# Processes inferred from CH4 and CO2 observed during the airborne GLAM campaign above the Mediterranean

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## GLAM: Gradient in Longitude of Atmospheric constituents above the Mediterranean basin

# Acknowledgement


- P. Ricaud[1], R. Zbinden[1], V. Catoire[2], V. Brocchi[2], F. Dulac[3], E. Hamonou[3], J.-C. Canonici[4], L. El Amraoui[1], S. Massart[5], B. Piguet[1], U. Dayan[6], P. Nabat[1], J. Sciare[7], M. Ramonet[3], M. Delmotte[3], A. G. di Sarra[8], D. Sferlazzo[8], T. Di Iorio[8], S. Piacentino[8], P. Cristofanelli[9], N. Mihalopoulos[10], G. Kouvarakis[10], S. Kleanthous[7], M. Pikridas[7], C. Savvides[11], R. E. Mamouri[12], A. Nisantzi[12], D. G. Hadjimitsis[12], J.-L. Attié[1,13], H. Ferré[14], P. Theron[1], Y. Kangah[1], N. Jaidan[1], P. Jacquet[2], S. Chevrier[2], C. Robert[2], A. Bourdon[4], J.-F. Bourdinot[4], J.-C. Etienne[4]

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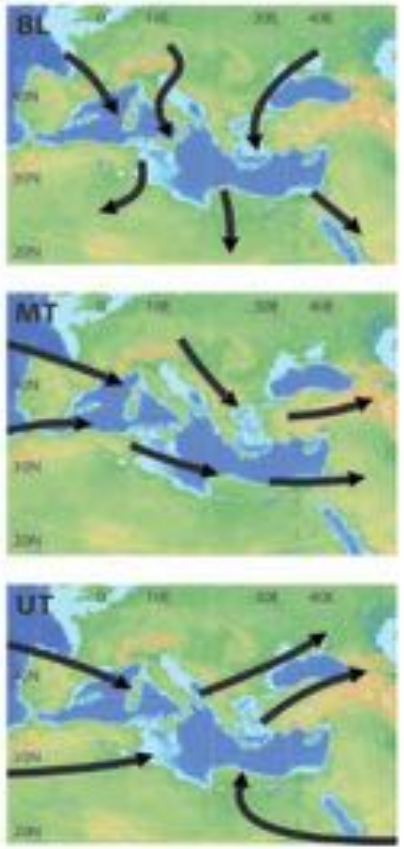
# Context

- The Mediterranean is located in a transitional zone between subtropical and mid-latitudes regimes, highly sensitive to climate change.
- Global or regional model simulations show a pronounced decrease in precipitation (2000-2100), especially in the warm season
- Polluted air masses may originate from Asia, Europe, Africa and North America

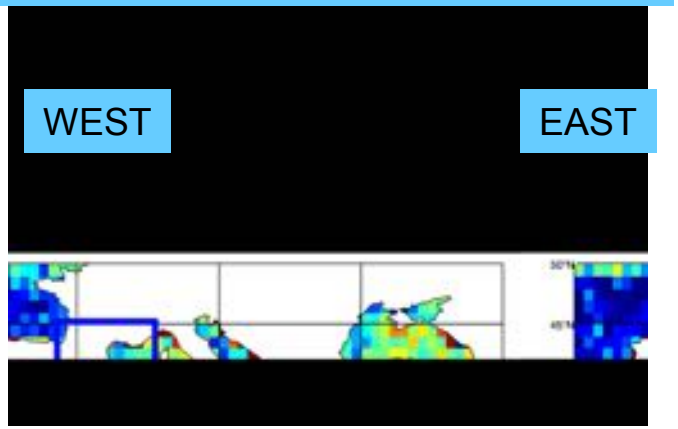
- CHARMEX/MISTRAL: Chemistry and Aerosol Experiment/Mediterranean Integrated STudies at Regional And Local Scales
- WP5: Variability & Trends



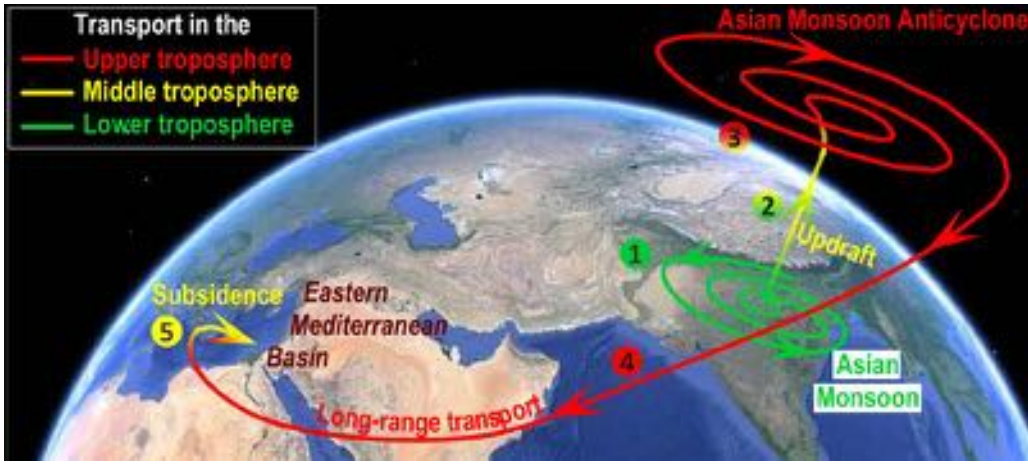

Lelieveld et al., 2002

# Motivations

Tropospheric $CH_4$ spaceborne measured by AIRS in summer




Impact of the Asian Monsoon Anticyclone on the Eastern Mediterranean Basin in the UT in summer



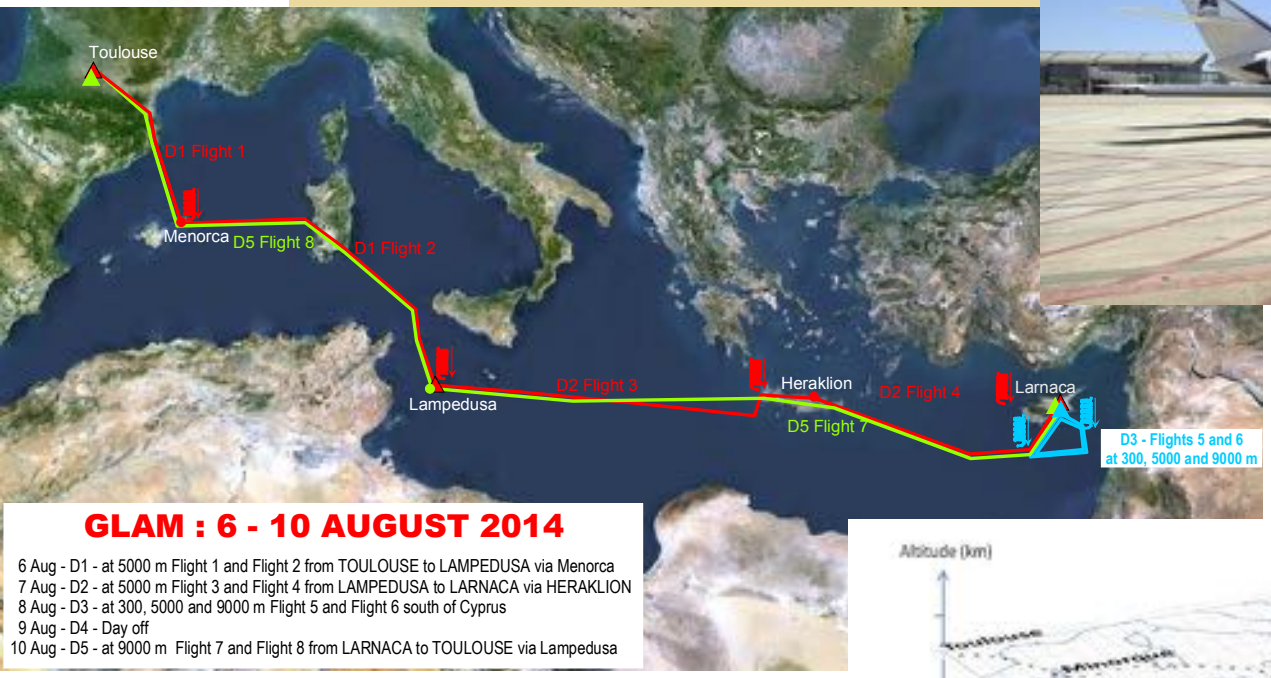

Ricaud et al., 2014

- East-West gradients observed and modelled over the Mediterranean Basin in summer in GHGs, as methane (CH4)
- Impact of the Asian pollutants/GHGs on the Eastern MB via the Asian Monsoon and its associated Anticyclone

# Objectives

- IMPACT of the ASIAN MONSOON ANTICYCLONE on the EASTERN MB
- Summertime airborne campaign
- East-West Gradient in the mid-to-upper Troposphere
- Vertical Profiling
- Pollutants/aerosols/GHGs

# The GLAM Campaign

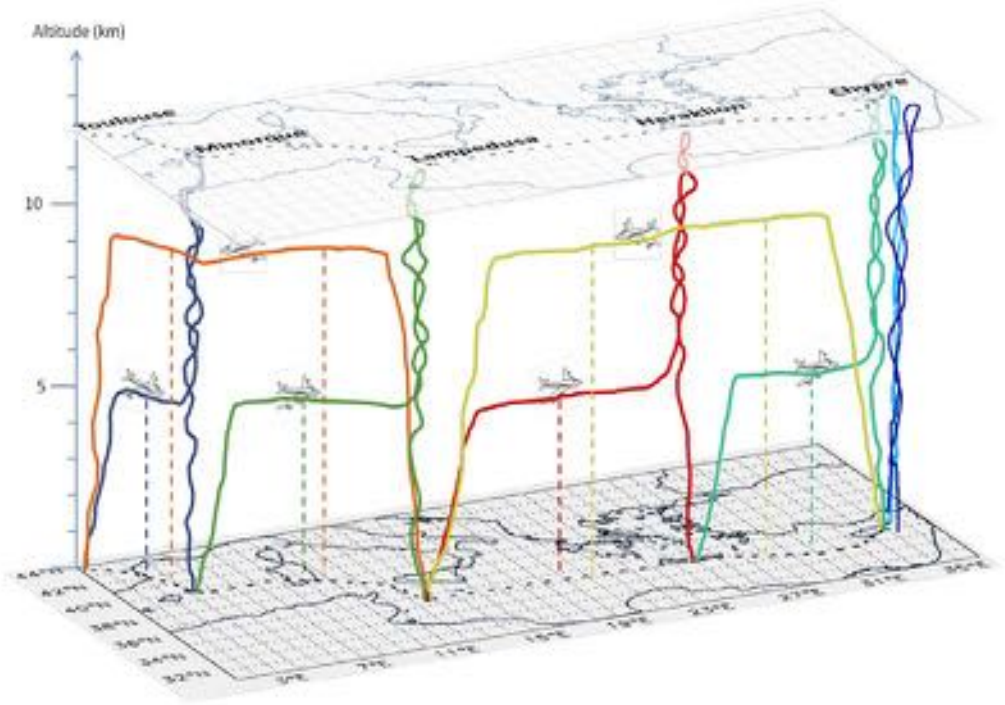




**GLAM : 6 - 10 AUGUST 2014**

6 Aug - D1 - at 5000 m Flight 1 and Flight 2 from TOULOUSE to LAMPEDUSA via Menorca
7 Aug - D2 - at 5000 m Flight 3 and Flight 4 from LAMPEDUSA to LARNACA via HERAKLION
8 Aug - D3 - at 300, 5000 and 9000 m Flight 5 and Flight 6 south of Cyprus
9 Aug - D4 - Day off
10 Aug - D5 - at 9000 m Flight 7 and Flight 8 from LARNACA to TOULOUSE via Lampedusa

9 km ←

5 km →



# Measured Parameters

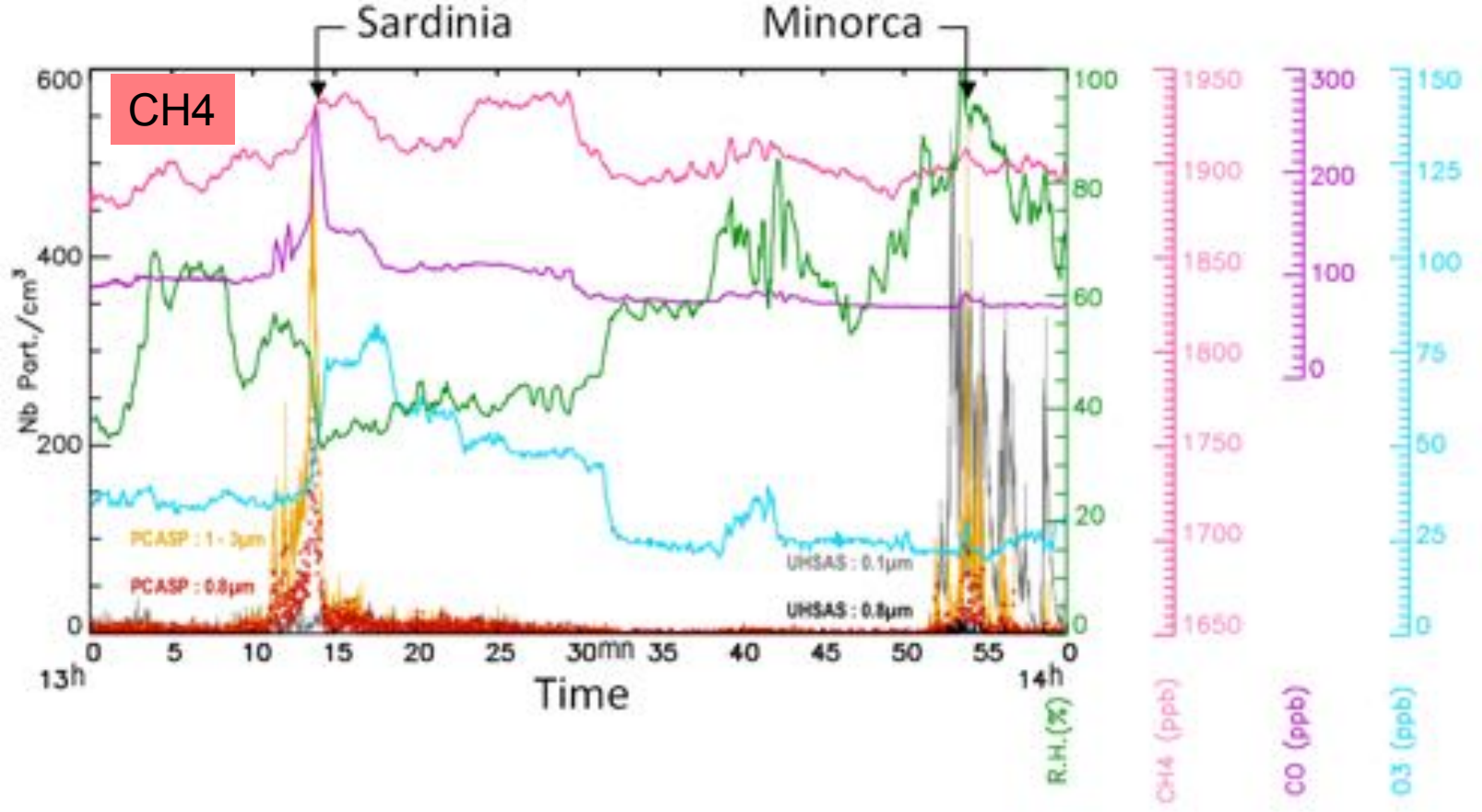
| | |
|---|---|
| **F-20** | $H_2O$, $O_3$, aerosol concentration & size distribution (0.2-3 µm), temperature, upward/ downward SW and LW radiations |
| **SPIRIT** | CO, $CH_4$, $N_2O$, $CO_2$ |

# Other Data sets

- CAMS / Chemical Forecast and Analyses
- ARPEGE / Meteorological Forecast
- MOCAGE / chemical compounds and aerosols
- ALADIN-Climat / aerosols
- Spaceborne observations / O3 and aerosols

- Surface stations / Chemical compounds and aerosols
  - Lampedusa, Italy
  - Heraklion, Greece
  - Cyprus

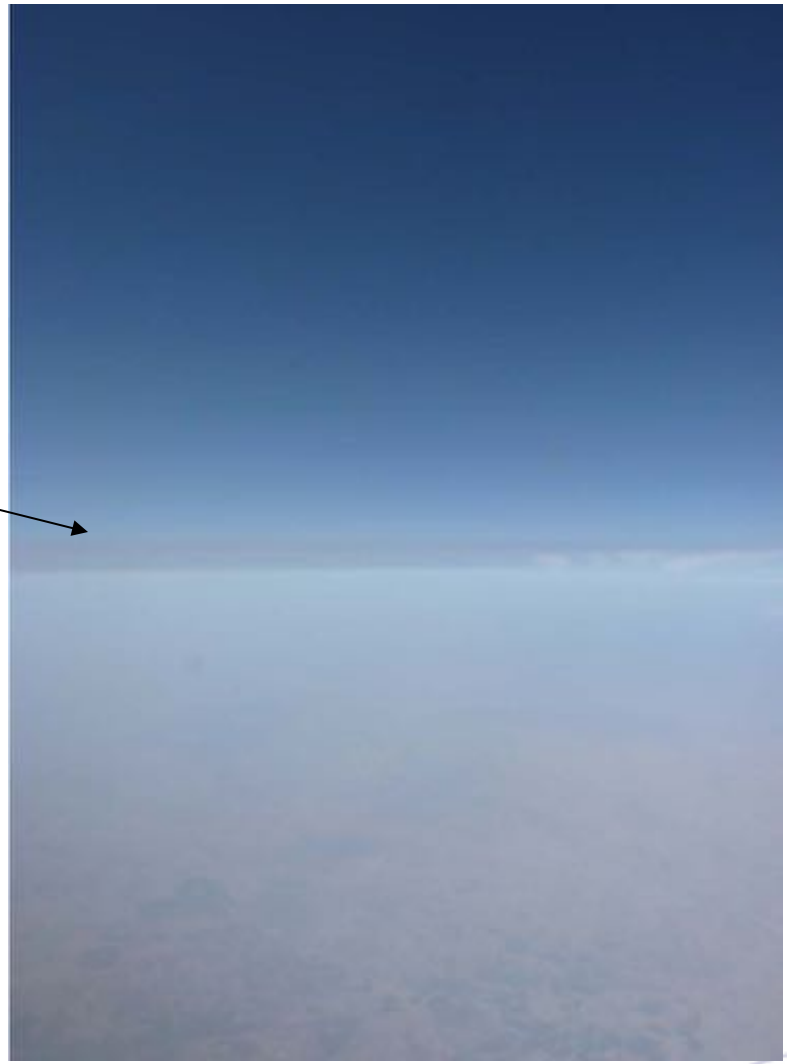
# In-situ Measurements on 10 Aug. at 9 km




On 10 Aug. 2014, 2 aerosol anomalies are detected at 9 km:

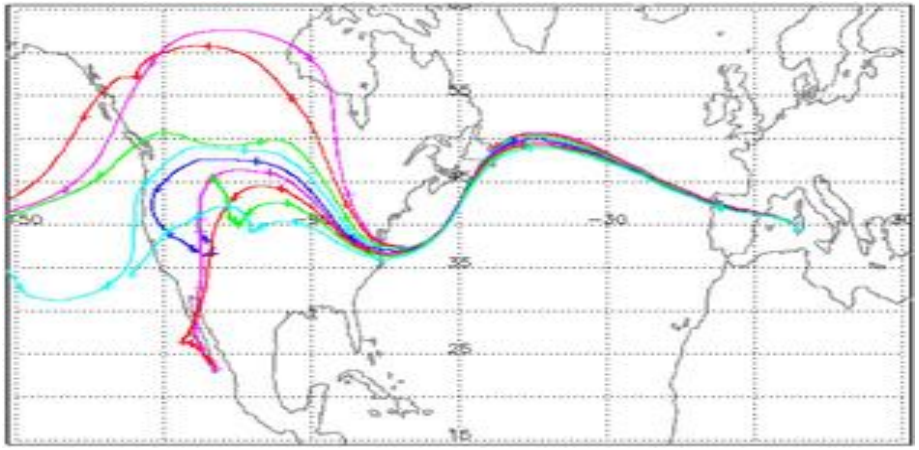
- At 13h13 UT, above Sardinia, a coarse size of particules is associated with a CO maximum, an $O_3$ and a $CH_4$ shift and a weak RH.
- At 13h55 UT, nearby Menorca, a fine size of particles is associated with high RH and no $O_3$, $CH_4$ and CO change.

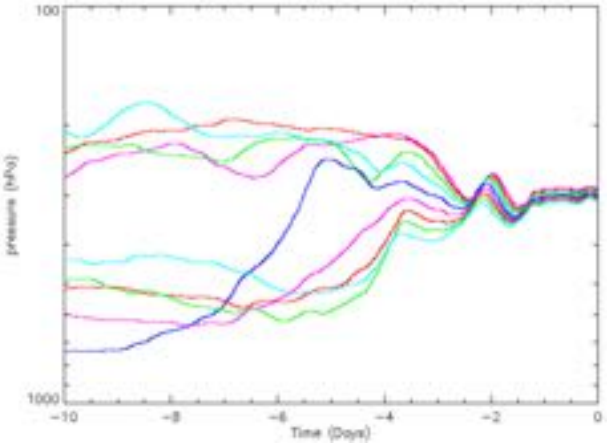
# Picture taken from the aircraft



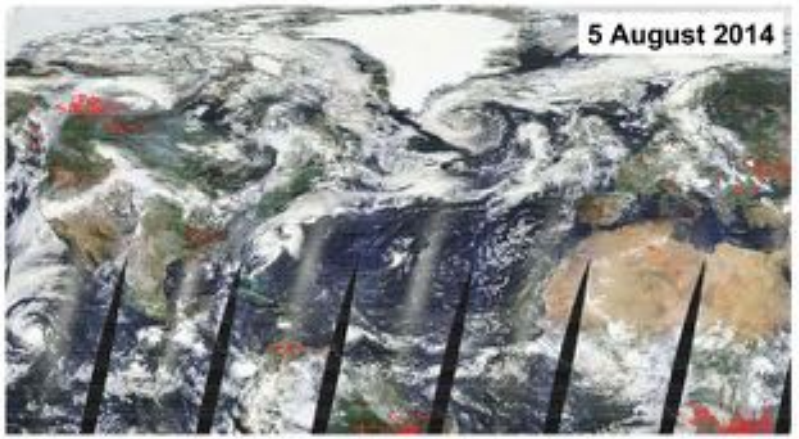
# Northern American Fires

10-day back trajectories from Sardinia on 10 August at 13h13 UT



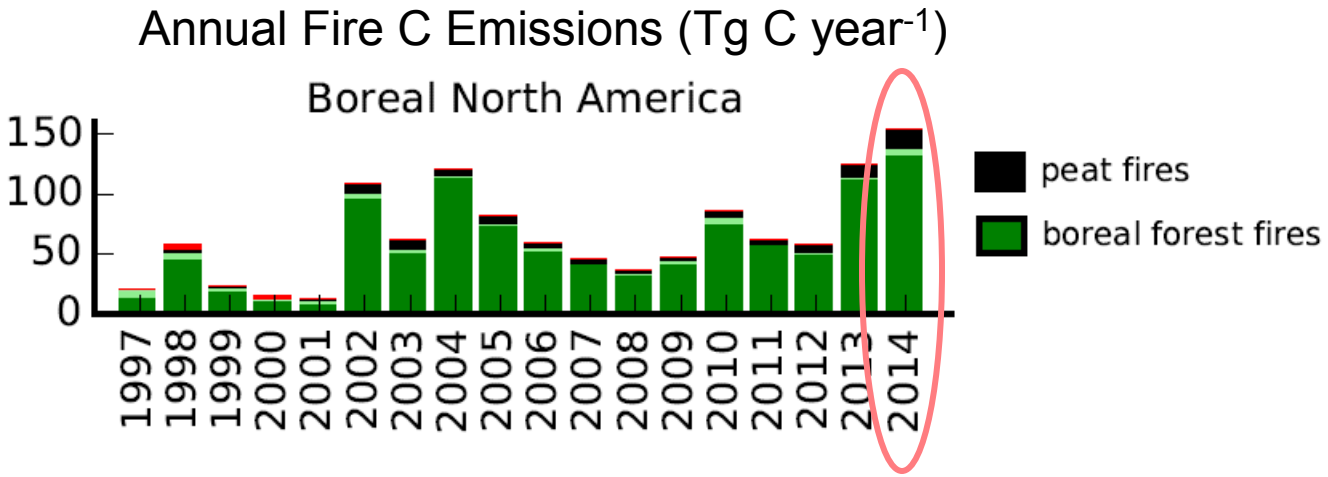


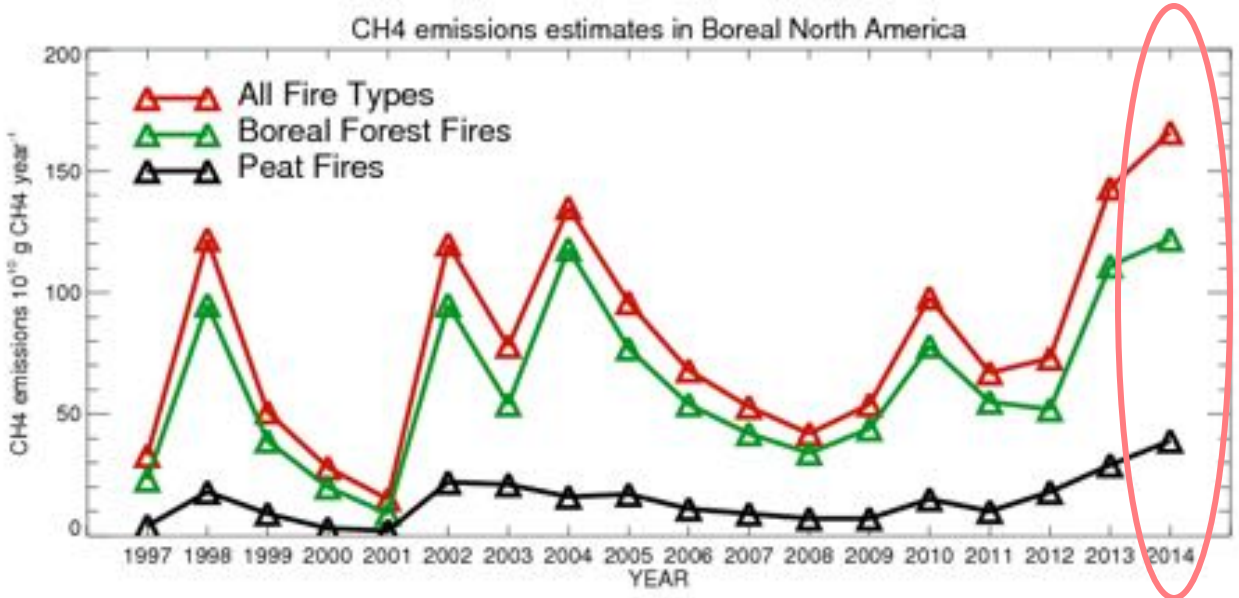

MODIS Fires on 5 August




Air parcels flew over Northern Territories end of July in the lowermost troposphere and were uplifted over the Atlantic Ocean on 6 August up to the upper troposphere (Warm Conveyor Belt) although pyroconvection to the middle troposphere cannot be ruled out.

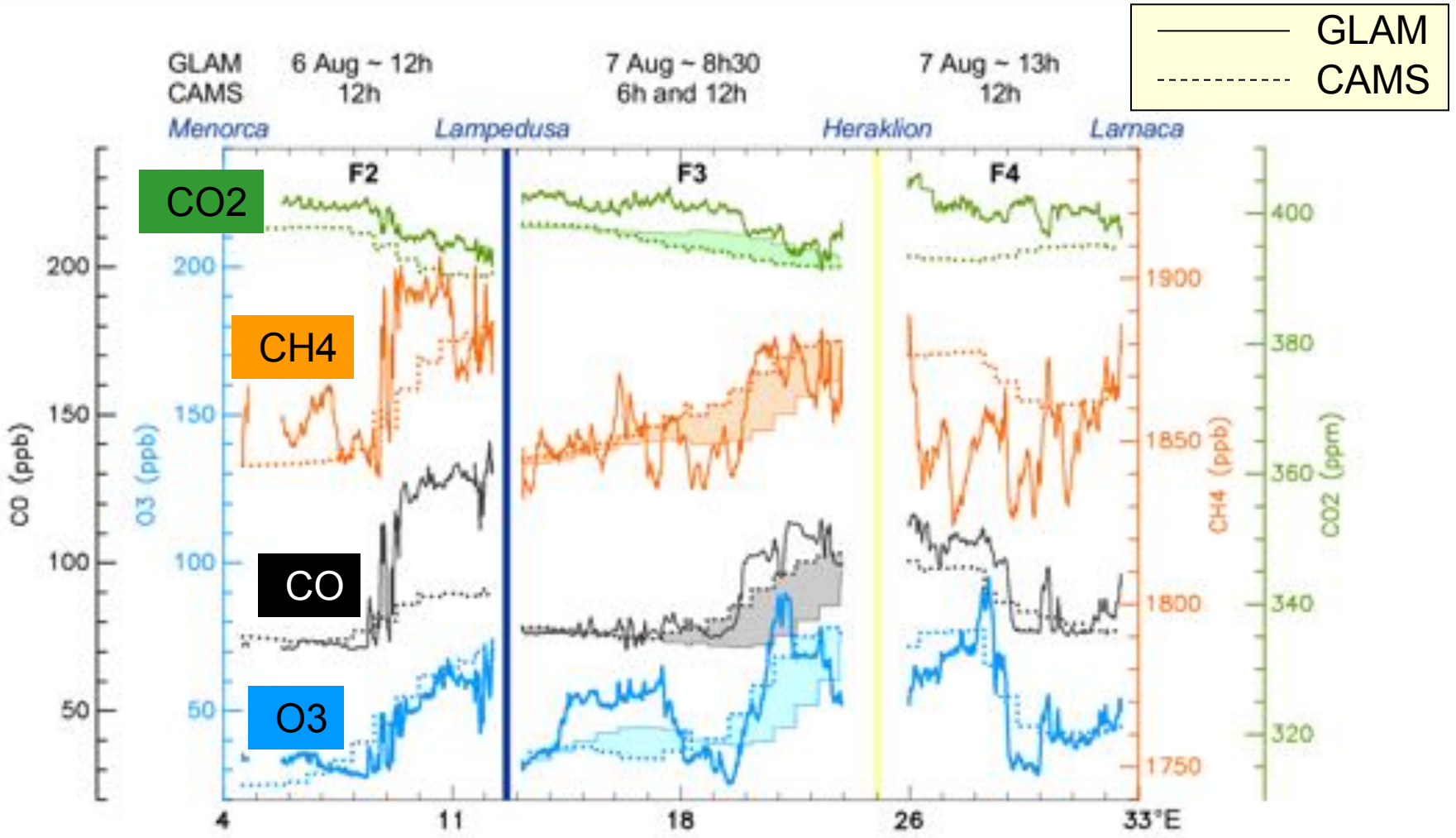
# Boreal North America




From the GFED inventory, the Boreal North America region, in terms of annual fire carbon and CH4 emissions, the year 2014 was the most intense over the period 1997-2014.

# West-East variability at 5 km

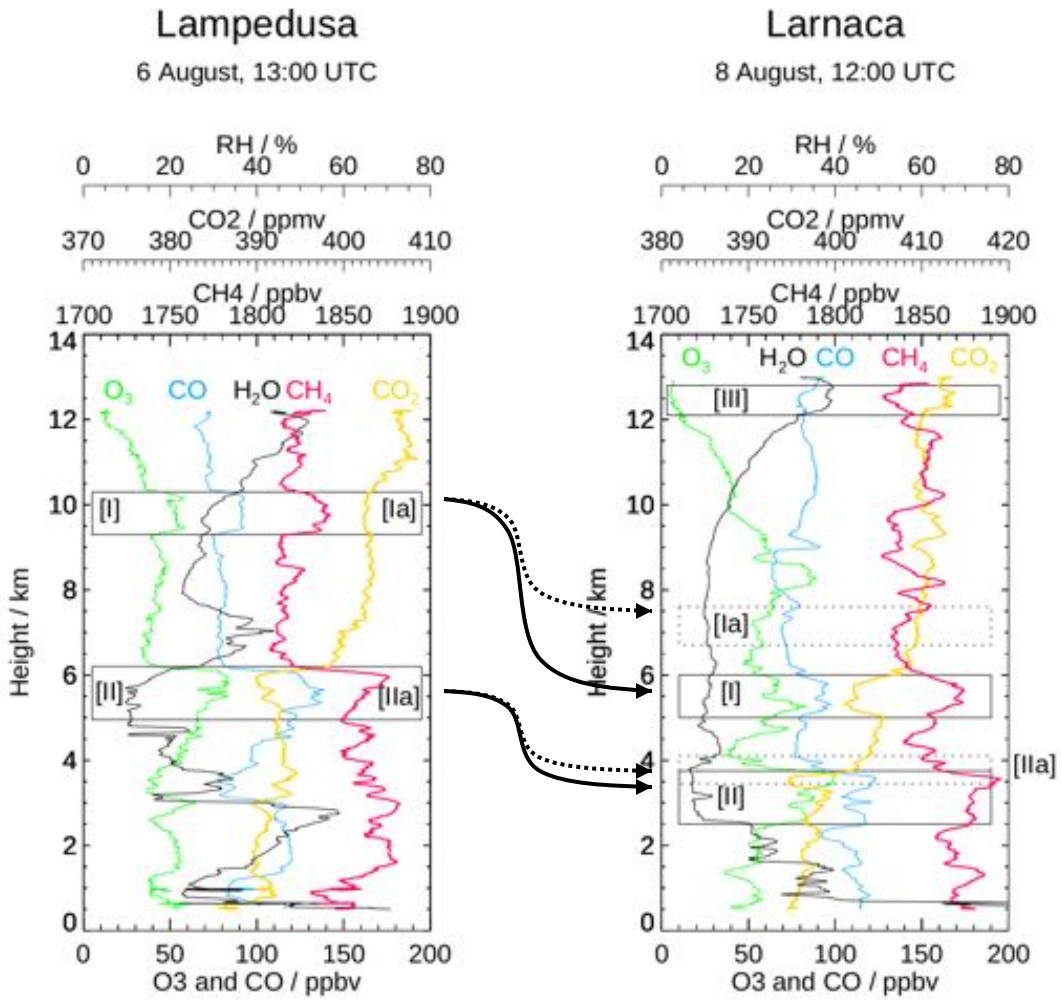


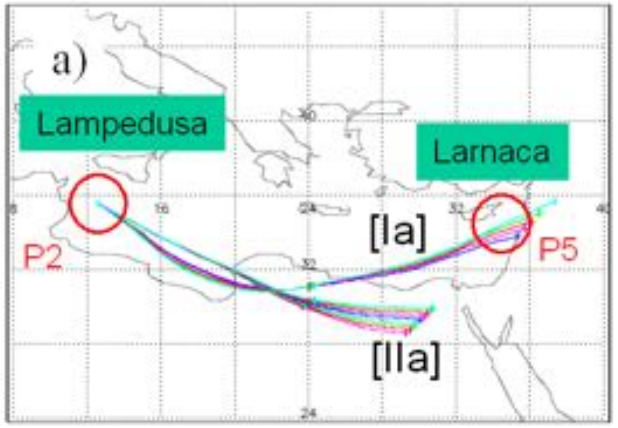

CO2: GLAM-CAMS consistent variability, with a +10 ppmv GLAM difference vs. CAMS

CH4: More variability in GLAM vs. CAMS

West-East Gradients are OK in Flights F2 and F3 but not in F4 (Heraklion-Larnaca)

# Subsidence




$\Omega_{GLAM}$ (I) ~ 2.5 cm s$^{-1}$

$\Omega_{GLAM}$ (II)~ 1.4 cm s$^{-1}$

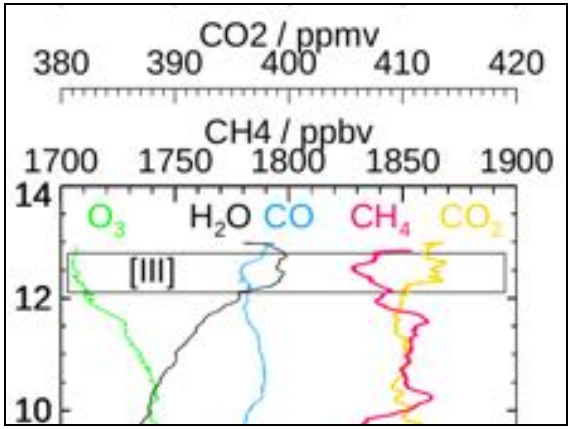
GLAM

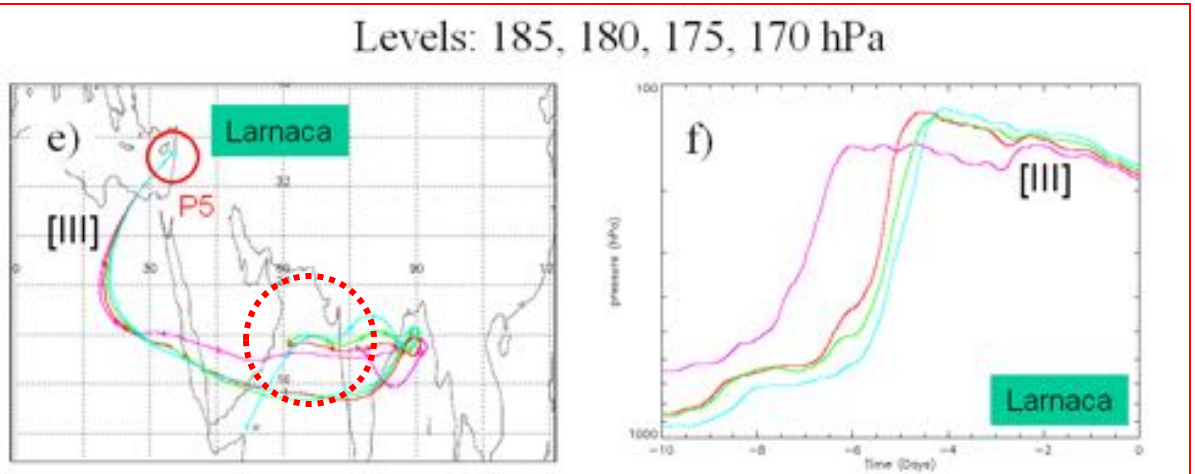
ECMWF

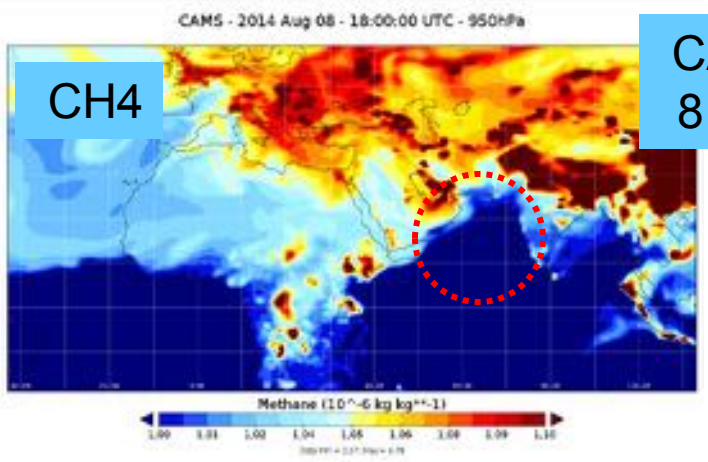
Mean subsidence rates consistent with meteorological data but some inconsistencies in forward trajectories and/or instantaneous subsidence rates

# Asian Monsoon Anticyclone & Arabian Sea Impact on the Eastern MB

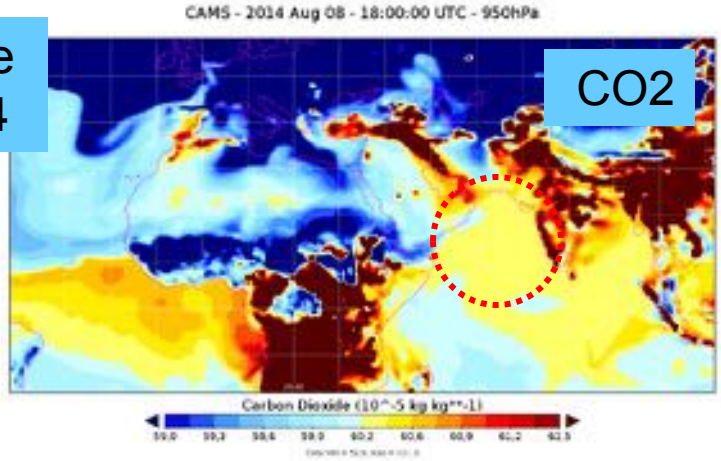
Larnaca 8 August 2014



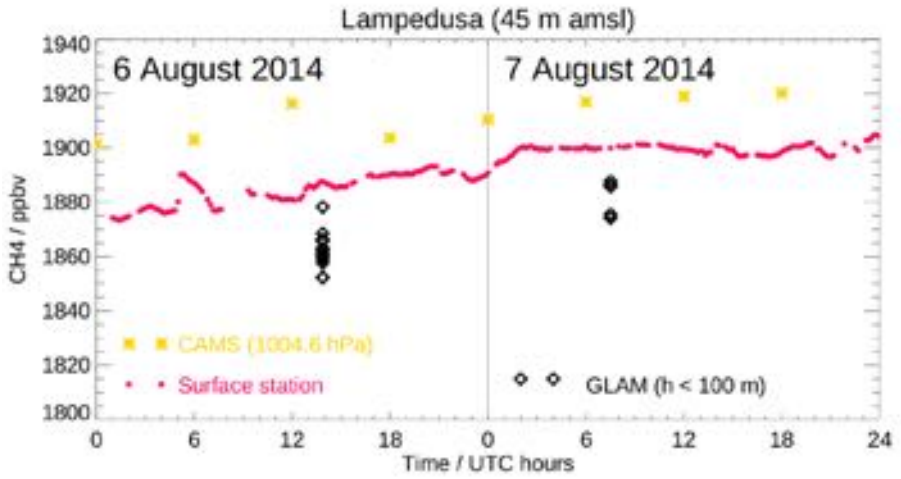




CAMS Surface 8 August 2014

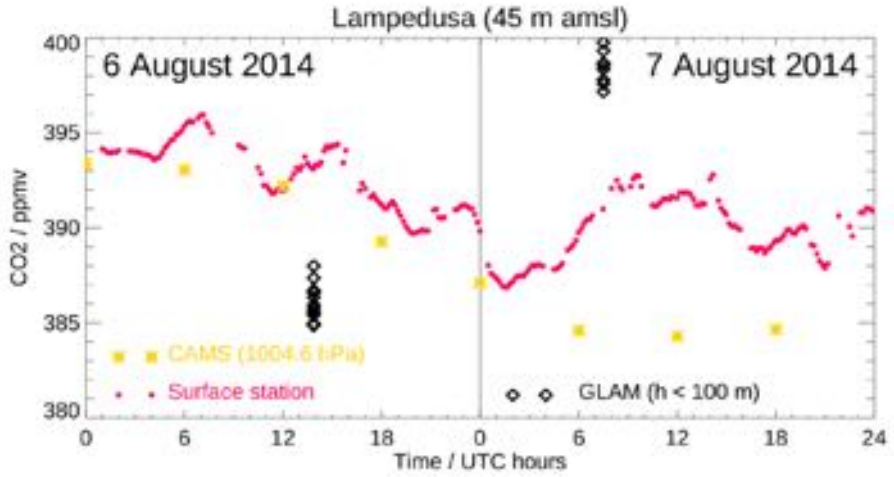



Impact of the Maritime Boundary Layer of the Arabian Sea to the Eastern Med UT via the Asian Monsoon Anticyclone: low CH4 and high CO2

# Surface Station (Lampedusa)




CH4




CO2

CH4: slight underestimation of GLAM vs. surface station (-20 ppbv, -1%), whilst CAMS overestimates vs. surface station (+20 ppbv, +1%)

CO2: no real conclusions, depends on the date considered

# Conclusions


- The GLAM airborne campaign
  - Intercontinental transport (N. American Fires, Arabian Sea)
  - Subsidence
  - East-West Variability
  - Surface stations
- Manuscript submitted to ACPD “Overview of the GLAM campaign”