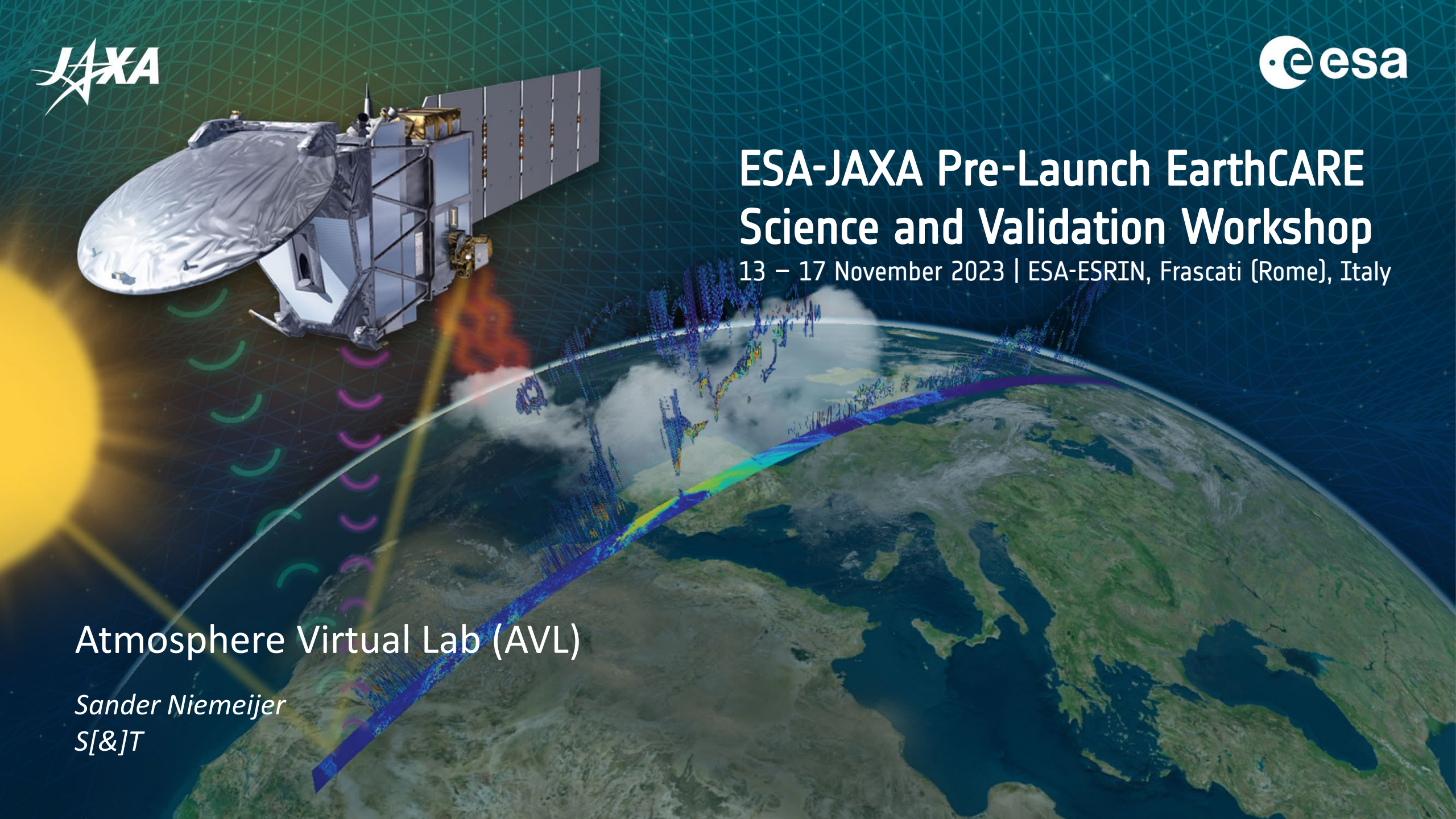
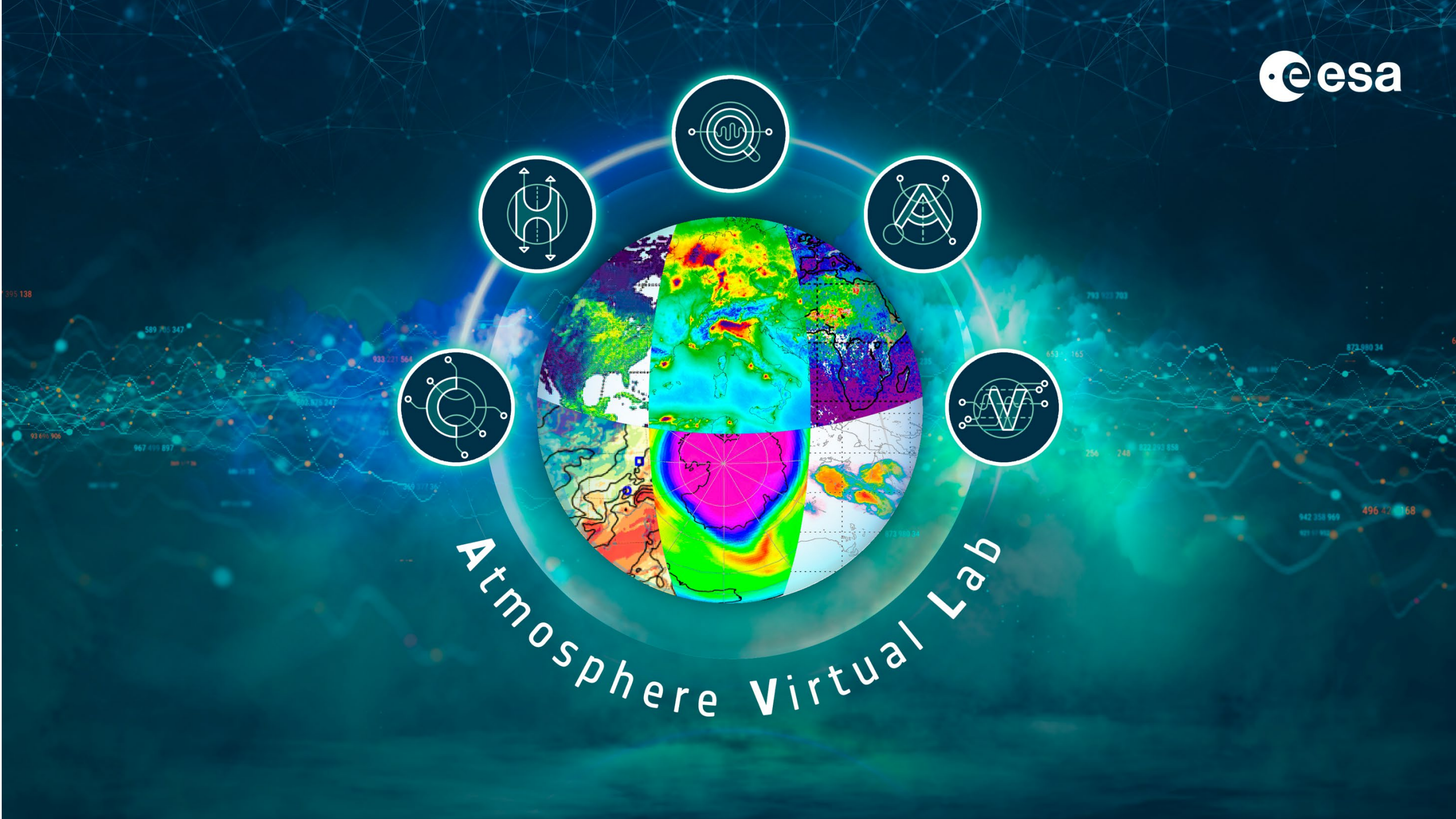


ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

Atmosphere Virtual Lab (AVL)

Sander Niemeijer
S[&]T


esa
Atmosphere Virtual Lab

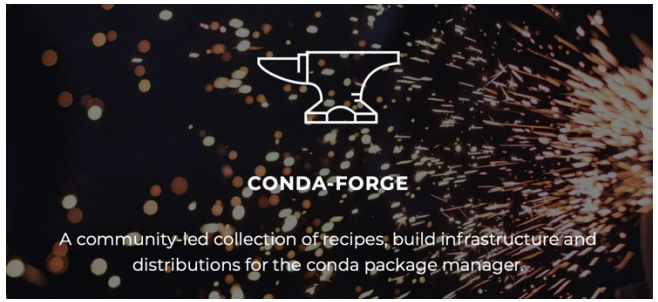
Everything Open Source and available via conda-forge

$ conda create -n avl

$ conda activate avl

$ conda install -c conda-forge atmosphere-virtual-lab

$ jupyter-lab



https://atmospherevirtuallab.org

```
[1]: import harp
```

```
[2]: product = harp.import_product("EarthCARE/ECA_EXAA_ATL_ICE_2A_20241231T183450Z_20230131T101502Z_39316D.h5")
```

```
[3]: print(product)
```

```
source product = 'ECA_EXAA_ATL_ICE_2A_20241231T183450Z_20230131T101502Z_39316D.h5'

double datetime {time=5086} [seconds since 2000-01-01]
double latitude {time=5086} [degree_north]
double longitude {time=5086} [degree_east]
long orbit_index
float altitude {time=5086, vertical=246} [m]
float surface_height {time=5086} [m]
float viewing_elevation_angle {time=5086} [degree]
float tropopause_height {time=5086} [m]
float ice_water_density {time=5086, vertical=246} [kg/m3]
float ice_water_density_uncertainty {time=5086, vertical=246} [kg/m3]
float ice_particle_effective_radius {time=5086, vertical=246} [m]
float ice_particle_effective_radius_uncertainty {time=5086, vertical=246} [m]
byte validity {time=5086, vertical=246}
long index {time=5086}
```

ECA_ATL_EBD_2A

Variables

The table below lists the variables that are present in the HARP product that results from an ir

field name	type	dimensions	unit
datetime	double	{*time*}	[seconds since 2000-01-01]
latitude	double	{*time*}	[degree_north]
longitude	double	{*time*}	[degree_east]
orbit_index	int32		
altitude	float	{*time*, *vertical*}	[m]
surface_height	float	{*time*}	[m]
viewing_elevation_angle	float	{*time*}	[degree]
tropopause_height	float	{*time*}	[m]
extinction_coefficient	float	{*time*, *vertical*}	[1/m]
extinction_coefficient_uncertainty	float	{*time*, *vertical*}	[1/m]
backscatter_coefficient	float	{*time*, *vertical*}	[1/m/sr]
backscatter_coefficient_uncertainty	float	{*time*, *vertical*}	[1/m/sr]
lidar_ratio	float	{*time*, *vertical*}	[sr]
lidar_ratio_uncertainty	float	{*time*, *vertical*}	[sr]
linear_depolarization_ratio	float	{*time*, *vertical*}	[]

EARLINET

Variables

The table below lists the variables that are present in the HARP product that results from an

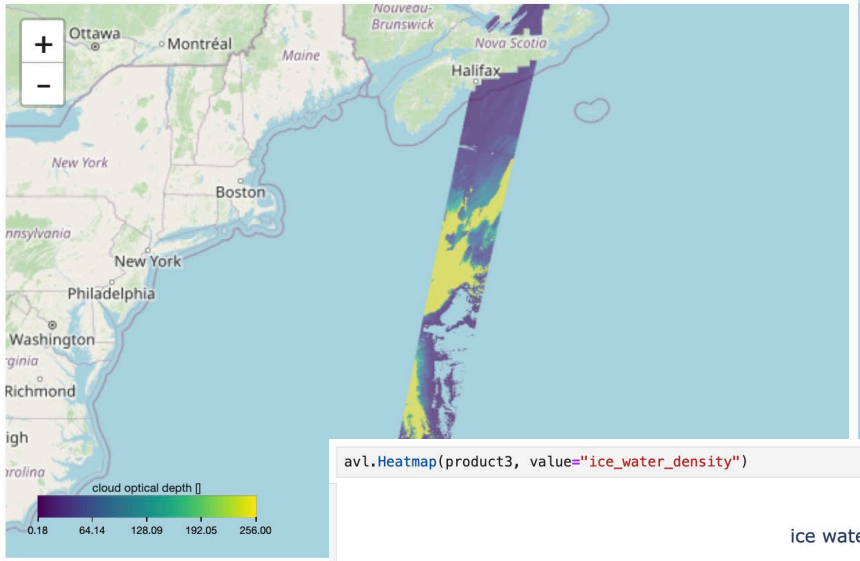
field name	type	dimensions	unit
datetime_start	double	{*time*}	[seconds since 1970-01-01]
datetime_stop	double	{*time*}	[seconds since 1970-01-01]
latitude	float		[degrees]
longitude	float		[degrees]
sensor_altitude	float		[m]
viewing_zenith_angle	float		[degrees]
wavelength	float	{*spectral*}	[nm]
altitude	double	{*vertical*}	[m]
backscatter_coefficient	double	{*time*, *spectral*, *vertical*}	[1/(m*sr)]
backscatter_coefficient_uncertainty	double	{*time*, *spectral*, *vertical*}	[1/(m*sr)]
extinction_coefficient	double	{*time*, *spectral*}	[1/m]
extinction_coefficient_uncertainty	double	{*time*, *spectral*, *vertical*}	[1/m]
index	int32	{*time*}	

EarthCARE products

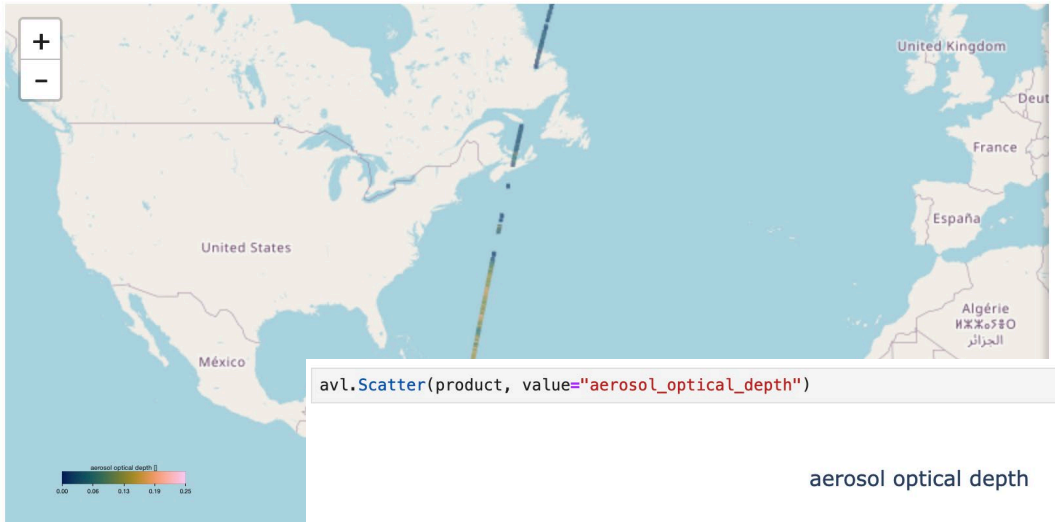
HARP product name	CODA product type	description
ECA_ACM_CAP_2B	EARTHCARE/ACM_CAP_2B	ATLID/CPR/MSI cloud and aerosol properties
ECA_AC__TC__2B	EARTHCARE/AC__TC__2B	ATLID/CPR synergetic lidar/radar classification
ECA_AM__ACD_2B	EARTHCARE/AM__ACD_2B	ATLID-MSI aerosol column descriptor
ECA_AM__CTH_2B	EARTHCARE/AM__CTH_2B	ATLID-MSI cloud top height
ECA_ATL_AER_2A	EARTHCARE/ATL_AER_2A	ATLID aerosol inversion
ECA_ATL_ALD_2A	EARTHCARE/ATL_ALD_2A	ATLID aerosol layers in cloud-free observations
ECA_ATL_CTH_2A	EARTHCARE/ATL_CTH_2A	ATLID uppermost cloud top height
ECA_ATL_EBD_2A	EARTHCARE/ATL_EBD_2A	ATLID extinction, backscatter, and depolarization
ECA_ATL_ICE_2A	EARTHCARE/ATL_ICE_2A	ATLID ice water content and effictive radius
ECA_BMA_FLX_2B	EARTHCARE/BMA_FLX_2B	BBR TOA solar and thermal fluxes
ECA_BM__RAD_2B	EARTHCARE/BM__RAD_2B	BBR TOA radiances
ECA_CPR_CLD_2A	EARTHCARE/CPR_CLD_2A	CPR cloud profiles
ECA_MSI_AOT_2A	EARTHCARE/MSI_AOT_2A	MSI aerosol optical thickness
ECA_MSI_CM__2A	EARTHCARE/MSI_CM__2A	MSI cloud mask, type and phase
ECA_MSI_COP_2A	EARTHCARE/MSI_COP_2A	MSI cloud optical thickness, cloud effective radius, ice crystal diameter, cloud water path, and cloud top temperature, pressure and height

added in HARP 1.19 in July 2023

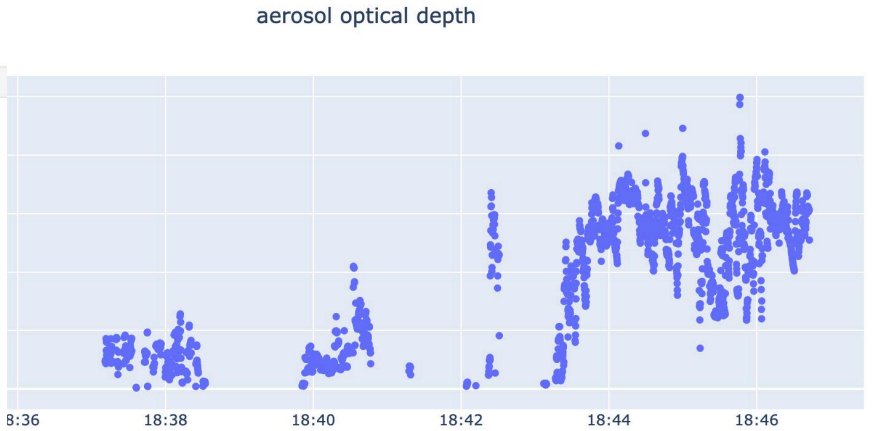
```
avl.Geo(product2, value="cloud_optical_depth")
```



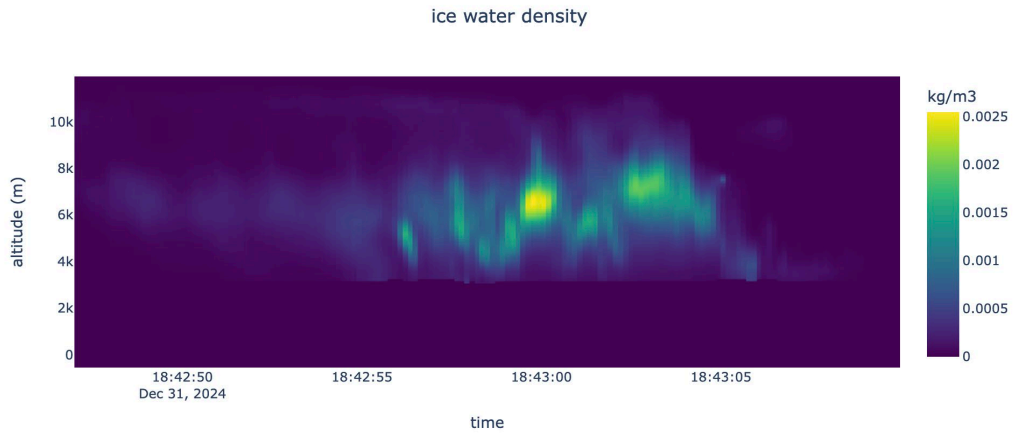

```
avl.Geo(product, value="aerosol_optical_depth", pointsize=3, colormap="cmc.batlow", colorrange=(0,0.25))
```



```
avl.Scatter(product, value="aerosol_optical_depth")
```



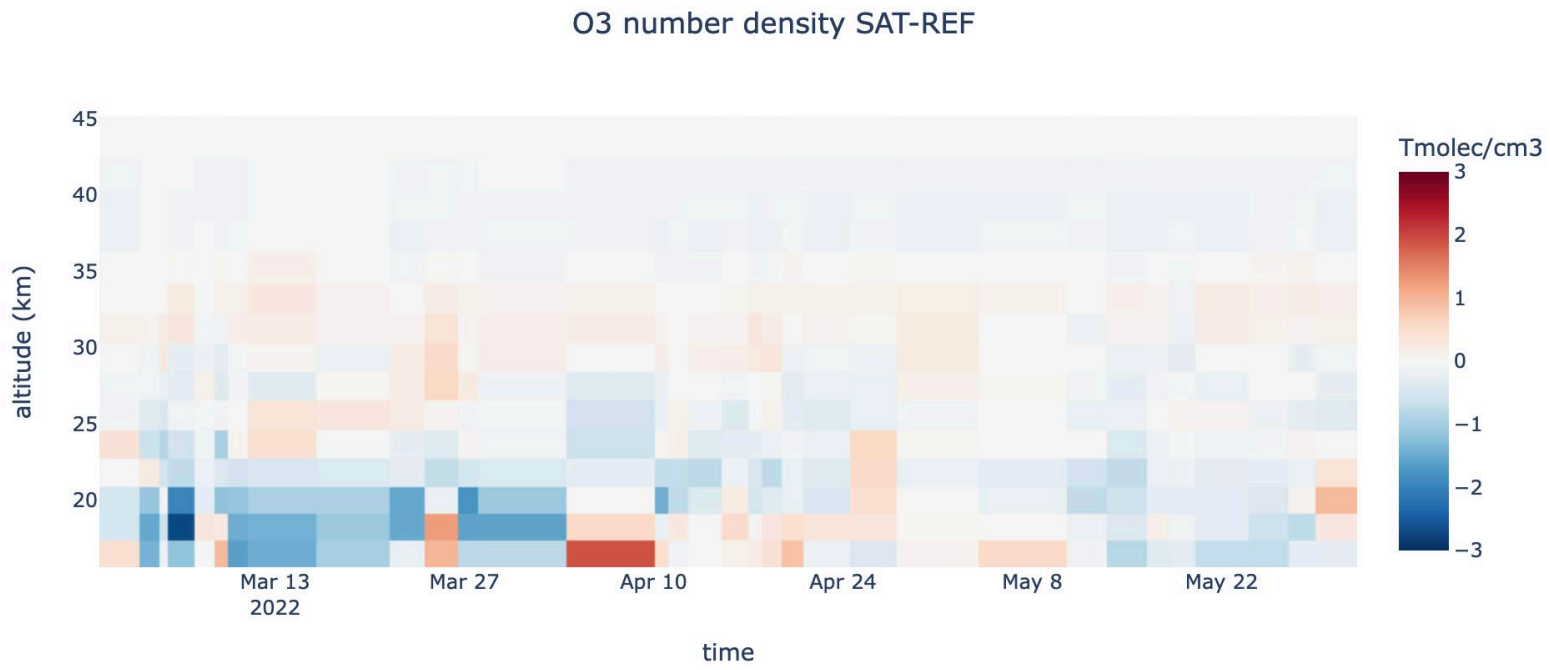

```
avl.Heatmap(product3, value="ice_water_density")
```



Intercompare EarthCARE against groundbased data

```
harpcollocate \
        -d 'datetime 24 [h]' \
        --point-in-area-yx \
        -aa 'valid(O3_column_number_density);validity !& 255' \
        -nx datetime -ny datetime \
        s5p \
        lidar \
        collocations.csv
```

example using S5P O3 profile against lidar



EarthCARE support in AVL

With AVL you can:

- Use HARP to import data from EarthCARE products in a common data structure (similar to other satellite missions and ground based data)
- Perform detailed collocations and inter-comparisons to validate the EarthCARE data against ground based measurements
- Perform interactive visualisations of EarthCARE in jupyterlab environments with the AVL plotting routines.

An overview of the EarthCARE products that are supported by HARP can be found in the HARP ingestion definition documentation. This also provides a description of the variables that are supported per product type and from where in the product they are taken.

> WARNING: EarthCARE products only contain height information relative to the reference ellipsoid. Even though HARP ingests these variables as `altitude` variables, the height values are not actual altitudes. Care must be taken when performing validations that require an accurate vertical grid. A future version of the EarthCARE products should include geoid height information to calculate actual altitudes. Once these products are released HARP will be updated to extract actual `altitude` variables.

Below are the example notebooks as were presented during the webinar on 26 June 2023:

- presentation - powerpoint
- demo1 - read and visualize ACM data - notebook, webpage
- demo2 - read and visualize MSI data - notebook, webpage
- demo3 - lidar profile comparison using S5P - notebook, webpage

https://atmospherevirtuallab.org/earthcare/

come visit us at the demo booth in the Cook room during the poster session

Atmospheric Toolbox

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QDOAS for Sentinel-4? QDOAS	1 7d
Plot S5P CH4 with unit of kilotons HARP	3 8d
Map Sentinel 5p CH4, SO2 and CO Data (Visan) HARP sentinel-5p,python	32 8d
Truncated file error with HARP for 2022 RPRO L2__NO2 Files for 2018-2019 HARP sentinel-5p,python	3 17d
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