Contribution des aérosols à l'extinction du rayonnement visible dans le cycle de vie du brouillard

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SIRTA: platform hosting the ParisFog field campaign, instrumentation, and database
HYGEOS: Extraction, generation of fog and aerosol data set

PreViBOSS applied research project (10/2010 – 09/ 2013)
500 k€ financed by the RAPID scheme (DGA/DGCIS for private-public)

Data acquisition: ParisFog (3 6-month campaigns !)
Instrumentation 135 k€ (IPSL+CNRM)
12 months staff experiment and data processing 55 k€ (IPSL+CNRM)
35 months study 170 k€ (HYGEOS)

Experiment + database + exploitation

The PreViBOSS project
Objectives & approach.

Prévision de la Visibilité
dans le cycle de vie du Brouillard
à partir d'Observations Sol et Satellite

Objectives

Extension of the database 'Visibility in the fog life cycle' (SIRTA+CNRM)
Exploitation of existing satellite products (EUMETSAT/SAF) (HYGEOS)
Identification of predictors to describe & forecast visibility (few hours) (HYGEOS+IPSL+CNRM)
According various experimental set-ups and fog types (HYGEOS+IPSL+CNRM)

Observation of particle properties to improve the visibility forecast in mist and fog

statistics & particles

- Long series of data
- Variability of situations
- Quality
- Consistence of the data set:
  - spatial (unique site);
  - temporal (resolution, cover, instrumental continuity);
  - physics.

Diversity of the parameters:
- Aerosol and droplet microphysics
- Optics
- Radiative
- Vertical profile
- Satellite

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Context
Difficulties to forecast fog.

Importance to forecast fog:
danger for transport activities
+ economical impact (~ tornadoes [Gultepe *et al.*, 2007])

Difficulties:
Fog is local event, highly heterogeneous in space, which depends on synoptic conditions as well as surface conditions and local meteo

Fog prediction techniques:
- Manual: radiosonde + NWP + local surface observations
- Statistical: depends on available information
- Nowcasting: satellite imagery + surface observations [Guidard and Tzanos, 2007]
- Numerical (1D and 3D): needs fine vertical resolution near the surface, fine horizontal reso for orography, soil, water, vegetation, and many processes to model:

Processes (Gultepe *et al.* [2007] quoting Duynkerke [1991]):
« … Cooling of moist air by radiative flux divergence, mixing of heat and moisture, vegetation, horizontal and vertical wind, heat and moisture transport within soil, horizontal advection, and topographic effects; he also emphasized that atmospheric stability location, and season affect the contributions from each factor. »
« Once the fog has formed, there are additional processes affecting the fog development such as longwave radiative cooling at the fog top, fog microphysics, shortwave radiation, and turbulent mixing. »

Outline

1) Methodology and definitions

2) Validation of the particle microphysical properties

3) Contribution of several size classes to extinction in the fog life cycle

4) Relation extinction - liquid water content in fog

5) Microphysical definition of fog and mist

1. Definitions

Fog life cycle and particles.

Fog life cycle:

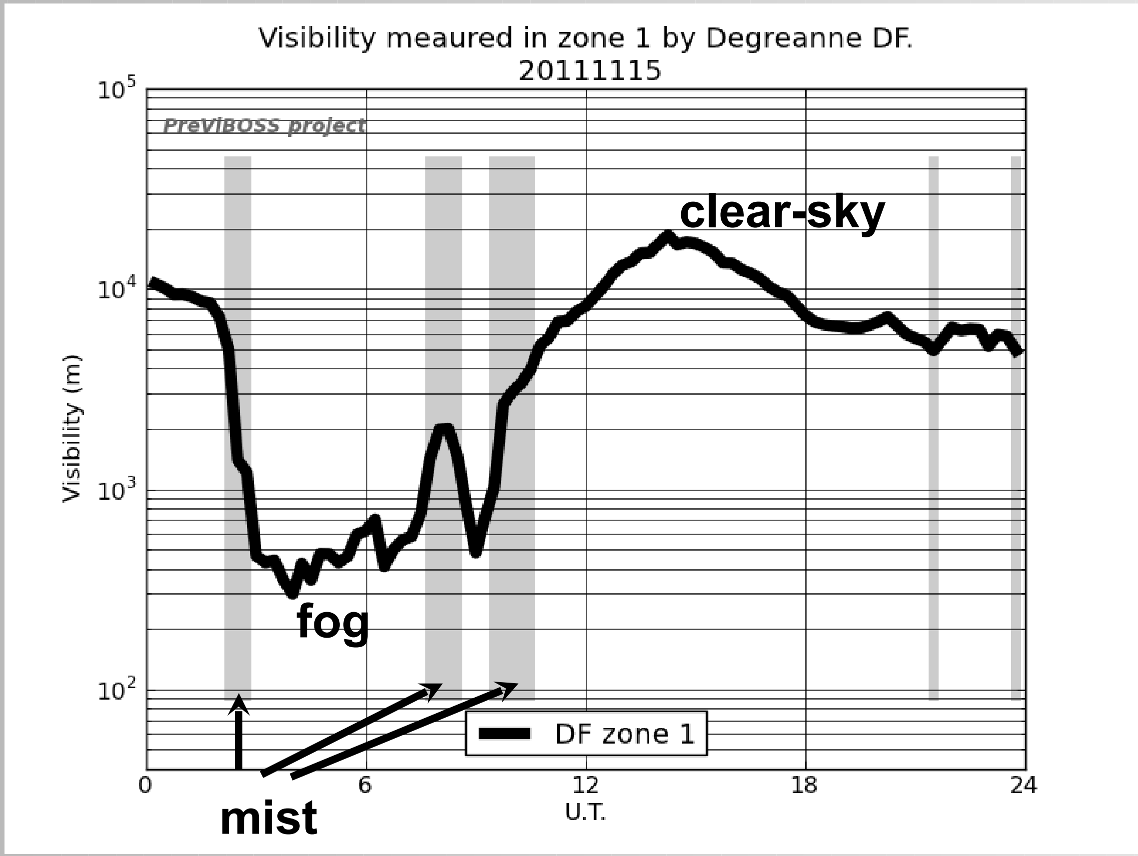
clear sky -mist – fog – mist - clear-sky

Several visibility regimes (convention):

Fog: visibility < 1000 m

Mist: 1000 < visibility < 5000 m

Clear-sky: visibility > 10 km



Particles:

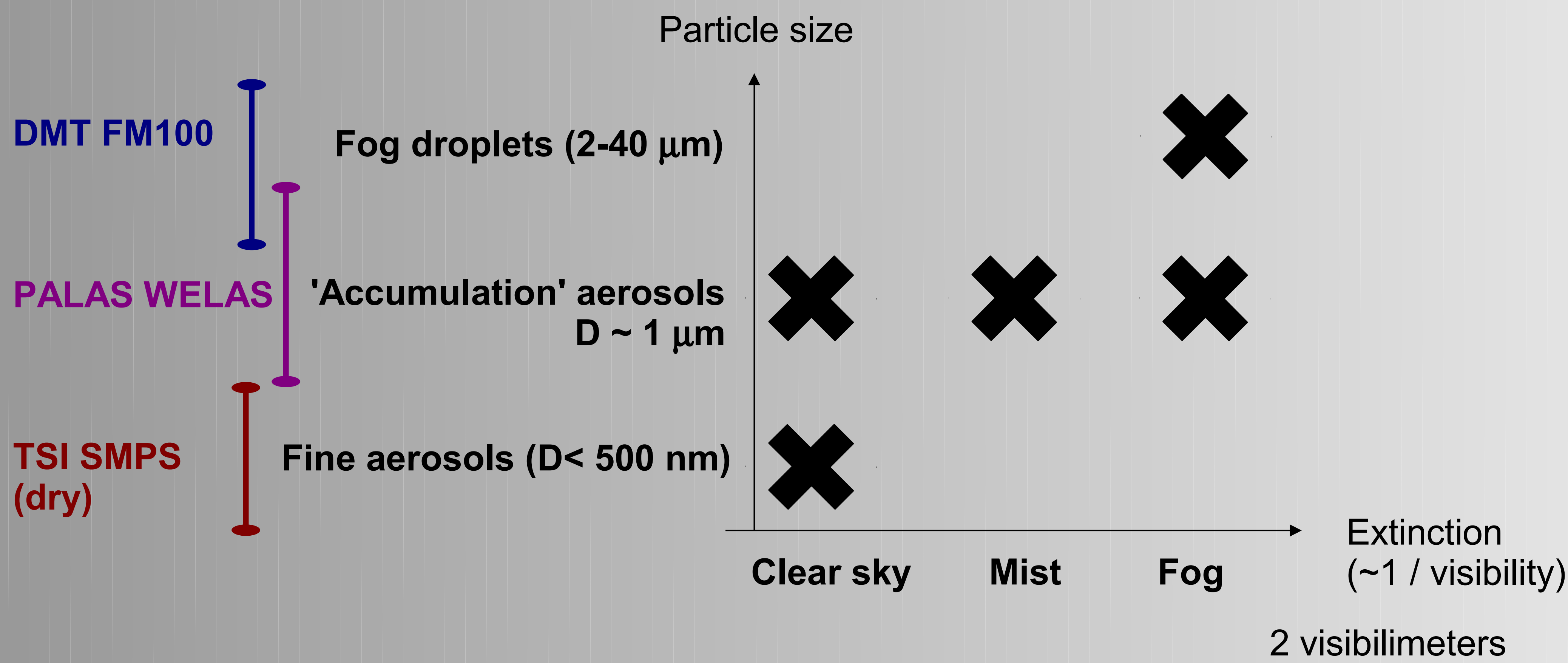
Aerosols (SMPS+WELAS)

Hydrated aerosols (WELAS)

Droplets (WELAS+FM100)

1. Methodology

Particle extinction coefficient: computed and observed.



Particle size distribution + Mie theory → **Particle extinction coefficient**

(3 values of refractive index)

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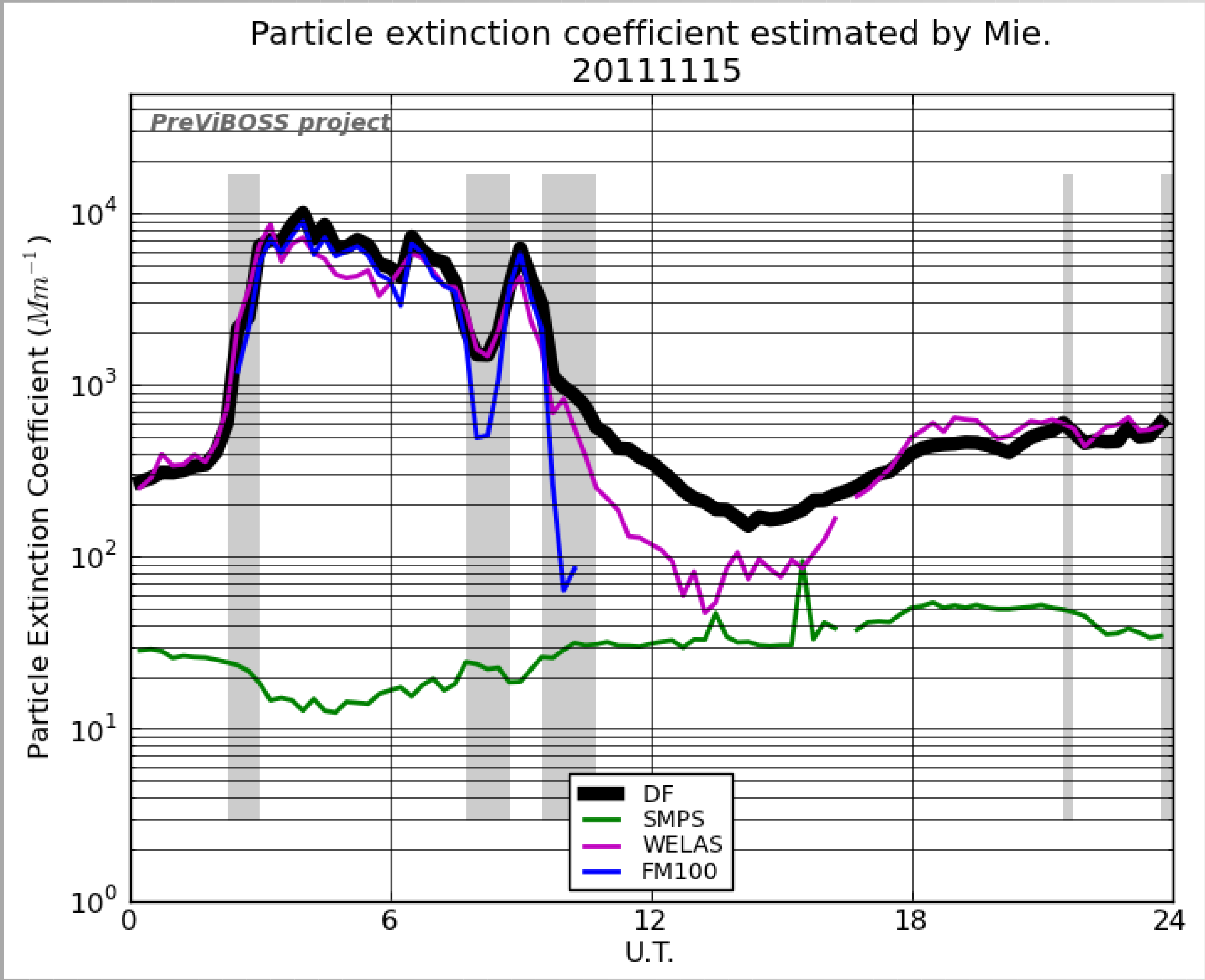
1. Methodology

Extinction reproduced in different regimes.



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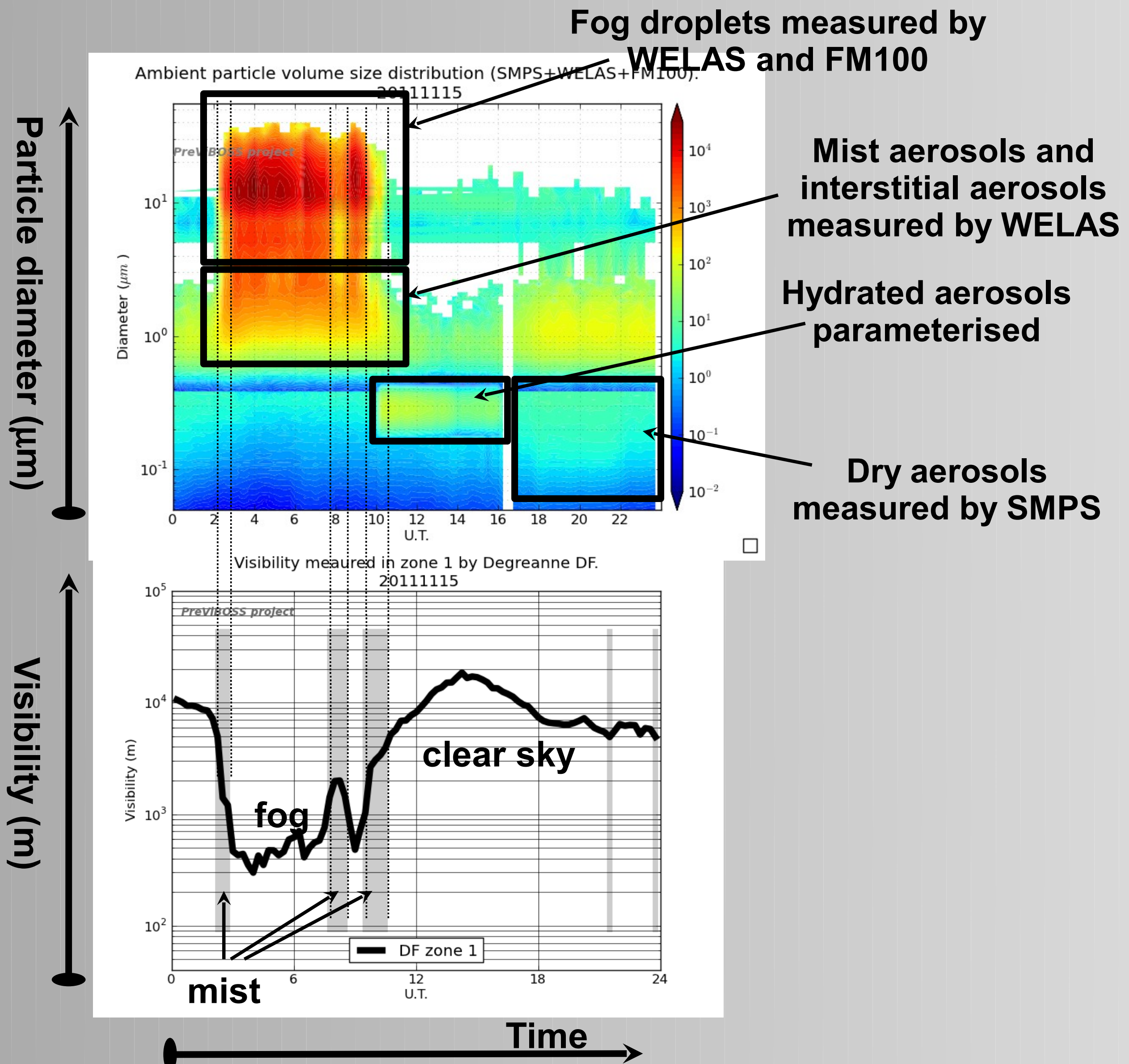
1. Methodology

Ambient size distribution in all regimes: instrumental association.



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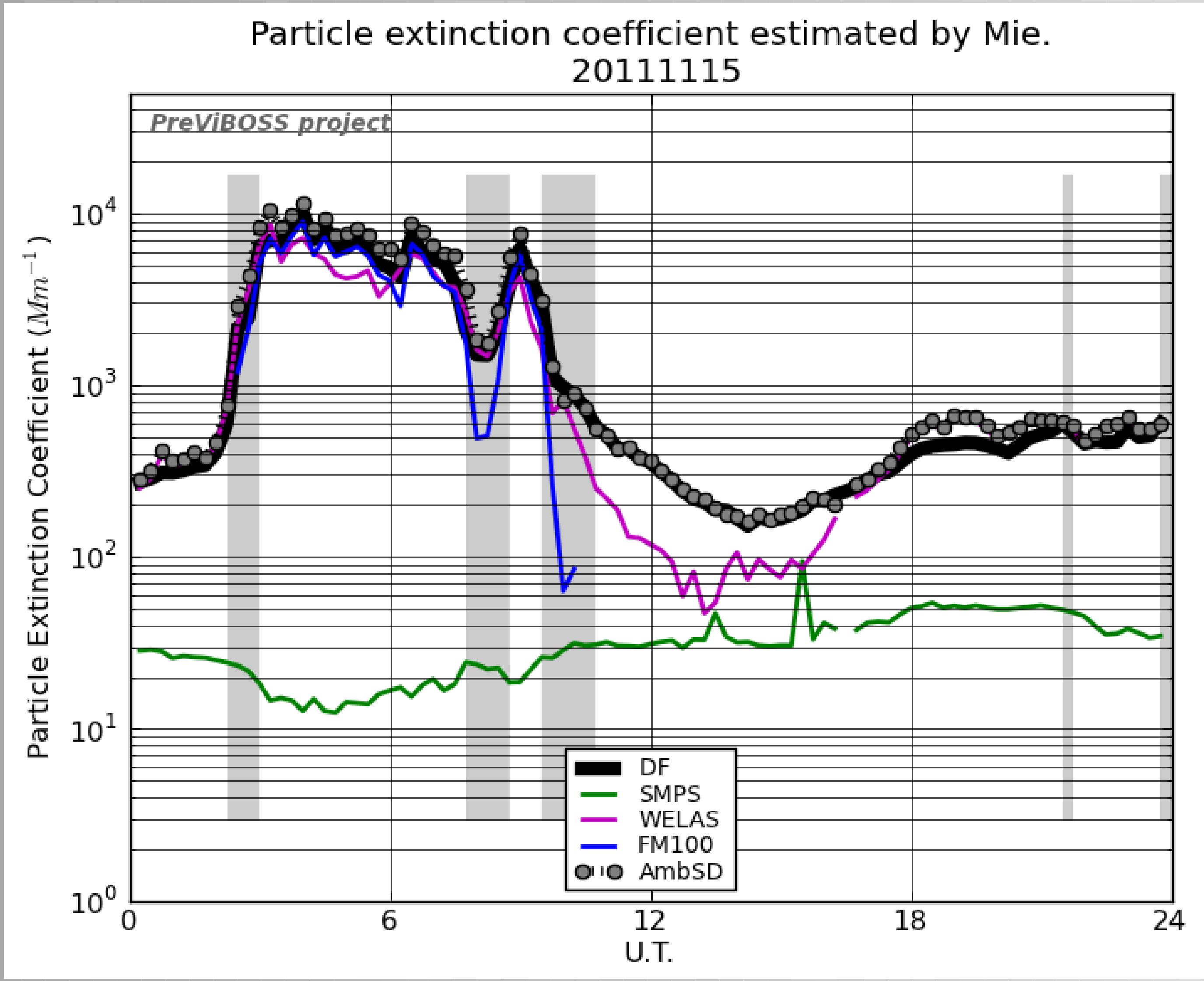
2. Validation of the particle microphysical properties

Particle extinction reproduced in all regimes.



November 2011

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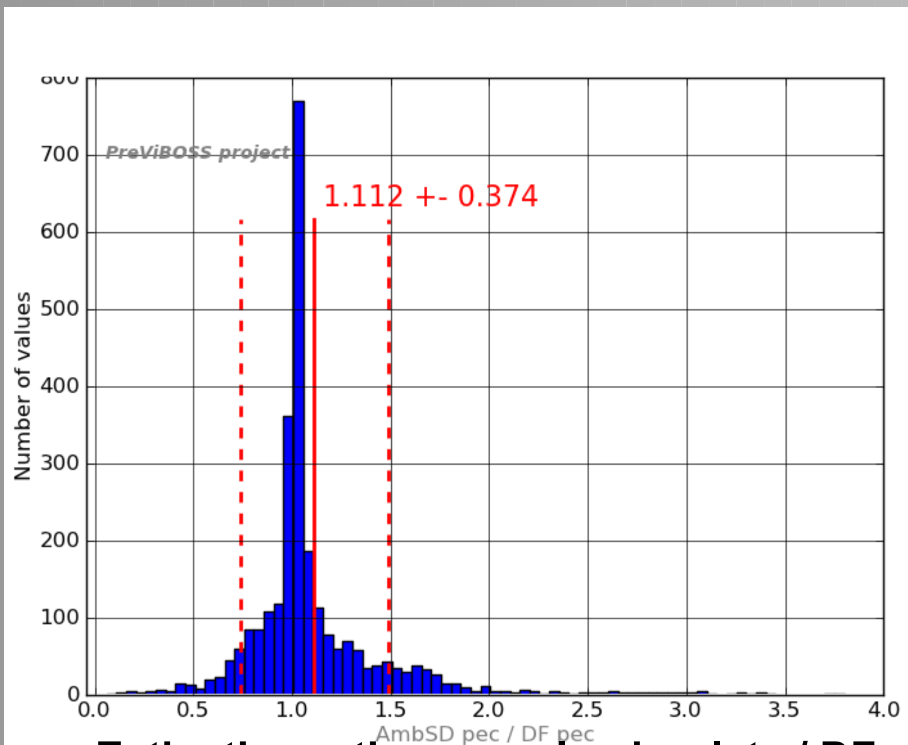
2. Validation of the particle microphysical properties

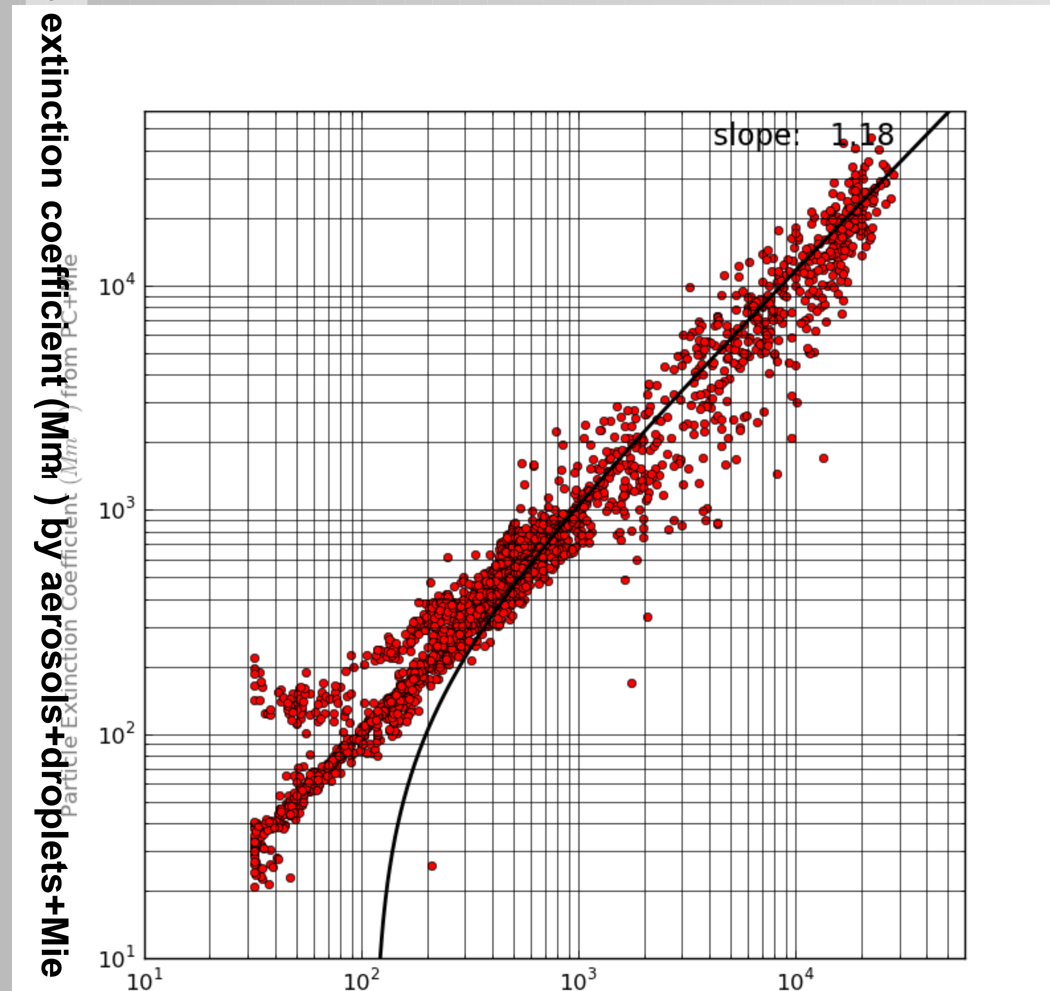
Particle extinction reproduced in all regimes.

ALL REGIMES



Extinction ratio aerosols+droplets / DF

Particle extinction coefficient (Mm⁻¹) by aerosols+droplets+Mie



Particle extinction coefficient (Mm⁻¹) by the DF visibilimeter

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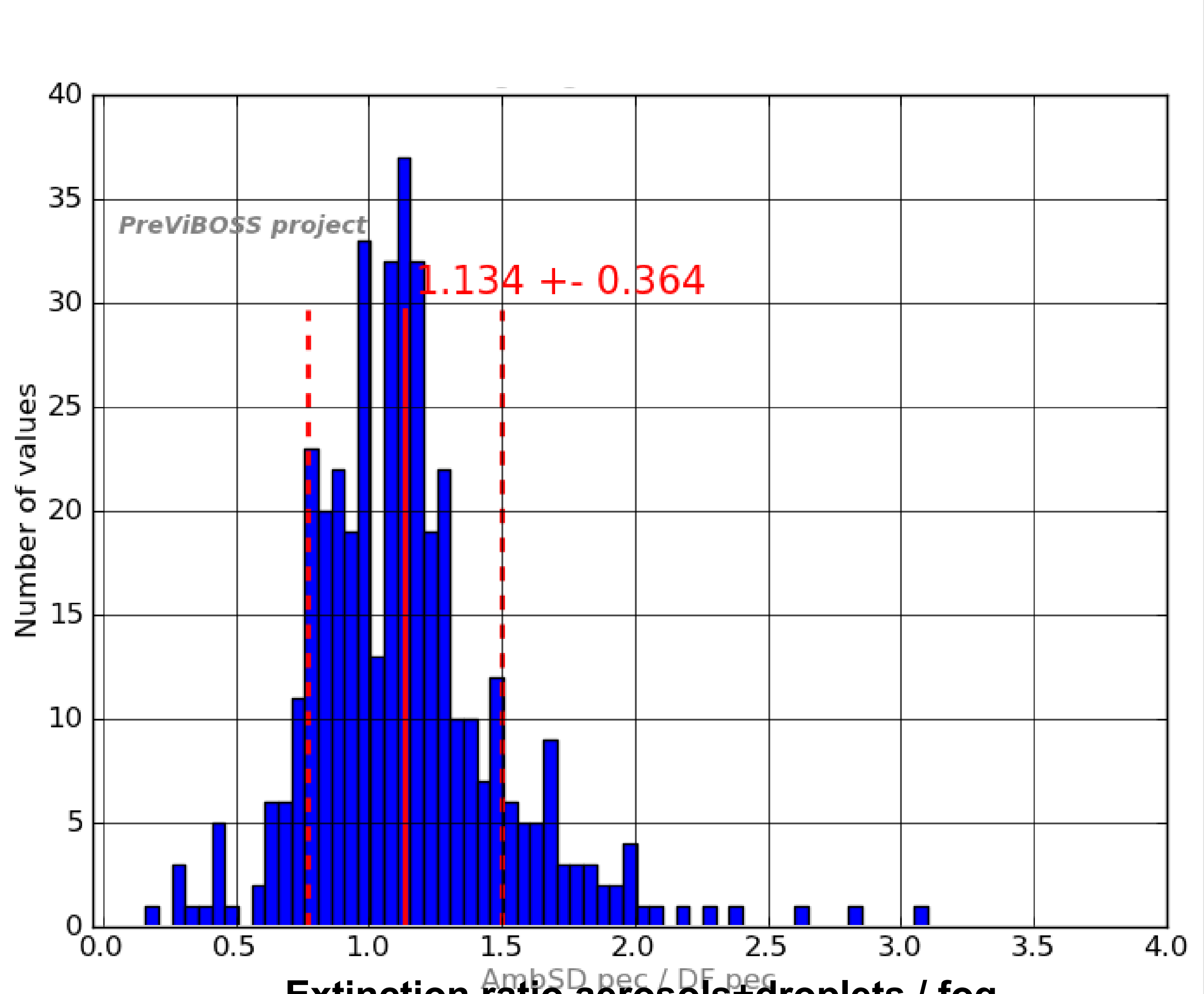
2. Validation of the particle microphysical properties

Particle extinction reproduced in fog.

FOG:



Extinction ratio aerosols+droplets / fog

Validated cases:
0.8 < ratio < 1.5

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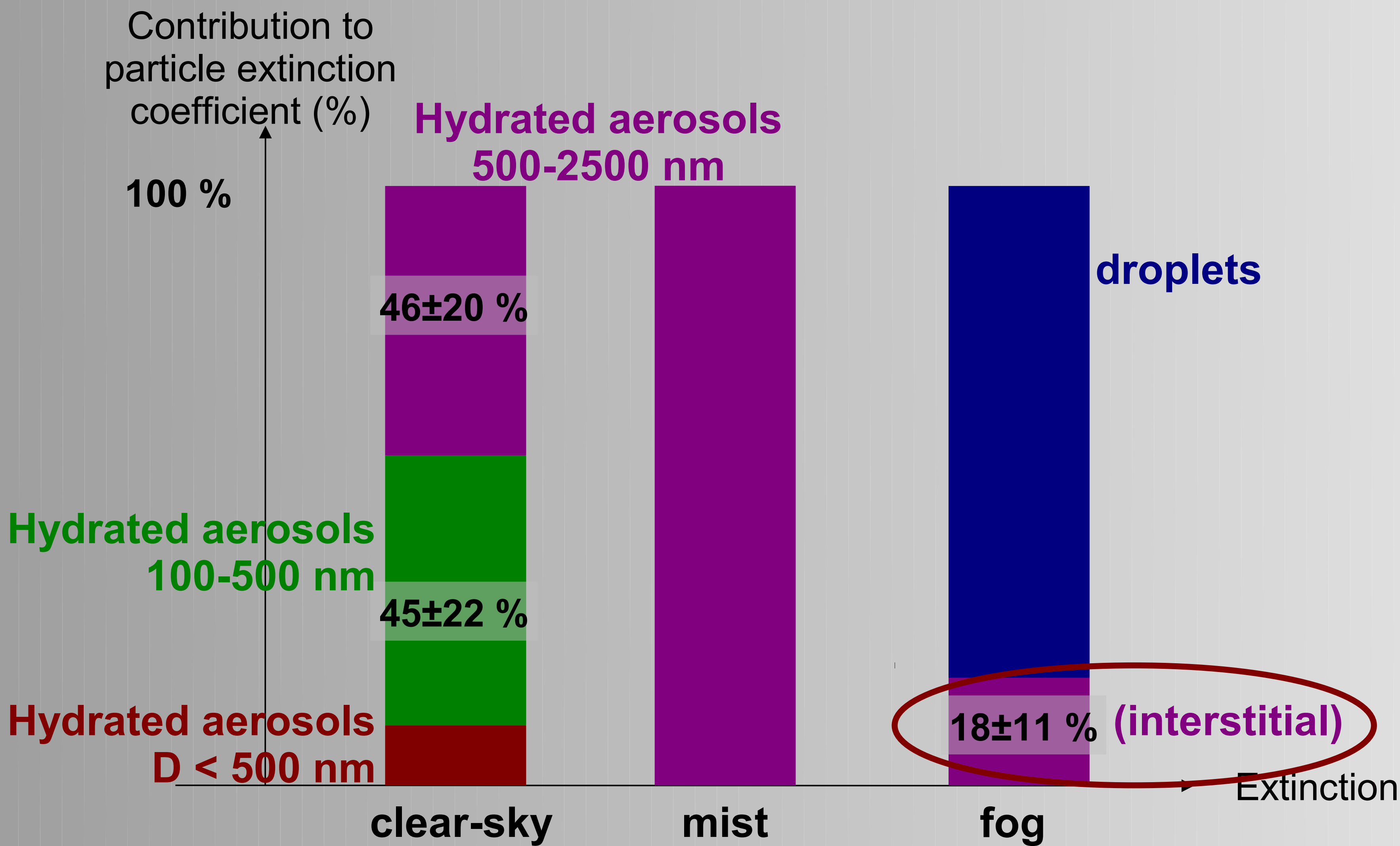
3. Contribution of several aerosol size classes to extinction

Variability in the fog life cycle.



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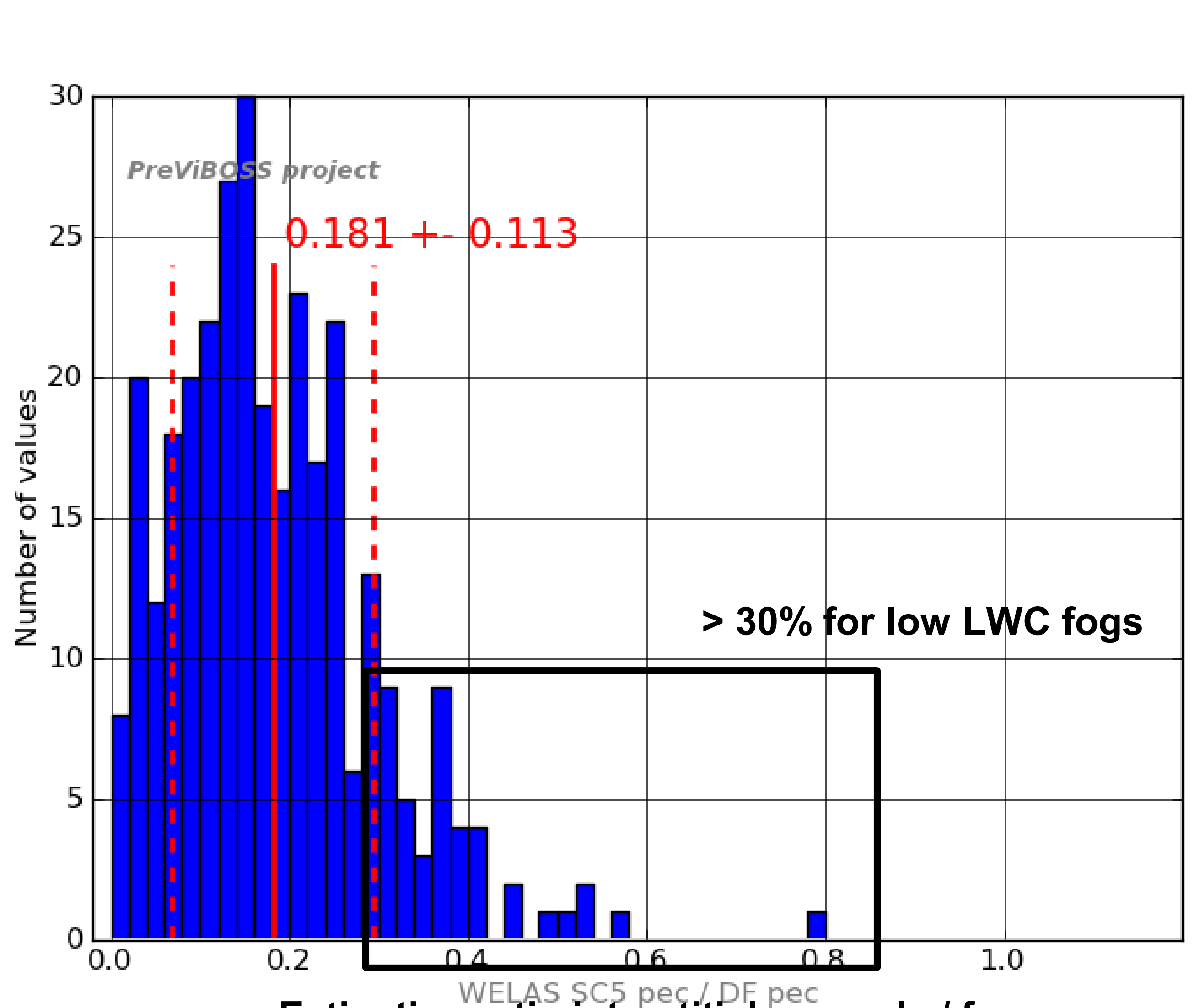
3. Contribution of several aerosol size classes to extinction

Variability by the interstitial aerosols in fog.

FOG:

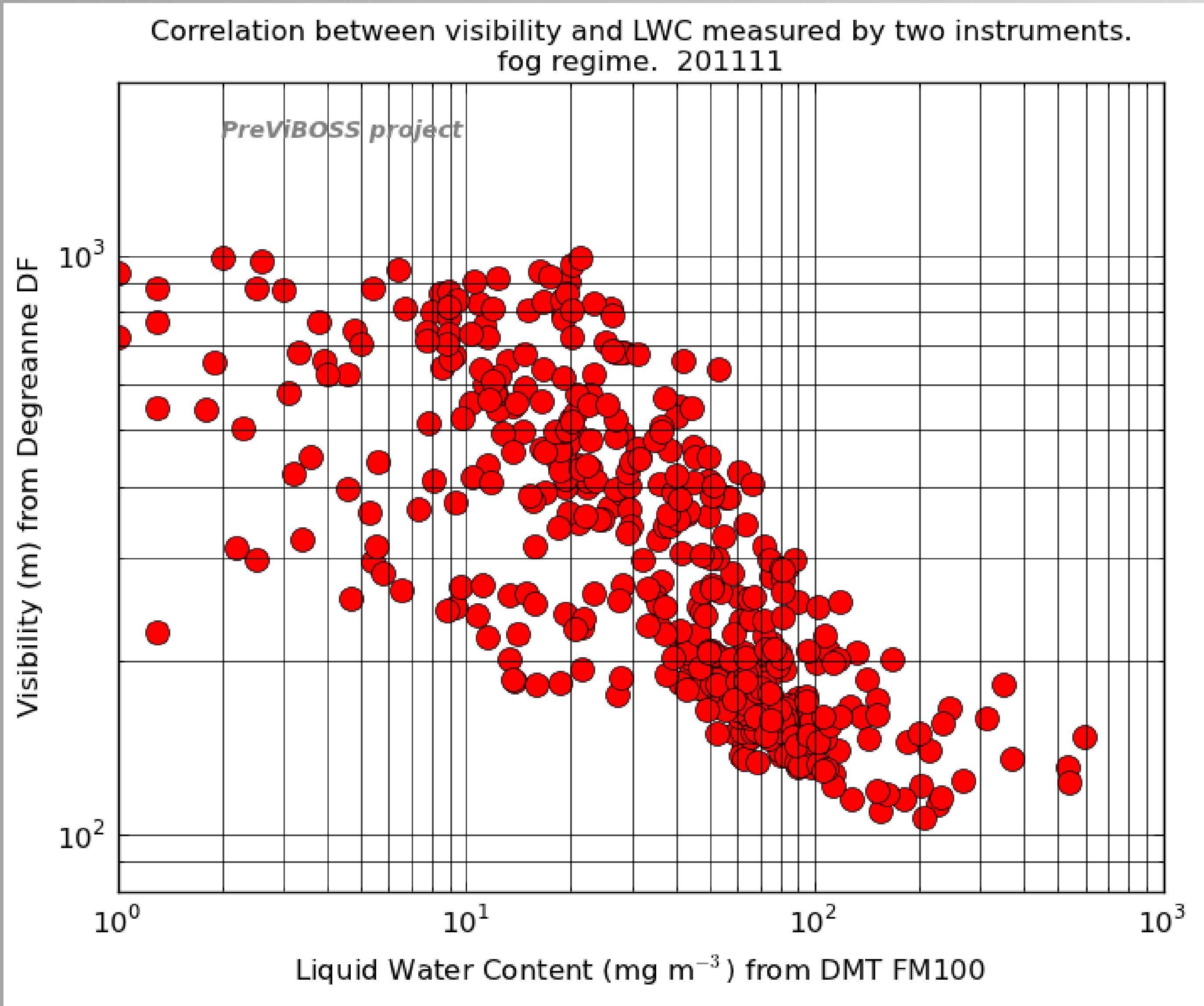


Extinction ratio interstitial aerosols / fog

4. Relation Liquid Water Content (LWC) - Visibility

All cases.

FOG:



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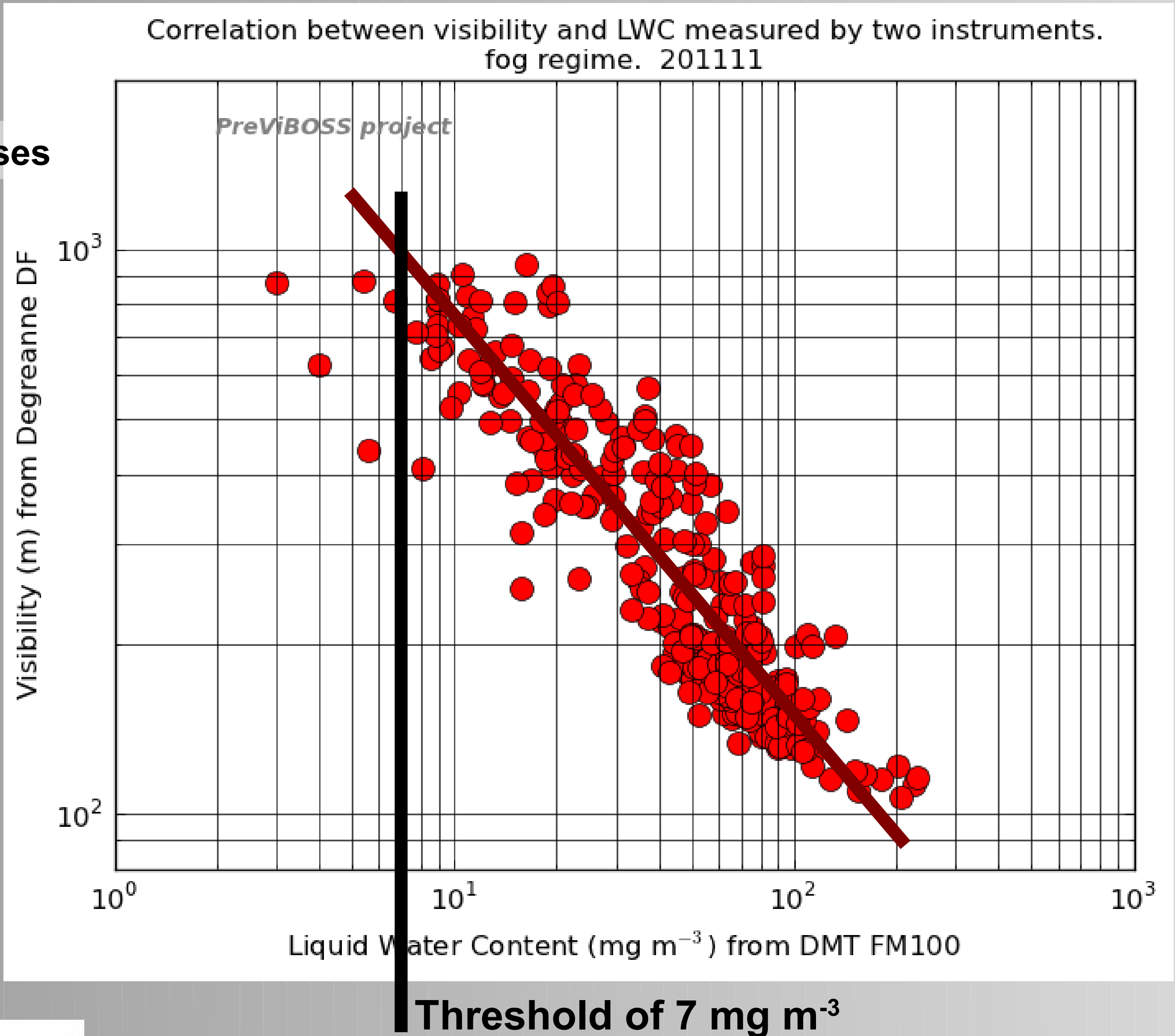
4. Relation LWC - visibility

Mist-fog: threshold in LWC.

FOG:

only validated cases



Threshold of 7 mg m^{-3}

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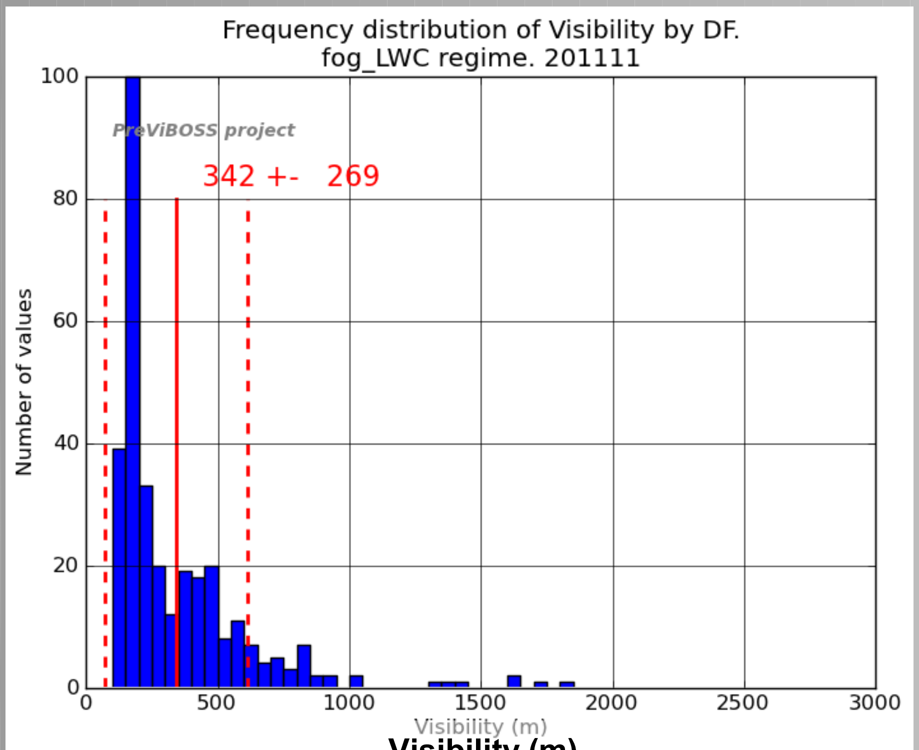
5. Mist and fog description

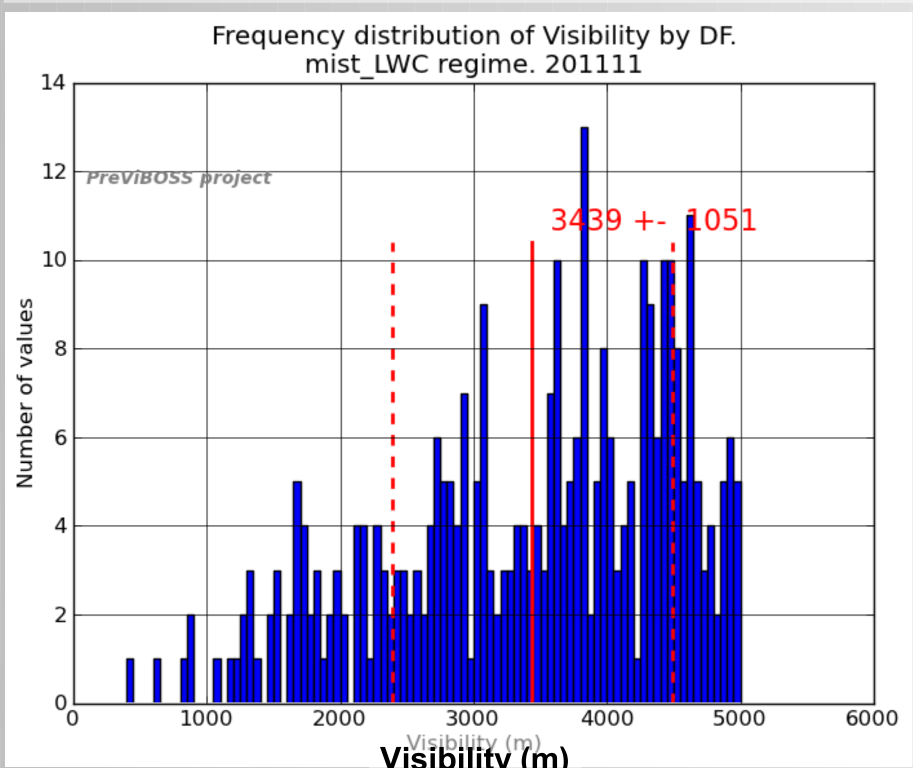
Visibility in mist and fog.

FOG: LWC < 7 mg m^{-3}



Visibility (m)

MIST: visibility < 5000 m and LWC < 7 mg m^{-3}



Visibility (m)

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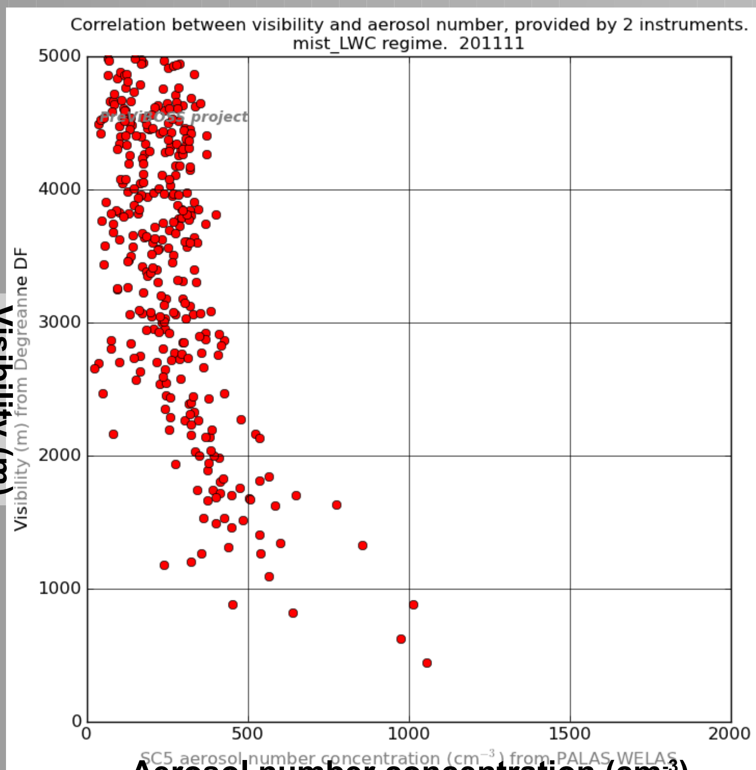
5. Mist and fog description

Aerosols of 500-2500 nm diameter.

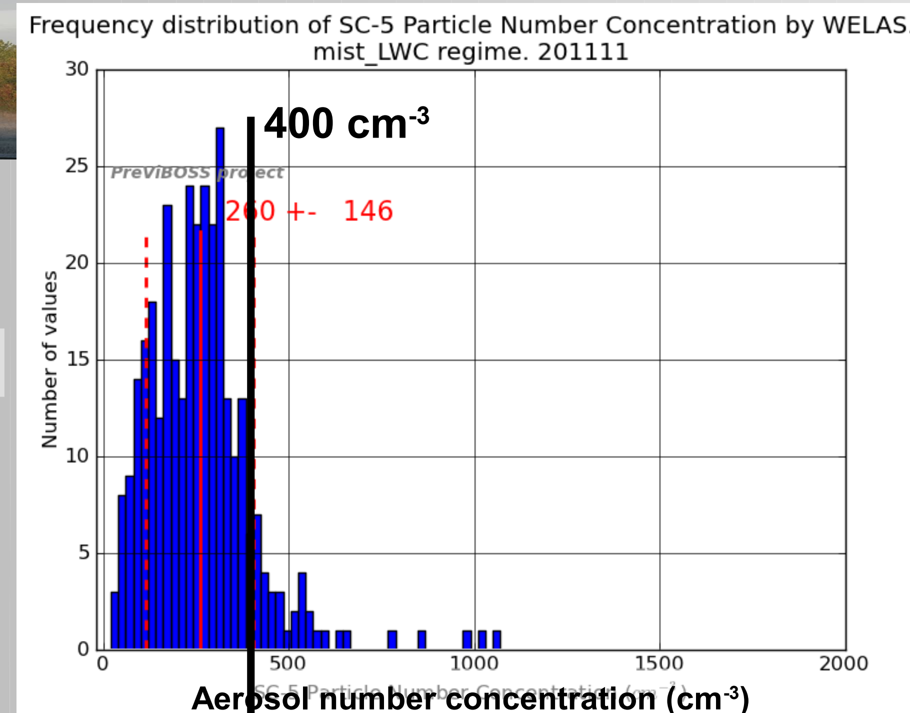
MIST:



Visibility (m)

Aerosol number concentration (cm^{-3})

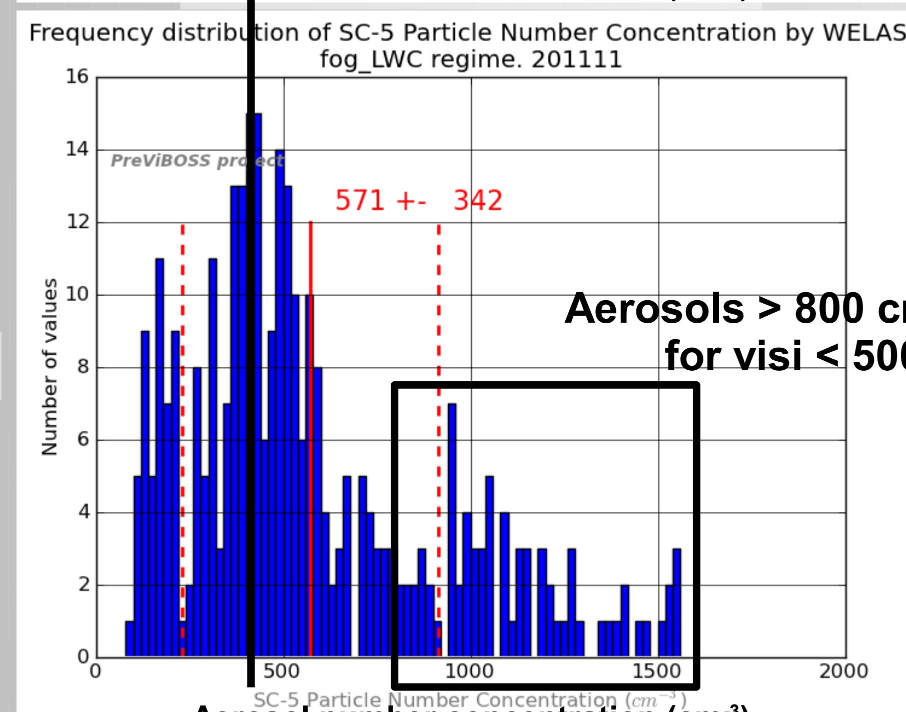
MIST:



400 cm^{-3}

Aerosol number concentration (cm^{-3})

FOG:



Aerosols > 800 cm^{-3} for visi < 500 m

Aerosol number concentration (cm^{-3})

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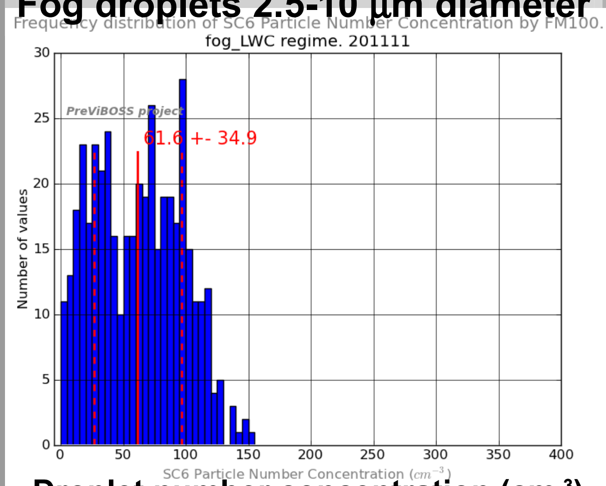
5. Mist and fog description

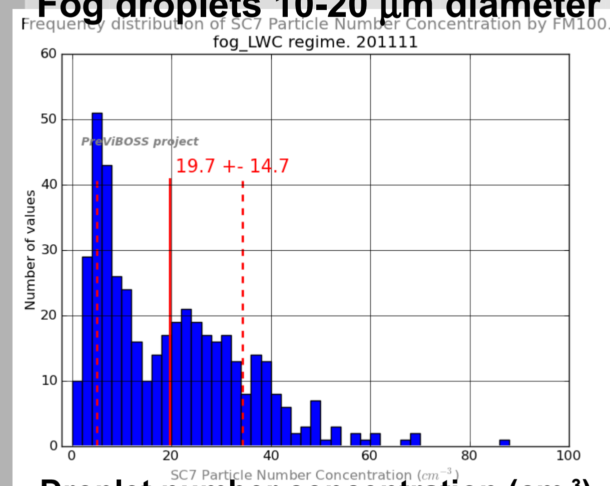
Droplets D > 2.5 µm.

Fog droplets 2.5-10 µm diameter



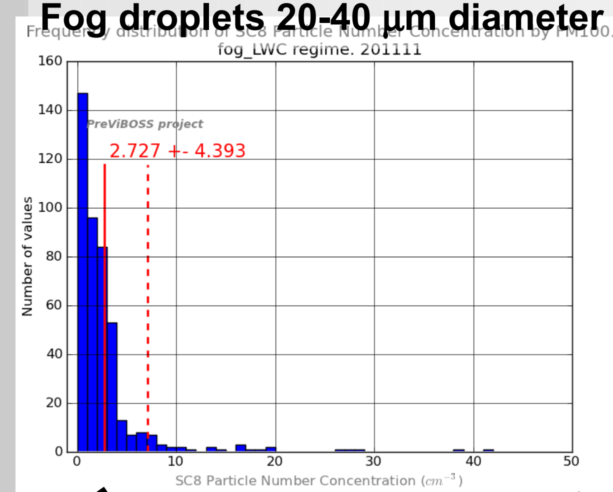
Droplet number concentration (cm^{-3})

Fog droplets 10-20 µm diameter



Droplet number concentration (cm^{-3})

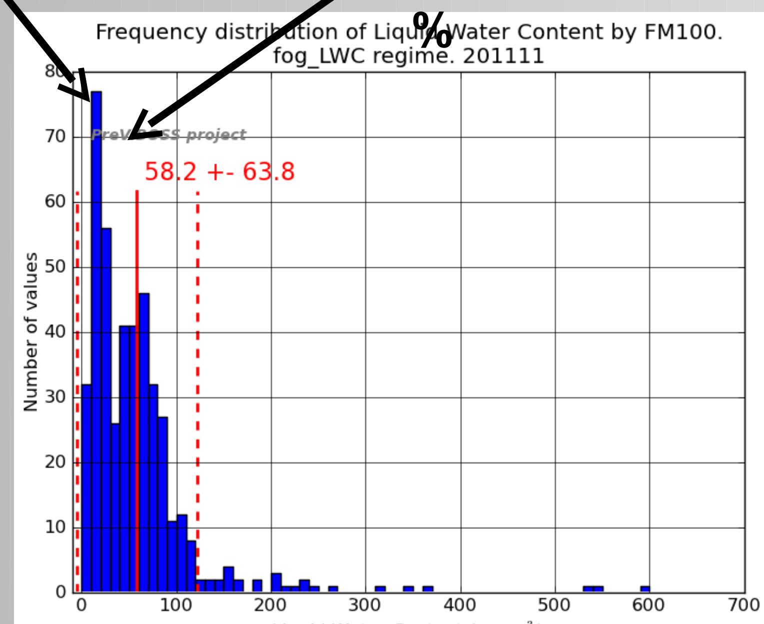
Fog droplets 20-40 µm diameter



Droplet number concentration (cm^{-3})

50%

33 %



Liquid Water Content (mg m^{-3})

Fog:
LWC > 7 mg m^{-3}
or
10-20 µm droplets > 4 cm^{-3}
20-40 µm droplets > 0.3 cm^{-3}

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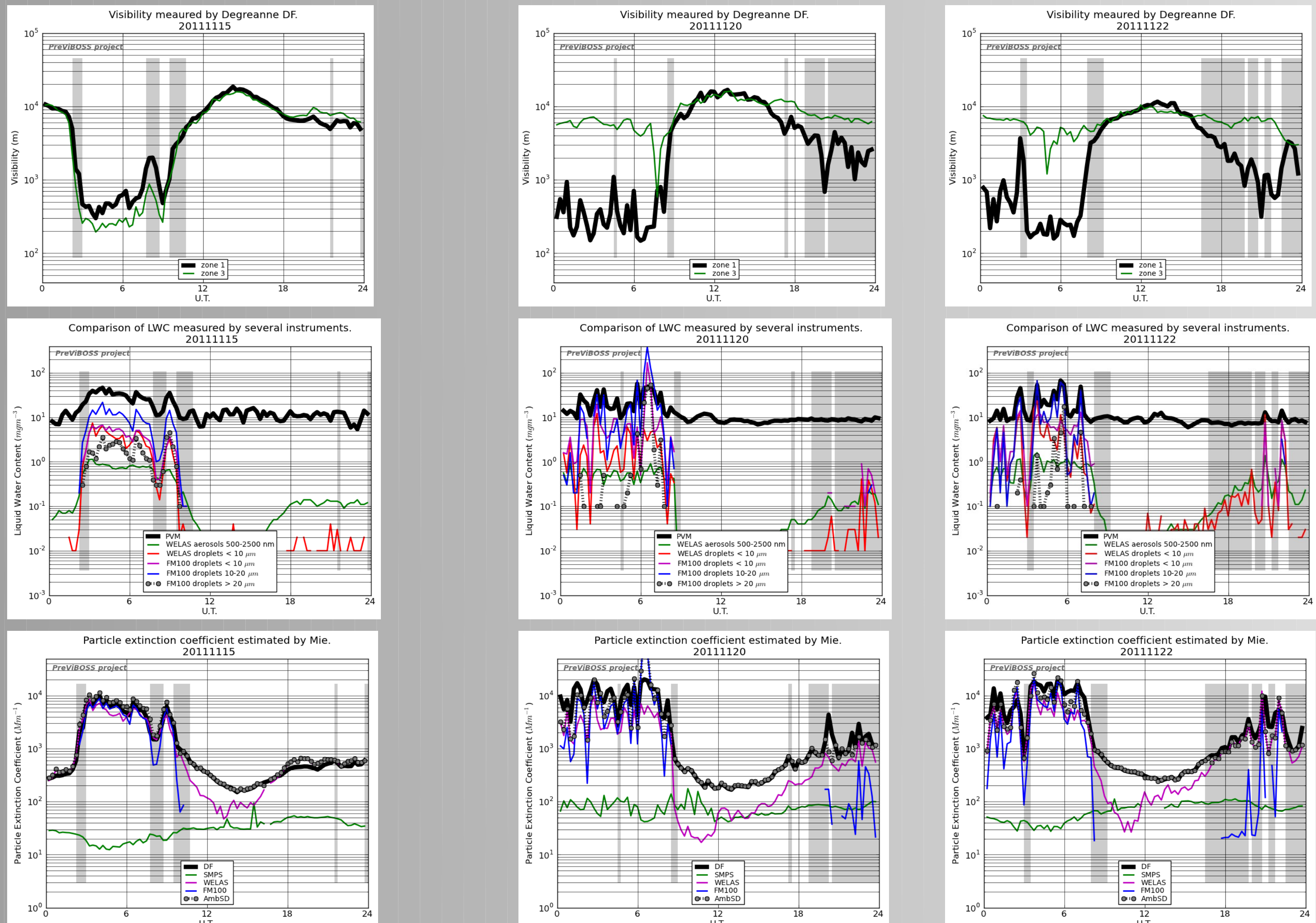
5. Mist and fog description

Validated and non-validated cases: fog homogeneity.



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6. Conclusions

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Experiment

Instrumental set-up ok for following contribution of different aerosol size classes to extinction in fog life cycle

Except for non homogeneous fog: droplets contributing to extinction are not observed by FM100

Validated/non-validated: 2 visibilimeters / meteo mast

Improvement: Instrument to measure 100-500 nm aerosols in ambient conditions

Study the impact of relative humidity on dry size distribution measured by SMPS

Mist

Visi=3500±1000 m, concentration=260±150 cm^{-3} hydrated aerosols

Fog

LWC < 7 mg m^{-3} (10-20 μm droplets < 4 cm^{-3}, 20-40 μm droplets < 0.3 cm^{-3})

Validation for homogeneous fogs

Visi=350±270 m, LWC=60±60 mg m^{-3}

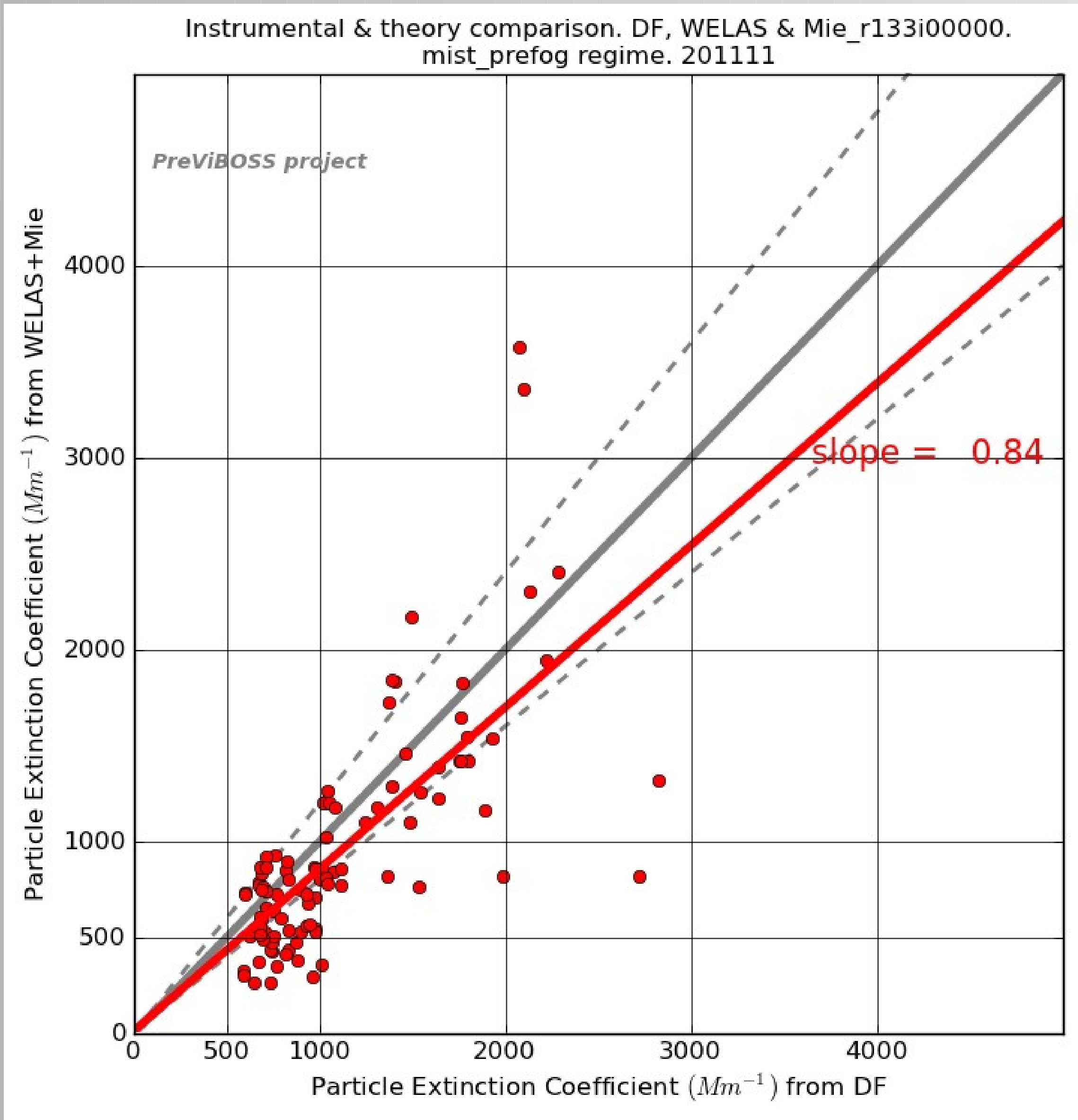
Importance of interstitial aerosols: 18±10% extinction (>30% in low LWC fogs)

In average twice more hydrated aerosols in fog than in mist (> 800 cm^{-3} in dense fogs)

~80 cm^{-3} droplets

2. Validation of the particle microphysical properties

Particle extinction reproduced in all regimes.



HYGEOS

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