SWIFT: Fast stratospheric ozone chemistry for global climate models

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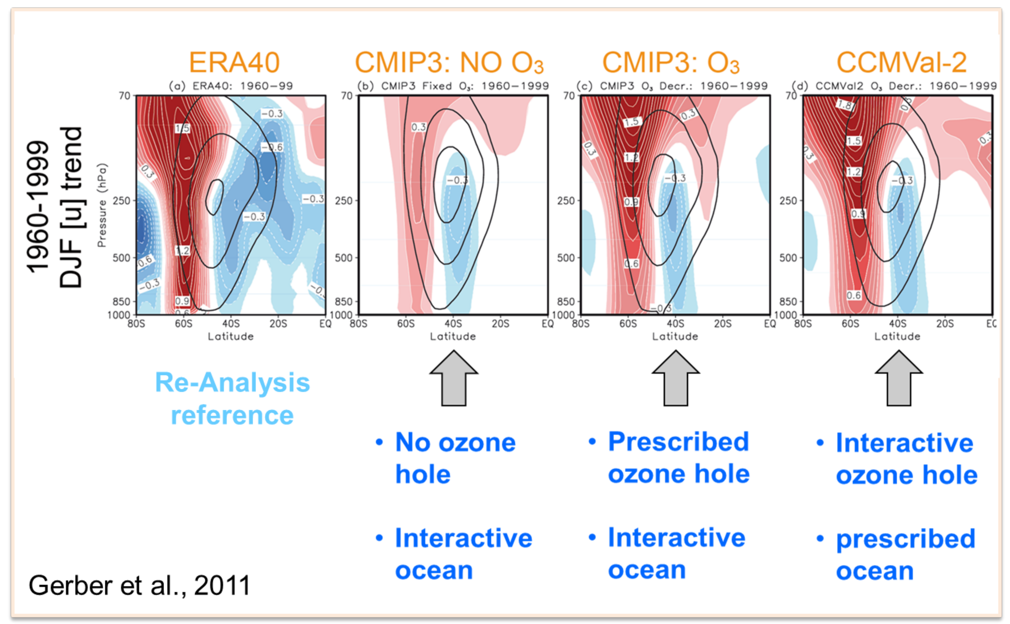
1. Introduction & Motivation

- The SWIFT model, is an extremely fast and interactive stratospheric ozone model, intended to replace prescribed ozone in GCMs.
- SWIFT consists of 2 modules:
  - a) Polar module (semi-empirical, polar vortex averaged ozone chemistry) .
  - b) **Extrapolar module, presented here.**

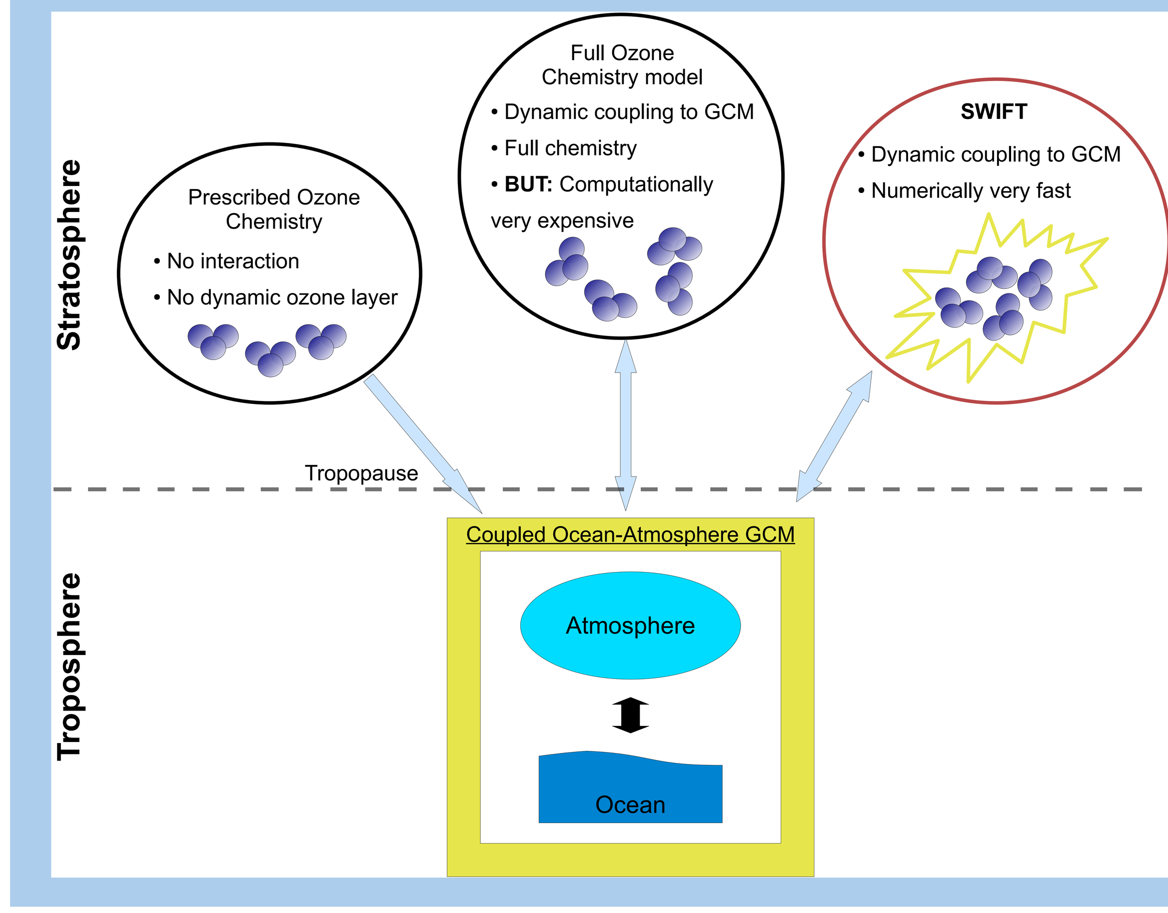
Motivation:

- Example of insufficient representation of stratospheric ozone and its impact on tropospheric dynamics.

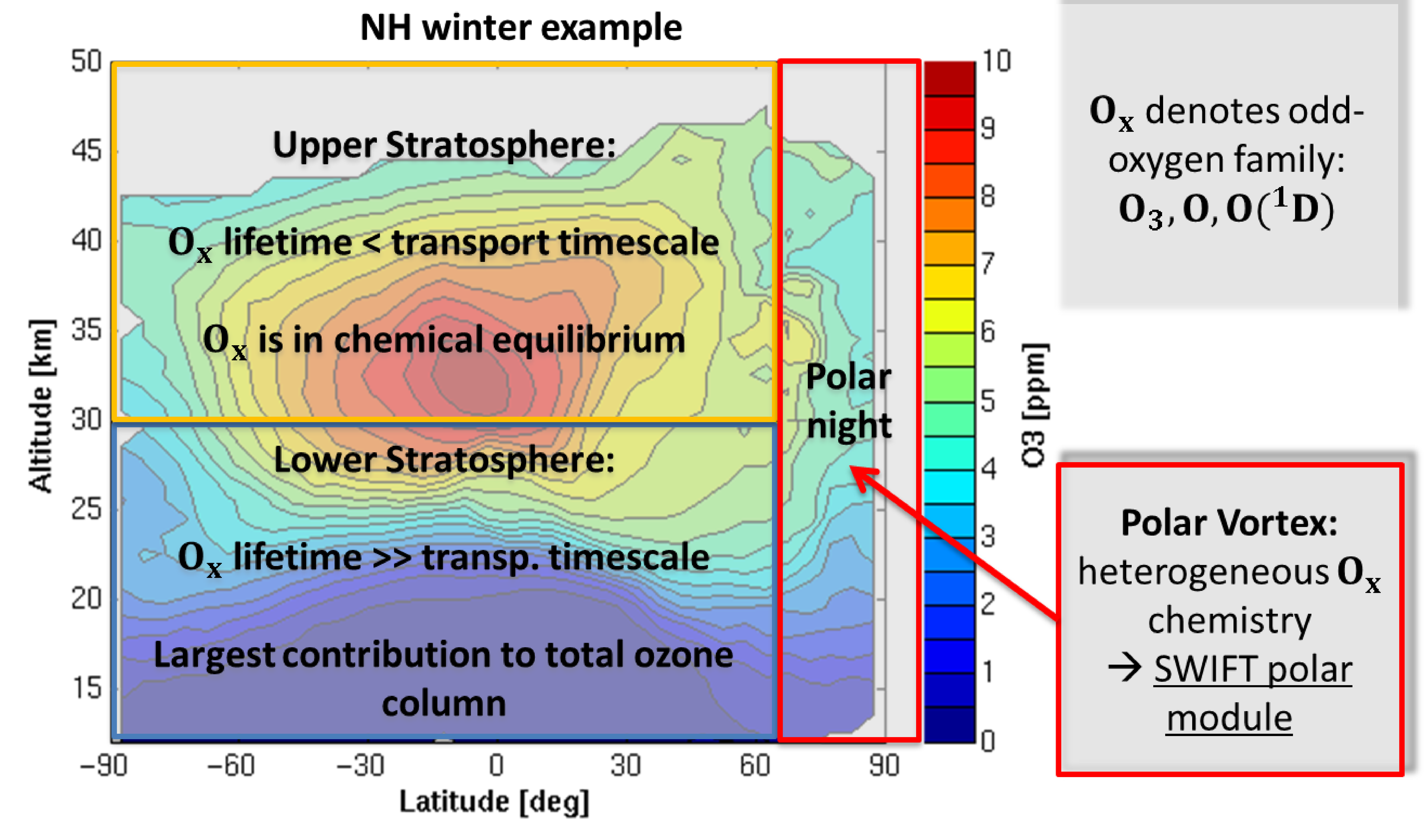
Southern hemispheric summer zonal wind trends: Model results



3 approaches to ozone chemistry for GCMs.



2. Chemical regimes in the stratosphere



O_x denotes odd-oxygen family: $O_3, O, O(^1D)$

3. Method: Repro-modeling

Definition: Repro-modeling is the parameterization of complex models by explicit algebraic functions via numerical fitting.

Method: Fit is applied to the numerical solution of differential equation systems (i.e. full chemistry model output).

Benefits:

- Extremely efficient and fast calculation.
- Few effective parameters.

Repro-modeling has been successfully applied to chemical models, e.g. Spivakovsky et al. (1990), Turanyi (1993), Lowe & Tomlin (2000)

One explicit function for global ozone loss and production rates over 24h:

$$\Delta O_x/24h = F(x_1, x_2, ..., x_9) : \mathbb{R}^9 \to \mathbb{R}$$

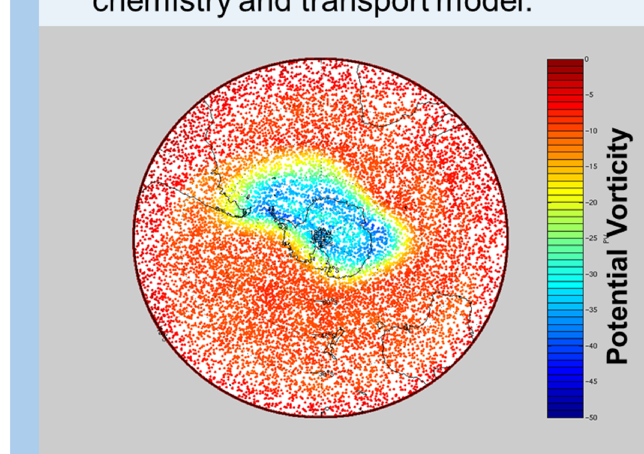
Solving this algebraic equation mimics the behavior of the full system of differential equations.

ΔO_x can be sufficiently described by only 9 variables:

Geographic and atmospheric variables:	Mixing ratios of ozone depleting chemical families:
→ **Latitude**	→ **Chlorine** (Cl_y)
→ **Altitude**	→ **Bromine** (Br_y)
→ **Temperature**	→ **Nitrogen-oxid** (NO_y)
→ **Overhead ozone**	→ **Water vapor** (H_2O)
	→ **Odd-oxygen** (O_x)

4. Training data for polynomials

➢ Full lagrangian stratospheric chemistry and transport model.



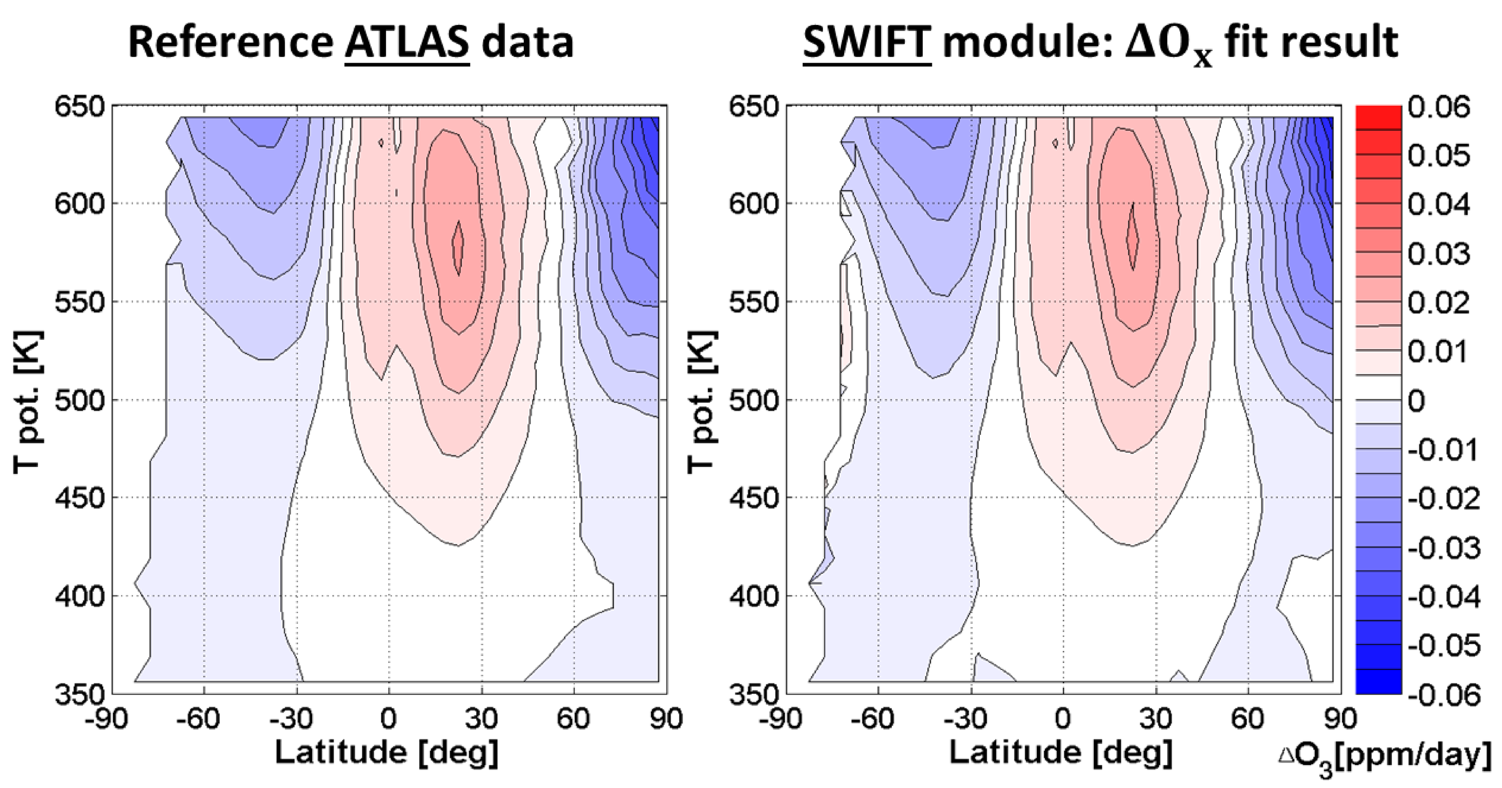
ATLAS trajectories, 20km altitude, south pole, dynamic tracer (PV); Src.: M. Rex

ATLAS model - training data

- Ozone change rates over 24h and the 9 variables are taken from ATLAS trajectories.
- ATLAS trajectories of one month yield a training data set with approx. 3 to 6 million data points.
- ΔO_x is fitted with polynomials on training data set.

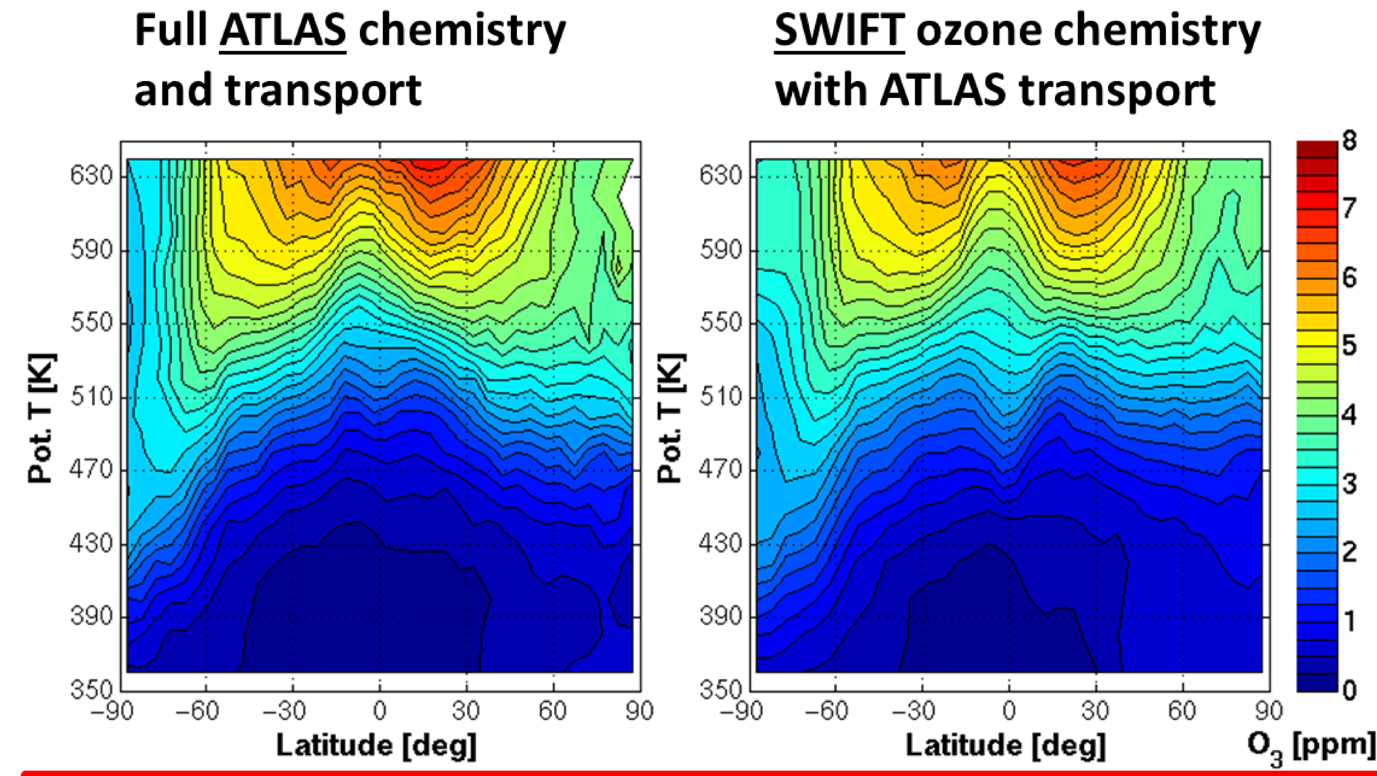
5. Results & Simulations

ΔO_x fit of monthly testing data set (July)



- ➢ Testing data set: ≈ 1.5 mio. data points (differs from training data).
- ➢ Monthly & zonal average
- ➢ Very good agreement!

Simulations with ΔO_x module:
O_3 mixing ratios after 5 months of SWIFT model run.



1 model month ≈ 1 day on 48 processors	1 model month ≈ 10 minutes on single processor

Summary

- The SWIFT extrapolar module employs a repro-modeling approach to determine algebraic equations (polynomials) to calculate ozone change rates in the stratosphere.
- Drastical reduction of computing time, in comparison to full CTMs.
- The polynomials are a function of **only** 9 variables, which are required as a model input.

Outlook

- Using the transport scheme of the ATLAS CTM, annual simulations yield promising results, **but** stability has to be improved.
- Regime for the upper stratosphere with polynomials calculating O_x concentrations.
- Implementation into the fully coupled chemistry climate model EMAC, in collaboration with Freie Universitaet Berlin.

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