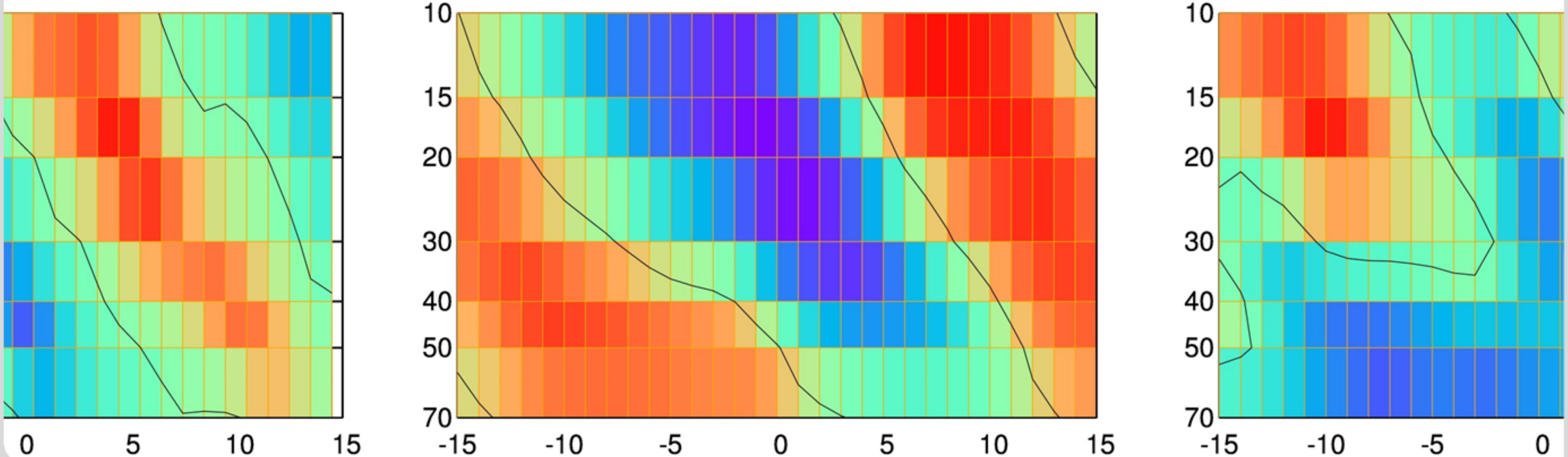
Karlsruher Institut für Technologie

Brewer-Dobson Circulation

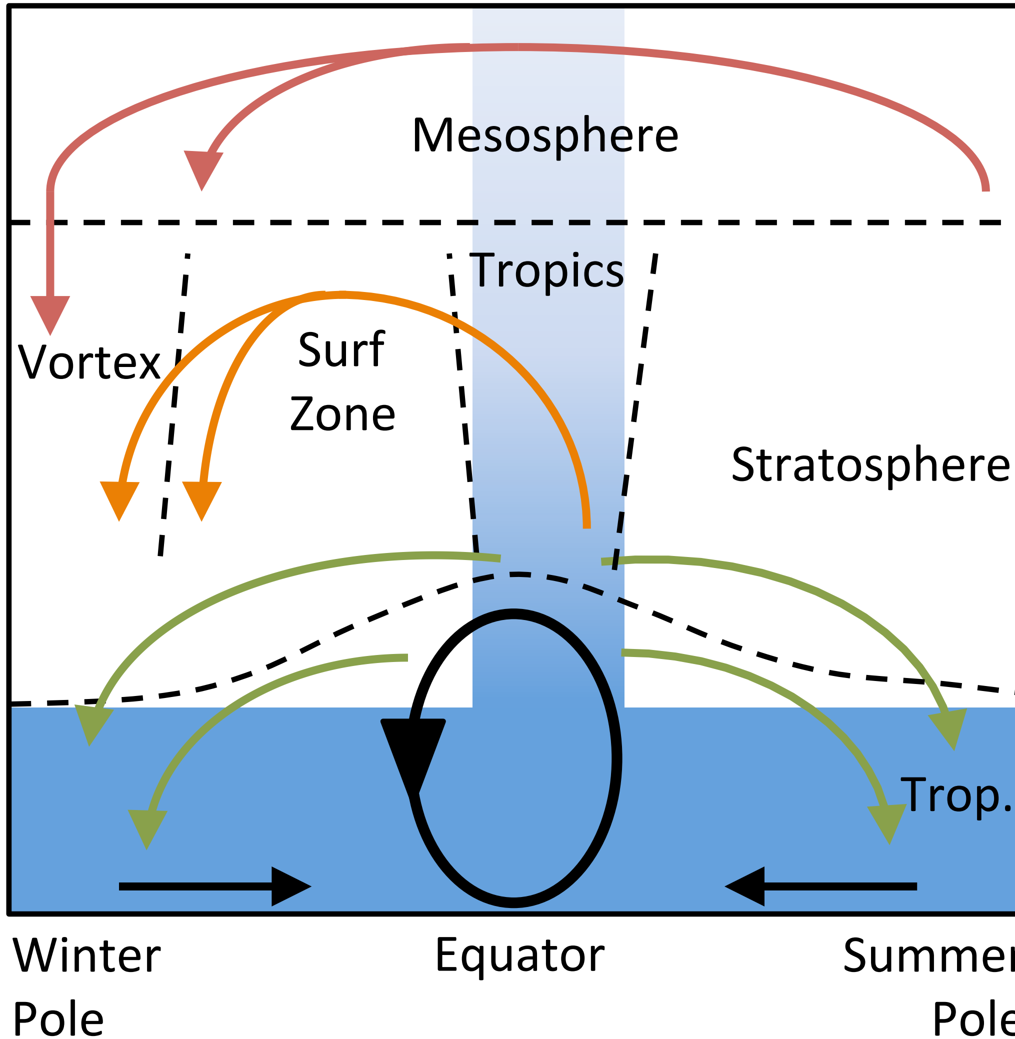
Peter Braesicke

IMK-ASF

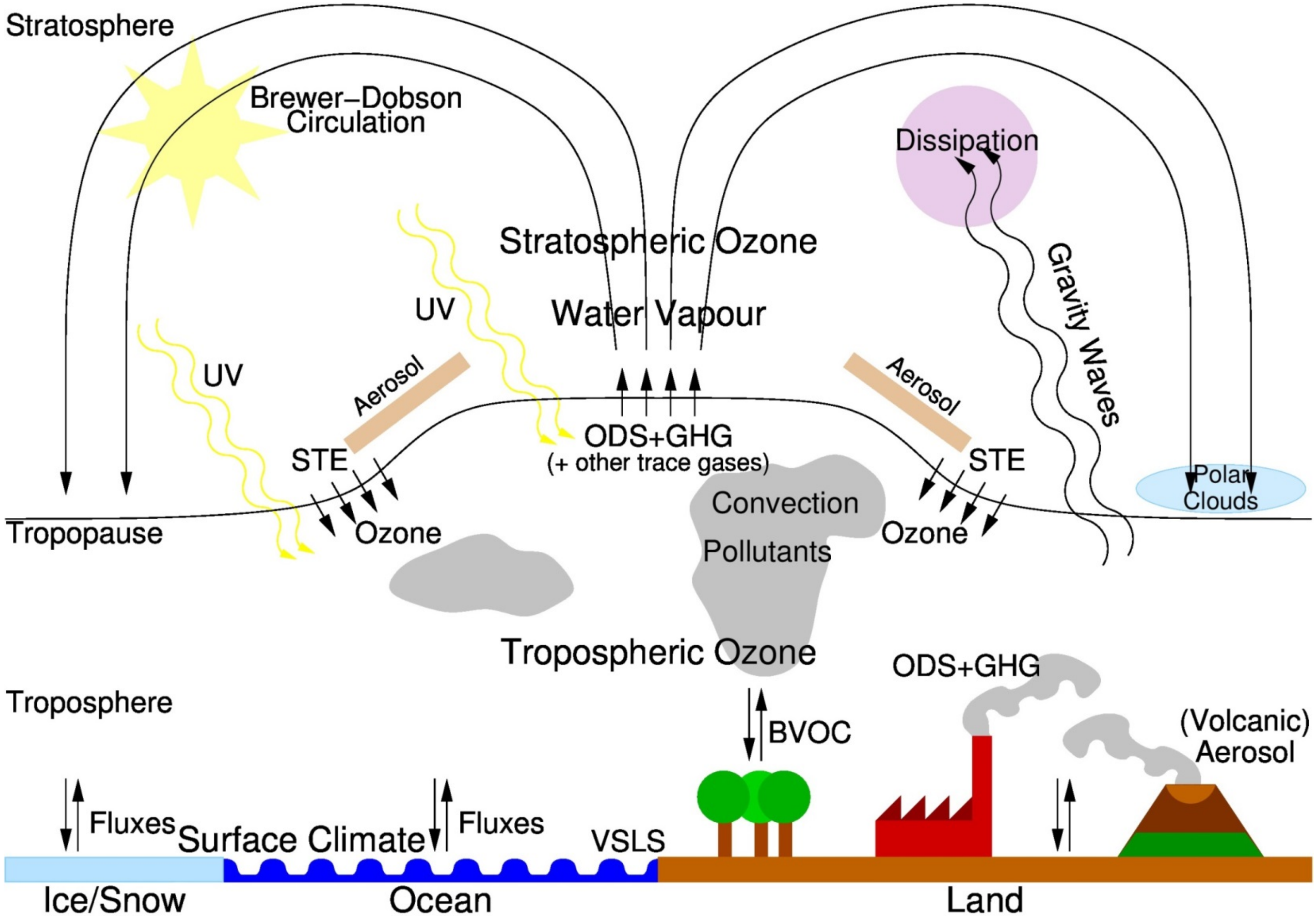


Structure: Brewer-Dobson Circulation

- What is the BDC?
- Brief History
- Measuring the BDC
- Climate Change?

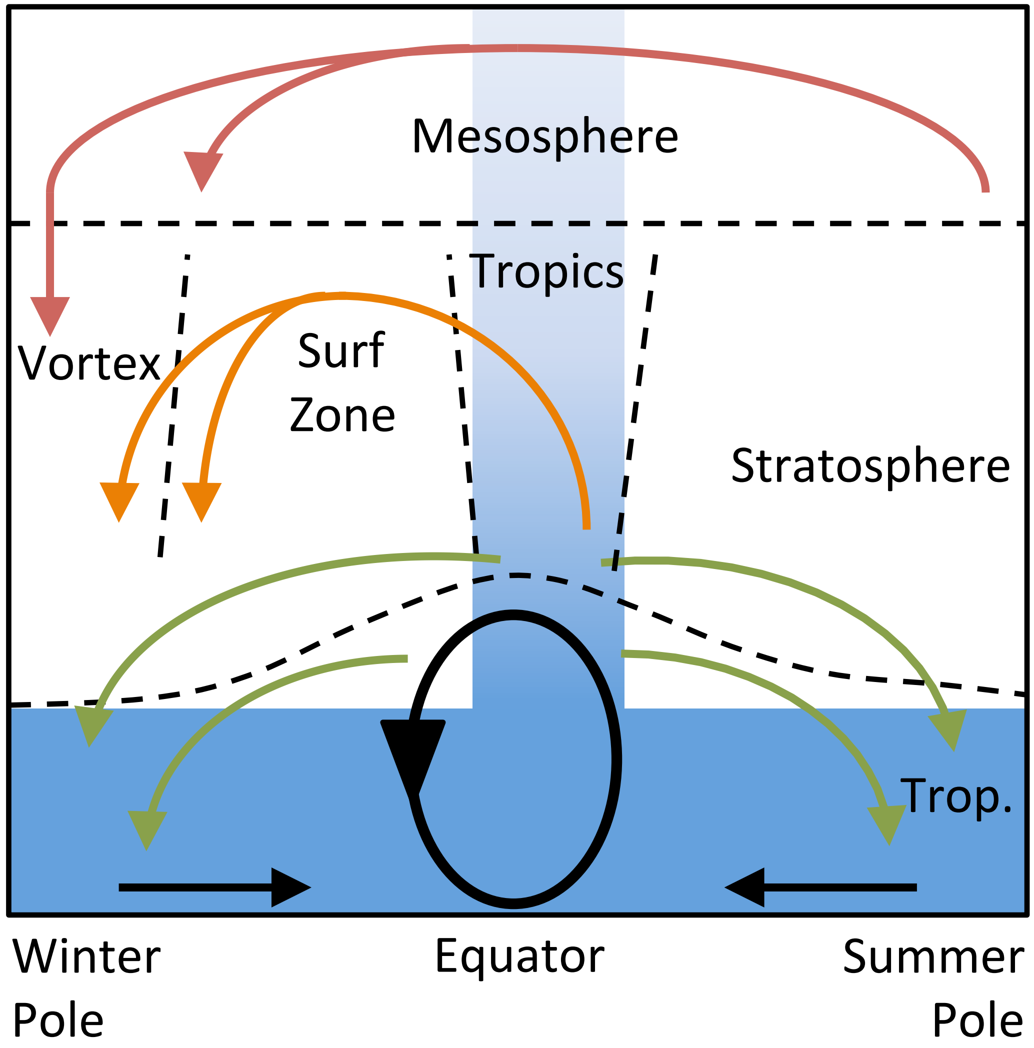


Broad View



Schematic of chemistry–climate interactions.

More Detail

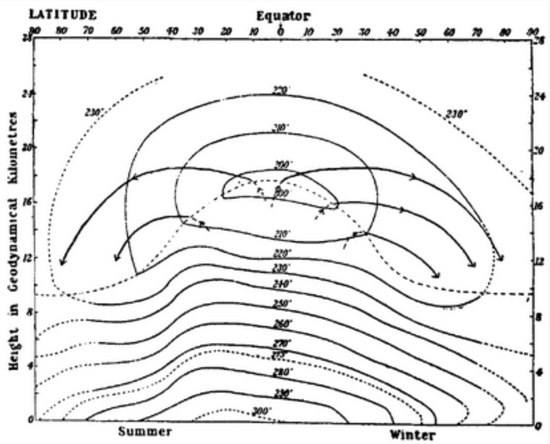


Mesosphere
Tropics
Vortex
Surf
Zone
Stratosphere
Trop.
Winter
Pole
Equator
Summer
Pole

Brewer Circulation

The story of the discovery of the Brewer-Dobson circulation serves as a great example of how crucial the historical setting at the time of the discovery can be. Brewer, working for the U.K. Met Office (with supervision by Dobson) during World War II, was in charge to investigate why high-altitude aircraft left condensation trails. Understandably, this was an unwanted phenomenon revealing flight tracks to the enemy. What Brewer needed were accurate measurements of temperature and frost point at flight altitude, and especially the latter proved difficult (and remains difficult to date).

Brewer eventually was able to obtain measurements that were accurate enough and he recalls: "... we got into the stratosphere. To my surprise, as the temperature turned up, the frost point turned down, and at the highest levels I could get no deposit ... it was clear that the reason that there were no [condensation] trails in the stratosphere was that the air was exceedingly dry. I would not have believed before I had started that the air could be so dry, but I saw it with my own eyes. I had plenty of trouble with people convincing them that we could really measure that dryness." These observations were presented by Dobson in his 1945 Bakerian Lecture to the Royal Society.



Isotherms over the Globe

FIG. 5. A supply of dry air is maintained by a slow mean circulation from the equatorial tropopause.

Left: Alan W. Brewer.
Right: Brewer's depiction of his envisioned circulation (from his 1949 paper).

Brewer then came up with an ingenious "prediction"/interpretation of this observed dryness at mid-latitudes (Brewer 1949): he concluded that the "... dryness is maintained by a slow circulation of the air in which air rises at the equator, moves poleward in the stratosphere, and then descends into the troposphere in temperate and polar regions ...". He therefore essentially described what we now call the Brewer-Dobson circulation.

http://birner.atmos.colostate.edu/bdc.html

A.W. Brewer

Karlsruher Institut für Technologie

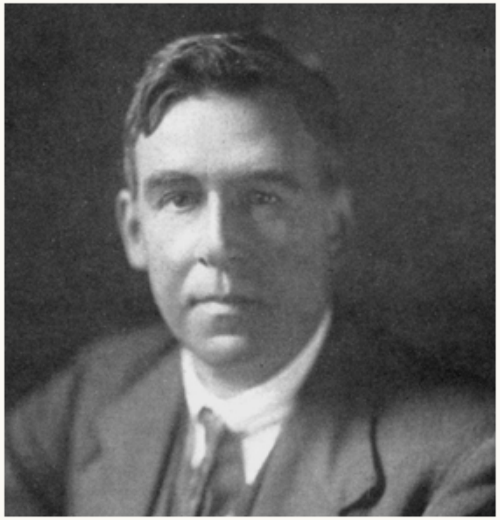
Alan West Brewer (1915 – 21 November 2007) was a Canadian-English physicist and climatologist. Born in Montreal, Canada and raised in Derby, England, he earned a scholarship to study physics at the University College of London. He received his M.Sc. there, and began to work for the Met Office in 1937. During World War II, he researched contrails for the Royal Air Force, making the discovery that the stratosphere is much drier than had been presumed. Later this observation led to the development of Brewer-Dobson circulation. Brewer worked at the Subdepartment of Atmospheric, Oceanic and Planetary Physics, University of Oxford from 1948 until 1962, when he became a professor at University of Toronto. In 1977, Brewer retired from the University of Toronto, returning to England, in Devon, where he farmed until nearly 80 years old.[1][2][3]

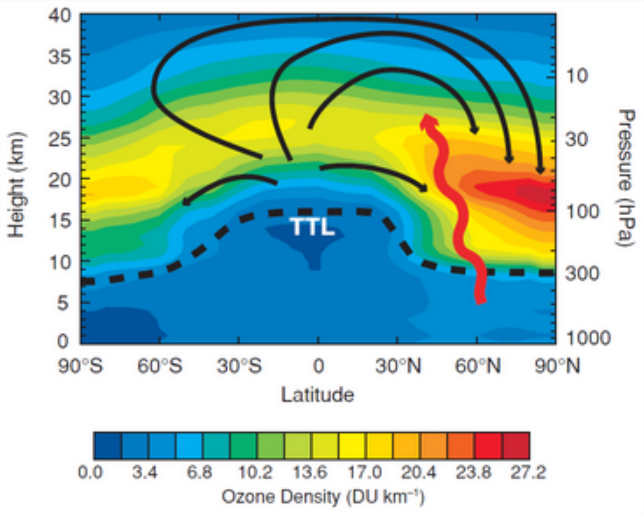
In late 1959, he and James Milford developed the Oxford-Kew ozone sonde.[4][5] He also developed the Brewer ozone spectrophotometer with Dave Wardle which is currently the most accurate instrument for measuring ozone.[6]

Brewer married Iris, another UCL physicist, in 1939. They had three children.[1]

Dobson Circulation

Interestingly, Dobson described the possibility of such a circulation as early as 1929, based on ozone column measurements (Dobson et al. 1929): "The only way in which we can reconcile the observed high ozone concentration in the Arctic in spring and the low concentration in the tropics ... would be to suppose a general slow poleward drift in the highest atmosphere with a slow descent of air near the poles ...". However, Dobson discarded this possibility (he didn't have vertical ozone profiles which would have given him much clearer evidence), and he remained very doubtful that such a circulation can really exist until the late 1950's.





Left: Gordon M. B. Dobson. Right: Ozone cross section from satellite data that clearly shows the pile-up of ozone in the high-latitude lower stratosphere due to the Brewer-Dobson circulation (from IPCC/TEAP special report, 2005).

It did not take very long until the Brewer-Dobson circulation made a real societal impact. Radioactive debris from the nuclear tests by the U.S. in the tropical Pacific, even though deposited into the tropical stratosphere and believed to stay in the stratosphere for many years, got transport poleward and downward back into the troposphere where it got quickly mixed down to the surface (as had been predicted by Brewer).

http://birner.atmos.colostate.edu/bdc.html

G.M.B. Dobson

Gordon Miller Bourne Dobson FRS (25 February 1889 - 11 March 1976) was a British physicist and meteorologist who did important work on ozone.

He was educated at Sedbergh School and Caius College, Cambridge where he graduated MA (Cantab and Oxon). He was later awarded DSc (Oxon).

He was appointed University Lecturer in Meteorology, Oxford. By studying meteorites he noticed that the temperature profile of the tropopause was not constant, as had previously been believed (hence the name stratosphere). In fact there was, he showed, a region where the temperature sharply rose. This, he proposed, was happening because UV radiation was heating ozone in what has become known as the ozone layer. He noted the connection between sunspots and weather, and measured the ultraviolet levels of our star.[1] He built the first Dobson ozone spectrophotometers and studied the results over many years. The Dobson unit, a unit of measurement of vertically integrated atmospheric ozone density, is named after him.

He was elected a Fellow of the Royal Society in May, 1927, awarded their Rumford Medal in 1932 and delivered their Bakerian lecture in 1945. [2]

He served as president of the Royal Meteorological Society from 1947 to 1949. [3] He was made CBE in 1951.

Transformed Eulerian Mean (TEM) Circulation

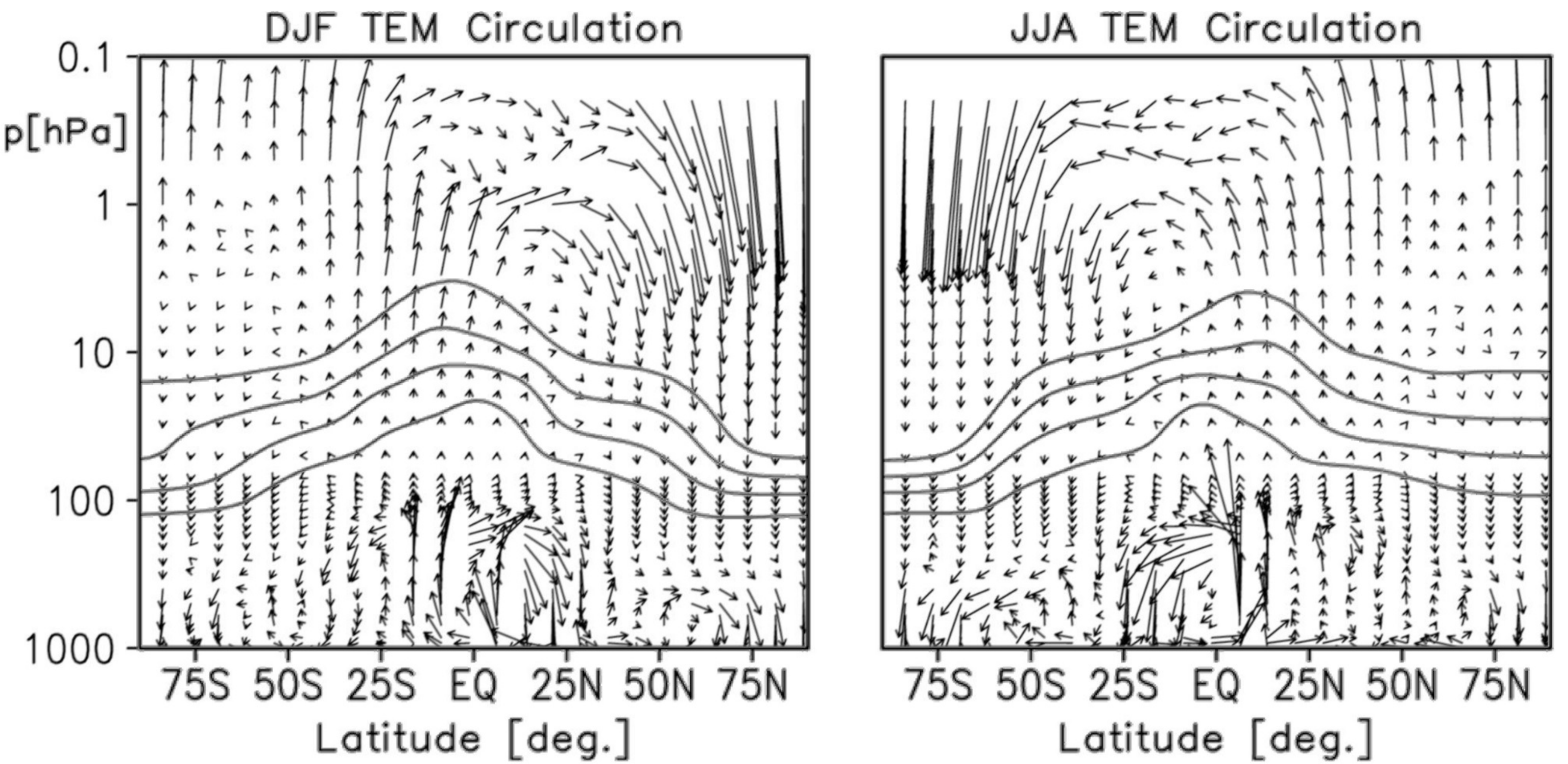
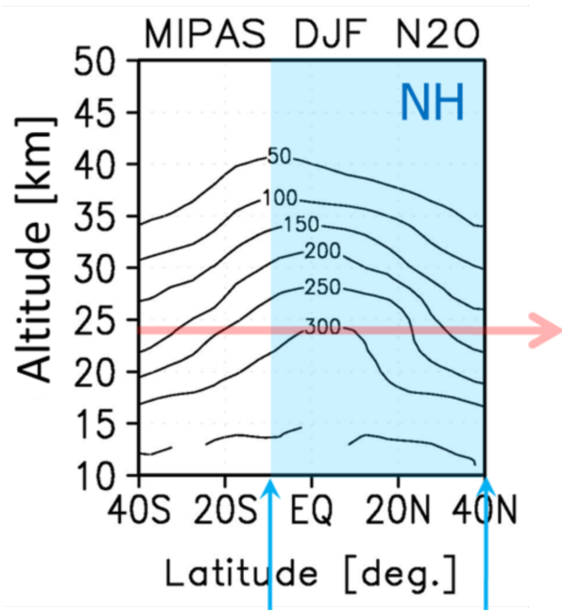


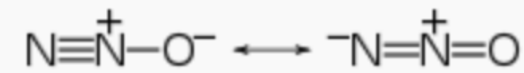
Figure 7: Residual circulation velocity vectors (scaled arrows) and isopleths of a long lived tracer (isolines) as a function of latitude and pressure for December-January-February (DJF; left) and June-July-August (JJA; right). Data from a chemistry-climate model for internal consistency.

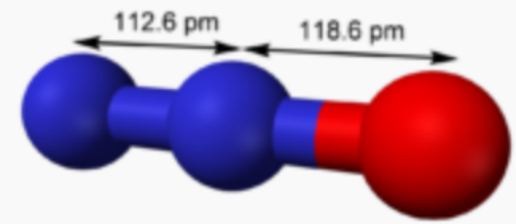
Nitrous Oxide (N2O)

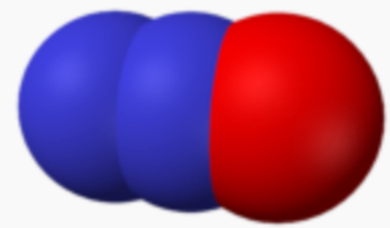
- Sources: Natural and anthropogenic (e.g. agriculture and land management)
- Lifetime: > 100 years
- Distribution:



Nitrous oxide	







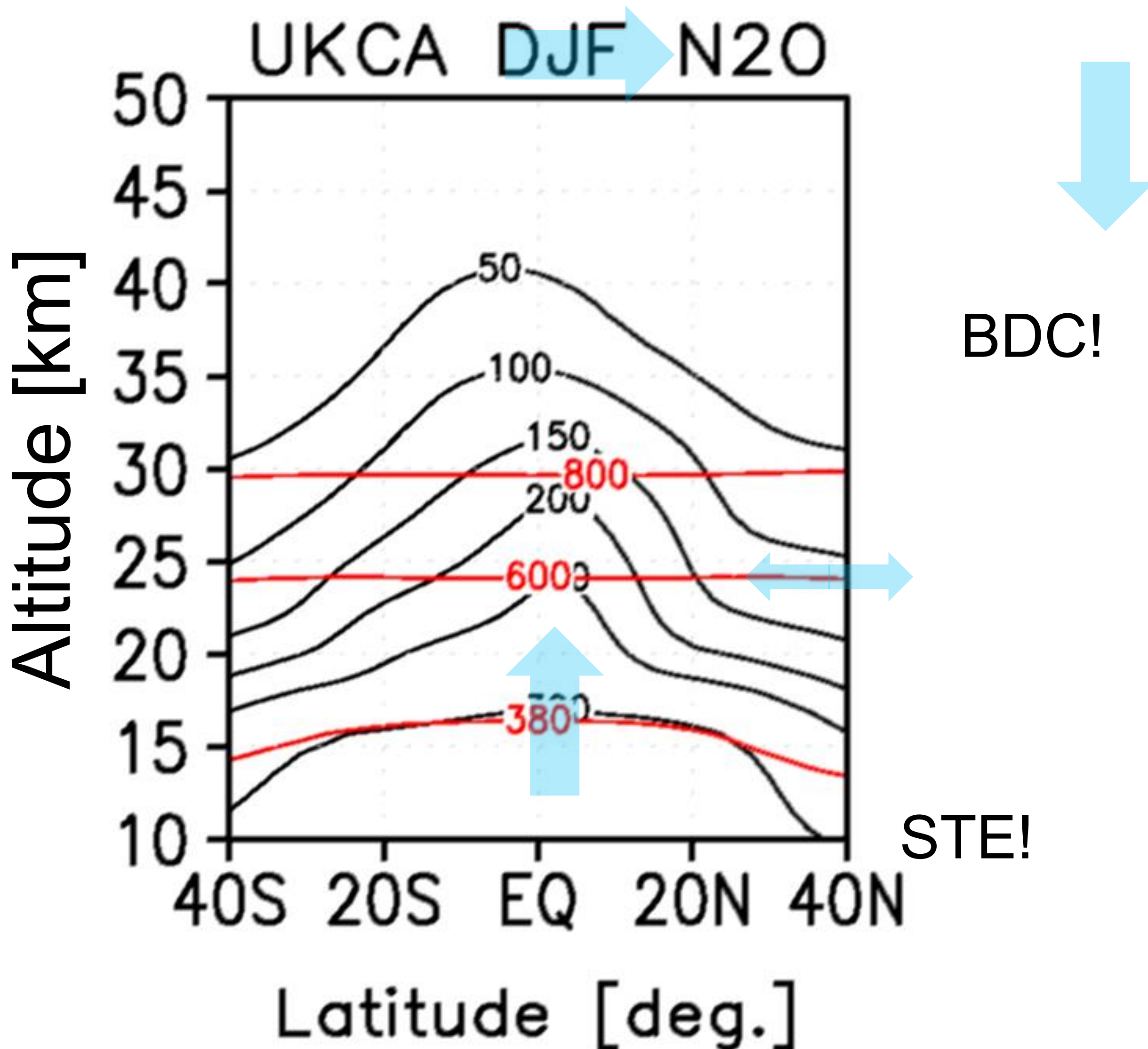
IUPAC name [hide]

Dinitrogen monoxide

Other names [hide]

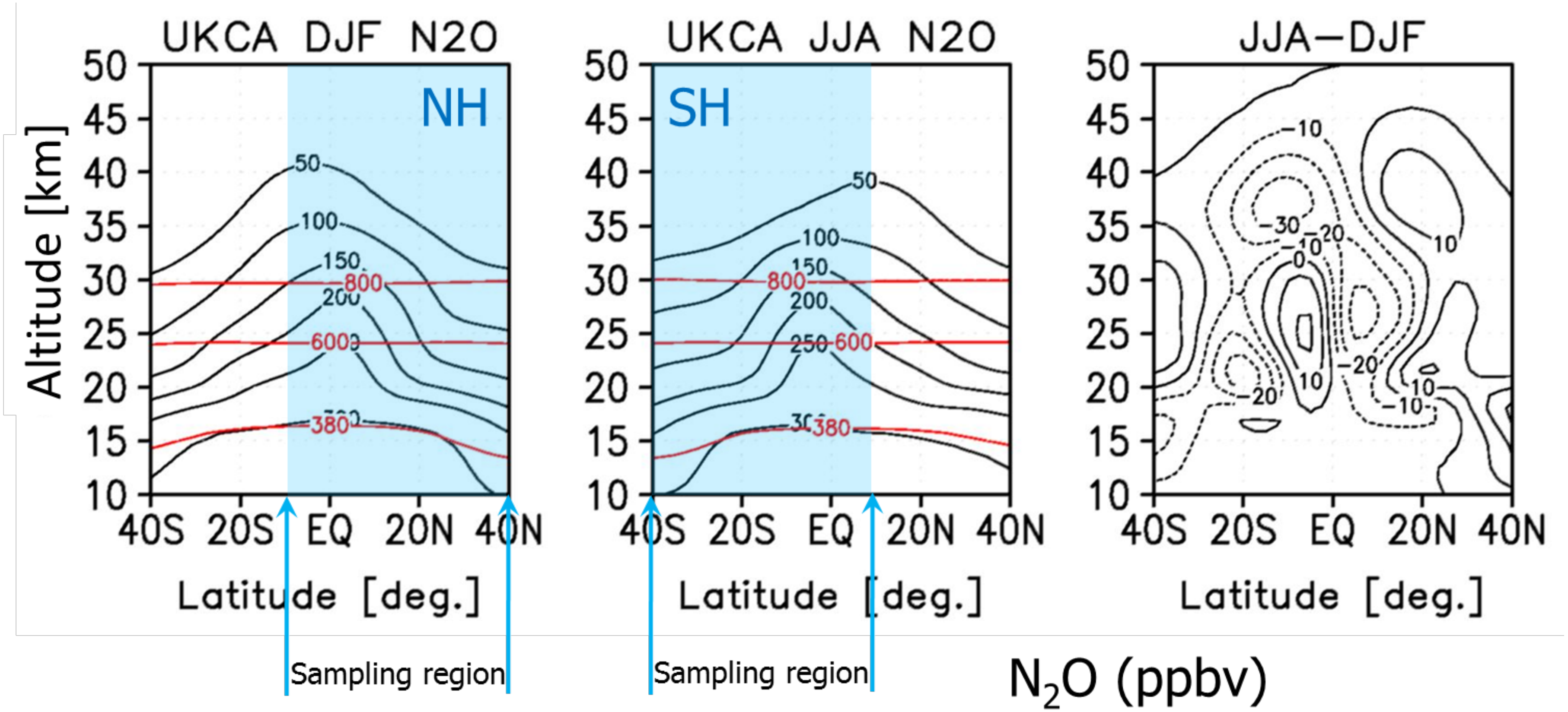
Laughing gas, Sweet air, Protoxide of nitrogen, Hyponitrous oxide

Wikipedia


UKCA DJF N2O
Altitude [km]
50
45
40
35
30
25
20
15
10
50
100
150
200
800
600
380
40S 20S EQ 20N 40N
Latitude [deg.]
BDC!
STE!

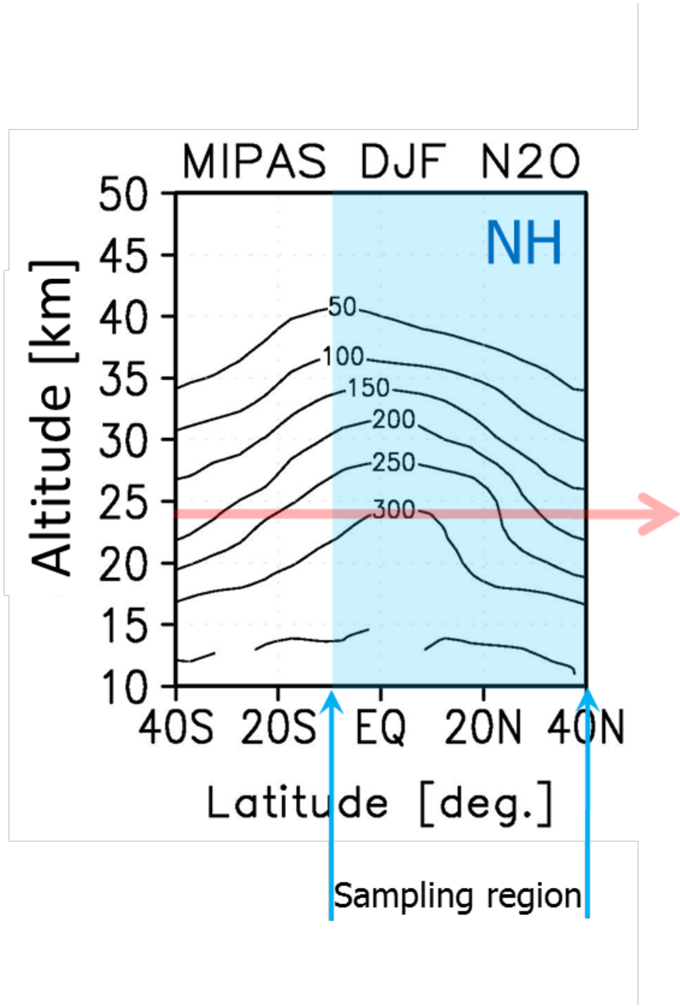
N_2O (ppbv)

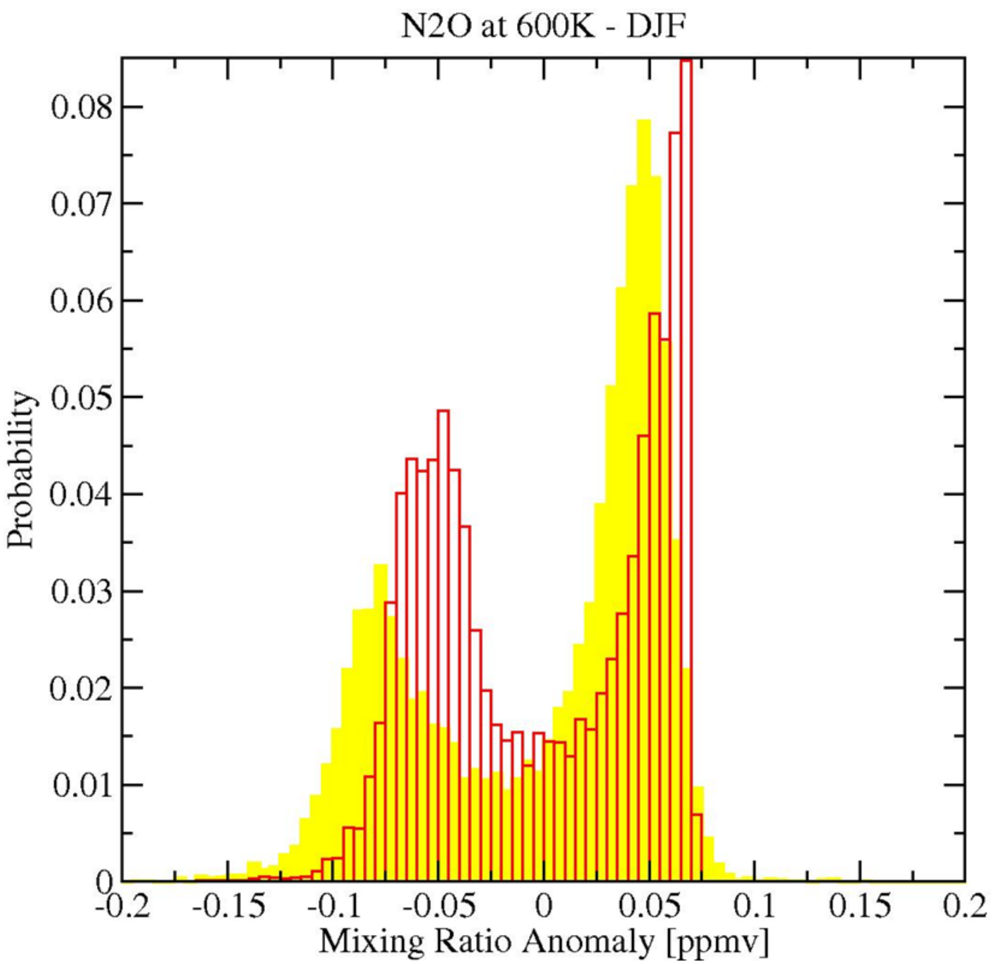
N_2O Distributions and Sampling



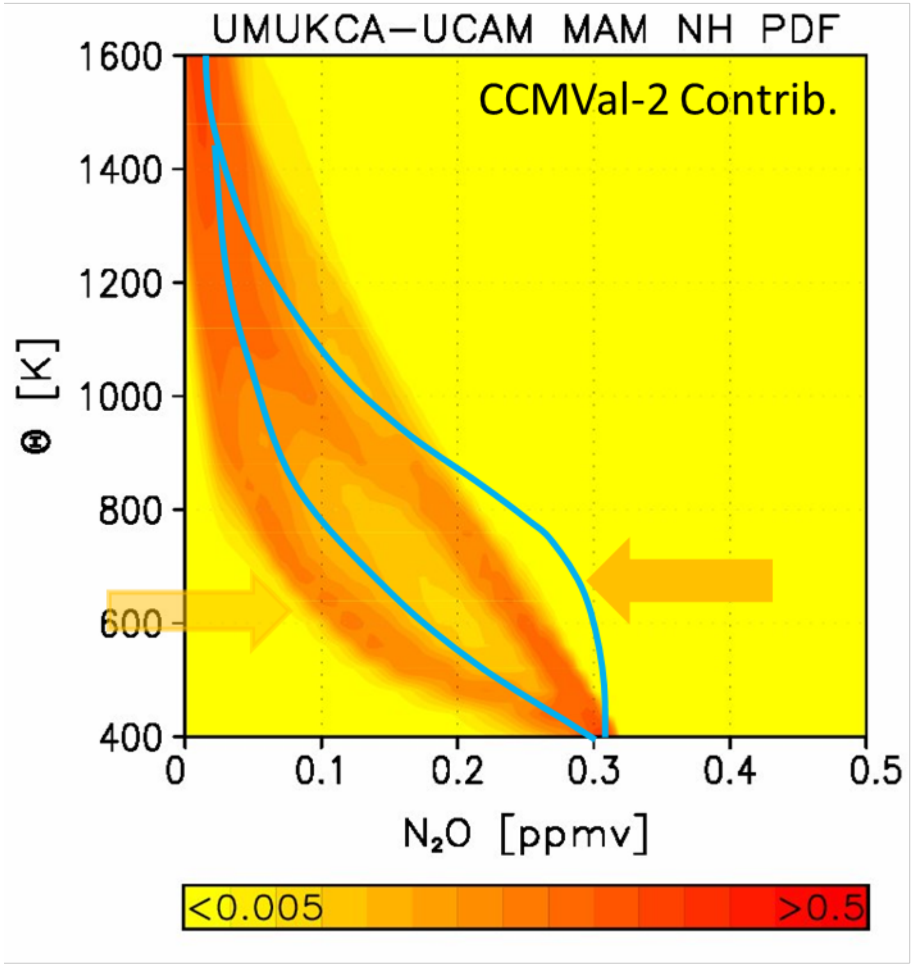
N_2O (ppbv)

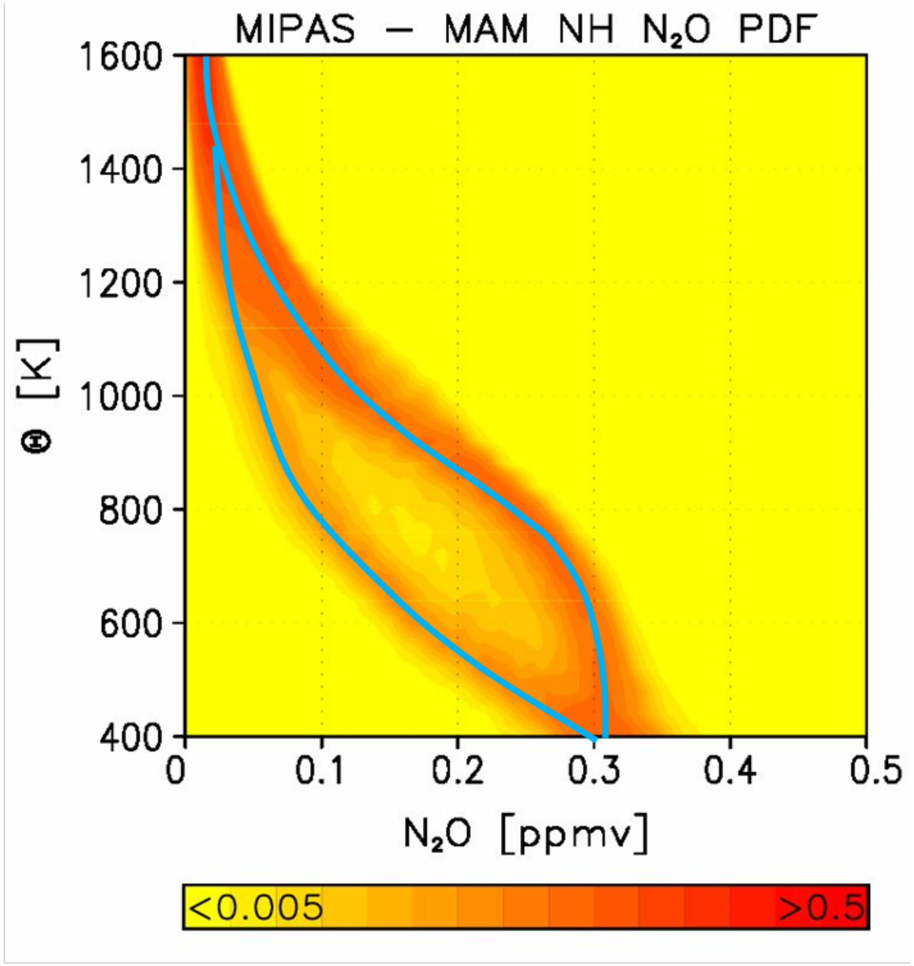
Probability Density Function (Histograms)





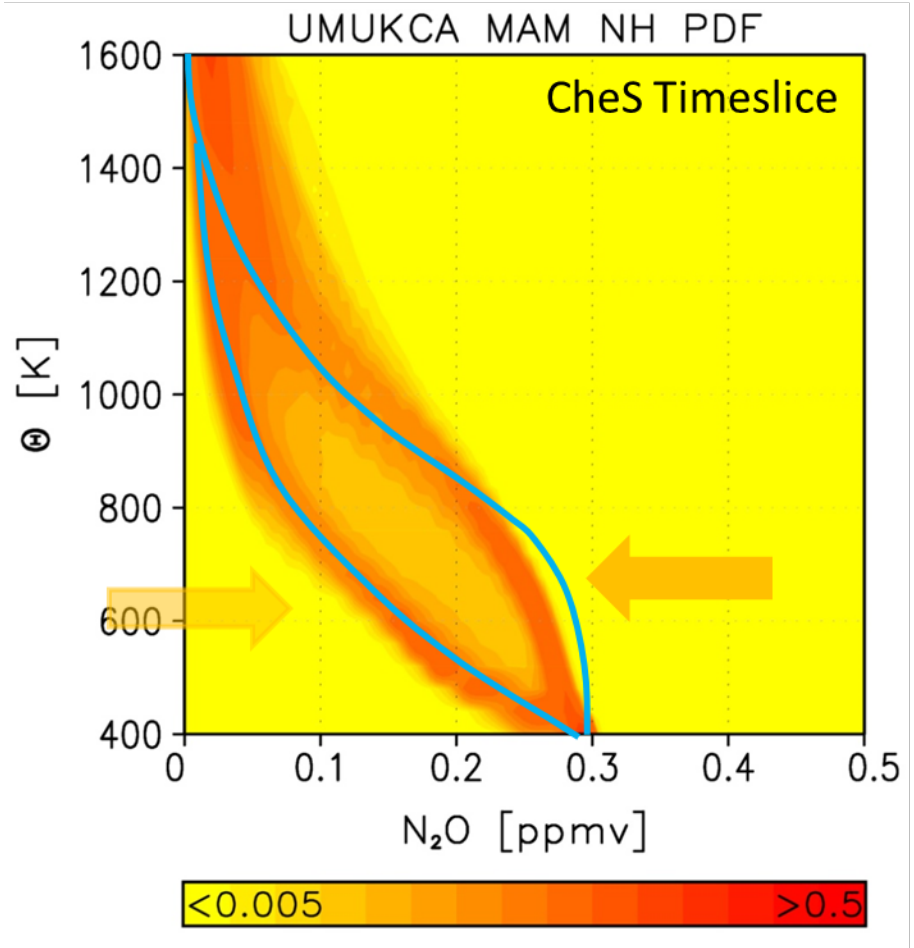
Model versus Observation

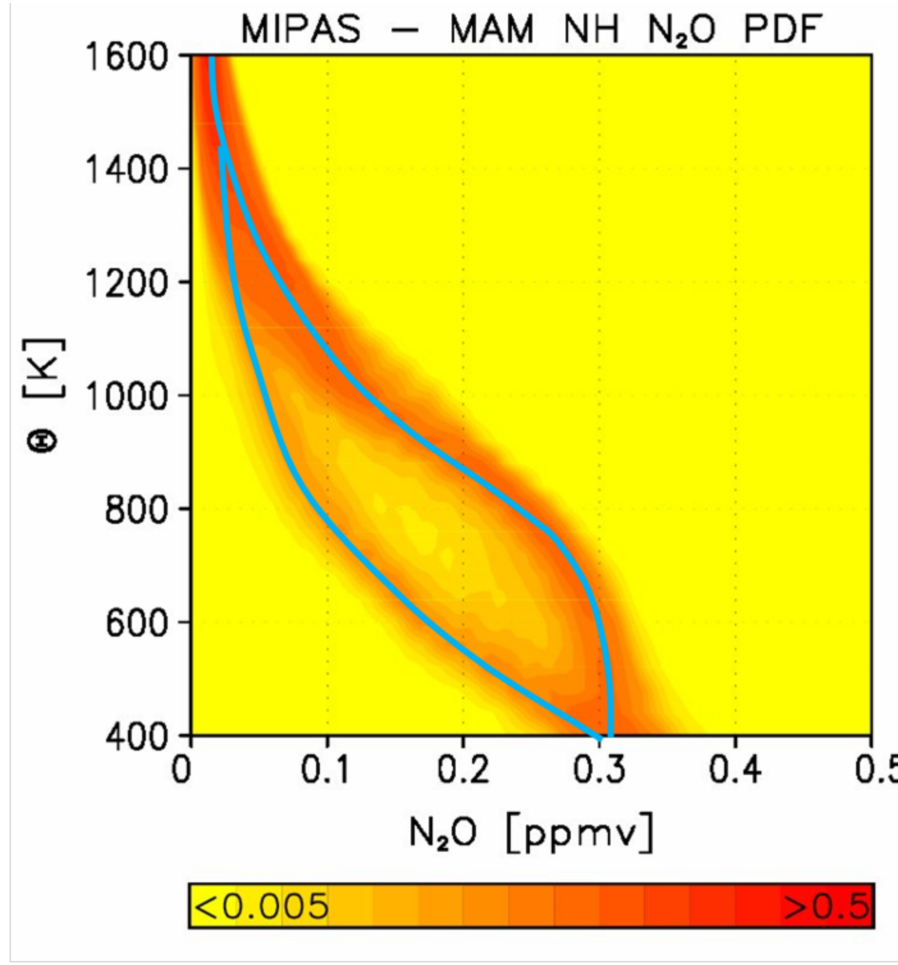




SPARC CCMVal Report, Chapter 5: Transport, 2010

Model versus Observation





Equatorial Zonal Mean Zonal Wind

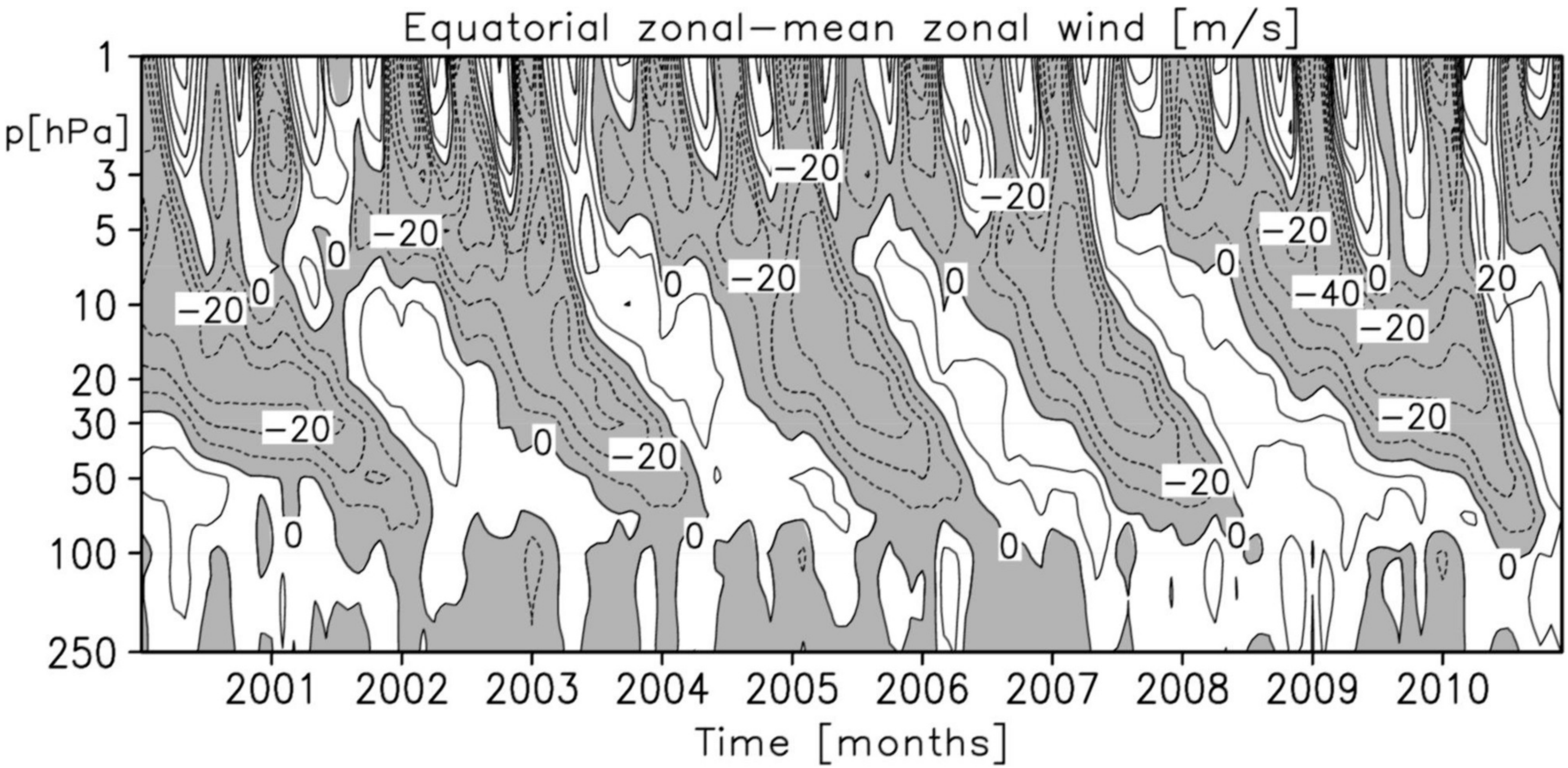
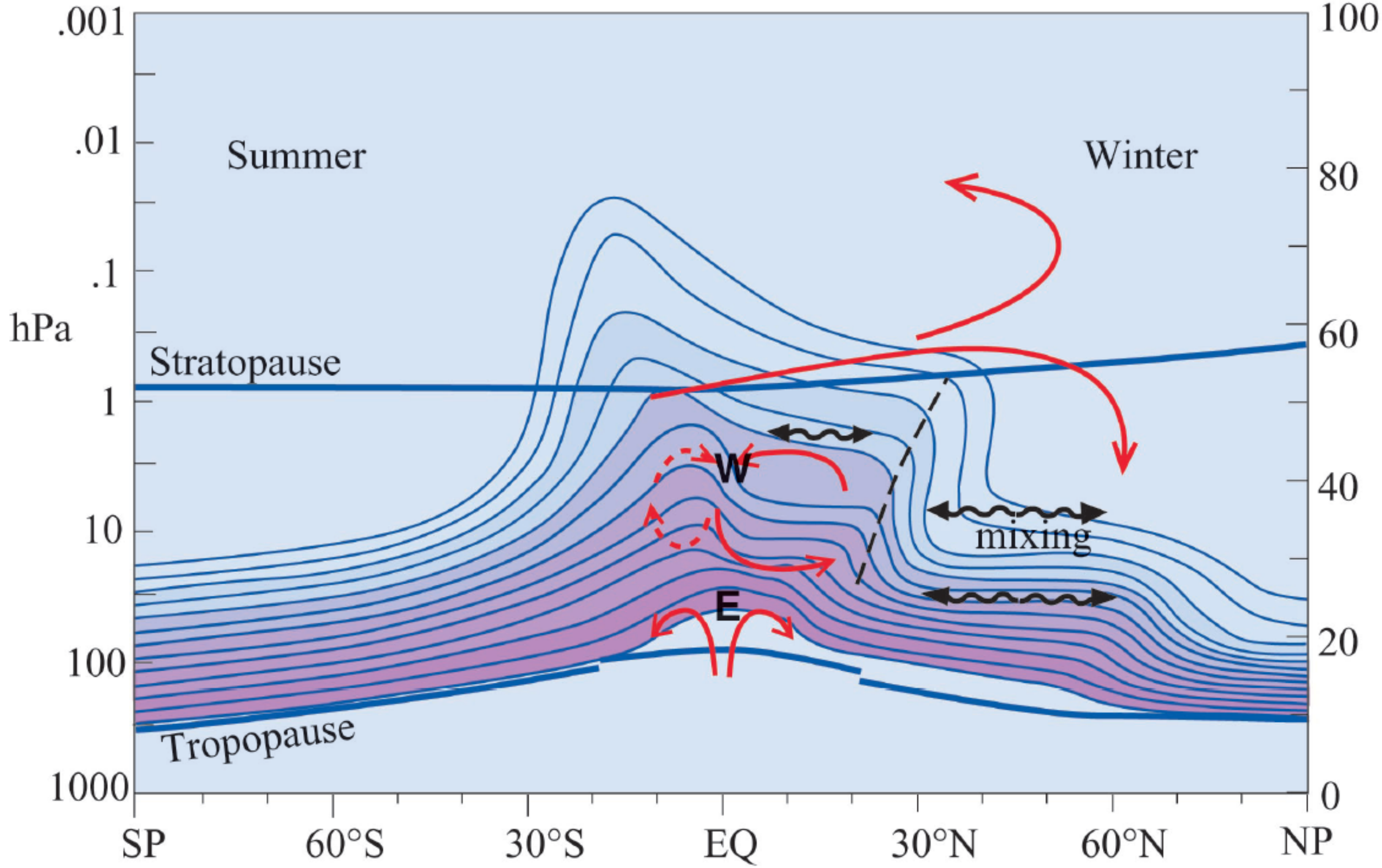


Figure 4: Equatorial zonal-mean zonal wind as a function of time and pressure. Data shown is monthly; year labels indicate beginning of the year; data from ERA-Interim.

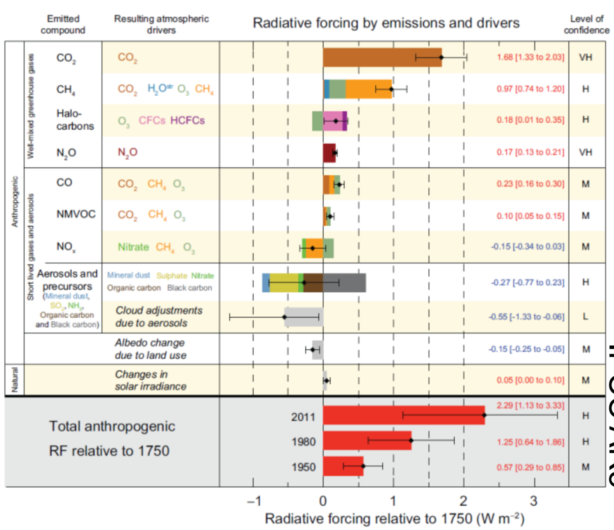
Complex View



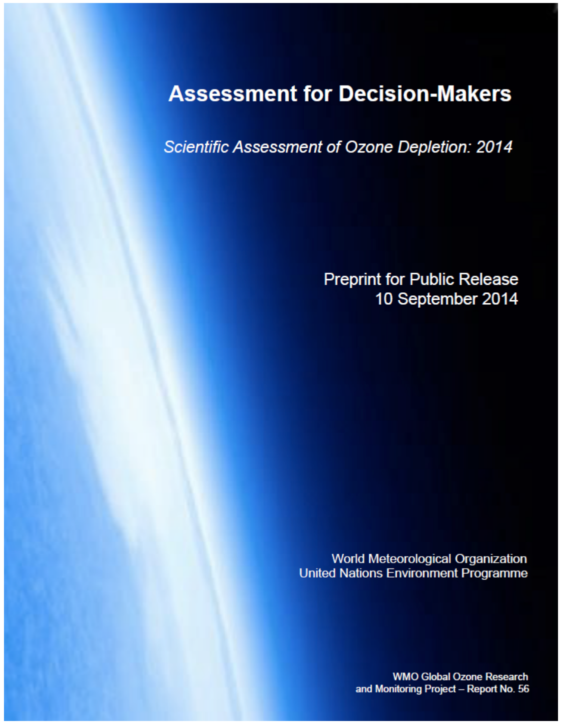
Baldwin et al., 2001

Why Bother?

- Is the BDC a good indicator of climate change?
  - Other metrics are related, e.g. age-of-air (derived from SF6, etc.)
  - Models seem to agree, but we need more observations …
- The BDC is impacting trends (and spatial variability) of other trace gases:
  - Nitrous Oxide and its spatial distribution
  - Ozone and related trend patterns



IPCC AR5



Climate Change Impact: Effect on Ozone

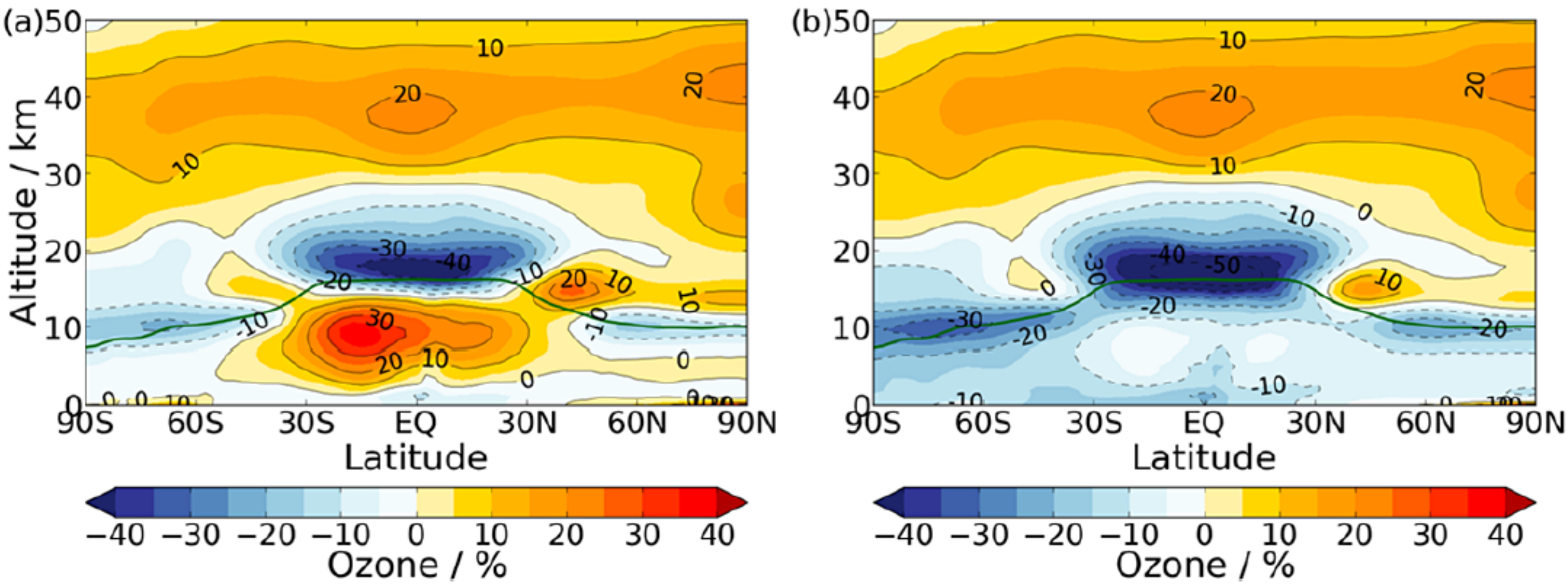


Figure 3. Annual mean, zonal mean changes (shading and contours) in ozone (%) relative to Base for **(a)** ΔCC8.5 and **(b)** ΔCC8.5(f LNO_x). Solid green lines indicate the height of the thermal tropopause of the Base run.

Banerjee, A., Archibald, A. T., Maycock, A. C., Telford, P., Abraham, N. L., Yang, X., Braesicke, P., and Pyle, J. A.: Lightning NO_x, a key chemistry–climate interaction: impacts of future climate change and consequences for tropospheric oxidising capacity, Atmos. Chem. Phys., 14, 9871-9881, doi:10.5194/acp-14-9871-2014, 2014.

Questions?

THANK YOU!