The ice problem in Sciamachy: Origin and solutions

By Ruud Hoogeveen

- Water/ice in Scia can give rise to:
  - Change in the etalon effect caused by the SiO_2 protective layer of Ch 1 - 5 detectors, as in GOME. This can lead to radiometric errors (up to 6% in GOME).
  - Absorption due to bulk ice layer.

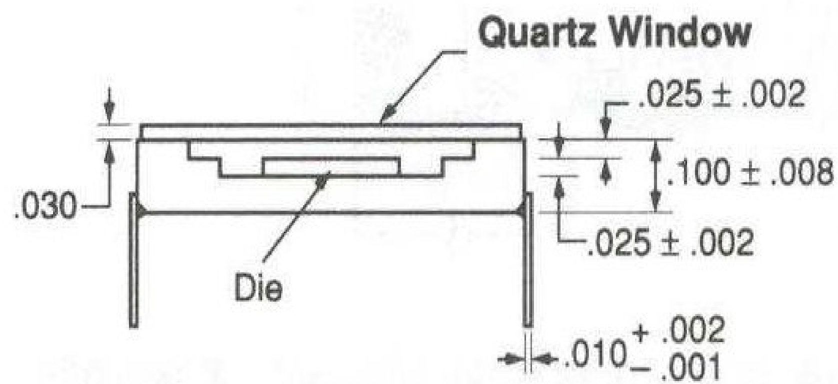
What cause the etalon?

- On the Si light-detecting material of the Scia Ch 1 - 5 detectors, there is a 2-3 micron layer of SiO_2.
- The reflection of the vac-SiO_2 I/F interferes with the SiO_2-Si I/F.
- Depending on λ and SiO_2-layer thickness, this is positive or negative interference, resulting in a modulation of the instrument response (afo λ).
- With ice-condensation, the modulation pattern shifts, resulting in an etalon in ratios of WLS spectra.

- Observed in GOME:
  - Changing-etalon effect caused up to few % errors.
  - Ice layer on the order of 5 nm.
  - Etalon changed every time detectors heated up after power down.

- Measures for SCIAMACHY:
  - Protective window on detectors
  - Application of a cold shield around detectors
  - Stable thermal environment

- Quartz window is
  AR coated on both sides.
- No etalon in the window.
- Condensation on window
  cannot cause an etalon.



- Small vent hole allows
  warm water vapor out, but no cold water vapor in
  due to cold shields around detector.

Observed changing etalon in Scia Ch 1-5

- Based on analysis of Günter Lichtenberg:
- During first cool-down etalon structures observed.
  - Due to ice growth?
  - Due to shrinkage of SiO_2 layer thickness or ?.
  - Due to change of index of refraction of SiO_2?
  - Due to shrinkage of Si light-detection layer, so that spectrum is projected on different pixels?
- With stable instrument last 3 options are excluded.
- After cool down, etalon is stable in time, indicating no ice grows on Ch 1-5.
- **Etalon problem as in GOME solved for Scia!!**

- Protective layer on InGaAs layer is $\lambda/4$, and thus AR coating, so no static etalon, and no changing etalon.
- Thick cold lens is part of FPA.
- Small vent hole in FPA to get rid of trapped water vapor after launch.

- For info: Ch 6 is at ~200 K, Ch 7/8 is at ~150 K.

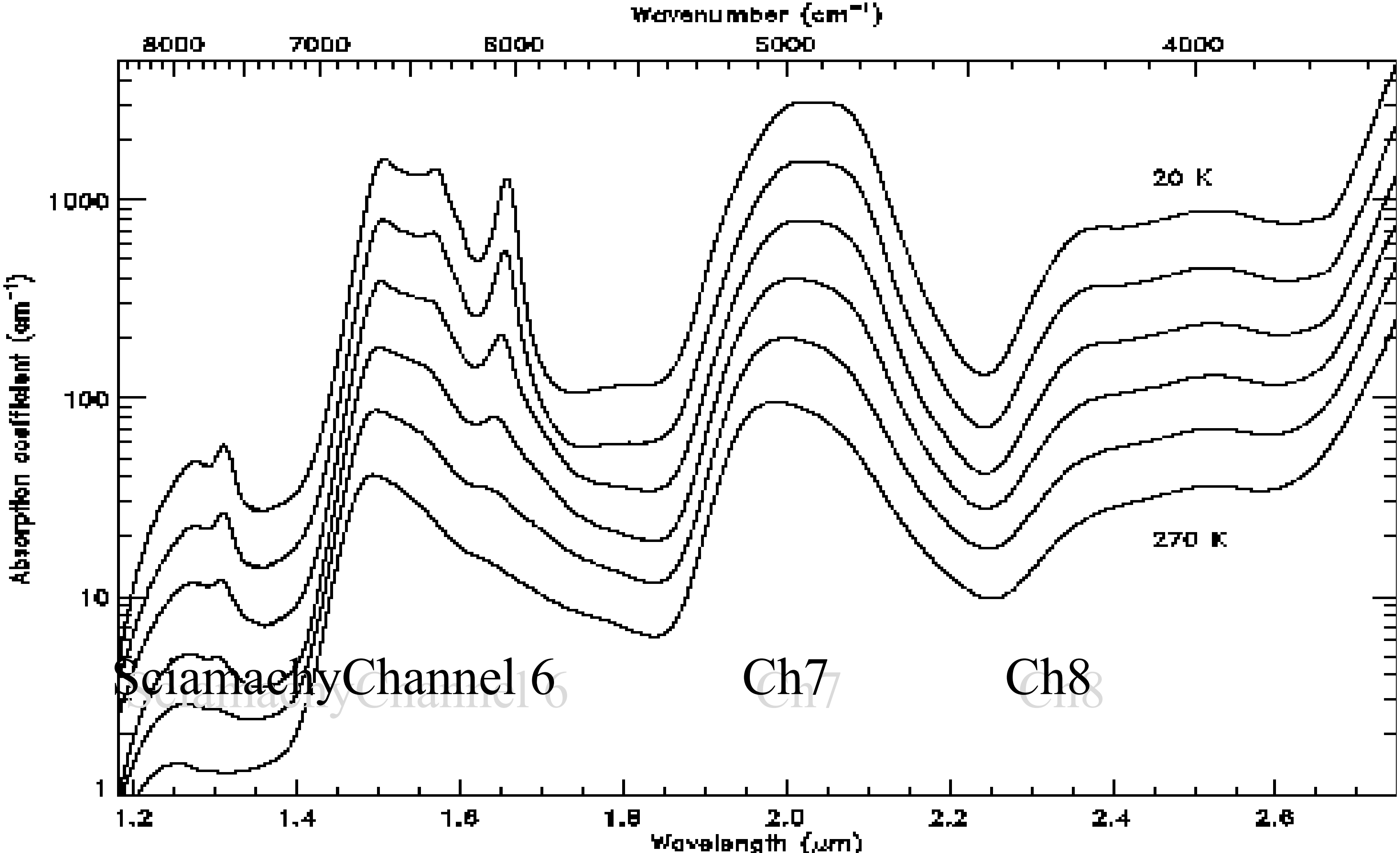
Observations for Ch 6 - 8

- After cool down, signal transmission of Ch 7/8 reduces in time (NOT Ch 6 !):
  - Order: 10 %/week.
  - Reduction larger in Ch 7 than Ch 8
  - Reduction largest in middle of array, less at edges.
  - Reduction looks like reduction of Ch 8 in OPTEC after vacuum leak.
- Ch 7&8 detector temps are not stable, but continuously increase in time.
- Decontamination is a reset to ‘nominal’ situation.

Most likely explanation

- Water vapor freezing on cold part of detector module, including outer surface of cold lens.
  - Signal reduction due to light absorption (see spectrum)
  - Layer thickness up to hundreds of microns.
  - Increase of emissivity/absorption of gold plated Al structure, leads to pick-up of thermal radiation of warm surroundings and thus increase in temperature.
  - Condensation point in Scia (i.e. vapor pressure) is below 200 K (Ch 6) and above 150 K (Ch 7/8)
  - Decontamination at 250 - 290 K easily blows off water.

Ice absorption spectrum



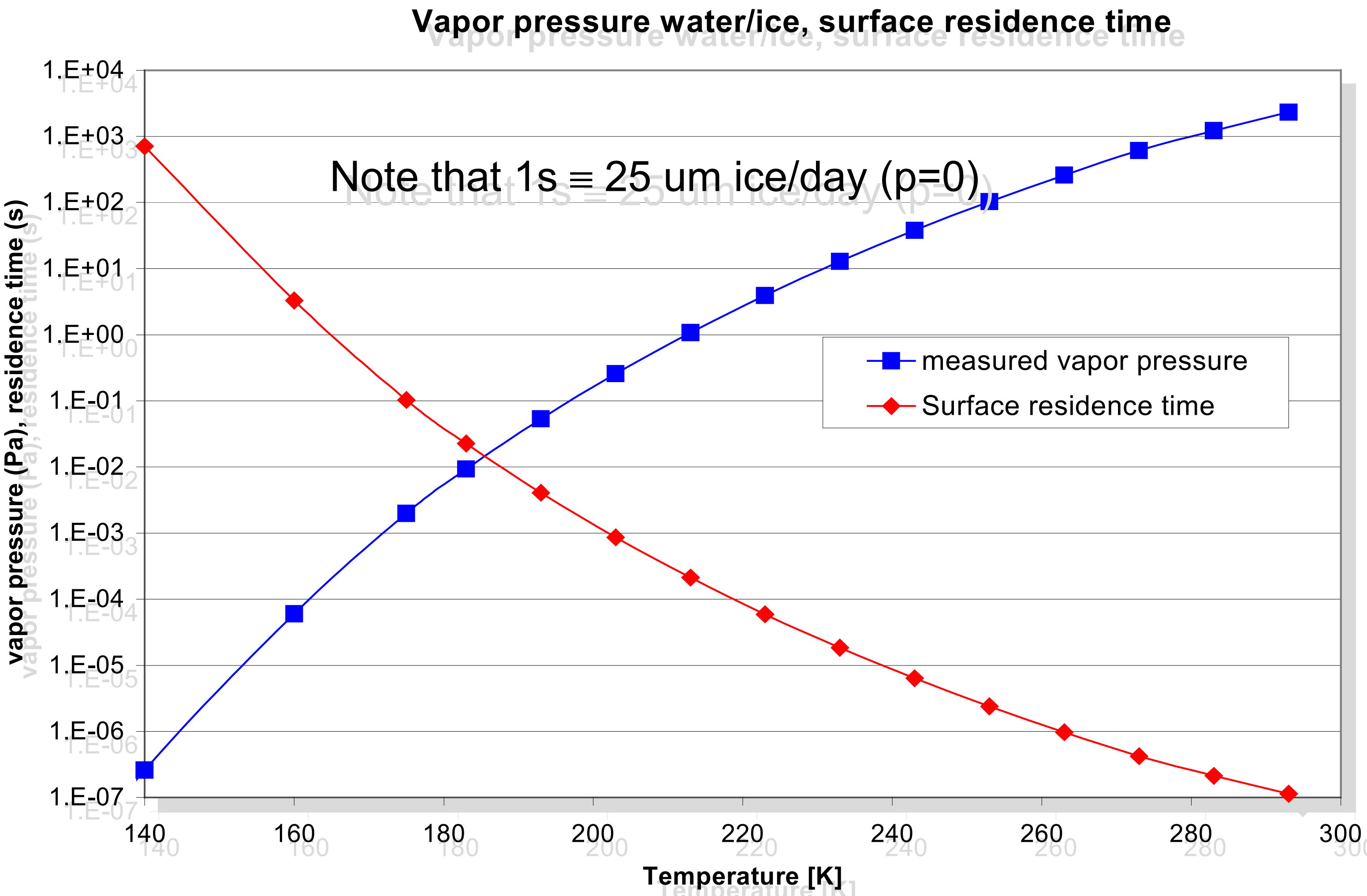
Origin of water

- Possible origins of water:
  - Scia instrument: Very unlikely, as we would have seen it in the OPTEC tests (cold for several months!)
  - Scia MLI, including 2 layers of water-absorbing kapton.
  - ENVISAT MLI, including kapton.
  - ENVISAT structure with Plastic Reinforced Carbon Fiber (few liters of water!).
- Current idea: Scia is okay, but MLI is as plastic bag around it, also trapping ENVISAT water vapor.
- Water vapor diffuses out of kapton and PRCF, time constant probably long (many months-years)

Possible measures

- Just wait! But how long? Years? No option!
- Decontaminate detectors AND instrument. Helps if only origin is Scia+Scia MLI. Speeds up diffusion, reduces vapor pressure inside MLI bag, possible below vapor pressure of 150 K. How many more decontaminations needed??
- Increase frequency of decontaminations
  - E.g., every 2 months, 7-10 days lost for special decont.
  - Use flash decontamination, only 2-3 days lost.
- Increase detector working temperature to above condensation point, so 160 K (170 K??).

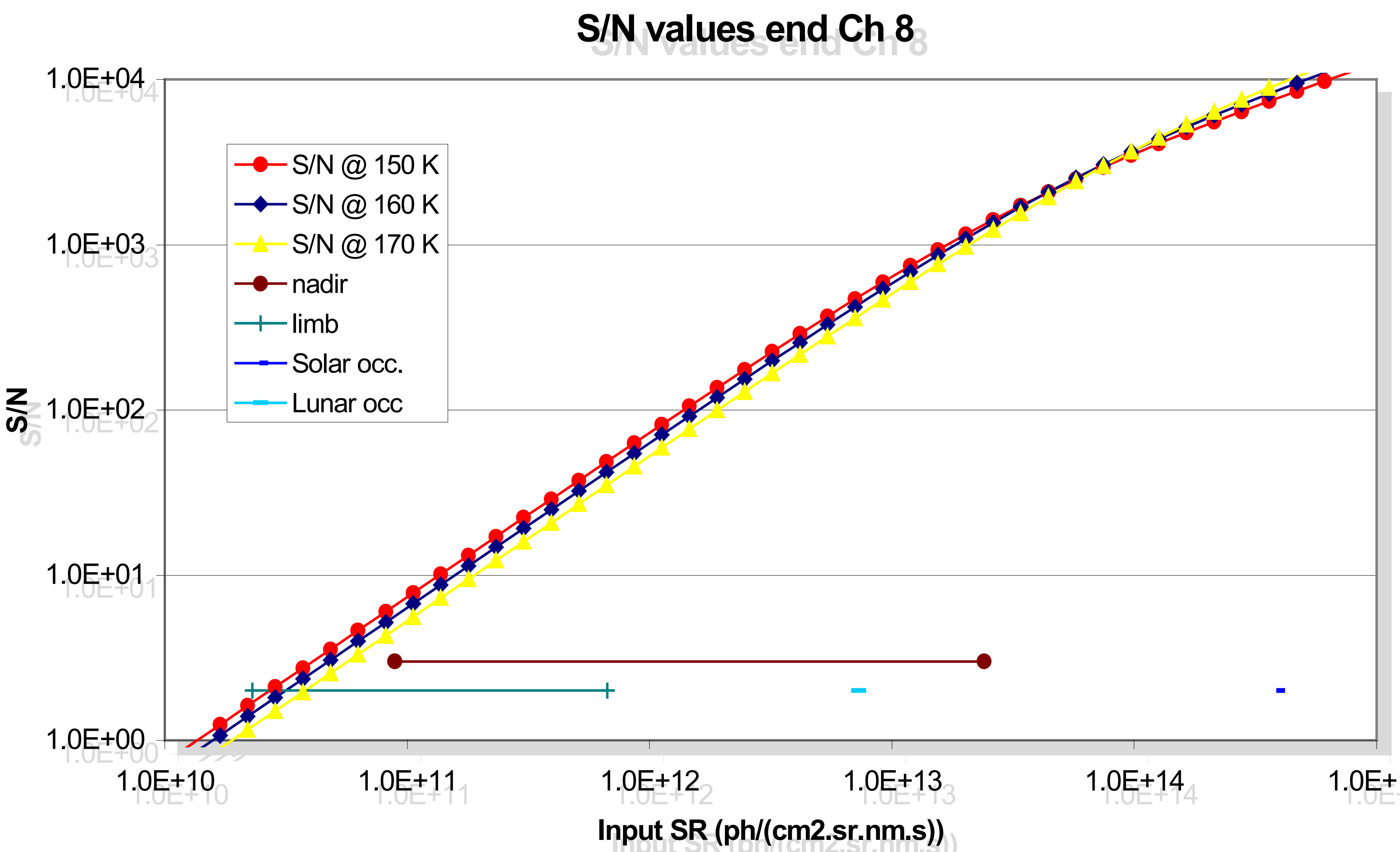
Water vapor pressure, surface res. time



Increased detector temperature

- 10 K corresponds to factor >10 in vapor pressure.
- If Tdet > condens. point, no ice, stable situation.
- S/N reduction for 10 K higher Tdet:
  - 35% in Ch 7 lowest input signals (no QE compens.)
  - 28% at begin and 14% at end Ch 8 (QE increase).
- Higher Tdet can be achieved by switching decont. heaters, so orbital variation in Tdet for Ch 1-8.
- First test to find condensation point was unsuccessful. Next try in December.

S/N versus Tdet, end of channel 8



- If Ch 7&8 remain at < 150 K:
  - DP should cope with reducing signals (~10%/week).
  - DP should cope with changing dark signals for Ch 7/8 (due to change in Tdet and due to ice-absorption of thermal background).
  - DP should cope with changing slit function by ice layer (TBC !!).
- If Ch 7&8 go to > condensation point:
  - DP should cope with 'large' orbital variation of detector temperatures of Ch 1-8.

Conclusion/summary

- Absolutely no problem in Scia's Ch 1 - 6.
- Ice problem in Scia's Ch 7&8, resulting in signal loss (now ~10%/week) and unstable temperature.
- Still under investigation, but several solutions are possible.
- Impact on data processor.

- **Good science with Ch 7&8 very well possible, but needs little more effort than foreseen.**