RE: SHORTERM MOBILITY Program Travel Grant - 2013
Sponsored by: dr. Vito VITALE, ISAC-CNR – Bologna

Report on Accomplishments during a visit to ISAC-Bologna - November 2013

Titolo del programma/Title of the research activity:

Extending Polar-AOD monitoring through the Arctic Winter

using Lunar Photometers

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Background

My visit to ISAC-CNR, Bologna was motivated by a long-standing collaboration between NOAA and ISAC, prompted by mutual interests pertaining to Polar research. Our interests focus on Polar climate studies involving aerosol characterizations and their impact on the surface radiation budget at high latitudes.

I have managed NOAA programs at South Pole and Barrow, Alaska (BRW) for many years and had opportunities to visit the Italian Research Stations at Terra Nova Bay, Dome Concordia and Ny-Alesund, Svalbard since 2002. I have participated in various campaigns at each of these sites, including a Sun photometer inter-comparison campaign (2006) and inter-calibration campaign (2008) and field work to characterize snow and ice properties (2002, 2011). Vitale and I oversaw the development of a portable photometer system that has subsequently been used at Dome C (2003-2004), on board a German research aircraft (2009), by Russians on a drifting ice island in the central Arctic Ocean (2013), and is next to be deployed at a refurbished climate observatory in northern Siberia (2014).

Motivation for Visit

In recent years, the need to extend photometric measurements through the dark winter months at high-latitudes has been recognized. On the basis of mutual interests, we aim to

develop a network of Arctic sites in which nighttime monitoring of AOD is possible, using sunlight reflected from the Moon. This offers a cost-effective way to advance our understanding of polar aerosols, using existing ISAC and NOAA/GMD infrastructure. The current focus is on Ny-Alesund, Svalbard (NYA) and Barrow, Alaska (BRW), where the deployment of lunar photometers will augment existing Sun photometer programs. During winter 2012/2013, I coordinated the development of lunar photometry program at BRW. The success of this project is summarized in the attached poster and provides a model for a similar program to be initiated at NYA.

Summary of Accomplishments

During my visit to ISAC I shared experience in the above endeavor and provided guidance in developing a lunar photometry program at NYA. The project will be undertaken, principally, in collaboration with the Physikalisch-Meteorologisches Observatorium Davos (PMOD), the Norwegian Institute for Air Research (NILU) and the Alfred Wegener Institute (AWI), Germany as described below. Establishing a lunar photometer program at NYA will greatly enhance aerosol research there and give ISAC leverage to seek additional funds for validating satellite retrievals and scaling raw Lidar data to AOD. The NYA AOD climatology will be completed and understanding of aerosol-related processes that occur during winter will be better understood.

The primary purpose of my visit was to provide specific logistical and scientific advice on how to expedite the deployment of such a system to NYA, including how to calibrate the photometer and process the raw data. The actual system will be very similar to the one used successfully at BRW this past winter (*see poster*). In this case, PMOD is developing the system, comprised of a modified precision filter radiometer (PFR) that will be mated to a lunar tracker, and a Campbell Scientific CR1000 datalogger. NILU will assist with the installation and operation, and AWI will provide comparable data from Star and Sun photometers and their Lidar system currently operating at NYA. A number of other agencies from the U.S., Canada, Spain and Poland are also collaborators engaged in similar monitoring activities as part of the ISAC-led Polar-AOD Programme.

In particular, I engaged in the following activities while visiting ISAC:

(i) provided an overview of the development, testing, calibration and deployments of the NOAA prototype lunar photometer to their baseline observatory near Barrow, Alaska (BRW), including calibration procedure and preliminary results (*also see poster attached*)

(ii) worked closely with ISAC researchers to evaluate computations of exo-atmospheric lunar irradiances using an ISAC algorithm. There is critical need of this data when deriving AOD from raw photometric data and we must be able to replicate the results from those produced by the United States Geologic Survey (USGS) Robotic Lunar Observatory (ROLO with high precision. **Figure 1** shows the progress made to date, in which comparisons between the ISAC results and those provided by USGS (T. Stone) are shown. Differences are probably due to the use of different data bases used to obtain geometric quantities that give Sun-Moon-Earth distance and lunar libration parameters with respect to their relative motions and lunar phase but are generally < 2%

(iii) conducted, via Skype and e-mail, communications with a number of individuals from other agencies involved in the project. In particular, conference calls were initiated with the group at PMOD responsible for designing and testing the lunar PFR, and with personnel at NILU in Norway, who will oversee their activity, arrange for the deployment of the system and its initial operation. In the process we also had a Skype session with a group in Spain that plans an eventual deployment of a third lunar system to ALOMAR. In the future, inter-calibration of the three (or more) Arctic lunar photometers is planned, as well as a Workshop to advance common goals

(iv) developed a specific work plan to expedite deployment of the ISAC/PMOD lunar system in collaboration with cooperating agencies during the 2013/2014 Arctic winter. Tasks include more thorough testing of the system at Davos, initial calibration during the November and December lunar cycles, January testing at ISAC-Bologna and final deployment and operation at NYA, February-April, 2014. Summer 2014 will be used to analyze data and make improvements before re deployment in November. During winter, preliminary analyses will be made as data are collected and can be compared with other systems operating simultaneously, e.g., the AWI Lidar and Star photometer and Sun photometers of NILU and AWI. Further comparisons are planned with the Polish Groups operating a Lidar and Sun photometer at Hornsund, Svalbard (nearby), as well as data collected at BRW and possibly Eureka, Canada where a third lunar system is to operate

(v) evaluated initial calibration results using data collected at Davos, applying a modified Langley Plot Method. I assessed performance of the prototype photometer on the basis of preliminary retrievals of AOD by ISAC (M. Mazzola). Results are shown in **Figure 2**; the raw data (*top*), Langley plots (*middle*) and derived values of AOD (*bottom*). Data for the short (0.368 micron) channel is very noisy due to low signal-to-noise ratio. On the basis of these evaluations suggestions were made to improve the PFR in final stages of testing, mainly to replace the 0.368 filter with one at 0.675 and reduce noise at 0.412

(vi) assisted in drafting a joint proposal to the Svalbard Science Forum (SSF) to obtain support for activities described above. If awarded, the grant will provide supplemental funds to continue operations in the future and organize a workshop bringing together the newly formed lunar community to advance the effort

(vii) provided input to an application by ISAC to fund the first international lunar photometer inter-calibration campaign and Workshop tentatively planned for autumn 2014; site to be determined. This will bring together the key participants and experts in the field to share ideas, solve common problems, assure protocols are adhered to and advance the goals of Polar-AOD in general

The goals of the visit were satisfactorily met. A great deal of enthusiasm for the deployment of the prototype lunar PFR to NYA resulted. Cooperation amongst the participants was reaffirmed and some technical obstacles were identified. A plan to improve the system was discussed with engineers at PMOD; mainly the need for new filters to replace the 368 and 412 nm channels. The ROLO data comparisons were completed with good success and the first Langley Plot analyses from the lunar PFR obtained. The first AOD time series were generated and show great promise.

Through the various communications conducted during my visit, we renewed interest in Polar-AOD activities, with plans being laid for a campaign and workshop(s). The combined, field activities and workshops will position ISAC to work more closely with the satellite and modeling communities in the future.

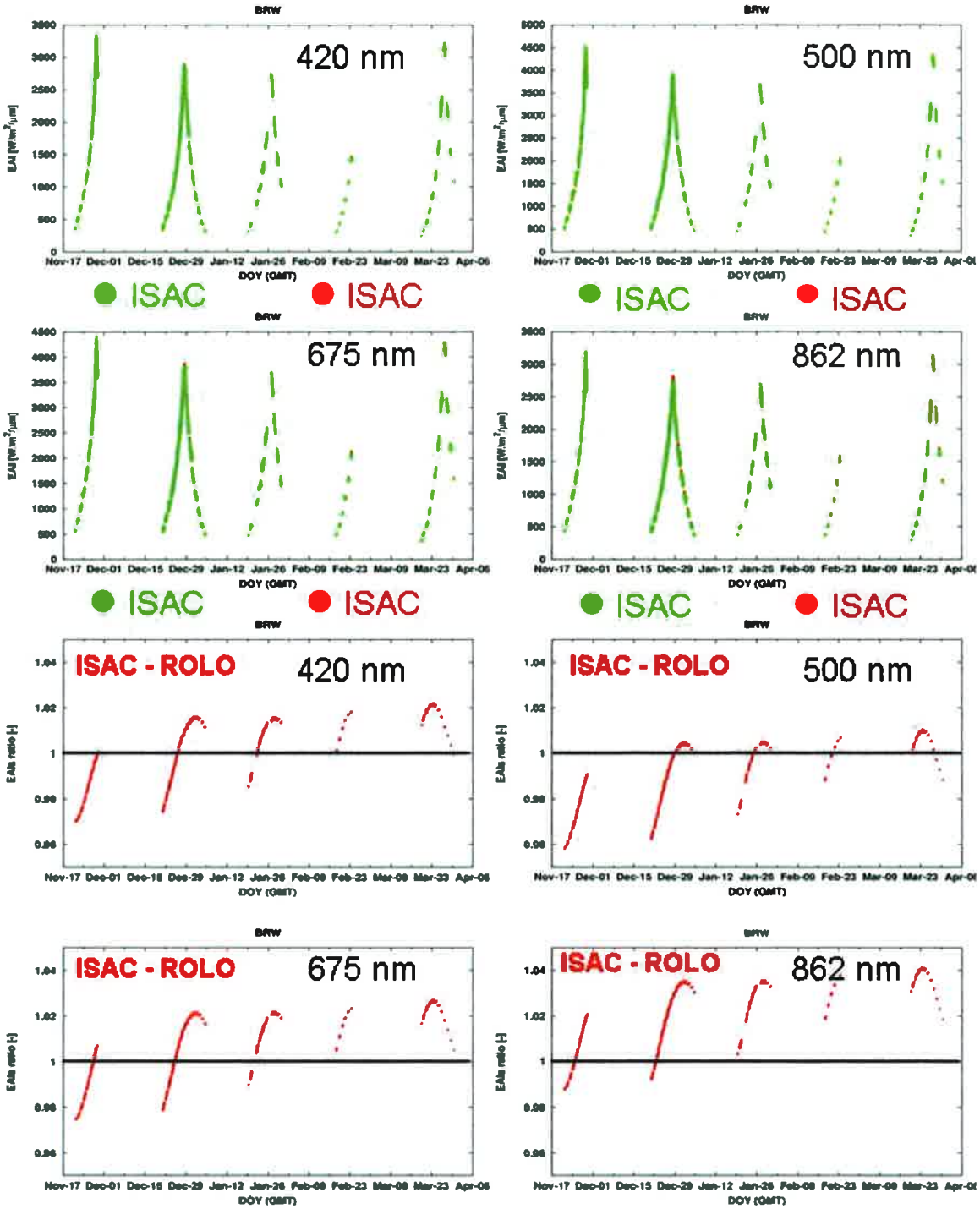

Figure 1. (*top four panels*) Exo-atmospheric irradiance computed for five successive lunar cycles at BRW during winter 2012/2013 computed using the ISAC algorithm (green) and the official USGS ROLO algorithm (red), indicated by wavelength; note auto-scaling, and (*bottom four panels*) the ratio of ISAC to ROLO results computed for each of the four wavelengths indicated. NOTE the biases and systematic, nonlinear features that are attributed to the use of different data bases to obtain geometric parameters to initialize the empirical models.

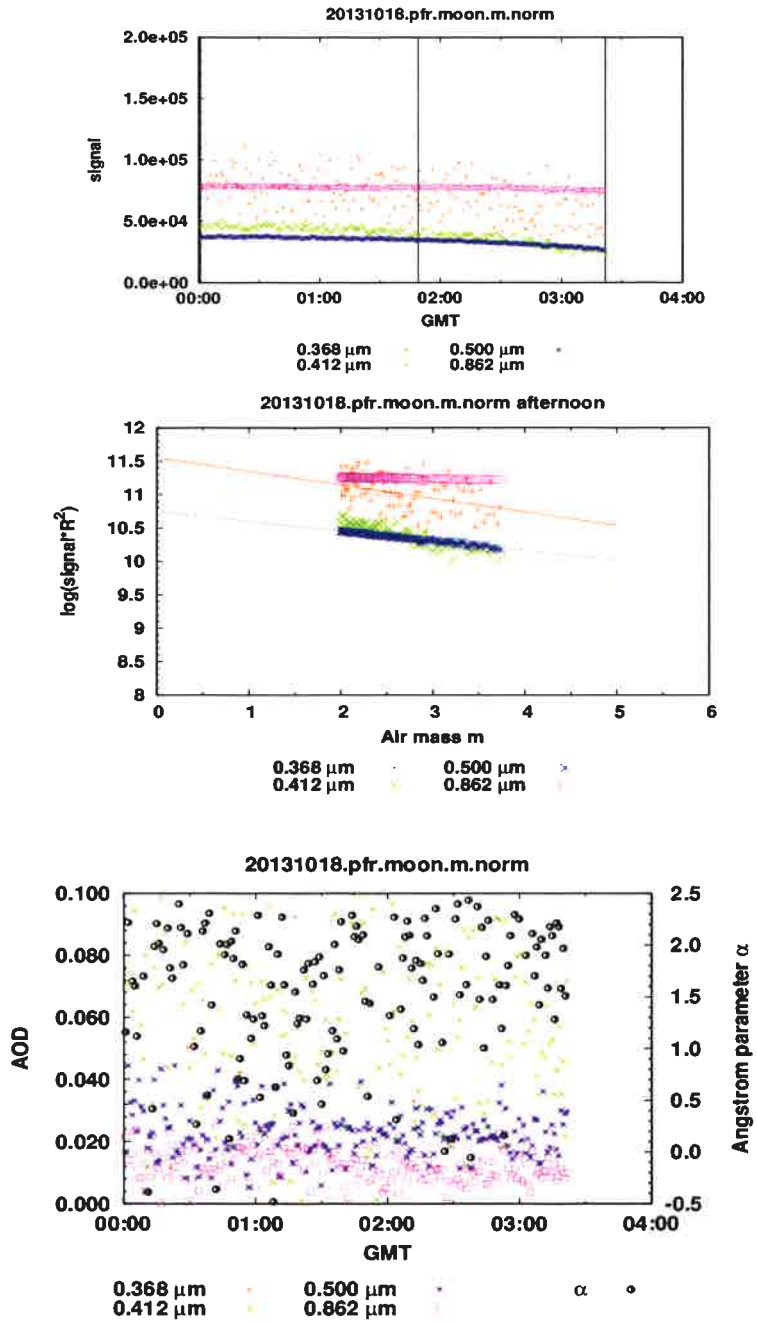

Figure 2. First results: (*top*) raw data from the prototype lunar PFR collected at Davos the night of 18 October 2013, color-coded by wavelength; (*middle*) Langley Plots obtained from the raw data shown in the top panel, from ≈ 1:50 to 3:30 GMT, or over airmass range, ≈ 2.0-3.8; (*bottom*) derived spectral AOD and Angstrom Exponents for the entire data set, resolved as one-minute values. Note the extreme noise in the 0.368 micron channel. Values are comparable to daytime measurements made using an AERONET Cimel the following morning showing validity of the calibration/analysis.

Robert S. Stone

Boulder, November 18, 2013

dr. Robert.S. Stone