Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft
Institut für Physik der Atmosphäre

Reactive Species in the upper troposphere and lower stratosphere: aircraft measurement and MECO(n) modelling

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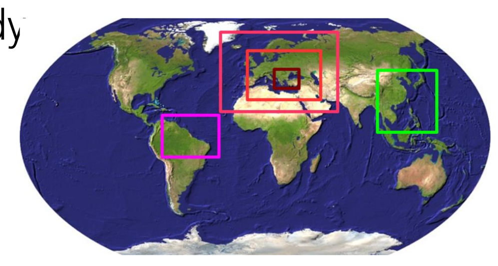
Abstract

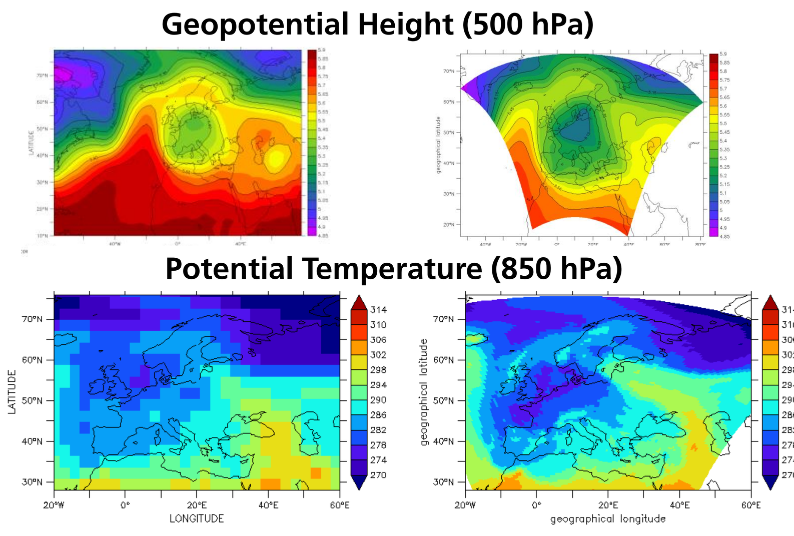
- **Reactive species** play an important role in the upper troposphere and lower stratosphere, as a changing chemical composition results in a changing radiative balance. Understanding key atmospheric processes in that region allows, e.g. quantifying the impact of aircraft emissions on composition and climate [1].
- Hence, evaluating modelled concentrations of reactive species with **aircraft observations** (IAGOS, HALO mission ML-Cirrus) allows to assess representation of atmospheric processes. Reactive species provide an efficient access to synoptic scale patterns, on which we focus in this study.
- We perform a specified dynamics simulation for the year 2014 with the modular global-regional chemistry-climate-model **MECO(n)**, which combines global modelling [2] with regional nesting [3].



- We use MECO(1), MESSy-fied **ECHAM** and **COSMO** models nested 1-time, nudged to ECMWF reanalysis with comprehensive chemistry and diagnostics.
- During the ML-Cirrus measurement campaign in March and April 2014, target regions were **Europe and the North Atlantic flight corridor (NAFC),** where a high density of air traffic occurs, and aviation contribution is analysed. In this study we present results on reactive chemical species, in particular **NO_y and ozone** [4, 5].

EMAC / MECO(n) modelling chain

- The combined system MECO(n) constitutes a new research tool, bridging the global to the meso-γ scale for atmospheric chemistry research [6].
- In our simulations we use chemistry calculated with the chemistry sub-model consistently from the surface to the stratosphere including **stratospheric and tropospheric chemistry**.
- EMAC and COSMO/MESSy are **parallelized** following a horizontal "domain-decomposition" including distributed memory.
- COSMO upper boundary increased in high top version to about 40 km (60 levels).



Overview on model domains

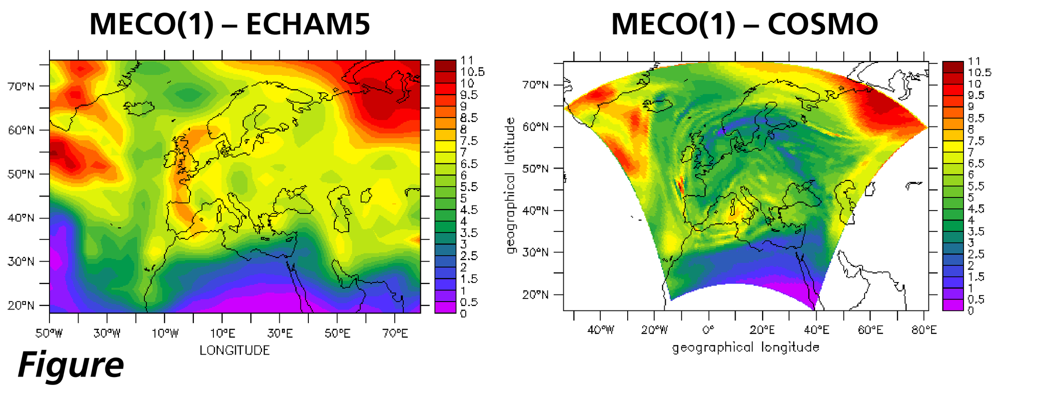
Model	Instance	Grid	Level	t [min]
EMAC	T42L90MA	128 x 64	90	12
COSMO	0,44° EU, L60	120 x 80	60	4

Bridging of scales – Regional nesting in MECO(n)

Requirements for design of model simulations to best support aircraft-based atmospheric observations are manifold and sometimes conflicting:

- High spatial and temporal resolution of model representation
- Short duration of simulations, computationally efficient
- Complex representation of considered species and processes

We apply the **nesting technique** to combine **high spatial resolution** in specific areas of interest with a **global** representation of the chemistry-climate-atmosphere-ocean system.



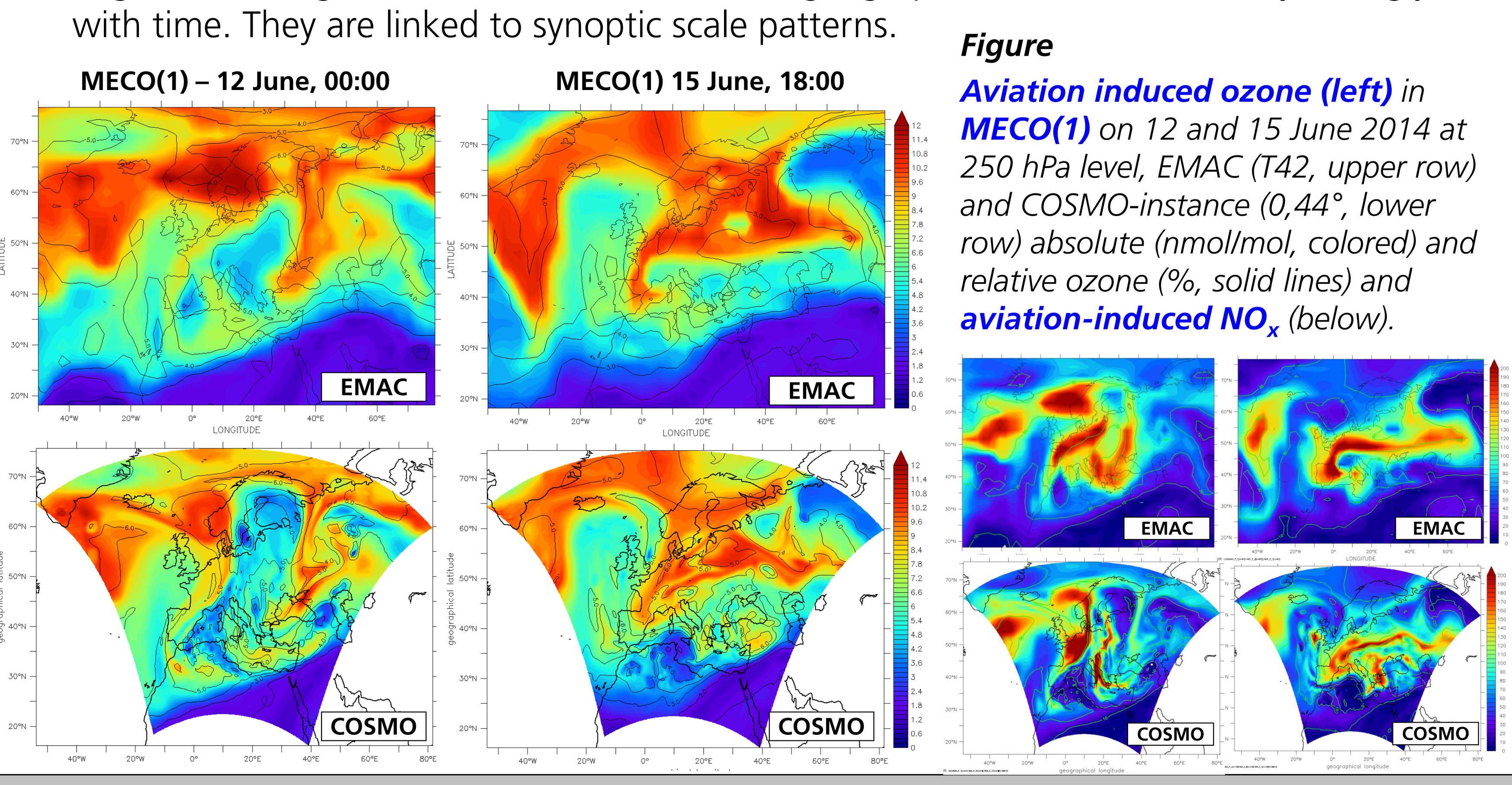
Figure

PV analysis on 340 K isentrope in MECO(1) *on 26 March 2014 at 250hPa level. COSMO (right) identifies synoptic scale structure for transport of from air masses arctic vortex region to the North Atlantic (NAFC).*

Objectives of hindcast simulation
(1) to develop an operational **modelling system** for supporting aircraft measurement; and
(2) to help **designing a campaign** for proof of evidence of aviation impact (NO_x-O_3).

Analysis of aviation impact

- Comprehensive **perturbation studies** allows to identify individual contributions by comparing two distinct simulations with identical meteorology (QCTM offline mode).
- Online model diagnostics identify regions of chemical **ozone production** (`diagtrac`), where air originates by **PV diagnose on isentropes** (`VISO`, *box above*), or analysis with high temporal resolution on measurement aircraft trajectories (`s4d`, *right box*).
- Regions with high **aviation contribution** are geographical confined and vary strongly with time. They are linked to synoptic scale patterns.



Figure

Aviation induced ozone (left) *in* ***MECO(1)*** *on 12 and 15 June 2014 at 250 hPa level, EMAC (T42, upper row) and COSMO-instance (0,44°, lower row) absolute (nmol/mol, colored) and relative ozone (%, solid lines) and* ***aviation-induced NO_x*** *(below).*

Ozone and NO_y concentrations

- The highly structured **Modular Earth Submodel System (MESSy)** allows using specific submodules required for investigation.

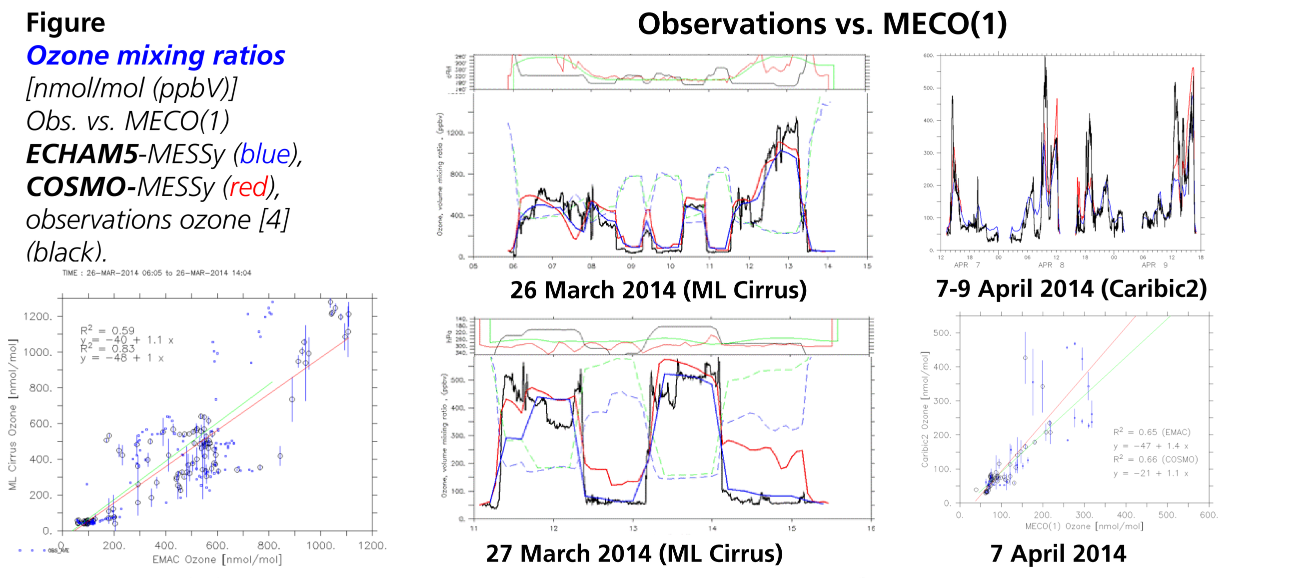


Figure
Ozone mixing ratios
[nmol/mol (ppbV)]
Obs. vs. MECO(1)
ECHAM5*-MESSy (blue),*
COSMO-*MESSy (red),*
observations ozone [4]
(black).

- MECO(1) model reproduces observed aircraft ozone observations with, in certain situations, slightly higher correlation in COSMO.
- In specific synoptic situations modelled values tend to be too low due incomplete representation, e.g. missing out downward transport of stratospheric air in tropopause fold, or latitudinal transport.

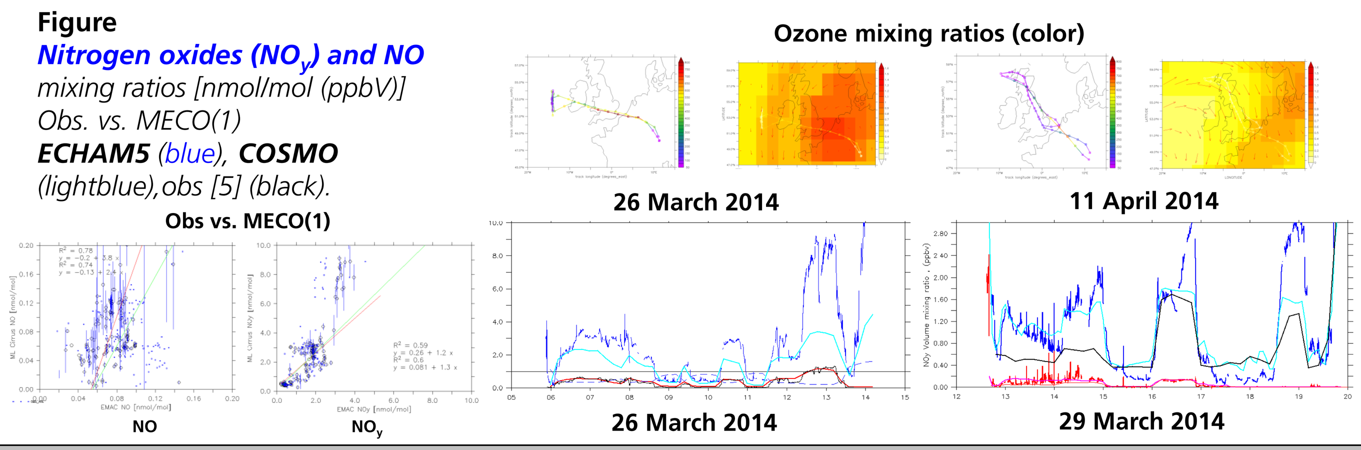


Figure
Nitrogen oxides (NO_y) and NO
mixing ratios [nmol/mol (ppbV)]
Obs. vs. MECO(1)
ECHAM5 *(blue),* ***COSMO***
(lightblue),obs [5] (black).

Conclusion

- Overall objective is to help to provide **proof of evidence** of atmospheric impact of aviation emissions by using aircraft based measurements.
- MECO(n) allows nesting of COSMO in EMAC with identical **chemical setups**, and a high consistency of meteorological and chemical species, show here for MECO(1) high top version (L60).

- Analysis of **measurement campaigns** from national research aircraft e.g. HALO, Falcon, IAGOS can be supported.

Acknowledgements

Part of this work has been supported by Eco2Fly, DLR project (2017-2020), comprising research to identify mitigation potential for aviation climate impact . Observational data were provided by IAGOS, Caribic2 and ML-Cirrus campaign team. High performance computing (HPC) simulations were performed at the Deutsches Klimarechenzentrum (DKRZ) in Hamburg.

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