ASSESSMENT OF THE NEAR SURFACE SENSITIVITY OF THE FULL SPECTRUM INITATION (FSI)-WFM-DOAS RETRIEVAL OF CARBON DIOXIDE COLUMN

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ABSTRACT

Atmospheric CO_2 concentrations, have been successfully retrieved from spectral measurements made in the near infrared (NIR) by the SCIAMACHY instrument, using a new retrieval algorithm called Full Spectral Initiation Weighting Function Modified Differential Optical Absorption Spectroscopy (FSI WFM-DOAS). Initial results from the algorithm are promising with visible structure evident within the retrieved spatial distributions. There is a good correlation between the ΔCO_2 anomaly of the in-situ ground-based measurements and the equivalent anomaly of the SCIAMACHY retrieved columns. All measurements are for the year 2003.

1. INTRODUCTION

Since the launch of the SCIAMACHY instrument on-board ENVISAT there is the ability to measure total vertical columns of CO_2 in the near infrared (NIR) using a new retrieval technique called Weighting Function Modified Differential Optical Absorption Spectroscopy (WFM-DOAS) (Buchwitz et al, 2000). The WFM-DOAS method is based on fitting the logarithm of a linearized radiative transfer model plus a low-order polynomial to the logarithm of the ratio of a measured nadir radiance and solar irradiance spectrum as measured by the SCIAMACHY instrument.

An initial assessment of this algorithm's sensitivity, described in Barkley et al, (2006) discovered it is necessary to include suitable *a priori* information within the retrieval in order to constrain the errors on the retrieved CO_2 columns. Using this premise, a new CO_2 retrieval algorithm called Full Spectral Initiation (FSI) WFM-DOAS has been developed which generates a reference spectrum for each individual SCIAMACHY observation, based on the known properties of the atmosphere and surface at the time of the measurement. As the calculation of radiances is computationally expensive, FSI is not implemented as an iterative scheme rather each reference spectrum only serves as the best possible linearization point for the retrieval. Each spectrum is generated using the radiative transfer model SCIATRAN, using several different sources of atmospheric and surface data that serve as input, the details of which are described in full in Barkley et al, (2006).

The FSI algorithm is only applied to cloud free pixels, determined using a cloud detection method outlined in Krijger et al, (2005), with the retrieved CO_2 vertical column density (VCD) normalized using the input a priori surface pressure to produce a column volume mixing ratio (VMR). Only CO_2 VMRs where the retrieval (statistical) fitting error is less than 5% and which lay in a range 340-400 ppmv are used. To avoid various instrumental issues that have hampered retrievals in the NIR channels the raw SCIAMACHY spectra have been calibrated in-house with corrections applied for non-linearity effects, associated with analogue-to-digital converter, and also the orbit specific dark current. To improve the quality of the FSI spectral fits, the latest version of the HITRAN molecular spectroscopic database has been implemented in SCIATRAN. Unlike other studies, adjustment of the absolute columns values *via* scaling factors has not been necessary. The advantage of the NIR over the thermal infrared is the sensitivity to changes in the CO_2 concentration in the lowermost part of the troposphere. This is demonstrated by the FSI averaging kernels (Fig. 1) which peak in the planetary boundary layer indicating that the FSI algorithm is sensitive to changes in the CO_2 near the surface., (i.e. where the signatures of carbon cycle surface fluxes are most evident).

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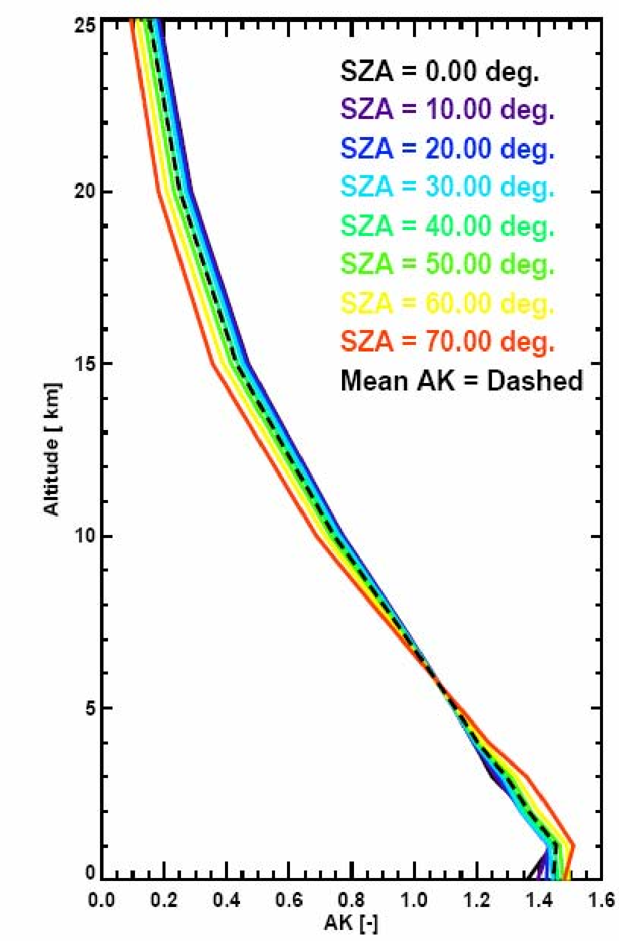

Figure 1. SCIAMACHY averaging kernel.

In a thought experiment, if one assumes that monthly averaged surface data is adequately representative of well mixed CO_2 below 5 km then at mid to high northern latitudes SCIAMACHY should see a seasonal signal smaller than that at the surface but which is in turn is larger than that of the true seasonal amplitude of the column integral (see Fig. 2).

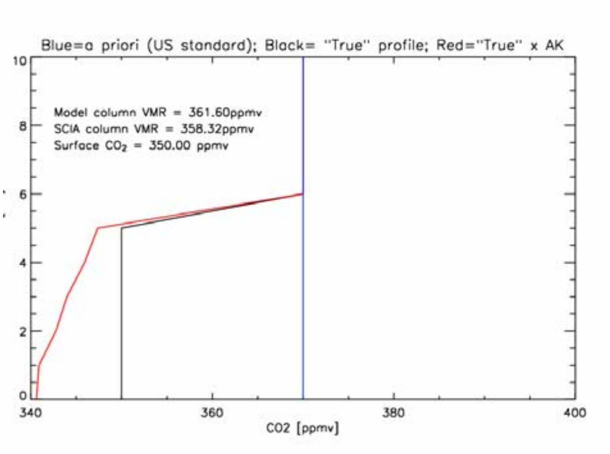

Figure 2. Plots of the "true" (black) and "observed" (red) CO_2 profiles for a fictional scenario whereby the extremes of the seasonal cycle are represented by a -20ppmv perturbation to the lower 5km (i.e. summer).

In Fig. 2, the *a priori* US standard profile is shown in blue. In the fictional scenario the seasonal cycle amplitude is 40ppmv at the surface but only 21.15ppmv in the (true) column VMR. Although SCIAMACHY observes a much bigger seasonal amplitude within the lower 5km owing to its increased sensitivity to these altitudes, the retrieved column seasonal cycle is only 26.69 ppmv since the perturbation is integrated over the column. SCIAMACHY therefore observes a larger seasonal signal amplitude compared to the true column and a smaller signal to that at the surface (Barkley et al. 2006d)

2. RESULTS

The first results of the FSI algorithm have been encouraging with SCIAMACHY/FSI CO_2 validated using both ground based Fourier Transform Infrared (FTIR) and model data (Barkley et al., 2006b). Analysis with respect to the FTIR data indicate a bias of approximately -4%, whilst comparison to the model data reveal an overestimation of the seasonal cycle by a factor of 2-3 and a smaller bias of about -2%.

Fig. 3 shows FSI measurements made within one degree latitude and longitude of the Deuselbach ground site and with a fitting error of 3% or better.

Fig. 3a shows the variation of the monthly mean retrieved CO_2 columns (red line) with the monthly mean in-situ CO_2 measurements (blue line). Standard deviations are given by the error bars. If only one measurement was made in a month, then no error bar is shown.

Fig. 3b shows the anomaly of the monthly mean of the FSI retrieved columns from the average of the monthly mean retrieved columns over the whole year (red line) and the anomaly of the monthly mean of the *in-situ* measured CO_2 from the average of the monthly mean retrieved columns over the whole year (blue line). To calculate the correlation, r, of the two series, only months where measurements are made by both instruments are included.

Fig. 4 shows the same plots for FSI retrieved columns within 3 degrees latitude and longitude of the Deuselbach ground site and with a fitting error of 3% or better.

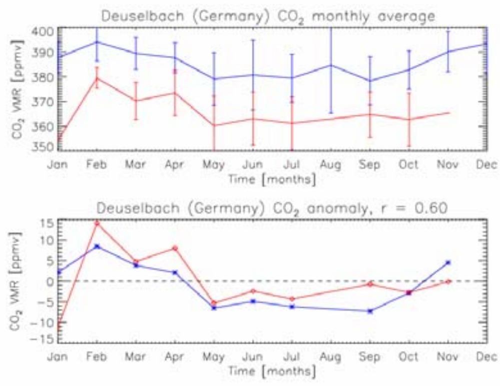

Figure 3a (top) and 3b (bottom). FSI measurements are made within 1 degree and with a fitting error of 3%.

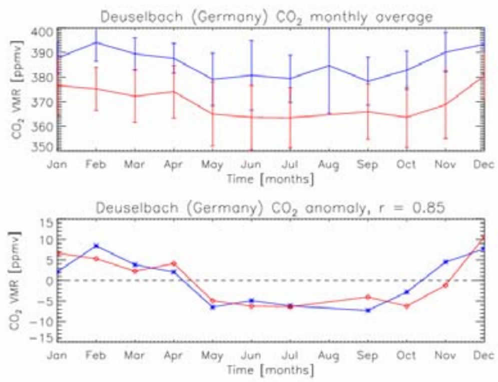

Figure 4a (top) and 4b (bottom). FSI measurements are made within 3 degrees and with a fitting error of 3%.

In the smaller retrieval area, Fig. 3, there are fewer retrievals made in a given month. The mean value for each month will be determined by fewer retrieved columns. January, in particular, has just one retrieved column, which is to be expected as the weather will be cloudy for much of this period. This measurement is very low for a winter monthly average, which leads to a poor correlation in the monthly anomalies (fig. 3b). The variability of near surface CO_2 is fairly significant, as shown in the in-situ standard deviation to be around ±10 ppmv. This measurement may have also been affected by partial cloud cover, which is one of the main sources of error for the retrievals.

By looking at a larger area, Fig. 4, the temporal variation in space of CO_2 is smoothed out, and the FSI anomaly closer resembles that of *in-situ* anomaly.

The retrieval anomalies over North America, in general, tend to closer resemble the anomalies of the ground station measurements, a reflection of the large, homogenous surroundings of these sites compared to the heterogeneous nature of the European landscape on the scale of a few degrees.

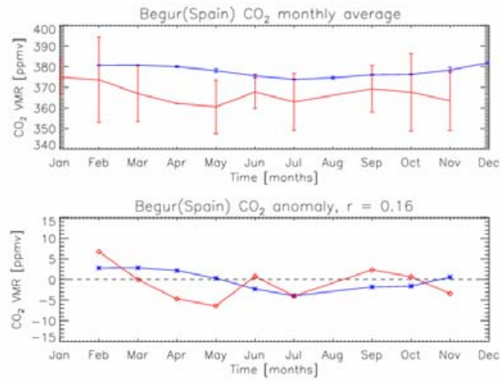

Figure 5a (top) and 5b (bottom). FSI measurements are made within 1 degree and with a fitting error of 3%.

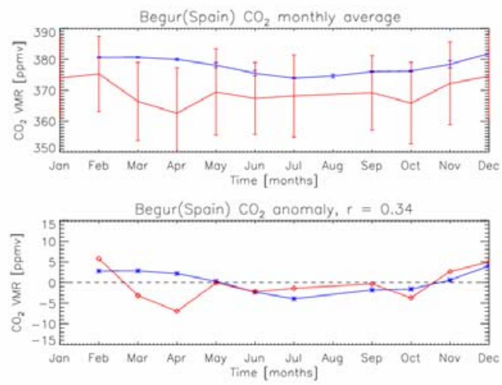

Figure 6a (top) and 6b (bottom). FSI measurements are made within 3 degrees and with a fitting error of 3%.

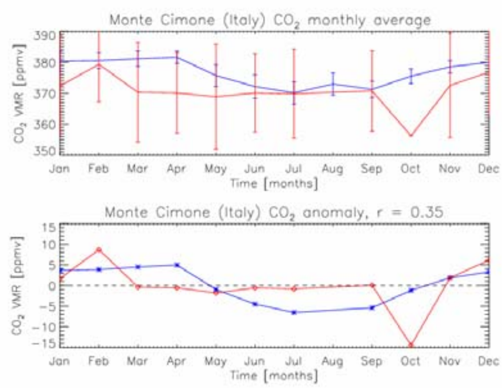

Figure 7a (top) and 7b (bottom). FSI measurements are made within 1 degree and with a fitting error of 3%.

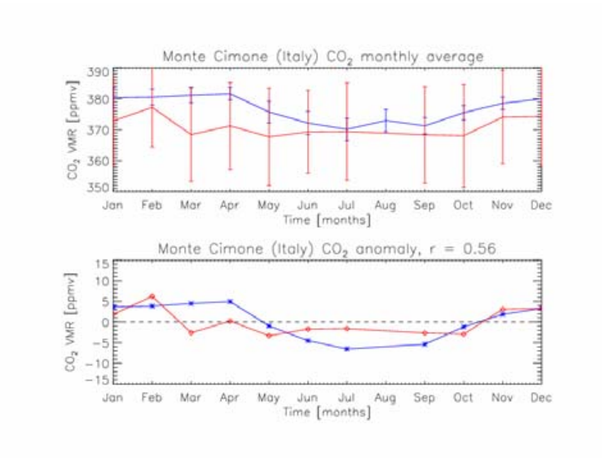

Figure 8a (top) and 8b (bottom). FSI measurements are made within 3 degrees and with a fitting error of 3%.

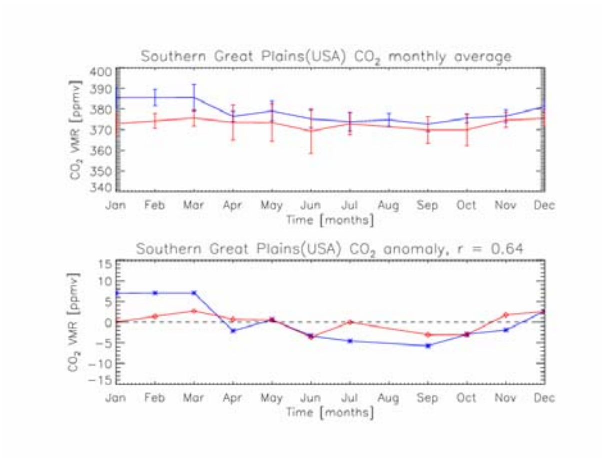

Figure 11a (top) and 11b (bottom). FSI measurements are made within 1 degree and with a fitting error of 3%.

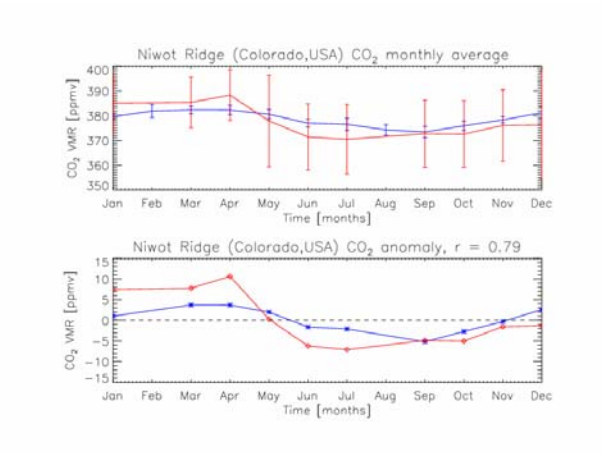

Figure 9a (top) and 9b (bottom). FSI measurements are made within 1 degree and with a fitting error of 3%.

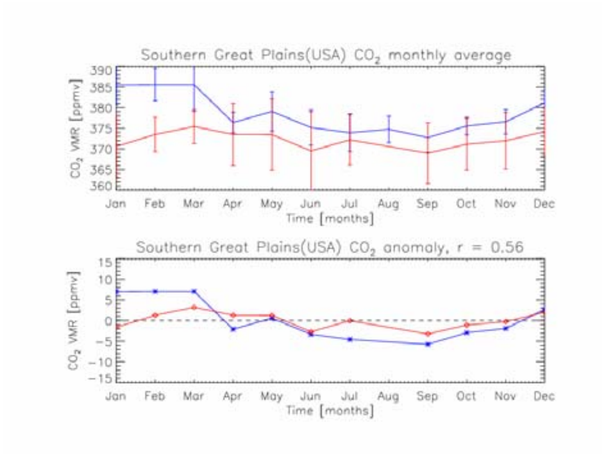

Figure 12a (top) and 12b (bottom). FSI measurements are made within 3 degrees and a fitting error of 3%.

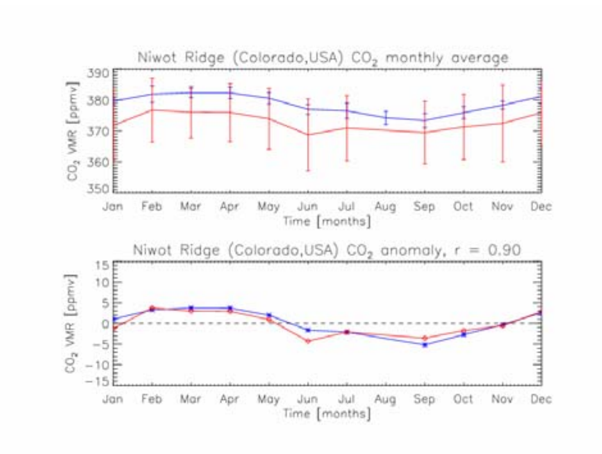

Figure 10a (top) and 10b (bottom). FSI measurements are made within 3 degrees and a fitting error of 3%.

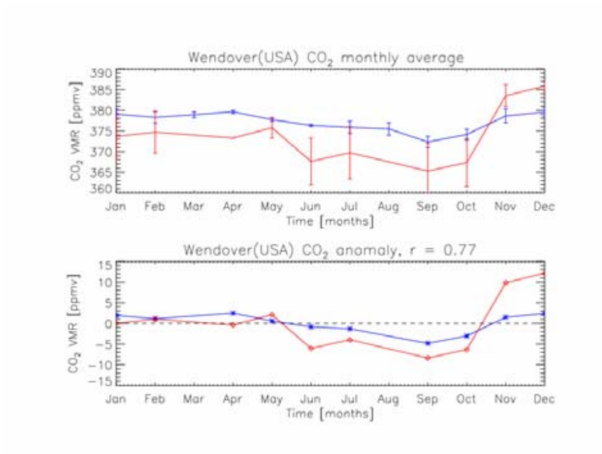

Figure 13a (top) and 13b (bottom). FSI measurements are made within 1 degree and with a fitting error of 3%.

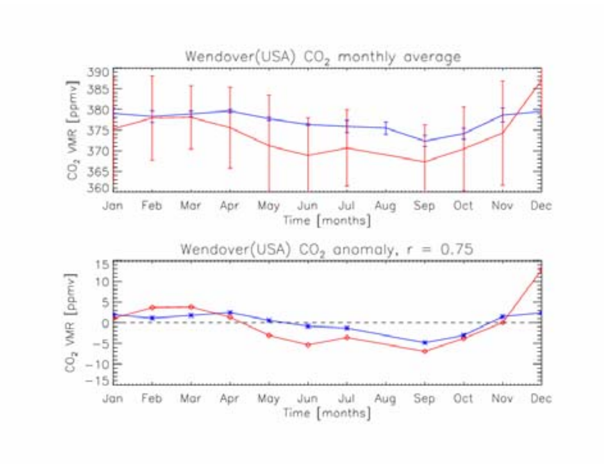

Figure 14a (top) and 14b (bottom). FSI measurements are made within 3 degrees and a fitting error of 3%.

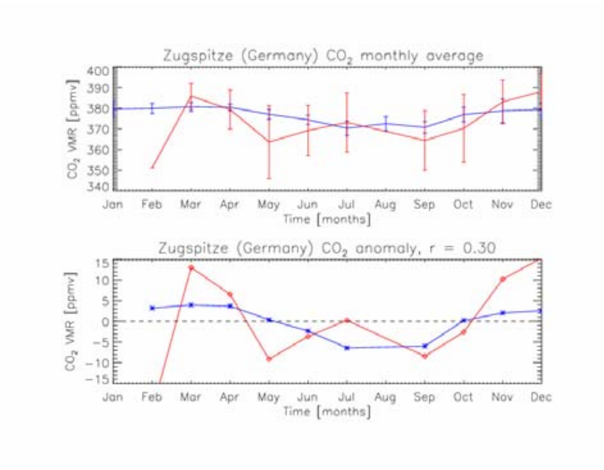

Figure 15a (top) and 15b (bottom). FSI measurements are made within 1 degree and with a fitting error of 3%.

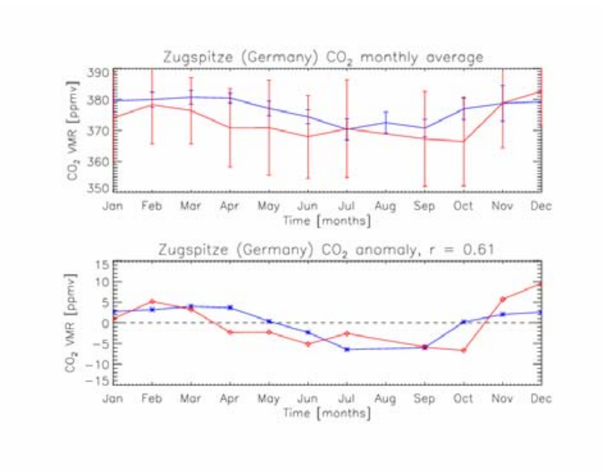

Figure 16a (top) and 16b (bottom). FSI measurements are made within 3 degrees and a fitting error of 3%.

3. CONCLUSIONS

It is difficult to compare FSI to *in-situ* ground based measurements correlated in both space and time, owing to the poor temporal and spatial coverage of the land based network. Owing to the variable nature of near surface CO_2 a much more appropriate validation of FSI is to compare the seasonal cycle amplitudes of the two instruments and to correlate their anomalies.

By averaging over a larger area, appropriate for global view sites which are chosen as they are representative of a large area, the spatial variation of CO_2 which is retrieved closer resembles the temporal variation of the surface site.

The seasonal cycle amplitudes (SCA) of FSI retrieved within 3 degrees of the station (Table 2) are closer to the ground base SCA than FSI retrieved within 1 degree.

Table 1: Summary of the in-situ ground based comparison over Western Europe and North America. The seasonal cycle amplitudes (SCA) are given both the ground based (g-b) and SCIAMACHY (SCIA) observations. The correlation between the FSI and in-situ anomaly time series is also given. FSI measurements have a fitting error of less than 3% and are within one degree of the station.

Surface station	g-b	SCIA	Correlation
Begur, Spain	8.0	14.4	0.16
Monte Cimone, Italy	11.5	23.1	0.35
Plateau Rosa, Italy	9.6	28.2	0.54
Deuselbach, Germany	15.8	25.2	0.60
Neuglobsow, Germany	20.4	28.8	0.50
Zugspitze, Germany	10.4	37.0	0.30
Niwot Ridge, Colorado USA	8.9	17.8	0.79
Southern Great Plains, Oklahoma, USA	12.8	6.3	0.64
Wendover, Utah, USA	7.3	20.5	0.77

Table 2: Summary of the in-situ ground based comparison over Western Europe and North America. The seasonal cycle amplitudes (SCA) are given both the ground based (g-b) and SCIAMACHY (SCIA) observations. The correlation between the FSI and in-situ anomaly time series is also given. FSI measurements have a fitting error of less than 3% and are within three degrees of the station.

Surface station	g-b	SCIA	Correlation
Begur, Spain	8.0	12.7	0.34
Monte Cimone, Italy	11.5	9.5	0.56
Plateau Rosa, Italy	9.6	13.4	0.48
Deuselbach, Germany	15.8	17.1	0.85
Neuglobsow, Germany	20.4	25.7	0.65
Zugspitze, Germany	10.4	16.3	0.61
	8.9	8.0	0.90
Niwot Ridge, Colorado USA	12.8	6.4	0.56
Southern Great Plains, Oklahoma, USA	7.3	19.8	0.75
Wendover, Utah, USA	8.0	12.7	0.34

4. REFERENCES

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