Role of thermodynamic and turbulence processes on the fog life cycle during SOFOG3D experiment

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Context and objective

Research questions

- What processes contribute to the transition from stable to adiabatic fog?
- What processes contribute to the dissipation of fog?


Flights delayed

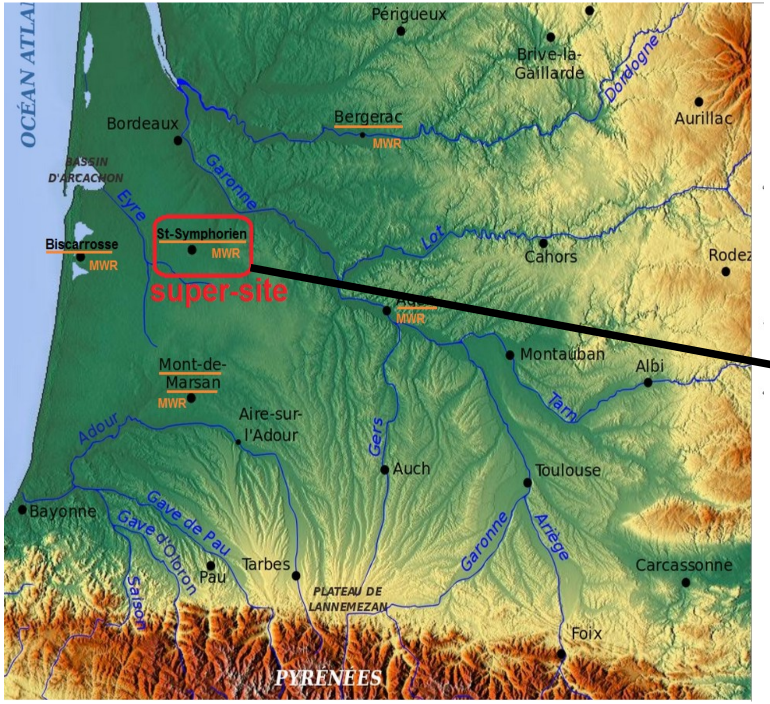

Pile-up on the Chaban bridge, Bordeaux

Tools:

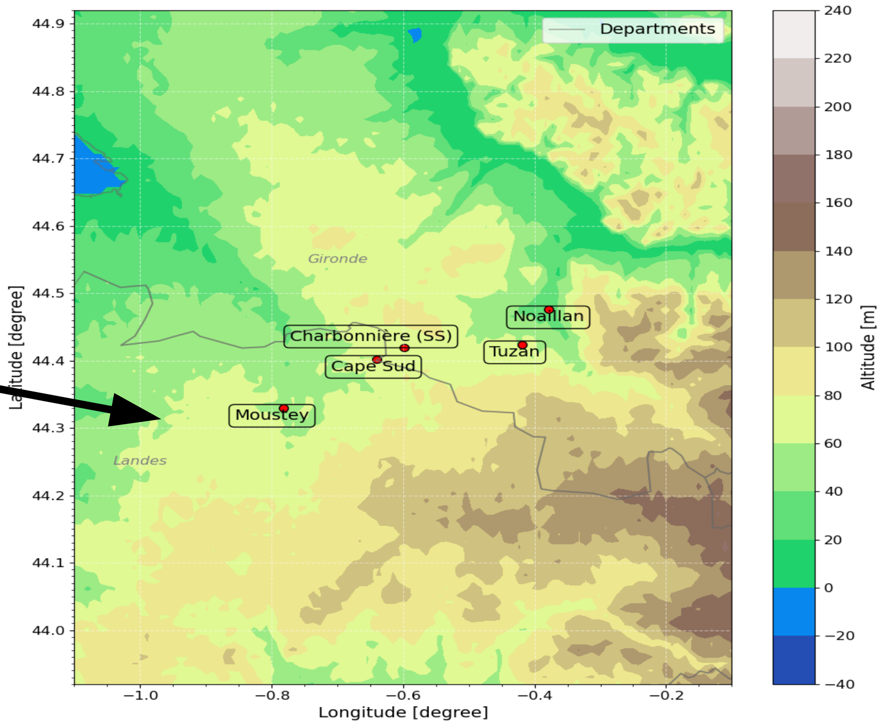
- In-situ and remote sensing measurements during SOFOG3D field campaign
- Adiabatic fog conceptual model to derive additional key fog variables unobserved

●Data and studied area

Orography of the Study area



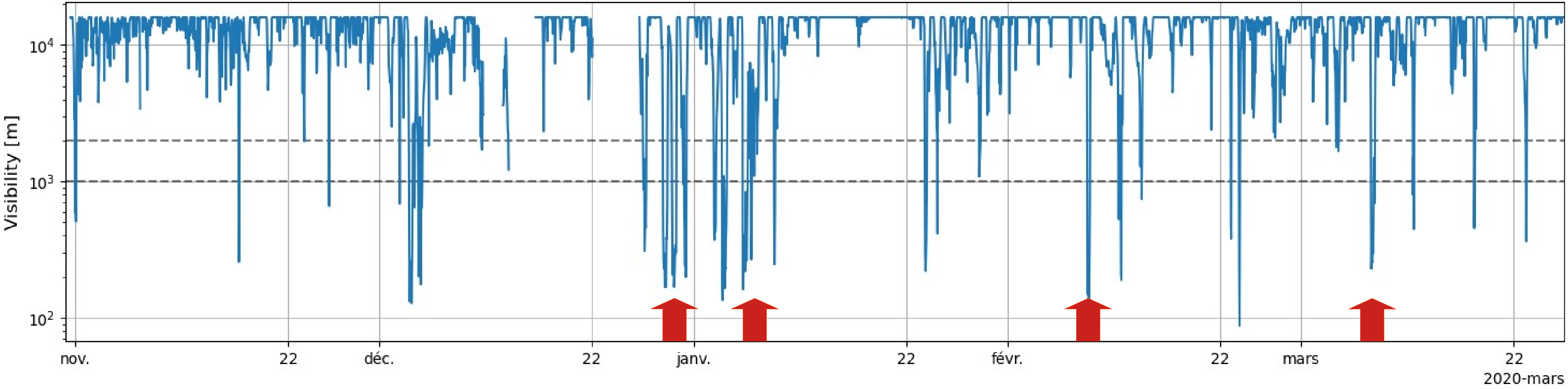
100 x 100 km around the supersite



5 weather stations around the supersite
(Visibility, temperature, wind, etc.)

Methodology

Visibility at the supersite, “La charbonnière”



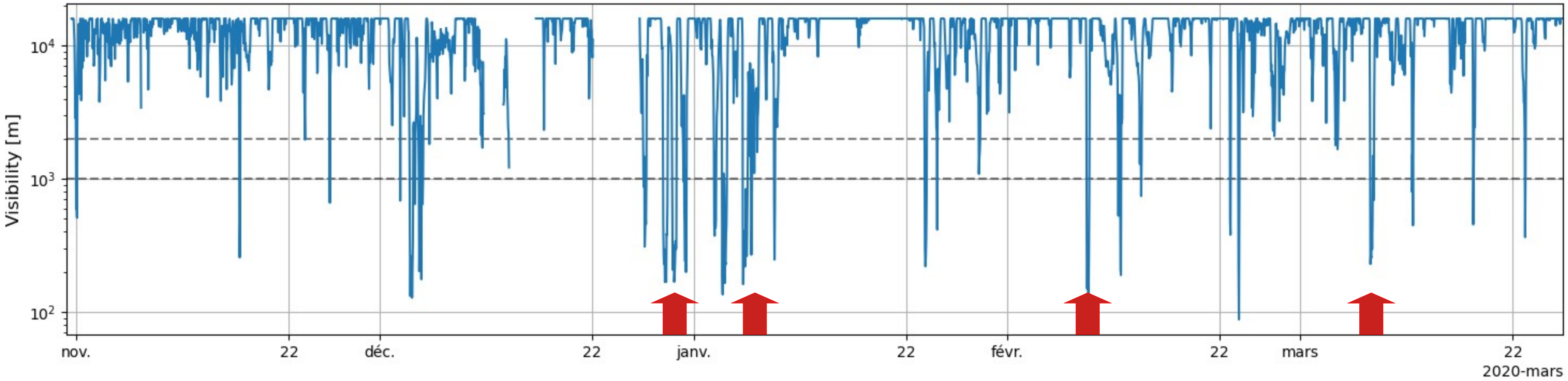
Based on *Tardif and Rasmussen (2007)*
31 fog cases observed at Charbonnière, supersite (SS)
during Nov 2019 – Mar 2020 period

4 heaviest fogs documented :

- **(2) radiation**
- **(2) radiation-advection**

Methodology

Visibility at the supersite



	Case study number	Formation time		Fog types	Dissipation time		Fog duration (hh:min)
		Date dd/mm/yyyy	Hours (UTC)		Date dd/mm/yyyy	Hours (UTC)	
Rad	IOP 5	28/12/2019	22:40	Radiation	29/12/2019	11:00	12:20
	IOP 6	05/01/2020	20:40	Radiation	06/01/2020	08:40	12:00
Rad-Adv	IOP 11	08/02/2020	20:40	Advection-radiation	09/02/2020	03:40	7:00
	IOP 14	07/03/2020	21:20	Advection-radiation	08/03/2020	04:00	6:40

Methodology

- **Remote sensing at the supersite**

Basta Mini
Cloud, fog thickness

Windcube V2
Wind & TKE

Radiometer Hatpro
LWP & stability

CL31
CBH – fog dissipation

Methodology

Fog conceptual model

In-situ and remote sensing data

T, P, visibility, LWP, CTH

Fog adiabatic conceptual model

Toledo et al., 2021

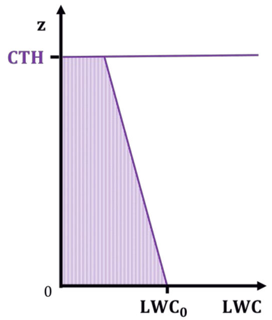
Fog key parameters:
equivalent adiabaticity &
Reservoir

Equivalent adiabaticity by closure

$$\alpha_{eq}^{closure} = \frac{2\left(LWP - LWC_0 CTH\right)}{\Gamma_{ad}\left(T, P\right) CTH^2}$$

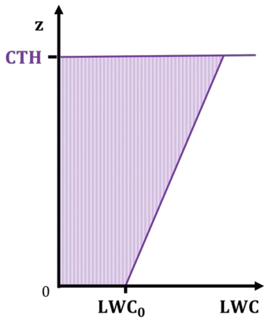
Transition from stable to adiabatic fog

$\alpha_{eq} < 0$



LWC is higher in the lower fog layers:
Shallow stable fog

$\alpha_{eq} > 0$

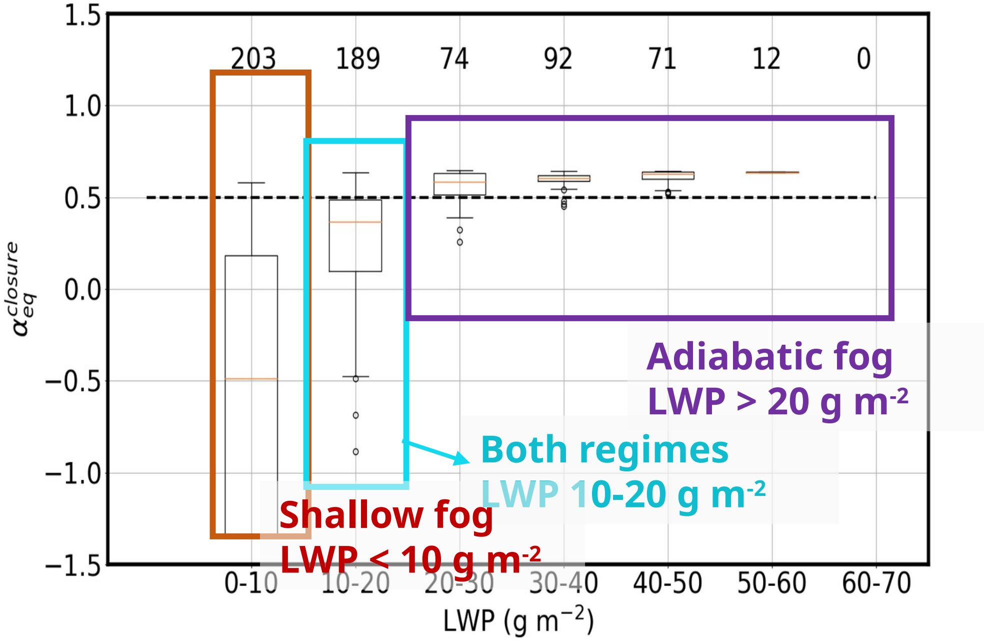


LWC increases with height
→ Adiabatic fog
→ Fog is transitioning from shallow to adiabatic

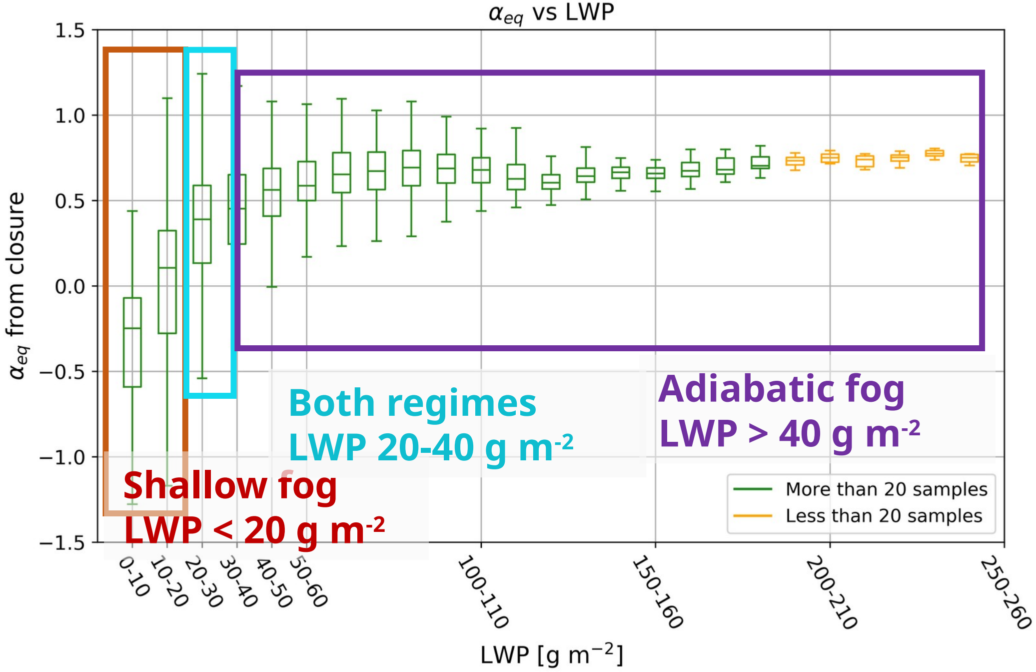
Methodology

Fog conceptual model

SOFOG3D



SIRTA



- Low fog LWP at SOFOG3D

Toledo et al., 2021

- Equivalent adiabaticity by closure consistent at both sites – used to define the transition stable/adiabatic fog

- More fog LWP at SIRTA

● Methodology

Fog conceptual model

Critical and Reservoir LWP

This defines two new variables, the **Critical LWP** (CLWP) and the **Reservoir LWP (RLWP)**

Critical LWP (CLWP)

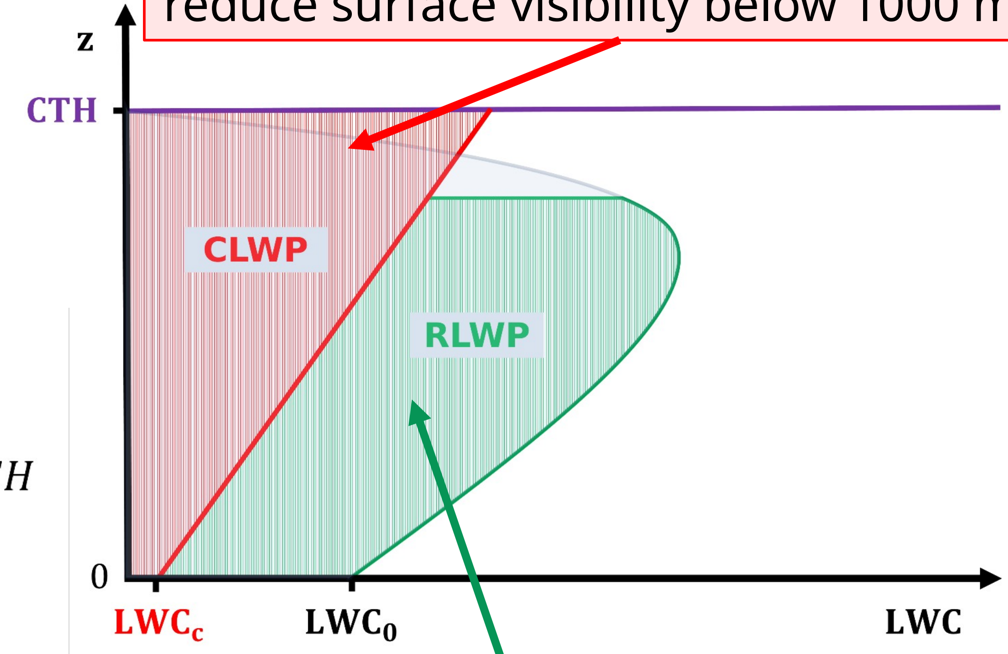
$$CLWP = \frac{1}{2} \alpha_{eq}\, \Gamma_{ad}(T,P)\, CTH^2 + LWC_c\, CTH$$

Reservoir LWP (RLWP)

$$RLWP = LWP - CLWP$$

$$RLWP = RLWP(LWP, CTH, T, P)$$

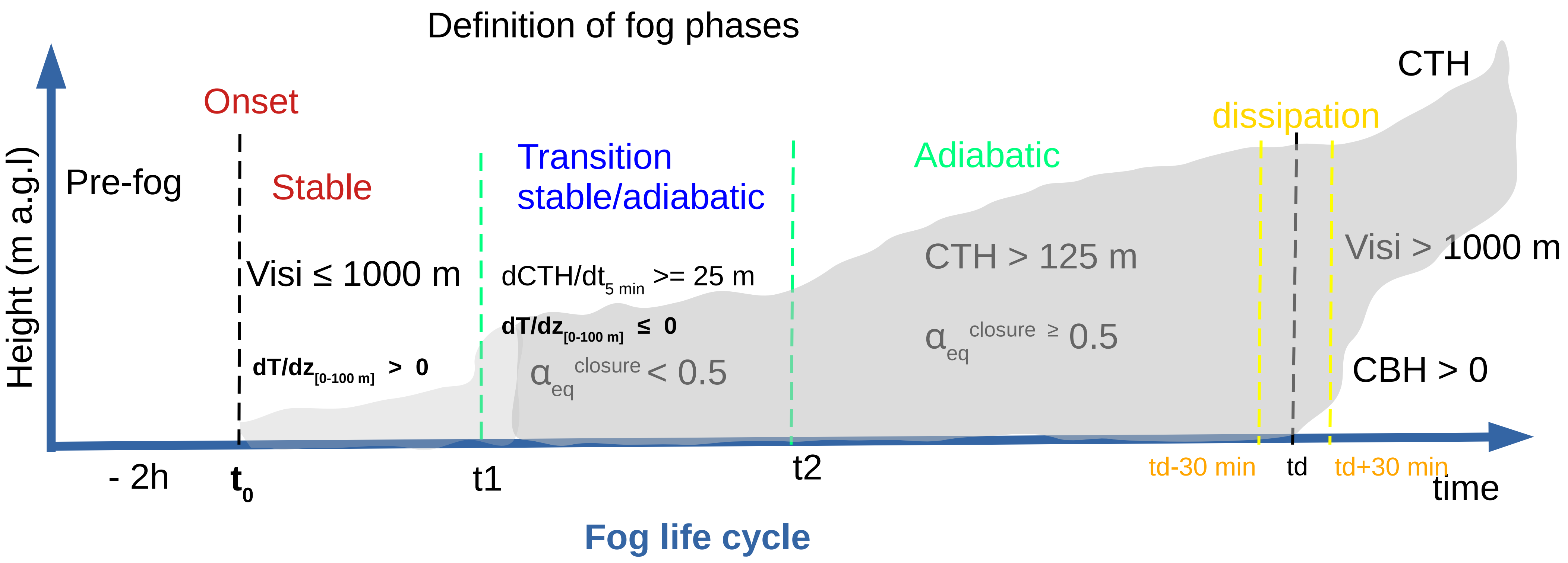
CLWP: Minimum LWP needed to fill a fog layer with a thickness of CTH, and reduce surface visibility below 1000 m



RLWP: Excess of LWP that enables fog to persist at the surface – nowcasting

Toledo et al., 2021

Methodology

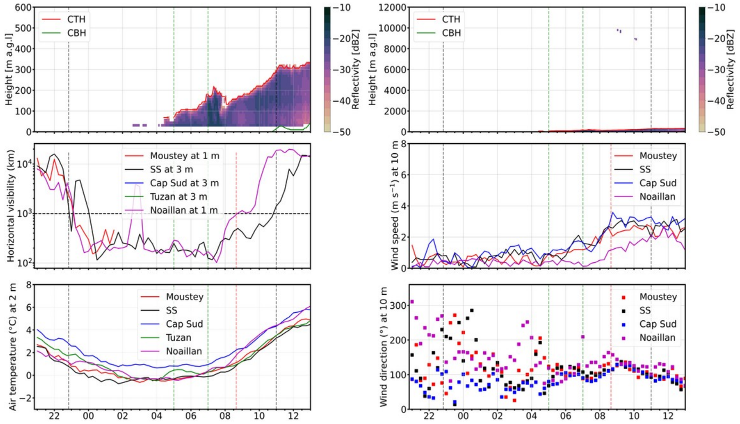


t1: start of the transition
t2: end of the transition
td: dissipation time

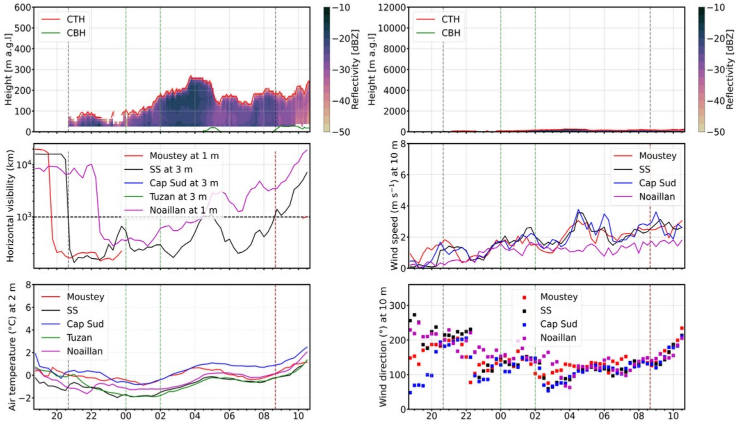
• Fog formation, evolution and dissipation processes

Rad

IOP 5



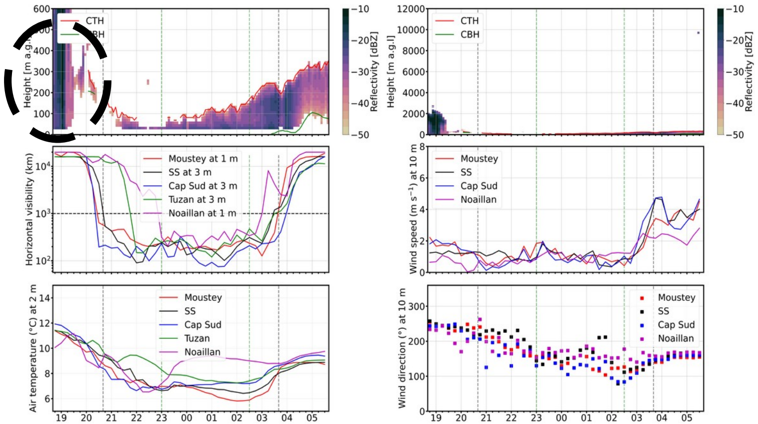
IOP 6



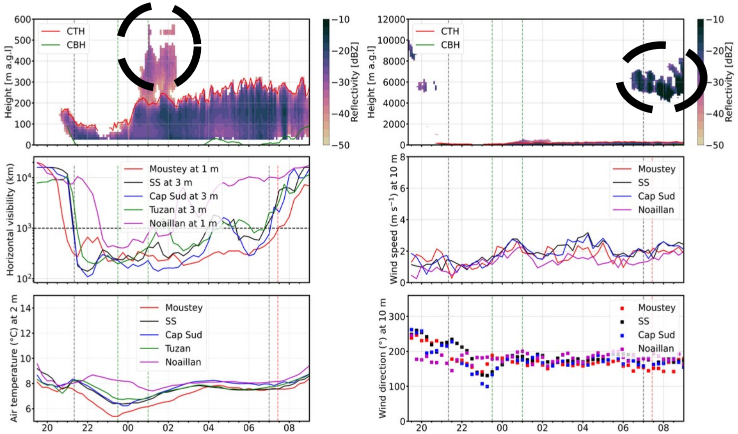
- Formation: Cloud free – East-West gradient of fog onset – low wind – cooling rate
- Transition: Increase in wind and temperature
- Dissipation: WS > 2 m/s

Rad-Adv

IOP 11



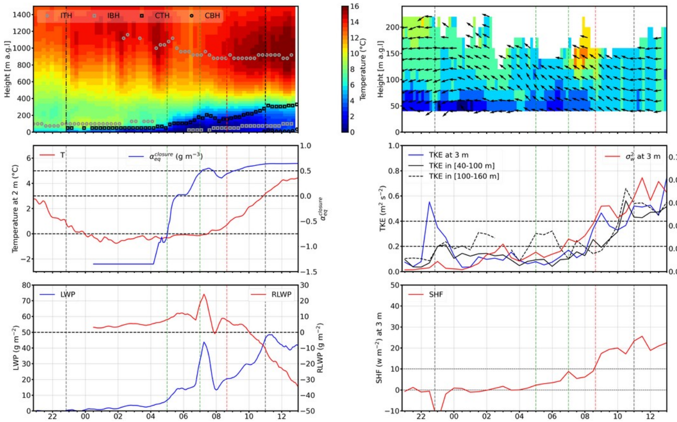
IOP 14



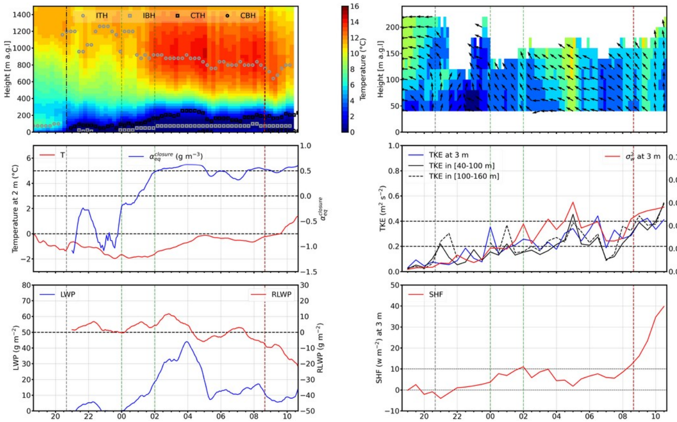
- Formation: Rain/stratus – East-West gradient – low wind – cooling rate
- Transition: Increase in wind and temperature
- Dissipation: WS > 2 m/s

• Fog formation, evolution and dissipation processes

Rad **IOP 5**

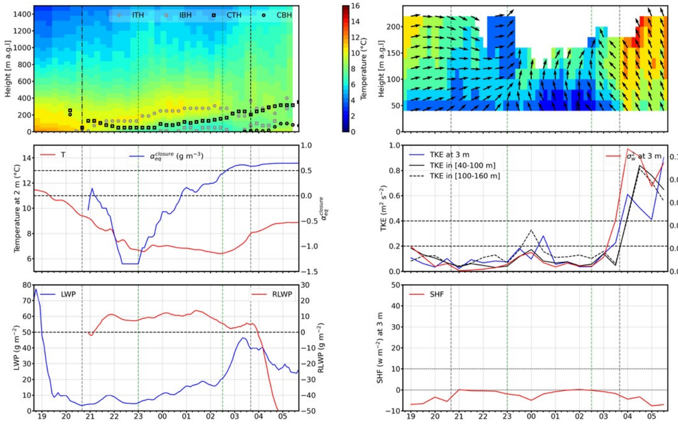


IOP 6

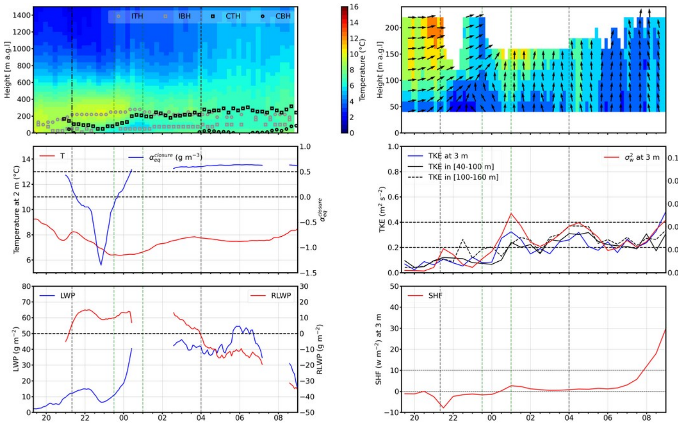


- Formation: Easterly jet – synoptic
- Stable : TKE < 0.2 $m^2 s^{-2}$ and σ_w^2 < 0.02 $m^2 s^{-2}$
- Transition stable/adiabatic (TKE [0.2 – 0.4 $m^2 s^{-2}$] and σ_w^2 [0.02 – 0.04 $m^2 s^{-2}$], SHF [0 – 10 W m^{-2}])
- Dissipation by turbulence (TKE > 0.4 $m^2 s^{-2}$ and σ_w^2> 0.04$m^2 s^{-2}$ and SHF > 10 W m^{-2}]) – thermal and mechanic – RLWP (< 0) estimated an early (1h before) dissipation

Rad-Adv **IOP 11**



IOP 14

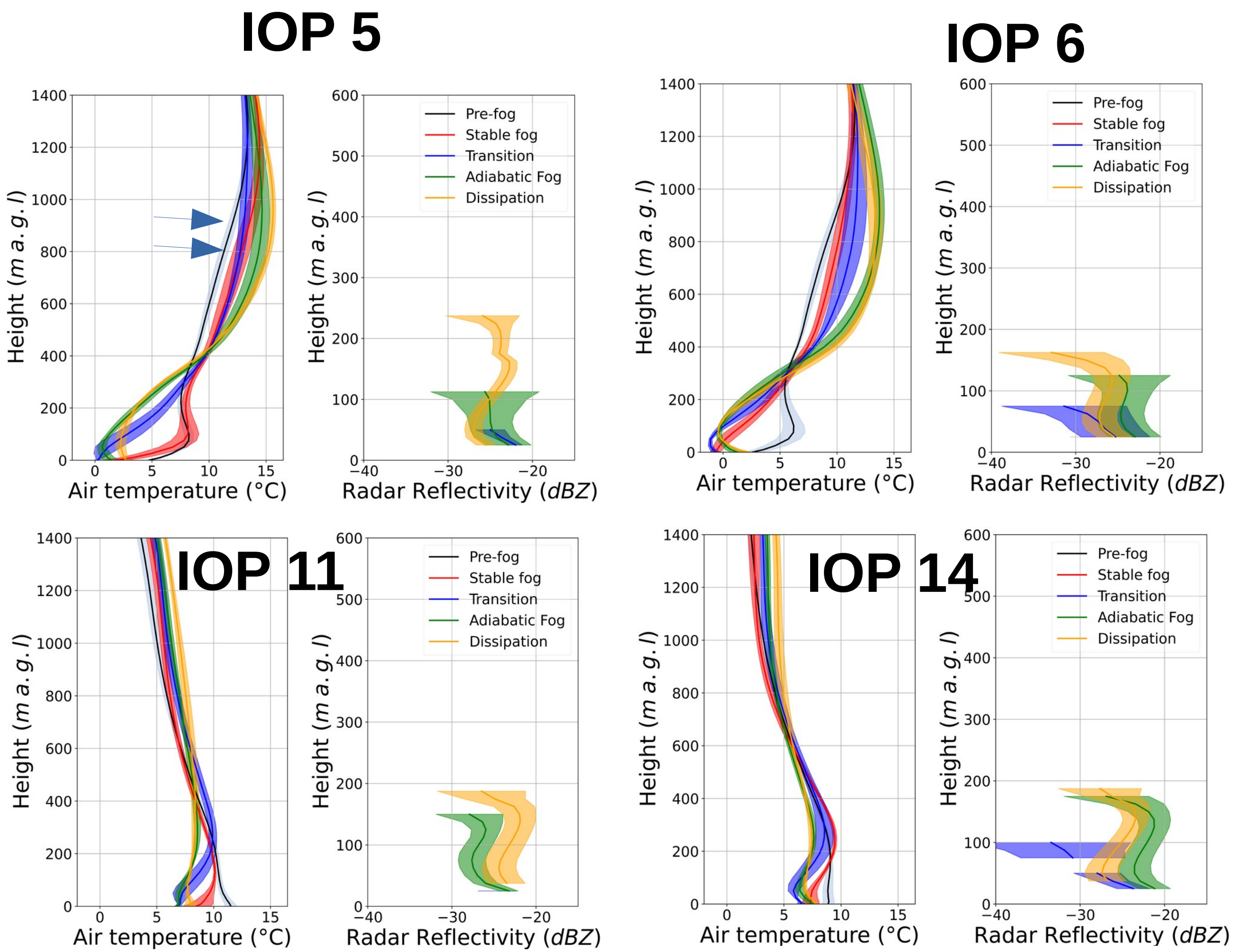


- Formation: Westerly jet (Atlantic inflow) –
- Stable : TKE < 0.2 $m^2 s^{-2}$ and σ_w^2 < 0.02 $m^2 s^{-2}$
- Transition stable/adiabatic mechanical turbulence: (TKE [0.2 – 0.4 $m^2 s^{-2}$] and σ_w^2 [0.02 – 0.04 $m^2 s^{-2}$], SHF < 0 W m^{-2}])
- Dissipation: southerly flow – turbulence (TKE ≥ 0.3 $m^2 s^{-2}$ and σ_w^2> 0.04 $m^2 s^{-2}$) – thermal and mechanic – RLWP (< 0) estimated the dissipation time

• Fog formation, evolution and dissipation processes

Rad

Rad-Adv



- Transition stable/adiabatic more marked in radiation fog – lowering of the inversion top height
- Link between temperature inversion strength and fog lifetime

Summary

- Radiation fog cases have longest lifetime (more than 12 hours) linked to very cold atmospheric conditions associated with a continental easterly nocturnal low-level jet – stable/adiabatic fog transition driven by advection (TKE [0.2 – 0.4 $m^2 s^{-2}$] and σ_w^2 [0.02 – 0.04 $m^2 s^{-2}$], SHF [0 – 10 W m^{-2}]) – dissipation in daytime by thermal and mechanical turbulence (TKE > 0.4 $m^2 s^{-2}$ and σ_w^2 > 0.04 $m^2 s^{-2}$ and SHF > 10 W m^{-2})

- Advection-radiation case studies have shortest lifetime linked to the low surface boundary layer stability due to the vertical mixing generated by the westerly strong wind –transition phase is driven by advection (TKE [0.2 – 0.4 $m^2 s^{-2}$] and σ_w^2 [0.02 – 0.04 $m^2 s^{-2}$], SHF < 0 W m^{-2}) – the dissipation phase is driven by night-time warm air advection generating mechanical turbulence (TKE at least 0.3 $m^2 s^{-2}$ and σ_w^2 > 0.04 $m^2 s^{-2}$).

- This study also demonstrates the importance of using instrumental synergy (with microwave radiometer, wind lidar, weather station, and cloud radar) and a fog conceptual model to better predict fog characteristics and dissipation time at nowcasting ranges.

Thank you for your attention

Merci pour votre attention

Questions

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