Solar ultraviolet measurements in Aosta (Italy): an analysis of short- and middle-term spectral variability

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Key points

- ▶ A **general retrieval algorithm** for atmospheric (e.g. columnar ozone) and environmental (e.g. effective albedo) parameters from global solar irradiance spectra was developed;
- ▶ a **high-quality series** of global solar irradiance spectra was analyzed and compared with radiative transfer model estimates;
- ▶ a **new extraterrestrial spectrum** was employed and the residuals of the analysis are discussed.

Introduction

A high-quality series of ground-based solar ultraviolet measurements has been recorded since 2007 at the Environmental Protection Agency of Aosta Valley (Alpine Region, Northern Italy, 570 m a.s.l.). A **double-monochromator Bentham DTM300 spectroradiometer** (Fig. 1), equipped with a nearly-perfect cosine response diffuser, has been used to measure global irradiance spectra in the range 290-500 nm, on a 15-minutes basis. The uncertainty was fully characterized (Diémoz et al., 2010). **Comparisons against QASUME** show average differences within few percents (2% in 2007, 0% in 2009 and 0.5% in 2011).

Figure 1, the optics of the Bentham spectroradiometer used in this work (left) and the QASUME spectroradiometer (right) during an intercomparison in 2011.

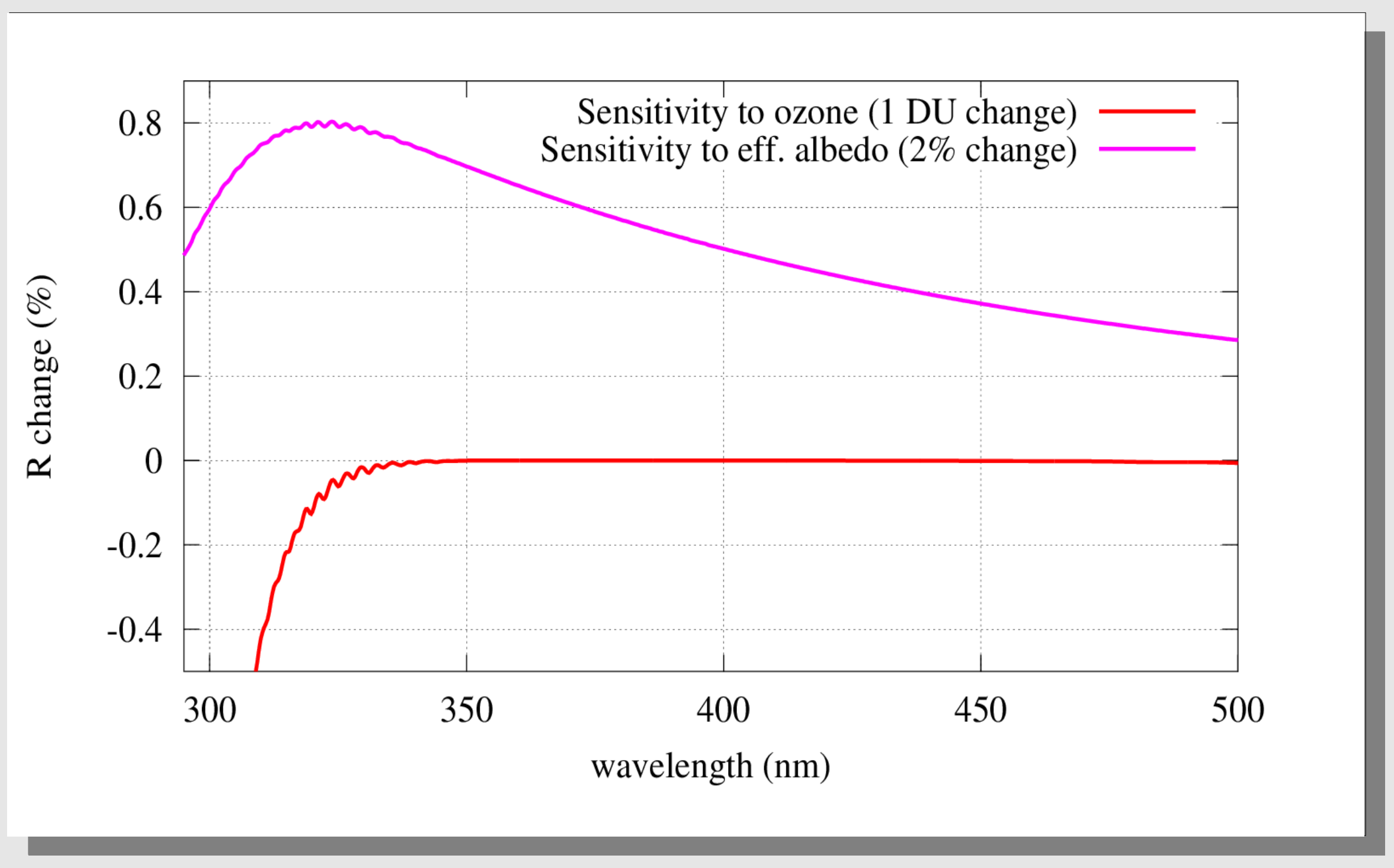


Figure 2, example of sensitivity functions for ozone (perturbation: 1 DU) and effective albedo (perturbation: 2%).

Retrieval algorithm

A **new retrieval algorithm**, based on the Gauss-Newton method, was developed to analyze the short- and middle-term variability of the series and the effects of the most influencing factors. The **ratio between a modeled** (libRadtran 1.6beta) **and a measured spectrum**, which depends on the model input parameters (or a reduced set of parameters), is **linearized**:

$$\mathbf{R}(\lambda) \equiv \mathrm{MOD}(\lambda, x_1, x_2, \ldots, x_n) / \mathrm{MEAS}(\lambda) \approx 1 + \mathbf{K}\,\Delta\mathbf{X}$$

K is the (uncertainty-weighted) Jacobian of the function **R** and **ΔX** is an estimate of the difference between the model parameters and the "true" values. The n^{th} column of matrix **K** represents the **spectral sensitivity** to parameter x_n (Fig. 2). ΔX is calculated using the least squares method (pseudoinverse, SVD algorithm) and then, since the model is not linear, the procedure is **iterated** until convergence. The covariance matrix between the parameters can be easily calculated from the measurement uncertainty since all operations are linear.

In the present work, the algorithm was used to retrieve the **total ozone column**, the **effective albedo** and a **constant factor**, which roughly takes into account any possible calibration offset and, more significantly, the cloud/aerosol opacity.

Retrieval results

The **total ozone column** retrieved from the UV irradiance was compared with measurements from a MKIV Brewer (Fig. 3). The deviations have a median of -1 DU and an inter-quartile range (IQR) of 6 DU in clear skies conditions (respectively -0.3 DU and 10 DU for all sky conditions). These values are comparable to the results obtained with similar algorithms using global irradiance spectra (Bernhard et al., 2003). A seasonal cycle in the retrieval-measurements deviation is clearly seen, which is probably due to the unknown ozone and aerosol profiles and their seasonal variations.

In the complex Alpine environment, the **effective albedo** is an important, and difficult to measure, parameter. The albedo retrieved during clear sky days was qualitatively compared with snow depth observations (at the two closest mountain stations to the measuring site) and snow coverage estimates from the MODIS satellite. The seasonal cycle of the retrieved effective albedo qualitatively agrees with observations. Spring and summer snowfalls on the mountains surrounding the valley site, even outside the local horizon, are clearly revealed by the algorithm (Fig. 4).

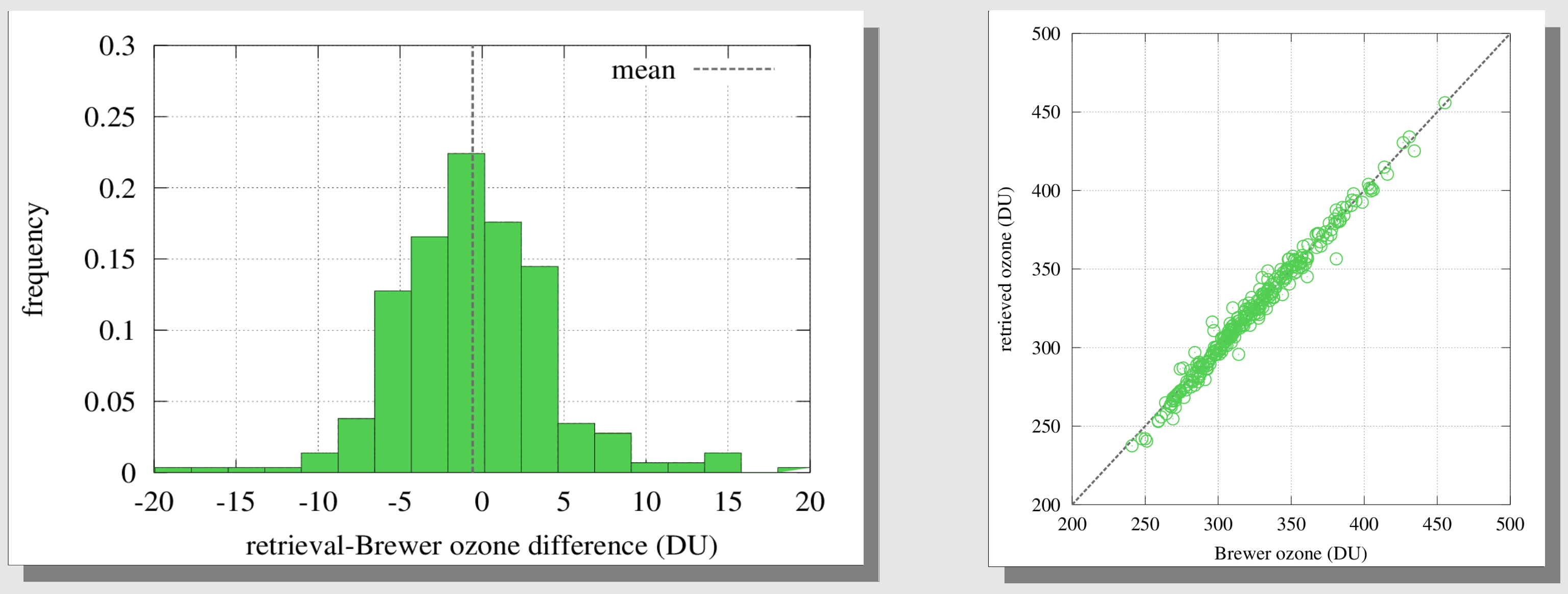
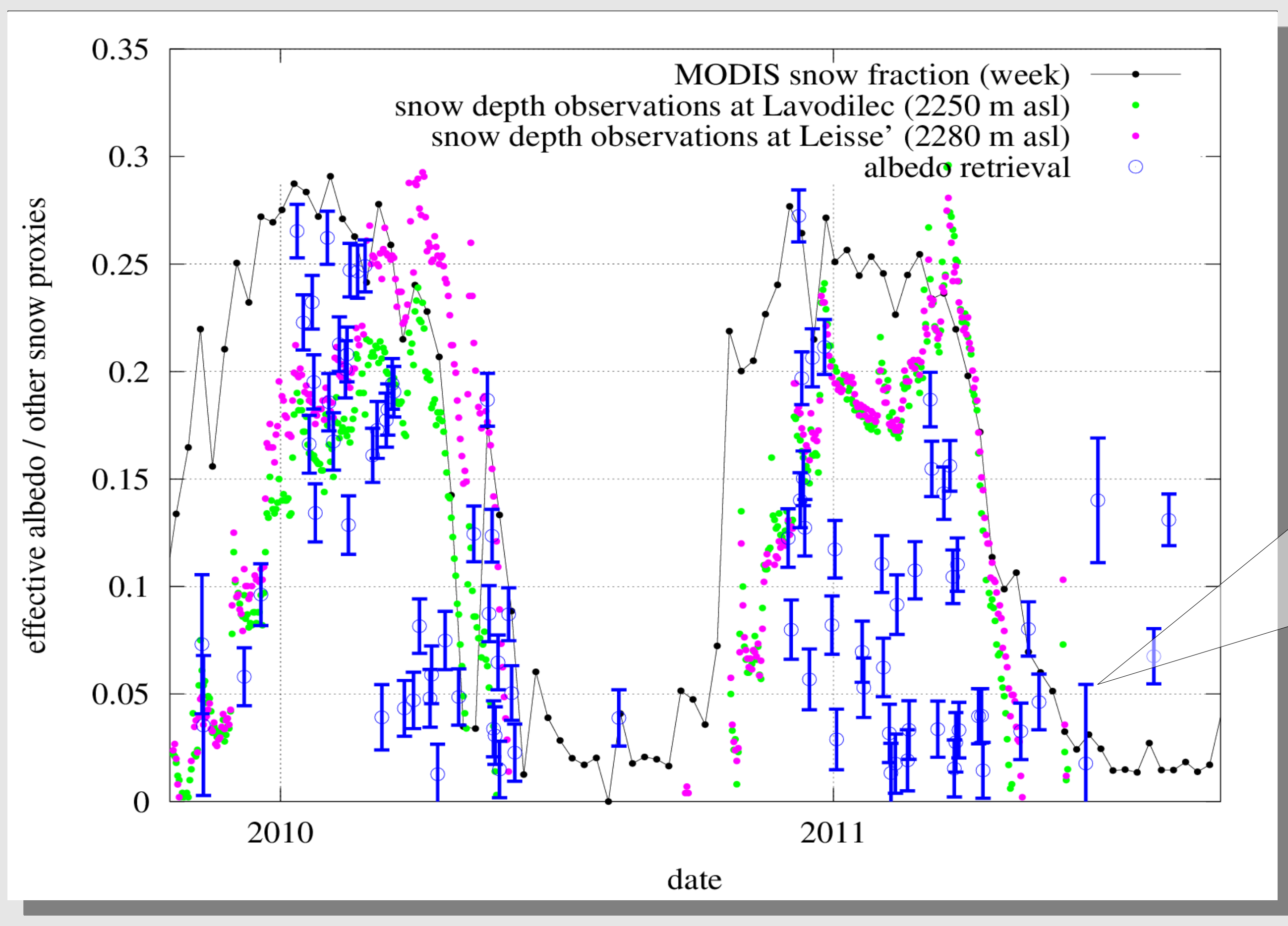


Figure 3, frequency distribution of the differences between the retrieved and measured ozone (left) and scatterplot of the retrieved and measured ozone values (right). Clear sky data are used for both charts.



Spring and summer snowfalls are clearly revealed by the algorithm.

Figure 4, retrieved albedo for years 2010 and 2011. Superimposed are the snow depth observations at the two nearest measurement stations and the MODIS snow fraction over the Aosta Valley. The proxy data were scaled to the effective albedo magnitude to allow visual comparison.

Extraterrestrial spectra

Several extraterrestrial spectra were used as input to the algorithm. The residuals are depicted in Fig. 5. Notably, the new spectrum **COKITHQA**, developed by the PMOD/WRC in the framework of the Joint Research Project "Traceability for surface spectral solar ultraviolet radiation" (EMRP ENV03), was tested. The residuals show that below 330 nm the variations are considerably higher than e.g. Atlas plus MODTRAN. Remarkably, a second band of high variations occur between about 420 and 440 nm.

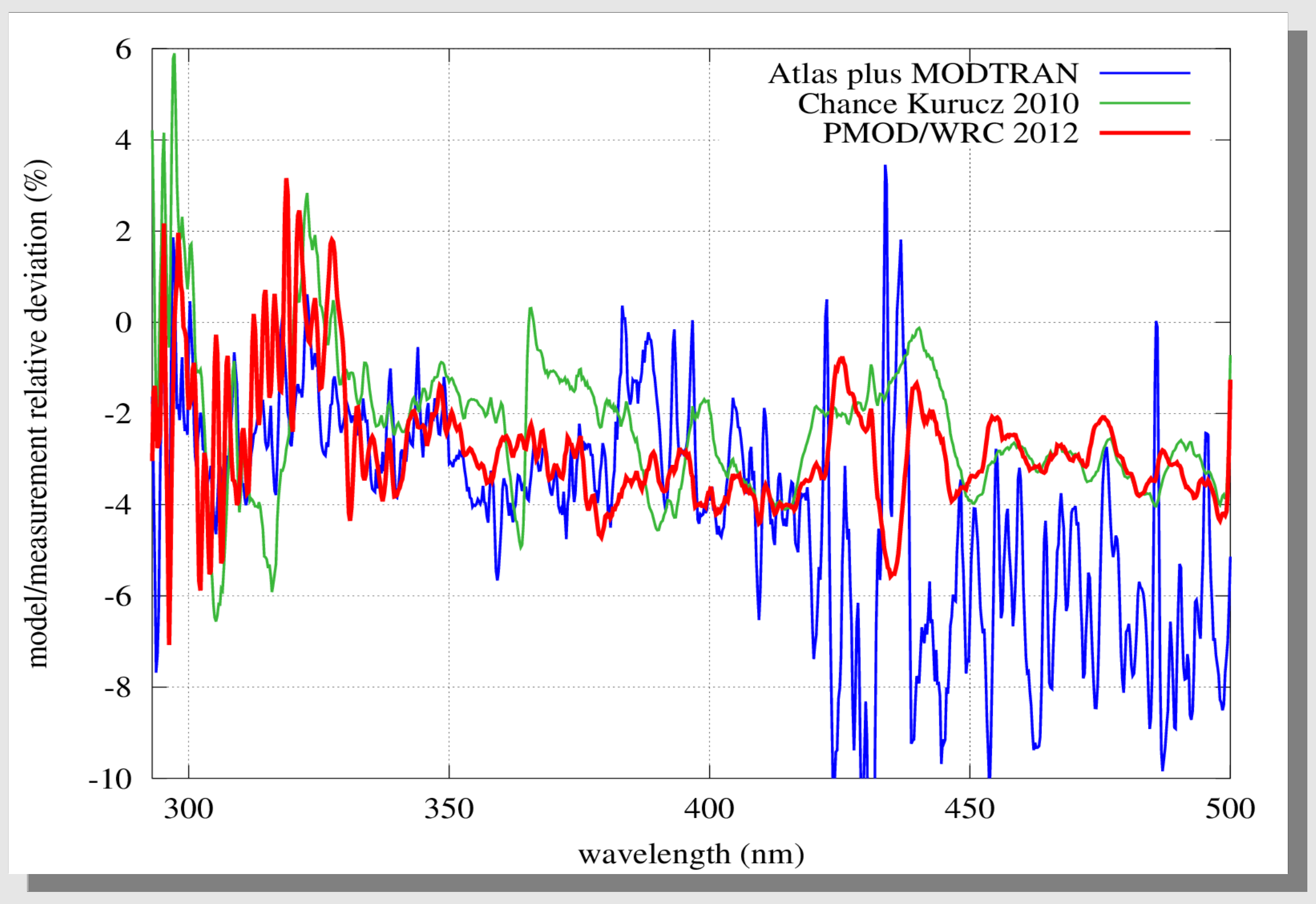


Figure 5, residuals from the analysis for clear sky measurements.