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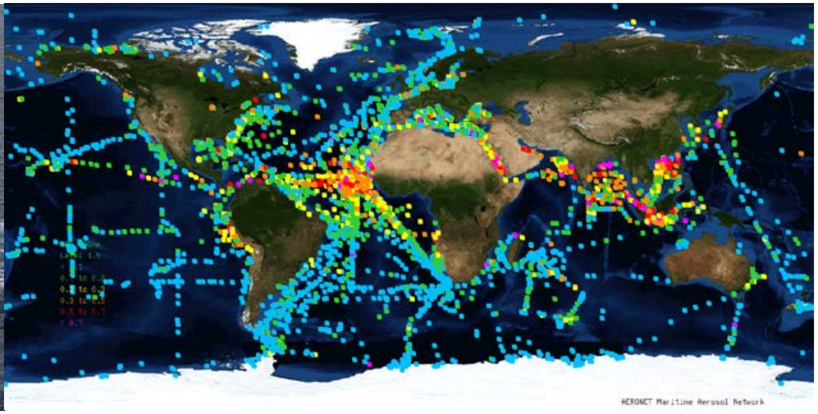
Listen to the ocean



Autonomous marine hyperspectral radiometers for determining solar irradiances and aerosol optical properties

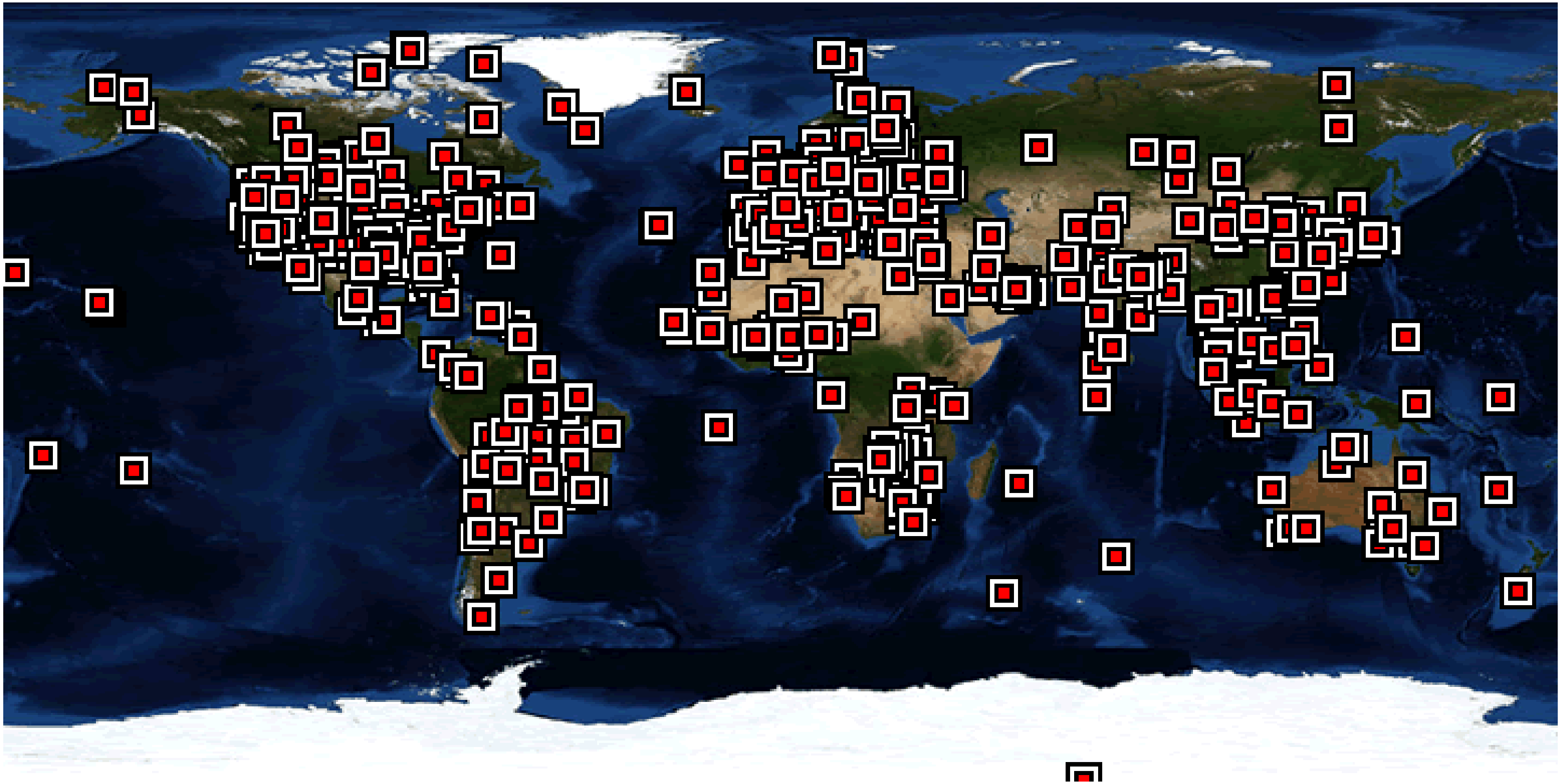
Tim Smyth (PML), John Wood (Peak Design Ltd.) and Victor Estelles (Valencia)

Atmos. Meas. Tech., 10, 1723-1737, doi: 10.5194/amt-10-1723-2017

Why?

1. Need for hyperspectral irradiances, partitioned into **direct and diffuse components**.
   – Modelling / observing incident light field, check for variability
2. Need for determining **aerosol optical thickness** in the marine environment
   – Currently sparsely observed

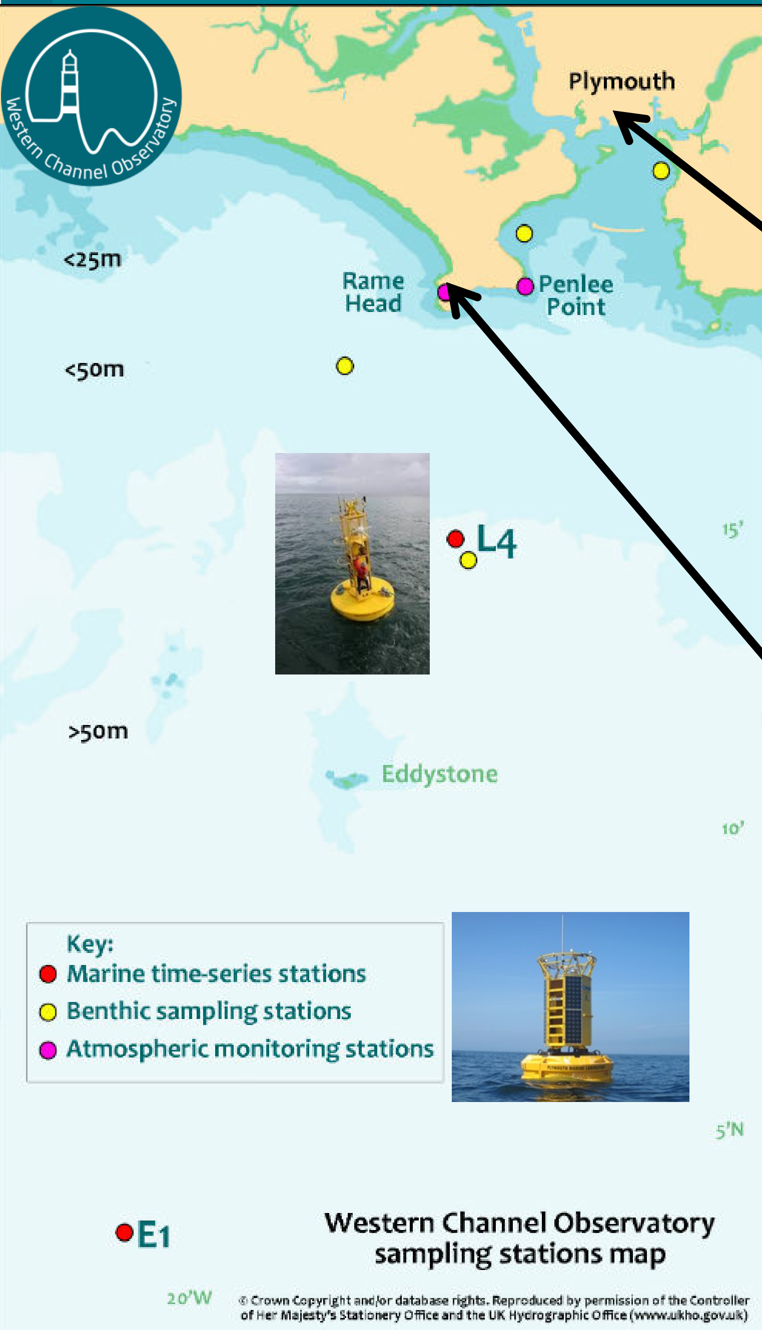
The problem



NASA: AERONET

Sparse ocean coverage

Partial solution – island / coastal observations



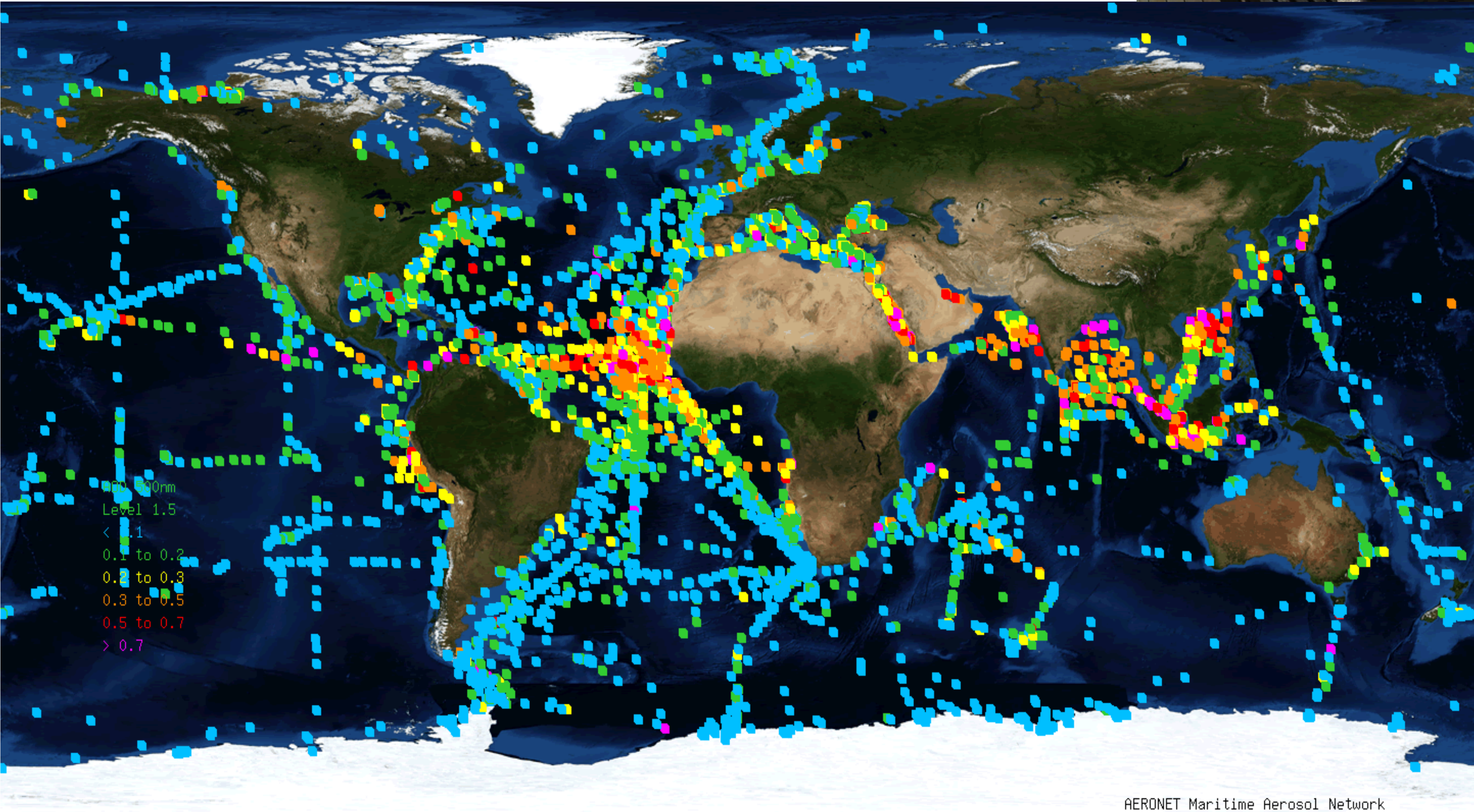
- 2001 – present
- EuroSkyRad (POM)
- Automated control & processing
- Estelles et al. (2012a,b); Campanelli et al. (2012)

- 1998; 2014 – present
- AERONET (CIMEL)
- Photons calibration

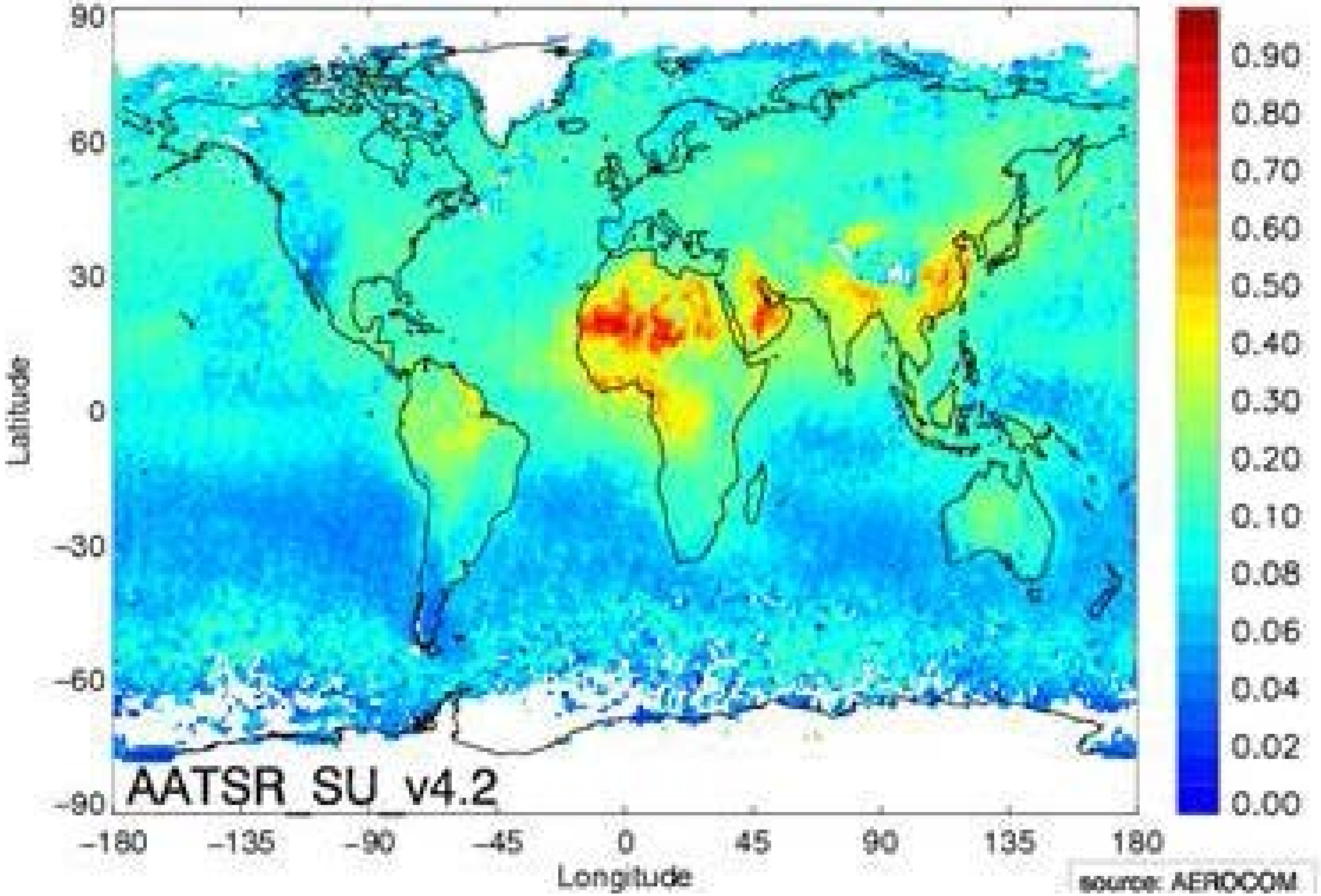
DOI
10.1016/j.atmosenv.2012.07.024
10.5194/acp-12-11619-2012;
10.1016/j.atmosenv.2011.09.070

Partial solution – manual observations

- AERONET Maritime Aerosol Network (MAN)



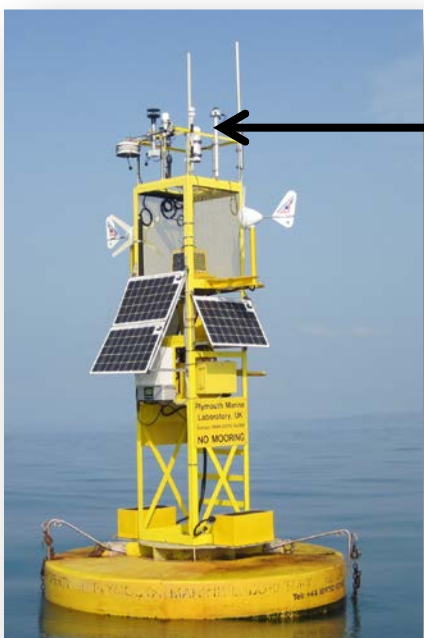
Partial solution – satellite Earth Observation



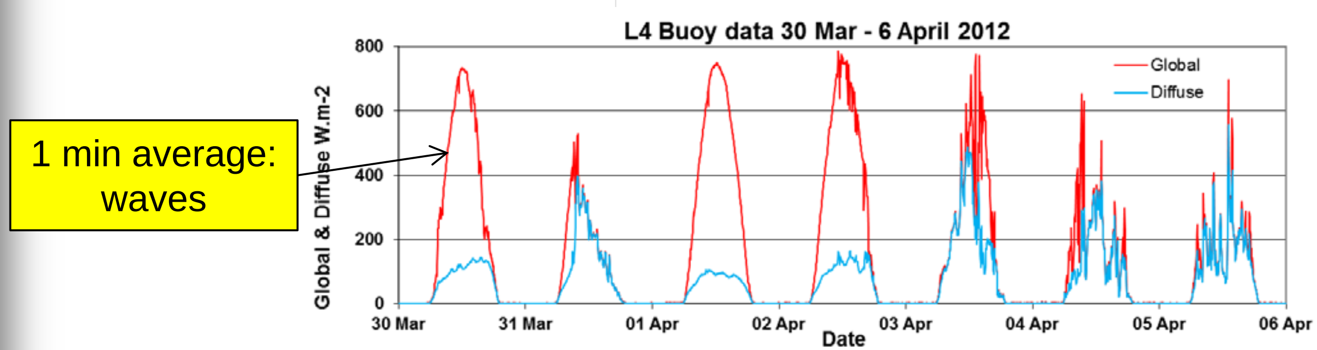
Source: ESA AEROSOL-CCI

Ideal solution – automated observations

- Based on idea by Reynolds et al. (2001)
  - Shipboard fast-rotating shadowband spectral radiometer;
  - **Autonomous**, **but with moving parts;**
- Modify the SPN1 sunshine pyranometer (Delta-T)
  - Global (Total) and Diffuse solar radiation from 400-2700 nm





Reynolds et al. (2001) *Journal of Atmospheric and Oceanic Technology,* **18,** 200-214.

Aerosol optical depth: calculation

$$V_{G\lambda} = V_{H\lambda} + V_{D\lambda} \qquad (1)$$

G (global), λ (wavelength), H (horizontal) and D (diffuse).

- normalise by the relative solar zenith angle (θ_r):

$$V_{N\lambda} = V_{H\lambda} \sec \theta_r \qquad (2)$$

- calibrate against known standard instruments
- also clear, stable sky Langley calibration ($V_{0T\lambda}$)

$$V_{N\lambda} = V_{T\lambda} \exp(-\tau_\lambda m) \qquad (3)$$

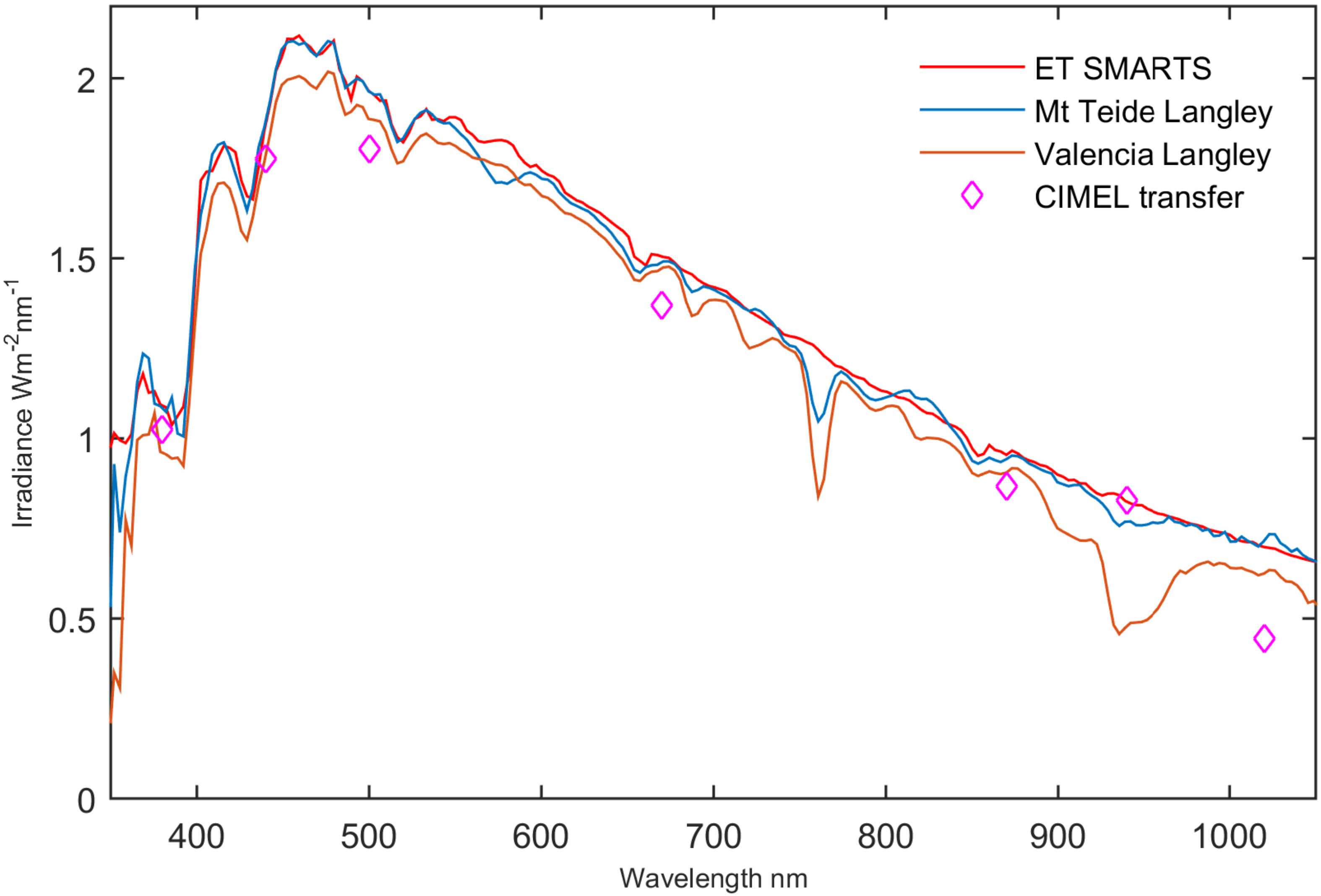
τ_λ (optical thickness) and m (air-mass)

- Expanding for Rayleigh (R), Aerosol (A) and Ozone (O):

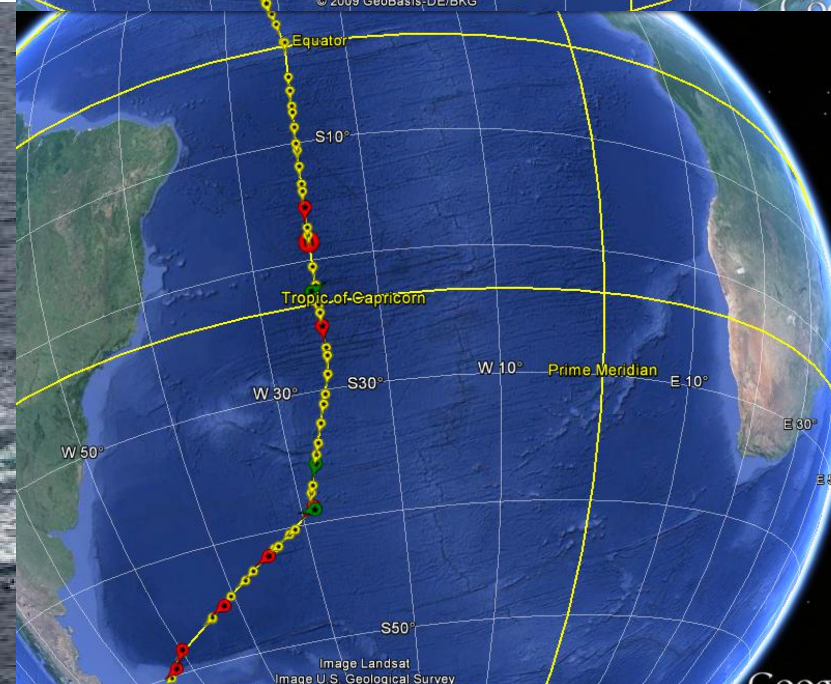
$$V_{N\lambda} = \frac{V_{0T\lambda}}{r^2} \exp(-(\tau_{R\lambda} + \tau_{A\lambda} + \tau_{O\lambda})m) \qquad (4)$$

- Rearrange and solve for $\tau_{A\lambda}$

Calibration: Modelling, Langley plot, transfer



Field testing – AMT24: Sep – Nov 2014



Field testing – AMT24: Sep – Nov 2014

AS161

- 7 optical fibres direct 7 low-cost optical benches (Avantes – AS161);
- 128 pixel detectors, resolution 6nm (350nm – 1050nm);
- **Channels read in parallel (<1s);**
- **Cheaper spectrometer: difficult to maintain calibrations;**
- **Wavelengths are different for each reading.**
- **10 (500ms) readings (1s for 10s; every min)**

Zeiss (MMS1)

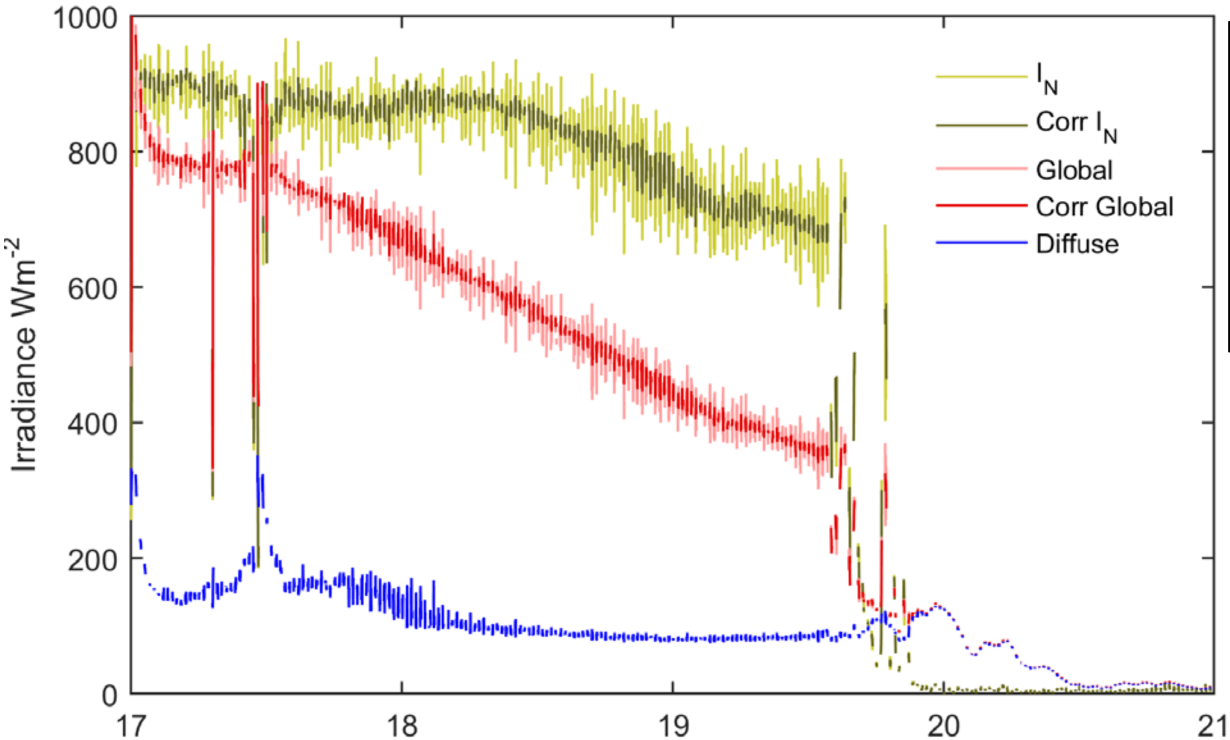
- 7 fibres via multiplexer to a single spectrometer;
- 256 pixel detector, resolution 3.5nm (350nm – 1050nm);
- **Zeiss v. stable & sensitive spectrometer;**
- **All channels same sensitivity and wavelengths;**
- **Channels are measured sequentially over 20s, every min**

Essential ancillary measurements

- VectorNav VN100 inertial orientation sensor
- GPS

Field-work: additional issues to sort data (1)

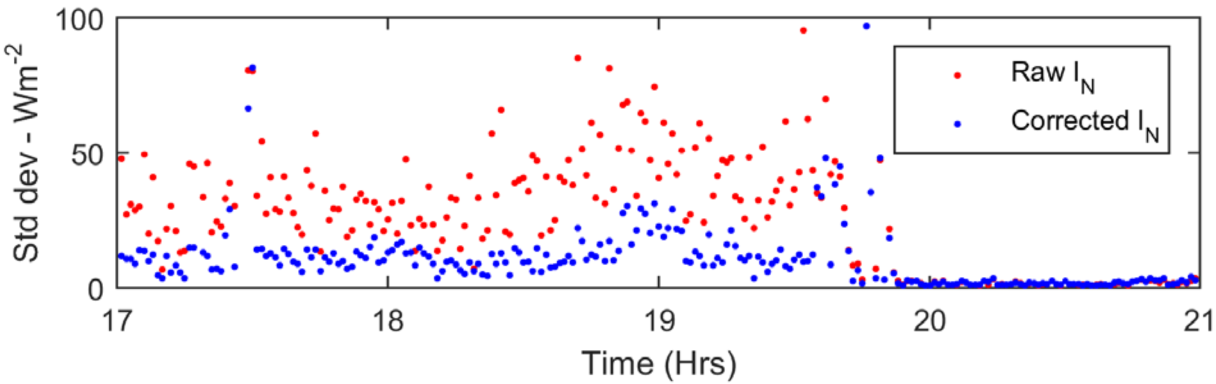
Platform motion



30 Oct 2014

Correction assumes:

- Invariant diffuse
- Angle of incidence on tilted plane

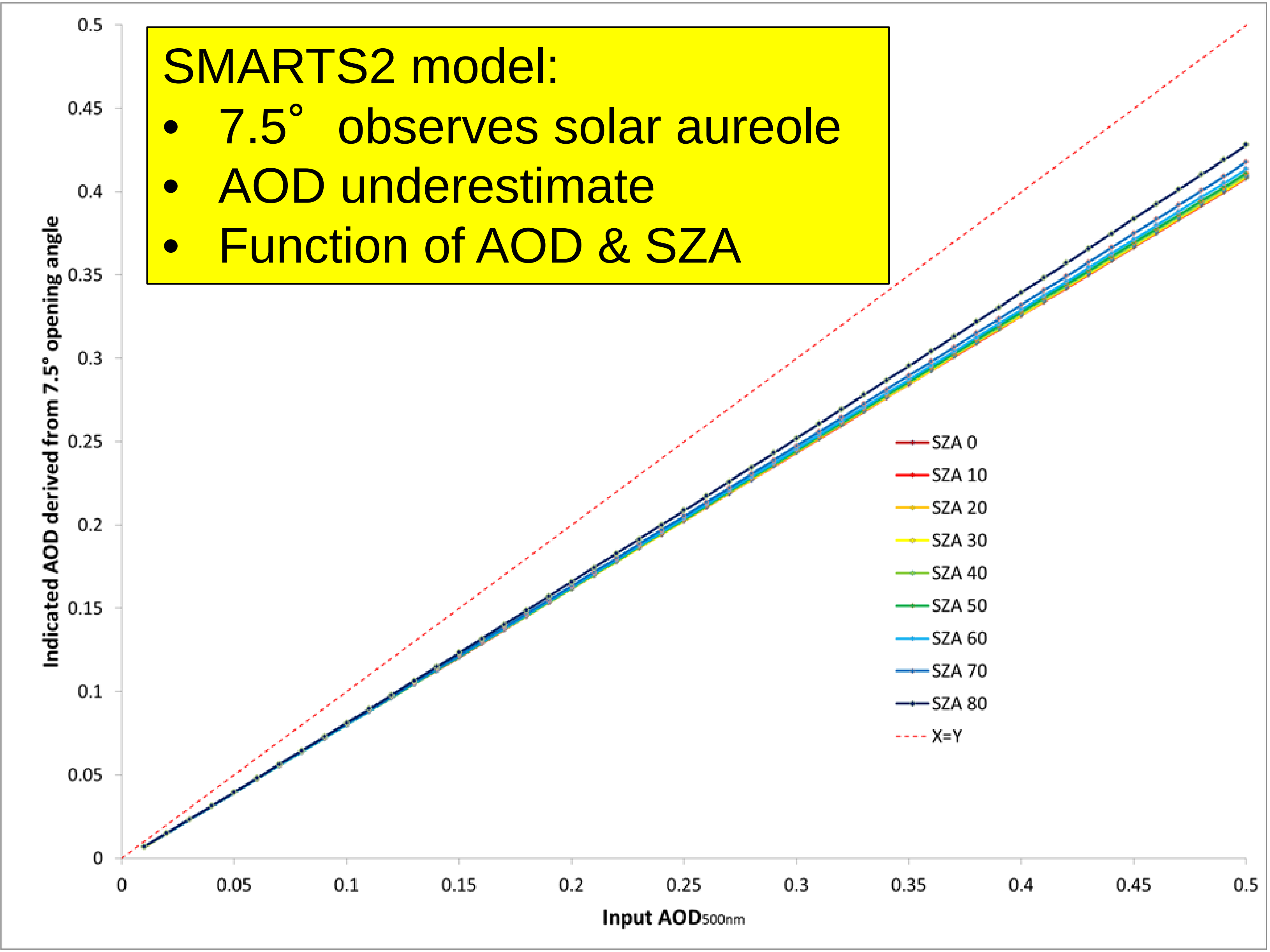


Result:

- 80% reduction in std deviation

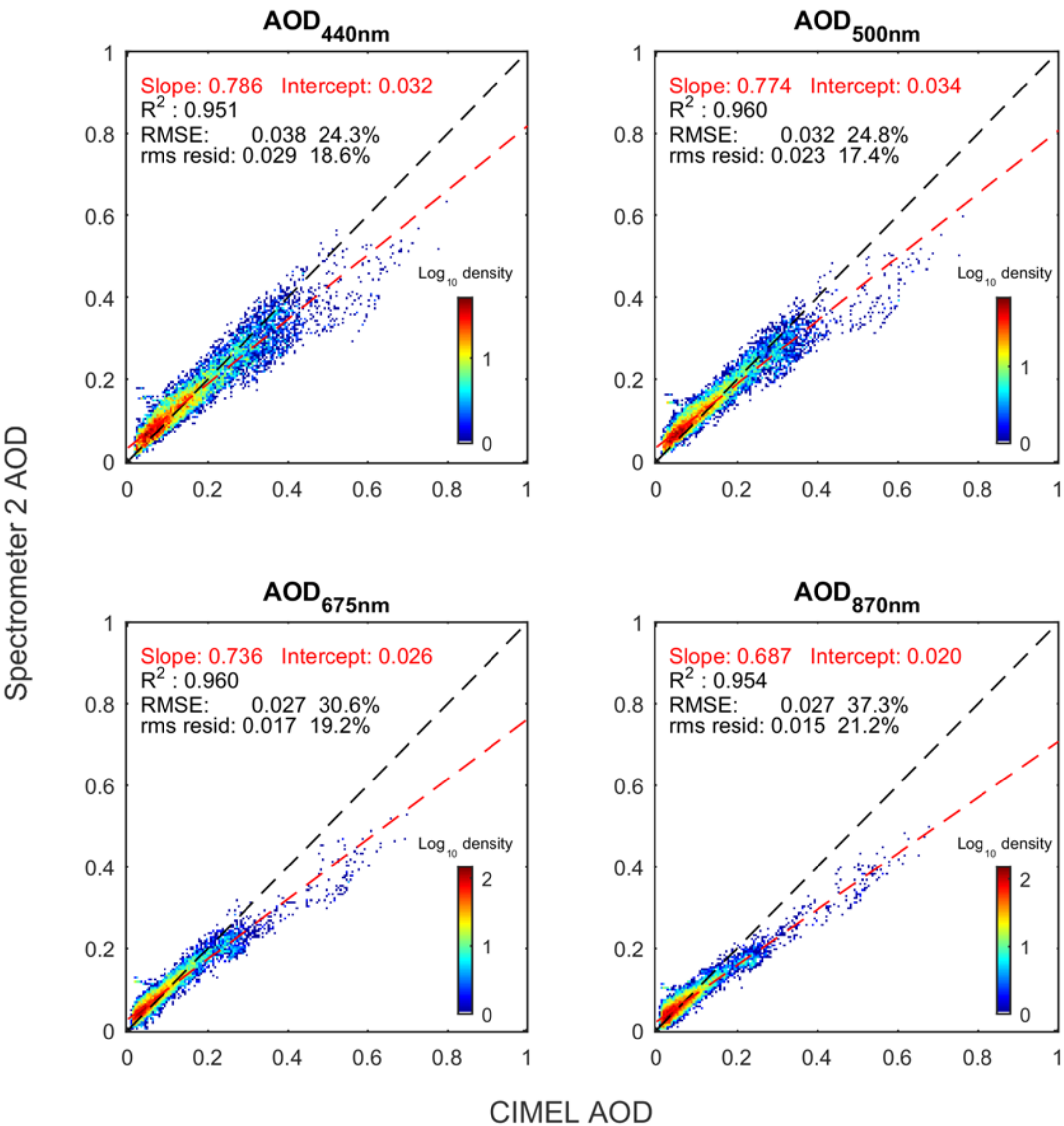
Field-work: additional issues to sort data (2)

Instrument effective field-of-view (SZA)



Field-work: additional issues to sort data (2)

Instrument effective field-of-view (SZA)



- Valencia: CIMEL Post cruise intercomparison
- Clearly shows offset
- Correction f(SZA,λ)

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Field-work: additional issues to sort data (2)

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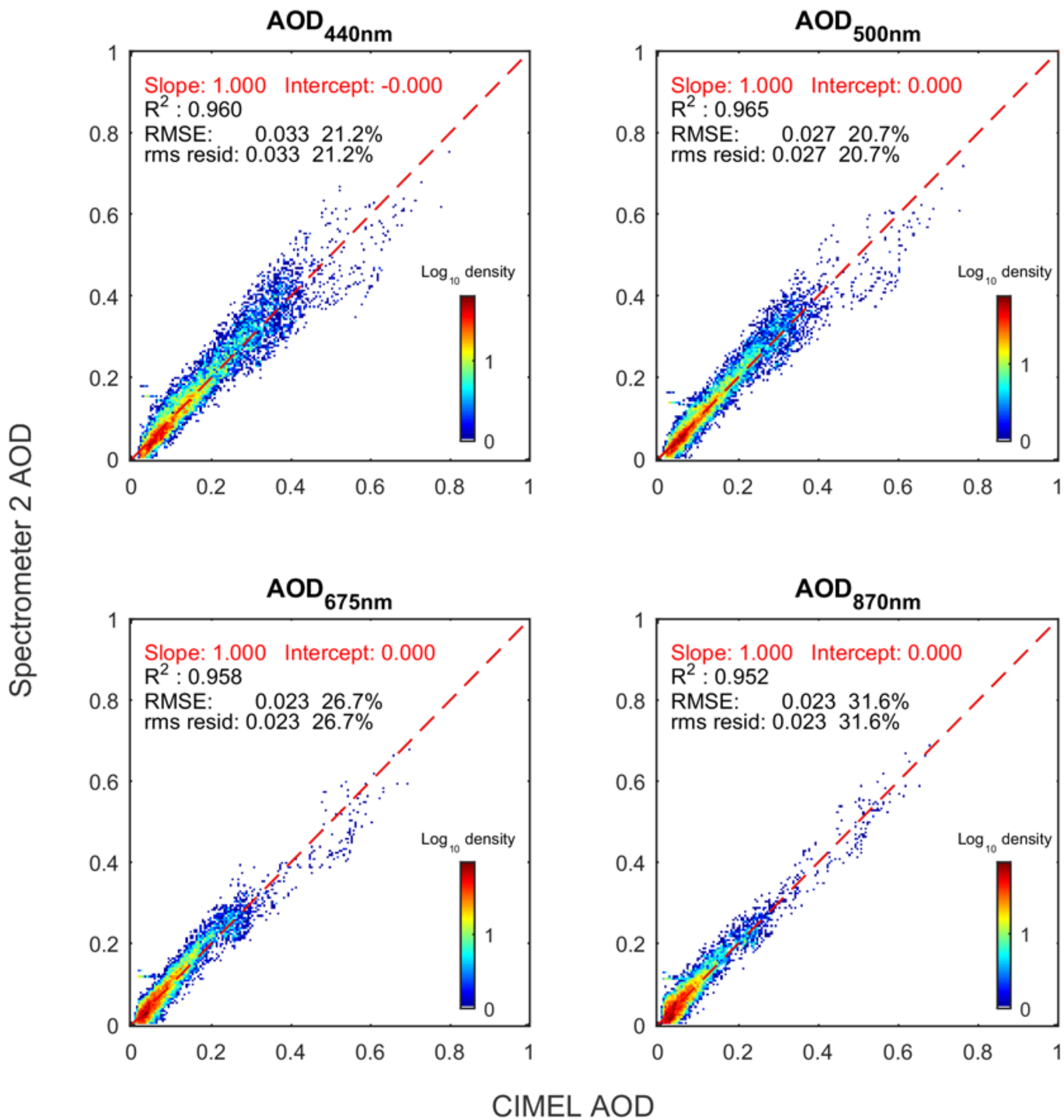

- Valencia: CIMEL Post cruise intercomparison
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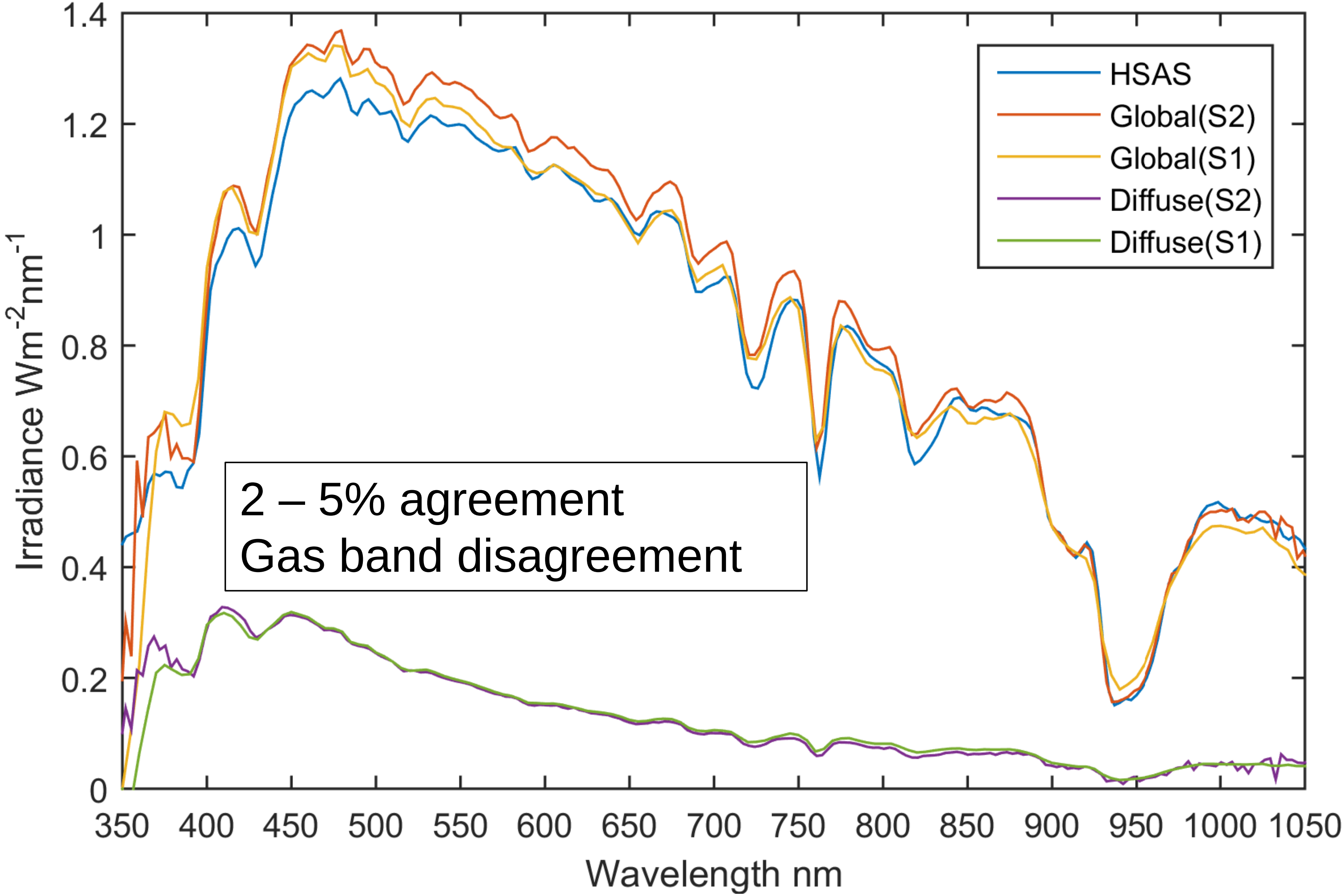
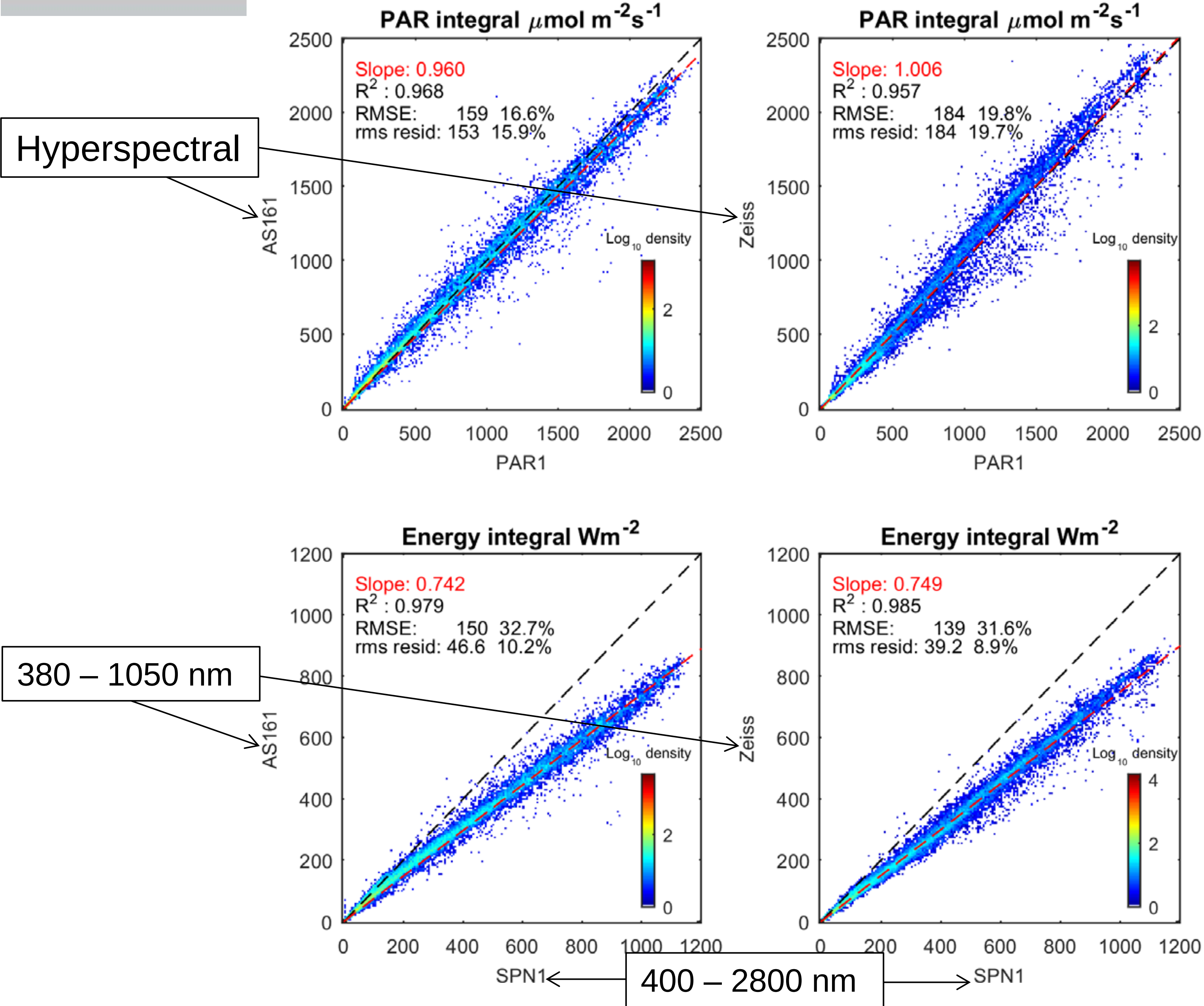
Spectral intercomparison

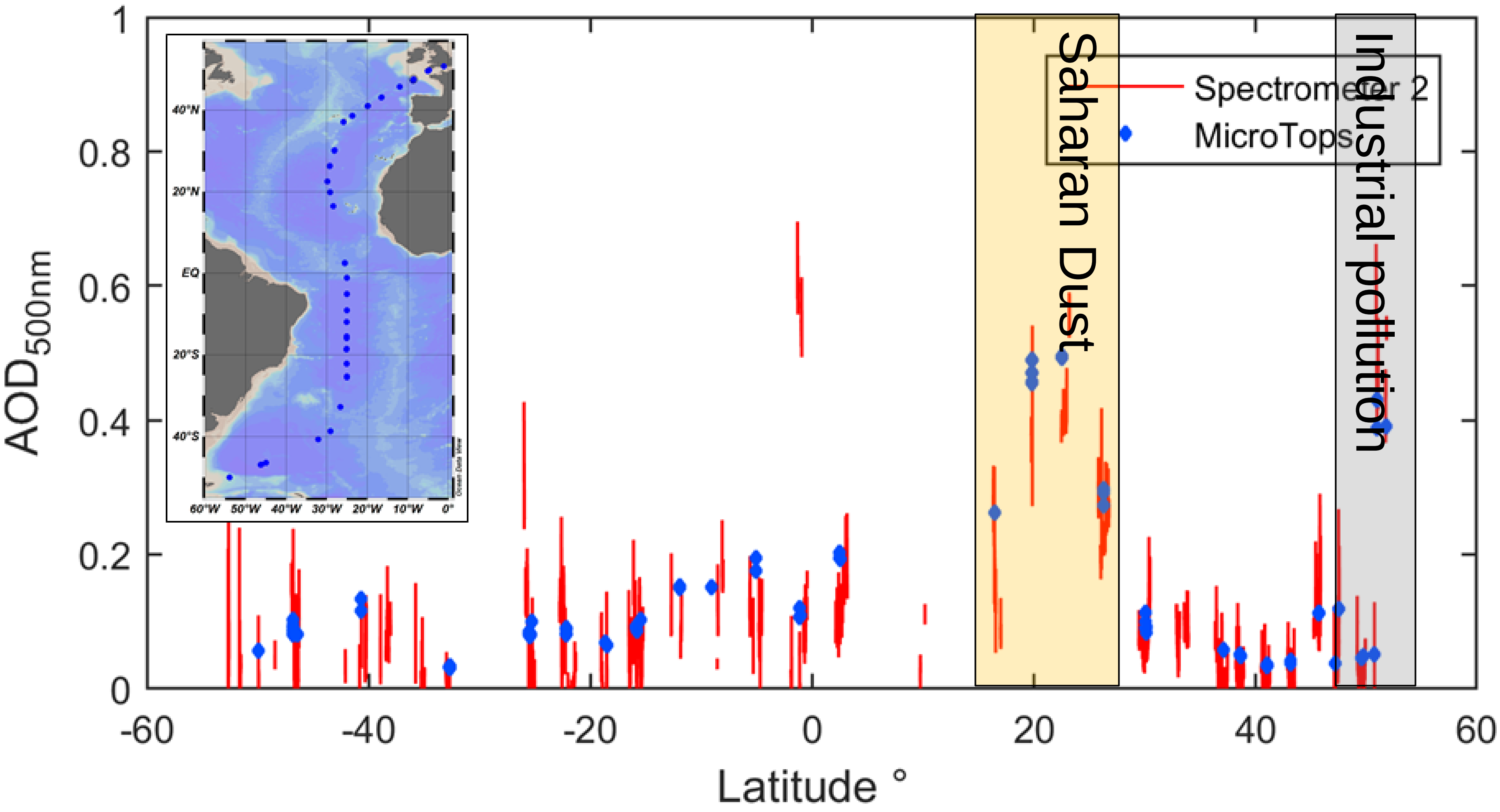
12:00 GMT 04 October 2014



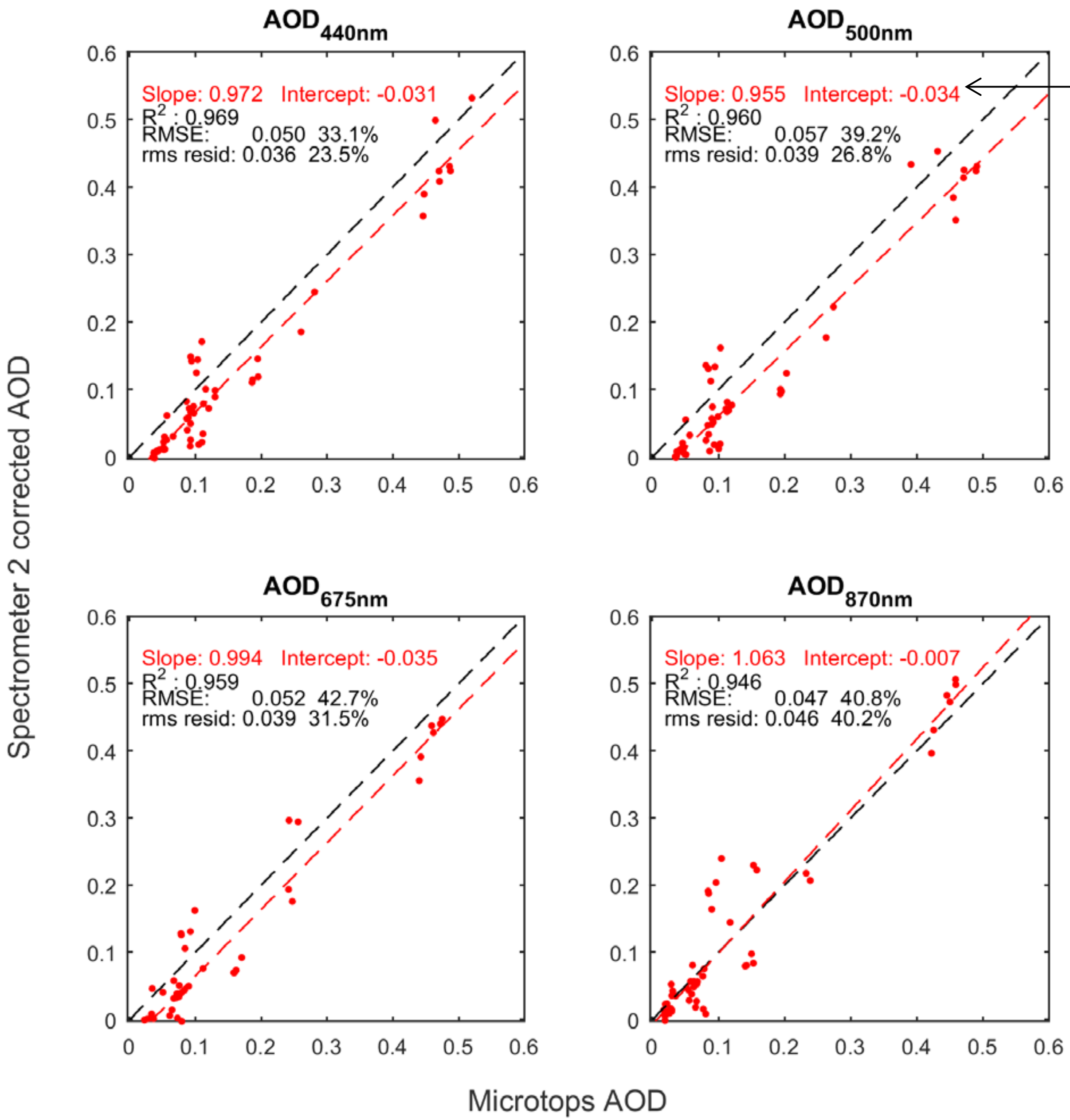
Integrated PAR / Irradiance: AMT24 time-series



AOD intercomparison: AMT24 time-series



AOD intercomparison: AMT24 time-series



cf. bias ~0.02

Conclusions

- Hyperspectral diffuse and global irradiance measured;
- Pyranometers ruggedised to withstand marine environment
  - Long-term deployments on moorings (mid-latitude);
  - Wide range of conditions (mid-latitudes, tropics, higher-latitudes(?));
- Calibration protocol established;
- Correction for ship-movement & FOV implemented;
- AOD estimates comparable with existing instrumentation

Atmos. Meas. Tech., 10, 1723–1737, 2017
www.atmos-meas-tech.net/10/1723/2017/
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Autonomous marine hyperspectral radiometers for determining solar irradiances and aerosol optical properties

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Thank you