4. D2.2 Database of satellite-based observations of stratospheric smoke layers.

4.1. Overview

StratoFIRE WP2 aims to (a) detect major events of stratospheric aerosol transport and identify the cases related to pyroCb injections and (b) to provide to WP3, WP4, and WP5 the necessary ground-based and satellite observations for the stratospheric aerosol layers, with focus on the specific extreme smoke events (e.g., Canadian 2017, Australian 2019-2020) as well as any future event within the project period.

Towards addressing StratoFIRE Scientific Questions, identification of the major stratospheric perturbations in both hemispheres resulting from extreme smoke events is of high importance. In addition, space-borne datasets have to be extensively used to provide a broader spatiotemporal characterization of specific events and the estimation of the PyroCb source strength/emissions at the tropopause, with focus on specific extraordinary stratospheric smoke cases, inventoried in StratoFIRE WPs.
Towards these objectives, StratoFIRE will make use of several satellite-based observations to probe the upper troposphere - lower stratosphere, during individual intense pyroconvective events, as documented, categorized and inventoried in global pyroCb databases in D2.1.

The present section provides an overview of satellite-based observations used in the StratoFIRE, namely:

- GLOSSAC, which is used in D3.1
- OMPS
- MLS
- CALIPSO-CALIOP, which is a cornerstone of the StratoFIRE WP2 satellite-based observational component

In the following we provide a short introduction to each dataset and describe the files which are distributed by the project.

4.2. GLOSACC

The Global Space-based Stratospheric Aerosol Climatology, or GloSSAC, is a 43-year climatology of stratospheric aerosol properties focused on extinction coefficient measurements by the Stratospheric Aerosol and Gas Experiment (SAGE) series of instruments through mid-2005 and later from mid-2017 and on the Optical Spectrograph and InfraRed Imager System (OSIRIS) and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) data thereafter (Thomason et al., 2018). SAGEIII/ISS data is also incorporated in GloSSAC to extend the climatology to the present and to test the approach used to correct OSIRIS/CALIPSO data particularly during the time when overlap measurements are available. Data from other space instruments and from ground-based, air and balloon borne instruments to fill in key gaps in the data set. The end result is a global and gap-free data set focused on aerosol extinction coefficient at 525 and 1020 nm and other parameters on an 'as available' basis.

The StratoFIRE database includes the GloSSAC version 2.2, which has been extended through December 2021. A description of the dataset and the updates compared to previous versions is given here:
https://asdc.larc.nasa.gov/documents/glossac/quality_summaries/GloSSAC_Product_Quality_Summary_v2.2.pdf. The source of the original file is:
https://asdc.larc.nasa.gov/project/GloSSAC/GloSSAC_2.2

Description of the dataset

File name: StratoFIRE_GloSSAC_V2.2_Glossac_Aerosol_Extinction_Coefficient_1979-2021_zm_mm.nc

Time Period and resolution: 1979-2021, monthly

Domain: Zonal averaged, 80 height levels

Variables:

StratoFIRE_GloSSAC_V2.2_Glossac_Aerosol_Extinction_C...	StratoFIRE_GloSSAC_V2.2_Glossac_Aerosol_Extinction_Coefficient_19...	Local File
alt	alt	1D
Glossac_Aerosol_Extinction_Coefficient	GloSSAC Aerosol Extinction Coefficient	Geo2D
lat	Latitude	1D
time	time	1D
wavelengths_glossac	GloSSAC Measurement wavelength	—

Table 2 List of all variables in StratoFIRE_GloSSAC_V2.2_Glossac_Aerosol_Extinction_Coefficient_1979-2021_zm_mm.nc

4.3. OMPS

The Ozone Mapping and Profiler Suite (OMPS) on board the Suomi National Polar-orbiting Partnership (NPP) satellite launched in October 2011 consists of the sensors designed to acquire ozone profiles and total ozone measurements (Pan et al., 2019). The three spectrally overlapping sensors scan the air masses and measure the scattering of solar irradiance within 10 minutes. Two out of the three sensors are part of the nadir module; The Total Column Nadir Mapper (TC-NM) measures total column ozone while the Nadir Profiler (NP) measures ozone vertical profiles. The third and last sensor called Limb Profiler (LP) measures vertical ozone profiles (in UV and VIS spectral ranges) spanning from the upper troposphere to the mesosphere with a higher vertical resolution that ranges between 2-3 km.

The StratoFIRE database includes the OMP version 2.0, which has been extended through December 2021. A description of the dataset and the updates compared to previous versions is given here: https://asdc.larc.nasa.gov/documents/glossac/quality_summaries/GloSSAC_Product_Quality_Summary_v2.2.pdf. The the original MPS-NPP LP L2 Aerosol Extinction Vertical Profile swath multi-wavelength daily 3 slit Collection 2 V2.0 data are accessible from the Goddard Earth Sciences Data and Information Services Center (GES DISC), https://doi.org/10.5067/CX2B9NW6FI27

Description of the dataset

File name: STRATOFIRE_OMPS-NPP_LP_L3_AER_MONTHLY_v1.0_201203_202301_mm.nc

Time Period and resolution: 2012/03-2023/01, monthly

Domain: Global, 41 height levels

Variables:

OMPS-NPP_LP_L3_AER_MONTHLY_v1.0_201203_202301.nc	Suomi-NPP OMPS Limb Profiler Gridded Aerosol Data	Local File
Altitude	Altitude	1D
ExtinctionAvg	Extinction coefficient average	Geo2D
ExtinctionStDev	Extinction coefficient standard deviation	Geo2D
ExtinctionStErr	Extinction coefficient standard error	Geo2D
ExtRatioAvg	Aerosol to molecular extinction ratio	Geo2D
ExtRatioStDev	Aerosol to molecular extinction ratio standard deviation	Geo2D
ExtRatioStErr	Aerosol to molecular extinction ratio standard error	Geo2D
Latitude	Latitude	1D
Longitude	Longitude	1D
NumDensAvg	number density average	Geo2D
NumGoodScreen	Number of screened samples	Geo2D
NumSamples	Number of possible samples	Geo2D
Pressure	Background pressure average	Geo2D
ScatteringAngle	Scattering angle average	Geo2D
StratColumn	Aerosol stratospheric column optical depth	Geo2D
Temperature	Background temperature average	Geo2D
time	time	1D
TropopauseAltitude	Tropopause altitude average	Geo2D
Wavelength	Wavelength	1D

Table 3 List of all variables in STRATOFIRE_OMPS-NPP_LP_L3_AER_MONTHLY_v1.0_201203_202301_mm.nc

4.4. MLS

The Microwave Limb Sounder (MLS) aboard the Aura satellite is part of the Earth Observing System (EOS) and since August 2004, provides daily daytime/night-time measurements of ozone profiles (~3500 profiles each day) on a global scale as well as trace gases from the upper troposphere to the upper mesosphere (~90km). Aura MLS vertically scans the Earth's atmosphere limb in five broad regions of the electromagnetic spectrum ranging between 118 GHz and 2.5 THz and measures thermal radiance emissions. Contrary to similar instruments that measure emissions in a direction perpendicular to the spacecraft flight direction, MLS scans the atmosphere directly ahead of the Aura satellite which follows a sun-synchronous near-polar orbit with ascending equatorial crossing time of ~13:45 local time (LT). The MLS retrieves water vapour from the 190 GHz radiometer and ozone from the 240 GHz spectral band using optimal estimation approach with a high vertical resolution that spans between 2.5-3km from the upper troposphere to the lower mesosphere and a 5km vertical resolution in the upper mesosphere.

The StratoFIRE database includes the MLS version 5.0, which has been extended through December 2022. A description of the dataset is given here: https://mls.jpl.nasa.gov/data/v5-0_data_quality_document.pdf The original MLS Level 3 data described here can be obtained from the NASA Goddard Space Flight Center Earth Science Data and Information Services Center (GES-DISC, see https://disc.gsfc.nasa.gov/)

Description of the dataset

File name: STRATOFIRE_H2O_MLS_v5_2005-2022_mm.nc

Time Period and resolution: 2005-2022, monthly

Domain: Global, 55 pressure levels

Variables:

STRATOFIRE_H2O_MLS_v5_2005-2022.nc	N/A	Local File
H2O_PressureGrid	H2O_PressureGrid	–
lat	Latitude	1D
lev	Pressure	1D
lon	Longitude	1D
std_dev	Standard Deviation of Water	Geo2D
time	Time	1D
value	Average Value of Water	Geo2D

4.5. CALIPSO-CALIOP

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) mission (Winker et al., 2010) is a joint satellite project, developed, operating and maintained in close and ongoing collaboration between the National Aeronautics and Space Administration (NASA), the United States space agency, and the Centre National D'Études Spatiales (CNES), the French space agency. The satellite CALIPSO was launched on April 28th, 2006, to be integrated in the Afternoon-Train (A-Train) constellation of sun-synchronous polar-orbit satellites hosting a suite of three Earth-observing instruments, in a near-nadir-looking configuration: a single channel 645 wide field-of-view camera (WFC), a three channel (8.65, 10.6, 12.05 μm) Imaging Infrared Radiometer (IIR), and the principal payload, the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) lidar (Hunt et al., 2009). The primal instrument, CALIOP, is a dual-wavelength polarization-sensitive elastic backscatter Nd:YAG lidar, that transmits linear polarized light pulses at 532 and 1064 nm, and accordingly, makes separate range-resolved measurements of the backscattered signals by atmospheric features, and specifically, of the parallel and perpendicular components of the backscattered photons at 532 nm with respect to the polarization plane of CALIOP emitted beam, and the total backscatter intensity at 1064 nm.
Because CALIPSO dataset is the cornerstone of the StratoFIRE WP2 satellite-based datasets, we provide an extensive description of main characteristics of the satellite platform and the dataset of interest.

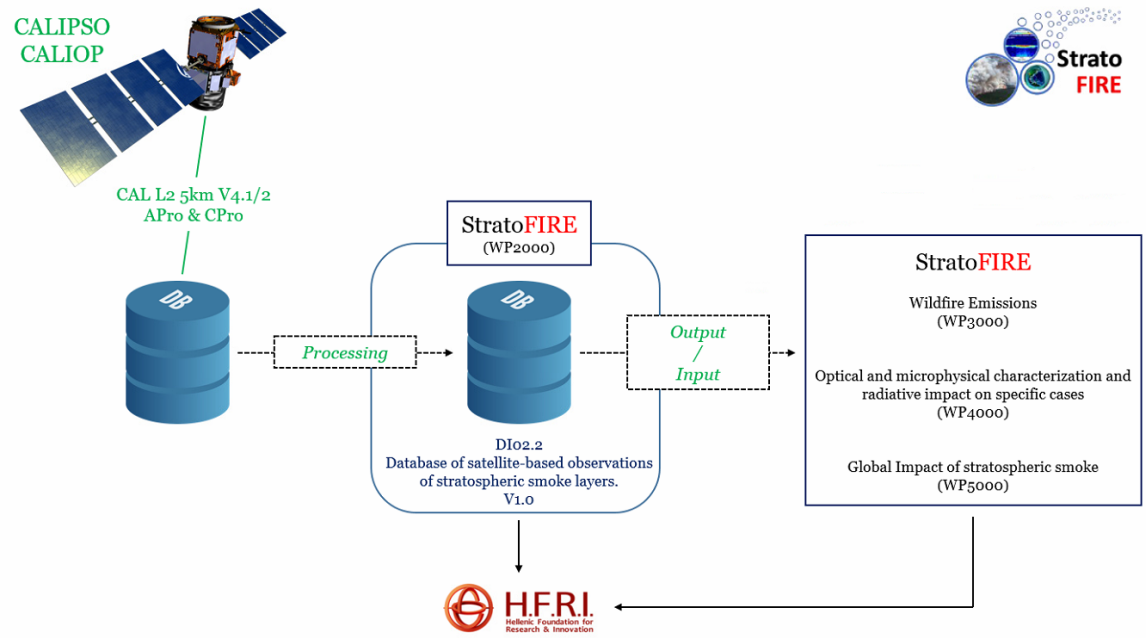


Figure 7 StratoFIRE Work Logic for CALIPSO-CALIOP.

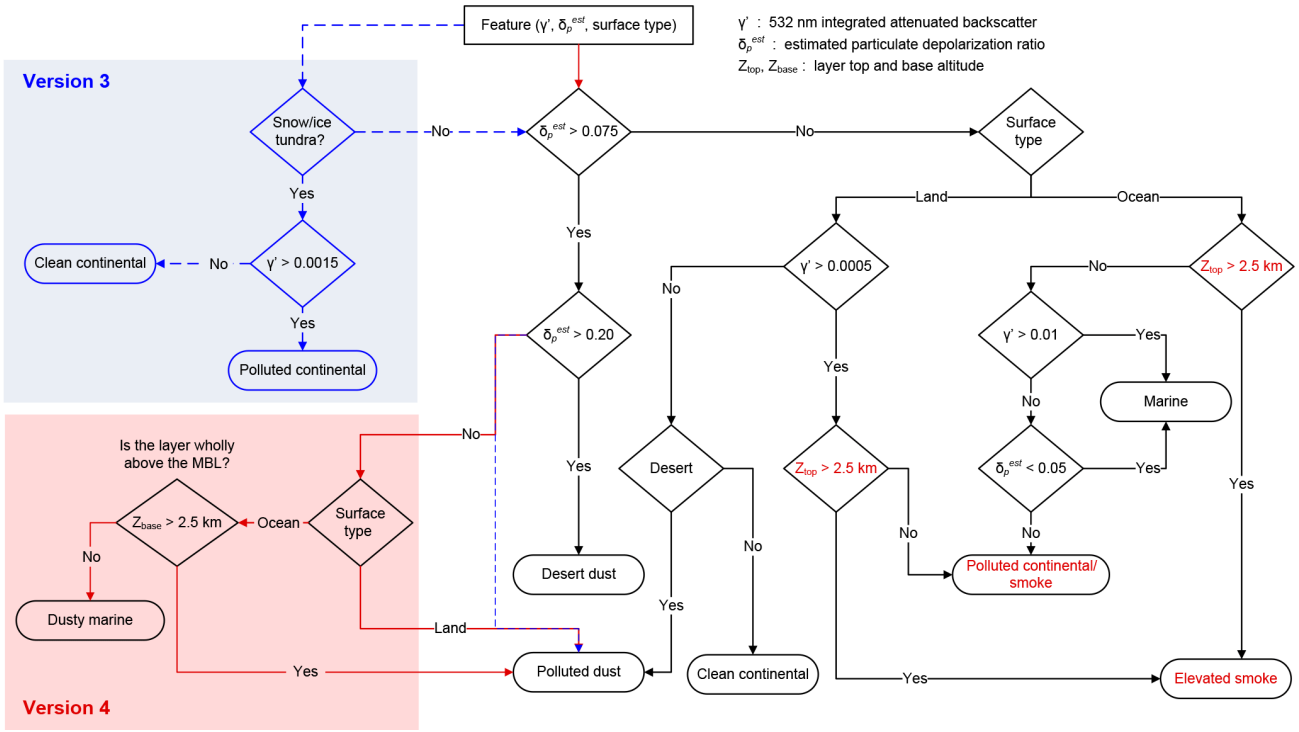


Figure 8 Flowchart of the CALIPSO aerosol subtype selection scheme for tropospheric aerosols (source:(Kim et al., 2018)).

CALIOP measurements and products are provided in different levels of processing. The received measurements of attenuated backscatter from molecules and particles are provided in 1/3 km horizontal and 30 m vertical resolution and reported in CALIOP Level 1 data products. Subsequently, CALIOP Level 1 measurements are processed to CALIOP Level 2 products, following a sophisticated chain of algorithms that perform a sequence of functions, including the fundamental for the retrievals daytime and nighttime calibration of the three receiver channels, layer detection and cloud-aerosol discrimination. In addition, in the process to retrieve particulate extinction profiles, an intermediate aerosol classification and Lidar Ratio selection algorithm for feature detection classifies atmospheric features between "clear-air", "tropospheric aerosol", "stratospheric aerosol", "cloud", "surface", "subsurface", "totally attenuated", and aerosol and cloud features of "low/no confidence". The algorithm modules further classify atmospheric features categorized as "tropospheric aerosol" between "marine", "dust", "polluted continental/smoke", "clean continental", "polluted dust", "elevated smoke" and "dusty marine" (Kim et al., 2018) – (Figure 10), and in the case of "stratospheric aerosol" between "PSC aerosol", "volcanic ash", and "sulfate/other"– (Figure 11).

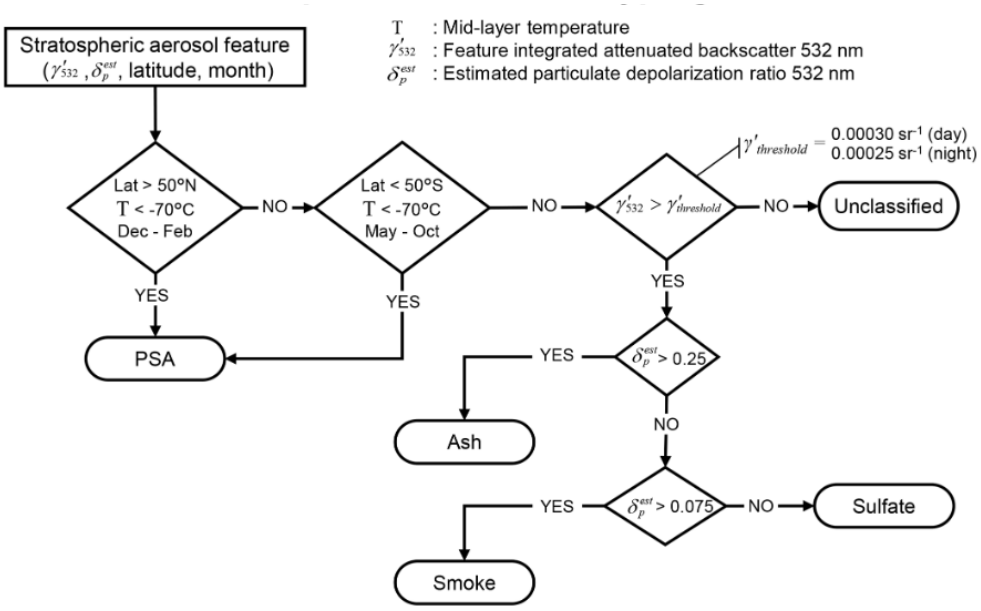
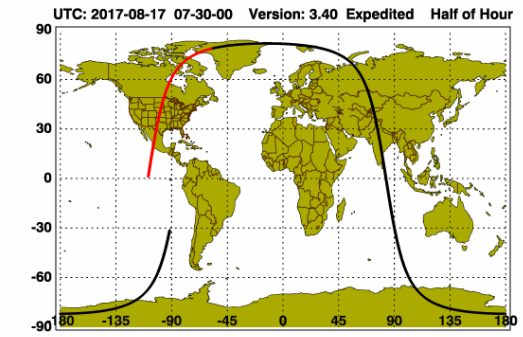
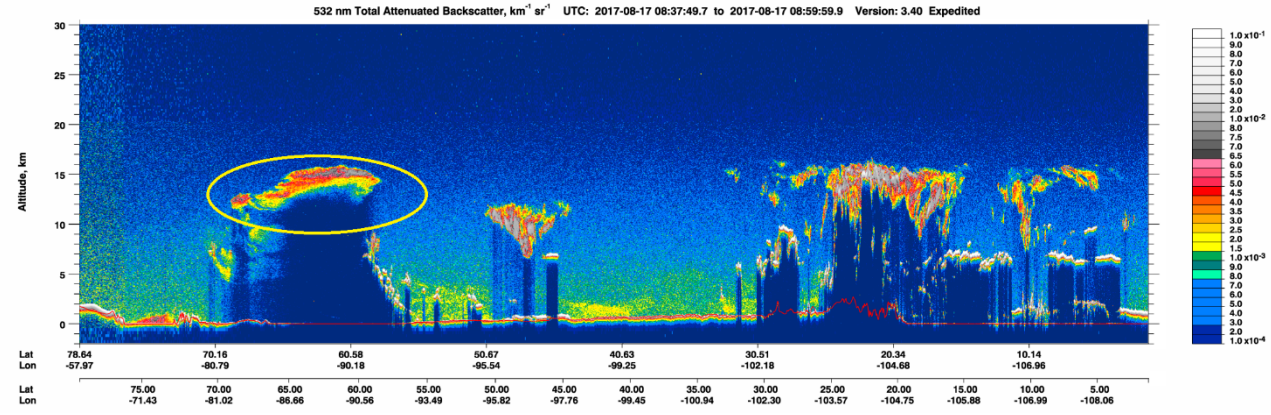
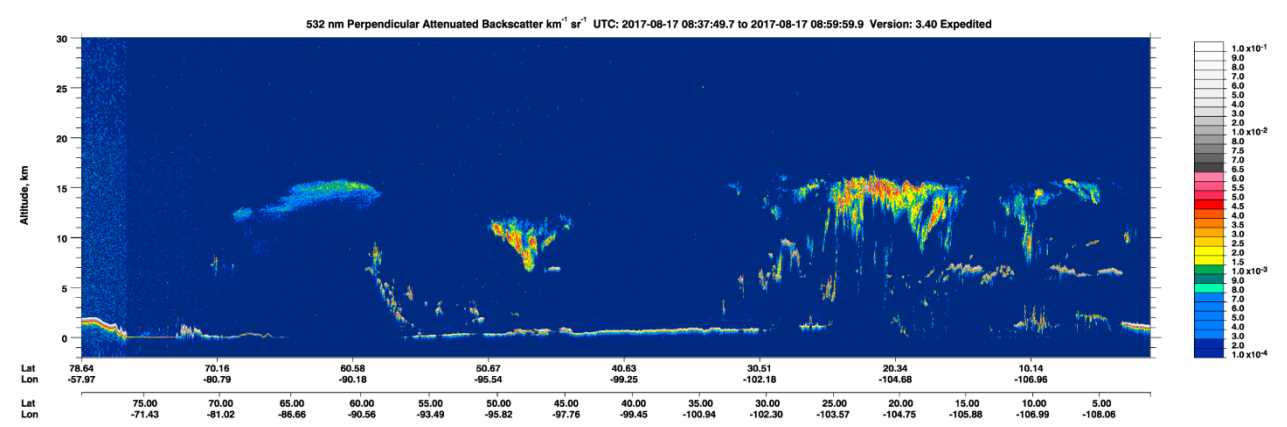


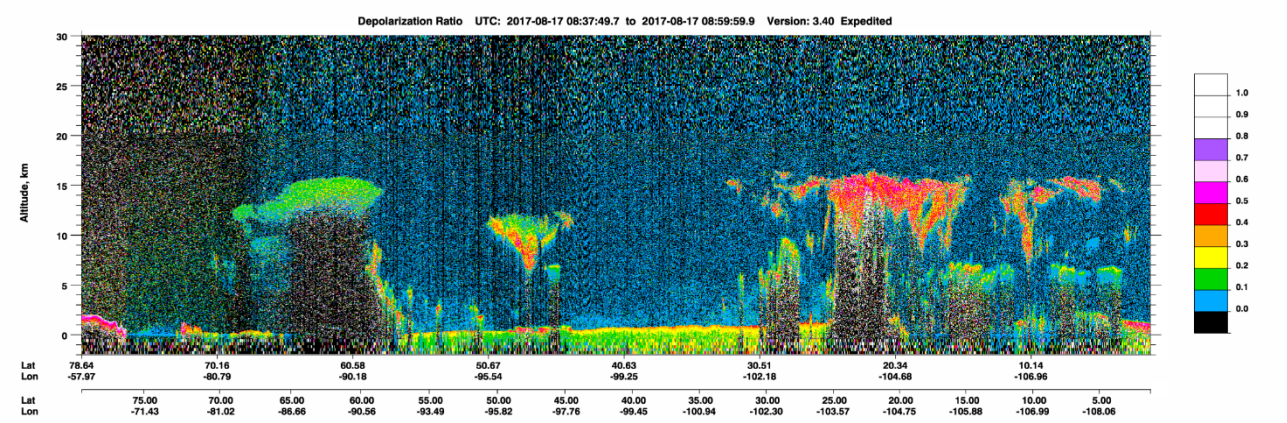
Figure 9 Flowchart for stratospheric aerosol subtyping in the V4.5.

During the massive Pacific Northwest (PNW) event in August 2017, smoke injected into the lower stratosphere. An example CALIOP observation of one of the earliest smoke plumes detected from the event (Torres et al., 2020) is shown in the panels of Figure 12. More specifically, Figure 12 provides the CALIPSO overpass (Fig. 12a), the total attenuated backscatter 532nm (Fig. 12b), the perpendicular attenuated backscatter at 532nm (Fig. 12c), the volume depolarization ratio at 532nm (Fig. 12d), and the feature type classification for the selected example scene (Fig. 12e).






532 nm Perpendicular Attenuated Backscatter km-1 sr-1 UTC: 2017-08-17 08:37:49.7 to 2017-08-17 08:59:59.9 Version: 3.40 Expedited
Altitude, km
Lat
Lon


Depolarization Ratio UTC: 2017-08-17 08:37:49.7 to 2017-08-17 08:59:59.9 Version: 3.40 Expedited
Altitude, km
Lat
Lon

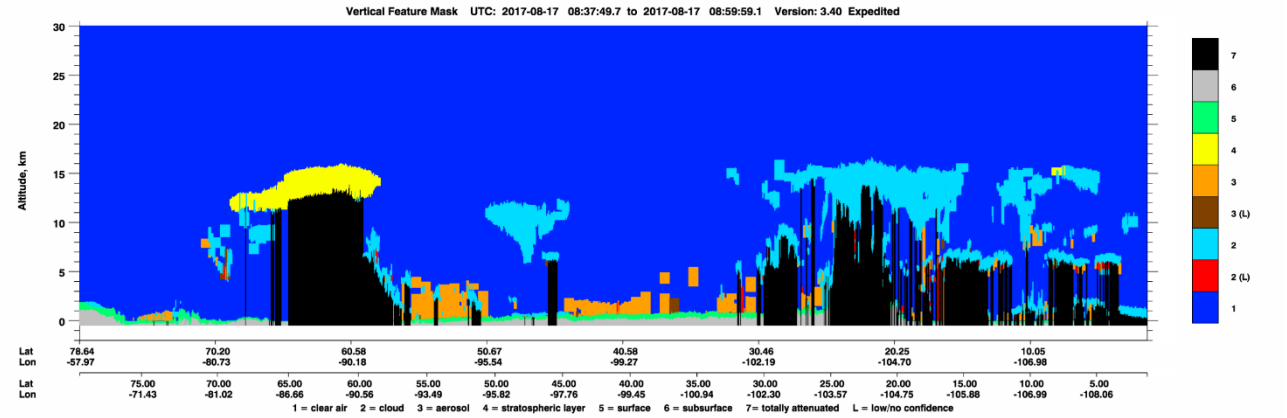


Figure 10 PyroCb smoke plume from the PNW event on 17th of August 2017 in the proximity of Quebec Province, Canada. During the massive PNW event smoke injected into the lower stratosphere: CALIPSO overpass (Fig. 12a), the total attenuated backscatter 532nm (Fig. 12b), the perpendicular attenuated backscatter at 532nm (Fig. 12c), the volume depolarization ratio at 532nm (Fig. 12d), and the feature type classification for the selected example scene (Fig. 12e).

Description of the dataset

File name: collection of netcdf files. Example: StratoFIRE_lat_c_-7.5_lon_c_-137.5_062006-052021.nc

Time Period and resolution: 06/2006-05/2021, tracks

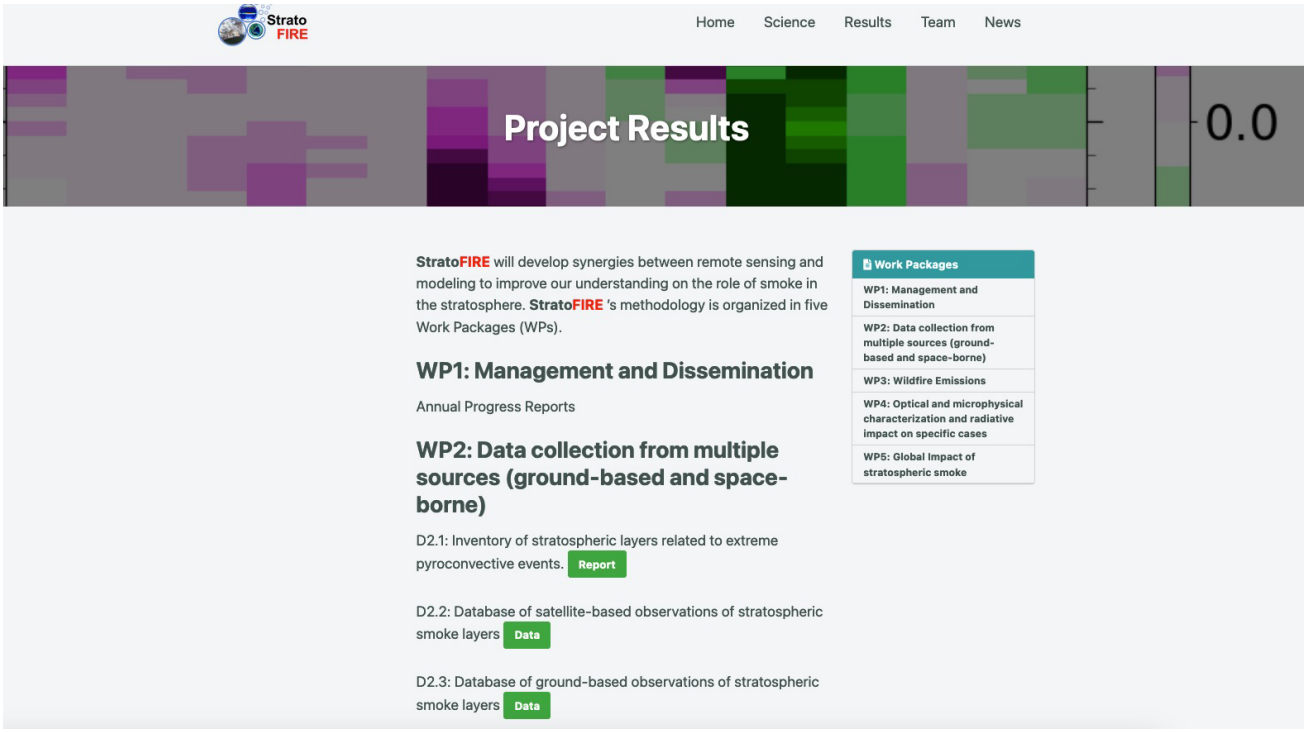
Domain: Global, 399 height levels

Variables:

StratoFIRE_lat_c_7.5_lon_c_-97.5_062006-052021.nc	StratoFIRE_lat_c_7.5_lon_c_-97.5_062006-052021.nc	Local File
Backscatter_Coefficient_532nm_mean	Backscatter Coefficient 532nm - mean	2D
Backscatter_Coefficient_532nm_SD	Backscatter Coefficient 532nm - SD	2D
Extinction_Coefficient_532nm_mean	Extinction Coefficient 532nm - mean	2D
Extinction_Coefficient_532nm_SD	Extinction Coefficient 532nm - SD	2D
Height	km	1D
Tropopause_Height_mean	Tropopause Height - mean	1D
Tropopause_Height_SD	Tropopause Height - SD	1D

4.6. Database access

Access to the HFRI- StratoFIRE D2.2 dataset is provided via the project's Webpage. The user should go to Results tab and the select the deliverables of each work package, as demonstrated in Picture 3.



Picture 3 The satellite-based database of D2.2 is accessible from the webpage.