Supplementary Material

1 Satellite missions

The satellite missions considered at the time of writing (March 2024) as primary users of HYPERNETS data are provided in Table 1. This list will obviously evolve in time and is generally expected to grow over the coming decade, particularly for Newspace operators.

Table 1 Overview of satellite missions providing water or land surface reflectance data.

Satellite/Instrument	Agency	Launch date	Spectral coverage
VIIRS	NOAA	Oct 2011	402-2275 nm Multispectral + TIR
Pléiades	CNES/EADS	1A: Dec 2011 1B: Dec 2012 Neo3-6: Apr 2021+	450-915 nm Multispectral
Landsat 8&9/OLI	NASA/USGS	8: Feb 2013 9: Sep 2021	423-2300 nm Multispectral + TIR
Worldview	DigitalGlobe	WV3: Aug 2014	400-2365 nm Multispectral
Planet Dove Planet Superdove	Planetlabs	Dove: 2015 + many SuperDove: 2019	430-885 nm Multispectral
Sentinel-2/MSI	ESA (Copernicus)	A: Jun 2015 B: Mar 2017 C: 2024? D: ?	442-2202 nm Multispectral
Sentinel-3/OLCI	EUMETSAT/ESA (Copernicus)	A: Feb 2016 B: Apr 2018 C: 2024? D: ?	400-1020 nm Multispectral
PRISMA	ASI (Italy)	Mar 2019	400-2500 nm Hyperspectral
GOCI-2 (geo)	KIOST	Feb 2020	370-885 nm Multispectral
ENMAP	DLR (Germany)	Apr 2022	420-2450 nm Hyperspectral
EMIT	NASA	Jul 2022	380-2500 nm Hyperspectral
MTG (geo)	EUMETSAT	I1: Dec 2022 I2: 2024? I3: 2025? I4: ?	400-2200 nm Multispectral + TIR
PACE	NASA	Feb 2024	340-890 nm Hyperspectral 940-2260 nm Multispectral
SABIA-Mar	CONAE	2024?	Multispectral
GLIMR (geo)	NASA	2026?	340-1040 nm Hyperspectral
CHIME	ESA	2028?	Hyperspectral
LSTM	ESA (Copernicus)	2028?	Multispectral
SBG	NASA	2028?	400-2500 nm Hyperspectral + TIR
Newspace	Various	Frequent!	Multispectral+

			Hyperspectral
Many others ...	Various	?	Multispectral+ Hyperspectral

2 Summary of validation sites

The HYPERNETS validation sites running at the time of writing (2024-03-12) are summarised in Table 2 and Table 3 for water and land sites respectively.

Table 2 Overview of existing WATERHYPERNET validation sites. Each site has a 4 letter code ("ID").

Location, ID and Organisation	System	Latitude (°)	Longitude (°)	Water type	First measurement passing QC
Acqua Alta (VEIT) CNR (Brando et al. 2023)	PANTHYR	45.31428	12.5083	coastal	2019-09-26
RT1 Oostende (RTBE) VLIZ (Vansteenwegen and Vanhellemont 2023)	PANTHYR	51.24640	2.91933	turbid, coastal	2019-12-23
Etang de Berre (BEFR) LOV (Doxaran and Corizzi 2023)	HYPSTAR®	43.44231	5.09718	eutrophic, lake	2021-02-24
Acqua Alta (VEIT) CNR (Brando et al. 2023)	HYPSTAR®	45.31425	12.50825	coastal	2021-04-20
Gironde Estuary (MAFR) LOV (Doxaran and Corizzi 2023)	HYPSTAR®	45.54389	-1.04195	very turbid	2021-11-10
Rio de la Plata (LPAR) CONICET (Dogliotti et al. 2023)	HYPSTAR®	-34.81799	-57.89591	very turbid, coastal	2021-12-16
Lake Garda (GAIT) CNR (Brando et al. 2023)	HYPSTAR®	45.57694	10.57944	clear/macrophytes, lake	2022-06-09
Zeebrugge (M1BE) RBINS (Goyens and Gammaru 2023)	HYPSTAR®	51.36055	3.11815	very turbid marine	2023-02-26
Thornton Bank (TBBE) RBINS	PANTHYR	51.53277	2.95510	coastal	2023-05-11
Wraysbury (WRUK) NPL/RBINS	HYPSTAR®	51.46380	-0.52927	reservoir	2023-07-05
Chesapeake Bay (CBUS) UMBC	PANTHYR	39.12351	-76.34890	coastal	2023-11-02

Table 3 Overview of existing LANDHYPERNET validation sites. Each site has a 4 letter code ("ID").

Location, ID and Organisation	System	Latitude (°)	Longitude (°)	Land Surface type	First measurement passing QC
ATB, Germany (ATGE) GFZ (Saberioon et al. 2023)	HYPSTAR®	52.466778	12.959778	agricultural (bare soil)	2022-10-16
Barrax SRIX4VEG site, Spain (BASP) NPL (Sinclair et al. 2023)	HYPSTAR®	39.049139	-2.075917	agricultural	2022-07-20
Demmin, Germany (DEGE) GFZ (Saberioon et al. 2023)	HYPSTAR®	53.868278	13.268556	agricultural	2021-07-29
Gobabeb HYPERNETS, Namibia (GHNA) NPL (De Vis et al. 2023)	HYPSTAR®	-23.60153	15.12589	desert	2022-05-20
Jarvselja, Estonia (JAES) UT	HYPSTAR®	58.281975	27.312959	mixed forest	2023-04-14
Lonzee, Belgium (LOBE) RBINS	HYPSTAR®	50.551493	4.745911	agricultural	2023-05-03
Princess Elisabeth Research Station, Antarctica (PEAN) RBINS	HYPSTAR®	-71.940128	23.30526	snow	2022-01-24
Wytham Woods, UK (WWUK) NPL (Morris et al. 2023)	HYPSTAR®	51.777206	-1.338494	deciduous forest	2022-04-26

3 Land surface reflectance viewing geometries

The viewing geometries for upwelling radiance are illustrated in Figure 3 for land surface reflectance measurements.

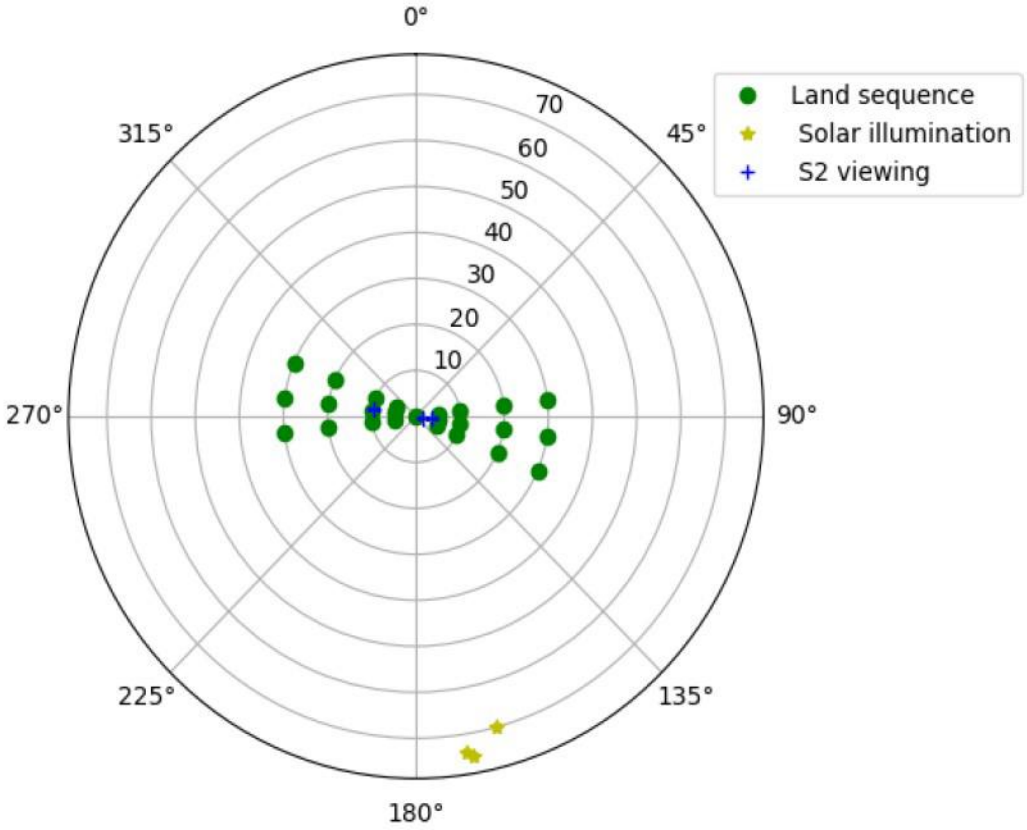

Figure 3. Polar plot showing the typical land protocol viewing geometries for the LANDHYPERNET network. As an example, the Sentinel-2 viewing geometries and solar geometries (during Sentinel-2 overpass) for the Wytham Woods site in January 2022 are shown for comparison (De Vis, Howes, et al., n.d.).

4 Summary of demonstration results

This section summarises the findings of exploitation of early prototype data from HYPERNETS, including both the new HYPSTAR® system, which is the primary focus of the present Perspective Article, and the PANTHYR system (Vansteenwegen et al. 2019), which is based on the mature COTS TRIOS/RAMSES radiometer and used for water applications.

The **PANTHYR** has been used for **validation of satellite-derived water reflectance** in the following studies:

- (Vanhellemont 2020) used PANTHYR data from the Oostende and Acqua Alta sites to test variants of the ACOLITE atmospheric correction software for Landsat-8/OLI, Sentinel-2/MSI and the constellation of Planetscope Dove satellite data.
- (Vanhellemont and Ruddick 2021) used PANTHYR from the Oostende site to test four different atmospheric correction algorithms for Sentinel-3/OLCI satellite data.
- (Braga et al. 2022) used PANTHYR data from the Acqua Alta site as well as AERONET-OC and WISPSTATION data to test two different atmospheric correction algorithms for hyperspectral PRISMA data.
- (Vanhellemont 2023) used PANTHYR from the Oostende site to test two different atmospheric correction algorithms for the constellation of Planet Superdove satellite data
- (Ruddick et al. 2024) used PANTHYR data from the Oostende site to test two different atmospheric correction algorithms for Sentinel-2/MSI satellite data.

The **HYPSTAR®** has been used for **validation of satellite-derived water reflectance** in the following studies:

- (Ruddick et al. 2024) used HYPSTAR® data from six sites to test the Sentinel-3/OLCI standard atmospheric correction.
- (Doxaran et al. 2024) used HYPSTAR® data from the Berre lagoon and Gironde Estuary to validate 8 atmospheric correction algorithms for Sentinel-2/MSI, Landsat-8&9/OLI, Sentinel-3/OLCI and Aqua/MODIS satellite data.
- (Dogliotti et al. 2024) used HYPSTAR® data from the La Plata Estuary site to validate standard atmospheric correction algorithms for Landsat-8&9/OLI, Sentinel-2/MSI, Sentinel-3/OLCI, the PlanetScope SuperDoves constellation, SNPP&JPSS1/VIIRS, AQUA/MODIS and PRISMA satellite data.
- (Gonzalez Vilas et al. 2024) used HYPSTAR® data from six sites to test the Sentinel-3/OLCI standard atmospheric correction and two atmospheric correction algorithms for Sentinel-2/MSI.

The **HYPSTAR®** has been used for **validation of satellite-derived land surface reflectance** in the following studies:

- (Morris et al. 2024) used HYPSTAR® data from the Wytham Woods site to validate top of canopy reflectance from Sentinel-2 and Landsat-8/9.

HYPERNETS data has been also been used for **environmental monitoring** (without satellites) in the following studies over water:

- (Goyens et al. 2022) used PANTHYR and HYPSTAR® data to monitor water quality and cyanobacteria blooms in the Blankaart drinking water reservoir.
- (Lavigne et al. 2022) and (Ruddick et al. 2024) used PANTHYR data from the Oostende site and HYPSTAR® data from the Zeebrugge site to monitoring seasonal variability of phytoplankton species composition (*Phaeocystis globosa*).

Finally, although the HYPERNETS network was designed for radiometric validation at bottom of atmosphere, the instrument system and data processing is also relevant for **vicarious calibration** of satellites at top of atmosphere in the cases where the deployment site is sufficiently spatially homogeneous and well-characterised:

- (De Vis et al. 2024) demonstrates use of the HYPSTAR® at Gobabeb (Namibia) and the Princess Elisabeth Antarctica base for vicarious calibration of Sentinel-2, Landsat-9 and PRISMA.

5 Publicly released datasets

Pending the completion of web data portals, beta release datasets have been released publicly as follows:

- The first **WATERHYPERNET/PANTHYR** hyperspectral datasets with both pre- and post-deployment calibration coefficients have been distributed via ZENODO – see
    - (Brando et al. 2023) for the Acqua Alta site (October 2019–October 2020 and November 2020–March 2022) and
    - (Vansteenwegen and Vanhellemont 2023) for the Oostende site (December 2019–August 2020 and February 2022–November 2022).
- The first beta-release **WATERHYPERNET/HYPSTAR®** hyperspectral datasets up to April 2023 have been distributed via ZENODO – see
    - (Goyens and Gammaru 2023) for the Zeebrugge (M1BE) site,
    - (Brando et al. 2023) for Lake Garda (GAIT),
    - (Doxaran and Corizzi 2023) for the Gironde Estuary (MAFR),
    - (Brando et al. 2023) for Acqua Alta (VEIT),
    - (Doxaran and Corizzi 2023) for the Etang de Berre (BEFR) and
    - (Dogliotti et al. 2023) for the La Plata Estuary (LAPR).
- The first beta-release **LANDHYPERNET/HYPSTAR®** hyperspectral datasets up to April 2023 have been distributed via ZENODO – see
    - (De Vis et al. 2023) for the Gobabeb site (GHNA)
    - (Morris et al. 2023) for the Wytham Woods site (WWUK)
    - (Sinclair et al. 2023) for the temporary Barrax site (BASP)
    - (Saberioon et al. 2023) for the ATB/Marquardt site (ATGE)
    - (Saberioon et al. 2023) for the DEMMIN site (DEGE) and
    - (Piegari et al. 2023) for the IFEVA site

It is noted that **not all of these sites are suitable for satellite validation**, since some may be spatially very heterogeneous.

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