THE GLAM* AIRBORNE CAMPAIGN ACROSS THE MEDITERRANEAN BASIN

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*GLAM = Gradient in Longitude of Atmospheric constituents above the Mediterranean basin
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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.

- In terms of anthropogenic pollution sources, the Mediterranean is at the confluence of three continents (Europe, Africa and Asia) and the impact of these distinct continental sources as the industrial and densely populated coastal areas or the forest fires is still not fully understood, especially on the ozone ($O_3$) and carbon monoxide (CO) budgets in which methane ($CH_4$) interplays through complex reactions with nitrogen oxides (NOx).

- Polluted air masses may originate from Asia, Africa and North America.

- CHARME/MISTRAL

- WP5: Variability & Trends
Motivations

Tropospheric CH$_4$ spaceborne measurements by AIRS in summer

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

East-West gradients observed and modelled over the Mediterranean Basin (MB) in summer in GHGs, as methane (CH4) and nitrous oxide (N$_2$O)

Impact of the Asian pollutants/GHGs on the Eastern MB via the Asian Monsoon and its associated Anticyclone

Ricaud et al., ACP, 2014

Kangah et al., AMTD, 2018
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 - 9000 m Flight 7 and Flight 8 from LARNACA to TOULOUSE via Lampedusa

9 km

5 km

Falcon 20
### Measured Parameters

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<tr>
<td><strong>F-20</strong></td>
<td><strong>H\textsubscript{2}O, O\textsubscript{3}, aerosol concentration &amp; size distribution (0.2-3 (\mu\text{m})), temperature, upward/ downward SW and LW radiations</strong></td>
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<tr>
<td><strong>SPIRIT</strong></td>
<td><strong>CO, CH\textsubscript{4}, N\textsubscript{2}O, CO\textsubscript{2}</strong></td>
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**SPIRIT**
Other Data sets

- CAMS / Chemical Forecast and Analyses
- ARPEGE / Meteorological Forecast
- MOCAGE / chemical compounds and aerosols
- ALADIN-Climat / aerosols
- Spaceborne observations / O3 and aerosols
- Back-trajectories from HYSPLIT and FLEXPART

- 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 Minorca, a fine size of particles is associated with high RH and no O$_3$, CH$_4$ and CO change.
Northern American Fires

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

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 although pyroconvection to the middle troposphere cannot be ruled out.
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.
Saharan dust outbursts from Africa were measured propagating in the tropics towards the Caribbean Sea. The air parcels originated from Minorca were originated from Africa then Florida before being uplifted to the upper troposphere over the Atlantic Ocean by a Warm Conveyor Belt.
On several occasions prior and during the GLAM campaign, CALIOP/CALIPSO has sampled smoke over Northern Atlantic and dust away from Florida, as on 5 August 2014, consistently with MOCAGE.
The Saharan dust outburst detected by SEVIRI propagating from Africa to the Mediterranean Basin on 10 August is mainly concentrated below 5 km.
Aerosol Profiles

GLAM and surface Lidar aerosol profiles are consistent
Asian Monsoon Anticyclone & Arabian Sea
Impact on the Eastern MB

Impact of the Maritime Boundary Layer of the Arabian Sea to the Eastern Med UT via the Asian Monsoon Anticyclone: low $O_3$, CO and CH$_4$, high H$_2$O and CO$_2$
Synthesis

- The GLAM airborne campaign
  - Intercontinental transport
  - East-West Variability
  - Surface stations

- Proposed new airborne campaigns focussed on the link between the Eastern Mediterranean and the Arabian Sea
COSAC: Continental and Oceanic Sources of pollutants, greenhouse gases and aerosols in the Arabian sea Corridor

4-yr project submitted to the French ANR
600 k€ budget
Source, Transport & Ageing
Pollutants, GHGs and Aerosols
Airborne campaign
  Falcon 20
  August 2020
  Toulouse (France) to Duqm (Oman)
  Instruments SPECIES and SPIRIT
  Aerosol Lidar
Surface measurements in Oman and in Cyprus
Modelling & Satellite

WRF Chem Model
Planetary Boundary Layer in Oman and the Arabian Sea
Upper Troposphere in Cyprus
O₃, CO, NO₂, NOₓ, HNO₃, NH₃, H₂CO, OCS
CO₂, CH₄, H₂O and N₂O
Aerosols (radius < 20 um)
COSAC Collaborations

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