Remote Sensing of Precipitation

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Outline

- Measuring Rain
- Temporal and Spatial Variability of Rain
- Remote Sensing Techniques
- Precipitation and Radiometry
- Use of mm/submm Radiometry for Severe Weather Monitoring and Rain Quantification

Measuring Rain (1/2)

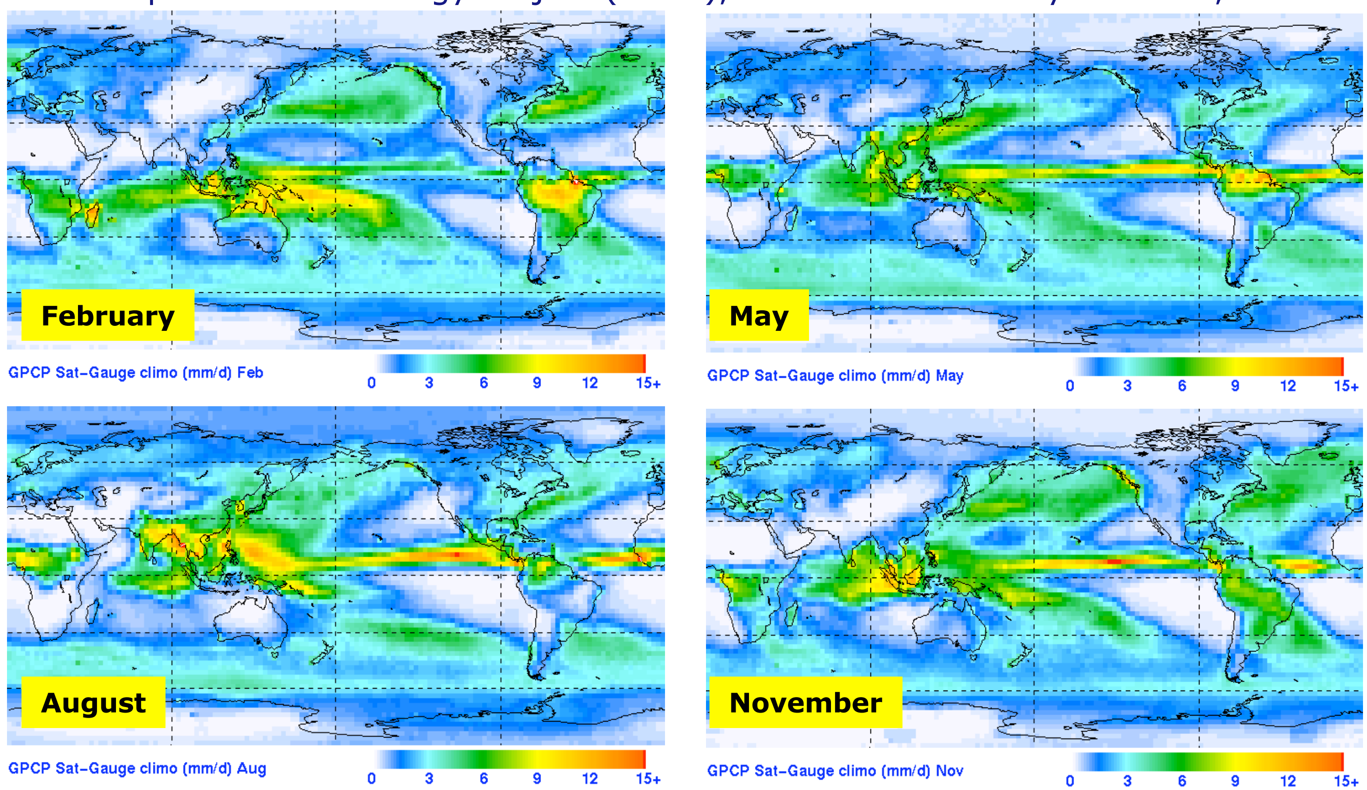
- Rain directly impacts on human activities
- Key factor to follow climate change and to study energy/water budgets
- Where, when, how much?
- Estimation of rain and its forecast poorly characterized because of its high variability

	Temporal variability	*Spatial characteristics*
Convective cell	***Few minutes***	***4 km***
Rain system	***Few hours***	***100 km***
Cyclone	***Few days***	***1000 km***

Measuring Rain (2/2)

- Where we are now (from space borne view)
  > Monthly/weekly/daily global from IR+VIS+MW+gauges
  > Instantaneous 5/10 km from active/passive microwave LEO

Global Precipitation Climatology Project (GPCP), 2.5° x 2.5° monthly rain rate, 1979-2006



User Requirements

- Position Paper from Rizzi *et al*. (2006)
  > only liquid precipitation shown here

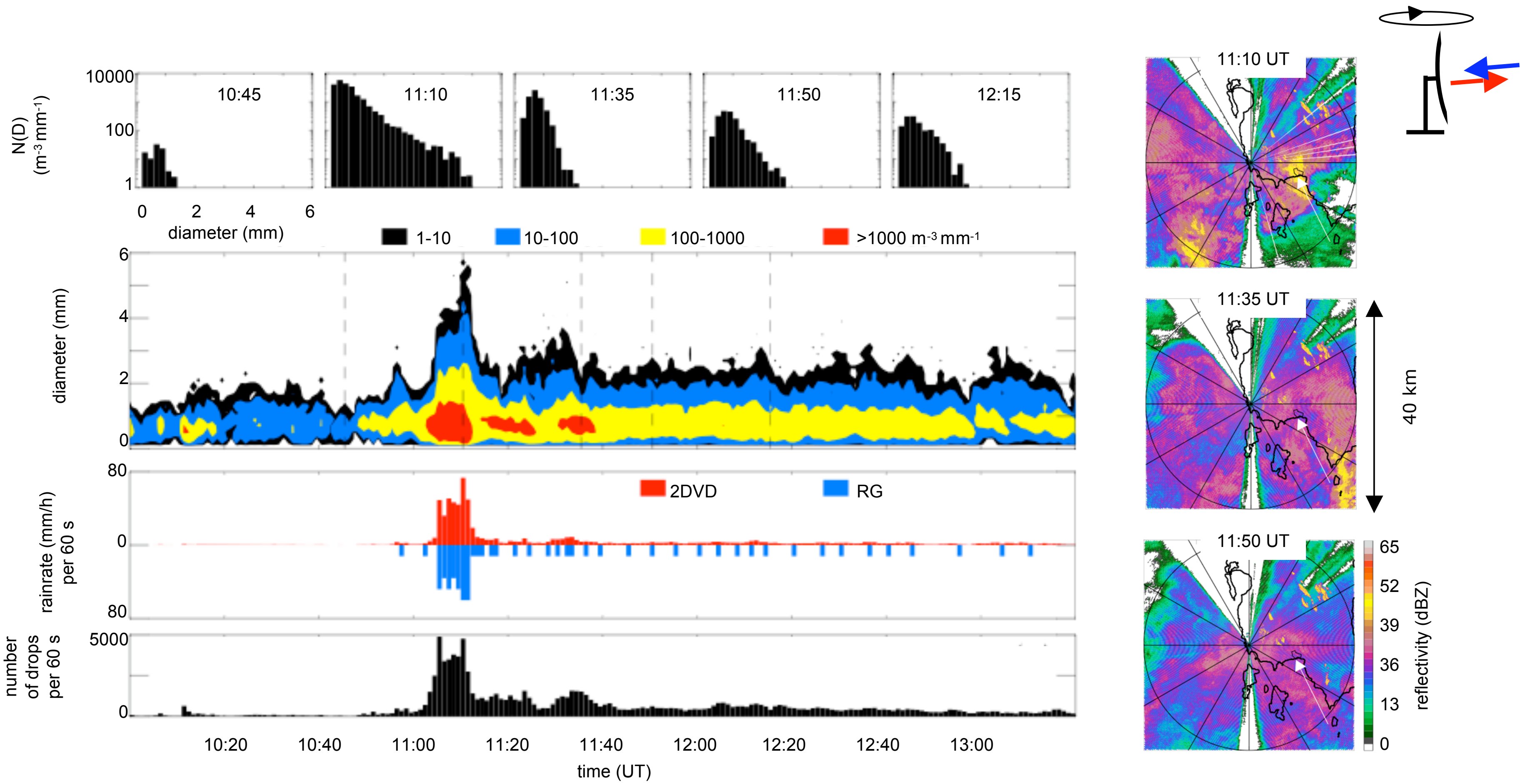
Position Paper – Cloud, Precipitation and Large Scale Land Surface Imaging Version 1.k 06/03/06
(NWP : numerical weather prediction; NWC : nowcasting)

accuracy | horizontal spatial resolution | vertical spatial resolution | observation cycle | delay

Table 2 of 8		Accuracy (r.m.s.)				Bias	Stabil	Δx (km)			Δz (km)			Δt (h)			δ (h)			Priority		Note
Parameter	Application	Unit	thresh	break	obj			thresh	break	obj	thresh	break	obj	thresh	break	obj	thresh	break	obj	global	hi lat	
Precipitation profile (liquid)	NWP global	%	100	50	20			50	15	5	3	2	0.2	12	3	1	6	2	0.5	1	2	11,12,13,14
	NWP regional	%	100	50	20			20	5	2	2	1	0.1	6	1	0.5	0.5	0.1	0.02	1	2	11,12,14
Precipitation rate at surface (liquid)	NWP global	%	100	50	20			50	15	5	-	-	-	12	3	1	6	2	0.5	1	2	11,12,14
	NWP reg.,	%	100	50	20			20	5	2	-	-	-	6	1	0.5	0.5	0.35	0.25	1	2	11,12,14
	Climate	mm/h	10	5	2	0.125	0.003	250	50	5	-	-	-	12	6	3	720	72	6	1	2	
	Hydrology (> 10 mm/h)	%	20	10	5			30	10	1	-	-	-	3	0.25	0.08	0.25	0.17	0.08	1	2	
	Hydrology (1-10 mm/h)	%	40	20	10			30	10	1	-	-	-	3	0.25	0.08	0.25	0.17	0.08	1	1	
	Hydrology (< 1 mm/h)	%	80	40	20			30	10	1	-	-	-	3	0.25	0.08	0.25	0.17	0.08	1	1	
Precipitation detection (liquid)	NWP global	HR/FAR	50/50	95/10	99/2			50	15	5	-	-	-	12	3	1	6	2	0.5	4	4	15
	NWP regional	HR/FAR	50/50	95/10	99/2			20	5	2	-	-	-	6	1	0.5	0.5	0.35	0.25	4	4	15
	NWC	HR/FAR	50/50	70/40	85/20			5	2	0.1	-	-	-	6	1	0.25	0.25	0.17	0.08	1	1	15
Precipitation type	NWP global	classes	3	4	6			50	15	5	-	-	-	12	3	1	6	2	0.5	4	4	16
	NWP reg.,	classes	3	4	6			20	5	2	-	-	-	6	1	0.5	0.5	0.35	0.25	3	3	16
	Climate	classes	3	4	6			250	50	5	-	-	-	12	6	3	720	72	6	3	3	16

Variability of Rain (1/2)

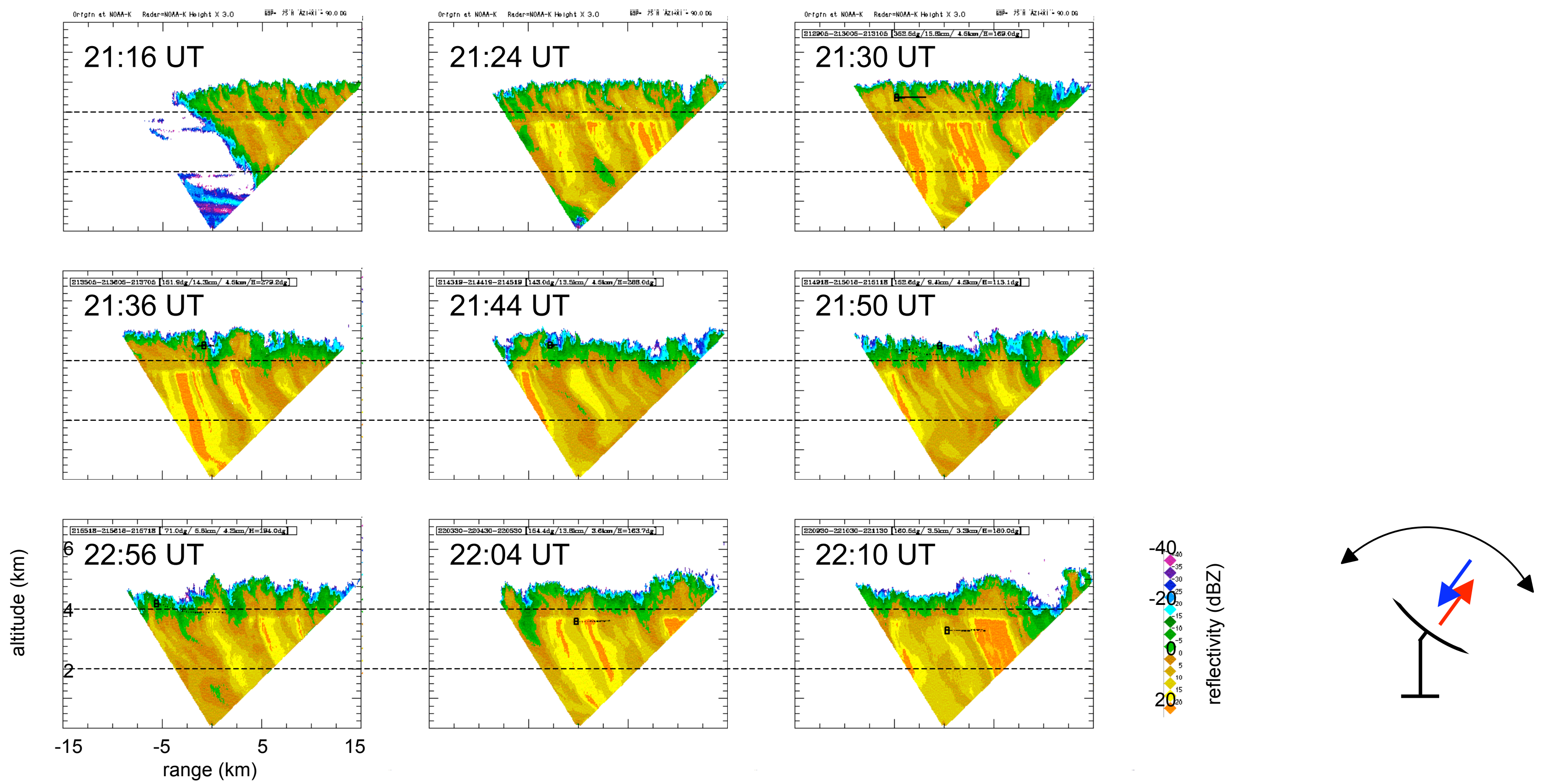
- High temporal and spatial variability
  (example: ISREX Experiment, Methoni, Greece, 09/03/04)



(from Defer and Anagnostou, Adv. in Geo., 2006)

Variability of Rain (2/2)

- Variability also along the vertical due to kinematic, thermodynamic and microphysics processes
  (example: ABFM Experiment, KSC, Florida, 03/02/01 - NOAA-ETL K band (35 GHz))



(Martner et al., report on the ABFM Project, 2002)

Measuring Precipitation

- Rain gauges and disdrometers
  > local measurements
- Operational/research ground-based radar
  > long range capability but mostly over land in habited area
- Airborne/LEO space borne radar
  > campaign dedicated/snapshot
  > GEO radar (Nexrad In Space)
- Space borne radiometry
  > LEO (SSMI, TMI, AMSU : operational;
  Madras and Saphir Megha-Tropiques : in 2009)
  > GEO (GEO IR + LEO MW)
- Cell phone links

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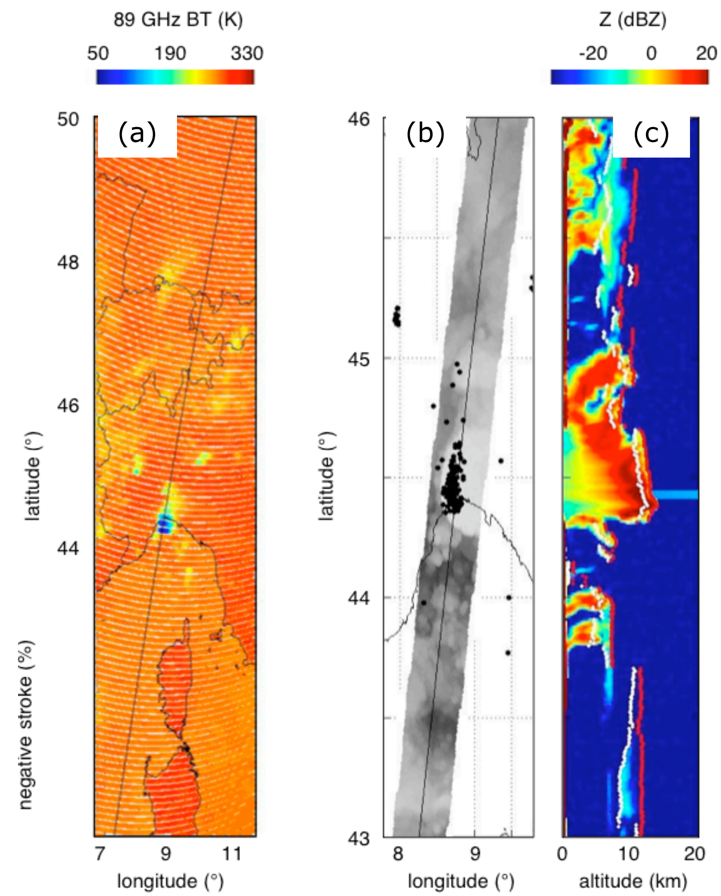
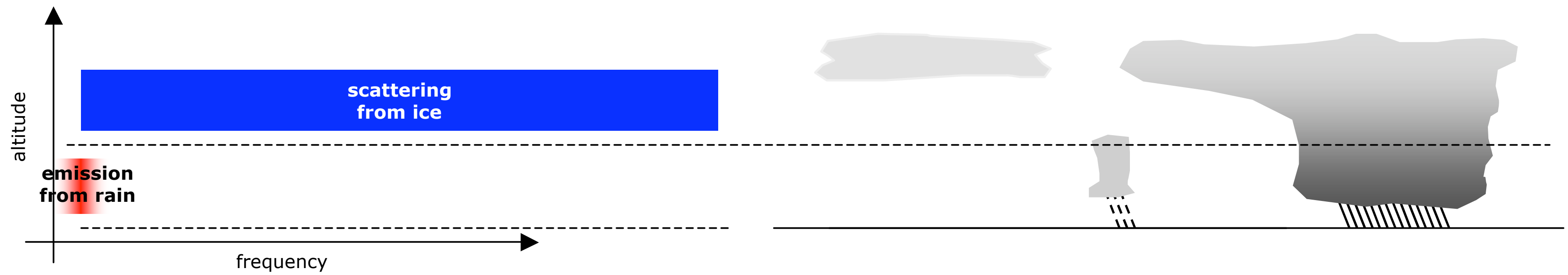
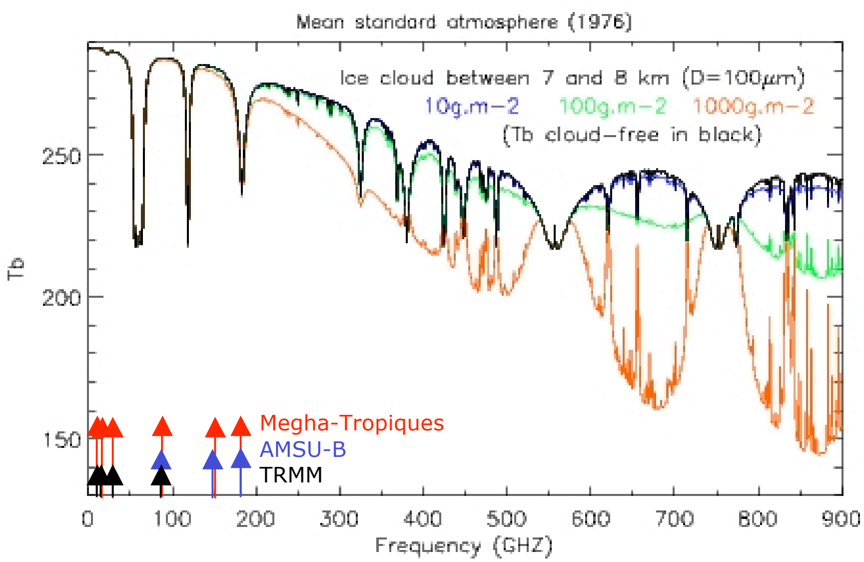


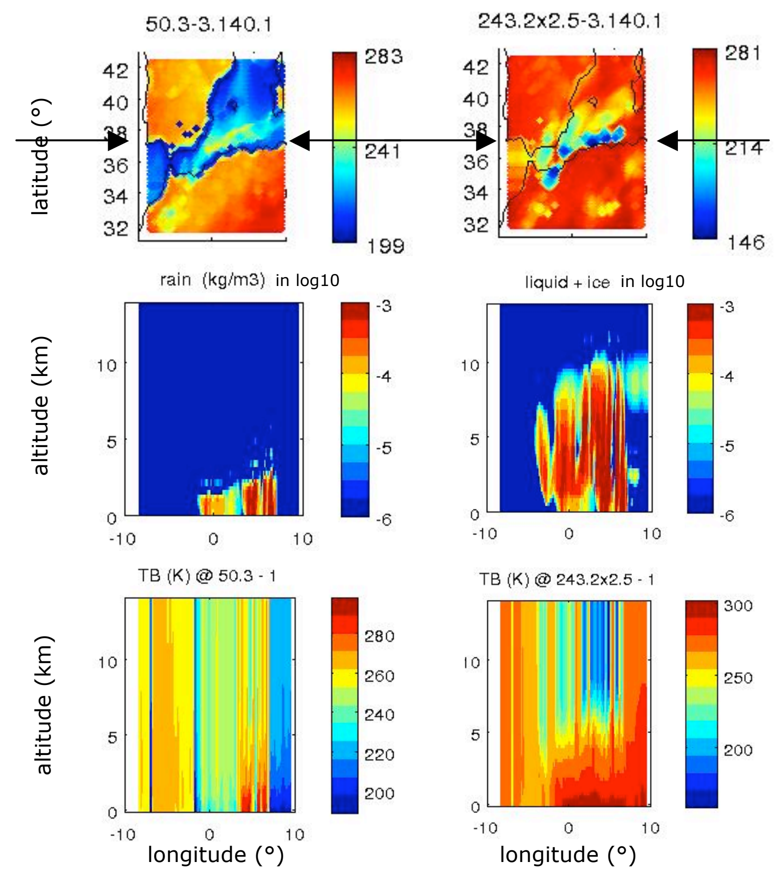
A-Train AMSRE 85 GHz V brightness temperatures (a), A-Train IIR 10.6 µm radiances (b) and vertical cross section of reflectivity from A-Train CLOUDSAT radar and top (bottom) of the first cloud layer measured with A-Train CALIOP lidar in red (white) over the Ligurian Sea at 01:40 UT on 16/08/06.

Precipitation and Radiometry



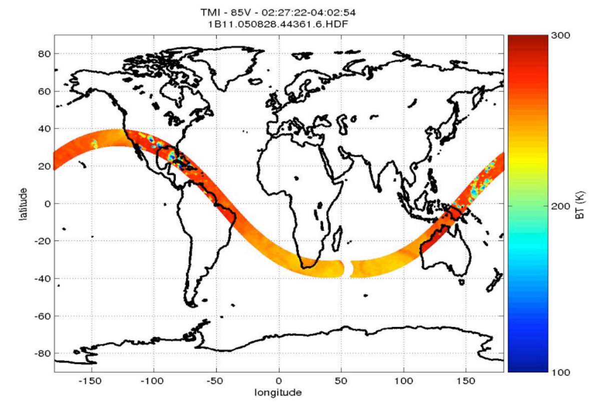


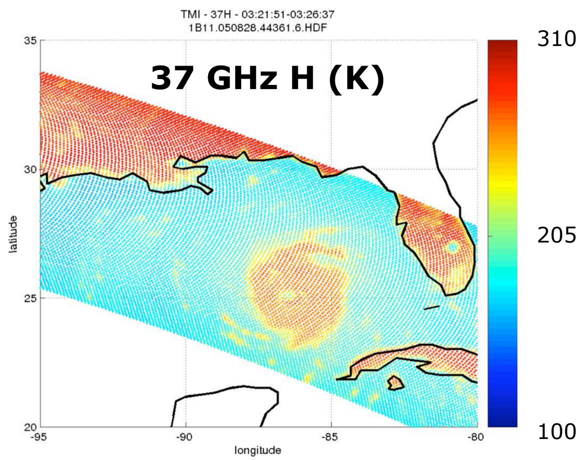
Simulated brightness temperatures up to 900 GHz for a standard atmosphere (water vapor: 14.2 kg.m^{-2}, surface temperature: 288 K) with a mono-disperse (100μm) ice cloud between 7 and 8 km (53° angle, emissivity set to 1, ice density set to 0.9)

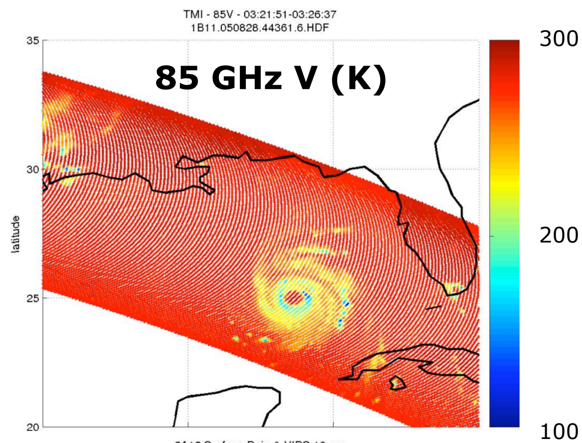


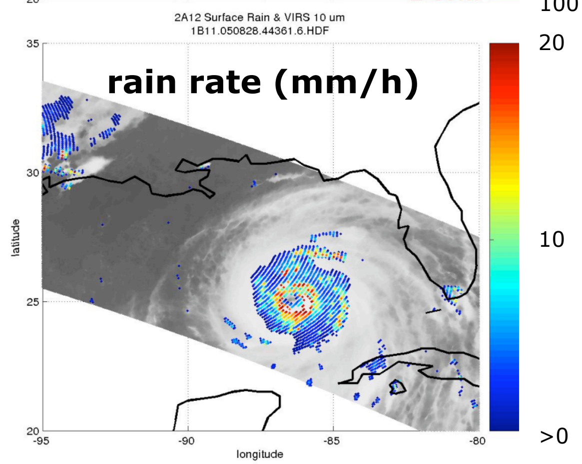
Precipitation with Space Radiometry : TRMM

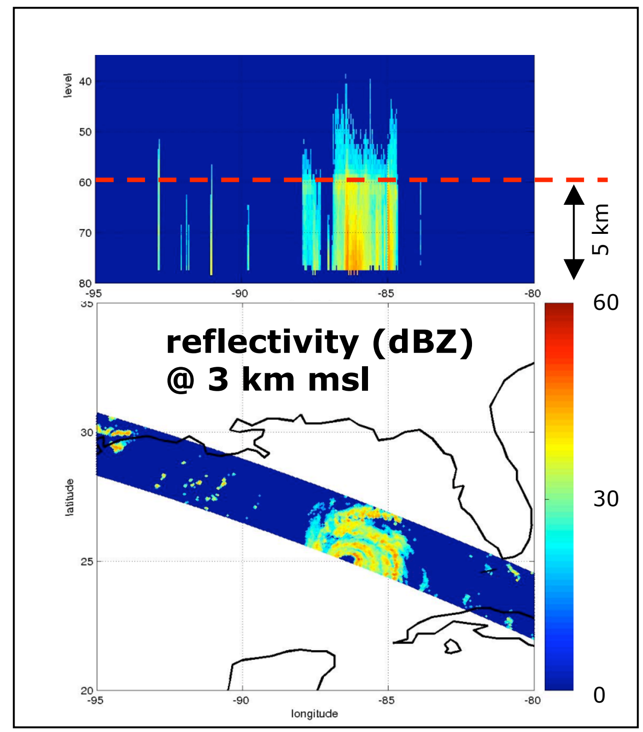
- Tropical Rainfall Measuring Mission (TRMM)
  - > Hurricane Katerina (05/08/05)











Retrieving Rain Properties from Radiometry

- Radiative transfer simulations

- Algorithms developments
  > Bayesian
  > neural network
  > quality of the results linked to the quality of the database and how it is representative of reality

- Validation activities
  > dedicated ground-based validation campaigns
  > TRMM precipitation radar

Using the 10-90 GHz Frequency Range

- Adequate performances for instantaneous rain retrieval from low orbits (eg TRMM)
- Temporal averages are strongly affected with sampling bias
- Poor revisiting time from LEO satellites for monitoring of severe weather events

  > use of multiple platforms (GPM) BUT still limited to 3h sampling

  > GEO satellites BUT poor spatial resolution for reasonable antenna size in the usual microwaves

3-m antenna	54 GHz, resolution = 50 km 380 GHz, resolution = 12 km

Interest of mm/submm Radiometry on GEO

- A solution : ***Use of mm/submm radiometry from geostationnary orbit***

- Limiting conditions :
  > No operational observations above 190 GHz
  > High sensitivity to the ice phase

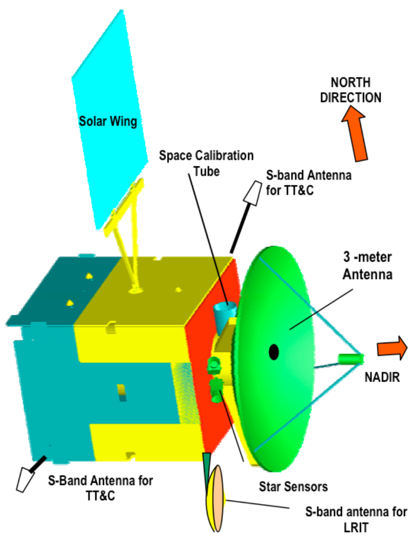
- Some activities using AMSU-B data (89, 150 & 183 GHz) and Megha-Tropiques soon

- Airborne instruments but no study on precipitation

- GOMAS mission proposed to ESA

GOMAS Mission

- Geostationary Observatory for Microwave Atmospheric Sounding (GOMAS) (Bizzari *et al*., 2005)
  - > precipitation estimate with a high temporal sampling, for now-casting
  - > temperature/humidity profiling



O_2		O_2		H_2O		H_2O		O_2	
54 GHz		118 GHz		183 GHz		380 GHz		425 GHz	
ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)
56.325	50	118.750±0.018	6	183.310±0.300	300	380.197±0.045	30	424.763±0.030	10
56.215	50	118.750±0.035	12	183.310±0.900	500	380.197±0.400	200	424.763±0.070	20
56.025	250	118.750±0.080	20	183.310±1.650	700	380.197±1.500	500	424.763±0.150	60
55.520	180	118.750±0.200	100	183.310±3.000	1000	380.197±4.000	900	424.763±0.300	100
54.950	300	118.750±0.400	200	183.310±5.000	2000	380.197±9.000	2000	424.763±0.600	200
54.400	220	118.750±0.700	400	183.310±7.000	2000	380.197±18.000	2000	424.763±1.000	400
53.845	190	118.750±1.100	400	183.310±17.000	4000	340.0 optional/auxiliary	8000	424.763±1.500	600
53.290	360	118.750±1.500	400					424.763±4.000	1000
52.825	300	118.750±2.100	800						
51.760	400	118.750±3.000	1000						
50.300	180	118.750±5.000	2000						

Frequency selection for the GOMAS mission (Bizzari *et al*., 2005)

Investigating Potential of mm/submm Radiometry

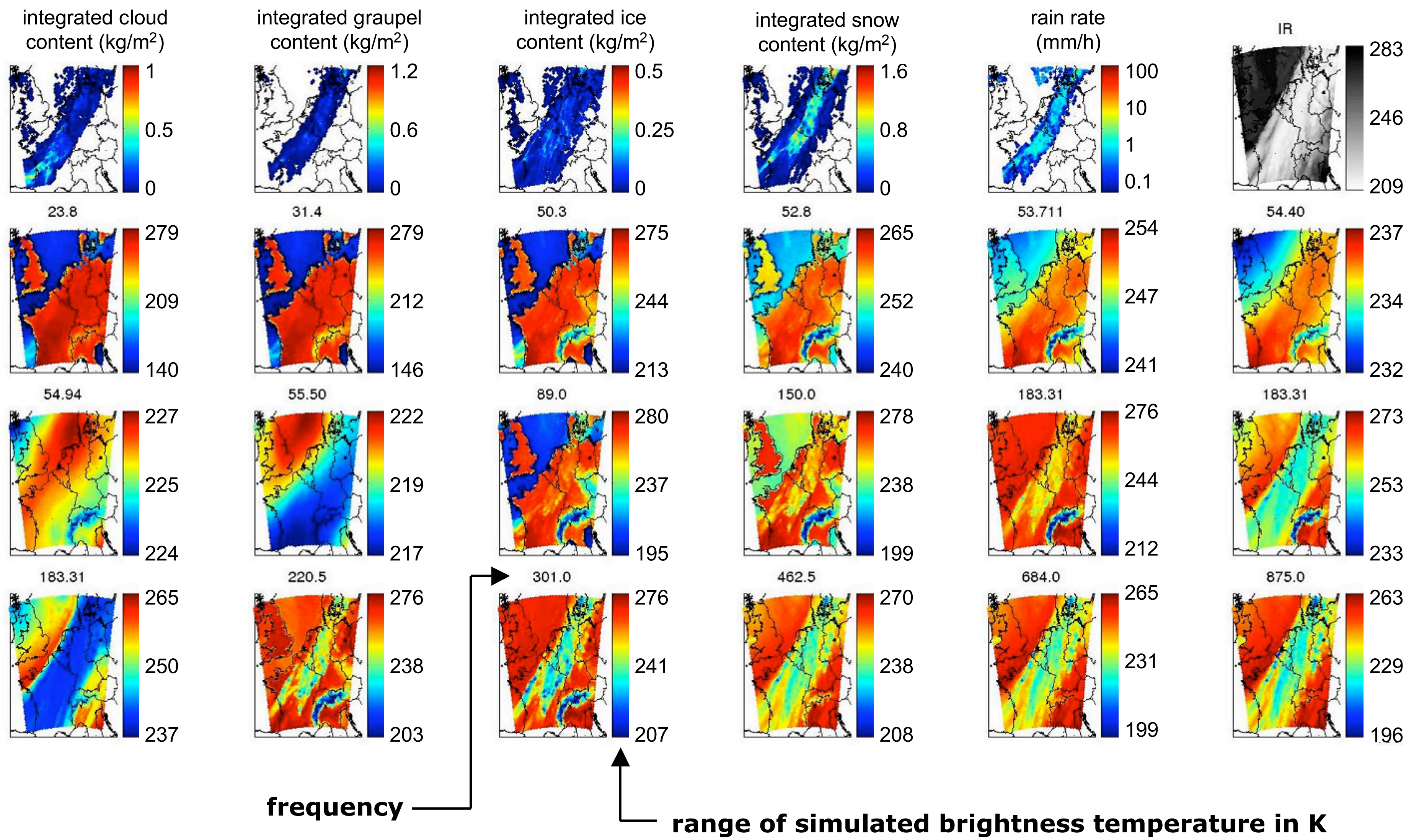
- Observations above 183 GHz are rare !
  > only airborne demonstrators

- Use of cloud resolving models interfaced with radiative transfer codes
  > it requires cloud/radiative simulations as representative as possible

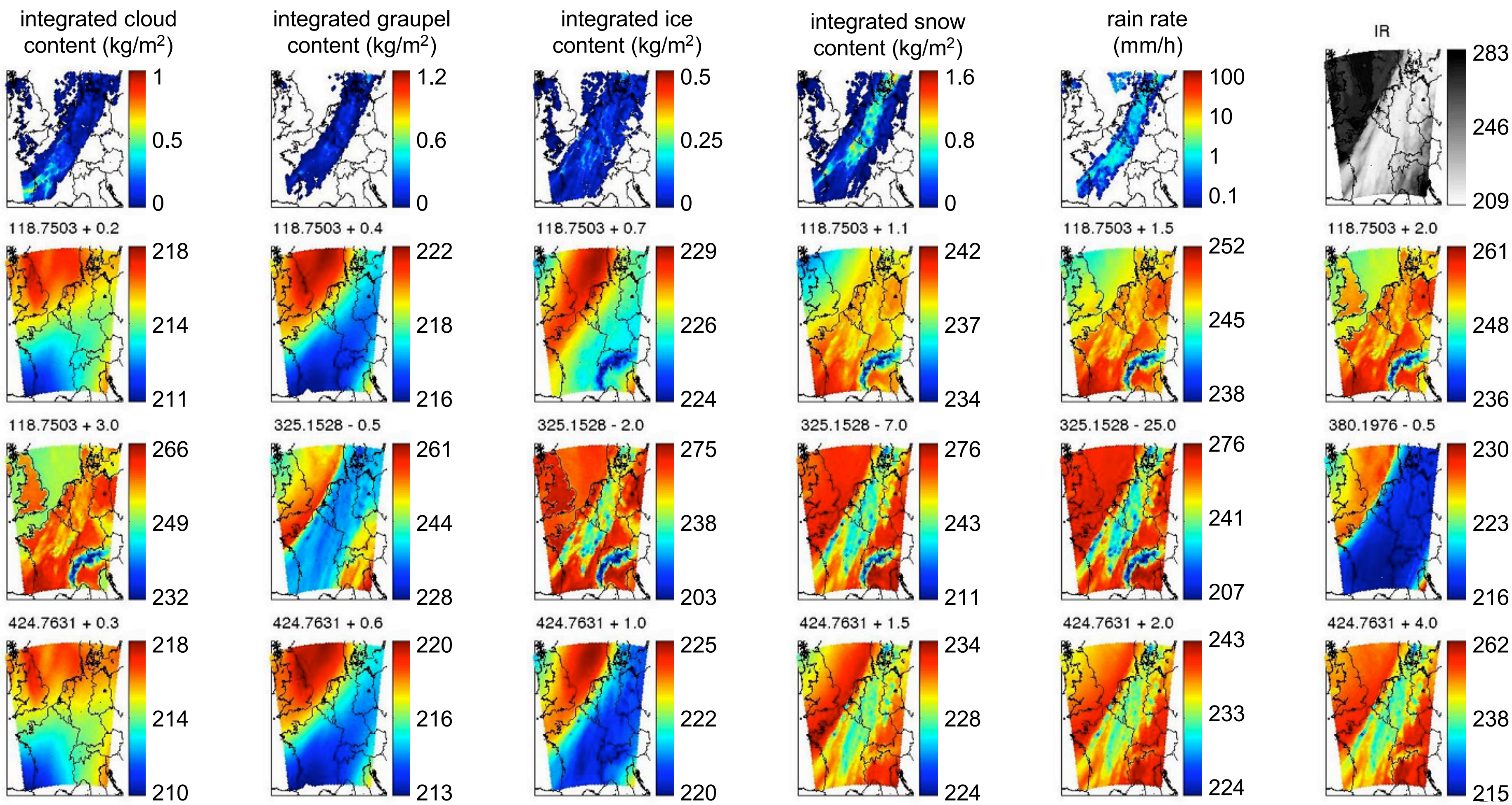
- Cloud resolving model MésoNH (Lafore *et al*., 1998)
  > SIMGEO microphysics database (Chaboureau *et al*., 2008)

- Atmospheric Transmission at Microwaves (ATM) radiative transfer code (Pardo *et al*. 2001)
  > one needs to take into account carefully the properties of the icy particles (density, permittivity; Meirold-Martner *et al*., 2007)

Simulating mm/submm GOMAS Observations (1/2)



Simulating mm/submm GOMAS Observations (2/2)

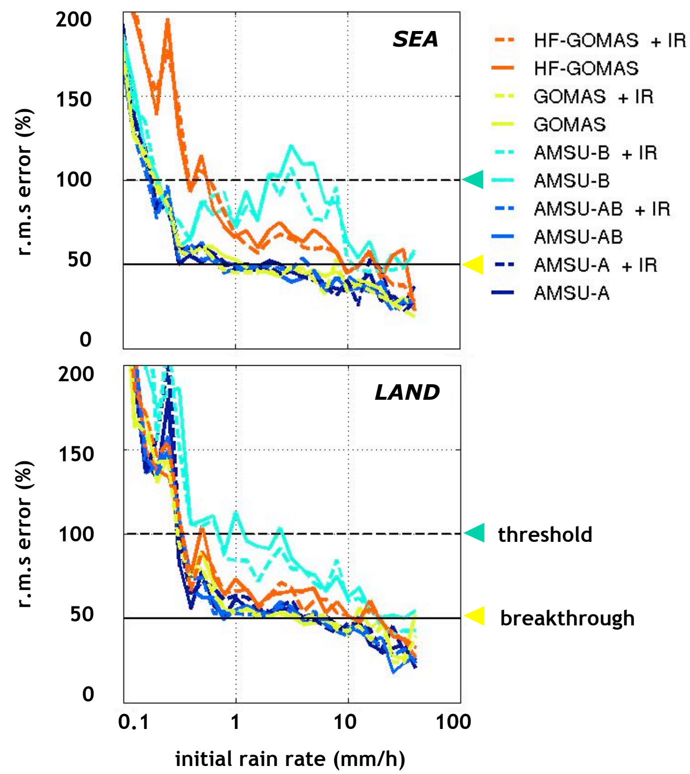


Retrieving Rain from GOMAS Simulations

- Combination of mm/submm channels such as GOMAS can provide an estimate of rain rate with an error of 50% for rain rate > 1 mm/h

- Satisfying performances of mm/submm channel combination for rain detection (not shown)

- Capability of retrieving liquid and ice hydrometeor profiles (not shown)



Performance of the rain rate retrieval schemes for different frequency sets, with or without IR channel, quantified by r.m.s errors (in %) as function of the rain rate.

Summary

- Potential of mm/submm radiometry for rain detection and quantification demonstrated through modeling studies (Surussavadee, 2006; Defer *et al*., 2008)

- High interests from Research Community, Operational and Space Agencies

- **Technology available now in Europe**

- Building and operating airborne demonstrators to
    i) validate instrumental concepts (frequency sets, scan strategy…)
    ii) validate cloud and radiative transfer models
    iii) investigate scientific questions