2015 update

GPM ACTIVITIES IN SPAIN

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[thanks to Ziad Haddad, Ana Barros, Ramesh Kakar, Chris Kummerow]

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Outline

- Multiple scattering calculations
- DSD research [modeling]
- Case studies over Spain
- Climate models validation
- New equipment

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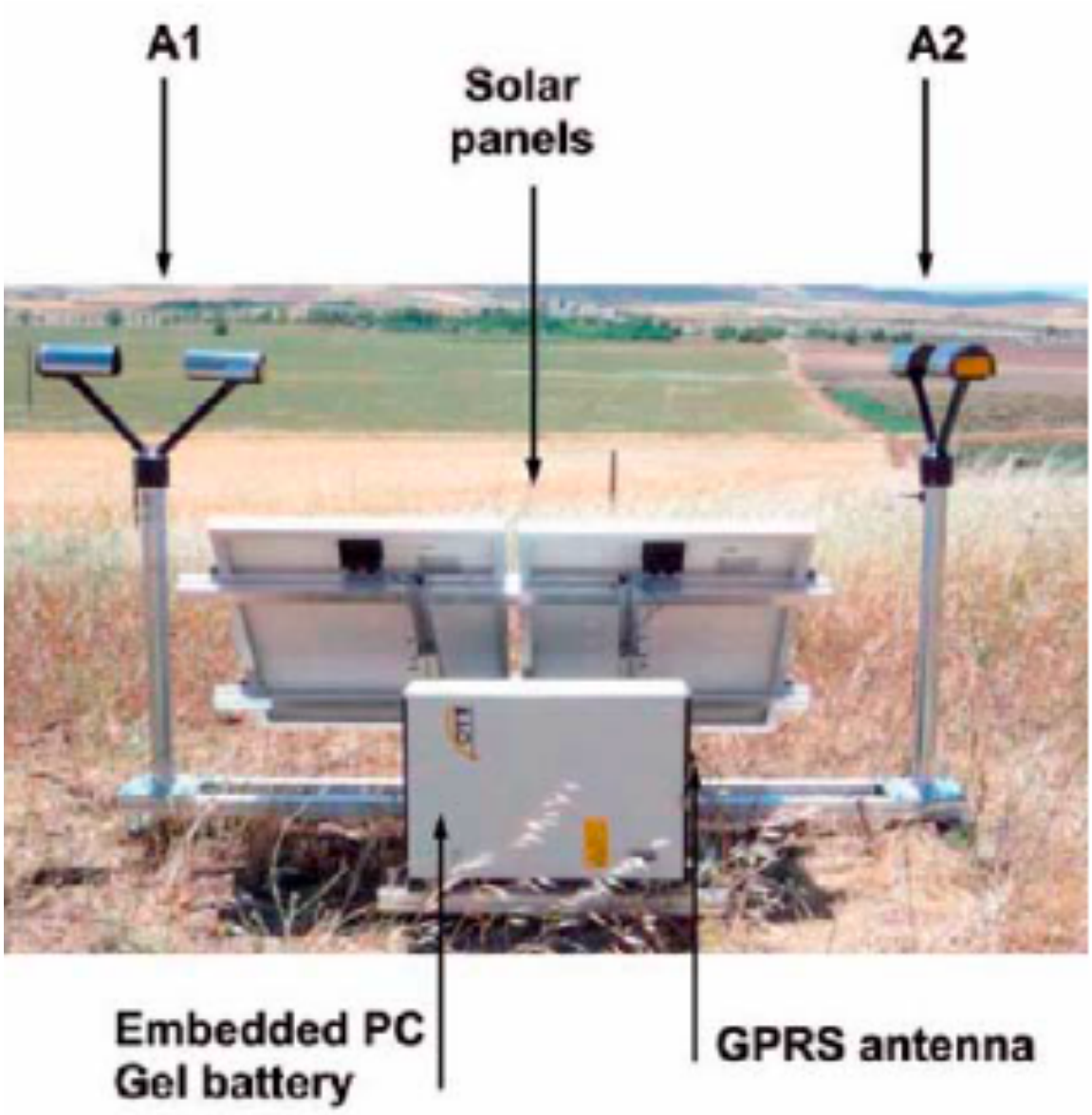

F. J. Tapiador; R. Checa; M. de Castro. 2010.
An experiment to measure the spatial variability of rain drop size distribution using sixteen laser disdrometers.
GEOPHYSICAL RESEARCH LETTERS. 37

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IPHEx Integrated Precipitation & Hydrology Experiment

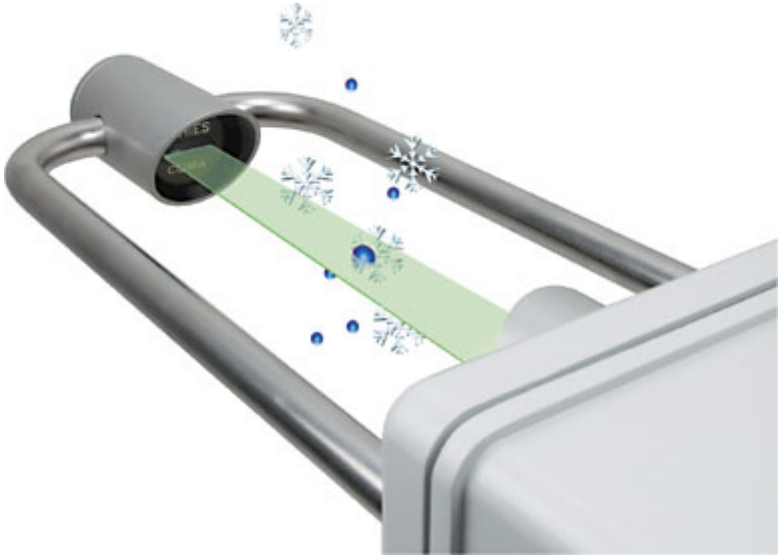
Home | Project Overview | Field Campaign | Modeling | Data Center | Documents | News | Contacts

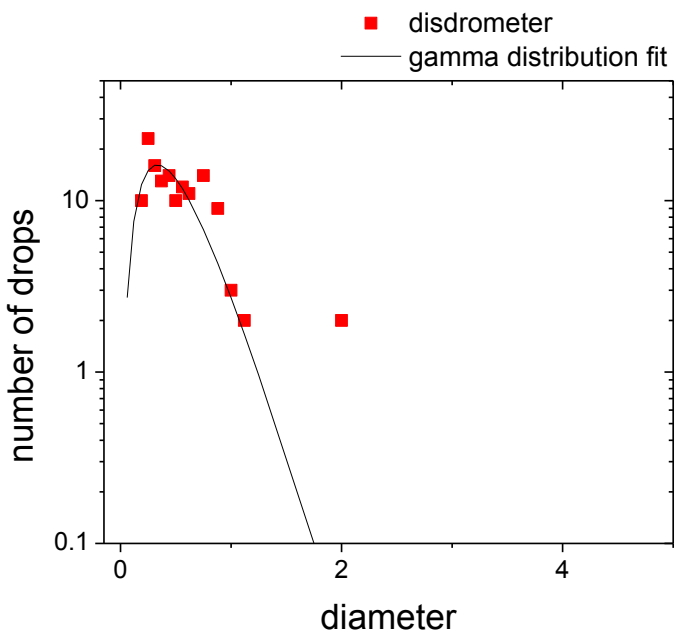
- Study area (GSM and Pigeon Basin)
- Instrumentation & Sensors
- Long-term GV observations
- PK monitoring site
- IPHEX 2014: IPHEX-GVFC
  - Extended IPHEX-GVFC
  - IOP IPHEX-GVFC
- Download Data

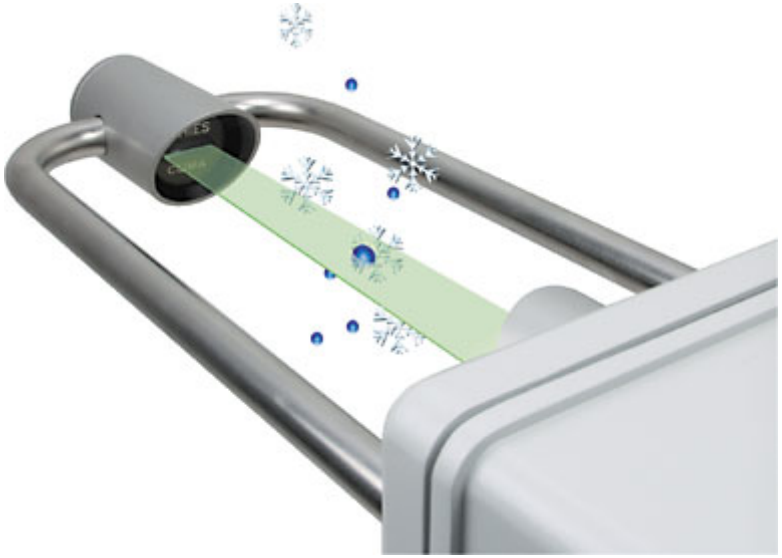
Instrumentation and sensors

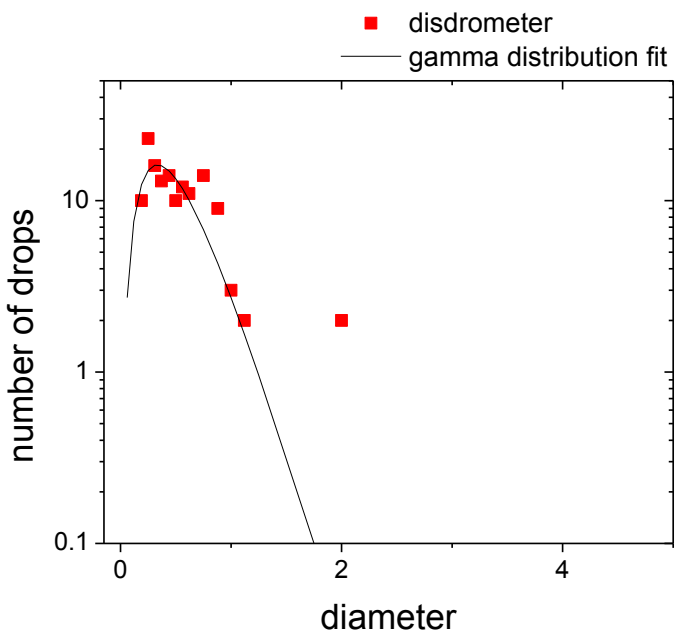
For details about any instrument deployed on the field click the links provided.

Sensor	Provider	Inventory
Rain Gauges	Duke University	44: TB03/0.2; TB03/0.1; HS305A Click for details
Precipitation volume and rain rate	Nasa-IFloods	38 (Soil moisture/temperature) Click for details
Disdrometers	Duke-UCLM	12 PARSIVEL (P1)
Drop size distribution	Duke	3 PARSIVEL (P2)
	NASA	8 PARSIVEL (P2)
	NASA	3 Joss and Waldvogel acoustic disdrometer (JWD); 3 additional maintained by NOAA
	NASA	5 2-Dimensional Video Disdrometer (2DVD)




disdrometer
gamma distribution fit
number of drops
10
1
0.1
0
2
4
diameter

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10
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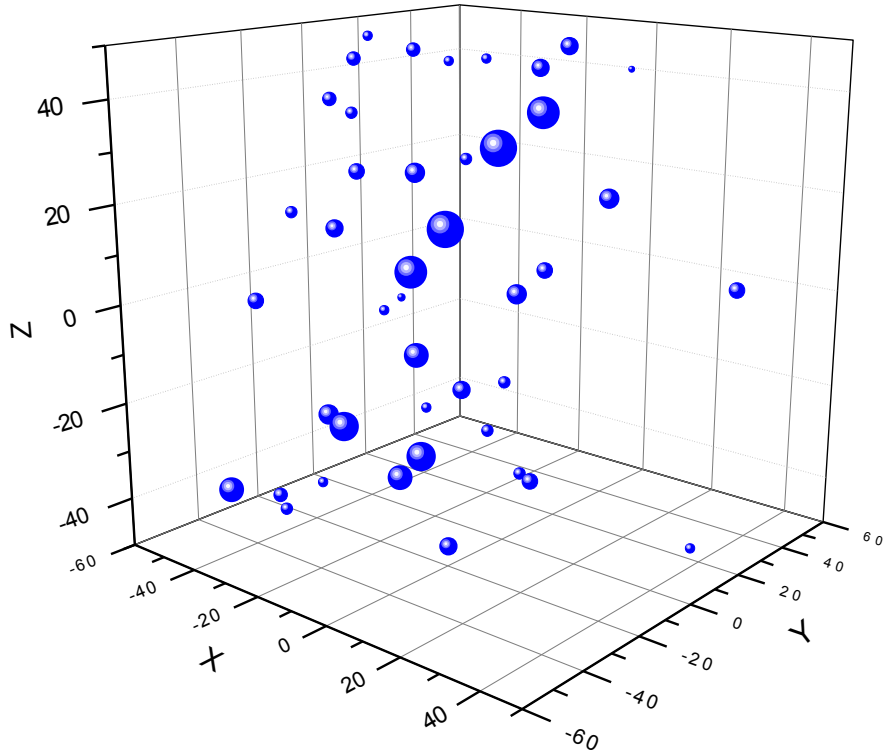
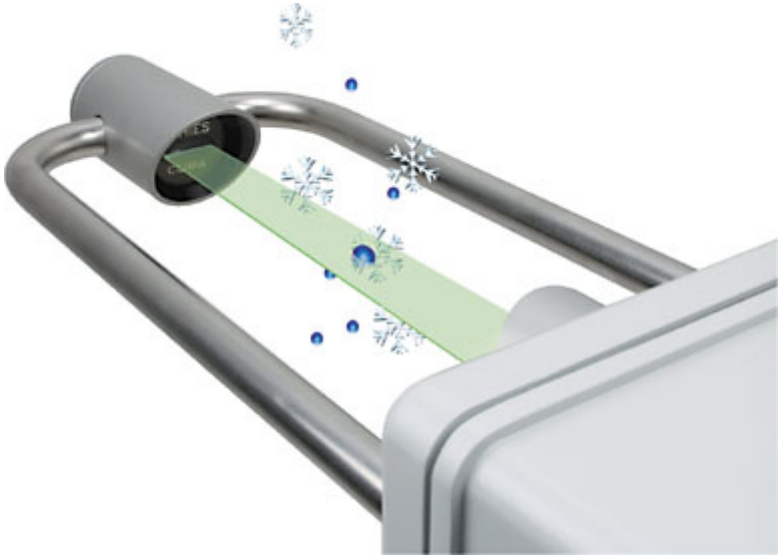
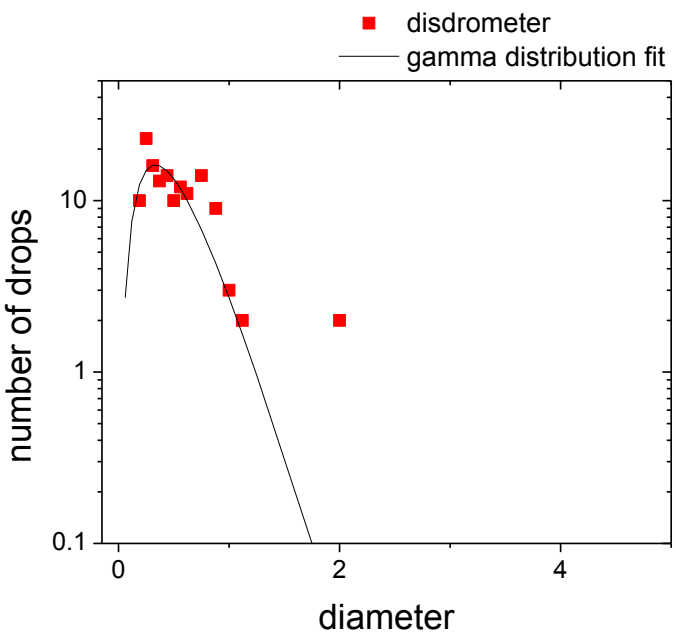
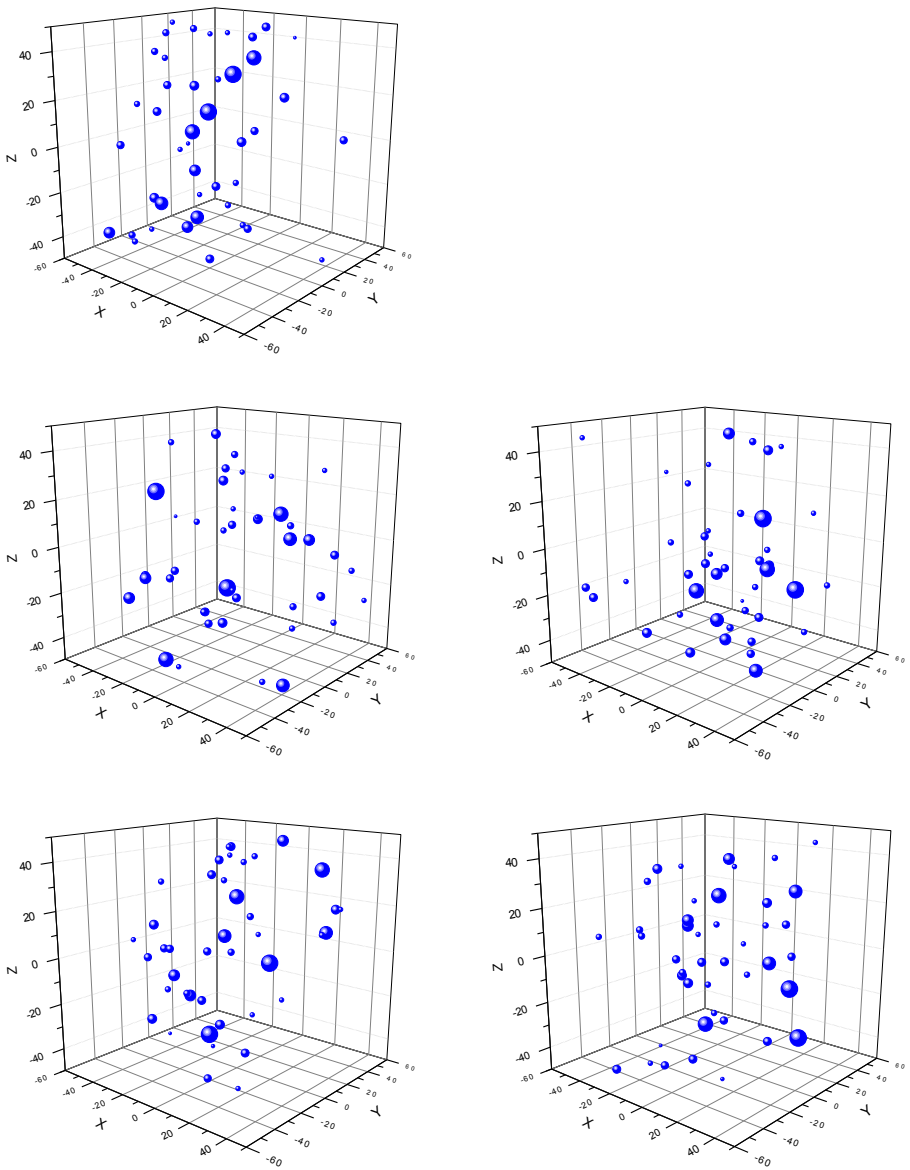

Z
40
20
0
-20
-40
X
-60
-40
-20
0
20
40
Y
60
40
20
0
-20
-40
-60

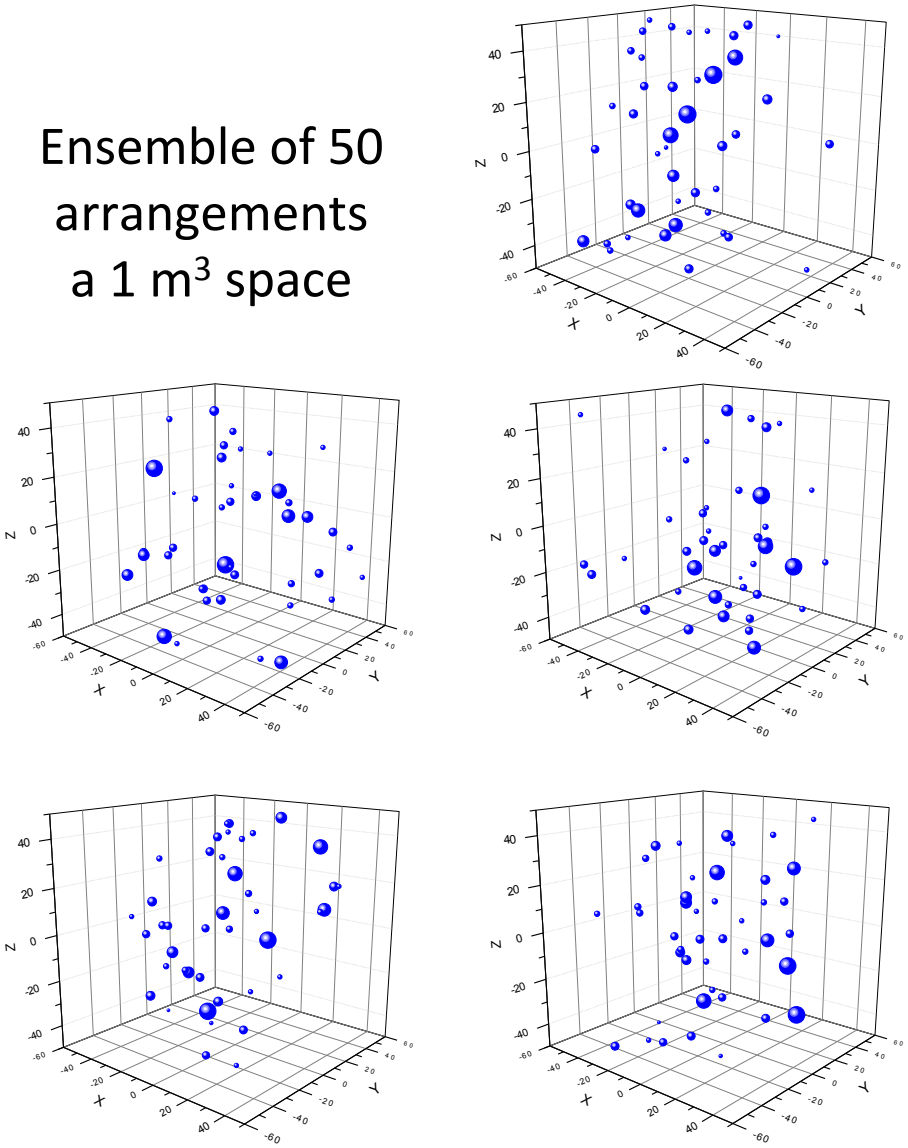






[spherical drops; drop size is exaggerated in these plots]

Ensemble of 50 arrangements a 1 m^3 space



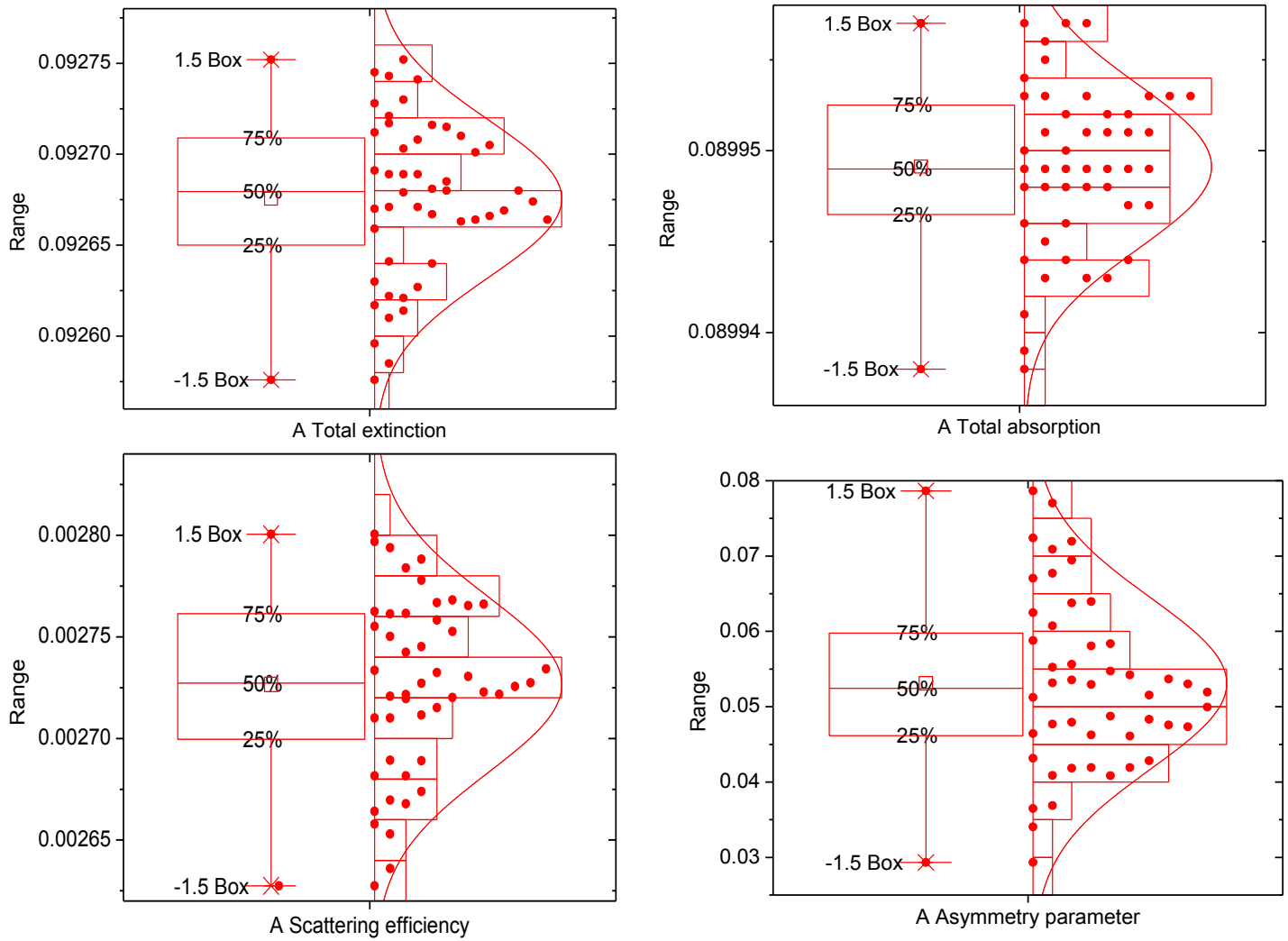
T-matrix multiple scattering calculations for a variety of arrangements, frequencies and temperatures

· Complex refractive index depends on temperature, (salinity) and frequency

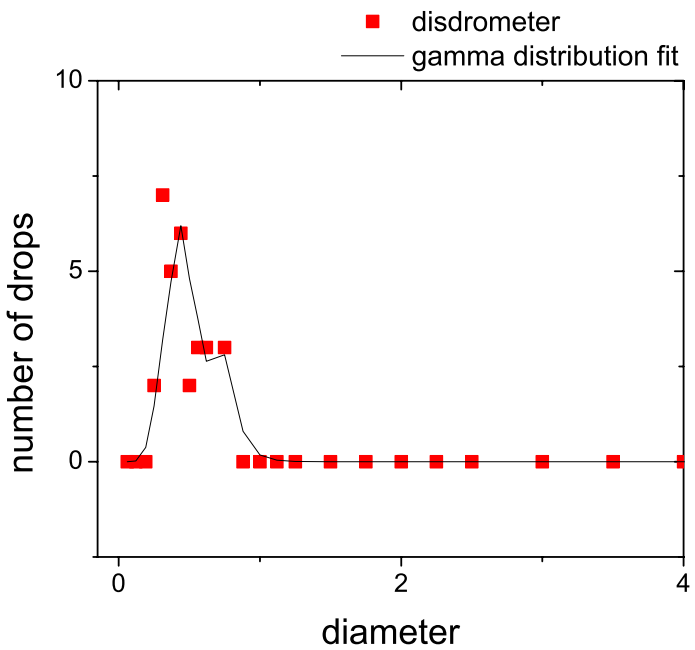
· Length scale factor depends on frequency

X-band, 5 ºC

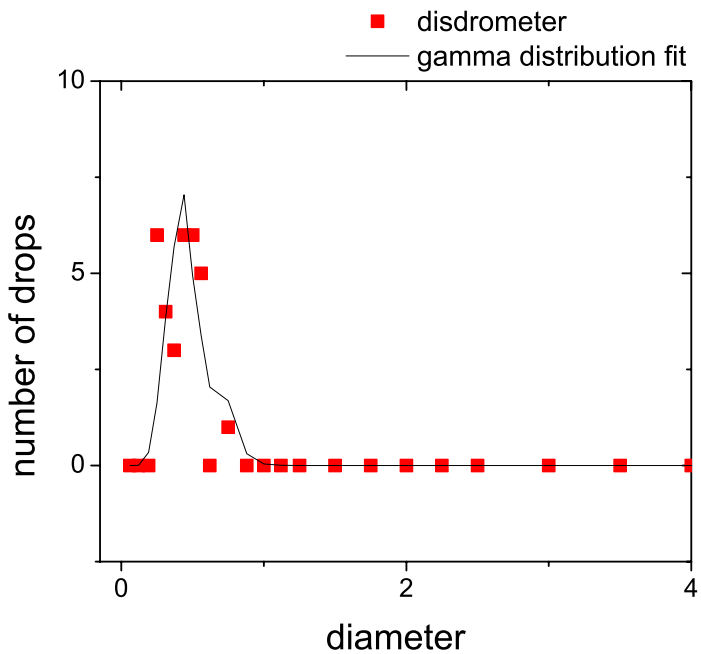
Spread of radiometric quantities within the ensemble (same DSD)



X-band; 5 ºC

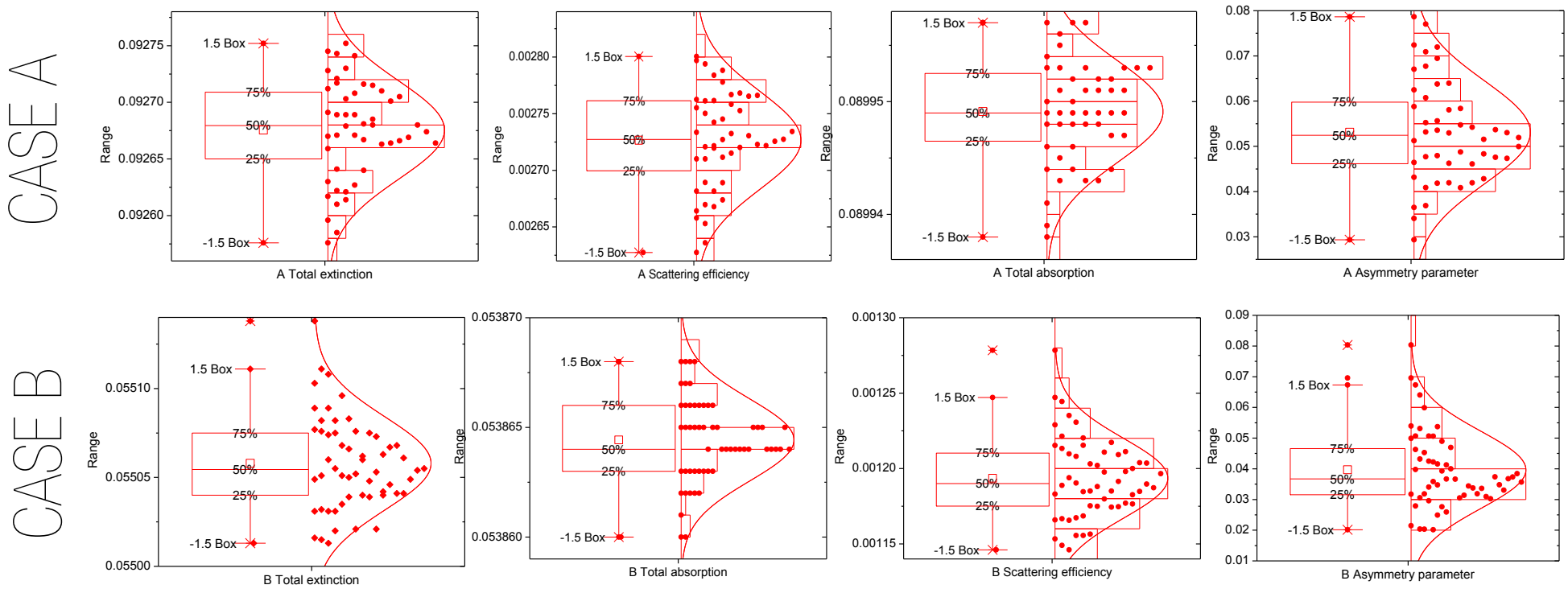


10 min ➔



CASE A **CASE B**

X-band; 5 ºC



Plan: Ka, Ku bands, more Ts, more RDSDs

Problem: computing time / memory reqs

- Multiple scattering calculations
- DSD research [modeling]
- Case studies over Spain
- Climate models validation
- New equipment

Issue

- Empirical fits to the gamma function are not proper PDFs

$$n(D)_{Tes} = N_0^* F_\mu(D/D_m)$$

$$F_\mu(X) = \frac{\Gamma(4)}{4^4} \frac{(4+\mu)^{4+\mu}}{\Gamma(4+\mu)} X^\mu e^{-(4+\mu)X}$$

Why do we want DSDs to be probabilistic (N_T-linked with PDFs)?

- Mathematical consistency: robust parameter estimation requires PDFs.
- Physical modeling: DSD comes from a random process.
- We want a coherent set of units.
- To build a Z/R relationship with independent parameters.
- To analyze microphysics in terms of physically-meaningful parameters [not a and b].

What is a PDF?

$$\left.\begin{aligned} p(D) &\in [0,1] \\ \int p(D)dD &= 1 \\ p(D_1 \bigcup D_2 \bigcup \ldots D_n) &= \sum_{i=1}^{n} p(D_i) \end{aligned}\right\} p(D) \in \mathbb{R}, p(D) \geqslant 0$$

$$n(D) = N_T \cdot p(D)$$

PDF—based DSD model

TABLE 2. Summary of the RDSD modeling with the number of drops per volume N_T, the sample mean m, and the sample variance σ^2 as the independent variables, including the moments and the equations for the Z–R relationship; $\Gamma(\cdot)$ is the gamma function and $\gamma(\cdot)$ is the incomplete gamma function.

Raindrop size distribution
$n(D) = N_T D^{\mu} \Lambda^{\mu+1} \dfrac{e^{-\Lambda D}}{\Gamma(\mu+1)}$
Independent variables N_T, m, and σ^2
$\Lambda = m/\sigma^2$
$\mu = (m^2 - \sigma^2)/\sigma^2$
Parameters
$k_1 = 1.0$ for Z in $\mathrm{mm^6\,m^{-3}}$
$k_2 = \pi/6000$ for W in $\mathrm{mm^3\,m^{-3}}$
$k_3 = 6\pi/10\,000$ for R in $\mathrm{mm\,h^{-1}}$
$D_{\min}$ diameter of the smallest measurable drop
$D_{\max}$ diameter of the largest measurable drop
$v_1 = 3.78$, $v_2 = 0.67$ (Atlas and Ulbrich 1977)

Main moments

$$Z = k_1 N_T \Lambda^{-6} \frac{\gamma(\mu+7, D_{\max}\Lambda) - \gamma(\mu+7, D_{\min}\Lambda)}{\Gamma(\mu+1)}$$

$$W = k_2 N_T \Lambda^{-3} \frac{\gamma(\mu+4, D_{\max}\Lambda) - \gamma(\mu+4, D_{\min}\Lambda)}{\Gamma(\mu+1)}$$

$$R = k_3 v_1 N_T \Lambda^{-(3+v_2)} \frac{\gamma(\mu+4+v_2, D_{\max}\Lambda) - \gamma(\mu+4+v_2, D_{\min}\Lambda)}{\Gamma(\mu+1)}$$

$$D_m = \Lambda^{-1} \frac{\gamma(\mu+5, D_{\max}\Lambda) - \gamma(\mu+5, D_{\min}\Lambda)}{\gamma(\mu+4, D_{\max}\Lambda) - \gamma(\mu+4, D_{\min}\Lambda)},$$ does not depend on N_T

$$\sigma_m^2 = \Lambda^{-2} \frac{\gamma(\mu+6, D_{\max}\Lambda) - \gamma(\mu+6, D_{\min}\Lambda)}{\gamma(\mu+4, D_{\max}\Lambda) - \gamma(\mu+4, D_{\min}\Lambda)} - \left[\frac{\gamma(\mu+5, D_{\max}\Lambda) - \gamma(\mu+5, D_{\min}\Lambda)}{\gamma(\mu+4, D_{\max}\Lambda) - \gamma(\mu+4, D_{\min}\Lambda)}\right]^2,$$ does not depend on N_T

Scaled intercept parameter N_w (depends on N_T, m, and σ^2)

$$N_w = \frac{4^4 k_2}{\pi \rho_w} N_T \Lambda \frac{[\gamma(\mu+4+v_2, D_{\max}\Lambda) - \gamma(\mu+4+v_2, D_{\min}\Lambda)]^5}{\Gamma(\mu+1)[\gamma(\mu+5, D_{\max}\Lambda) - \gamma(\mu+5, D_{\min}\Lambda)]^4}$$

Tapiador et al. 2014, J. of Hydromet.

Parameters

N_T, m, σ^2

m and σ^2 are physically related because of hydrodynamics

[m, σ^2] are highly correlated in real rainfall

so you end up with just [N_T, D_m]

How does this approach differs from other DSDs?

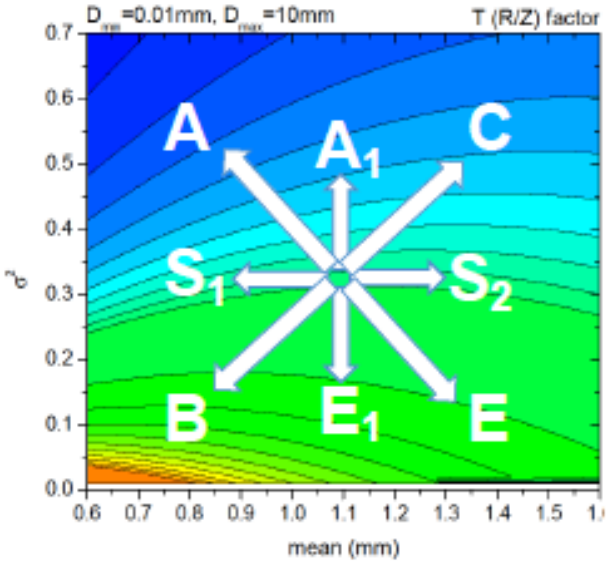
$$n(D) = N_T \cdot p(D) = N_T D^{\mu} \Lambda^{\mu+1} \frac{e^{-\Lambda D}}{\Gamma(\mu+1)}$$

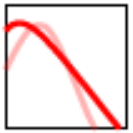
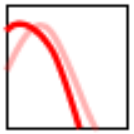
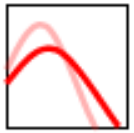
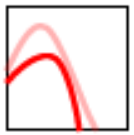
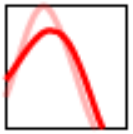
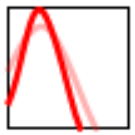
Only apparently similar to for instance Ulbrich's DSD:

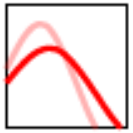
$$n(D)_{Ulb} = N_0 D^{\mu} e^{-\Lambda D}$$

[Note that units for N_0 are $m^{-4-\mu}$]

Microphysics



A	m	↓	small drops	↑		Accretion
	σ^2	↑	large drops	↑		
B	m	↓	small drops	↑		Break-up
	σ^2	↓	large drops	↓		
C	m	↑	small drops	↓		Coalescence
	σ^2	↑	large drops	↑		
E	m	↑	small drops	↓		Evaporation
	σ^2	↓	large drops	↓		
			large drops	↑		
S_1	m	↓	small drops	↓		Size sorting
	σ^2	=	large drops	↓		
S_2	m	↑	small drops	↑		Size sorting
	σ^2	=	large drops	↑		
A_1	m	=	small drops	↑		Accretion
	σ^2	↑	large drops	↑		
E_1	m	=	small drops	↓		Evaporation
	σ^2	↓	large drops	↓		



Coalescence

Microphysics
Quantitative evolution of the DSD

Microphysics
Quantitative evolution of the DSD

$$\lim_{t\to s}\frac{1}{t-s}\int_{|y-x|>\epsilon} p(s,x;t,y)dy = 0;$$

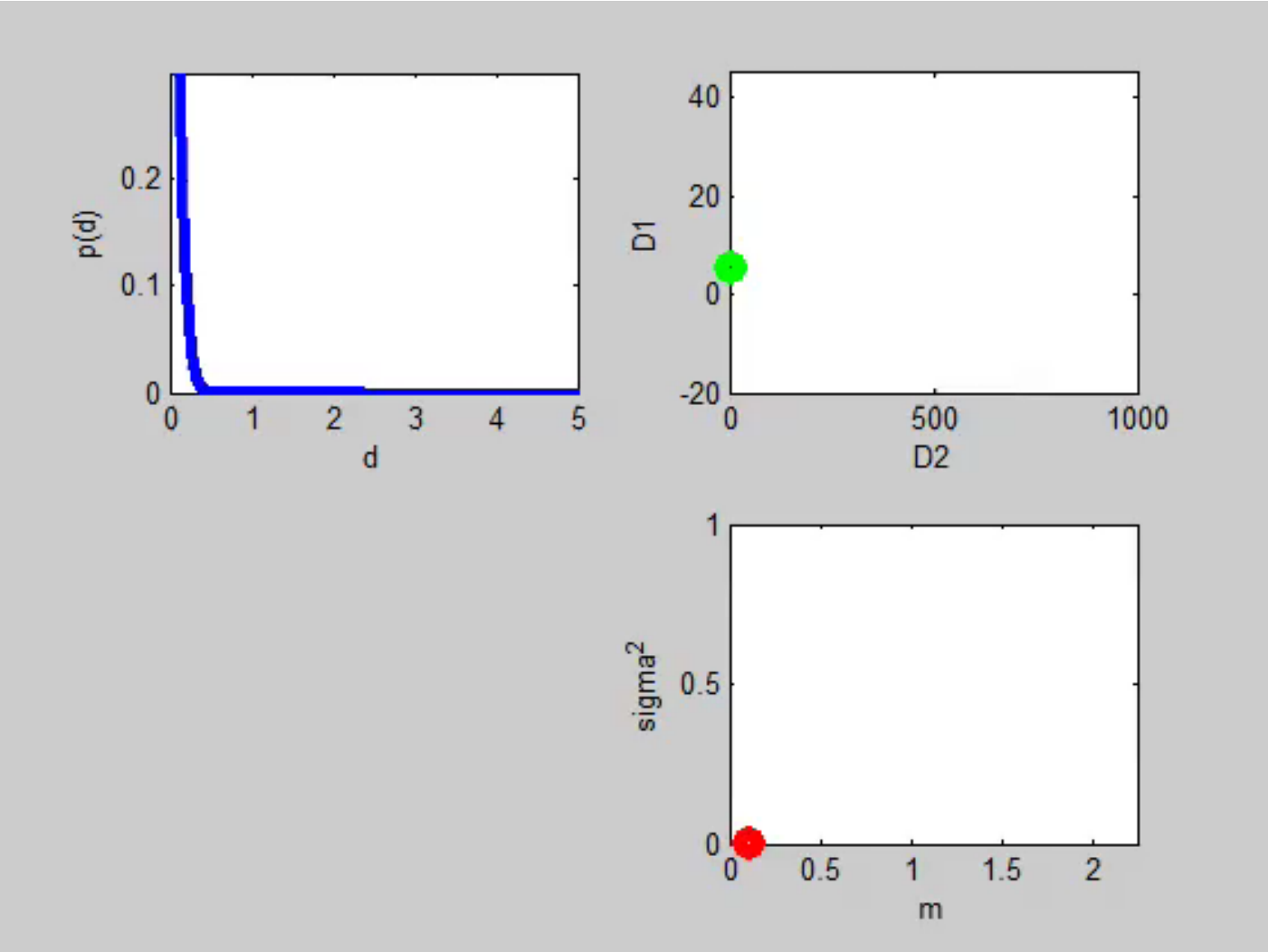
$$\lim_{t\to s}\frac{1}{t-s}\int_{|y-x|>\epsilon} (y-x)p(s,x;t,y)dy = f(s,x) = D^{(1)};$$

$$\lim_{t\to s}\frac{1}{t-s}\int_{|y-x|>\epsilon} (y-x)^2p(s,x;t,y)dy = g^2(s,x) = D^{(2)};$$

Microphysics
Quantitative evolution of the DSD

$$\lim_{t\to s}\frac{1}{t-s}\int_{|y-x|>\epsilon}(y-x)x^{\mu_x}\Lambda^{\mu_x+1}\frac{e^{-\Lambda_x x}}{\Gamma(\mu_x+1)}y^{\mu_y}\Lambda^{\mu_y+1}\frac{e^{-\Lambda_y x}}{\Gamma(\mu_y+1)}dy = D^{(1)}$$

$$\lim_{t\to s}\frac{1}{t-s}\int_{|y-x|>\epsilon}(y-x)^2x^{\mu_x}\Lambda^{\mu_x+1}\frac{e^{-\Lambda_x x}}{\Gamma(\mu_x+1)}y^{\mu_y}\Lambda^{\mu_y+1}\frac{e^{-\Lambda_y x}}{\Gamma(\mu_y+1)}dy = D^{(2)}$$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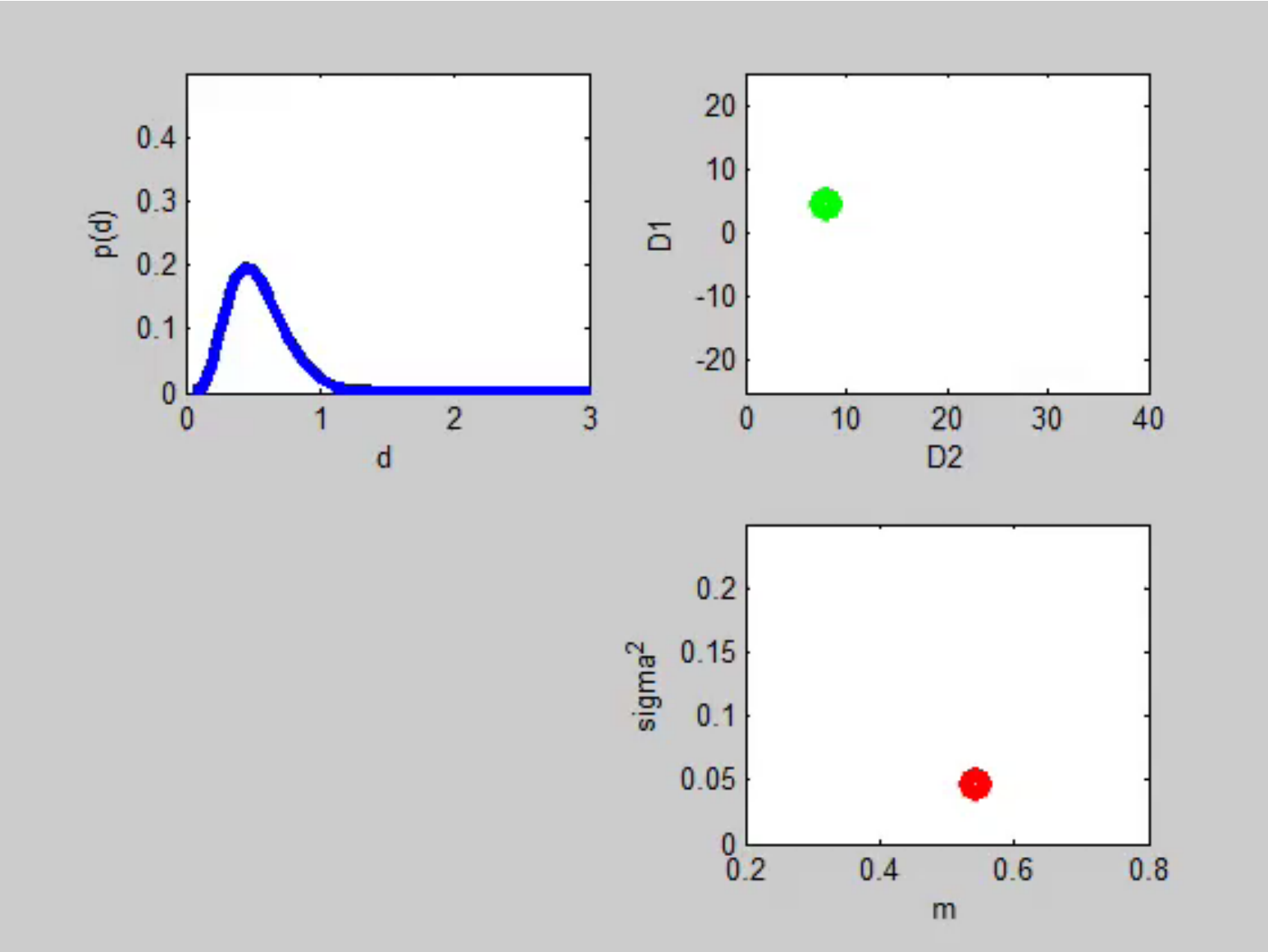
0.2
0.1
0
0
1
2
3
4
5
d
D1
40
20
0
-20
0
500
1000
D2
sigma2
1
0.5
0
0
0.5
1
1.5
2
m


p(d)
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0.3
0.2
0.1
0
0
1
2
3
d
D1
20
10
0
-10
-20
0
10
20
30
40
D2
sigma2
0.2
0.15
0.1
0.05
0
0.2
0.4
0.6
0.8
m

Polarimetric radar

$$Z_e = \frac{\lambda^4}{\pi^5 |K_w|^2} k_4 \frac{\Lambda^{\mu+1}}{\Gamma(\mu+1)} N_T \int_{D_{min}}^{D_{max}} D^\mu e^{-\Lambda D} \sigma_b(D,\lambda) dD$$

$$k = 4.343 \cdot k_5 \frac{\Lambda^{\mu+1}}{\Gamma(\mu+1)} N_T \int_{D_{min}}^{D_{max}} D^\mu e^{-\Lambda D} \sigma_e(D,\lambda) dD$$

$$P_s = k_6 \frac{\Lambda^{\mu+1}}{\Gamma(\mu+1)} N_T \int_{D_{min}}^{D_{max}} D^\mu e^{-\Lambda D} \sigma_s(D,\lambda) dD$$

$$P_e = k_6 \frac{\Lambda^{\mu+1}}{\Gamma(\mu+1)} N_T \int_{D_{min}}^{D_{max}} D^\mu e^{-\Lambda D} \sigma_e(D,\lambda) dD$$

$$P_a = N_T \frac{\int_{D_{min}}^{D_{max}} D^\mu e^{-\Lambda D} \sigma_s(D,\lambda) a(D,\lambda) dD}{\int_{D_{min}}^{D_{max}} D^\mu e^{-\Lambda D} \sigma_s(D,\lambda) dD}$$

Using those equations, it is possible to retrieve N_T and build tables for m and σ^2.

- Multiple scattering calculations
- DSD research [modeling]
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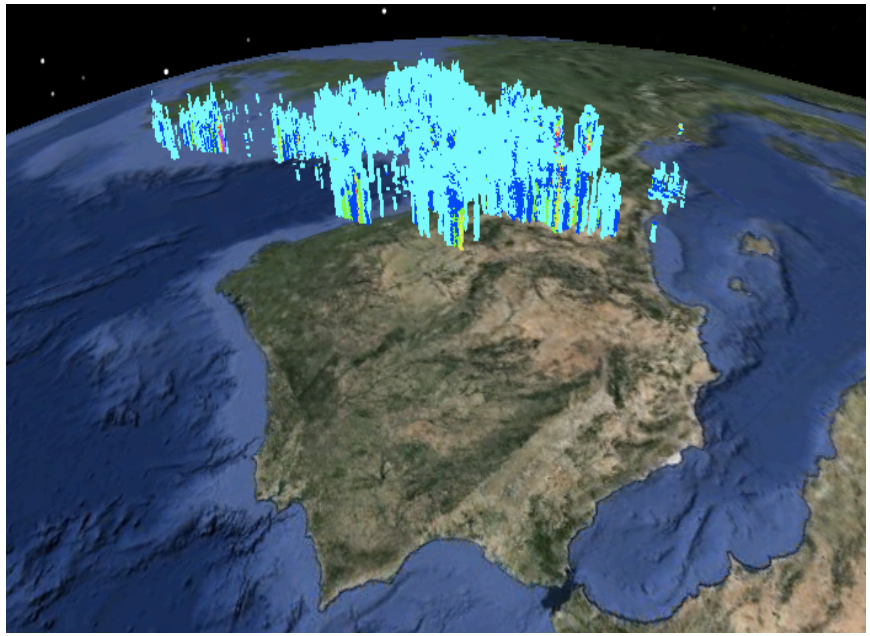
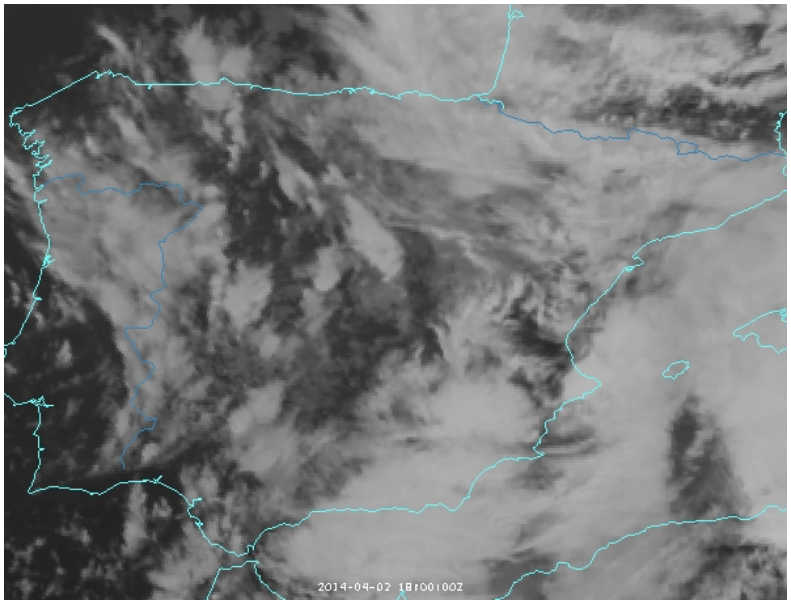
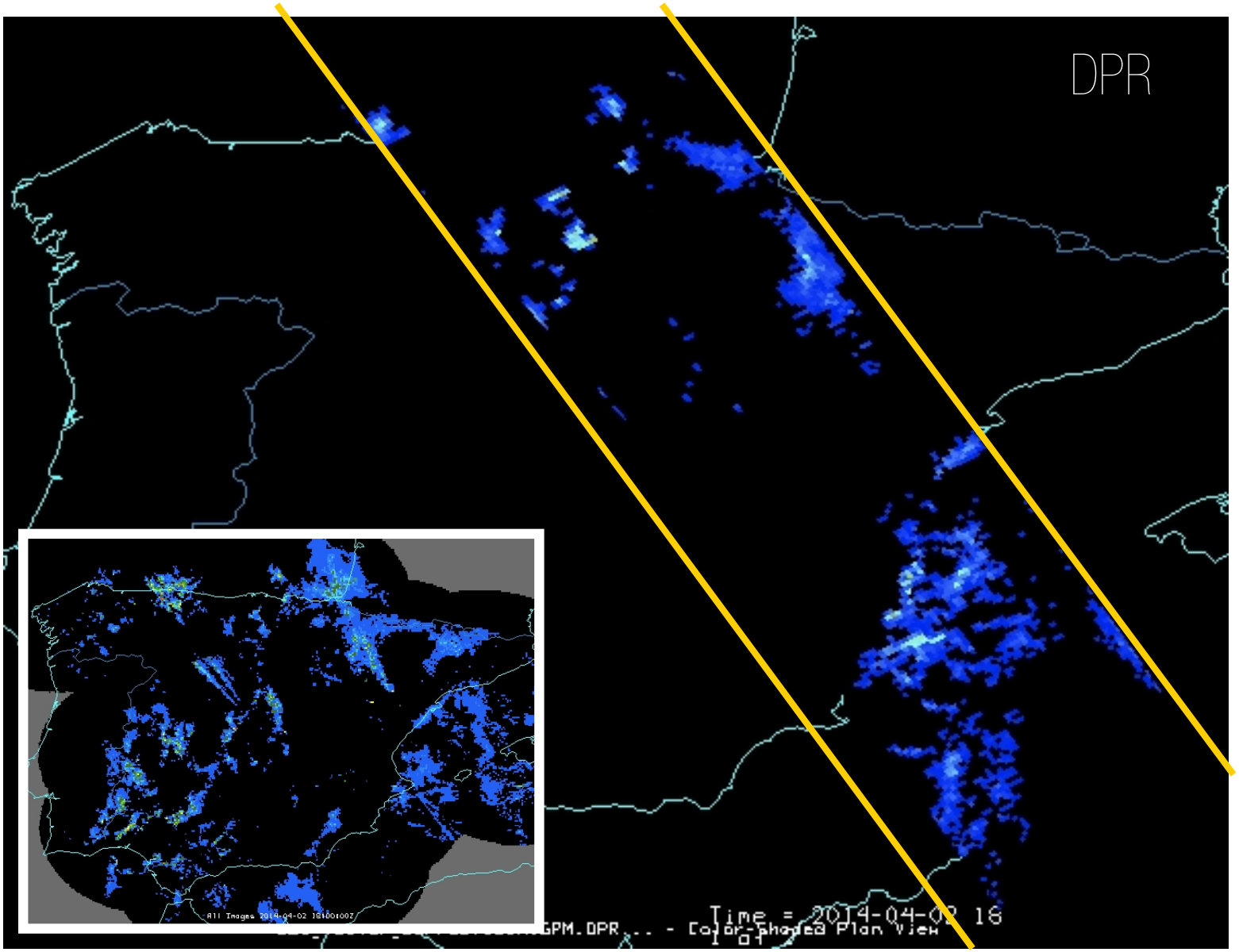
Multisource [GPM+Meteosat+GR+Models]
Case Studies

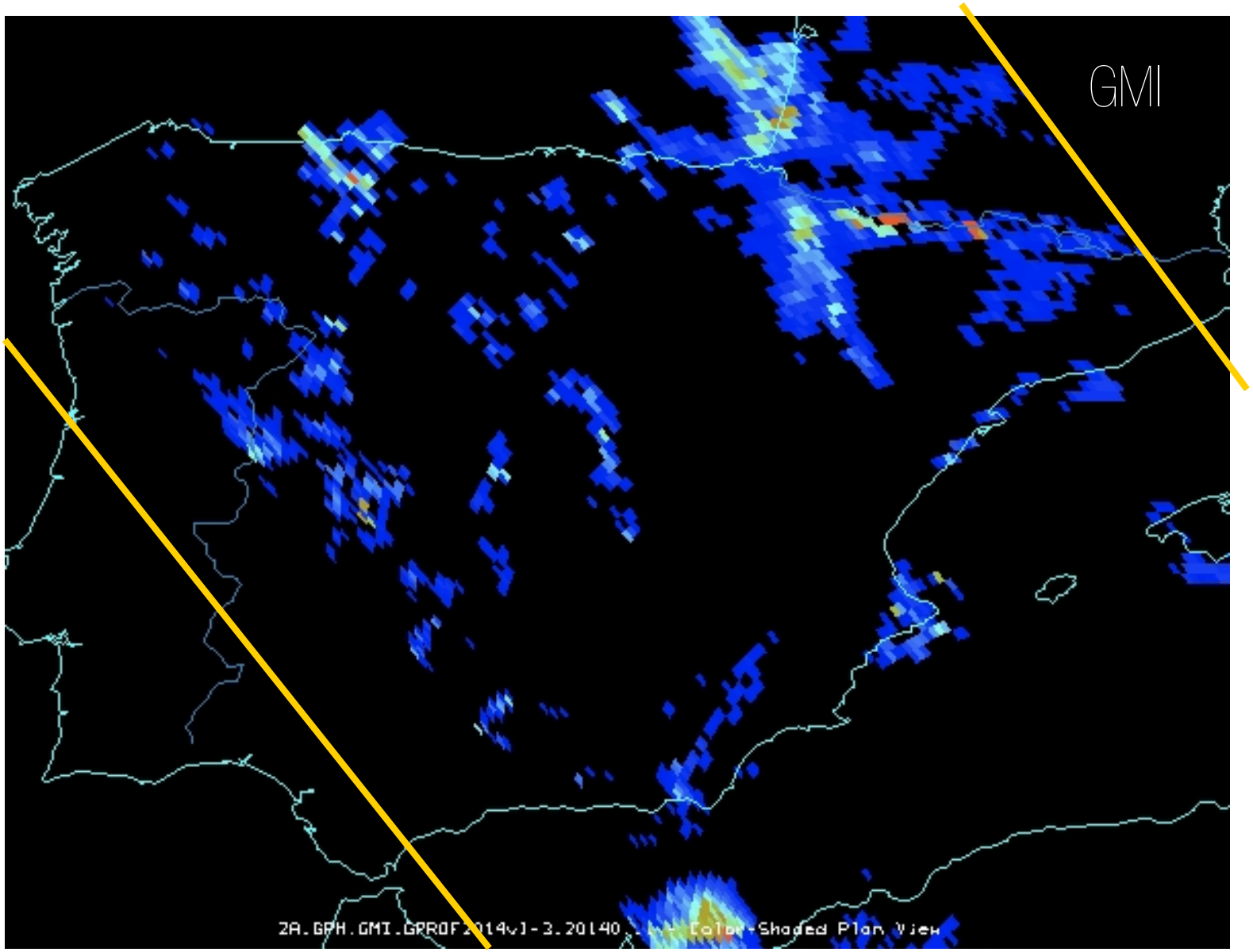
DRP on GOOGLE EARTH



METEOSAT IR10.8




DPR
Time = 2014-04-02 16
GPM.DPR ... - Color-Shaded Plan View


GMI
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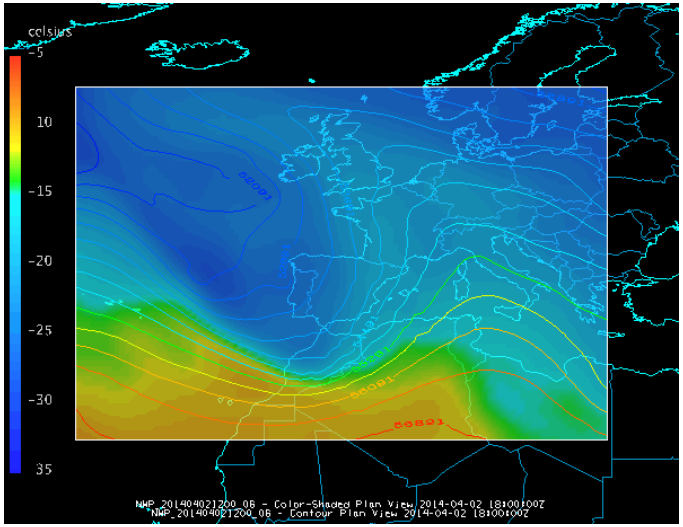
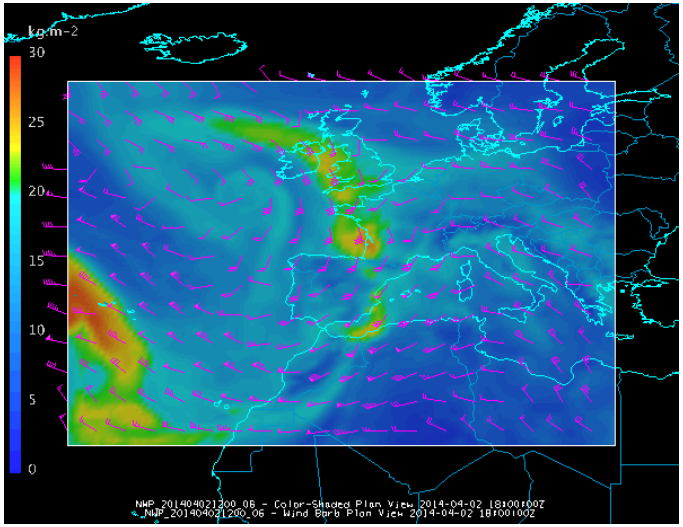
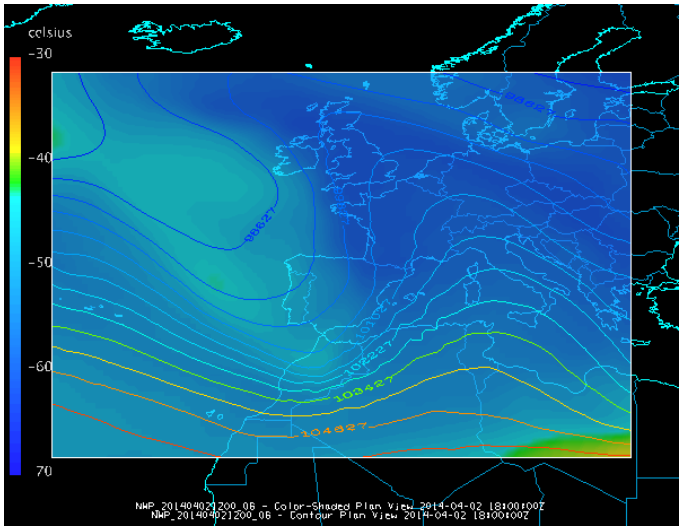
Color-Shaded Plan View



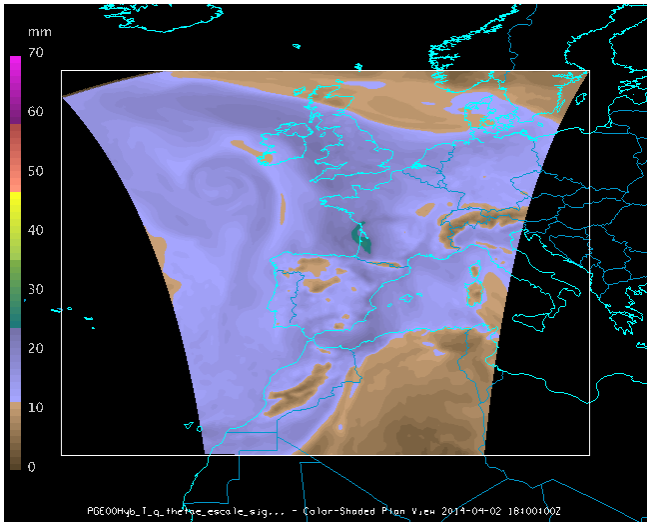
Z and T @500 hPa



TOTAL COLUMN WATER



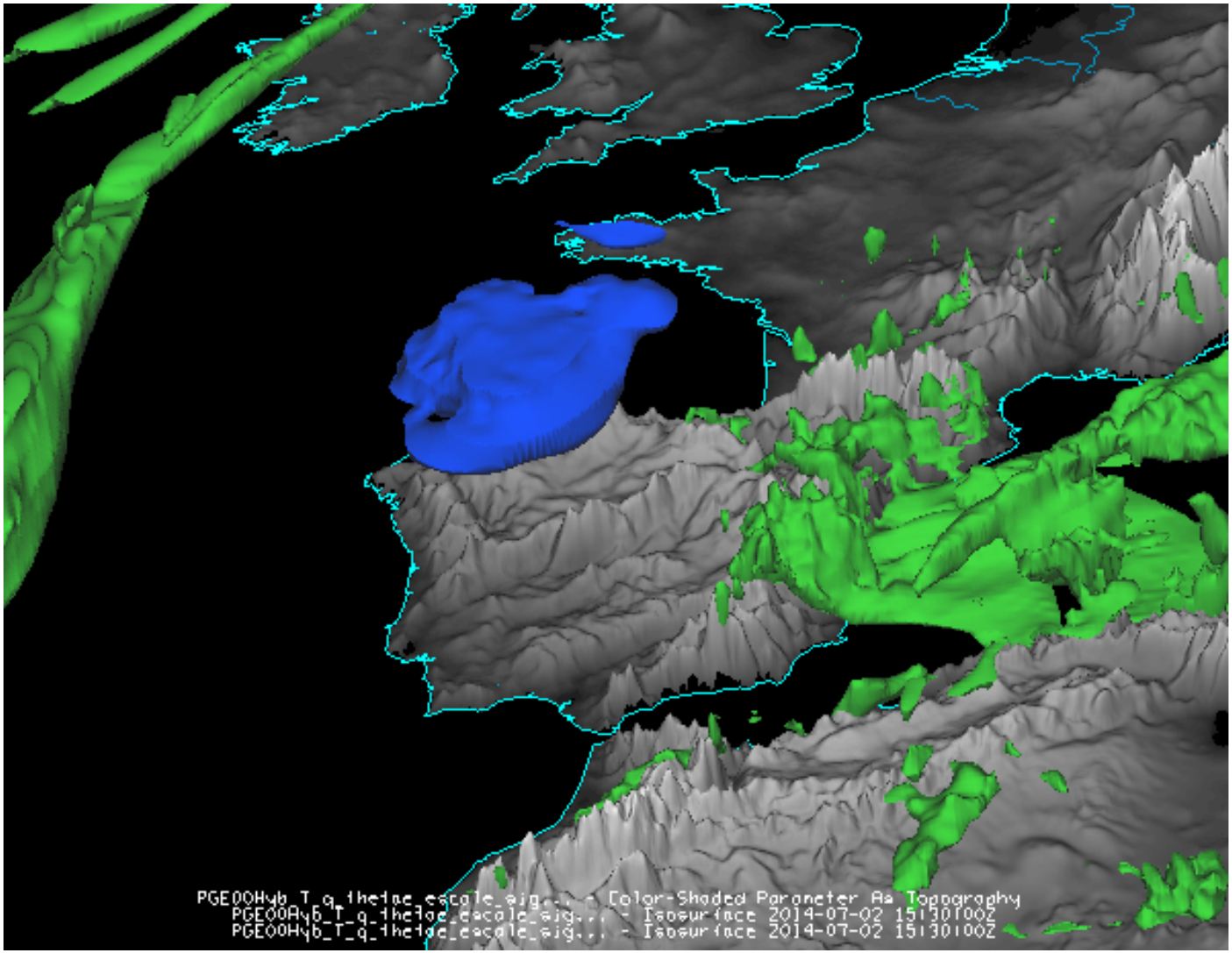
Z and T @250 hPa



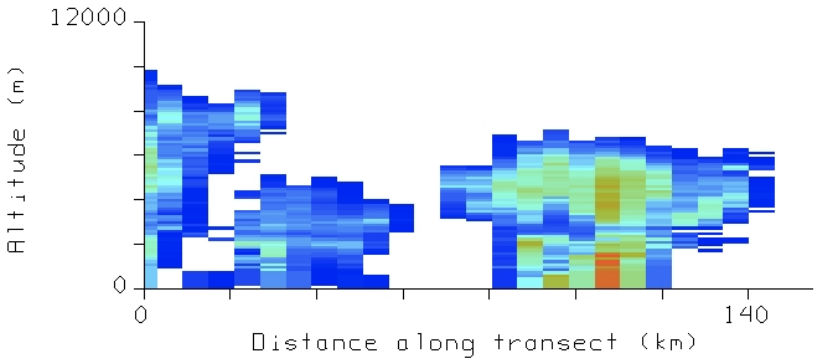
TPW

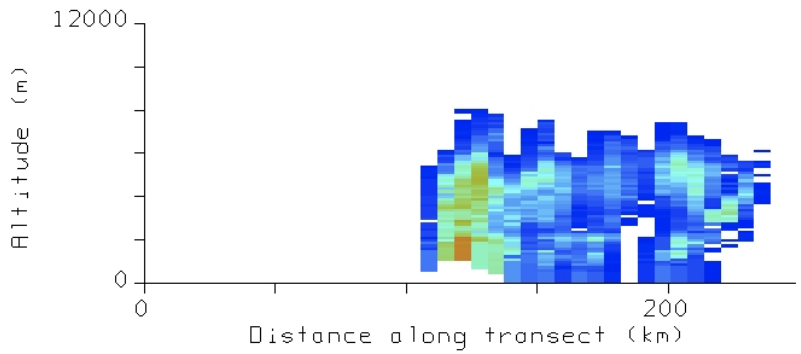
ECMWF MODEL

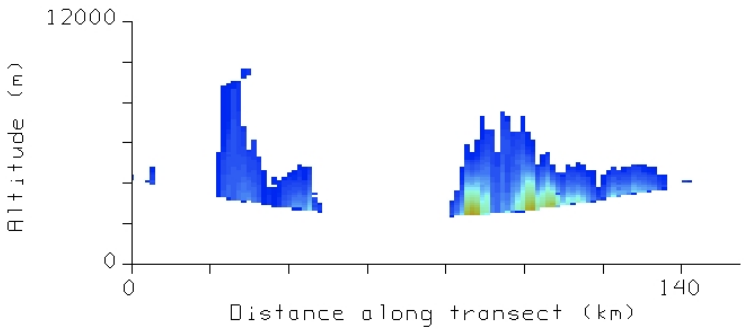
σ_T=2 (blue), σ_q=2 (green)

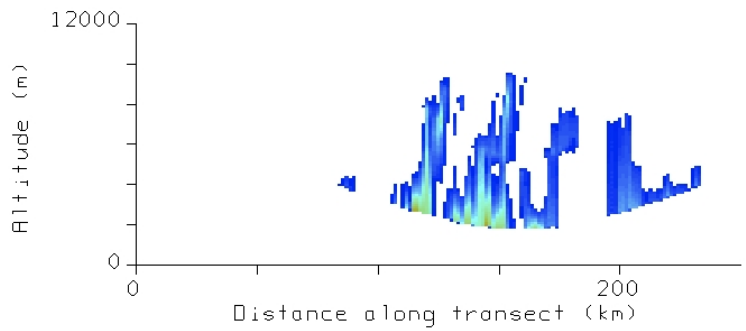


Ground Radar – DPR comparisons

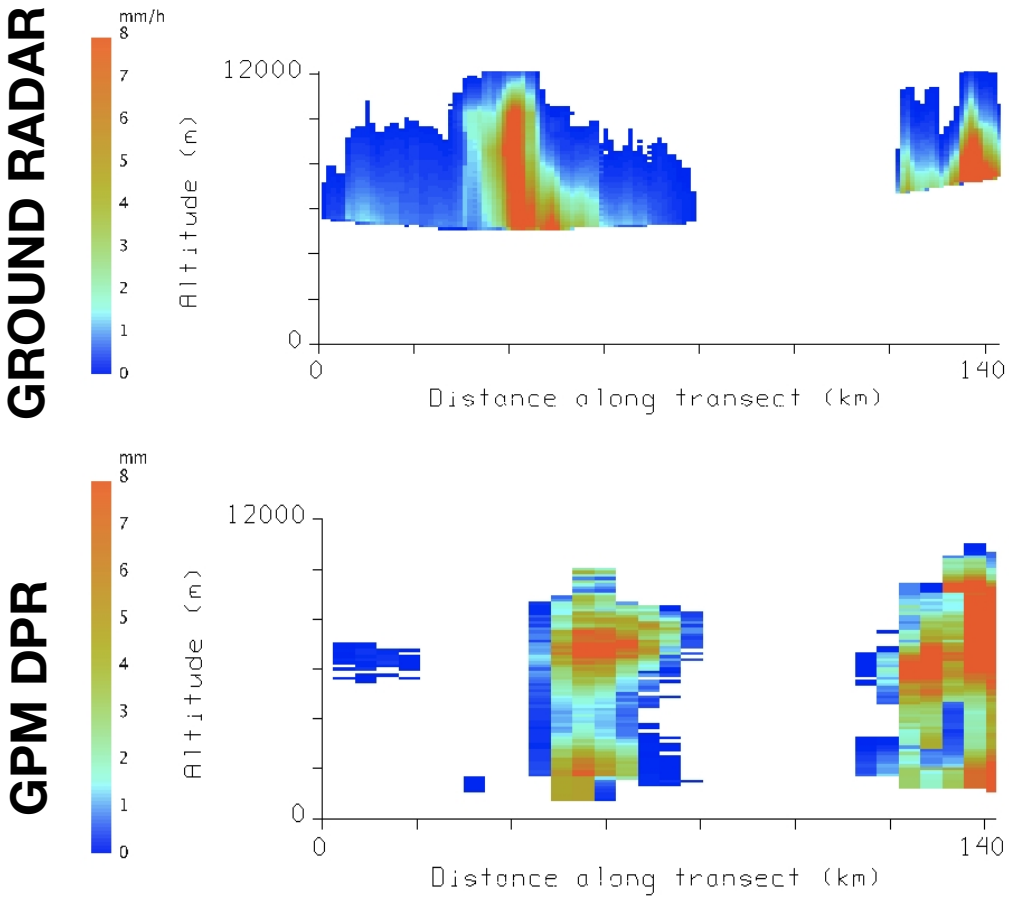


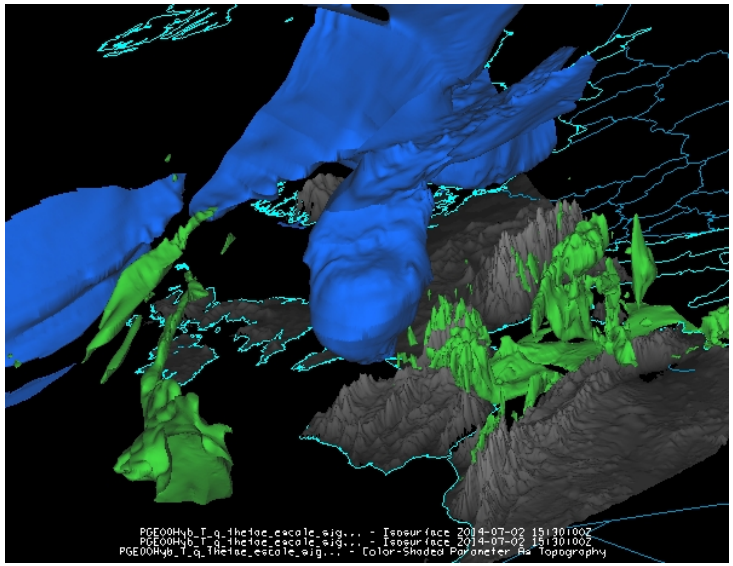




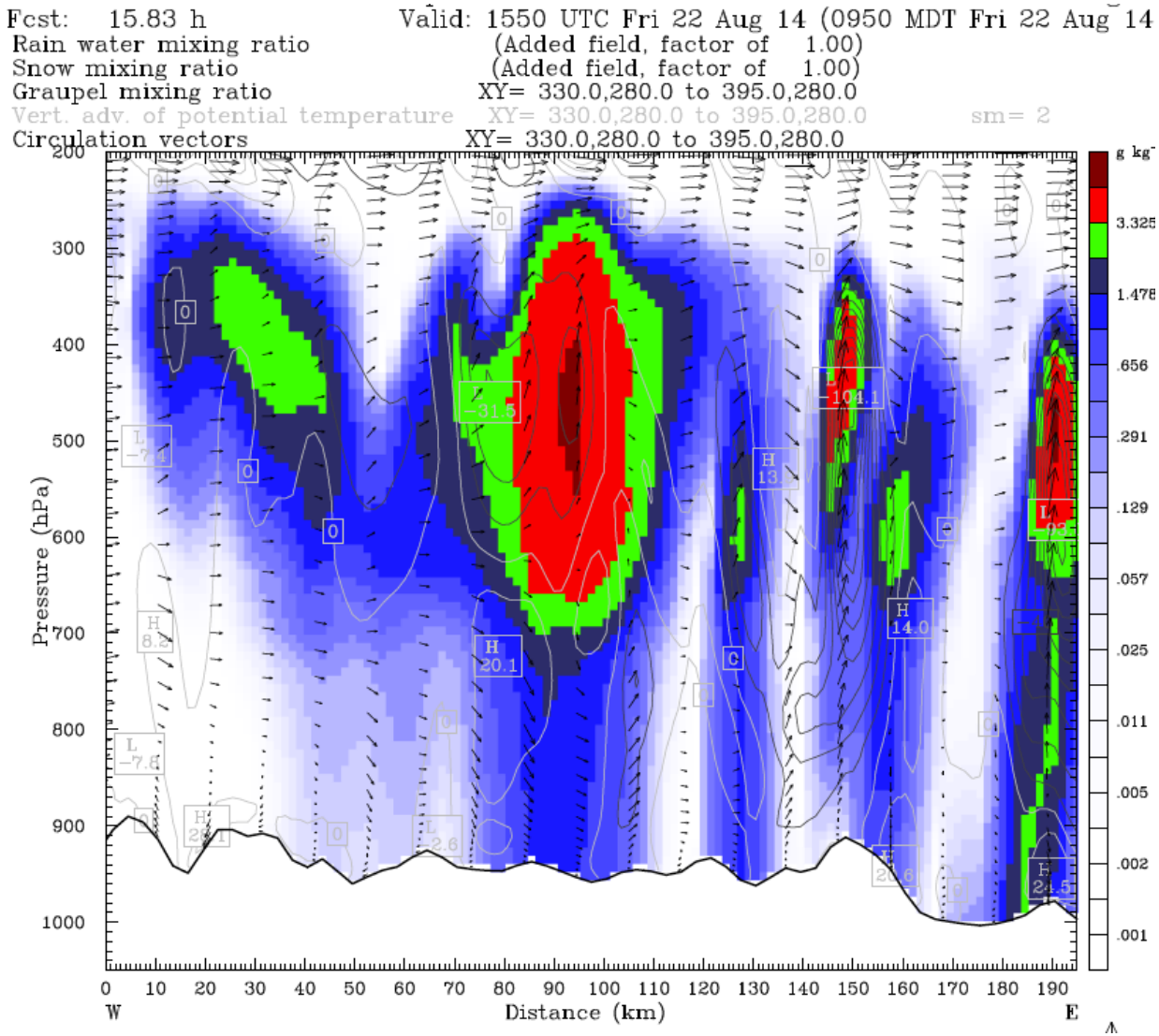


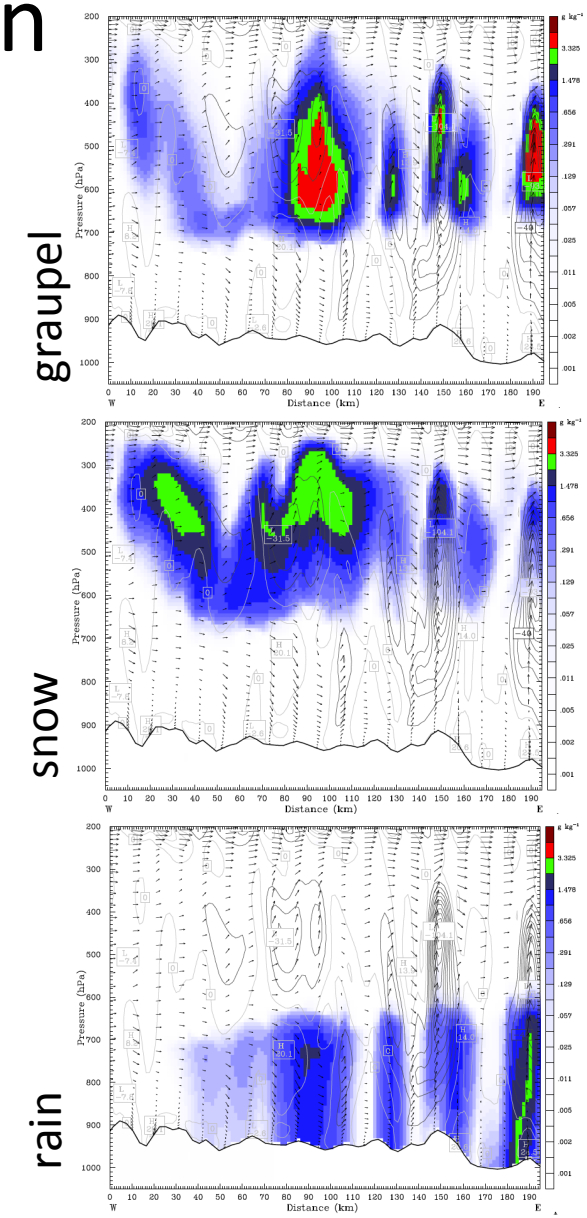
Ground Radar – DPR comparisons



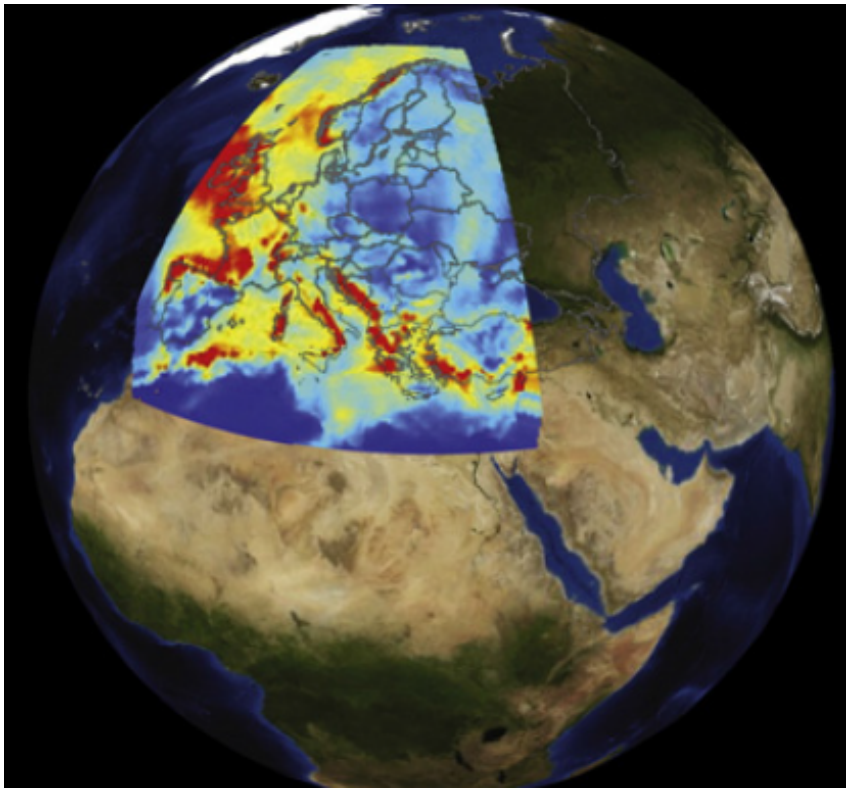


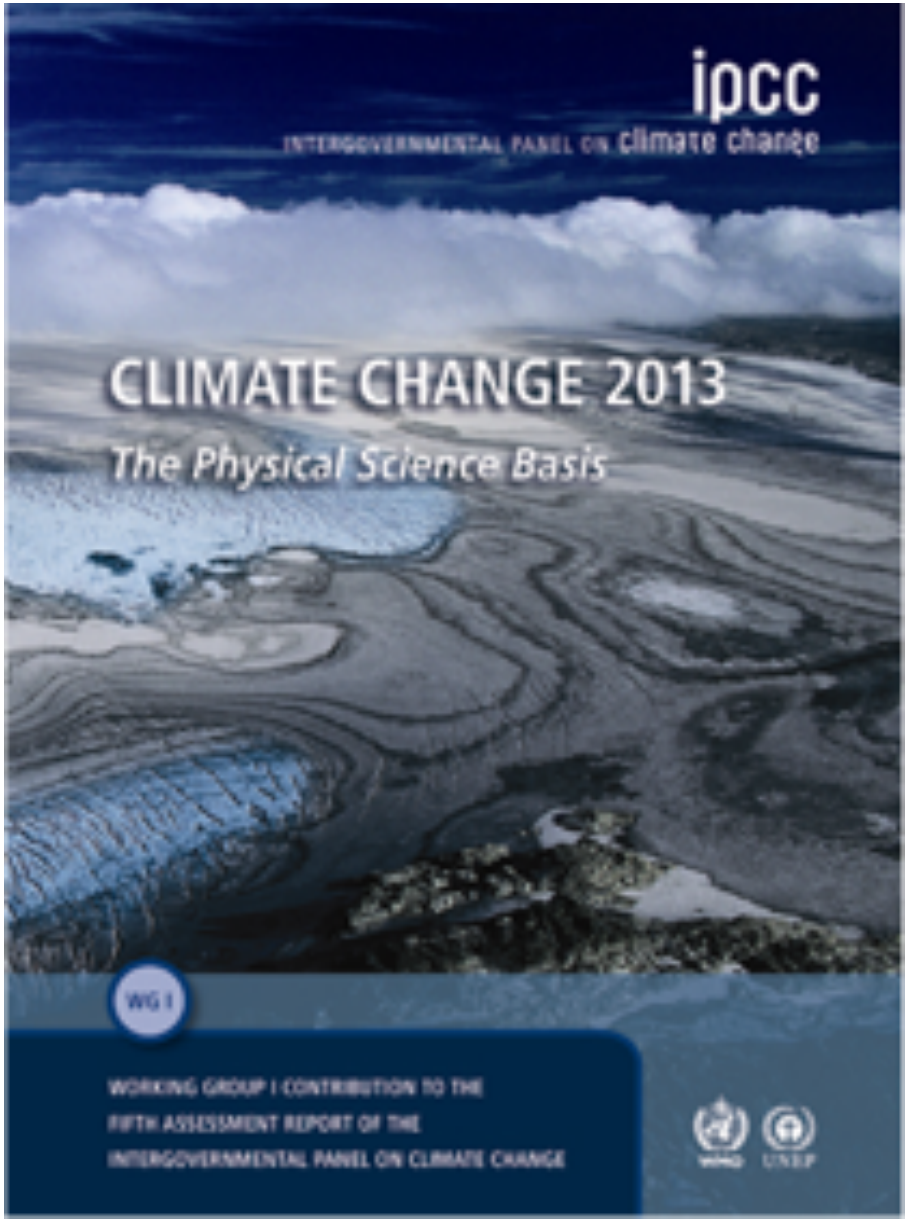
WRF modeling at 3 km resolution



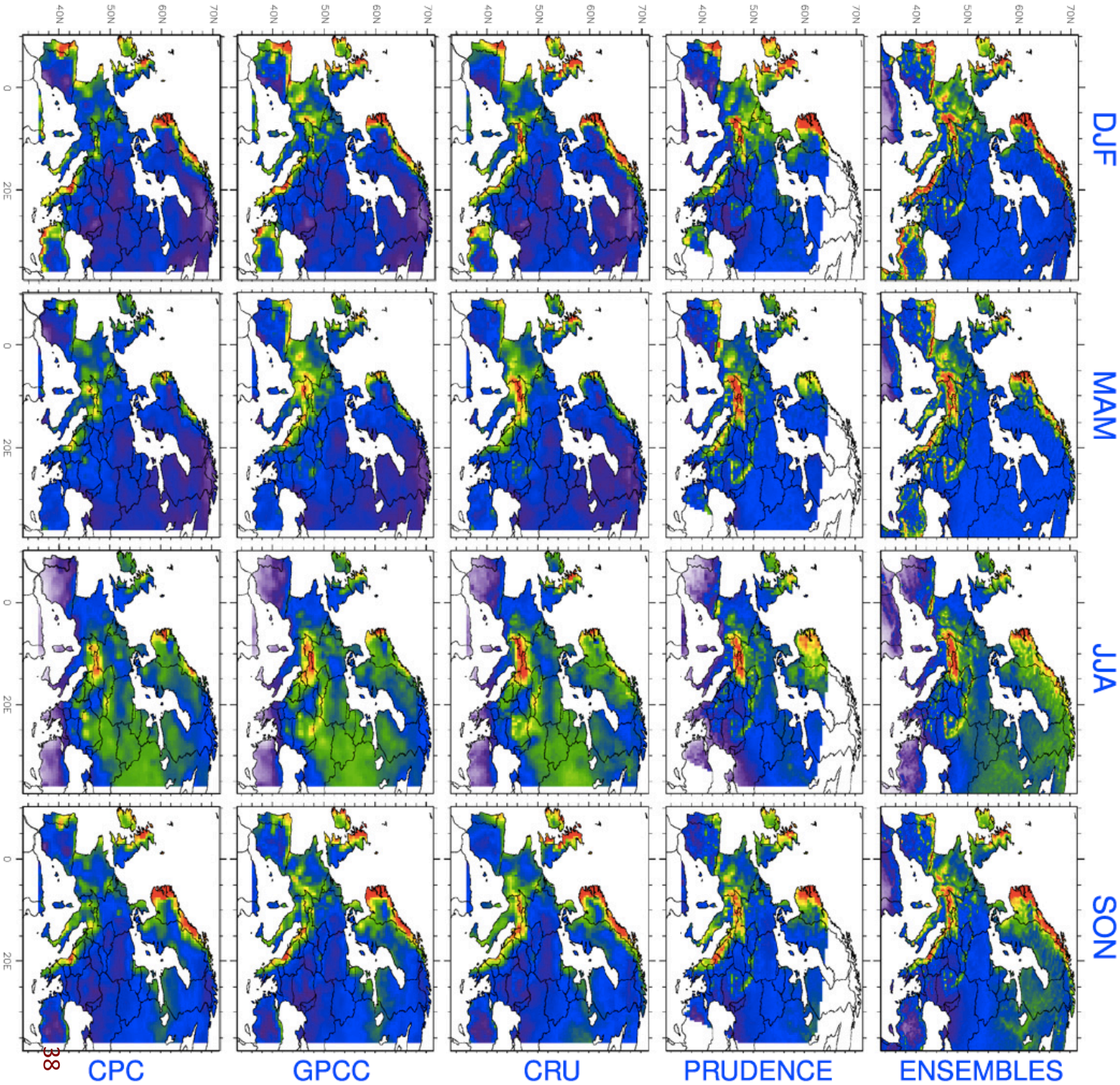


Multiple scattering calculations
DSD research [modeling]
Case studies over Spain
Climate models validation
New equipment

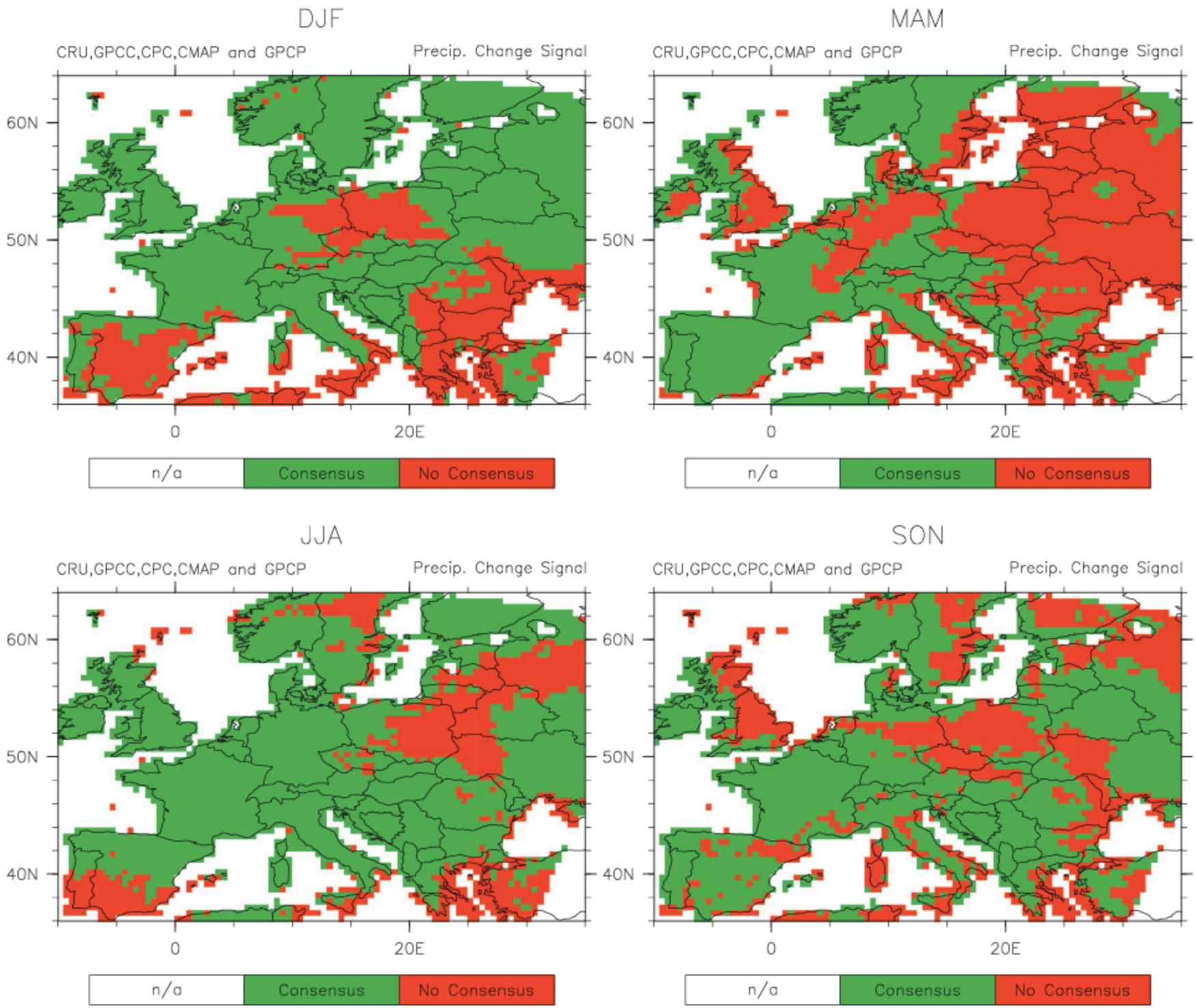




THE PROBLEM OF THE REFERENCE DATABASE



Tapiador, 2008, Journal of Climate



Tapiador, 2010, Journal of Climate

- Multiple scattering calculations
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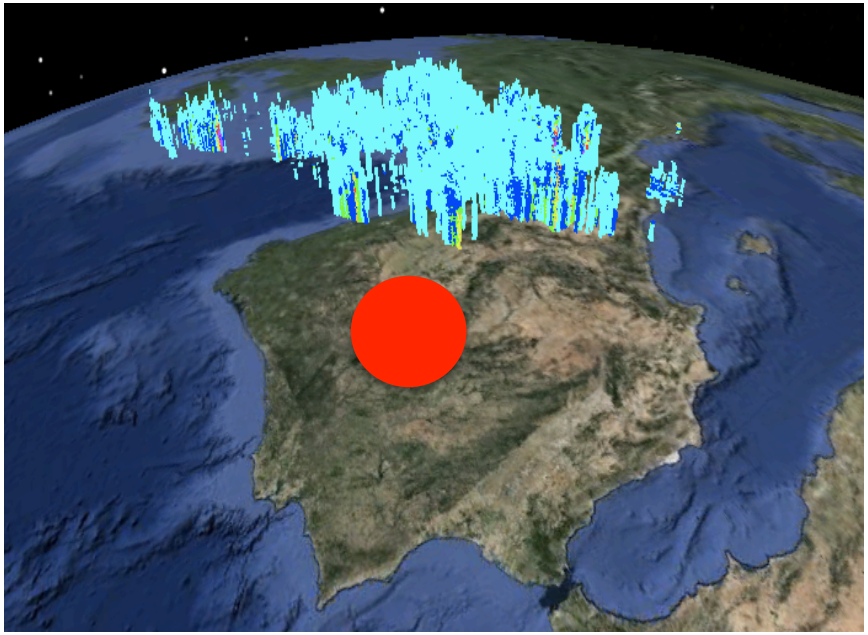
more disdrometers

current radar

Guardiola-Albert, C; Rivero, C; Monjo, R; Díez-Herrero, A.; Yagüe, C; Bodoque, J.M.; Tapiador, F.J. 2015. **Quantitative precipitation estimation in a small mountainous catchment using X-band radar data for convective and stratiform events**. Submitted to *Journal of Hydrology.*



new radar by 2016

(fingers crossed)

TECHNICAL DATA

SYSTEM	METEOR 60DX	
Mode	Doppler, Dual-Polarization	
Type	mobile	fixed
Operating Frequency Range	9300 – 9500 MHz (X-Band)	
Pulse Width	0.3 µs – 3.3 µs	
Pulse Repetition Frequency [PRF]	250 – 3000 Hz, user selectable	
Typical Operational Range / Technical Range	100 km / 600 km	
Maximum Velocity	± 96 m/s	
System Phase Stability	0.5°	

Thanks