

# Development of first moon photometric measurements at Arctic stations

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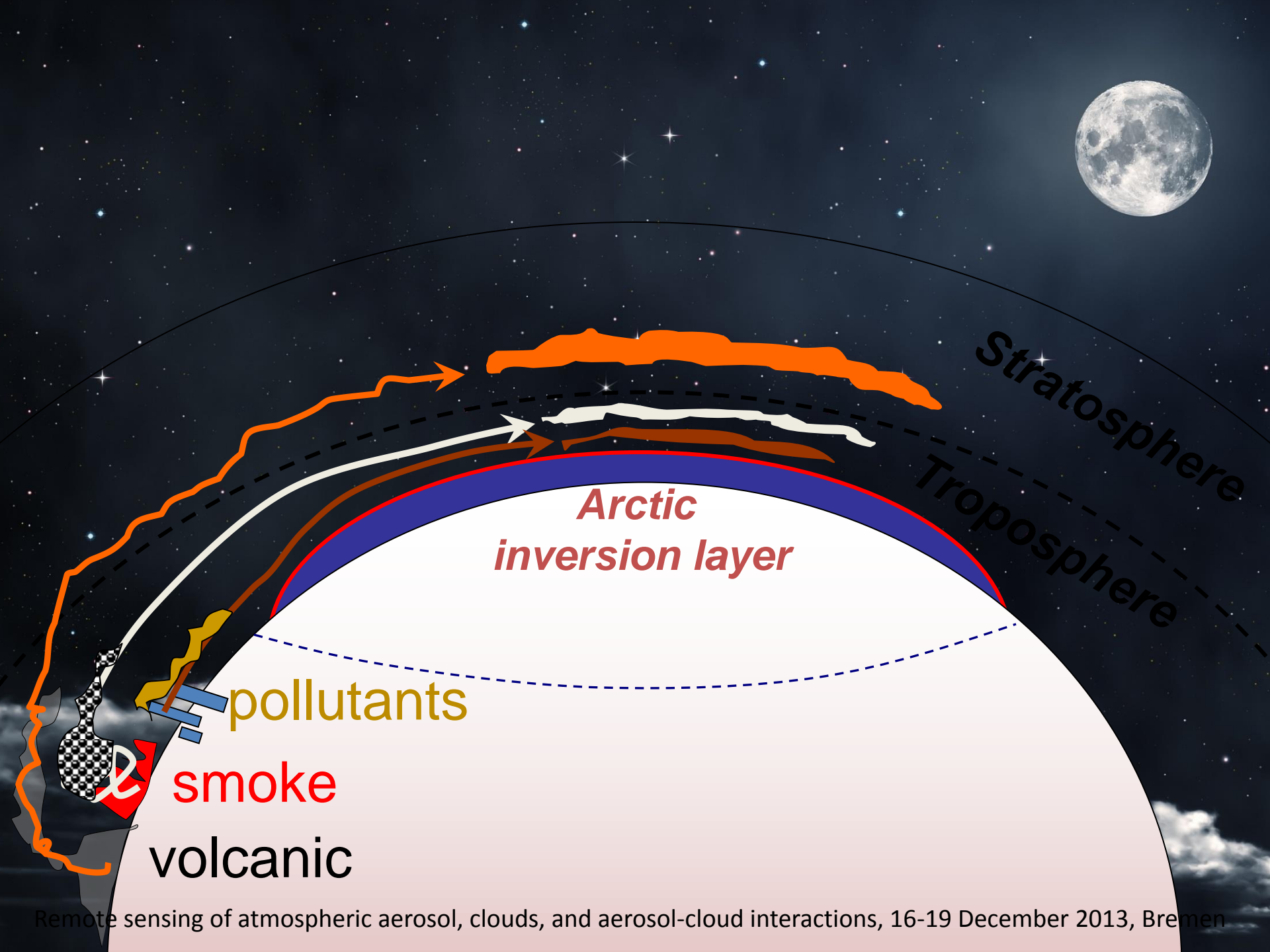
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## Outline

- why night-time measurements?
- from Sun to Moon observations
- present: first measurements at Barrow
- near future: plans for Ny-Ålesund
- summary/other info



Stratosphere

Troposphere

**Arctic  
inversion layer**

pollutants

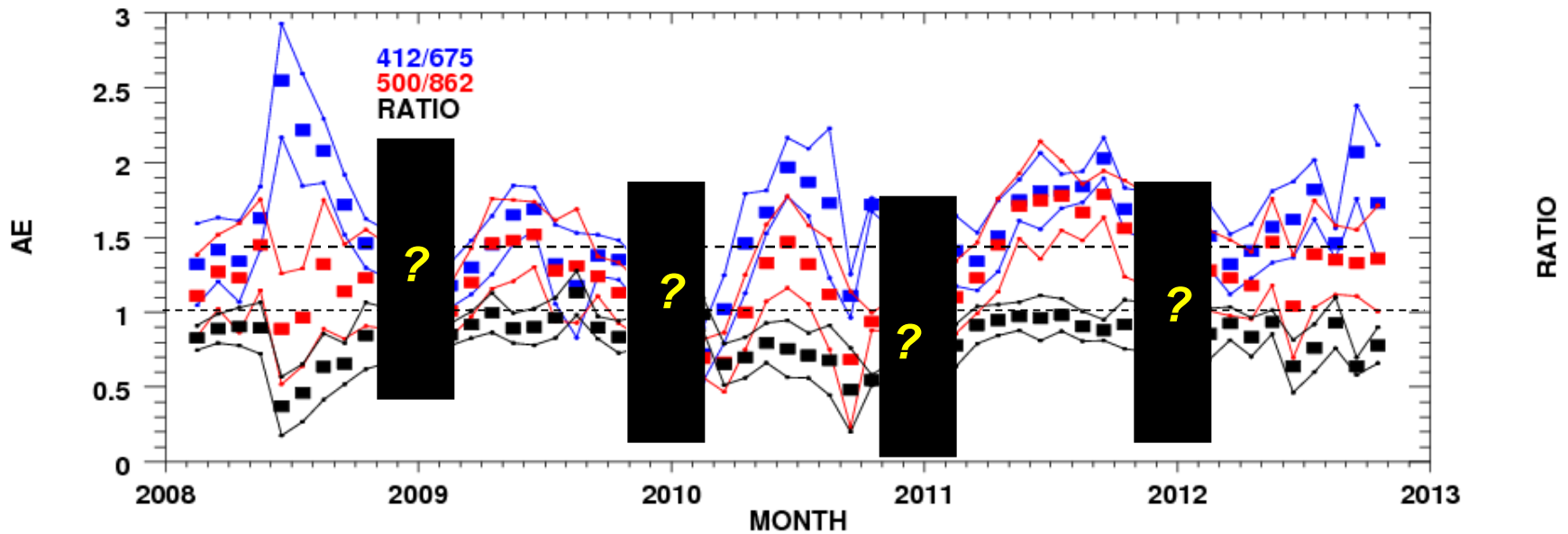
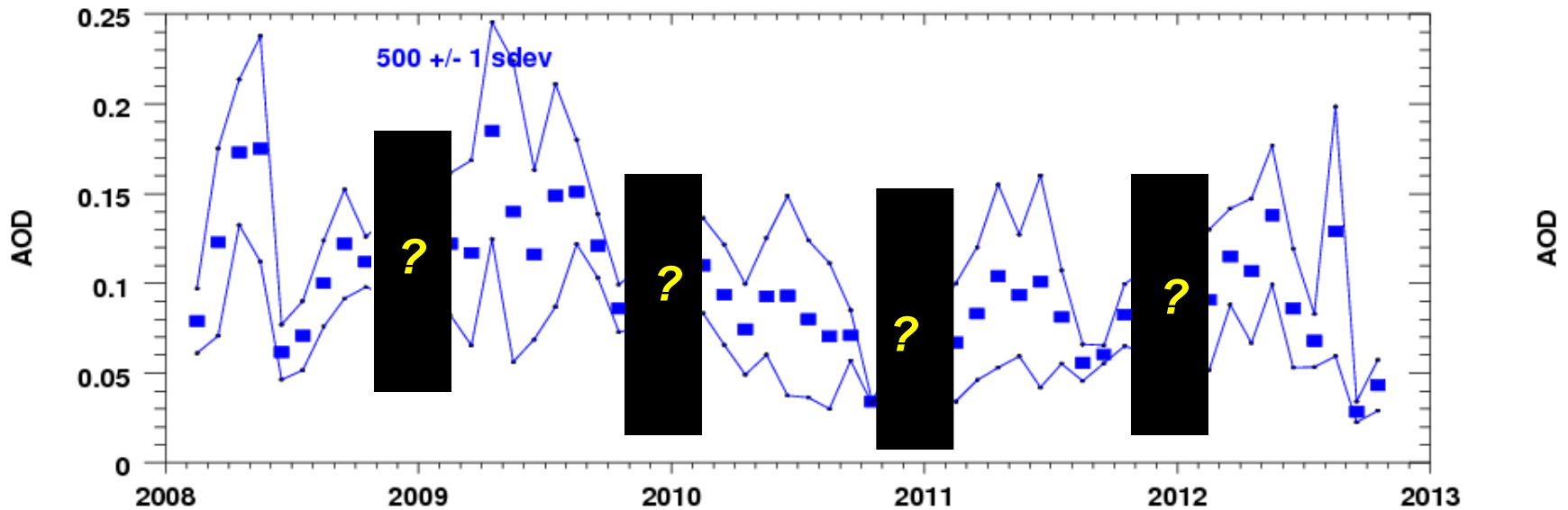
smoke

volcanic

# Barrow, AK

2008 - 2012 MONTHLY

R.S Stone



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## Letter

*Nature* **439**, 453-456 (26 January 2006) | doi:10.1038/nature04449; Received 21 June 2005; Accepted 14 November 2005

### A climatologically significant aerosol longwave indirect effect in the Arctic

Dan Lubin<sup>1,3</sup> & Andrew M. Vogelmann<sup>2,3</sup>

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Correspondence to: Dan Lubin<sup>1,3</sup> Correspondence and requests for materials should be addressed to D.L. (Email: [dlubin@ucsd.edu](mailto:dlubin@ucsd.edu)).


**The warming of Arctic climate and decreases in sea ice thickness and extent<sup>1,2</sup> observed over recent decades are believed to result from increased direct greenhouse gas forcing, changes in atmospheric dynamics having anthropogenic origin<sup>3,4,5</sup>, and important positive reinforcements including ice-albedo and cloud-radiation feedbacks<sup>6</sup>. The importance of cloud-radiation interactions is being investigated through advanced instrumentation deployed in the high Arctic since 1997 (refs 7, 8). These studies have established that clouds, via the dominance of longwave radiation, exert a net warming on the Arctic climate system throughout most of the year, except briefly during the summer<sup>9</sup>. The Arctic region also experiences significant periodic influxes of anthropogenic aerosols, which originate from the industrial regions in lower latitudes<sup>10</sup>. Here we use multisensor radiometric data<sup>7,8</sup> to show that enhanced aerosol concentrations alter the microphysical properties of Arctic clouds, in a process known as the 'first indirect' effect<sup>11,12</sup>. Under frequently occurring cloud types we find that this leads to an increase of an average 3.4 watts per square metre in the surface longwave fluxes. This is comparable to a warming effect from established greenhouse gases and implies that the observed longwave enhancement is climatologically significant.**


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## ABSTRACT


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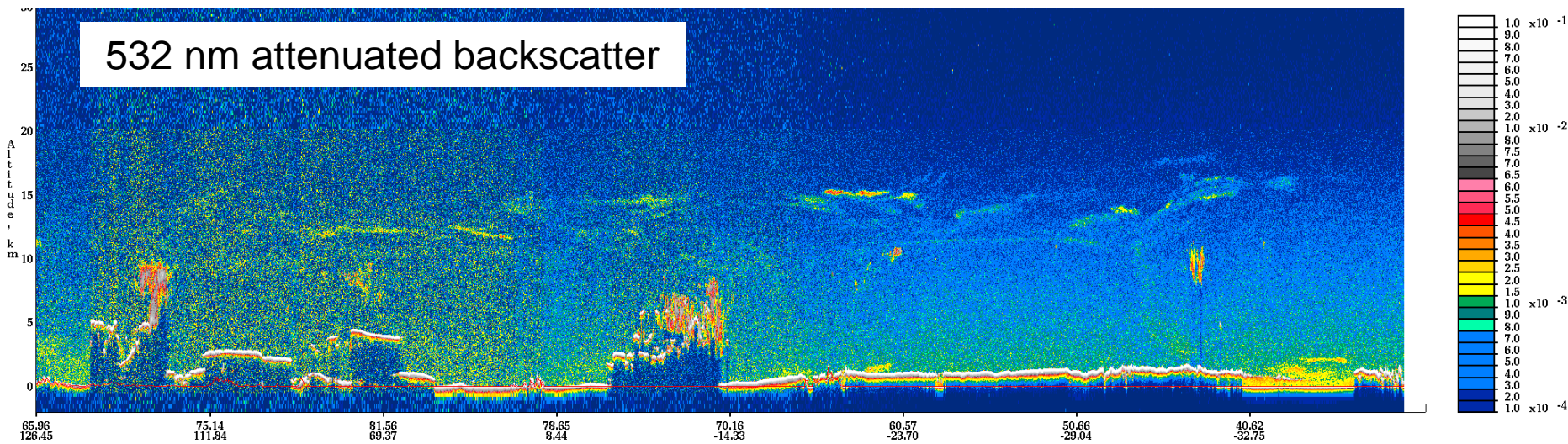
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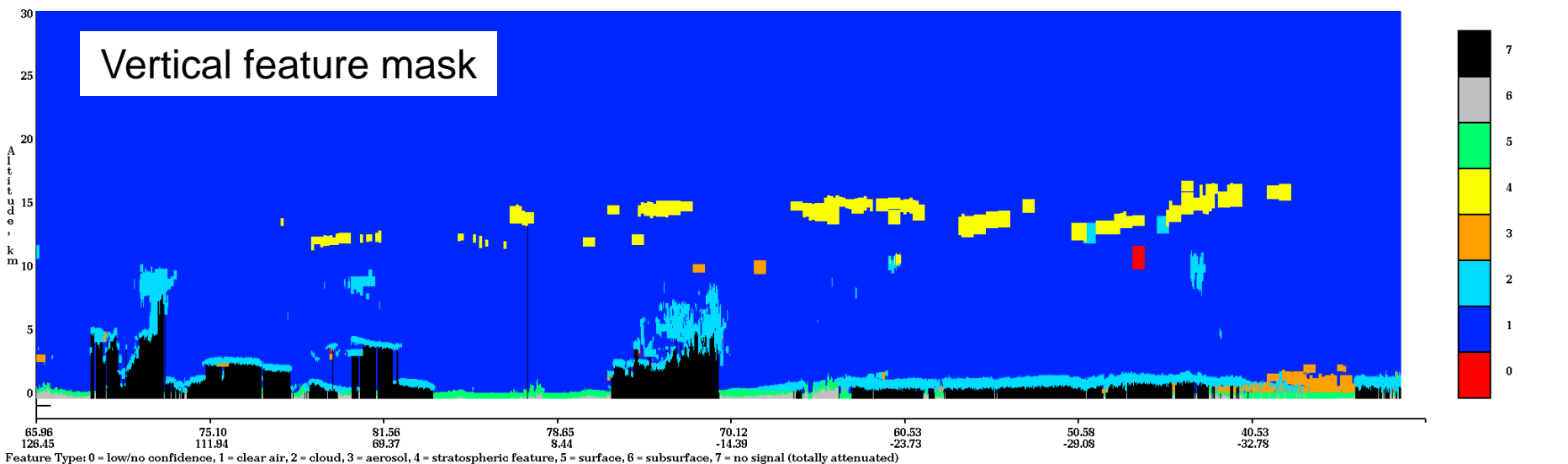
## SEARCH PUBMED FOR

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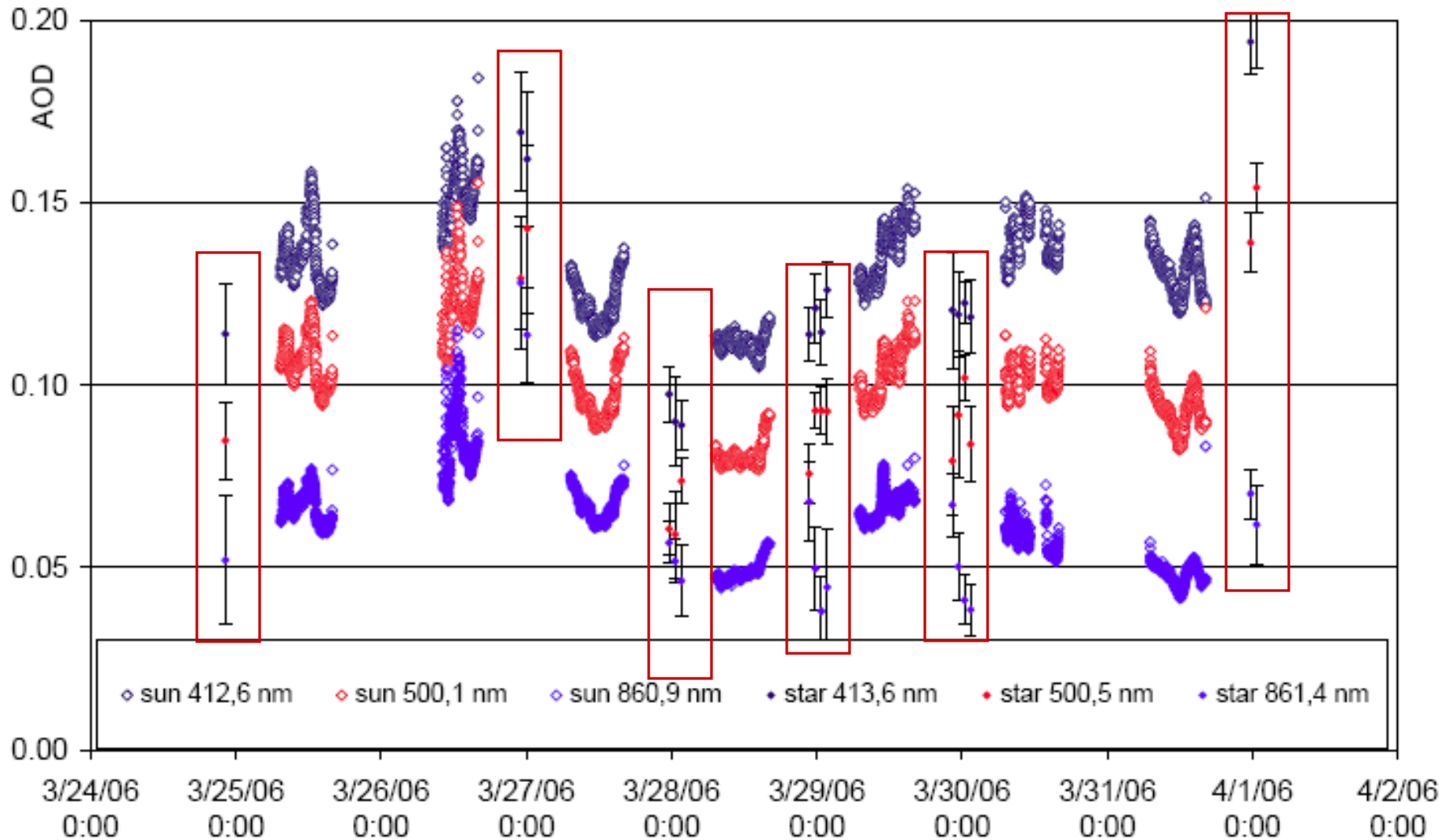


**CALIPSO** time-height cross-section showing Sarychev Volcanic Aerosol ~ July 2009



Remote sensing of atmospheric aerosol, clouds, and aerosol-cloud interactions, 16-19 December 2013, Bremen

# Star Photometer

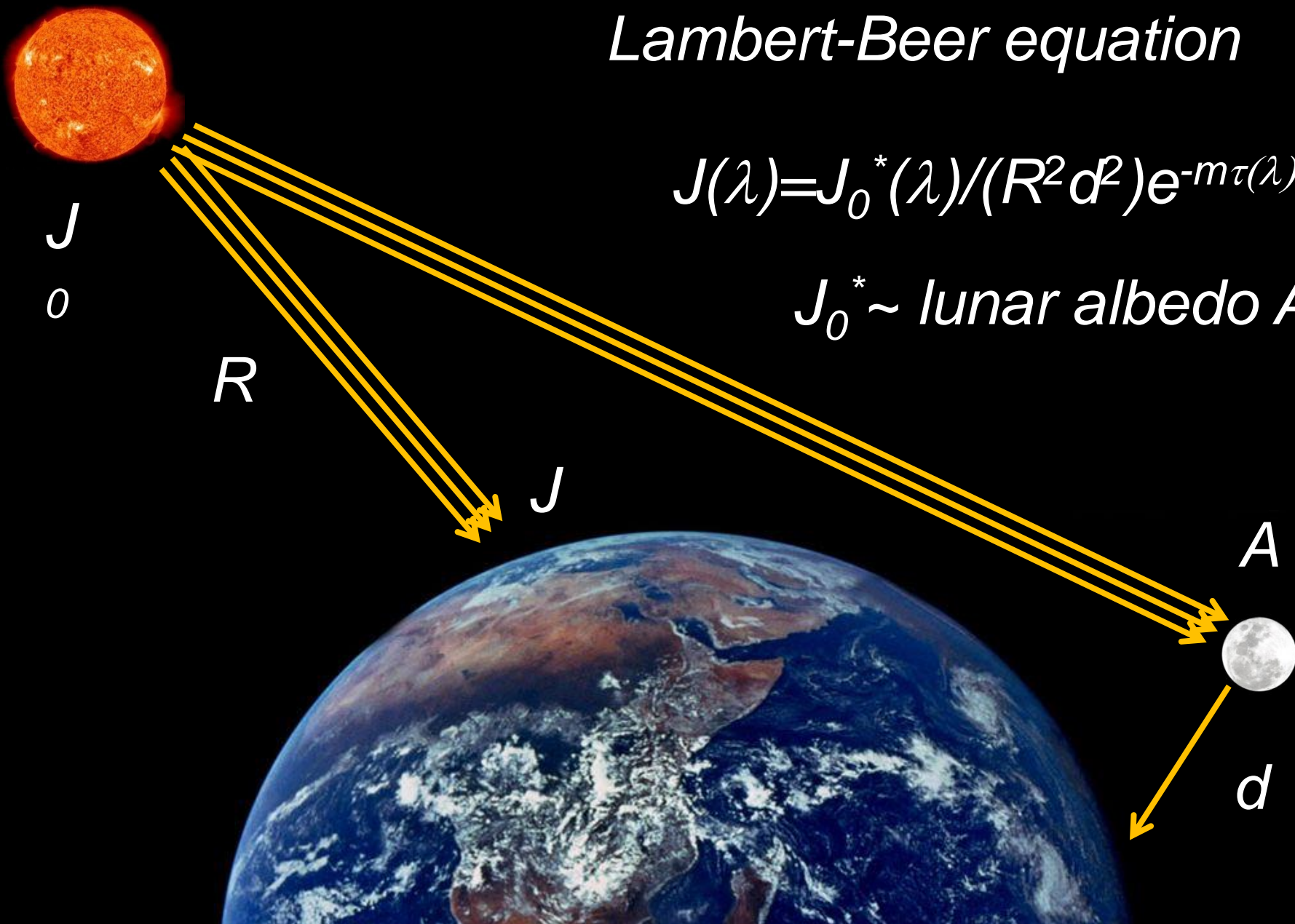


$$J(\lambda) = J_0(\lambda) / R^2 e^{-m\tau(\lambda)}$$

*Lambert-Beer equation*

$$J(\lambda) = J_0^*(\lambda) / (R^2 d^2) e^{-m\tau(\lambda)}$$

$J_0^* \sim$  lunar albedo  $A$





# Lunar Calibration

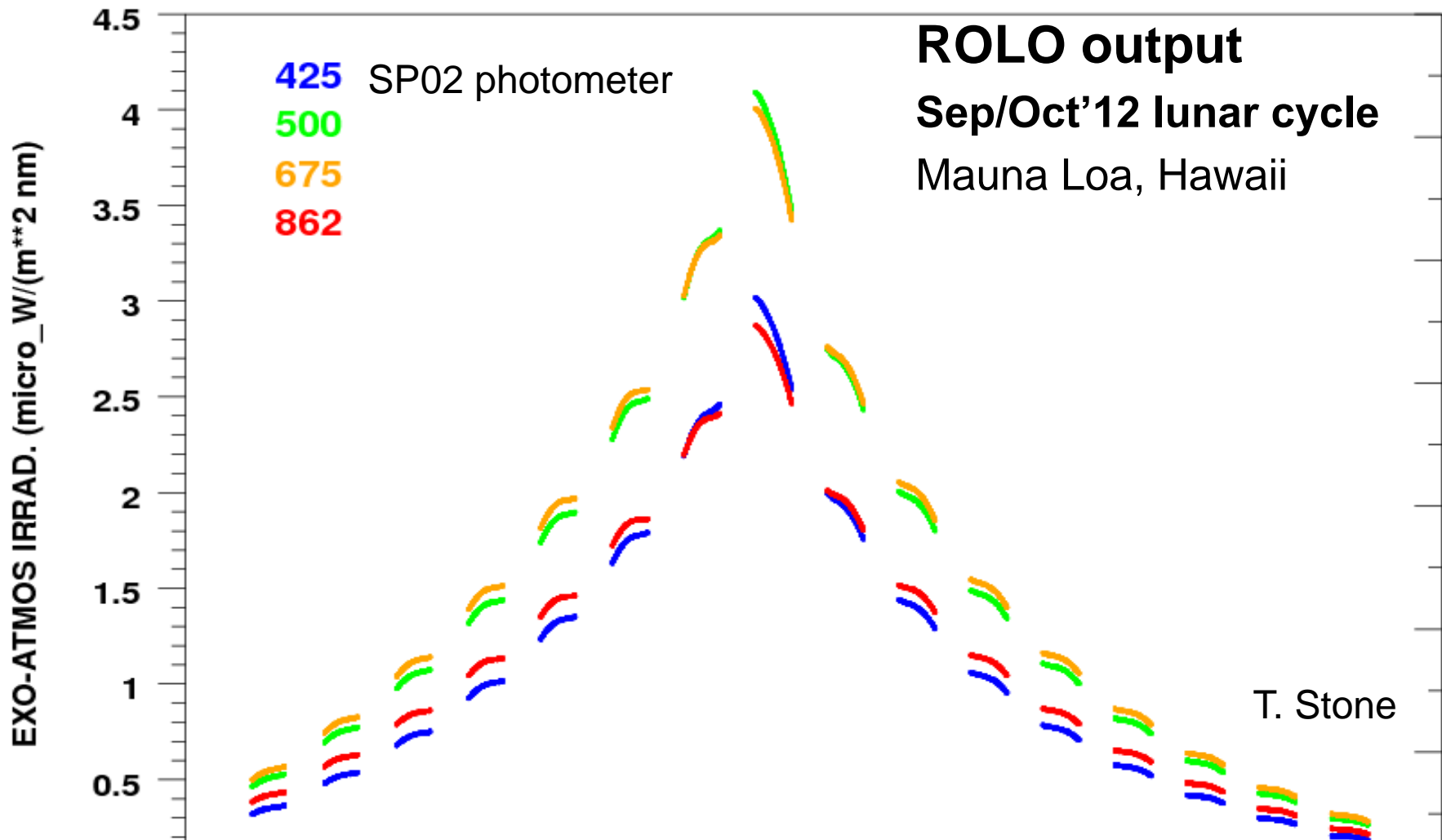
## ROLO - Robotic Lunar Observatory

- measurement and modeling of the lunar reflectance  $A$
- dependence on geometry: absolute phase angle  $g$ , selenographic latitude and longitude of the observer ( $\theta$ ,  $\phi$ ) and lunar terminator  $\Phi$
- 32 spectral bands (350-2400 nm)
- spectral interpolation with lunar soil samples

$$\ln A_k = \sum_{i=0}^3 a_{ik} g^i + \sum_{j=1}^3 b_{jk} \Phi^{2j-1} + c_1 \theta + c_2 \phi + c_3 \Phi \theta + c_4 \Phi \phi + d_{1k} e^{-g/p_1} + d_{2k} e^{-g/p_2} + d_{3k} \cos[(g - p_3)/p_4], \quad (10)$$

18 coeffs.

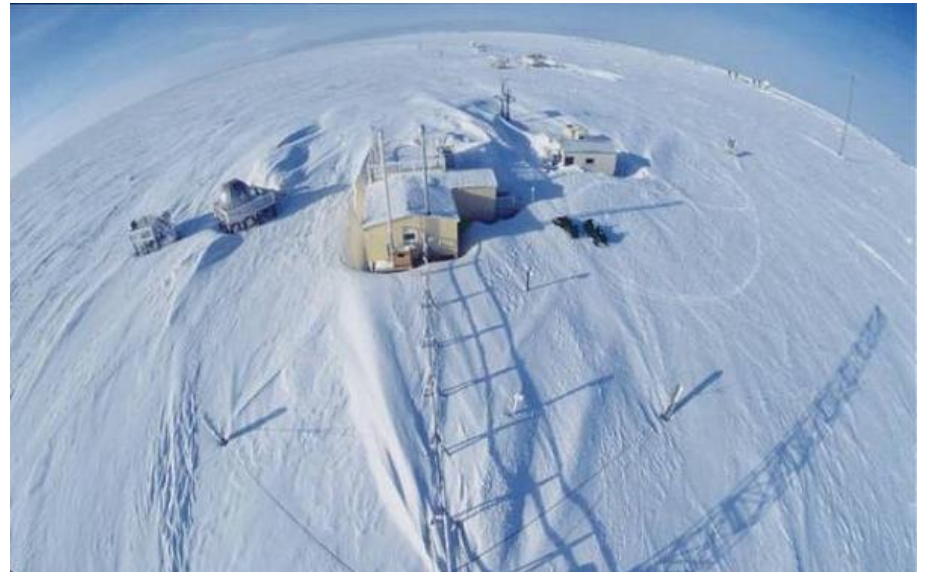
Hugh H. Kieffer and Thomas C. Stone, "The Spectral Irradiance of the Moon", *Astronom. J.* 129, 2887-2901 (2005)



Waxing Crescent — First Quarter — Waxing Gibbous — Full Moon — Waning Gibbous — Last Quarter — Waning Crescent

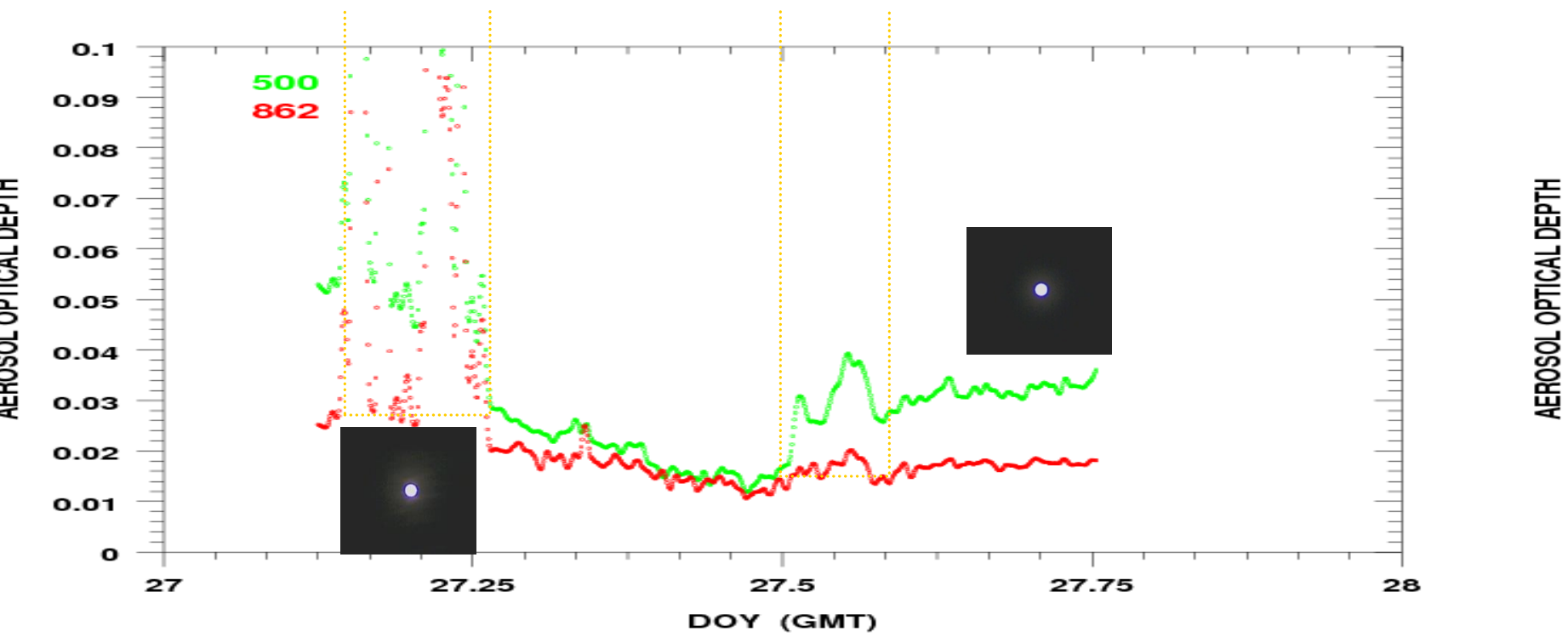
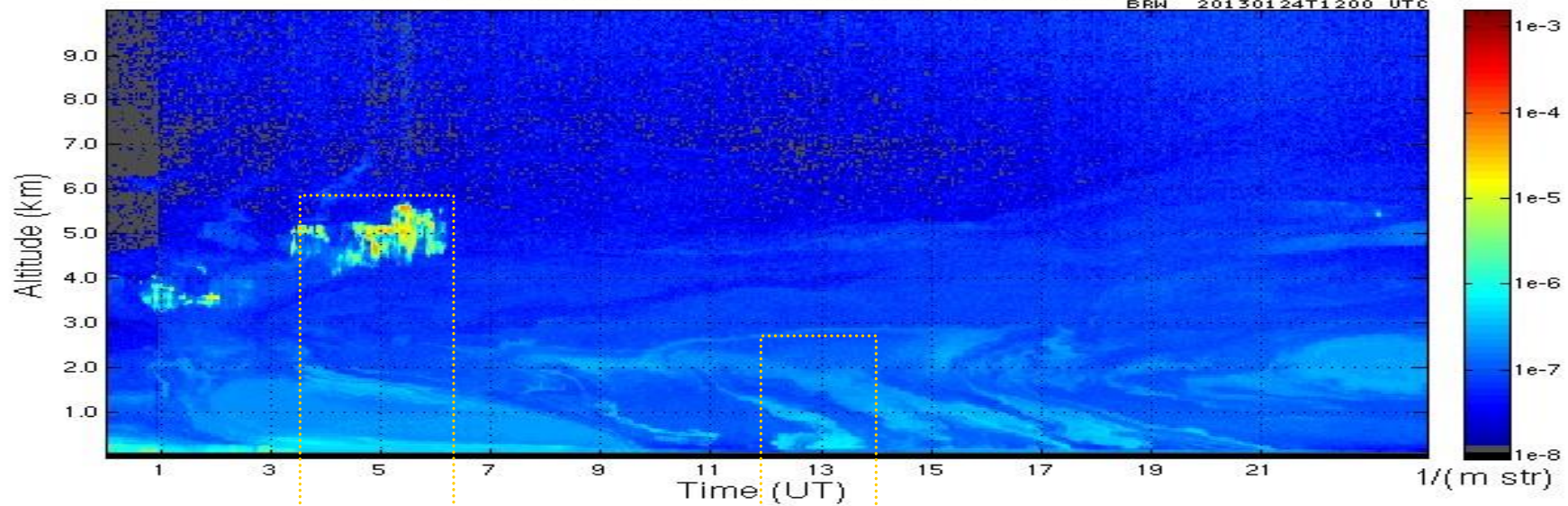
# First measurements at Barrow

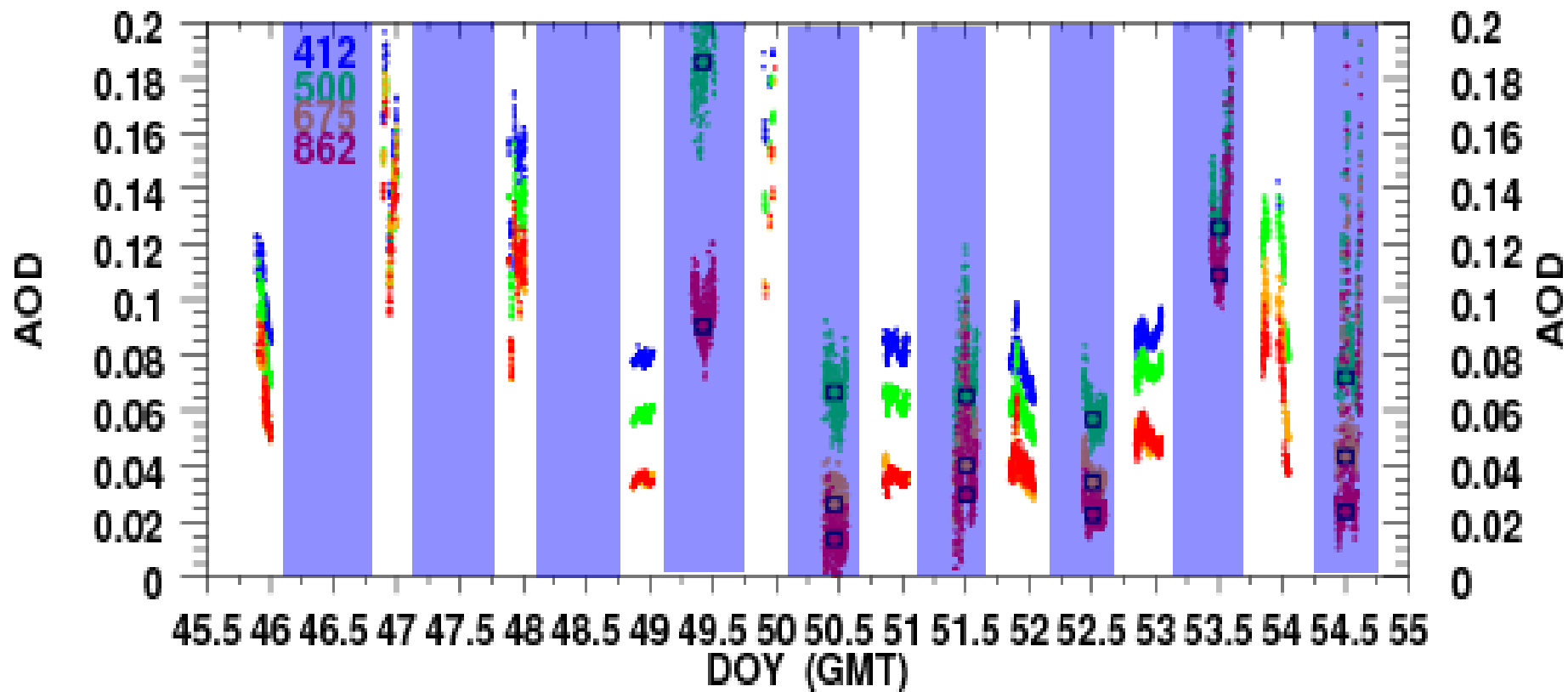
- Measurements performed with a modified Carter-Scott SP02 sun photometer (425, 500, 675 and 862 nm)
- Calibration performed during two lunar cycles at Mauna Loa, Hawaii (st. dev. < 2%)
- Measurements performed during five lunar cycles at Barrow, Alaska



Aerosol backscatter cross section 27-Jan-2013

BRW 20130124T1200 UTC





## Day and night time series for 17-25 February 2013

# Next step: Ny-Ålesund

We are going to deploy a prototype of lunar photometer (modified PFR) in Jan 2014

Lunar Arctic-coordinated remote sensing of aerosols (project submitted to SSF)

perform coordinated aerosol observations at Ny-Ålesund and Hornsund

- contribute to close the gap in the AOD climatology for the station
- establish Svalbard as a key satellite validation site using a suite of passive and active ground-based instruments



# PFR modifications

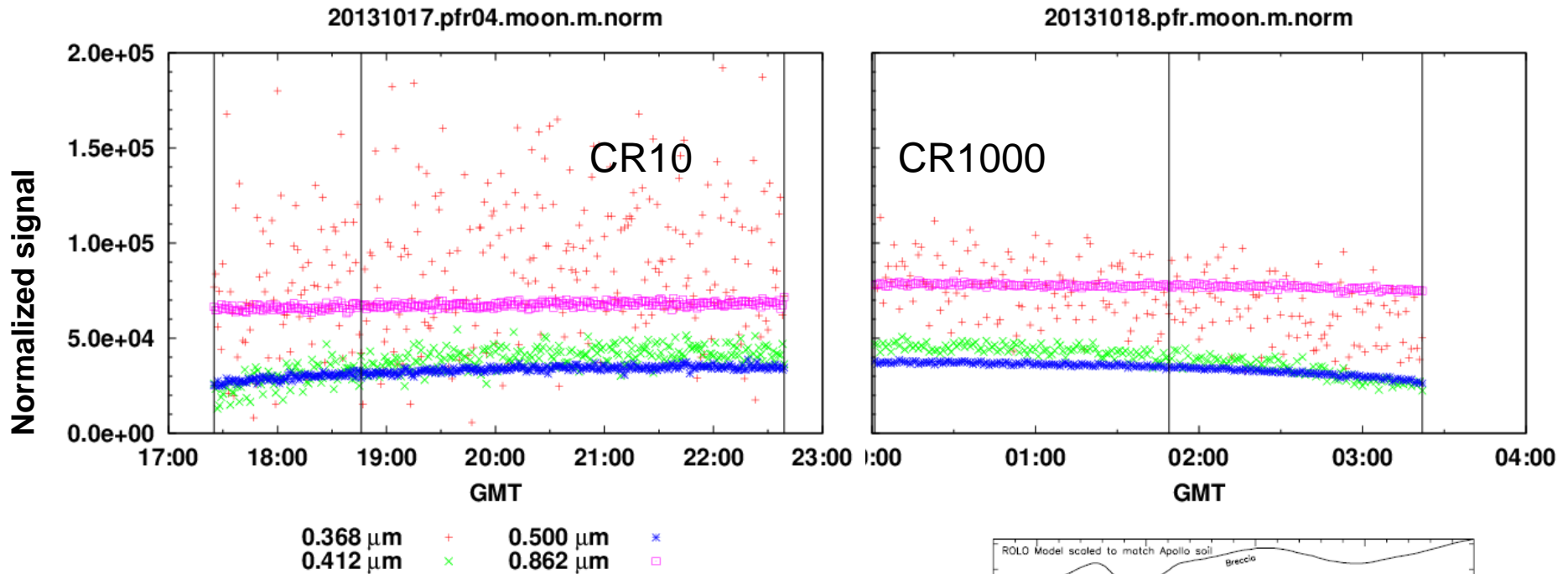
Required signal gain respect to sun  
 $3 - 6 \cdot 10^5$

Wehrli et al.

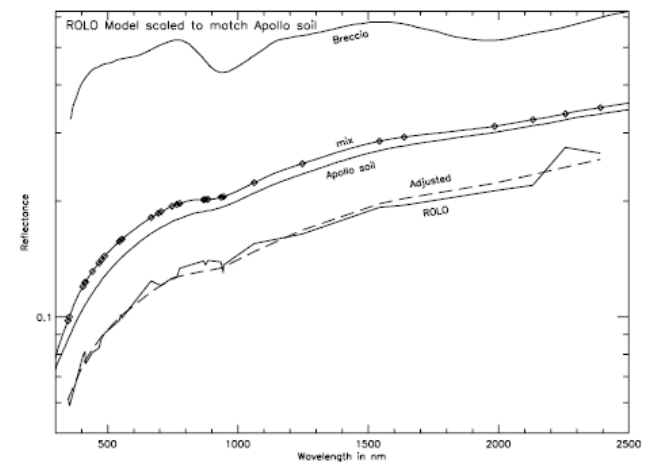
Ways to improve PFR design for low-level signal:

• 1 <sup>st</sup> and 2 <sup>nd</sup> stage amplifications	2-4 $10^4$
• Wider filters, e.g. 10 or 20 nm (now 5 nm)	3
• Larger sensor aperture 5 mm (now 3 mm)	2.75
• Telecentric collimator e.g. 12.5/5 mm	6.25
• Chopper $\approx 1$ Hz (modified shutter mechanism)	?
eliminate DC-offset propagation, Drift	→ improved sensitivity
eliminate temperature drift	→ improved stability
Synchronous A/D conversion in PFR	→ digital interface
'true' signal integration ( $\approx 0.5$ sec, VFC)	→ improved S/N

# PFR tests in Davos: signals

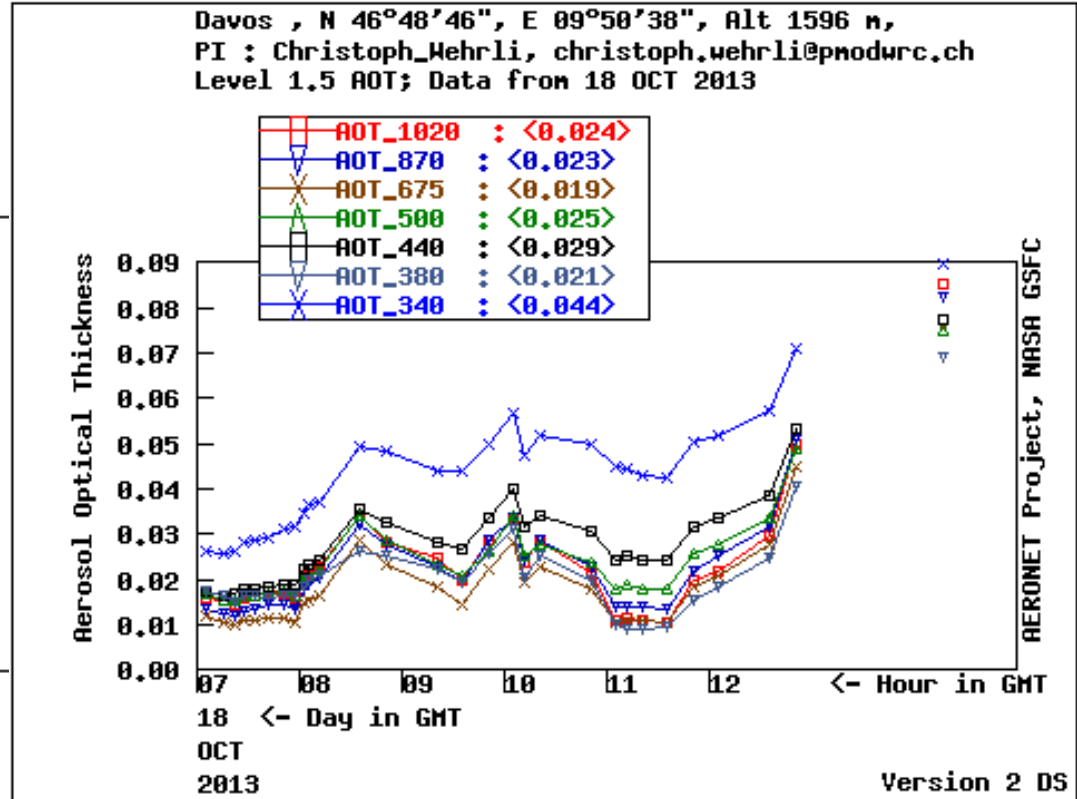
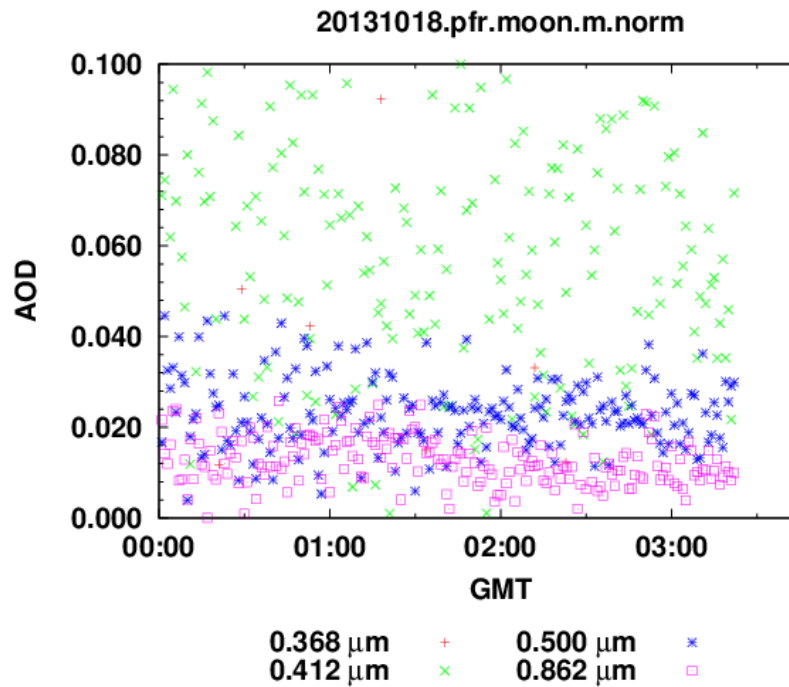


Filters at 368 nm and 412 nm will be replaced by 450 nm and 675 nm in order to increase the S/N ratio





# PFR tests in Davos: AOD

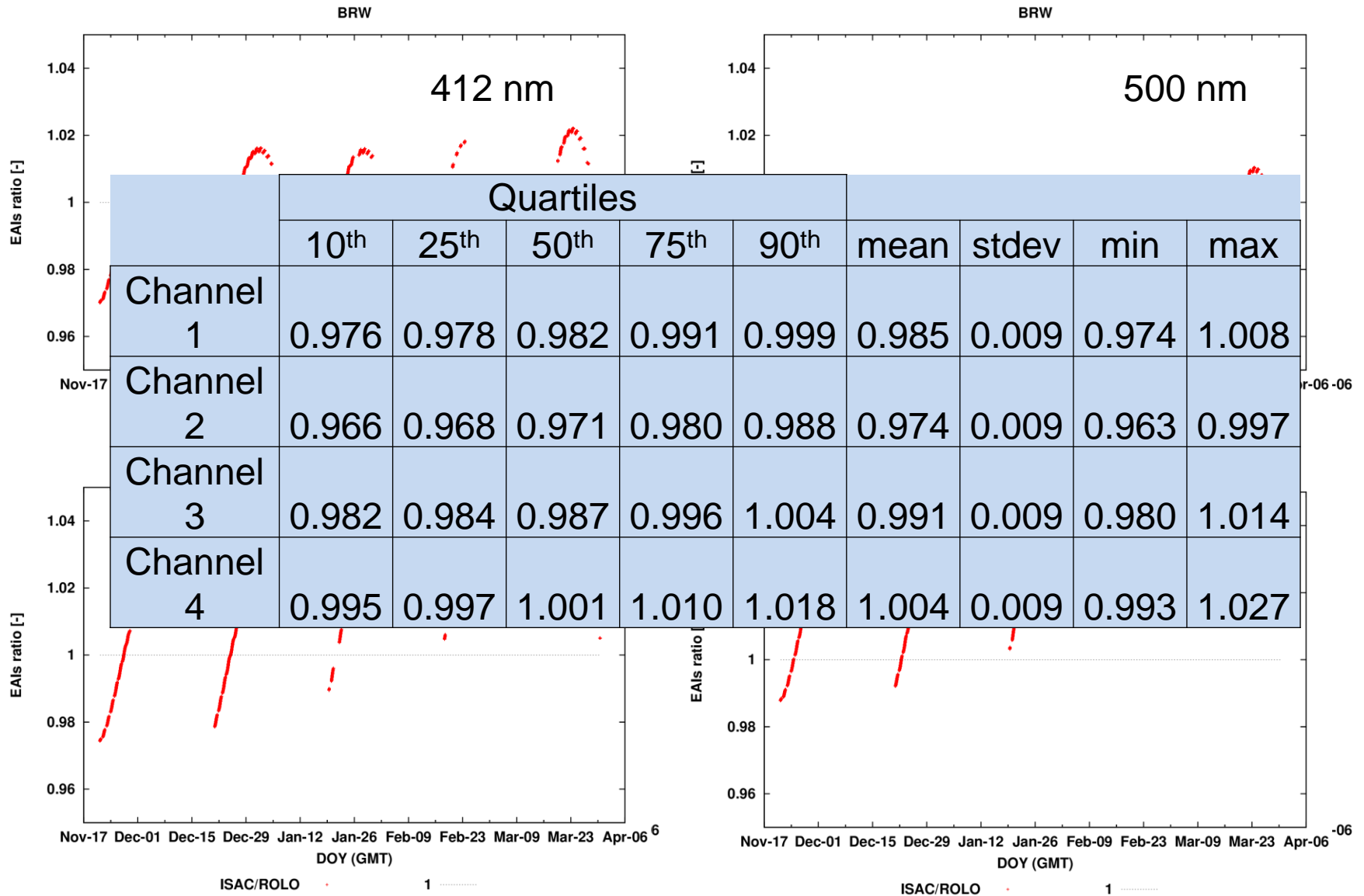


## Summary and other info

- AOD will be easily available also during (polar) night using moon as light source
- Preliminary measurements already performed at Barrow and (soon) at Ny-Ålesund and show good quality
- Cimel is going to sell a lunar version of their photometer  
-> AERONET?
- Sherbrook University (Canada, N. O'Neill) and Valladolid University (Spain, V. Cachorro C. Toledano) plan to deploy lunar Cimels at Eureka and Andennes
- Barreto et al. from AEMET already published some measurements taken at Izaña (Canary Island) for AOD and CWC



# Alternative ROLO implementation



# PFR signals estimation

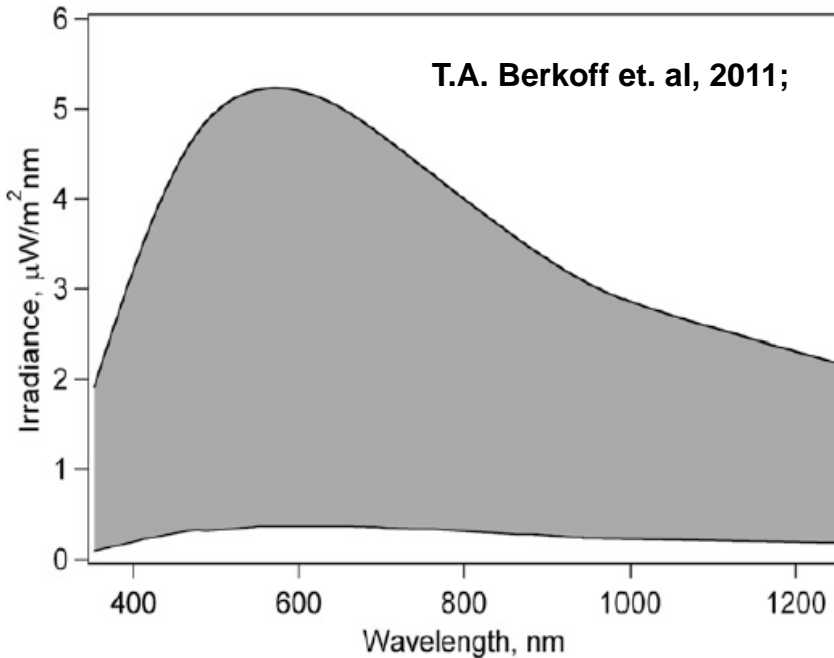


FIG. 1. Nominal range in lunar spectral irradiance (gray region) at the surface of Earth for full moon to quarter phase (0.5 disk illumination).

IRRAD	R	G	B	V
SUN [Wm <sup>-2</sup> nm <sup>-1</sup> ]	0.9	1.9	1.8	1.3
PFR [V]	3.5	3.8	3.7	4.1
MOON [μWm <sup>-2</sup> nm <sup>-1</sup> ]	3	5	3	2
PFR [μV]	11.7	10.0	6.2	6.6

**Required signal gain 3 – 6 10<sup>5</sup>**