GLORIA observations of biomass burning pollution products in the Southern hemisphere UTLS region during the SouthTRAC HALO aircraft campaign September-November 2019

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Institute of Meteorology and Climate Research - Atmospheric Trace Gases and Remote Sensing

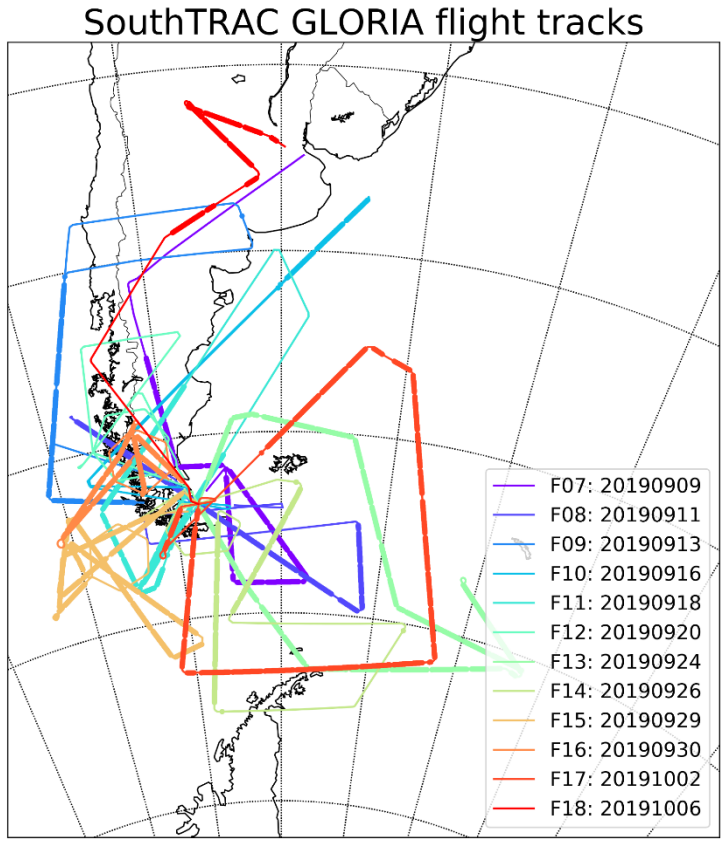
The SouthTRAC HALO aircraft campaign

- Joint atmospheric aircraft research project by German research centers and universities (https://www.pa.op.dlr.de/southtrac/)
- Research aircraft: HALO (https://www.halo.dlr.de/)
- Base: Río Grande (Tierra del Fuego)
- Time: 2 phases: 6 Sep – 9 Oct and 2 Nov – 15 Nov, 2019
- Research themes:
  - Gravity waves in the Southern Hemisphere
  - Coupling processes at the Southern Hemisphere tropopause: UTLS composition and dynamics in the Southern Hemisphere from observations and models
  - Impact of the Antarctic vortex on the SH-UTLS
  - **Biomass burning and transport of biogenic emissions in the southern Atlantic upper troposphere**

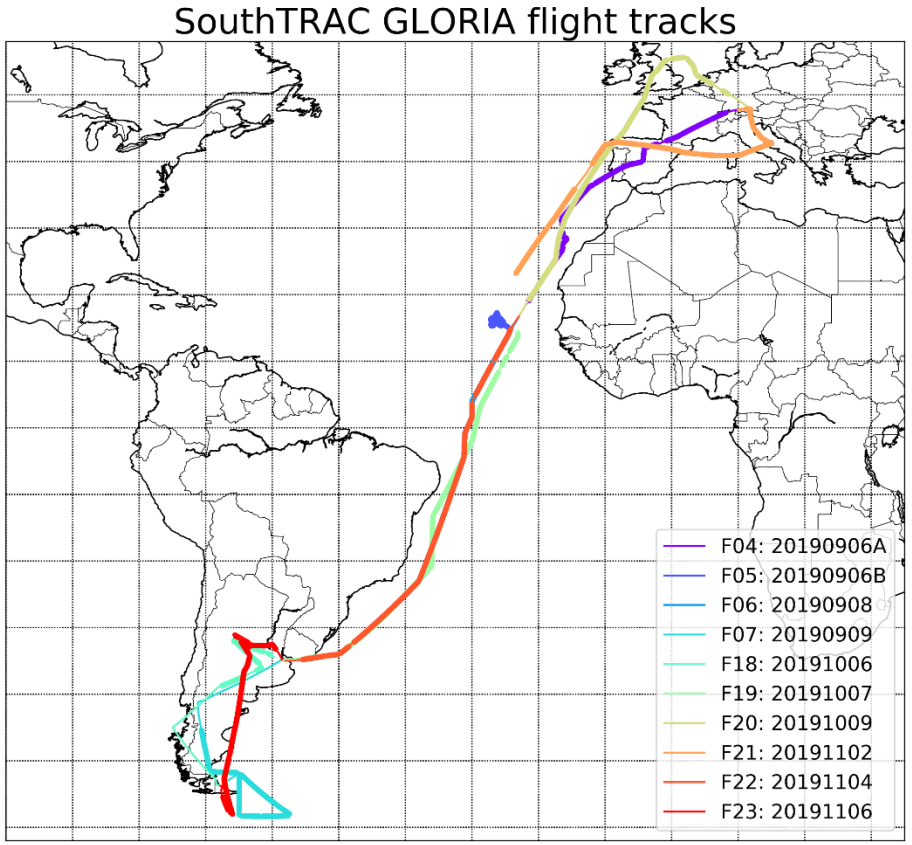
  → **first results by the GLORIA infrared limb sounder are shown in this contribution**

SouthTRAC flight tracks

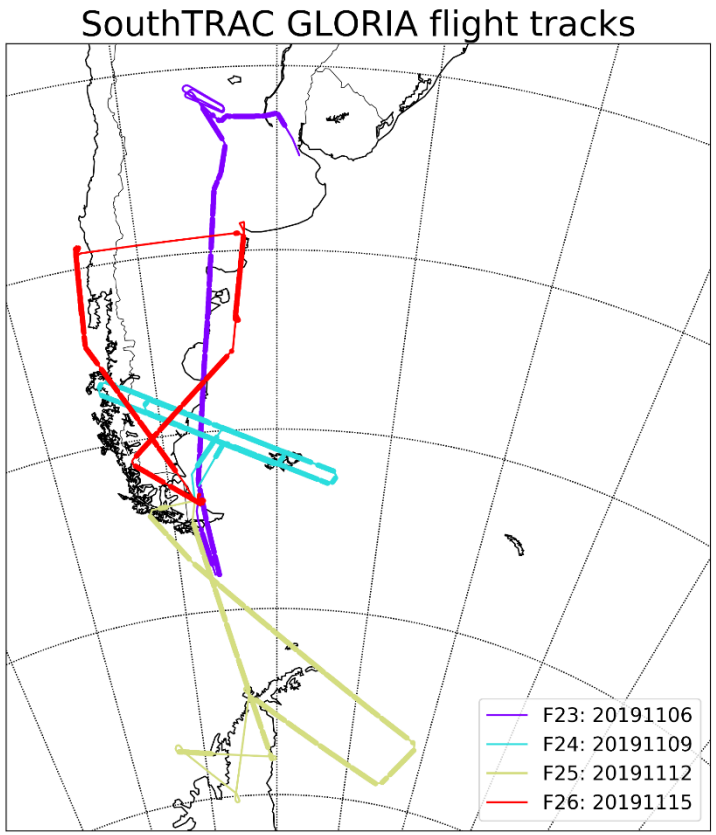
Phase 1



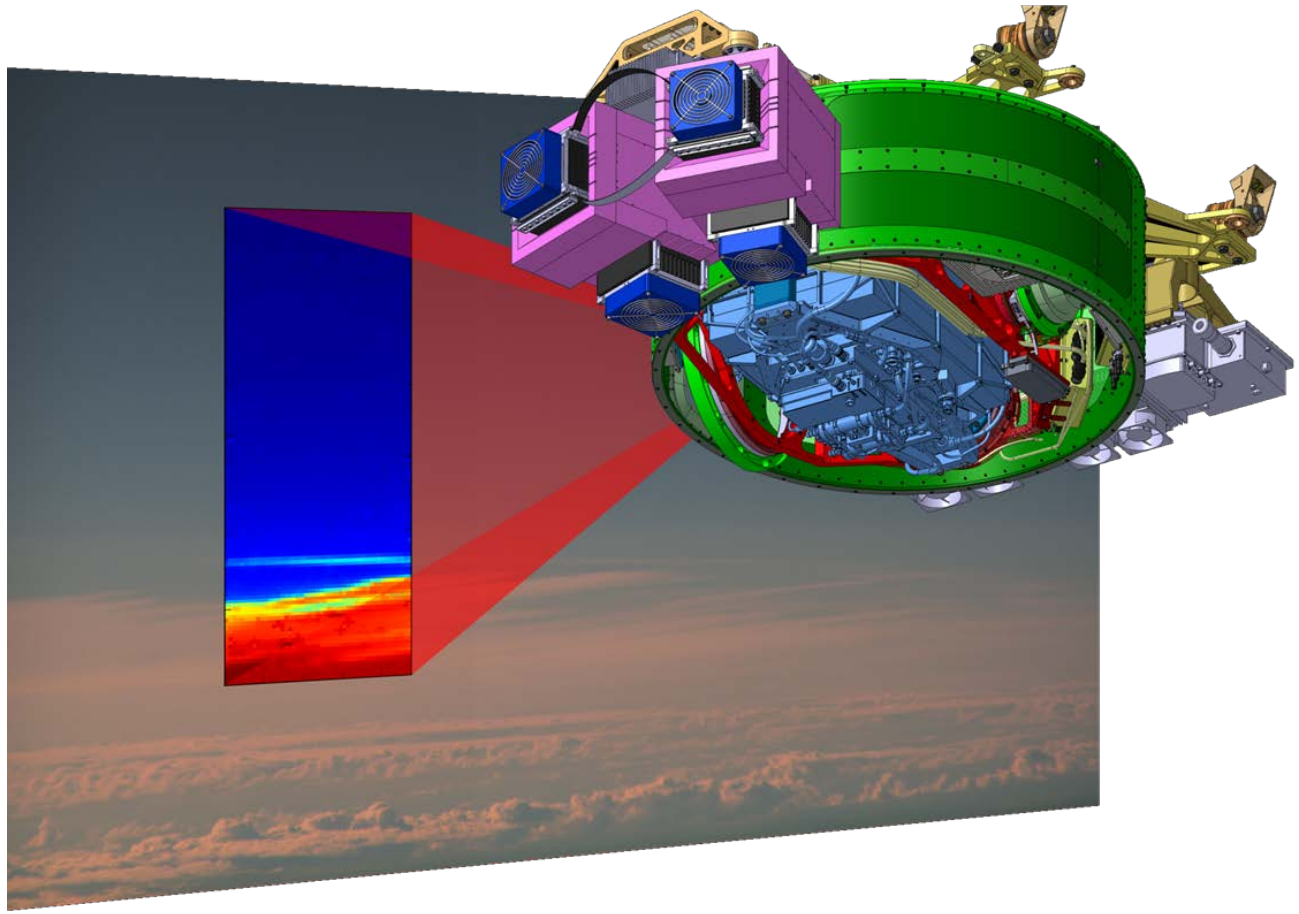
Transfers



Phase 2



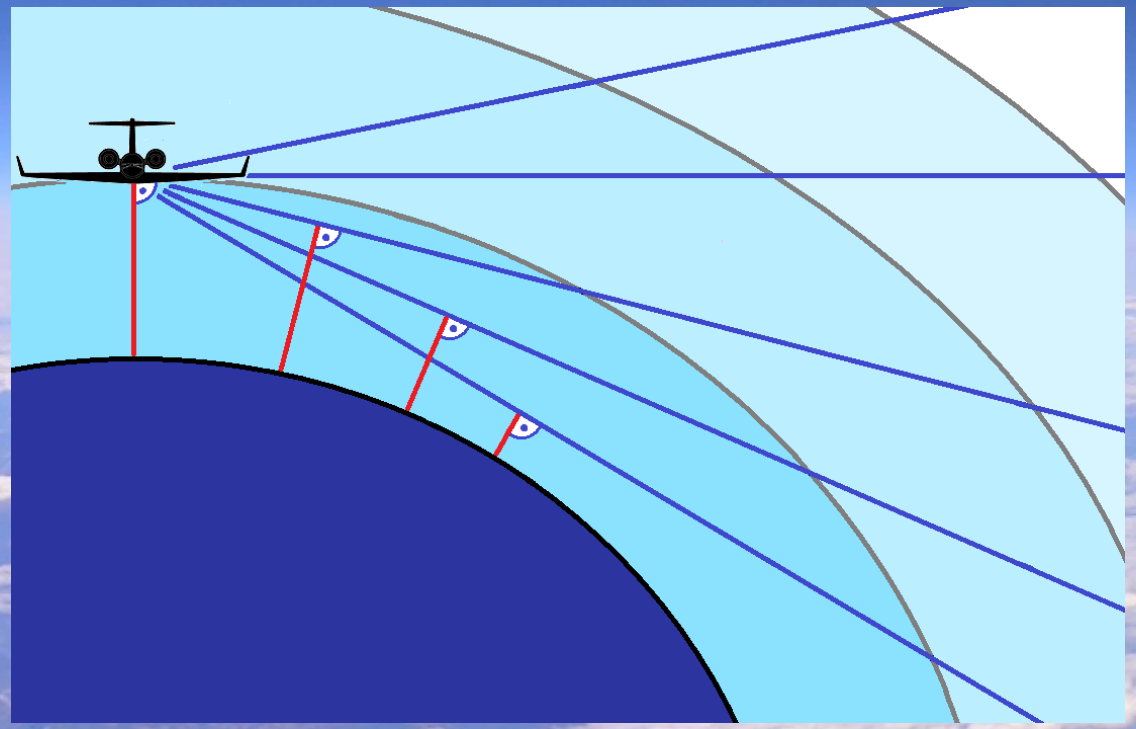
GLORIA
(Gimballed Limb Observer for Radiance Imaging of the Atmosphere)

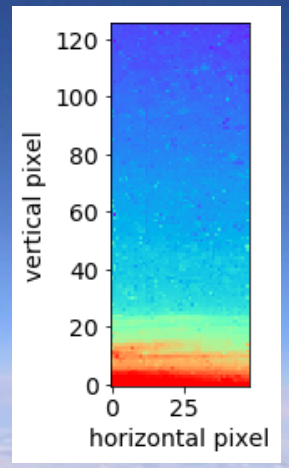


- Airborne limb imaging FTS
  - HALO and Geophysica
- Mounted in gimbaled frame
  - compensates aircraft movements
  - allows tomographic measurement
- 48 x 128 pixel
  - ~150 m spatial sampling at tangent point
- Spectral properties
  - coverage: 780-1400 cm^{-1}
  - sampling: up to 0.0625 cm^{-1}

Riese et al. (AMT 2014)
Friedl-Vallon et al. (AMT 2014)

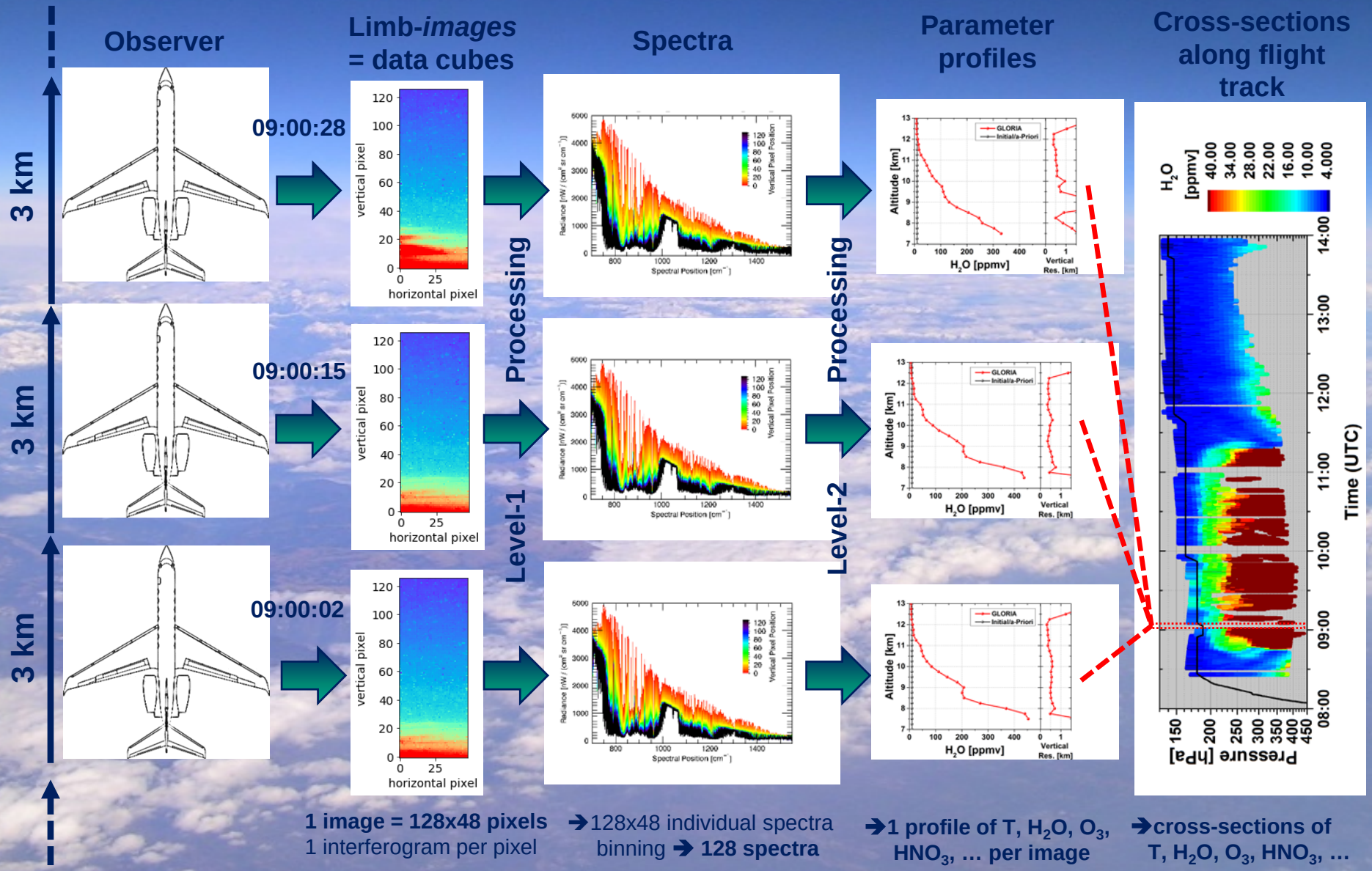
GLORIA: observation geometry





- Measurement mode: infrared limb-imaging with high spectral resolution
- 128 pixel rows, different viewing angles, simultaneously!

GLORIA: from observations to trace gas curtains



Biomass burning polluting the UTLS

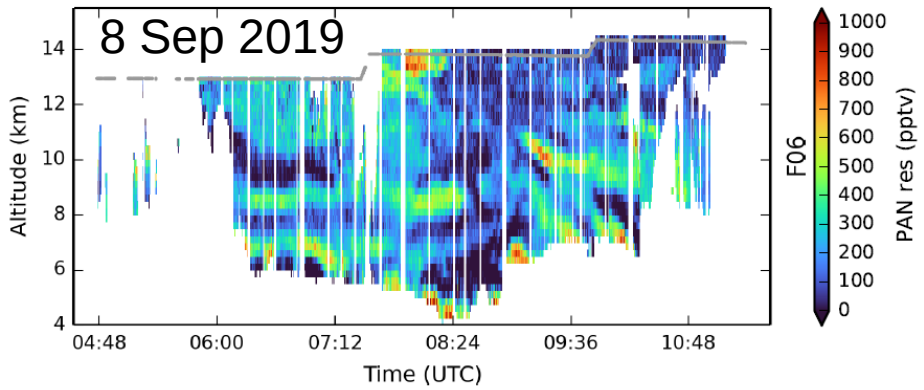
The UTLS, an important atmospheric layer with strong gradients in dynamics and composition

- Region where much infrared radiation escapes to space because of the low abundance of water vapour above
- Ozone is most effective as greenhouse gas: influenced by pollution in the UTLS (NO_y, VOCs)
- Cirrus clouds may be influenced by aerosol particles

Biomass burning: higher uncertainties compared to other sources of trace gases

- Location/time of occurrence: detection relies on the frequency and coverage of satellite observations used to make estimates of fire emissions
- Type of the compounds emitted: depending on the kind of the fuel
- Amounts of detected compounds: depending on the intensity of the fire as well as the atmospheric conditions above, pyroconvection can occur → plume rise above the PBL → impact on plume transport

Some pollution trace gases derived from GLORIA

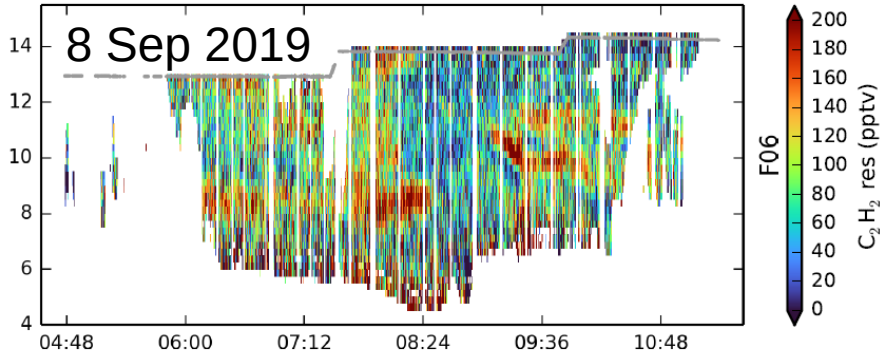


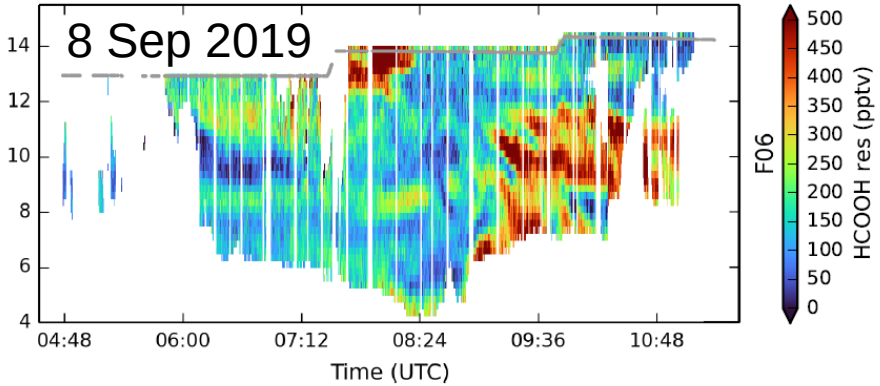
Peroxyacetyl nitrate (PAN, $CH_3COO_2NO_2$)

- product of oxidation or photolysis of NMVOC, sources are fuel combustion, biomass burning and biogenic emissions
- destroyed by thermal decomposition
- lifetime: 1 h at 298 K and a few months in the cold upper troposphere
- source of NO_x

Acetylene, ethyne (C_2H_2)

- product of combustion of bio- and fossil fuels and biomass burning
- reaction with OH is the major sink in the troposphere
- lifetime: few weeks

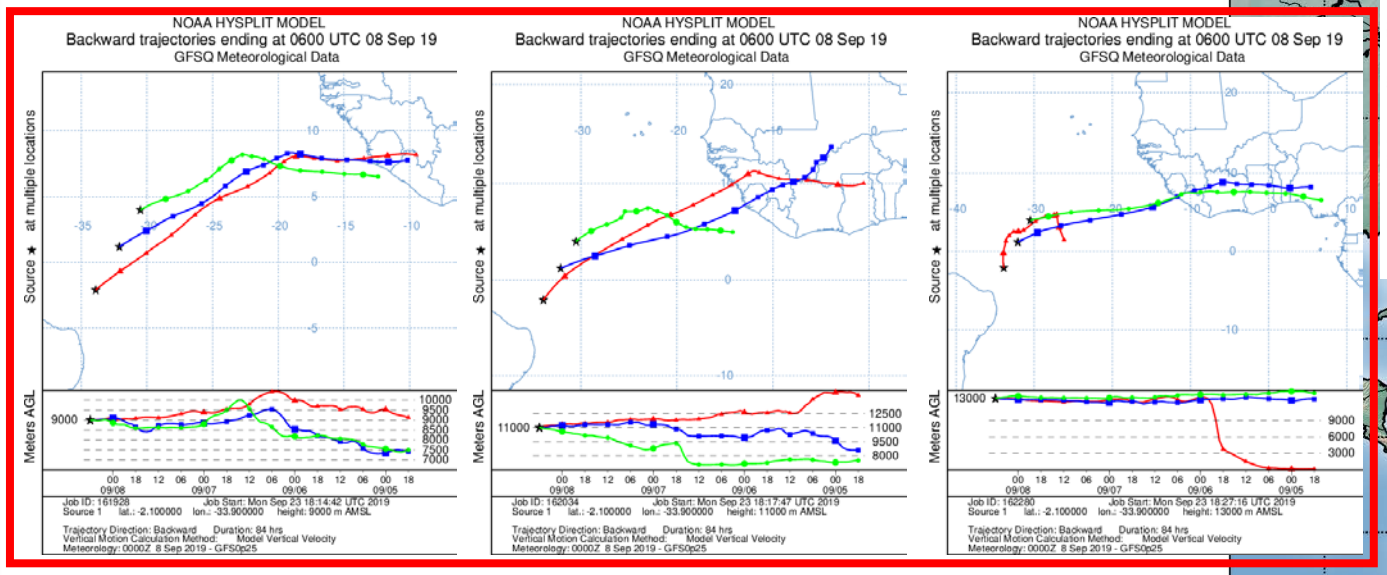


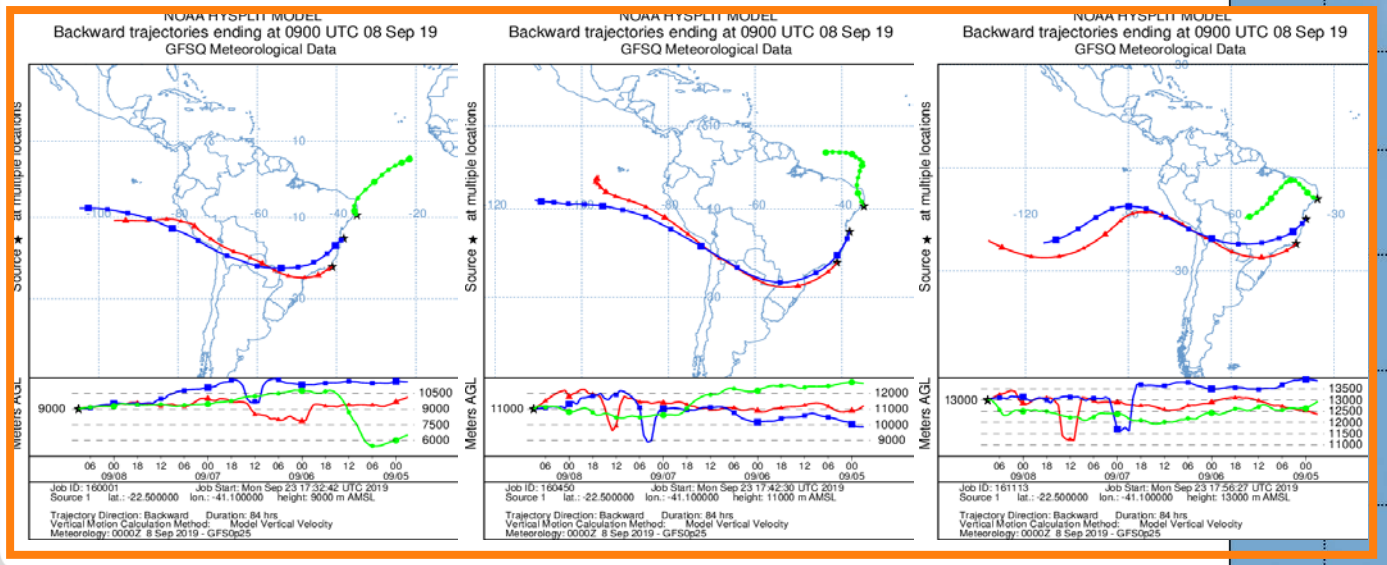


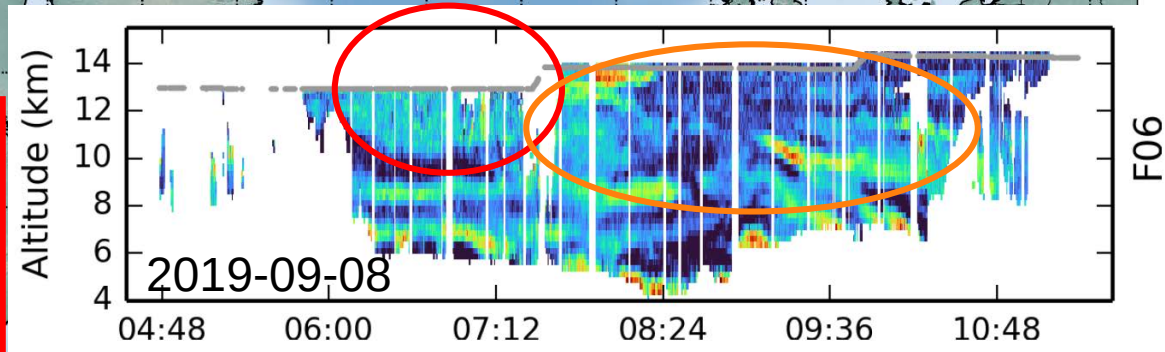
Formic acid (HCOOH)

- sources: biogenic emissions, biomass burning and fossil fuel combustion
- sinks in the troposphere: wet deposition depending on the acidity, dry deposition, reaction with OH
- lifetime: few days (boudary layer), up to weeks (free troposphere)

Transfer flights to phase 1



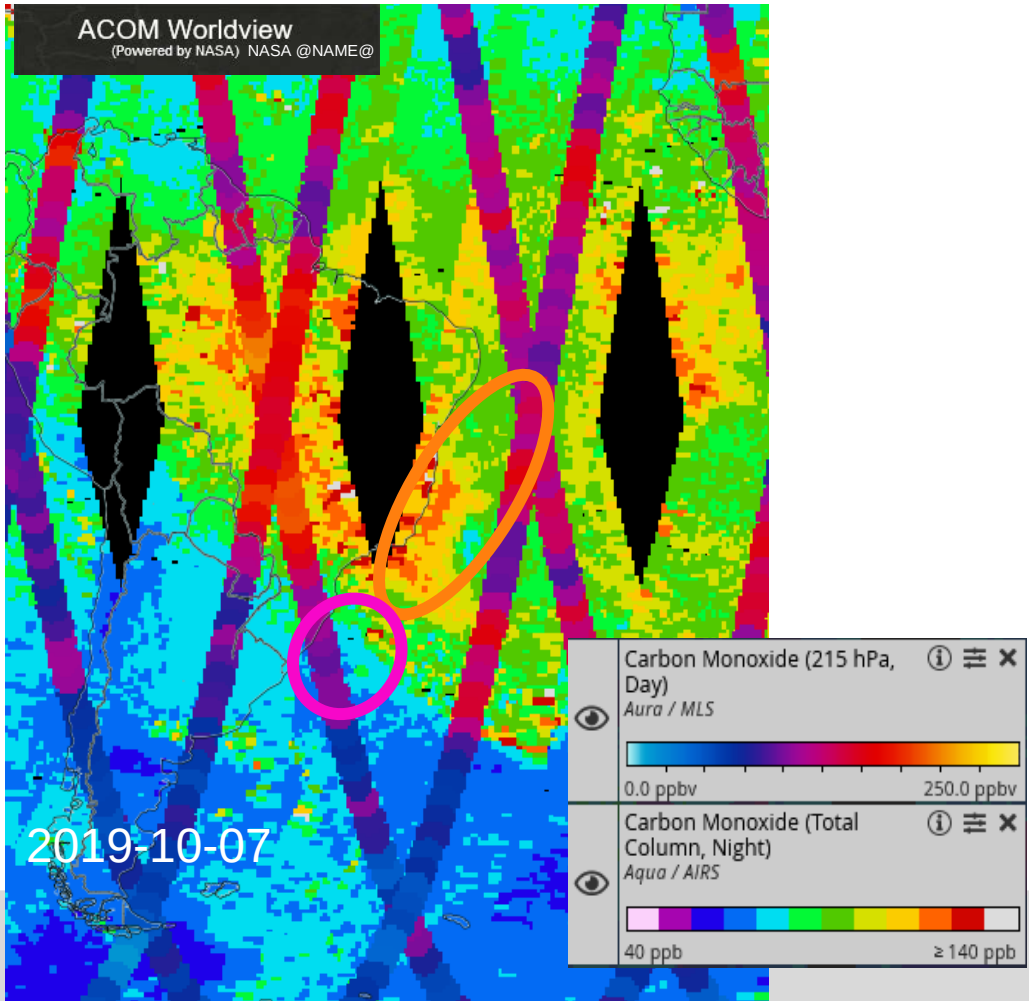




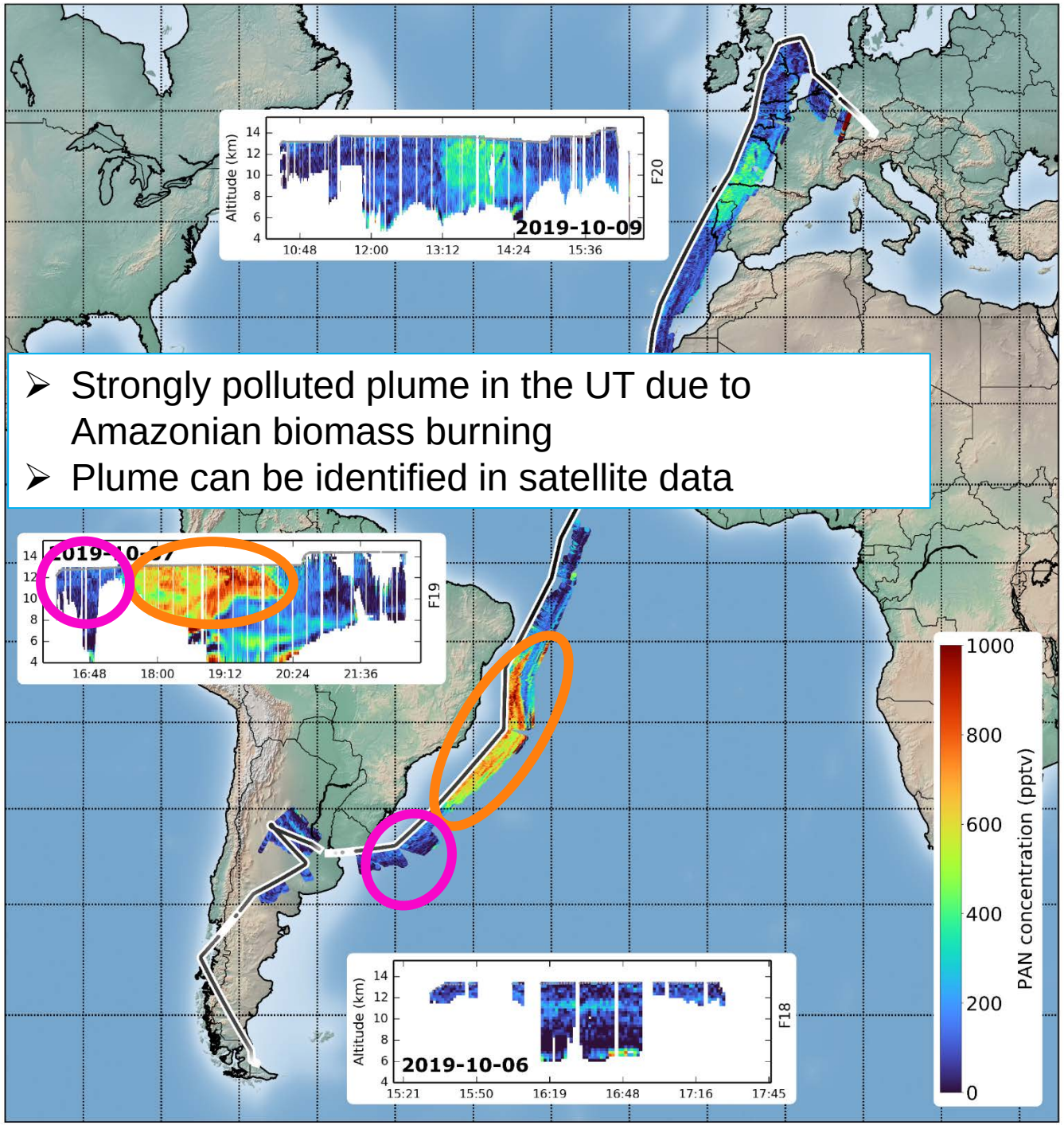
- Polluted air masses with different origin (Africa and S-America) sampled during one flight

https://www.ready.noaa.gov/HYSPLIT_traj.php
Stein et al., *10.1175/BAMS-D-14-00110.1*
Rolph et al., 10.1016/j.envsoft.2017.06.025

Transfer back from phase 1:
PAN derived from GLORIA in comparison to satellite data of CO from MLS@215 hPa and total CO column amounts by AIRS

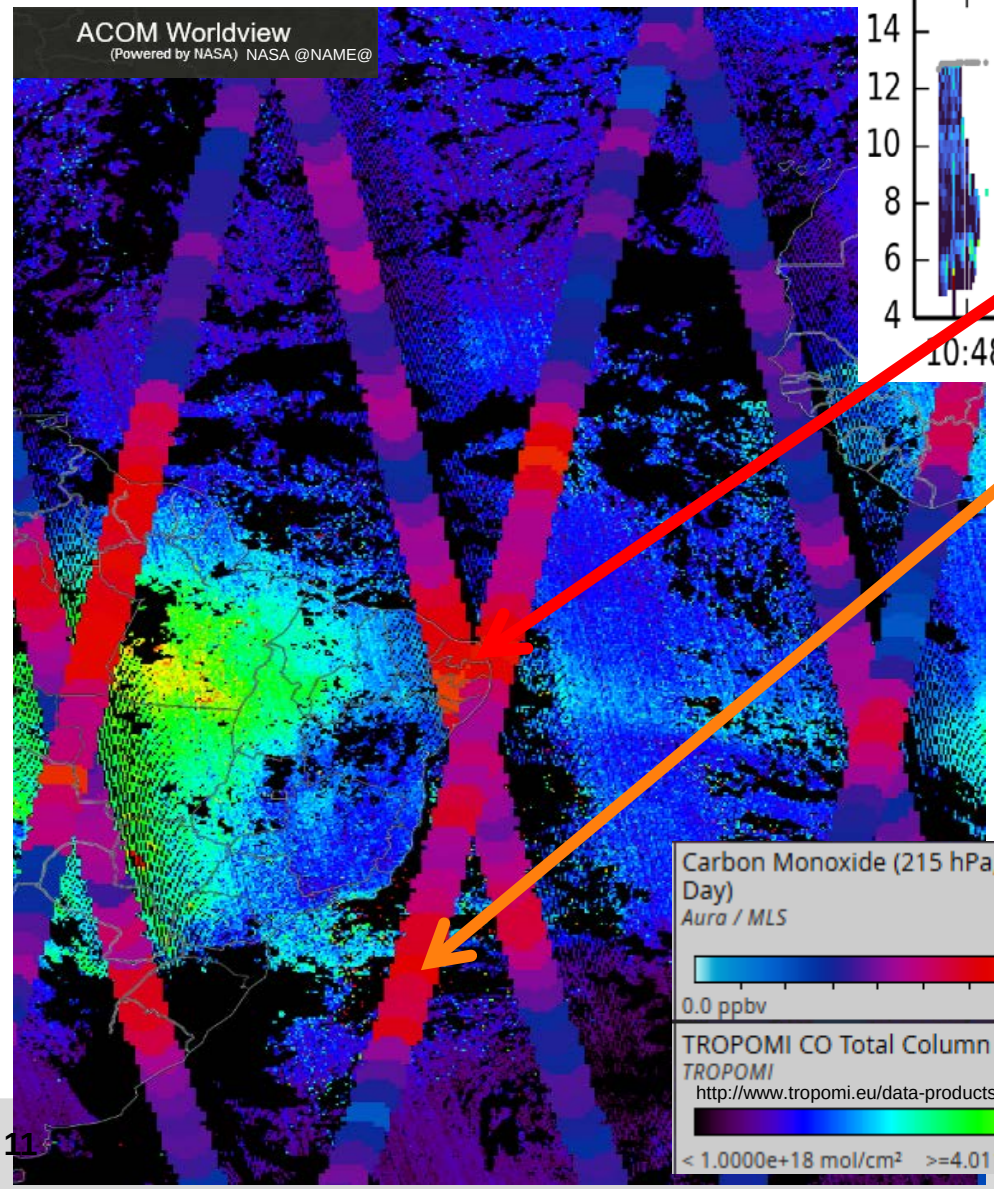


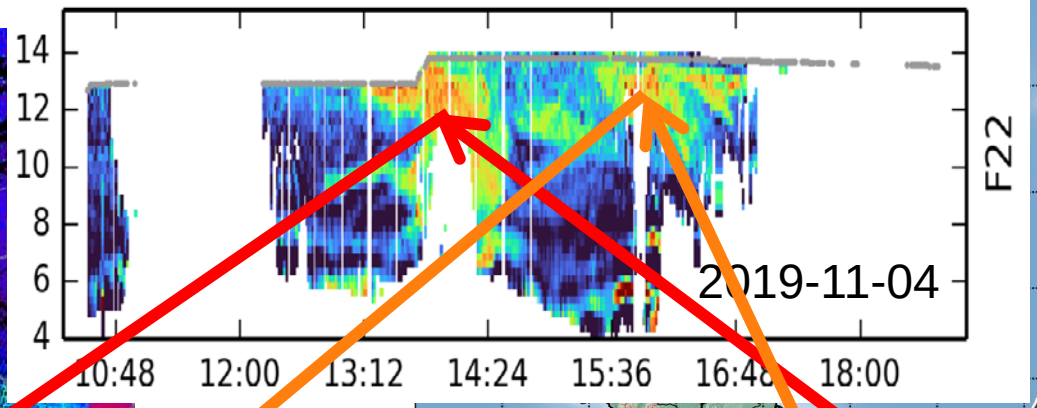
https://airs.jpl.nasa.gov
GES DISC - ML2CO_NRT: MLS/Aura Near-Real-Time L2 Carbon Monoxide (CO) Mixing Ratio V004; MLS - Carbon Monoxide



- Strongly polluted plume in the UT due to Amazonian biomass burning
- Plume can be identified in satellite data

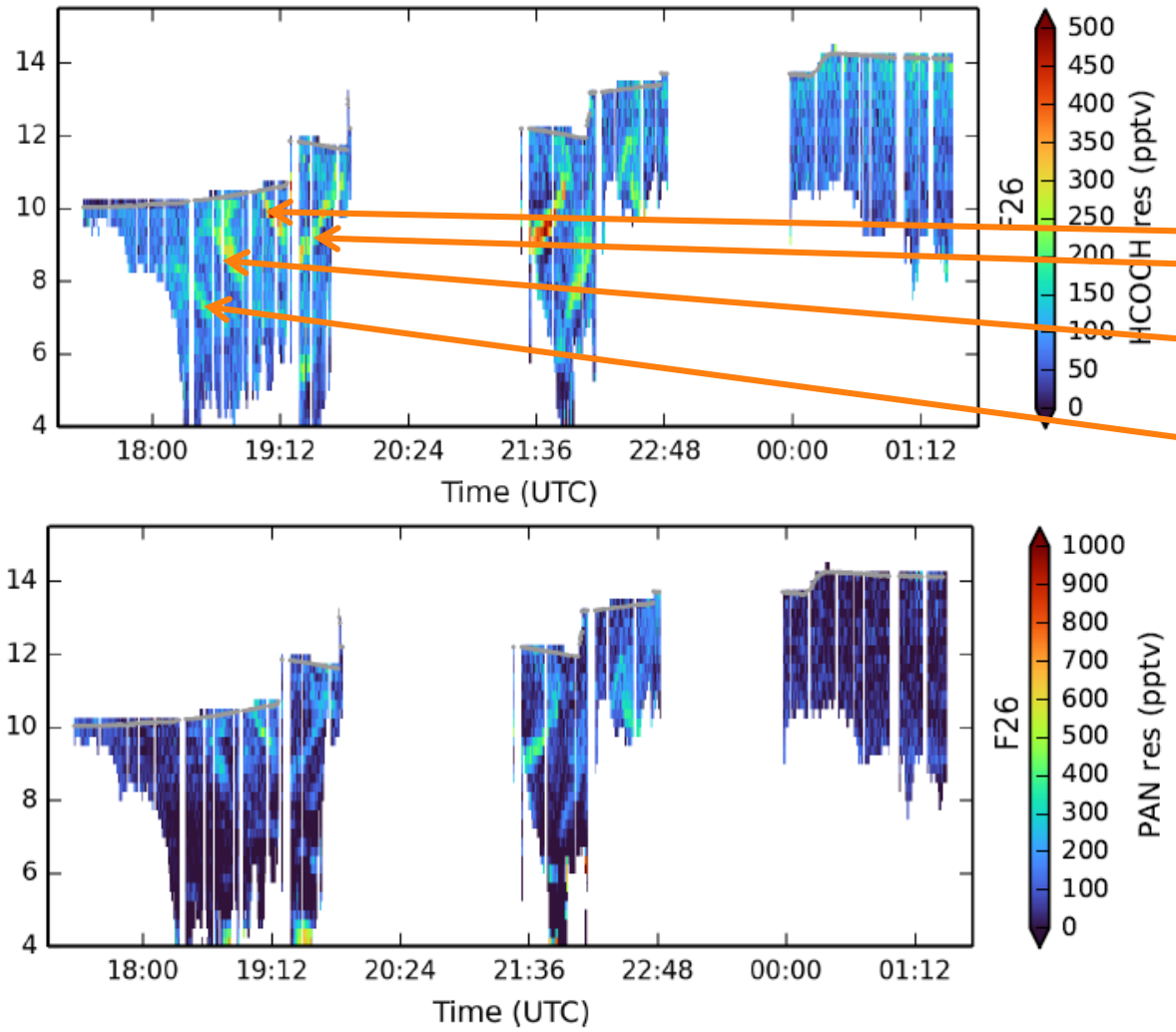
Transfer to phase 2:
PAN derived from GLORIA in comparison to satellite data of CO from MLS@215 hPa and total CO column amounts by TROPOMI

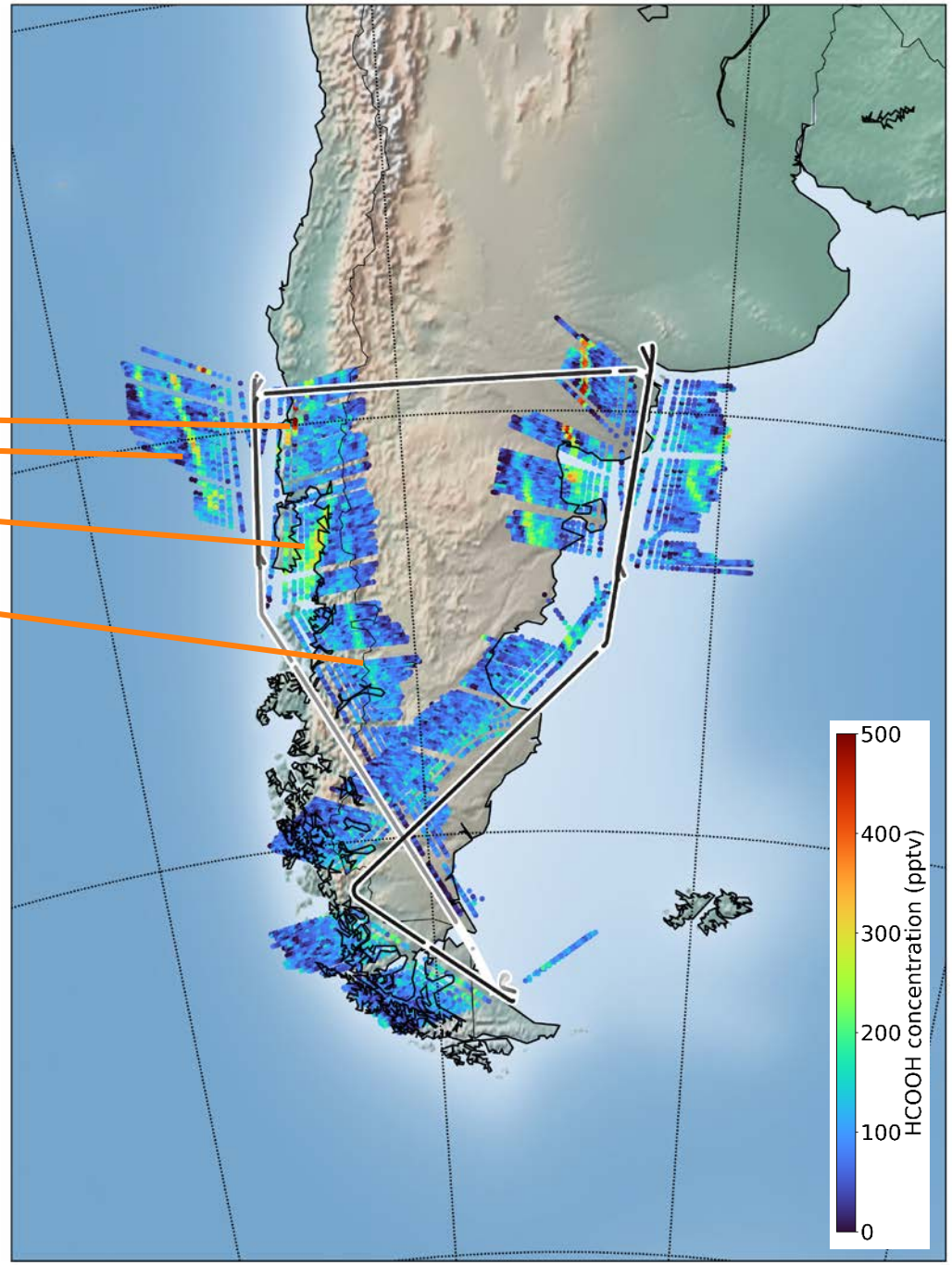




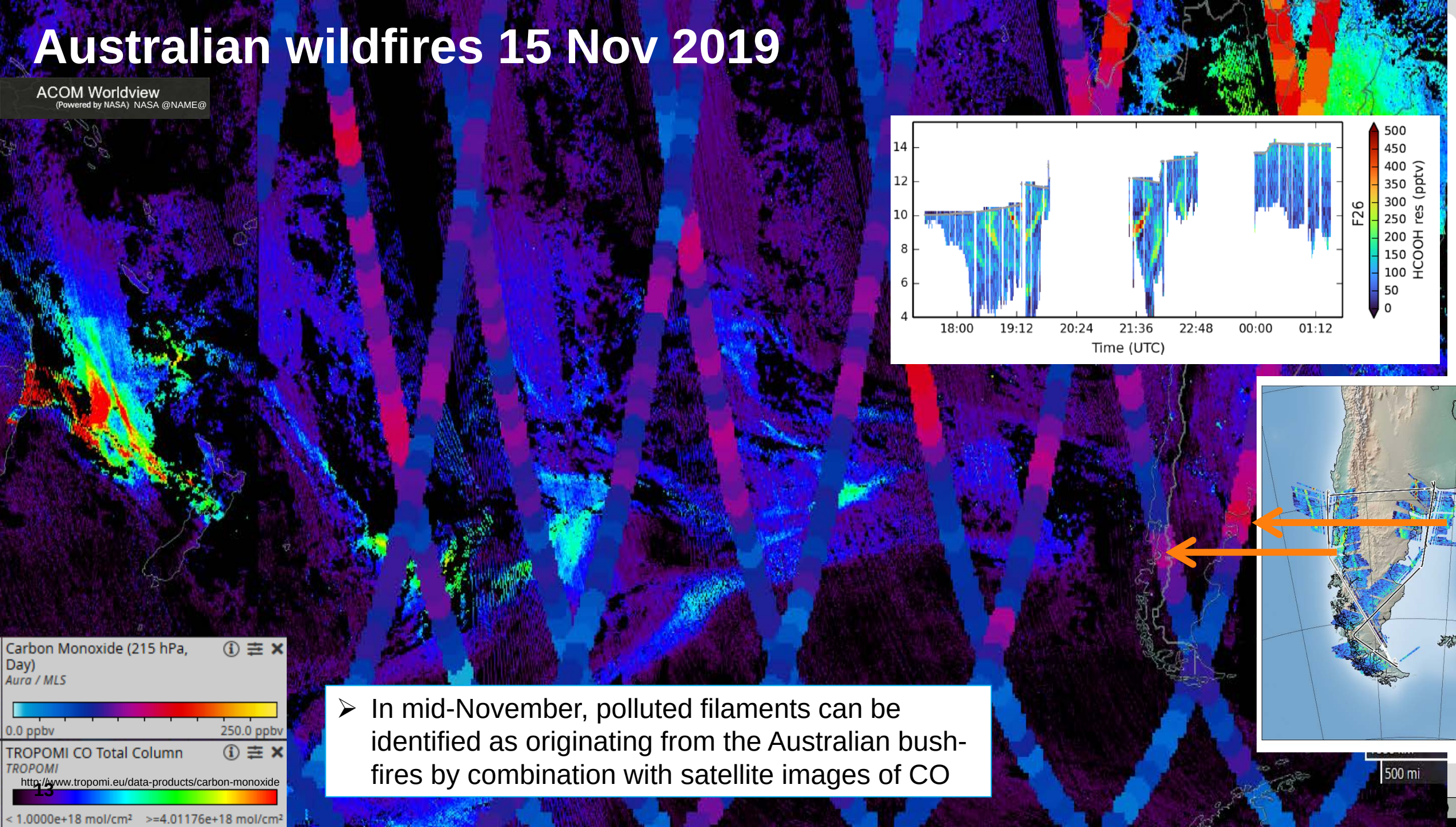
- Different plumes can be identified in GLORIA data and satellite images

Australian wildfires 15 Nov 2019





Australian wildfires 15 Nov 2019



- In mid-November, polluted filaments can be identified as originating from the Australian bush-fires by combination with satellite images of CO

Summary and outlook

Due to intense biomass burning in the Amazon region and Australia, the upper troposphere of the southern hemisphere was strongly polluted.

- Highly resolved vertical/along-track distributions of pollutant species in the mid-upper troposphere have been obtained by the GLORIA instrument during the SouthTRAC HALO aircraft campaign in Sep-Nov 2019.
- During various flights, strongly enhanced concentrations of these species have been observed.
- The enhanced values of e.g. PAN, C_2H_2 and HCOOH are correlated with enhanced CO at 250 hPa as measured by MLS.
- Source attribution by trajectory analysis combined with satellite observations showed that upper tropospheric pollution from Africa, S-America and Australia biomass burning has been captured by the observations.
- Future work:
  - Correlation between different species: information about lifetimes/burning conditions
  - Analysis in combination with the HALO in-situ observations of CO, NO_y, O_3
  - Model evaluation and process studies combined with model analysis e.g. EMAC/ICON-ART/CLAMS

Acknowledgements

- HALO pilots and crew
- Local support in Rio Grande
- GLORIA-Team in Jülich and Karlsruhe
- DFG HALO-SPP 1294
- NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport and dispersion model and READY website (https://www.ready.noaa.gov)
- Use of imagery from the NASA @NAME@ application (https://worldview.earthdata.nasa.gov), part of the NASA Earth Observing System Data and Information System (EOSDIS)."