Don Davis

Quantifying Atmospheric Chemistry Perturbation from Medium-size Asteroid Impacts in the Ocean

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Motivation

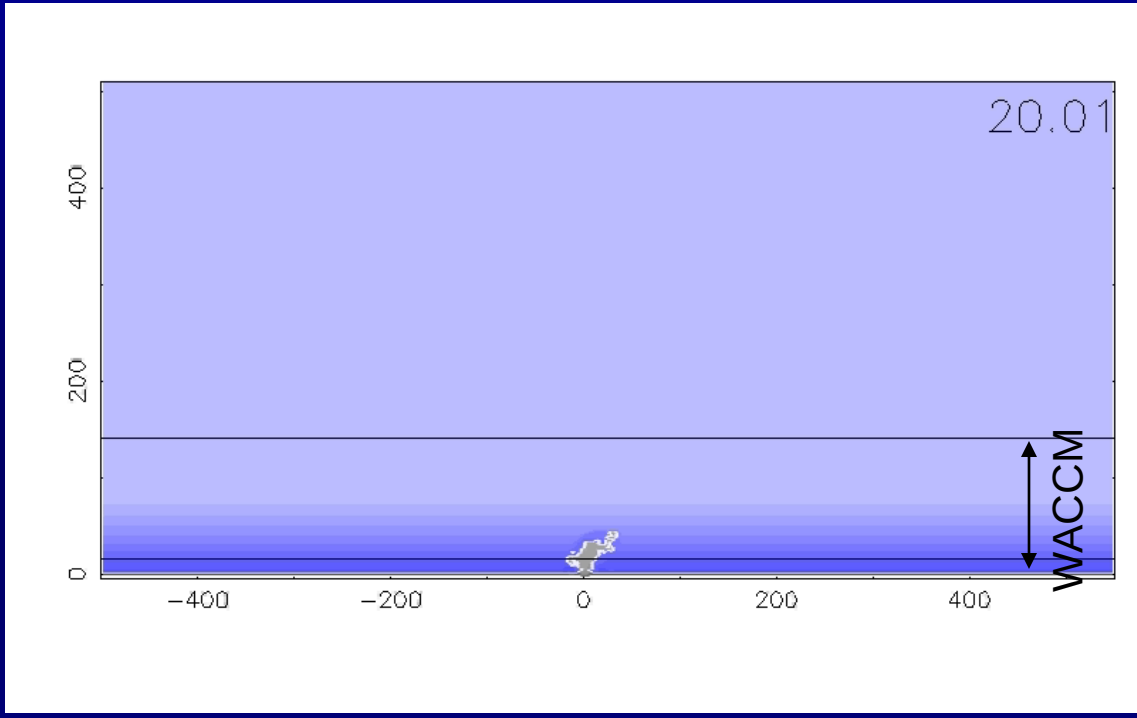
- There is still a large number of undiscovered Near-Earth Objects between 500 m and 1 km
- Little quantitative work has been done on the perturbation of atmospheric chemistry in a collision of medium-size impacts with the Earth
- Oceanic impacts are almost 3 times more probable than continental impacts

Approach:

Combine 3D impact simulations with 3D atmospheric GCM simulations to investigate the perturbation of atmospheric chemistry in oceanic impacts

Impact Simulations

500 m Impactor



Target:

Atmosphere: standard

Ocean: water, d_{oc}= 4 km

Crust: granite

Asteroid Impactor:

ρ_{imp}= 2.63 g/cm^3

D_{pr}= 500 m & 1 km

v_{imp}= 18 km/s

Θ_{imp}=45º

- 3D hydrocode SOVA (*Shuvalov, 1999*)
- Starting Resolution: 20 cppr in impact region, decreasing outward
- Several hundred thousands tracers to characterize shock state

Impact Results

Water (liquid and vapor) is ejected well into the thermosphere

500 m impactor

M_{wat}~ 4.4×10^{12} kg

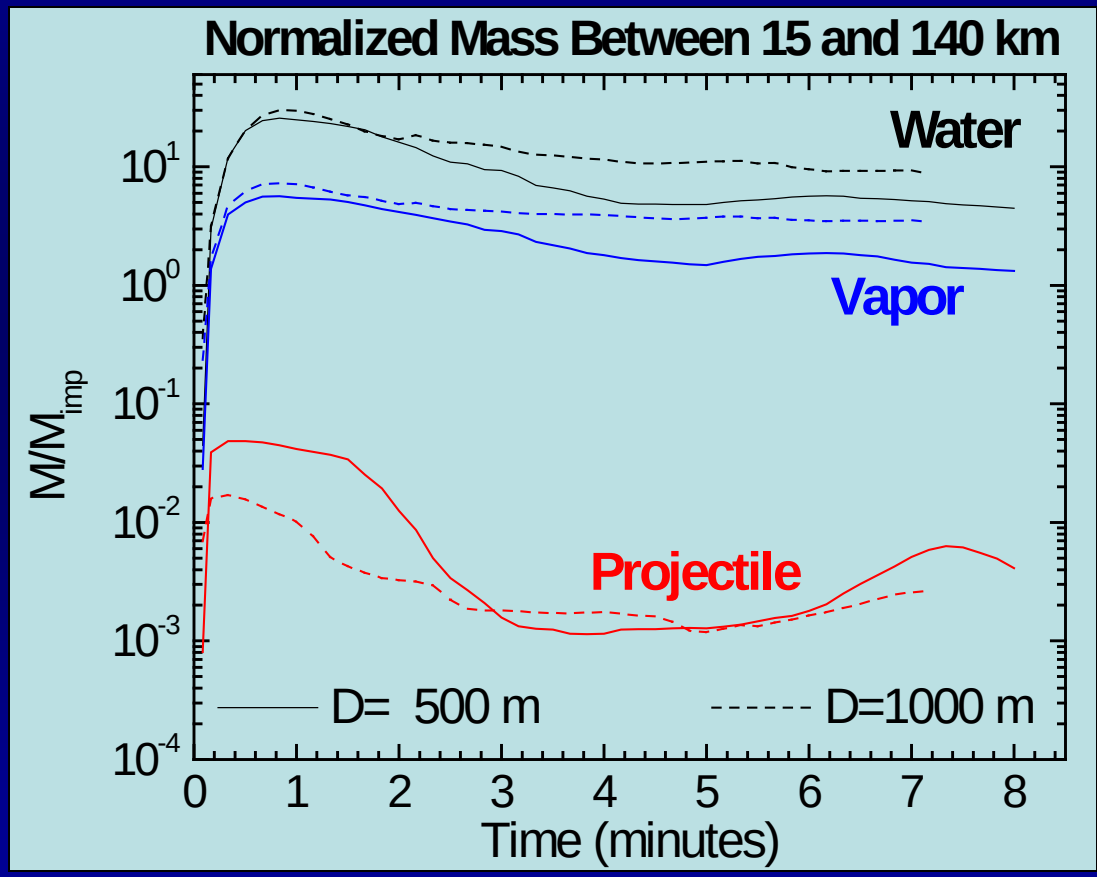
M_{vap}~ 10^{12} kg

1 km impactor

M_{wat}~ 4.4×10^{13} kg

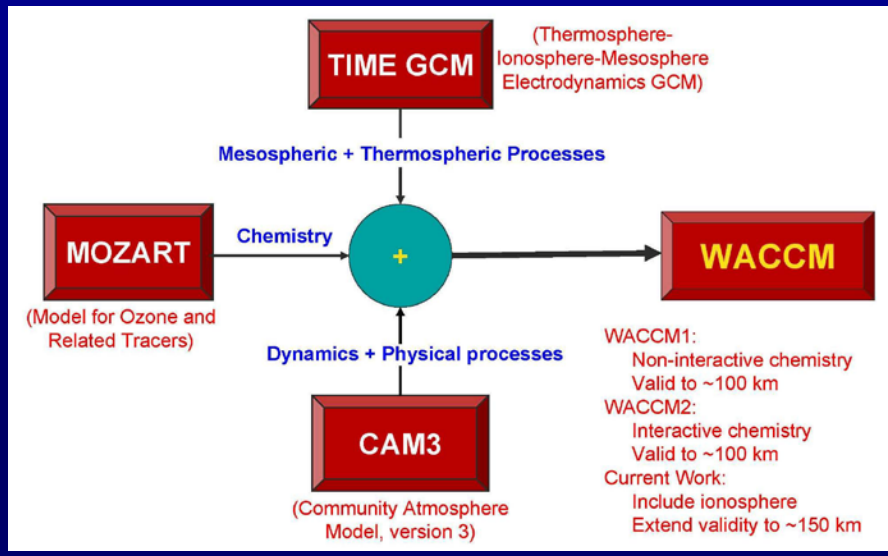
M_{vap}~10^{13} kg

No oceanic crust ejected



Whole Atmosphere Community Climate Model 3548

(*Garcia et al. 2007; Kinnison et al. 2007; Marsh et al. 2007*)



Developed to describe relations and feedbacks between dynamics, chemistry and radiation of lower and upper atmosphere

- **Horizontal resolution:**
  1.9º×2.5º (lat×lon)
- **Vertical resolution** (66 levels to 140 km):
  UTrop/LStrat: <1 km; M/UStrat: 1-2 km; Mes./LTherm: 3 km
- **Chemistry module describes reactions and photolytic processes in the middle and upper atmosphere**
  (57 species, including all members of the O_x, NO_x, HO_x, ClO_x, and BrO_x chemical families, 41 photolysis rates, 93 gas-phase reactions, 17 heterogeneous reactions)

Atmospheric Simulations

Initial condition: northern hemisphere winter conditions

Assumptions:

1) Impact in the subtropical Pacific Ocean, 30°N
1) Ignore water in troposphere (below 15 km)
2) Use only water vapor up to 140km (WACCM upper level)

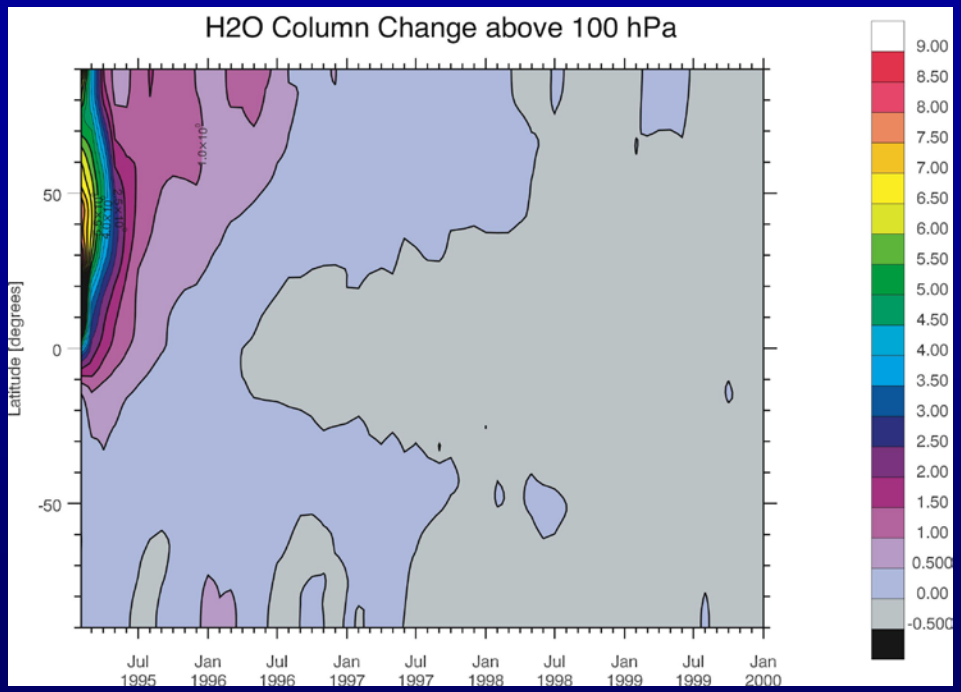
NO_x and Halogens: Use Birks et al. (2007) approach

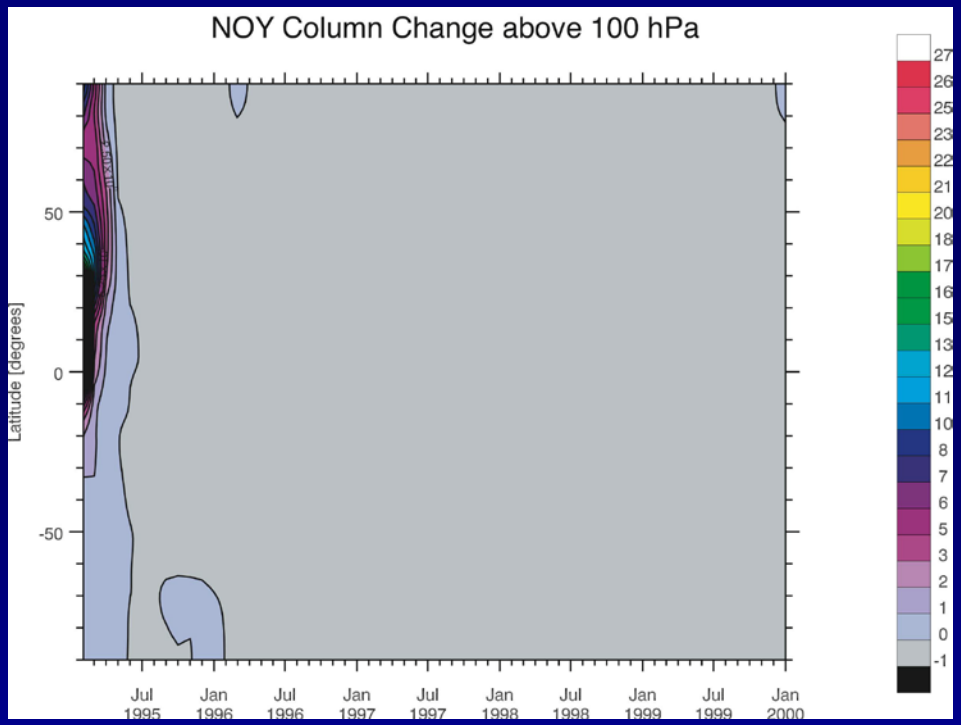
$$M_{NO} \sim 10^{-3} \times M_{vap}$$

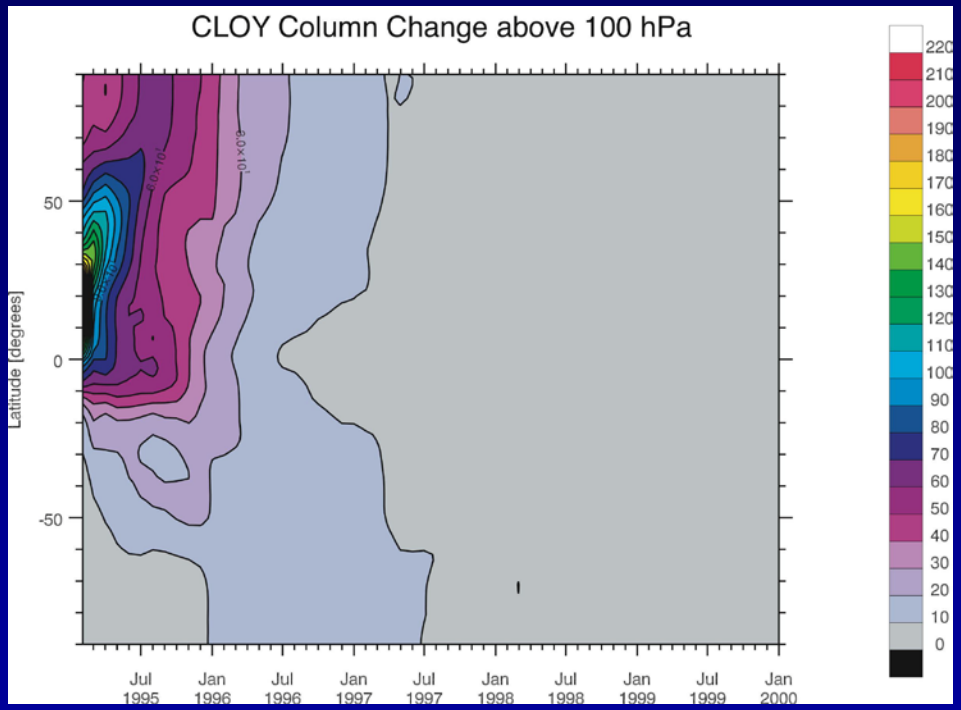
$$M_{Cl} \sim 2 \cdot 10^{-3} \times M_{vap}$$

$$M_{Br} \sim 3 \cdot 10^{-6} \times M_{vap}$$

1 km Impactor

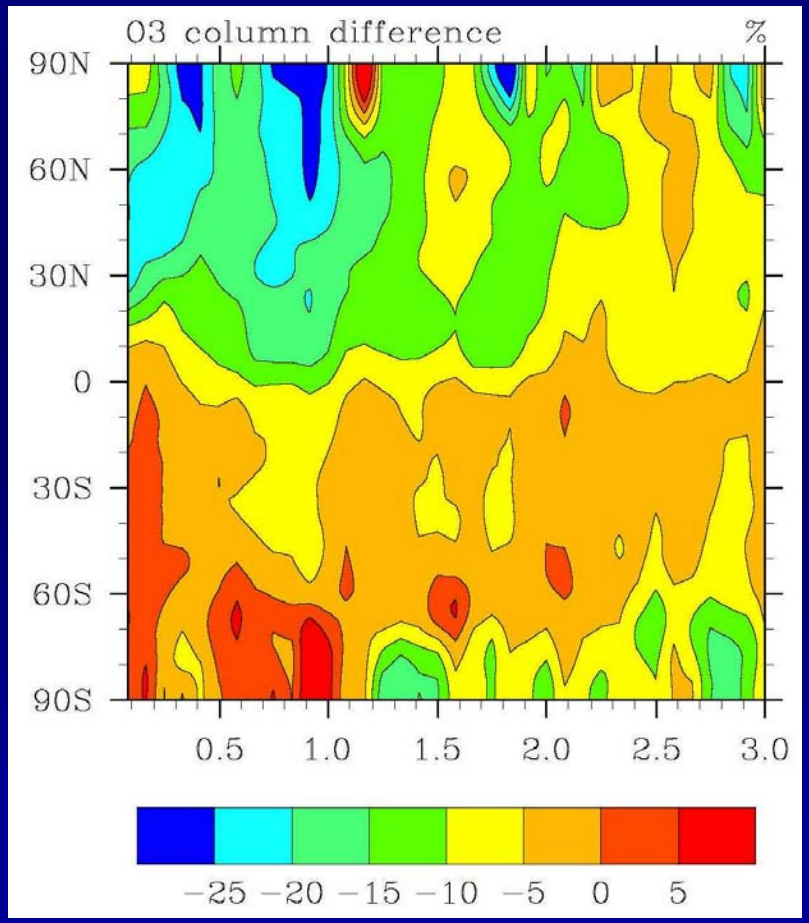






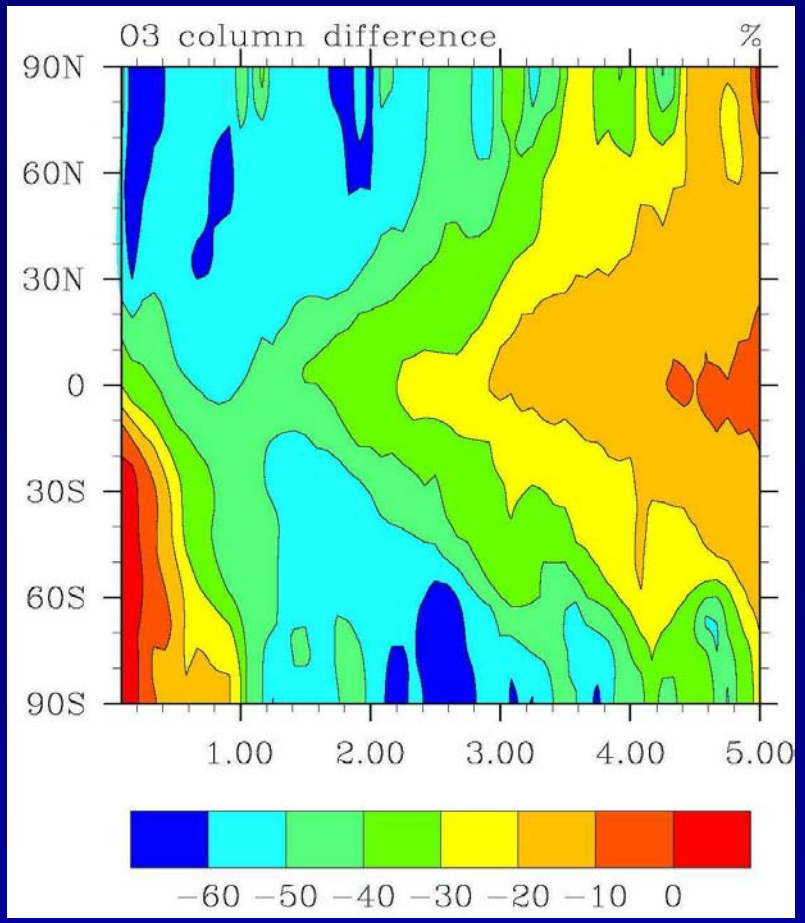
500 m Impactor

Mild regional ozone depletion for about 1 yr

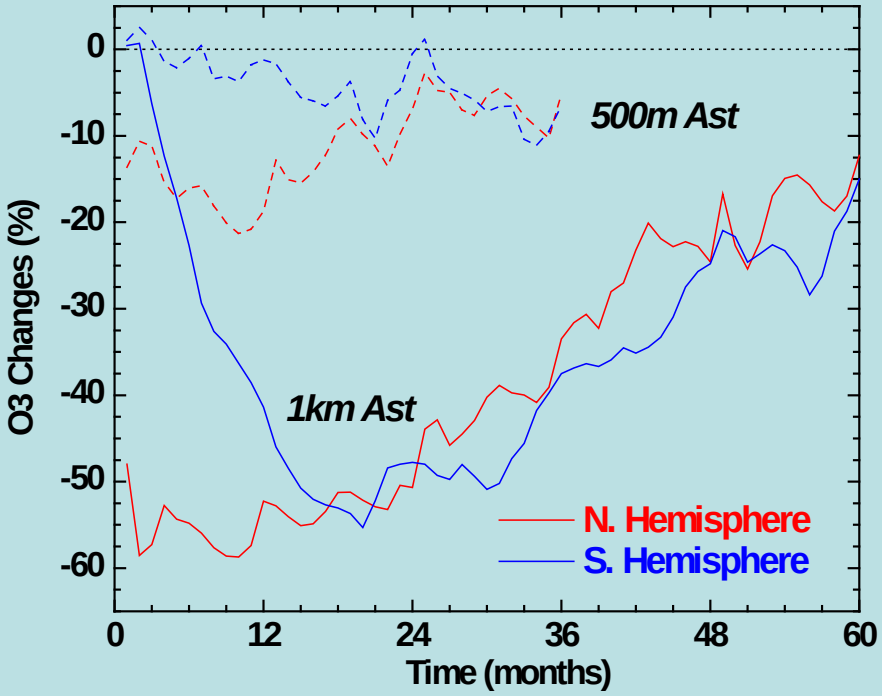


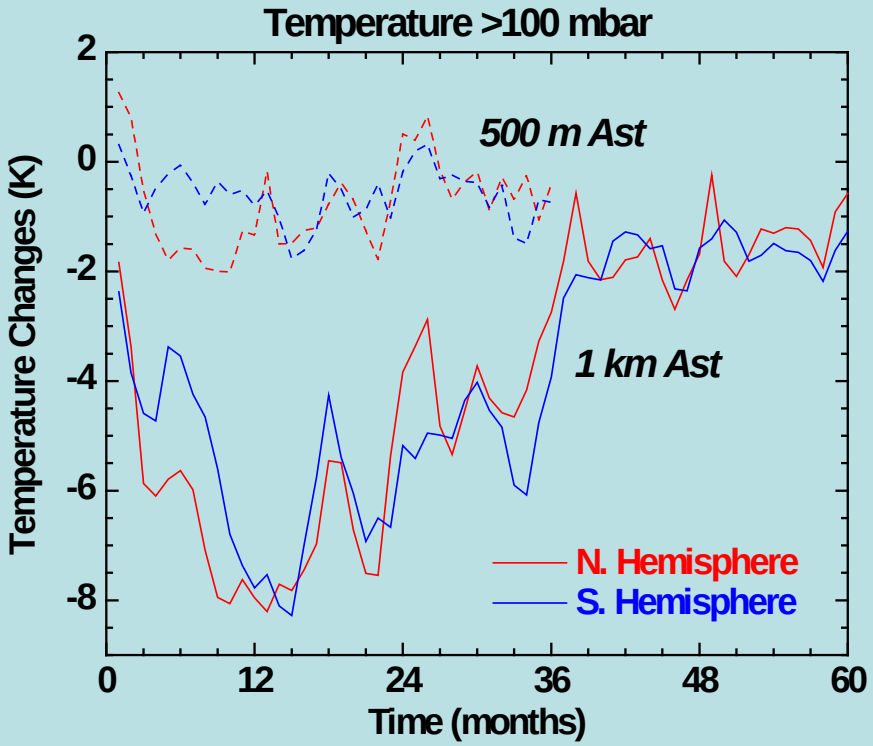
1 km Impactor

Significant global ozone depletion for at about 3 yrs

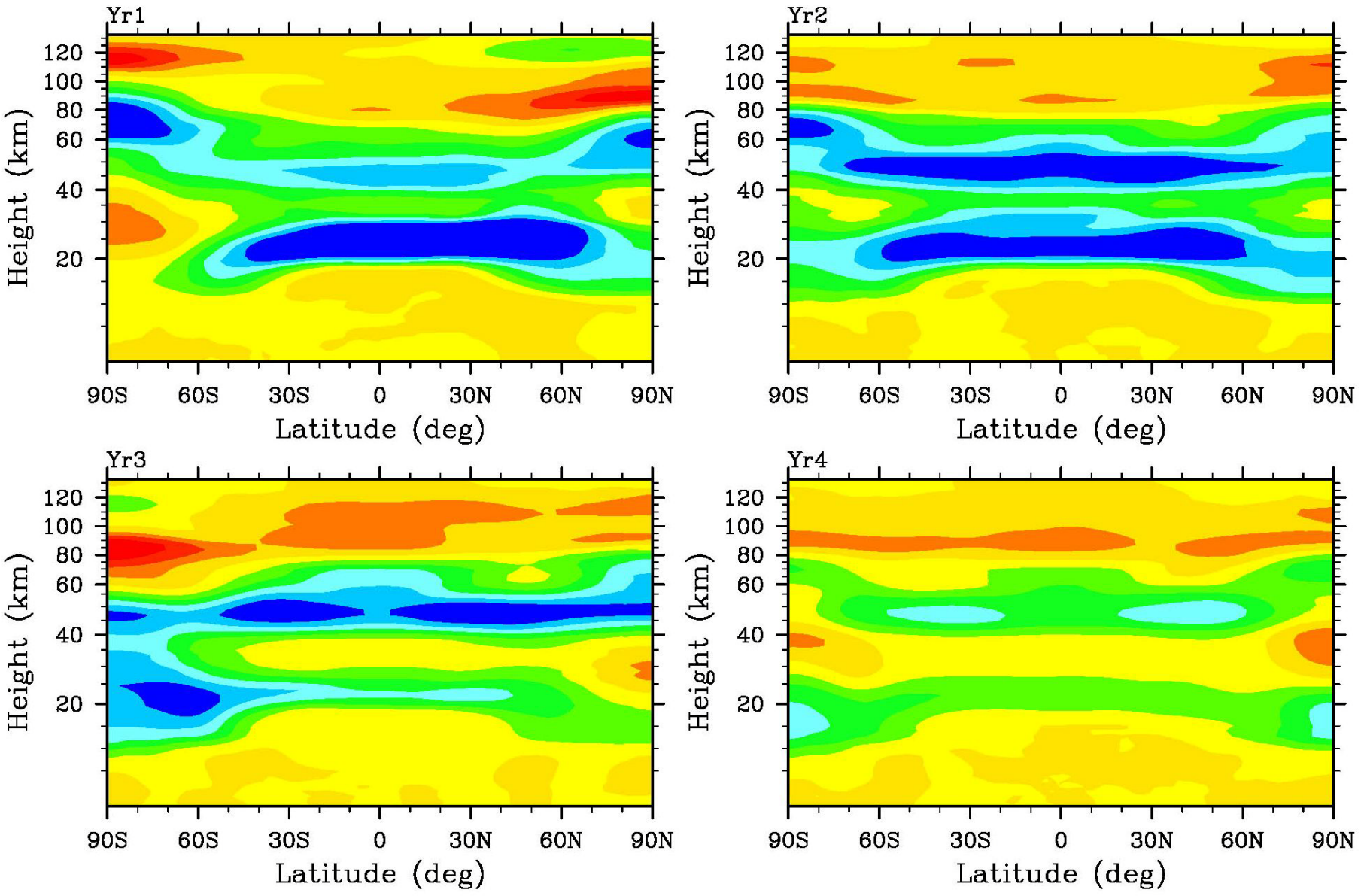


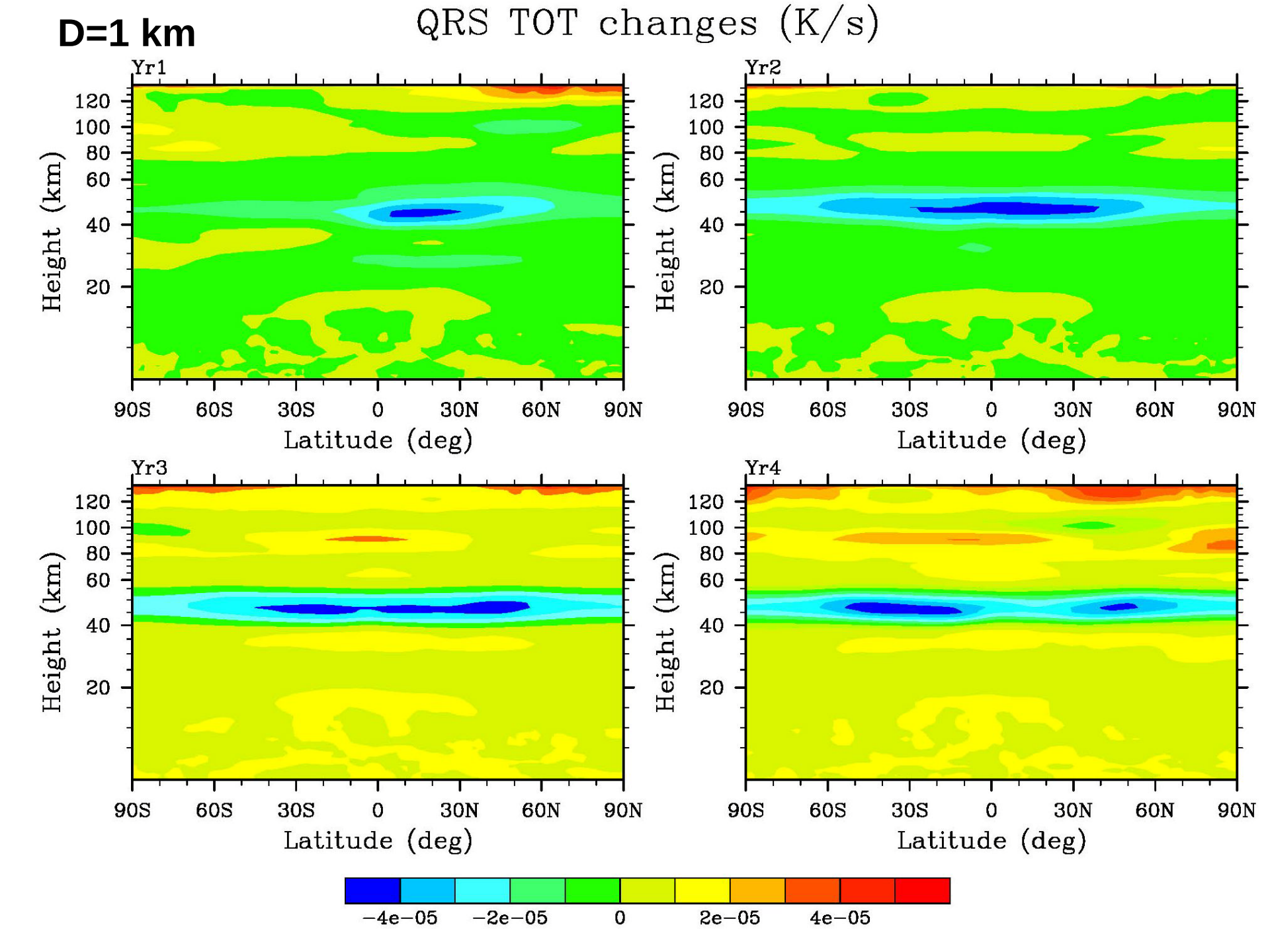
Ozone - Temperature

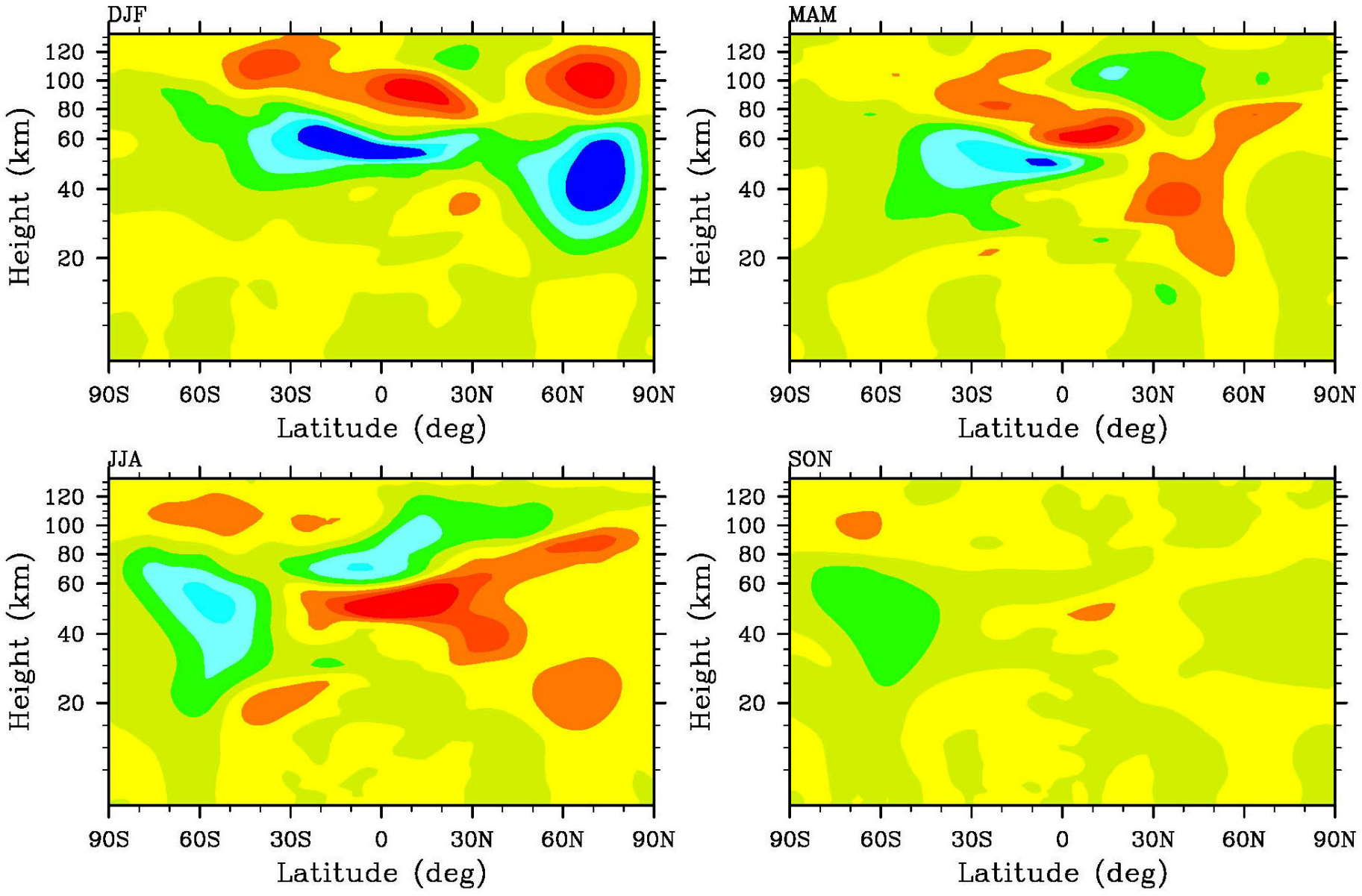




D=1 km


Temperature Changes (K)
Yr1
Yr2
Yr3
Yr4
Height (km)
120
100
80
60
40
20
90S
60S
30S
0
30N
60N
90N
Latitude (deg)
−15
−9
−3
3
9


D=1 km
QRS TOT changes (K/s)
Yr1
Yr2
Yr3
Yr4
Height (km)
120
100
80
60
40
20
90S
60S
30S
0
30N
60N
90N
Latitude (deg)
−4e−05
−2e−05
0
2e−05
4e−05


Yr1 Zonal Wind Changes (m/s)
DJF
MAM
JJA
SON
Height (km)
120
100
80
60
40
20
90S
60S
30S
0
30N
60N
90N
Latitude (deg)
−40
−20
0
20