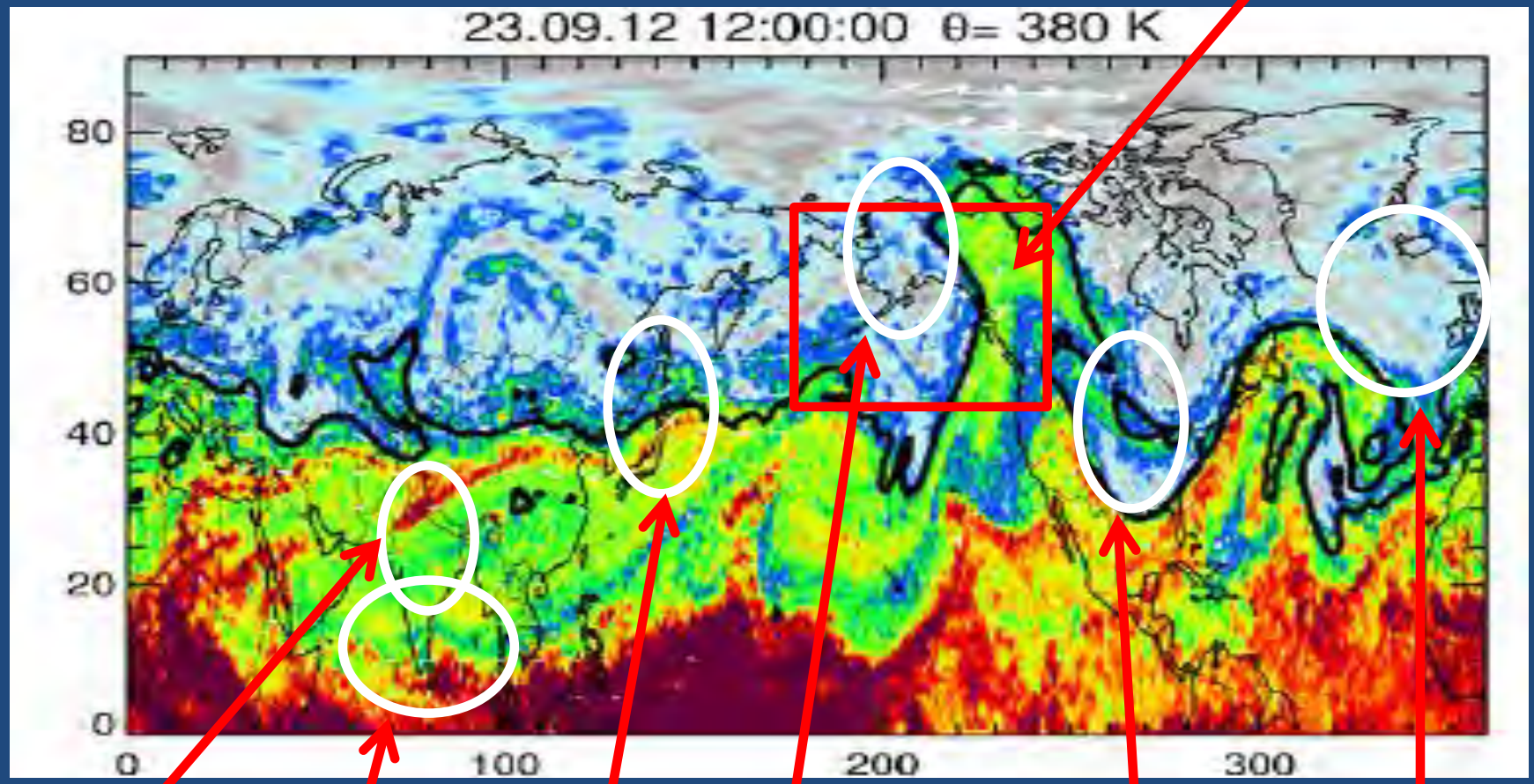
PHILEAS:
Probing High Latitude Export of air from the Asian Summer Monsoon

Peter Hoor, Martin Riese, Rolf Müller
Christian Rolf, Daniel Kunkel, Felix Plöger, Baerbel Vogel,
Stephan Borrmann, Andreas Engel, Michael Höpfner, Mira Pöhlker, Michael Volk, Jörn Ungermann, Franziska Köllner, Helmut Ziereis, Laura Tomsche, Sören Johansson, Valentin Lauther, Tanja Schuck, and Johannes Schneider and the PHILEAS TEAM

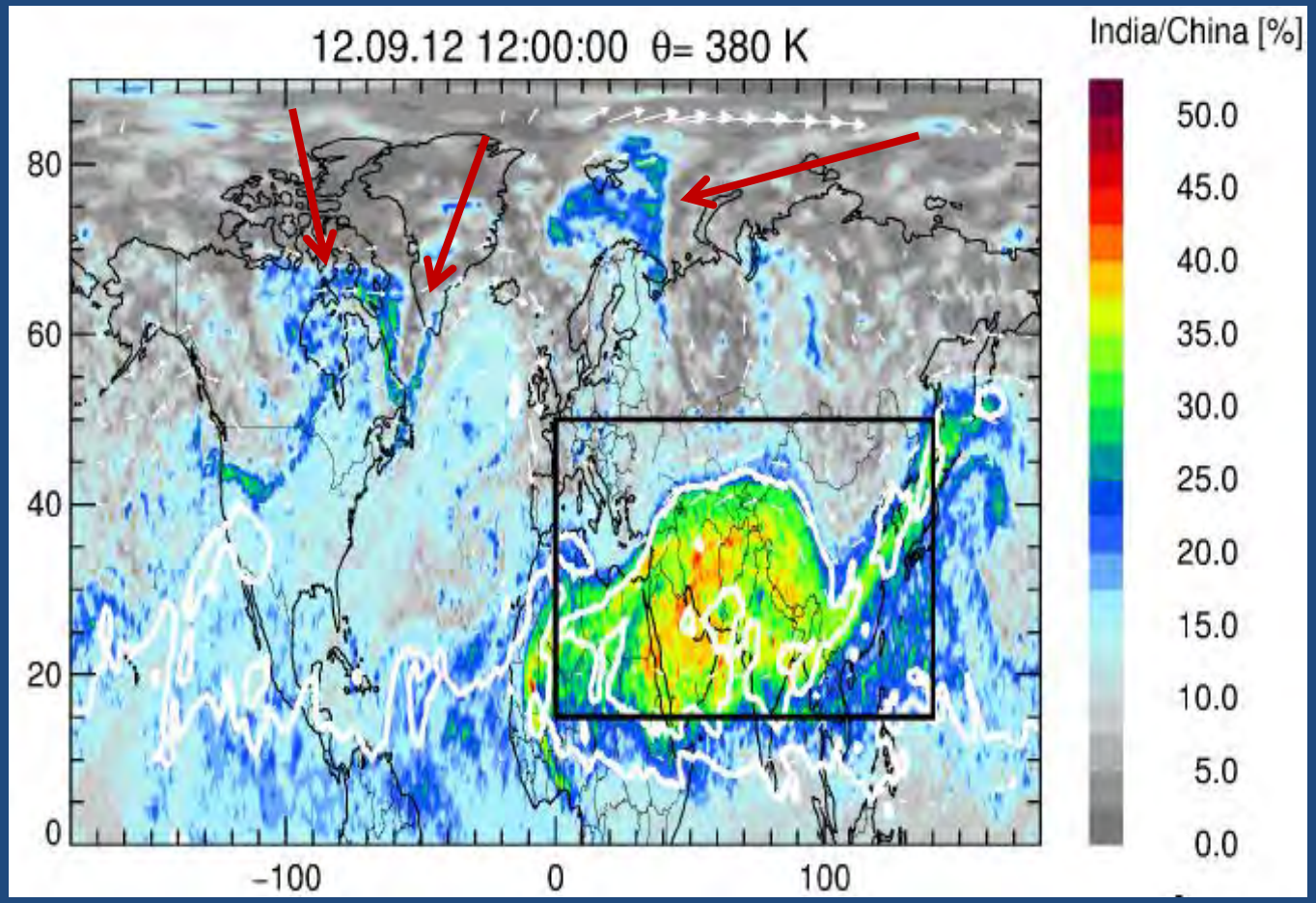
PHILEAS: Season and Location

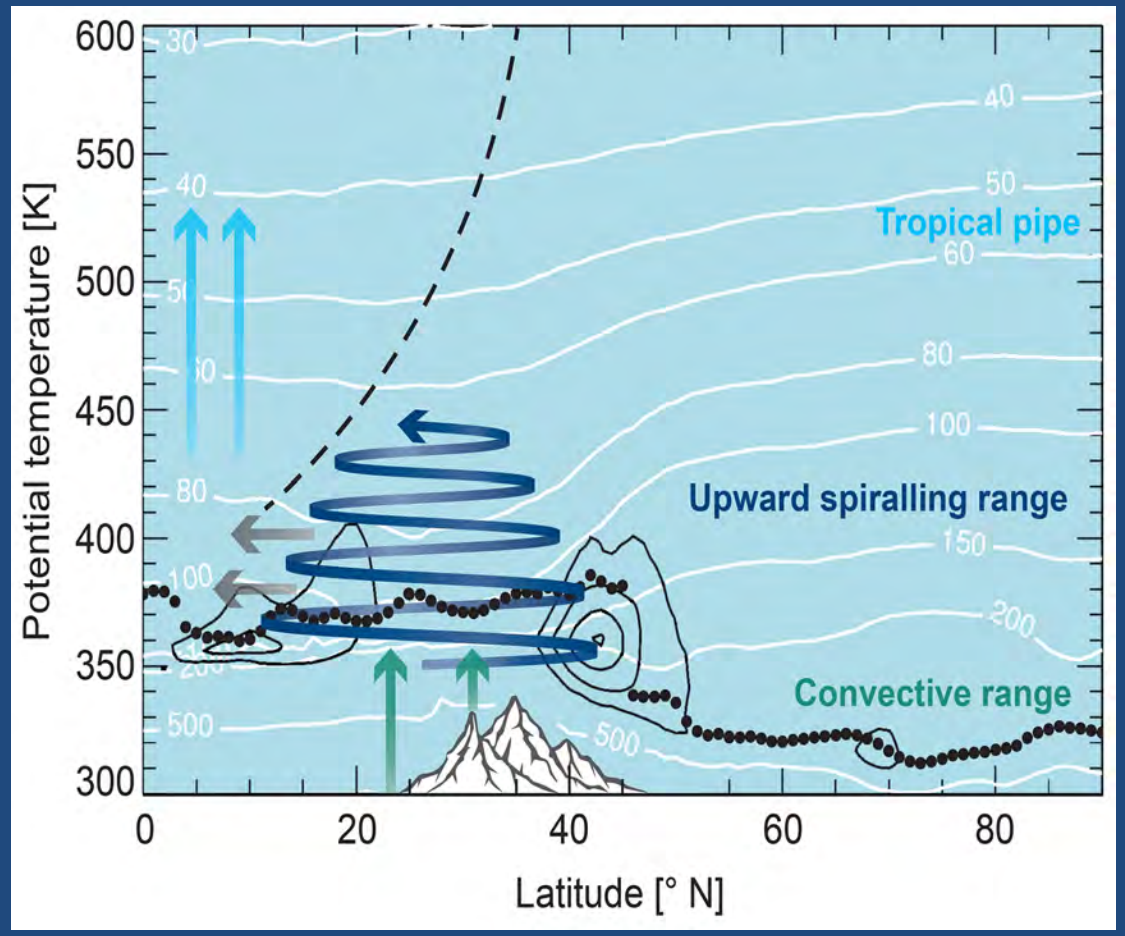


Vogel et al, 2016

Importance of the ASM

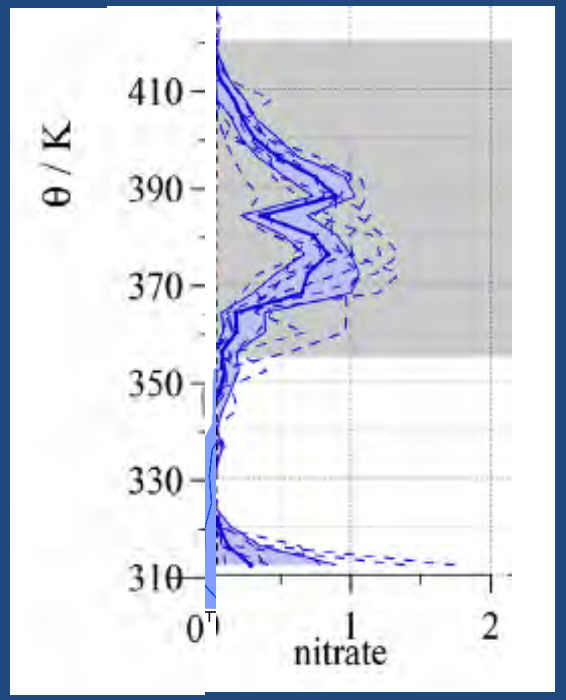
Export and mixing of monsoon air at 380 K into mid and high latitudes

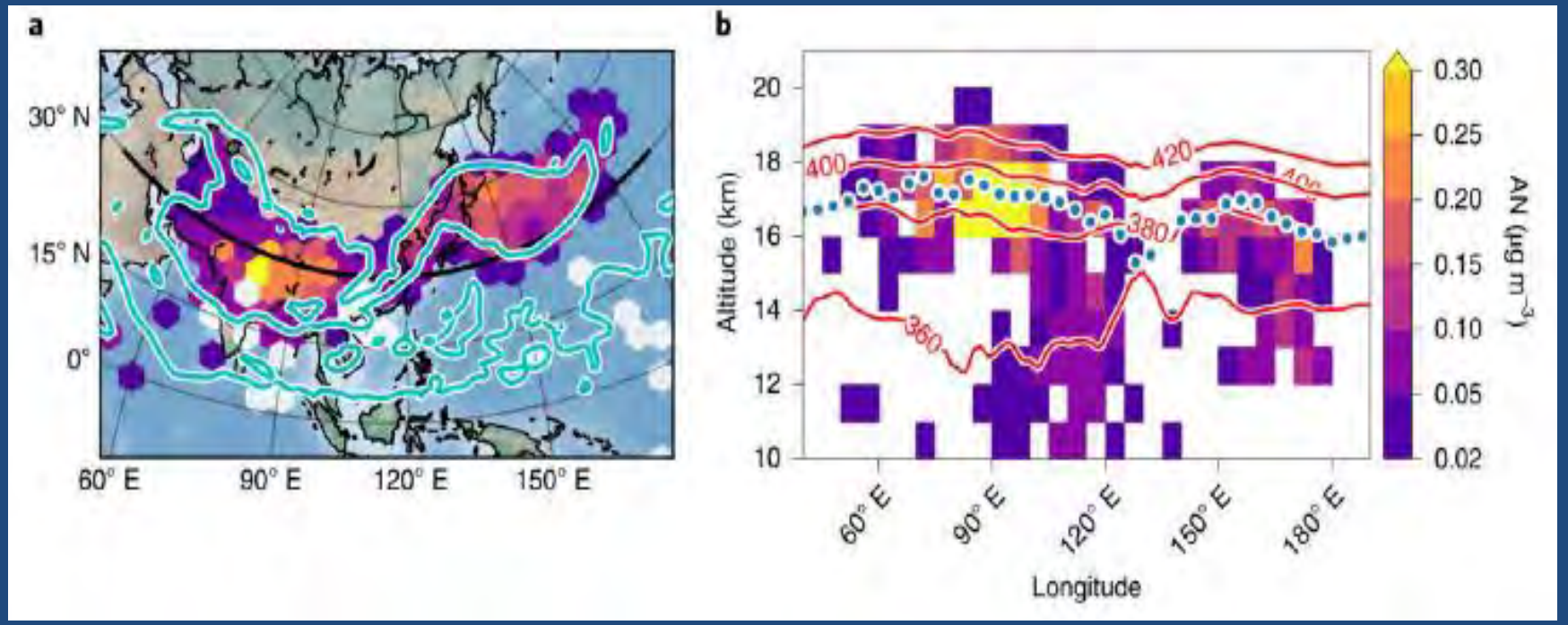




Vogel et al., 2016, 2019

Research question 2:



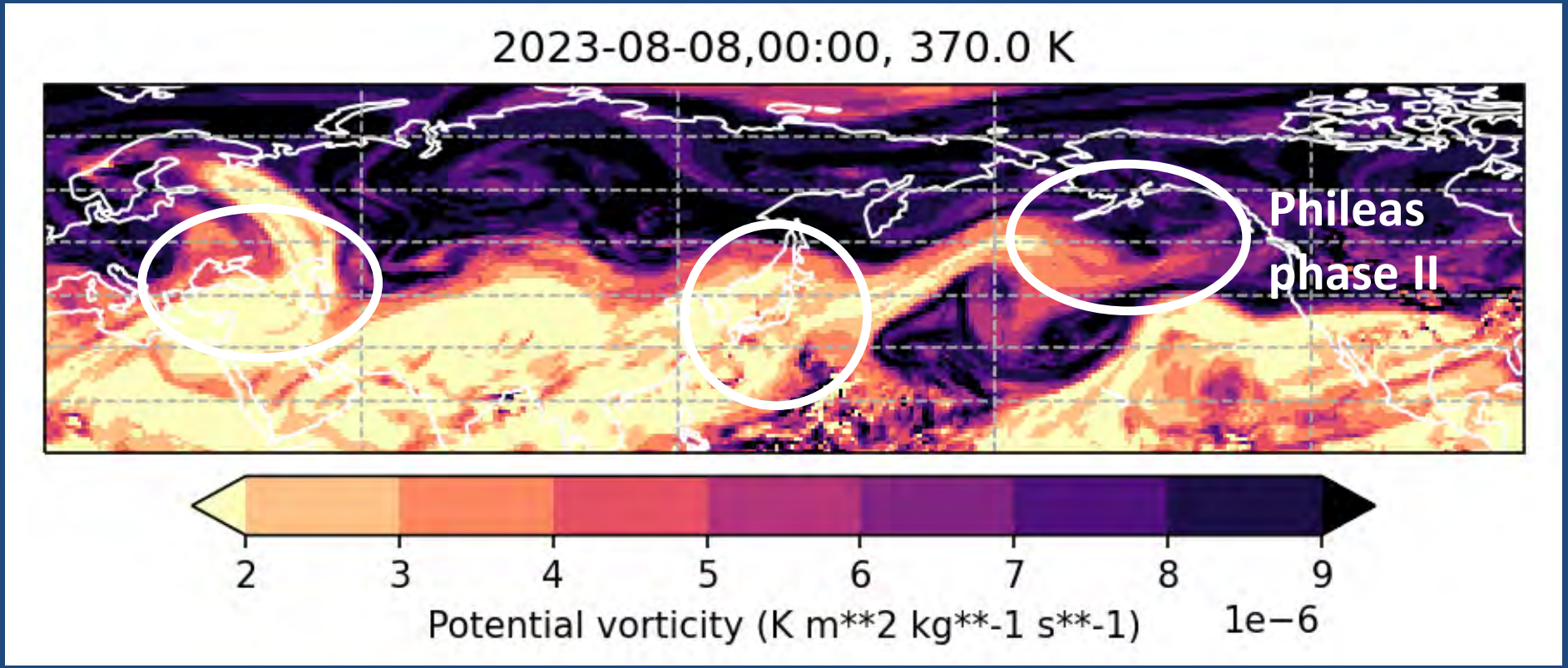


How do **gas-phase and particulate constituents evolve** in large-scale eddies which are shed from the monsoon anticyclone?

Höpfner et al., Nat. Geoscience, 2019, Appel et al., 2022

In a nutshell: Sample export of monsoon air at different stages of chemical and dynamical evolution

PHILEAS phase I/III Europe



How does the **Asian summer monsoon** affect the **gas phase** and **aerosol composition** of the extratropical UTLS and LMS ?

Instrument	Target Parameter	Technique	Institution
GLORIA	Ammonium nitrate, NH_3, O_3, H_2O, HNO_3, PAN, C_2H_6, C_2H_2, HCOOH, …, temperature	Imaging IR Limb Sounder	KIT / FZ Jülich
AMICA	COS, CO, CO_2	OA-ICOS	FZJ
DOAS	BrO, IO, OClO, O_3, NO_2, HONO, CH_2O, $C_2H_2O_2$, $C_3H_4O_2$	UV/vis spectrometer	U Heidelberg
AIMS	HCl, HNO_3, $ClONO_2$, SO_2	Mass spectrometer	DLR-IPA
BCPD	cloud droplet size distributions.	Back-scatter with Polarization Detection	U Mainz
BAHAMAS	meteorological and avionic data	BAsic Measurement And Sensor System	DLR-FX
FAIRO	O_3	UV/Chemilumincscence	KIT
FISH	total/gas-phase H_2O	Lyman-Alpha Hygrometer	FZ Jülich
GhOST-MS	SF_6, CFC-12, wide range of halogenated species (e.g. CH_2Br_2, $CHBr_3$, halons, C_2Cl_4, C_2HCl_3, $CHCl_3$, CH_2Cl_2 , CH_3Cl)	GC-MS	U Frankfurt
HAGAR-V	CO2 SF6, CFCs, Halon-1211 NMHCs, short- and long-lived chlorocarbons, HFCs	NDIR GC-ECD GC-MS	U Wuppertal
AENEAS	NO, NO_y	Chemiluminescence	DLR-IPA
ERICA	Aerosol composition and size distribution	Mass spectrometry	U Mainz/ MPIC-Mainz
UMAQS	CO, N_2O, CH_4, C_2H_6	QCL Absorption Spectrometer	U Mainz

PHILEAS coverage

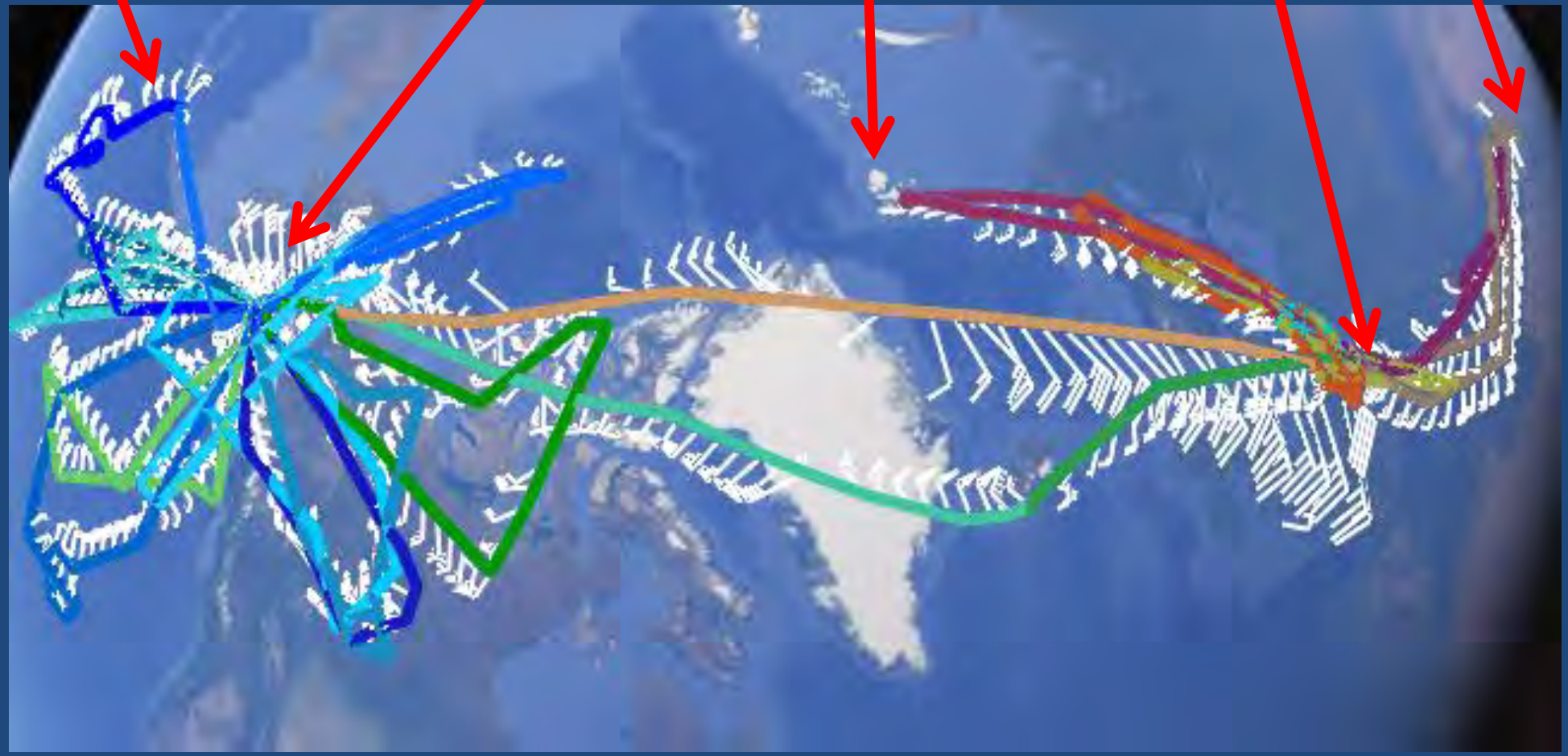
Spitsbergen

Jordan

Adak Island

Anchorage

Oberpfaffenhofen



08.Aug - 26.Sep
20 research flights

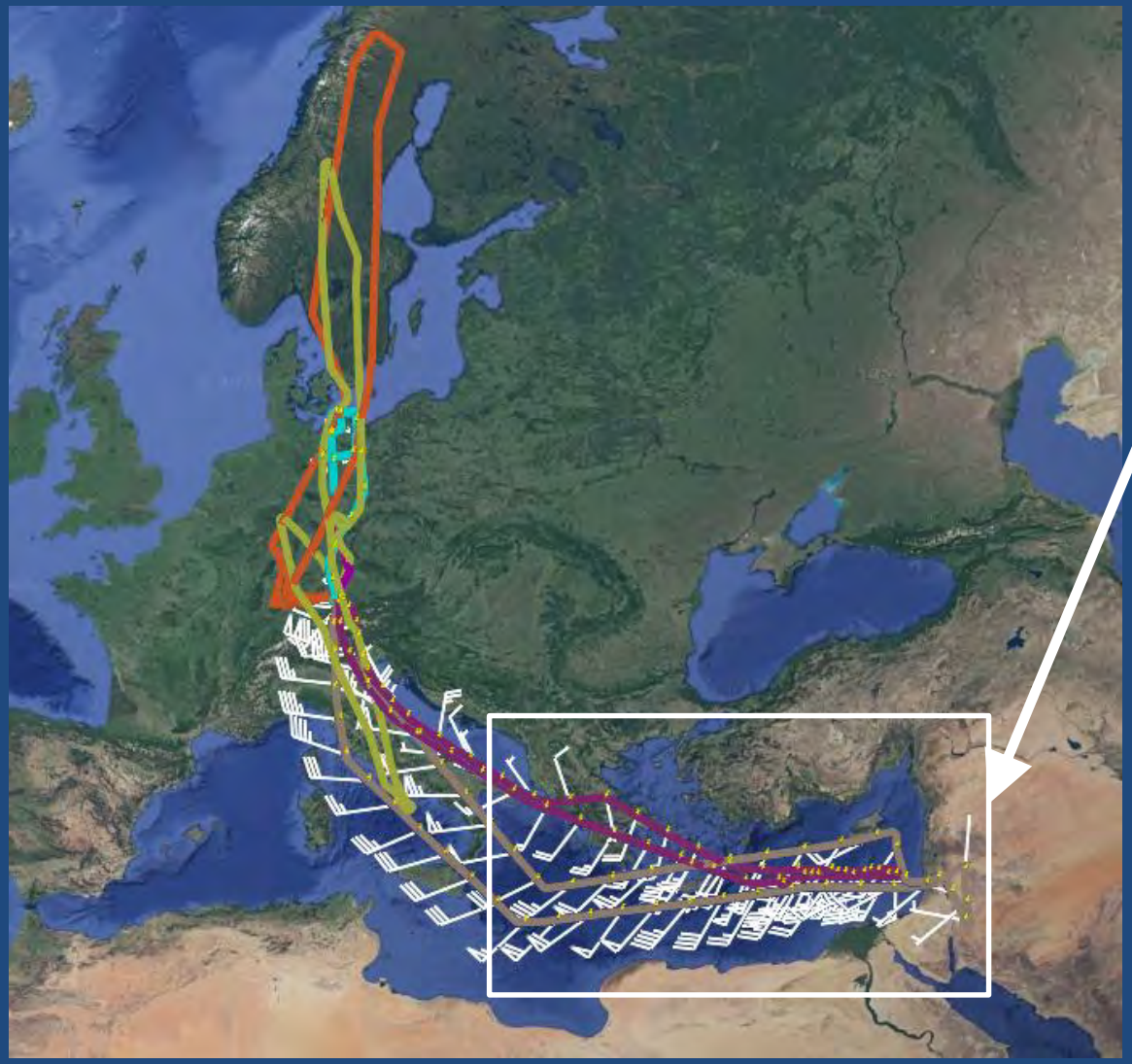
- transfers from/to Alaska

- Europe
  Phase I: 4 flights prior
  Phase III: 1

- Alaska:
  15 flights

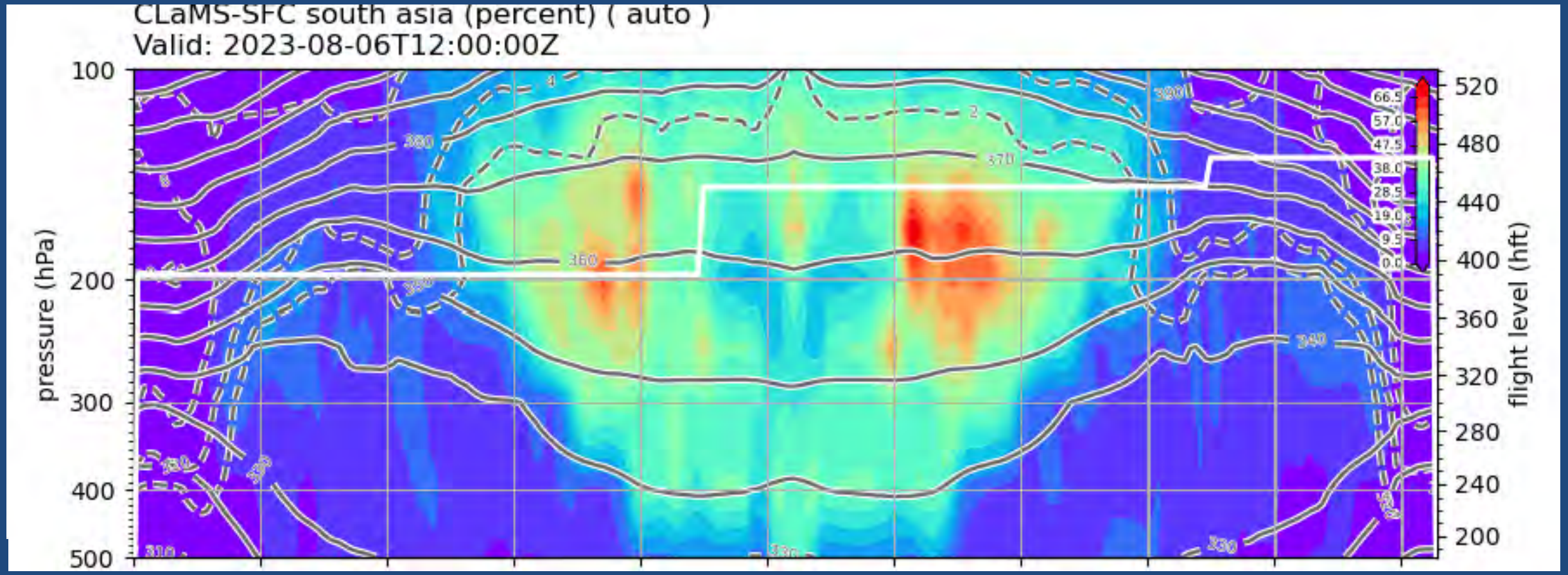
PHILEAS Phase 1: Monsoon over Europe

F02
2023-08-06

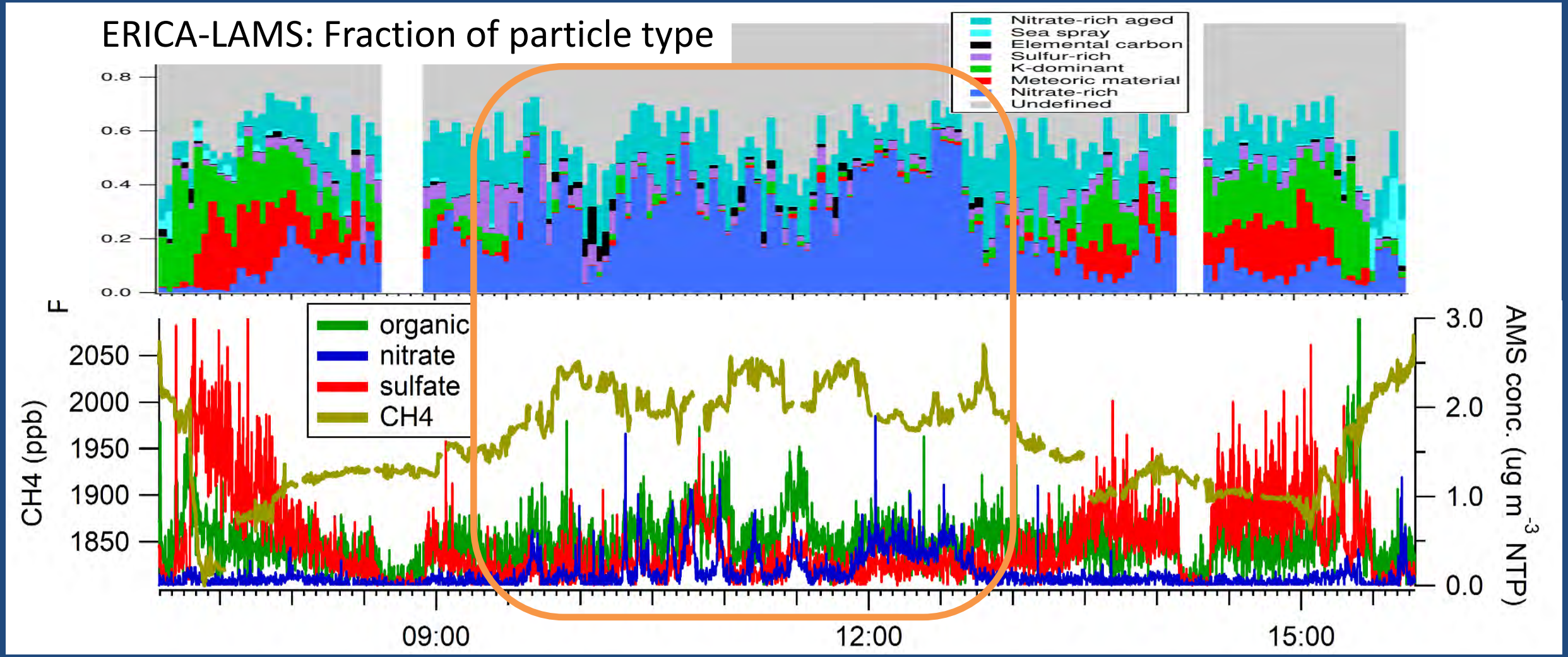


PHILEAS Phase 1: Monsoon over Europe

F02 2023-08-06 South east asian tracer (CLaMS)

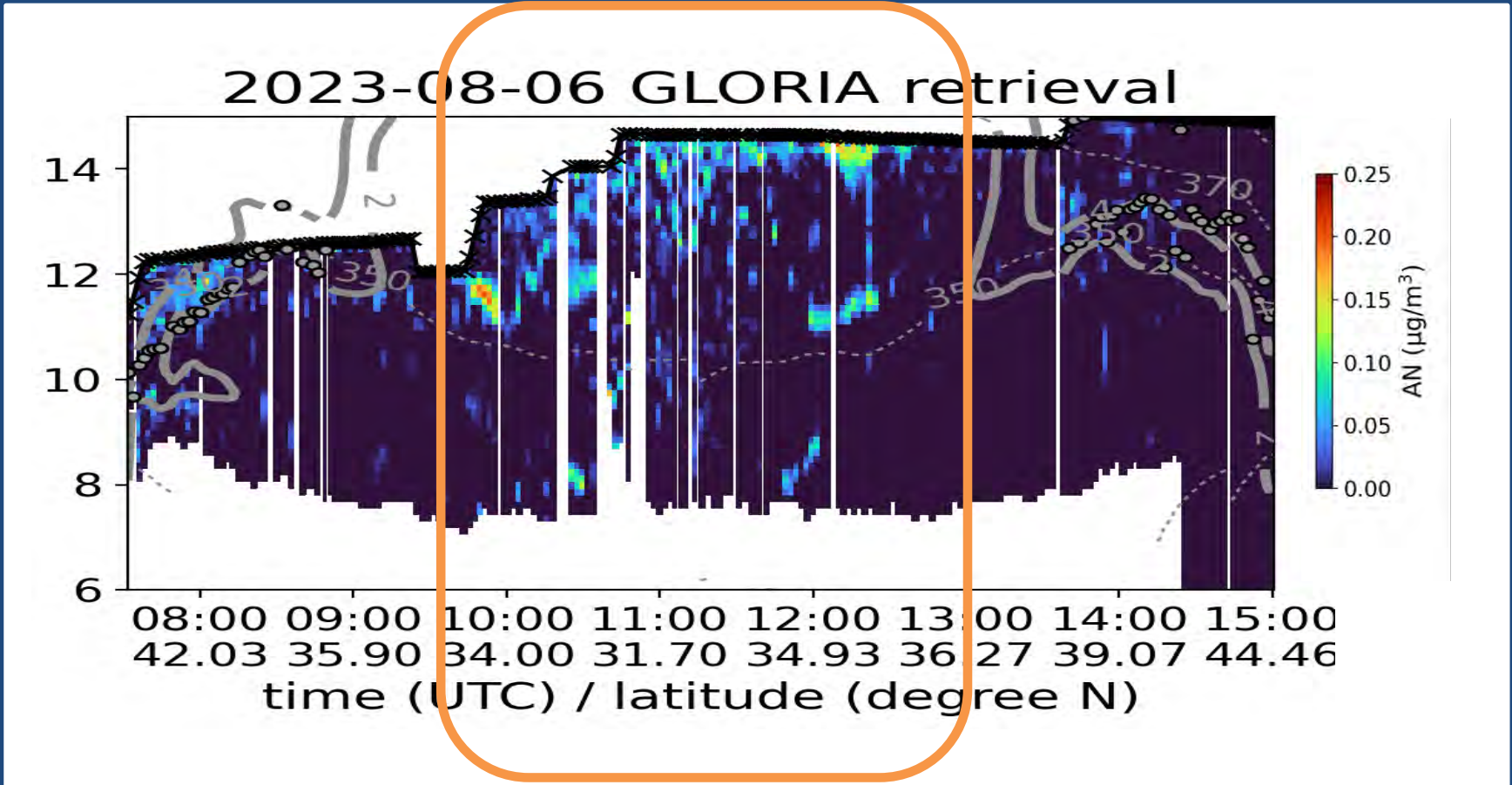


PHILEAS Phase 1: Monsoon over Europe



ERICA: High nitrate fraction in aerosol particle composition
Transport of ammonium nitrate and organic aerosol into the extratropical stratosphere associated with the Asian monsoon outflow

PHILEAS Phase 1: Monsoon over Europe

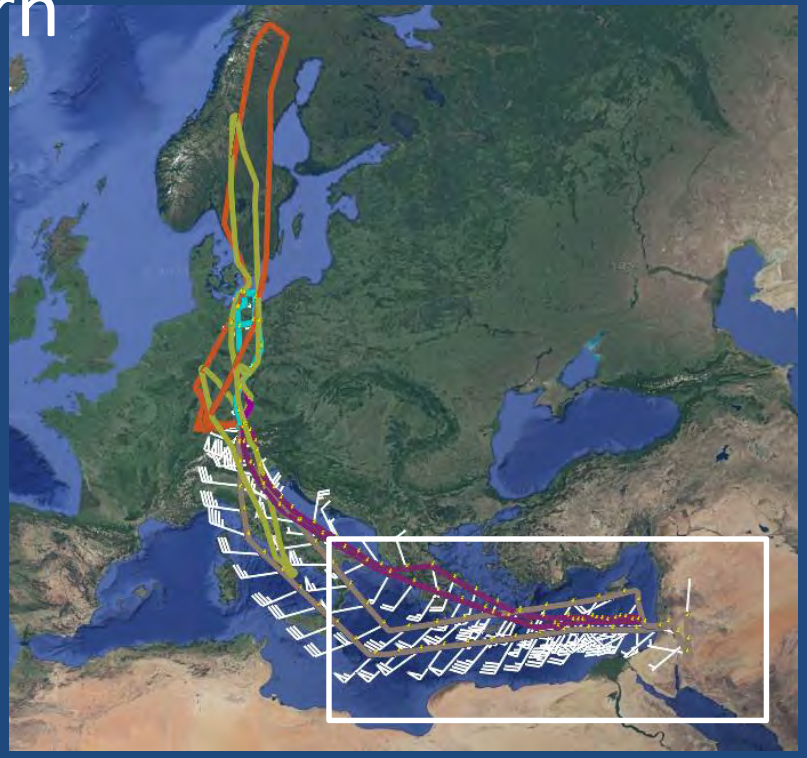


GLORIA (preliminary): enhancements of ammonium nitrate (AN),
(J. Ungermann, FZJ)

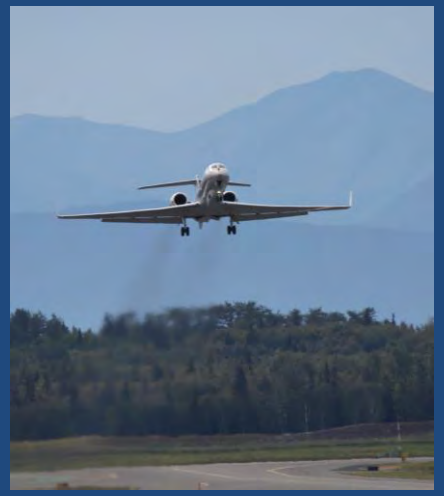
PHILEAS Phase 1: Monsoon over Europe

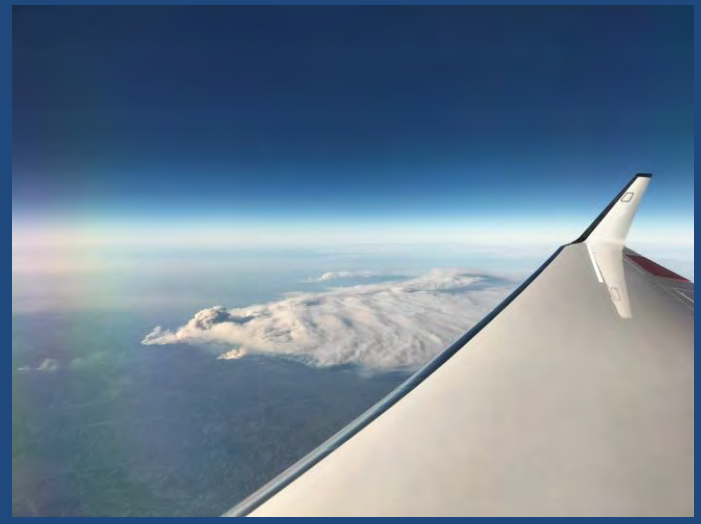
F02 2023-08-06: Asian monsoon air over Eastern Europe

- Very fresh air from the AMA over the eastern Mediterranean upper troposphere
- characterized by high methane and nitrate fraction, also enhanced organics

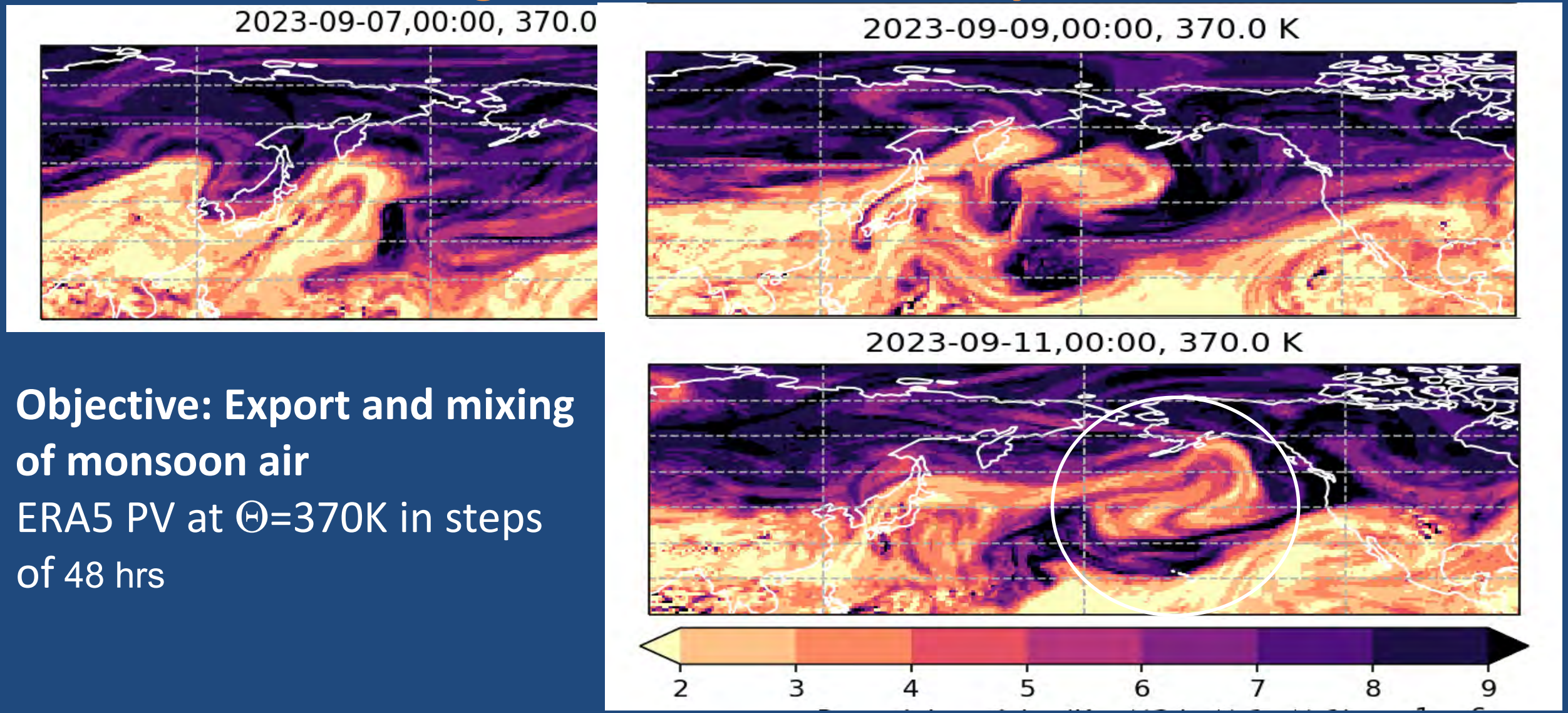


PHILEAS Phase 2, Anchorage: High latitude transport of monsoon air





In a nutshell: Sample export of monsoon air at different stages of chemical and dynamical evolution



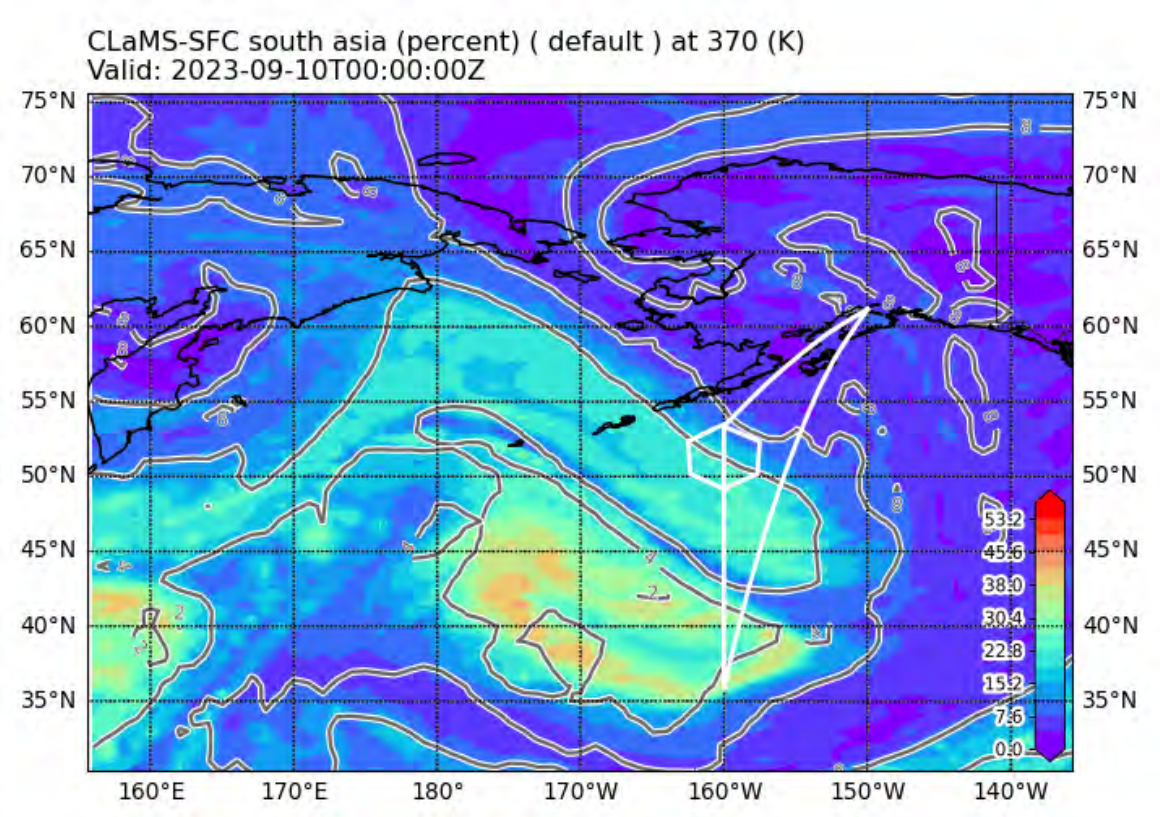
Objective: Export and mixing of monsoon air

ERA5 PV at Θ=370K in steps of 48 hrs

PHILEAS Phase 2: High latitude export

Objective: Mixing of monsoon air

CLaMS simulation of asian monsoon tracer for two different days (Theta= 370K)

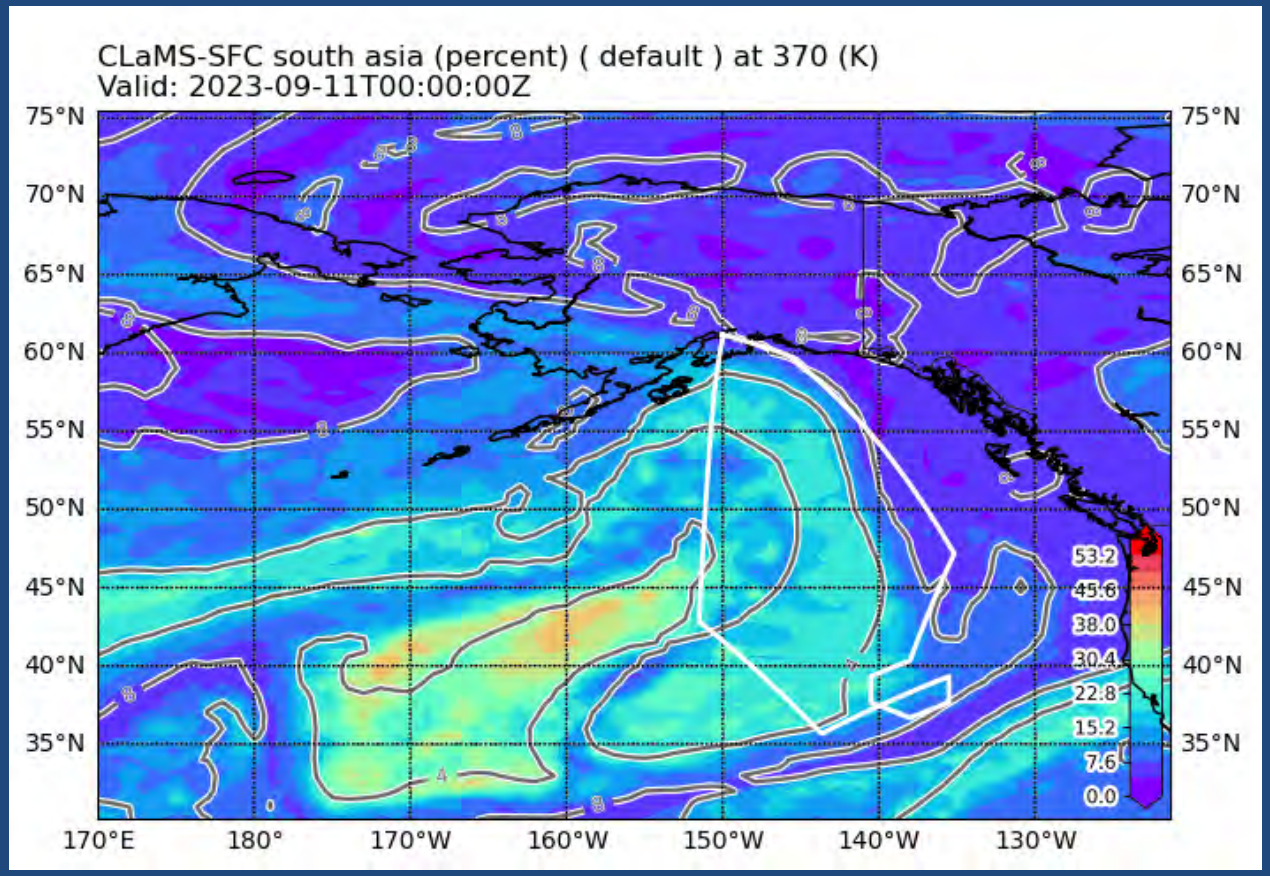


F13

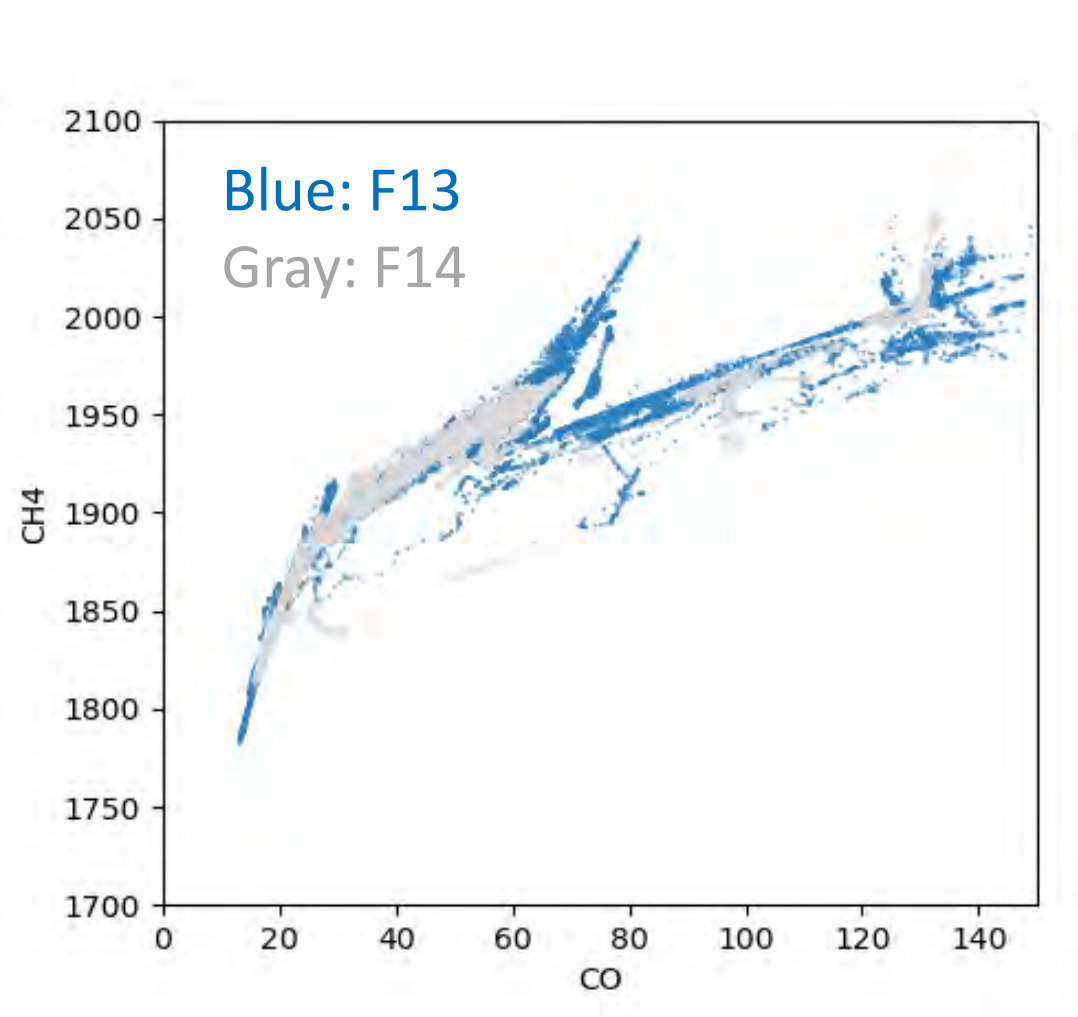
2023-09-09

F14

2023-09-10

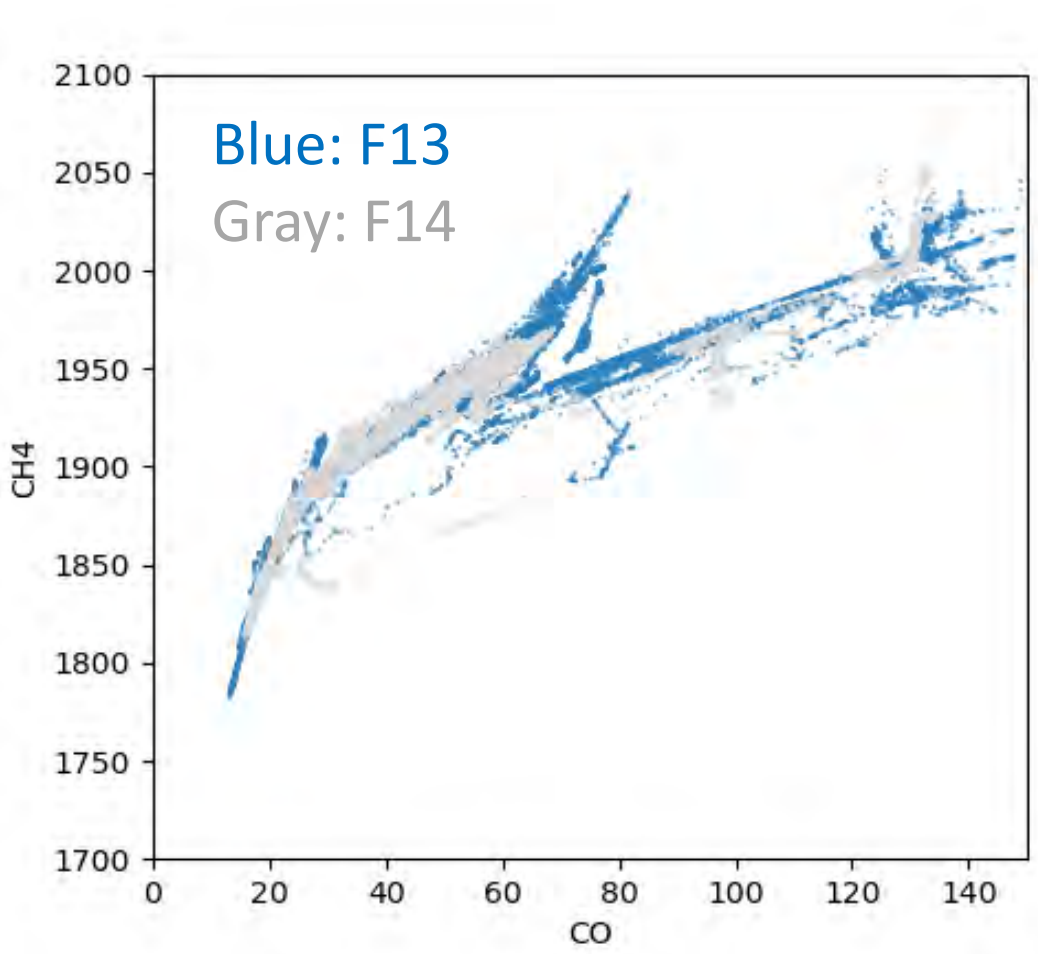


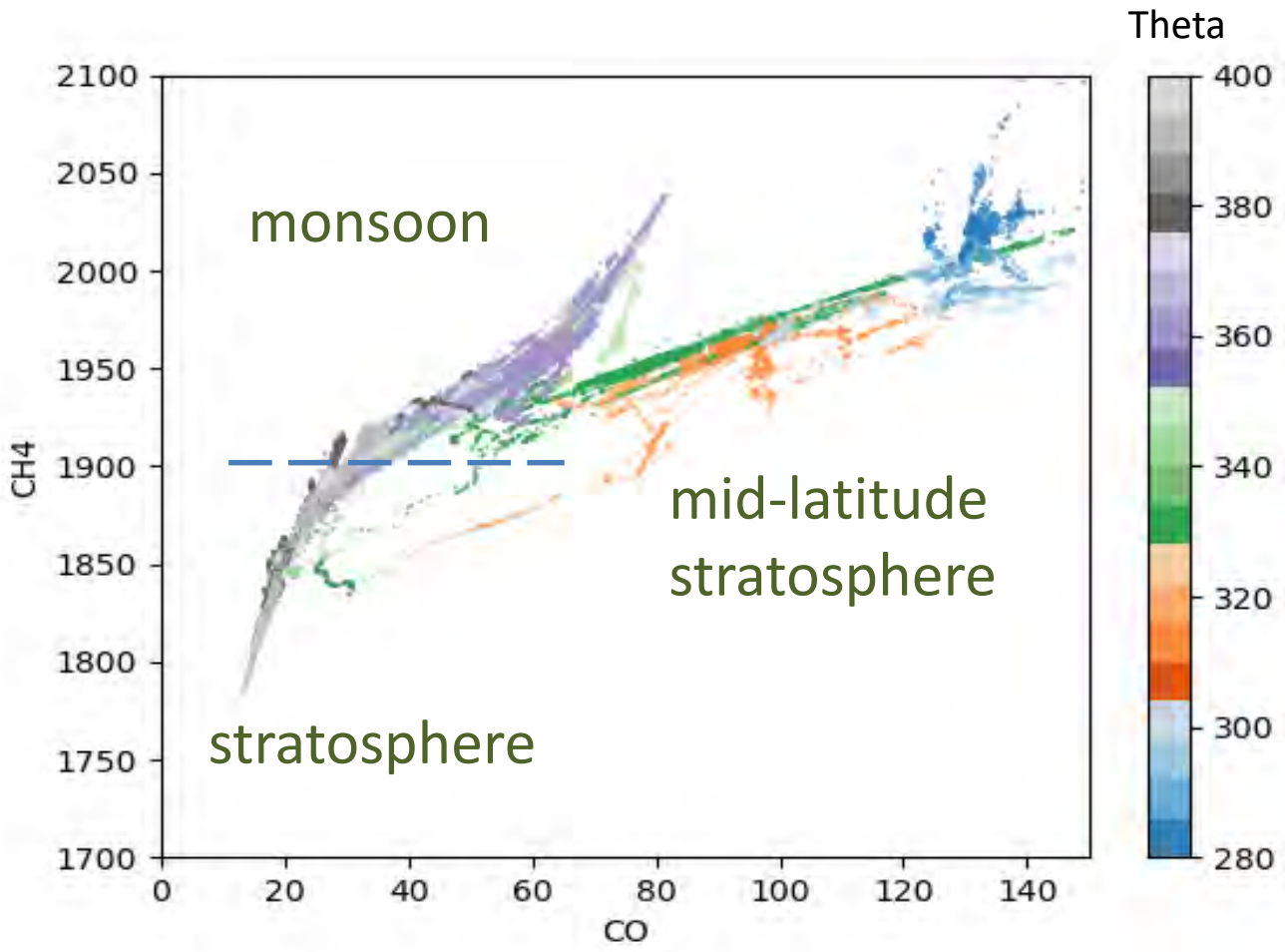
PHILEAS Phase 2: High latitude export



Very good matching of both flights: Same air mass characteristics for both flights

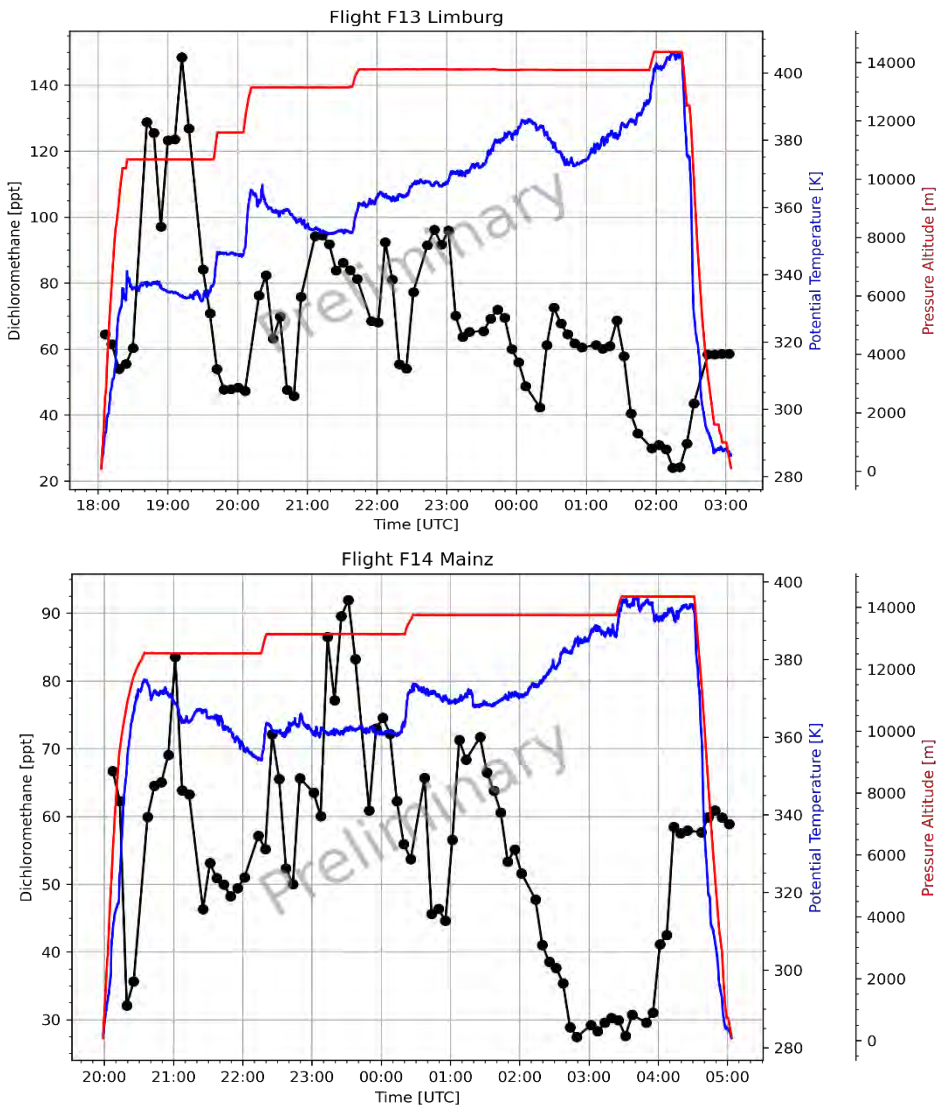
PHILEAS Phase 2: High latitude export

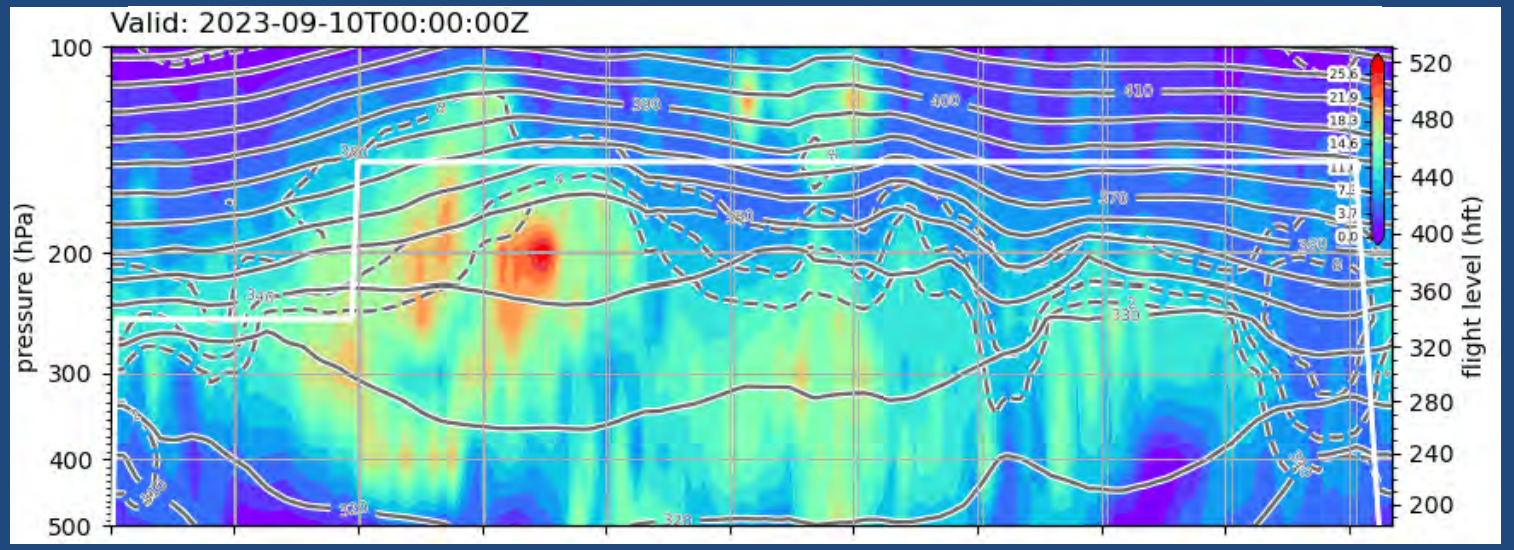


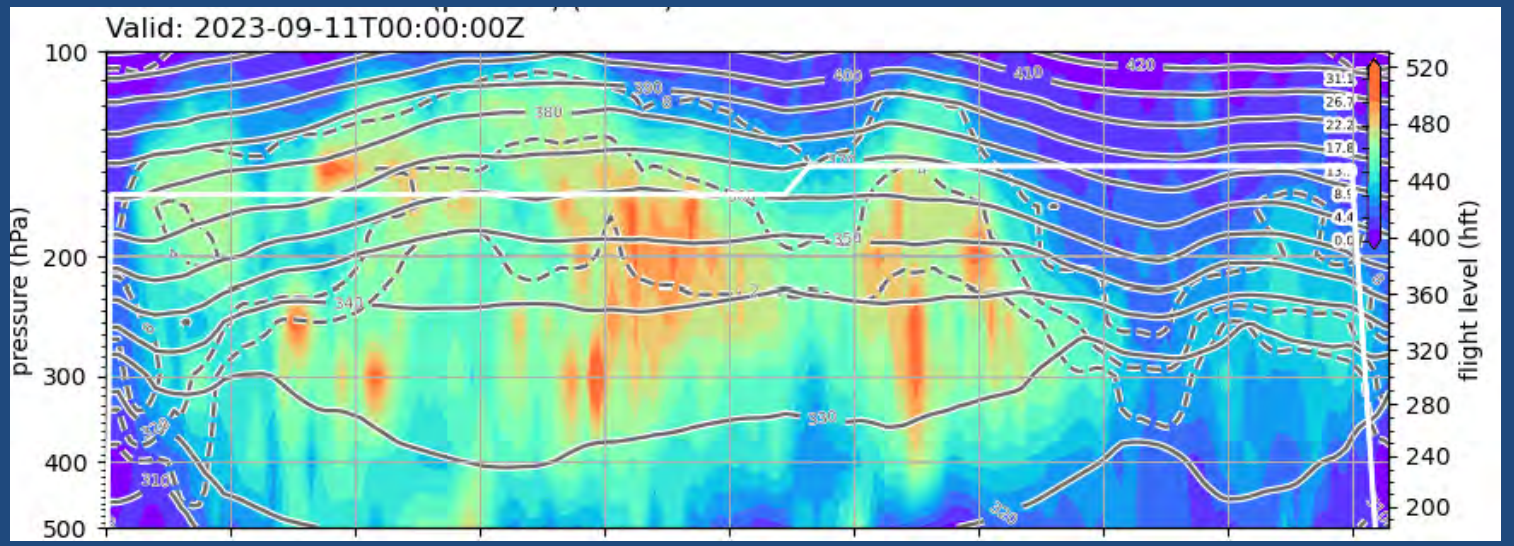


Very good matching of both flights: Same air mass characteristics for both flights and same mixing characteristics for both flights, very different properties at different levels

PHILEAS Phase 2: High latitude export







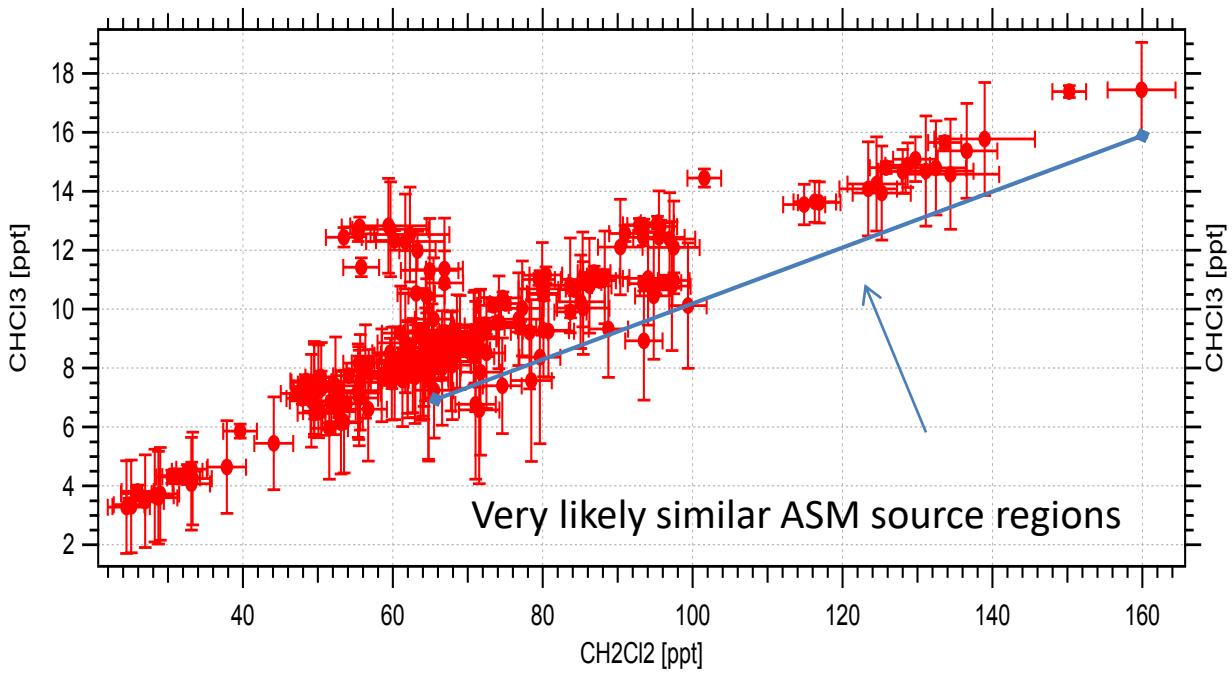
Evolution of Dichloromethane (Monsoon tracer) and vertical structure

Ghost (M. Jesswein, A. Engel, GU Frankfurt/Main)

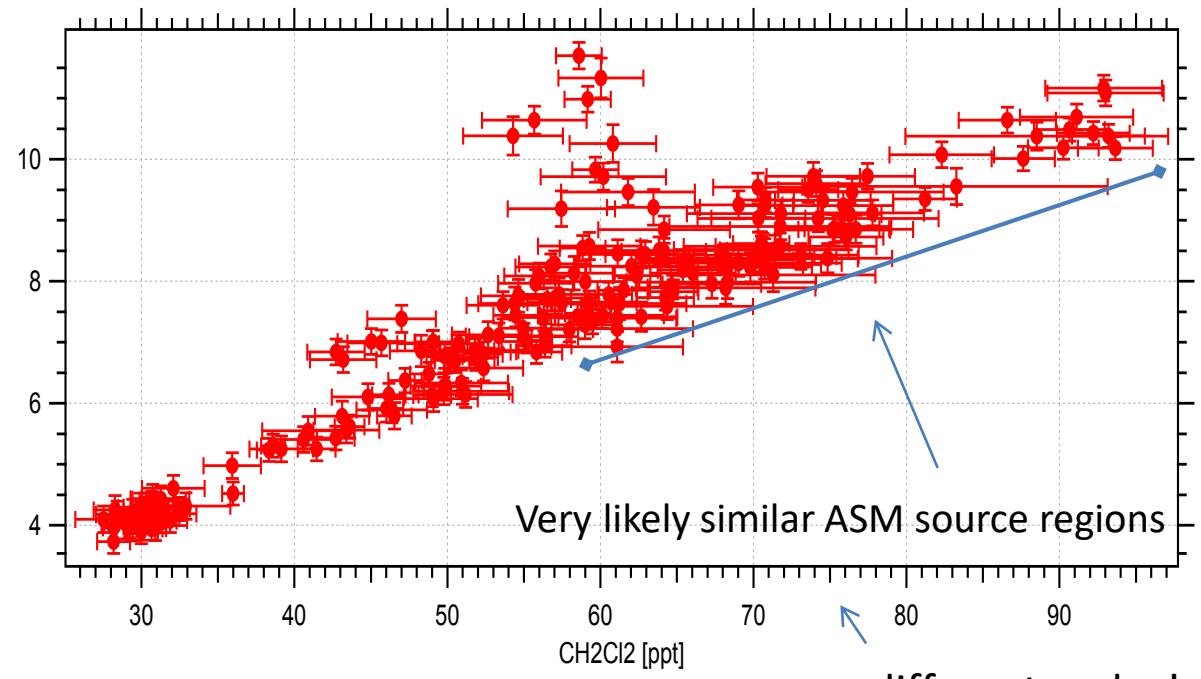
PHILEAS Phase 2: High latitude export

Dichloromethane and Trichloromethane correlated and strongly enhanced: monsoon air

F13



F14

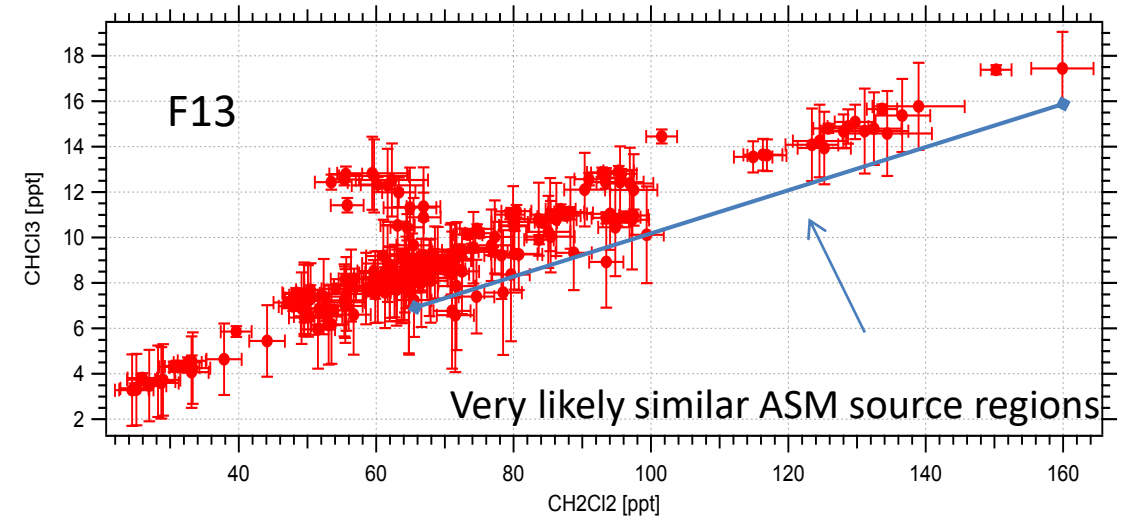


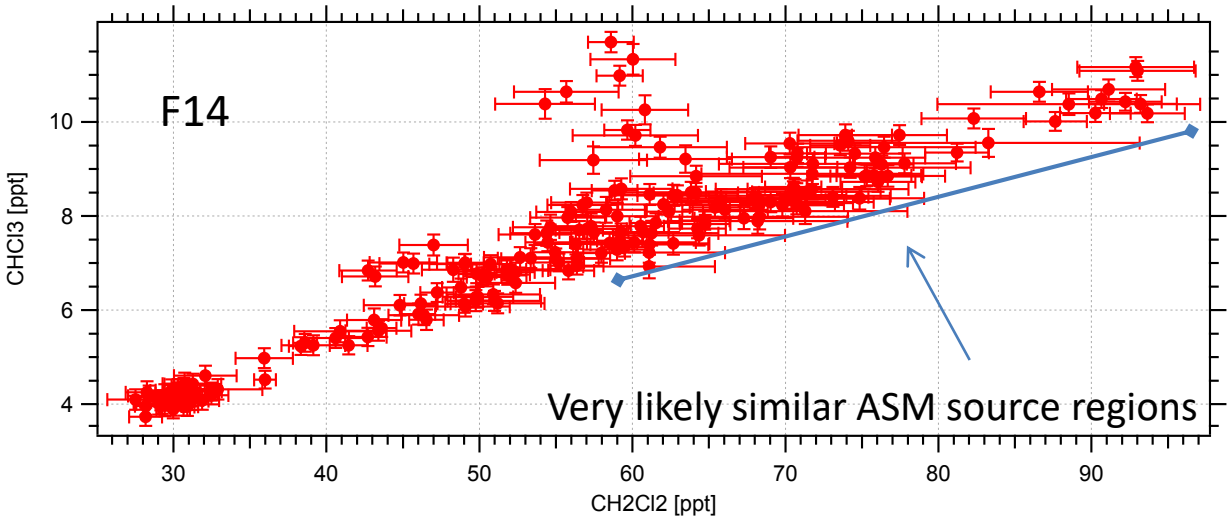
different scales!

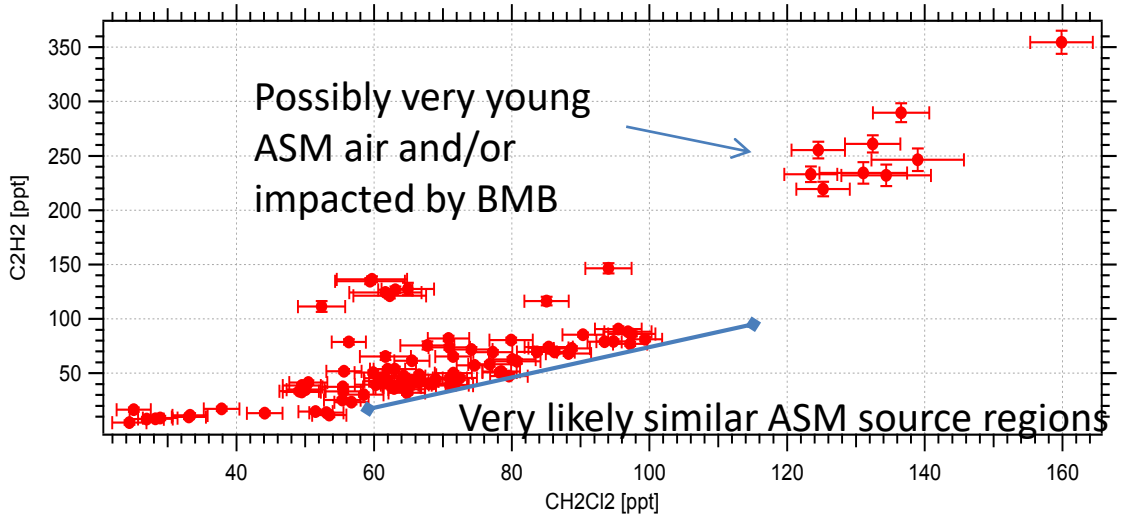
Strong evidence for monsoon outflow: Chemical correlations typical for south east asian (monsoon region) sources

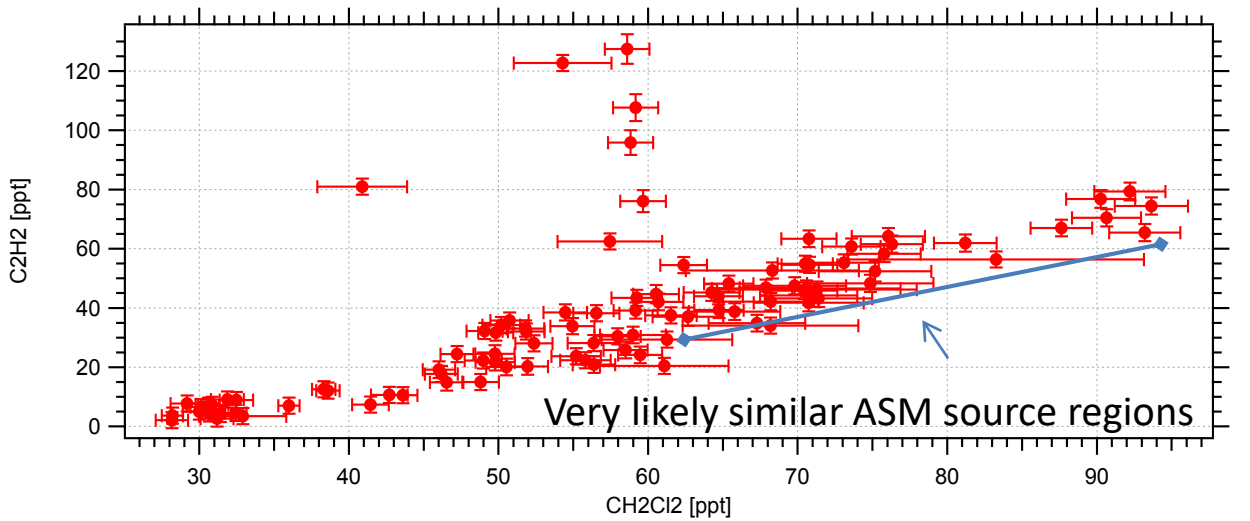
HAGAR-V (V.Lauther, R.v. Luijt, J. Strobel, M.Volk, BU Wuppertal)

PHILEAS Phase 2: High latitude export



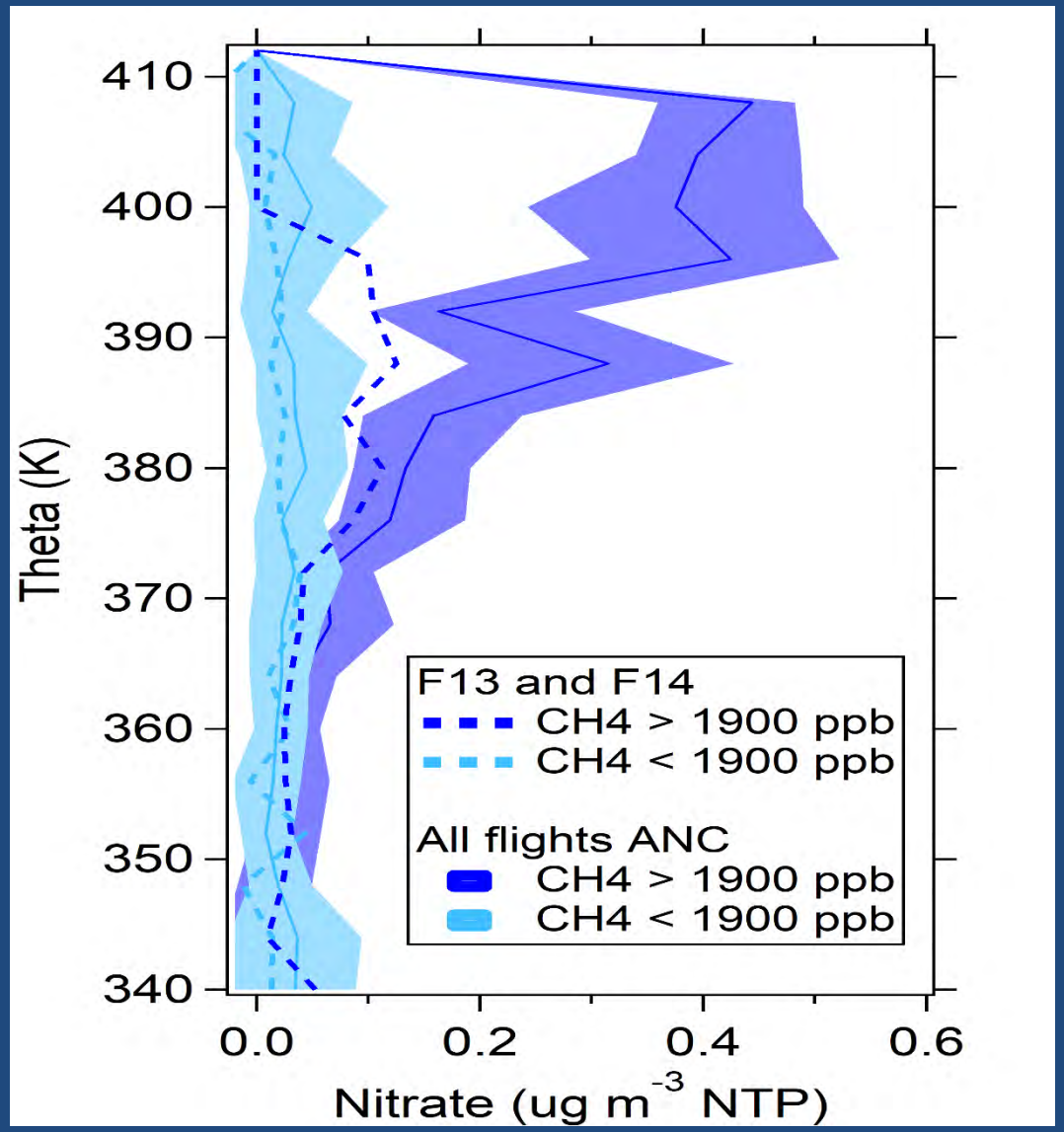






HAGAR-V (V.Lauther, R.v. Luijt, J. Strobel, M.Volk, BU Wuppertal)

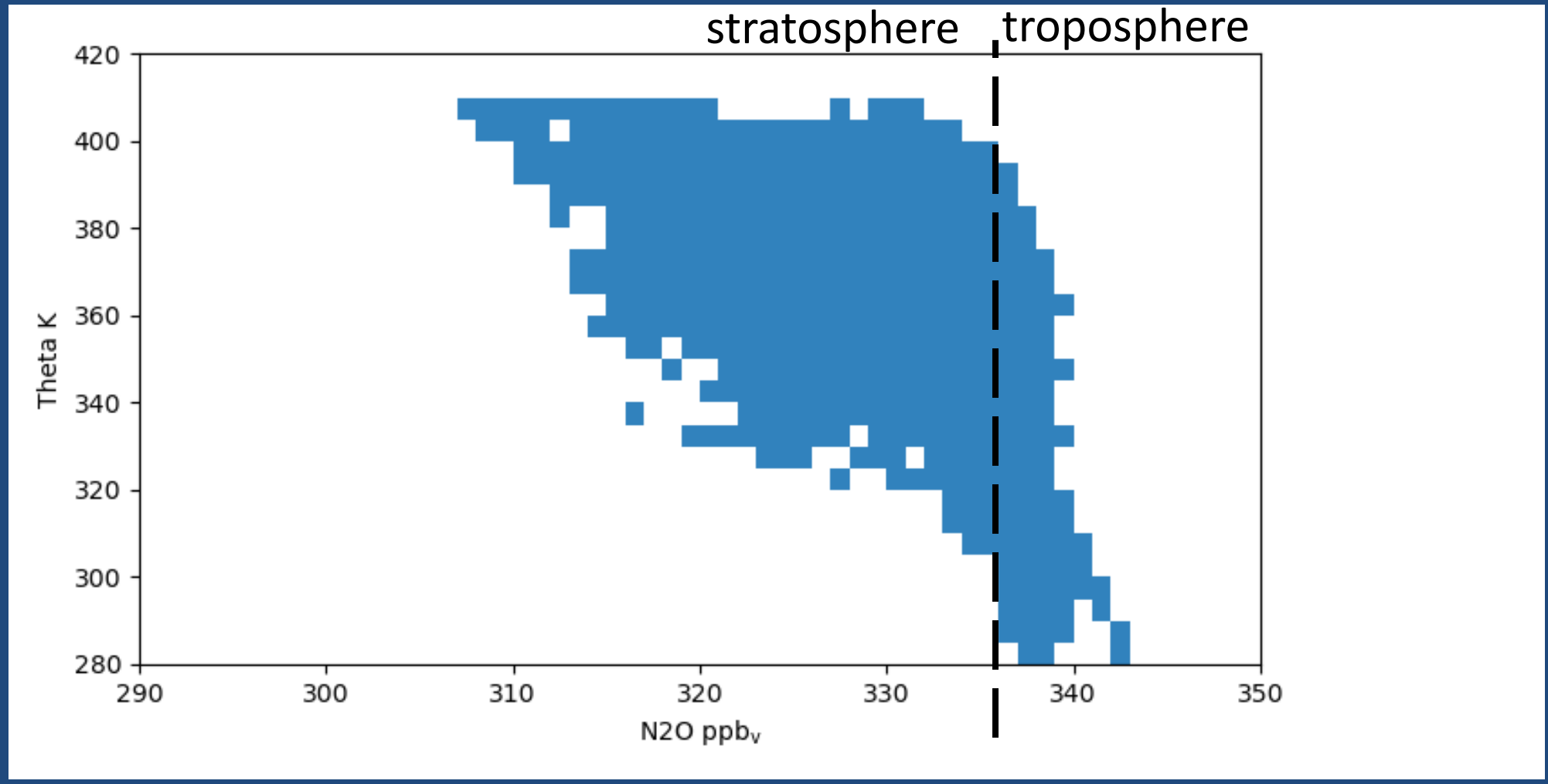
PHILEAS Phase 2: High latitude export



Effect on aerosols?
transport of nitrate-rich particles to high latitudes for Θ > 360 K
Export from the AMA-region

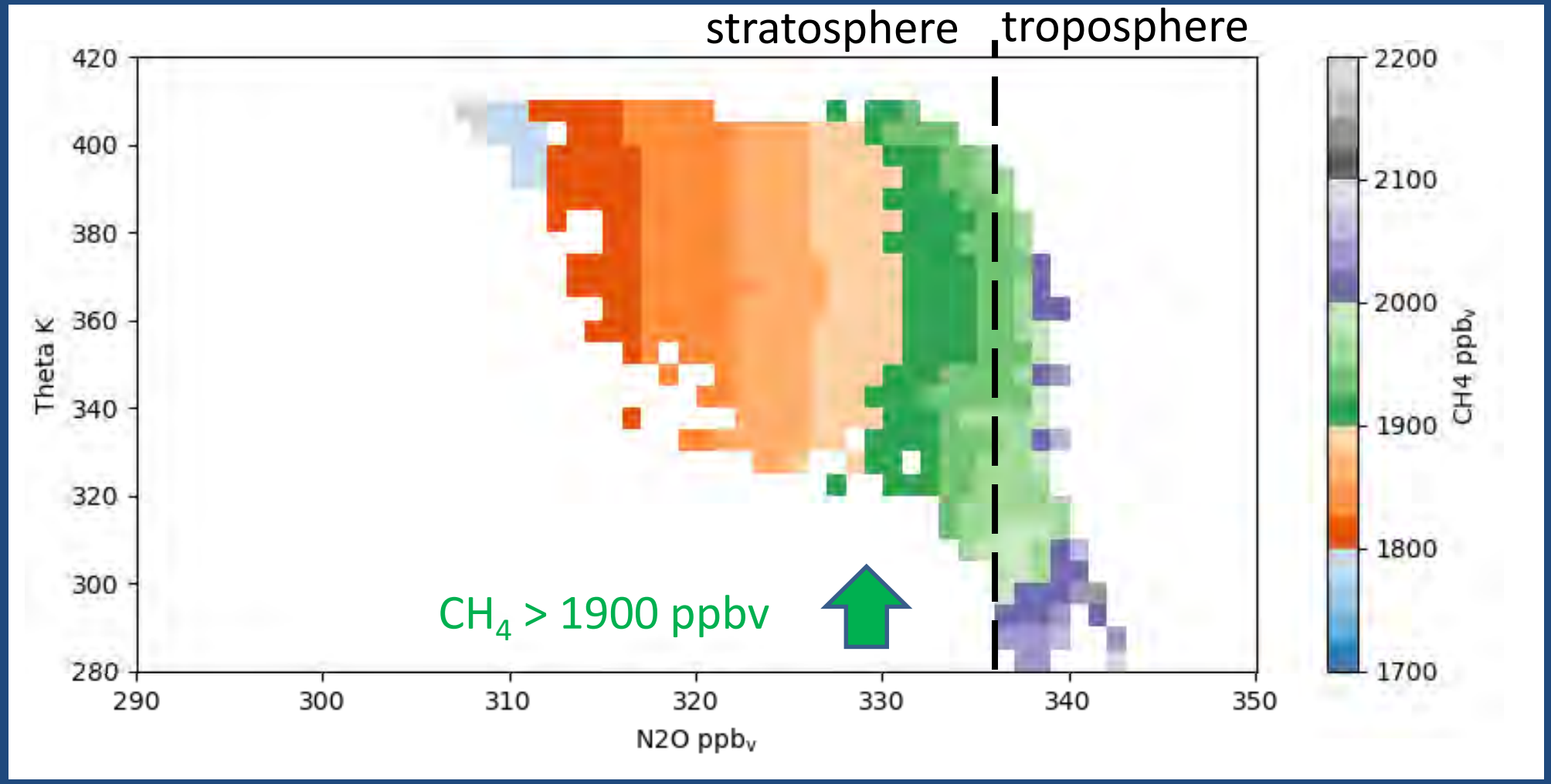
(F. Köllner, J. Schneider, S. Borrmann, O. Eppers, F. Ekinci, MPIC Mainz/JGU Mainz)

PHILEAS Phase 2: High latitude export



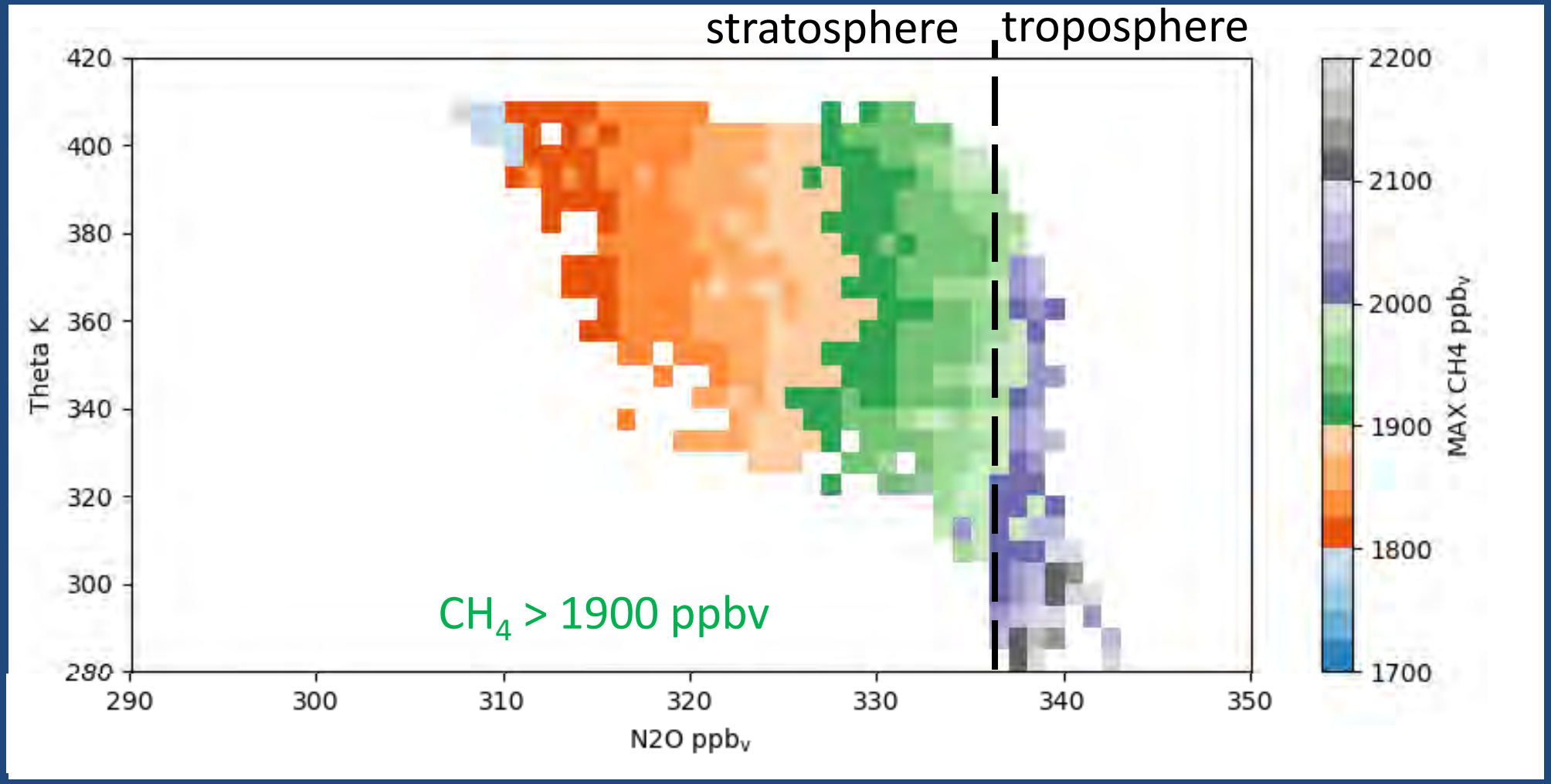
Import into the stratosphere: N_2O < 337 ppbv separates tropospheric and stratospheric air

PHILEAS Phase 2: High latitude export



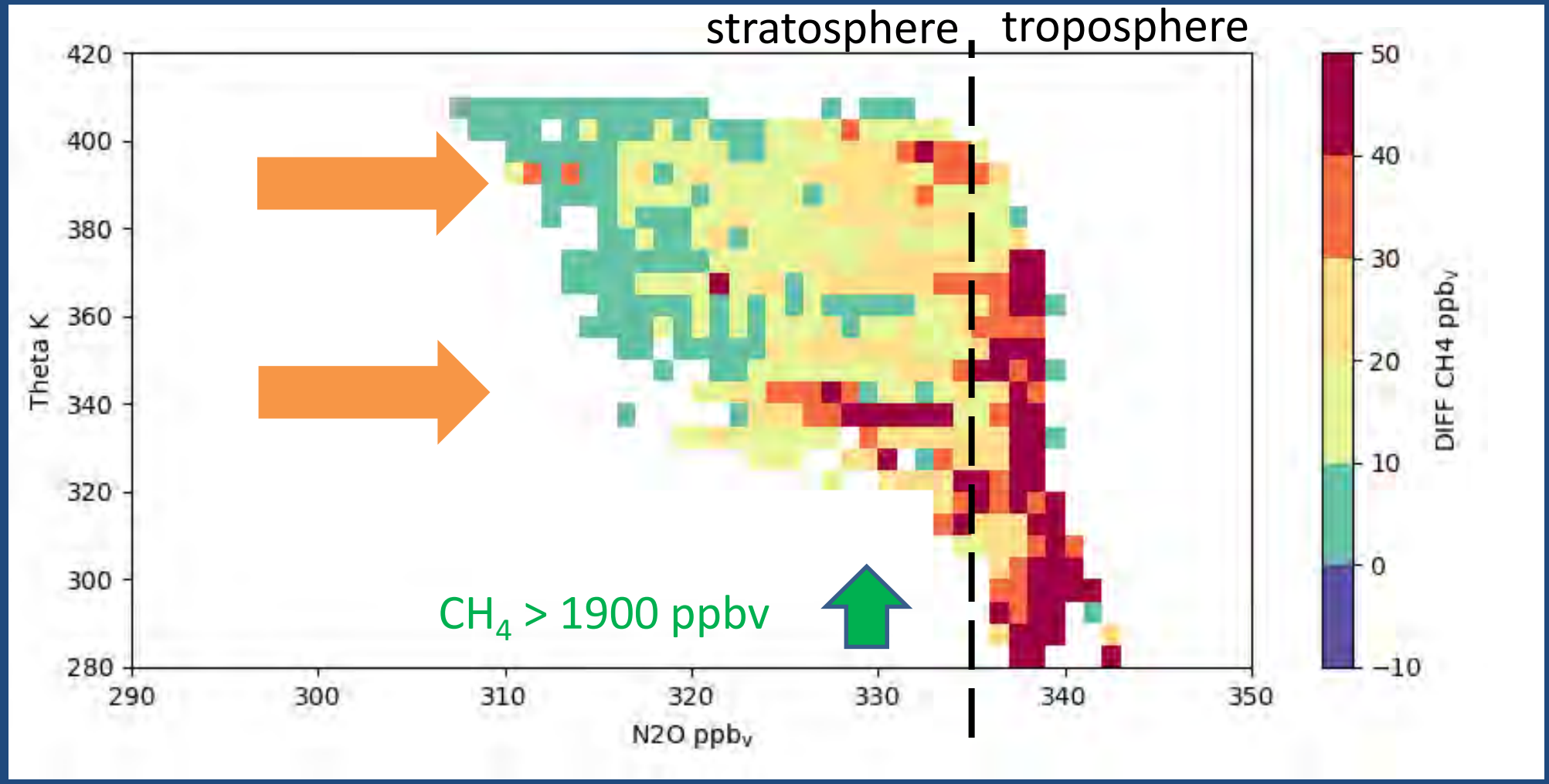
CH_4 > 1900 ppbv for N_2O < 337 ppbv: stratospheric air

PHILEAS Phase 2: High latitude export



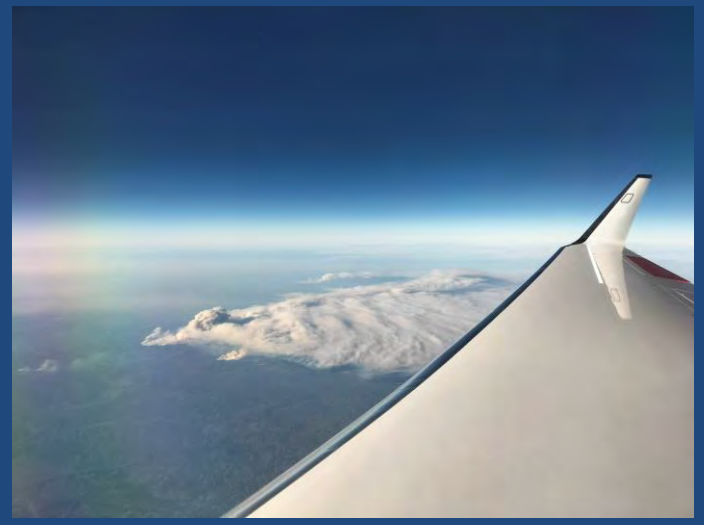
Maximum values of CH_4 > 1900 ppbv found even deeper in the stratosphere

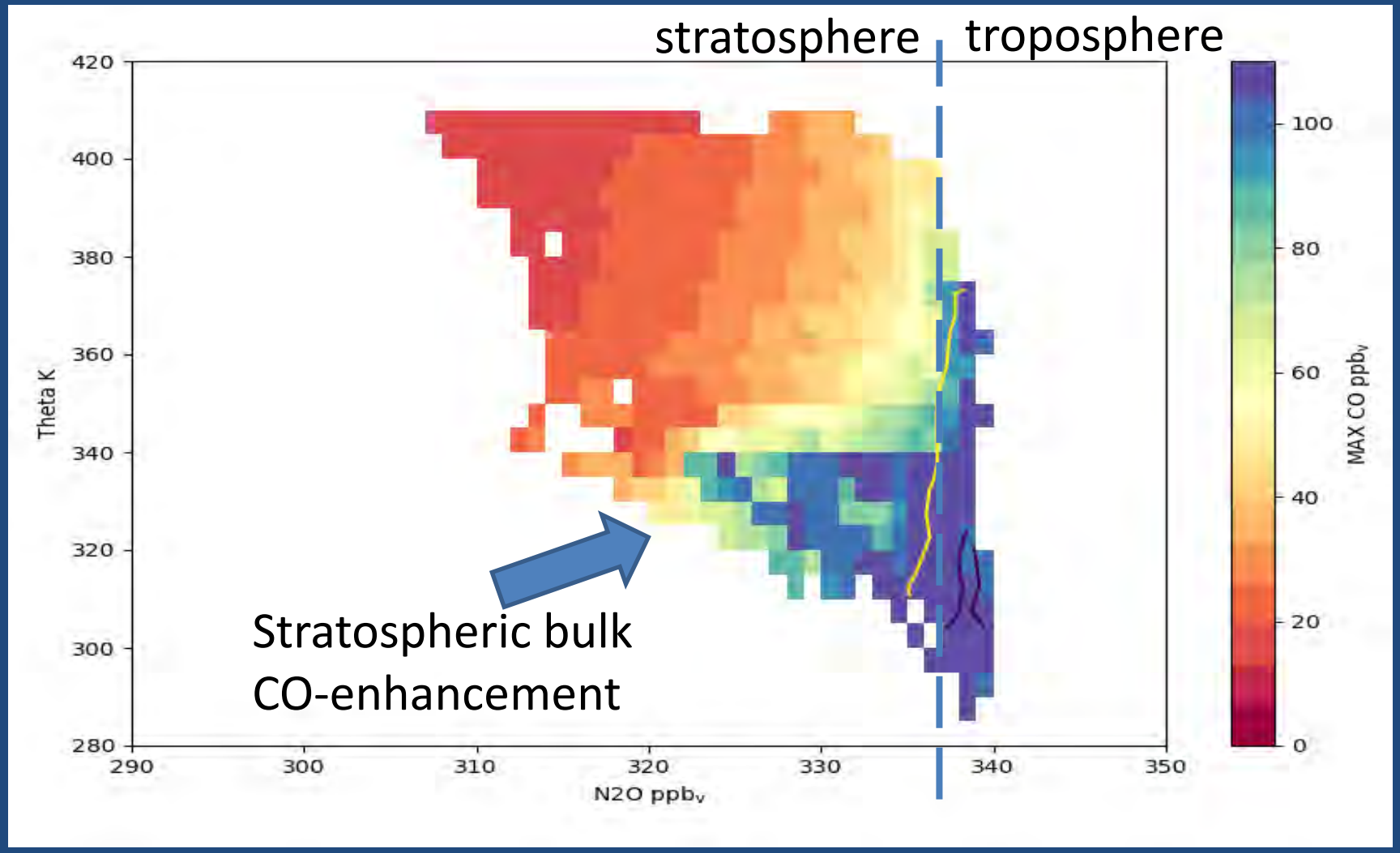
PHILEAS Phase 2: High latitude export



Import into the stratosphere: CH_4 > 1900 ppbv found for N_2O < 337 ppbv: Transport and mixing of air from East Asia into the stratosphere! Two prominent isentropic levels

PHILEAS Phase 2: Biomass burninng (?)

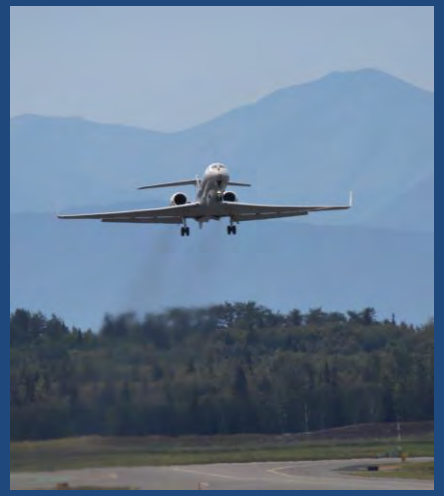


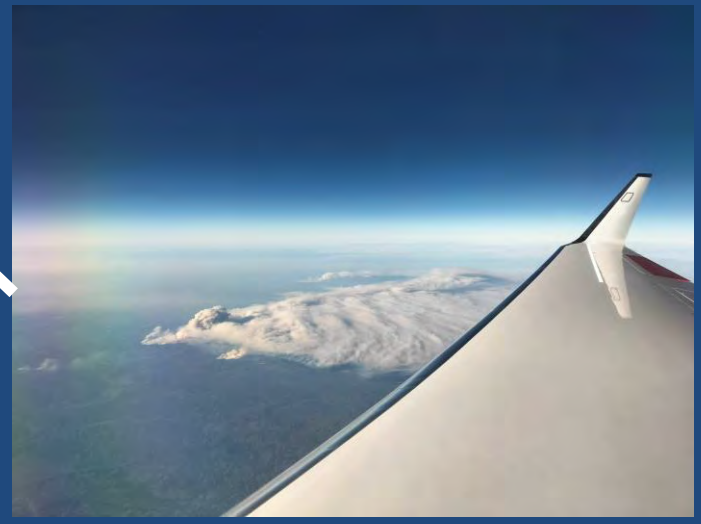


Large CO enhancements in the stratosphere: Pollution potentially from biomass burning

PHILEAS Phase 2, Anchorage:

Biomass burning





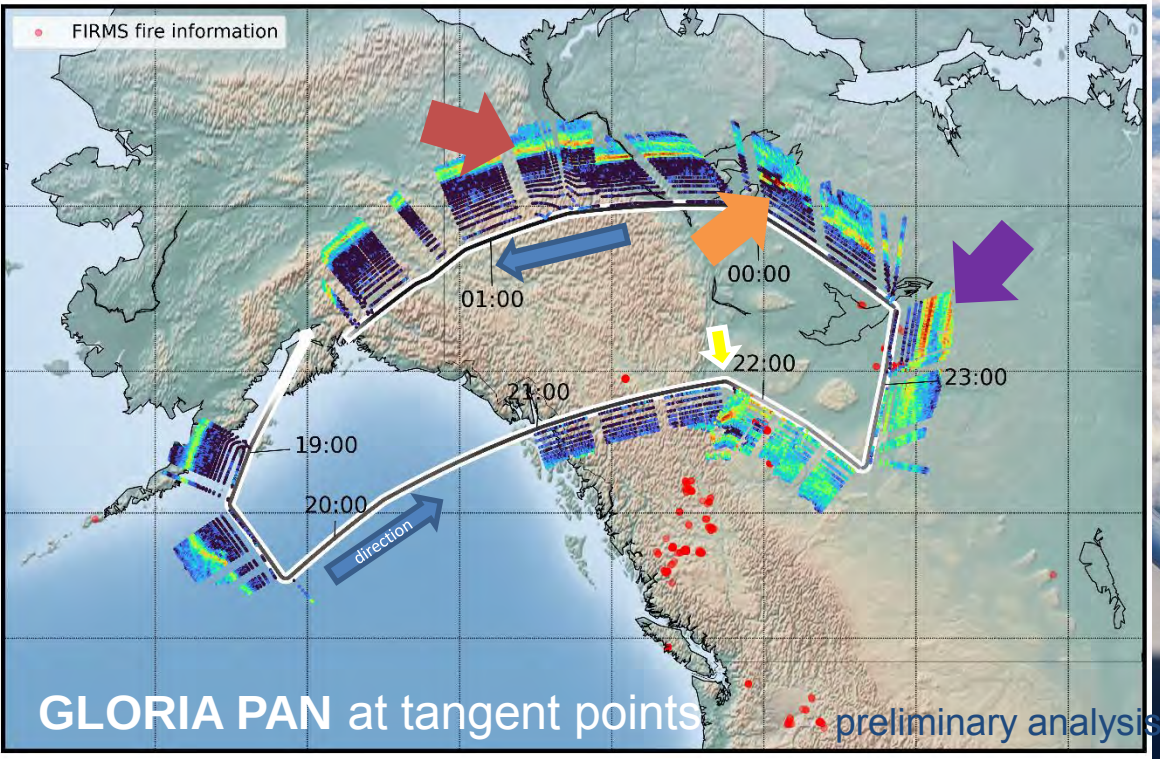
GLORIA@PHILEAS: Biomass burning during flight on 2023-09-07

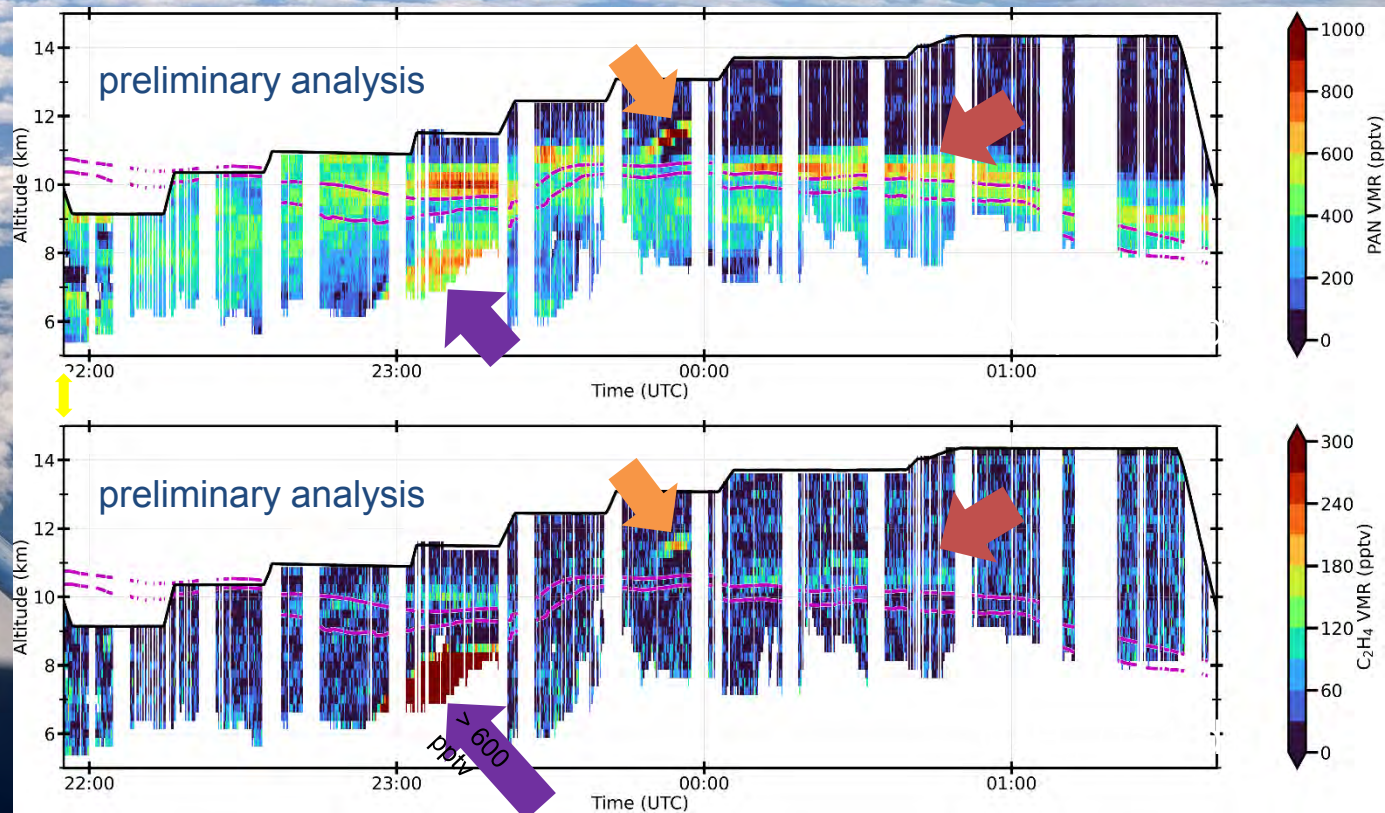
S. Johansson, KIT

Picture: E. Kretschmer (KIT)

Stratospheric entry?

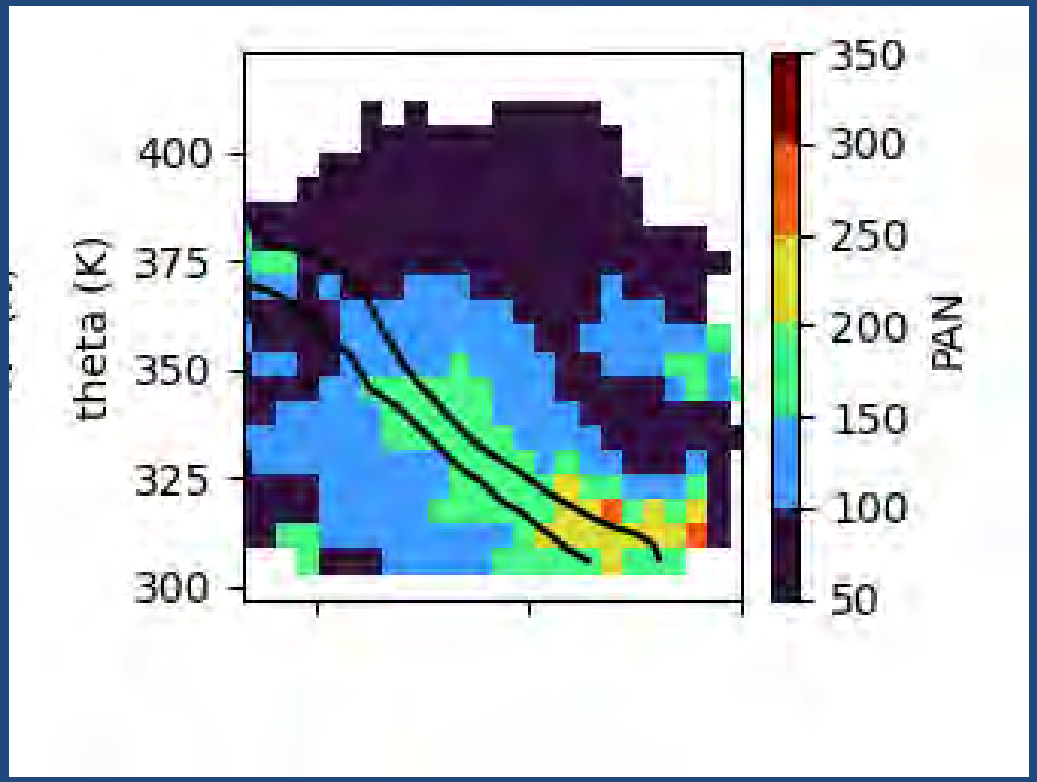
Layer of aged pollution



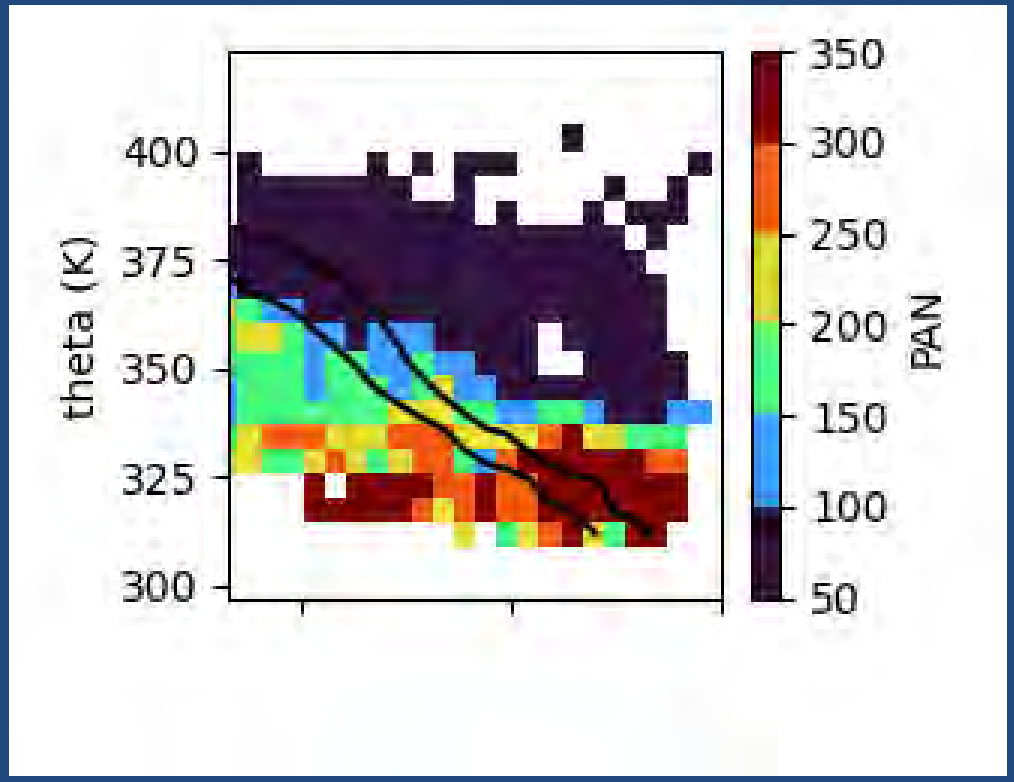


PHILEAS Phase 3: Large scale impact

WISE



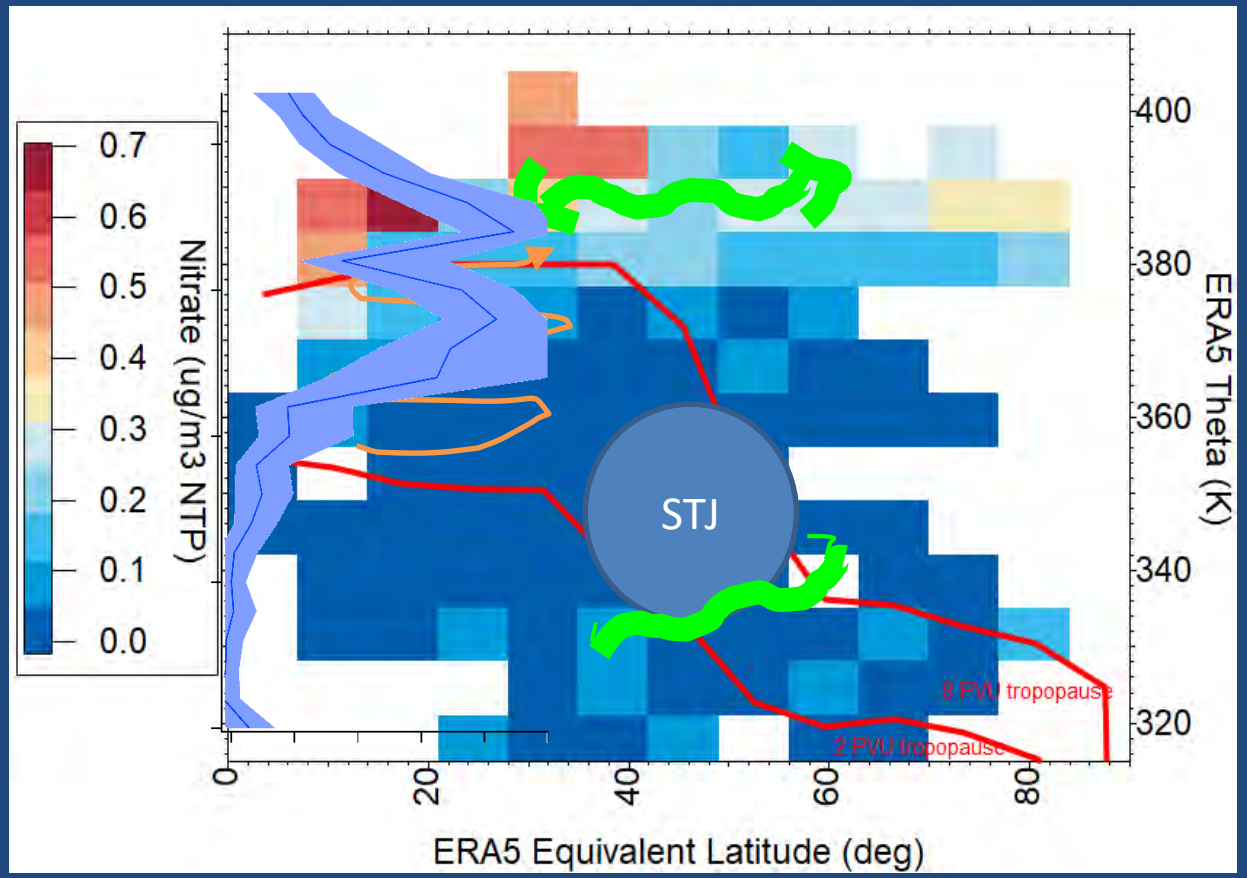
PHILEAS



Study large scale impact and interannual / regional differences:
PAN strongly enhanced during PHILEAS, above and around the tropopause (<340K)

(J. Ungermann, FZ-Jülich)

Transport of from the AMA into the ExLS



Rapid export of AMA enriched in nitrate Containing particles (AN) and aged pollution, and CH4

Slow diabatic ascent in the AMA allows for particle formation and grwoth

Rapid export of pollution enriched in CO and VOCs from East Asia

Köllner et al., in prep

PHILEAS first results

- Asian monsoon air over the Eastern Mediterranean
- Detection of nitrate enriched particles far from the AMA
- Export of nitrate containing particles from monsoon into the lowermost stratosphere
- Two ‚export' regimes below/above approx. 360 K

- Biomass burning and massive pollution impact on the lowermost stratospheric composition

PHILEAS: A great team!