Ice supersaturated regions: properties and validation of ERA-Interim reanalysis with IAGOS in situ water vapour measurements

EGU2020-9301

Philipp Reutter, Patrick Neis, Susanne Rohs, Bastien Sauvage, Peter Spichtinger and Andreas Petzold

Publication available at:
https://www.atmos-chem-phys.net/20/787/2020/
Motivation (i)

Cirrus clouds and their potential formation regions, so-called ice supersaturated regions (ISSRs), with values of relative humidity with respect to ice exceeding 100 %, occur frequently in the tropopause region. It is assumed that ISSRs and cirrus clouds can change the tropopause structure by diabatic processes, driven by latent heating due to phase transition and interaction with radiation.

For many research questions, a three-dimensional picture including a sufficient temporal resolution of the water vapour fields in the tropopause region is required. This requirement is fulfilled nowadays by reanalysis products such as the European Centre for Medium-Range Weather Forecasts (ECMWF) ERAInterim reanalysis.
Motivation (ii)

However, for a meaningful investigation of water vapour in the tropopause region, a comparison of the reanalysis data with measurement is advisable, since it is difficult to measure water vapour and to assimilate meaningful measurements into reanalysis products.

Here, we present an intercomparison of high-resolution in situ measurements aboard passenger aircraft within the European Research Infrastructure IAGOS (In-service Aircraft for a Global Observing System; [www.iagos.org](http://www.iagos.org)) with ERA-Interim.

Temperature and humidity data over the North Atlantic from 2000 to 2009 are compared relative to the dynamical tropopause.
Methodology

- Aircraft-based measurements of atmospheric state variables and chemical composition usually refer to the aircraft flight altitude or pressure level, respectively.

- In the present work, the humidity data will be separated relative to the tropopause height (dynamical tropopause @ 2 PVU) in order to study the humidity in the tropopause region.

- The vertical data will be distributed into three main layers: upper troposphere (UT), tropopause layer (TP) and lower stratosphere (LS) in accordance with Thouret et al. (2006). Furthermore, UT and LS are each separated into three subclasses (Table 1).

- Focus on the North Atlantic region (40 to 60° N and –65 to 5° E)

<table>
<thead>
<tr>
<th>Region</th>
<th>Short name</th>
<th>$p_{ap} - p_{tp}$ (hPa)</th>
<th>Number of measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowermost stratosphere</td>
<td>LS3</td>
<td>–90</td>
<td>3,203,483</td>
</tr>
<tr>
<td></td>
<td>LS2</td>
<td>–60</td>
<td>4,237,245</td>
</tr>
<tr>
<td></td>
<td>LS1</td>
<td>–30</td>
<td>5,268,138</td>
</tr>
<tr>
<td>Tropopause layer</td>
<td>TL</td>
<td>0</td>
<td>5,643,057</td>
</tr>
<tr>
<td>Uppermost troposphere</td>
<td>UT1</td>
<td>+30</td>
<td>4,649,883</td>
</tr>
<tr>
<td></td>
<td>UT2</td>
<td>+60</td>
<td>2,647,935</td>
</tr>
<tr>
<td></td>
<td>UT3</td>
<td>+90</td>
<td>909,120</td>
</tr>
</tbody>
</table>

Table 1: The data set is distributed into three main layers: the upper troposphere, tropopause layer and lowermost stratosphere. The outer layers are additionally subdivided into three sublayers. The distribution criterion is the pressure difference between aircraft pressure $p_{ap}$ and the tropopause pressure $p_{tp}$ with the range of ±15 hPa. Additionally, for every flight layer, the number of IAGOS measurements between 2000 and 2009 is presented.
**Results**

Comparison between IAGOS and ERA

**Vertical profile of temperature**

- As expected by definition, the tropopause layer shows the coldest mean temperatures, with 216.1 and 216.5 K for IAGOS and ERA, respectively.
- Overall, the comparison between IAGOS and ERA shows a very good agreement.

**Vertical profile of water vapour**

- The comparison between IAGOS and ERA shows a good overall agreement.
- A clear dependence of the distribution with height is visible. The lowest median values of the water vapour VMR are observed, as expected, in the uppermost layer (LS3). In contrast, the lowermost level (UT3) shows the largest mean values of the water vapour mixing ratio.
Results

Comparison between IAGOS and ERA

• Since cloud formation is governed by the relative humidity rather than the water vapour mixing ratio, the relative humidity with respect to ice RHi is investigated.

• The overall results show two different regimes. In the troposphere, up to the tropopause layer, the statistics cover the whole range of possible saturation values.

• In the tropopause layer, still a significant amount of the data is exceeding values of RHi > 100 %, both in the in situ data as well as in the ERA data set. However, the whisker in Figure indicates that ERA has less data points with a higher supersaturation compared to IAGOS.

• In the stratospheric layers, the median of the RHi values is decreasing strongly. However, ice supersaturation is still possible, especially in the lowest stratospheric layer (LS1). The statistics of ISSRs in higher levels provided by the ERA data set show clearly less occurrence of this feature compared to IAGOS.

• Since ISSRs are an important factor for the formation and lifetime of contrail cirrus (Kärcher, 2018), a good model representation of the abundance of ice supersaturation in this region is important for an adequate description of the Earth’s radiative budget.
Results

• For a more distinct look at the occurrence of ISSR, we illustrate the statistic evaluation with cumulative probability.

• Each layer is depicted with its own colour. It is clearly visible that ERA and IAGOS behave differently for RHi > 100 %, especially for the tropospheric layers.

• ERA deviates from the IAGOS measurements concerning values larger than RHi = 100 % by showing less data points and weaker supersaturations.

• This is an important finding, because it points to a misrepresentation in ERA of ice supersaturation in the UT and tropopause region, which is the formation region of in situ cirrus.

Cumulative distribution of RHi for every height level in the IAGOS (a) and ERA (b) data sets. The vertical blue line denotes saturation with respect to ice.
more and detailed information can be found in the recently published manuscript:

Ice supersaturated regions: properties and validation of ERA-Interim reanalysis with IAGOS in situ water vapour measurements
Atmos. Chem. Phys., 20, 787–804, 2020
https://doi.org/10.5194/acp-20-787-2020
© Author(s) 2020. This work is distributed under the Creative Commons Attribution 4.0 License.

https://www.atmos-chem-phys.net/20/787/2020/

unless otherwise indicated, all figures and tables from Reutter et al., 2020