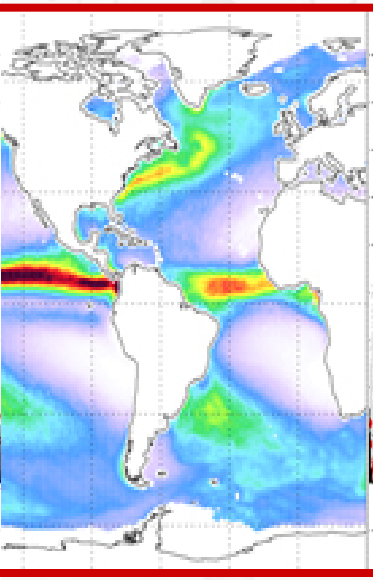
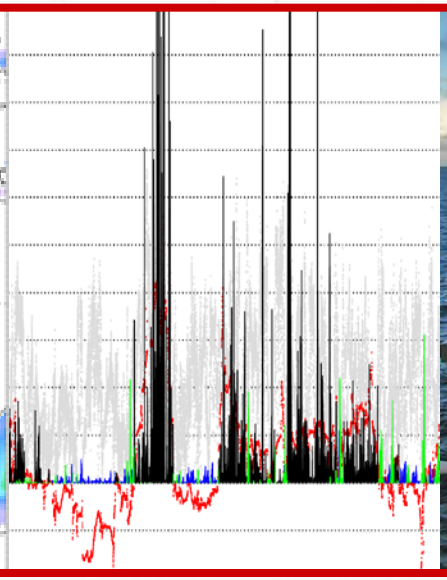
OceanRAIN

Christian Klepp [1]

[1] KlimaCampus, Initiative Pro Klima, University of Hamburg, Germany

christian.klepp@zmaw.de

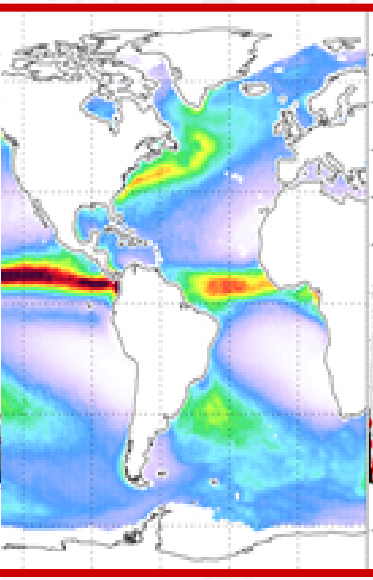
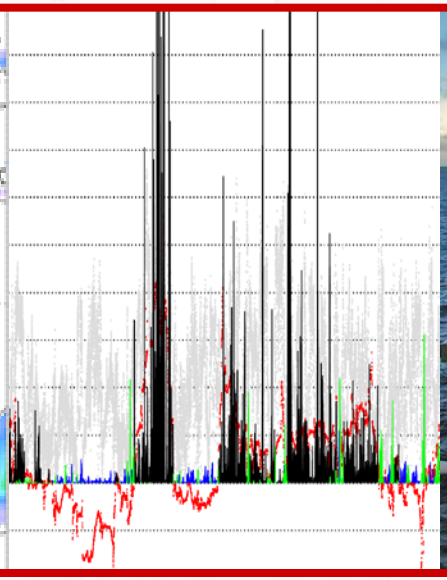
OceanRAIN

Ocean Rain And Ice-phase precipitation measurement Network for surface validation

Christian Klepp [1]

[1] KlimaCampus, Initiative-Pro-Klima, University of Hamburg, Germany

christian.klepp@zmaw.de

MABANAFT

Acknowledgements: Ship operators, Mabanaft – Initiative Pro Klima, Eigenbrodt
S. Bakan, A. Dahl, C. Benecke, K. Bumke, … and many others …

Outline

- Why Ocean*RAIN*
- Instrumentation
- Data Set Construction
- Measurement Examples
- HALO NARVAL North
- Conclusions

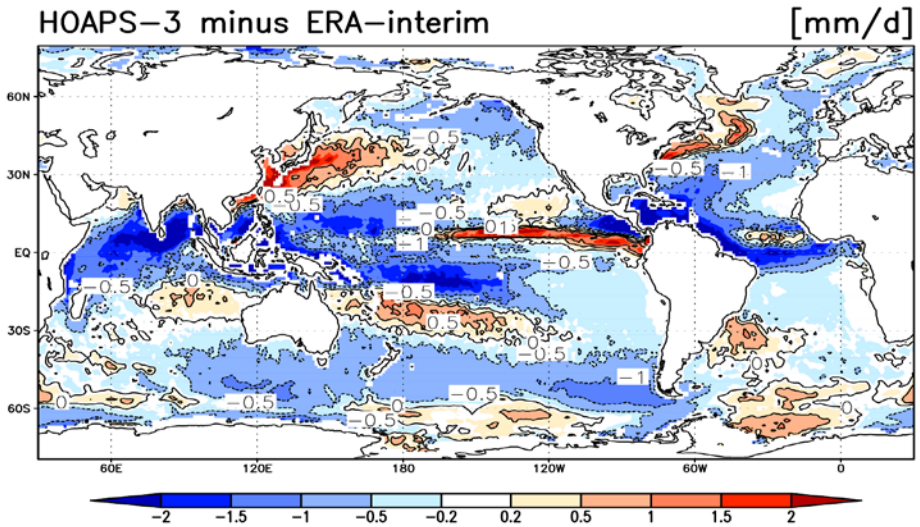
Why Ocean*RAIN*

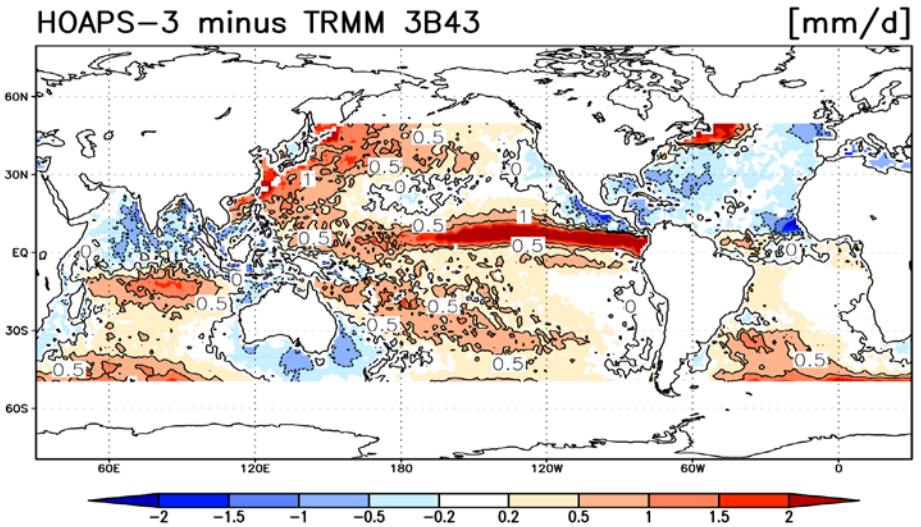
- Precipitation flux is ECV
- Energy and water cycle
- Freshwater flux
- Intermittent parameter
- different phases (types)
- measurements notoriously difficult → large uncertainties
- high spatio-temporal coverage → satellites
- direct / indirect / statistical / physical retrieval algorithms approches

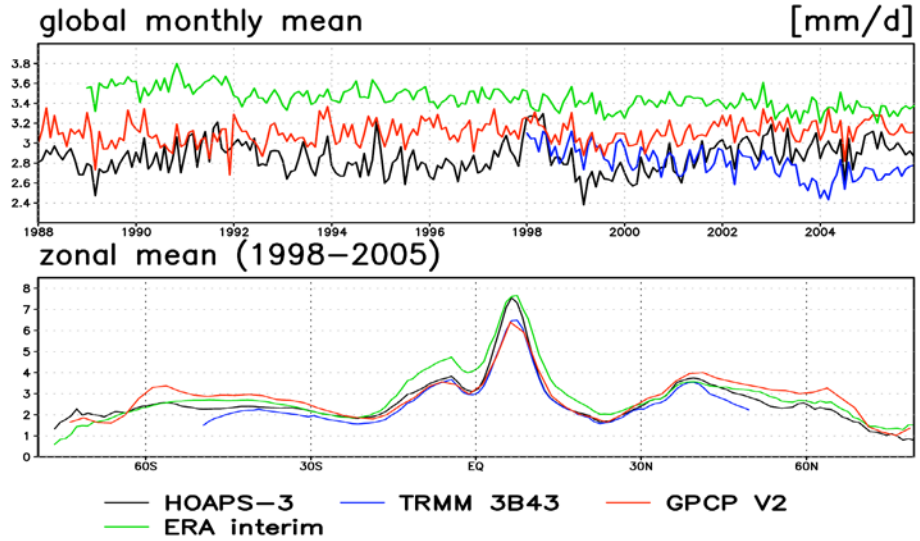
→ **which retrieval is correct / incorrect where and why…**

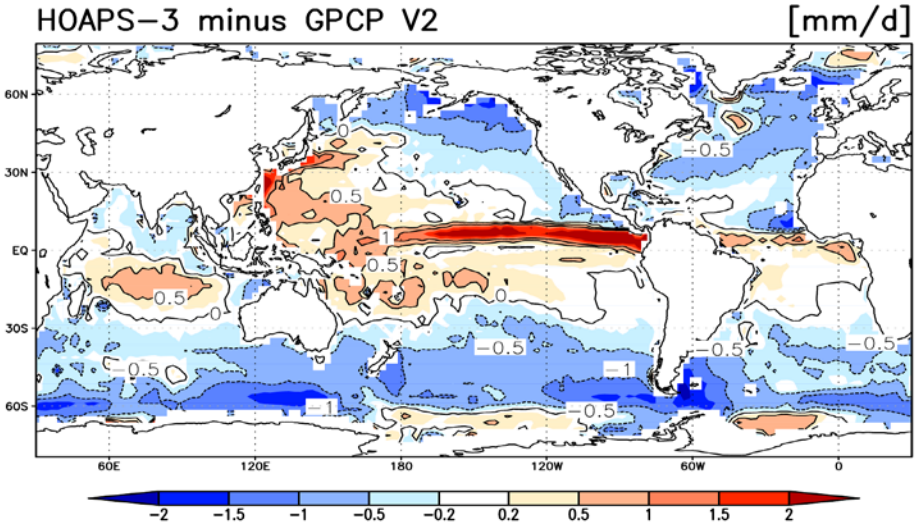
Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite data

Andersson, Klepp, Fennig, Bakan, Graßl, Schulz, 2011









- Satellite and re-analysis and model data substantially differ
- no phase information
- light intensites, snow, mixed-phase challenges (CPR)
- surface validation data needed
- GPM-GV: new spaceborne sensor generations calibrated with land-based data
- land surfaces: radar / GPCC; oceans void of in-situ data
- lack of suitable in-situ instruments for shipboard usage
  VOS
  buoys and ship gauges

Atlas of Surface Marine Data, SOC, ICOADS, NOCS, OceanSITES, SAMOS …

Taylor (2000): "…no more than a few thousand samples worldwide…"

- IPWG, GPM-GV, SeaFlux, OceanObs recommendation:
  "…urgently needed is the provision of high quality surface validation data in oceanic areas using innovative ship based instruments"

…to overcome these limitations: **OceanRAIN**

- 2005 LOFZY--HOAPS, Klepp et al (2010) Tellus, 96% snow detection accuracy
- 2009 KlimaCampus and MPI-M Hamburg
- 6 years of funding by Mabanaft, Initiative Pro Klima

- usage of *unique* shipboard optical disdrometers onboard ships
- long-term comprehensive statistical basis of precipitation
- rain, snow, mixed-phase
- minute resolution particle size distributions
- occurrence, intensity, accumulation
  - for validation of satellite, re-analysis and model data
  - radar calibration
  - error characterization of GPM era retrievals, HOAPS4, Cloudsat …
  - statistical and process study analysis
  - point to area analysis
  - climate regionalization

Automatic Measurement System: Optical Disdrometer ODM470

Publications since 2001: Großklaus, Ulbrich, Bumke, Clemens, Lempio, Klepp

Klepp, C., 2014. The Oceanic Shipboard Precipitation Measurement Network for Surface Validation – OceanRAIN J. Atmos. Res., Special Issue of the International Precipitation Working Group IPWG6, submitted.

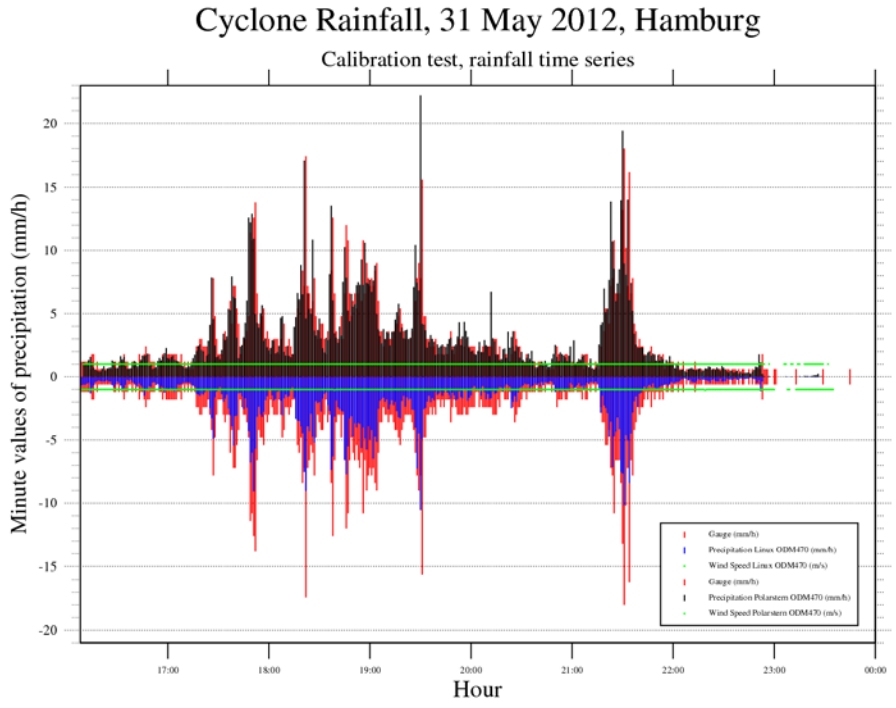
Advantages over existing optical disdrometers

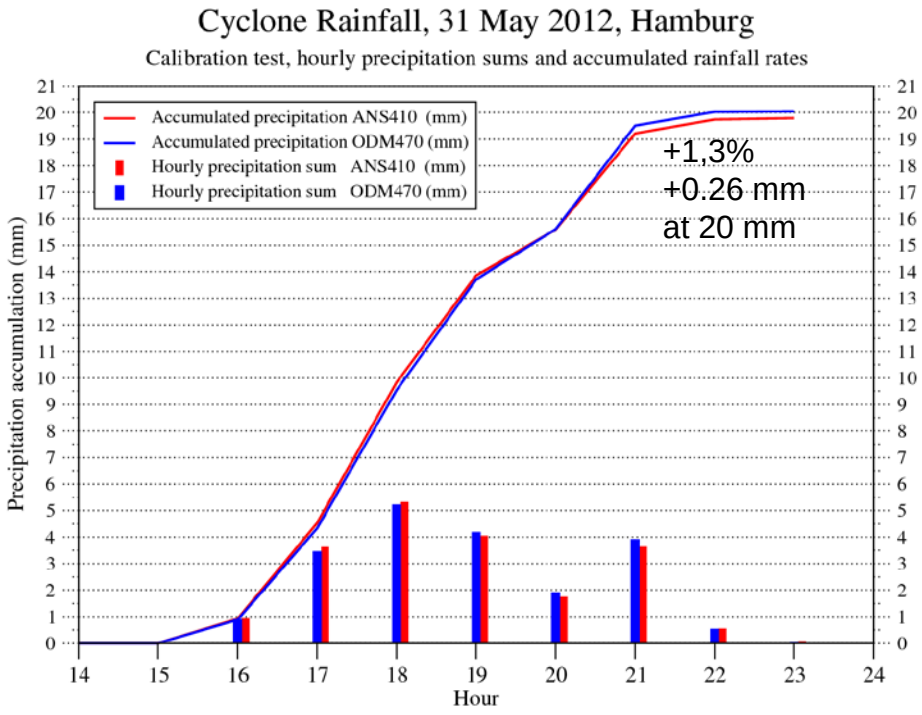
- cylindrical volume
- pivoting
- high dynamic range
- all weather
- rain and snowfall algorithm, PSD
- automatic system
- low maintenance requirements

… developed by
Geomar,
Eigenbrodt and Ocean*RAIN*

Tested and calibrated during field campaigns
Bumke, 2002; Lempio, 2007; Klepp, 2010

Calibration
Spherical particles from 0.5 to 22 mm
Disdrometer-constant for precip volume scaling
ANS410 gauge vs ODM470 disdrometer
Windspeed < 1 m/s to avoid gauge undercatch





Long-term Ocean*RAIN* data ingest

Since 2010: 7 disdrometers onboard 8 ships, > 500.000 spectra … steadily growing

R/V Celtic Explorer

K/V Senja

R/V Aranda

R/V Polarstern

R/V Akademik Ioffe

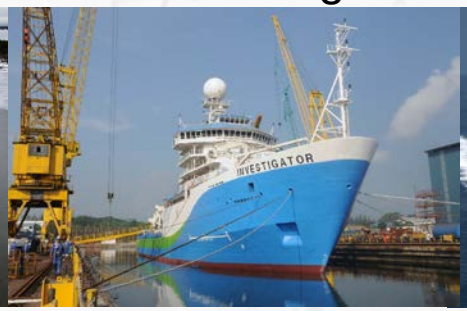
R/V Maria S. Merian

R/V Sonne

R/V Meteor

R/V S.A. Alguhas II

R/V Investigator



R/V Sonne II

Long-term Ocean*RAIN* data ingest

Since 2010: 7 disdrometers onboard 8 ships, ~ 500.000 spectra … steadily growing

R/V Celtic Explorer

K/V Senja

R/V Aranda

R/V Polarstern

R/V Akademic Ioffe

R/V Maria S. Merian

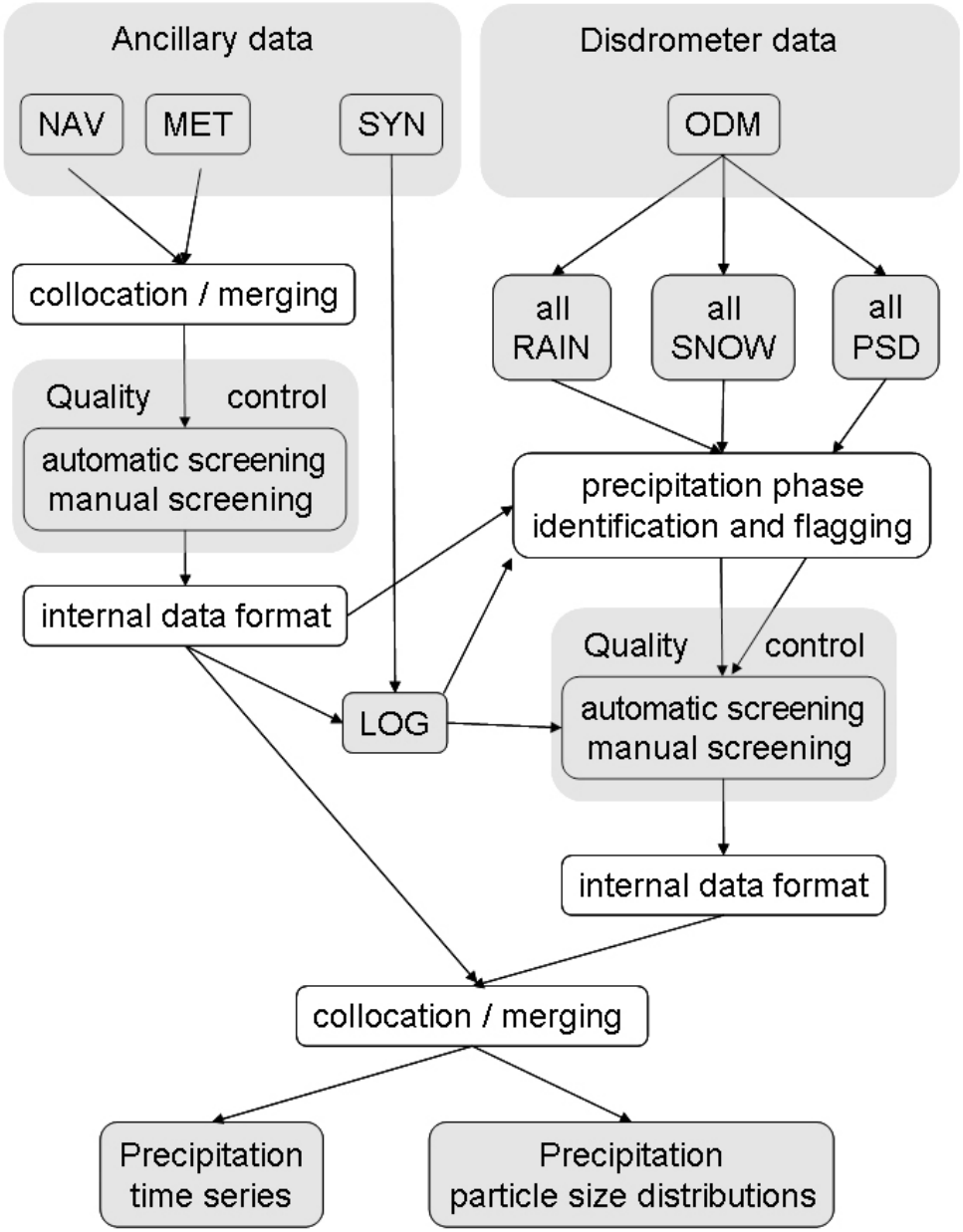
R/V Sonne

R/V Meteor

R/V S.A. Alguhas II

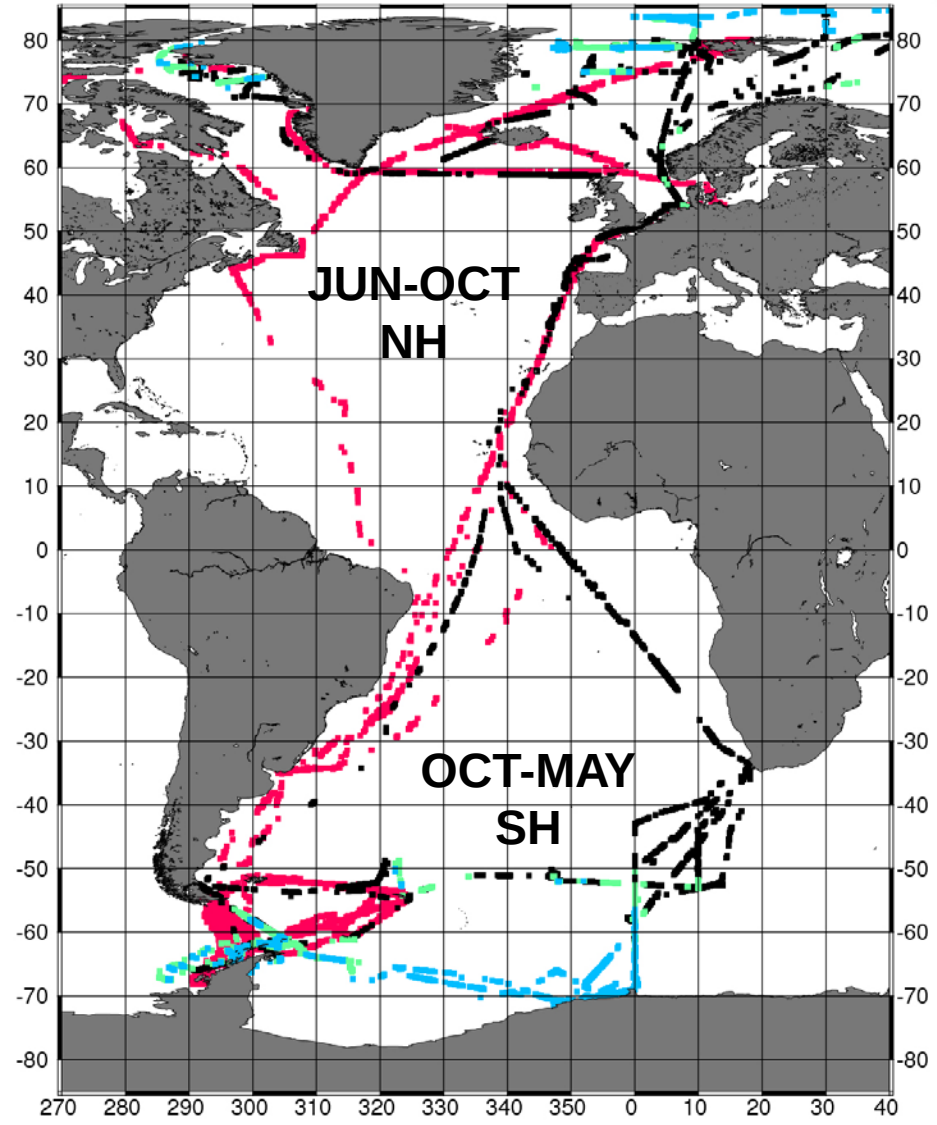
R/V Investigator

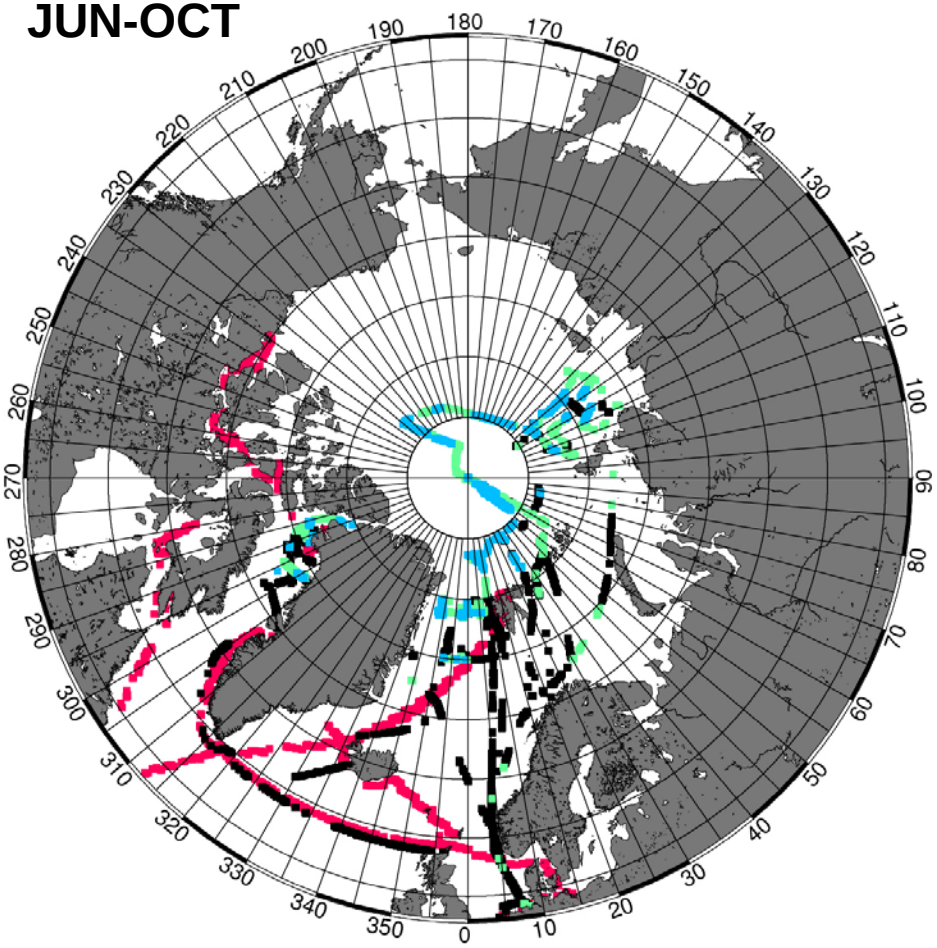
R/V Sonne II



parameter	unit or value range	source
line count	[ ]	calculated
date	DDMMYYYY	common to all
time	HHMM [UT]	common to all
minute of the day	1-1400	calculated
latitude	-90° to 90°	NAV
longitude	-180° to 180°	NAV
air temperature	°C	MET
dew point temperature	°C	MET
relative humidity	%	MET
sea level pressure	hPa	MET
relative wind speed	m/s	MET
relative wind direction	deg	MET
absolute wind speed	m/s	MET
absolute wind direction	deg	MET
global radiation	W/m^2	MET
horizontal visibility	m	MET
low cloud base height	m	MET
maximum wind speed	m/s	MET
ship rain gauge	mm/h	MET
precipitation rate	mm/h	ODM
relative wind speed	m/s	ODM
precipitation flag	0=rain, 1=snow, 2=mixed	calculated

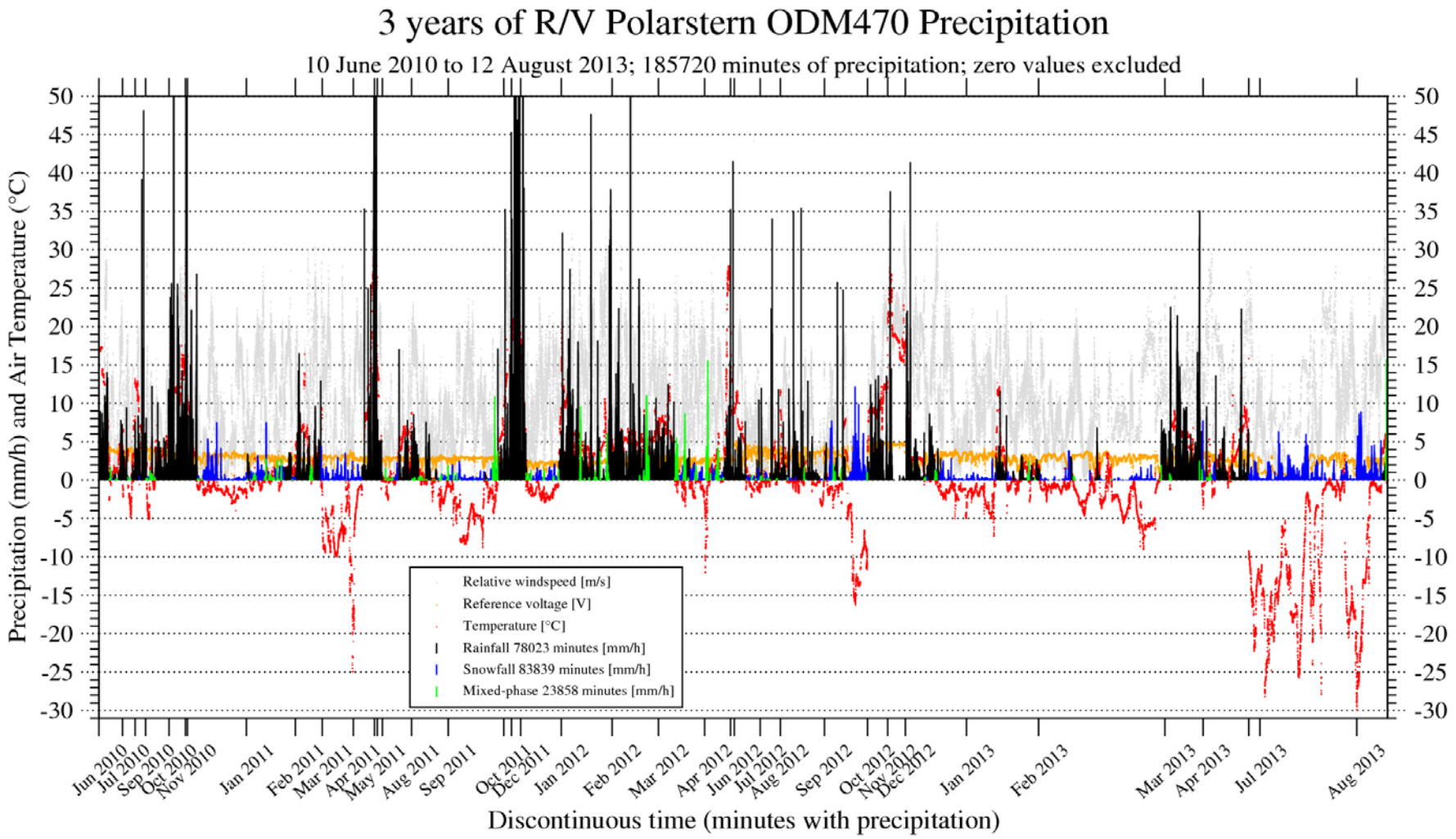
4 years precipitation tracks of R/V Polarstern and 3 years R/V Akademik Ioffe





R/V 'Polarstern' and R/V 'Akademik Ioffe' precipitation tracks

SV areas of interest for: GPM-GV, Cloudsat, SSMIS, MT … + wintertime data



78023 minutes of rainfall (black)
83839 minutes of snowfall (blue)
23858 minutes of mix-phase (green)

185720 minutes of precipitation equiv. 14.4% of the time

Precipitation occurrence, intensities and accumulations

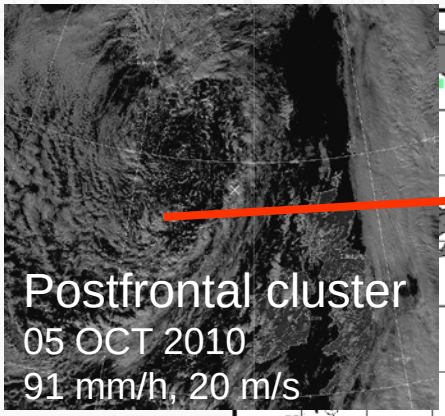
Precipitation occurred in **10.4 %** of the time (89,6%)
with 5% (**48%**) rain, 3.6% (**34.5%**) snow, 1.8% (**17.5%**) mixed-phase
a total accumulation of **927.16 mm**
with **88.2%** rain, **8.4%** snow, **3.4%** mix-phase

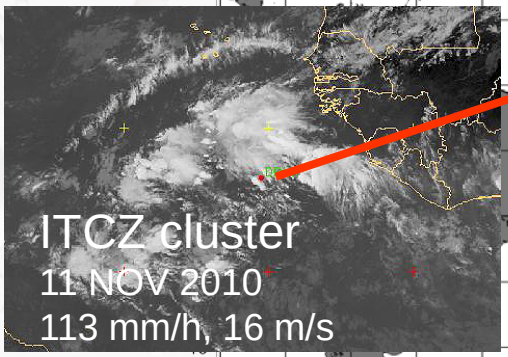
Intensity	Type	Rel%		Abs%	Volume (mm)	Vol%
			rainfall	4.5	817.29	100
< 0.5 mm/h	28493	66		3.0	61.41	7.5
0.5 to 5 mm/h	13000	30		1.4	329.61	40.3
> 5 mm/h	1602	4		0.1	426.27	52.2
			snowfall	3.3	77.77	100
< 0.5 mm/h	28976	92		3.0	35.52	45.7
0.5 to 5 mm/h	2476	8		0.3	41.41	53.3
> 5 mm/h	8	0.02		0.001	0.84	1.0
			mixed-phase	1.8	32.10	100
< 0.5 mm/h	16288	95		1.7	9.91	30.8
0.5 to 5 mm/h	795	5		0.09	16.68	52.0
> 5 mm/h	45	0.3		0.01	5.51	17.2

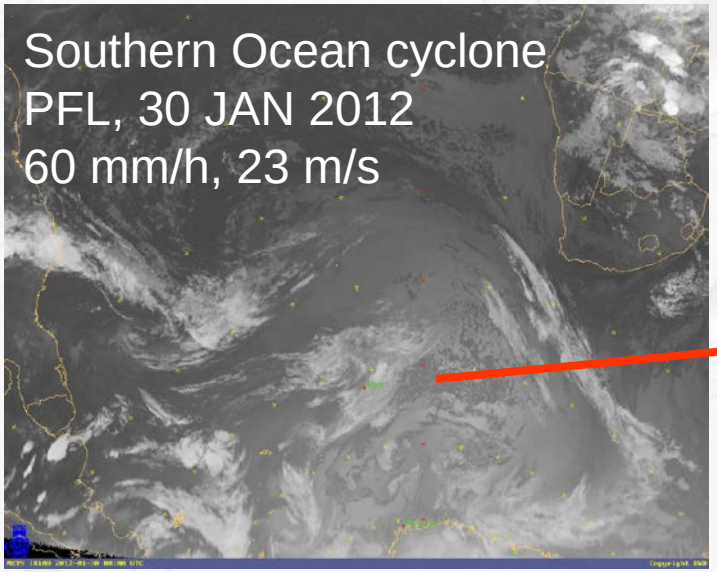
Extremes

147 minutes > 30 mm/h (green)
64 minutes > 60 mm/h (blue)
27 minutes > 100 mm/h (red)

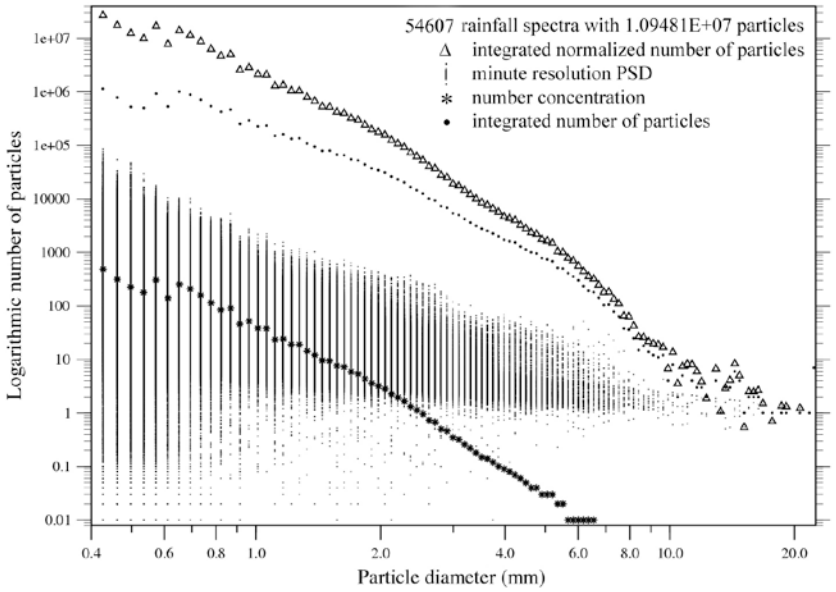
- Intense cyclones in stormtrack peaks up to 187 mm/h
- ITCZ up to 113 mm/h

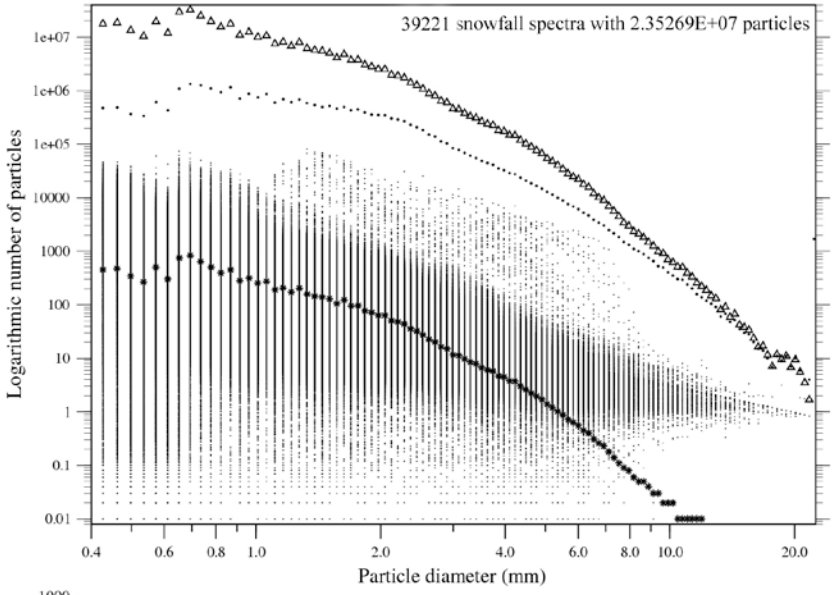


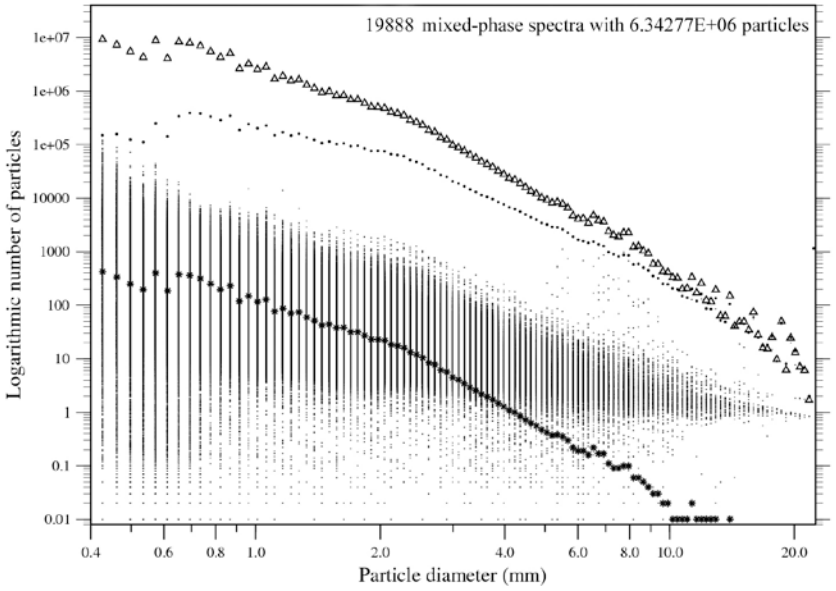


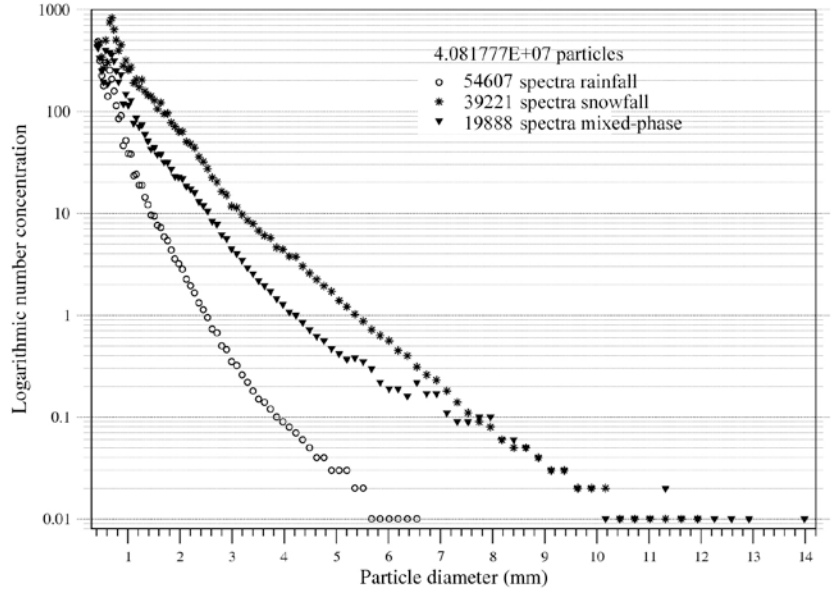


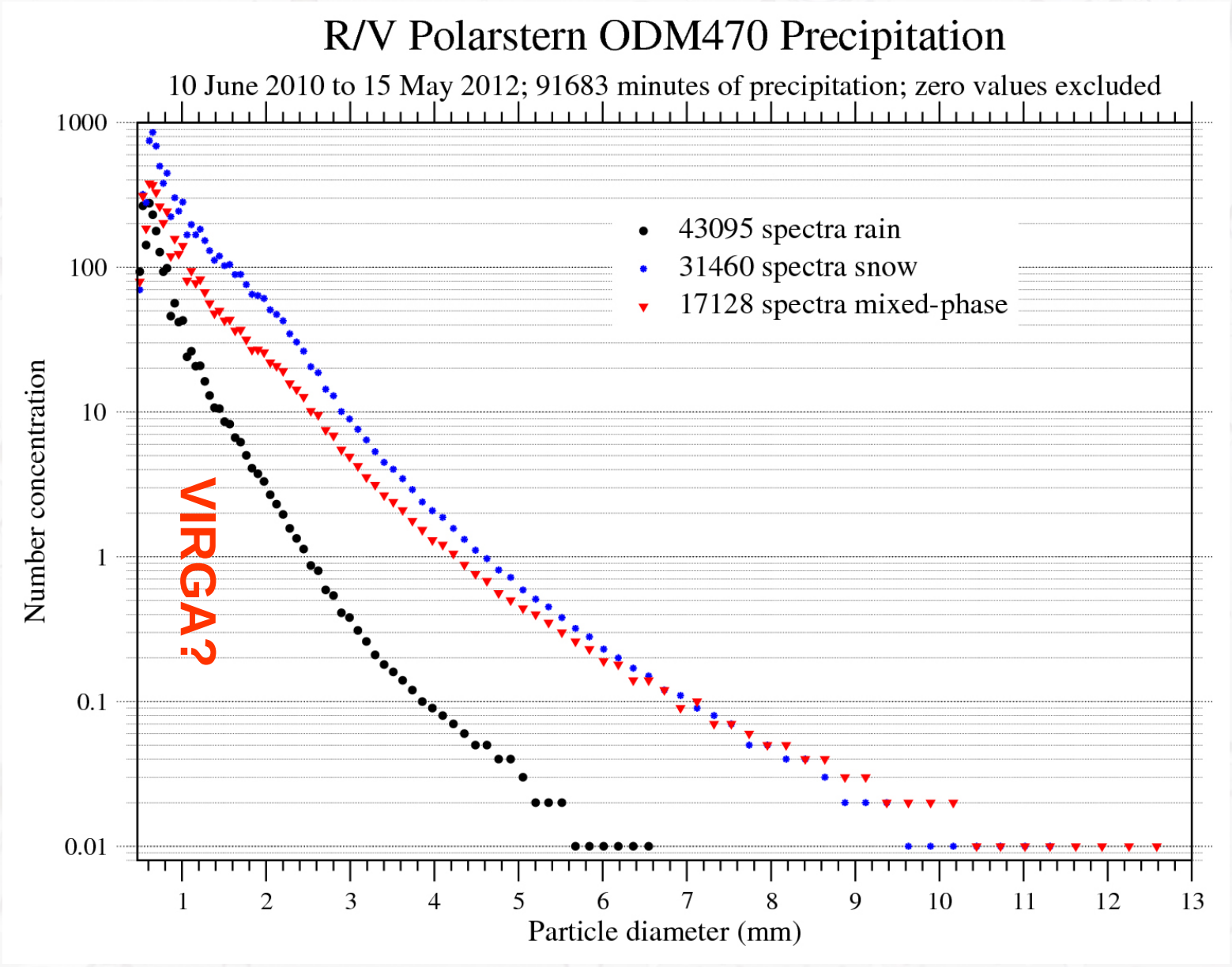
27 months ODM470 precipitation R/V "Polarstern" from 10 June 2010 to 07 October 2012





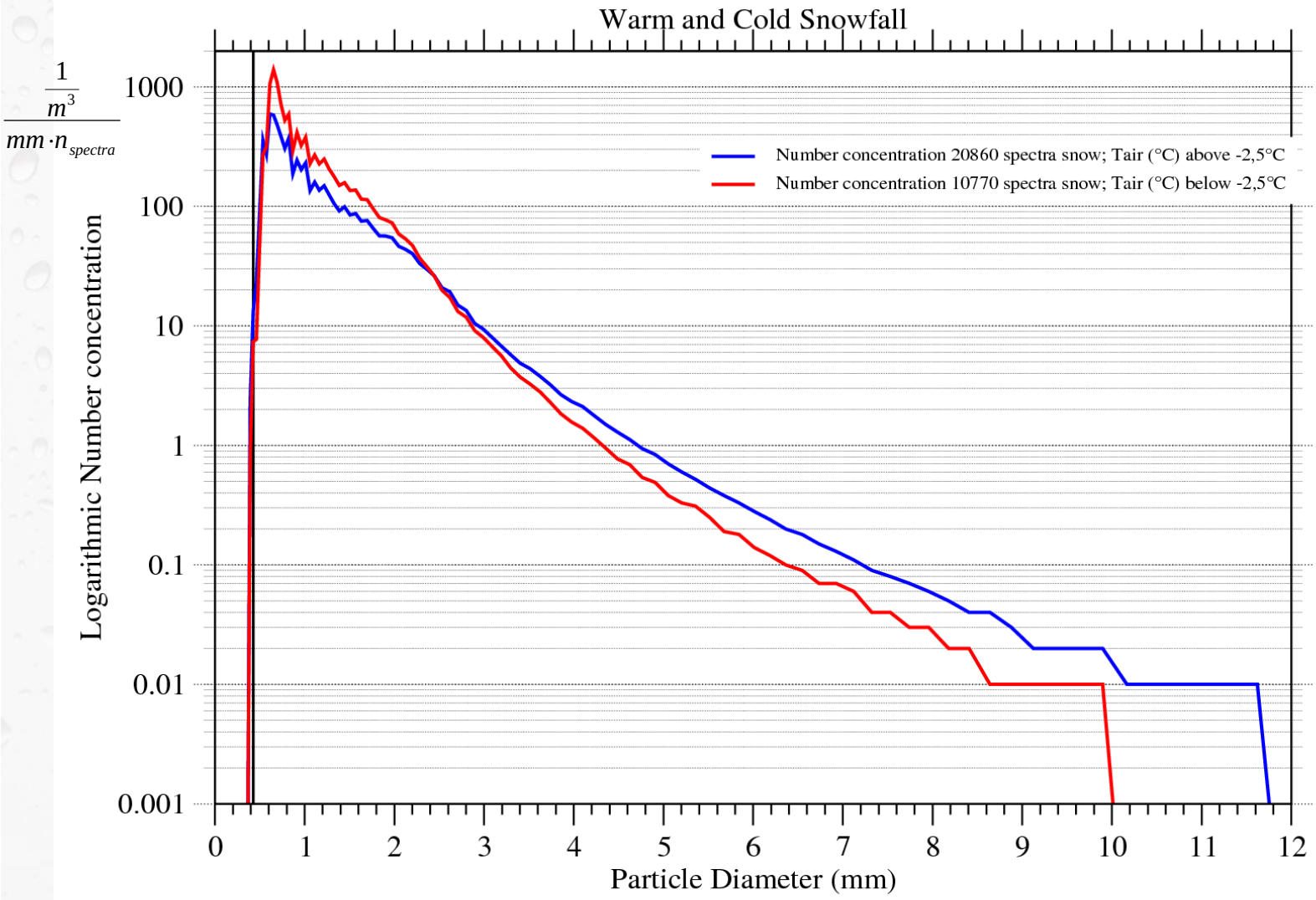


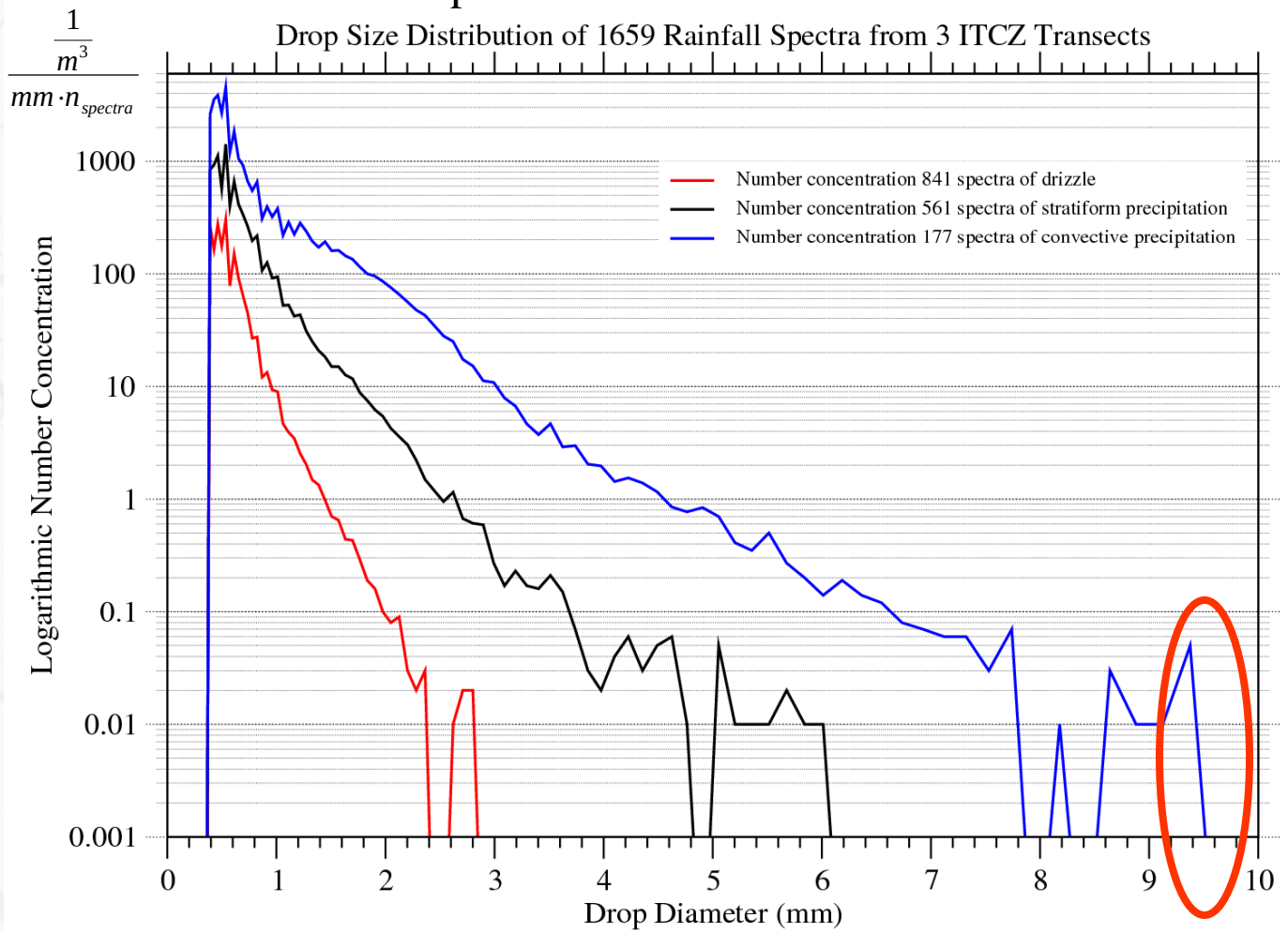



R/V Polarstern ODM470 Precipitation
10 June 2010 to 15 May 2012; 91683 minutes of precipitation; zero values excluded
43095 spectra rain
31460 spectra snow
17128 spectra mixed-phase
VIRGA?
Number concentration
1000
100
10
1
0.1
0.01
1
2
3
4
5
6
7
8
9
10
11
12
13
Particle diameter (mm)

Cold and warm snowfall conditions

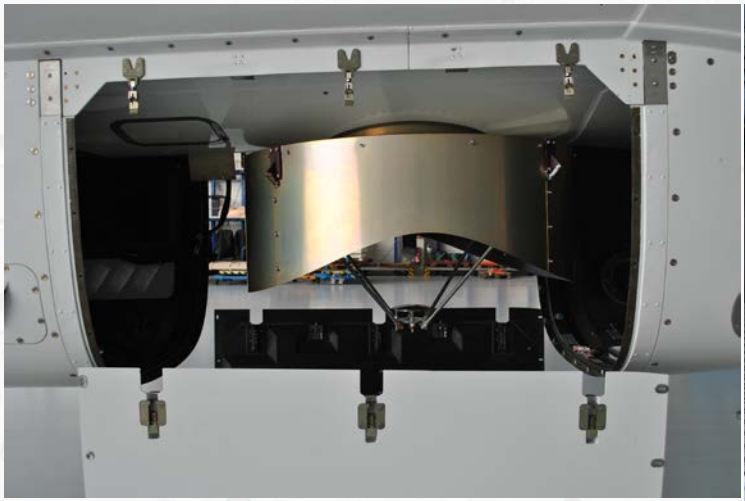
2 years of ODM470 Polarstern Precipitation




Shipboard ODM470 ITCZ Rainfall
Drop Size Distribution of 1659 Rainfall Spectra from 3 ITCZ Transects
$\frac{1}{m^3}$
$mm \cdot n_{spectra}$
Logarithmic Number Concentration
1000
100
10
1
0.1
0.01
0.001
Number concentration 841 spectra of drizzle
Number concentration 561 spectra of stratiform precipitation
Number concentration 177 spectra of convective precipitation
0
1
2
3
4
5
6
7
8
9
10
Drop Diameter (mm)
9.5 mm

HALO NARVAL North

…to advance our understanding of clouds and moist processes
…to what extent are postfrontal convective cloud regimes precipitating
…to validate HOAPS 4 (SSMIS collocations) and Cloudsat underflights



HAMP Bellypod: Active and Passive Remote Sensing

- 36.5 GHz Cloud Radar
- 23 channel microwave radiometer (22-197 GHz)
- WALES water vapor differential absorption lidar (532 nm)
- Dropsondes

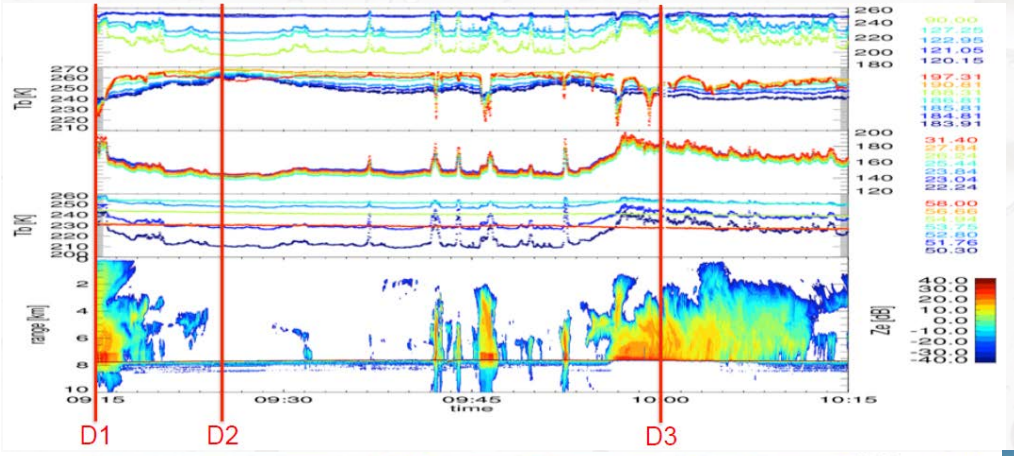
5 flights of 10h each

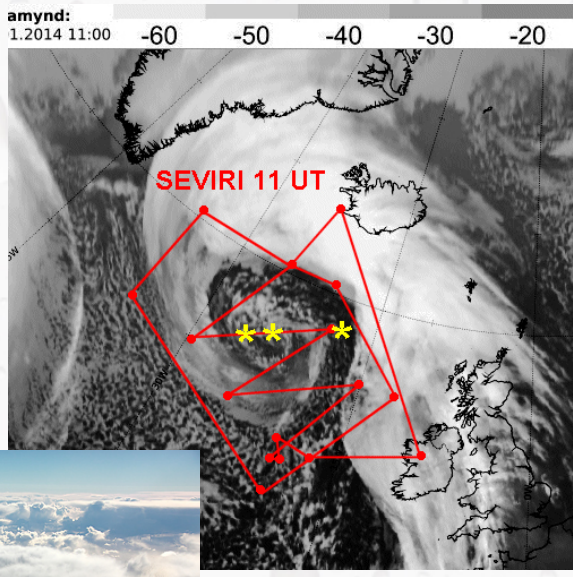
47 dropsondes

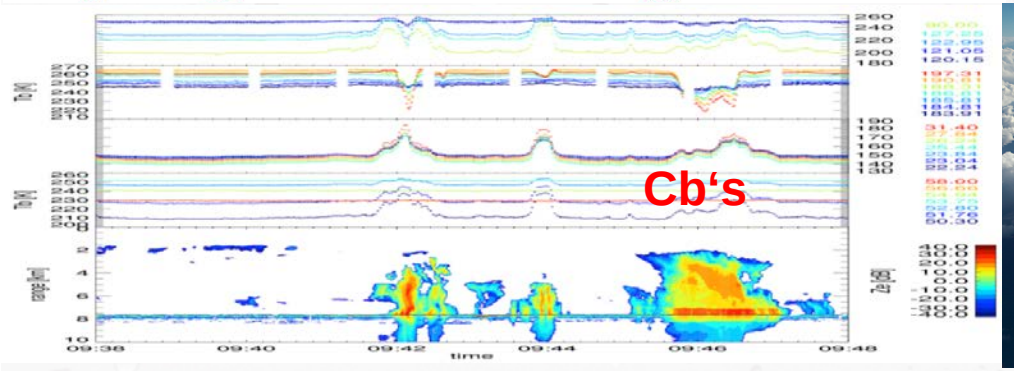
5 Cloudsat underflights

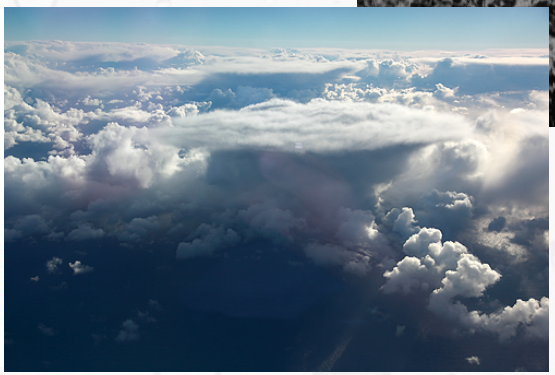
16 SSMIS collocations

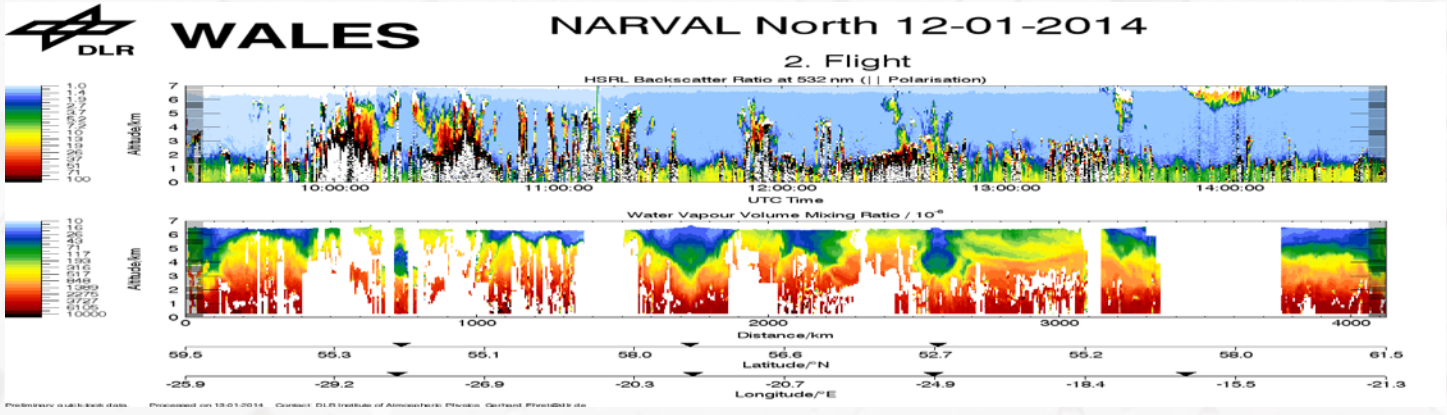
Point to Area Scale Dependent Resolution of Convective Precipitation

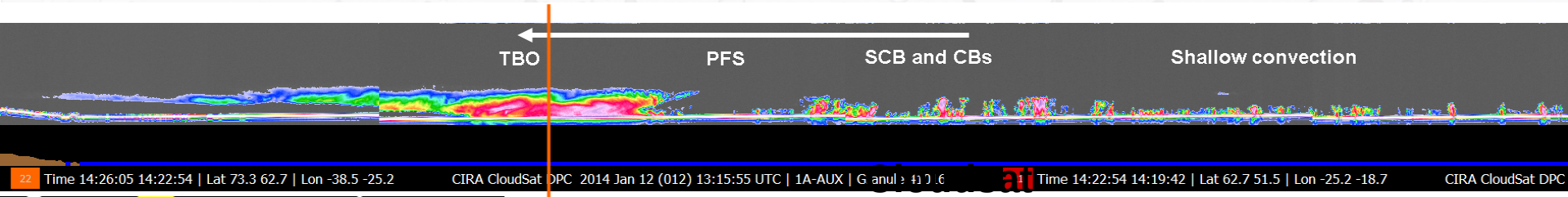


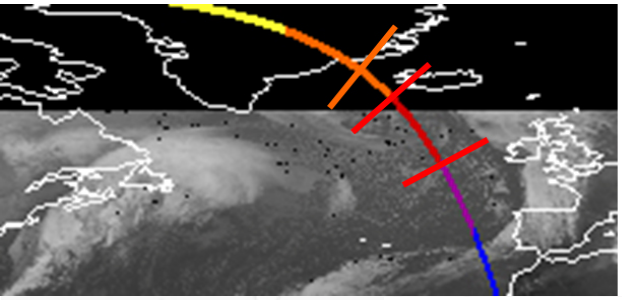










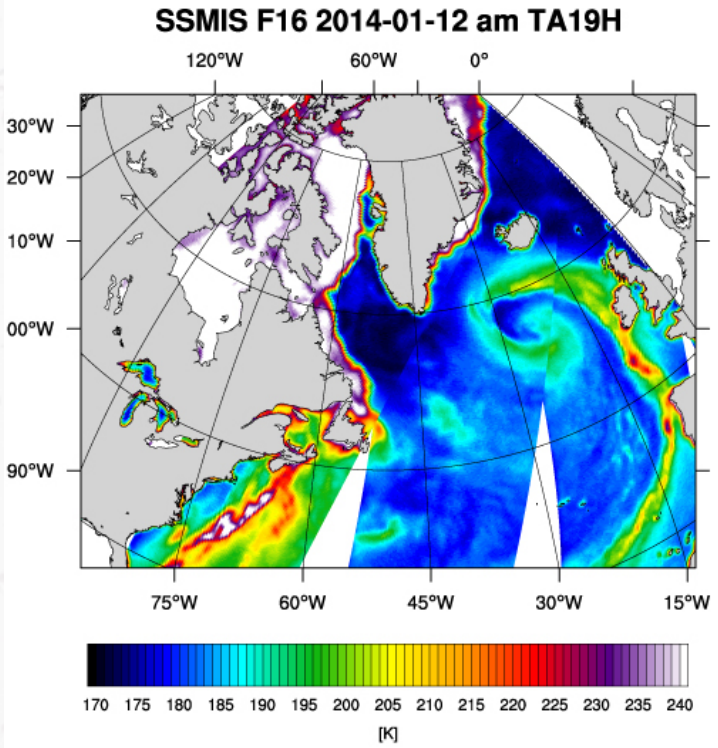


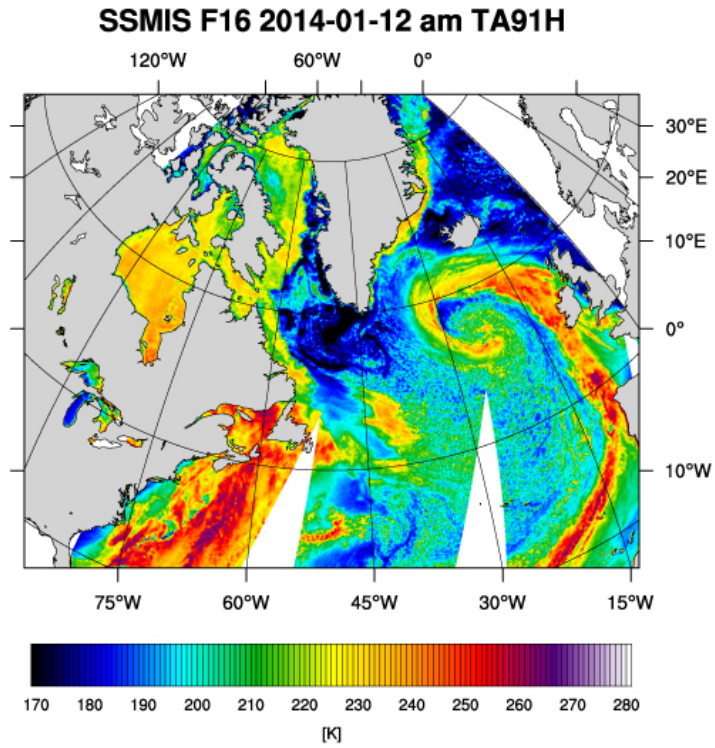
Border of red and orange track

Cloudsat

SSMIS FCDR Ta

Courtesy: K. Fennig, A. Andersson





Conclusions

- To date the only disdrometer-based systematic oceanic precipitation collection effort
- Automatic measurement system operates long-term with 6 instruments
- ~500.000 precipitation spectra
- Occurrence, intensities, accumulation, phase (rain, snow, mixed)
- Atlantic Ocean from Arctic to Antarctica, ITCZ, subtropics, Pacific Ocean
- Precipitation occurs in about 10 to 14% of the time
- PSD data exhibits differences between rain, snow and mixed-phase

- **Ocean*RAIN*** data applicable for:
  - improving our knowledge on oceanic precipitation
  - validation of satellite, re-analysis and model data → **HOAPS** e.g. through Kollsat
  - calibration of new-era spaceborne precipitation sensors
  - point to area investigations
  - statistics and process studies
  - microphysical differences of land/ocean precip
  - …
  - HOAPS (J. Burdanowitz)
  - Cloudsat (A. Nather)

Going truly global: Combination of HOAPS4/GPCC + GRDC + OceanRAIN

R/V Polarstern mast in 45 m height on 2 October 2012 in the Arctic

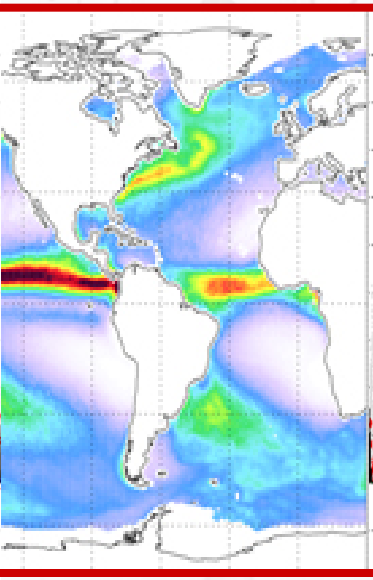
OceanRAIN

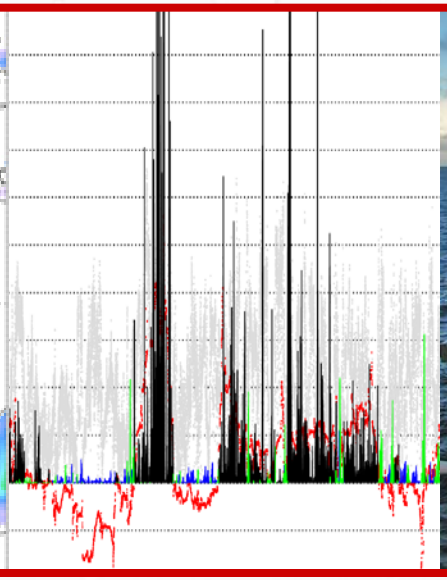
Ocean Rain And Ice-phase precipitation measurement Network for surface validation

Christian Klepp [1]

[1] KlimaCampus, Initiative-Pro-Klima, University of Hamburg, Germany

christian.klepp@zmaw.de





MABANAFT

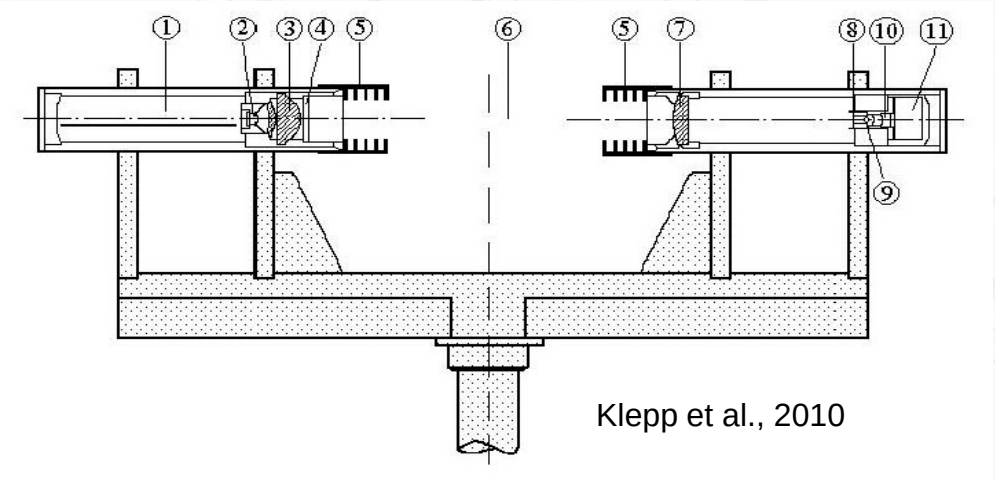
Acknowledgements: Ship operators, Mabanaft – Initiative Pro Klima, Eigenbrodt
S. Bakan, A. Dahl, C. Benecke, K. Bumke, and many others

Outline

- Why OceanRAIN
- The optical disdrometer ODM470
- Ocean*RAIN* data ingest and methodology
- Measurement examples
- HALO NARVAL *NORTH*

Automatic Measurement System: Optical Disdrometer ODM470

Publications since 2001: Großklaus, Ulbrich, Bumke, Clemens, Lempio, Klepp



Klepp et al., 2010

- sensitive volume volume 120 mm x 22 mm
- photoelectric barrier IR-LED
- reference voltage attenuates with occurrence of hydrometeors
- a size dependant light extinction measures cross-sectional area
- 128 size bins
- measurement interval 1 minute
- allocated bins
- number of particles per bin
- residence time of particles
- relative wind speed

ODM470
IRSS88
Cup anemometer
Embedded PC
UPS

Particle size distributions

n(bin) = particle size distribution density (Clemens, 2002)
by particle counting N(bin)

$$n(\mathrm{bin}) = \frac{\mathrm{N(bin)}}{\mathrm{L} \cdot \mathrm{D} \cdot \mathrm{T} \cdot \sqrt{\mathrm{ff}^2 + (\mathrm{v}_\infty(\mathrm{bin}))^2}}$$

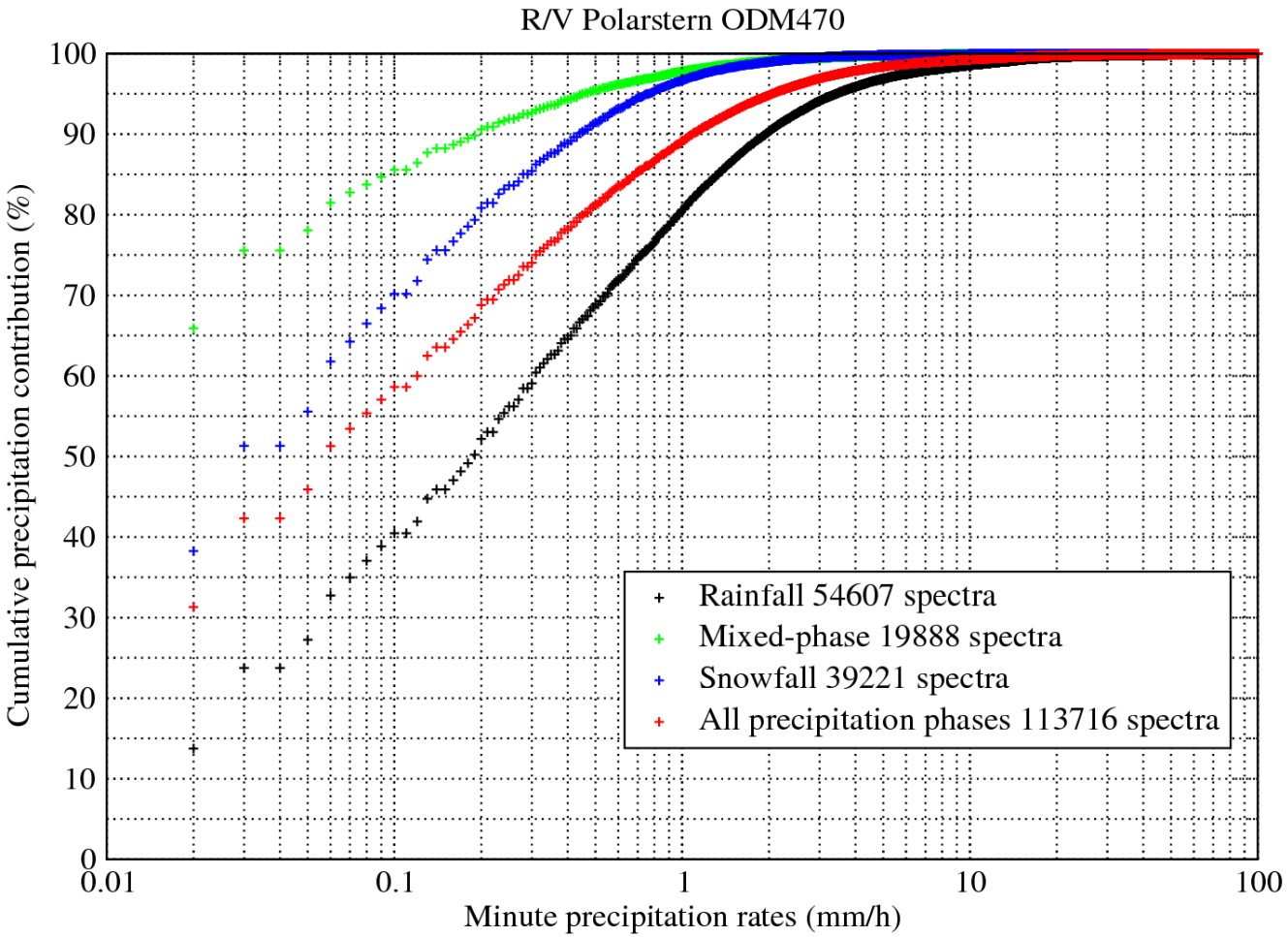
after Großklaus (1996)

Rain and snowfall algorithm

$$\mathrm{R} = 3600 \cdot \sum_{\mathrm{bin}=0}^{128} n(\mathrm{bin}) \cdot V_\infty(\mathrm{bin}) \cdot M_{\mathrm{tr}}(\mathrm{bin}).$$

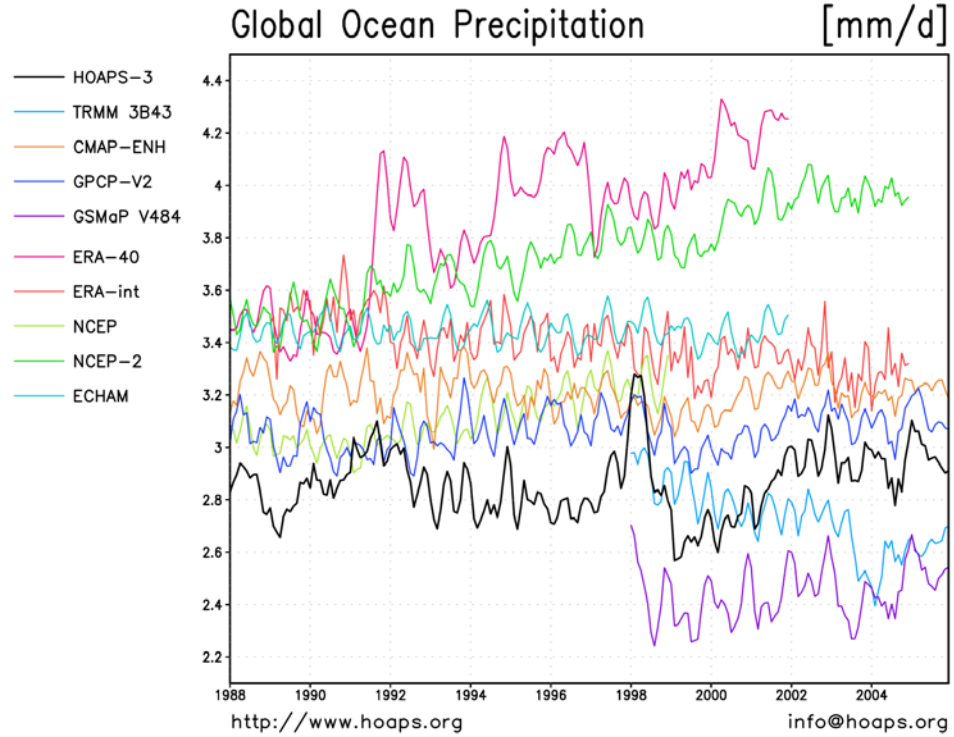
Rain:
→ Atlas and Ulbrich, 1974

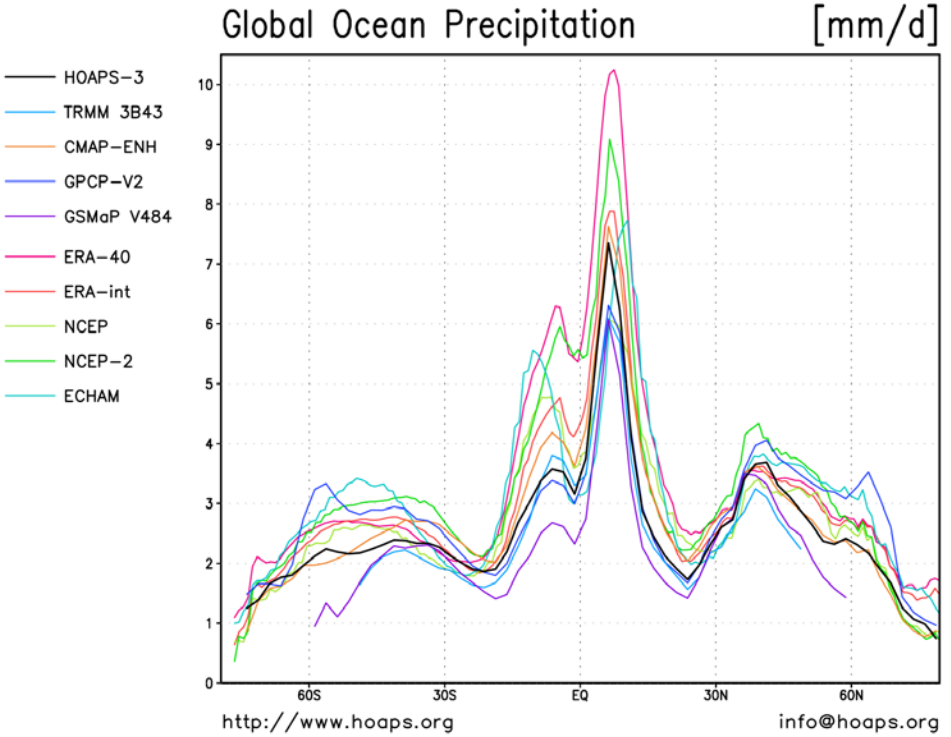
Snow: (liquid water equivalent)
→ Hogan, 1994 with one common parameterization for lump graupel (Lempio, 2007)


Precipitation probability density functions
R/V Polarstern ODM470
Cumulative precipitation contribution (%)
Minute precipitation rates (mm/h)
0.01
0.1
1
10
100
0
10
20
30
40
50
60
70
80
90
100
Rainfall 54607 spectra
Mixed-phase 19888 spectra
Snowfall 39221 spectra
All precipitation phases 113716 spectra

Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite data

Andersson, Klepp, Fennig, Bakan, Graßl, Schulz, 2011

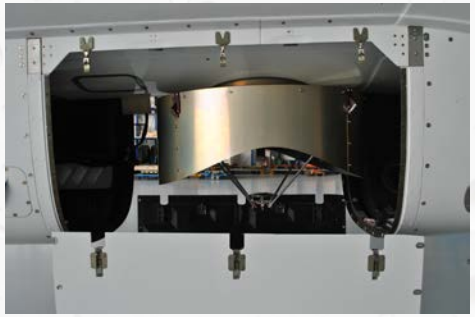


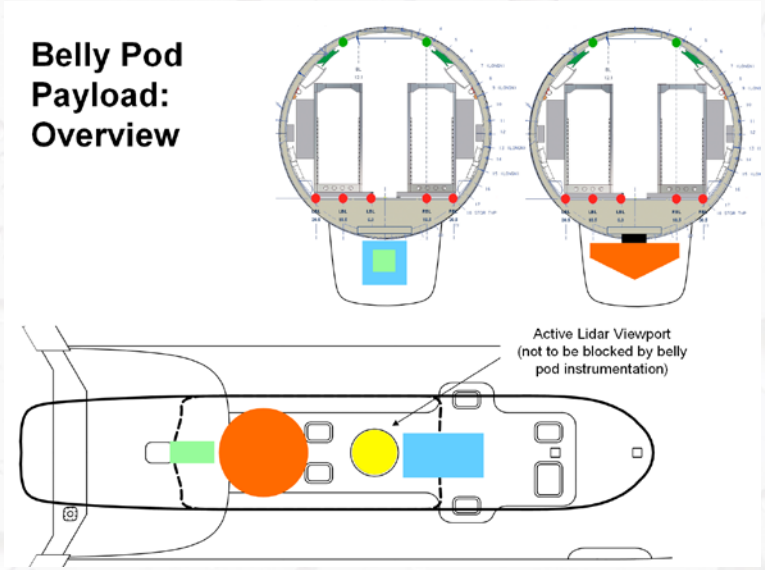


NARVAL NORTH

03 - 22 JAN 2014

HALO HAMP instrumentation





Collocated HAMP/CLOUDSAT/HOAPS4 data for P2A analysis

Show example an short overview from flight report

- **HAMP Belly pod:**

PMW and AMC remote sensing

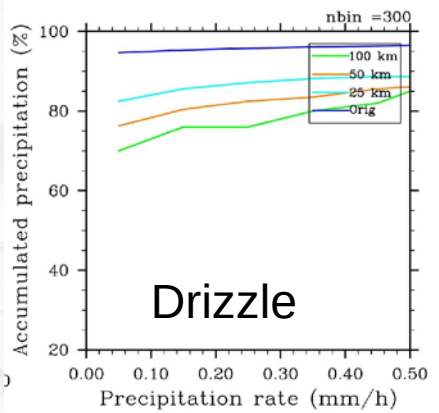
- Radiometers: 22-32 Ghz, 51-59 GHz, 119 and 183 GHz LWP, Precip, humidity profiles
- 36 GHz Cloud radar Z-R
- WALES water vapor differential absorption lidar , aerosol

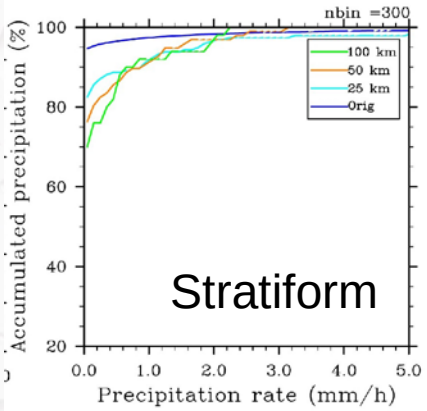
PDF Accumulated Precipitation (%) vs rain rate (mm/h)

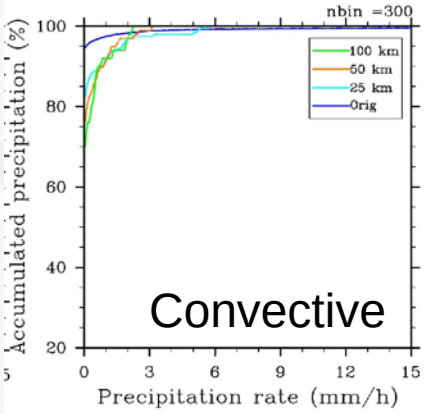
for combined ship data in 4 resolutions

20344 values (0.2 km)
194 values (25 km)
97 values (50 km)
50 values (100 km)

- Line of data in time
- "100 ships in parallel"
- Representativeness of 3 transects
- More data available







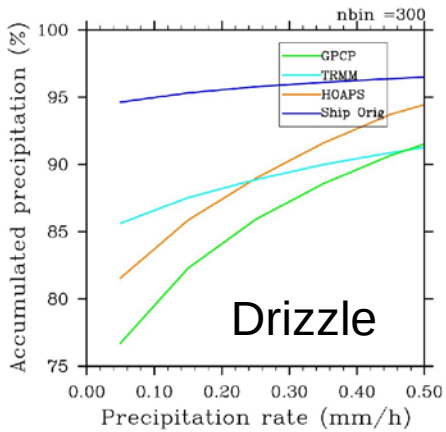
PDF Accumulated Precipitation (%) vs rain rate (mm/h)

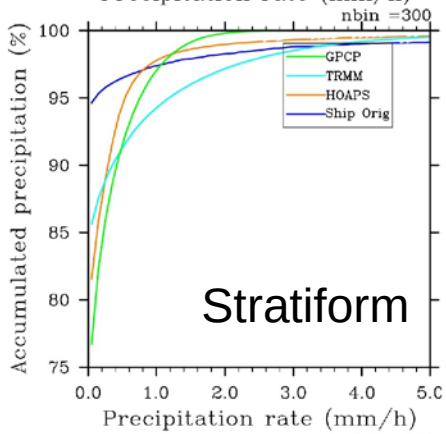
for ship data and different satellite datasets

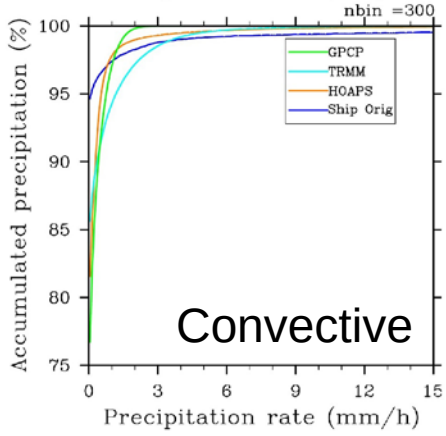
Climatologies 1998-2005

All zero values included
Bin width = 0.1 mm/h

- Instantaneously sampled area
- Point to Area Problem
- Spatial differences
- Different thresholds
- Retrieval peculiarities







Outlook

Validation for satellite based // re-analysis data sets … (statistical vs case study)
- Retrieval constraints… mainly through statistical PSD
- SV for GPM-GV, Mehgatropique, Cloudsat, SSMIS …
- From PSD number concentrations to reflectivity…
- Point to area statistics…(HALO)

New publications: IPWG special issue in J. Atm. Res.
Flux News Newsletter article (*sail.msk.ru/**newsletter.php***)

Validation of Virga-Precipitation → Jörg precip phase, HOAPS uncertainties → Andree Cloudsat

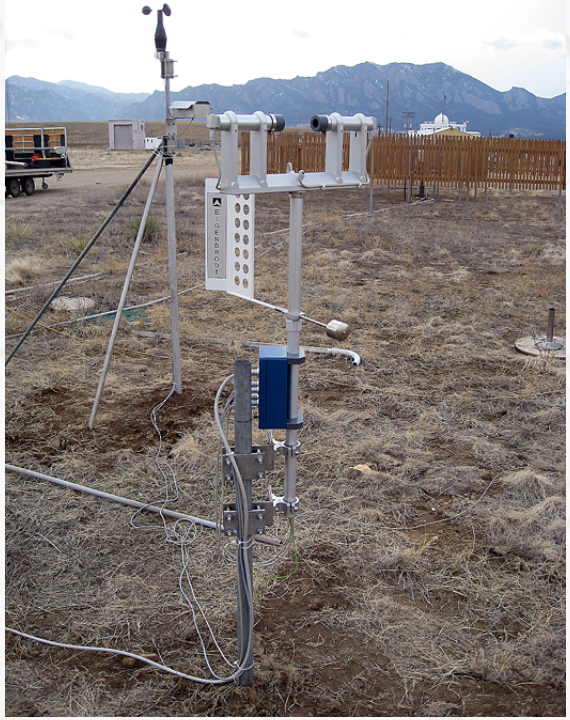
ITCZ work
Regionalization
HOAPS4 process studies
Satellite data set evaluations

WMO SOLID PRECIPITATION INTERCOMPARISON EXPERIMENT

S P I C E

Marshall Test Site, Boulder

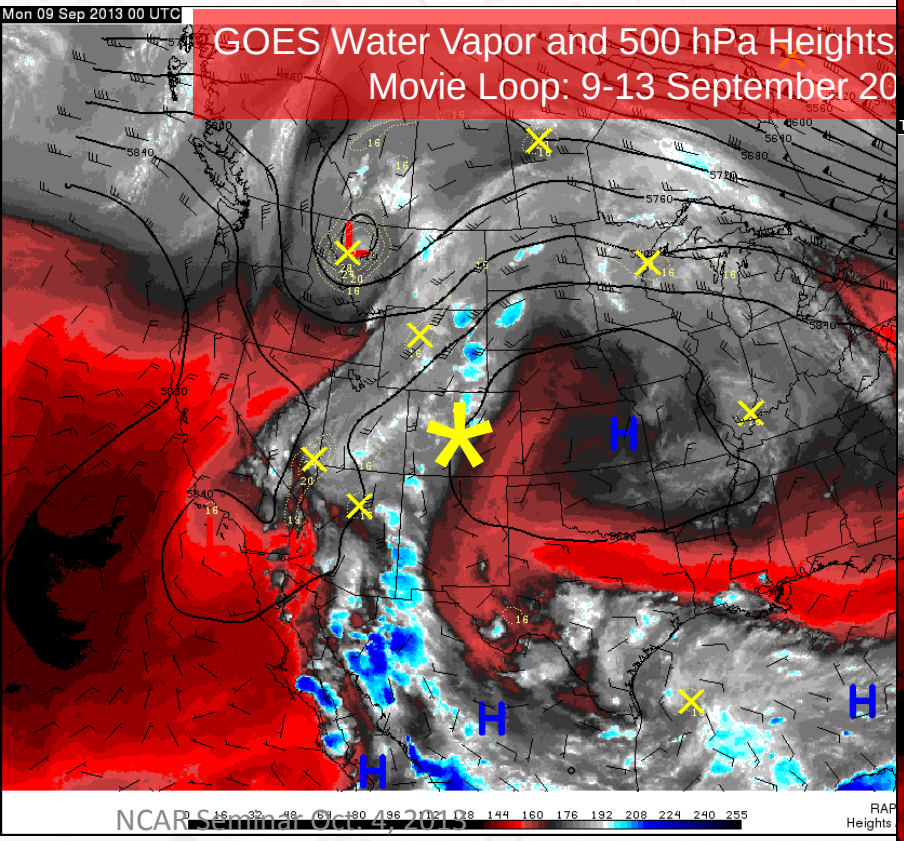
ODM470 vs OTT Parsivel, Video-disdrometer, MRR, Geonor, FDIR gauges …

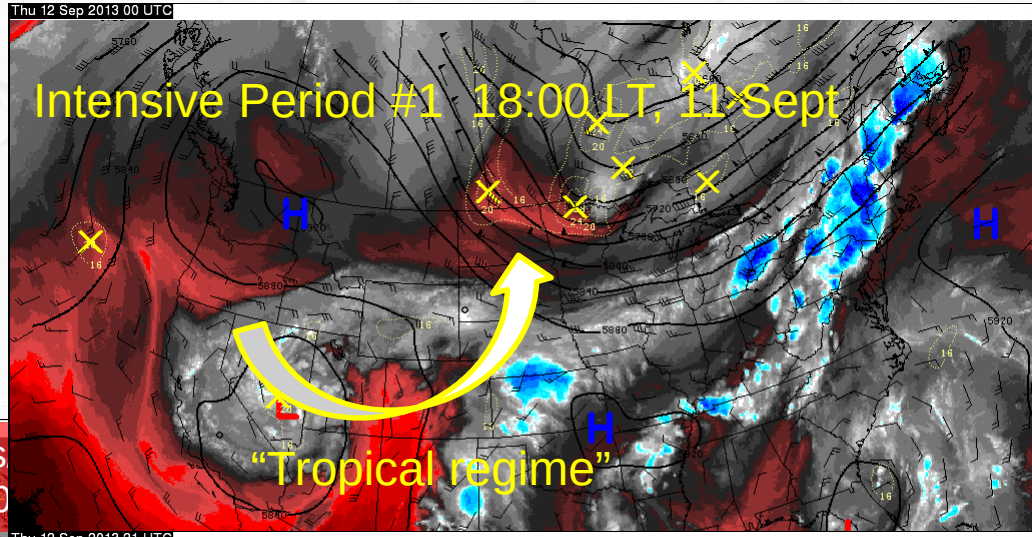


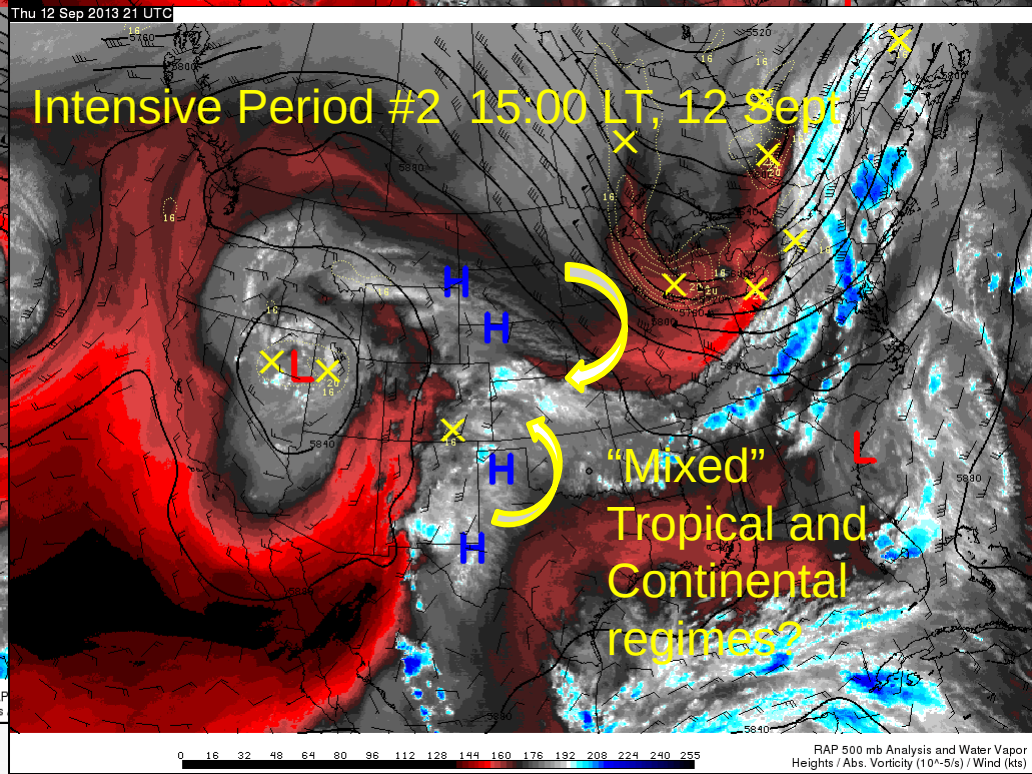
… **international intercomparison project** … involve the participation of **numerous observing sites (14)**, and **continuous and frequent observations of precipitation**, snow depth and ancillary variables over a long period of time, sampled by a number of **instruments of different makes** supplied by different providers.

Colorado Front Range Flood
9-13 September 2013

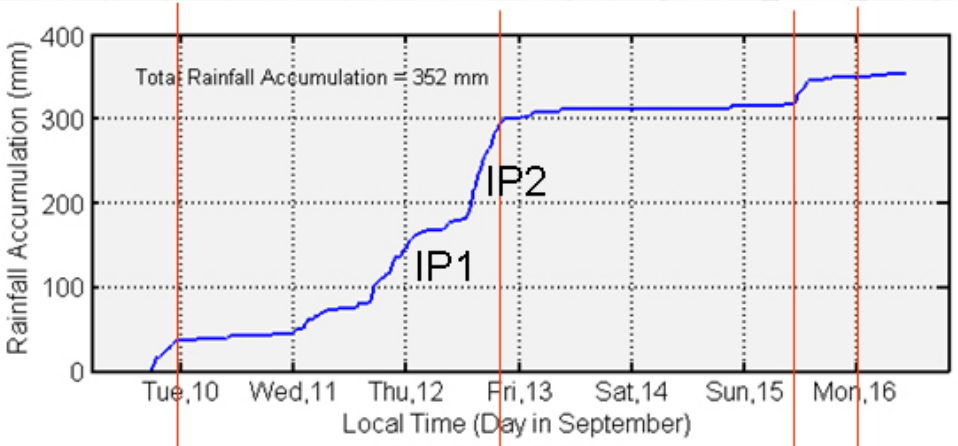
courtesy of NCAR, Dr. P. Kucera







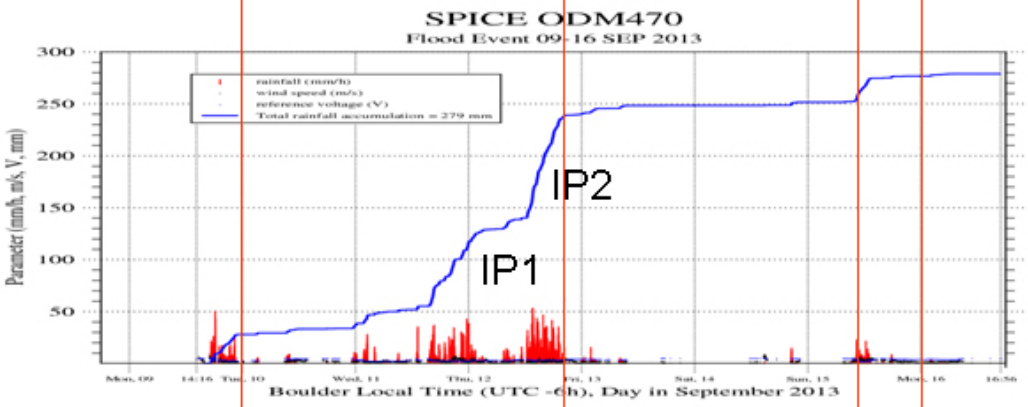
Parsivel



Total 352 mm
123.5% of reference
+23.5% to reference

Local time

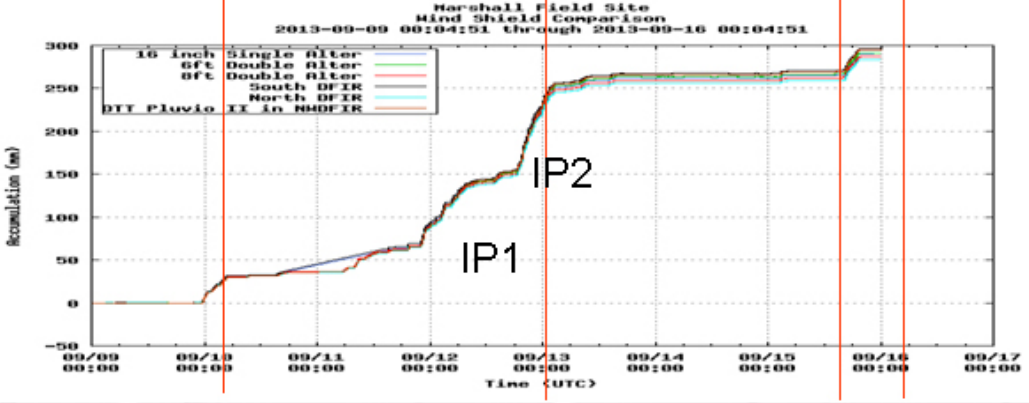
ODM470



Total 279 mm
97.9% of reference
-2.1% to reference

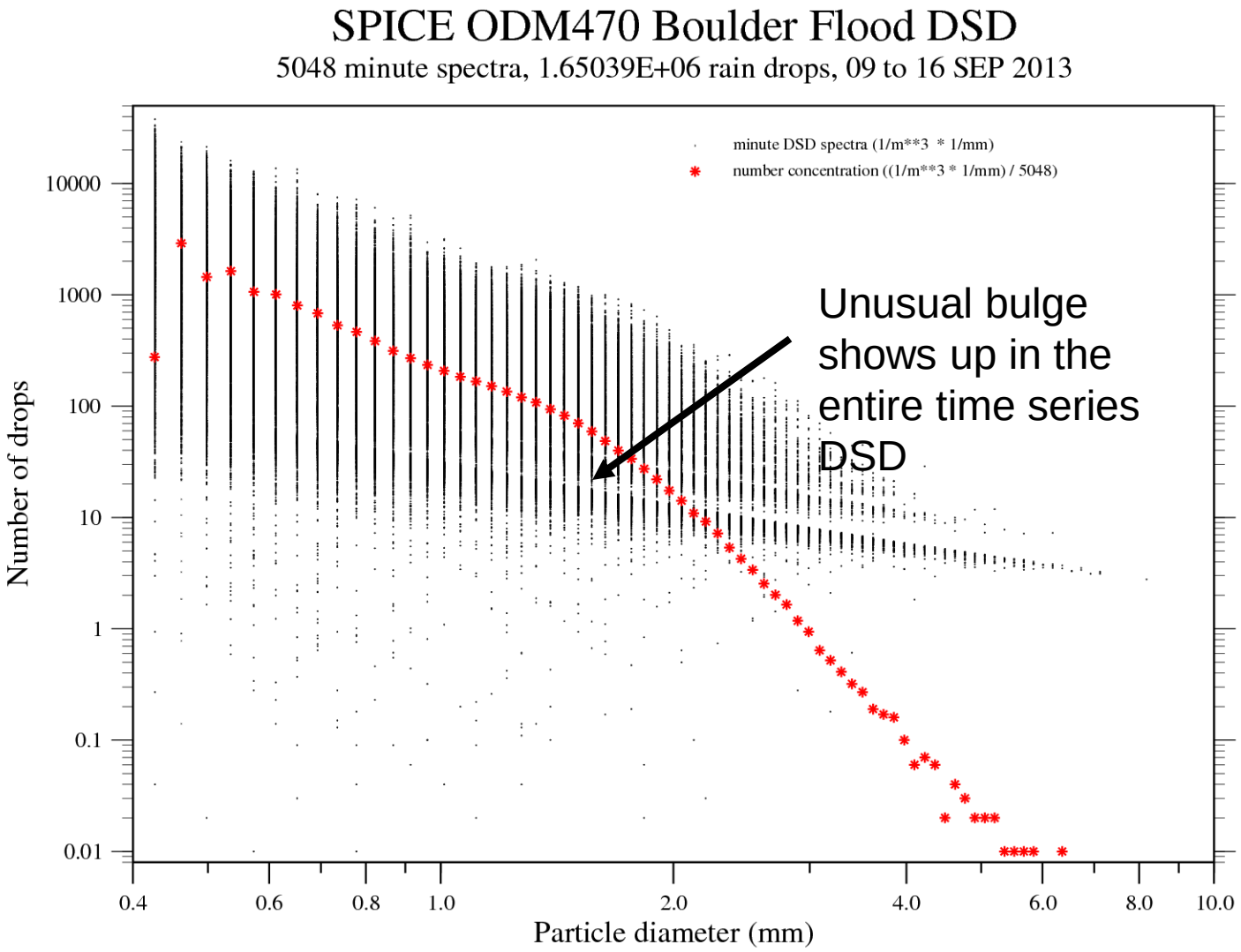
Local time

Weighing Gauges



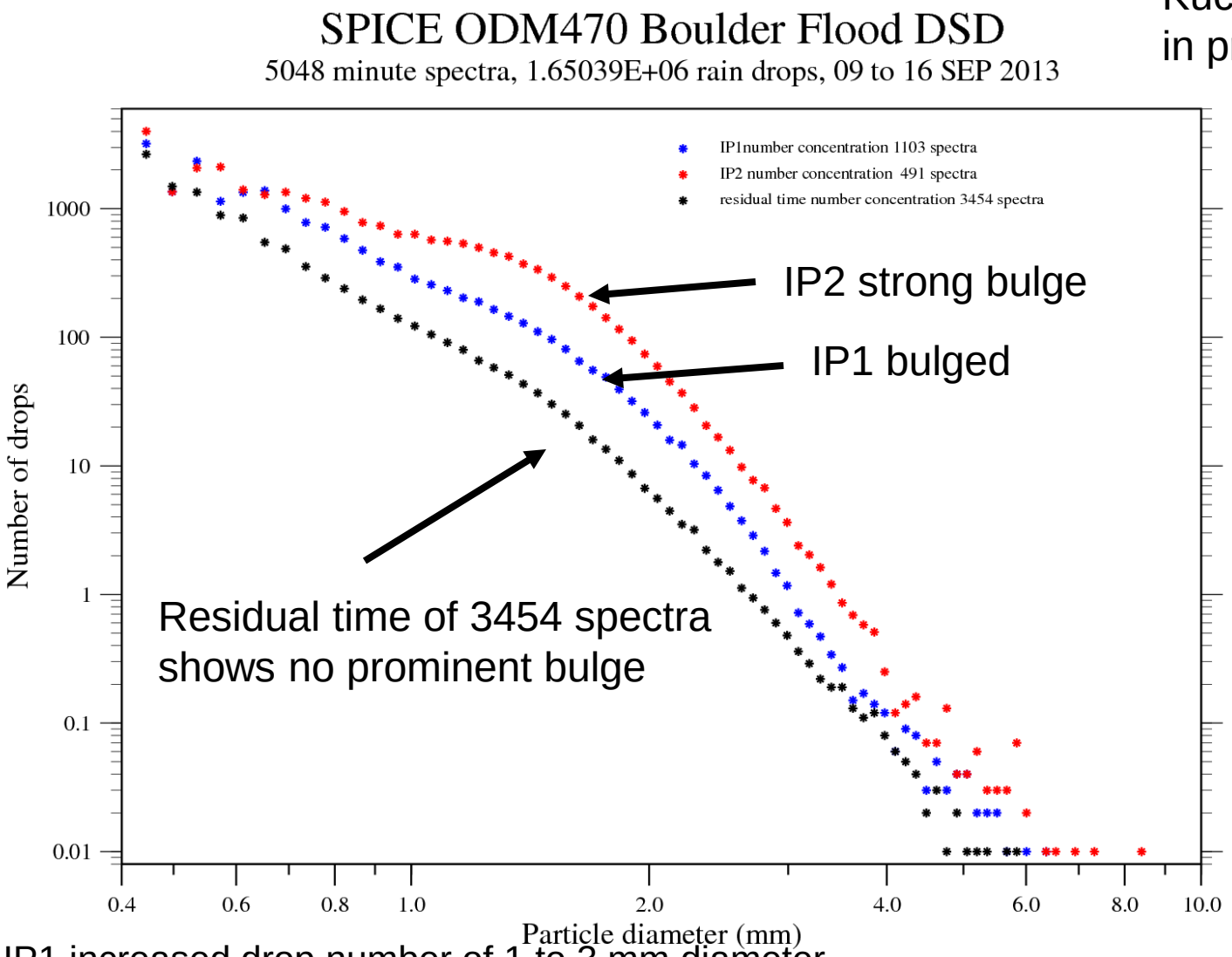
Total ~285 mm
REFERENCE

UTC time



Black: individual 5048 minute spectra range
Red: number concentration (1/m**3 * 1/mm) / 5048

Kucera and Klepp, in preparation



- IP1 increased drop number of 1 to 3 mm diameter
- IP2 increase in drops between 1 and 2 mm diameter; overall larger drop numbers
- coincides with observations