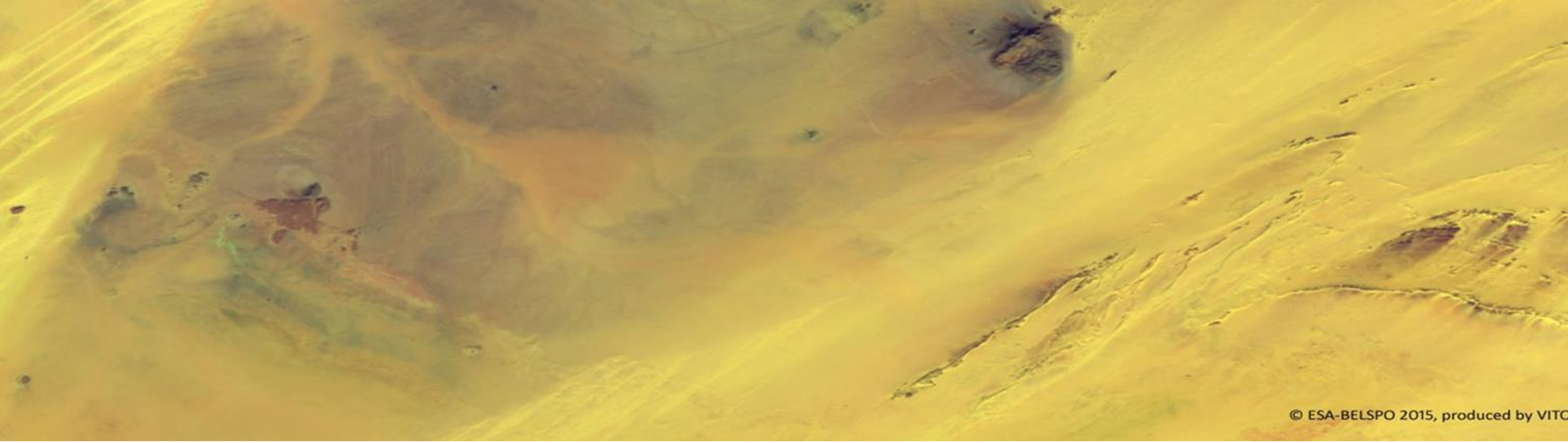


PROBA-V Vicarious Calibration :

Investigation into the impact of in-orbit temperature variation

LIME (Lunar Irradiance Model ESA) model

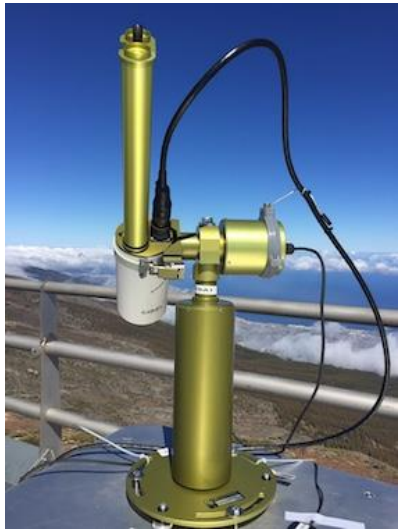
Sindy Sterckx, Stefan Adriaensen (VITO)

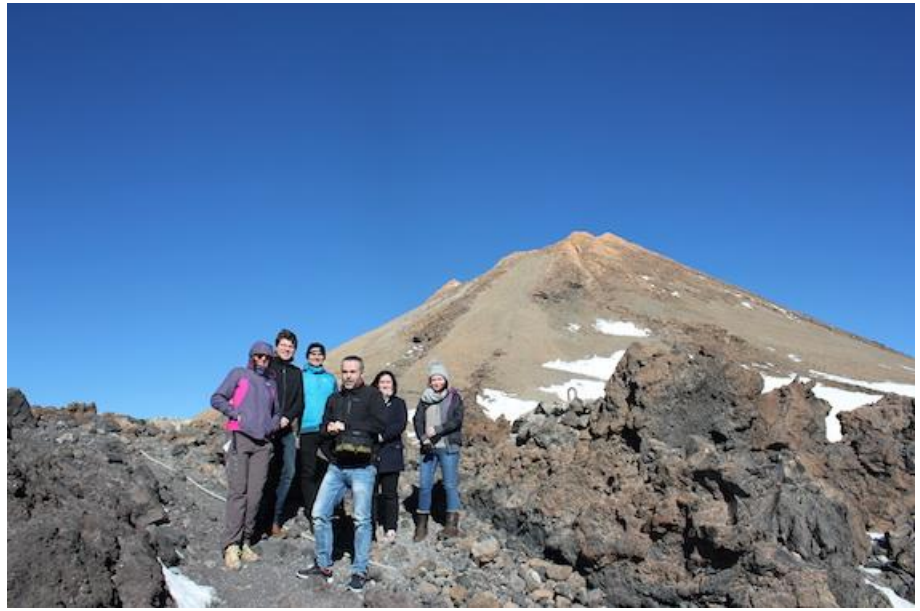
LIME Model

- LIME = Lunar Irradiance Model of ESA
- Developed under ESA contract from 2017-2019
  - NPL (UK), UVa (ES) and VITO(BE)
- CIMEL instrument at 6 different wavelengths at 440,500,675,870,1020,1640 [nm]
- The LIME model is derived from +/-300 (automated) irradiance measurements of the moon at Pico Teide (Tenerife)
- The model simulates the exo-atmospheric total irradiance to be observed by any sensor within the 400nm – 2500nm wavelength range
- Input to the model :
  - Timestamp,location -> observations between 2 and 90 degrees are accepted (both sides)
  - Sensor spectral response
- The approach to derive the model is highly similar to the USGS ROLO model (Kieffer and Stone, 2005) : the C parameter set was made band specific.
- The model is capable of providing the Degree of Linear Polarization (DoLP) as an output.
- The uncertainty at reflectance level is max 2%

LIME Model : consortium

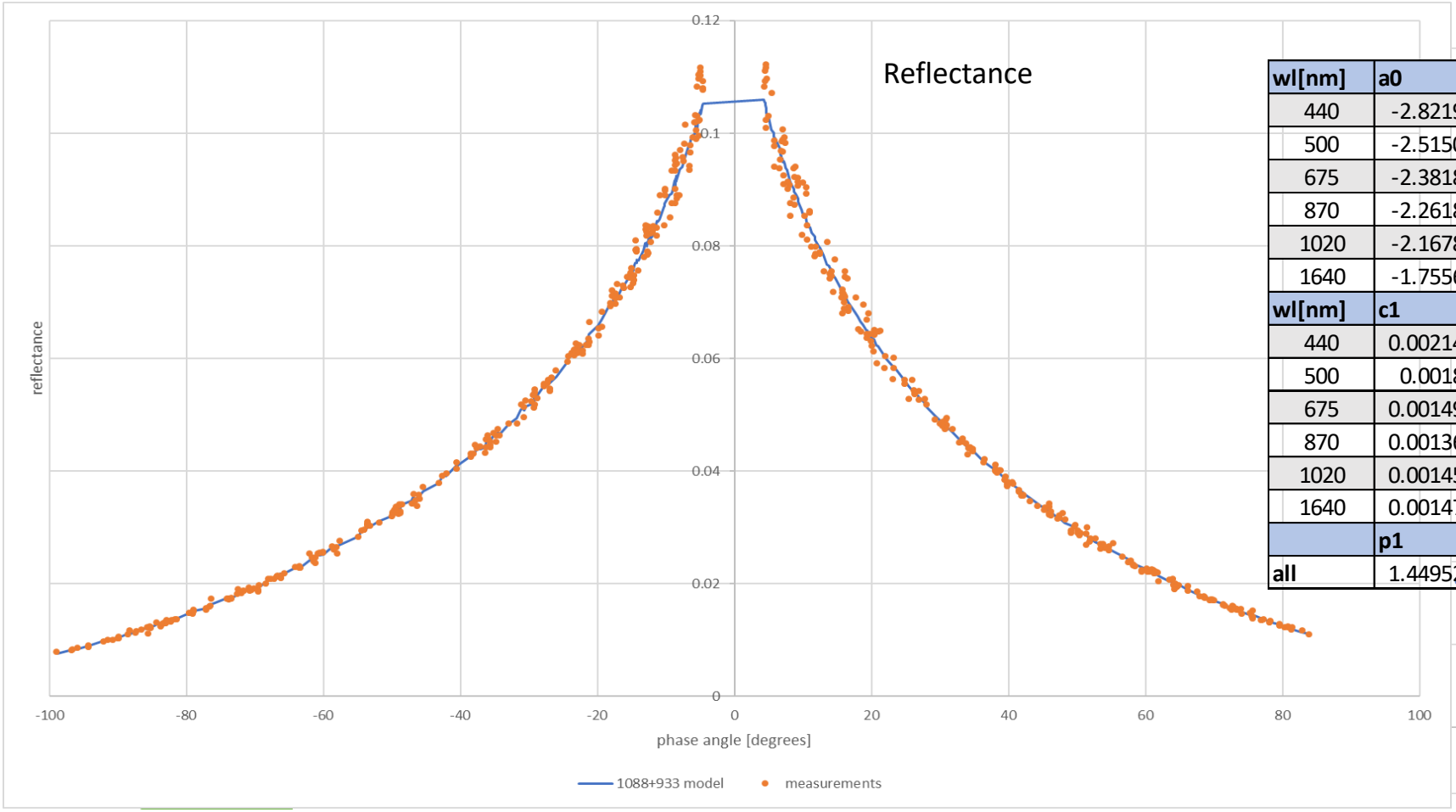
- NPL : calibration of the instrument and uncertainty (both measurement and model)
- UVa : instrument automated operation @Tenerife (incl. database) and performing Langley estimations
- VITO : model derivation and uncertainties





LIME Model

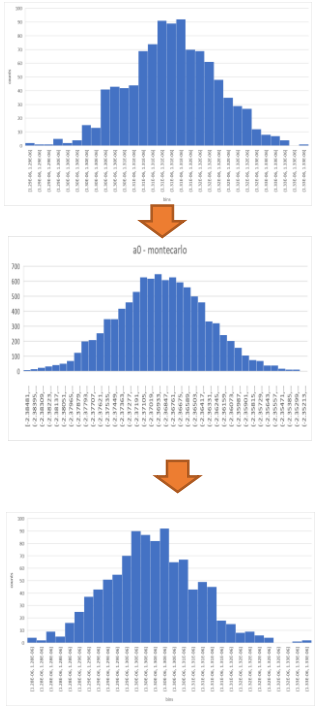
- **Lunar Irradiance Measurements CIMEL 440nm (@Tenerife)**



wl[nm]	a0	a1	a2	a3	b1	b2	b3
440	-2.82195	-0.67058	-0.35391	-0.01226	0.059246	0.005286	-0.00426
500	-2.51509	-1.01093	-0.06614	-0.09286	0.054643	0.009163	-0.00532
675	-2.38188	-0.67037	-0.28114	-0.0469	0.053769	0.006141	-0.00345
870	-2.26185	-0.60165	-0.31416	-0.03947	0.054968	0.010404	-0.00499
1020	-2.16789	-0.59006	-0.31791	-0.03482	0.057767	0.015604	-0.00728
1640	-1.75563	-0.60829	-0.27471	-0.04719	0.053116	0.006556	-0.00364
wl[nm]	c1	c2	c3	c4	d1	d2	d3
440	0.002143	0.000571	0.001373	0.000412	0.393375	0.590169	0.000999
500	0.00182	0.000218	0.001304	0.000555	0.840597	0.388049	-0.00117
675	0.001496	0.000229	0.001521	0.000706	0.328802	0.496161	-0.00061
870	0.001364	8.25E-05	0.001628	0.000624	0.376939	0.479259	-0.00021
1020	0.001457	-3.04E-05	0.001754	0.001015	0.456871	0.453514	-0.00094
1640	0.001473	5.62E-05	0.001497	0.00094	0.420775	0.315047	-0.00021
	p1	p2	p3	p4			
all	1.449524	19.68723	10.78809	8.994821			

LIME Model : uncertainty

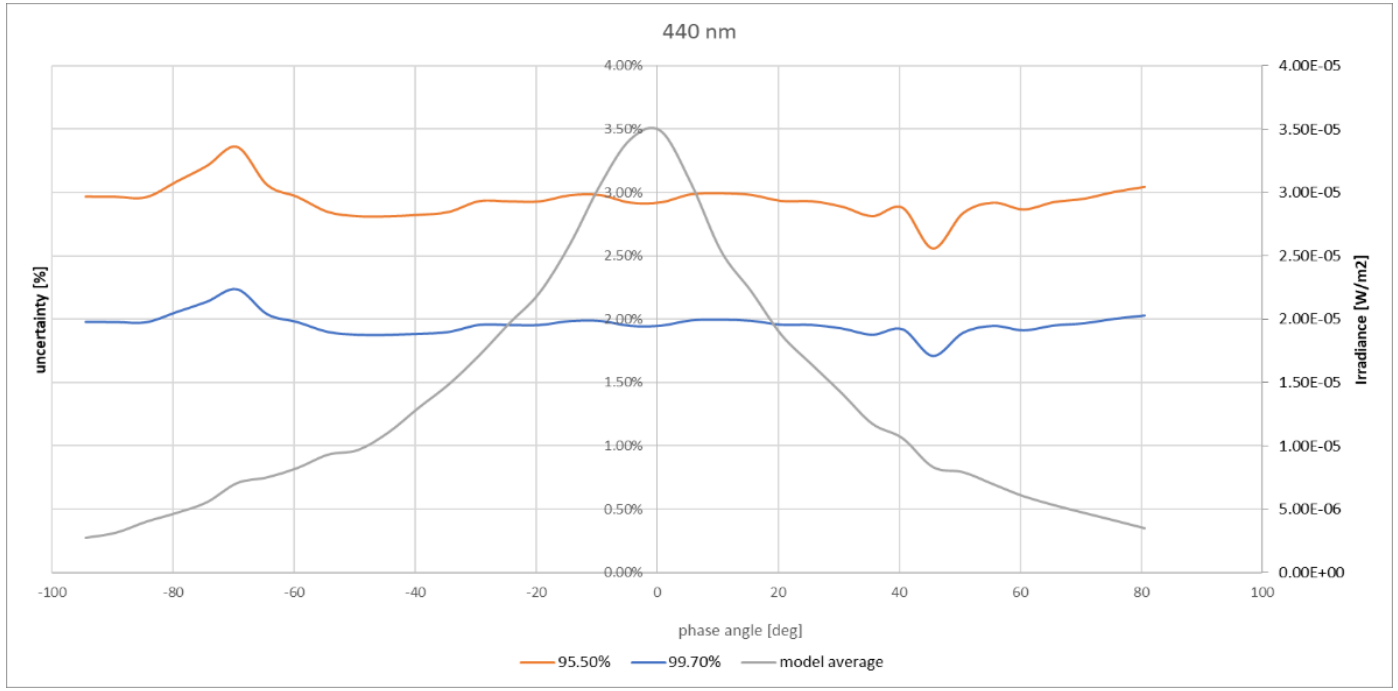
- The uncertainty at model wavelengths is derived using Monte Carlo analysis : every input measurement to the model has been perturbated 1000 times



Input irrad perturbated 1000x based upon meas. uncertainty

Results : 1000 models

1000 model results per observation



Uncertainty is established at 2% (2 sigma)

LIME Model : comparison

- Comparisons with sensors and other models :
  - PROBA-V : large time series, fixed phase angle (+/-7°)
  - Pleiades-B : small dataset, full phase angle coverage
  - GIRO (model) : detailed time-series

  Project reports on a dedicated cal-val portral CEOS
  http://calvalportal.ceos.org/lime

  - Sentinel-3B : limited comparison

  Published : Nemenan M. et al, "*Use of Moon Observations for Characterization of Sentinel-3B Ocean and Land Color Instrument*", 2020

- Ongoing :
  - AIR-LUSI data comparison to LIME : possibility to look at spectral performance of the model.

- In general agreements are quite good between sensor and model. More comparisons are needed to reveal model weak points (like phase dependency)

LIME Model : future

- The model development is ongoing (‘maintenance’)
  - Extra measurements for geometry
  - ‘improvements’ to the model are planned : non-linear part of the model, solar irradiance, …
- The uncertainties defined do not cover the complete model process
  - Lunar reflectance spectrum interpolation
  - Application of spectral response function
- Possible phase angle dependency needs to be addressed
  - PROVA-V experimental phase supports this action
- More in depth comparison between LIME AIR-LUSI is ongoing : evaluation spectral performance,…

LIME Model : conclusion

- ESA has succeeded to build a new Lunar irradiance model in about 2 years (2017-2019. Maintenance is assured for the next 4 years.
- The model has been applied operationally to calibrate PROBA-V
- Improvements to the model are planned in the next 2 years