Intercomparison of three algorithms for retrievals of volcanic SO_2 from AIRS data

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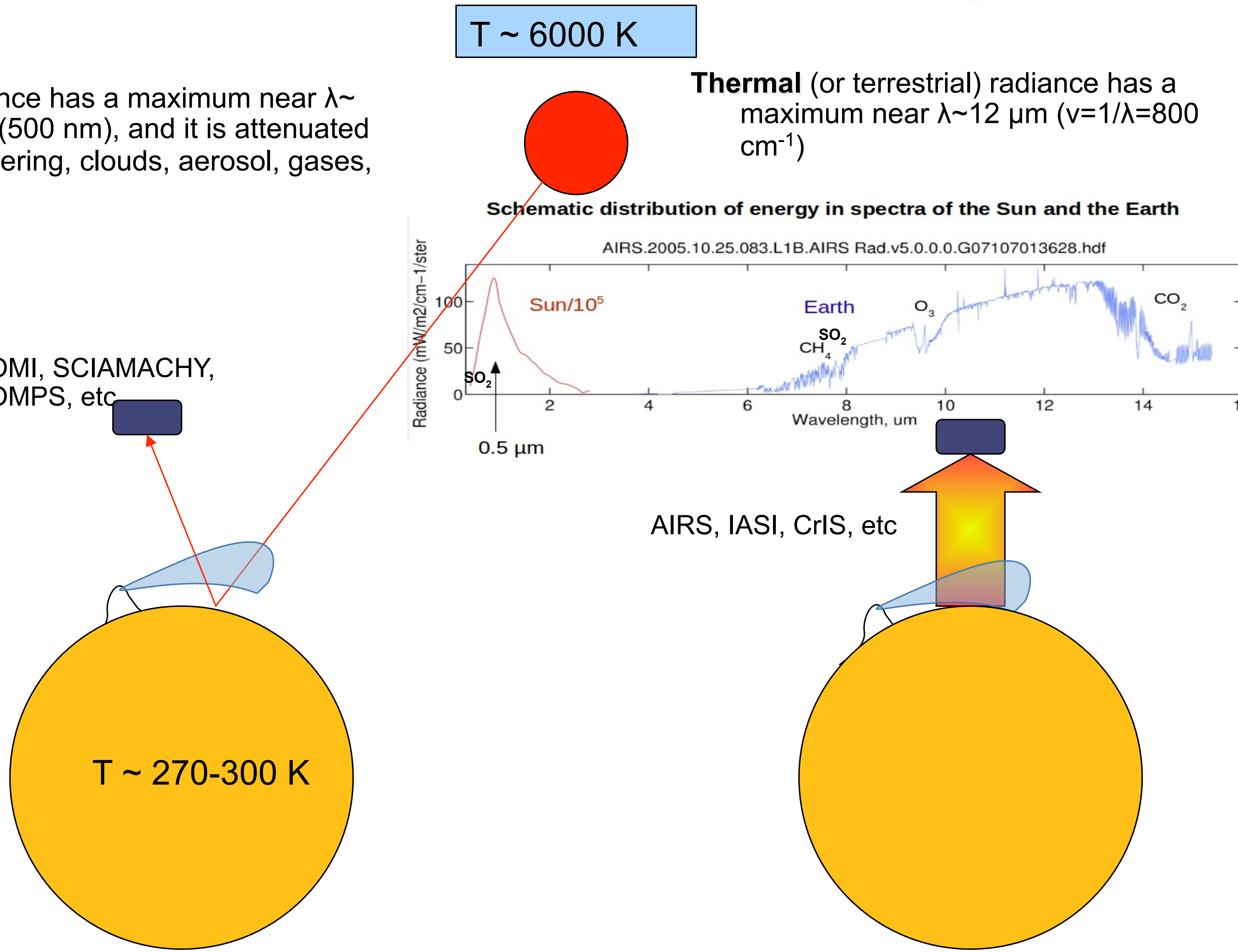
Solar UV and thermal IR techniques

Solar radiance has a maximum near λ~ 0.5 μm (500 nm), and it is attenuated by scattering, clouds, aerosol, gases, etc

Thermal (or terrestrial) radiance has a maximum near λ~12 μm (v=1/λ=800 cm^{-1})



Main advantages and disadvantages

Solar UV

Good sensitivity to stratosphere, upper and lower troposphere

Need solar light for measurements

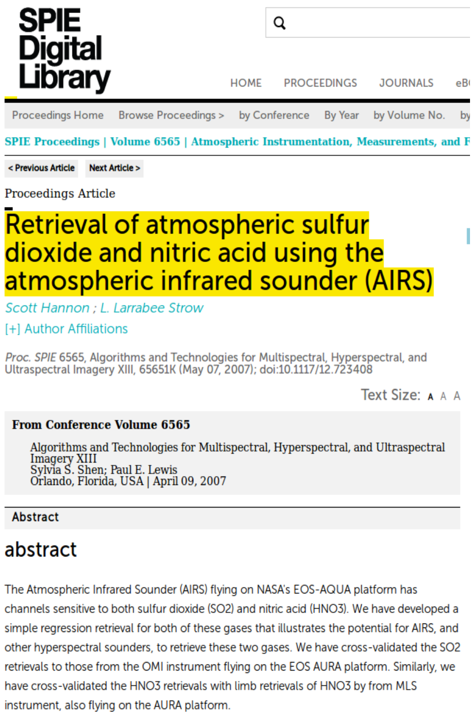
Terrestrial TIR

Sensitivity to lower troposphere is reduced

Do not need solar light, capable to measure day and night, including polar areas

Outline

This report presents comparisons between SO2 volcanic results obtained by 3 TIR techniques and 2 UV techniques.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Proceedings Article

Retrieval of atmospheric sulfur dioxide and nitric acid using the atmospheric infrared sounder (AIRS)

Scott Hannon ; L. Larrabee Strow

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From Conference Volume 6565

Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XIII
Sylvia S. Shen; Paul E. Lewis
Orlando, Florida, USA | April 09, 2007

Abstract

abstract

The Atmospheric Infrared Sounder (AIRS) flying on NASA's EOS-AQUA platform has channels sensitive to both sulfur dioxide (SO2) and nitric acid (HNO3). We have developed a simple regression retrieval for both of these gases that illustrates the potential for AIRS, and other hyperspectral sounders, to retrieve these two gases. We have cross-validated the SO2 retrievals to those from the OMI instrument flying on the EOS AURA platform. Similarly, we have cross-validated the HNO3 retrievals with limb retrievals of HNO3 by from MLS instrument, also flying on the AURA platform.

1) A retrieval techniques developed at UMBC by Scott Hannon and Larrabee Strow (HSA).

2) A modified (fast) HSA. It is under testing now. Currently both algorithm are realized in MATLAB language. Our goal is a development of a FORTRAN-based code based on one algorithm or another. This code may be introduced into the GSFC computer system.

Both UMBC algorithms use a fast radiation transfer code SARTA . [*Strow, L., H. Motteler, R. Benson, S. Hannon, and S. De Souza-Machado(1998), Fast computation of monochromatic infrared atmospheric transmittances using compressed look-up tables, J. Quant. Spectrosc. Rad.Trans., 59(3-5), 481 – 493.*]

3) The UMBC retrievals are being compared with the retrievals by a code developed by F. Prata (NILU, Norway) that is also in use at the GSFC in NRT mode.

UV SO2 techniques for OMI/Aura and OMPS/NPP have been developed at the GSFC

Eruptions

Today we consider two cases.

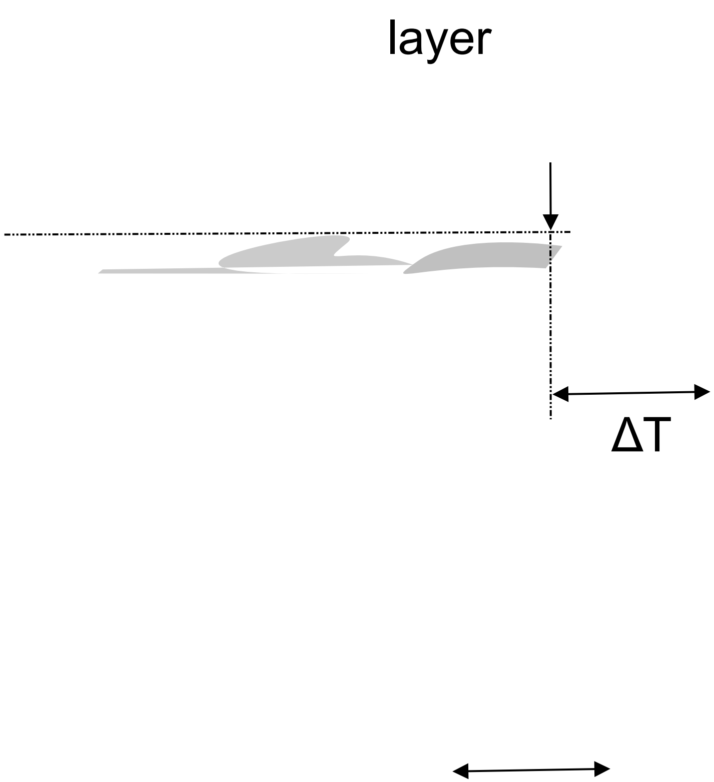
Tropical Kelut eruption (7° 55′ 48″ S, 112° 18′ 28.8″ E, Indonesia, February 2014).

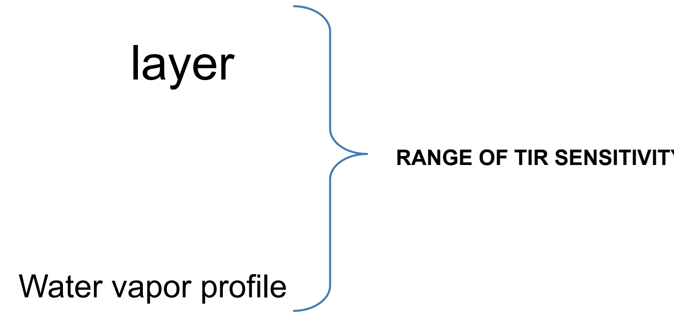
High latitude Bardarbunga eruption (64° 38′ 27.6″ N, 17° 31′ 40.8″ W, Iceland, September 2014)

These eruptions represent two extreme cases.

In the tropical conditions a high Sun elevation over horizon favors for UV measurements. Enhanced humidity in the boundary layer makes TIR measurements in the lower troposphere difficult. TIR data are available day and night (ones per day and once per night), UV data are available for day only (once per day).

High latitude locations make possible measurements of a given location many times per day: TIR – up to 10-12 times, UV makes possible to see a plume a few times per day. However, reduced S/N for UV is a problem, especially for low Sun.



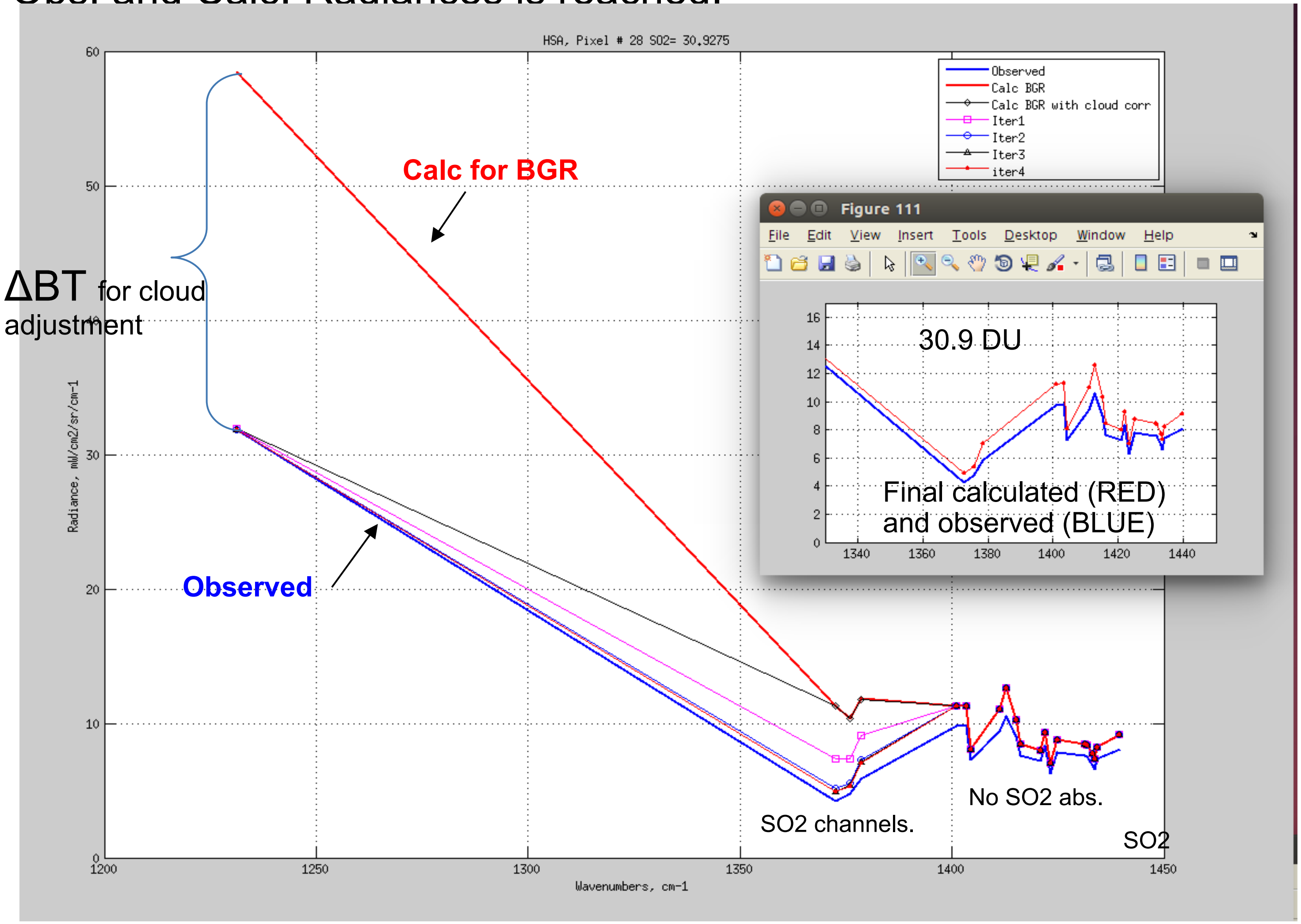


Tropical areas are characterized by a high tropopause and a humid boundary layer. TIR retrievals are possible only at altitudes with **diminishing temperature** (below 20 km here). Another problem is **high humidity** in the boundary layer: H_2O has a significant absorption in the spectral region of SO_2.

SO_2 is perturbed in a selected layer (16-19 km here) until calculated and observed radiances come in agreement.

SO2 algorithm by Hannon-Strow (HS)

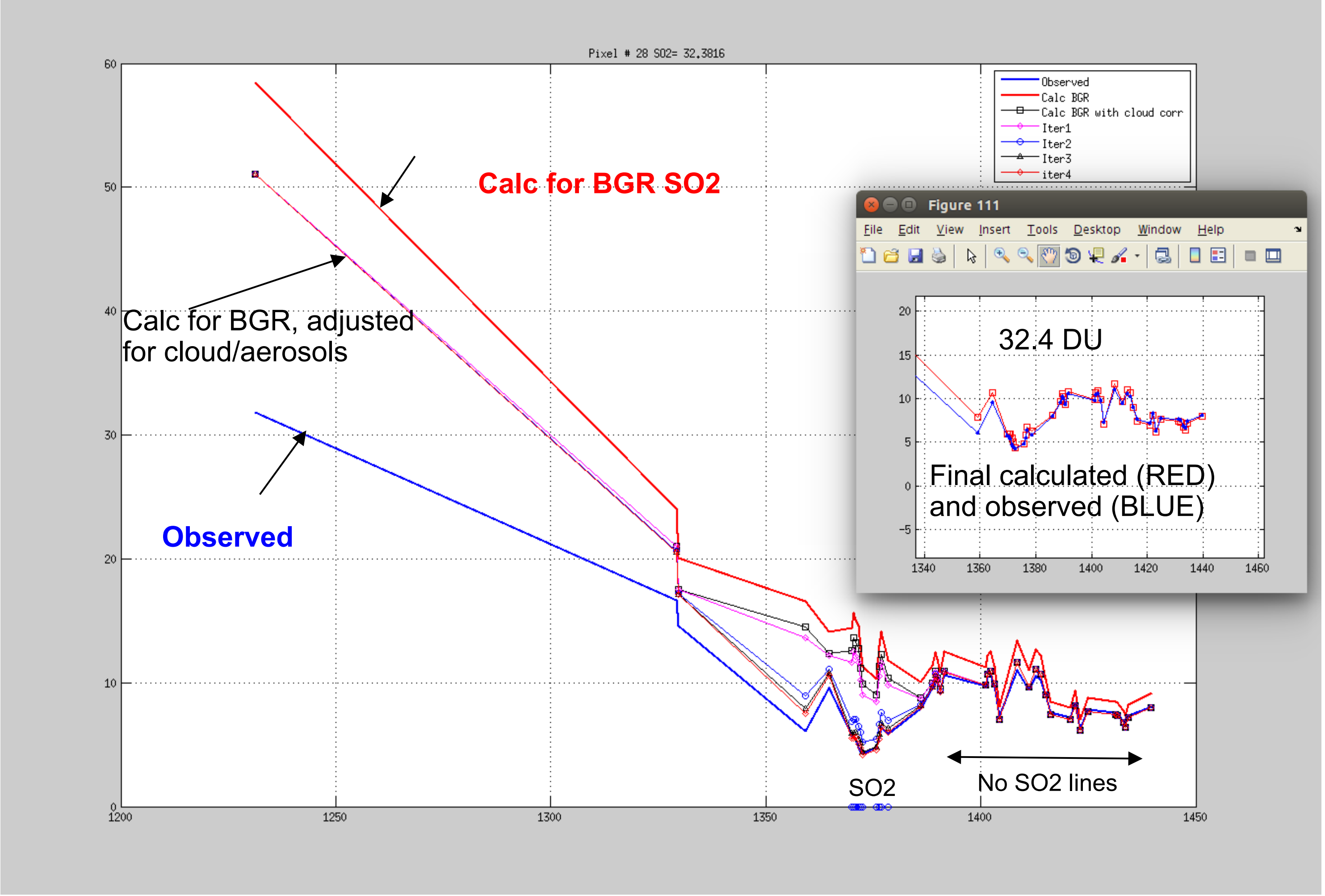
1. Channel 1231.25 cm-1 is used for cloud adjustment (BT = T(cloud top))
2. Radiances in "***No SO2***" channels are recalculated for "***SO2***" channels using background SO2 + perturbations using a pre-trained linear regression matrix.
3. Difference between the recalculated (predicted) radiance and observed radiance is a measure of SO2 amount
4. Recalculation is repeated with different SO2 perturbation until minimal difference between Obs. and Calc. Radiances is reached.



BT = T(cloud top)

Modified HS algorithm (under development)

1. Cloud adjustment applied.
2. Radiance for background SO2 clouds/aerosols free atmosphere is calculated (RED LINE)
3. Attenuation factor for each pixel is obtained as ratio of R=Calc/OBS for "***no so2***" channels
4. Any radiance calculated further by SARTA is divided by R
5. SO2 is perturbed, sensitivity as (CalcNew-CalcOld)/(SO2New-SO2OLd) is obtained
6. Iteratively SO2 is perturbed to minimize (Calc-Obs)



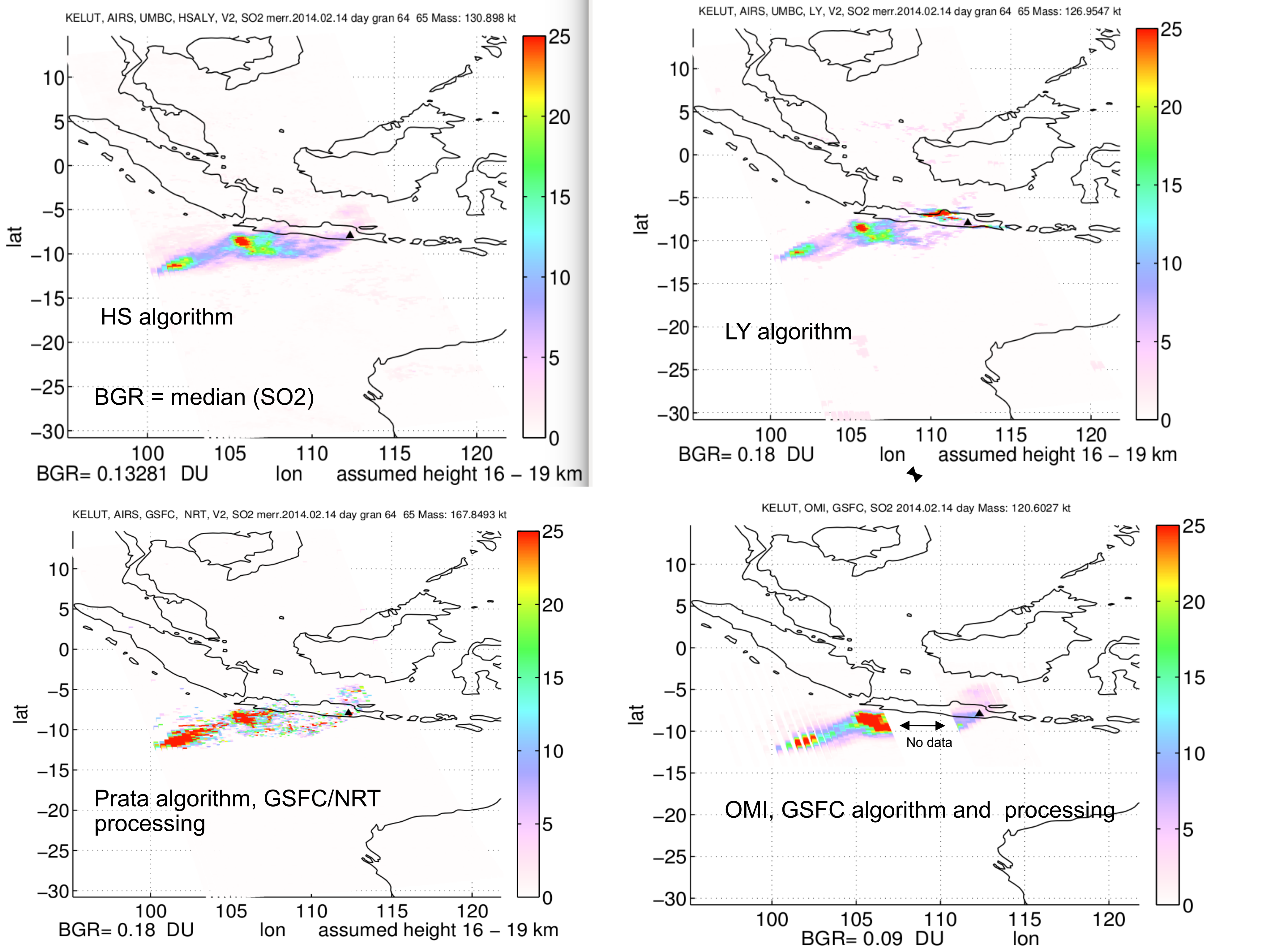
Radiance in UMBC techniques **is calculated at any iteration** and based on **actual temperature and humidity profiles** (MERRA or GEOS-5), surface emissivity , surface pressure, SST (AIRS L3).

Algorithm by Fred Prata (NILU, Norway)

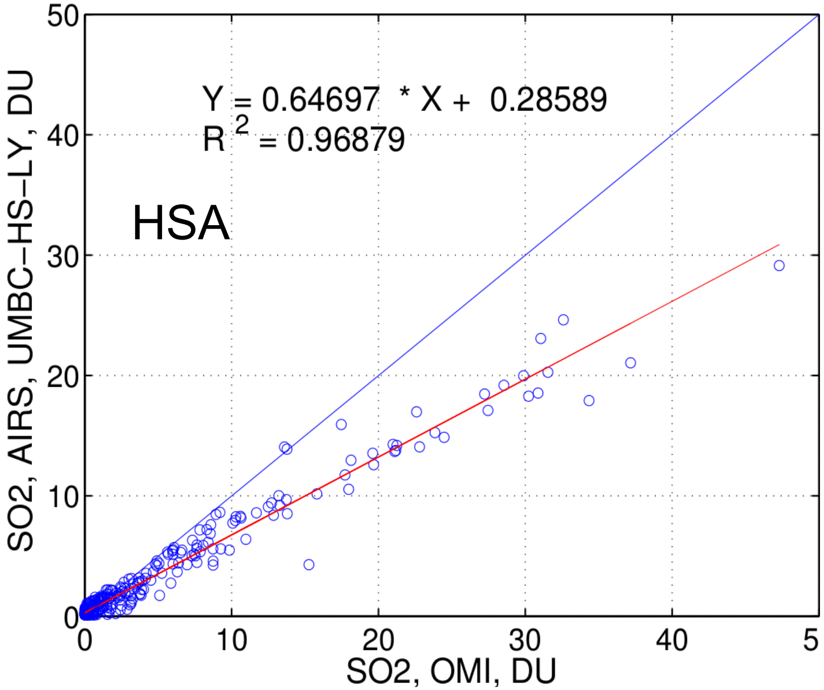
Layers with peaks at 5, 7, 10, and 15 km are assumed. The retrieval makes a linear combination of SO_2 found in these layers with an optimal estimation technique (Rodgers, 2000).

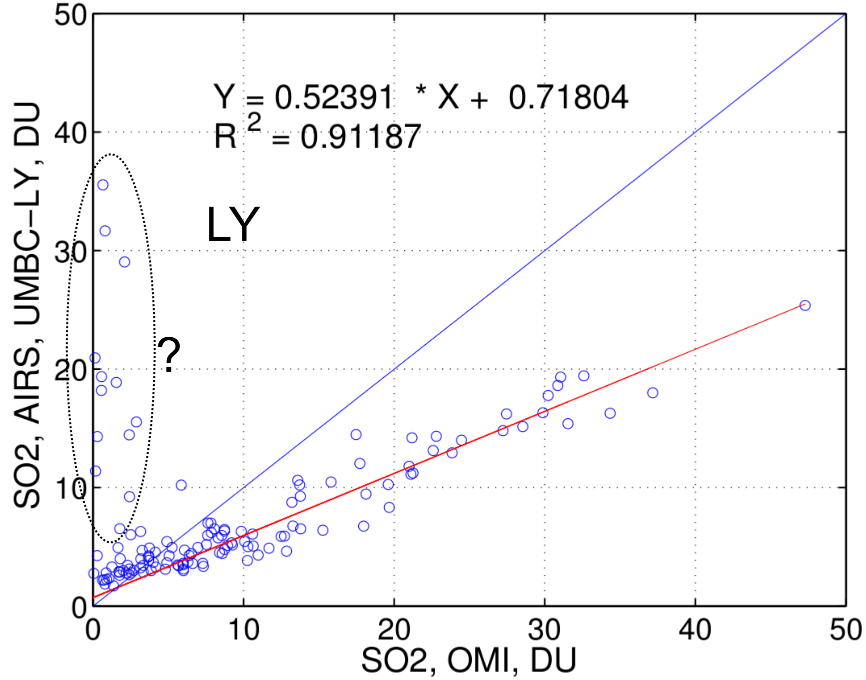
The code uses **climatological "global average"** atmospheric parameters. The code makes use of **pre-calculated radiance** using the Modtran radiative transfer code.

GSFC NRT product uses a “fast” Prata's code. A “slow” code is supposed to be more accurate, but we have not found differences for a high-latitude case.

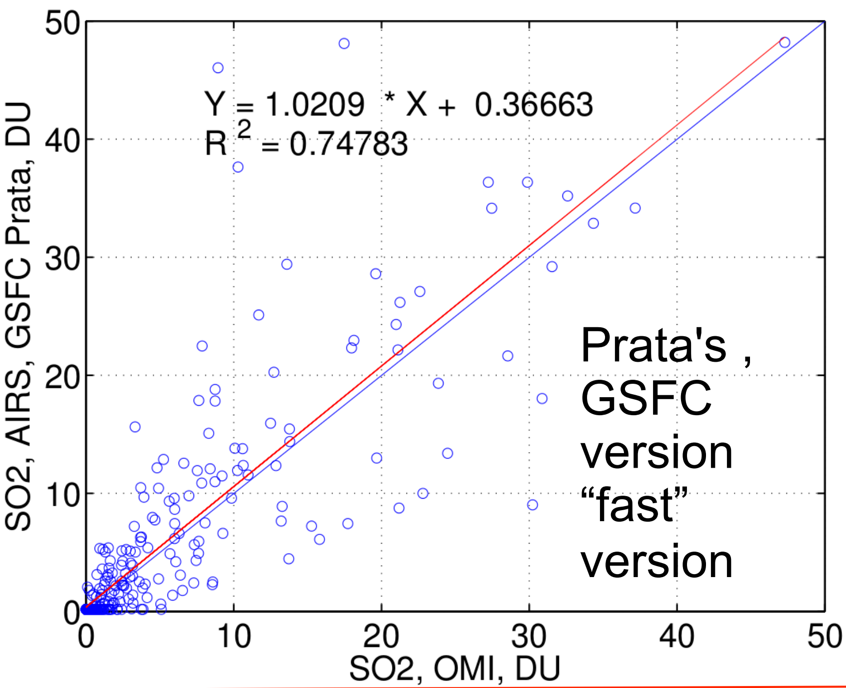

KELUT, AIRS, UMBC, HSALY, V2, SO2 merr.2014.02.14 day gran 64 65 Mass: 130.898 kt
HS algorithm
BGR = median (SO2)
BGR= 0.13281 DU
lon
assumed height 16 – 19 km
lat
KELUT, AIRS, UMBC, LY, V2, SO2 merr.2014.02.14 day gran 64 65 Mass: 126.9547 kt
LY algorithm
BGR= 0.18 DU
lon
assumed height 16 – 19 km
lat
KELUT, AIRS, GSFC, NRT, V2, SO2 merr.2014.02.14 day gran 64 65 Mass: 167.8493 kt
Prata algorithm, GSFC/NRT processing
BGR= 0.18 DU
lon
assumed height 16 – 19 km
lat
KELUT, OMI, GSFC, SO2 2014.02.14 day Mass: 120.6027 kt
No data
OMI, GSFC algorithm and processing
BGR= 0.09 DU
lon
lat

KELUT 2014.02.14: AIRS, 3 algorithms VS OMI (0.5°x0.5°)

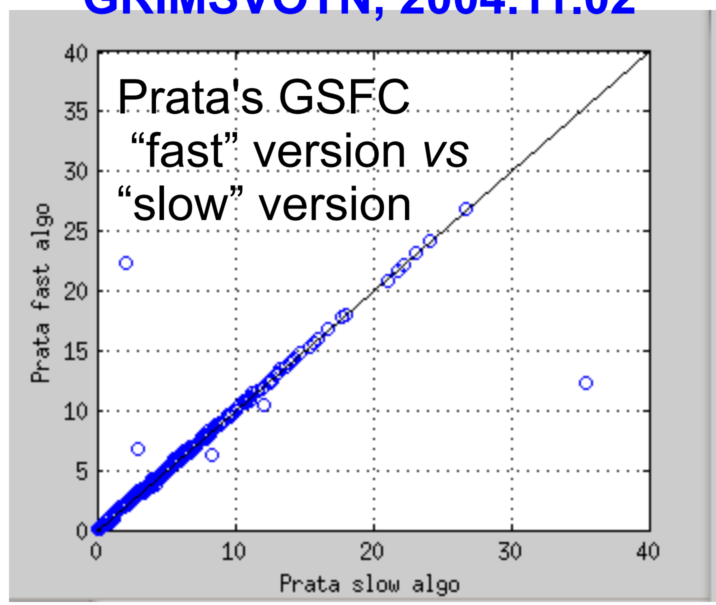




HSA



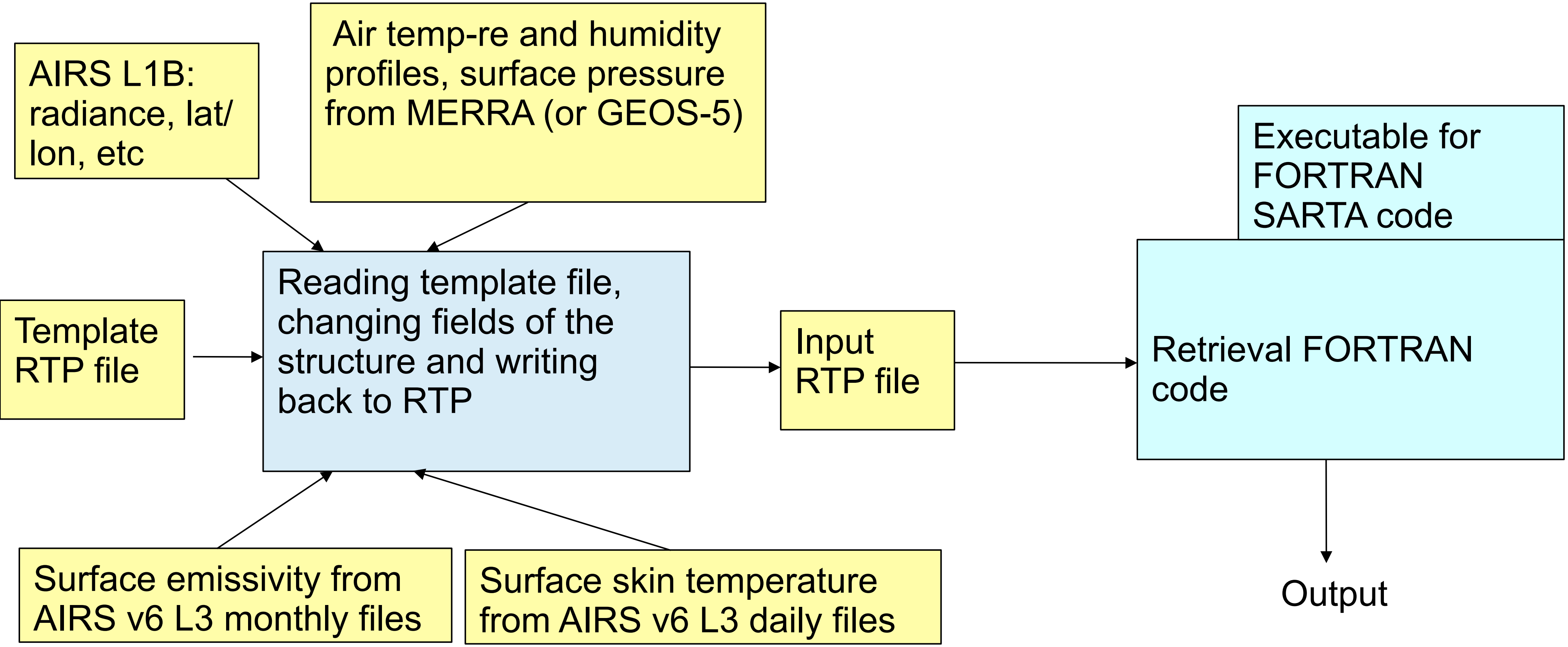
GRIMSVOTN, 2004.11.02



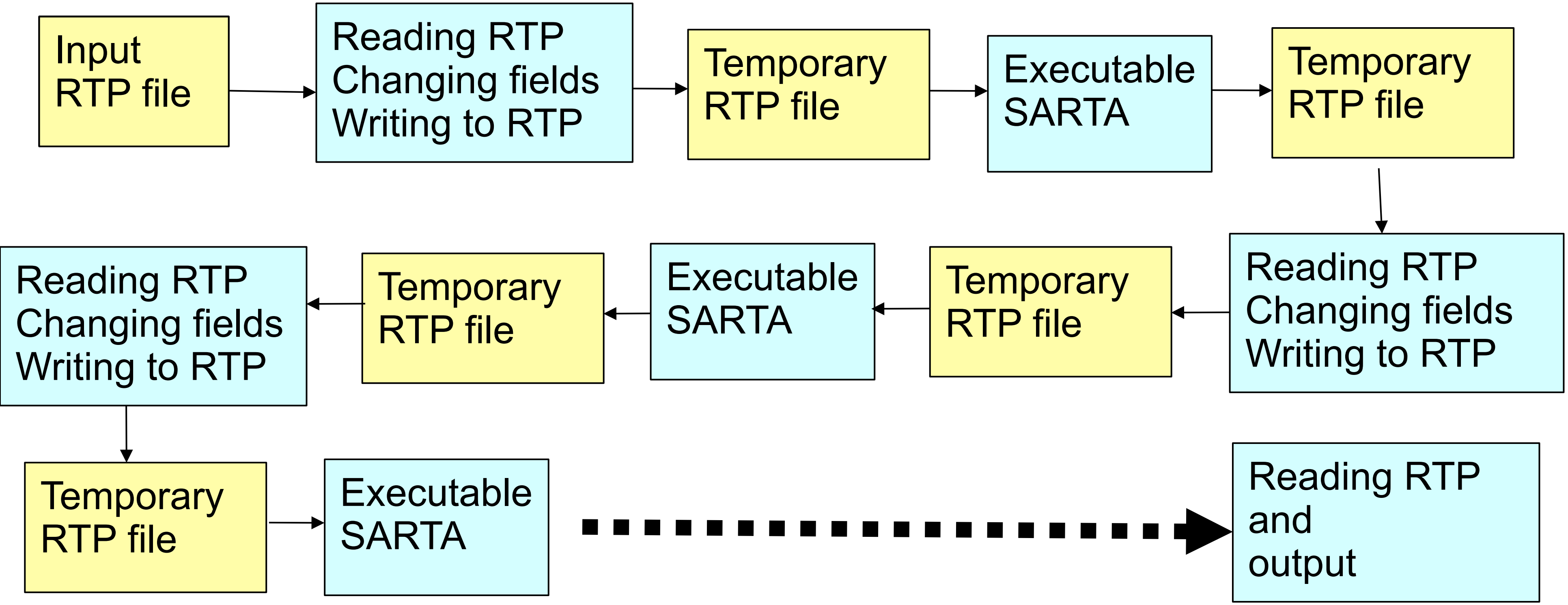
Next slides are AIRS SO_2 processed using two algorithms: UMBC (Hannon-Strow, HS) and Prata for Bardarbunga volcano, September 9, 2014

Night time

Development of FORTRAN SO2 code for GSFC



Retrieval FORTRAN code



CONCLUSIONS

1. TIR instruments (AIRS, IASI, CrIS, TANSO) have advantages and disadvantages compared to UV instruments (GOME, SCIAMACHY, OMI, OMPS).

2. Modified HS code works faster that original HS code (~0.5 minute vs 1.0 minute per granule).

3. Prata's algorithm looks less accurate than both UMBC codes. This is connected with climatological information instead of actual values of important parameters (e.g. temperature).

4. Locations of pixels with increased SO2 are the same, so for detection volcanic plumes both UMBC and Prata's codes are equivalent.