Quality control of WATERHYPERNET measurements using AERONET-OC data

Presented by Kevin RUDDICK (RBINS)

Data from WATERHYPERNET/AERONET-OC sites:

Acqua Alta/AAOT [PI V. Brando + G. Zibordi/B.Bulgarelli]

La Plata/RdP-EsNM [PI A. Dogliotti]

Chesapeake Bay [PI K. Turpie + D. Aurin]

WATERHYPERNET support from:

Q. Vanhellemont (PANTHYR processing)

D. Vansteenwegen, M. Beck and F. Ortenzio (PANTHYR system)

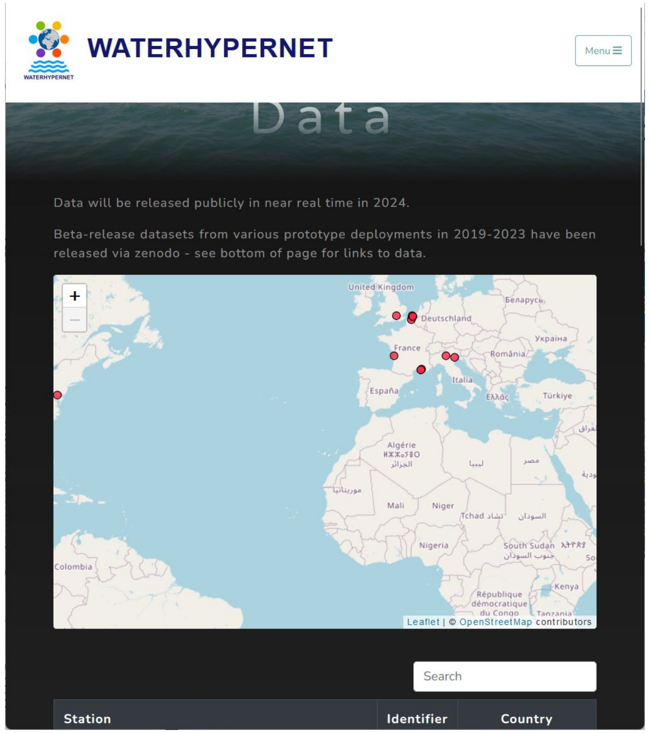
P. De Vis and C. Goyens (HYPSTAR processing)

J. Kuusk and K. Laizans (HYPSTAR instrument)

A. Corizzi and D. Doxaran (HYPSTAR system)

HYPERNETS

AERONET-OC success story as motivation for HYPERNETS
A data users perspective



Multispectral
Public data distribution
Very reliable data quality

Hyperspectral !
NOT YET Public data distribution
NEED TO REACH Very reliable data quality

! Data comparison AERONET-OC vs WATERHYPERNET !

Added value of hyperspectral: Multispectral in situ can spot most A/C problems BUT
Only hyperspectral in situ data can validate the new capabilities of hyperspectral satellites (phytoplankton species, etc.)

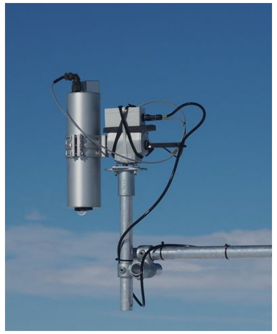
HYPERNETS

HYPERNETS in a single slide

INSTRUMENTS

Automated hyperspectral measurements

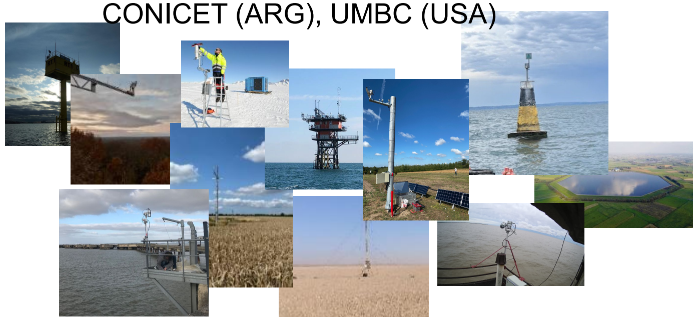
PANTHYR system
[Vansteenwegen et al, 2019]
400-900nm, 10nm FWHM



HYPSTAR® system
[Kuusk et al, 2024]
380-1700nm, 3-10nm FWHM

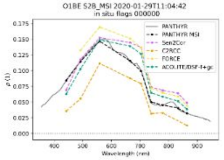
NETWORK

RBINS (BE, coordinator)
+ VLIZ (BE), CNR (IT), LOV (FR), NPL (UK), GFZ (D), TARTU (ES), CONICET (ARG), UMBC (USA)

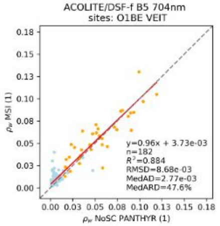


11 water and 5 land sites currently operating
Slow expansion expected in 2024-25 ...

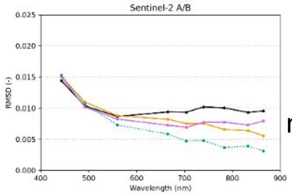
DATA PROCESSING and ANALYSIS



e.g. one matchup



one band (S2/704nm), many matchups



spectral stats, many matchups

Prototype network has provided validation data and information to:
Sentinel-2A&B, Sentinel-3A&B/OLCI, Landsat-8&9, Planetscope Doves and Superdoves, PRISMA, Pléiades, ENMAP, MODIS-A&T, VIIRS-1&2,...

OBJECTIVE: To validate **all** VIS/NIR spectral bands (400-1700nm, @3nm FWHM) for **all** satellite missions measuring water or land surface reflectance

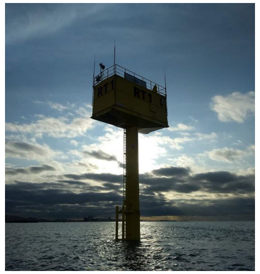
and preparing for:
ACIX, DESIS, MTG and SEVIRI, EMIT, CHIME, LSTM, **PACE**, GLIMR, SBG, PROBAV-CC, GOCI, SABIAMAR, **various Newspace**, ... (national hyperspectral imagers from Canada, Norway, Australia, ...)

[Ruddick et al, 2024; https://doi.org/10.3389/frsen.2024.1372085]

HYPERNETS

Water sites currently/recently running for satellite validation

VLIZ: Oostende



CONICET: La Plata

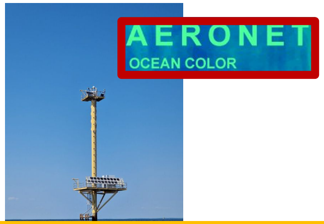
TODAY: HYPSTAR

CNR: Lake Garda

CNR: Acqua Alta

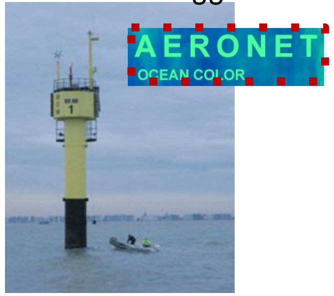
TODAY: HYPSTAR+PANTHYR

UMBC: Chesapeake



TODAY: PANTHYR

RBINS: Zeebrugge



LOV: Gironde

RBINS: Thornton

NPL: Wraysbury

[WATERHYPERNET: Ruddick et al, 2024; https://doi.org/10.3389/frsen.2024.1347520]

HYPERNETS

Method and suggested terminology

Water-leaving radiance reflectance

Water-leaving radiance

$$\rho_w(\lambda, \theta, \phi) = \pi \frac{L_w(\lambda, \theta, \phi)}{E_d^{0+}(\lambda)}$$

wavelength

Nadir viewing angle

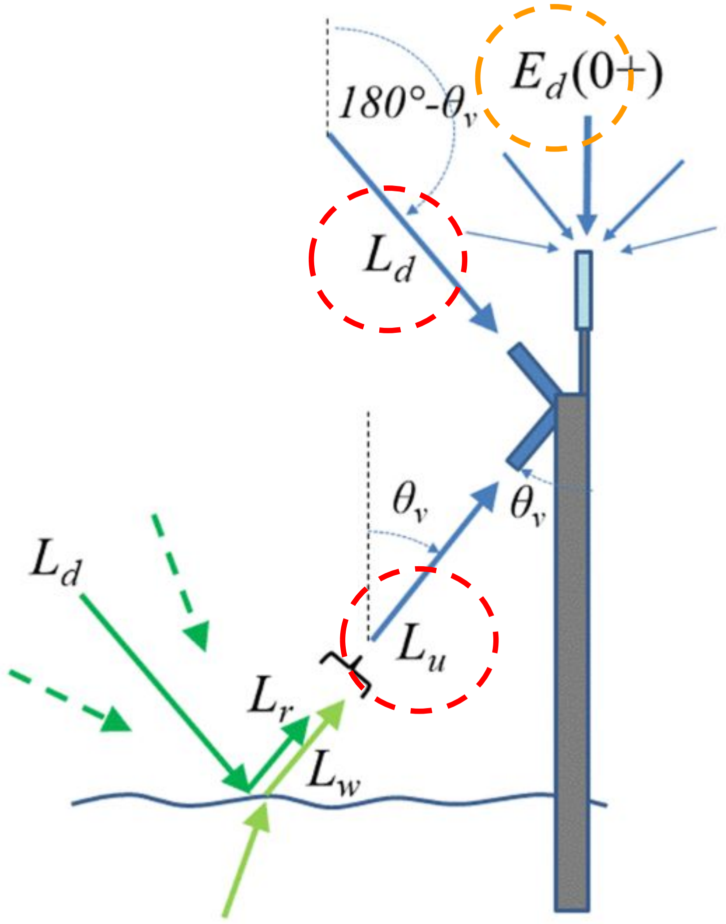
Relative azimuth angle to sun

Downwelling irradiance

$L_w = L_u - L_r$

Model $L_r = \rho'_F(W) * L_d$

Wind



HYPERNETS

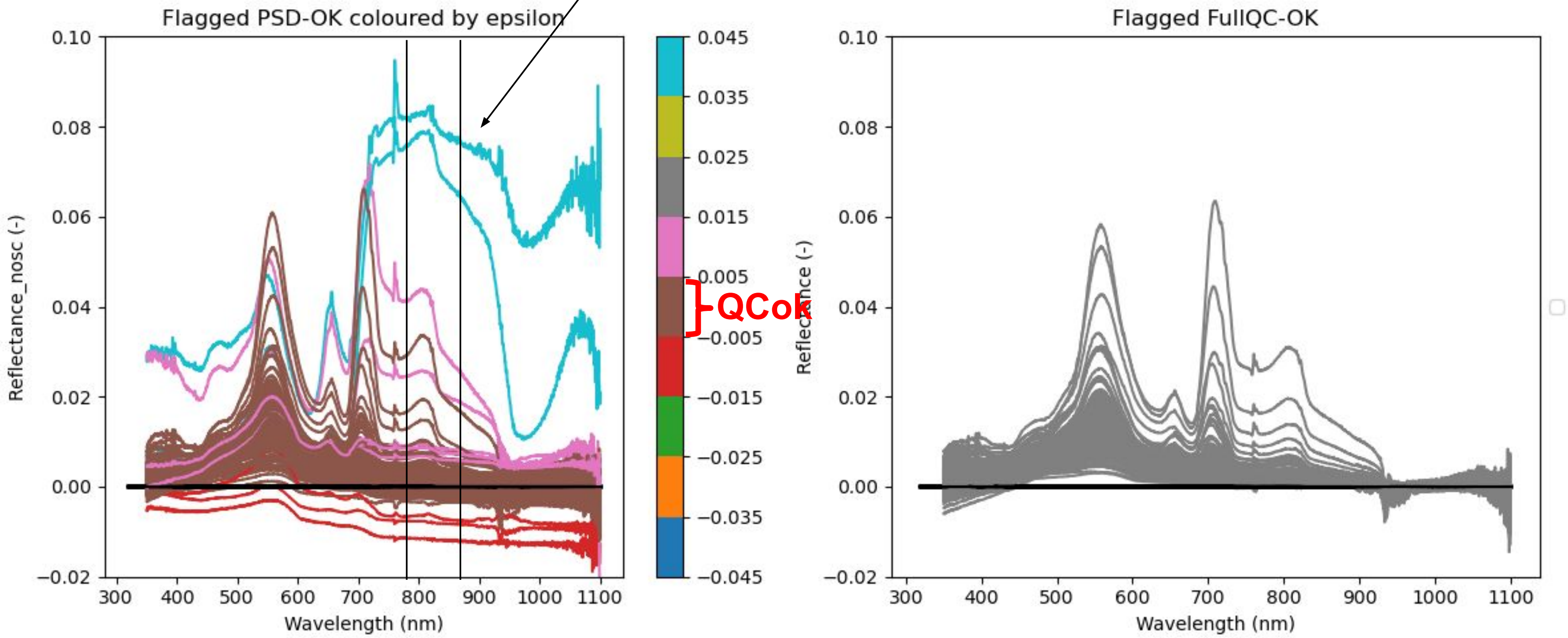
HYPSTAR QC and work in progress

- HYPSTAR processor v2.0 already has maaaany QC checks [De Vis and Goyens et al, 2024]
  - Ed clear sky test is particularly useful
    - E.g. clouds, birds on sensor, severely fouled Ed sensor, etc.
    - Currently set at Ed_measured > 0.5*Ed_ClearSky (need to tighten to 0.8…)
- "site-specific" QC consists of:
  - Identification of bad pointing azimuth angles by analysis of 2023 data
    - e.g. Lu (or Ld) pointing at structure
  - Identification of bad deployments dates/periods by site PI
    - e.g. known wrong azimuth pointing or fouling

  \+
  - High SimSpec epsilon (self-consistent NIR reflectance spectral shape)
    - Identifies most non-water targets, e.g. boats, sunglint, floating vegetation, etc.
    - !!! Causes false negatives for extremely turbid waters (site-specific threshold or refinement of SimSpec… ?)

E.g. Wraysbury reservoir (UK) [PI A. Bialek]

Cyanobacteria bloom with floating scum! [QCfail]

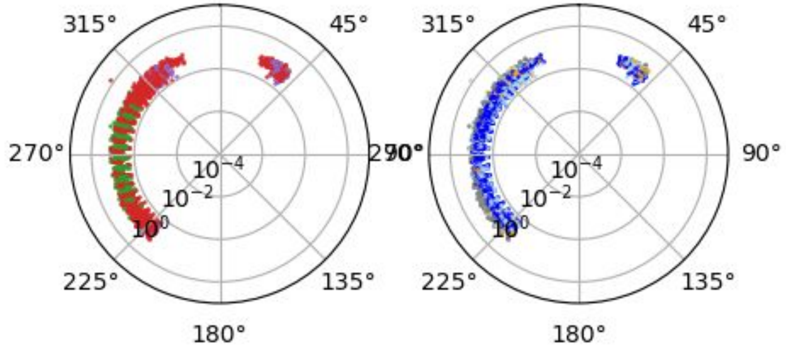


NIR similarity spectrum test ("epsilon") identifies bad non-water spectra

Check for bad pointing angles (QC from L2A to L2B)

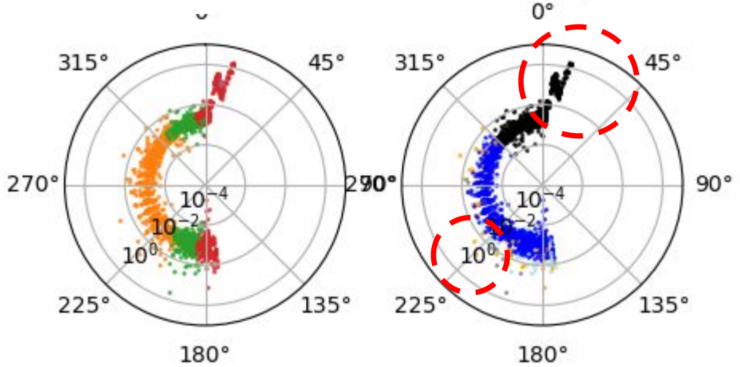
Rhow800 radius (centre=0, outside=1)
Vs
Polar pointing azimuth angle (0°=to North)

All L2A (colour=SZA) | L2B (blue=OK, other=reject)

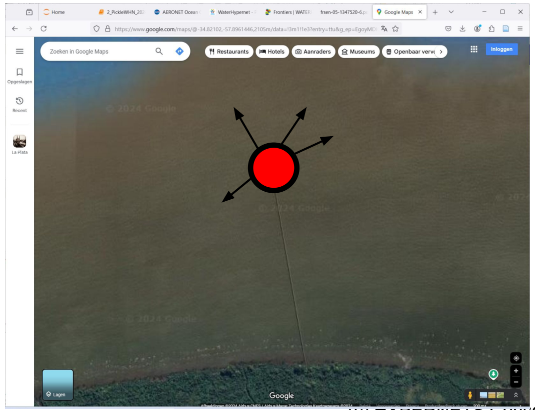


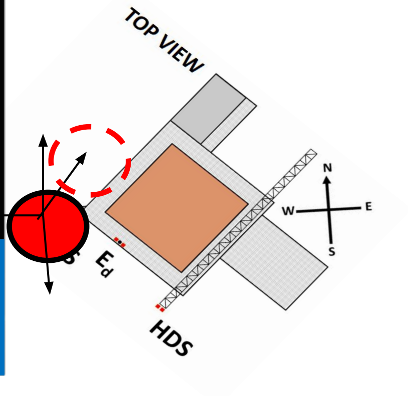
All selected pointing angle OK

All L2A (colour=SZA) | L2B (blue=OK, other=reject)

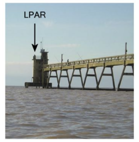


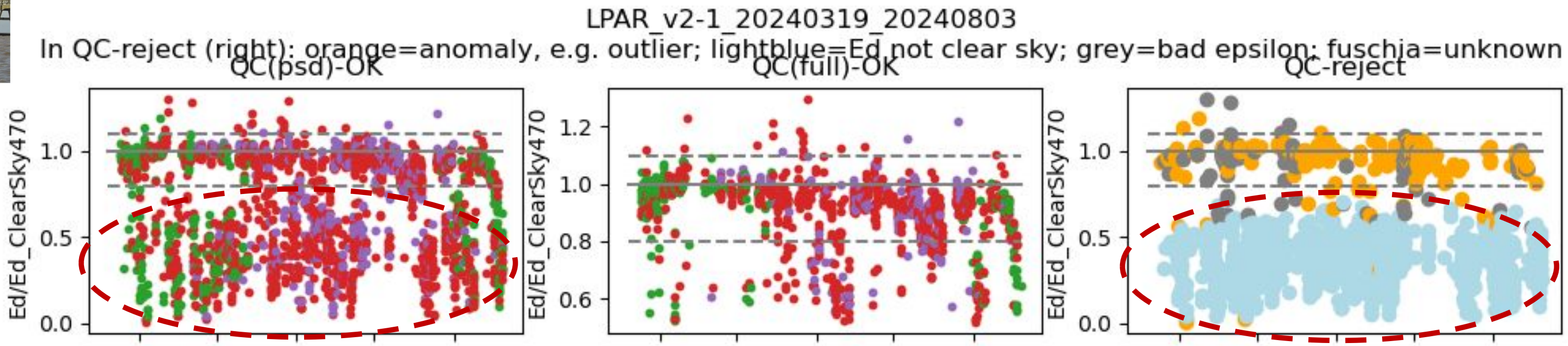
QC reject when pointing at obstruction





Ed (downwelling irradiance) time series - compared to clear sky model





cloudy

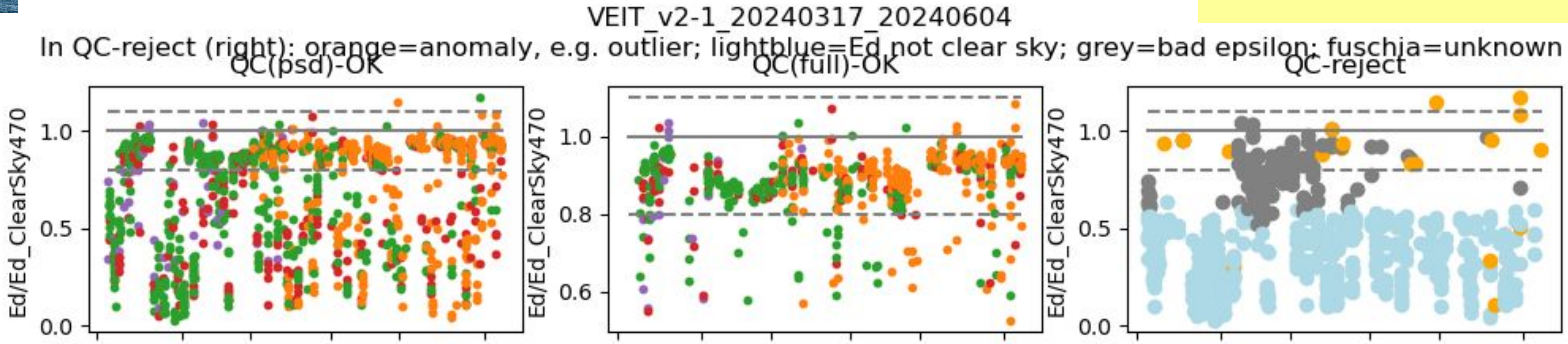
BUT need to increase threshold to reject more

rejected

Before extra QC

Extra QC OK

Extra QC rejected (high epsilon, Low Ed, etc.)



HYPERNETS vs AERONET-OC comparison methodology

- AERONET v3 lev15 data, downloaded 2024-09-04
- HYPERNETS v2.1 processing (2024-09-04) with GDAS winds and SimSpec epsilon<0.01 QC

- Analysis by site and deployment period
- Using only HYPERNETS 90° and 270° relative azimuth (not 135° or 225°)
- Acqua Alta HYPSTAR collocated and pointing same relative azimuth (PANTHYR opposite corner/direction)
- Chesapeake Bay and La Plata different corners sometimes opposite relative azimuth (so no BRDF diff)

- <u>Matchup</u>
- Time difference <60 mins
- HYPERNETS temporally interpolated to AERONET-OC if 2 bounding measurements, otherwise NN
- HYPERNETS spectrally interpolated to AERONET-OC band

HYPERNETS

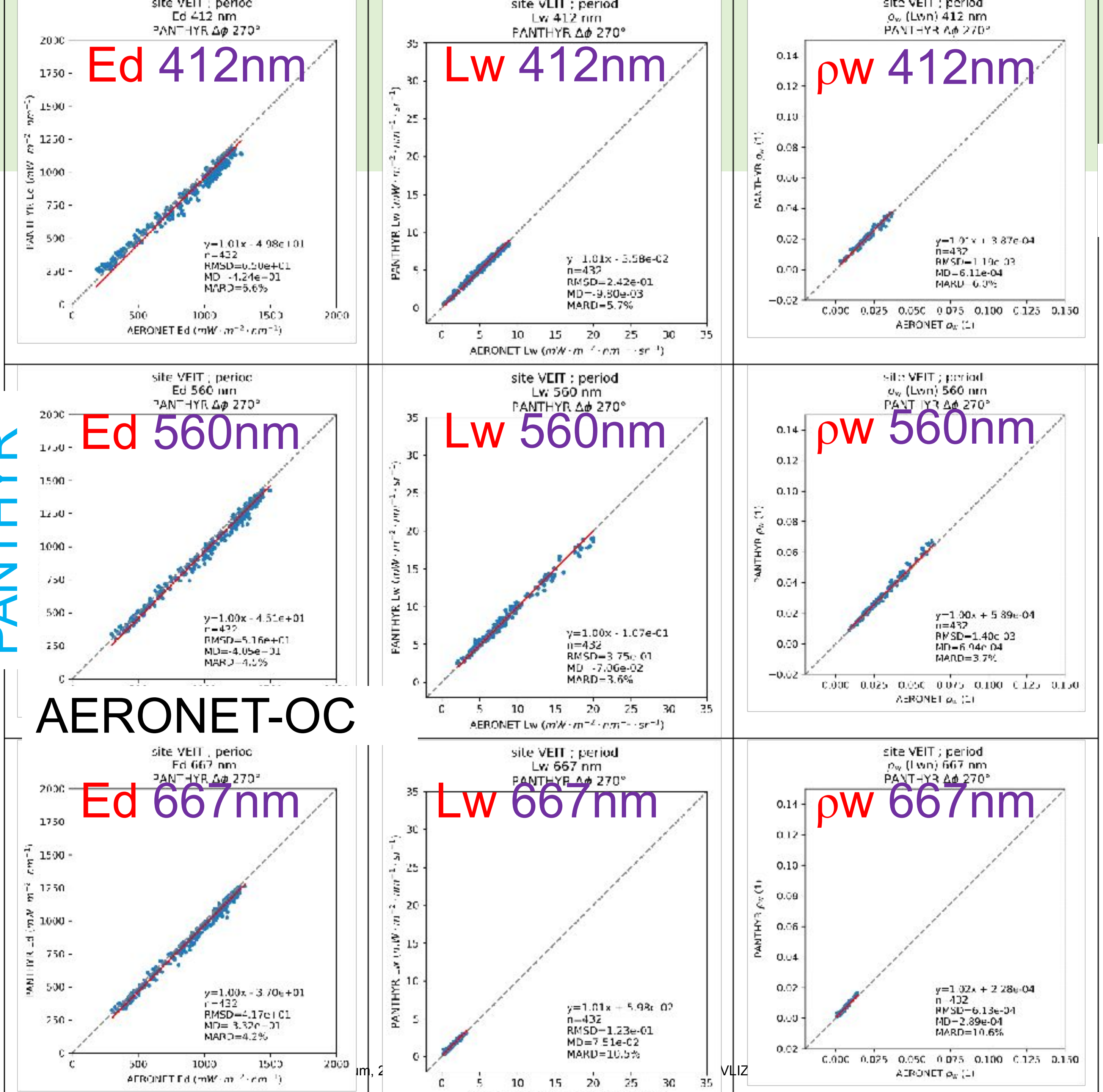
Acqua Alta/PANTHYR
2023-01-01 to -12-31

HPI: Brando

API: Zibordi/Bulgarelli

Ed good, some diffs
Lw good, some scatter
Rhow good

Next step:
closer analysis of outliers, differences and uncertainties



RMSD=0.0012
MRD=6.0%

RMSD=0.0014
MRD=3.7%

RMSD=0.0006
MRD=10.6%

HYPERNETS

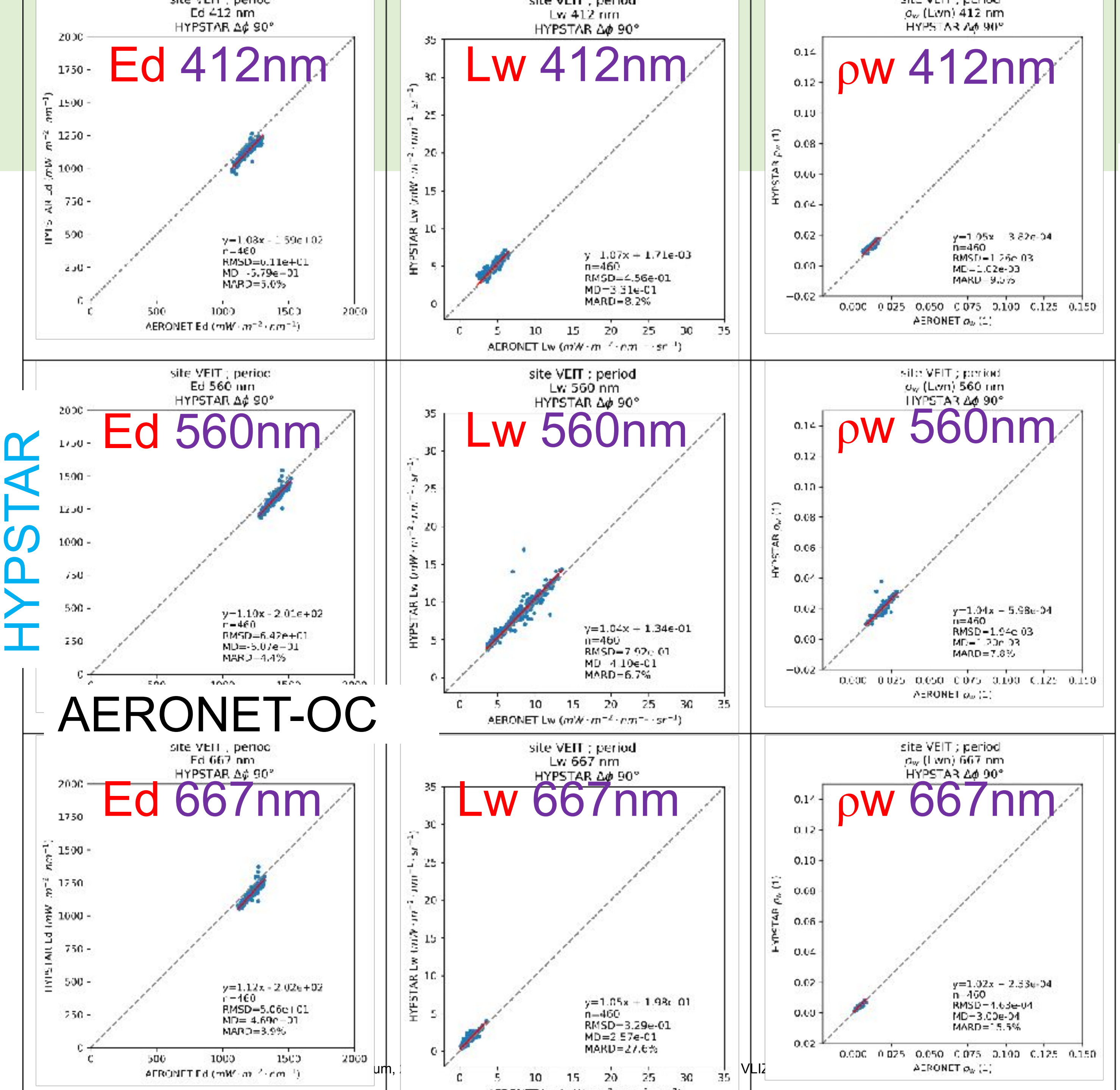
Acqua Alta/HYPSTAR
2024-06-04 to -07-31

HPI: Brando

API: Zibordi/Bulgarelli

Ed systematic diff?
Lw some outliers

Next step:
closer analysis of outliers, differences and uncertainties



RMSD=0.0013
MRD=9.5%

RMSD=0.0019
MRD=7.8%

RMSD=0.0005
MRD=15.5%

HYPERNETS

esa

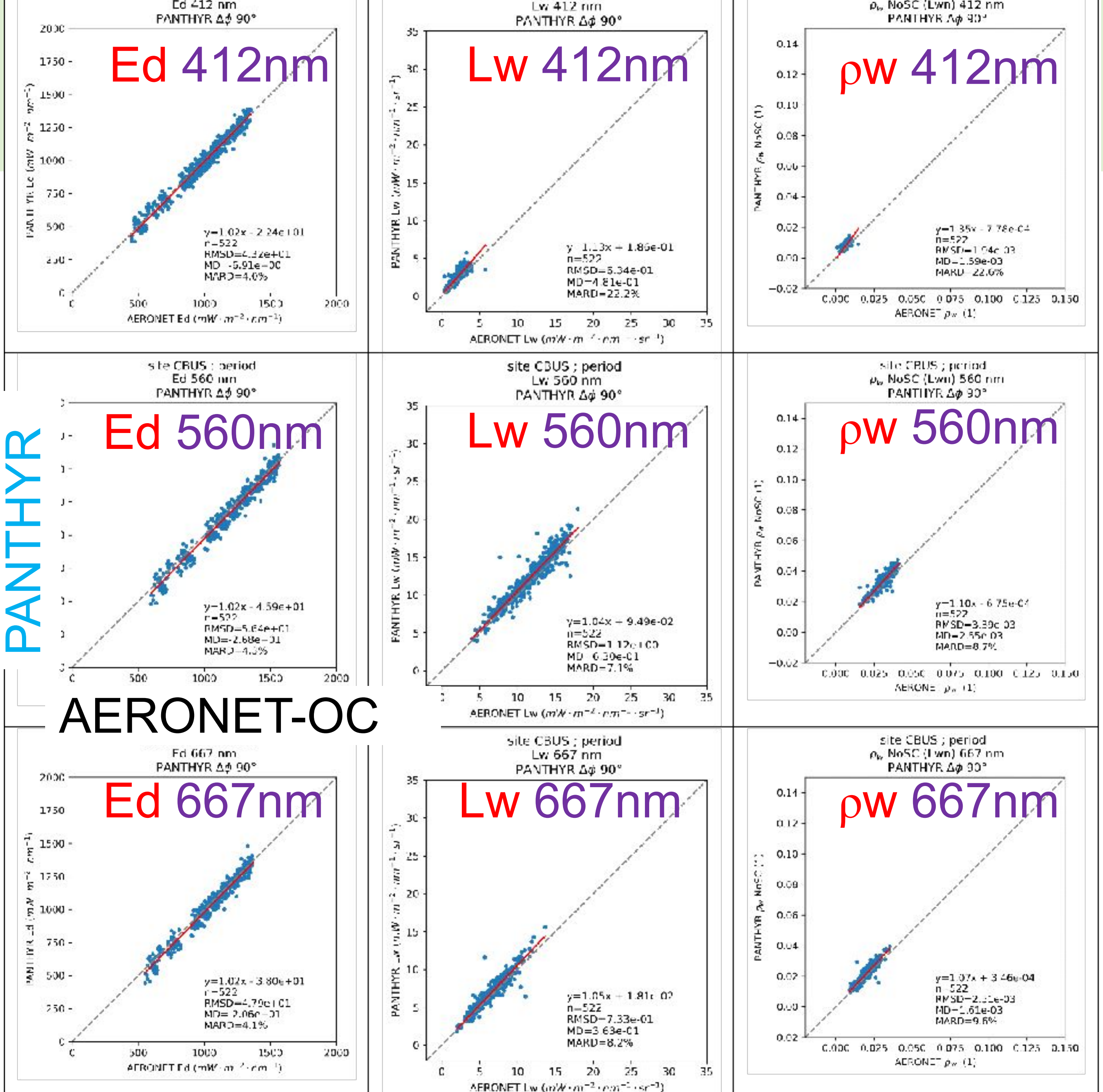
Chesapeake Bay
2024-06-01 to -07-21

HPI: Turpie

API: Aurin

Ed scatter
Lw some outliers
RHOw moderate

Next step:
closer analysis of outliers, differences and uncertainties



RMSD=0.0019
MRD=22.6%

RMSD=0.0034
MRD=8.7%

RMSD=0.0026
MRD=9.6%

HYPERNETS

Analysis of differences between HYPERNETS and AERONET-OC

Radiometry
Upwelling radiance, Lu
Downwelling (sky) radiance, Ld
Downwelling irradiance, Ed

} Calibration
Characterisation
(HYPSTAR thermal,
Ed angular…)

Modelling
Wind speed, W ← Some differences AERONET vs HYPERNETS
Modelled Air-water interface reflection, ρ'_F

Matchup protocol
Pointing azimuth +/-90° (platform effects)
Wavelength matching (esp 400nm?)
Temporal matching (e.g. linear interpolation <60 mins)

Deployment
Platform perturbations (optical, hydrodynamic wakes), tilt, pointing

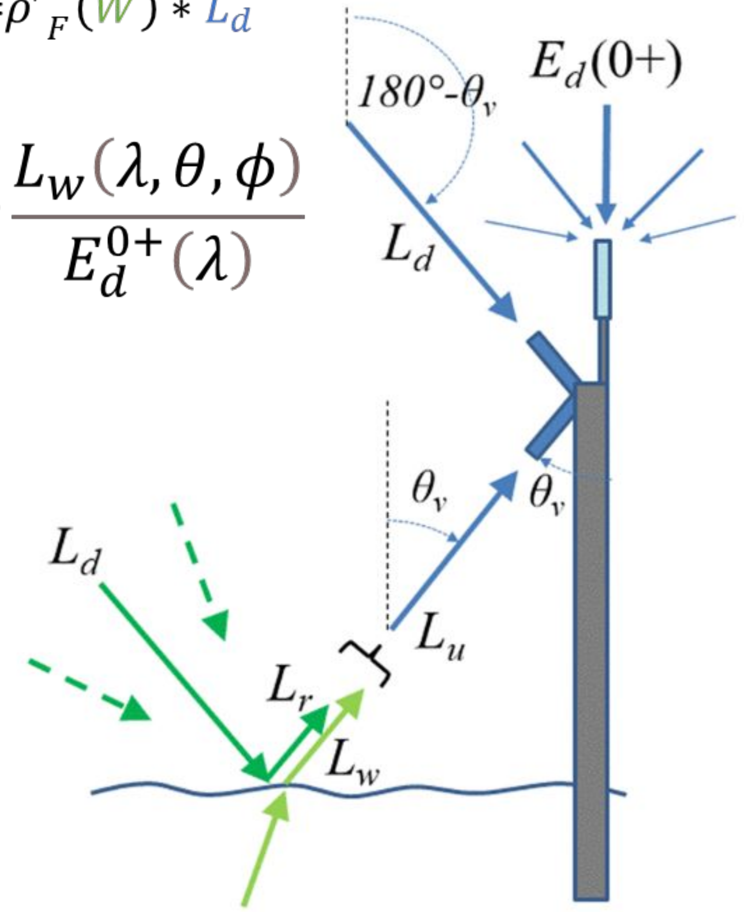
Processing
Replicate filtering ← Min/mean
QC strictness + NIR SimSpec ← Outliers! scatter

Other
Hardware failures (pantilt, radiometer)
Foreoptics contamination ← Some bad periods … clear sky Ed and Ld monitoring!

$$L_w = L_u - L_r$$

Model $L_r = \rho'_F(W) * L_d$

$$\theta, \phi) = \pi \frac{L_w(\lambda, \theta, \phi)}{E_d^{0+}(\lambda)}$$



HYPERNETS

CONCLUSIONS

- HYPERNETS aims to measure water (and land surface) reflectance 380-1040 nm (-1680 nm) hyperspectrally for validation of all optical satellite missions with water reflectance (OLCI, S2, L8/L9, Planet, ENMAP, PACE … CHIME, etc.
  - Added value of HYPERNETS is hyperspectral (essential for validating added value of hyperspectral satellites)
- Current status: 11 water + 5 land sites, transitioning from R&D to pre-operational
- Comparison with AERONET-OC extremely valuable for identifying problems … validating measurement uncertainties
- Some sites/periods satisfactory, some not …
- NEXT:
  - Detailed analysis of HYPERNETS vs AERONET-OC all available sites/periods
  - Refinement of HYPERNETS QC: outliers, scatter (… systematic differences?)
  - HYPERNETS Ed cosine response and thermal correction
  - Measurement uncertainty analysis
- THANKS TO AERONET-OC staff for amazing work!

Acknowledgements and References

- EU/H2020 HYPERNETS and ESA/HYPERNET-POP funding
- AERONET and HYPERNETS site PIs for care and perseverance!
- AERONET-OC team for calibration, processing and guidance
- Site owners for support

- References
- All HYPERNETS publications collected at https://www.hypernets.eu/from_cms/publications

- HYPERNETS concept: [Ruddick et al, 2024; https://doi.org/10.3389/frsen.2024.1372085]
- WATERHYPERNET network: [Ruddick et al, 2024; https://doi.org/10.3389/frsen.2024.1347520]
- HYPSTAR radiometer: [Kuusk et al, 2024; https://doi.org/10.3389/frsen.2024.1347507]
- PANTHYR radiometer system and processing [Vansteenwegen et al, 2019; https://doi.org/10.3390/rs11111360]
- HYPSTAR processing [De Vis and Goyens, 2024; https://doi.org/10.3389/frsen.2024.1347230]