Aerosol direct radiative forcing in the shortwave at a regional scale over the western Mediterranean : airborne observations and RTM simulations

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Scientific objective

What are the Aerosol Direct Radiative Forcings (ΔF)
in the shortwave:

at the **surface** (ΔF_{BOA})

at the **top** (ΔF_{TOA})

and **inside** the atmosphere (ΔF_{ATM})

in the western Mediterranean during ADRIMED ?

Motivation

ΔF in the Mediterranean:

- significant values for different aerosol types
- high spatial and temporal variabilities
- only a few studies with airborne observations

Strategy of the study

ADRIMED field campaign (June 2013)

Airborne observations (ATR-42)

→ data for GAME inputs

→ aircraft pyranometers: downward and upward SW fluxes

↕ **observations vs simulations**

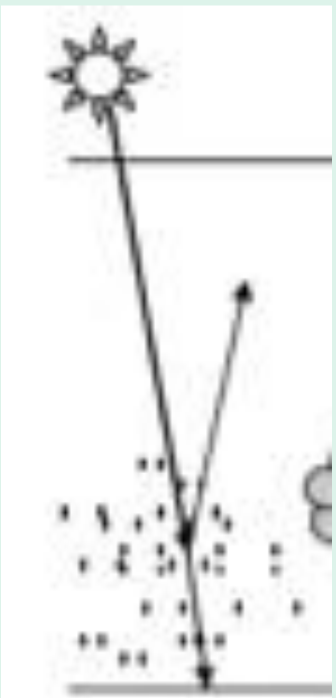
Radiative Transfer Model (GAME)

→ GAME outputs: downward and upward SW fluxes

↳ ΔF_{BOA}, ΔF_{TOA} and ΔF_{ATM}

Methodology: radiative transfer calculations

Input GAME parameters



solar incident flux

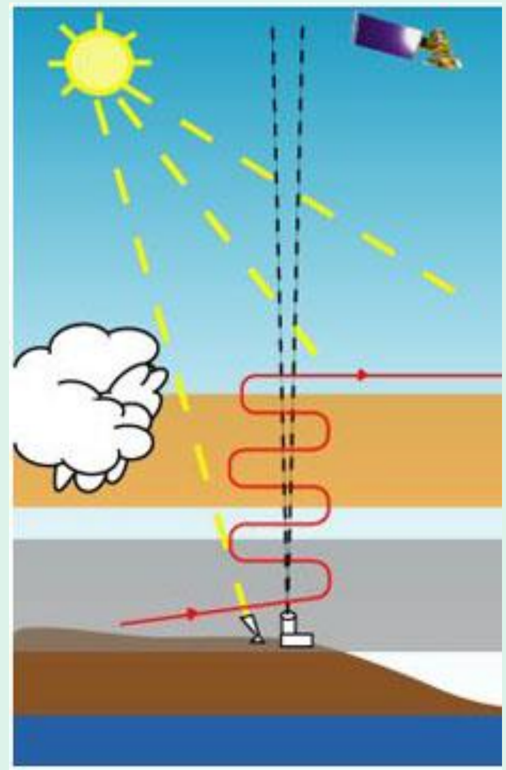
vertical profiles

- aerosol optical properties at 7λ (AOD, ω_o, g)

- atmospheric parameters (T, P, RH, O_3)

surface albedo

Data from



solar zenithal angle

instrumented aircraft

(ATR42 SAFIRE)

Ground: AERONET

Sea: Jin et al. (2004) table

Instrumentation of the aircraft

(ATR42)

Aerosols

1. Optical coefficients

CAPS	σ_{ep} at 530 nm	
3-λ nephelometer	σ_{sp} and σ_{bsp} (450, 550, 700 nm)	

→ **AOD, ω_o, g** **(but only at a few wavelengths)**

↓

2. Aerosol size distribution

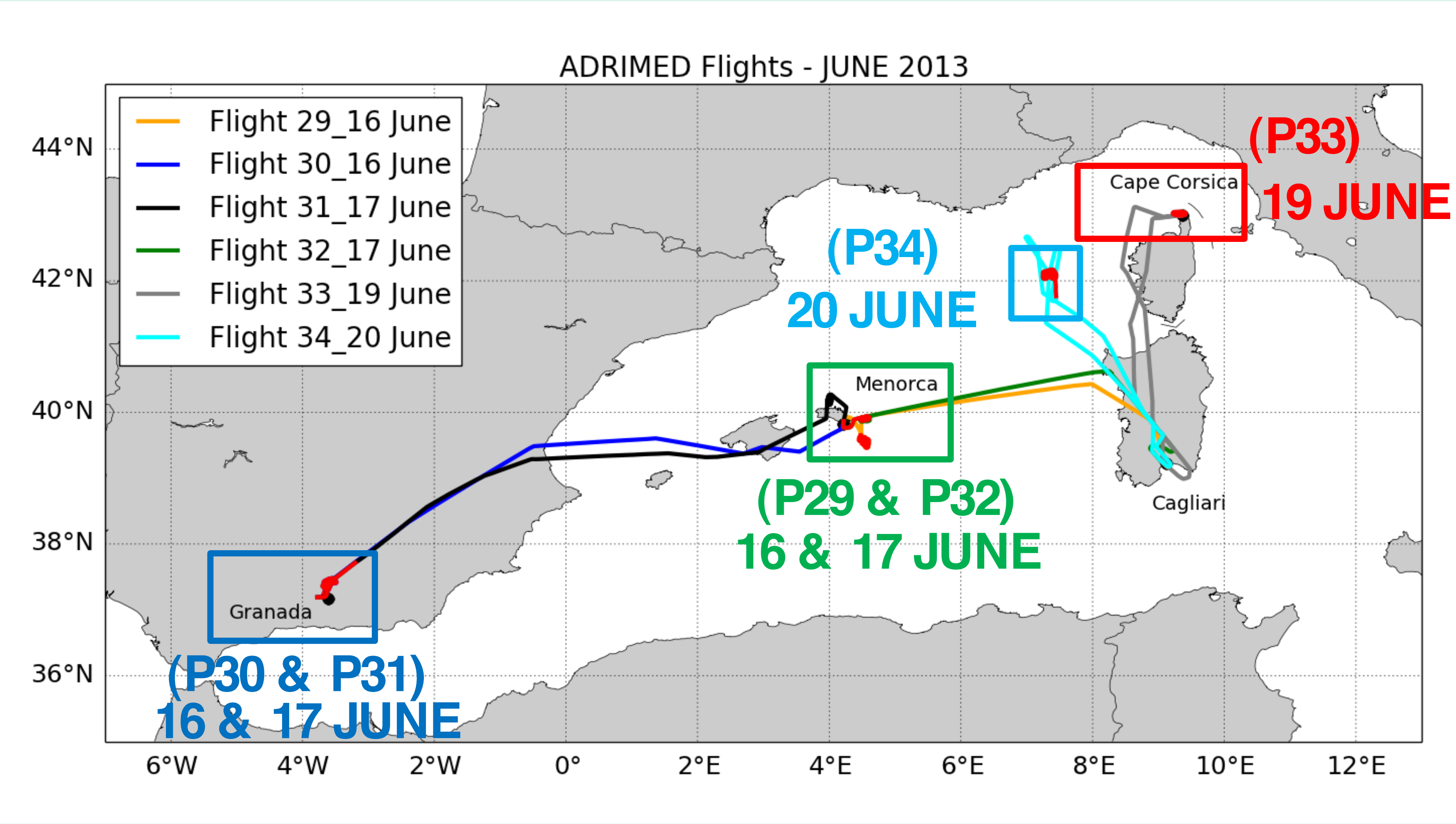
UHSAS	99 channels, 40-690 nm	
OPC GRIMM	30 channels, 0.25-32 µm	

→ **Mie at the 7λ (450 to 2130 nm)**

Downward and upward fluxes

2 SW pyranometers placed above and below the aircraft (0.285-2.8 µm)

ADRIMED vertical profiles in the western basin

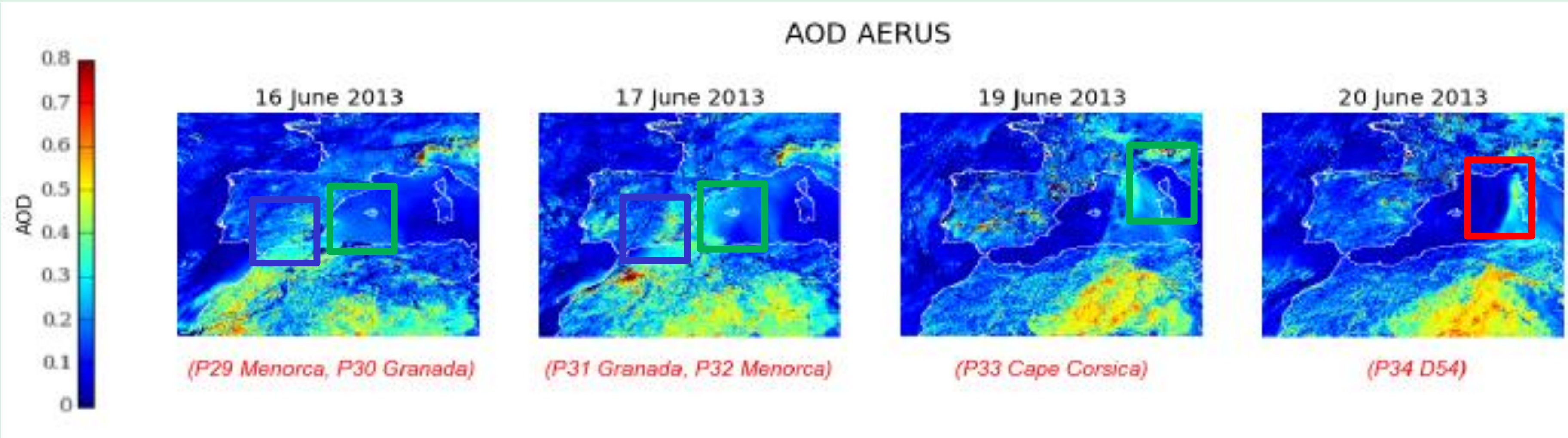


6 vertical profiles (until 5 km) :

2 GRANADA, 2 MENORCA, 2 CORSICA

AOD conditions

16-20 June 2013: dust outbreaks in the western basin



AOD_{440} 0.27 0.18 0.23 0.20 0.19 0.50

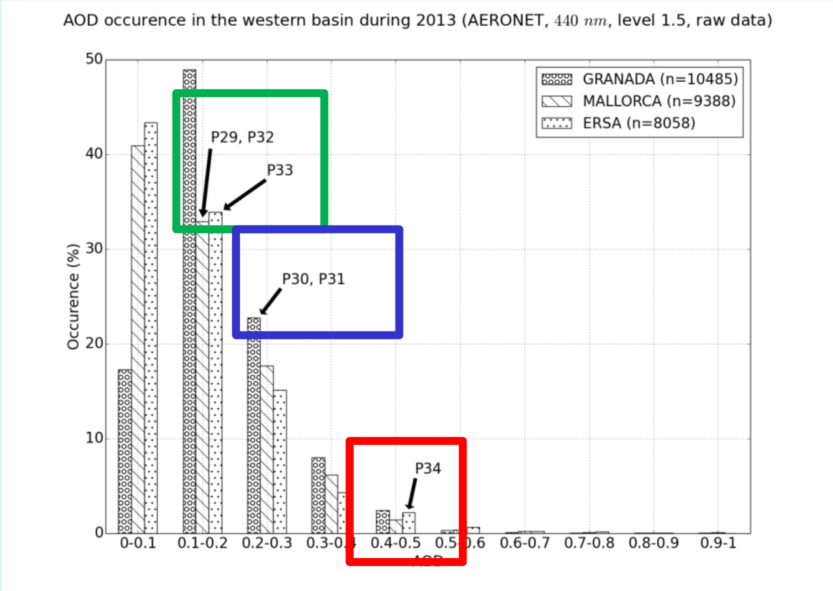
Moderate AOD levels

P29, P32, P33: 1/3 of 2013 cases

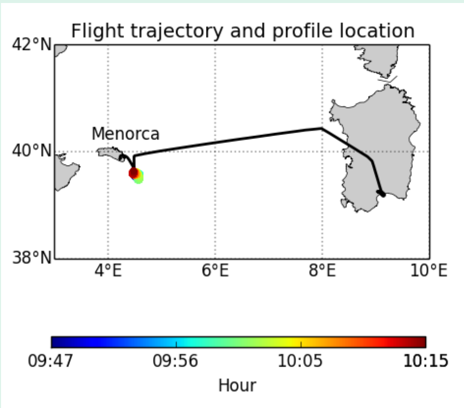
P30, P31: 1/4 of 2013 cases

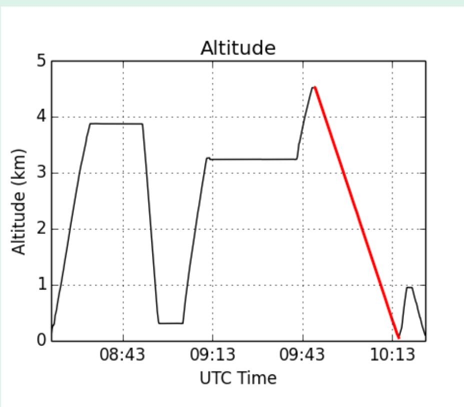
1 high AOD case

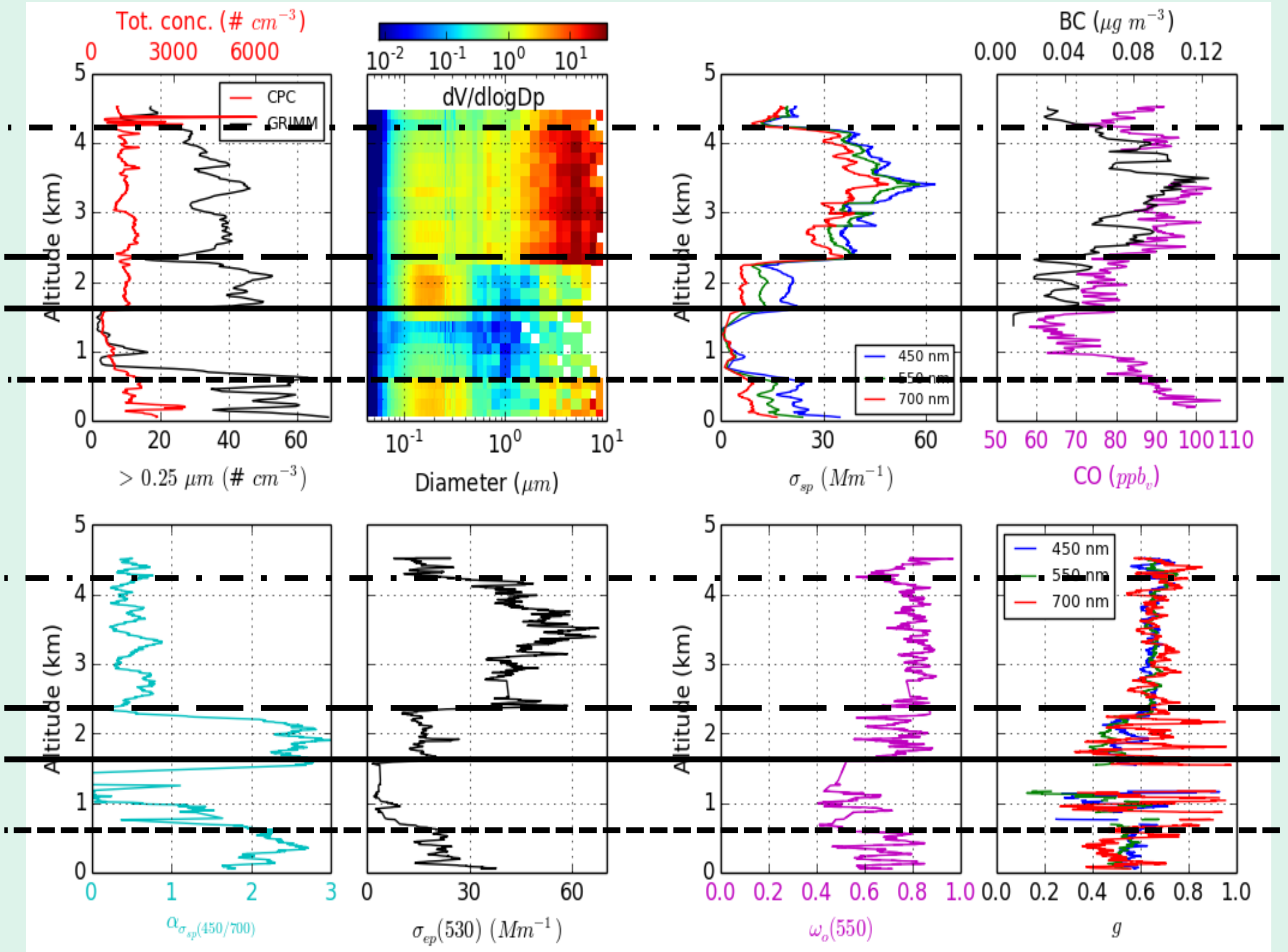
P34: 2% of 2013 cases



Results: AIRBORNE observations (e.g. P29)

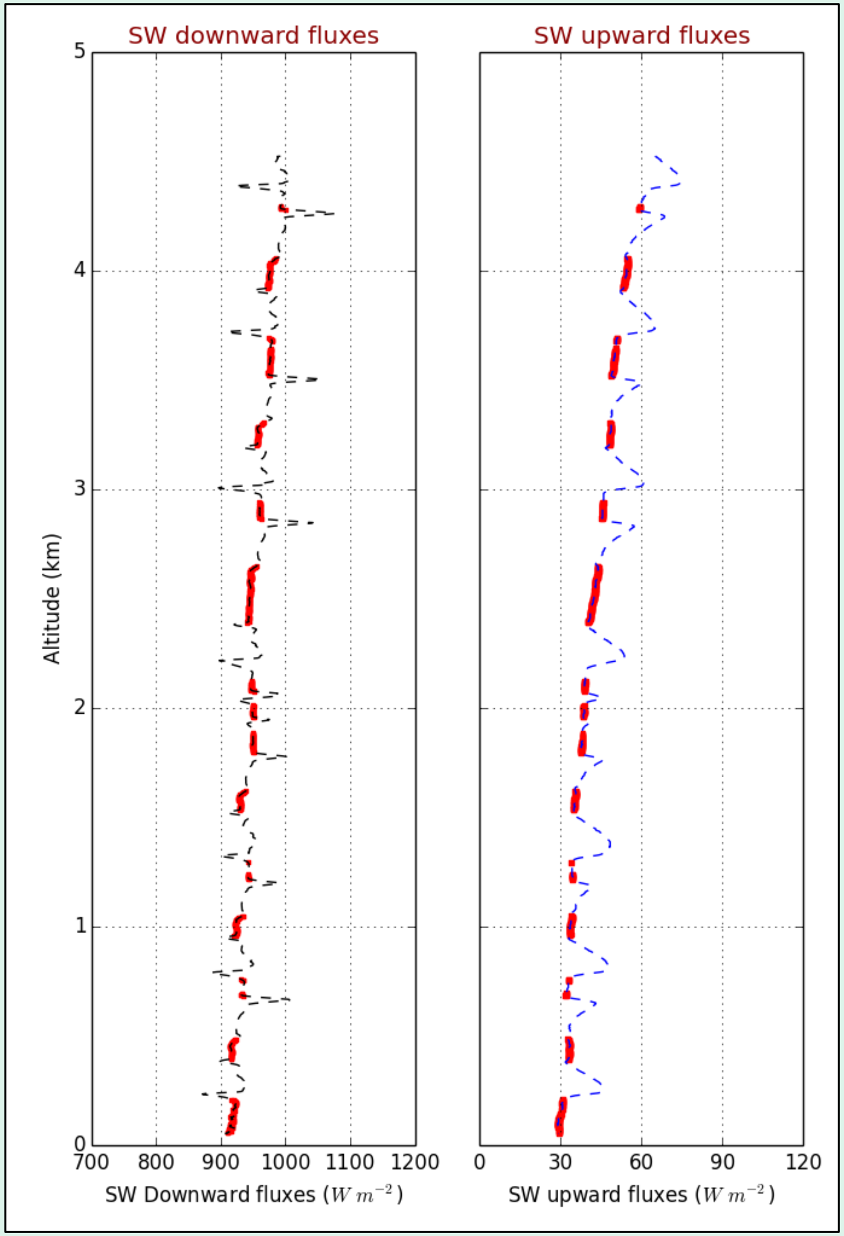




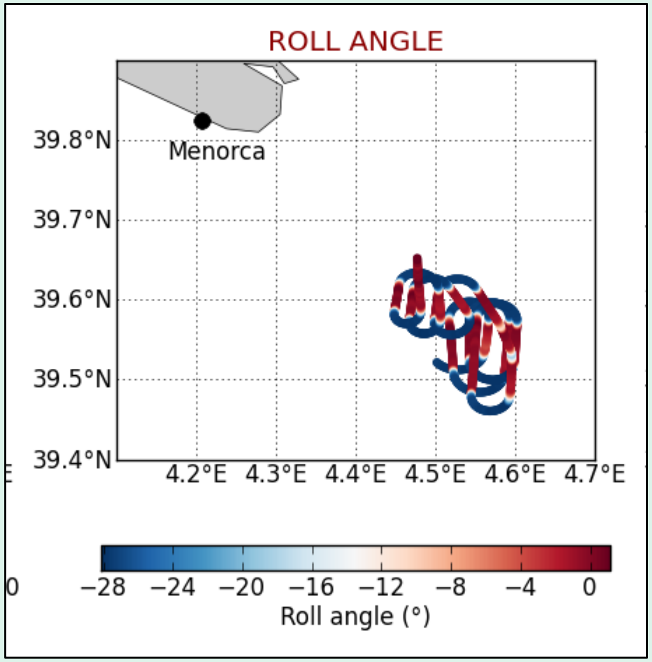


Profile	$å_{\sigma_{sp}}$	$å_{\sigma_{ep}}$	AOD		ω_o		g	
ID	$OBS_{450/700}$	$AER^{(level)}_{440/675}$	OBS_{450}	$AER^{(level)}_{440}$	OBS_{450}	$AER^{(level)}_{440}$	OBS_{450}	$AER^{(level)}_{440}$
29	0.90	$0.86\ (\pm 0.06)^{(2.0)}$	0.14	$0.18\ (\pm 0.00)^{(2.0)}$	0.83	$0.96(\pm 0.02)^{(1.5)}$	0.63	$0.67(\pm 0.01)^{(2.0)}$

Results: observed fluxes (P29)

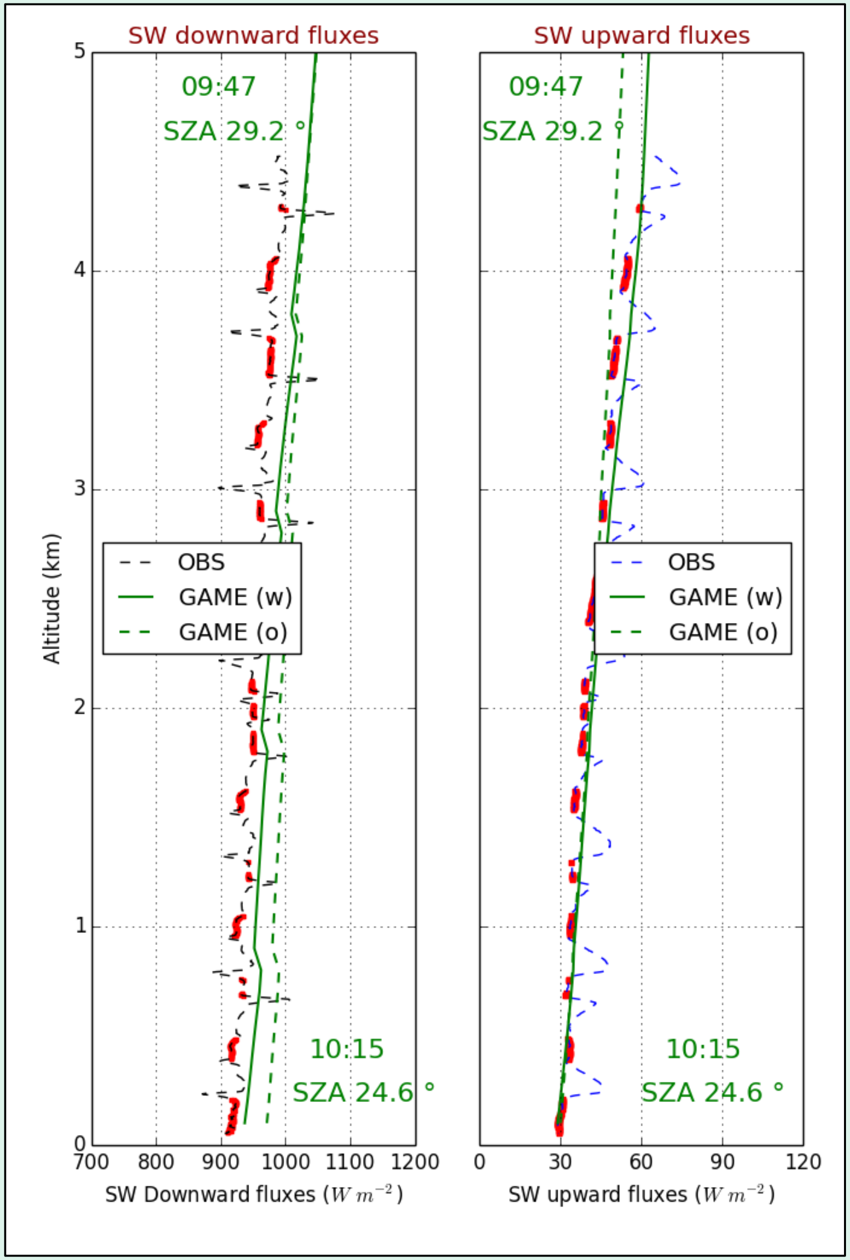


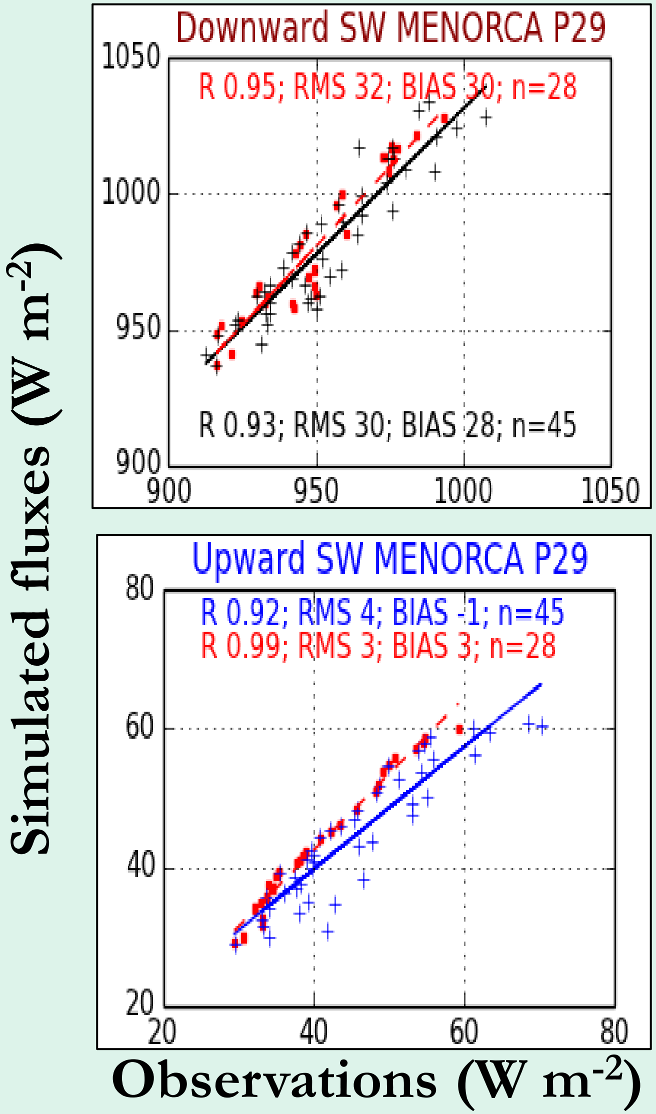
Aircraft trajectory



Red dots:
only flux data got with an horizontal aircraft (roll angle < 1° and pitch angle < 2°)

Results: GAME simulations & observations (P29)





Correct agreement between simulations and observations

Direct Radiative Forcings (ΔF_{BOA}, ΔF_{TOA}, ΔF_{ATM})

Profile ID	alb_{870}	SZA °	$å_{\sigma_{sp}}$	$AOD(450)$	$\omega_o(450)$	$g(450)$	ΔF_{BOA} ($W m^{-2}$)	ΔF_{TOA} ($W m^{-2}$)	ΔF_{ATM} ($W m^{-2}$)
29 (sea)	0.02	27	0.90	0.14	0.83	0.63	−33.2	−9.6	+23.6
30 (land)	0.27	32	0.50	0.25	0.86	0.66	−18.9	−4.2	+14.7
32 (sea)	0.03	17	0.53	0.16	0.79	0.63	−44.3	−9.5	+34.8
33 (sea)	0.02	28	1.68	0.14	0.89	0.67	−24.0	−12.2	+11.8
34 (sea)	0.03	23	0.29	0.56	0.88	0.70	−87.0	−33.0	+54.0

cooling at the surface and at the top of the atmosphere
heating inside the atmosphere

Highest values for P34 with highest AOD

Forcing Efficiencies (FE_{BOA}, FE_{TOA}, FE_{ATM})

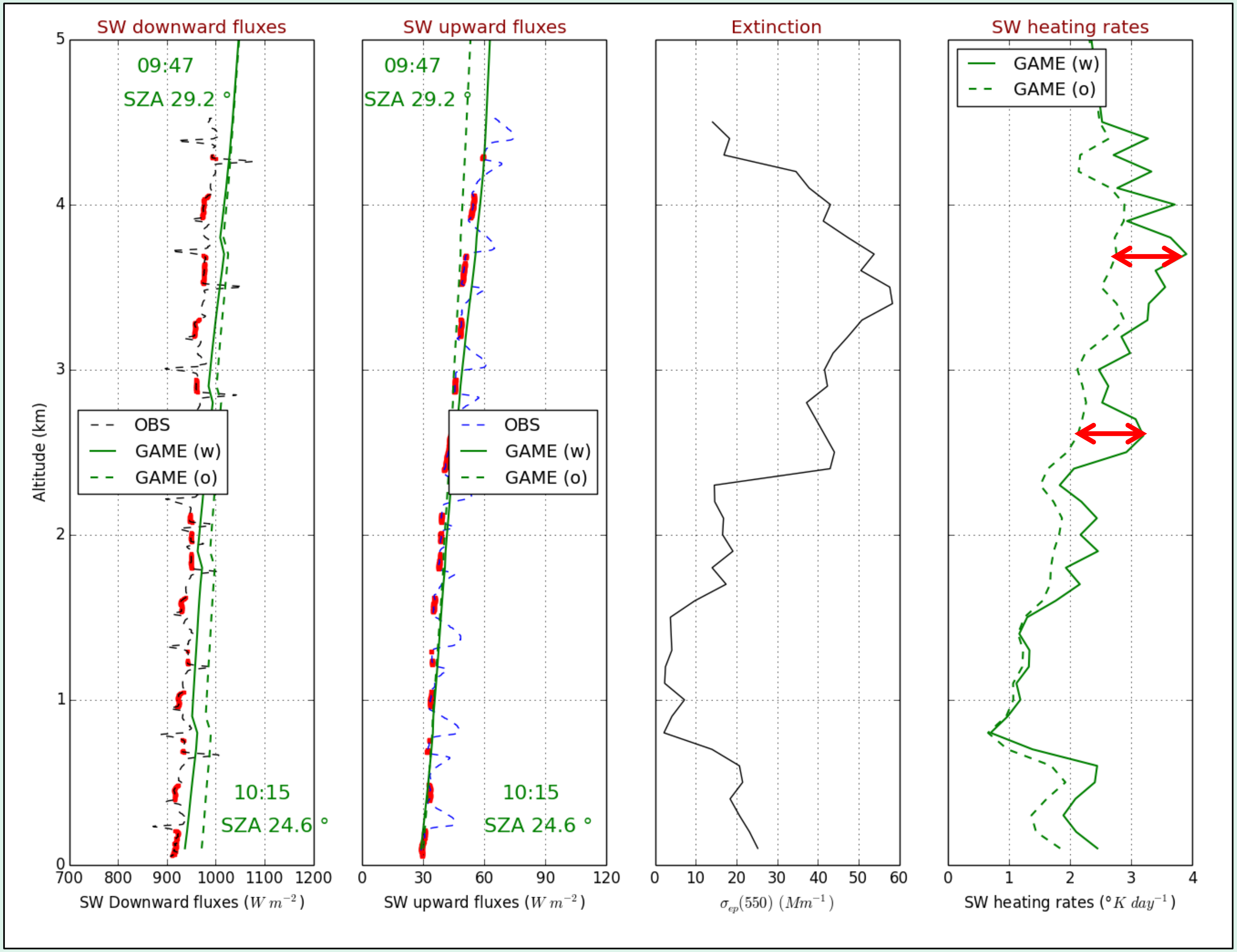
Profile ID	alb_{870}	SZA $^\circ$	$å_{\sigma_{sp}}$	$AOD(450)$	$\omega_o(450)$	$g(450)$	$\triangle F_{BOA}$ ($W m^{-2}$)	$\triangle F_{TOA}$ ($W m^{-2}$)	$\triangle F_{ATM}$ ($W m^{-2}$)	FE_{BOA} ($W m^{-2} AOD^{-1}$)	FE_{TOA} ($W m^{-2} AOD^{-1}$)	FE_{ATM} ($W m^{-2} AOD^{-1}$)
29 (sea)	0.02	27	0.90	0.14	0.83	0.63	−33.2	−9.6	+23.6	−239.8	−69.4	+170.3
30 (land)	0.27	32	0.50	0.25	0.86	0.66	−18.9	−4.2	+14.7	−75.5	−16.8	+58.7
32 (sea)	0.03	17	0.53	0.16	0.79	0.63	−44.3	−9.5	+34.8	−269.1	−57.7	+211.3
33 (sea)	0.02	28	1.68	0.14	0.89	0.67	−24.0	−12.2	+11.8	−173.7	−88.3	+85.4
34 (sea)	0.03	23	0.29	0.56	0.88	0.70	−87.0	−33.0	+54.0	−154.0	−58.4	+95.6

Highest FE for the two cases of Menorca (P29 and P32)

At equivalent AOD (forcing efficiency), importance of ω_o

To investigate: heating rates

(P29)



High amount of energy absorbed inside the atmosphere

Summary

- **6 vertical profiles until ~5 km:** 2 Granada, 2 Menorca, 2 Corsica
  - 5 moderate AOD levels: between 23 and 34 % of 2013 cases
  - 1 relatively high AOD case (0.50 at 440 nm)
- **Optical parameters: observations vs AERONET**
  - Correct agreement for P29 (AOD, g), discrepancy for ω_o
- **SW Flux: observations vs GAME**
  - Correct accordance for P29
- **Clear sky radiative forcings**
  - Significant ΔF; highest values for P34
  - For equivalent AOD (forcing efficiency), importance of ω_o
  - Importance of absorbed energy inside the atmosphere (implications ?)

Perspectives

- Paper draft for ACP special issue (sent to co-authors in the following weeks)
- Quantification of heating rates
- Comparison with 3D simulations (Aladin, RegCM, Chimere, Cosmo)

Thanks to all the teams involved in this study

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