The Cell Temperature of ECC Ozonesondes in Relation to the Measured Pump Temperature: Impact of Freezing and Boiling Effects on Long-Term Ozone Observations with Ozonesondes

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Motivation & Research Question

- Ozonesondes, launched with weather balloons, measure the ozone concentration through an electric current generated in the external circuit of an electrochemical cell.
- The current is directly related to the uptake rate of ozone in the sensing solution in the cells, provided that the flow rate and the temperature of the pump (T_{pump}), which bubbles the air in the sensing solution, are known/measured.
- Freezing or boiling of the sensing solutions negatively impacts the conversion of ozone into the measured cell current, underestimating the measured ozone concentrations.
- A proper cell temperature (T_{cell}) and its monitoring can be an important quality indicator.

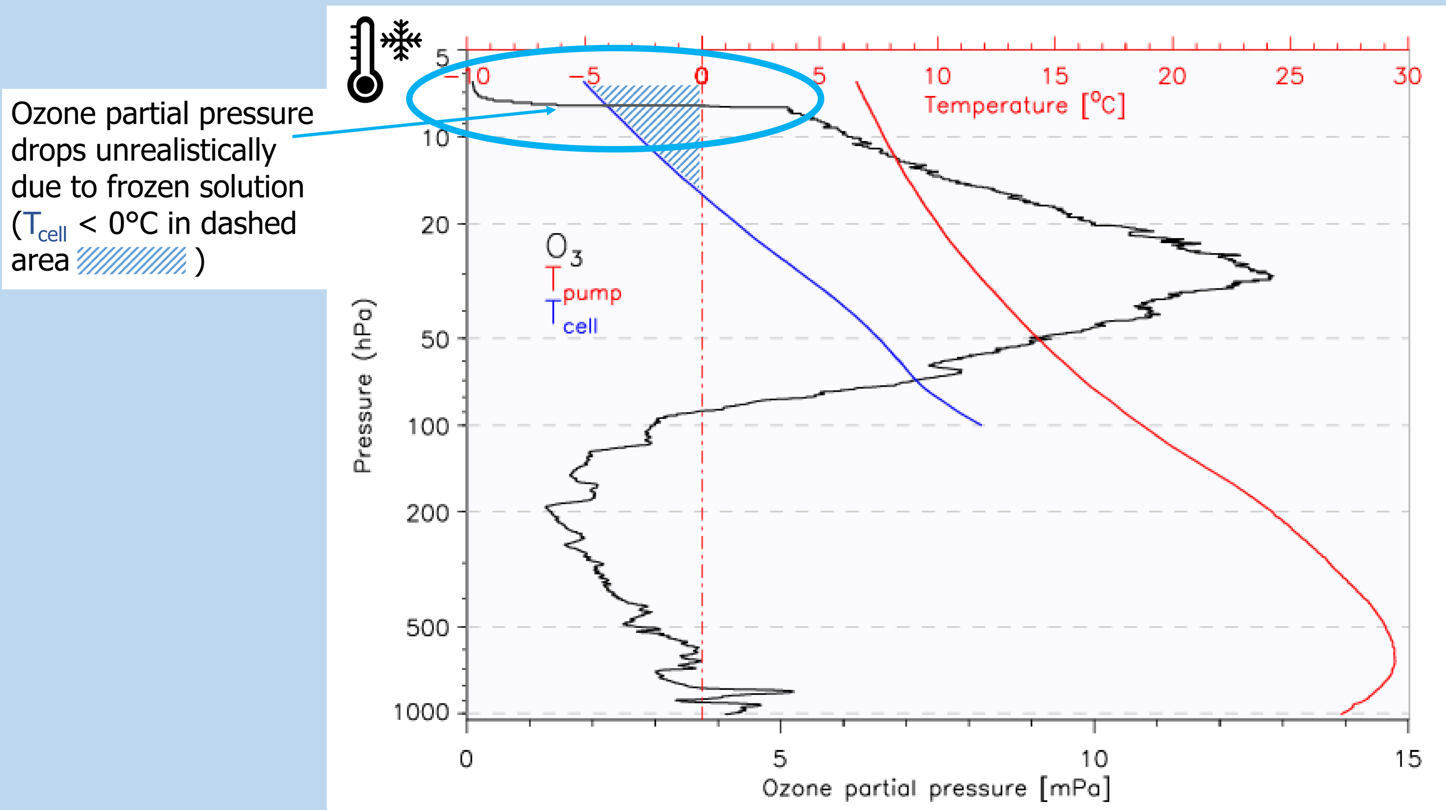
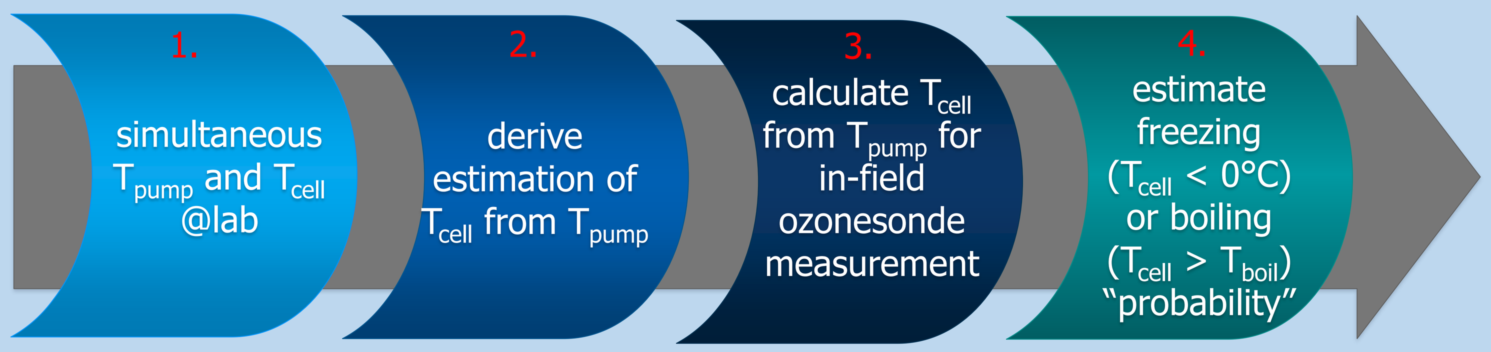


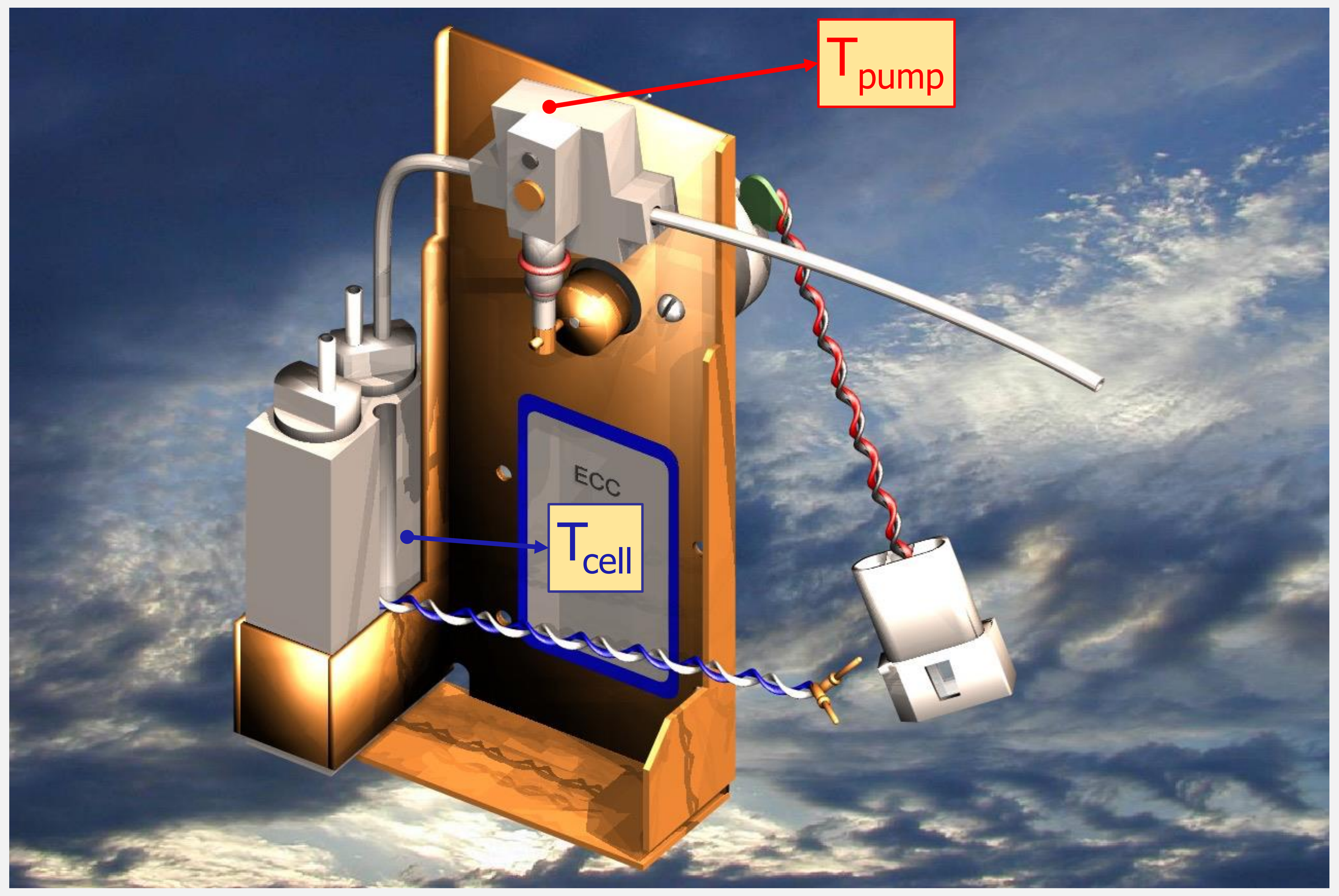
Fig. 1: Uccle (Belgium) ozone sounding on 2 October 2023, showing the measured ozone partial pressure (black) and pump temperature (red), and the derived cell temperature (blue) for P < 100 hPa.

Methodology



1. Simultaneous measurements of the pump and cell temperature of ozonesondes at different labs (World Calibration Centre for Ozonesondes in Jülich, MeteoSwiss in Payerne, Japan Meteorological Agency)
2. From those samples, estimate the relationship between cell temperature and pump temperature as a function of pressure, for different ozonesonde types.
3. Use this relationship to calculate the cell temperatures from the measured pump temperatures for each ozonesonde profile measured at a station.
4. Compare those generated cell temperatures with the freezing and boiling temperatures as a function of pressure, and calculate for each profile metrics that describe the probability of freezing and/or boiling of the sensing solution at the high-altitude levels of the profile.

Ozonesonde pump temperatures should be kept in an optimum range to avoid either freezing or boiling of the chemical solutions in the cells at low atmospheric pressures!



Lab results

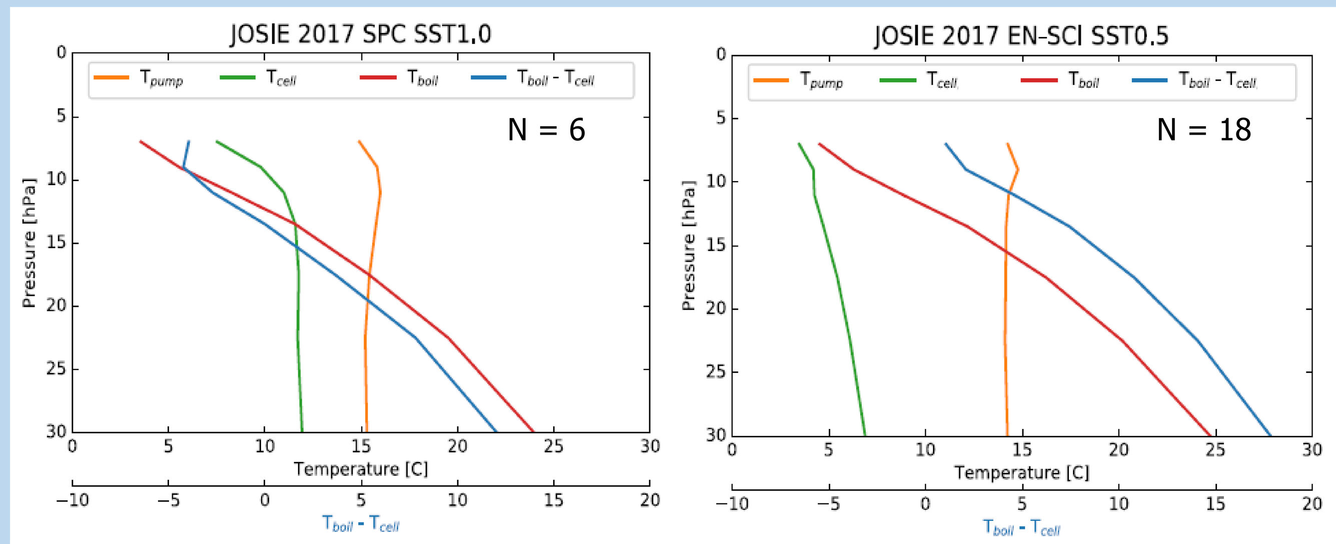


Fig. 2: Means of the simultaneous measurements of T_{pump} and T_{cell} for a sample of 6 Science Pump Corporation (SPC) ozonesondes and 18 Environmental Science (EN-SCI) ozonesondes during the Jülich Ozonesonde Intercomparison Experiment (JOSIE) campaign in 2017. Only measurements at pressure ranges lower than 30 hPa are shown. The calculated iboiling temperature T_{boil} is also drawn, as a function of the air pressure P.

- The cell temperature T_{cell} is significantly lower than the pump temperature T_{pump} : around 3-5°C for SPC, and around 7-10°C for EN-SCI for P < 30 hPa.
- The differences between both ozonesonde types are due to instrumental design: more efficient heat exchange between metal pump frame and (embedded: SPC) Teflon cells for SPC.
- As a consequence, SPC ozonesondes are more susceptible to boiling (T_{cell} > T_{boil} for P < 14 hPa in Fig. 2) than EN-SCI ozonesondes, the reverse is true for freezing.
- This is confirmed by the (mean) weight loss of the (cathode) sensing solution due to evaporation (or spraying out) during a simulation: 0.52±0.04 gr (EN-SCI) vs. 0.92±0.22 gr (SPC).
- From the graphs in Fig. 2, expressions are derived to estimate T_{cell} from T_{pump}, as a function of pressure, for SPC and EN-SCI ozonesondes separately.

Application to field ozonesonde data

- For ozonesonde station data records, we derive the cell temperatures from the pump temperatures, and estimate the boiling temperatures at the different pressure levels.
- For each ozone sounding, we estimate the (accumulated) percentage of a potentially frozen or boiled solution over all pressure levels P < 100 hPa.
- We analyze the time series of those percentages to link with e.g. abrupt changes in the total ozone content in the ozonesonde in comparison with a co-located or satellite overpass total ozone measurement.

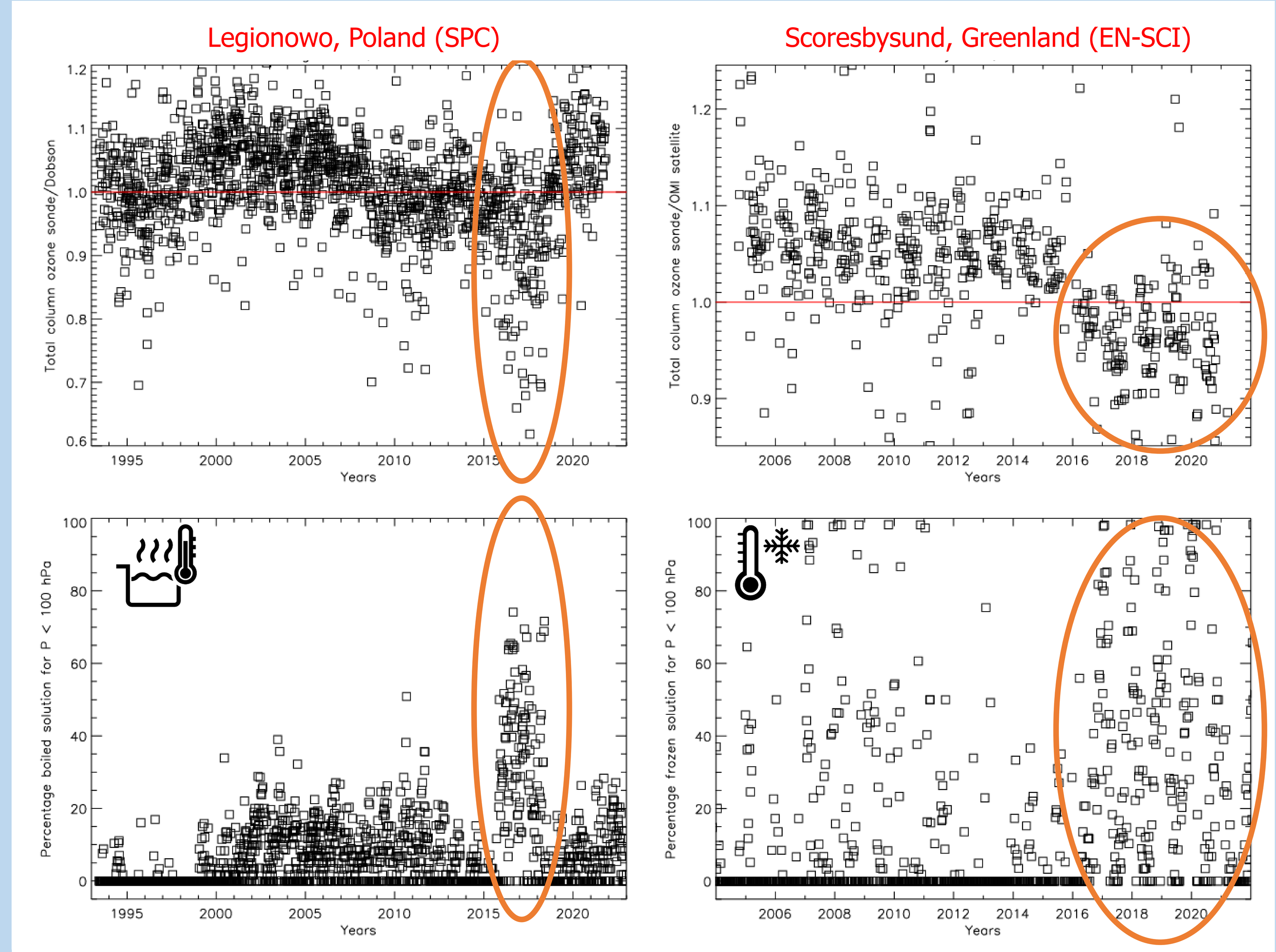


Fig. 3: Upper panels: Time series of the ratio of the total ozone column (i) integrated from the ozonesonde profile and (ii) retrieved from a co-located Dobson (left) or OMI satellite overpass (right). Lower panels: Time series of percentages of potentially boiled (left) or frozen (right) sensing solutions for pressure levels P < 100 hPa. Left panels: Legionowo, Poland, right panels: Scoresbysund, Greenland.

- For both stations, a drop in the ratios of the total ozone columns (i.e. underestimation of the total column ozone by the ozonesonde) seems to be associated with a higher occurrence of either boiling (Legionowo, SPC ozonesondes) or freezing (Scoresbysund, EN-SCI) of the sensing solutions.
- Unclear what caused the change of pump temperature characteristics during these periods (hardware? operating procedures?).
- Such changes will affect trends estimated from those ozonesonde time records!

Future work and further information

- Development of better and more appropriate metrics to detect potential freezing or boiling of the sensing solutions, based on the pump and cell temperatures.
- Such metrics can be used as Data Quality Indictors during the (near real-time) screening of vertical ozone profiles from ozonesondes.
- To avoid boiling, T_{pump} should be as low as possible, but to avoid freezing, T_{cell} >> 0°C. Therefore: T_{pump} > 5°C (SPC) and > 10°C (EN-SCI).

FOR MORE INFORMATION: