



## Supplement of

# Evaluation of $O_3$ , $H_2O$ , CO, and $NO_y$ climatologies simulated by four global models in the upper troposphere–lower stratosphere with IAGOS measurements

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#### S1 Metrics used: definition

The modified normalized mean bias (MNMB) and the fractional gross error (FGE) are based on averages between relative mean biases. For a set of observed values  $(o_i)_{i \in [\![1,N]\!]}$  and a set of simulated values  $(o_i)_{i \in [\![1,N]\!]}$ , these two metrics are defined as:

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$$MNMB = \frac{2}{N} \sum_{i=1}^{N} \frac{m_i - o_i}{m_i + o_i}$$
 (S1)

and

$$FGE = \frac{2}{N} \sum_{i=1}^{N} \left| \frac{m_i - o_i}{m_i + o_i} \right| \tag{S2}$$

Consequently, the same relative bias for a poor-ozone and a rich-ozone air mass has the same weight in the resulting MNMB. From these definitions, and assuming that  $m_i$  and  $o_i$  are always positive, we can also derive the following property:

$$10 \quad |MNMB| \le FGE \le 2 \tag{S3}$$

The FGE thus represents a boundary for the MNMB. The MNMB absolute value equals the FGE when all the individual biases  $m_i - o_i$  have the same sign.

Last, the Pearson correlation coefficient is defined as:

$$r = \frac{1}{N} \frac{\sum_{i=1}^{N} (m_i - \bar{m})(o_i - \bar{o})}{\sigma_m \sigma_o}$$
(S4)

15 where  $\bar{m}$  and  $\bar{o}$  are the mean values and  $\sigma_m$  and  $\sigma_o$  their respective standard deviations.

#### S2 Mean pressure relative to the tropopause



### O<sub>3</sub> – Whole year

**Figure S1.** Yearly horizontal distributions in the pressure difference between IAGOS ozone data and the model tropopause, from December 1994 until November 2017, for the four models (from left to right), in the UT (bottom) and the LS (top).



**Figure S2.** Boxplots synthesizing the seasonal and yearly horizontal distributions in the pressure difference between IAGOS ozone data and the model tropopause, from December 1994 (January 2001 for OsloCTM3) until November 2017, for the four models (from left to right), in the UT (bottom) and the LS (top).



**Figure S3.** Boxplots synthesizing the seasonal and yearly horizontal distributions in the pressure difference between IAGOS  $H_2O$  data and the model tropopause, from December 1994 (January 2001 for OsloCTM3) until November 2017, for the four models (from left to right), in the UT (bottom) and the LS (top).



**Figure S4.** Boxplots synthesizing the seasonal and yearly horizontal distributions in the pressure difference between IAGOS CO data and the model tropopause, from December 2001 until November 2017, for the four models (from left to right), in the UT (bottom) and the LS (top).



**Figure S5.** Boxplots synthesizing the seasonal and yearly horizontal distributions in the pressure difference between IAGOS  $H_2O$  data and the model tropopause, from December 1997 (January 2001 for OsloCTM3) until November 2017, for the four models (from left to right), in the UT (bottom) and the LS (top).