A FLEXIBLE AND ROBUST NEURAL NETWORK IASI-NH_3 RETRIEVAL ALGORITHM

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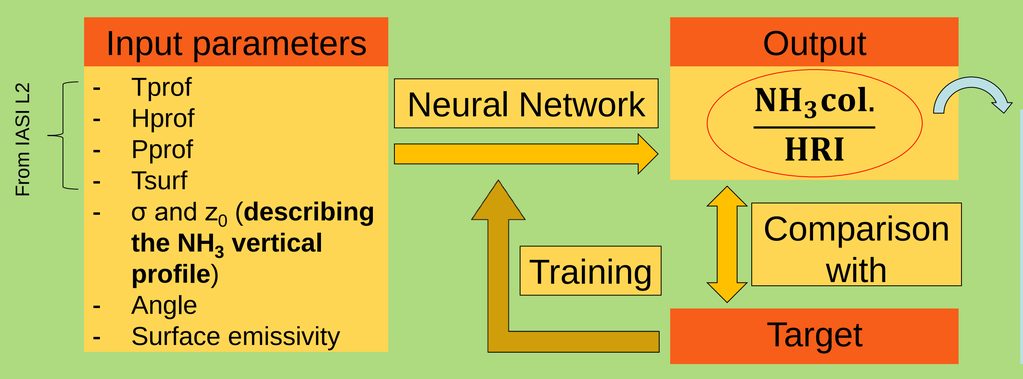
1- Introduction

- New method based on the calculation of **a spectral hyperspectral range index (HRI)** and subsequent conversion to NH_3 columns **via a neural network (NN)** [1].
- Extension of the HRI method presented in *Van Damme et al. (2014)* who used lookup tables (LUT) for the radiance-concentration conversion.
- The great strength of a NN lies in its ability to **cope with hundreds of input** parameters.
  - This offers a **lot more flexibility** than a two-dimensional LUT,
  - While **not requiring the expensive** and, in many cases, repetitive **calculation** of spectral fitting approaches.

2- Setup, Training and Evaluation

1. Construction of a **synthetic training set** using forward simulations with the Atmosphit line-by-line radiative transfer model.
2. **Training** of the Neural Network (Supervised learning):

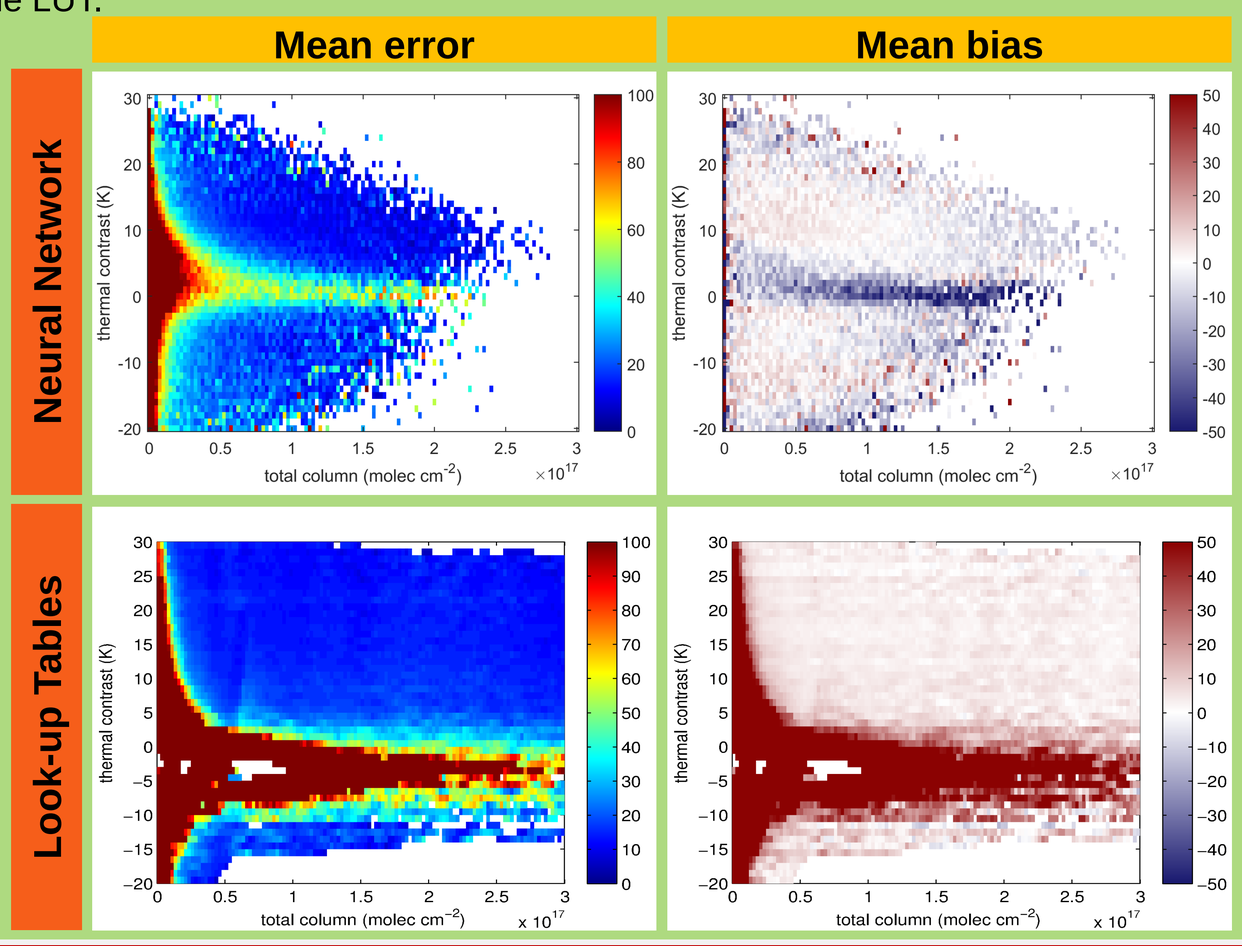


Uncertainty on the HRI translated in a linear way to the retrieved column. ⟹ Ensure a mean background close to zero.

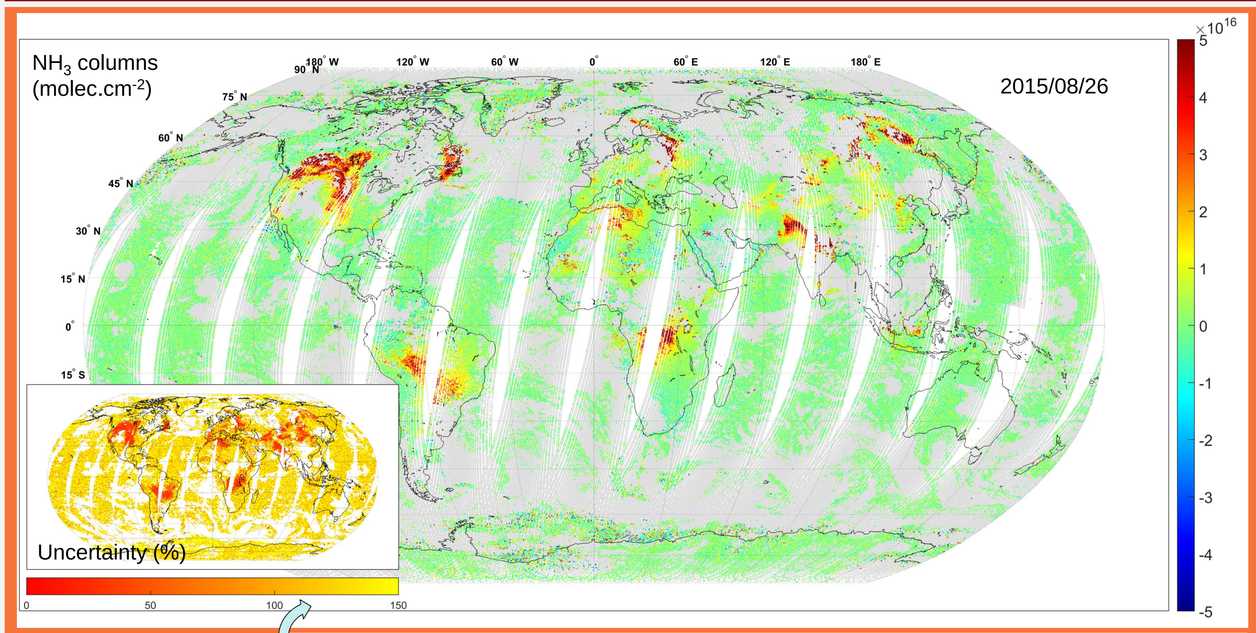
NH_3 col. = HRI x f(T,Tsurf,P,H_2O,σ,z_0,angle,surf. emissivity)

3. **Evaluation of the training**:

Calculation for the whole training set of the **mean relative error and bias** of the retrieved columns over the actual columns per bin of 1K of thermal contrast and 2.5x10^{15} molec.cm^{-2} of NH_3 column. Comparison with the mean error and bias for the LUT.

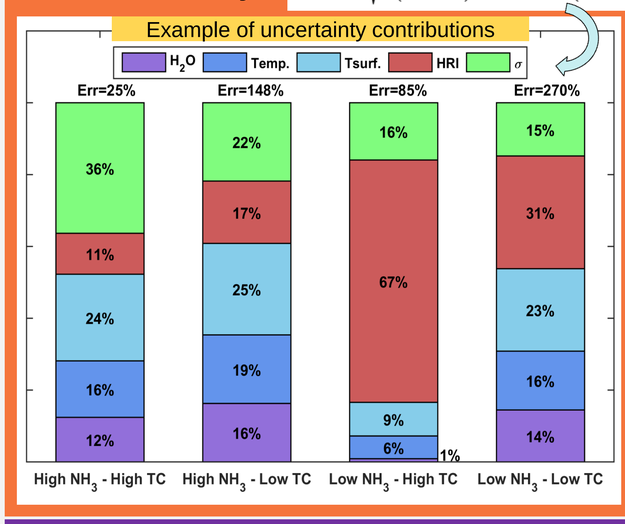


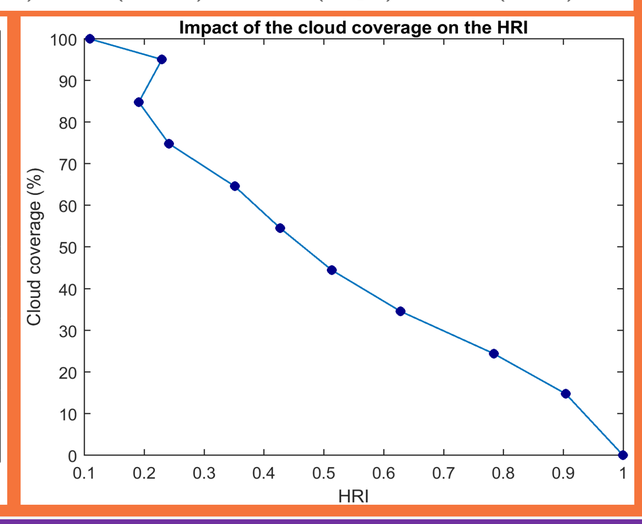
3- Retrieval and Uncertainty estimate



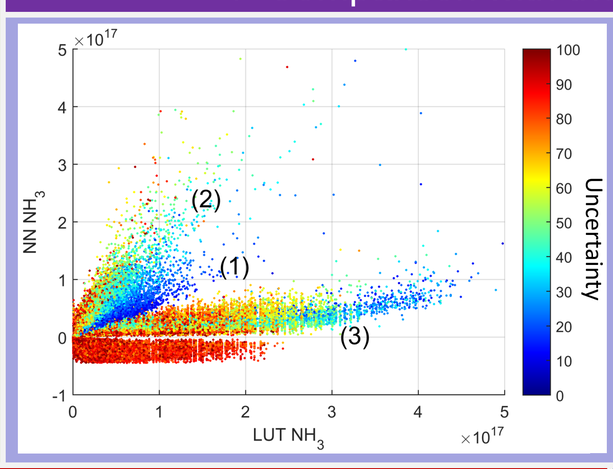
Estimation of the uncertainty:

$$s_{NH_3} = \sqrt{\left(\frac{\partial NH_3}{\partial HRI}\right)^2 s^2_{HRI} + \left(\frac{\partial NH_3}{\partial T}\right)^2 s^2_T + \left(\frac{\partial NH_3}{\partial Tskin}\right)^2 s^2_{Tskin} + \left(\frac{\partial NH_3}{\partial H_2O}\right)^2 s^2_{H_2O} + \left(\frac{\partial NH_3}{\partial \sigma}\right)^2 s^2_{\sigma}}.$$





4- Comparison with the HRI LUT-based method



1) High HRI and high thermal contrast (TC): Relative uncertainty below 25%. Excellent agreement between NN-based and LUT-based method.
2) High HRI and low positive TC: Relative uncertainty between 25-75%. NN columns > LUT columns.
3) Low HRI and low TC: NN columns << LUT columns. Reduction of the reported positive bias of the LUT.

5- Major strengths of the new IASI-NH_3 NN retrieval algorithm

Inherited from the LUT [2]

1. Computational efficiency
2. Full spectral range
3. Low dependency on forward model
4. No a priori information

Main advantages over the LUT

1. **Full atmospheric state** taken into account
2. **Full uncertainty analysis**
3. **Reduced bias**
4. **Flexible NH_3 vertical profiles**

Reference

[1] Whitburn, S., Van Damme, M., Clarisse, L., Bauduin, S., Heald, C.L., Hadji-Lazaro, J., Hurtmans, D., Zondlo, M.A., Clerbaux, C., Coheur, P.-F.: A flexible and robust neural network IASI-NH_3 retrieval algorithm., JGR (in revision), **2016**.

[2] Van Damme, M.,, Clarisse, L., Heald, C.L., Hurtmans, D., Ngadi, Y., Clerbaux, Y., Dolman, A.J., Erisman, J.W., Coheur, P.F.: Global distributions, time series and error characterization of atmospheric ammonia (NH_3) from IASI satellite observations, Atmos. Chem. Phys., 14, 2905-2922, doi:10.5194/acp-14-2905-2014, **2014**

6- Comparison with the GEOS-Chem CTM