Balloonsonde Measurements of Volcanic SO_2 in Costa Rica for Satellite Validation

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Motivation

Remote sensing of the SO_2 column is very sensitive to its vertical structure, and fresh volcanic SO_2 emissions in particular can be confined to a narrow range of altitudes. ***In situ* profiles of SO_2** are of great value for validation of satellite retrievals from space-based sensors. Here we describe a unique program of volcanic SO_2 profiling in Costa Rica using dual ozonesondes in tandem with regular ozonesondes downstream from nearby Turrialba Volcano, These soundings have been providing satellite instruments such as OMI, OMPS and nowTROPOMI valuable validation data for SO_2.

Observations of opportunity of volcanic SO_2

Almost from the onset of the Ticosonde balloonsonde program in Costa Rica in 2005, we began to observe notches in the electro-chemical concentration cell (ECC) ozonesondes. Since SO_2 will interfere with the redox reaction in the ECC, we suspected the "notched" profiles were due to plumes of SO_2 emitted from Turrialba. **Figure 1** shows notched ozone profiles from each year through 2014 and a time series of tropospheric ozone columns of SO_2 inferred from the assumption $\Delta[SO_2]_{notch} = -\Delta[O_3]_{notch}$. Through April 2018, we have found measureable SO_2 in 135 soundings.

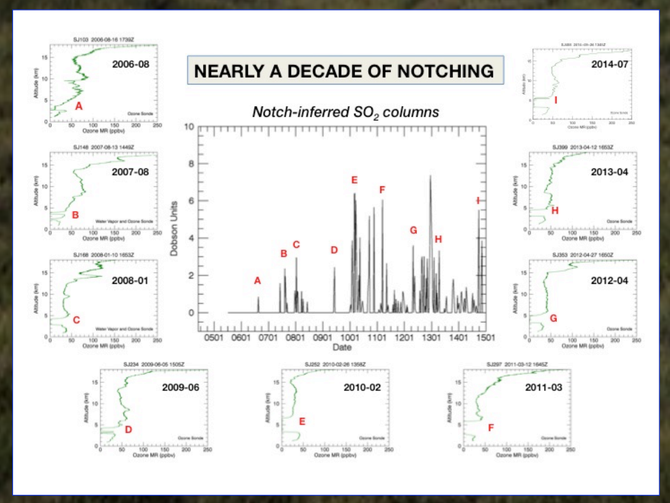

Figure 1

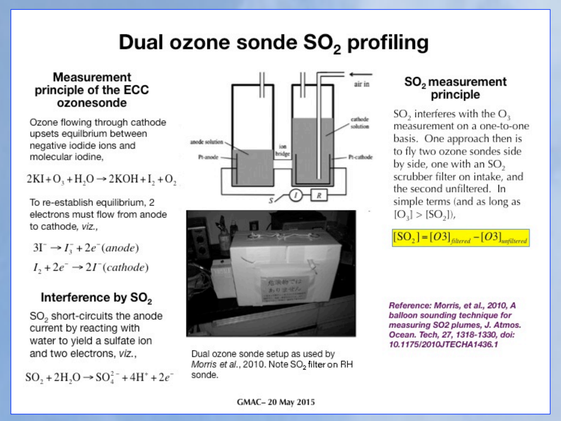

Figure 2

Dual ozonesonde profiling of SO_2

The dual ozonesonde method of *Morris et al.* [2010] is a direct approach to measuring the SO_2 mixing ratio (**Figure 2** at left). After a successful test sounding in Costa Rica in early 2012, the NASA OMI team has supported a series of dual ozonesonde launches for validation of the OMI SO_2 retrieval. As of April of 2018 we have obtained 48 dual ozone sonde profiles of SO_2 and tropospheric column measurements. Of these, 29 have measured SO_2 notches.

Comparisons with OMI and OMPS SO2 PCA retrievals

In **Figure 3** lower tropospheric (TRL) SO_2 retrievals using the Principal Components Analysis (PCA) algorithm for both OMI and OMPS are compared to the column SO_2 derived from the *in situ* dual sonde at San Jose, Costa Rica on 13 March 2015. The agreement between the retrievals and the sonde column on this day is very good. This and comparisons on other dates which we have done show that both OMI and OMPS TRL retrievals are low-biased with respect to our *in situ* column SO_2.

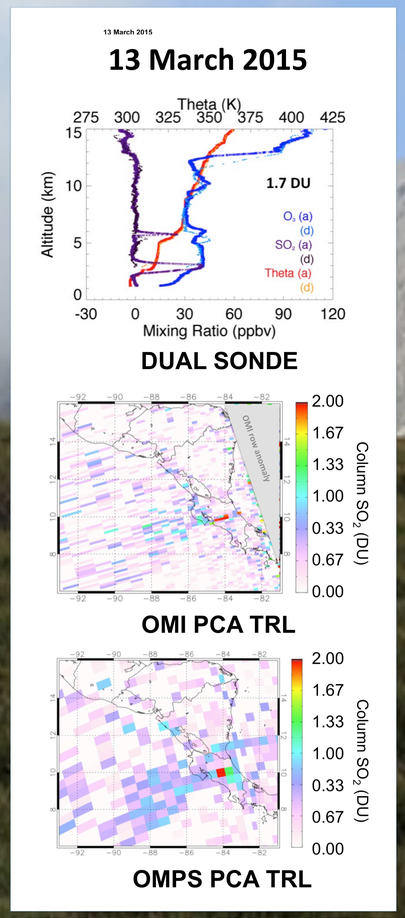

Figure 3

Developing a standalone SO_2 sonde

Two of us (Flynn and Morris) have been developing a new SO_2 sonde that is free of the dual sonde's constraint to SO_2 mixing ratios that are less than or equal to the background ozone. **Figure 4** shows profiles of SO_2 and ozone obtained this past March 23 in Costa Rica with a "triple sonde" payload consisting of a dual sonde and the new SO_2 sonde. In this instance, the new sonde (yellow trace) showed a peak value of SO_2 approaching 250 ppbv, while the dual sonde SO2 (the red/blue trace difference) was limited to ~30 ppbv. This successful field test demonstrates that the new SO_2 sonde will be a powerful new tool to make *in situ* measurements in the coming years.

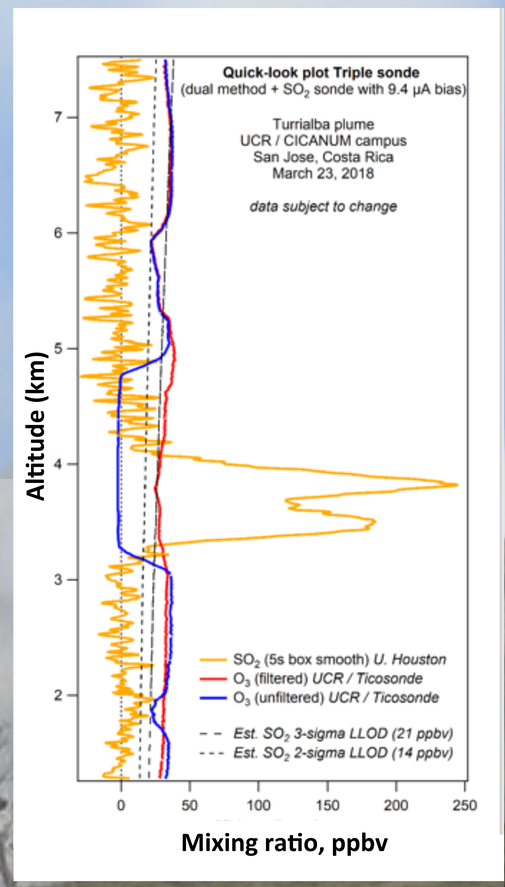

Figure 4

Validating TROPOMI SO_2

Ticosonde will be launching 18 dual sondes each of the next two years in support of NASA's contribution to the TROPOMI validation effort. The Ticosonde profiles will provide an excellent opportunitty validate the high resolution maps of SO_2 that TROPOMI will deliver on a daily basis.