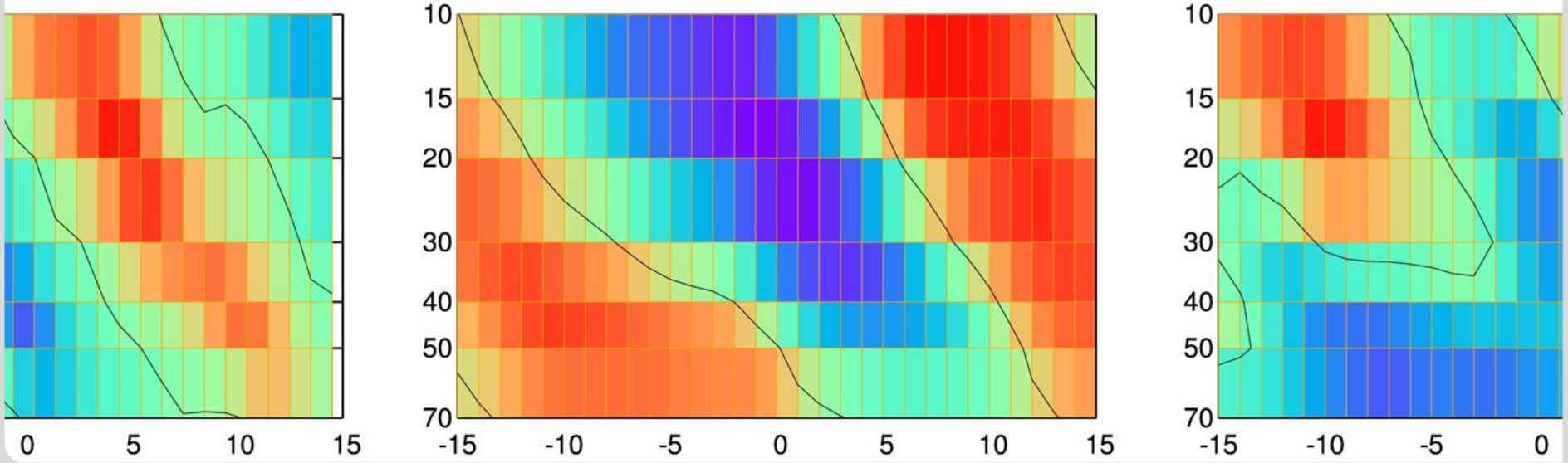
Karlsruher Institut für Technologie

Composition-Climate Interactions: Introduction

Peter Braesicke

IIMK-ASF



Structure

Composition-Climate Interactions
(with a focus on ozone and the Arctic)
(and in three parts)

- **Introduction**
  - **Structure of the atmosphere**
  - **Why does ozone matter?**
  - **Modelling the atmosphere**
- **The recent past**
  - **Observations (an aside: Antarctic climate change)**
  - **Simulations of the recent past**
- **Expectations for the future**
  - **Common sense (ozone recovery)**
  - **Projecting the future (surprises?)**

Vertical Structure

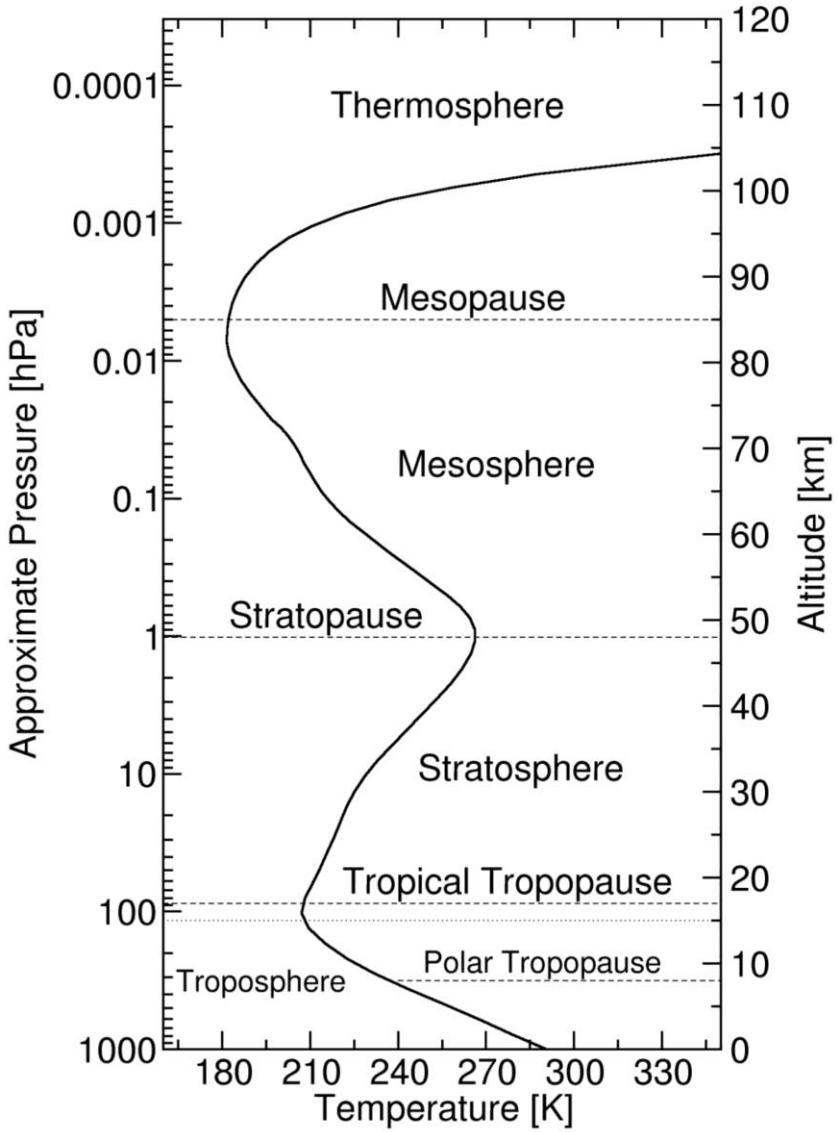
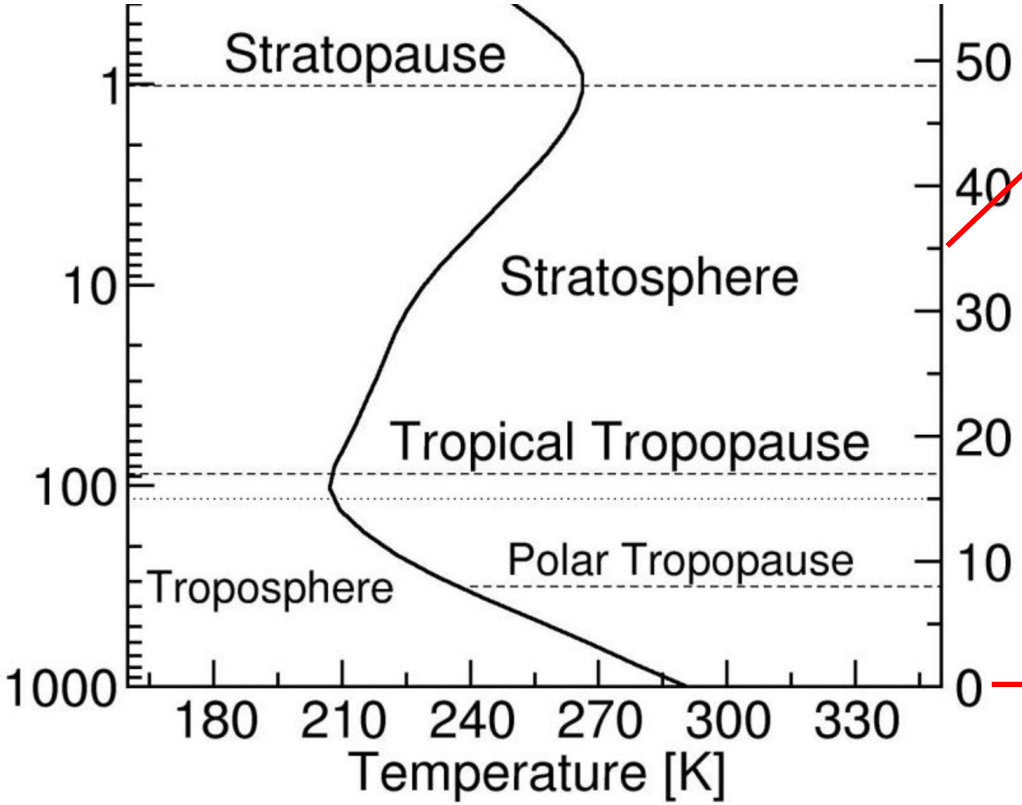
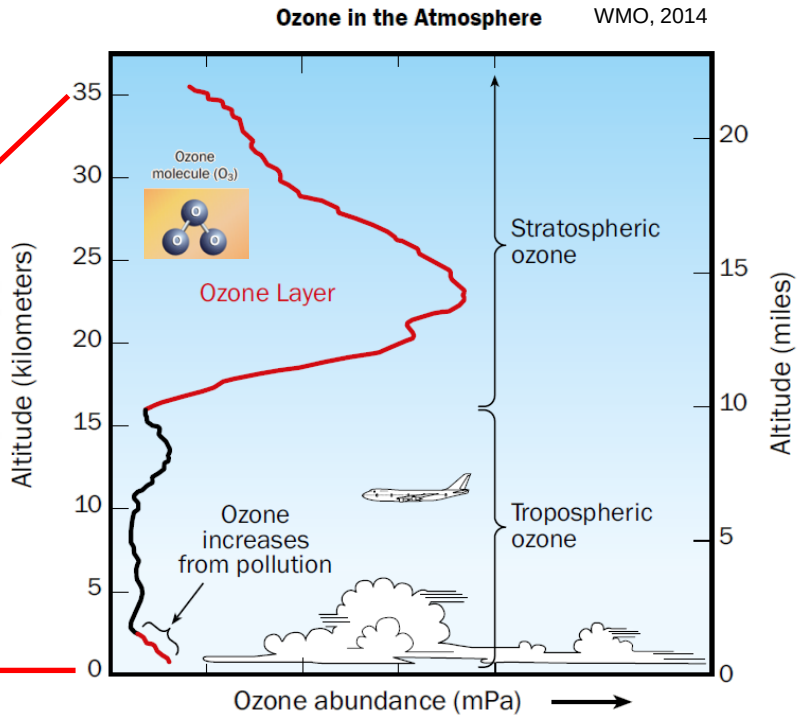


Figure 1: Mean temperature profile as a function of pressure/altitude.

Vertical Structure (Strat. - Trop.)





Braesicke, doi:10.1016/B978-0-12-382225-3.00227-9

Zonal Mean Temperature

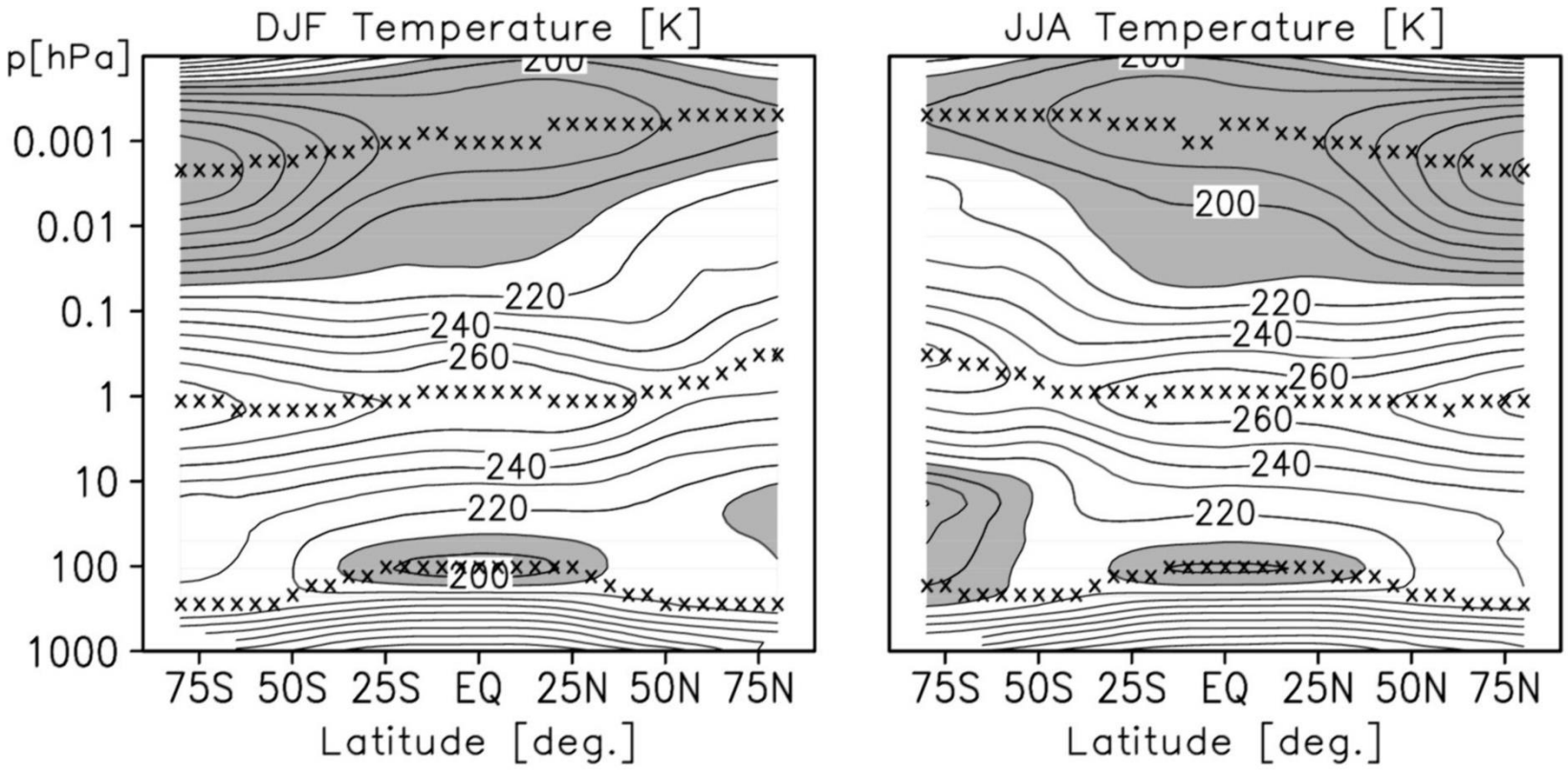


Figure 2: Zonal mean temperature as a function of latitude and pressure for December-January-February (DJF; left) and June-July-August (JJA; right). Crosses indicate the thermal tropopause, stratopause and mesopause (from bottom to top).

Zonal Mean Zonal Wind

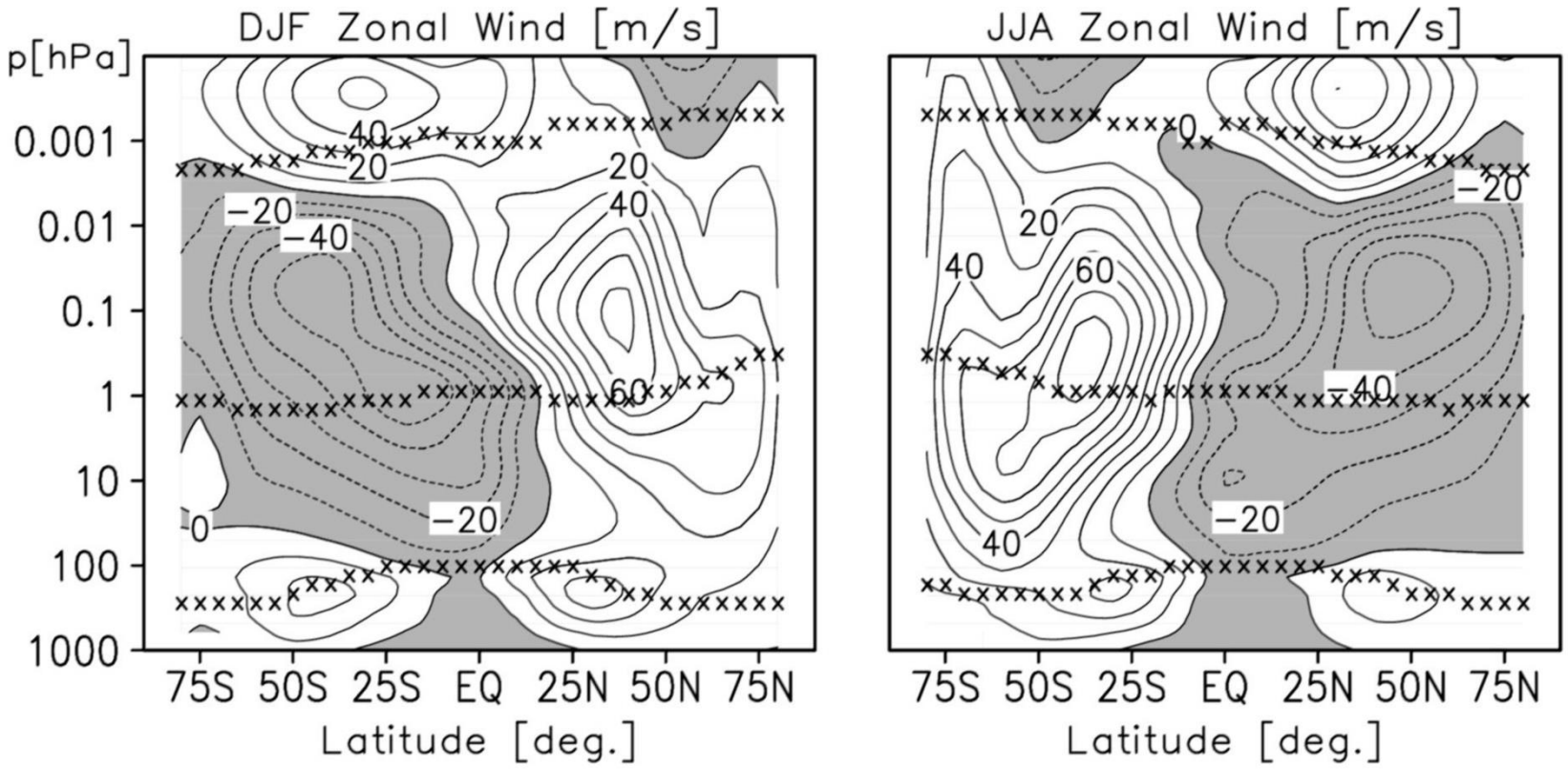


Figure 3: Zonal-mean zonal wind as a function of latitude and pressure for December-January-February (DJF; left) and June-July-August (JJA; right). Crosses indicate the thermal tropopause, stratopause and mesopause (from bottom to top).

Quasi-Biennial Oscillation

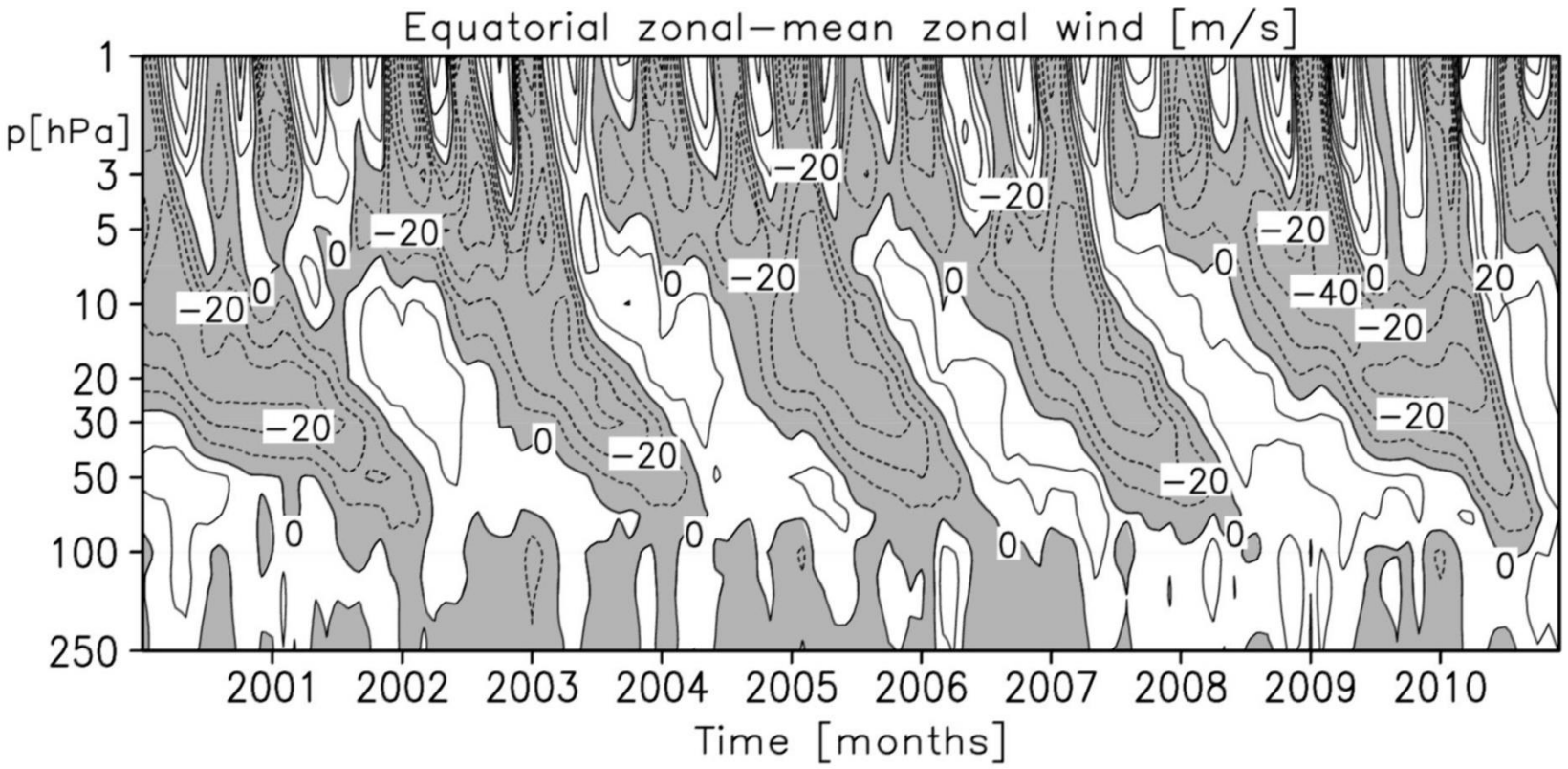
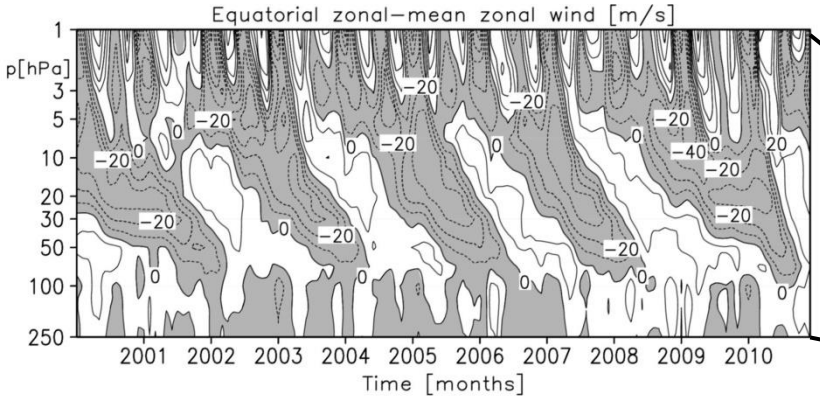


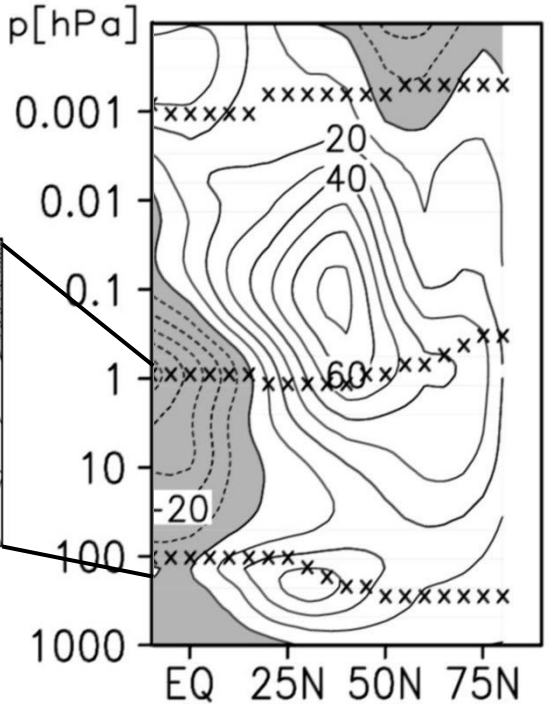
Figure 4: Equatorial zonal-mean zonal wind as a function of time and pressure. Data shown is monthly; year labels indicate beginning of the year; data from ERA-Interim.

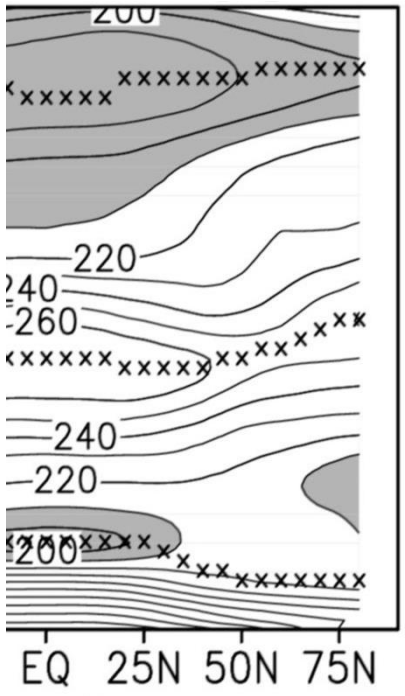
Linking Low and High Latitudes

Northern Hemisphere

Equator







Wind and Waves

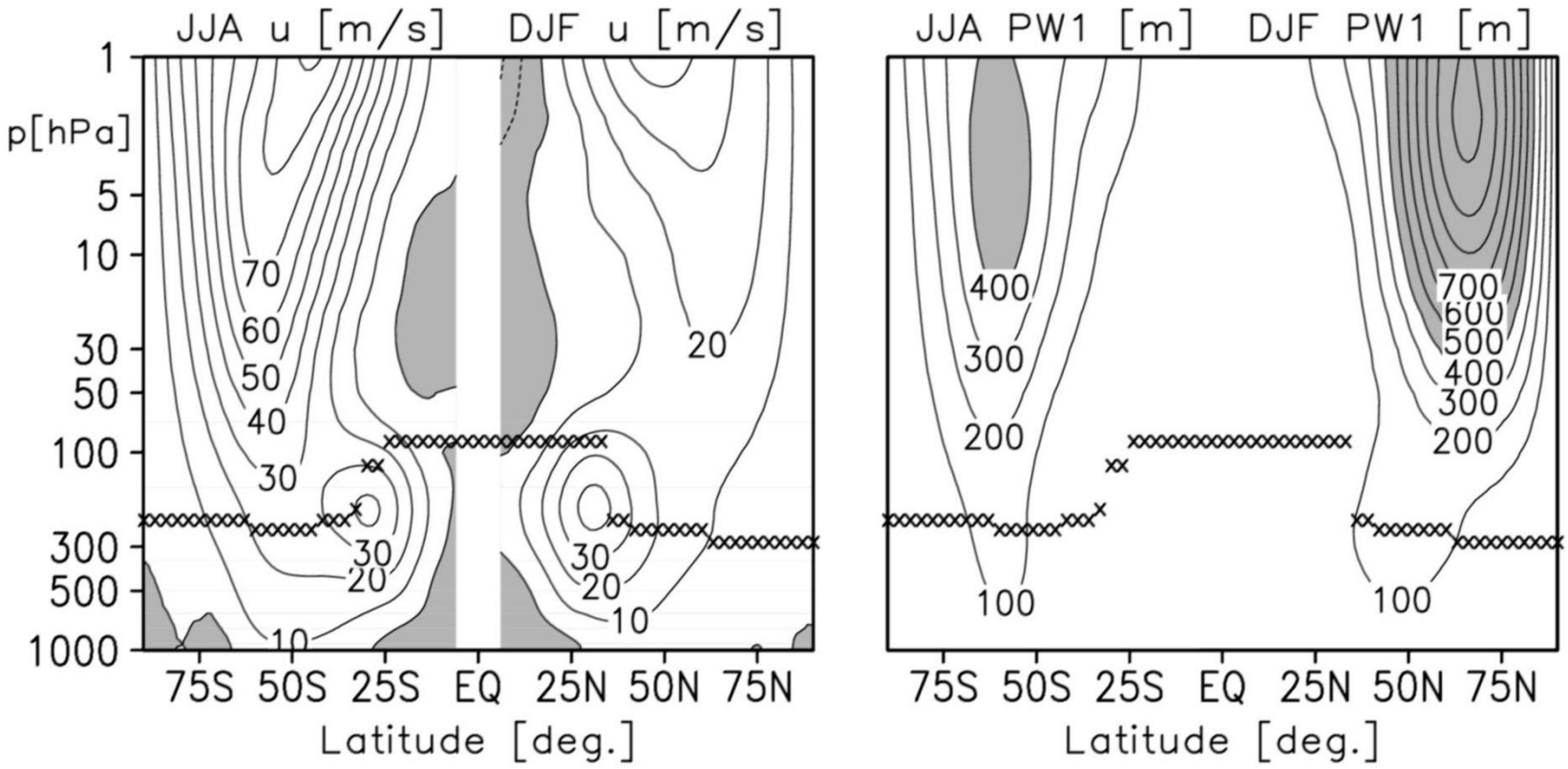
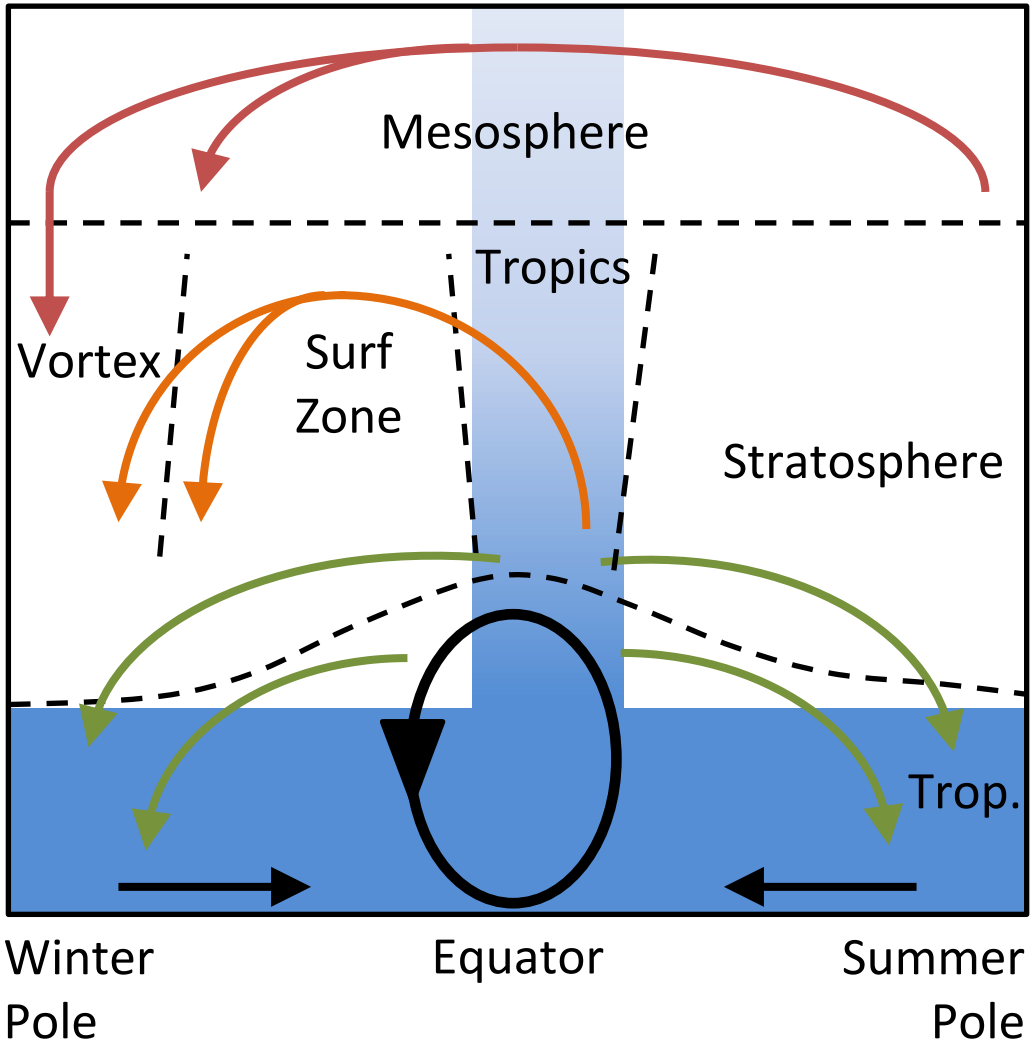


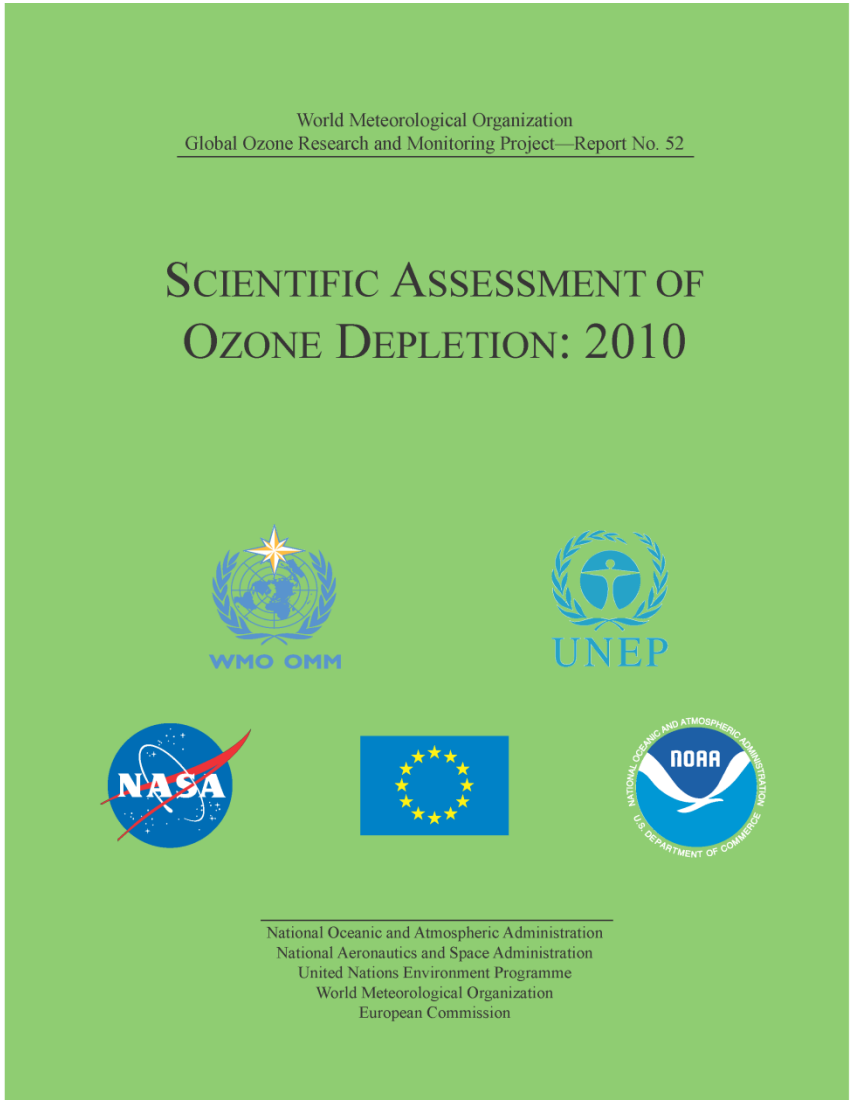
Figure 5: Zonal-mean zonal wind for the winter season as a function of latitude and pressure (left). Amplitude of planetary wave 1 (PW1) for the winter season as a function of latitude and pressure (right). Data from ERA-Interim.

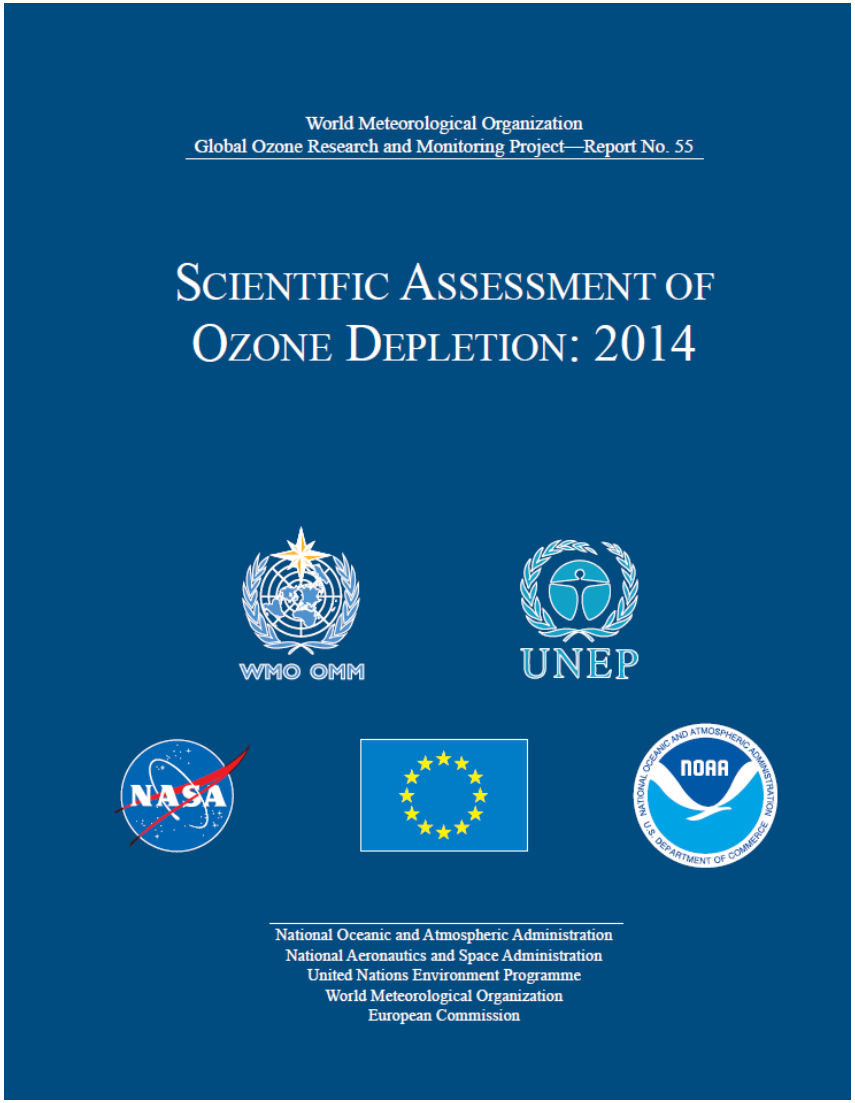
Brewer-Dobson Circulation



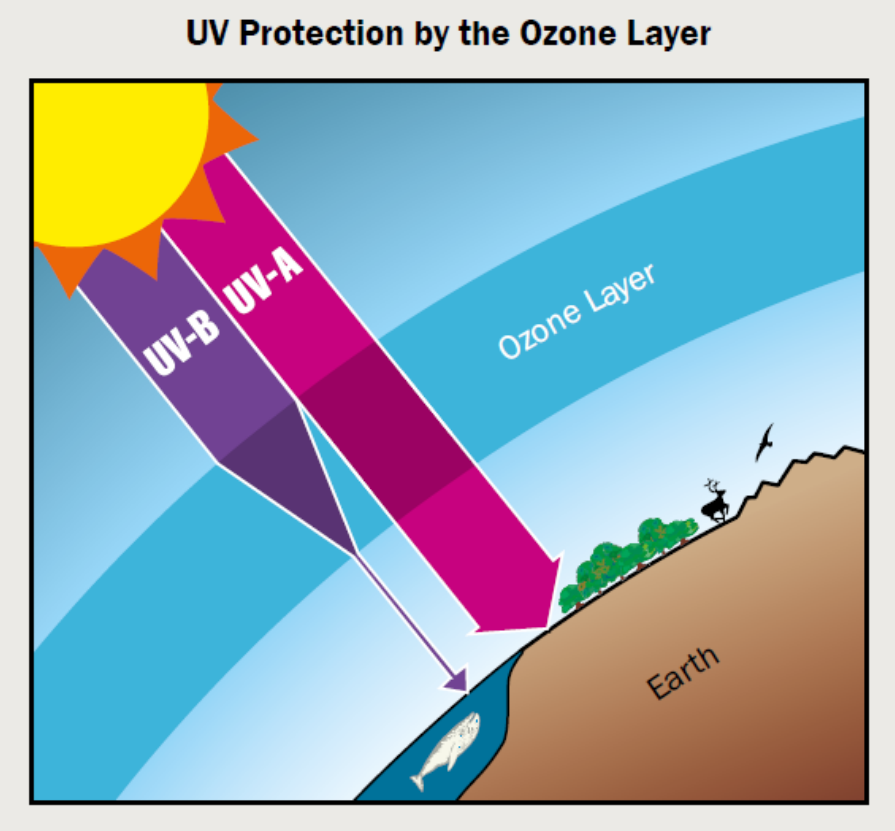
Conceptual structure of the Brewer-Dobson Circulation (BDC) following Plumb (2002).
SH Example: Braesicke et al., 2013

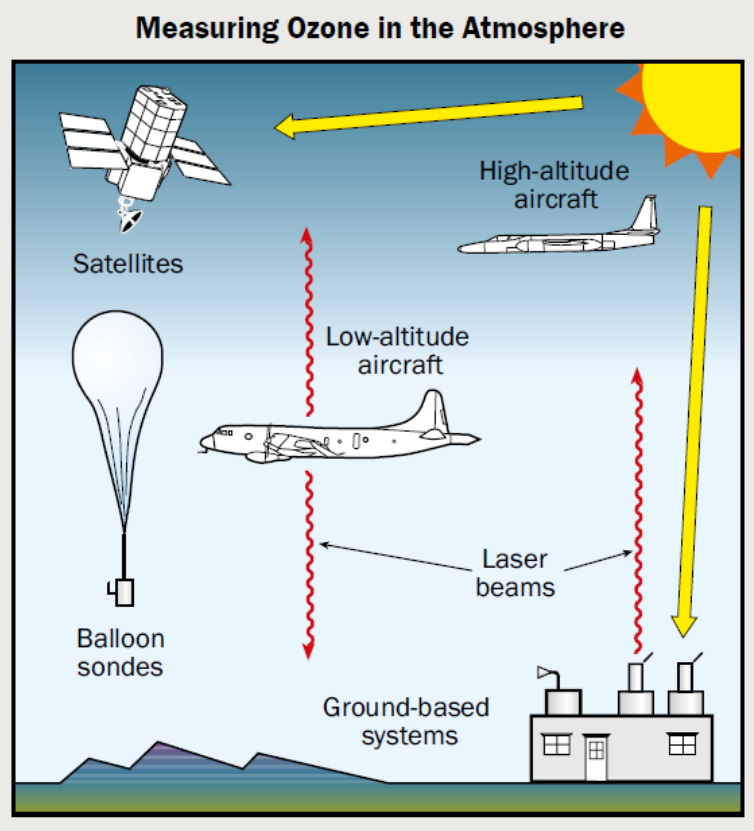
WMO Ozone Assessments





Measuring our Sun Glasses

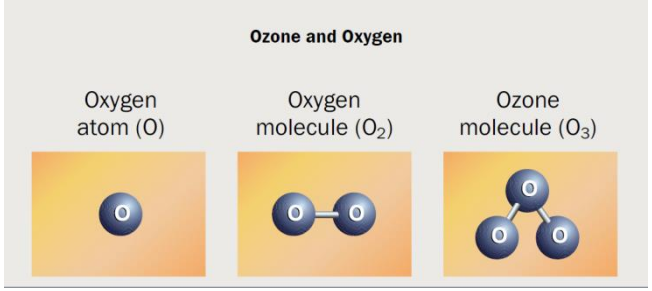


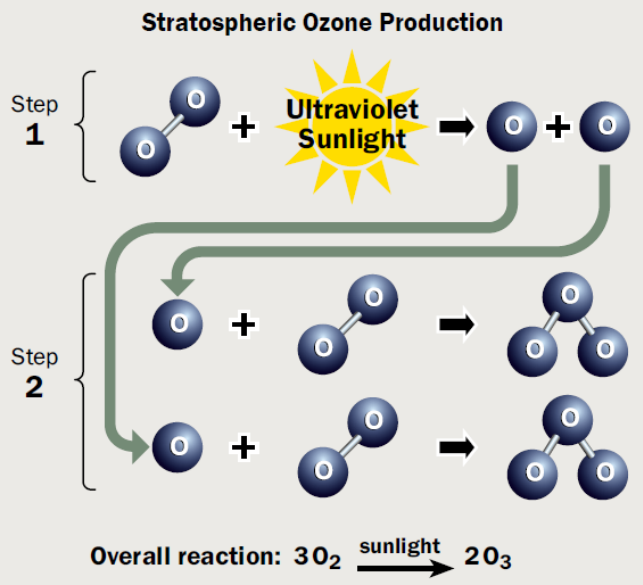


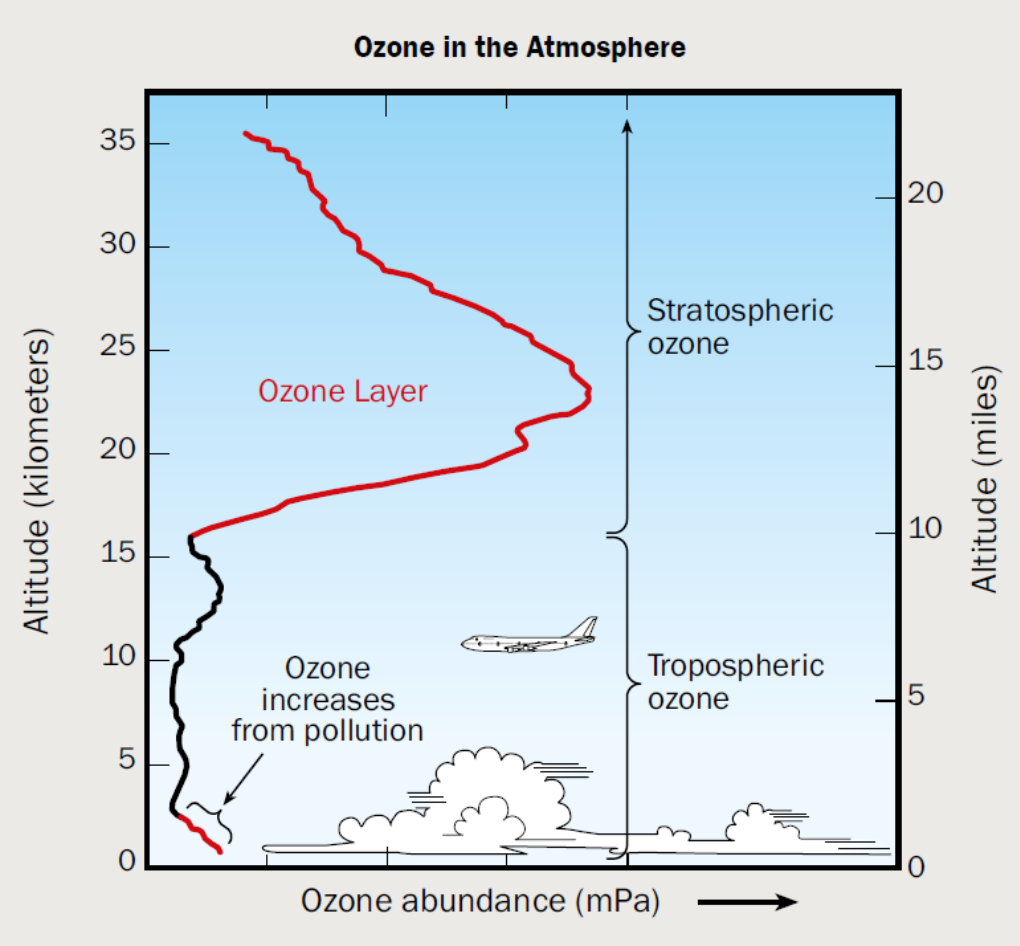
UV-B radiation: 280 to 315-nanometer (nm) wavelength
UV-A radiation: 315 to 400-nm wavelength

WMO, 2014

Ozone in the Atmosphere

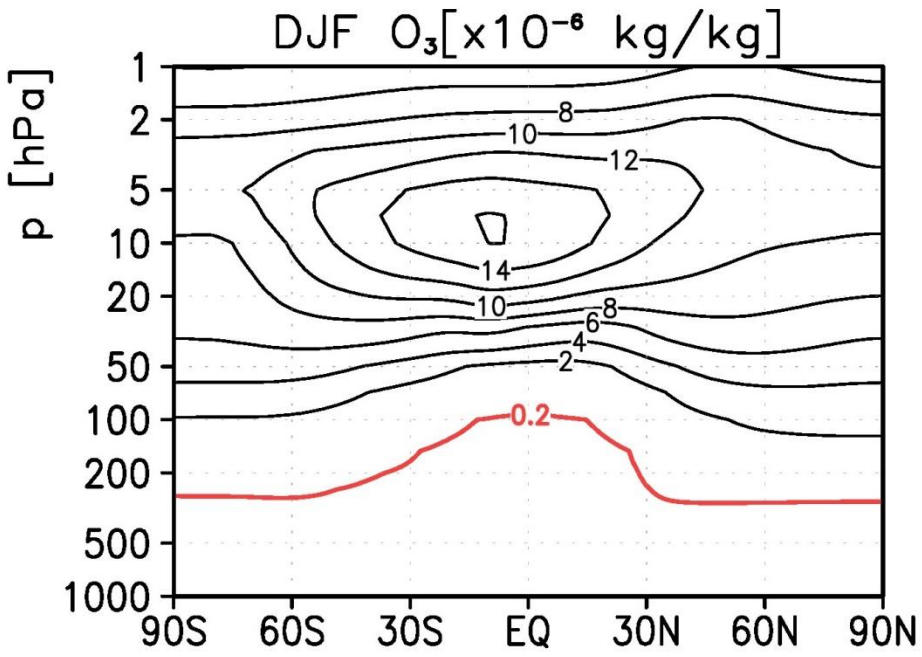




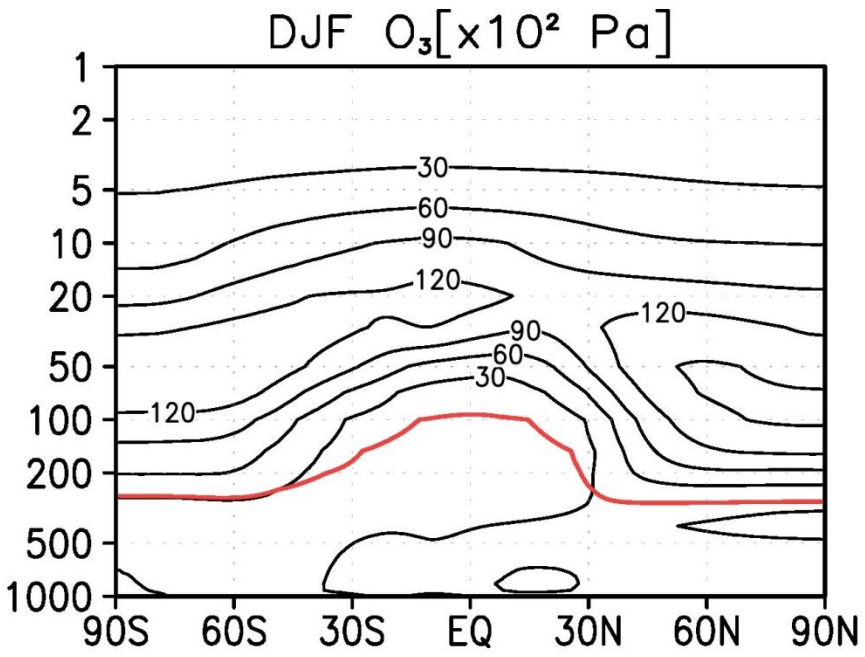


WMO, 2014

Vertical Sructure of Ozone



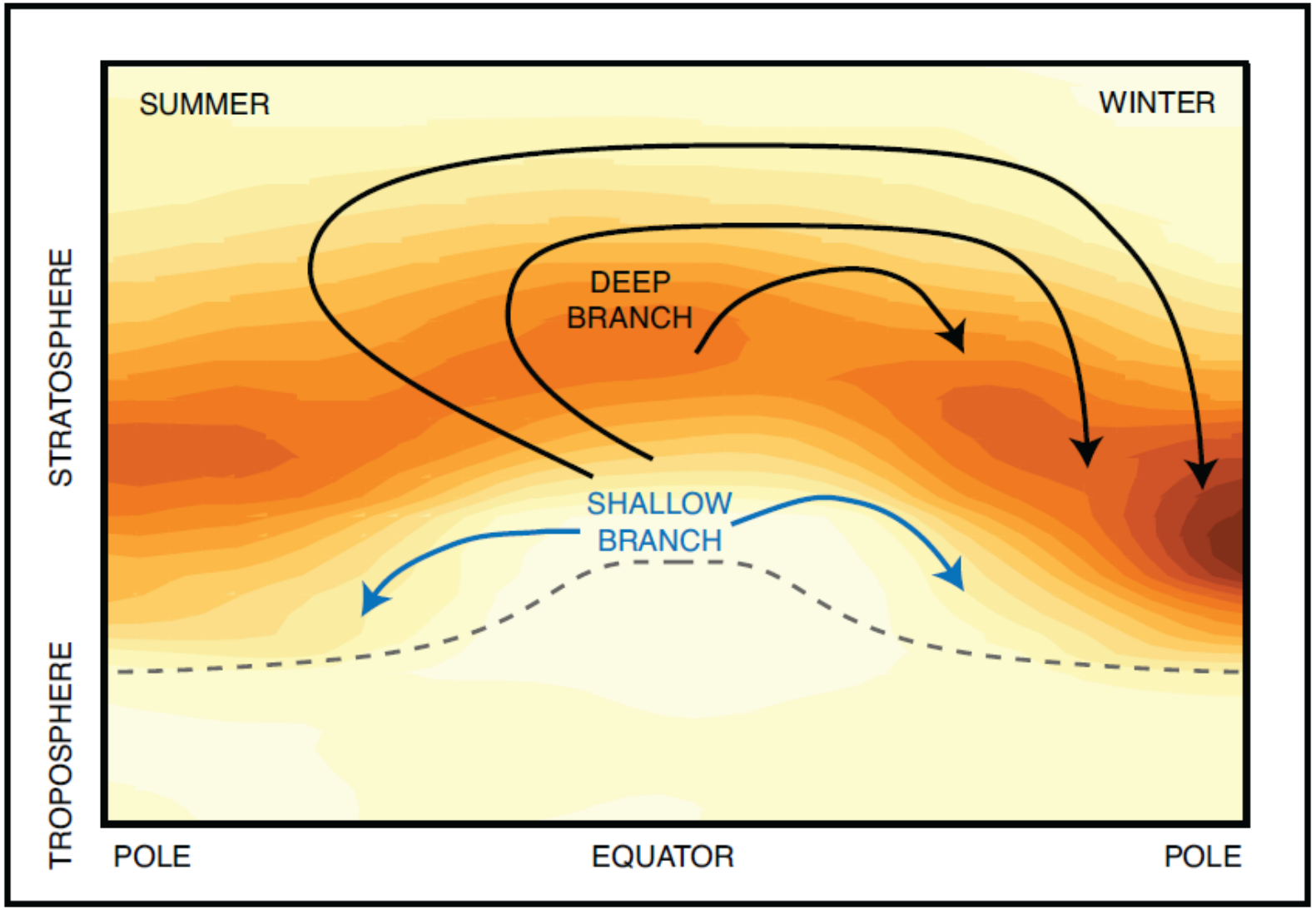
„Chemical View“



„Dynamical View“

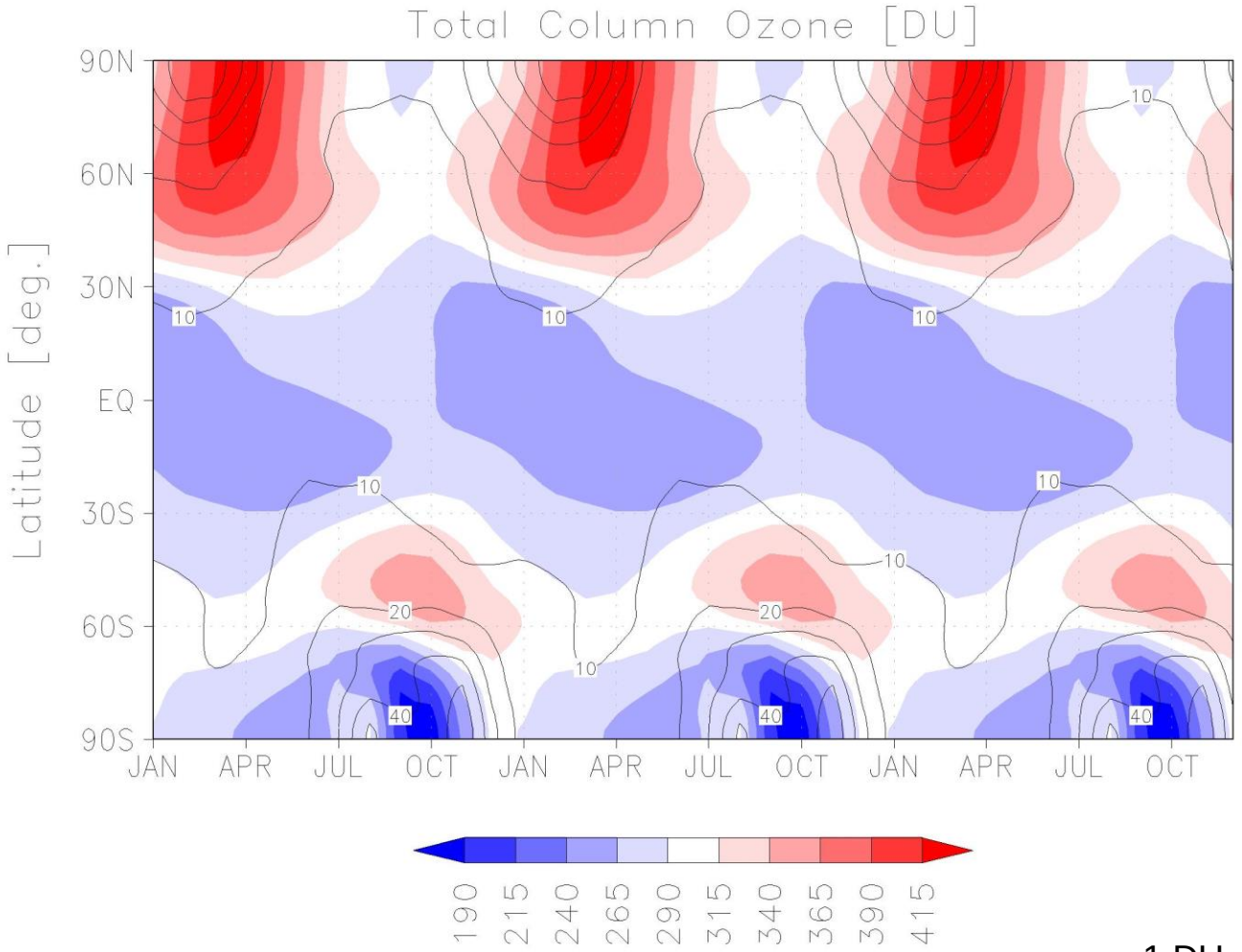
average molar mass of dry air: 28.97 g/mol
molar mass of ozone: 48 g/mol
ratio: 1.66, 14 kg/kg are 8.4 ppmv

Circulation and Ozone



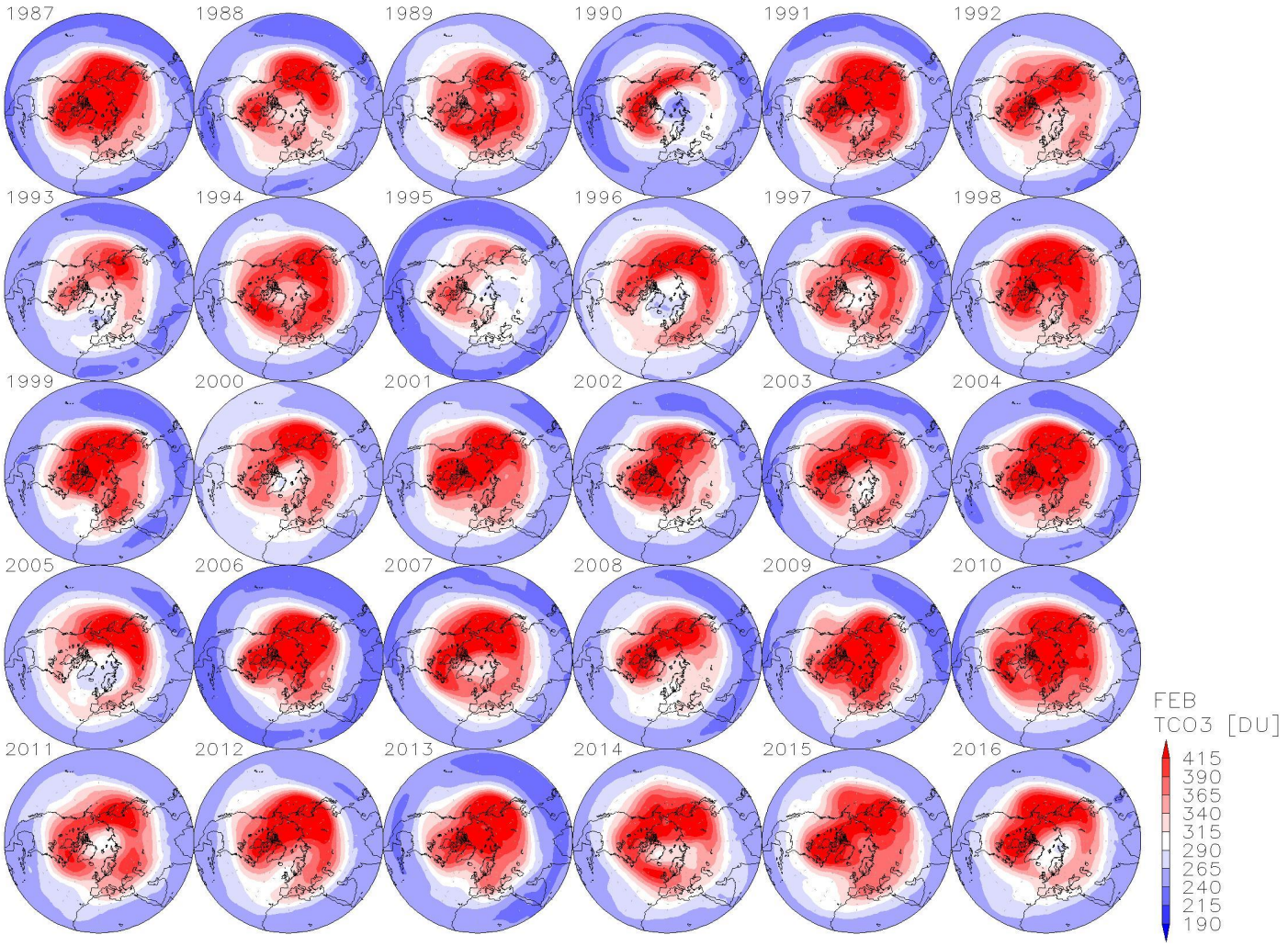
WMO, 2014

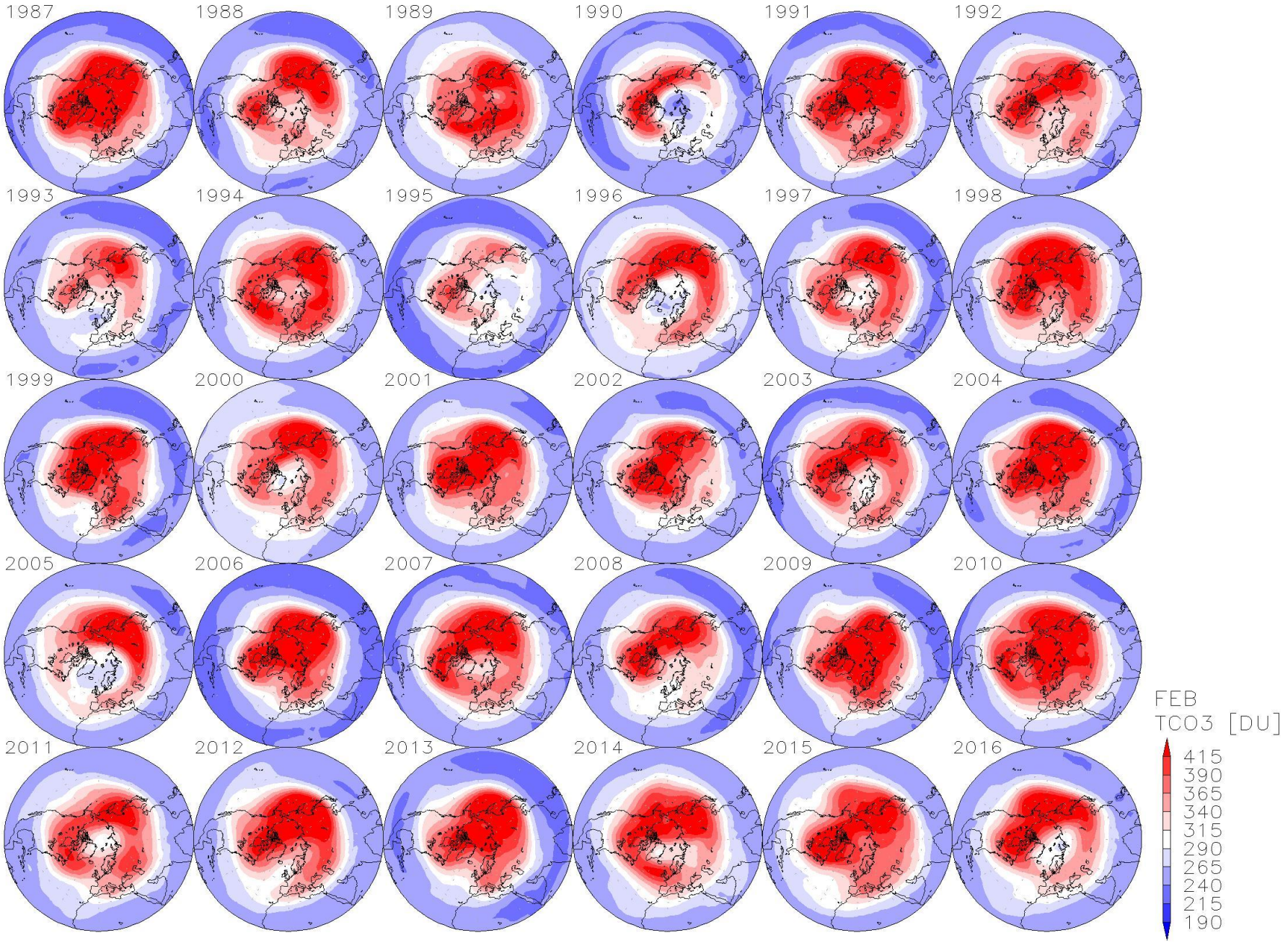
Annual Cycle of Total Column Ozone



1 DU=2.1415E-5 kg/m^2

NH Ozone in February

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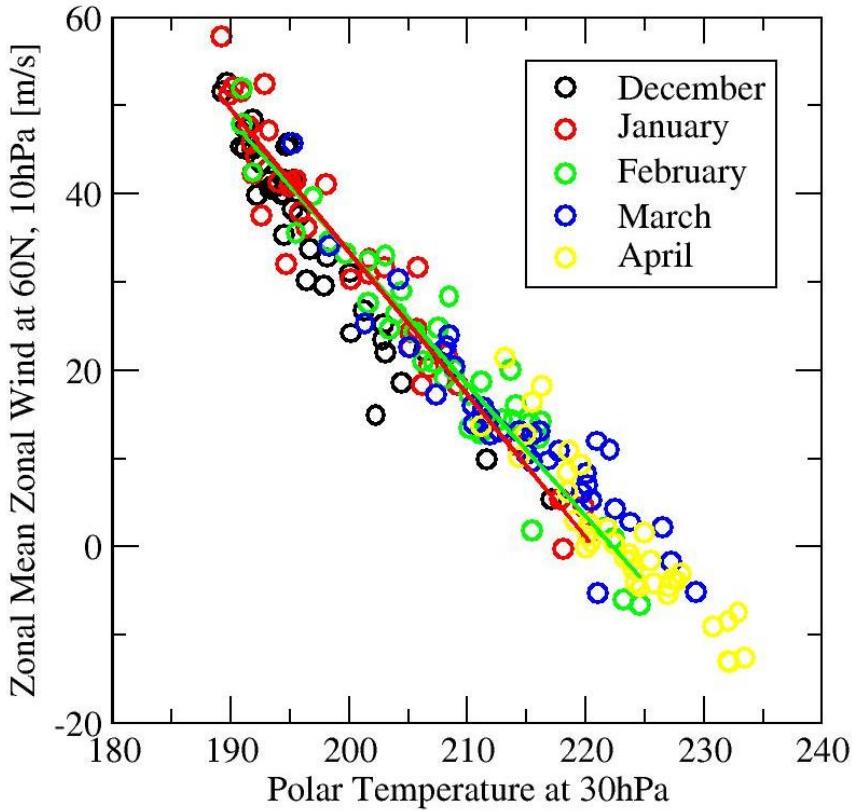
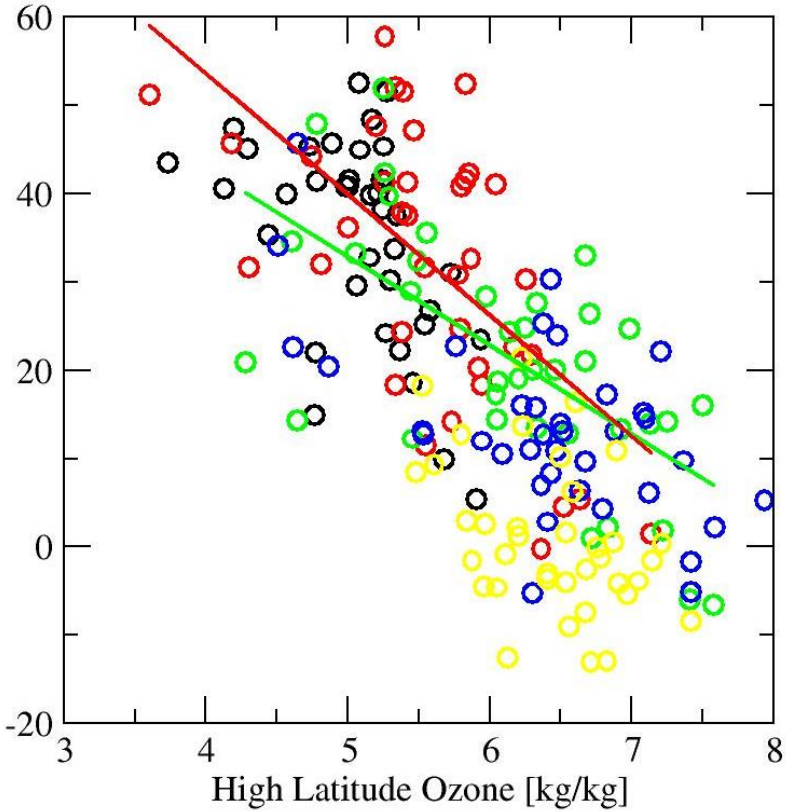
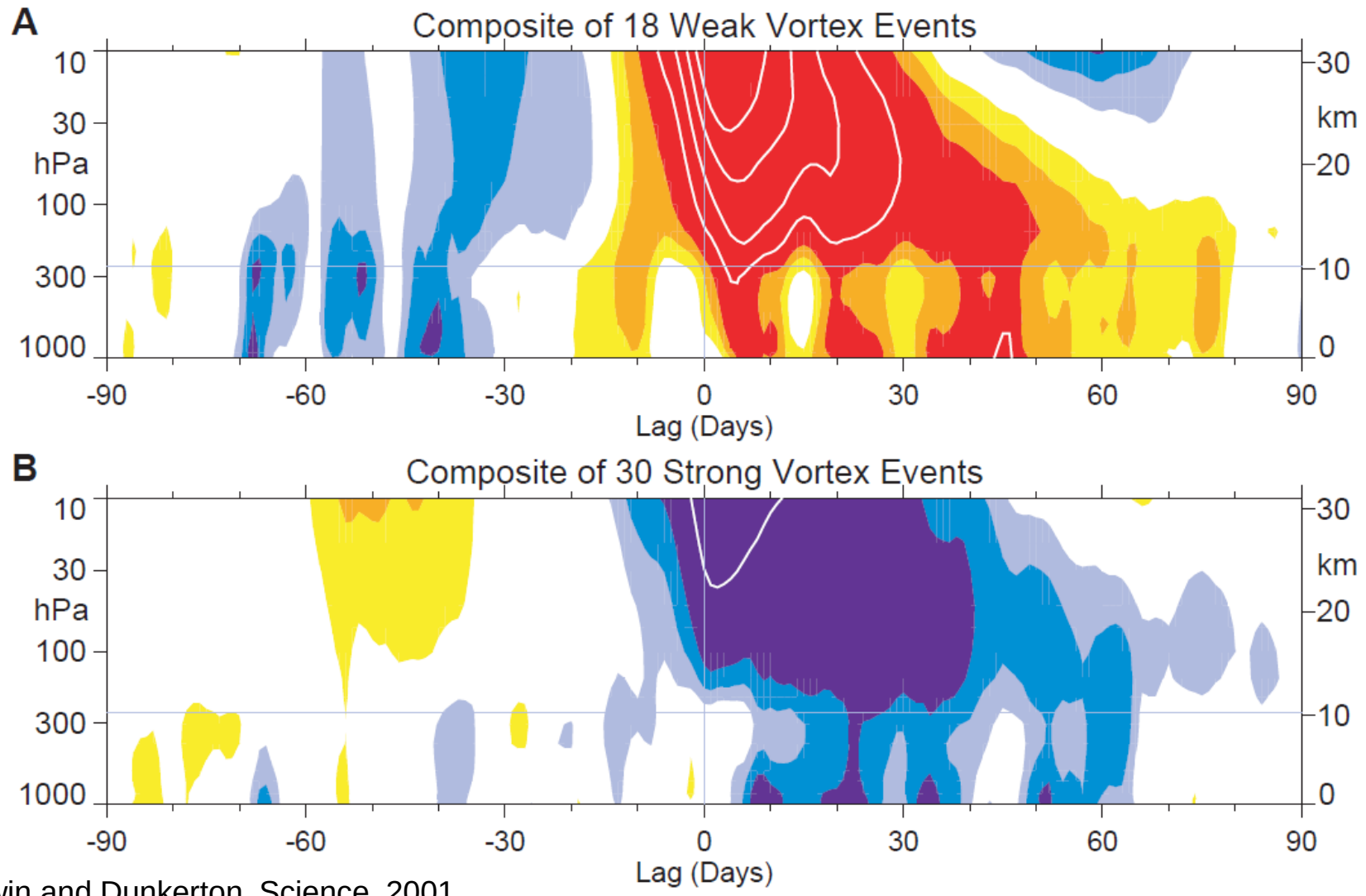
Polar Meteorology and Ozone



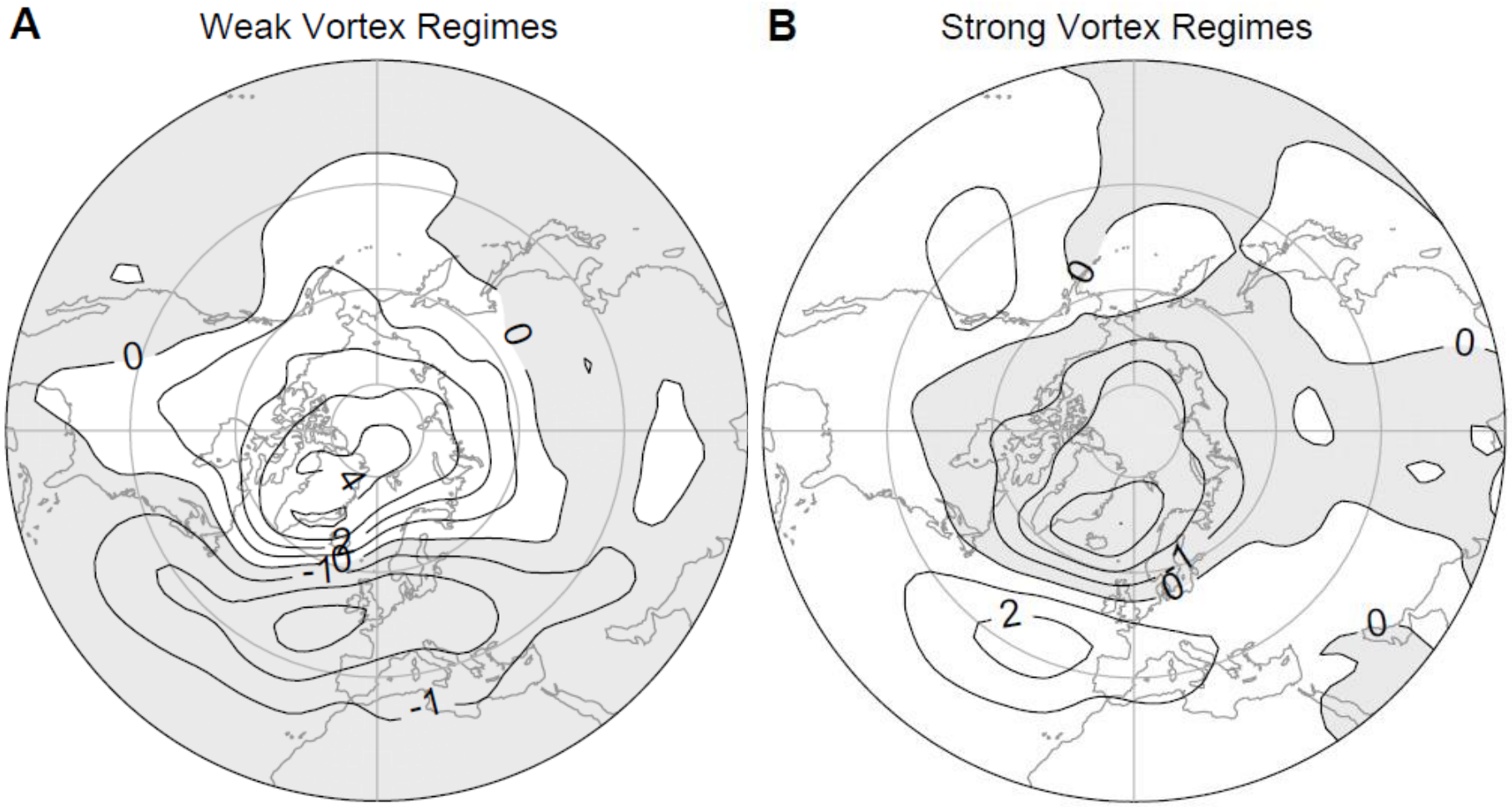


Dropping Paint …



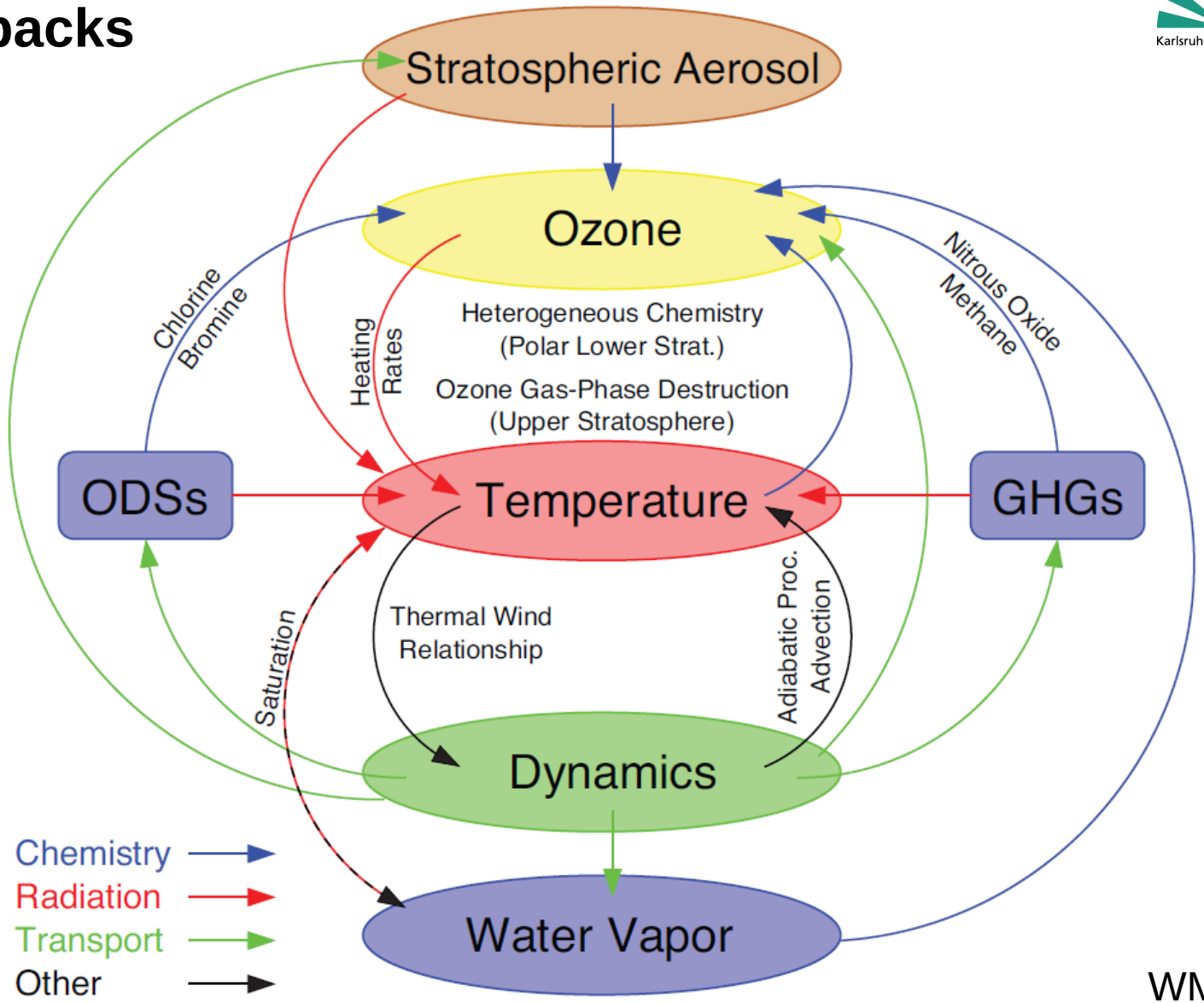
Baldwin and Dunkerton, Science, 2001

Dropping Paint …



Baldwin and Dunkerton, Science, 2001

Feedbacks



WMO, 2010

Modelling the Atmosphere

Observations

Mathematical Model

$$\frac{du}{dt} - \left(f + \frac{u\tan\phi}{a}\right)v = -\frac{1}{\rho a\cos\phi}\frac{\partial p}{\partial\lambda} - D_\lambda$$

$$\frac{dv}{dt} + \left(f + \frac{u\tan\phi}{a}\right)u = -\frac{1}{\rho a}\frac{\partial p}{\partial\phi} - D_\phi$$

$$\frac{\partial p}{\partial z} = -\rho g$$

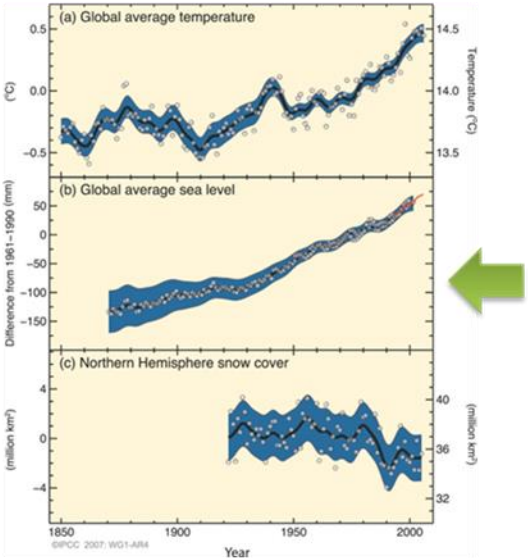
$$\frac{d\rho}{dt} + \rho\nabla\cdot\vec{v} = 0$$

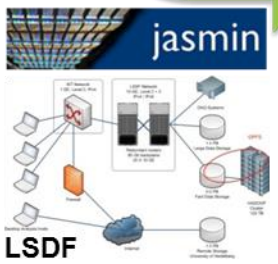
$$\rho c_v\frac{dT}{dt} + p\nabla\cdot\vec{v} = \dot{q}_{net}$$

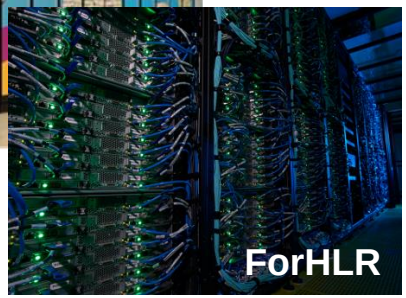
BVs

Numerical Model

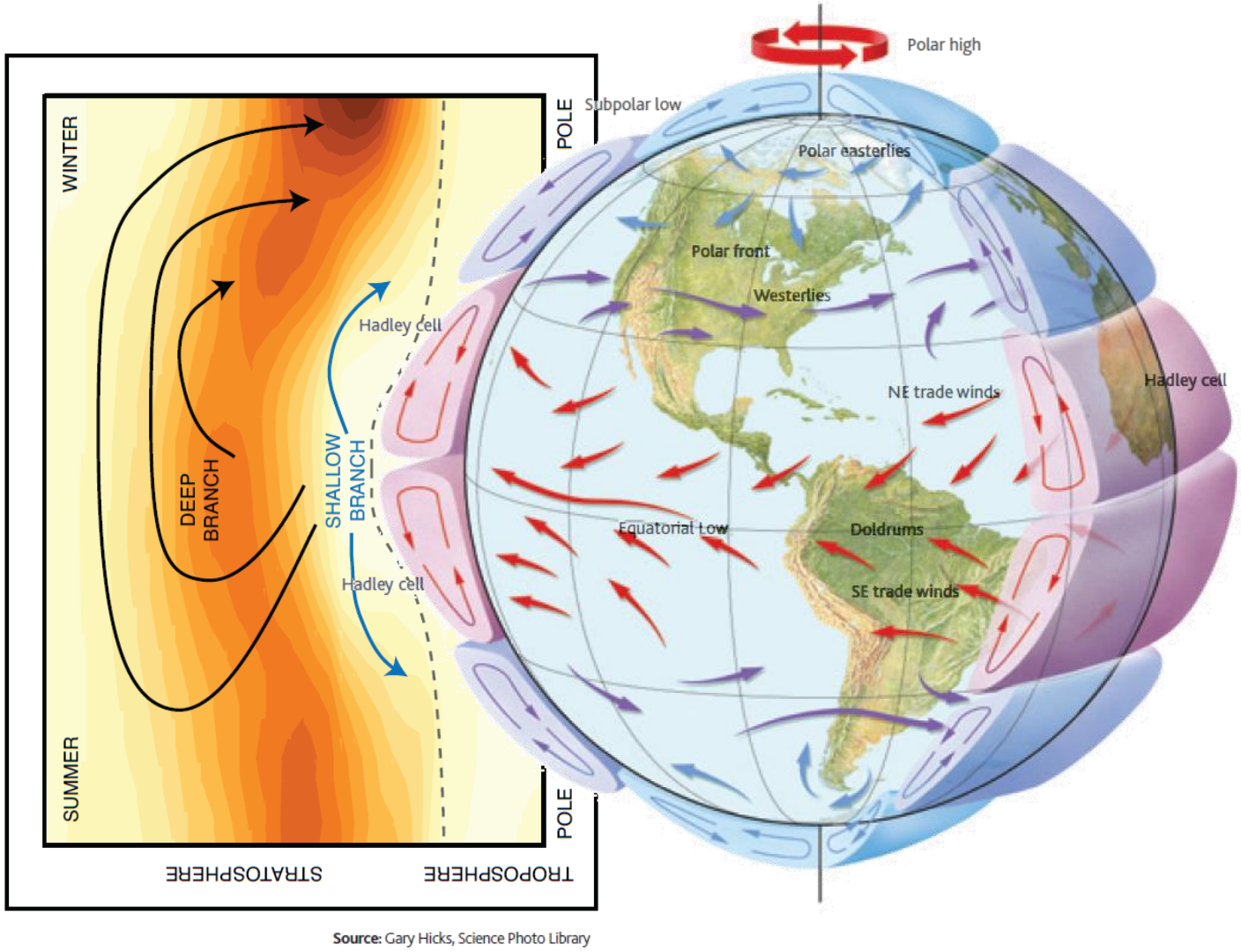
Processed observations





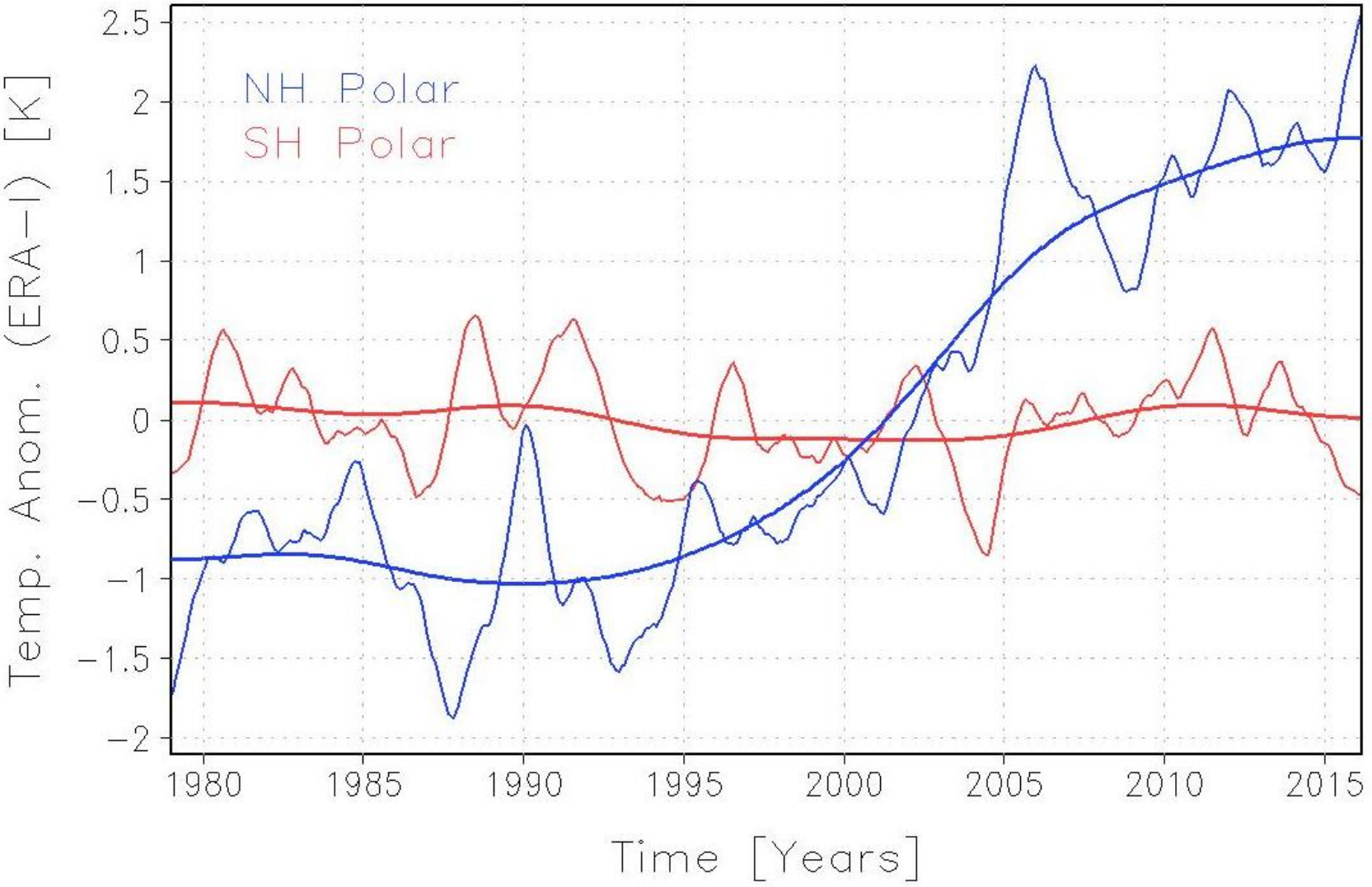


Global Circulation



Source: Gary Hicks, Science Photo Library

Surface Temperatures



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Thank you for your attention!

QUESTIONS?

A GREAT WIND IS BLOWING, AND THAT GIVES YOU EITHER IMAGINATION OR A HEADACHE. *CATHERINE II OF RUSSIA (1729-1796)*

Fluxes and Acceleration

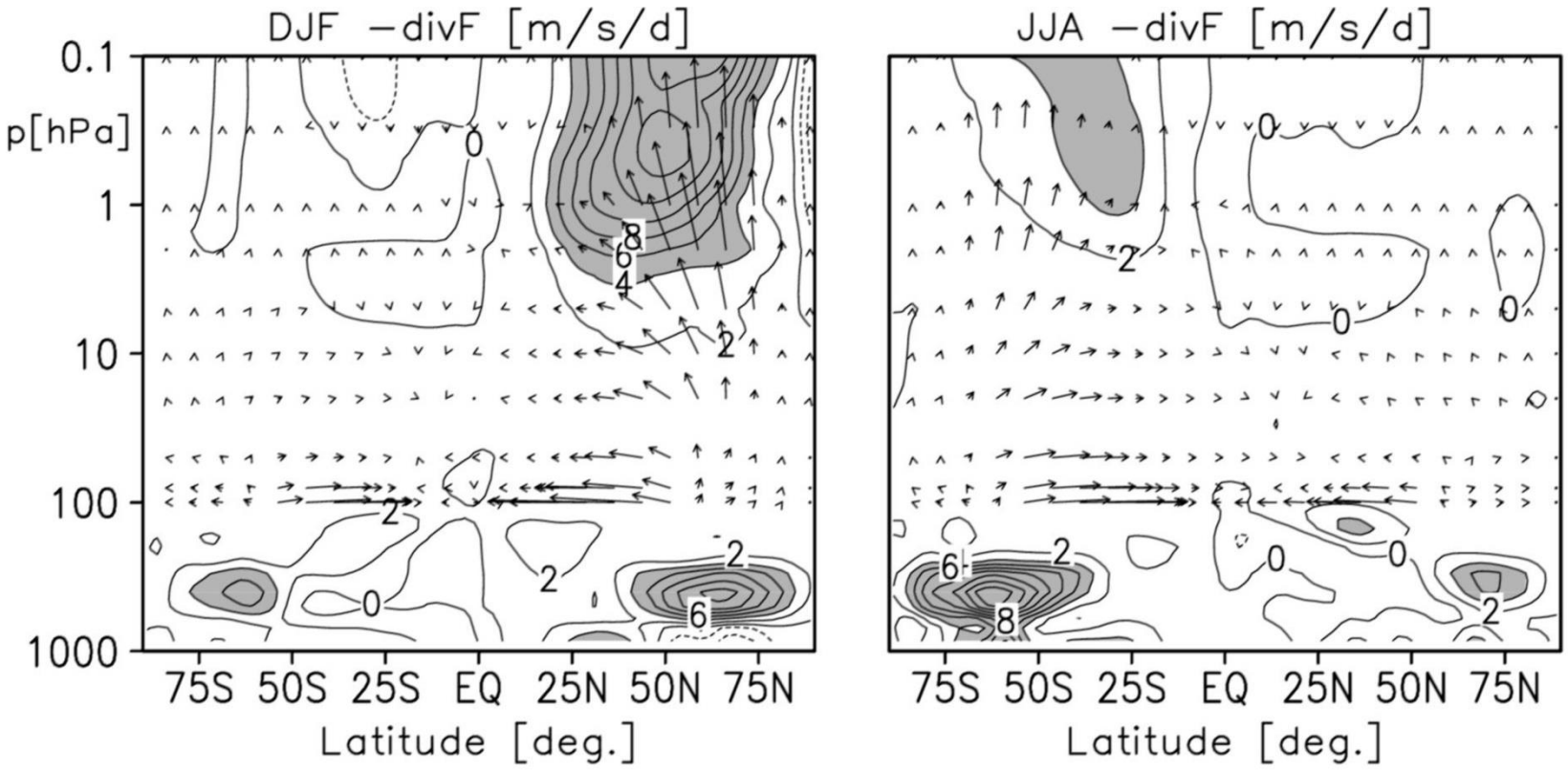


Figure 6: Eliassen-Palm flux vectors (arrows) and its convergence (isolines and shading) as a function of latitude and pressure for December-January-February (DJF; left) and June-July-August (JJA; right). Data from a chemistry-climate model for internal consistency with Figure 7.

Transformed Eulerian Means

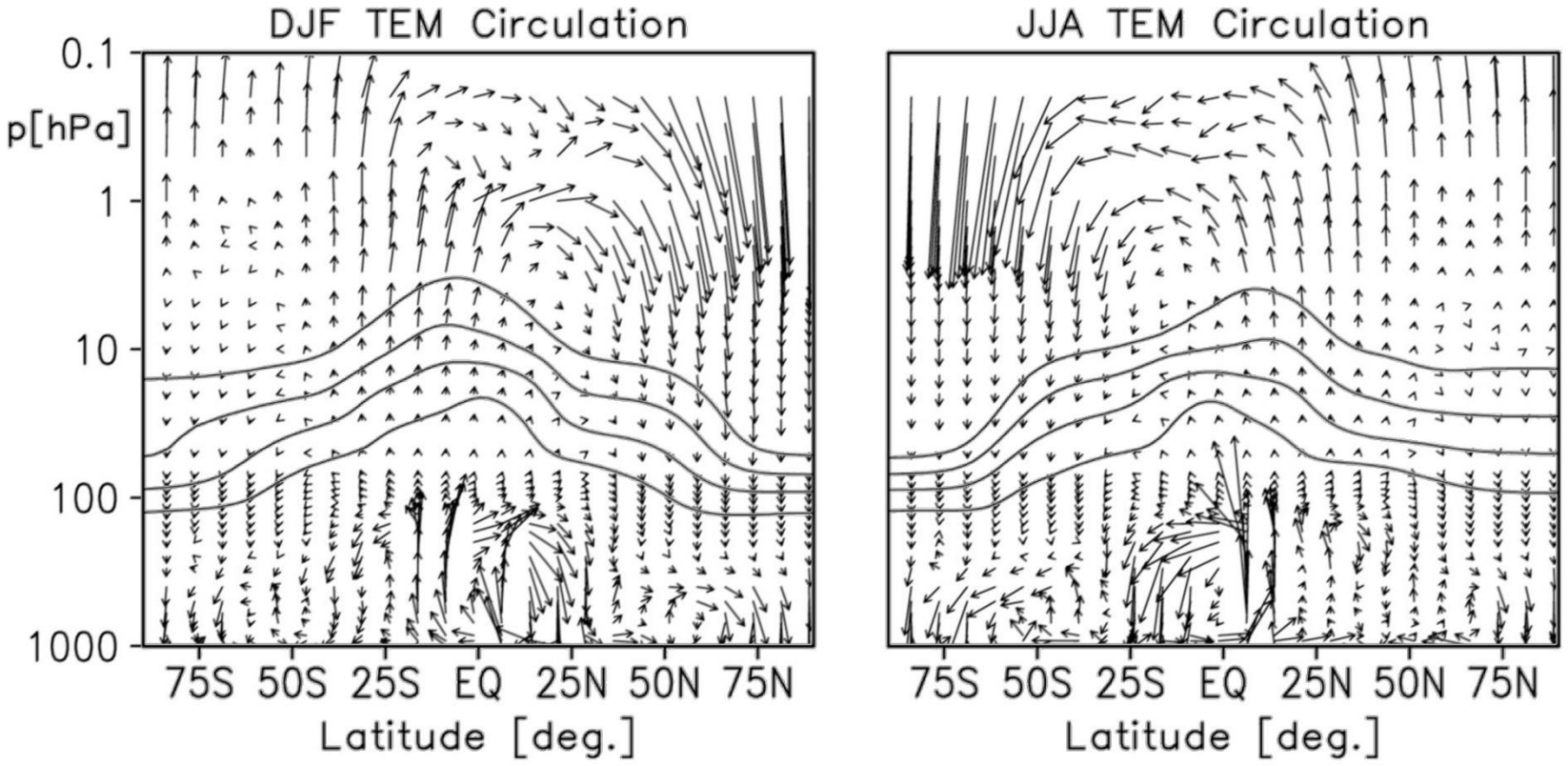
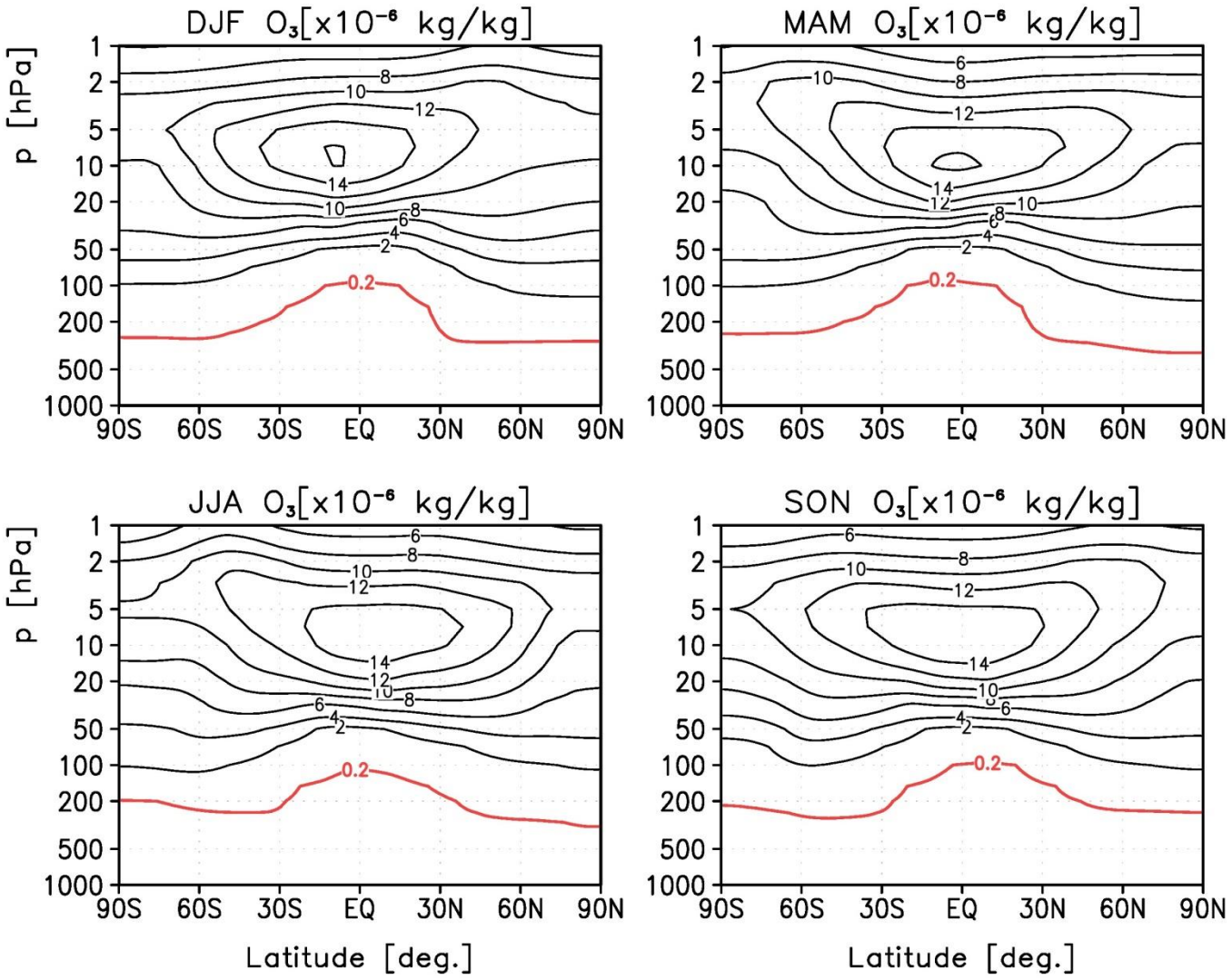


Figure 7: Residual circulation velocity vectors (scaled arrows) and isopleths of a long lived tracer (isolines) as a function of latitude and pressure for December-January-February (DJF; left) and June-July-August (JJA; right). Data from a chemistry-climate model for internal consistency.

Vertical Sructure of Ozone



Vertical Sructure of Ozone