An introduction to the GRUAN Processor

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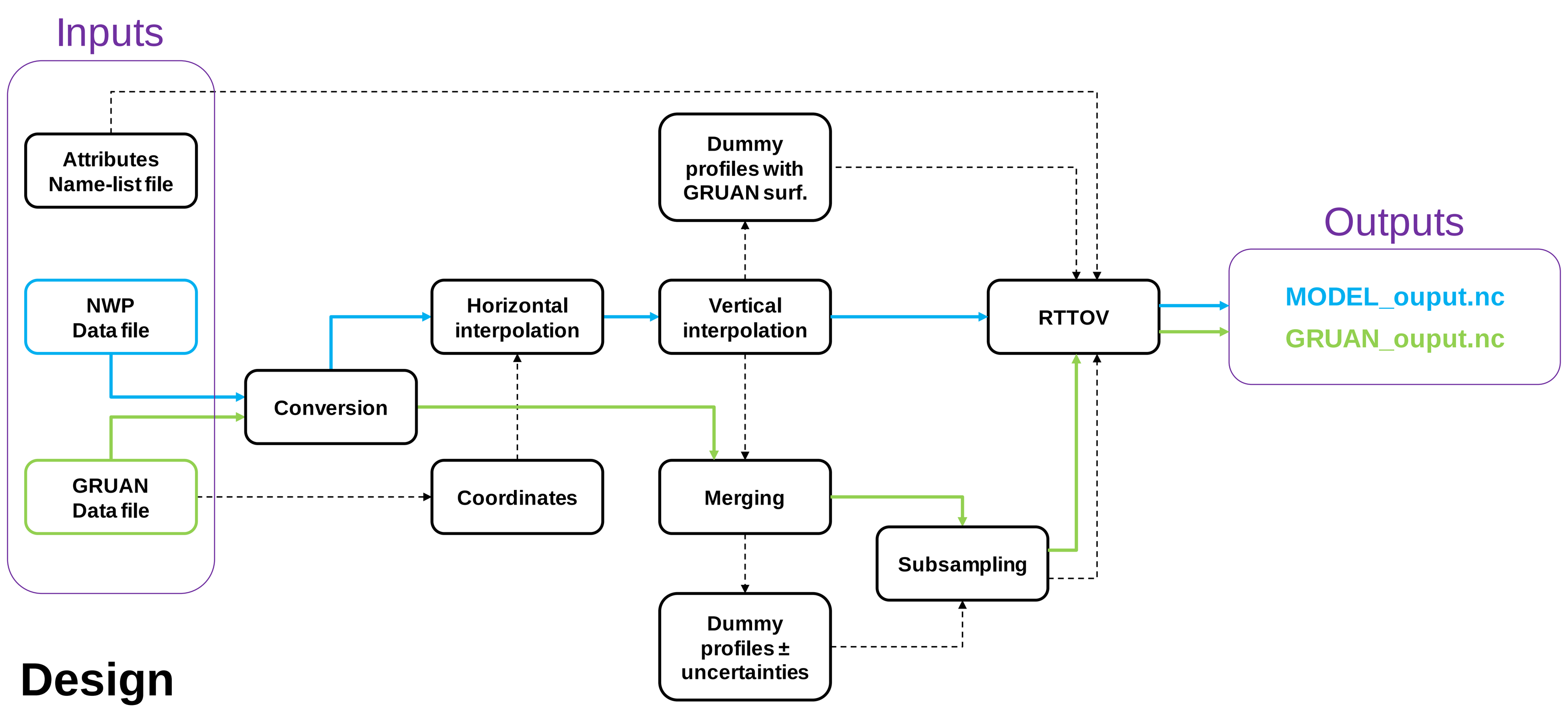
Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring

The characterisation of biases in satellite observations using Numerical Weather Prediction (NWP) models has become a mature technique over the past decade and has successfully been employed for the validation (or recalibration) of numerous instruments. However, although it is generally accepted that NWP uncertainties, in brightness temperature (BT) space, are about 0.1K for atmospheric temperature and 0.5-1K for humidity, no robust quantification has been conducted to date. The characterisation of uncertainties in NWP models is a major challenge that is addressed as part of the Horizon 2020 GAIA-CLIM project and the GRUAN Processor demonstrates how reference quality radiosonde data can be used to better understand and characterise model field uncertainties and how they can be propagated to uncertainties in simulated (L1B) radiances.

Background

NWP-based validations are typically done by comparing a set of observations to a NWP short-range forecast (i.e. m_{obs} - m_{NWP}). Consistency is achieved when this comparison satisfy : $|m_{obs} - m_{NWP}| < k\sqrt{\sigma^2 + u_{obs}^2 + u_{NWP}^2}$, where u_{obs} and u_{NWP} are the uncertainties associated to m_{obs} and m_{NWP}, σ the co-location/co-incidence uncertainty, and k a coverage factor representing the level of confidence required in the validation. The Met Office-led GAIA-CLIM work package 4 aims to estimate u_{NWP} accounting for radiative transfer modelling uncertainties, scale mismatch uncertainties, interpolation uncertainties, and NWP field uncertainties. The latter two components are derived from the GRUAN Processor.



Design

The GRUAN processor, based on EUMETSAT's NWPSAF RTTOV fast radiative transfer model and Radiance Simulator, is a collocation and radiance/BT simulation tool that allows the use of radiosonde observations to assess, both in observation and radiance/BT spaces, uncertainties associated with model data. Reference observations are provided by the GCOS Reference Upper-Air Network (GRUAN) which makes available Vaisala RS92 radiosonde measurements with traceable estimates of the measurement uncertainty and maximized data quality and continuity.

The schema (left) shows the processor top level design. Model fields are interpolated in time and space (horizontally) to match the radiosonde drift, and interpolated vertically on the processor fixed vertical grid (278 levels). In parallel, the radiosonde profiles are merged with those of the model to fill data gaps (e.g. above radiosonde ceiling), and sub-sampled on the processor fixed vertical grid. Model and radiosonde profiles, collocated and on the same vertical levels, are used to calculate top-of-atmosphere radiance/BT with RTTOV.

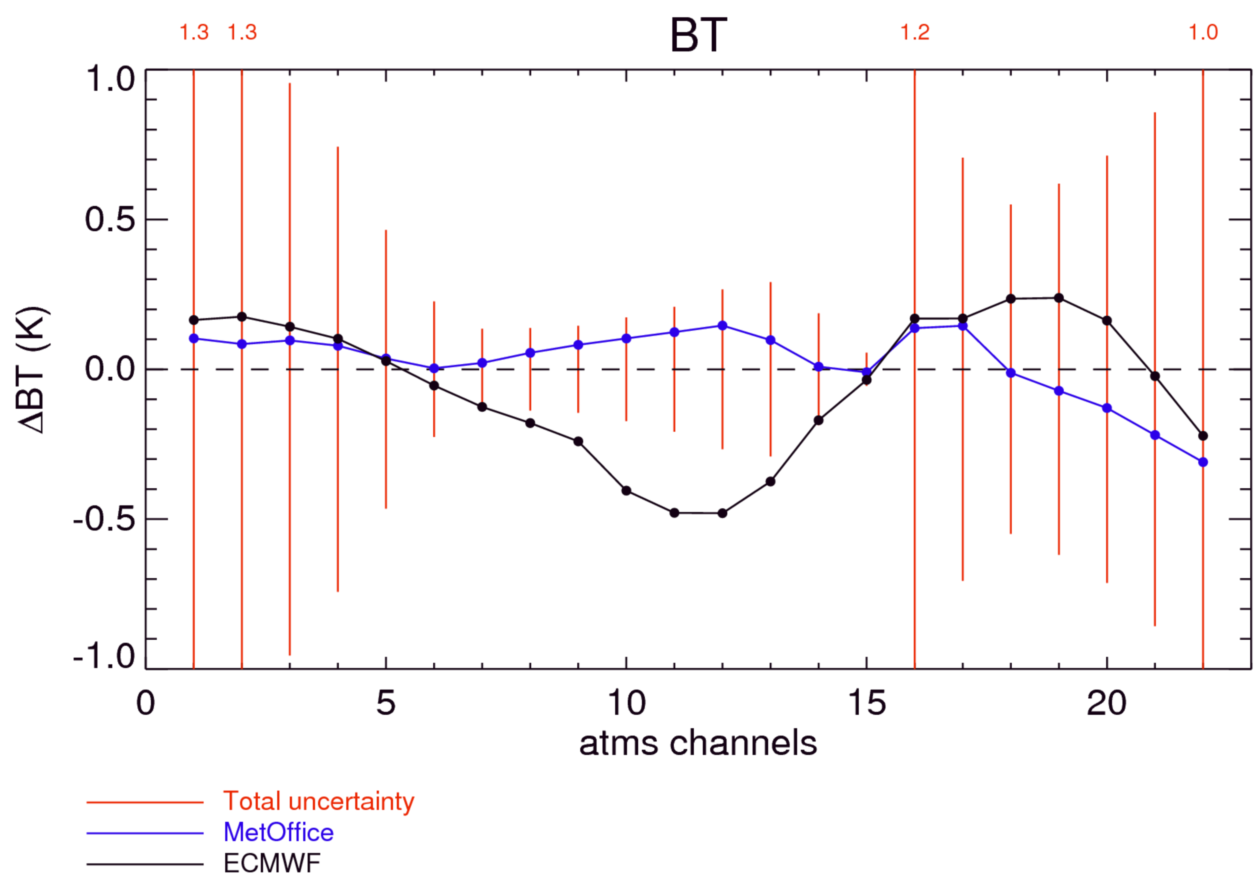
Still under development, the characterisation of the interpolation uncertainty, $\boldsymbol{\varepsilon}_{\text{int}}$, will allow the estimation of the standard deviation of the departure in predicted observations $\delta\mathbf{y}$:

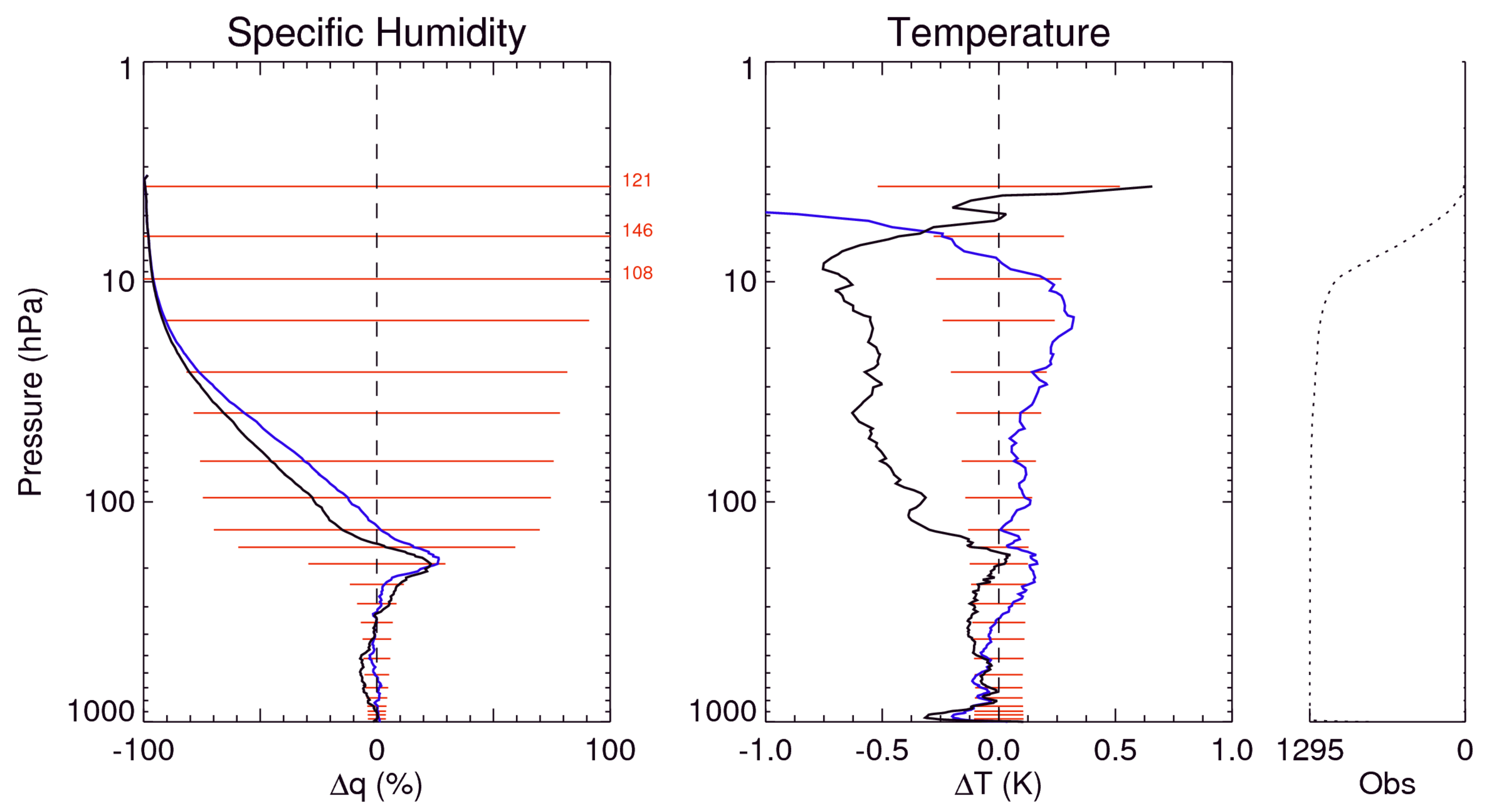
$$\delta\mathbf{y} \equiv \mathbf{y}_{NWP} - \mathbf{y}_{obs} \cong \mathbf{H}_{x_{obs}}^{t}(\mathbf{W}\boldsymbol{\varepsilon}_{NWP} + \boldsymbol{\varepsilon}_{\text{int}} - \boldsymbol{\varepsilon}_{obs})$$

where $\boldsymbol{\varepsilon}_{obs}$ and $\boldsymbol{\varepsilon}_{NWP}$ are the observation and model errors, and $\mathbf{W}$ the interpolation matrix. A sensitivity χ^2 test will be applied to $\delta\mathbf{y}$:

$$\chi_i^2 = (\delta\mathbf{y}_i - \overline{\delta\mathbf{y}})^T \mathbf{S}_{\delta\mathbf{y}}^{-1} (\delta\mathbf{y}_i - \overline{\delta\mathbf{y}})$$

to assess our estimation of NWP uncertainty.





Preliminary Results

GRUAN data from Lindenberg, Germany, 2013, has been processed along with model fields from the Met Office (blue) and ECMWF (black). The figures show, from left to right, the averaged departure from GRUAN observations (*NWP-GRUAN*) in simulated BT (K) at ATMS channel frequencies, in specific humidity (expressed in relative terms), in temperature (K), and the number of observations. Red bars show GRUAN uncertainty and total uncertainty propagated to BT space.

Using Met Office fields, temperature sensitive channels show departures within 0-0.1K in the troposphere (6-9), rising to 0.1-0.15K in the stratosphere (10-12). ECMWF fields show larger departure in those channels, down to -0.5K, mostly outside GRUAN uncertainty. Large departures in BT for ECMWF derive from ~0.5K negative departures in temperature (observation space) between 200 and 10hPa, not observed for the Met Office. Departures in humidity sensitive tropospheric channels (18-22) are within ±0.3K for both centres.

This work, consistent across different simulations both in the infra-red and in microwave domains, improves our knowledge of NWP uncertainty by providing an accurate channel-by-channel uncertainty characterisation.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640276.