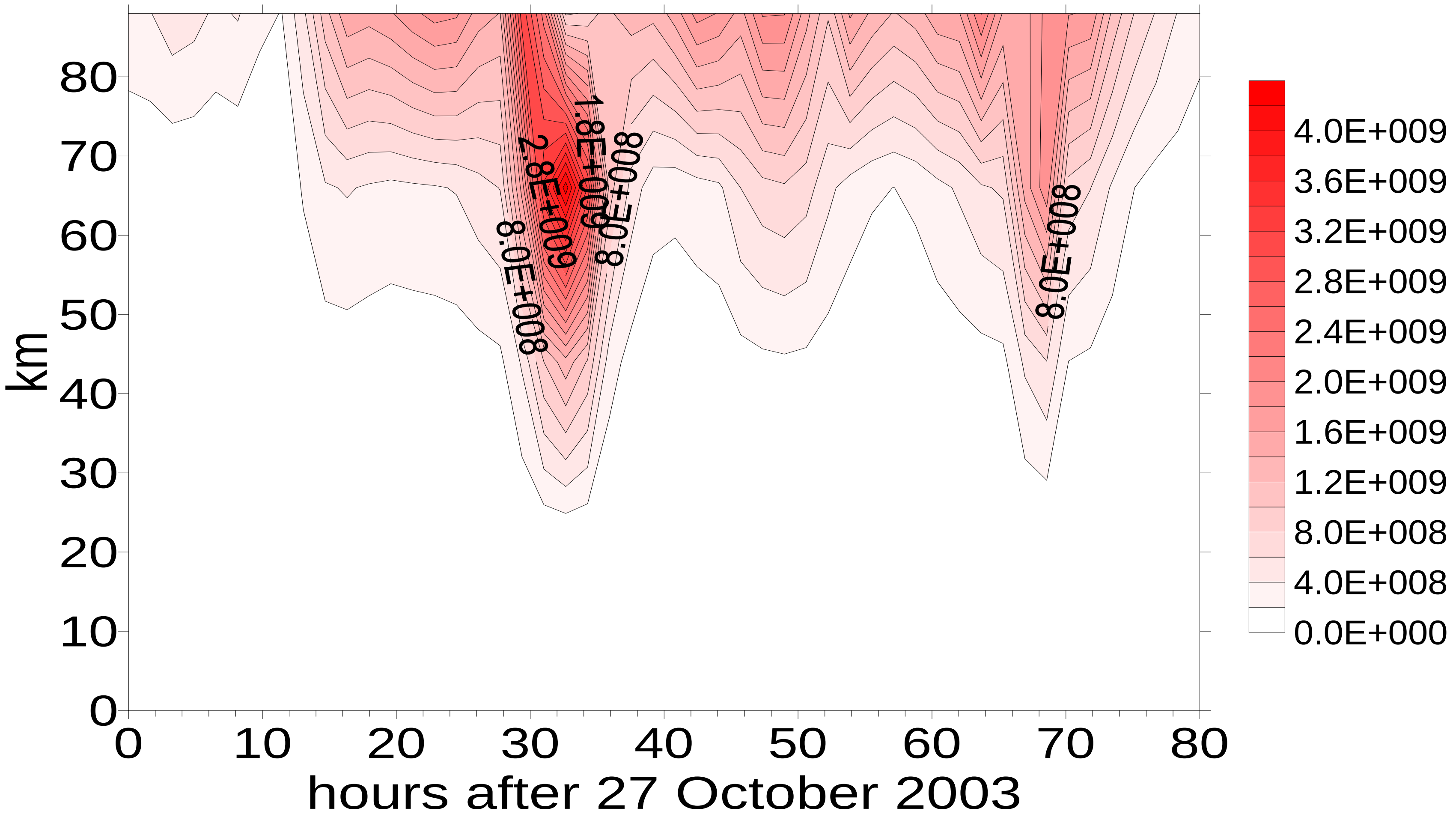
Calculated Ionization rates caused by electrons at 66 km (6 PM 28 October 2003)



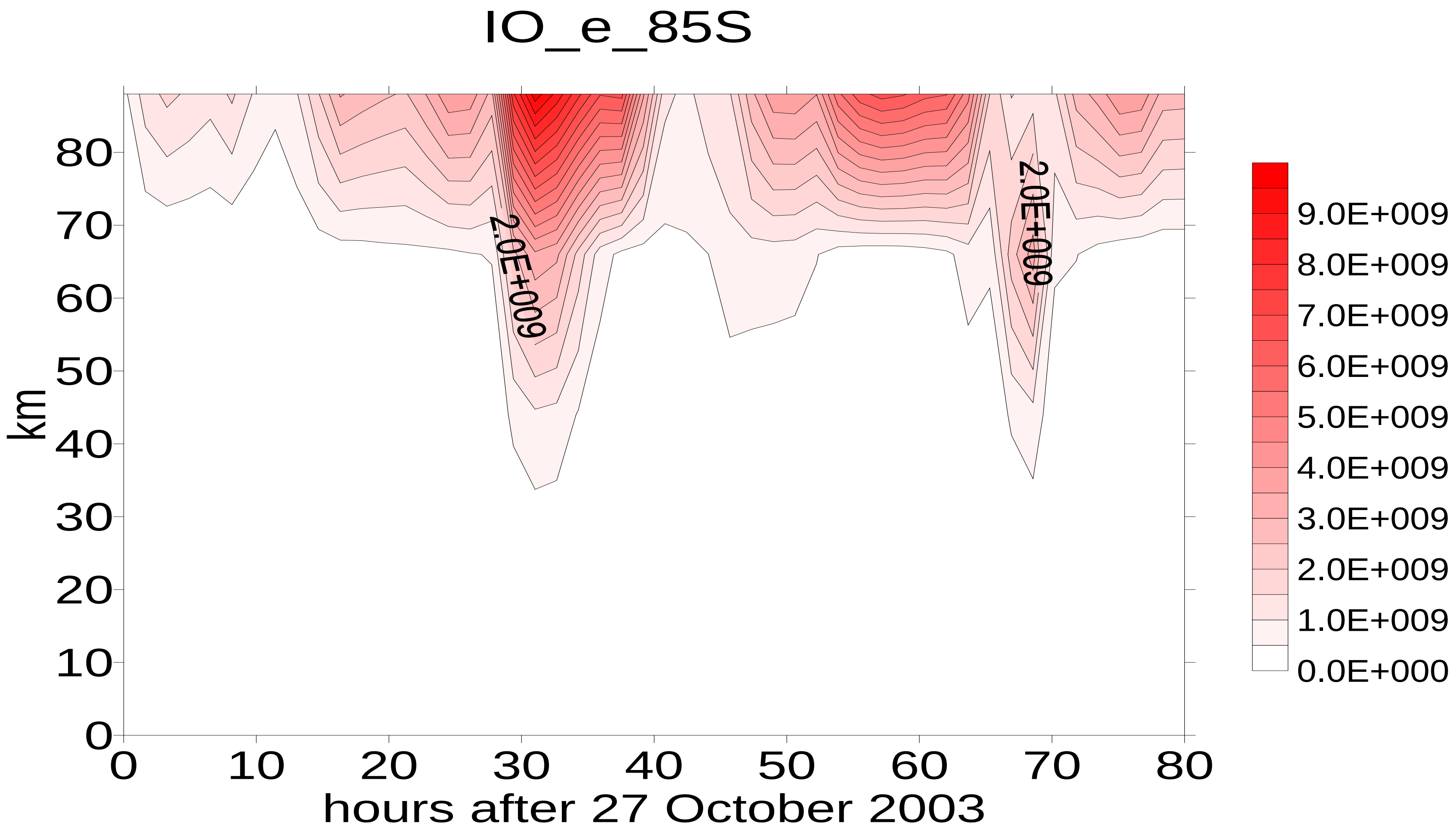
Ionization rates induced by solar protons at 75^0 N



Ionization rates caused relativistic electrons at 75^0N



Ionization rates caused by relativistic electrons at 85^{0}S



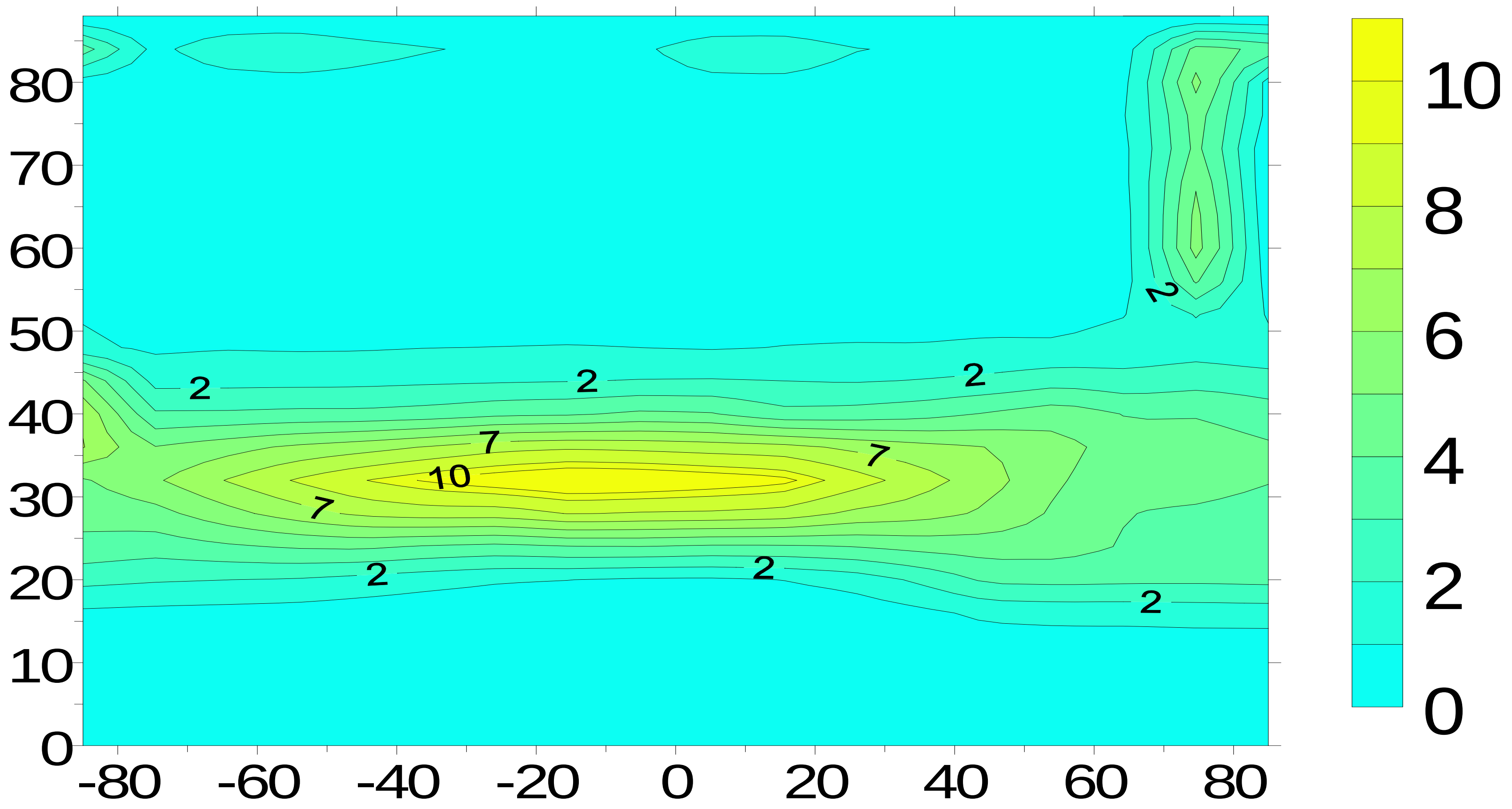
CHARM – CHemical Atmospheric Research Model

Model equations (0-90 km):

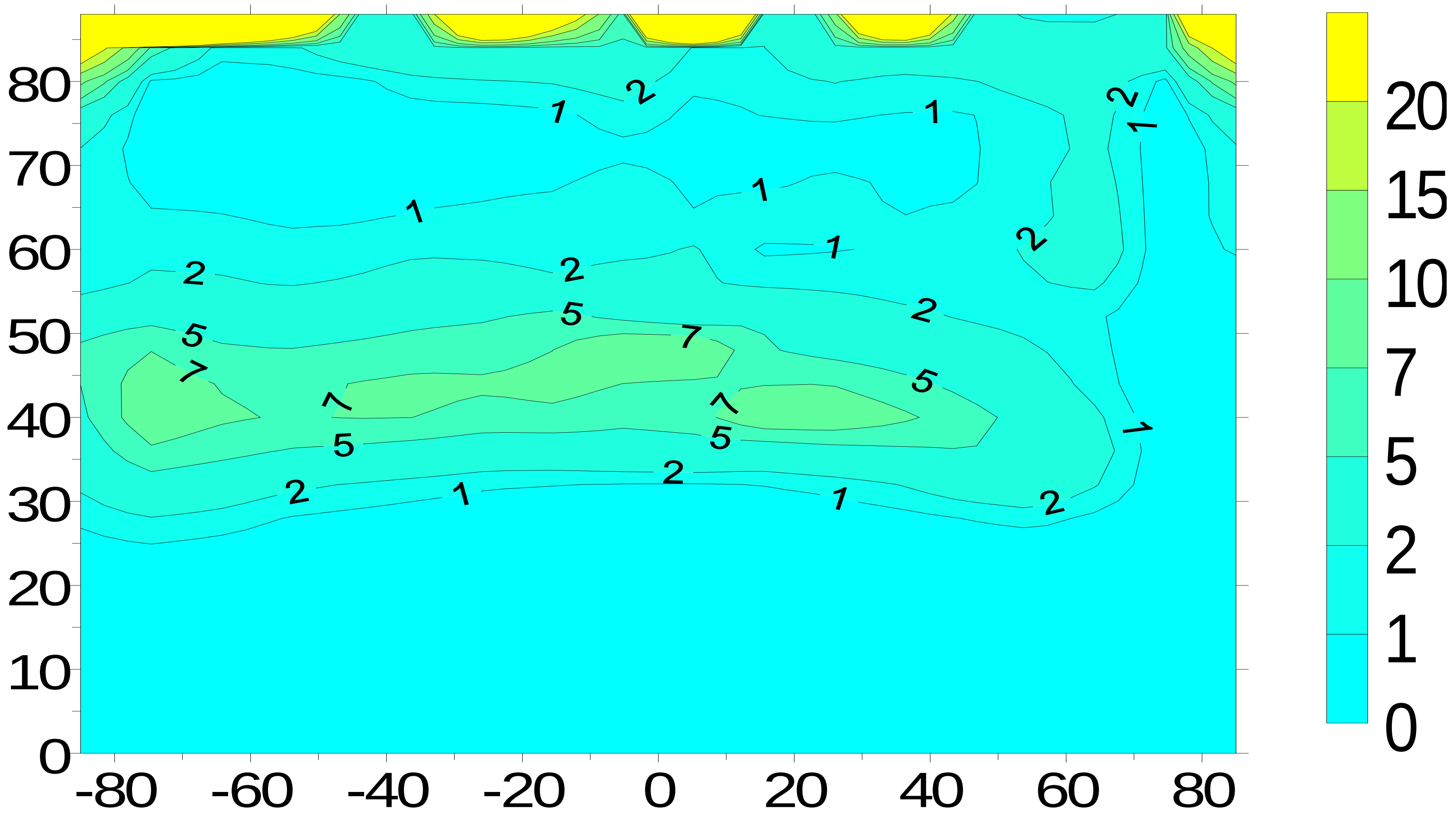
$$\frac{\partial\mu}{\partial t} + U\frac{\partial\mu}{a\cos\theta\partial\lambda} + V\frac{\partial\mu}{a\partial\theta} + W\frac{\partial\mu}{\partial z} = P_{AD} - L\mu$$

P, L – photochemical **Sources** and **Losses**
U, V, W – wind components (from **ARM)**
Number of **gas-phase** reactions– **73**; number of **photolysis** reactions - **38**
Chemical families method - **Turco, Whitten, 1974**
Advection scheme: **Prather, 1986**

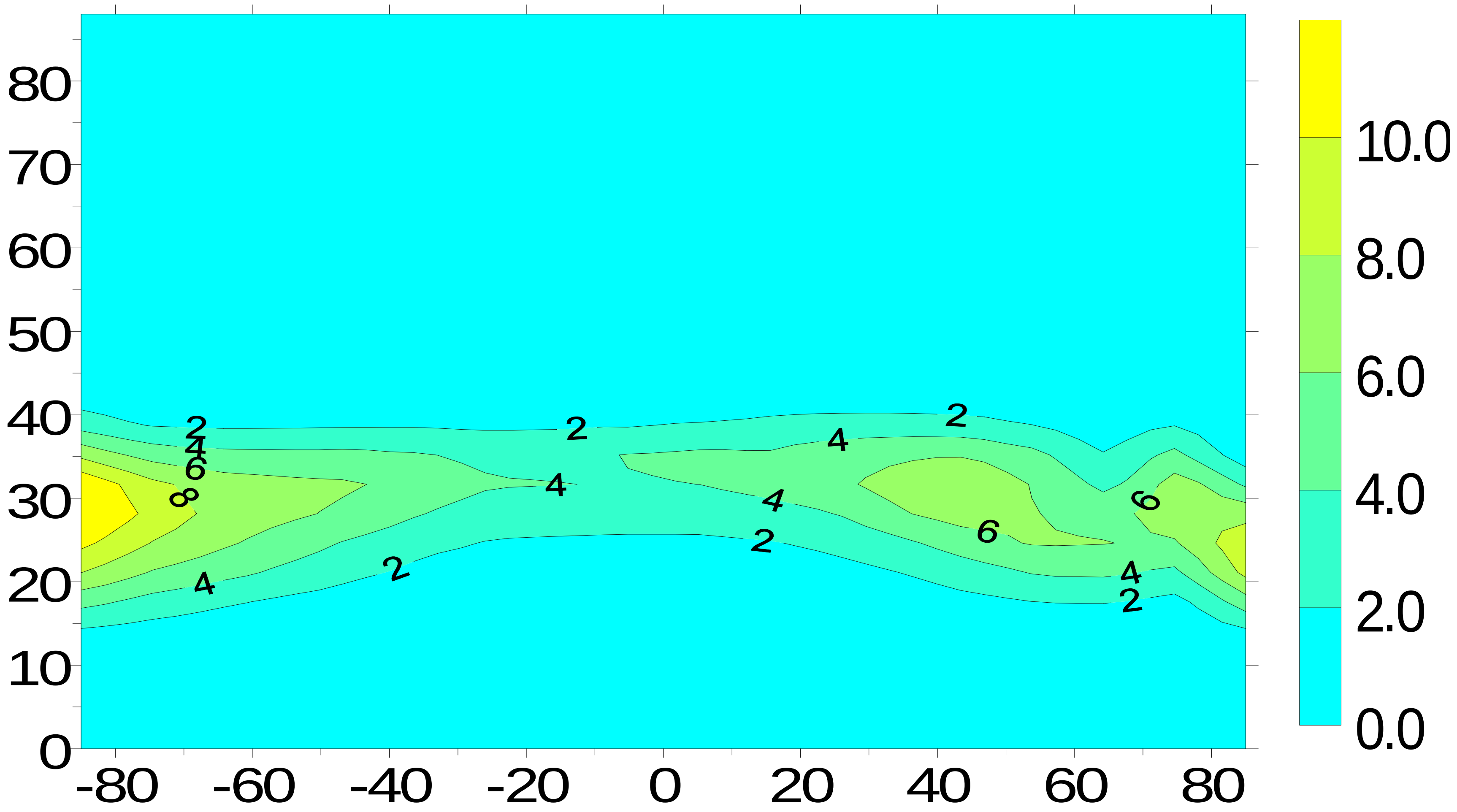
Ozone mixing ratio (ppmv) for 1st January
(3D simulation with CAO model)



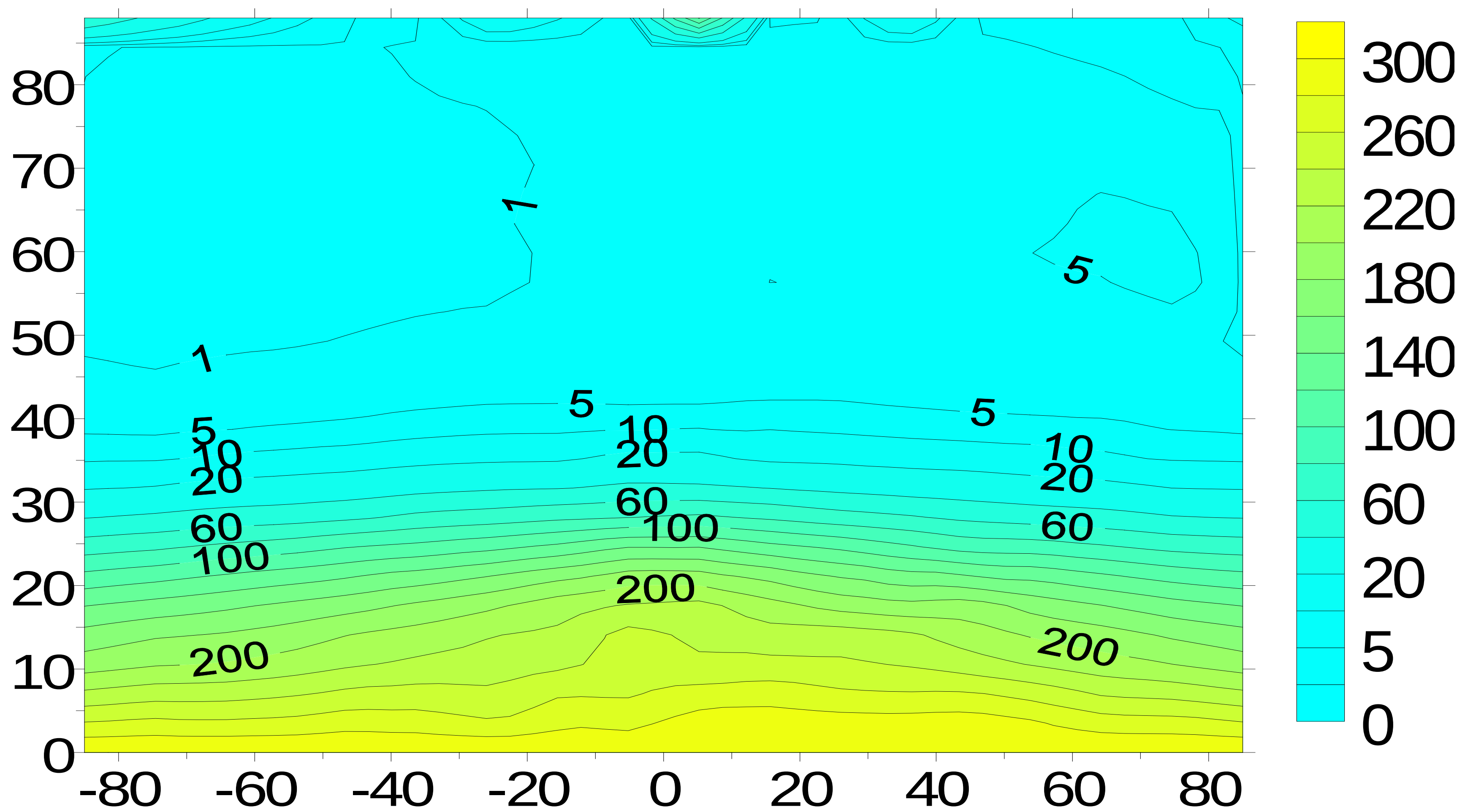
NO mixing ratio (ppbv) for 1st January
(3D simulations with CAO model)



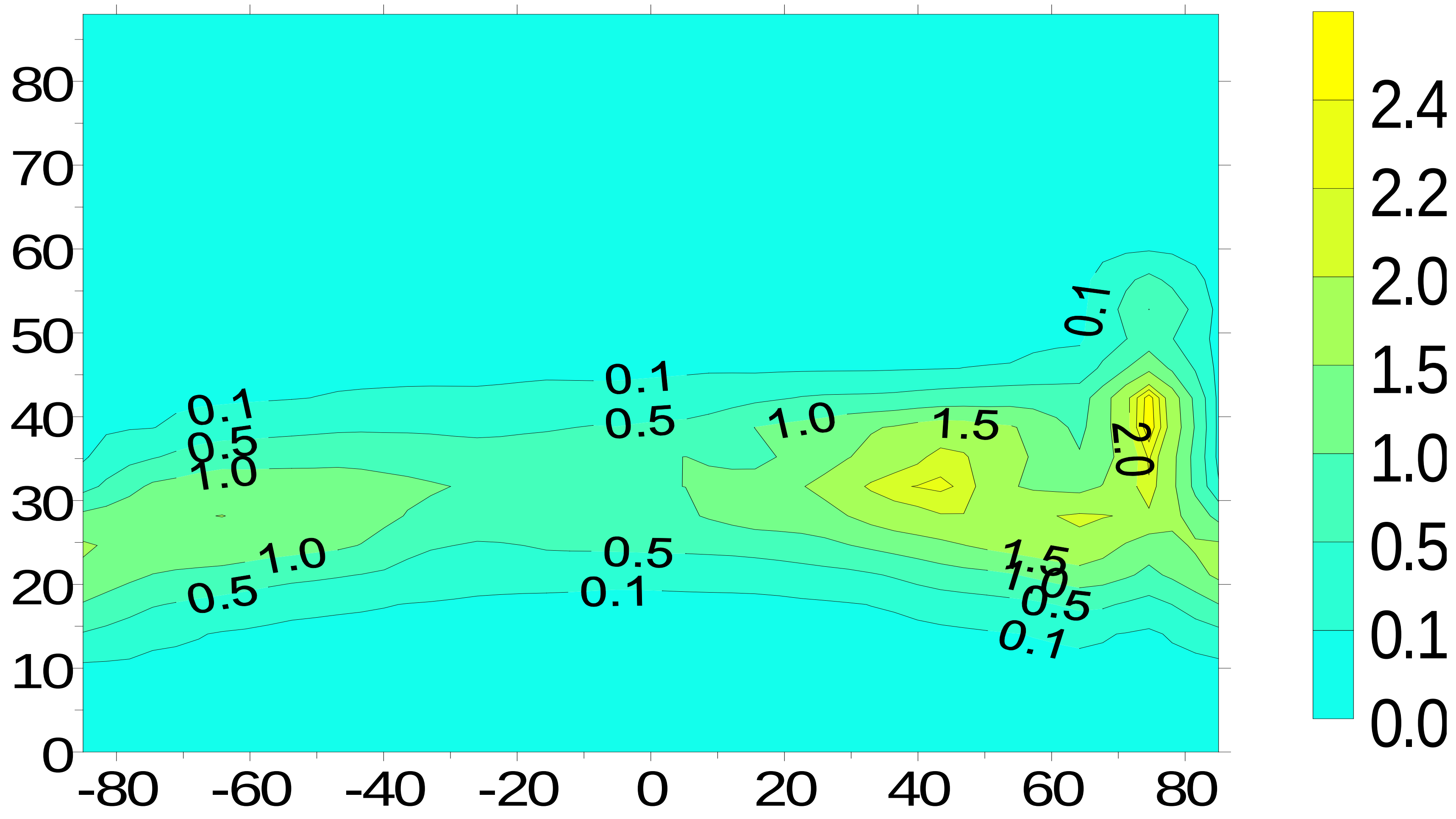
HNO3 mixing ratio (ppbv) for 1st January
(3D simulations with CAO model)



N2O mixing ratio (ppbv) for 1st January (3D photochemical simulations)



ClNO3 mixing ratio (ppbv) for 1st January
(3D photochemical simulations)



ARM -**A**tmospheric **R**esearch **M**odel (GCM)

Altitudes: **0-135 км**

Resolutions: vertical– **1 km;**

longitudinal – **10^{0}; l**atitudinal– **5^{0}**

time step – **5 min.**

Paramaterizations:

Heating - **O_2, O_3, H_2O (Strobel, 1978; Chou et al., 2002)**;

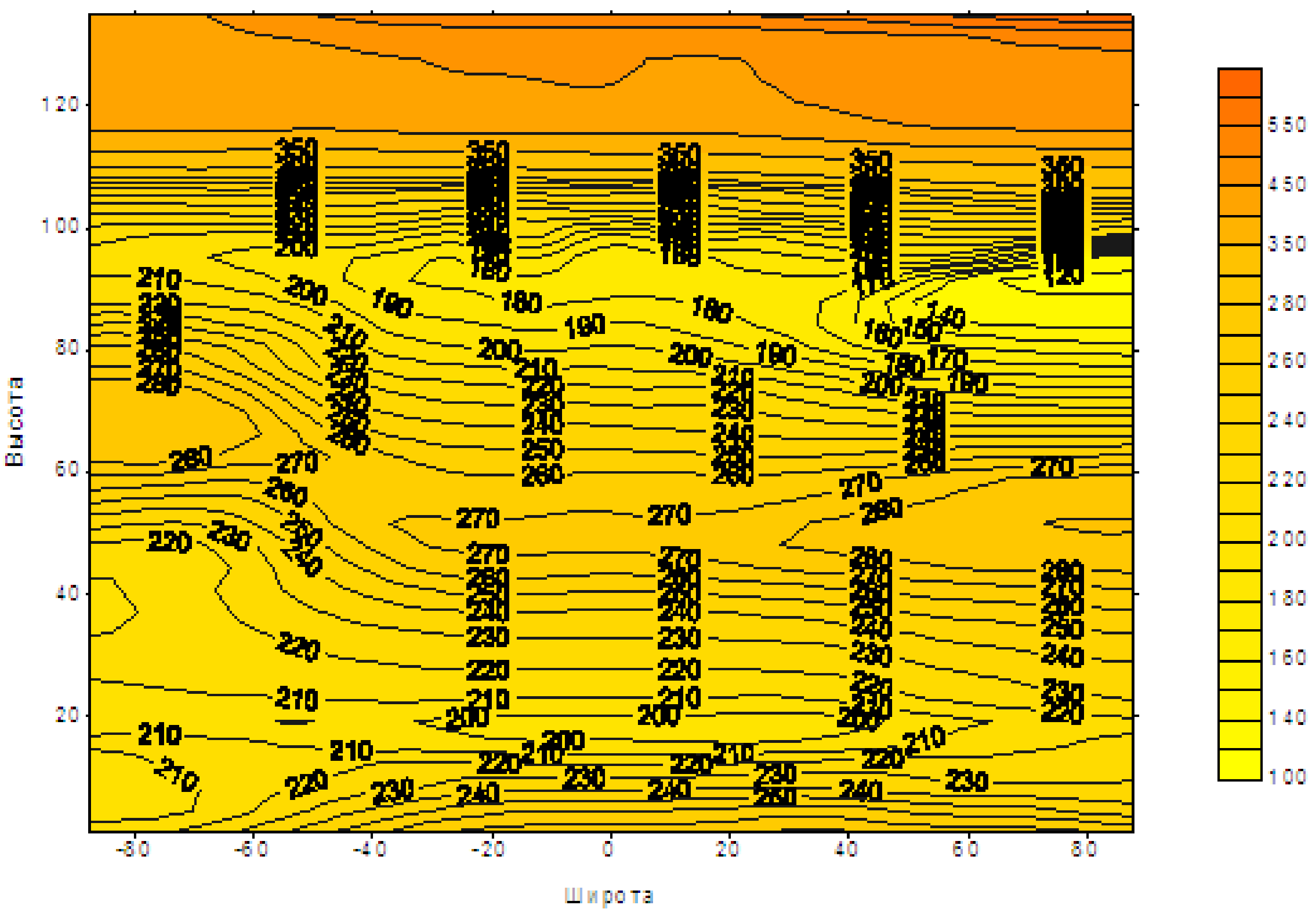
IR cooling- **CO_2, O_3, H_2O, NO**

(Chou et al., 2002; Fomichev, 2003; Kockarts, 1980),

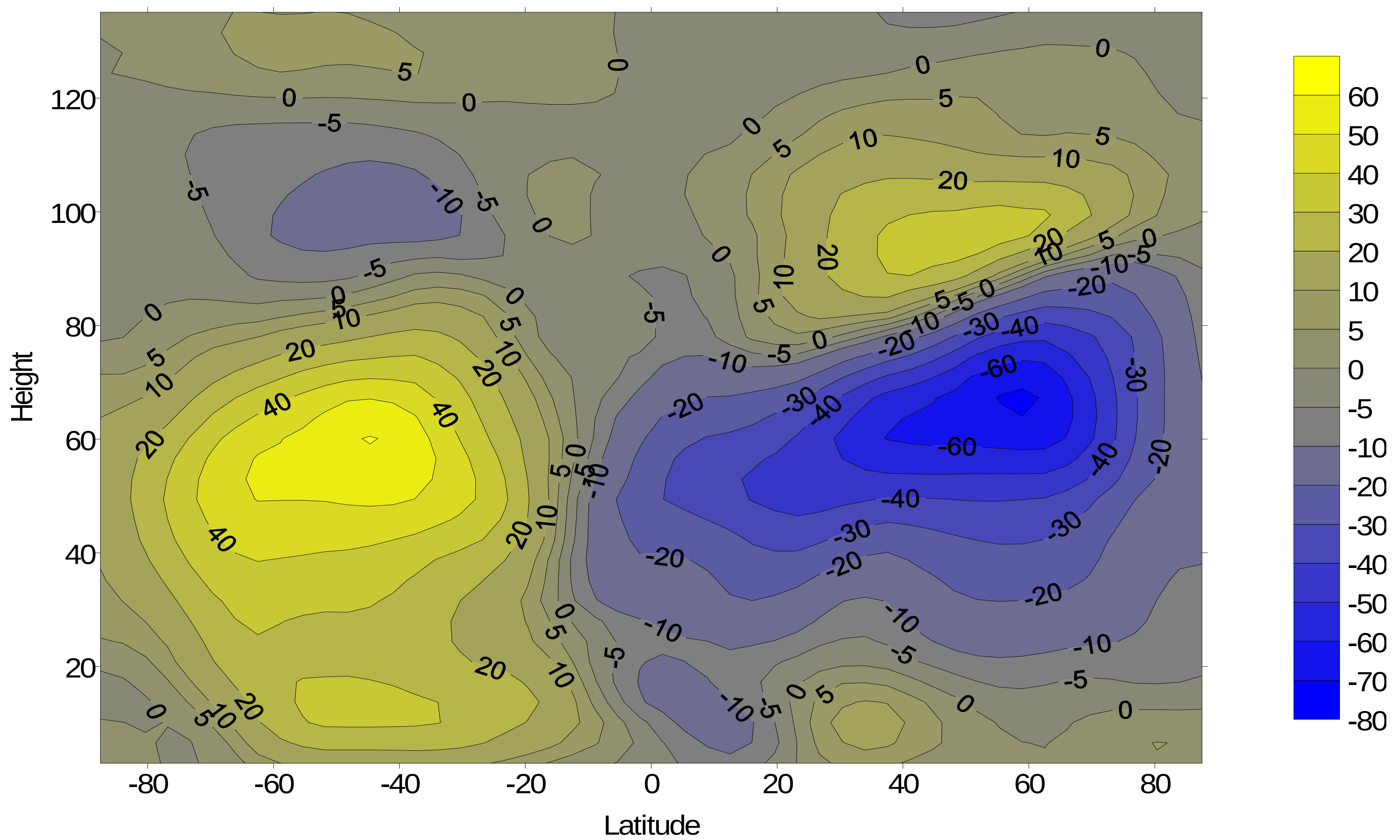
GWs **(Lindzen, 1981)**

Planetary waves at lower boundary

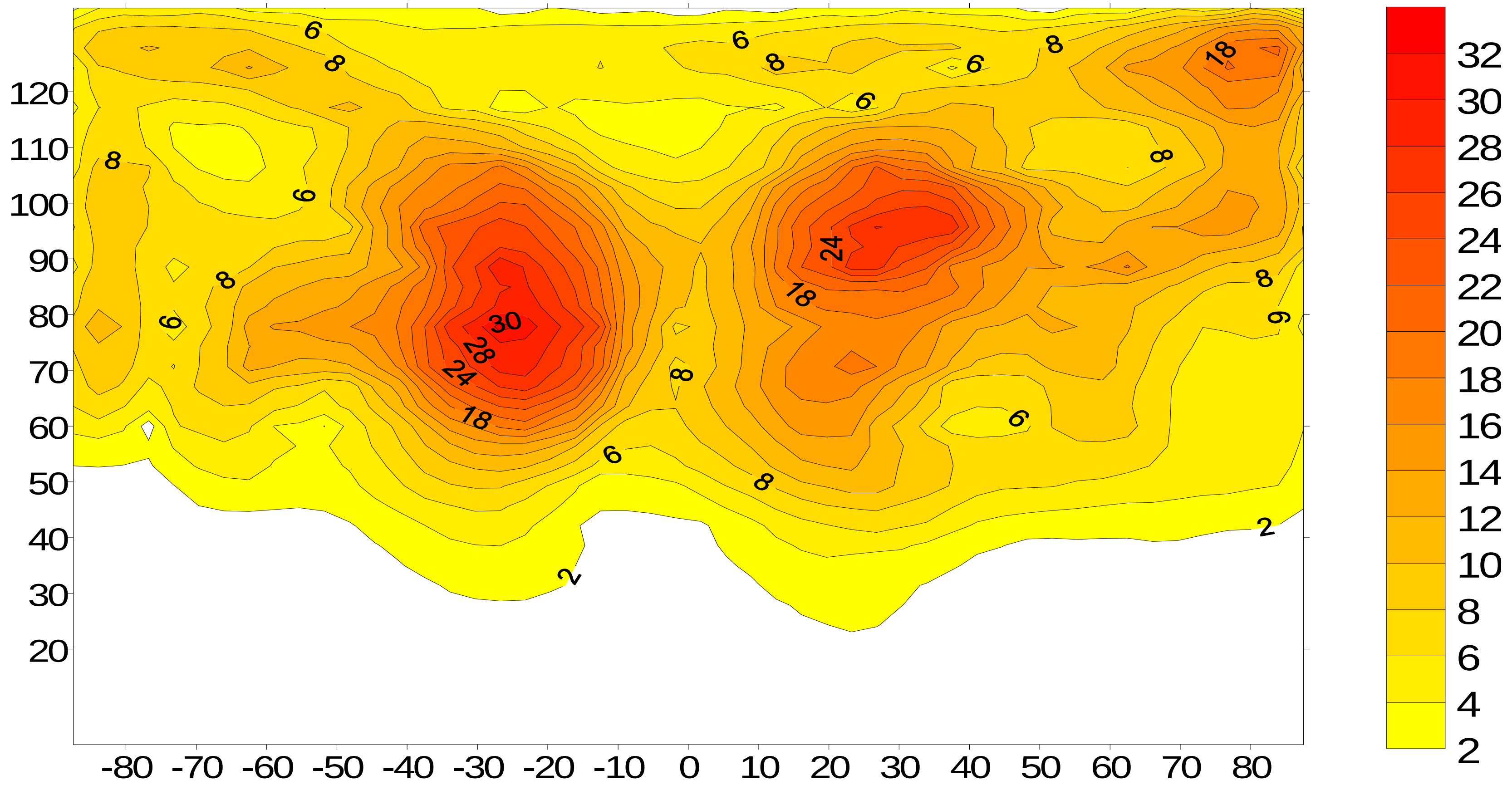
Temperature of the atmosphere for July (ARM model runs)



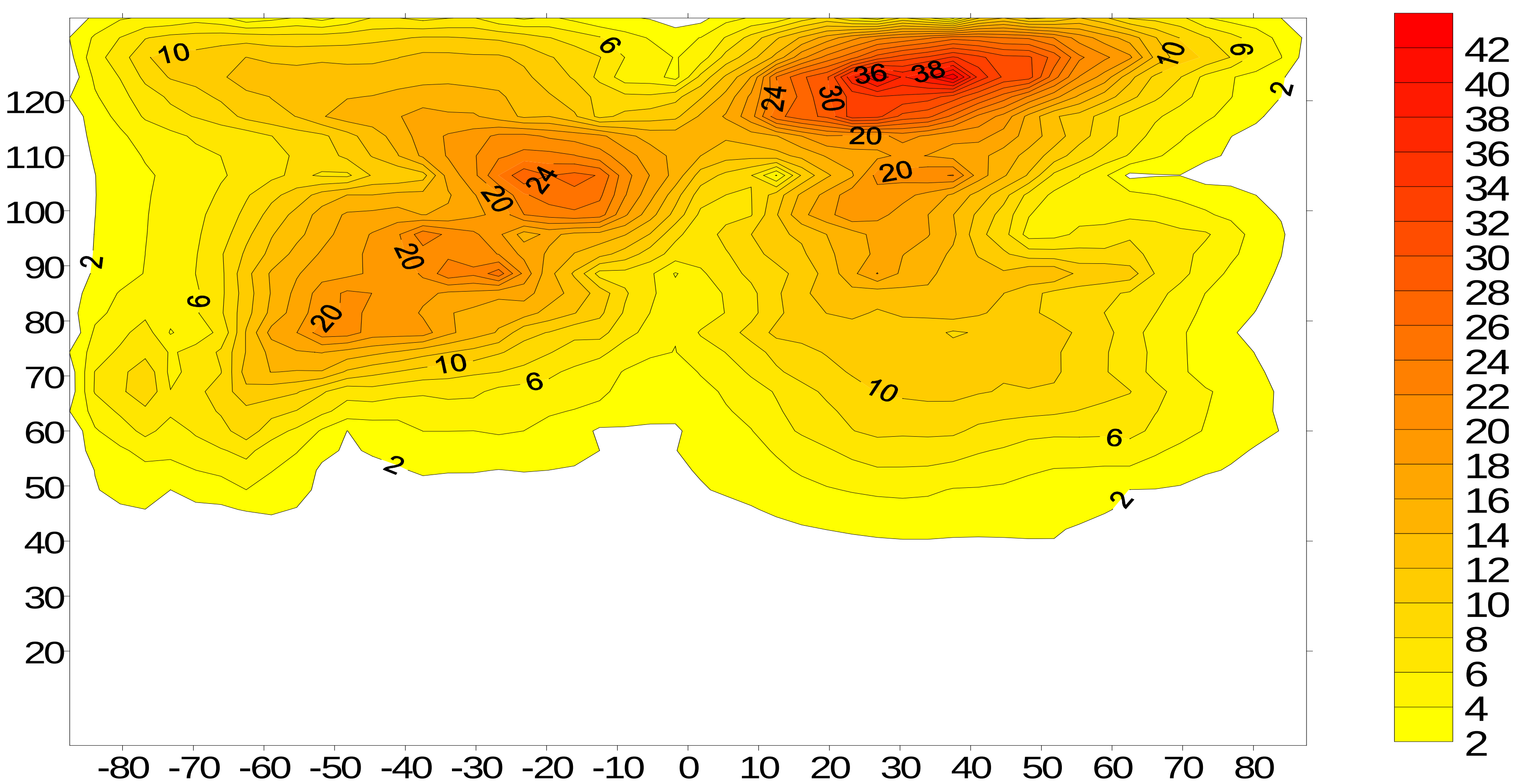
Zonal wind (m/s) for January
(ARM model runs)



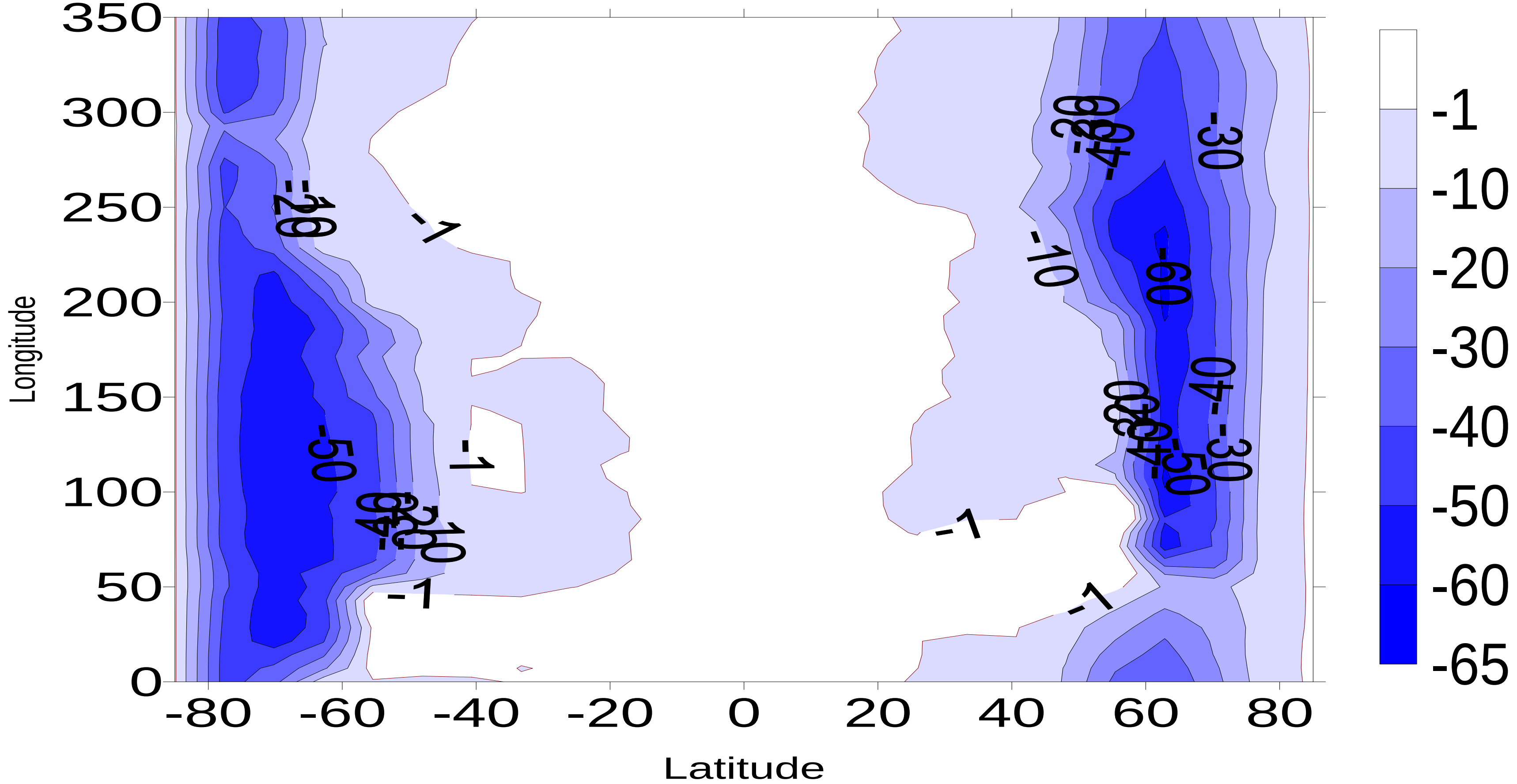
Tidal component (D) in zonal wind for 18 July



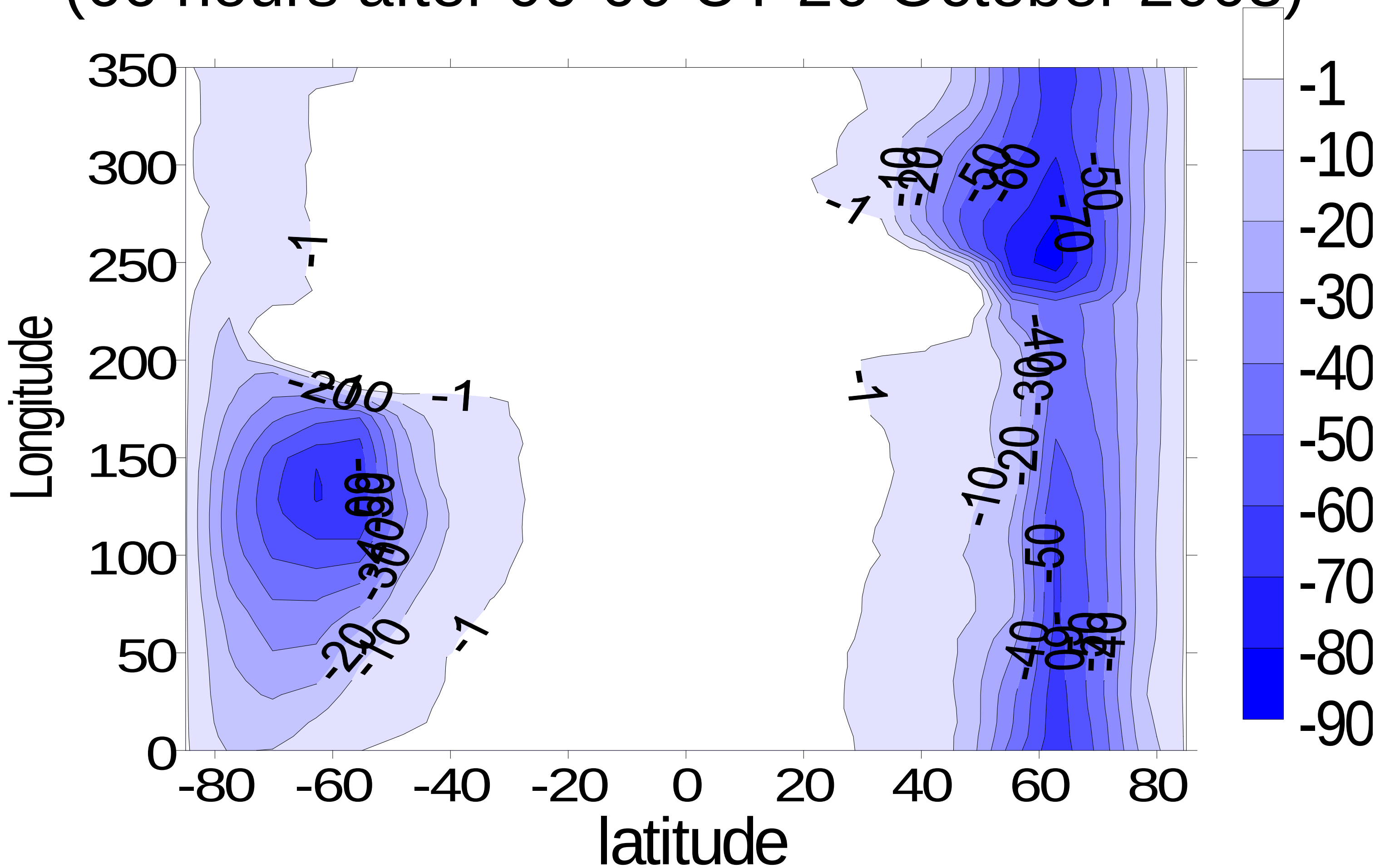
Tidal component (SD) in zonal wind for 18 July



3D Simulation of ozone response (%) at 66 km induced by joint effect of energetic particles (54 hours after 00-00 UT 26 October 2003)

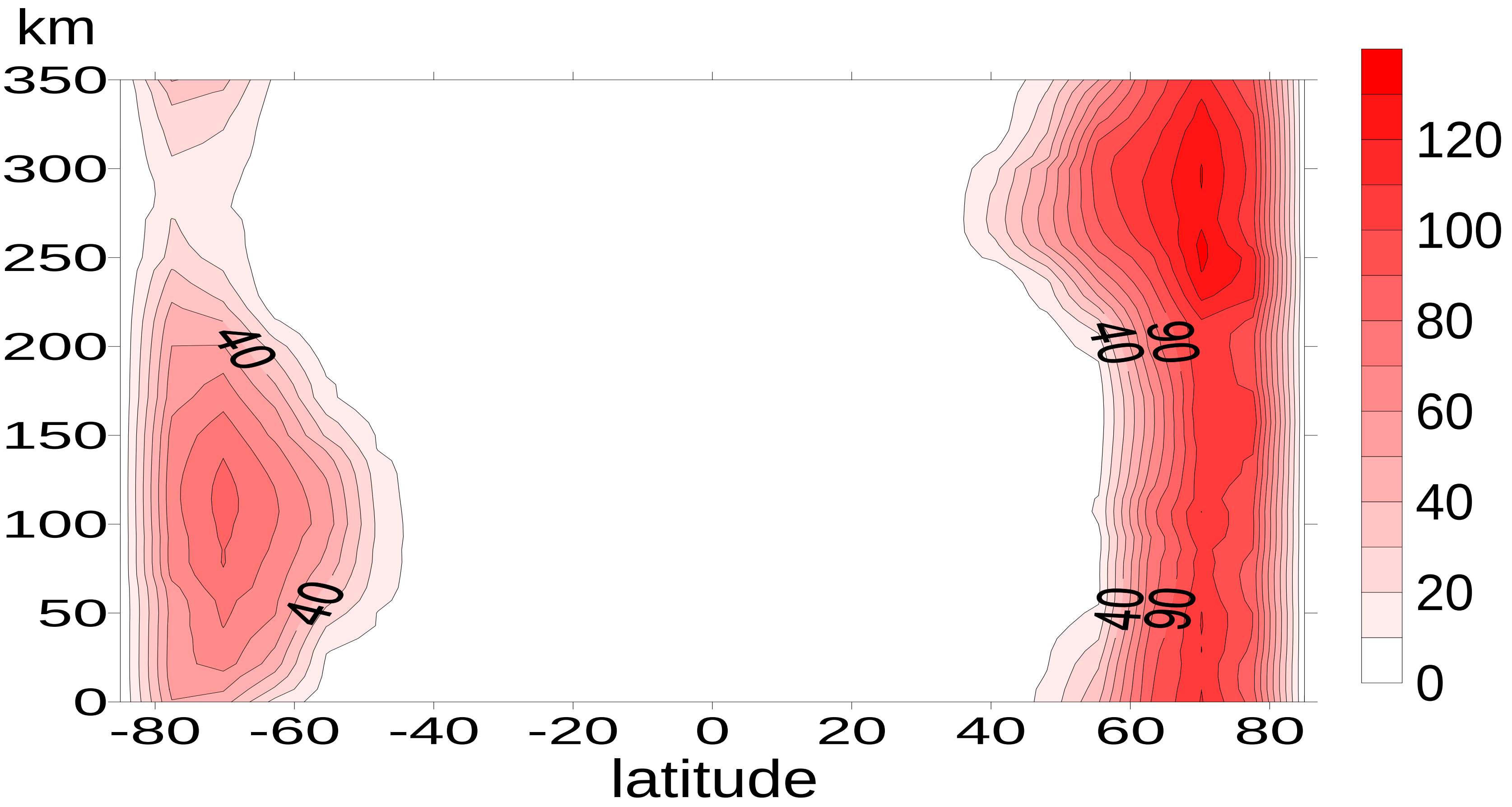


3D Simulation of ozone response (%) at 66 km induced by joint effect of solar protons and precipitating electrons (66 hours after 00-00 UT 26 October 2003)

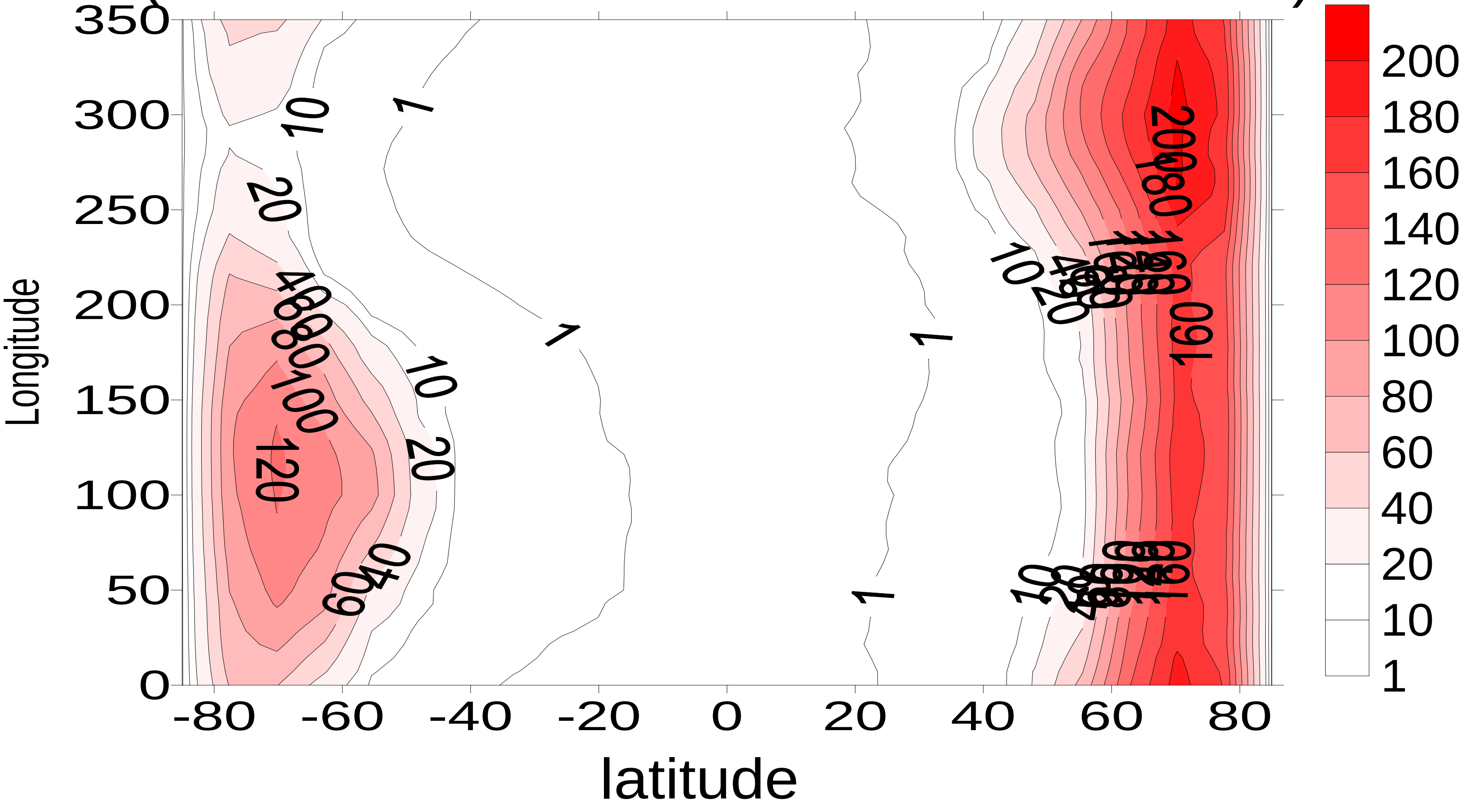


3D Simulation of **NOy response** (ppbv) at **66 km** induced by joint effect of solar protons and precipitating electrons

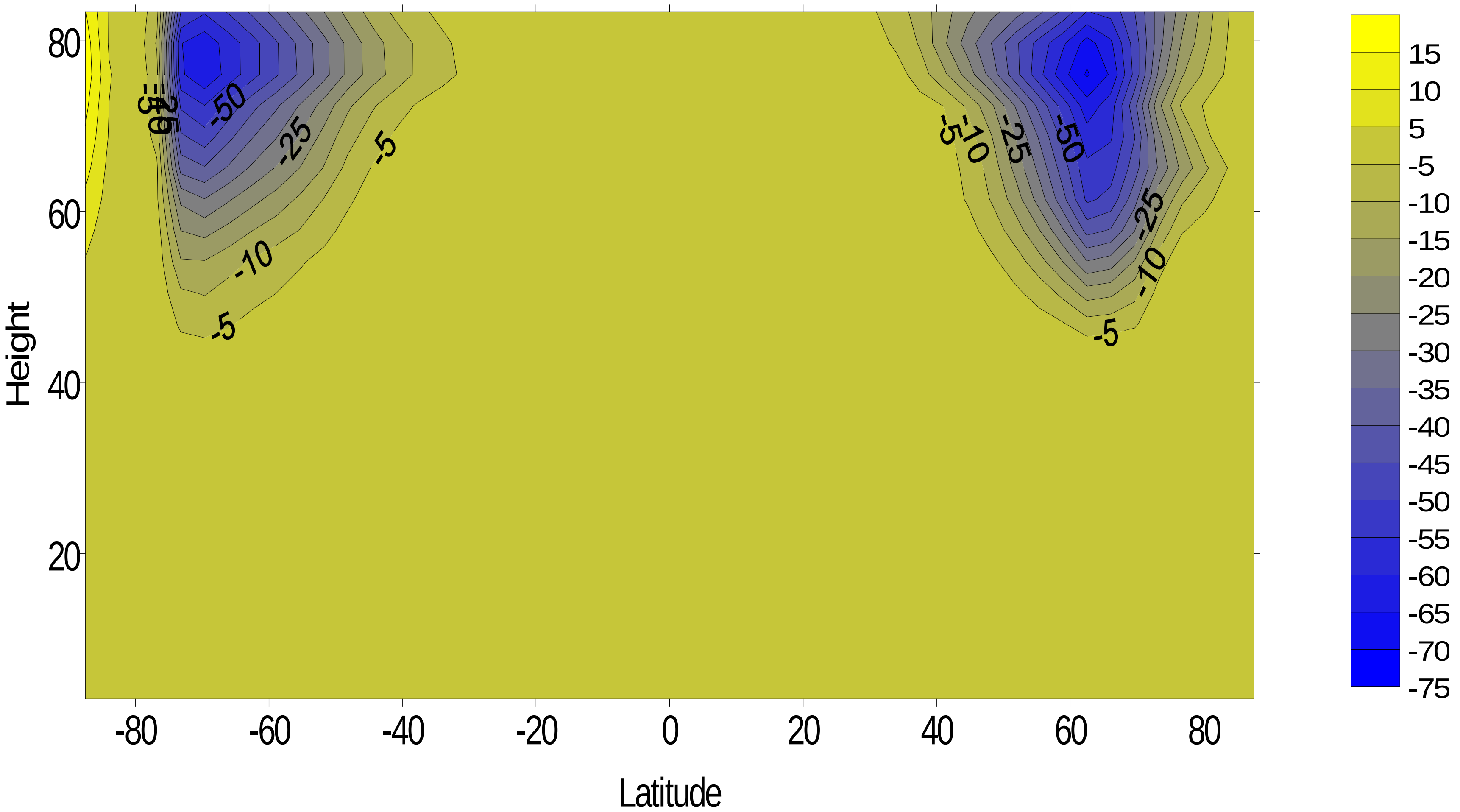
(54 hours after 00-00 UT 26 October 2003)



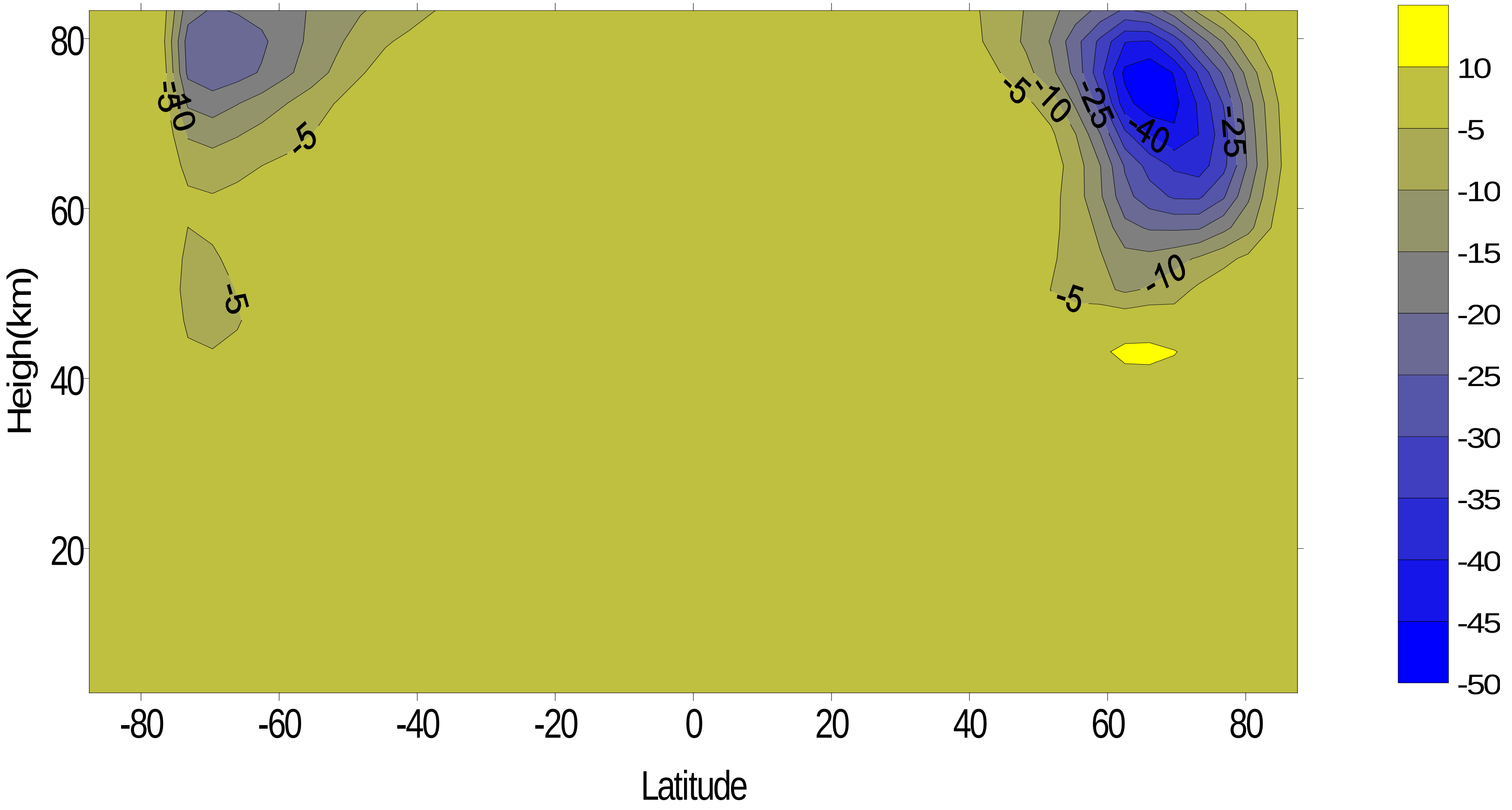
3D Simulation of **NOy response** (ppbv) at **66 km** induced by joint effect of solar protons and precipitating electrons (66 hours after 00-00 UT 26 October 2003)



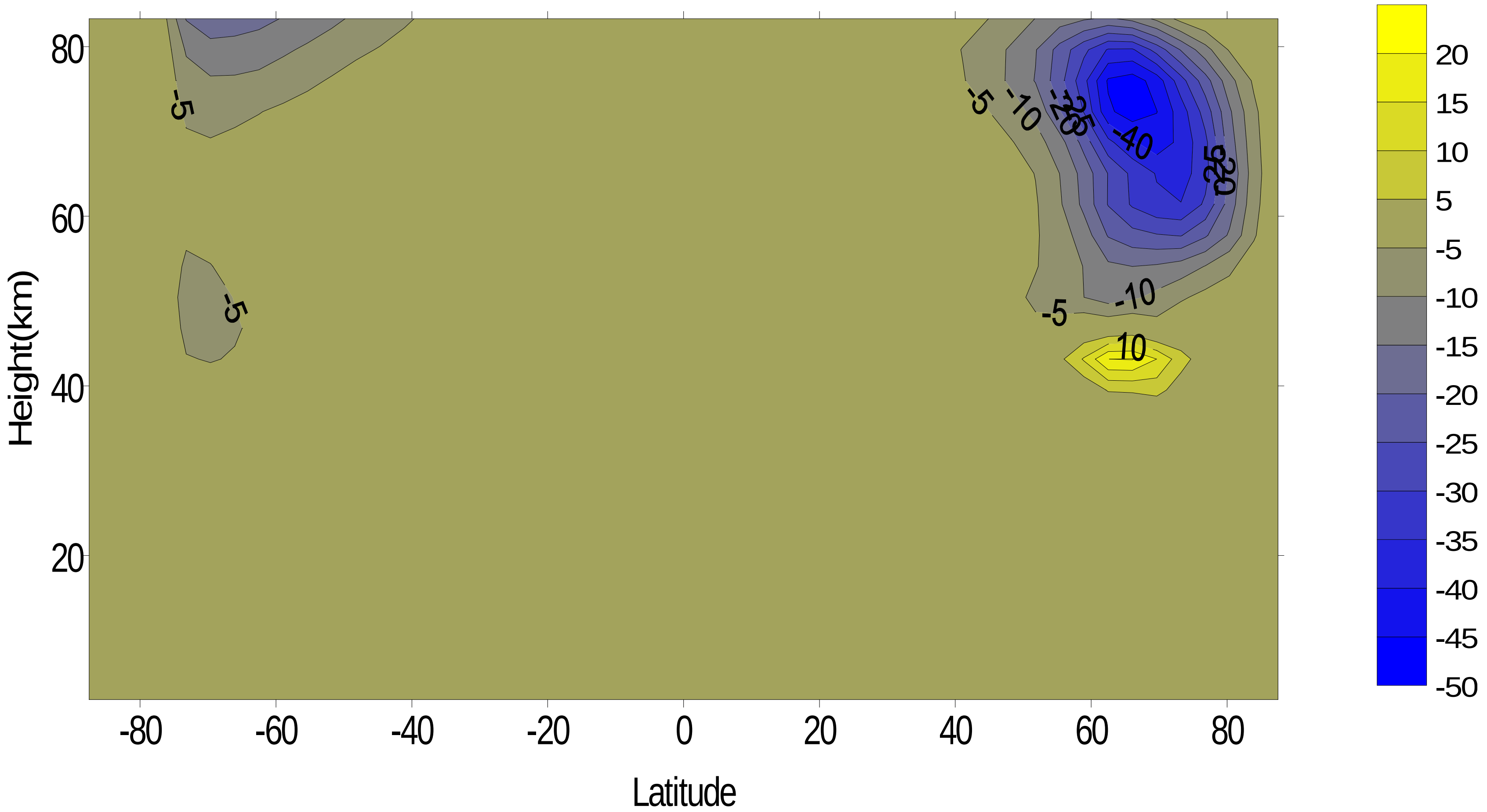
3D Simulation of ozone response induced by joint effect of solar protons and precipitating electrons (28 October 2003 12-00 UT)



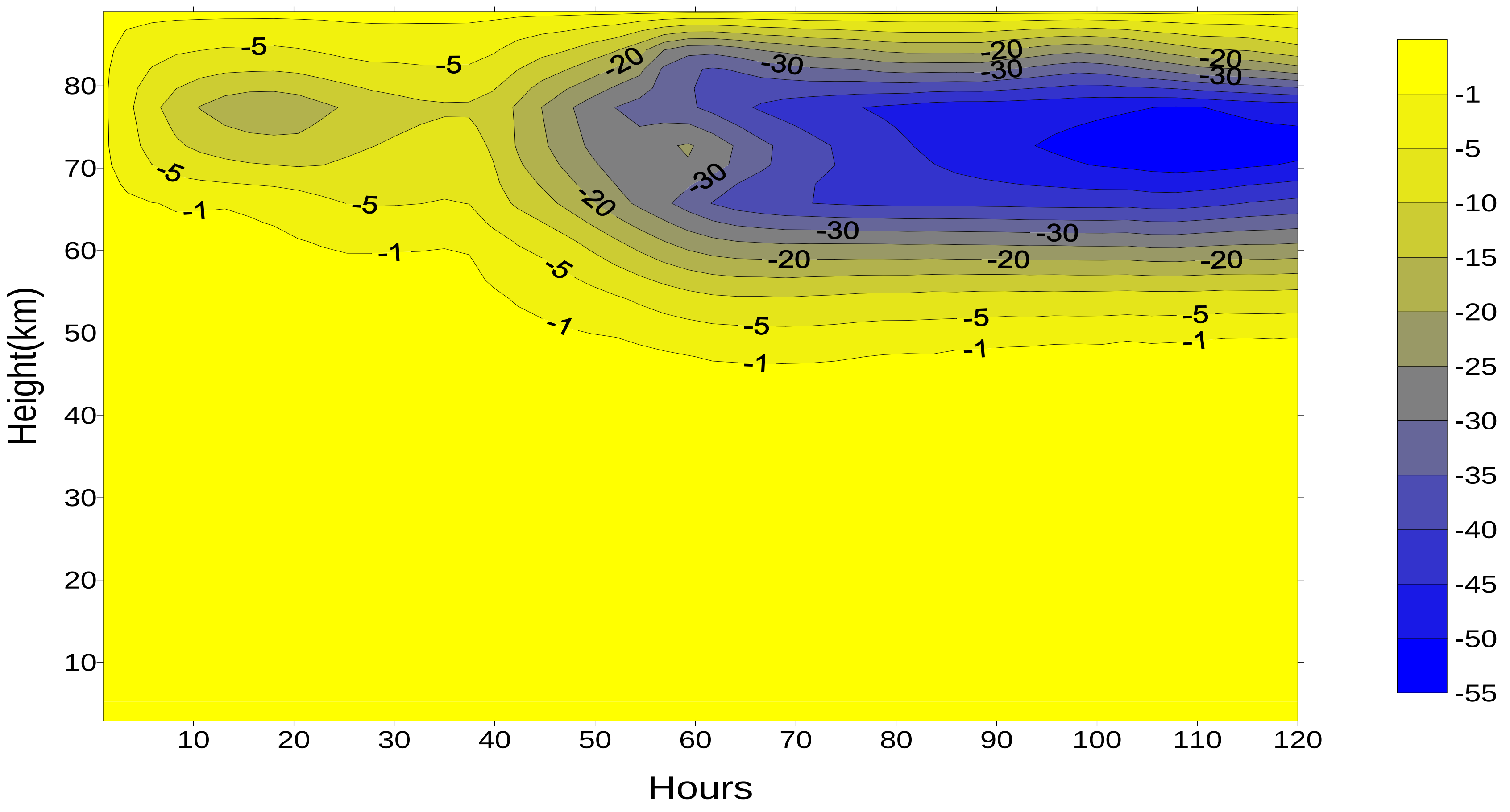
3D Simulation of ozone response induced by joint effect of solar protons and precipitating electrons (2 November 2003 12-00 UT)



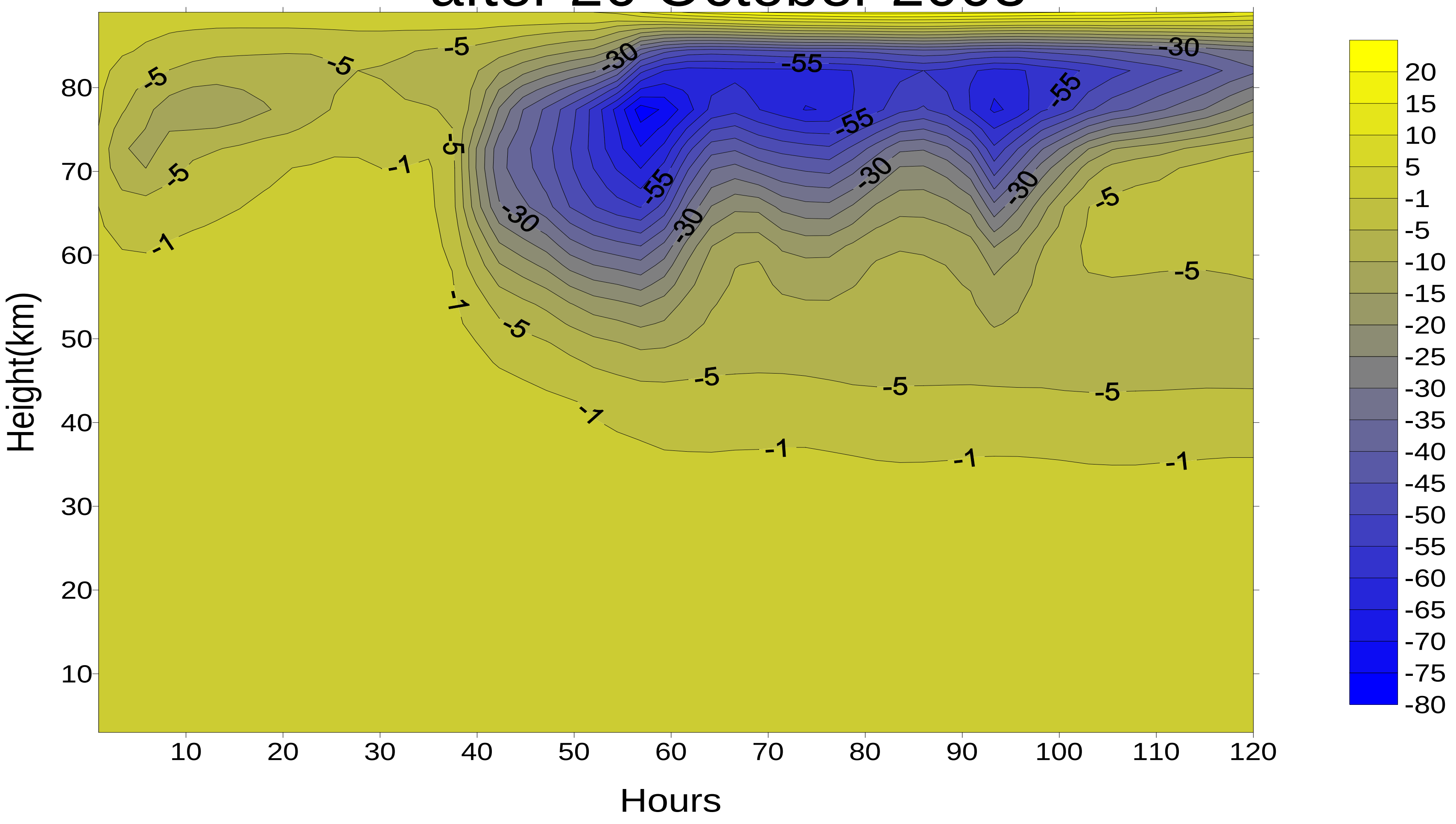
3D Simulation of ozone response induced by joint effect of solar protons and precipitating electrons (4 November 2003 12-00 UT)



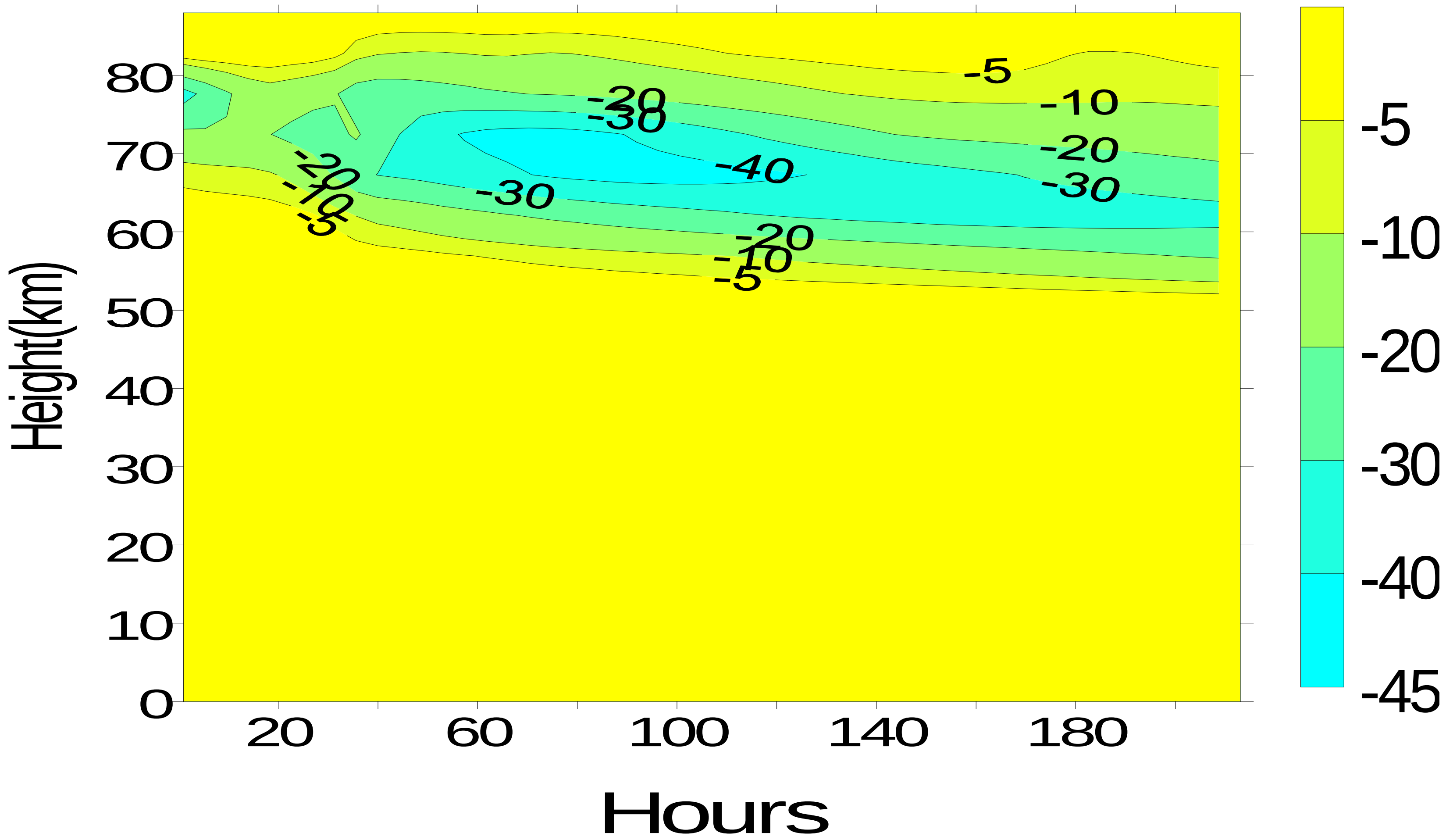
3D Simulation of ozone response (%) at 75 N induced by joint effect of solar protons and precipitating electrons after 26 October 2003



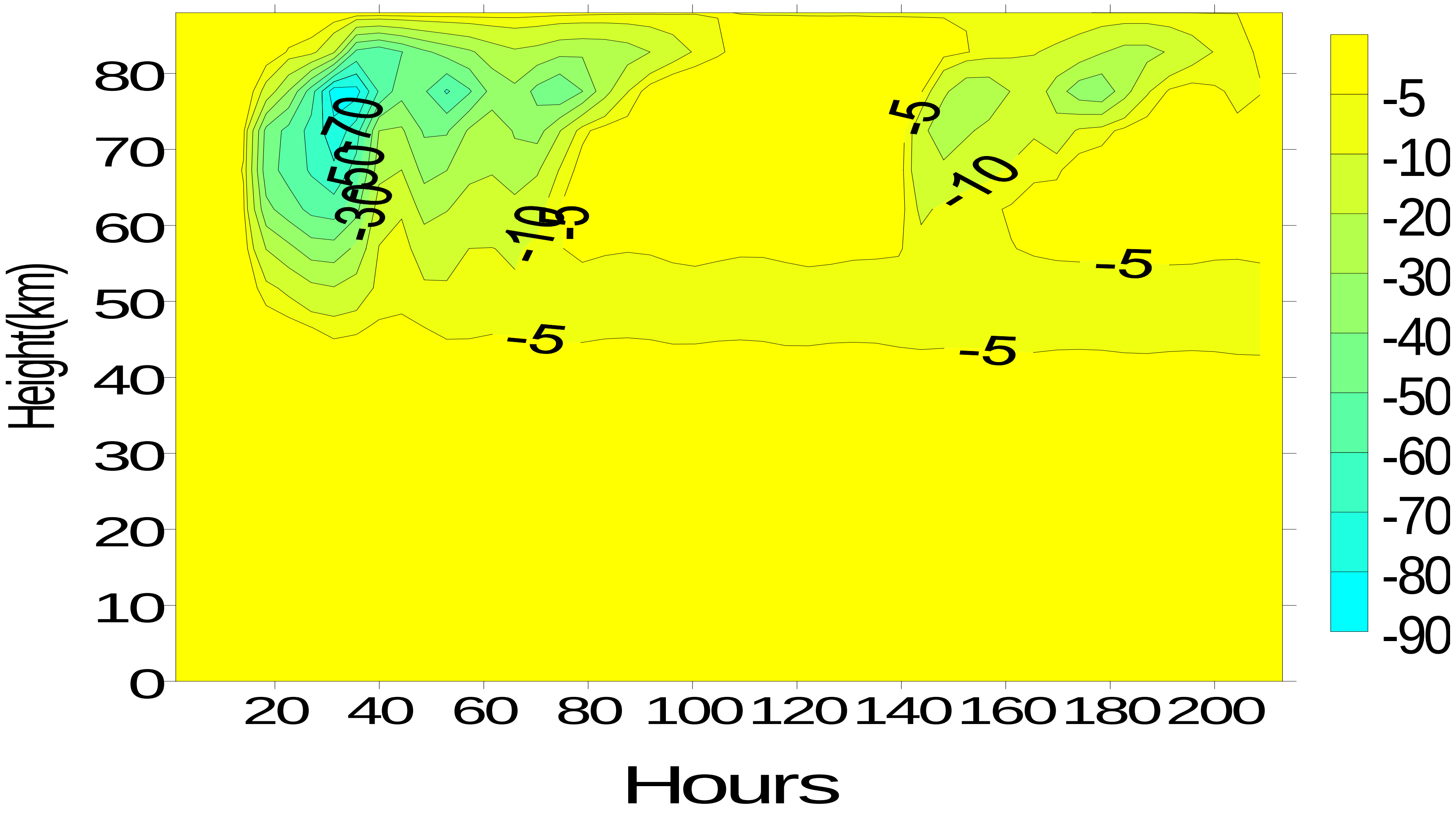
3D Simulation of ozone response (%) at 75 S induced by joint effect of solar protons and precipitating electrons after 26 October 2003



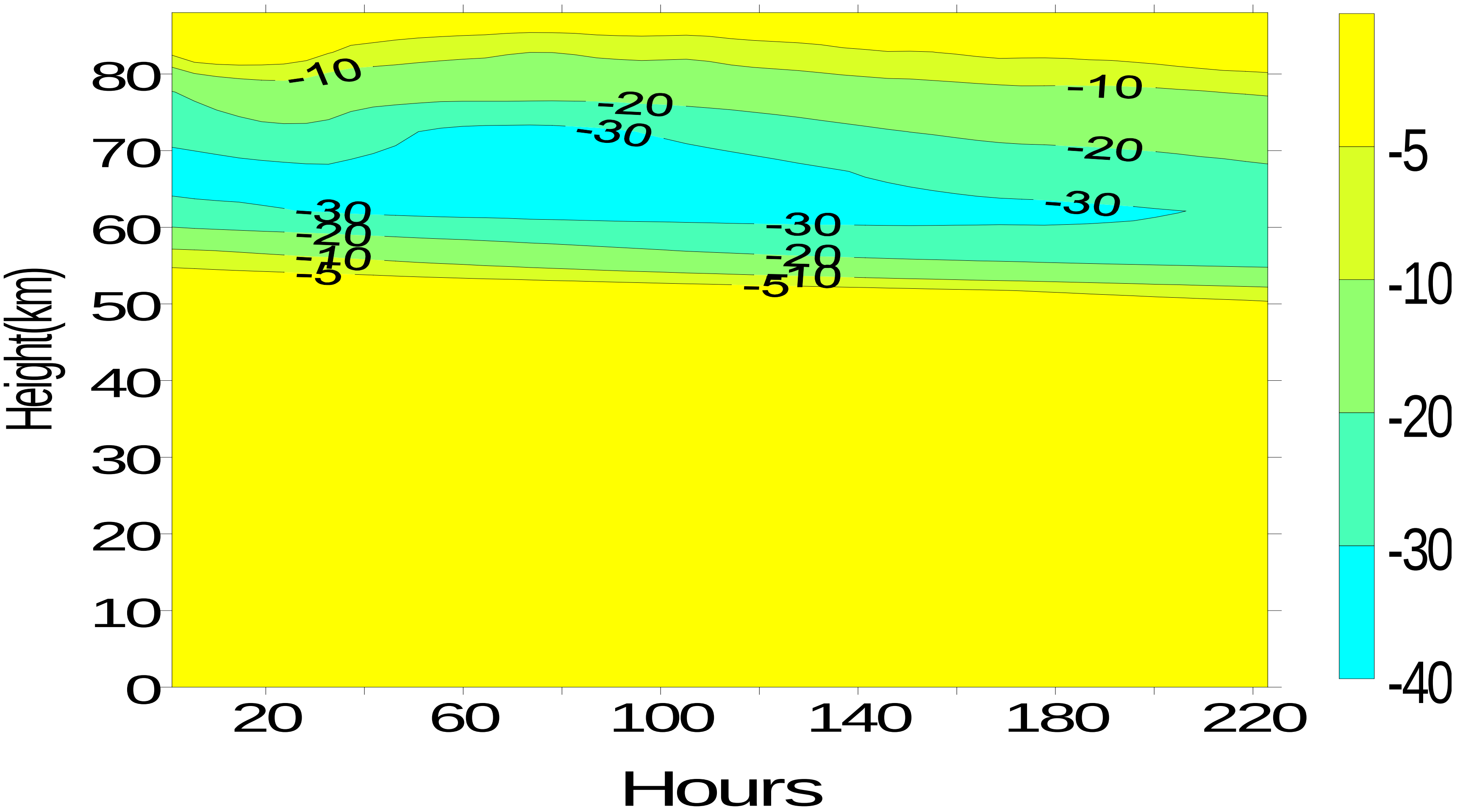
Ozone response (%) at 75 N induced by solar protons after 27 October 2003 (3D simulation)



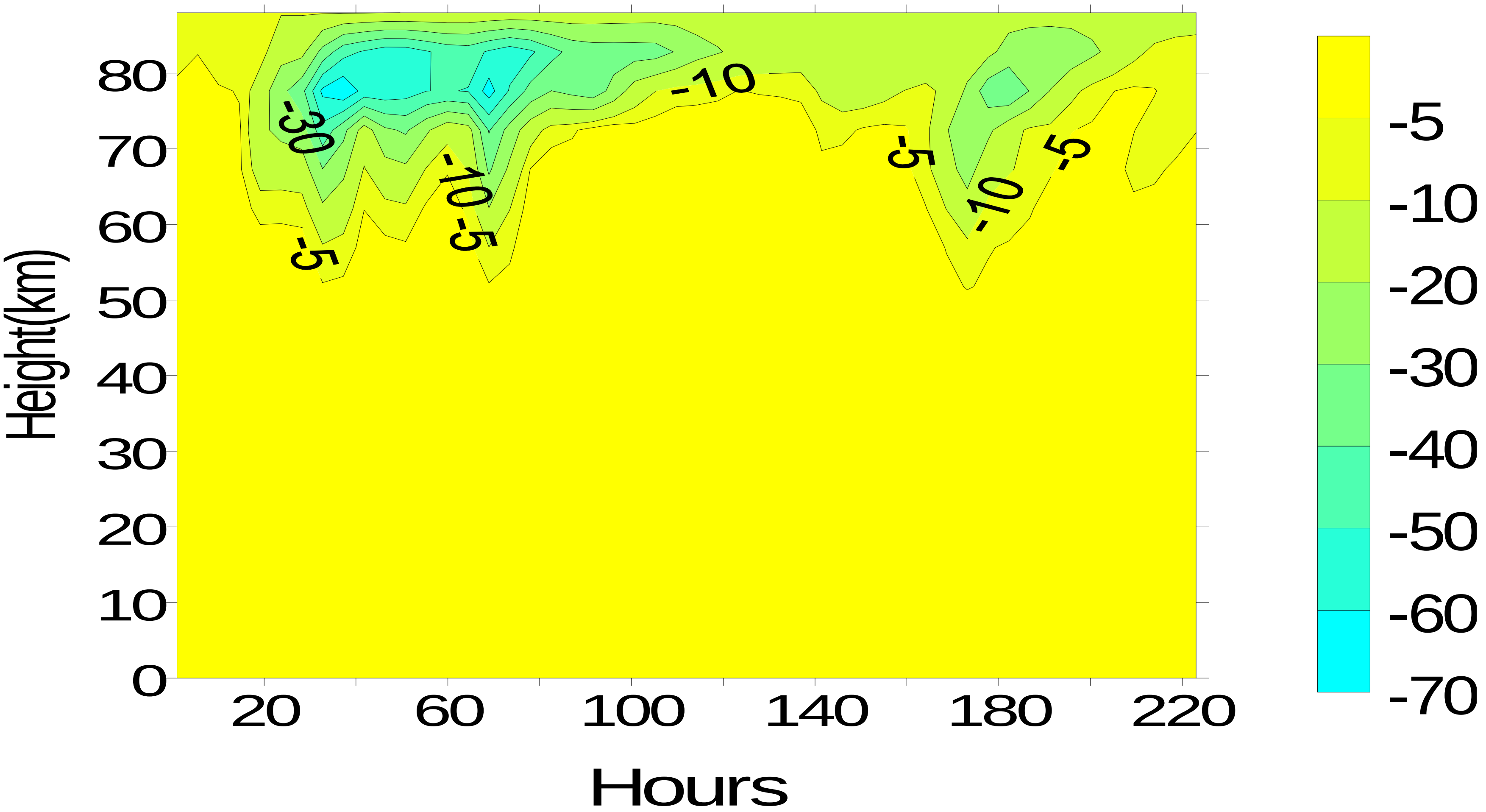
Ozone response (%) at 75 S induced by solar protons after 27 October 2003 (3D simulation)



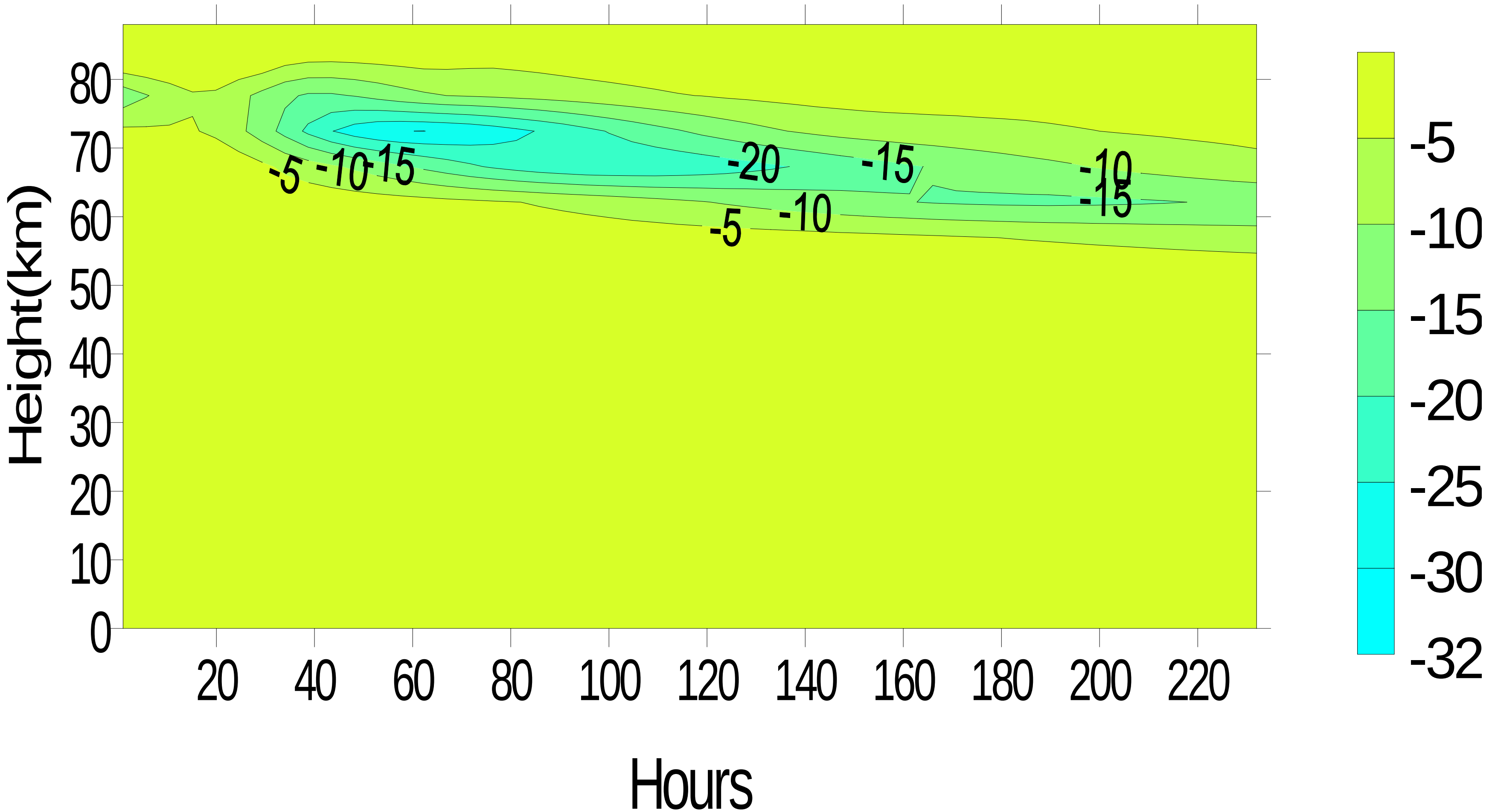
Ozone response (%) at 75 N induced by electrons after 27 October 2003 (3D simulation)



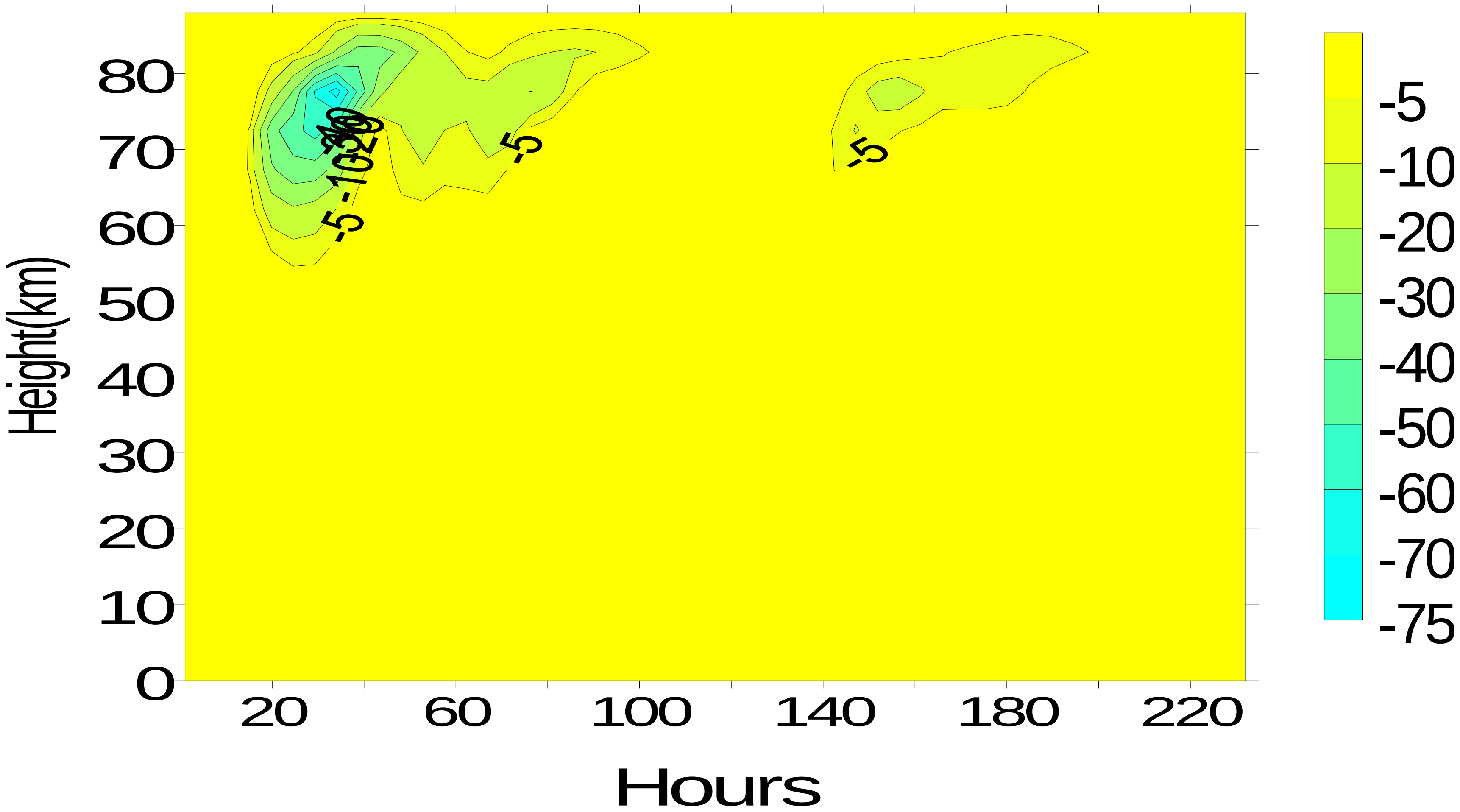
Ozone response (%) at 75 S induced by electrons after 27 October 2003 (3D simulation)



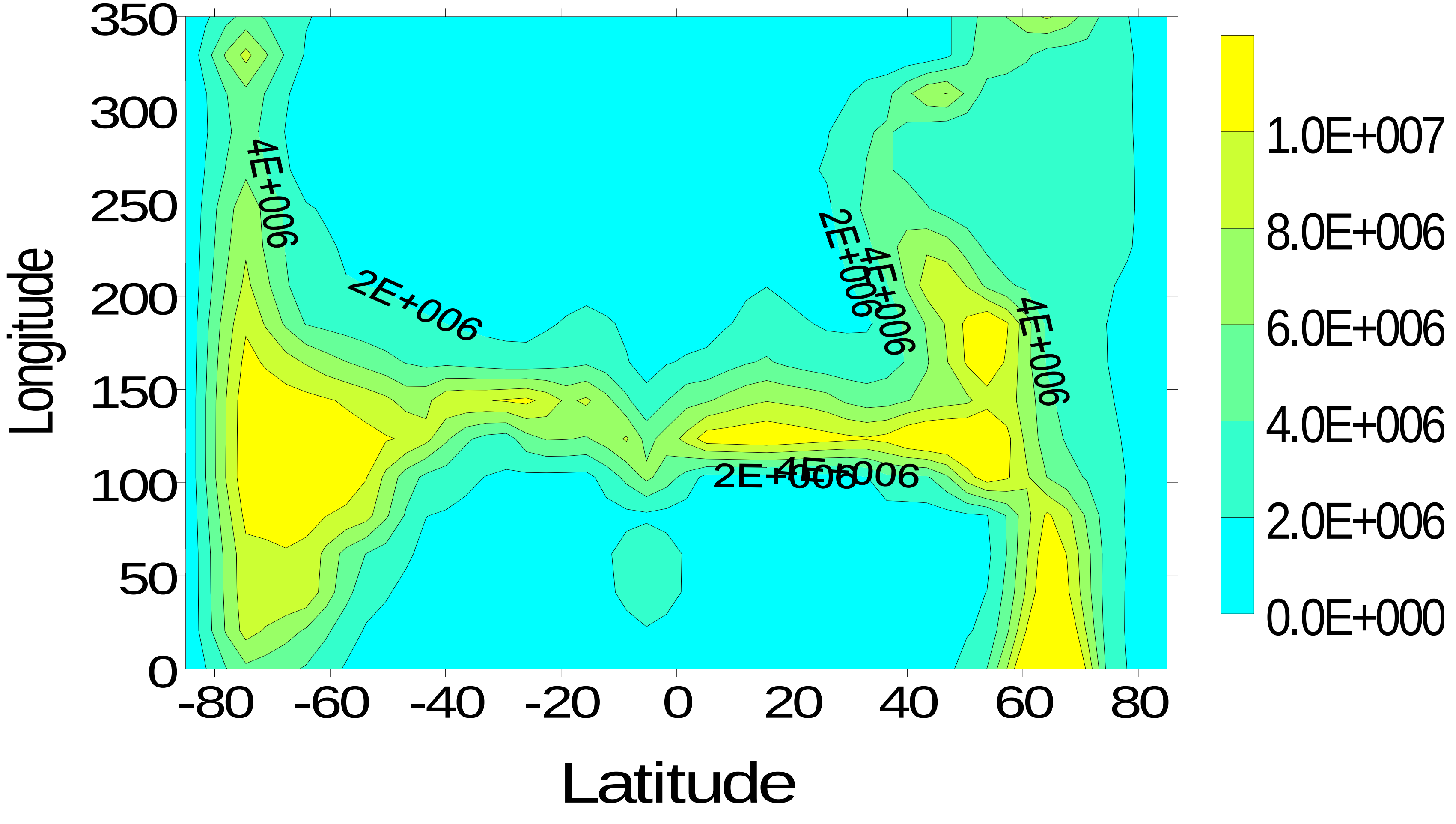
Ozone response (%) at 75 N induced by alfa-particles after 27 October 2003 (3D simulation)



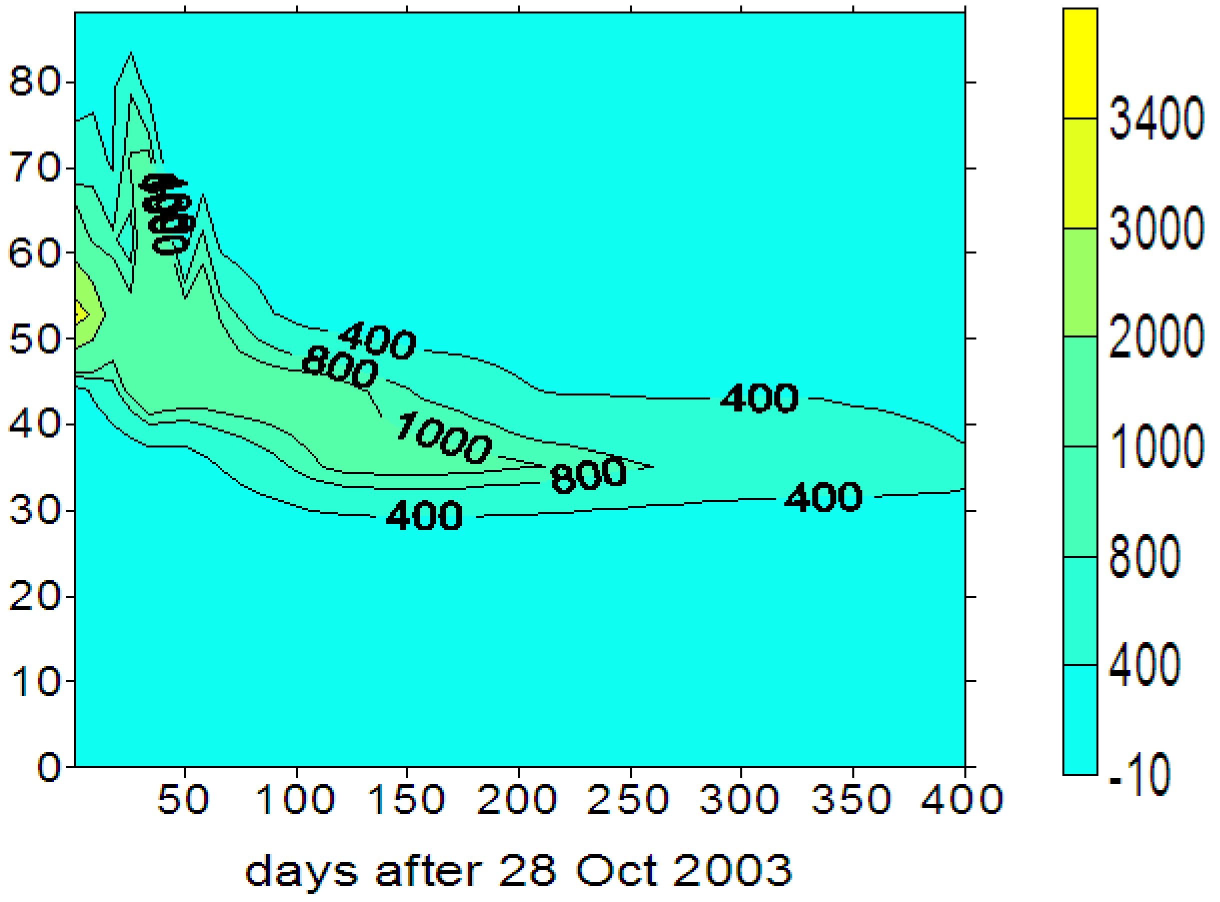
Ozone response (%) at 75 S induced by alfa particles after 27 October 2003 (3D simulation)



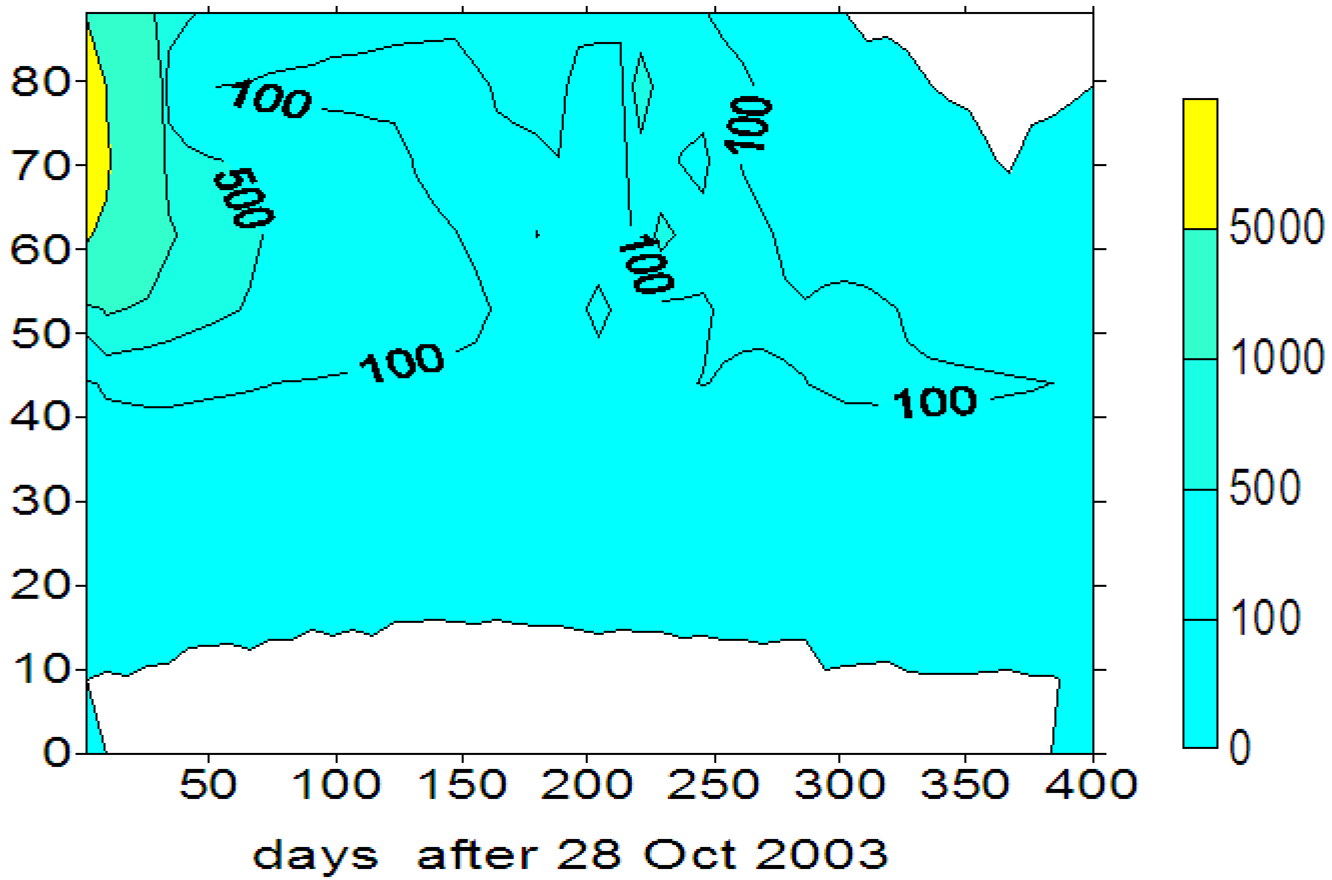
OH response at 66 km induced by joint effect of energetic particles for 11-00 UT 28 October 2003 (3D model simulations)



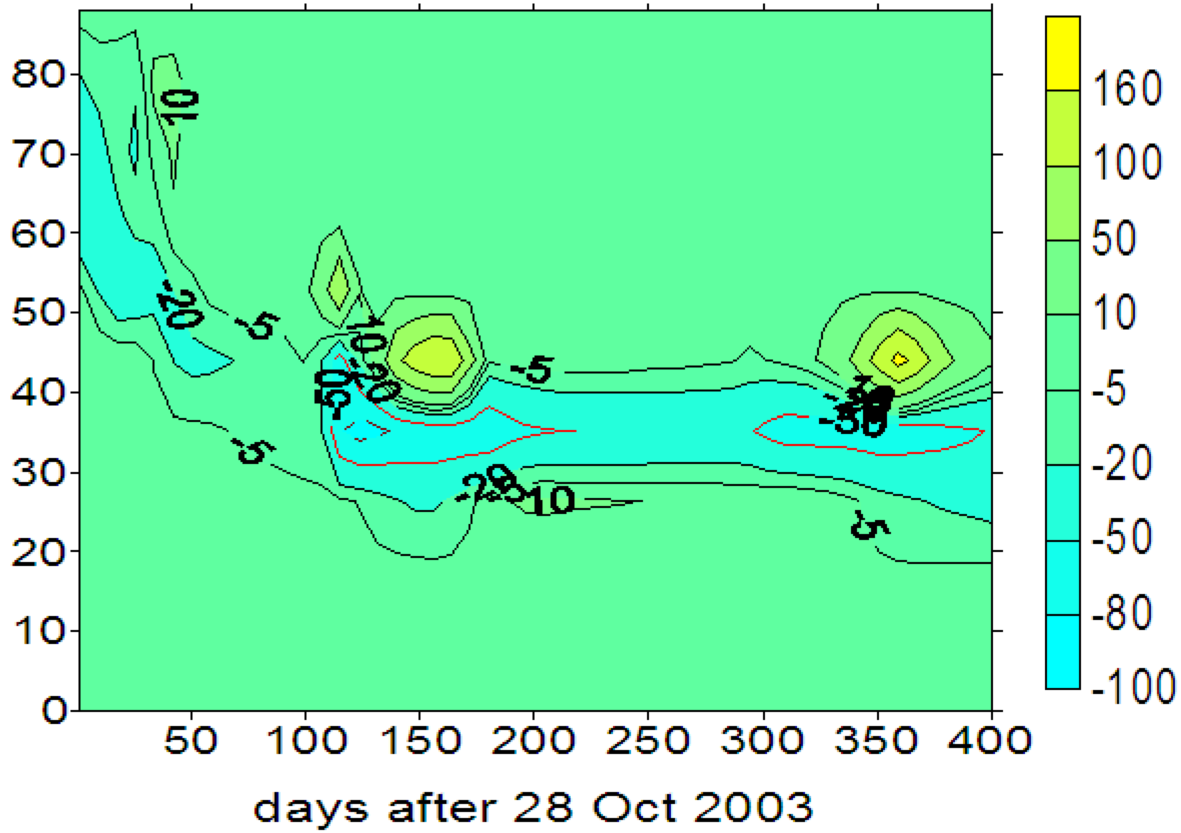
NOy response (%) induced by energetic particles in 2003-2004 at 75 N



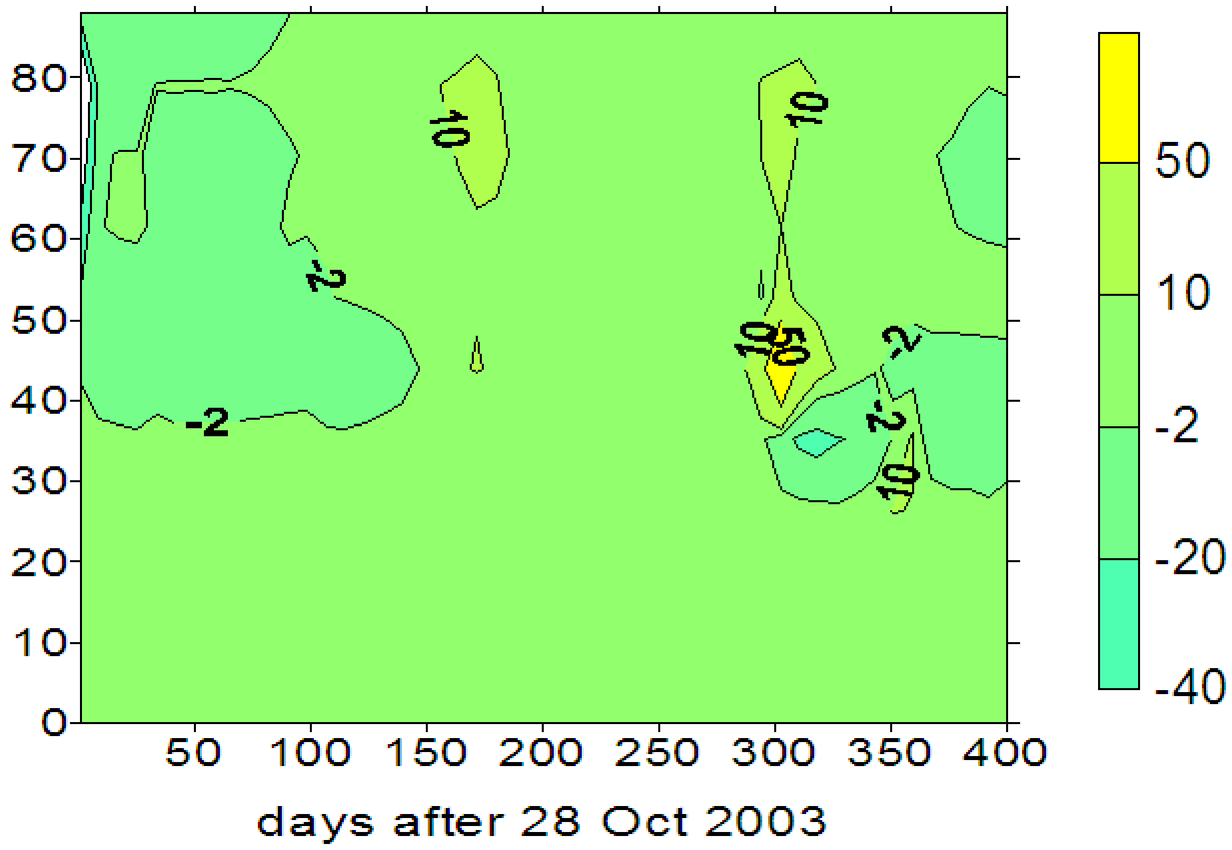
NOy response (%) induced by energetic particles in 2003-2004 at 75 S



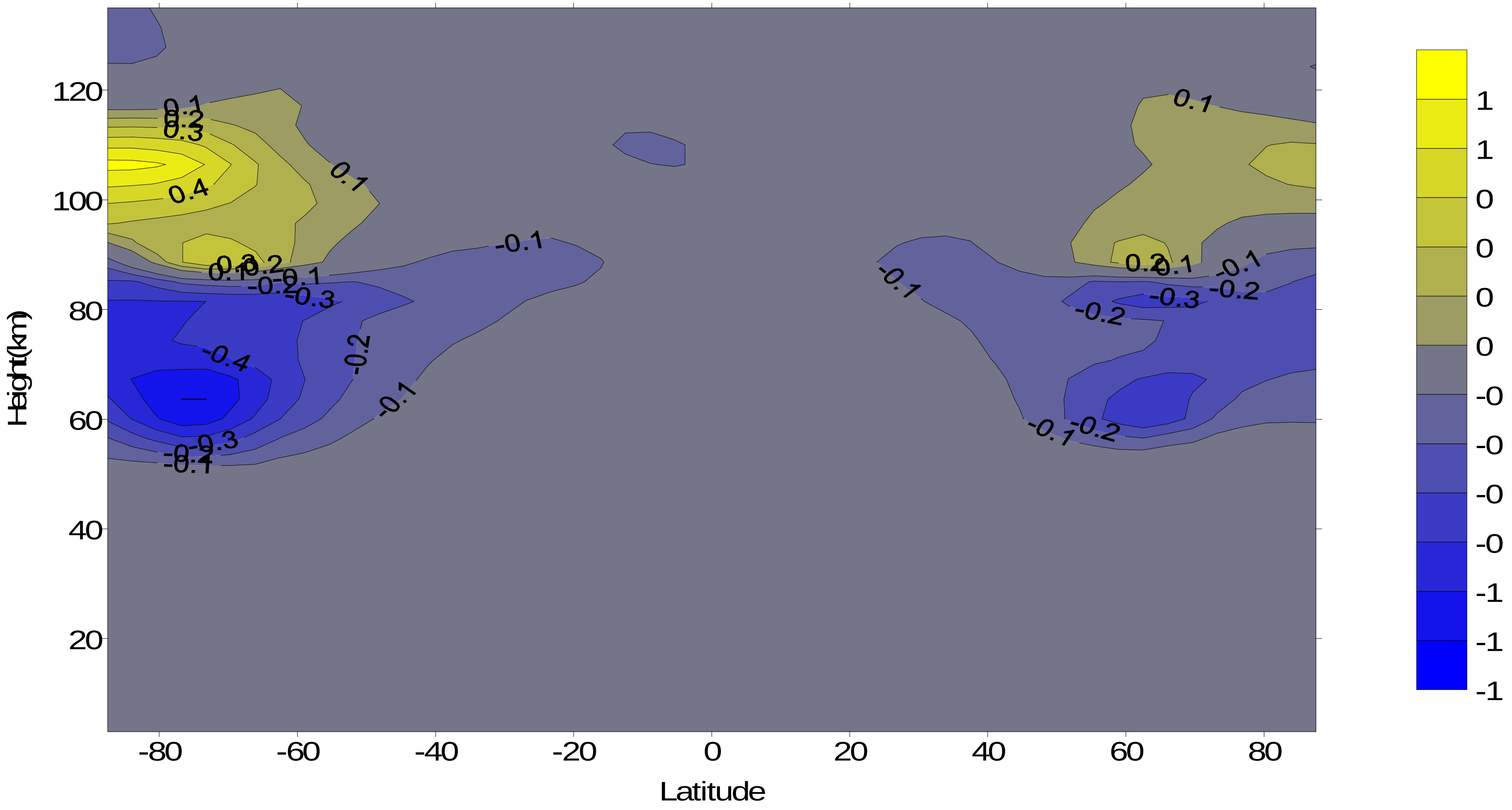
Simulated O3 response (%) induced by energetic particles in 2003-2004 at 75 N



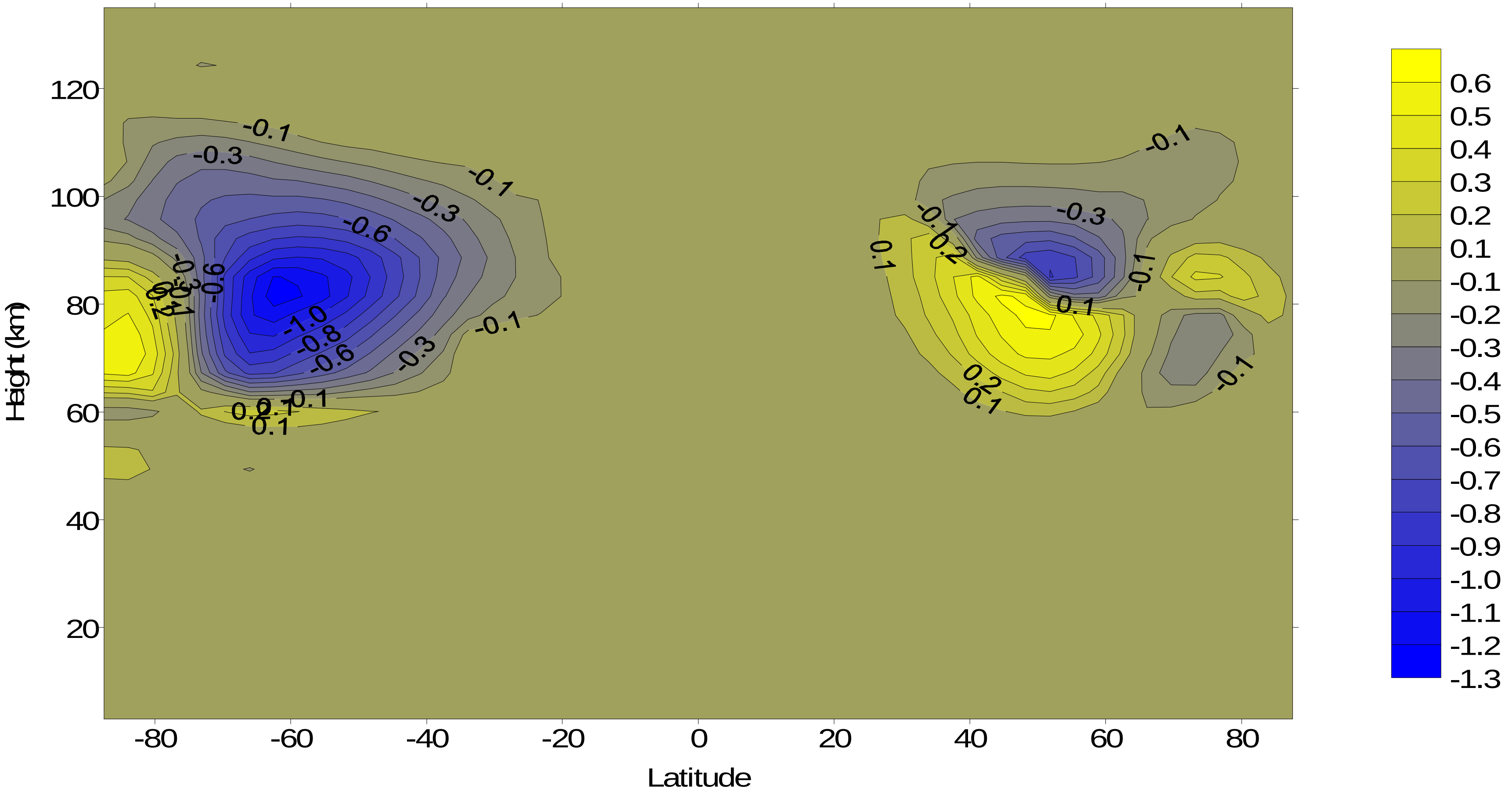
O3 response (%) induced by energetic particles in 2003-2004 at 75 S



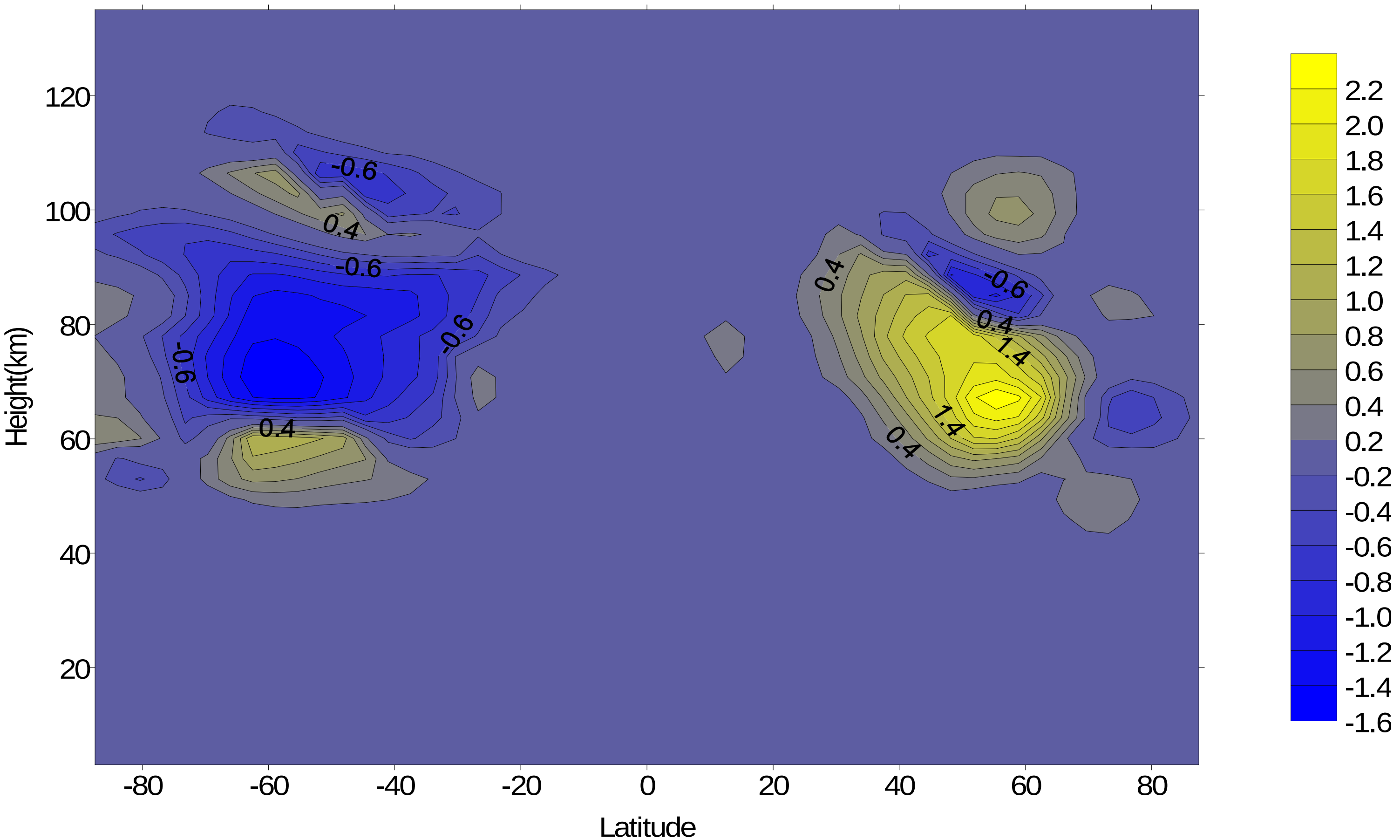
Temperature changes induced by SPE 28.10.2003
(ARM model runs)



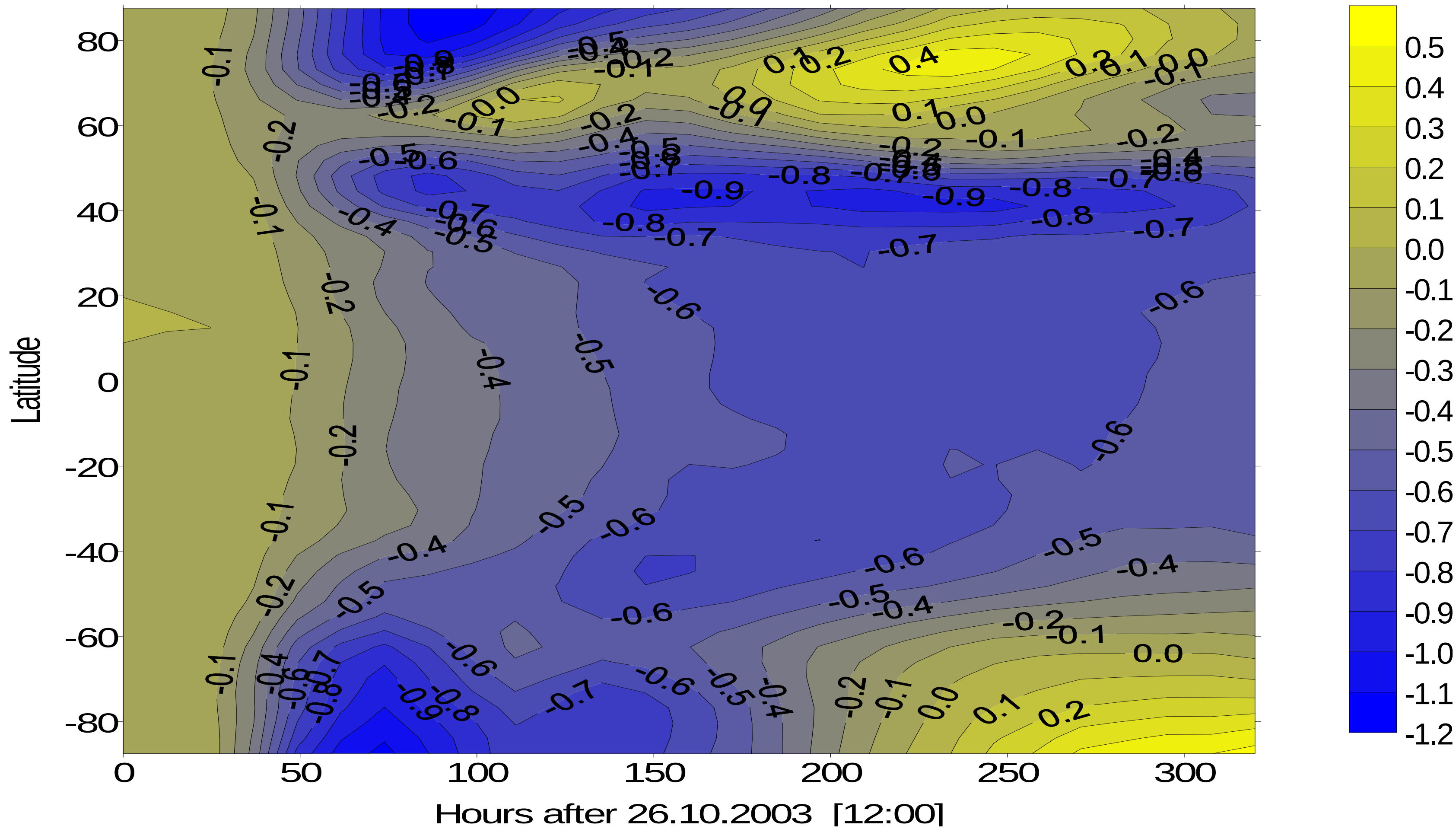
Changes in zonal wind (m/s) induced by SPE of 28.10.28
(ARM model runs)



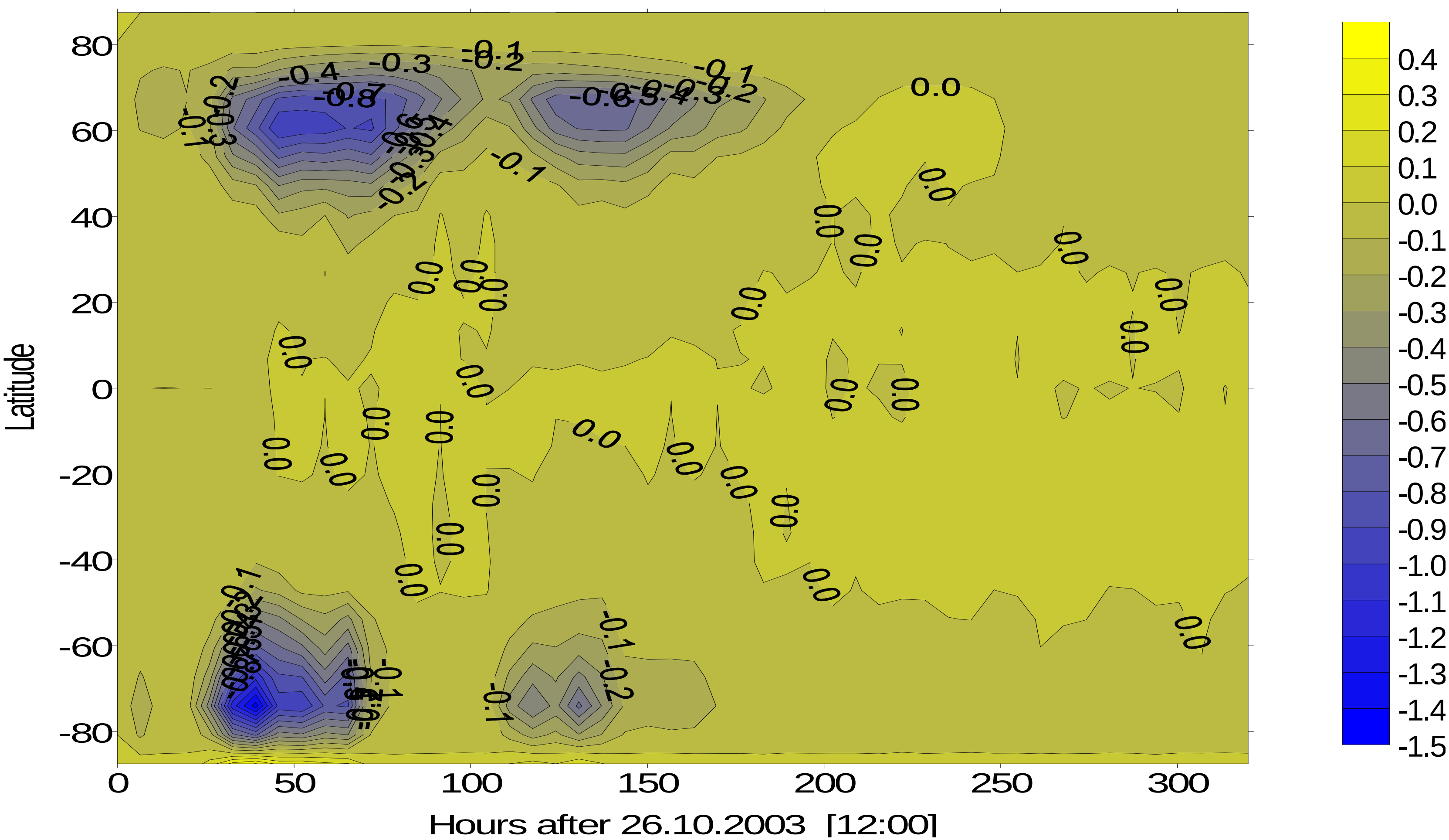
Changes in zonal wind magnitudes (absolute values) induced by SPE for 4 November 12-00 UT 2003 (simulations with ARM)



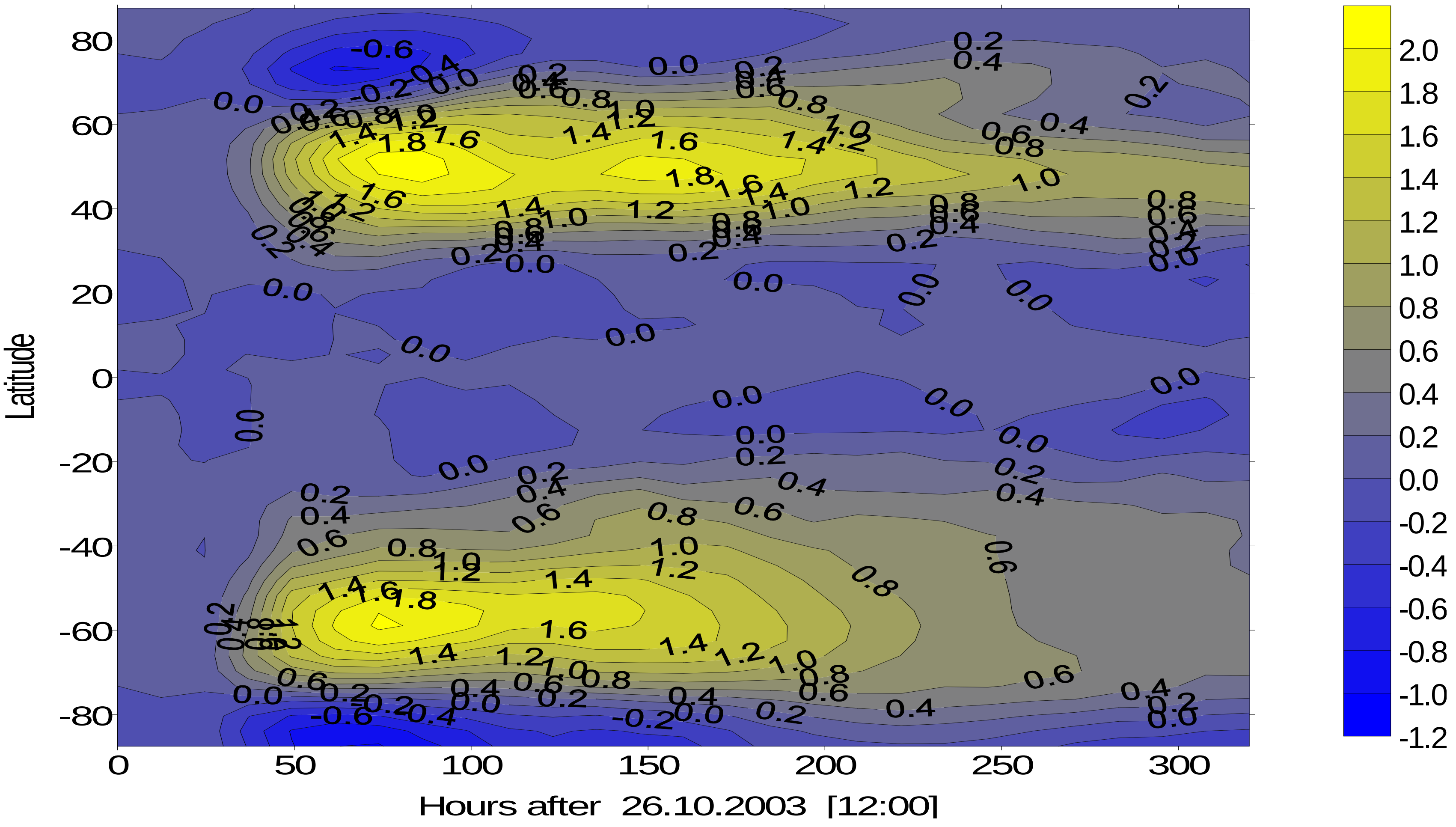
Changes in temperature caused by SPE 28.10.2003 at 72 km (GCM model runs)



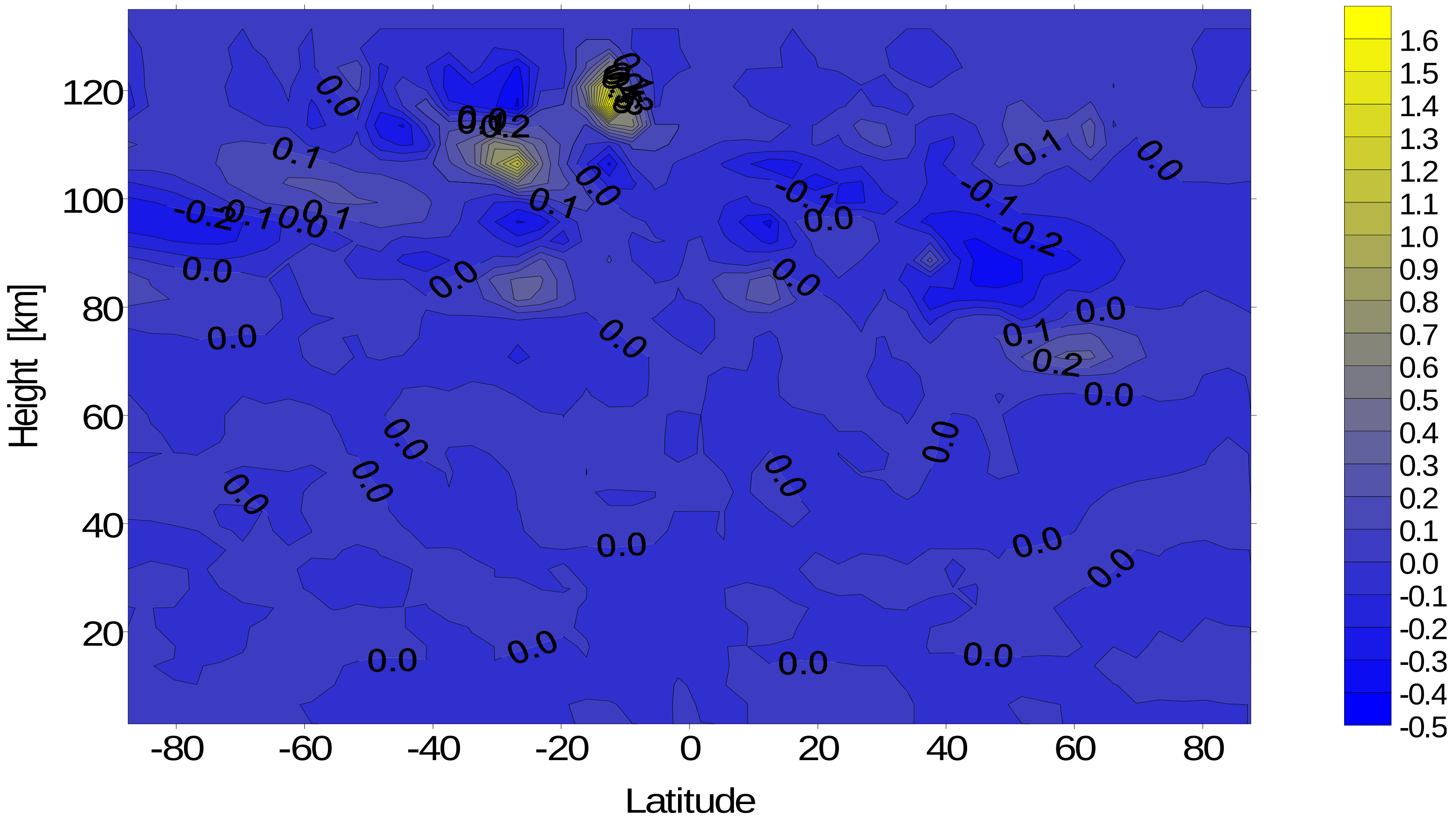
Changes in UV heating (K/day) at 72 km caused by SPE on 1st of November 12-00 UT 2003 (GCM simulations)



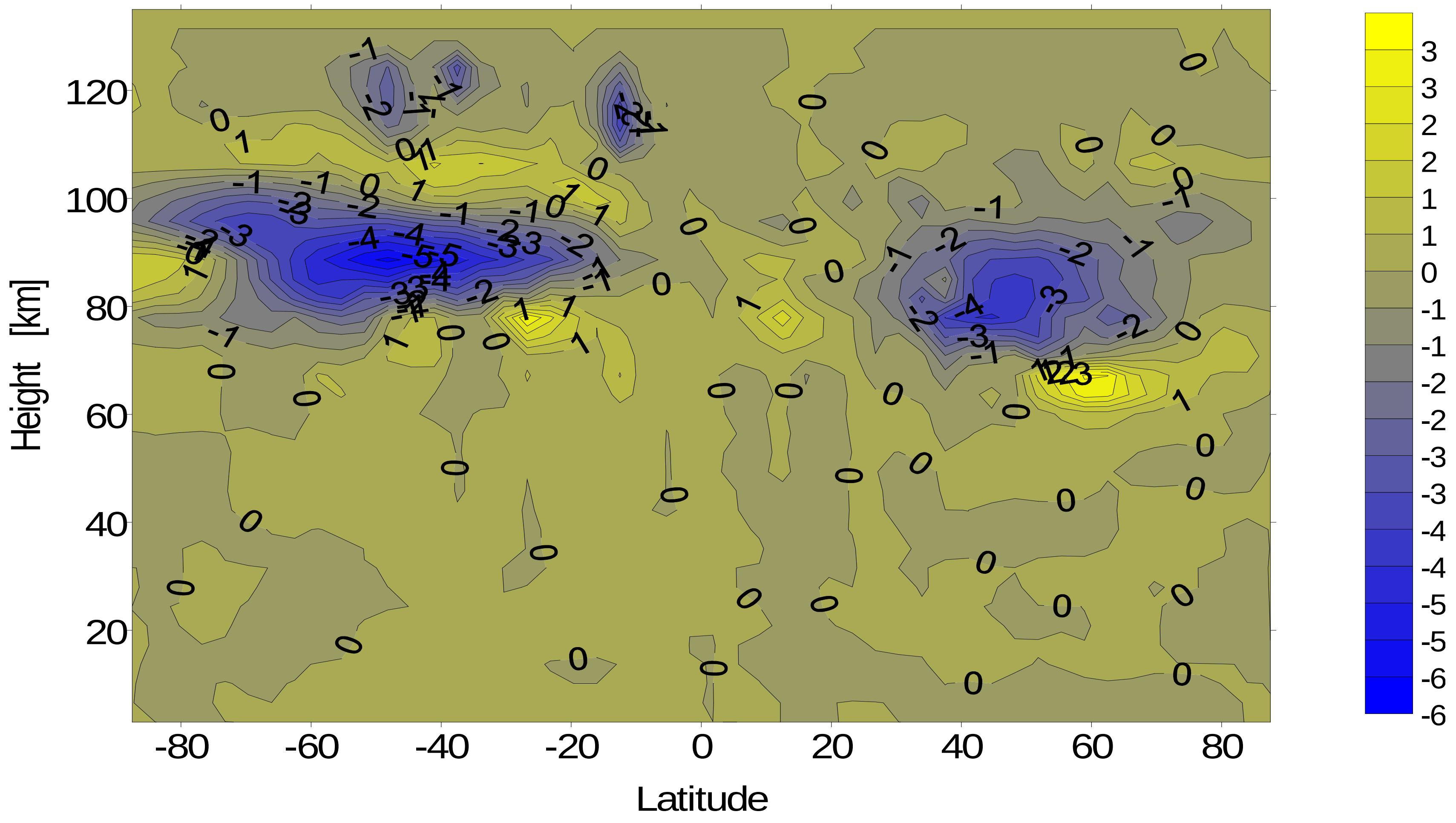
Changes in zonal wind induced by SPE 28.10.2003 at 72 km (GCM model runs)



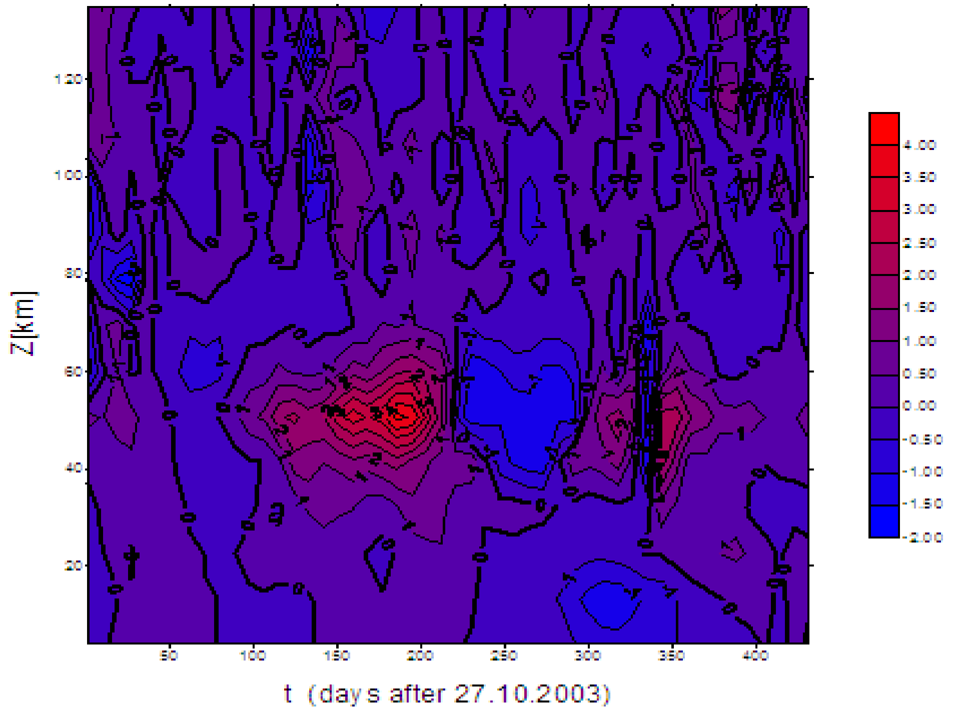
GWs input to SPE-induced temperature changes (K/day) on 1.11.2003 (GCM model runs)



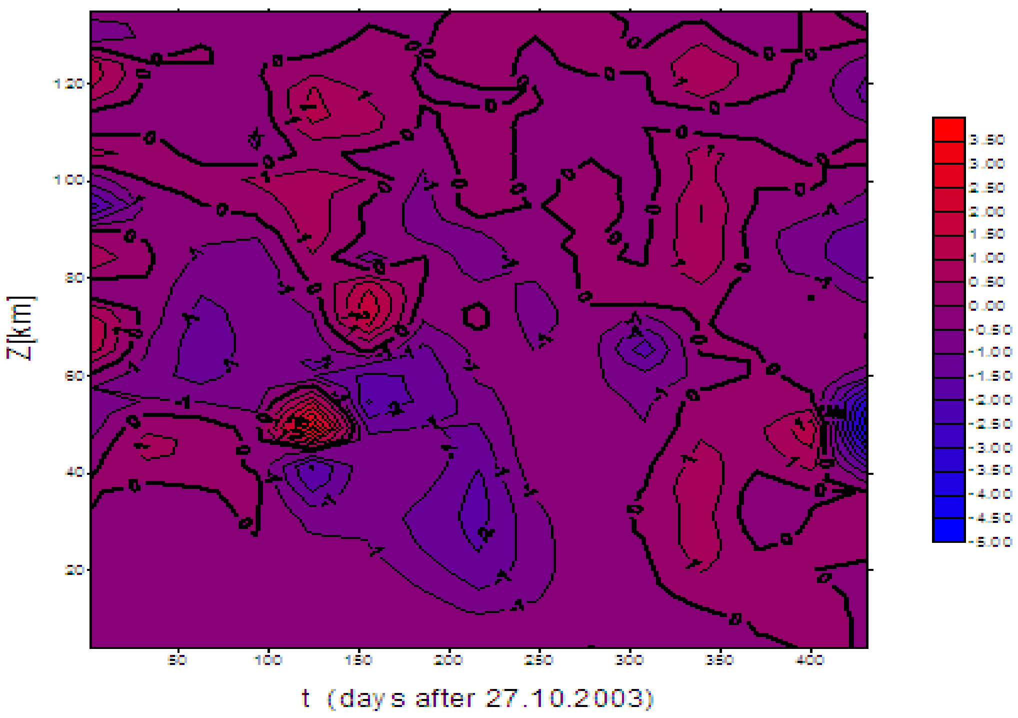
Changes in zonal wind (m/s/day) induced by GWs on 1.11.2003 as simulated by GCM



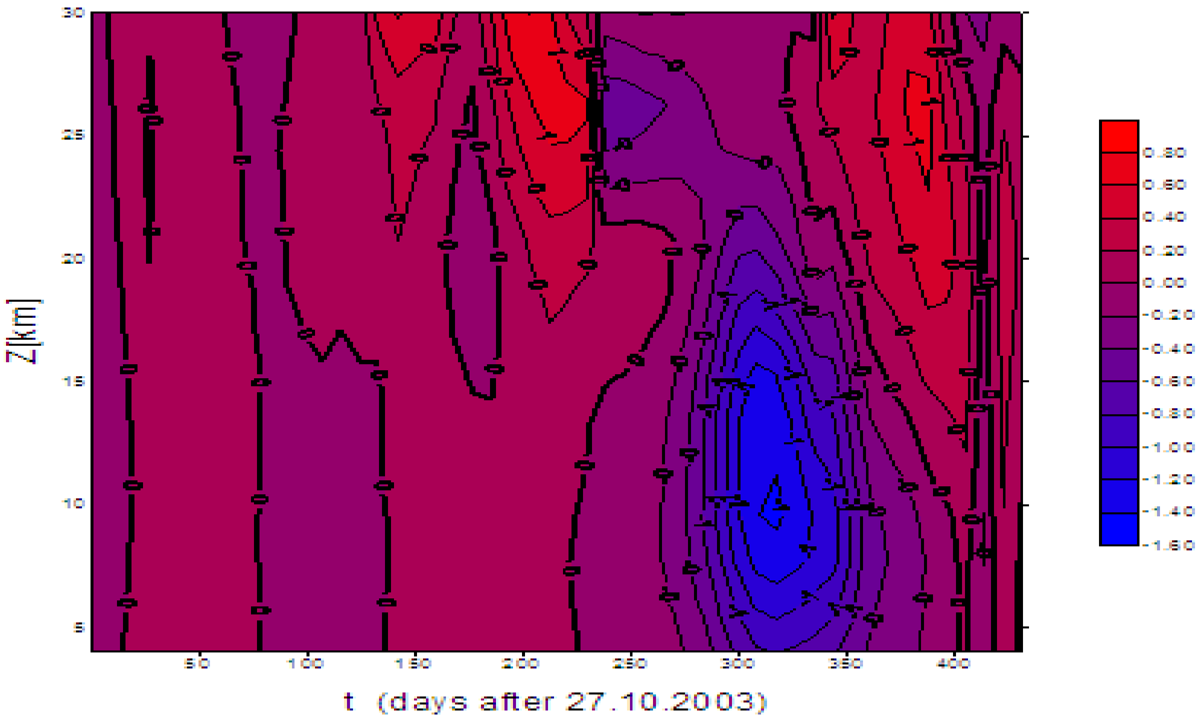
Changes in absolute values of zonal wind (m/s) initiated by particle-caused ozone depletion at 75 N (simulations with GCM)



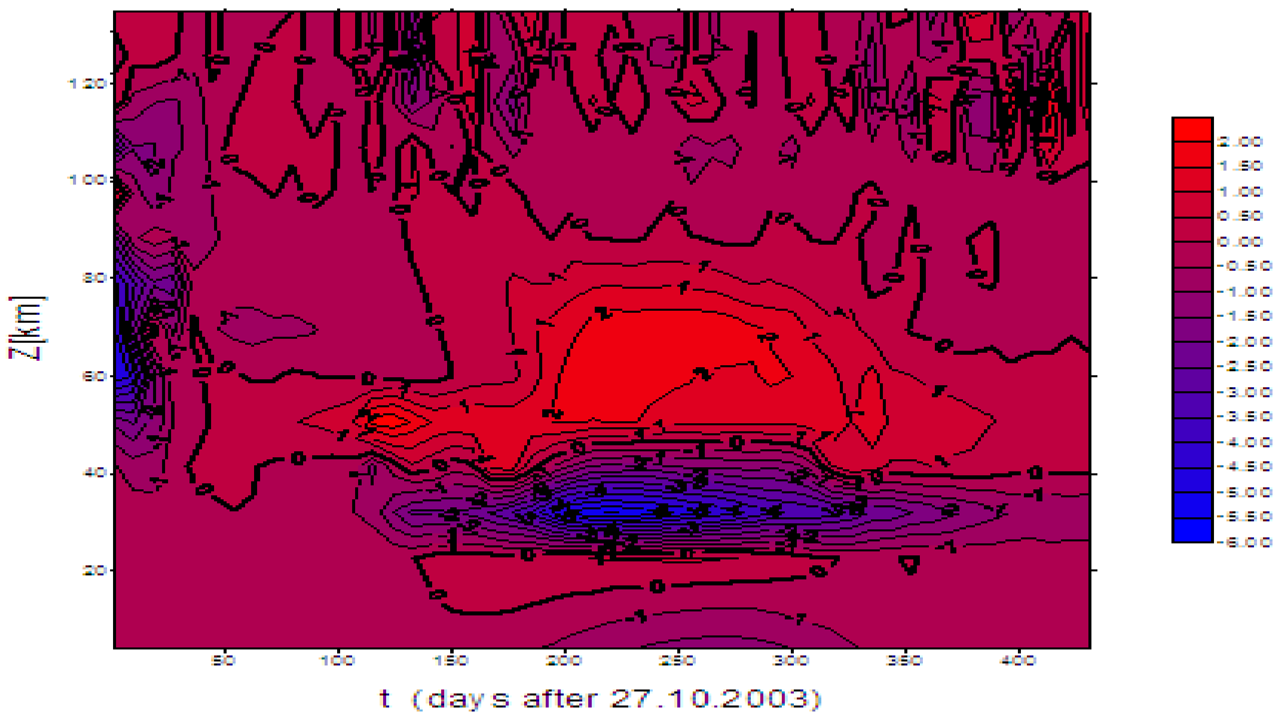
Changes in absolute values of zonal wind (m/s) initiated by particle-caused ozone depletion at 75 S (simulations with GCM)



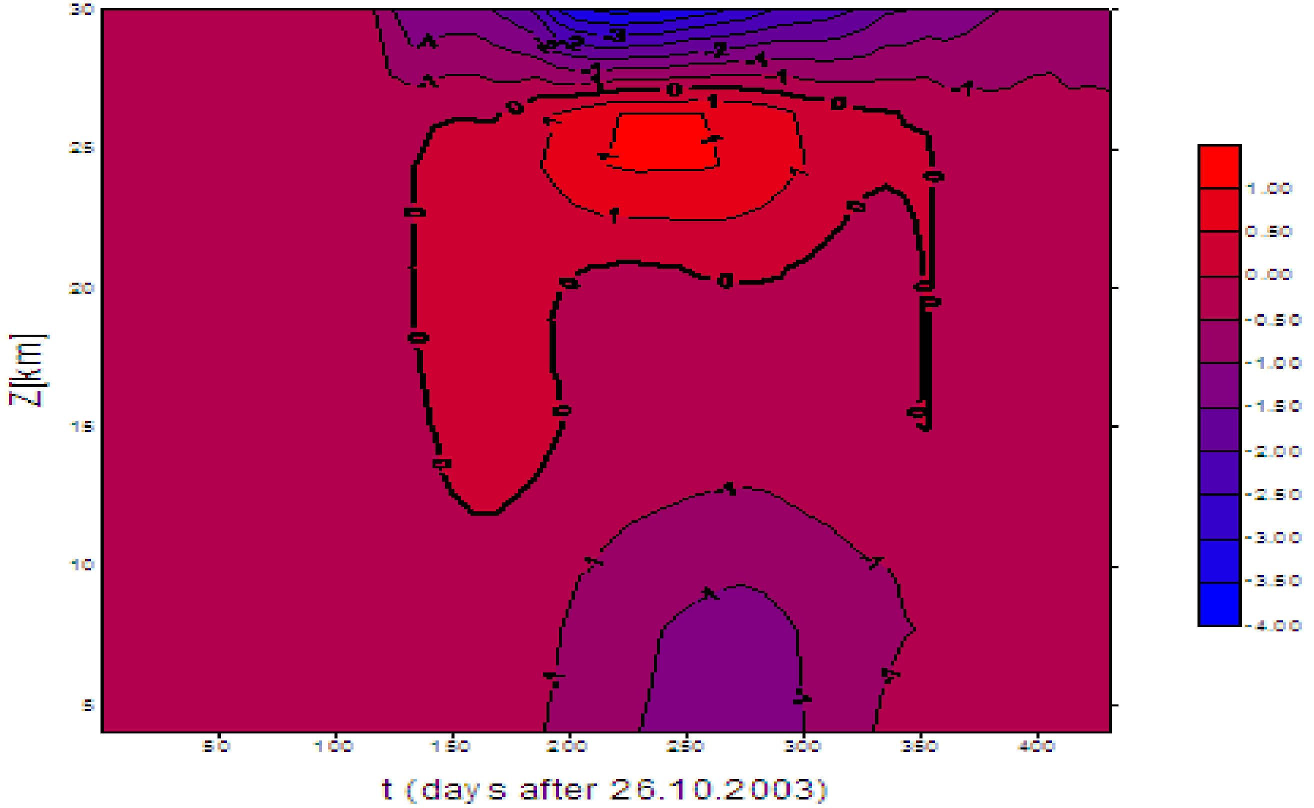
Changes in absolute values of zonal wind (m/s) initiated by particle-caused ozone depletion at 75 N (simulations with GCM)



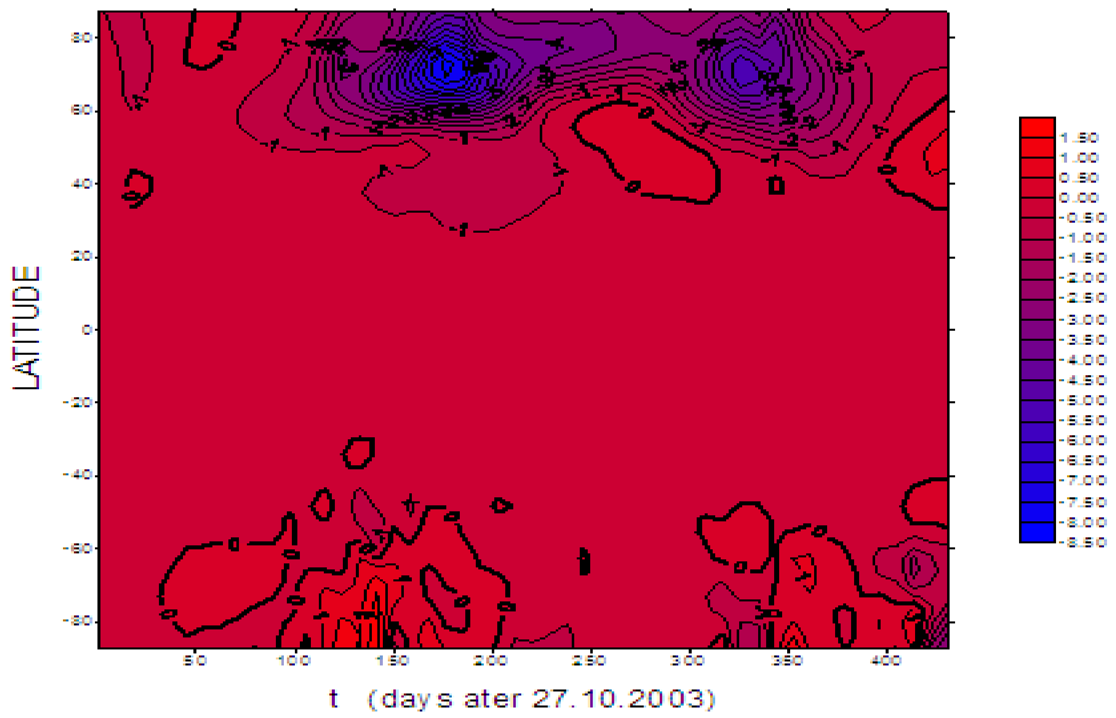
Changes in temperature (K)
initiated by particle-caused ozone depletion at 75 N
(simulations with GCM)



Changes in temperature (K)
initiated by particle-caused ozone depletion at 75 N
(simulations with GCM)



Changes in temperature (K) on global scale initiated by particle-caused ozone depletion at 37 km (simulations with GCM)



Conclusions

1) Energetic particles change chemical composition and transform wind and temperature fields via ozone depletion.

2) Such effects may induce long-term consequences due to downward transport during polar night.

3) The interaction between chemistry and dynamics leads to temperature effects in the troposphere.

- **Thank you for your attention !**