Koninklijk Meteorologisch Instituut

Institut Royal Météorologique

Königlische Meteorologische Institut

Royal Meteorological Institute

Climate change and the greenhouse gases water vapour and ozone

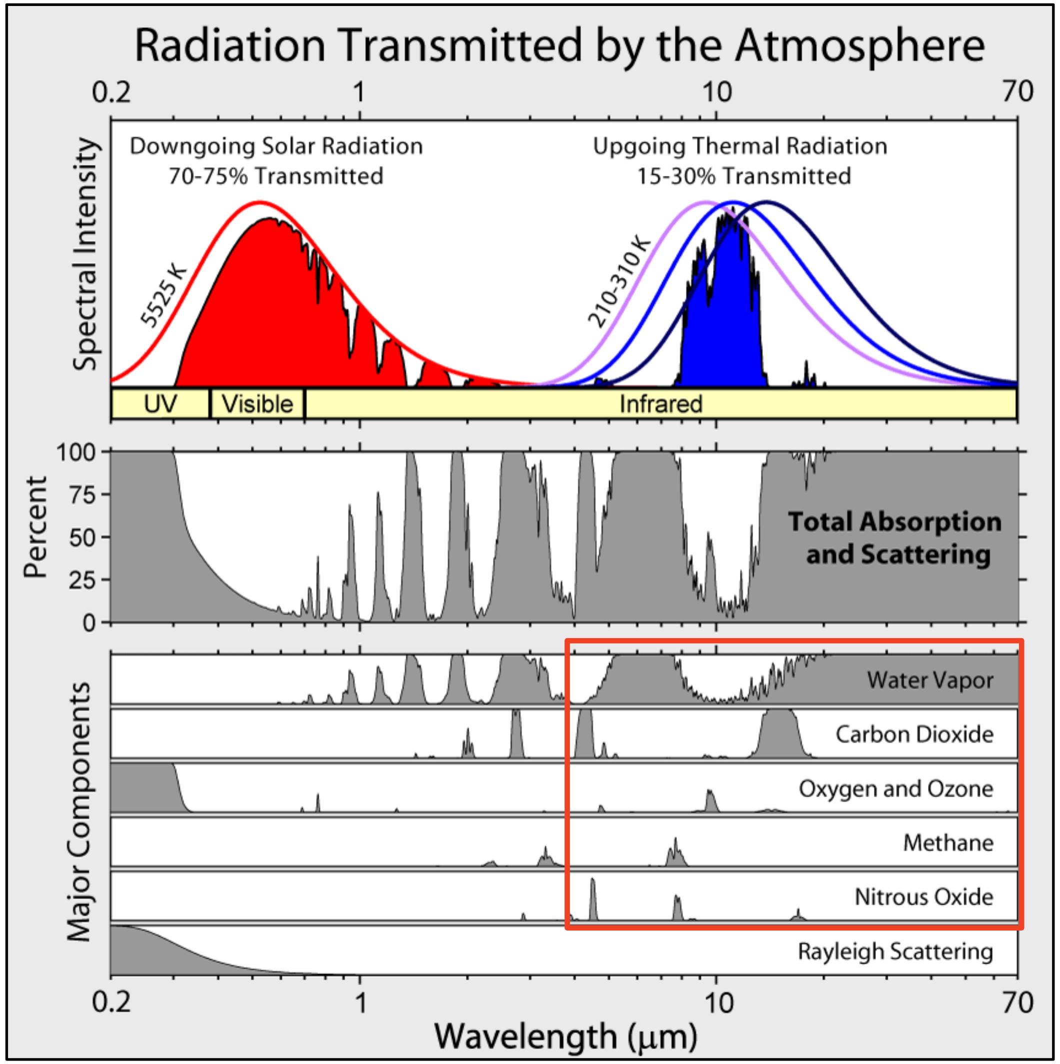
Roeland Van Malderen

Scientific Service “Observations”

Royal Meteorological Institute of Belgium

.be

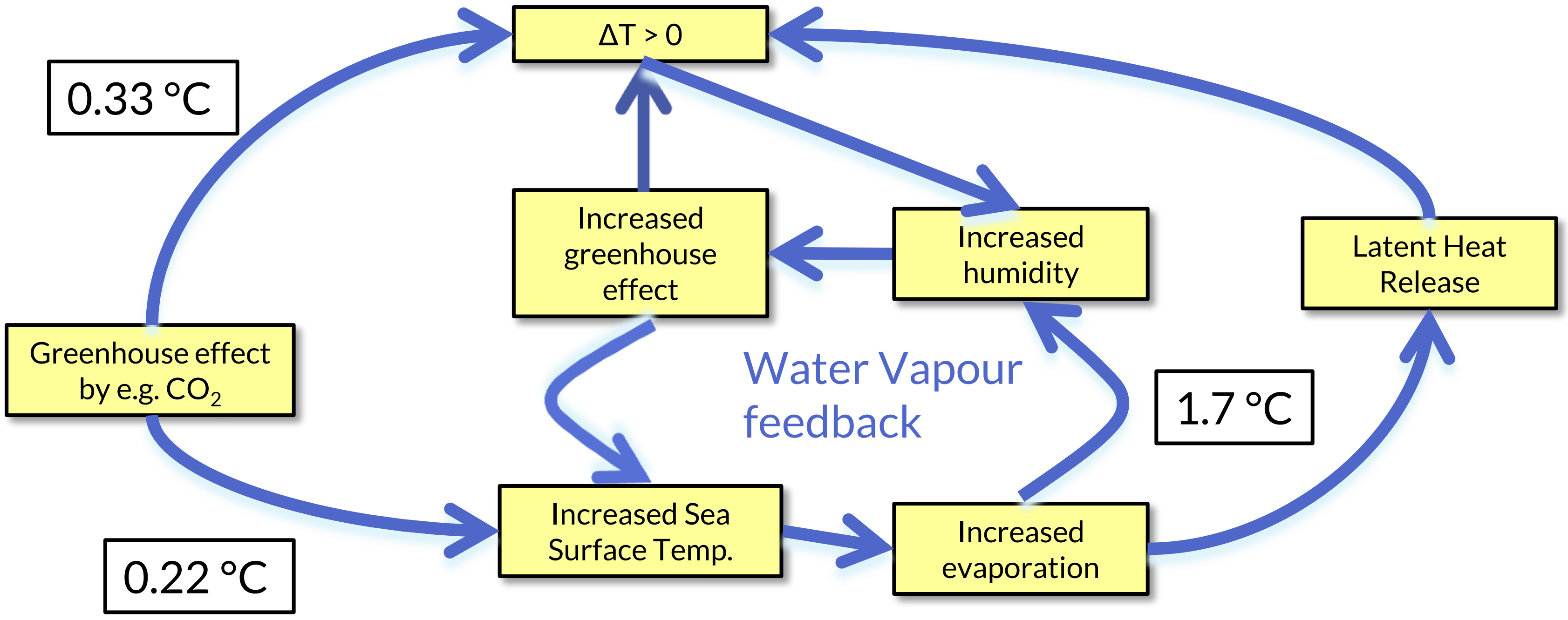
Introduction: greenhouse gases



Greenhouse gases!

- H_2O = the most important *natural* greenhouse gas (60%) as it absorbs and emits radiation across the entire longwave spectrum
- CO_2 has also some strong absorption bands in the IR (26%)
- especially O_3 (8%) in the UT acts as a greenhouse gas

Water Vapour: feedback



- More moisture is evaporated from the surface and total amount of water vapour in atmosphere increases
- Warm air can contain more water vapour than cold air (Clausius-Clapeyron)!
- This water vapour feedback mechanism increases the CO_2 warming by 2-3 times.

Water Vapour: how to "measure"?

Integrated Water Vapour

- highly variable, in space and time
- clouds! rain!

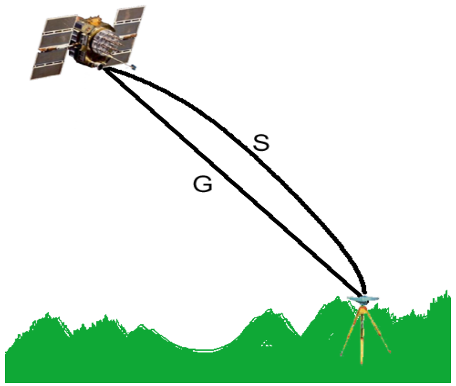
satellites

microwave
(oceans only)
e.g. SSM-I

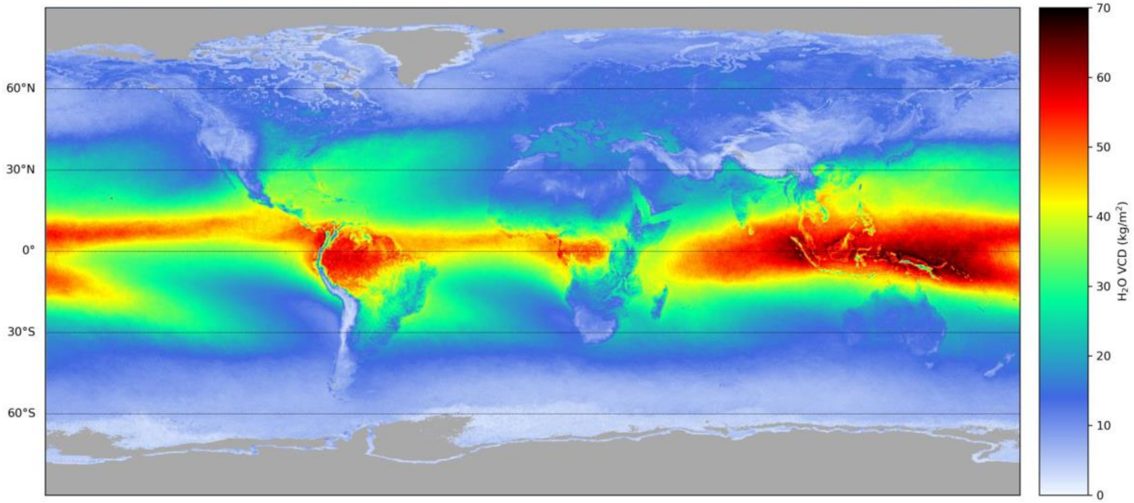
UV/VIS
e.g. GOMESCIA,
TROPOMI

Infrared
e.g. AIRS

NWP model reanalysis
e.g. ERA-interim, ERA5



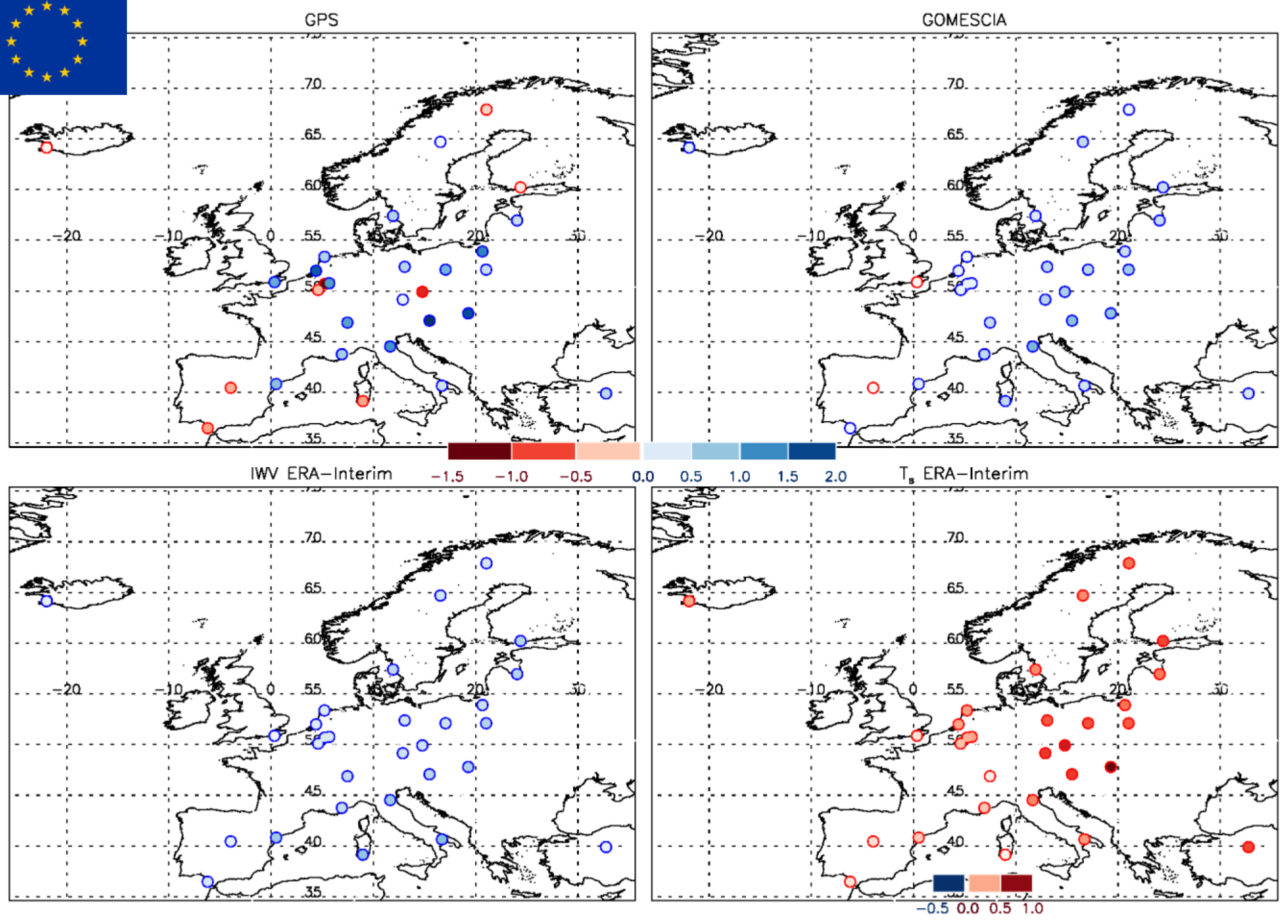
GPS (GNSS)



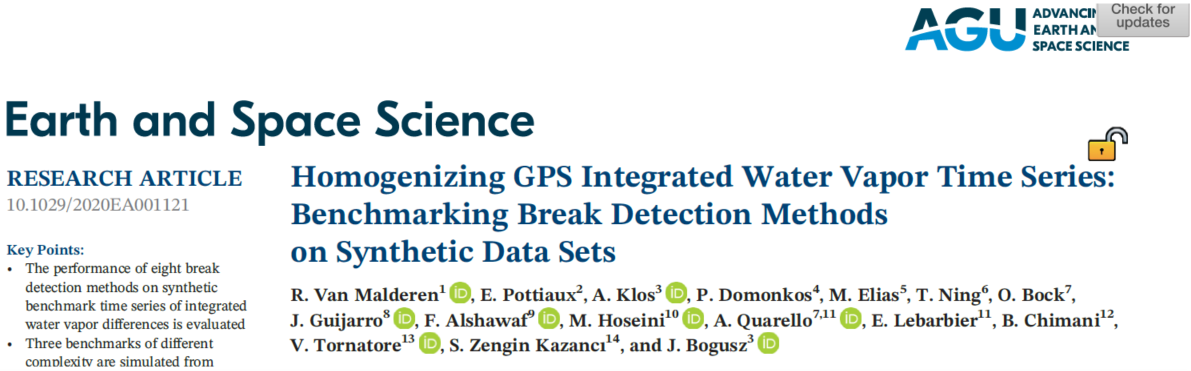
TROPOMI annual mean H_2O VCD 03/2018-03/2019

Water Vapour: trends

Integrated Water Vapour trend (mm/dec) 1996-2014 (GPS station > 10 yrs)



- IWV trends follow T_s trends globally
- differences between different datasets (but GOMESCIA and ERA-Interim not too different)
- due to inhomogeneities in GPS datasets:


AGU ADVANCING EARTH AND SPACE SCIENCE

Check for updates

Earth and Space Science

RESEARCH ARTICLE

10.1029/2020EA001121

Key Points:

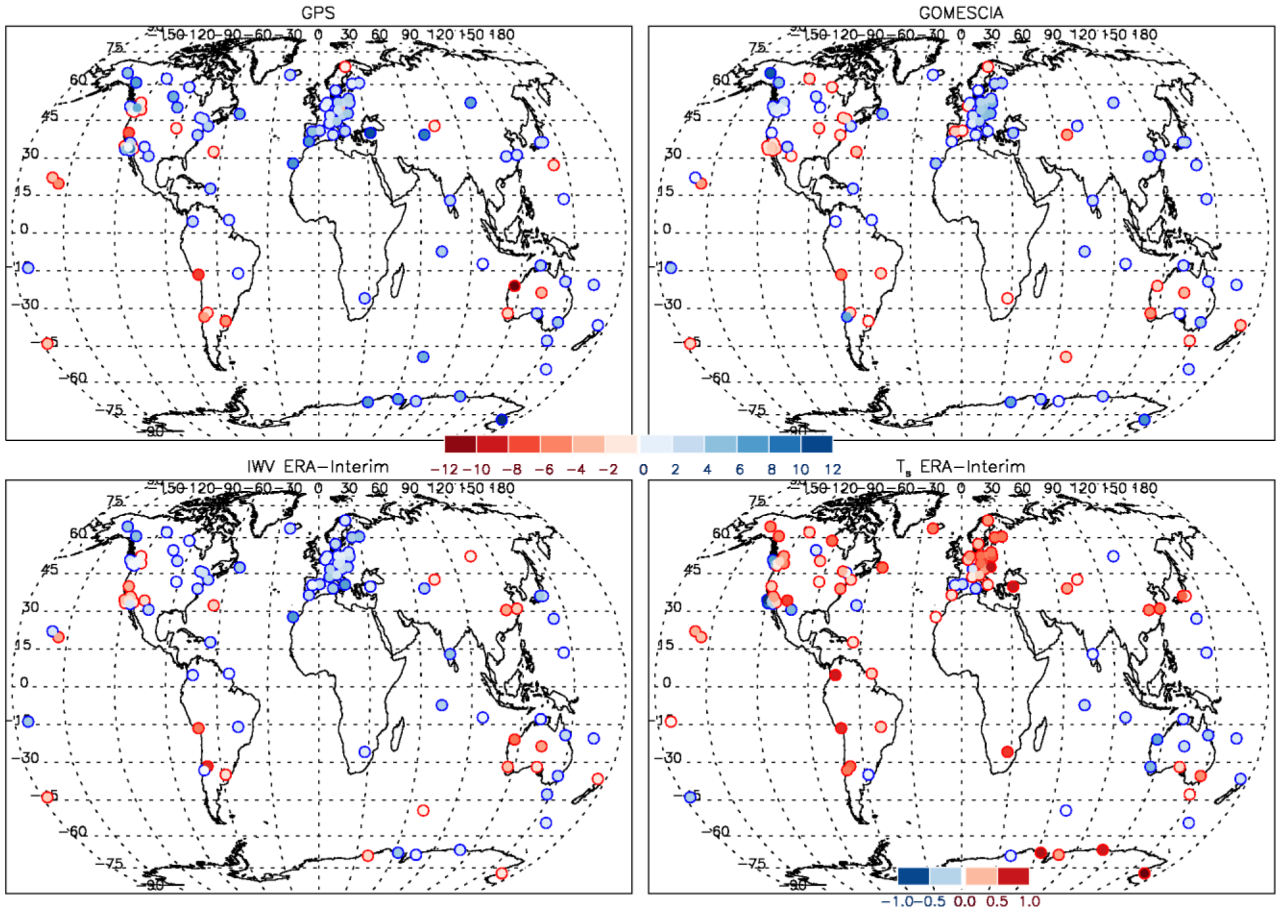
- The performance of eight break detection methods on synthetic benchmark time series of integrated water vapor differences is evaluated
- Three benchmarks of different complexity are simulated from

Homogenizing GPS Integrated Water Vapor Time Series: Benchmarking Break Detection Methods on Synthetic Data Sets

R. Van Malderen[1], E. Pottiaux[2], A. Klos[3], P. Domonkos[4], M. Elias[5], T. Ning[6], O. Bock[7], J. Guijarro[8], F. Alshawaf[9], M. Hoseini[10], A. Quarello[7,11], E. Lebarbier[11], B. Chimani[12], V. Tornatore[13], S. Zengin Kazancı[14], and J. Bogusz[3]

Water Vapour: trends

Integrated Water Vapour trend (%/dec) 1996-2010

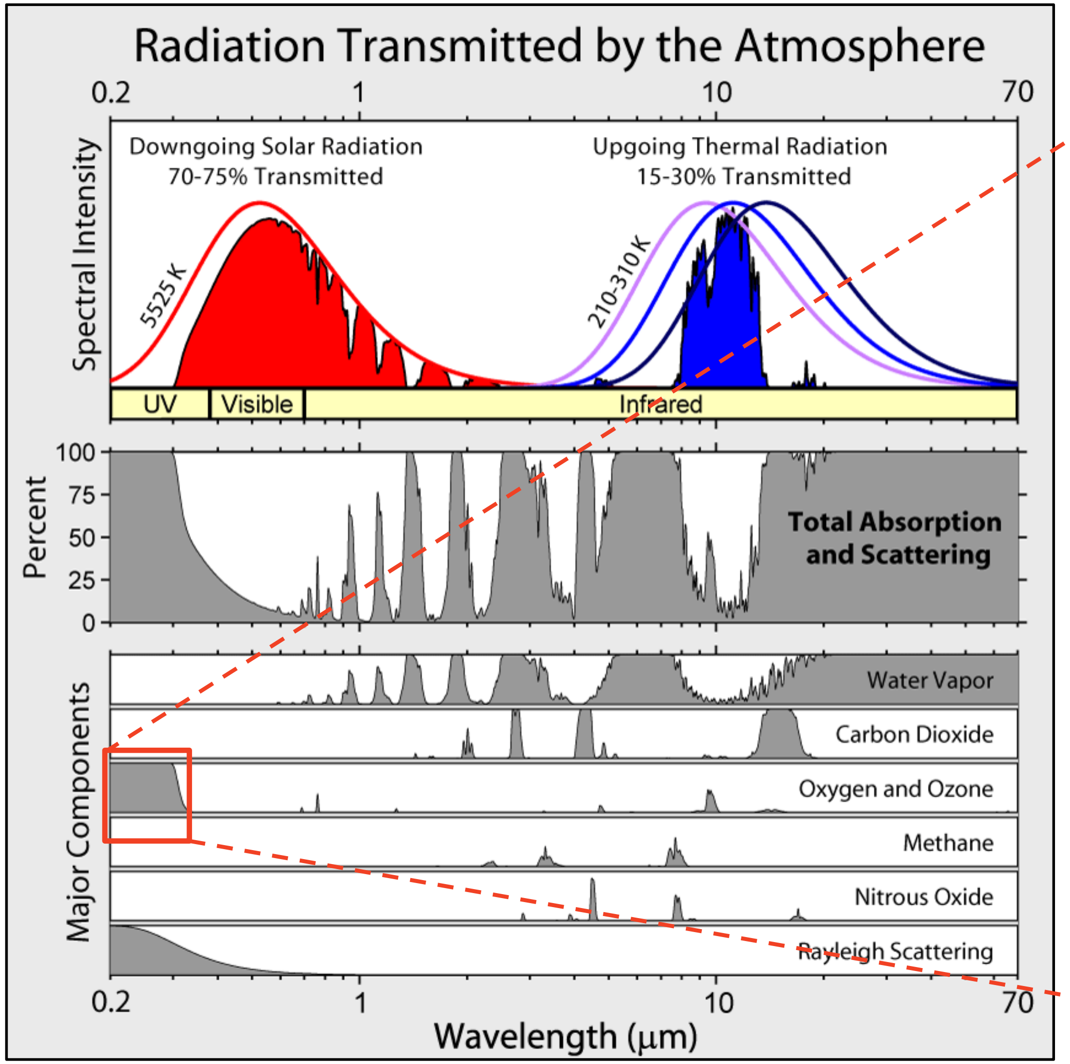


- IWV trends follow T_s trends globally
- differences between different datasets (but GPS and ERA-Interim not too different)

Water Vapour: conclusions

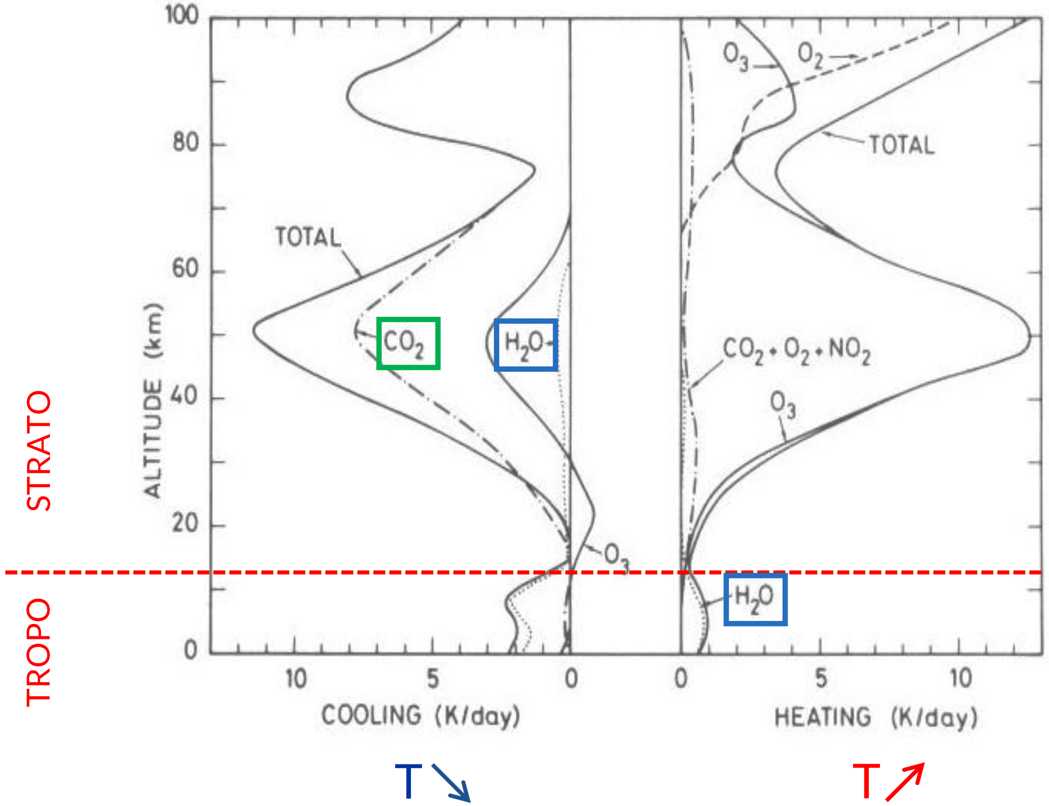
- Water vapour is the most important natural greenhouse gas
- Its variation is closely linked with the temperature variation (warming!)
- The water vapour feedback mechanism provides a strong positive feedback to the climate system.
- <u>NOT</u> discussed here: water vapour forms clouds, and the cloud feedback mechanism is another factor of uncertainty in climate predictions.

Ozone: chemistry in a nutshell



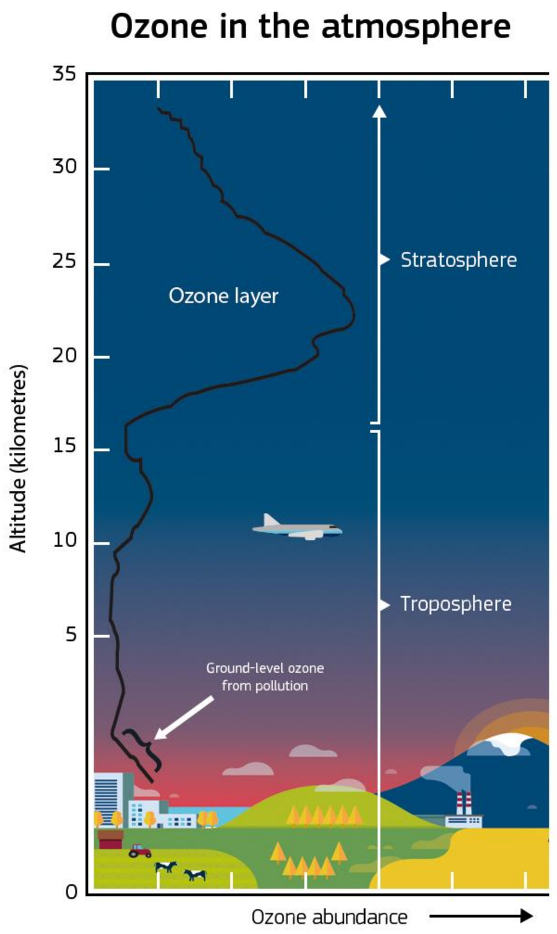
- O_3 (and to a lesser extent: O_2): very efficient in absorbing the harmful solar UV-radiation
- The formation/destruction reactions of ozone in the stratosphere lead to heating of the stratosphere due to conversion of the absorbed UV in thermal energy (Chapman).
- Stratospheric ozone is also destroyed by catalytic ozone loss reactions with Cl_x, NO_x, Br_x, HO_x, and even more efficient on the particles of polar stratospheric clouds.
- Other greenhouse gases (e.g. CO_2, H_2O, CH_4) cool the stratosphere.

Ozone: stratospheric cooling by GHGs



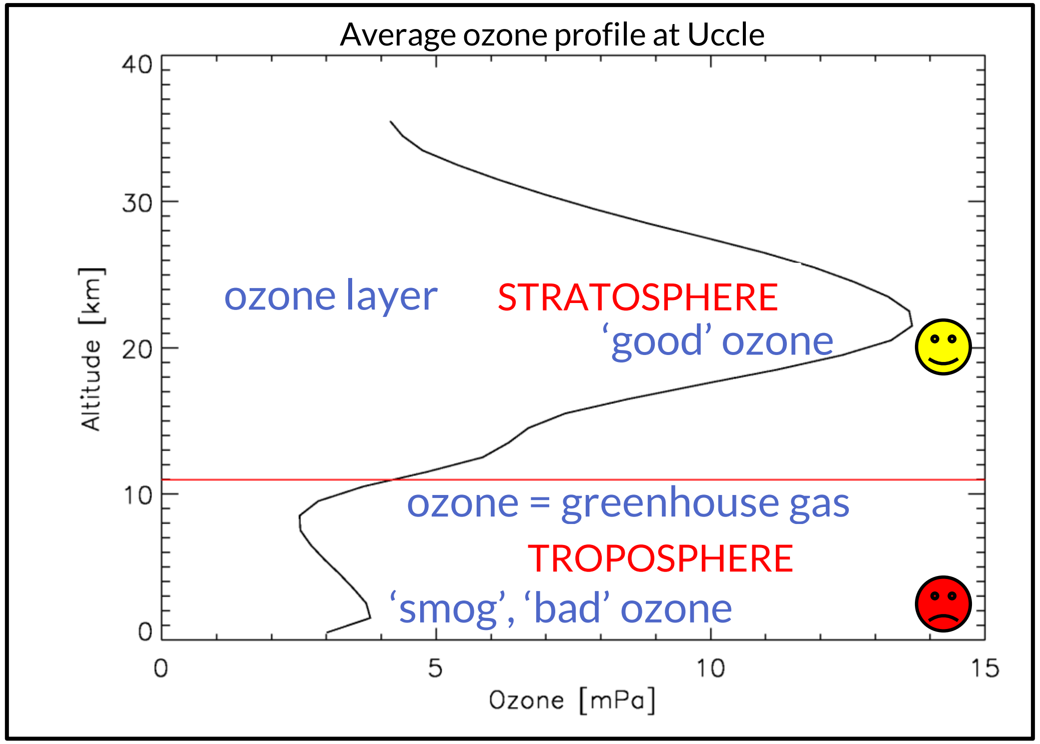
- O_3 (and to a lesser extent: O_2): very efficient in absorbing the harmful solar UV-radiation
- The formation/destruction reactions of ozone in the stratosphere lead to heating of the stratosphere due to conversion of the absorbed UV in thermal energy (Chapman).
- Stratospheric ozone is also destroyed by catalytic ozone loss reactions with Cl_x, NO_x, Br_x, HO_x, and even more efficient on the particles of polar stratospheric clouds.
- Other greenhouse gases (e.g. CO_2, H_2O, CH_4) cool the stratosphere.

Ozone: in the atmosphere



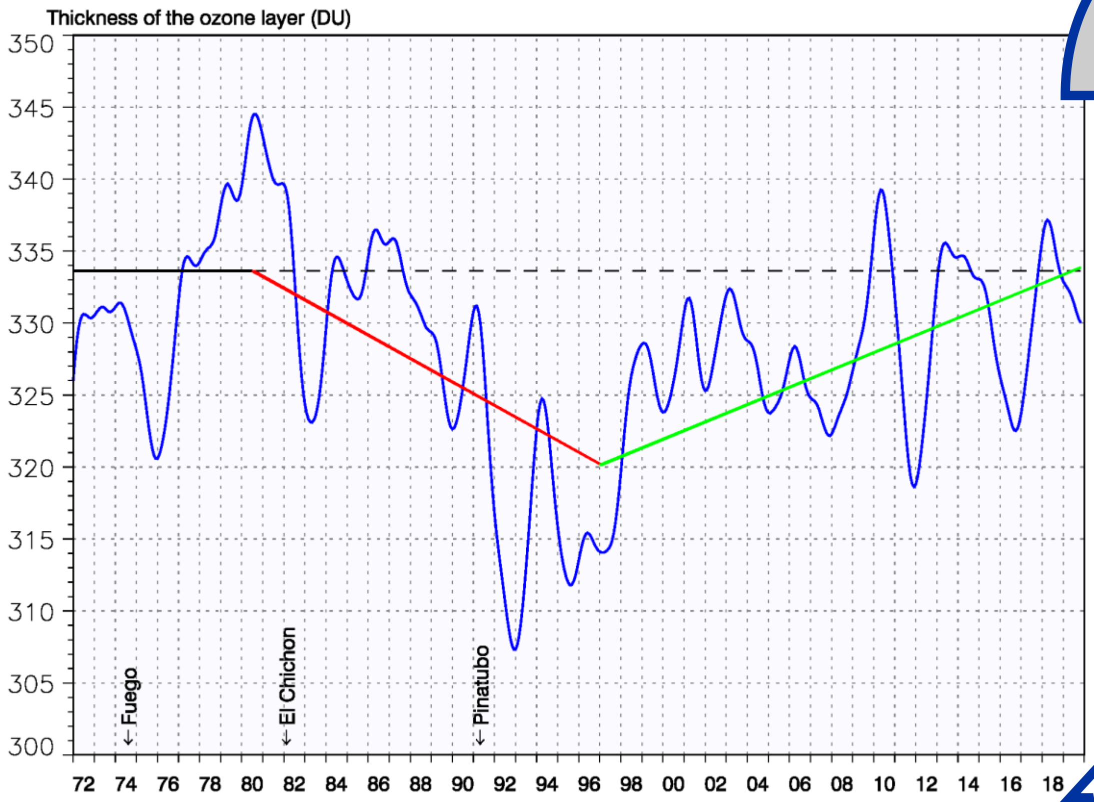
90%

10%

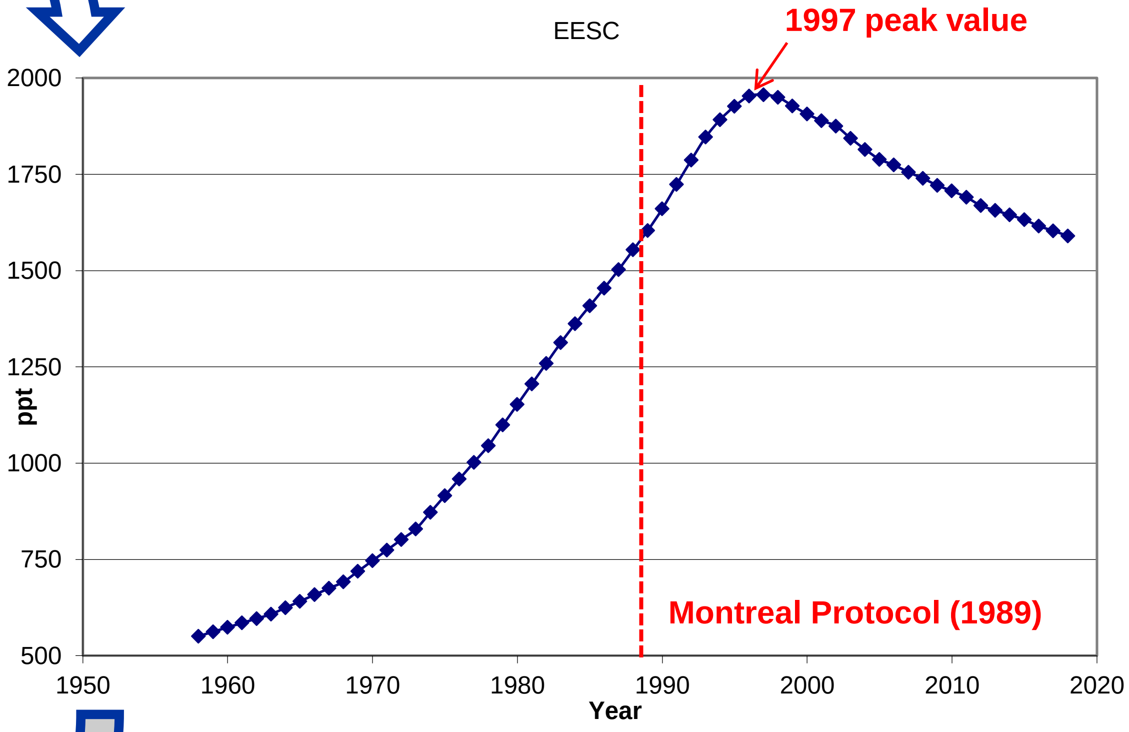


Ozone: variability

total ozone @ Uccle

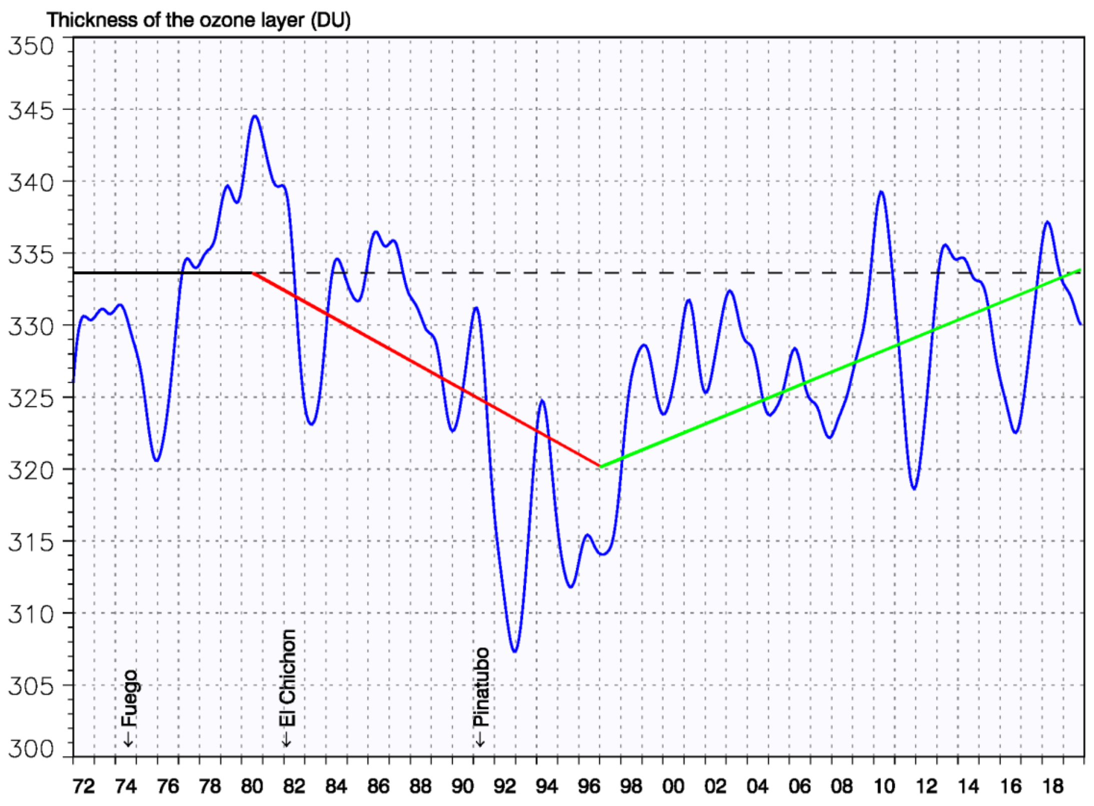


ozone depleting substances in stratosphere

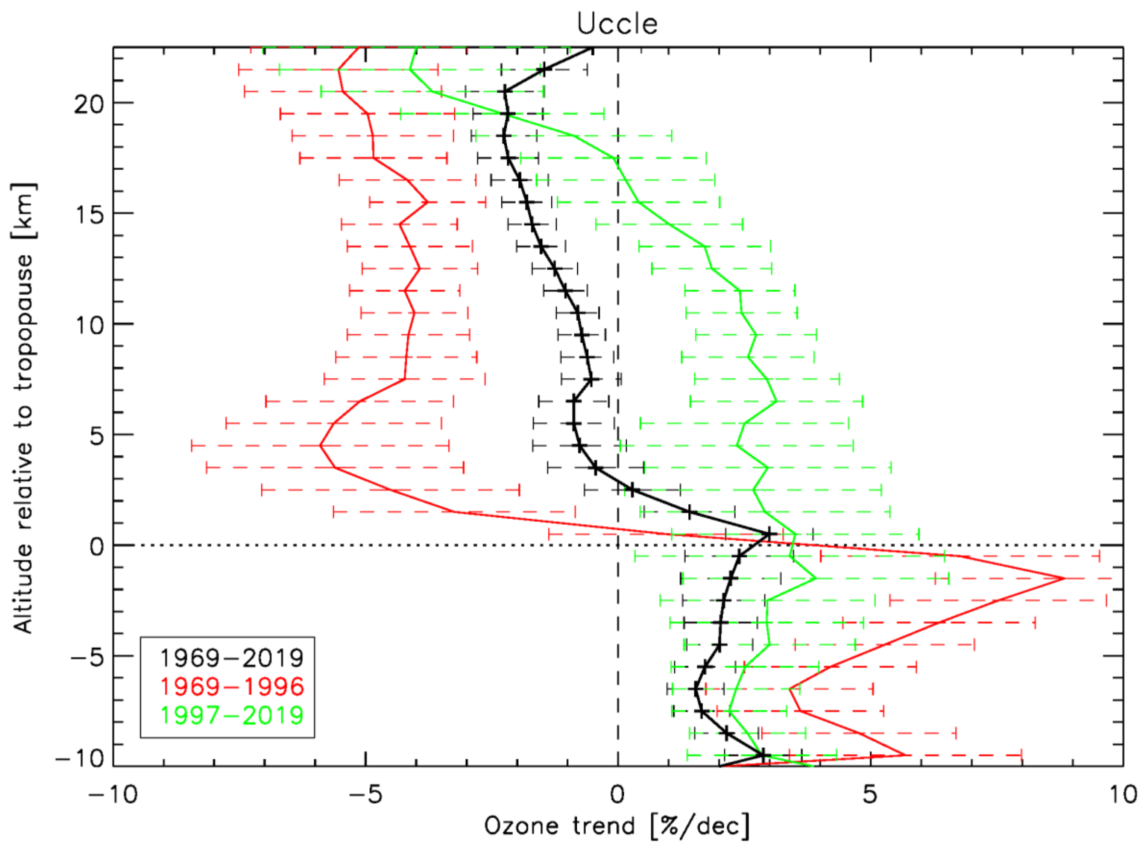


Ozone: variability

total ozone @ Uccle



vertical distribution of ozone trends



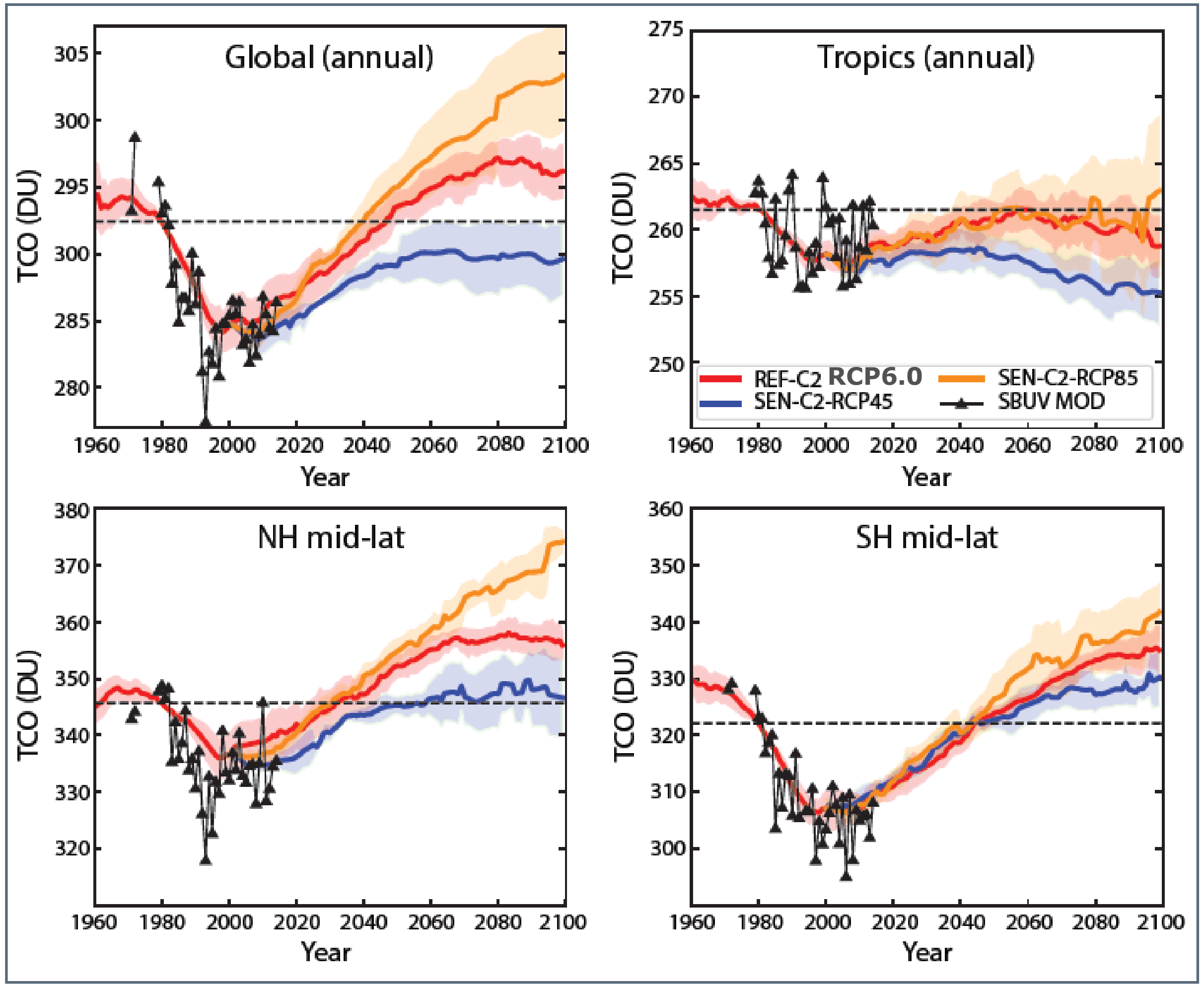
Ozone & climate

Ozone-climate is a 2-way interaction: climate→ ozone

Ozone recovery is/will be strongly influenced by the future trajectory of greenhouse gases (GHGs), through

- ✓ stratospheric temperature changes (cooling!)
  - ozone destruction processes less efficient
  - PSCs get former easier and more frequent?
- ✓ changes in the stratospheric circulation (e.g. strengthening of Brewer-Dobson circulation)
- ✓ chemical changes induced by the reactive GHGs, methane and nitrous oxide

models show differing amounts of ozone changes for different greenhouse gas scenarios: **ozone layer recovery is influenced by climate change** (and acting differently at different locations on Earth)



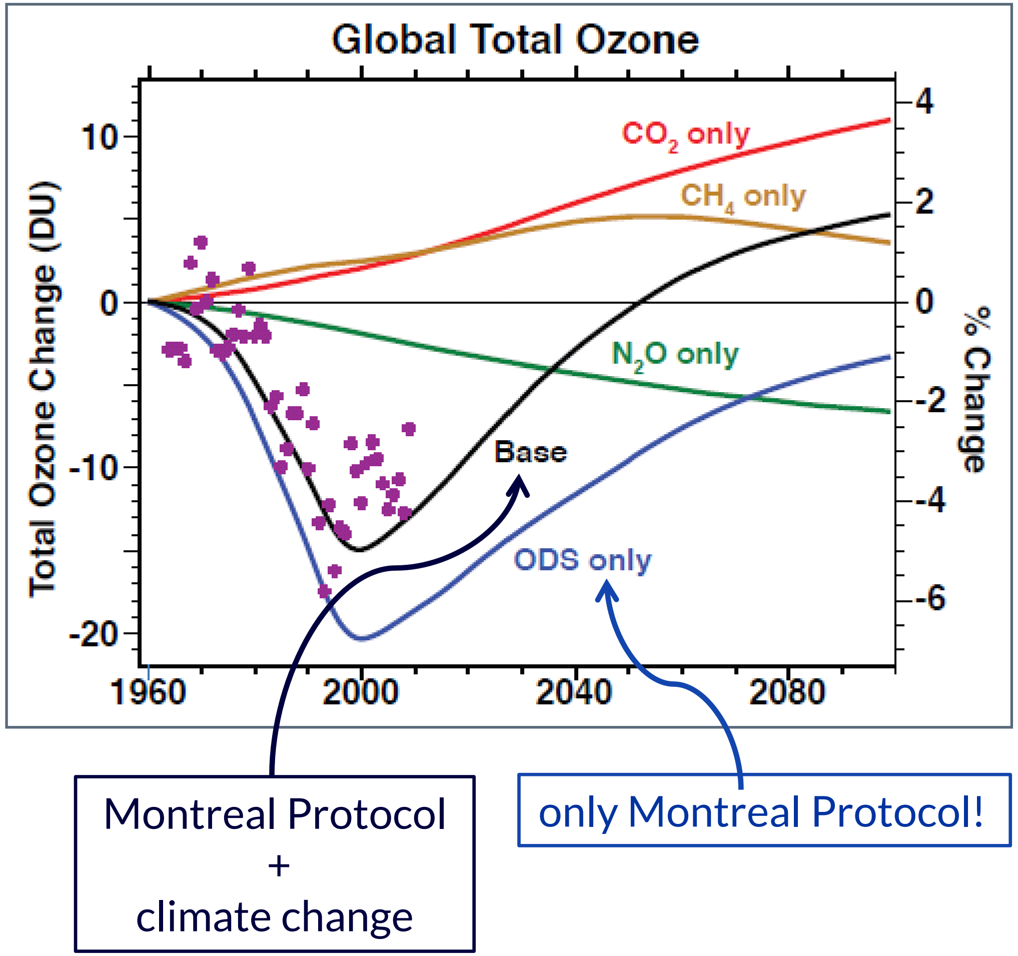
From WMO Scientific Assessment of Ozone Depletion, 2018

Ozone & climate

Ozone-climate is a 2-way interaction: climate→ ozone

Ozone recovery is/will be strongly influenced by the future trajectory of greenhouse gases (GHGs), through

- ✓ stratospheric temperature changes (cooling!)
  - ozone destruction processes less efficient
  - PSCs get former easier and more frequent?
- ✓ changes in the stratospheric circulation (e.g. strengthening of Brewer-Dobson circulation)
- ✓ chemical changes induced by the reactive GHGs, methane and nitrous oxide (main sources of catalysts HO_x and NO_x resp.)



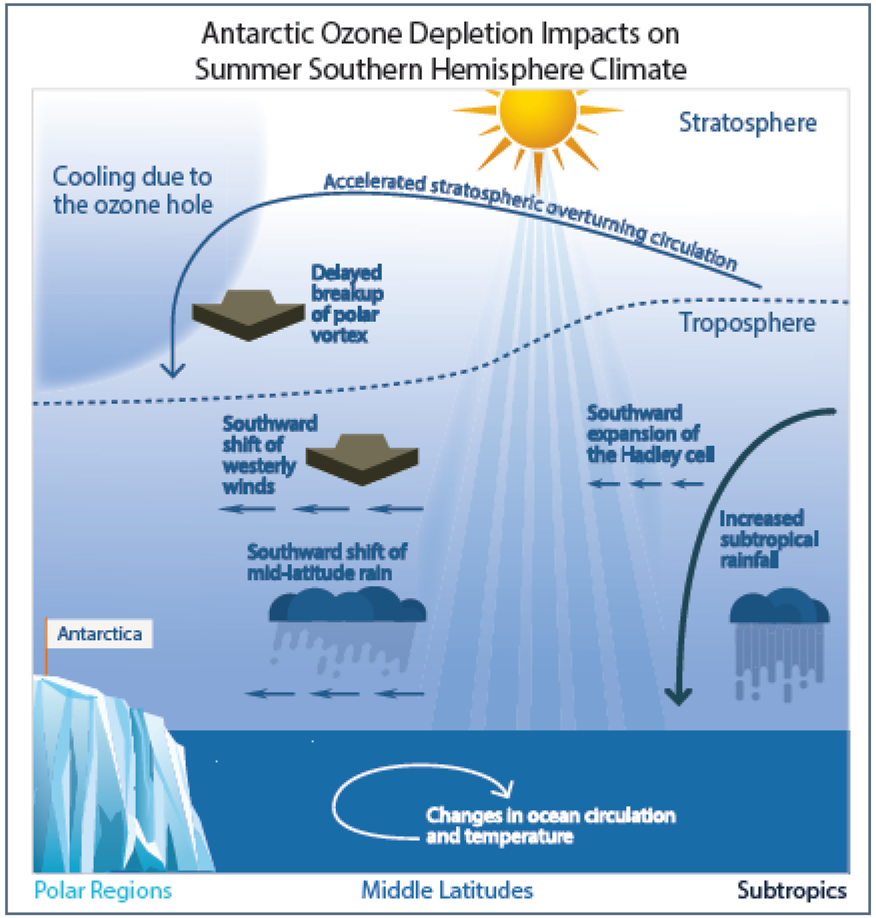
Ozone & climate

Ozone-climate is a 2-way interaction: ozone → climate

climate has been affected by ozone loss and will be influenced by the trajectory of ozone recovery

- ✓ stratospheric temperatures
- ✓ tropospheric circulation, temperatures and precipitation

- A poleward shift of the mid-latitude SH jet and the related storm tracks
- A poleward shift of the edge of the Hadley circulation
- A poleward expansion of the subtropical dry zones



From WMO Scientific Assessment of Ozone Depletion, 2018

Ozone: conclusions

- The past ozone time variability (CFCs, Montreal Protocol) impacted the temperature distribution in the stratosphere.
- Ozone in the upper troposphere is a greenhouse gas and its concentrations seem to have risen during the past decades (although slowdown since 2000s).
- Because of climate change, ozone recovery might become a super-recovery .
- The ozone hole has affected climate and weather in the Southern Hemisphere.

THANK YOU

Het Koninklijk

Meteorologisch Instituut

L'Institut Royal

Météorologique

The Royal Meteorological

Institute

Het KMI verleent een betrouwbare dienstverlening aan het publiek en de overheid gebaseerd op onderzoek, innovatie en continuïteit.

L'IRM fournit un service fiable basé sur la recherche, l'innovation et la continuité au public et aux autorités.

The RMI provides reliable public service realized by empowered staff and based on research, innovation and continuity.

KMI - IRM