Karlsruhe Institute of Technology

Extending ICON-ART - Comparison of Simulations with Aircraft Data in the Tropical and Extra-Tropical UTLS

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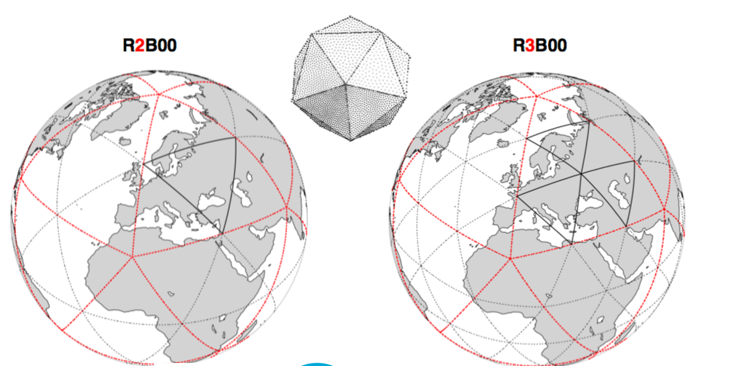
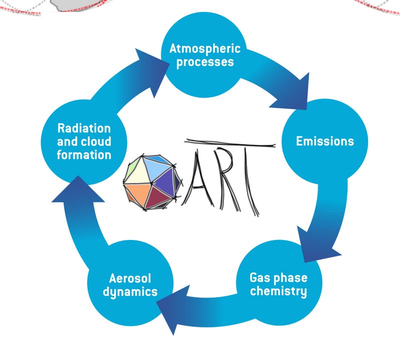
Introduction

The ICON-ART[1] model is an extension of the non-hydrostatic modelling framework ICON[2], jointly developed by the German Weather Service (DWD) and Max-Planck-Institute for Meteorology (MPI-M), and is used for numerical weather prediction as well as for future climate predictions. ICON-ART is developed at KIT with the goal to simulate interactions between trace substances and the state of the atmosphere.
We have extended ICON-ART by introducing an online photolysis module. This module uses in its core the latest version of Cloud-J[3]. In this study we present first insights of the performance of this module by comparing the results to aircraft campaign data.

ICON: ICOsahedral Nonhydrostatic modelling framework
ART: Aerosols and Reactive Trace substances

General Information about ICON-ART

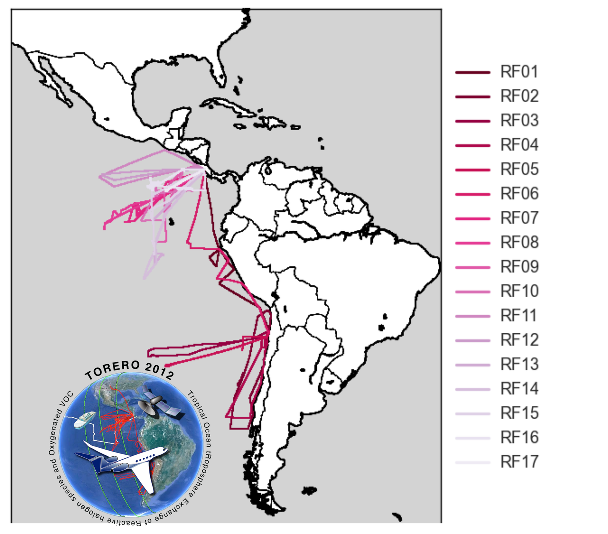




The extended modelling framework ICON-ART is developed in an analogous way to its predecessors COSMO-ART[4]. For the dynamics (transport and diffusion) of gaseous tracers, the original ICON tracer framework is used. For the model physics, numerical time integration follows a process splitting approach separating physical processes. Each process is called independently via an interface module. Currently, the processes of emission, dry and wet deposition, sedimentation, and first order chemical reactions are included.

ICON uses a triangular grid structure, which gives computational advantages. It allows to do efficient simulations from the global to the regional scale using the nesting technique, due to the hierarchical structure.

TORERO Campaign



https://www.eol.ucar.edu/field_projects/torero

stands for	Tropical Ocean Troposphere Exchange of reactive halogen species and oxygenated VOC
Time Period	15.01 - 26.02.2012
Region	Costa Rica / Chile
Instrument	HARP Actinic Flux Spectrometers
resolution	seconds

Setting up ICON-ART for TORERO Campaign

Initialisation: Every flight day at 12:00h via IFS **Horizontal resolution:** R2B06 (40 km)
Time Resolution: 15 min (8 min integration time step) **Interpolation**: Nearest Neighbour
Cut off of starting and landing episodes to guarantee matching albedo assumptions.

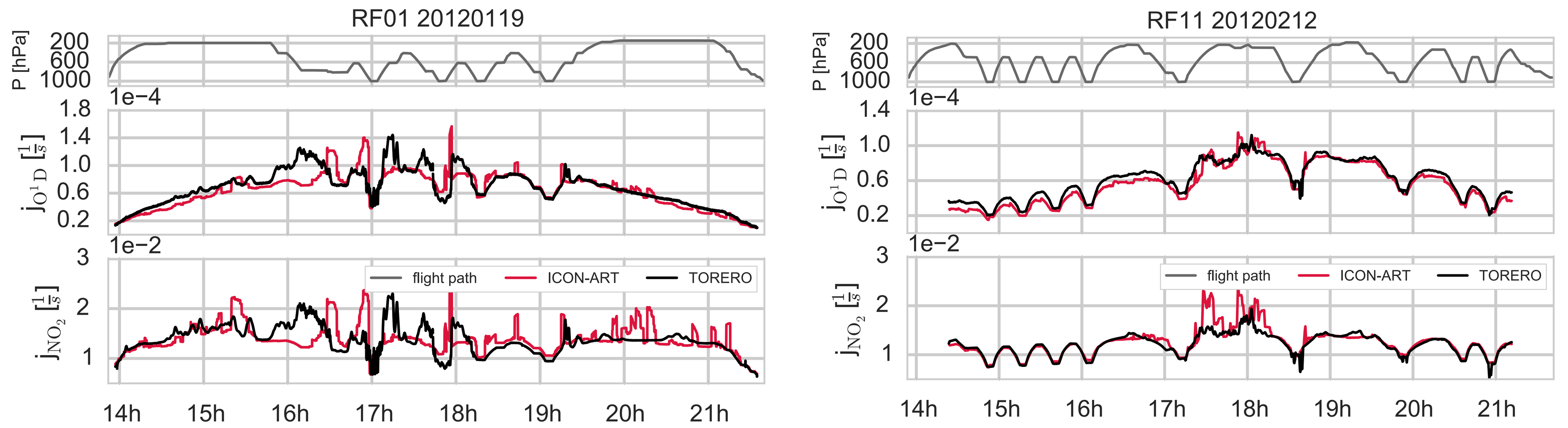


Fig. 1 Timeseries of the flight altitude in pressure coordinates and of photolysis rates JO1D and JNO2, both for measurement and simulation. Timeseries are shown with rolling mean.

Category Clear Sky

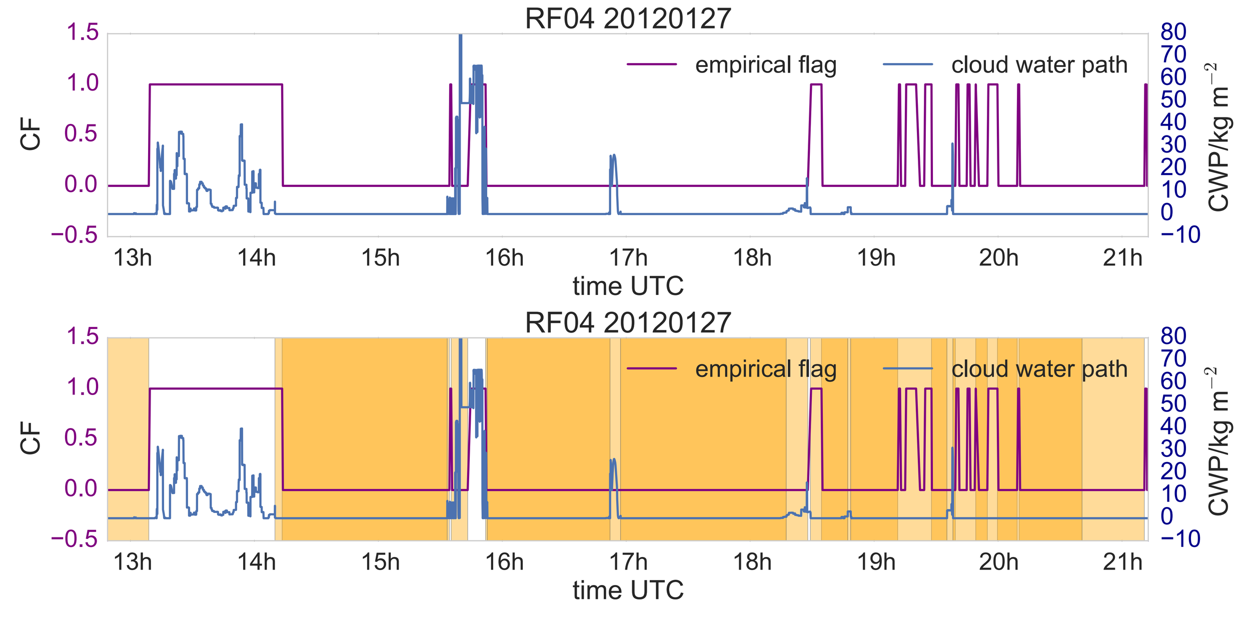


Fig. 2 Measures taken into account for generating clear sky flag. The empirical cloud flag and the column integrated cloud water path by ICON are shown.

Empirical cloud flag (CF): Based on a color index from the forward viewing telescope. They are manually compared with video footage.

Cloud water path (CWP): Standard microphysics product of ICON. A value of CWP smaller than 1 kg/m^2 indicates clear sky.

Clear sky category: In Fig 2. dark orange areas represent those time intervals where datapoints are added

Vertical Profile of JNO2

The values of the time series are binned to pressure values. For the two cases, clear sky and cloudy case for both shown flights, the agreement between measurement and simulation lies within the standard deviation. Both flights are chosen to be representative as best and worst case regarding to the correlation coefficient R (0.33 for **R**esearch **F**light RF01 and 0.98 for RF11 in clear sky).

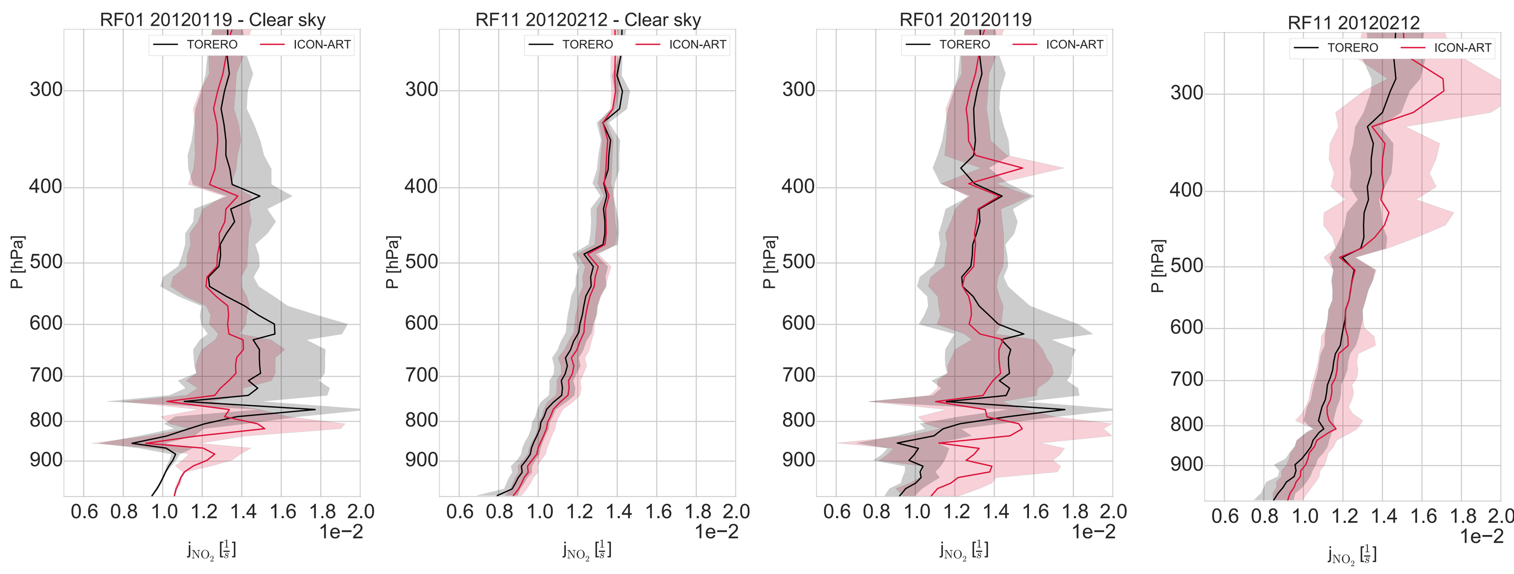


Fig. 3 Vertical profiles for two different flights, RF01 and RF11. Both cases, clear sky and all datapoints, are taken into account. In all four panels, the photolysis rate of the JNO2 channel is shown. Values are binned to pressure levels and the mean with the respective standard deviation is shown.

Results

Statistical results for clear sky category

Reaction	Bias (%)	RMSE (%)	Pearson's R
$O_3 \longrightarrow O^1D$	-5	20	0.88
$NO_2 \longrightarrow NO + O^3P$	-2	19	0.53
$CH_2O \longrightarrow H_2 + CO$	9	18	0.80
$H_2O_2 \longrightarrow OH + OH$	-1	18	0.75
$HNO_3 \longrightarrow NO_2 + OH$	-8	21	0.84

We compared 11 flights of the TORERO campaign for five different photolysis rates. Those are covering up different wavelength regions. Flights which has been excluded showed a fragmented time series after building up the clear sky category. A reasonable interpretation does not seem possible. To investigate the statistical results, all timeseries are merged into one dataset.

The relative bias (ICON-ART - TORERO) is below ± 10 % which indicates that we do not have to take into account systematical errors. The Root Mean Square Error (RMSE) lies within the expected measurement error. The correlation coefficient indicates that within the simulation the general variability is captured well.
For JNO2, the value of R is relatively low compared to the values of the other reactions. But it should be noted, that the correlation between measurement and simulation is very variable from flight to flight, ranging from 0.31 to 0.98.
The values of R indicate that the simulation is able to capture variations due to temporal and spatial variability caused by variations in temperature, pressure, overhead ozone column etc., for the clear sky case, reasonable.

Conclusion

The online photolysis module shows a good quantitive agreement to the measurement even when clouds are present.
We can state that with this extension we are able to perform reasonable simulation of photolysis rates on the regional scale. The extension of ICON-ART by the online photolysis module allows further development of the modelling framework. At the final stage, ICON-ART will give the ability to study tropospheric and stratospheric chemical processes, aerosol chemistry and aerosol dynamics.

References and Further Information

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