# On the use of in-service aircraft observations for the assessment of a long-term chemistry-climate simulation in the UTLS


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## Introduction

A wide variety of observation data sets are used to evaluate long-term simulations provided by chemistry-climate models (CCMs). However, the upper troposphere – lower stratosphere (UTLS) is hardly assessed in the models because of uncertainties in remote measurements, a limited area for balloon-borne observations and a limited period for aircraft campaigns. In this work, we extend and apply the methodology presented in Cohen et al. (2021) to project the data from commercial aircraft onto the model grid, and we assess the LMDZ-OR-INCA model on its climatologies in several key chemical species/families: ozone ($O_3$), carbon monoxide (CO), reactive nitrogen ($NO_y$) and water vapour ($H_2O$).

## Observation data set

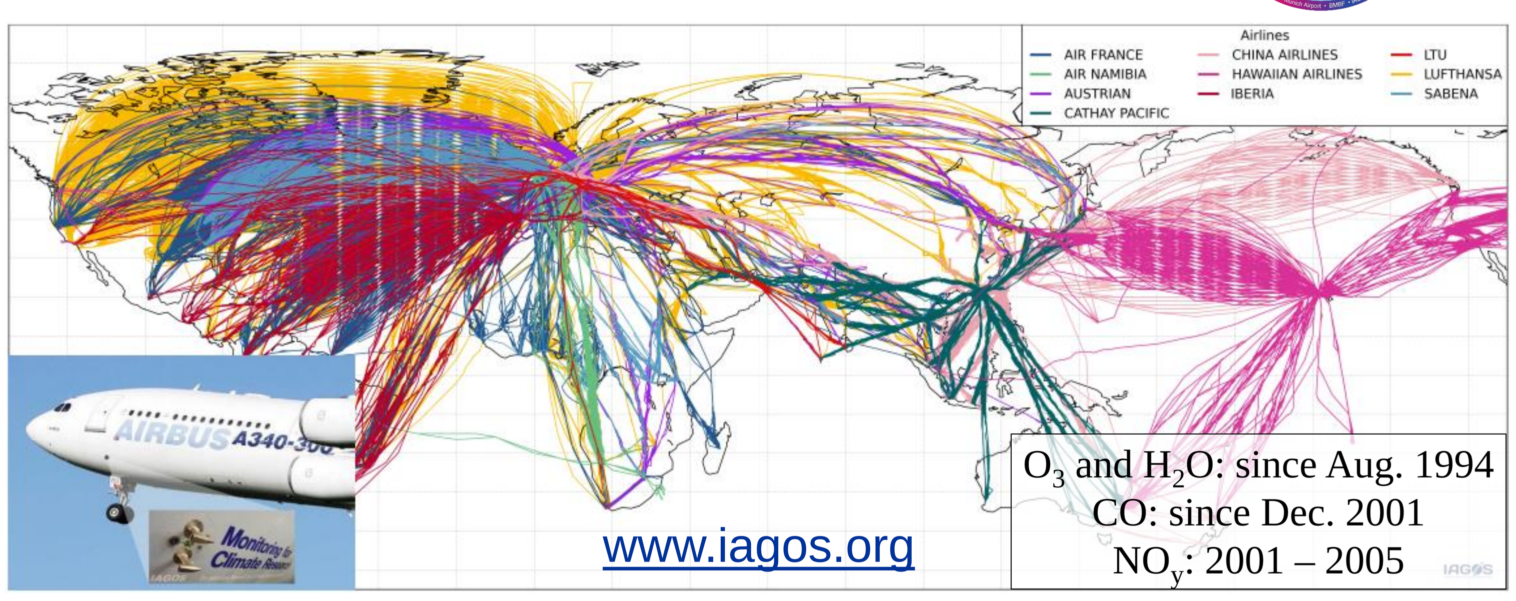


*Figure 1: Trajectories sampled so far by the IAGOS fleet. Bottom left: picture of an aircraft equipped with IAGOS instruments.*

IAGOS: In-service Aircraft for a Global Observing System

- In situ measurements on board several commercial aircraft
- Wide sampling in the northern extra-tropics and in some (sub-)tropical regions
- Cruise altitudes: around the extratropical tropopause, and in the tropical upper troposphere (UT)

## Model and simulation setup

The LMDZ-OR-INCA CCM couples online the LMDZ general circulation model, the ORCHIDEE dynamical vegetation model and the INCA model (Hauglustaine et al., 2004). The chemical scheme includes a state-of-the-art $CH_4$-$NO_x$-CO-NMHC-$O_3$ tropospheric photochemistry, stratospheric chemistry, and aerosols.

The current simulation has an horizontal resolution of 2.5° lon. x 1.25° lat., and 39 vertical levels up to 70 km. Horizontal winds are nudged toward the ERA-Interim reanalysis fields, and sea-surface temperatures are forced. The anthropogenic and biomass burning emissions are provided by the CEDS and the BB4CMIP (GFED4s) inventories, respectively. Biogenic emissions of hydrocarbons are calculated by ORCHIDEE.

## Methodological approach

**Why developing a new tool?**

The IAGOS data set has practically not been used for global model assessments because the transition between high-resolution measurement points and a regular grid is not easily done, and the IAGOS platform lacked a dedicated software.

**What has been done so far?**

For this purpose, Cohen et al. (2021) presented the Interpol-IAGOS software that consisted of a reverse interpolation of each measurement point onto the model monthly grid (Fig. 2). The current study includes more chemical species, and now applies to a daily grid. ➔ New products: IAGOS-DM (gridded) and INCA-M (masked)

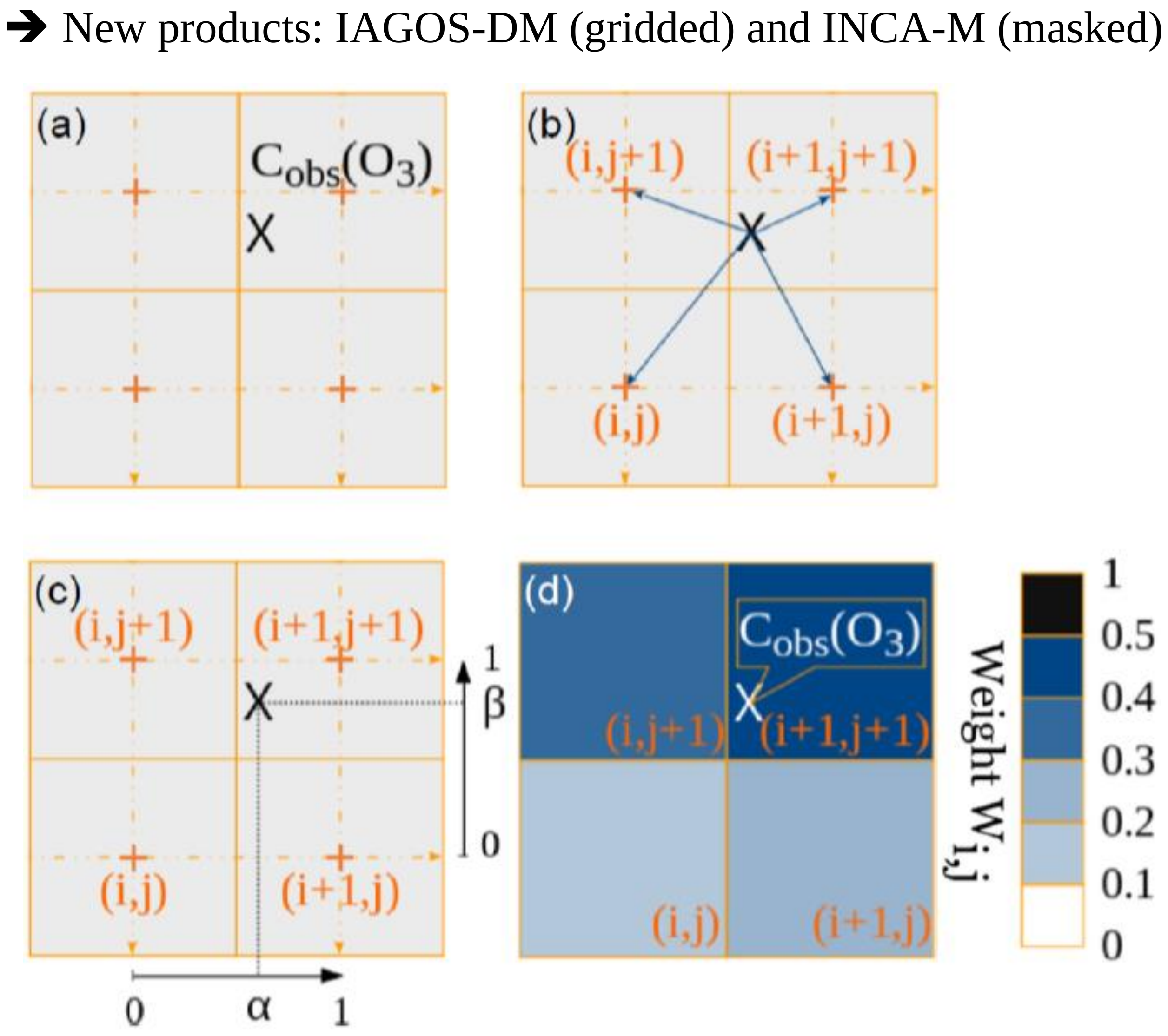


*Figure 2: 2D-schematic of the interpolation of a measurement point (black cross) onto the adjacent grid points (orange crosses). For each grid cell, a weight is calculated depending on the distance with the measurement location (d). These coefficients are then used to derive weighted monthly averages, and finally seasonal and annual climatologies (not shown). From Cohen et al. (2021).*

## Comparison model – observations

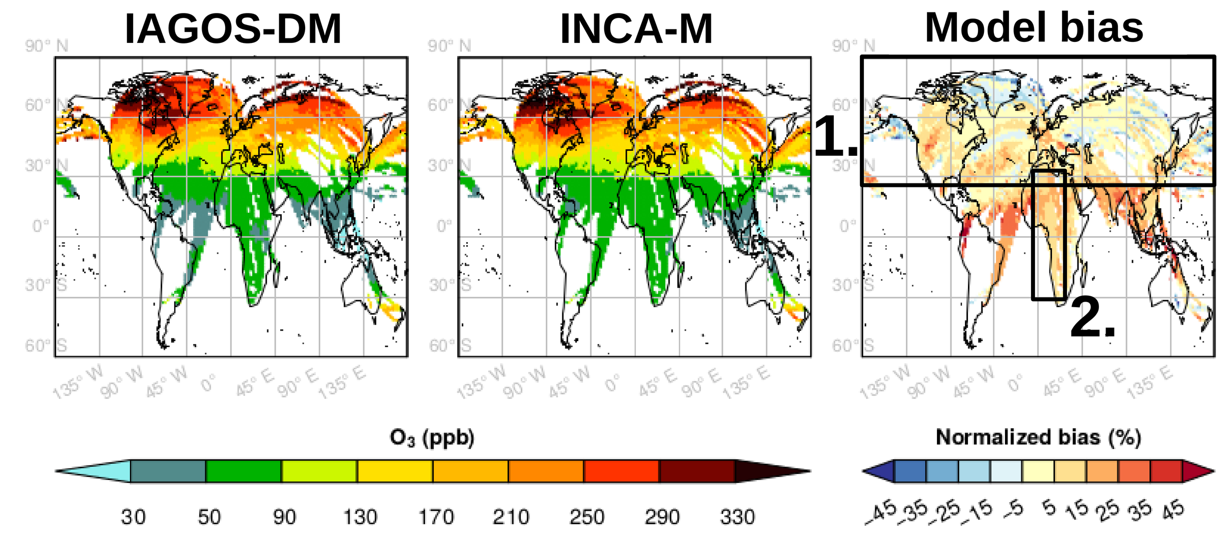


*Figure 3: Mean geographical distributions for ozone (1994 – 2017) as seen by the two data sets (left and center), and the model bias (right).*

### 1. Northern extra-tropics

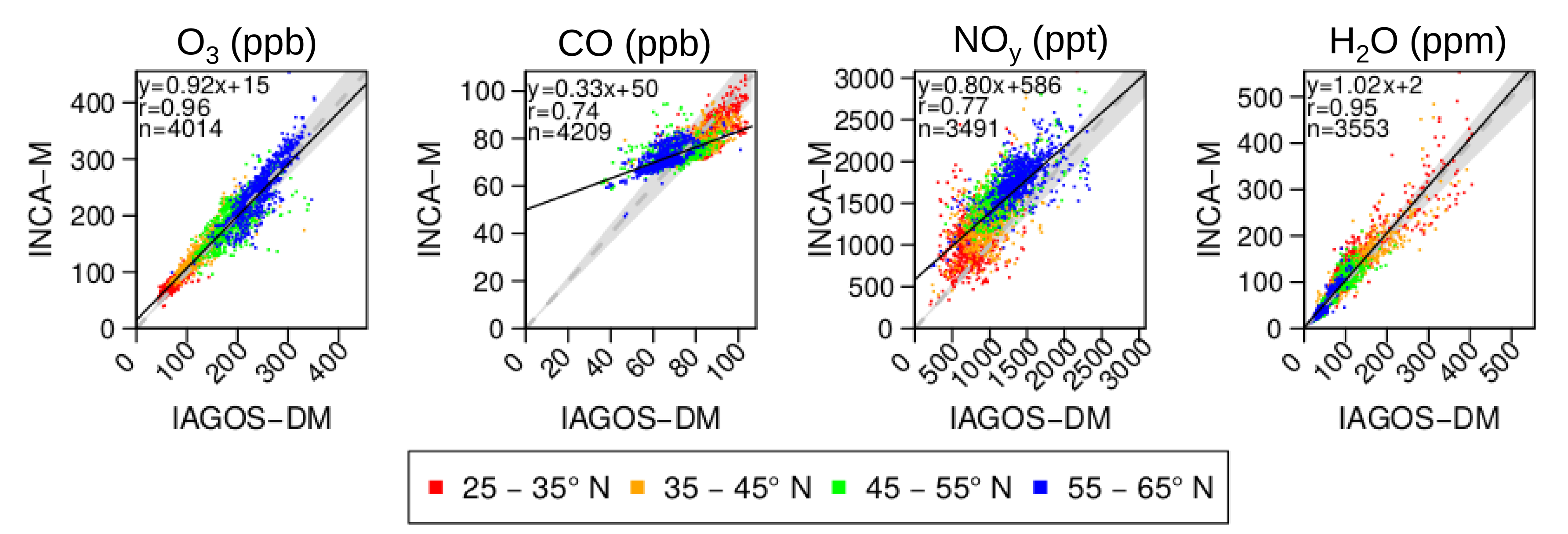


*Figure 4: Scatterplots comparing the model output to the gridded IAGOS data, in annual averages. The black line represents the linear regression fit.*

### 2. Tropical West Africa

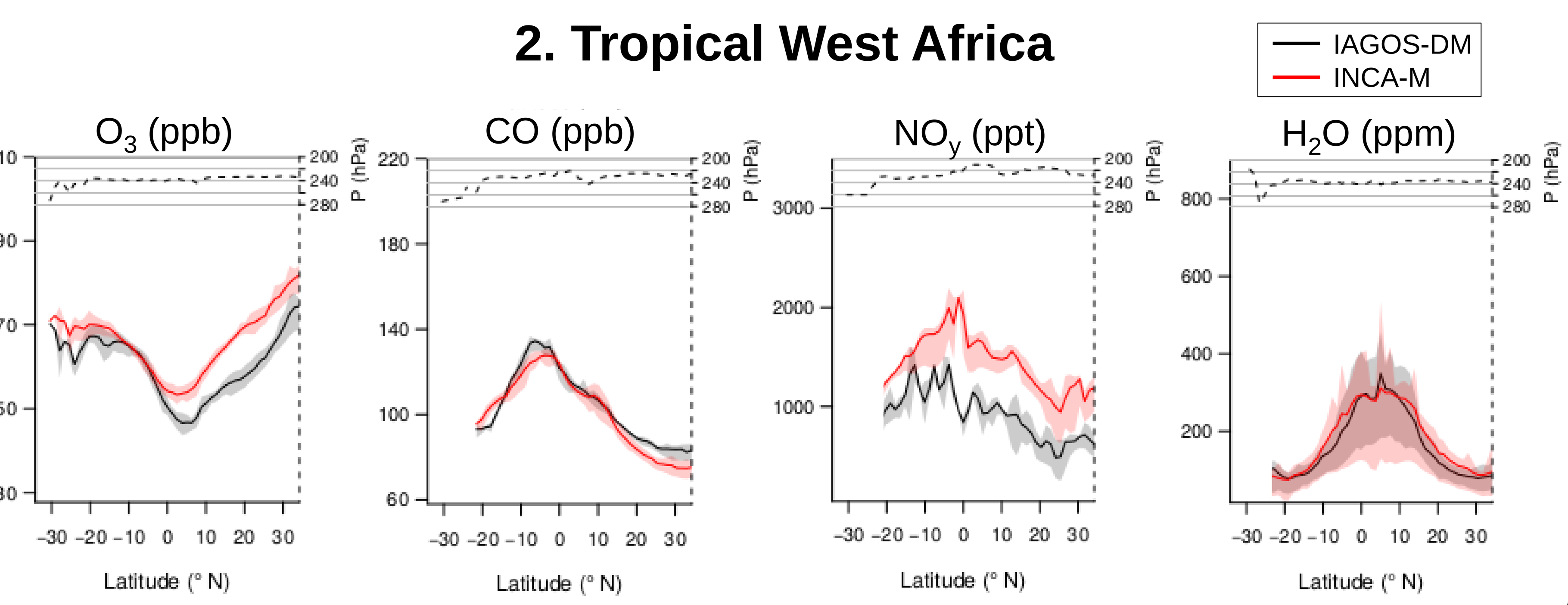


*Figure 5: Zonal cross sections as seen by IAGOS (black) and INCA (red) in the upper troposphere only, during the northern monsoon season (JJASO), in the (sub-)tropics between 5° W and 30° E, as defined in Lannuque et al. (2021, ACPD).*

## Results and conclusions

**1. Northern extra-tropics**

- $O_3$ and $H_2O$: Very good correlations and linear regression coefficients
- CO: Geographical variability underestimated (overestimated low CO values)
- $NO_y$: Mostly overestimated

**2. Tropical West Africa (during the summer monsoon season)**

- Good representations of CO and $H_2O$ ➔ ITCZ well represented
- $NO_y$ highly overestimated, probably because of an overestimated flash rate density
- Realistic $O_3$ south from the ITCZ, but positive bias in the north ➔ too much production during the transport, consistent with an excess in lightning $NO_x$

## Future prospects

- Investigate the role of lightning emissions on the comparisons ($NO_y$, $O_3$, OH ➔ CO)
- Sensitivity tests regarding several emission sources (e.g. in the frame of TOAR)
- Complementary study on the long-term trends in the extra-tropics
- Multi-model assessments against IAGOS (e.g. CCMI, ACACIA)
- Role of improved model vertical resolution: from 39 to 79 levels


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## References


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