Atmospheric Structure & Transport of Trace Gases

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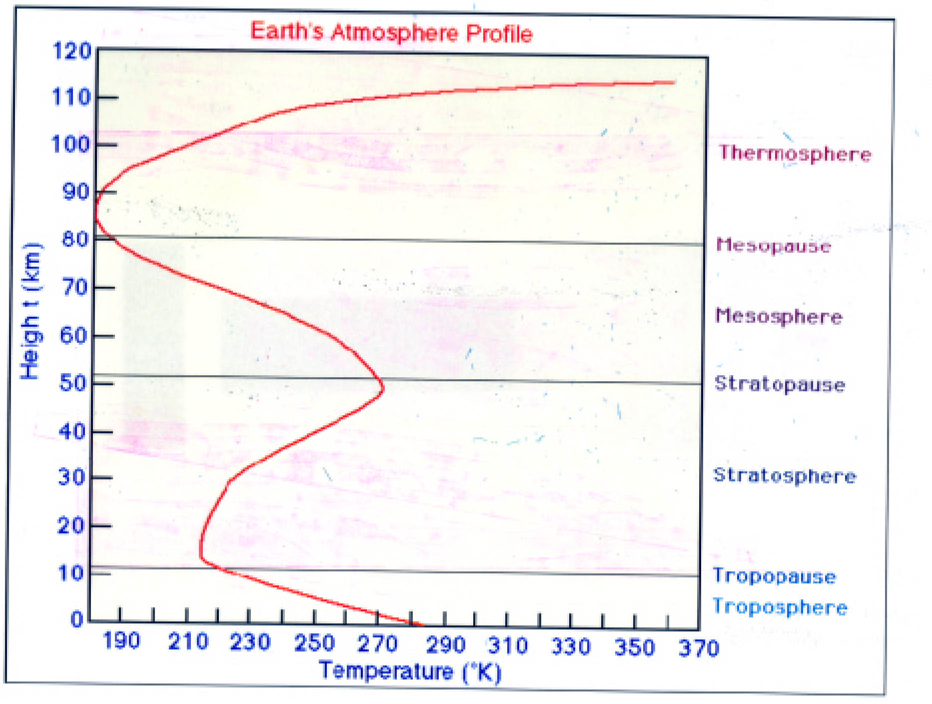


Diagnostic Equations

Eqn. of State

$$p = \rho R T$$

Hydrostatic Eqn.

$$dp = -g\rho\,dz \Rightarrow p \approx p_0 e^{-z/H}$$

$H = RT/g$ ↑ scale height.

Thermal Wind Relation

$$\frac{\partial u}{\partial \ln p} = \frac{R}{f}\left(\frac{\partial T}{\partial y}\right)_p \quad \text{(not at equator)}$$

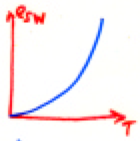
Clausius – Clapeyron Eqn.

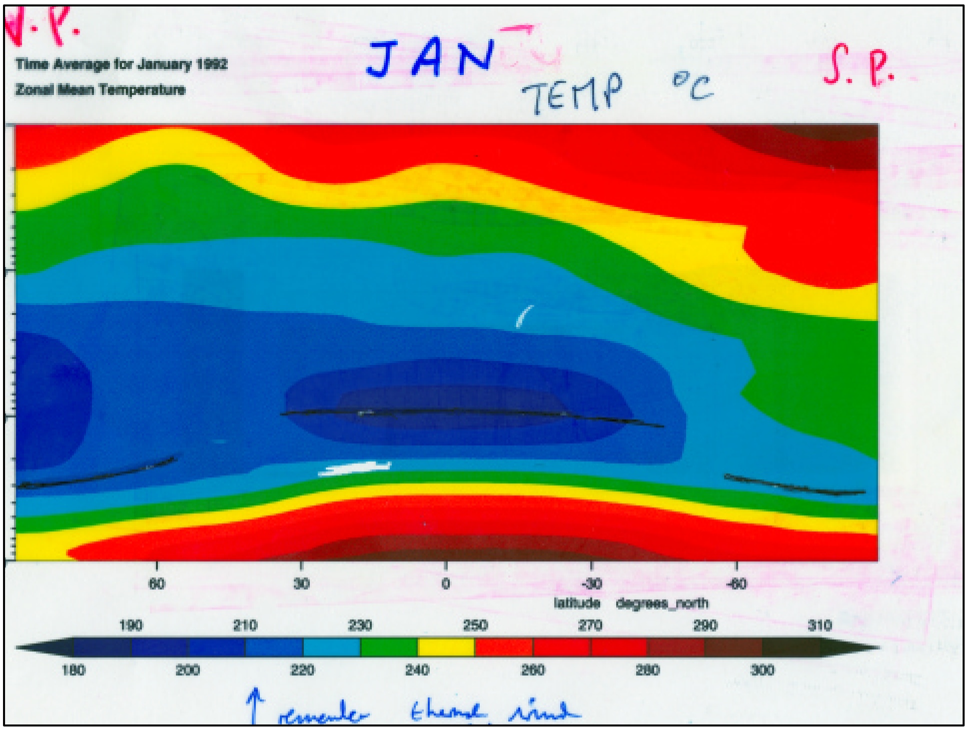
$$\frac{de_s}{dT} = \frac{l}{T\Delta\alpha}$$

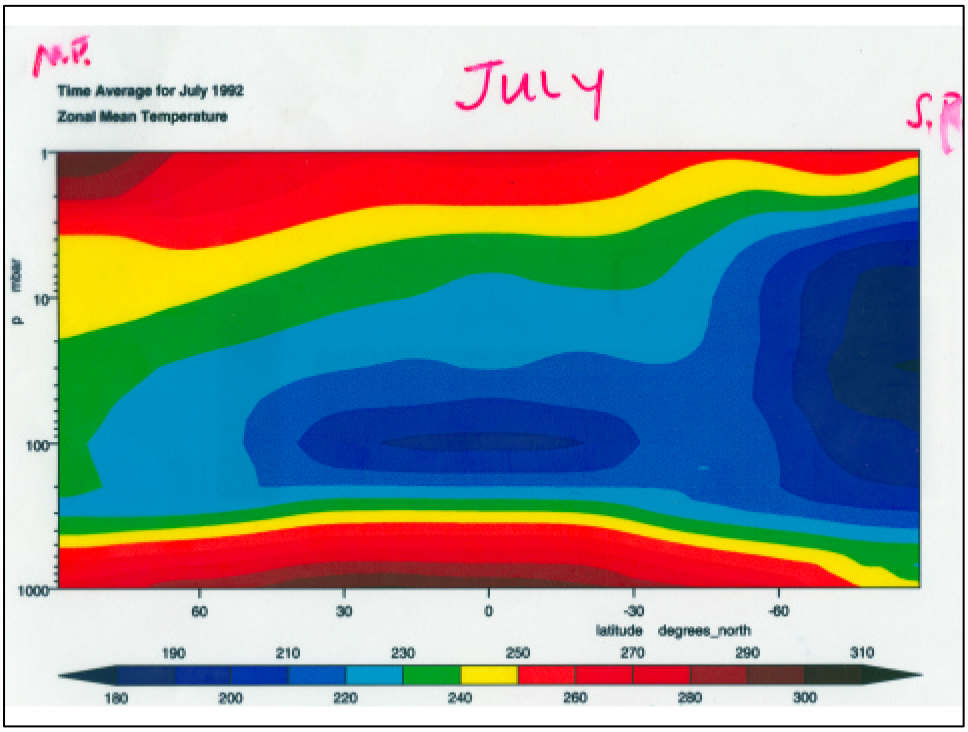
l ← specific latent heat

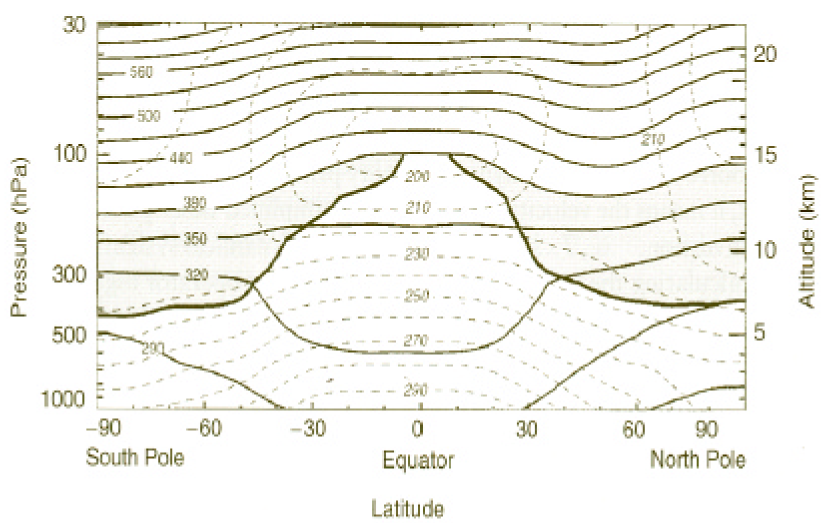
e_s: saturated vapour pressure.

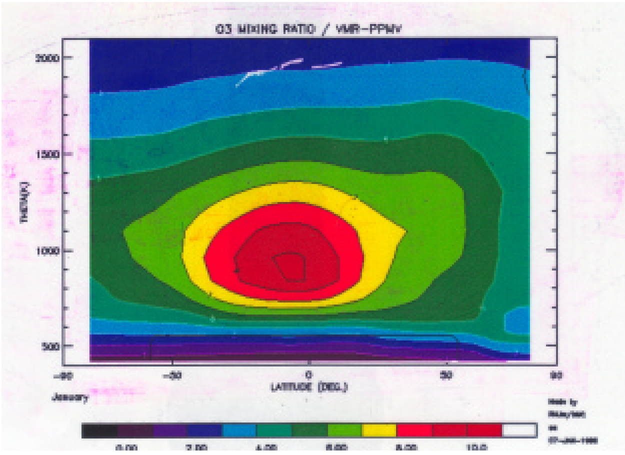
$\Delta\alpha$: difference in specific volumes between vapour & water

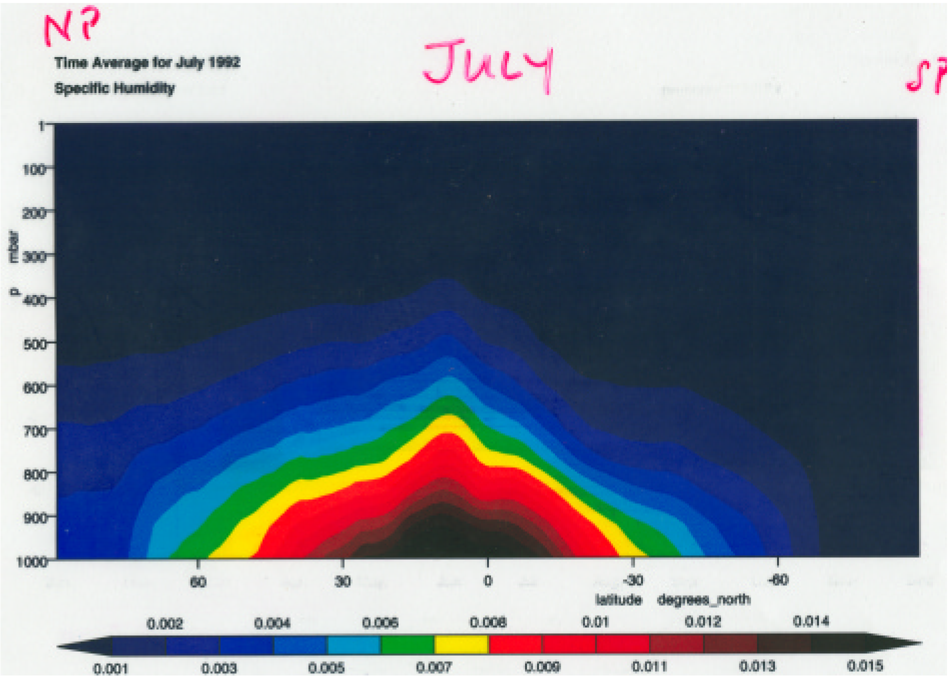


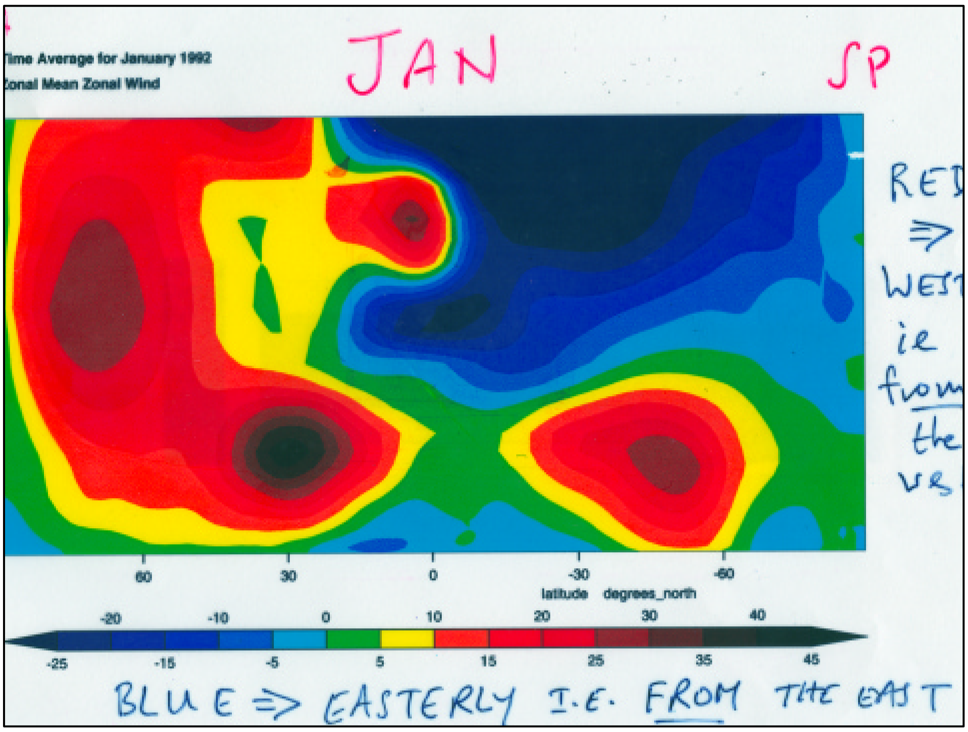


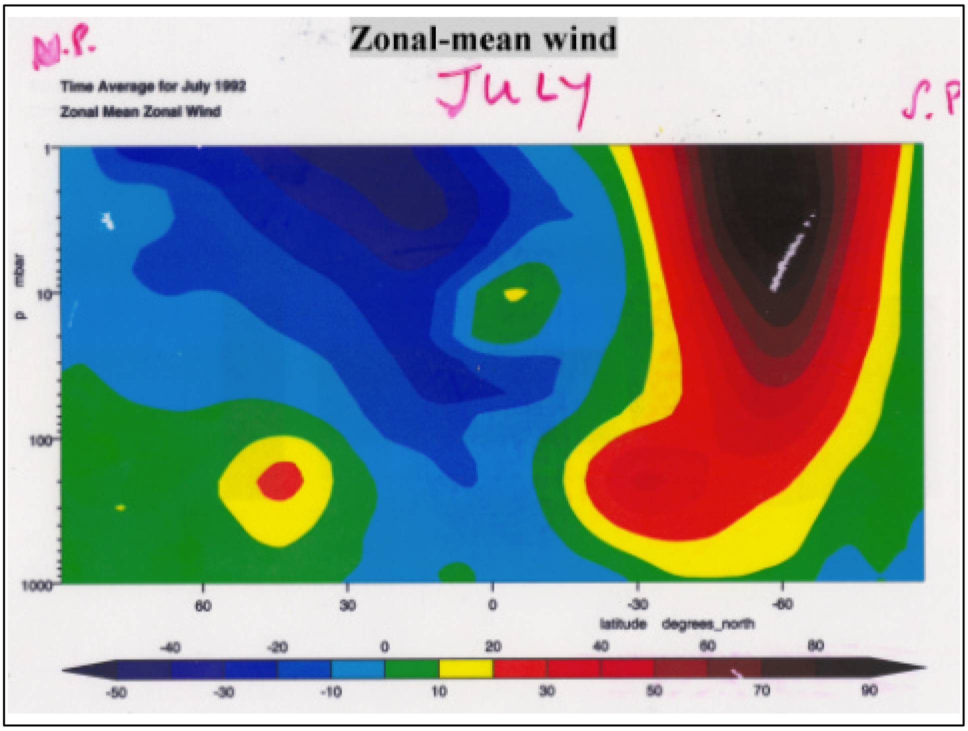

N.P.
Time Average for July 1992
Zonal Mean Temperature
JULY
S.P.
p mbar
1
10
100
1000
60
30
0
-30
-60
latitude degrees_north
190
210
230
250
270
290
310
180
200
220
240
260
280
300

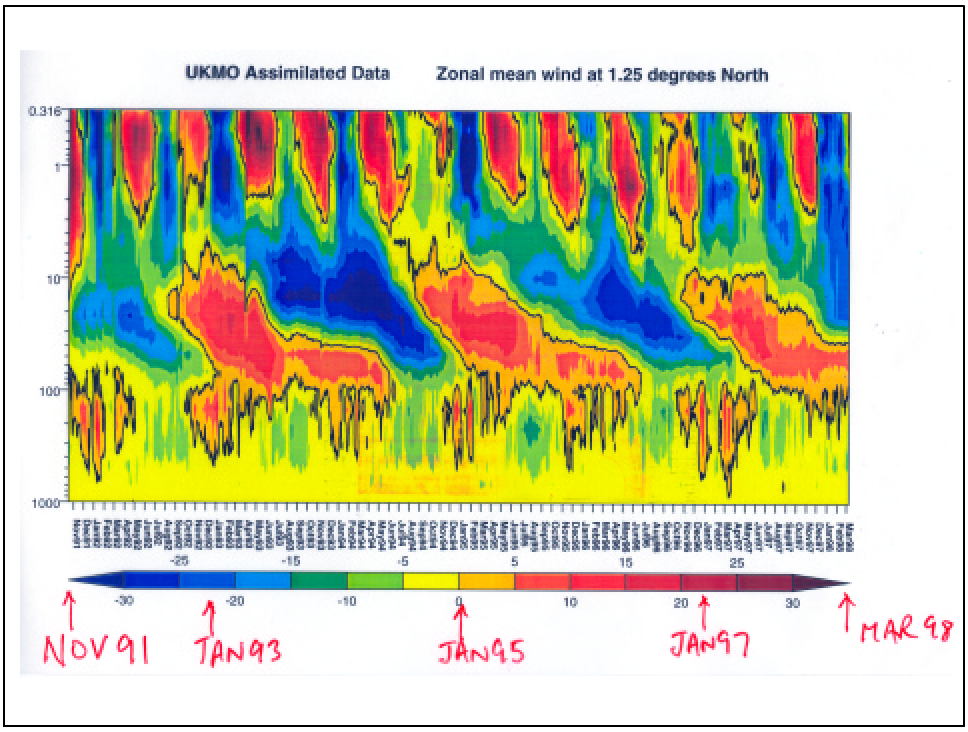

Pressure (hPa)
30
100
300
500
1000
Altitude (km)
20
15
10
5
560
500
440
380
350
320
290
200
210
230
250
270
290
−90
−60
−30
0
30
60
90
South Pole
Equator
North Pole
Latitude

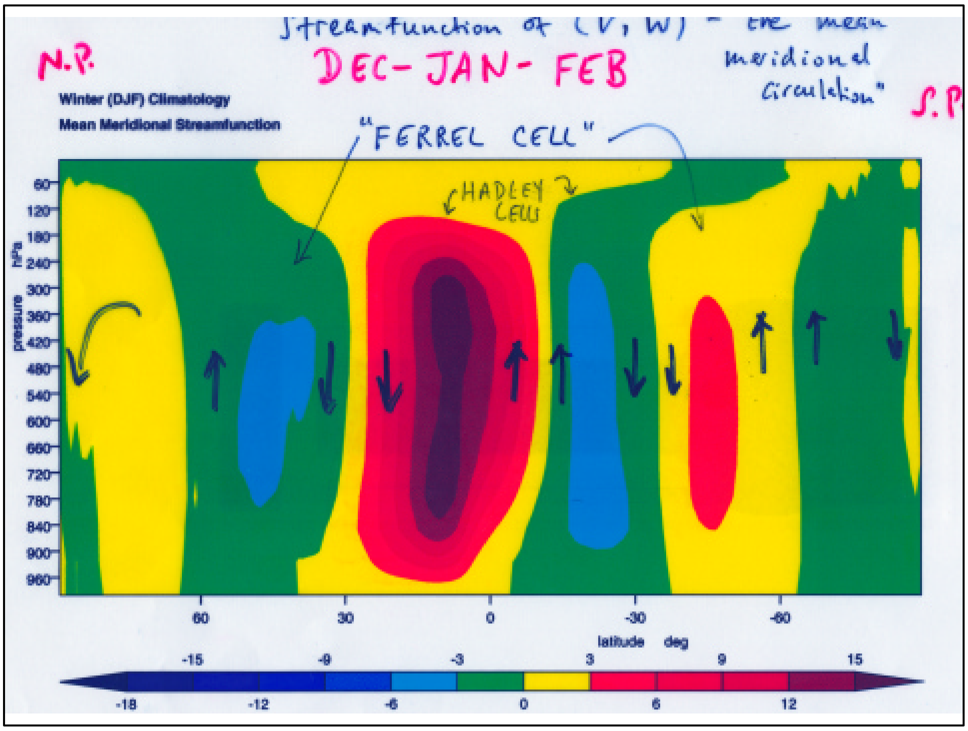

O3 MIXING RATIO / VMR-PPMV
2000
1500
1000
500
THETA(K)
-30
0
30
90
LATITUDE (DEG.)
January

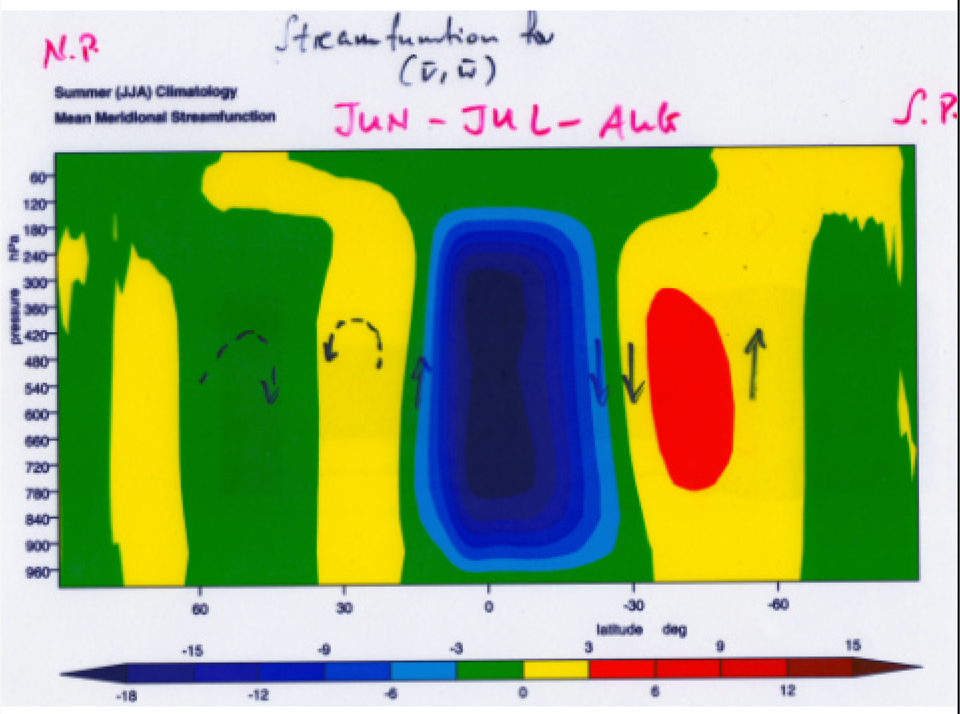

N?
Time Average for July 1992
Specific Humidity
JULY
S?
1
100
200
300
400
500
600
700
800
900
1000
p mbar
60
30
0
-30
-60
latitude degrees_north
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.001
0.003
0.005
0.007
0.009
0.011
0.013
0.015


Time Average for January 1992
Zonal Mean Zonal Wind
JAN
SP
RED ⇒ WEST ie from the W
60
30
0
-30
-60
latitude degrees_north
-20
-10
0
10
20
30
40
-25
-15
-5
5
15
25
35
45
BLUE ⇒ EASTERLY I.E. FROM THE EAST


N.P.
Zonal-mean wind
Time Average for July 1992
Zonal Mean Zonal Wind
JULY
S.P
p mbar
1
10
100
1000
60
30
0
-30
-60
latitude degrees_north
-40
-20
0
20
40
60
80
-50
-30
-10
10
30
50
70
90


UKMO Assimilated Data
Zonal mean wind at 1.25 degrees North
0.316
1
10
100
1000
-25 -15 -5 5 15 25
-30 -20 -10 0 10 20 30
NOV 91
JAN 93
JAN 95
JAN 97
MAR 98


N.P.
DEC-JAN-FEB
the mean meridional circulation"
S.P
Winter (DJF) Climatology
Mean Meridional Streamfunction
"FERREL CELL"
HADLEY CELLS
pressure hPa
60 120 180 240 300 360 420 480 540 600 660 720 780 840 900 960
60 30 0 -30 -60
latitude deg
-15 -9 -3 3 9 15
-18 -12 -6 0 6 12



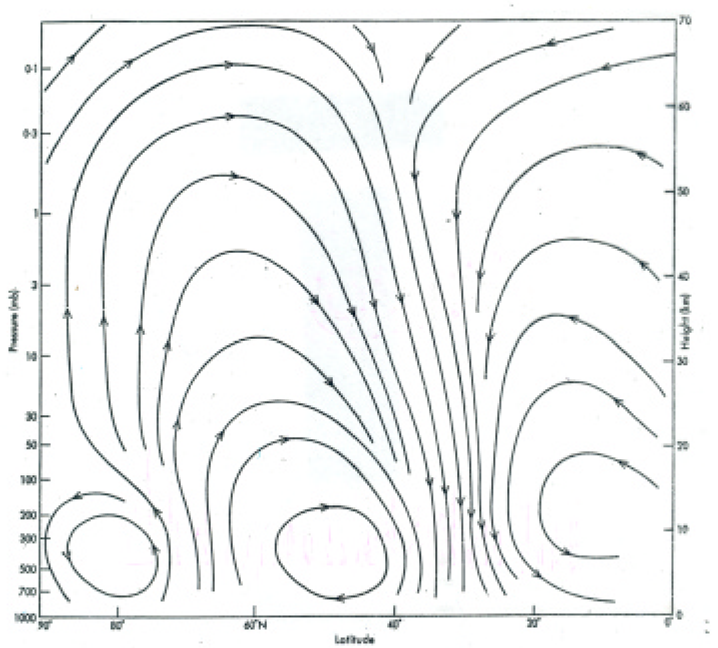
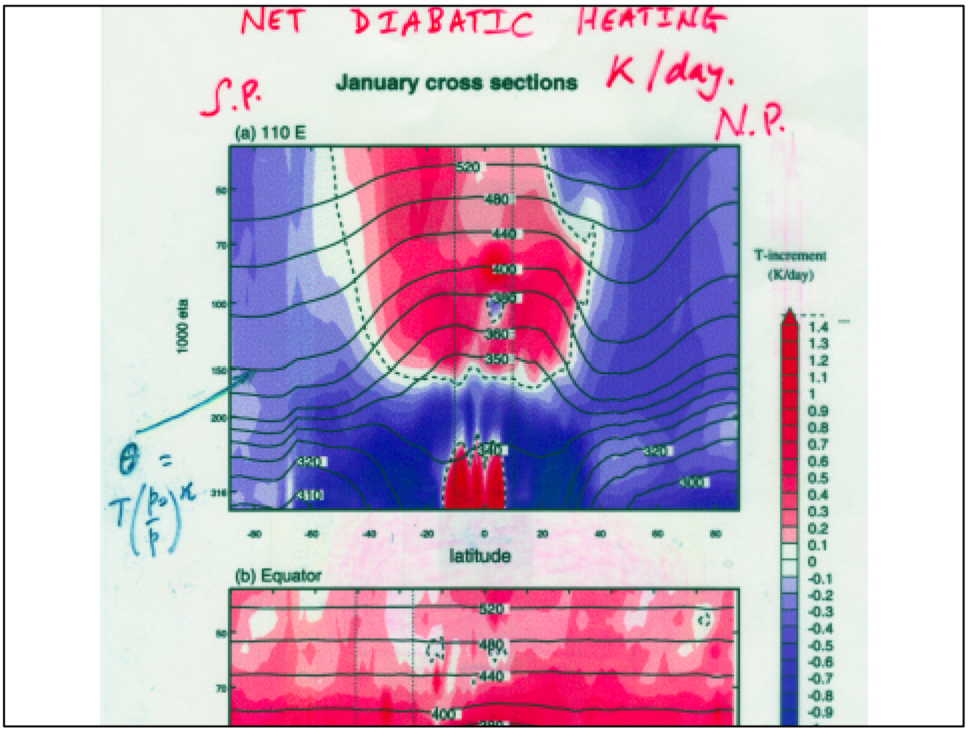
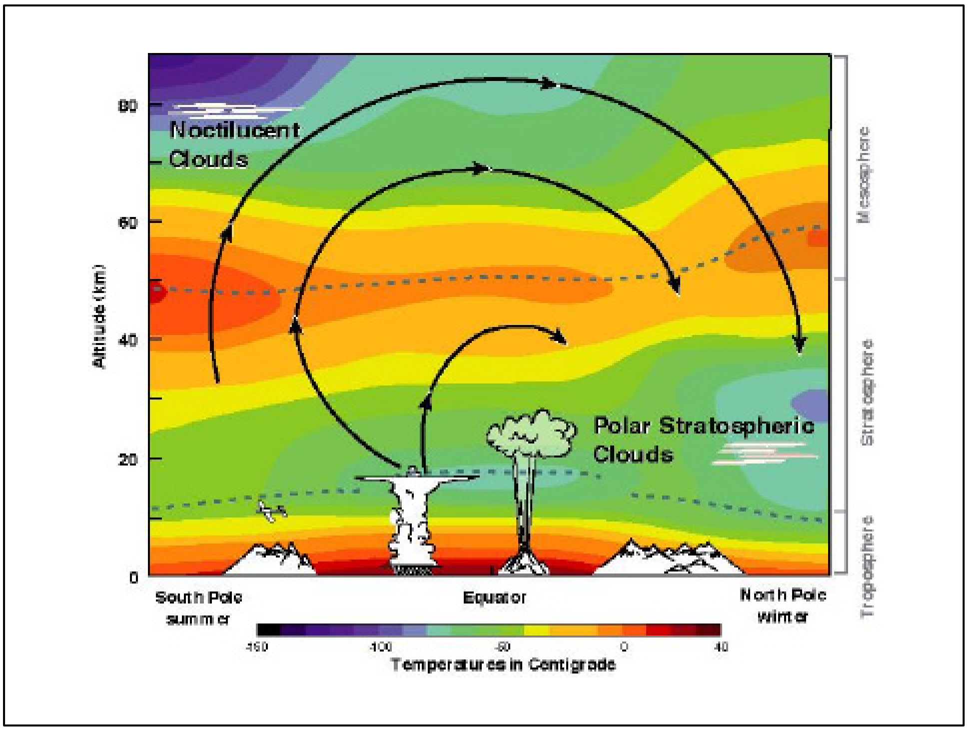
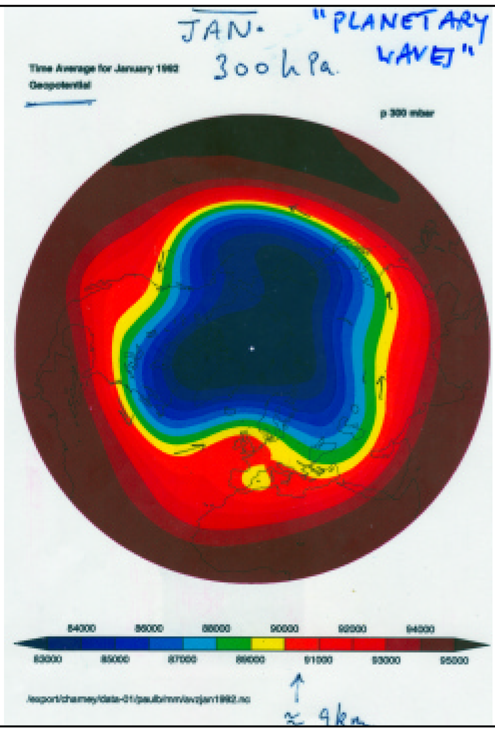
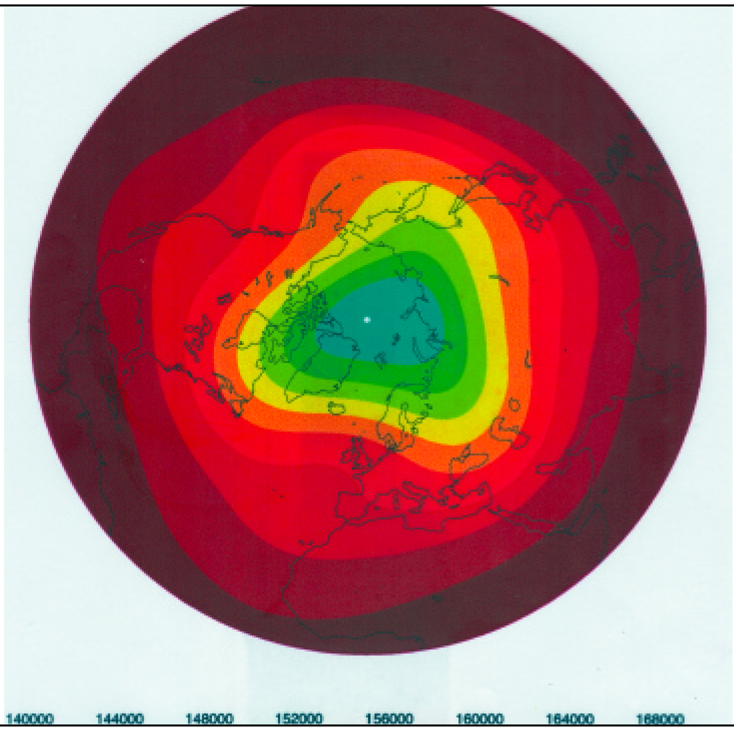


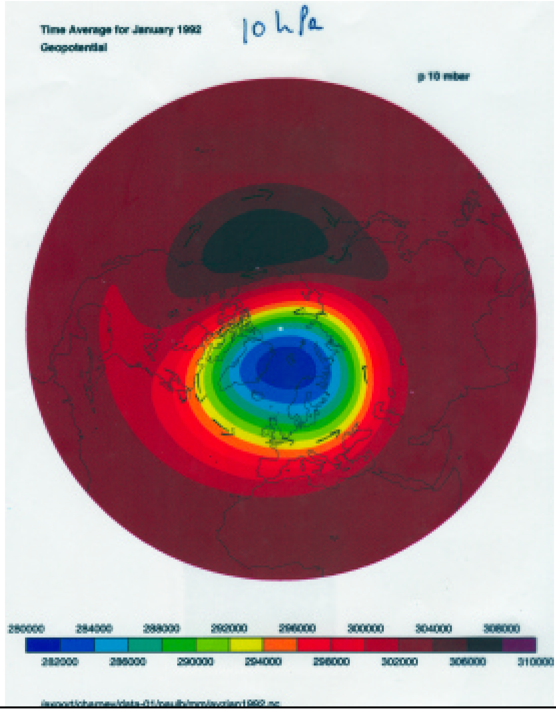
Figure 1.8 Schematic mean meridional circulation for Northern Hemisphere winter solstice

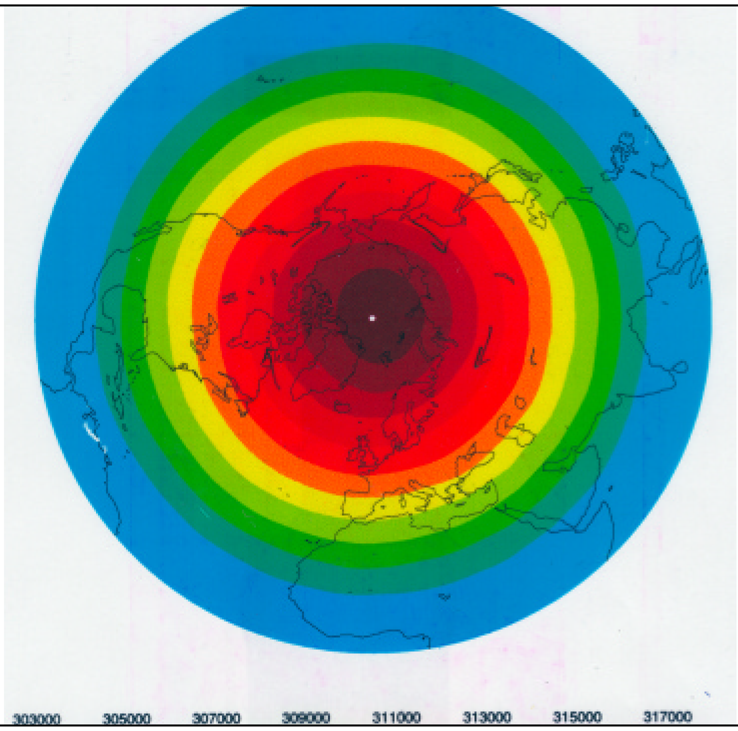

NET DIABATIC HEATING
January cross sections
K/day.
S.P.
N.P.
(a) 110 E
T-increment (K/day)
latitude
(b) Equator
1000 eta

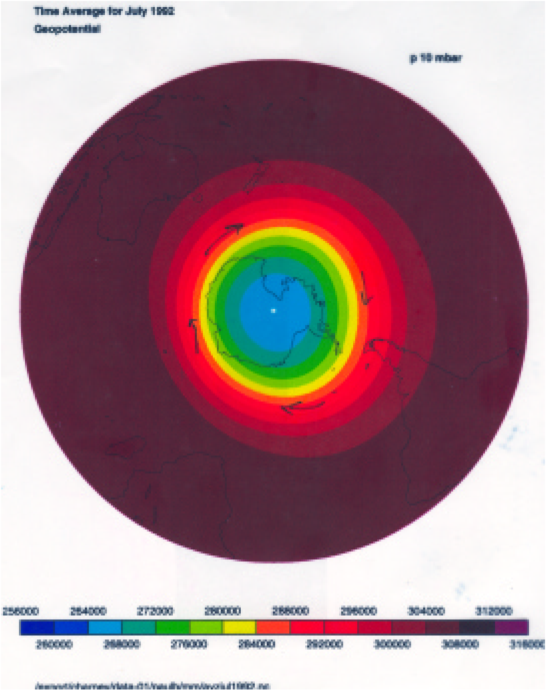

Noctilucent Clouds
Polar Stratospheric Clouds
Altitude (km)
South Pole summer
Equator
North Pole winter
Mesosphere
Stratosphere
Troposphere
Temperatures in Centigrade

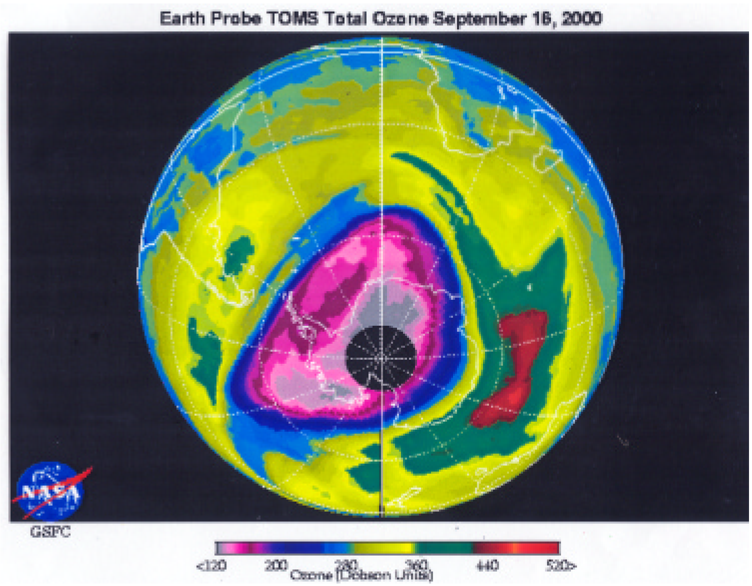

JAN.
300 hPa.
"PLANETARY WAVES"
Time Average for January 1992
Geopotential
p 300 mbar
84000
86000
88000
90000
92000
94000
83000
85000
87000
89000
91000
93000
95000
/export/charney/data-01/paulb/mm/avzjan1992.nc
≃ 9km


140000
144000
148000
152000
156000
160000
164000
168000


Time Average for January 1992
Geopotential
10 hPa
p 10 mbar
280000 284000 288000 292000 296000 300000 304000 308000
282000 286000 290000 294000 298000 302000 306000 310000


303000 305000 307000 309000 311000 313000 315000 317000


Time Average for July 1992
Geopotential
p 10 mbar
256000 264000 272000 280000 288000 296000 304000 312000
260000 268000 276000 284000 292000 300000 308000


Earth Probe TOMS Total Ozone September 16, 2000
NASA
GSFC
<120 200 280 360 440 520>
Ozone (Dobson Units)

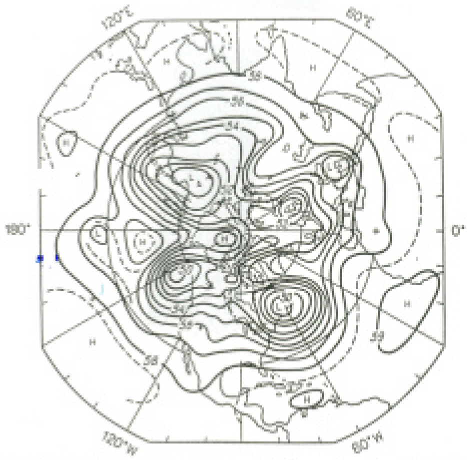
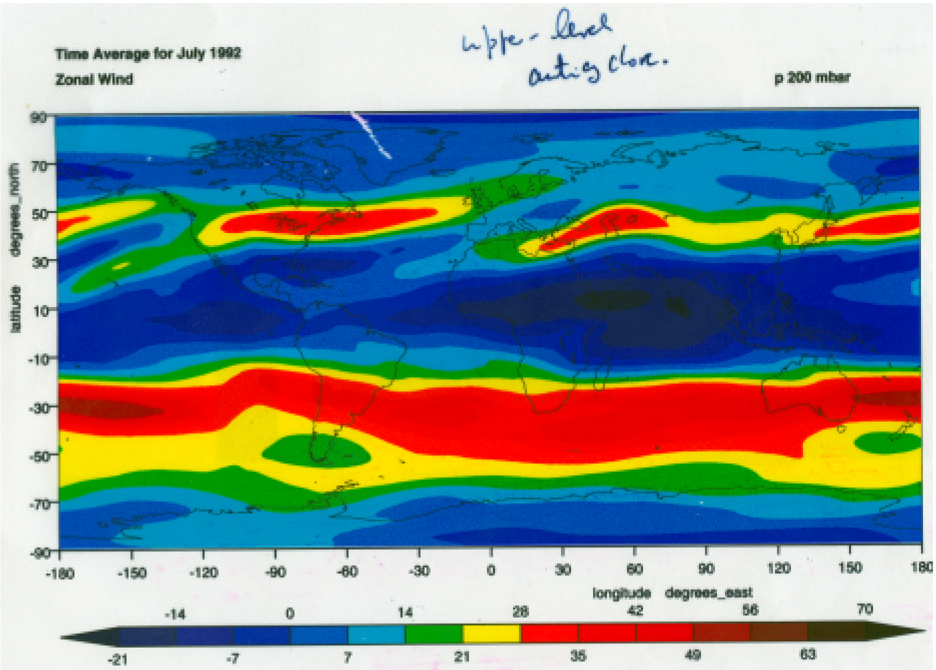
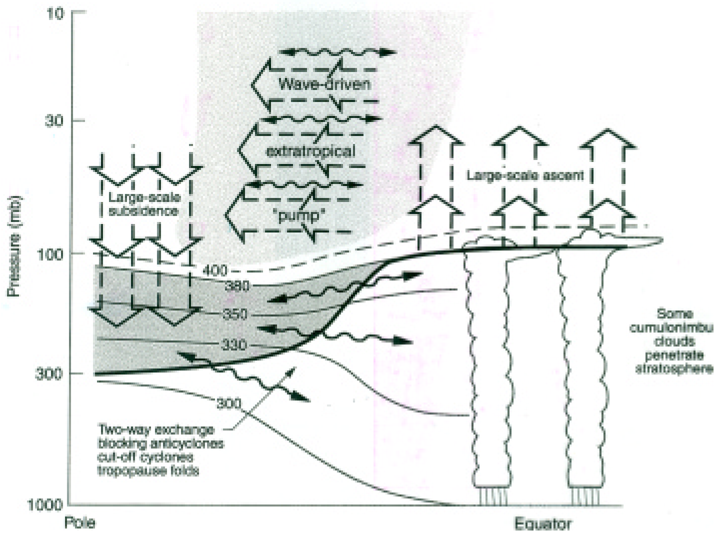
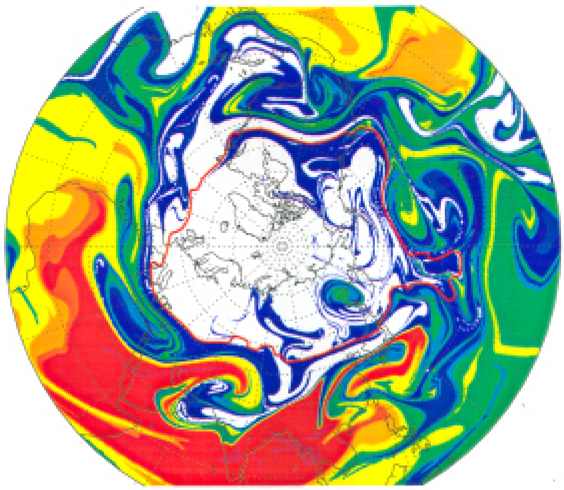
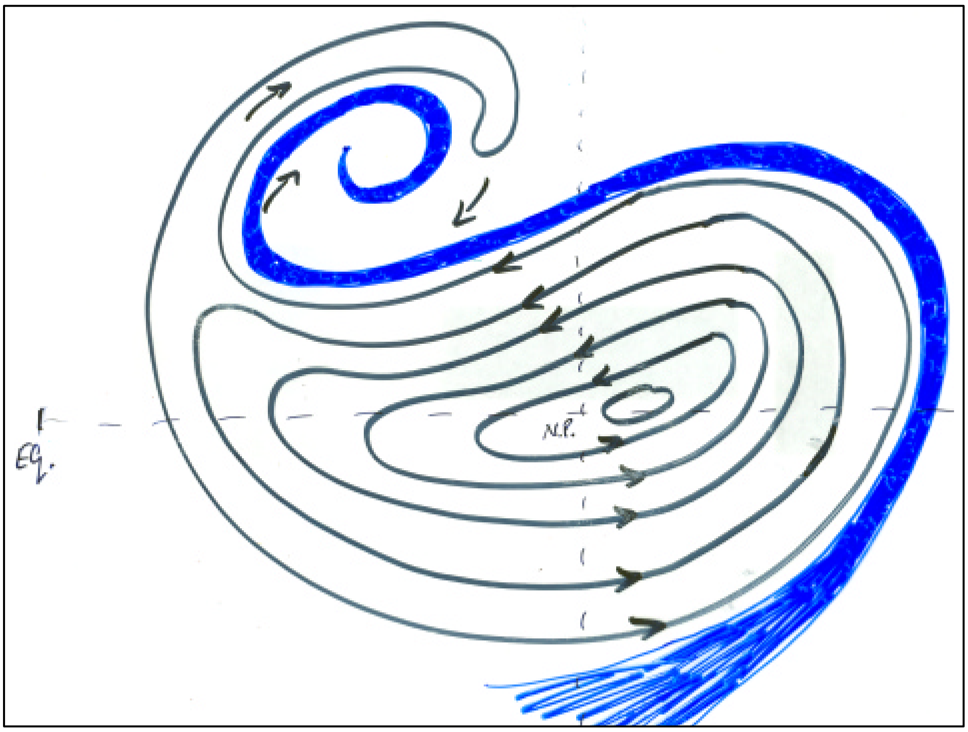


Fig. 2.6. A chain of atmospheric cyclones over the Arctic: equidistant levels of the isobaric surfac in northern hemisphere (L and H indicate cyclones and anticyclones, respectively). From [2.49]




10
30
100
300
1000
Pressure (mb)
Wave-driven
extratropical
"pump"
Large-scale subsidence
Large-scale ascent
400
380
350
330
300
Some cumulonimbu clouds penetrate stratosphere
Two-way exchange
blocking anticyclones
cut-off cyclones
tropopause folds
Pole
Equator



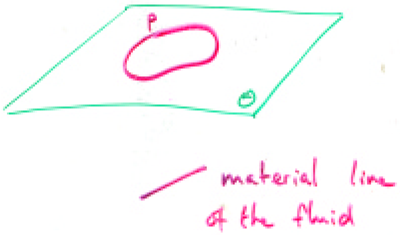


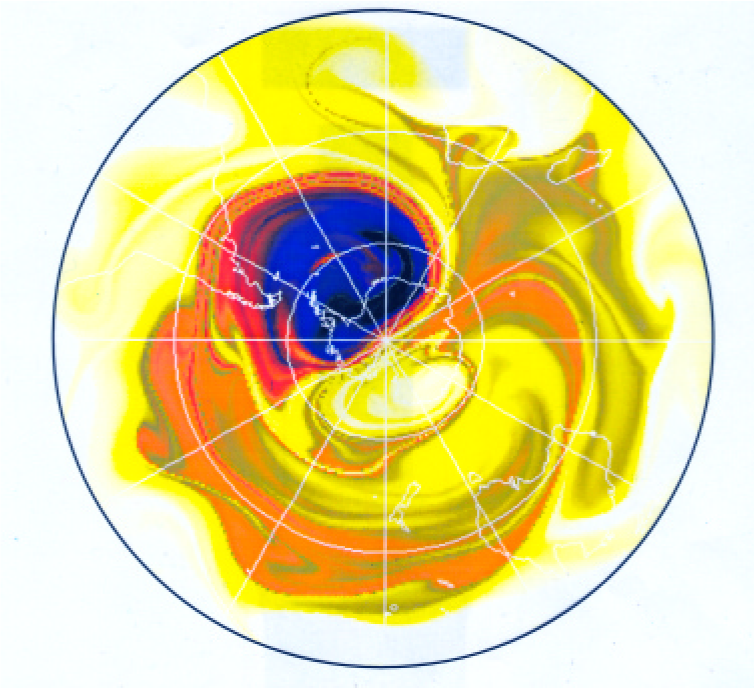
Potential Vorticity

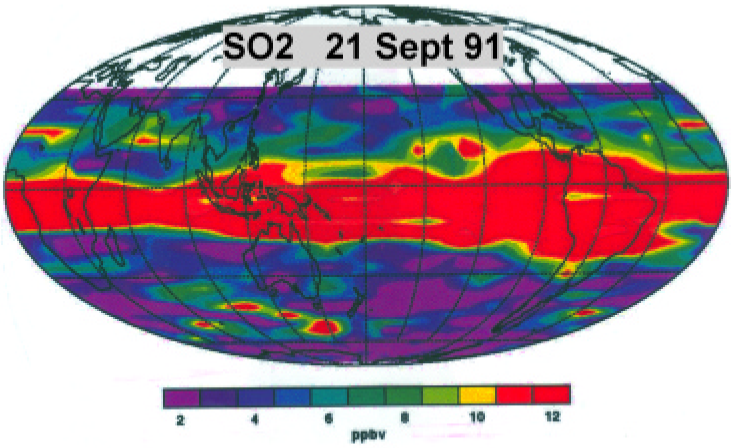
↓ scalar

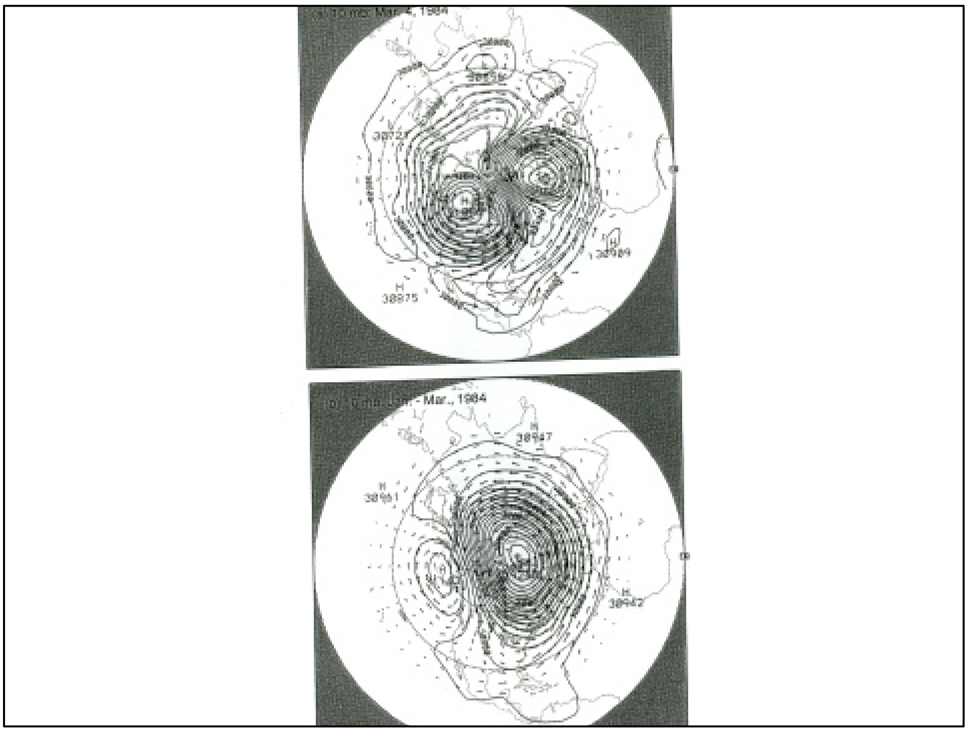
$$P = (\zeta_\theta + f)\frac{\partial\theta}{\partial p}$$

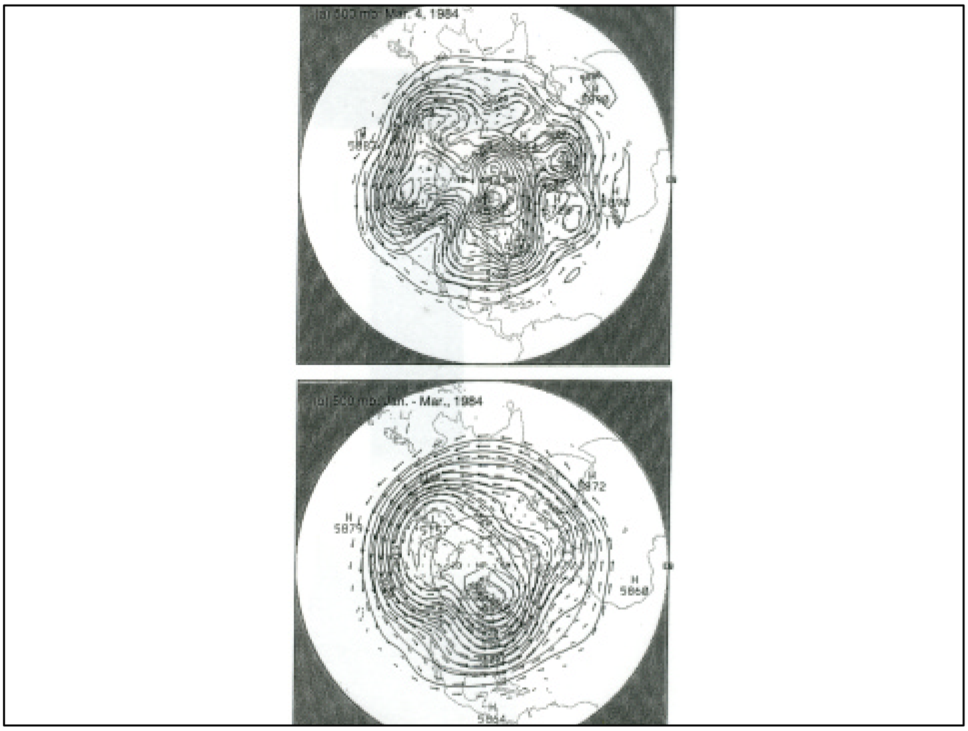
$$\frac{dP}{dt} = 0$$ (in absence of radiative heating & "friction")

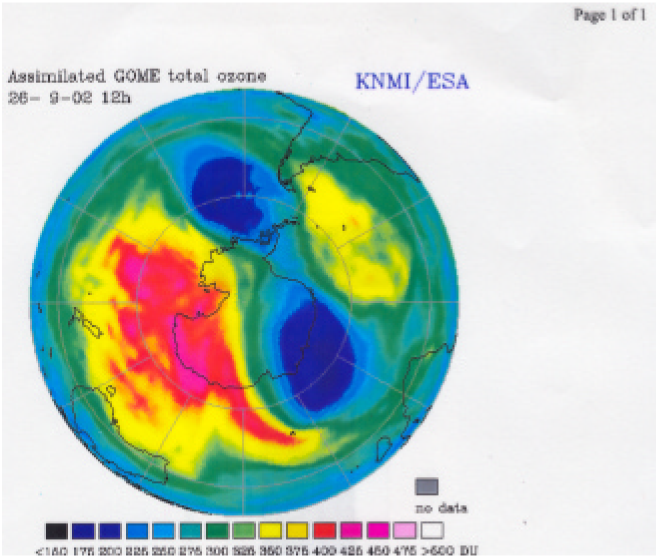


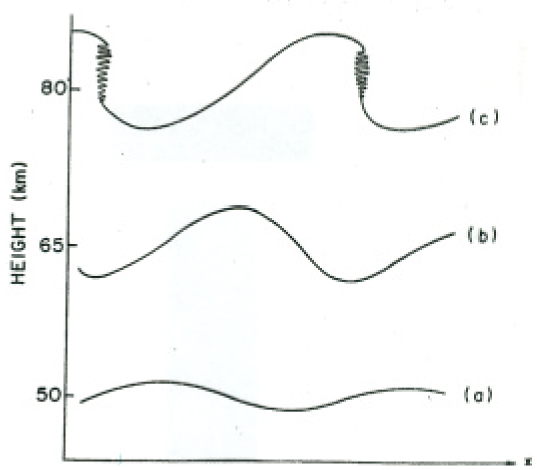


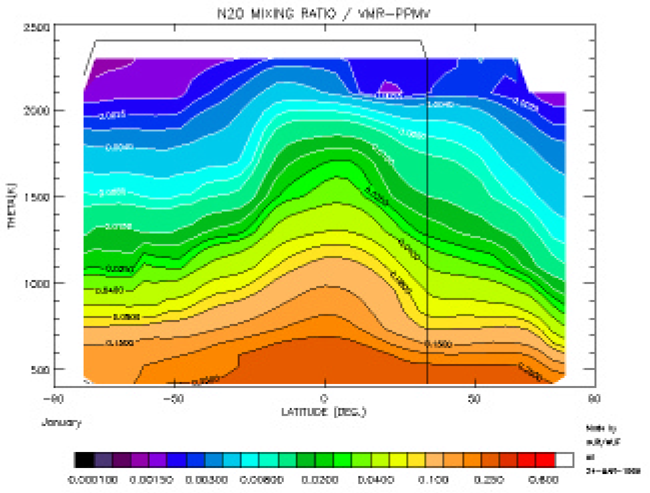

SO2 21 Sept 91
2
4
6
8
10
12
ppbv

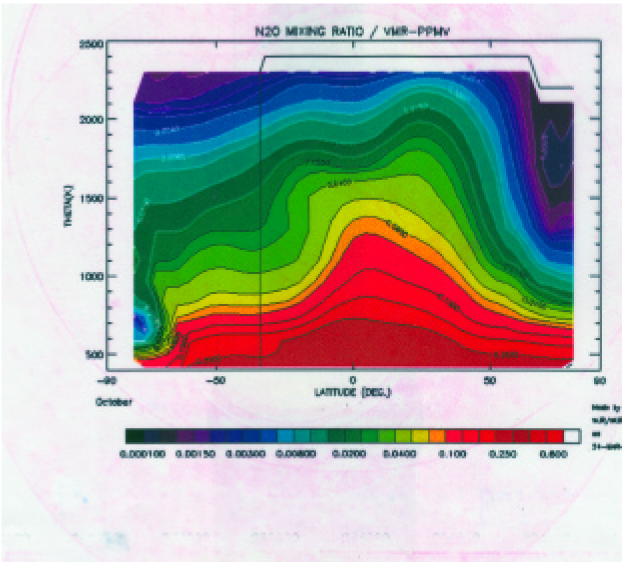

- Mar., 1984

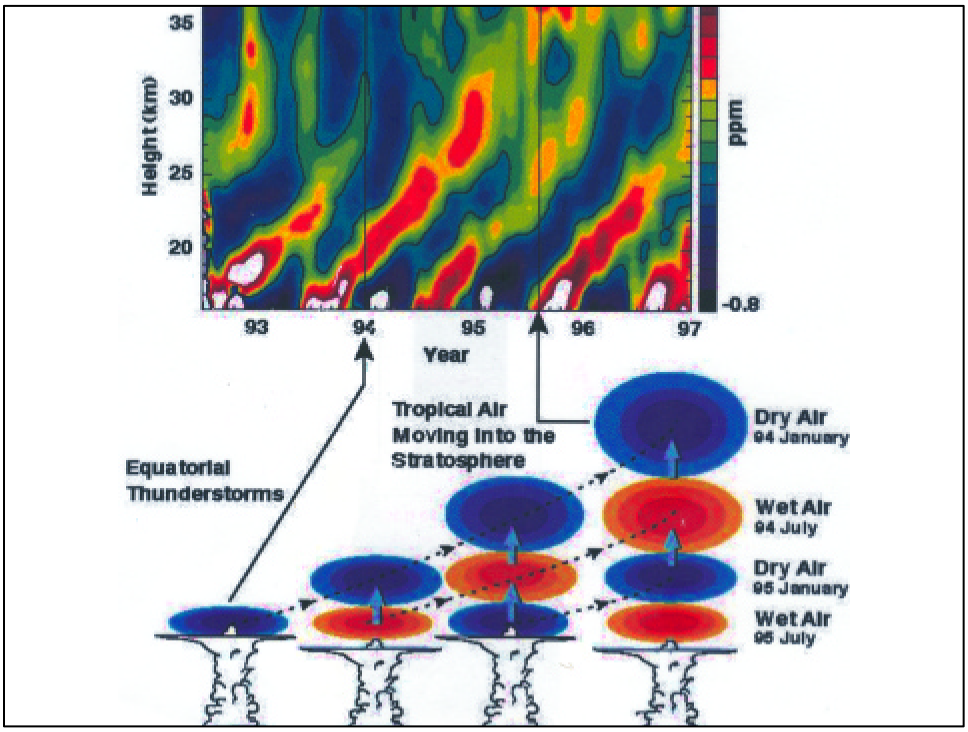

- Mar., 1984


Page 1 of 1
Assimilated GOME total ozone
26- 9-02 12h
KNMI/ESA
no data
<150 175 200 225 250 275 300 325 350 375 400 425 450 475 >500 DU


HEIGHT (km)
80
65
50
(c)
(b)
(a)
x


N2O MIXING RATIO / VMR-PPMV
THETA(K)
LATITUDE (DEG.)
January
0.000100 0.00150 0.00300 0.00800 0.0200 0.0400 0.100 0.250 0.600


N2O MIXING RATIO / VMR-PPMV
THETA(K)
LATITUDE (DEG.)
October
0.000100 0.00150 0.00300 0.00800 0.0200 0.0400 0.100 0.250 0.600


35
30
25
20
Height (km)
ppm
-0.8
93
94
95
96
97
Year
Tropical Air Moving Into the Stratosphere
Equatorial Thunderstorms
Dry Air
94 January
Wet Air
94 July
Dry Air
95 January
Wet Air
95 July

End