A new criterion to detect drizzle from ground-based: a potential new tool for model evaluation.

HD(CP)²

High definition clouds and precipitation for advancing climate prediction

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What is the reflectivity threshold to detect precipitation from ground-based radars?

-15 dBz

-20 dBz

-17 dBz

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Chin et al., 2000

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Kato et al., 2001

-17 dBz

Kogan et al., 2005

Ze is prone to calibration issues and biases occurring in the radar reflectivity measurements.

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-15 dBz

Chin et al., 2000

-20 dBz

Kato et al., 2001

-17 dBz

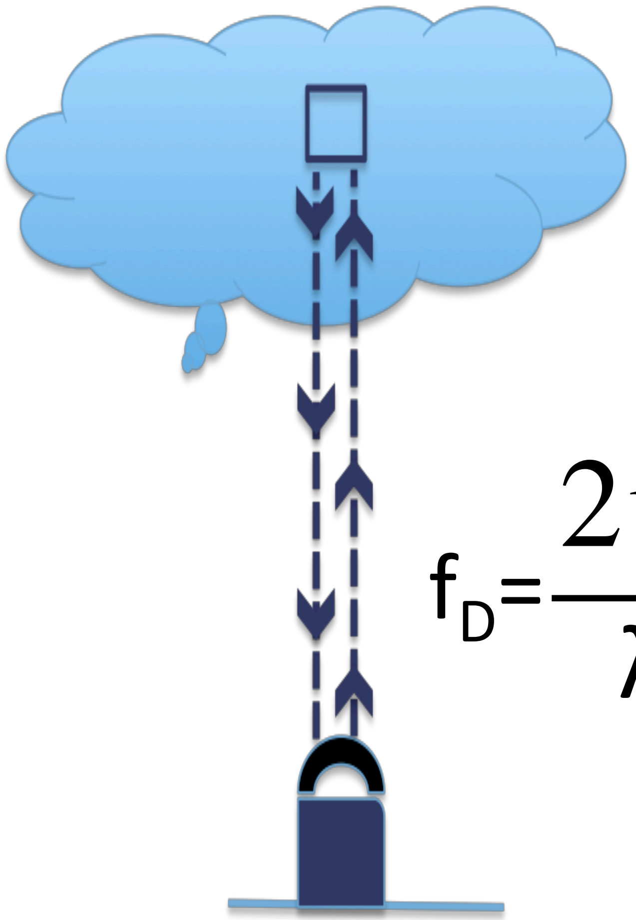
Kogan et al., 2005

Ze is prone to calibration issues and biases occurring in the radar reflectivity measurements.

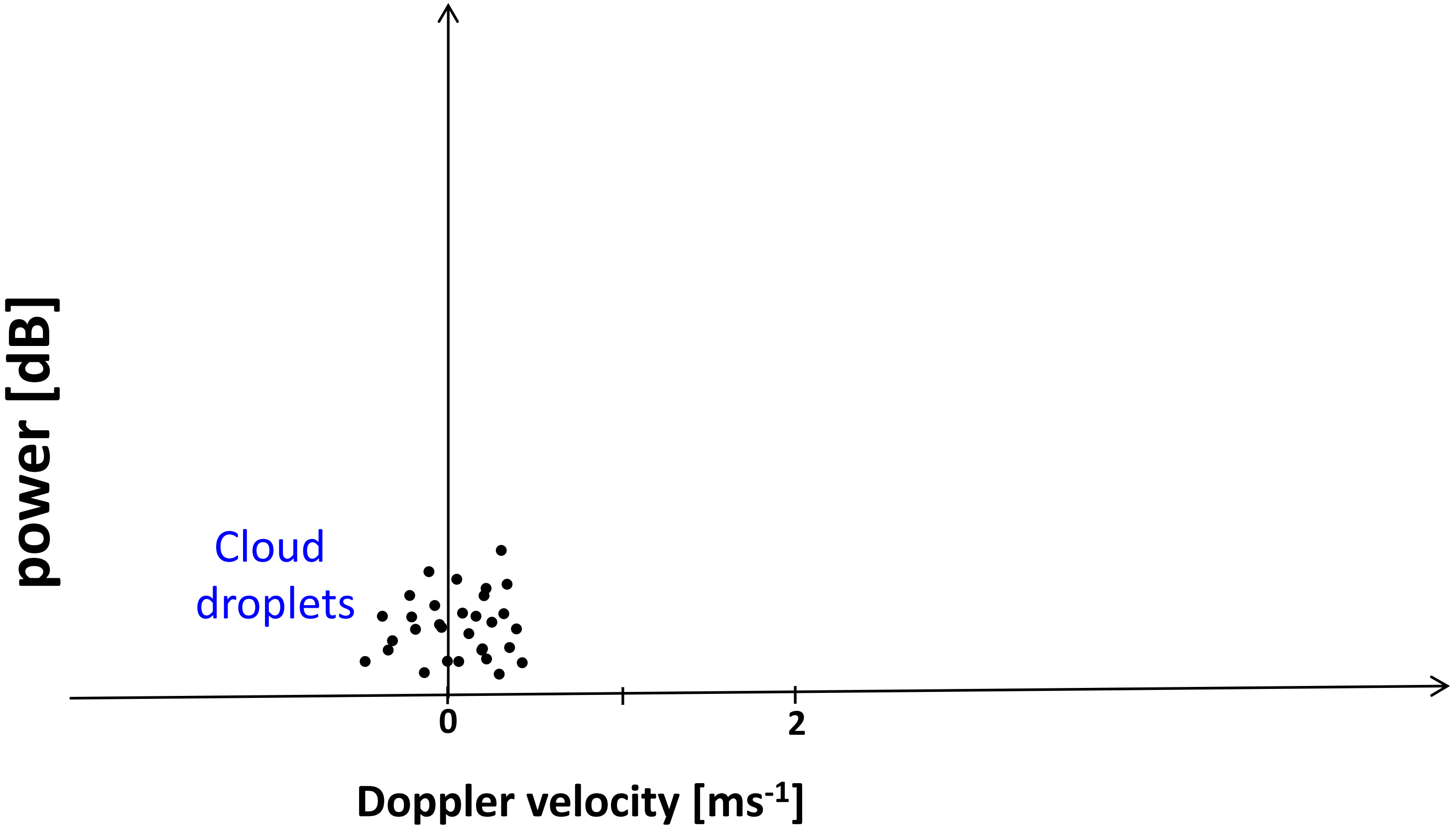
What else can we use?

How to improve the detection?

➔ *cloud radar Doppler (velocity) spectrum and skewness*



$$f_D = \frac{2 v_z}{\lambda}$$



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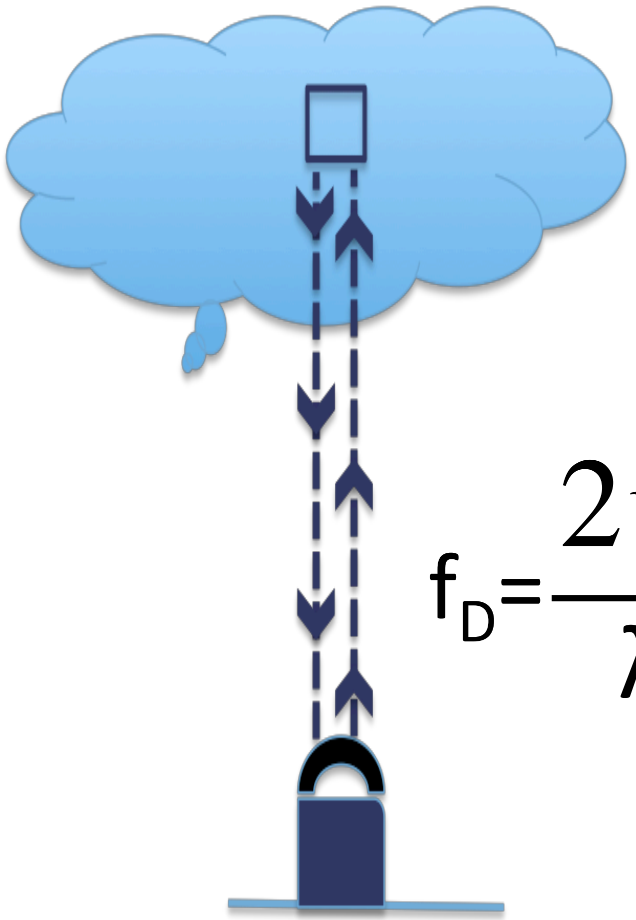

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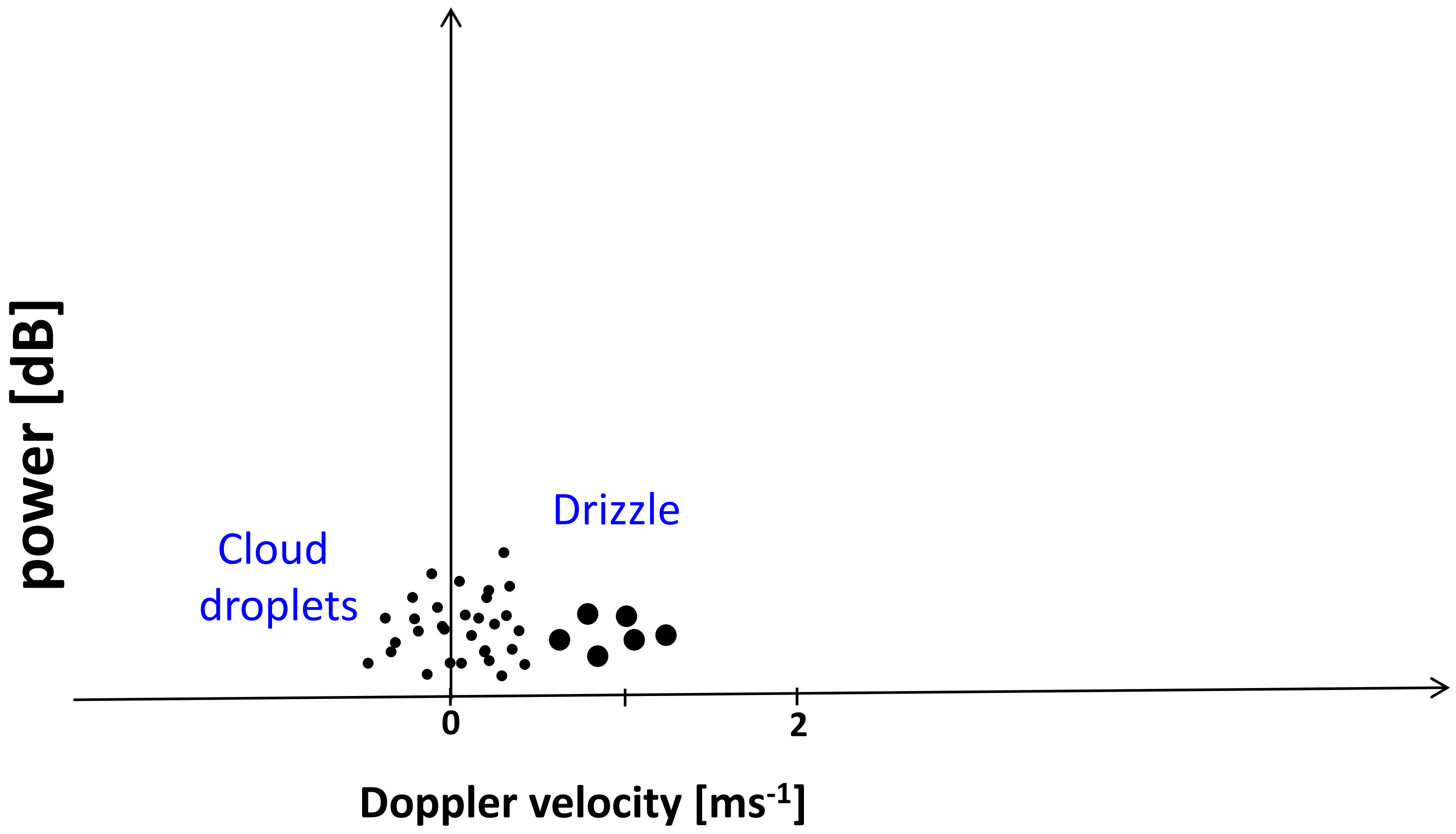

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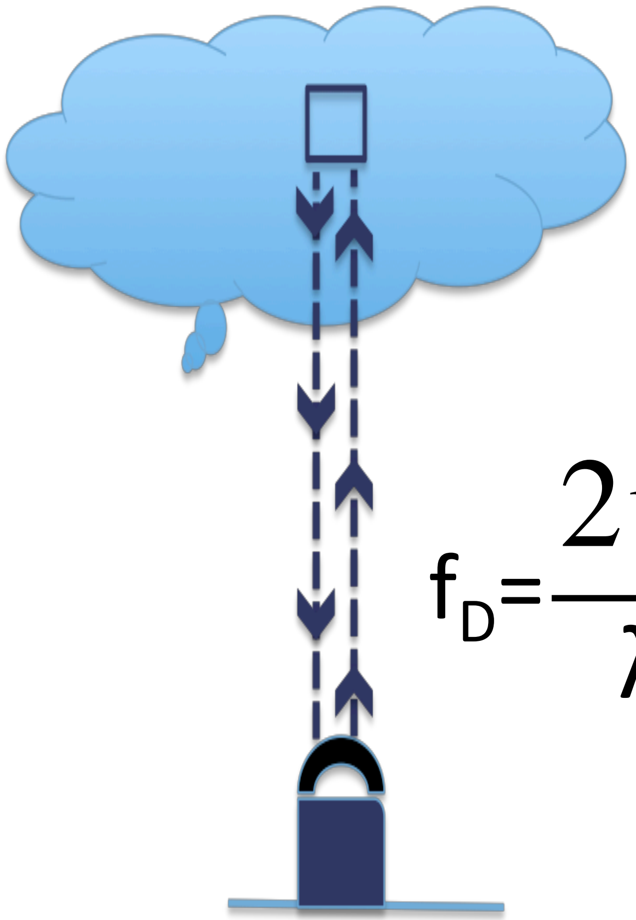

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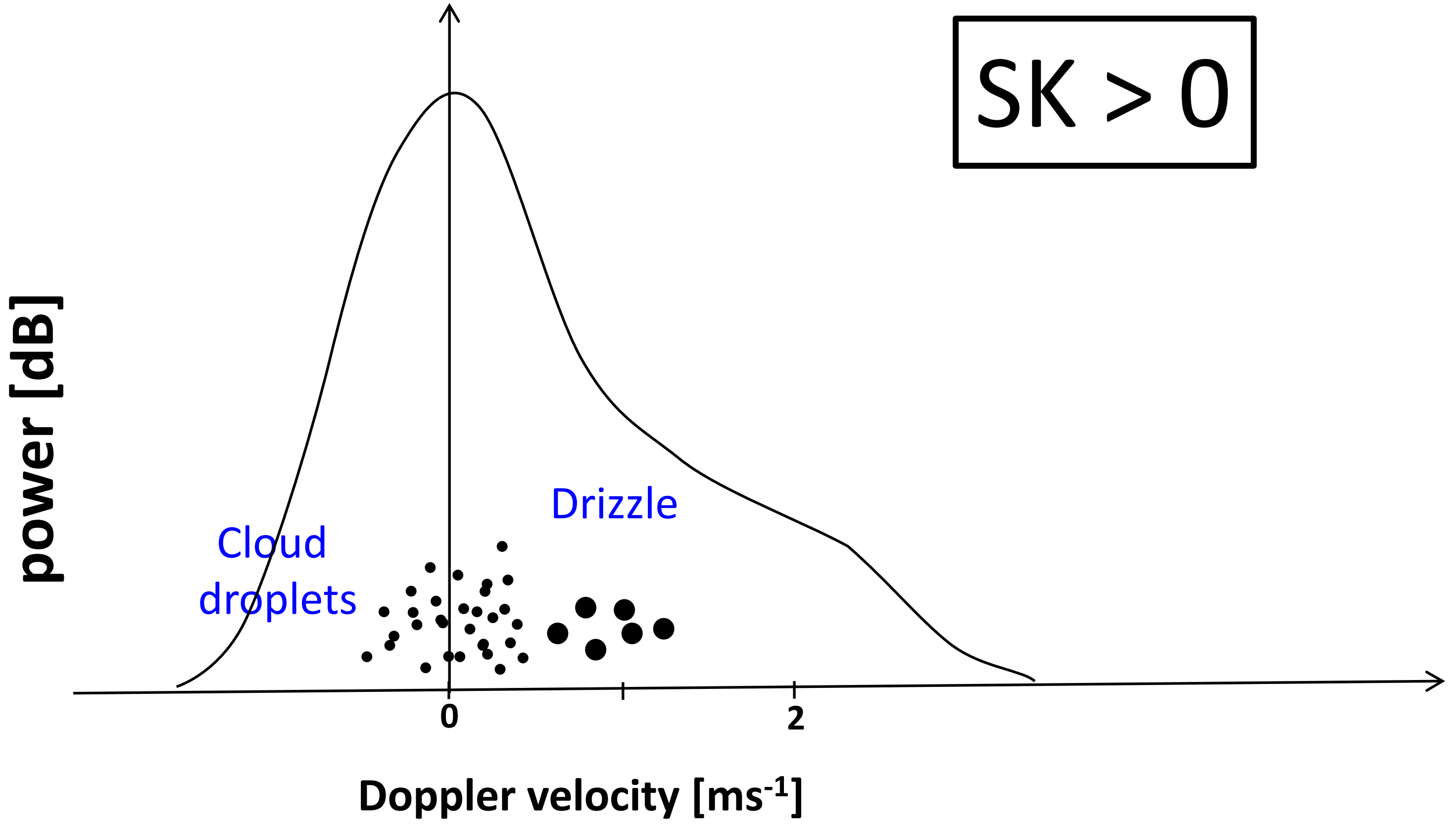
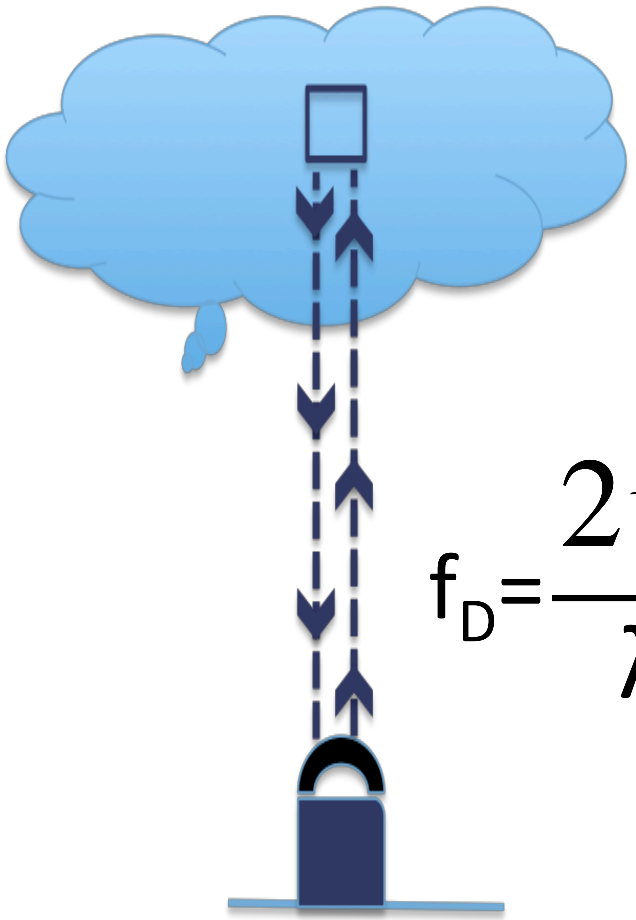


skewness (SK) : measures the degree of asymmetry of a given distribution

How to improve the detection?

➔ *cloud radar Doppler (velocity) spectrum and skewness*



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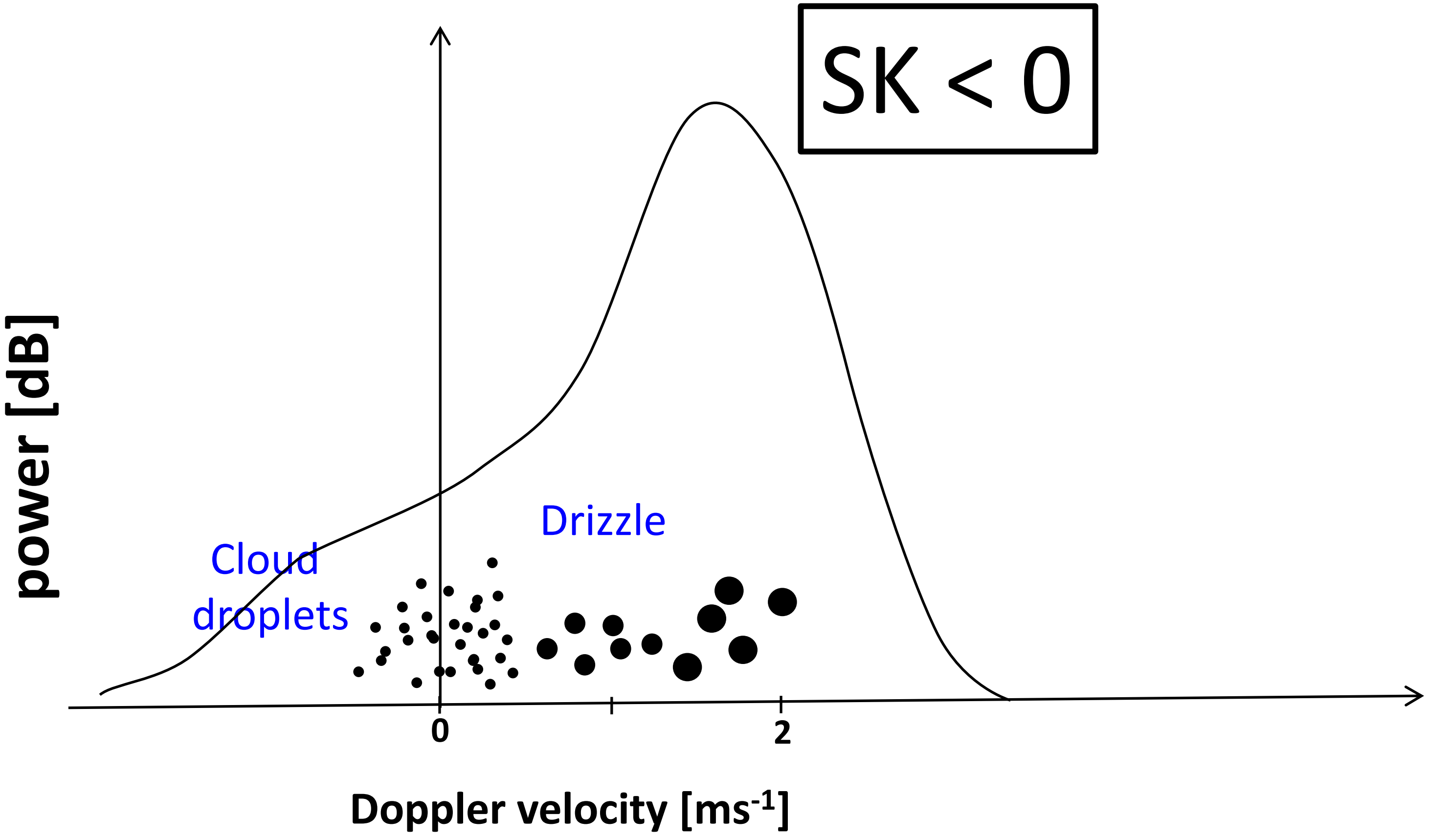
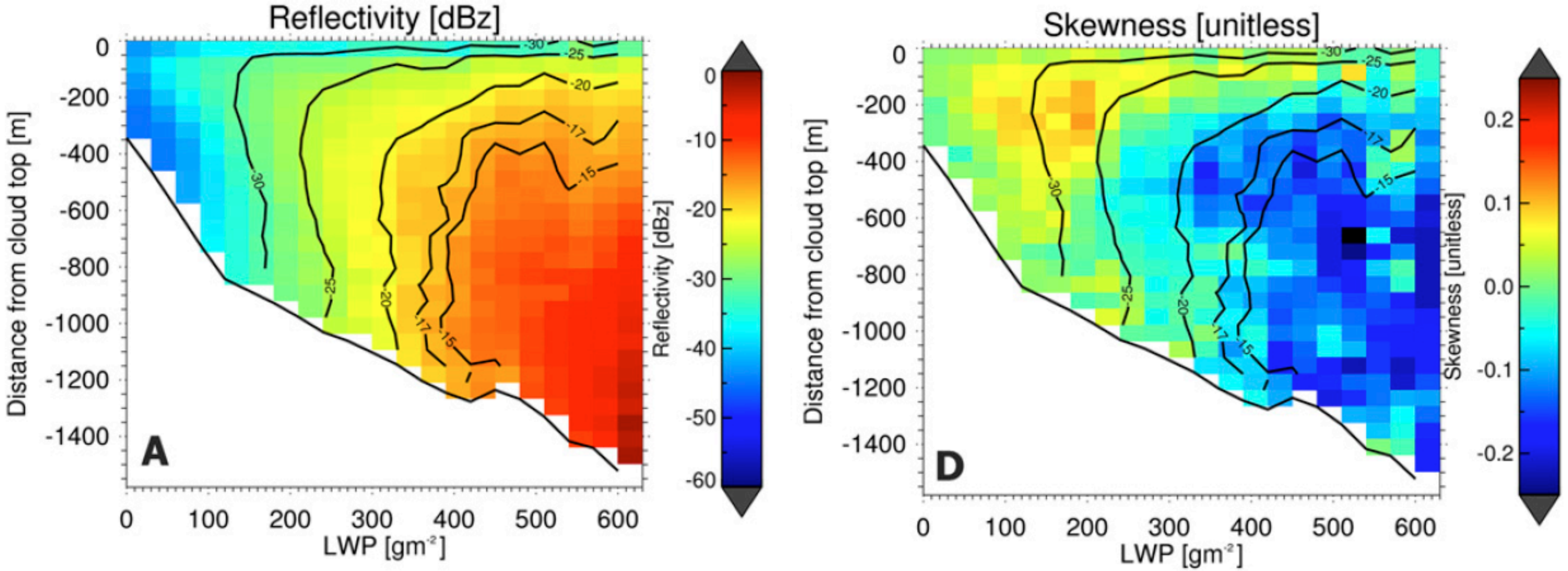


Skewness turns negative when drizzle dominates the Doppler spectrum

How can we use skewness to detect drizzle in obs?

Principle of CLAssification of Drizzle Status Algorithm (CLADS)

(from Acquistapace et al., 2019, JTECH)



As Ze increases, skewness changes sign, indicating growth of raindrops

Principle of CLAssification of Drizzle Status Algorithm (CLADS)

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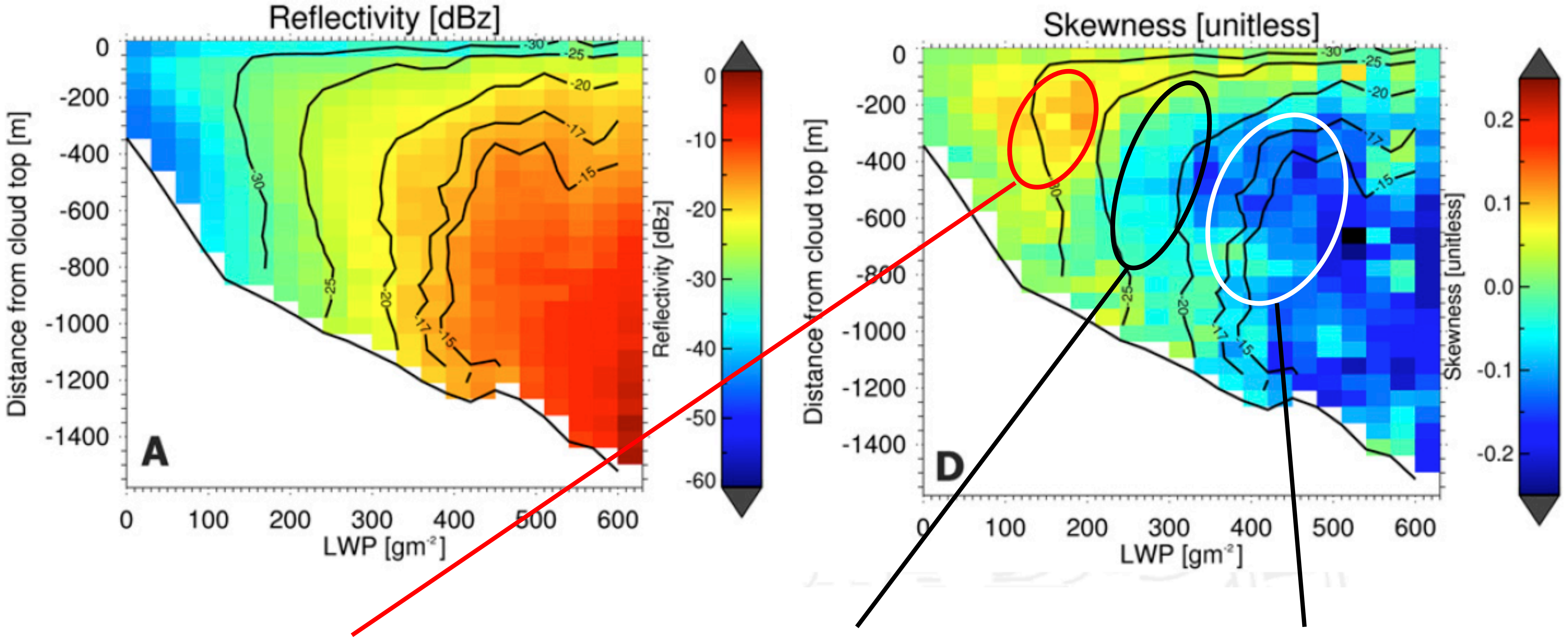
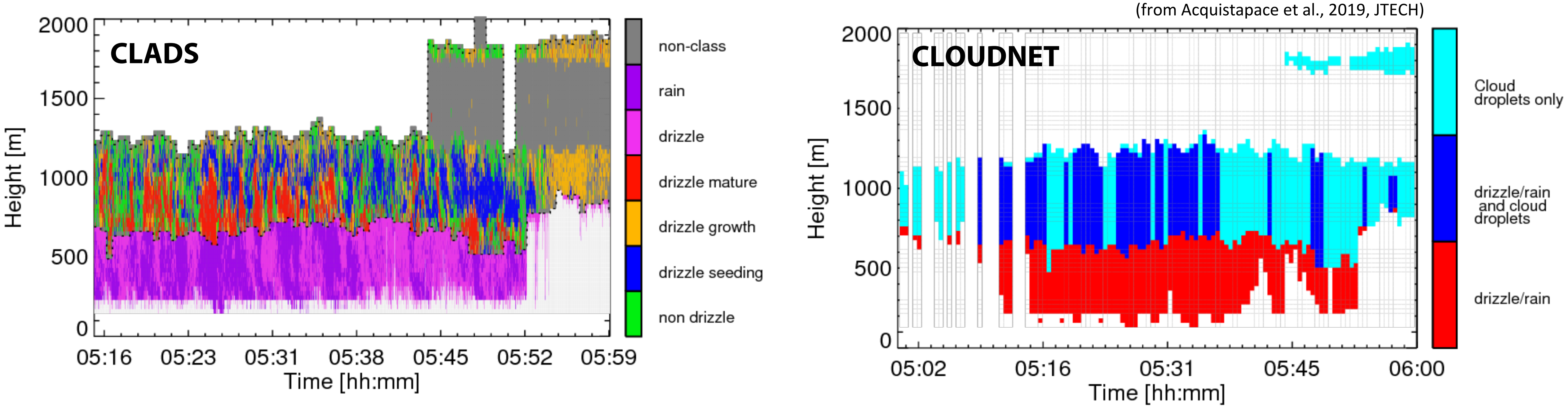


DRIZZLE ONSET
Sk > 0.3

DRIZZLE GROWTH
-0.3 < Sk < 0.3

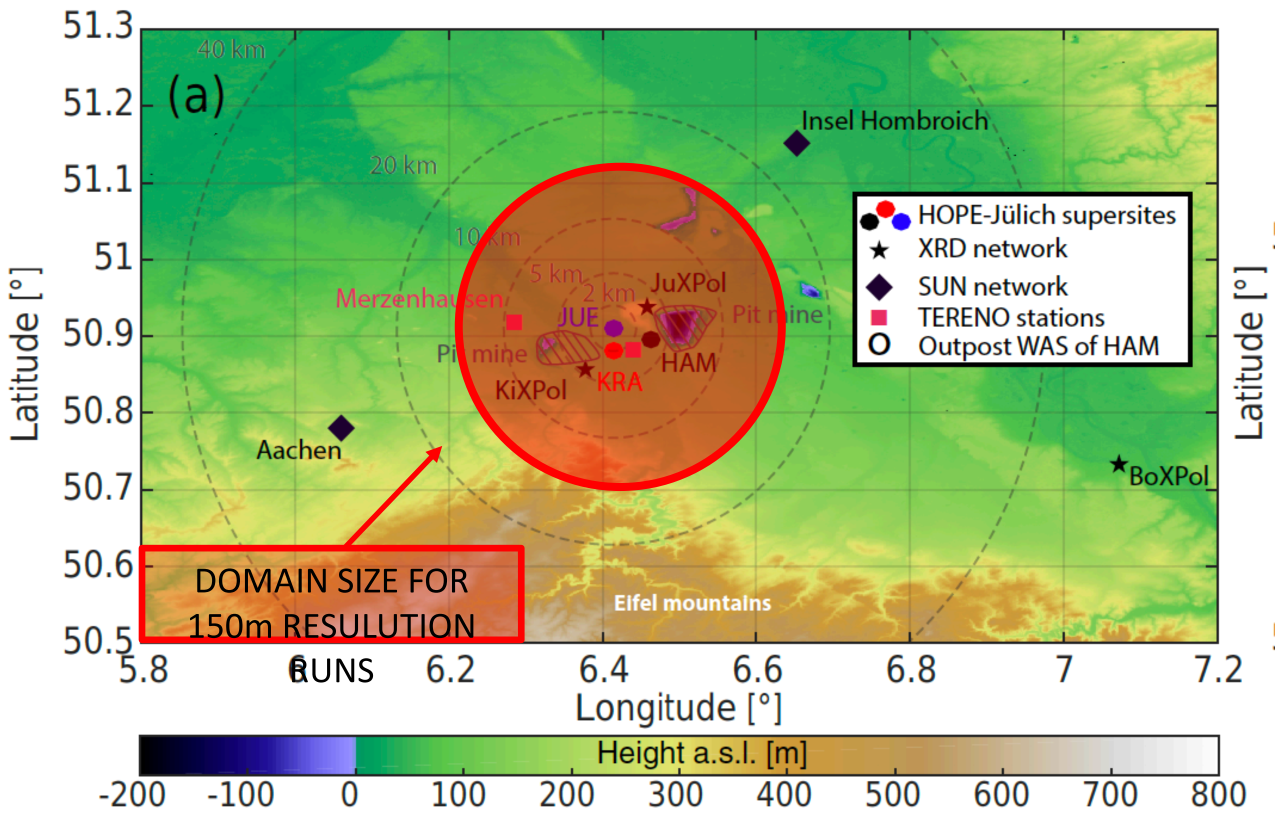
DRIZZLE MATURE
Sk < -0.3



More detailed classification of drizzle in the clouds

Can we use skewness to evaluate LES models?

The model : ICON-LEM



Domain size and topography
LES type simulation
(resolutions of 625, 312, 156 m)

no convection parameterization
3D Smagorinsky turbulence

parametrizations needed for:

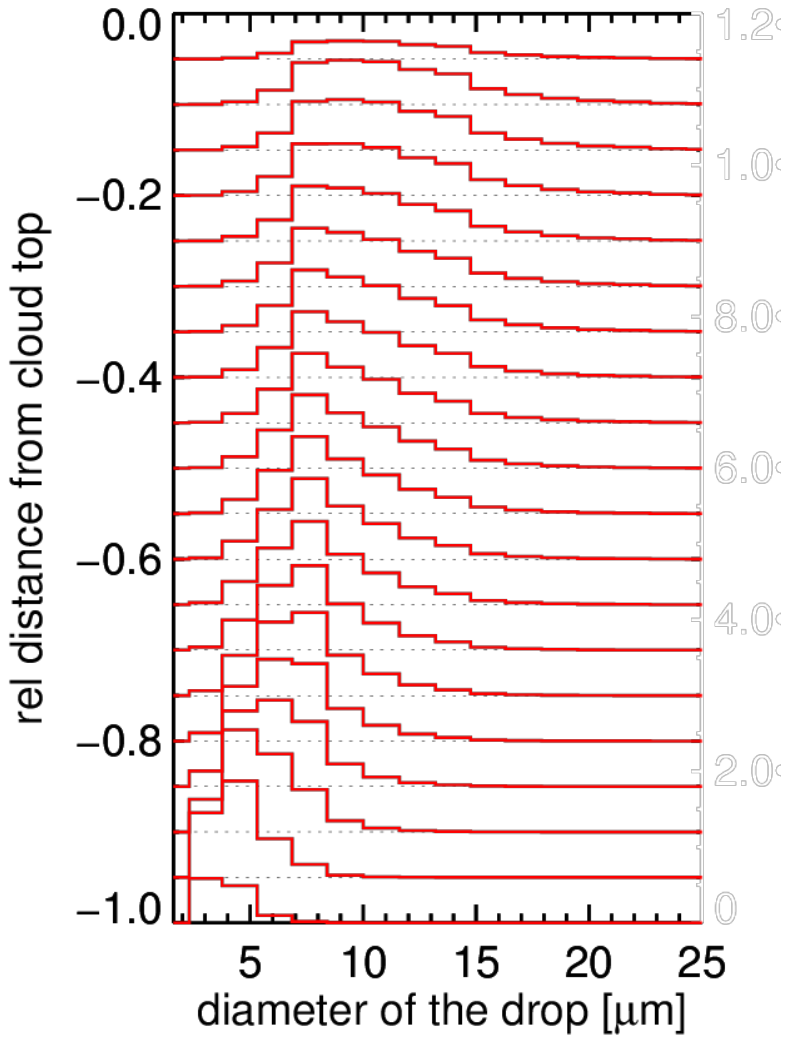
- land-surface processes
- sub-grid turbulence
- cloud microphysical processes
- radiative transfer

Forcing: IFS

(Heinze et al., 2017)

The radar forward simulator: PAMTRA

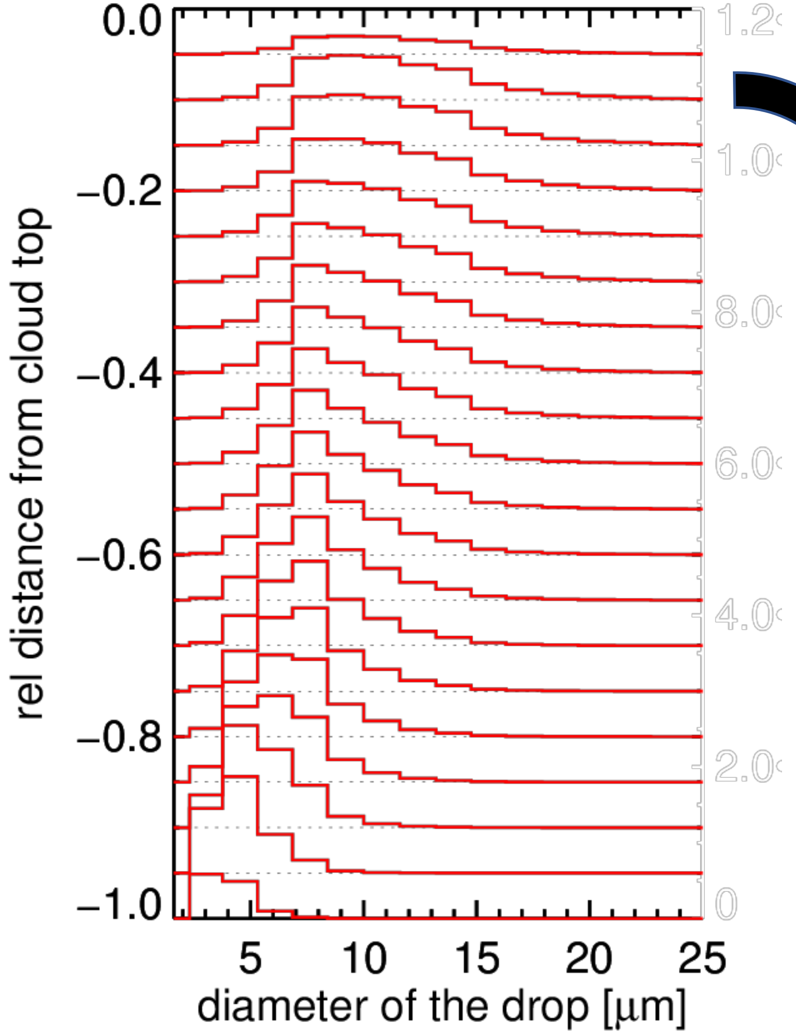
Drop size distributions (DSD)
Gamma function (ICON-LEM)



The radar forward simulator: PAMTRA

Drop size distributions (DSD)
Gamma function (ICON-LEM)

+ turbulence
+ vertical wind speed
+ radar spec



The radar forward simulator: PAMTRA

Drop size distributions (DSD)
Gamma function (ICON-LEM)

+ turbulence
+ vertical wind speed
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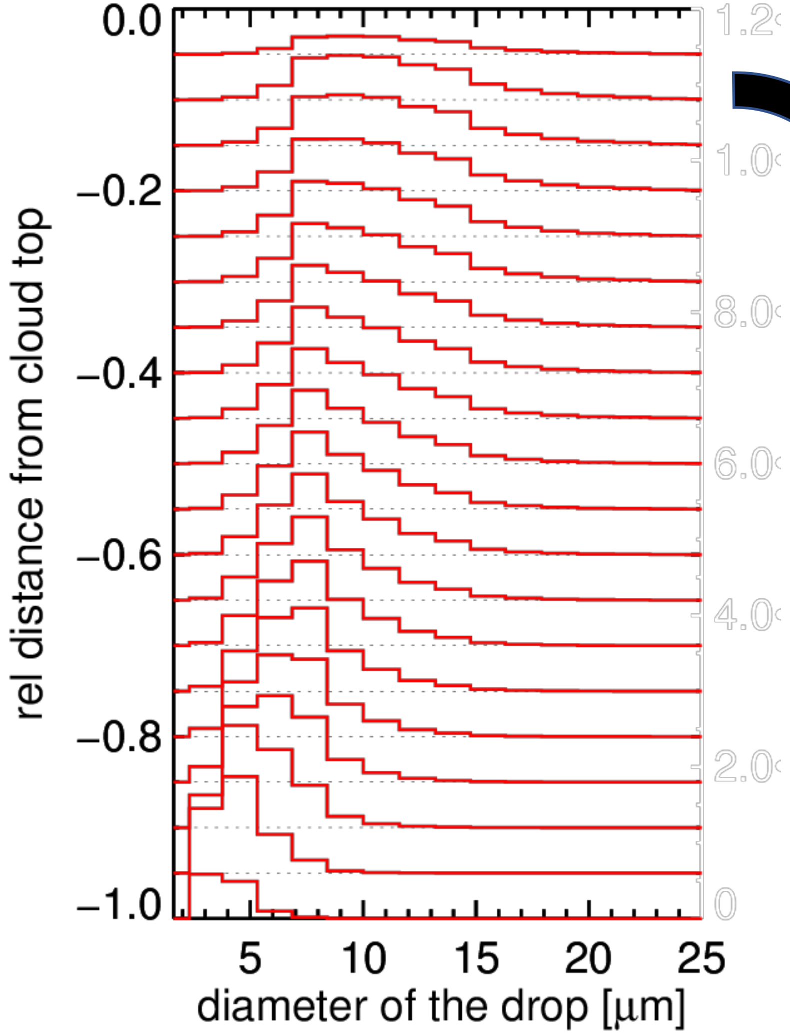
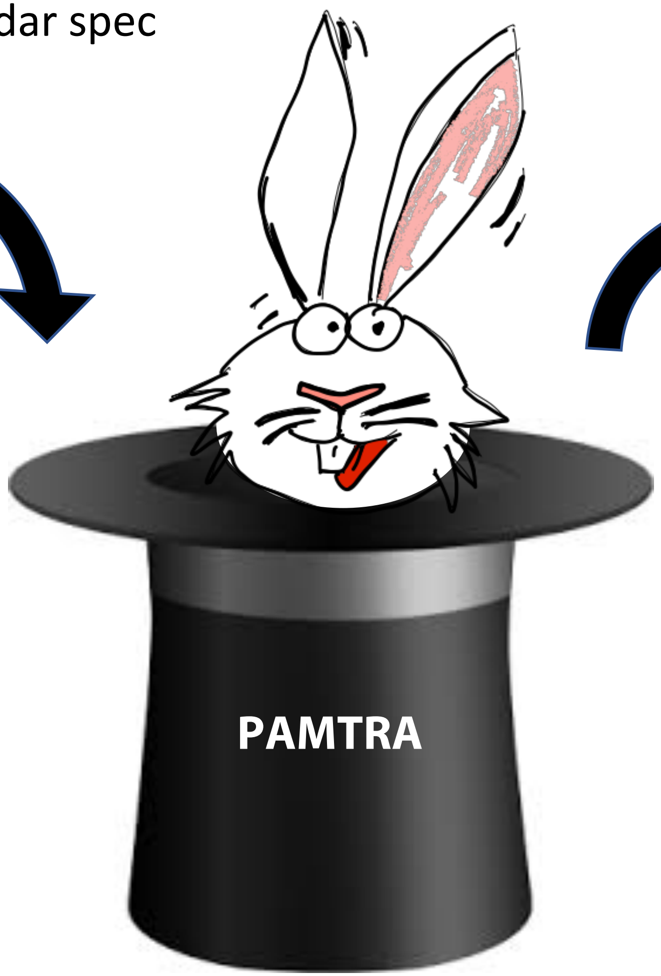
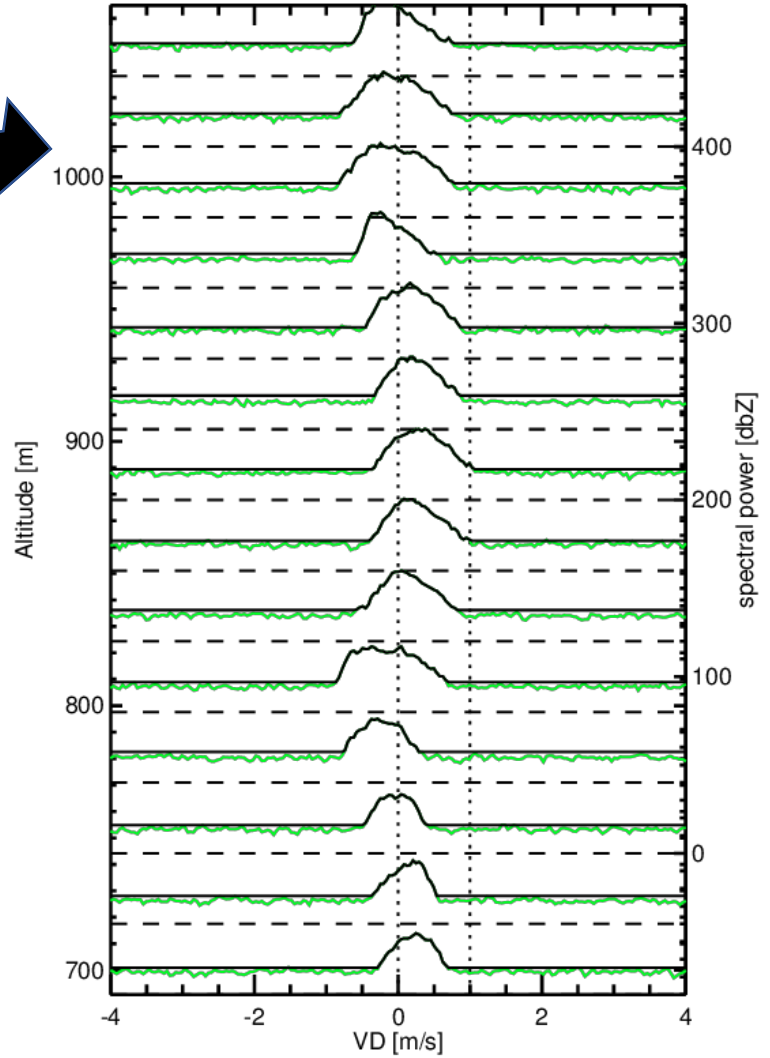
Simulated spectra and moments profiles

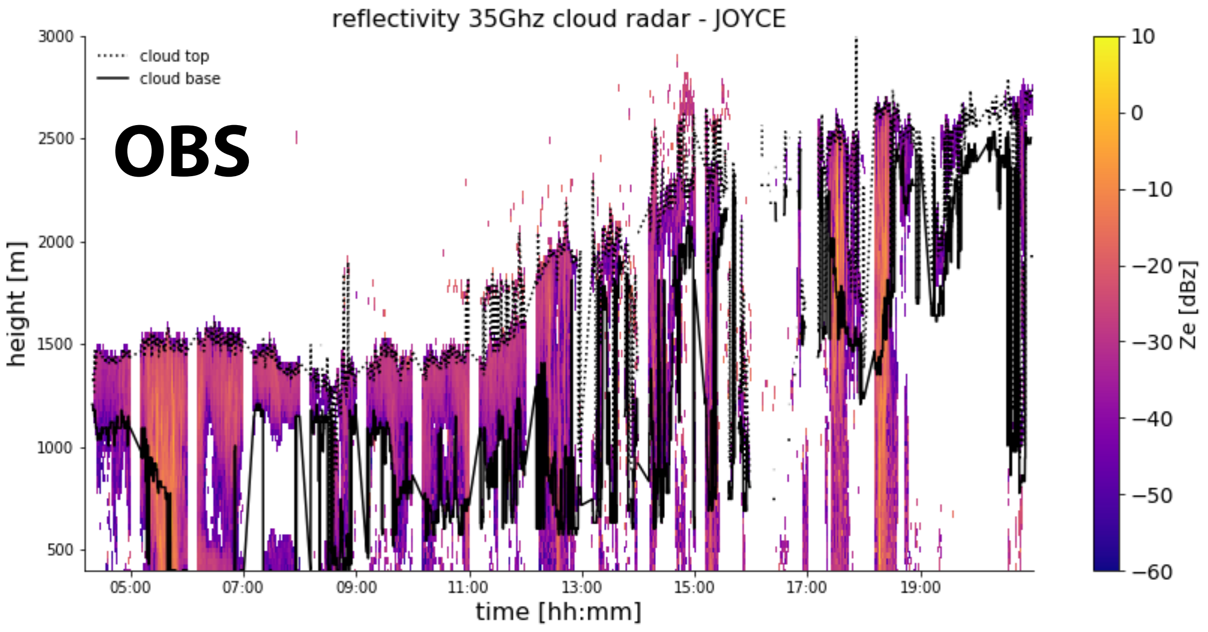


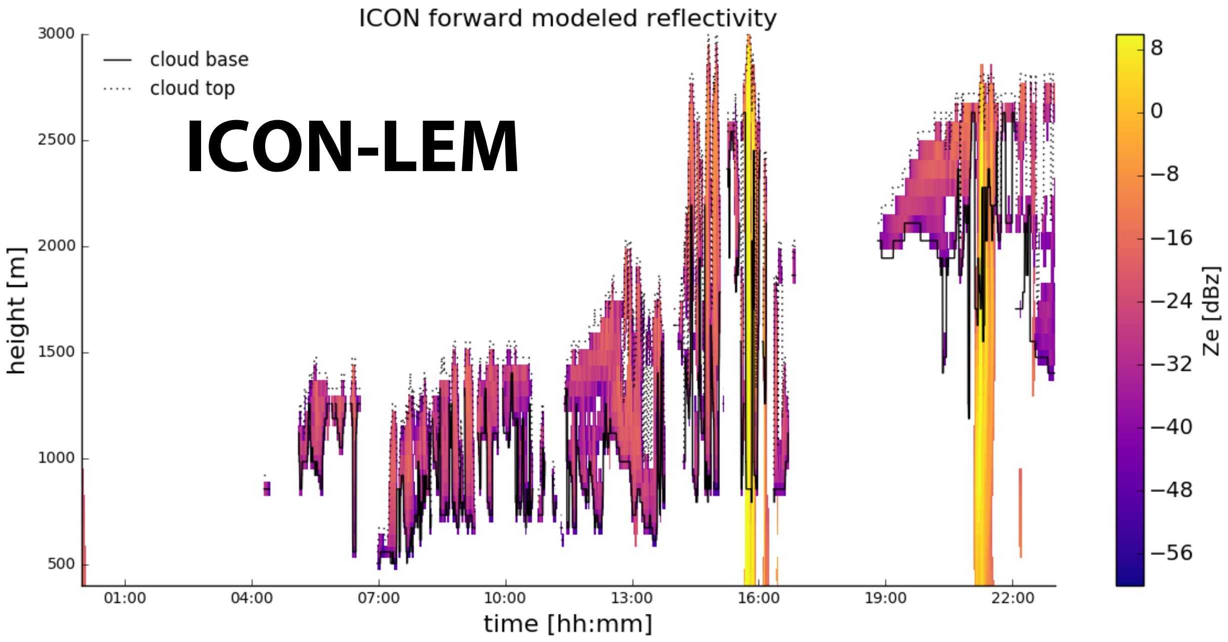


(credits for the bunny drawing: Dr. Pfitzenmaier)



Case study of the 17th June 2014: obs vs ICON-LEM





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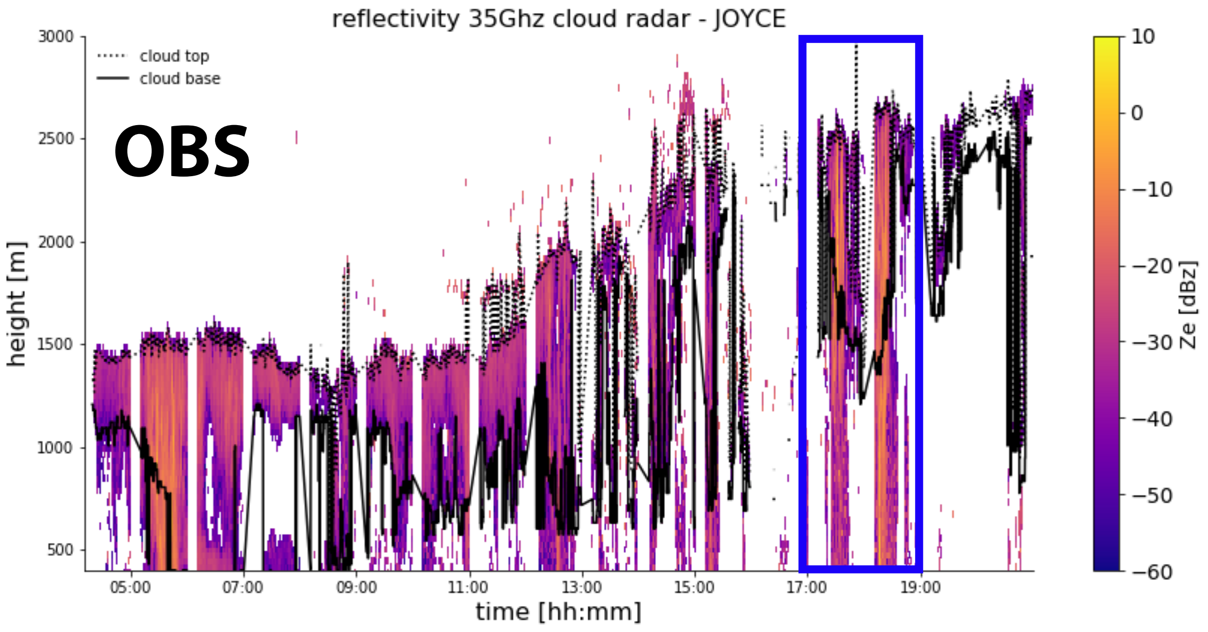
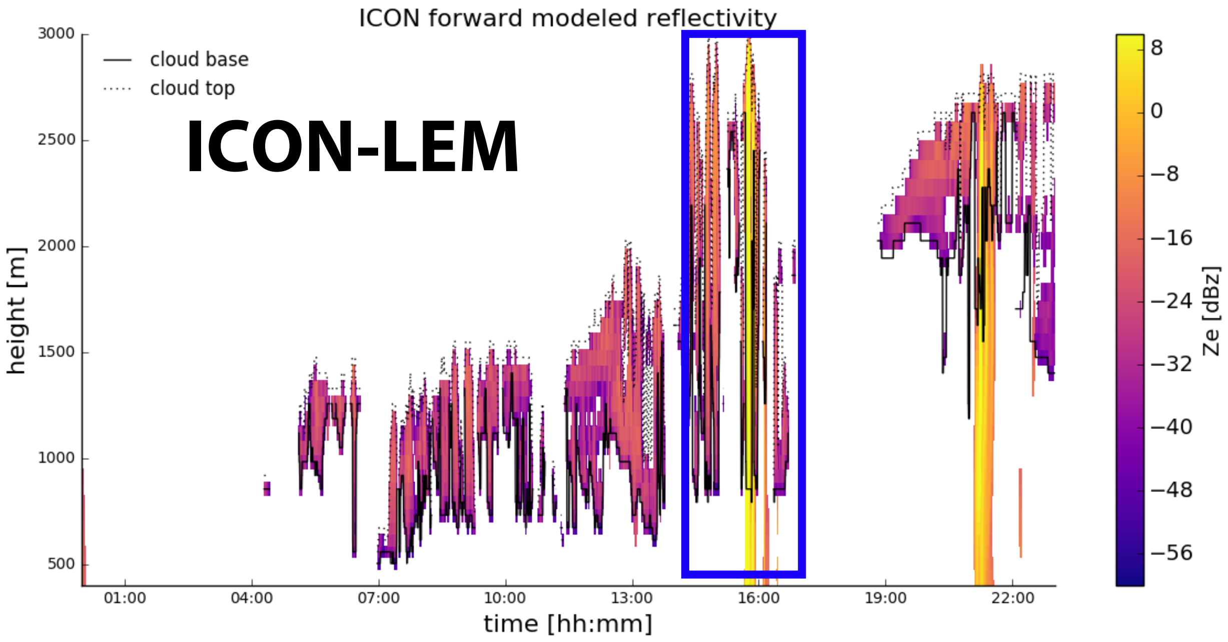
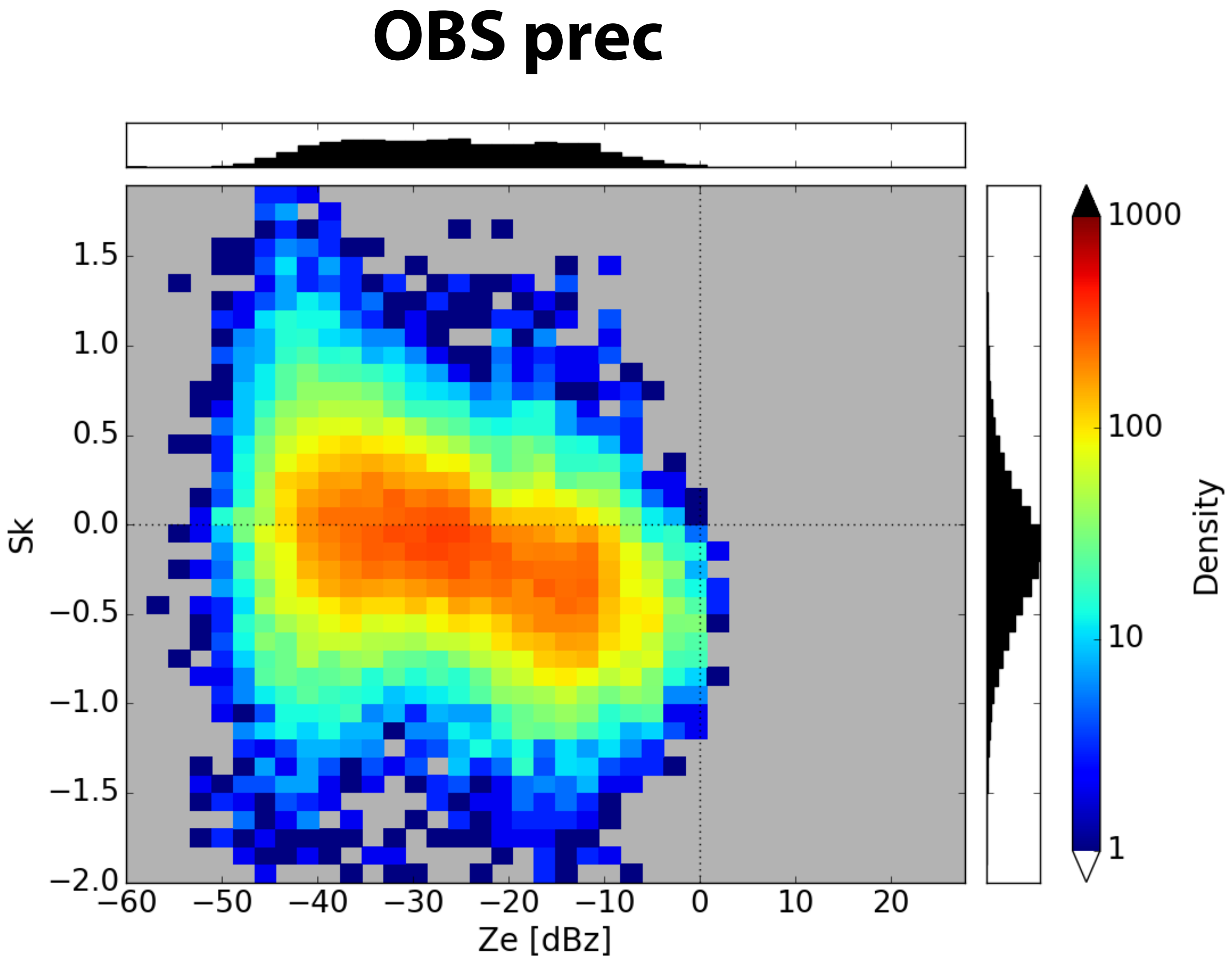
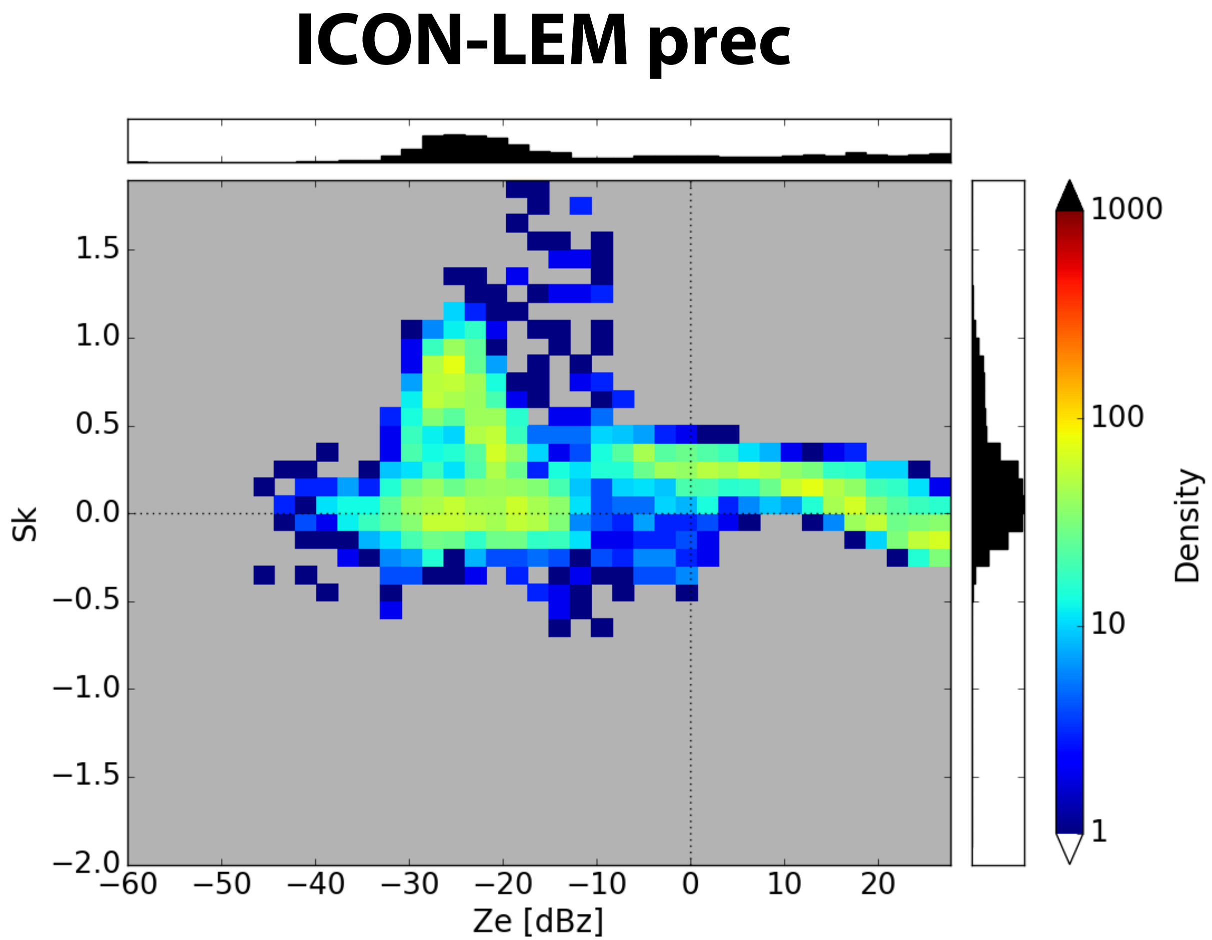




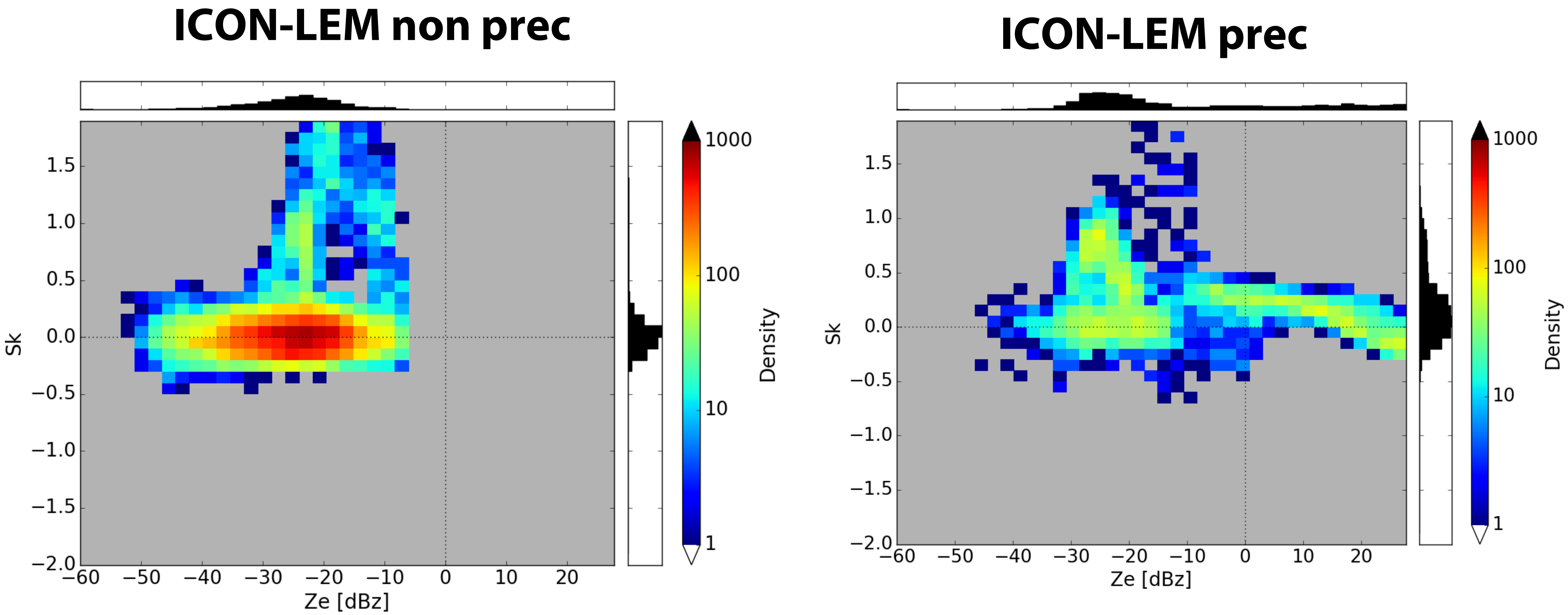
Looking at skewness transitions: focus on one hour





- In observations, Sk goes from positive to negative values as expected.
- Observations show smaller values of Ze compared to the model.
- In ICON-LEM, Skewness shows large positive values, and negative values are hardly smaller than -0.05

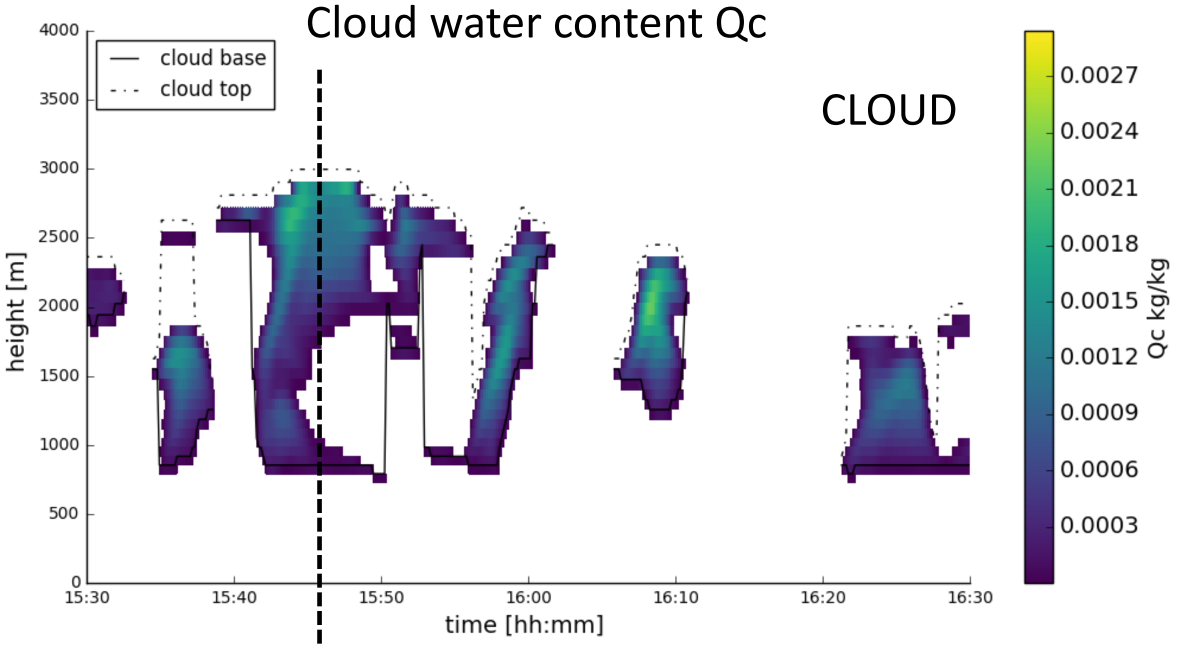
Looking at skewness transitions: focus on one hour

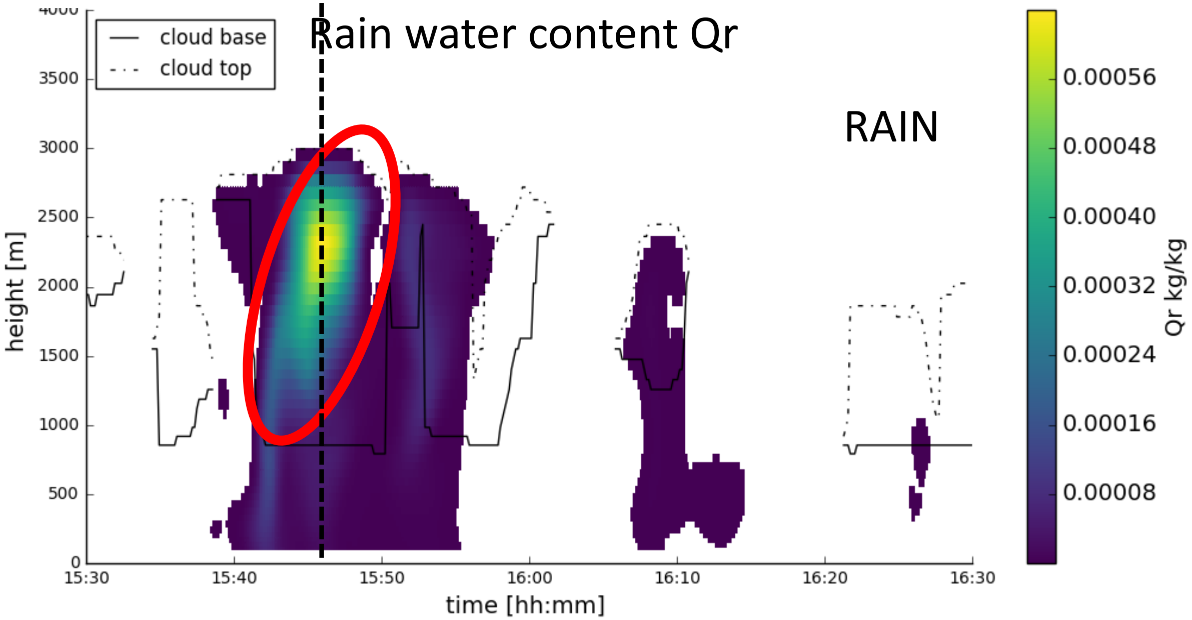


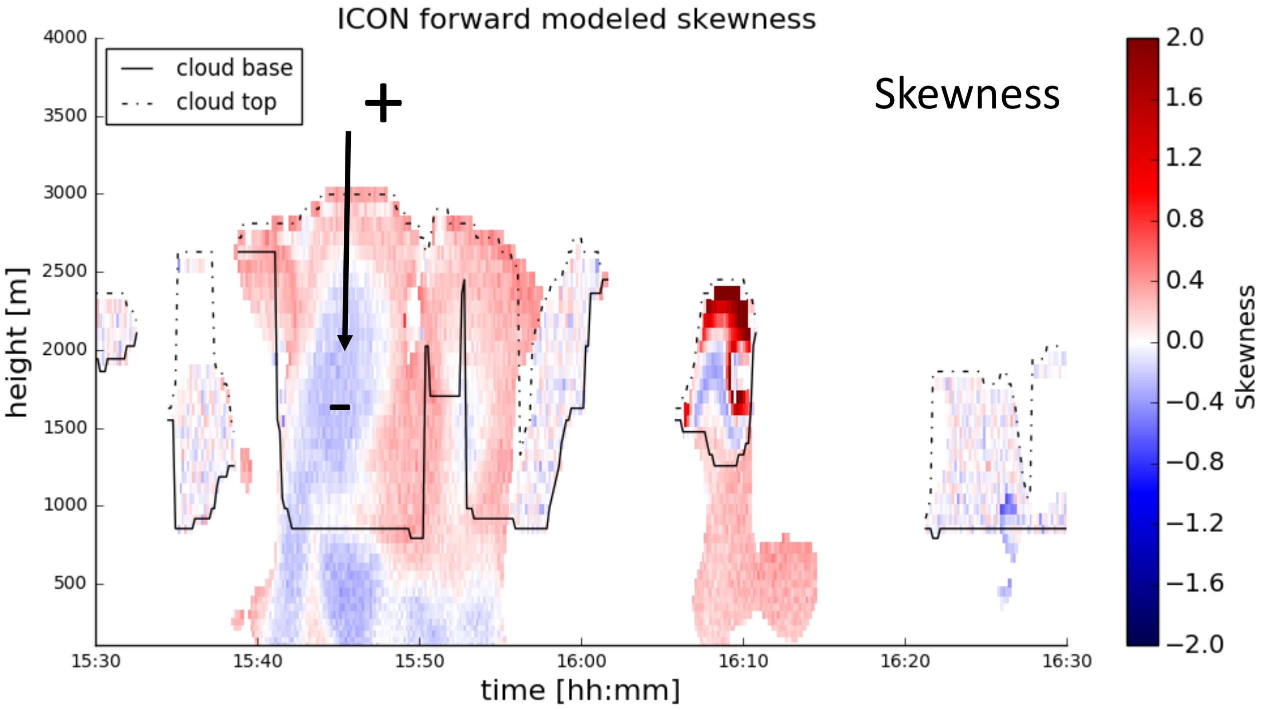
- In observations, Sk goes from positive to negative values as expected.
- Observations show smaller values of Ze compared to the model.
- In ICON-LEM, Skewness shows large positive values, and negative values are hardly smaller than -0.05
- In ICON-LEM, Ze > 0 dBz is associated with rain.

On what does the simulated skewness mainly depend?

Is there a transition in the skewness in the model due to rain?







- Skewness changes sign from positive to negative when rain develops, but the variation is very small.

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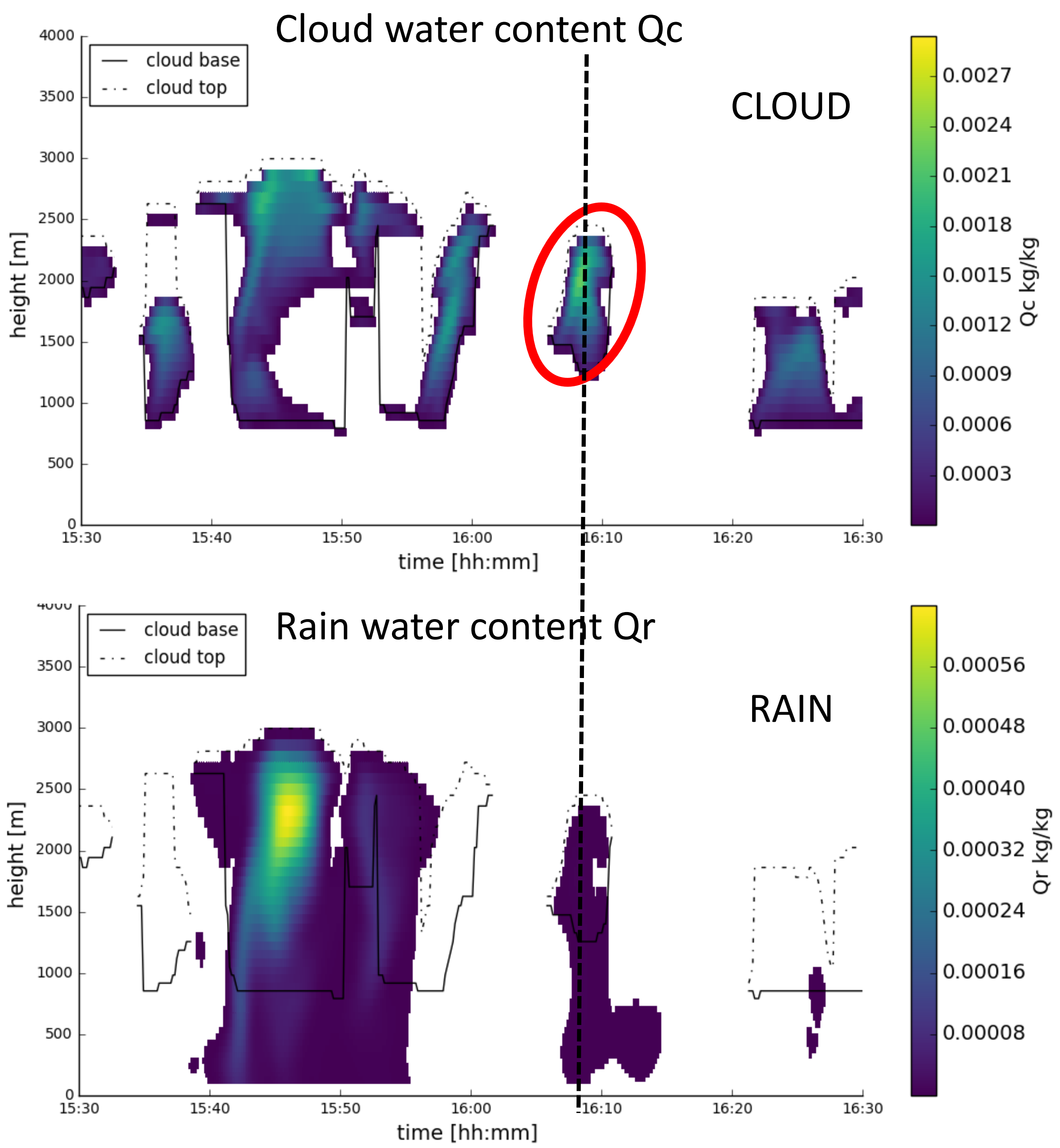

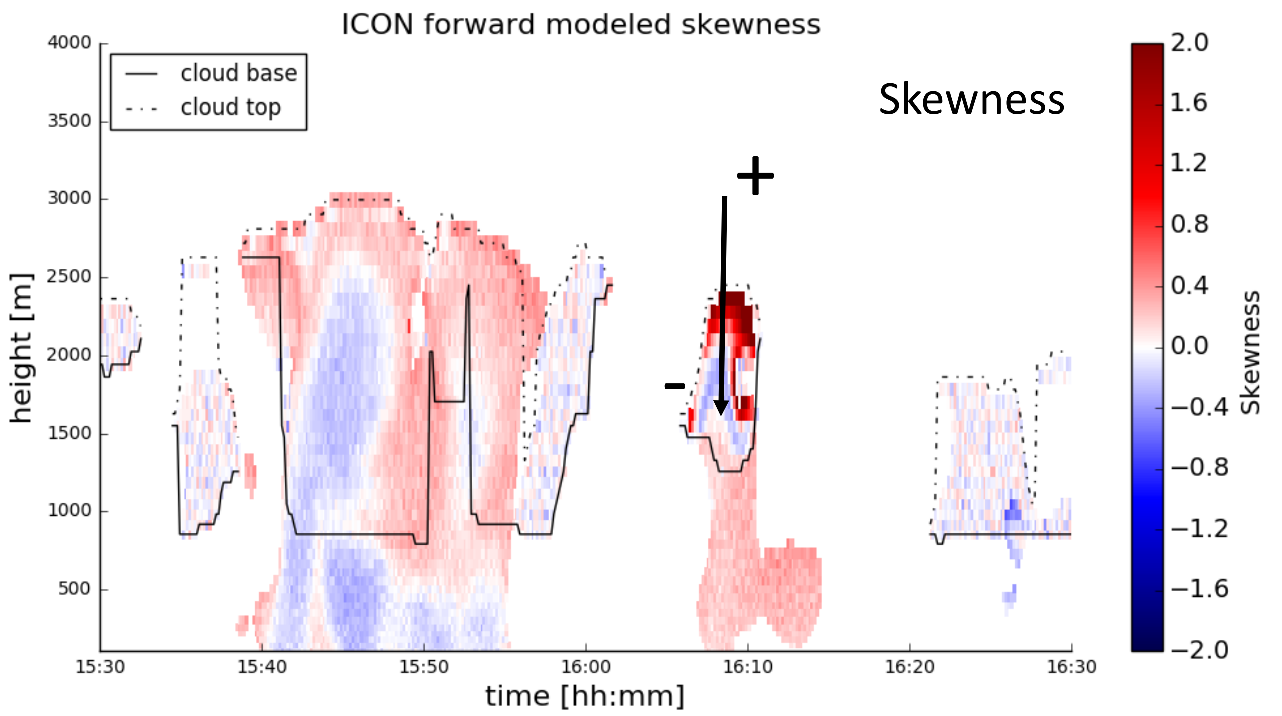

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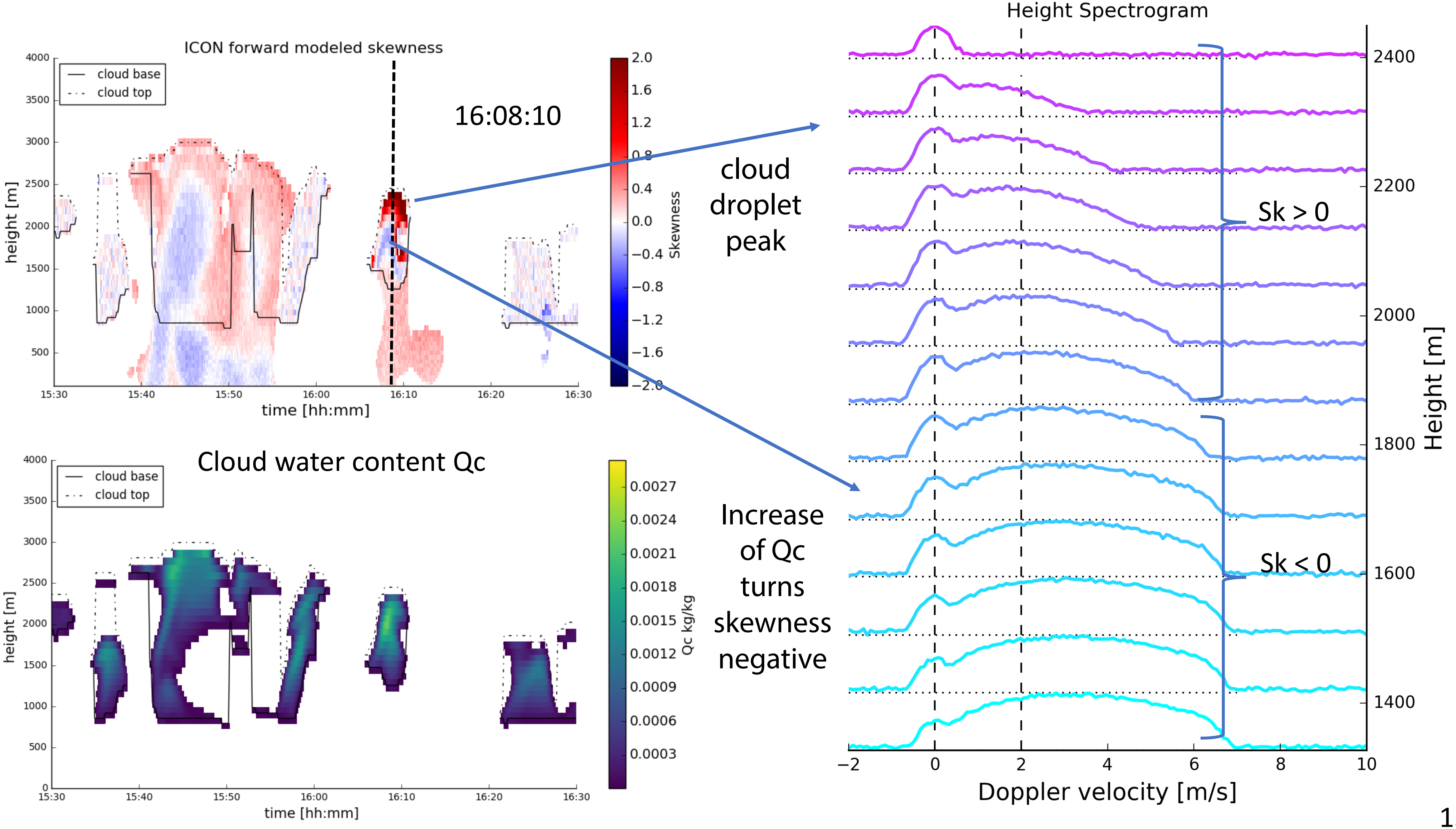
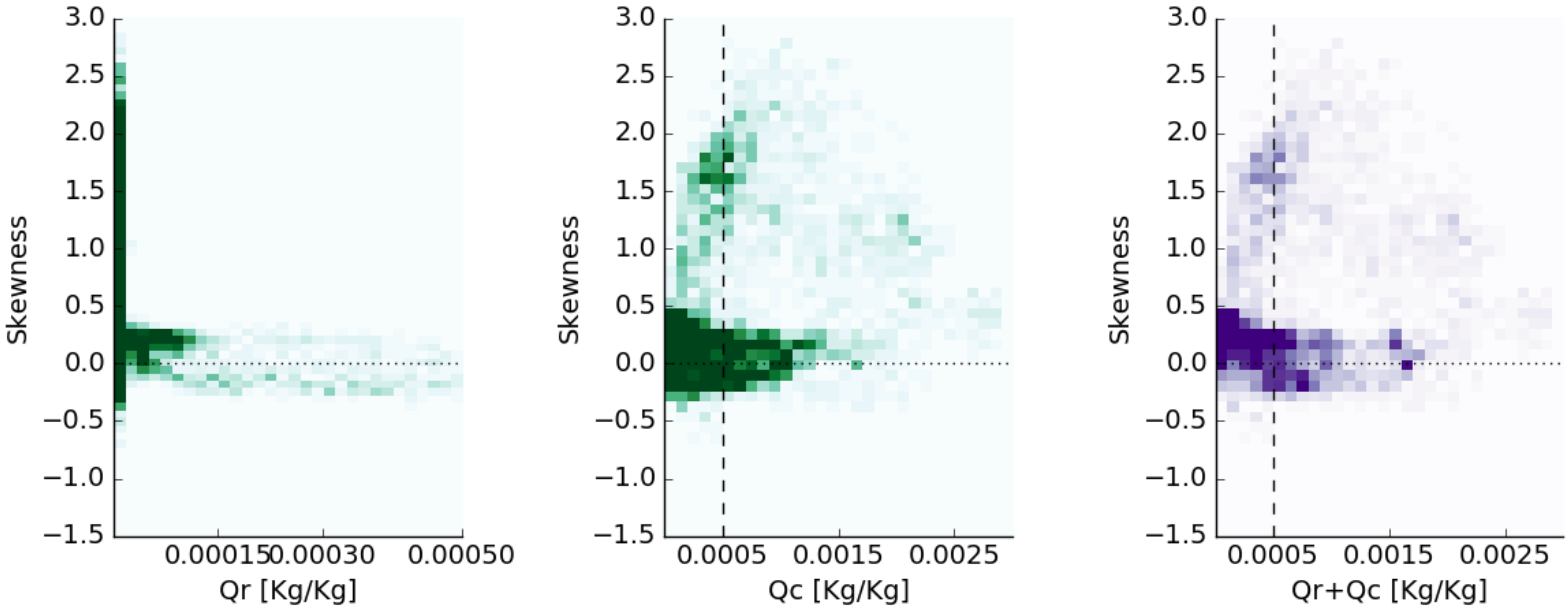


What controls the skewness signal in the model?

Qr = Rain water content Qc = Cloud water content



- Cloud water content controls the behaviour of Sk
- Rain water content contributes to turn skewness to negative values

Summary

<ins>How can we use skewness to detect drizzle in obs?</ins>

New **CLADS algorithm** (Acquistapace et al., 2019, JTECH) detects drizzle and classifies precipitation in cloud “better”

<ins>Can we use skewness to evaluate LES models?</ins>

in LES simulations, the signal in skewness is **very weak**, **but it’s there**

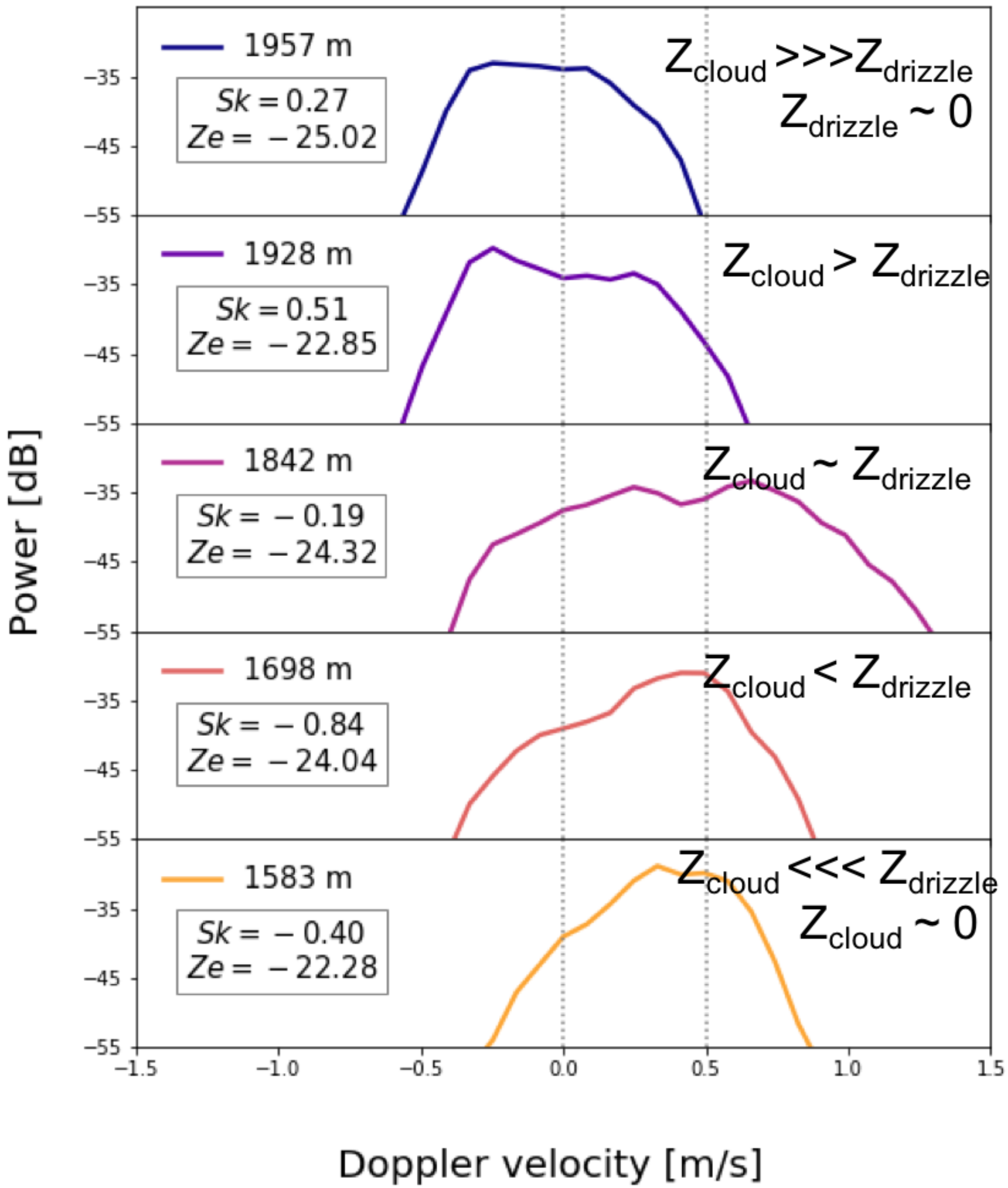
<ins>On what does the simulated skewness mainly depend?</ins>

Cloud water content (Q_c) mainly controls the behavior of skewness

for this case study: true in general?

Contact: cacquist@meteo.uni-koeln.de

Backup slides



1957 m
Sk = 0.27
Ze = −25.02
Zcloud >>>Zdrizzle
Zdrizzle ~ 0
1928 m
Sk = 0.51
Ze = −22.85
Zcloud > Zdrizzle
1842 m
Sk = −0.19
Ze = −24.32
Zcloud ~ Zdrizzle
1698 m
Sk = −0.84
Ze = −24.04
Zcloud < Zdrizzle
1583 m
Sk = −0.40
Ze = −22.28
Zcloud <<< Zdrizzle
Zcloud ~ 0
Power [dB]
Doppler velocity [m/s]

Example: skewness mask of the CLADS algorithm

purple boxes: pixels fullfilling the skewness criterion

Skewness bins > 0.3

0.13	0.002	-0.28	0.524	0.34
0.56	-0.12	0.89	0.78	1.43
0.2	0.14	0.33	-0.1	0.04
-0.24	0.22	0.67	0.23	0.001
-0.78	0.75	-0.2	0.98	-0.21

↓

grey boxes: pixels discarded.

Skewness bins > 0.3 with at least 3 neightbours larger > 0.3

0.13	0.002	-0.28	0.524	0.34
0.56	-0.12	0.89	0.78	1.43
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↓

green boxes: final selection of pixels from the mask.

Pixels selected by the mask

0.13	0.002	-0.28	0.524	0.34
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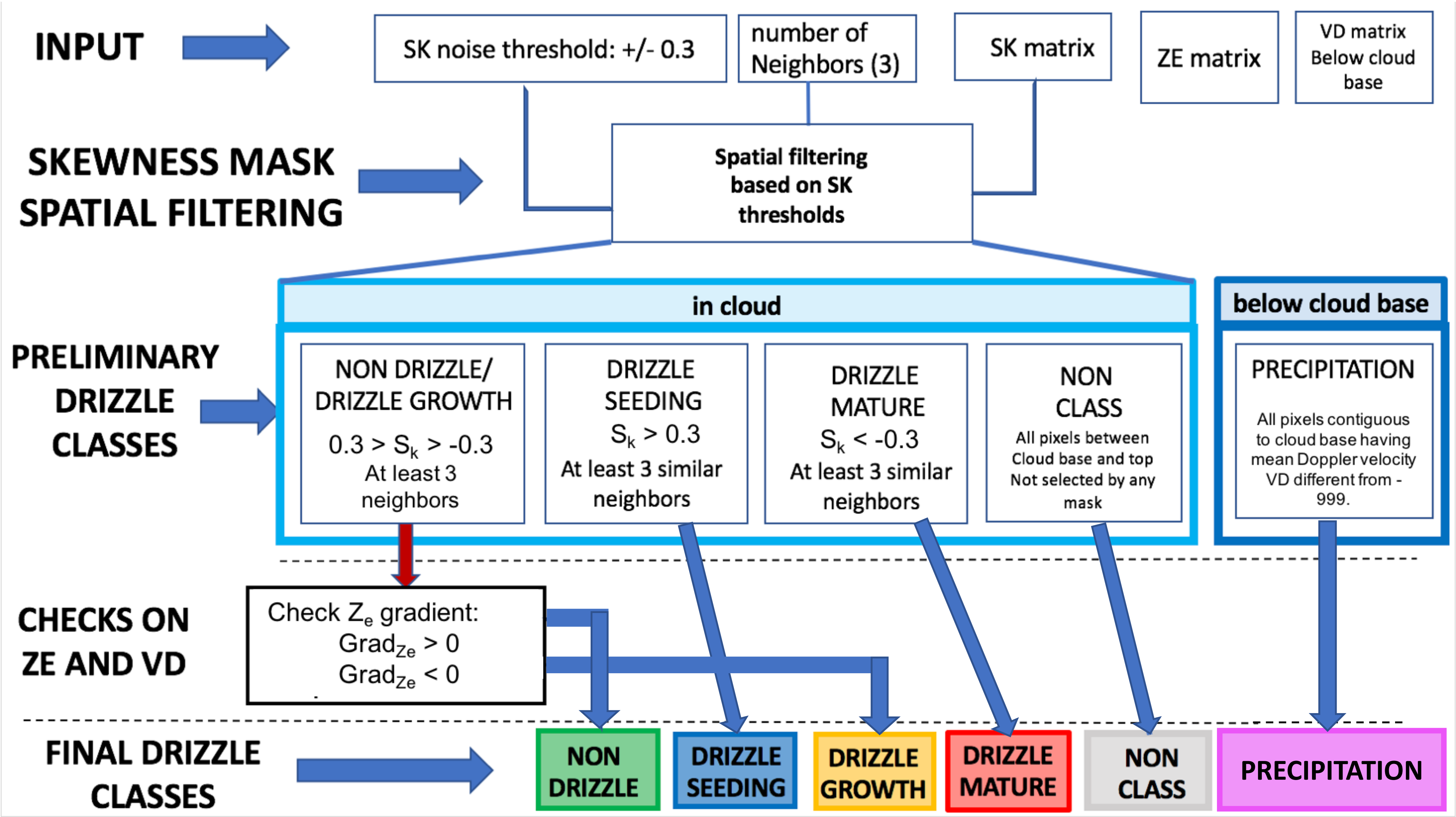
(From Acquistapace et al., 2018, JAS, under revision)

Flow chart of the algorithm for the CLAssification of the Drizzle Status (CLADS).



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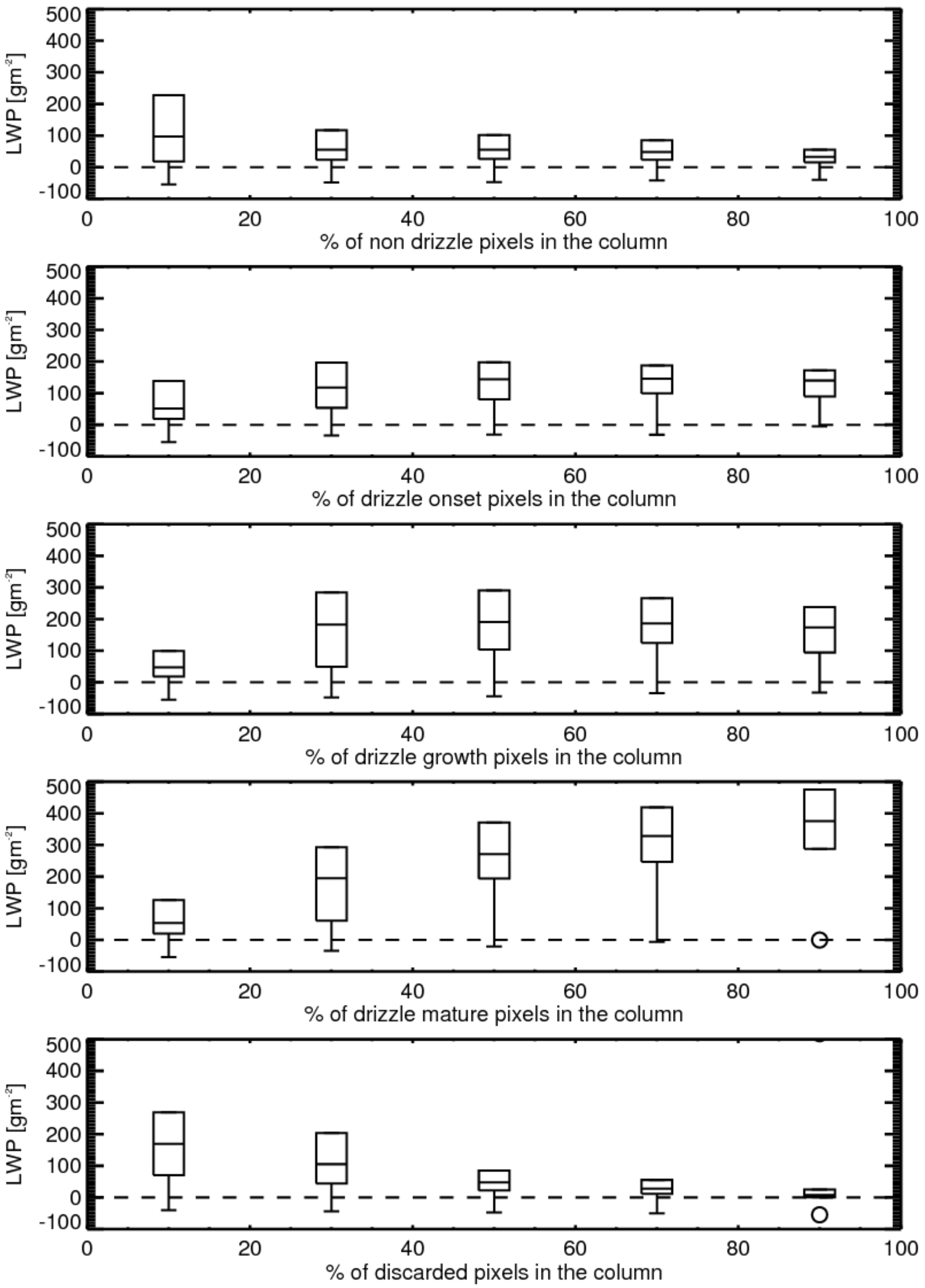
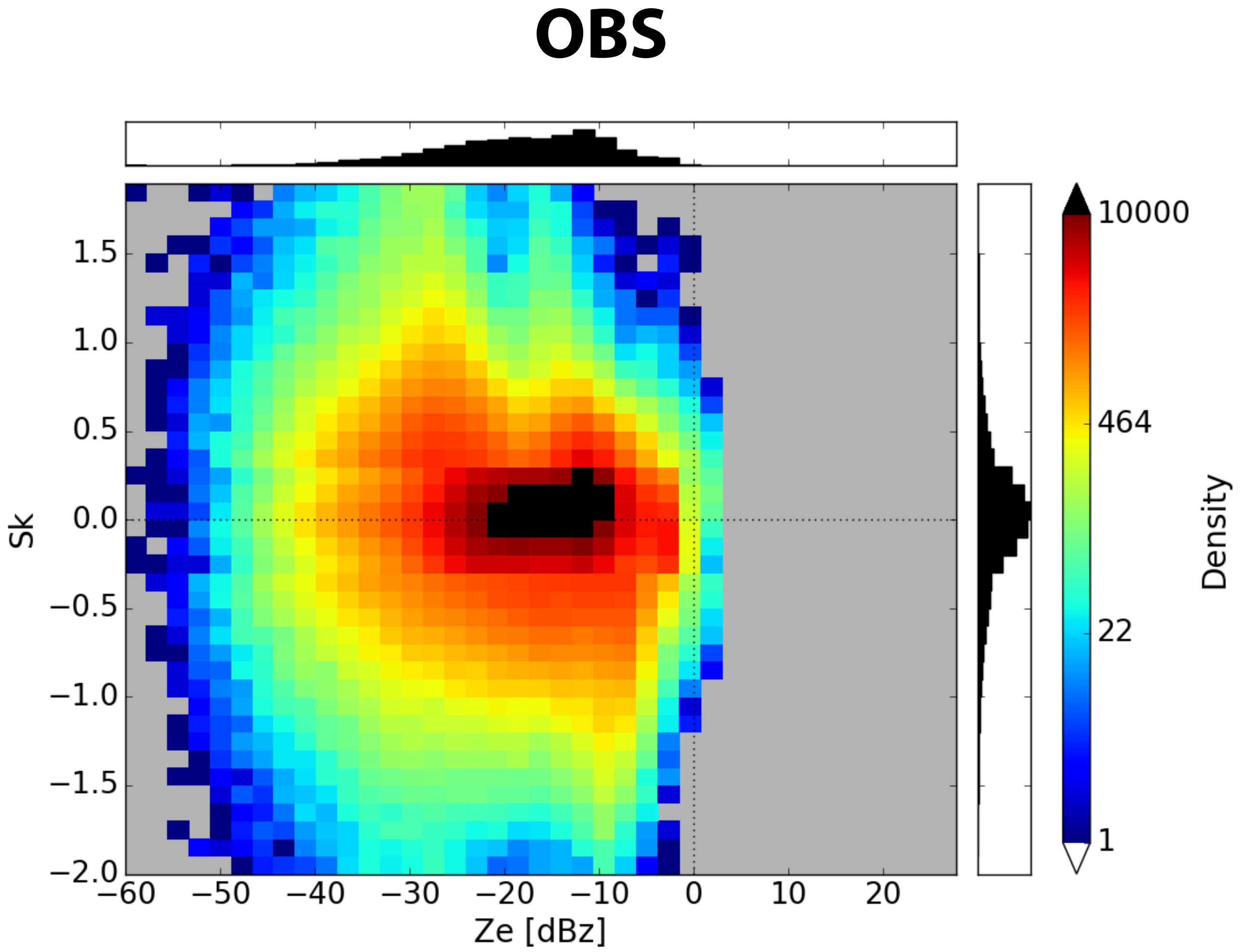
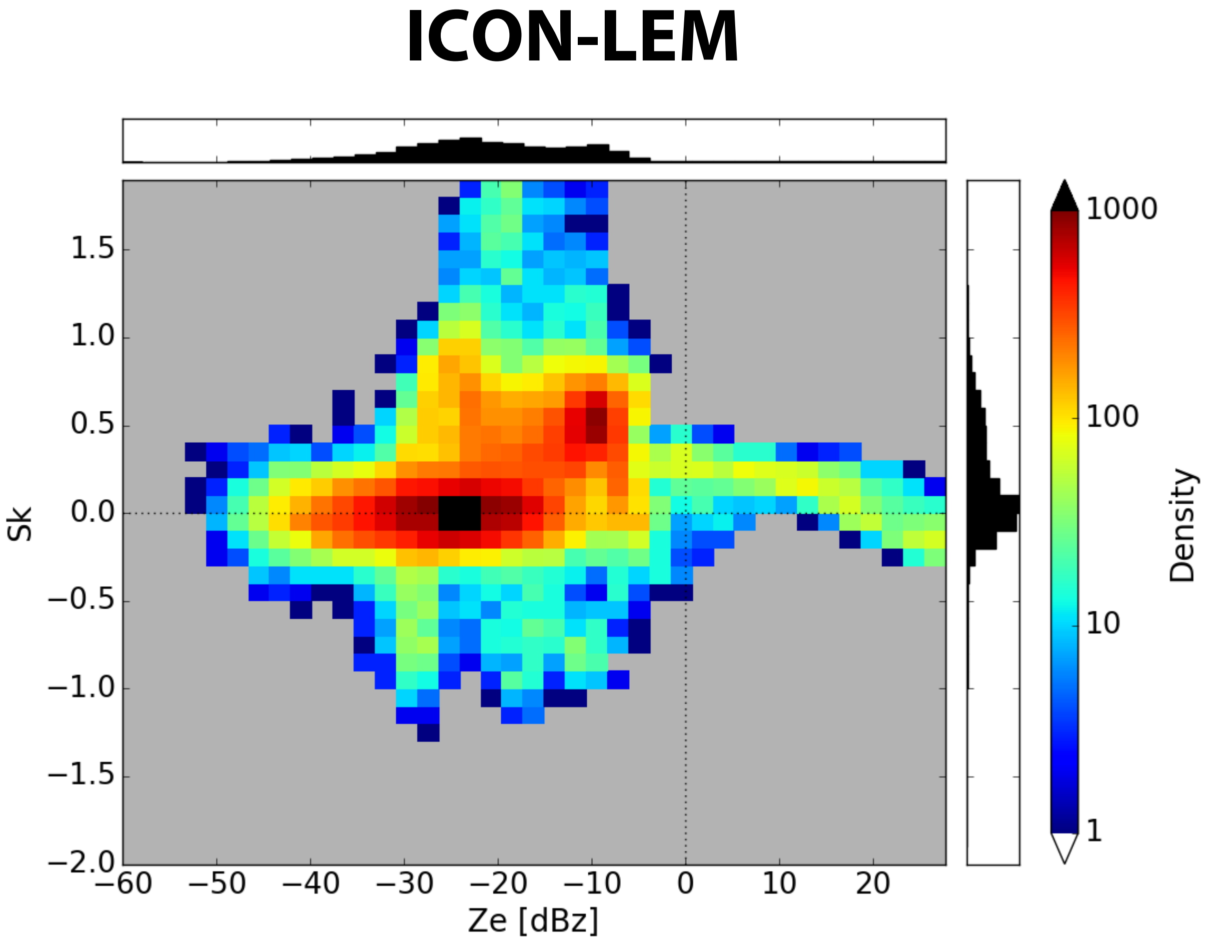
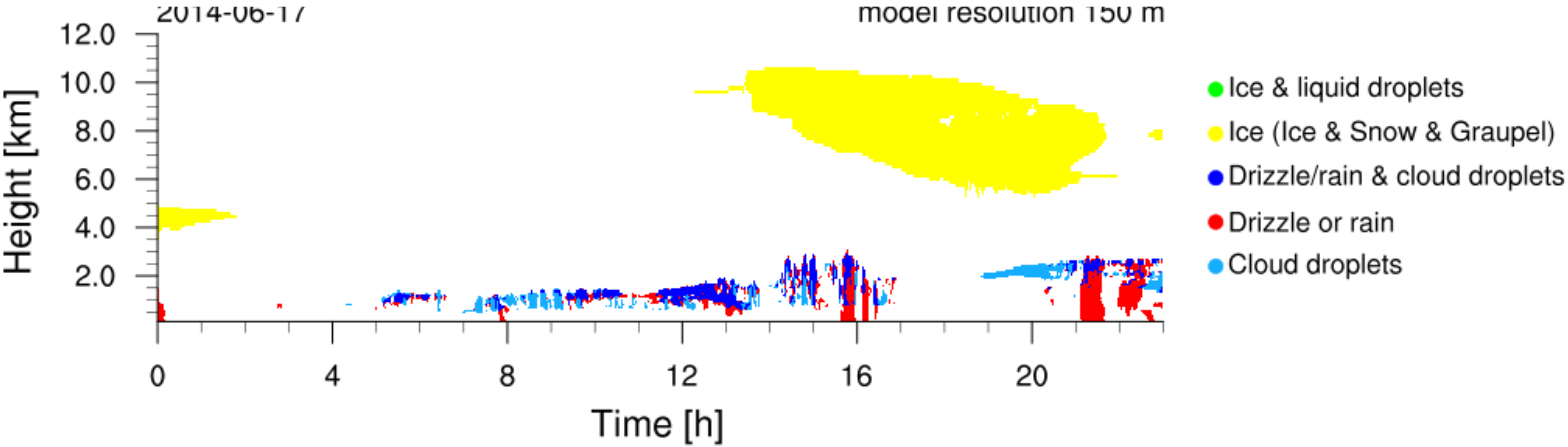

LWP [gm⁻²]
% of non drizzle pixels in the column
% of drizzle onset pixels in the column
% of drizzle growth pixels in the column
% of drizzle mature pixels in the column
% of discarded pixels in the column

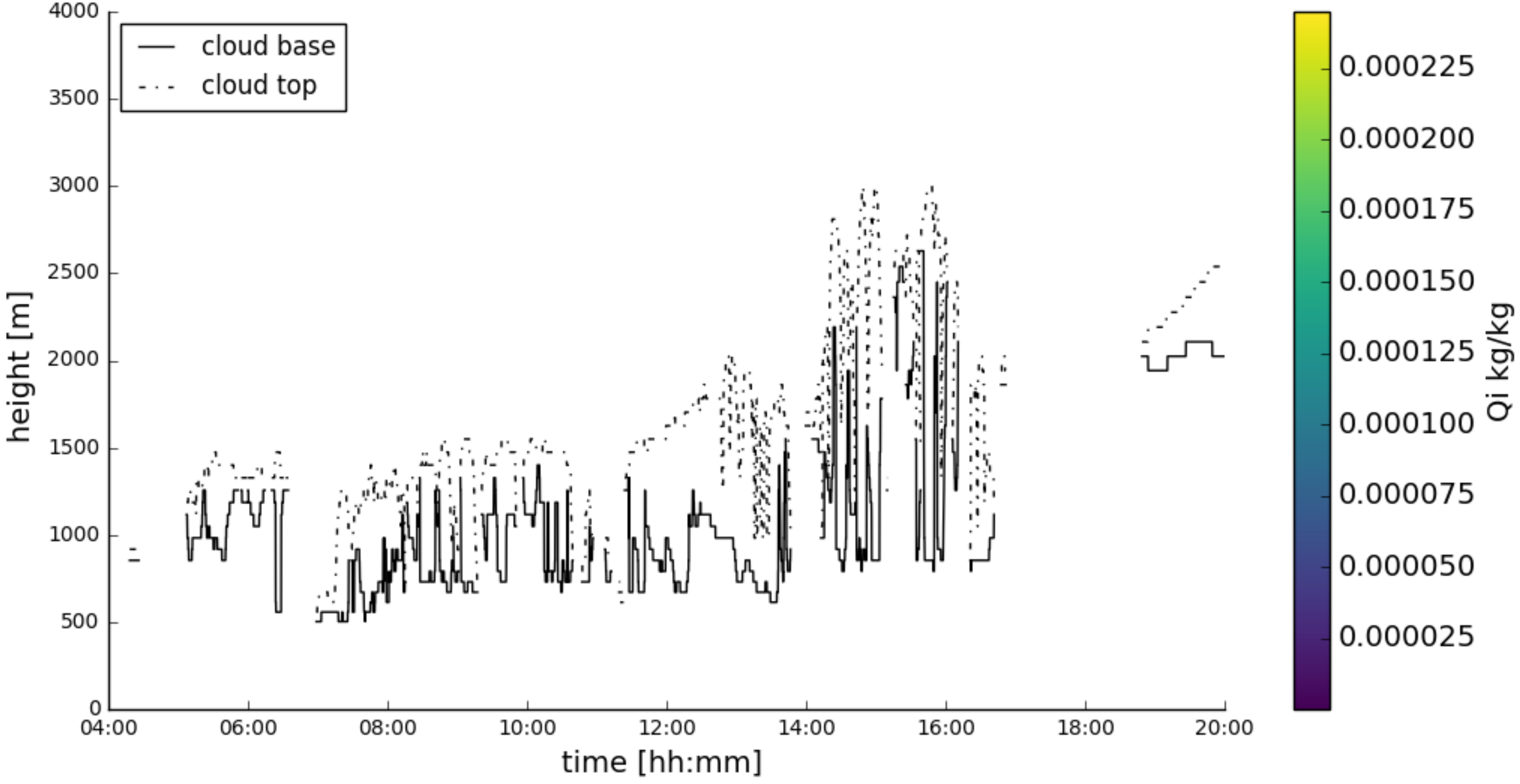
Skewness and reflectivity: range of the values in obs and model

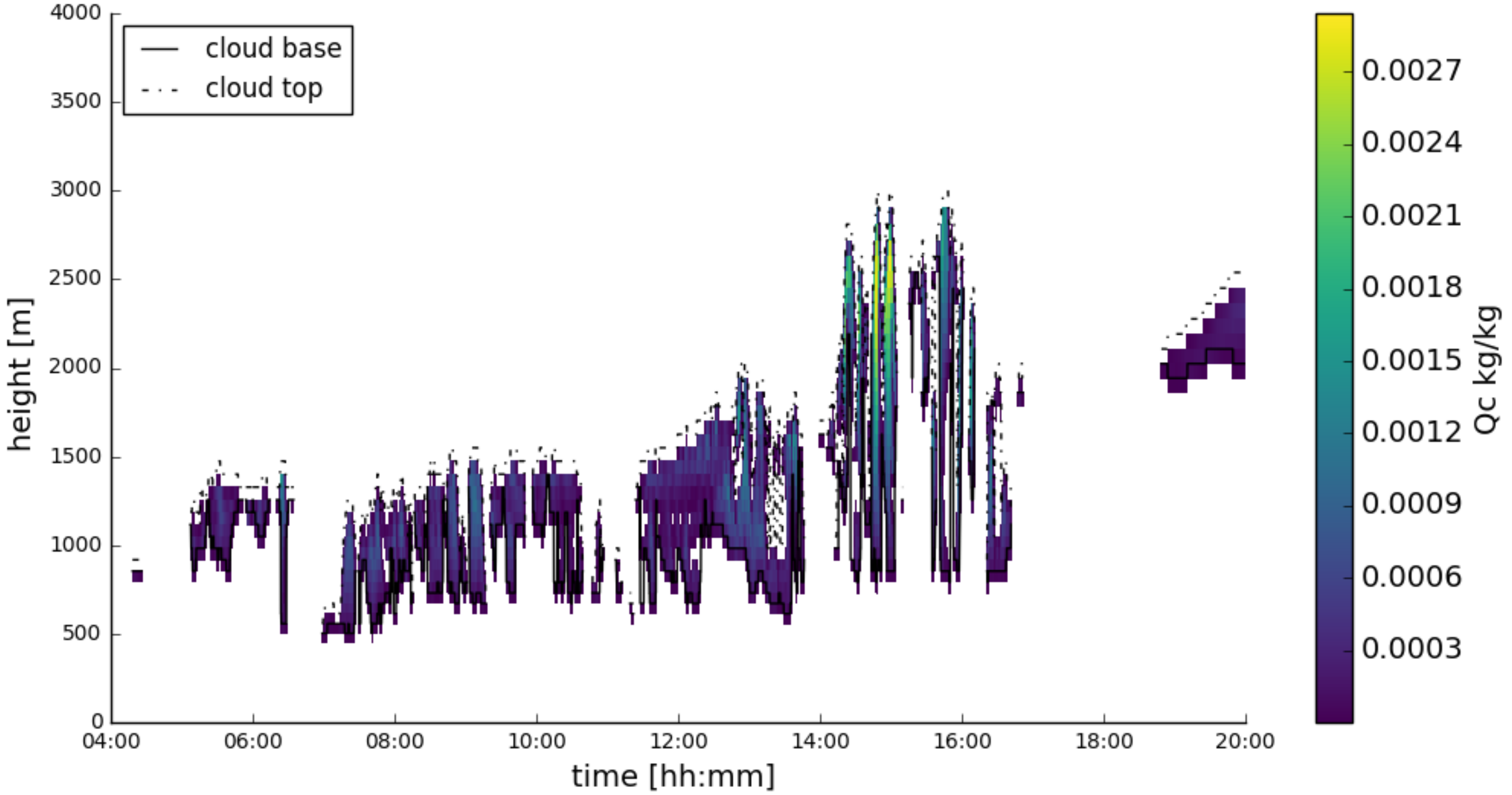




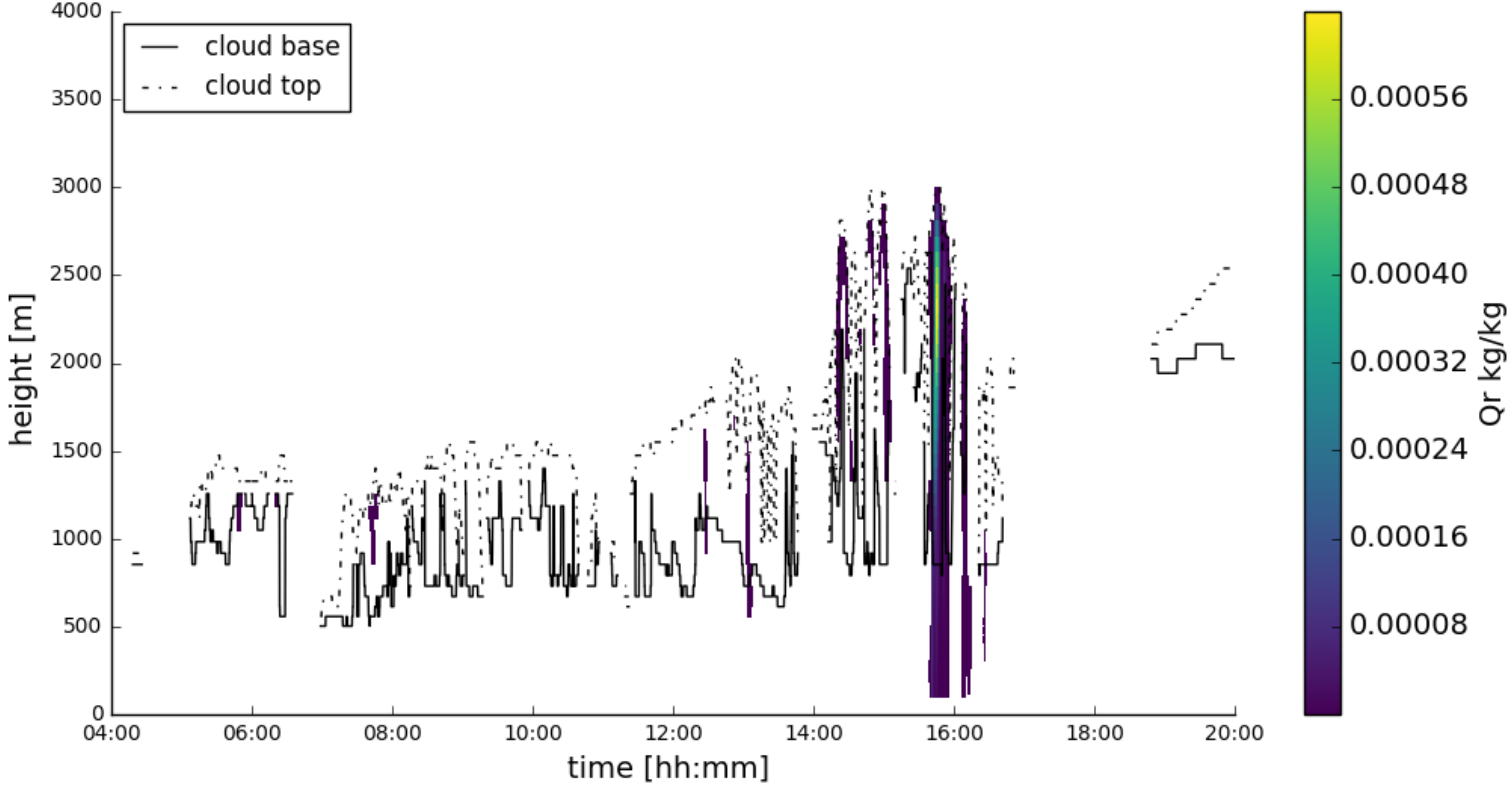
Case study of the 17th June 2014: obs vs ICON-LEM




cloud base
cloud top
height [m]
4000
3500
3000
2500
2000
1500
1000
500
0
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
time [hh:mm]
0.000225
0.000200
0.000175
0.000150
0.000125
0.000100
0.000075
0.000050
0.000025
Qi kg/kg

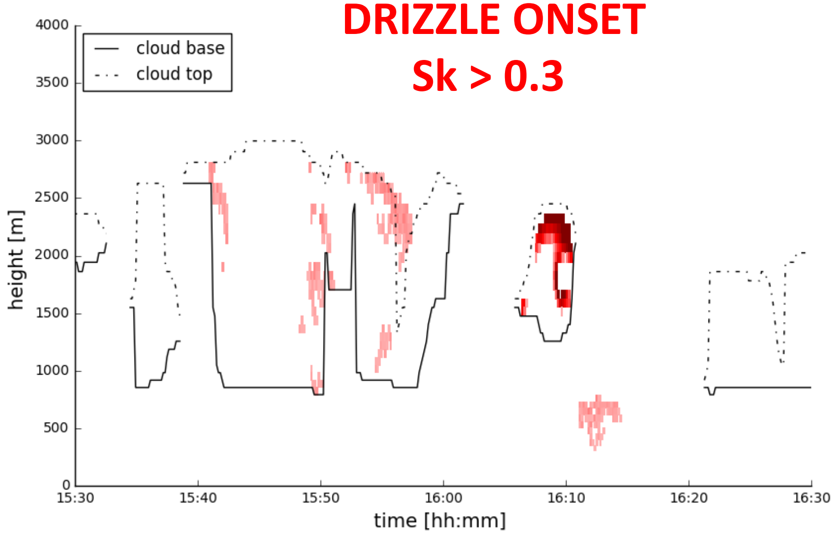


cloud base
cloud top
height [m]
4000
3500
3000
2500
2000
1500
1000
500
0
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
time [hh:mm]
0.0027
0.0024
0.0021
0.0018
0.0015
0.0012
0.0009
0.0006
0.0003
Qc kg/kg

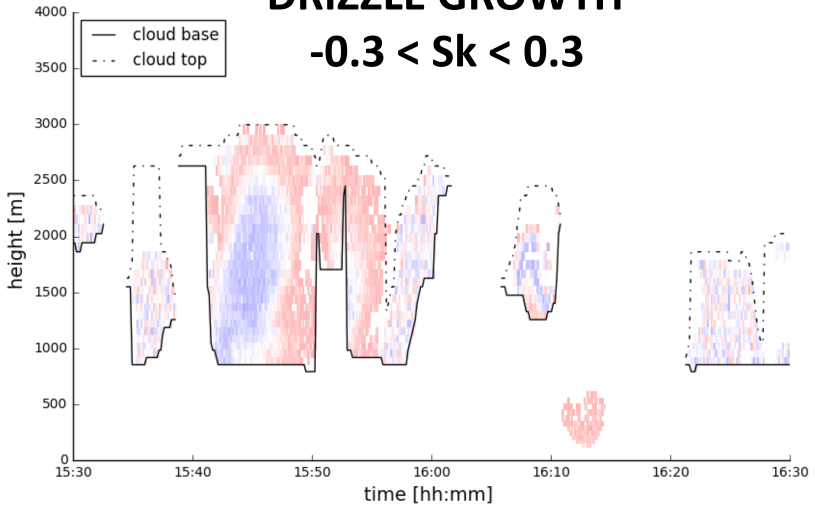

cloud base
cloud top
height [m]
4000
3500
3000
2500
2000
1500
1000
500
0
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
time [hh:mm]
0.00056
0.00048
0.00040
0.00032
0.00024
0.00016
0.00008
Qr kg/kg

CLADS applied to model data

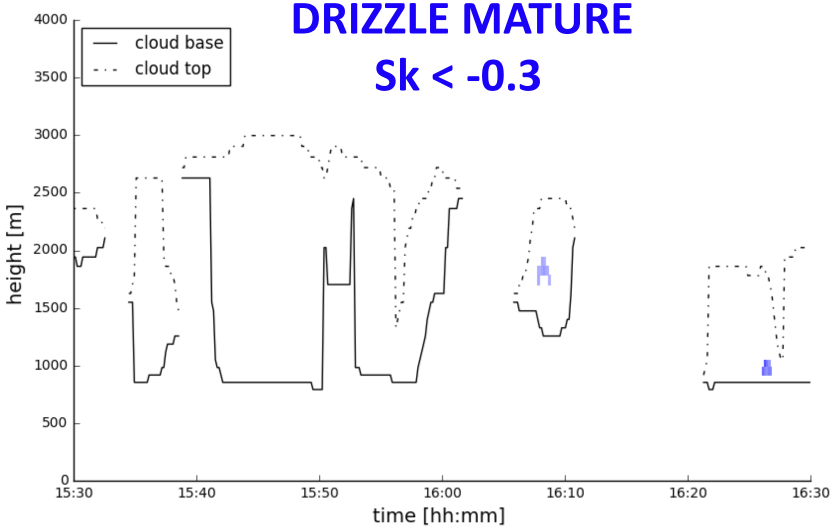
DRIZZLE ONSET
Sk > 0.3



DRIZZLE GROWTH
-0.3 < Sk < 0.3



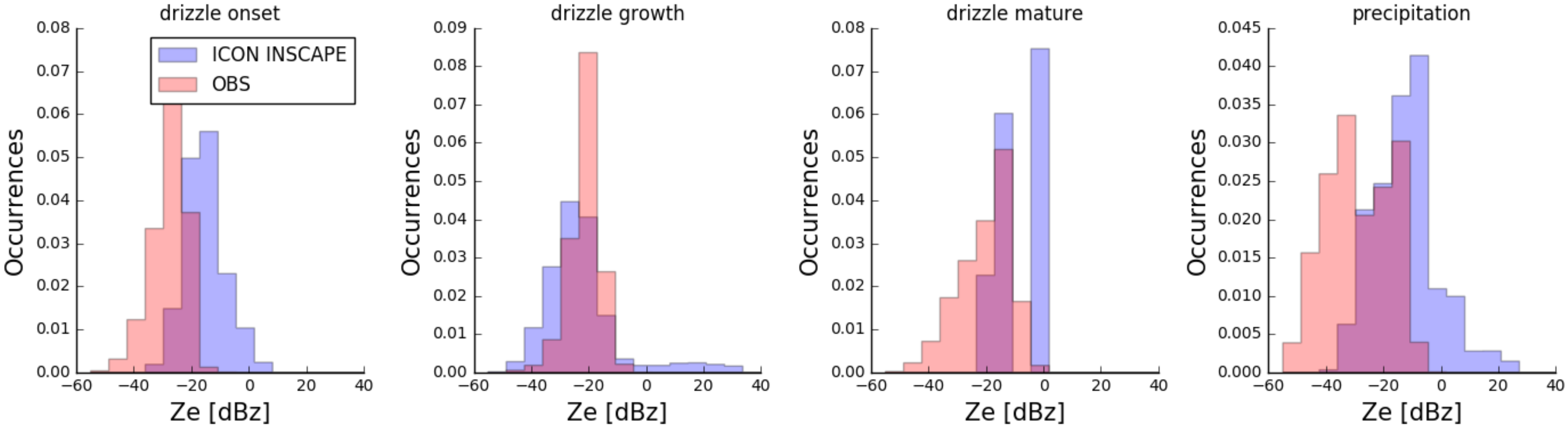
DRIZZLE MATURE
Sk < -0.3



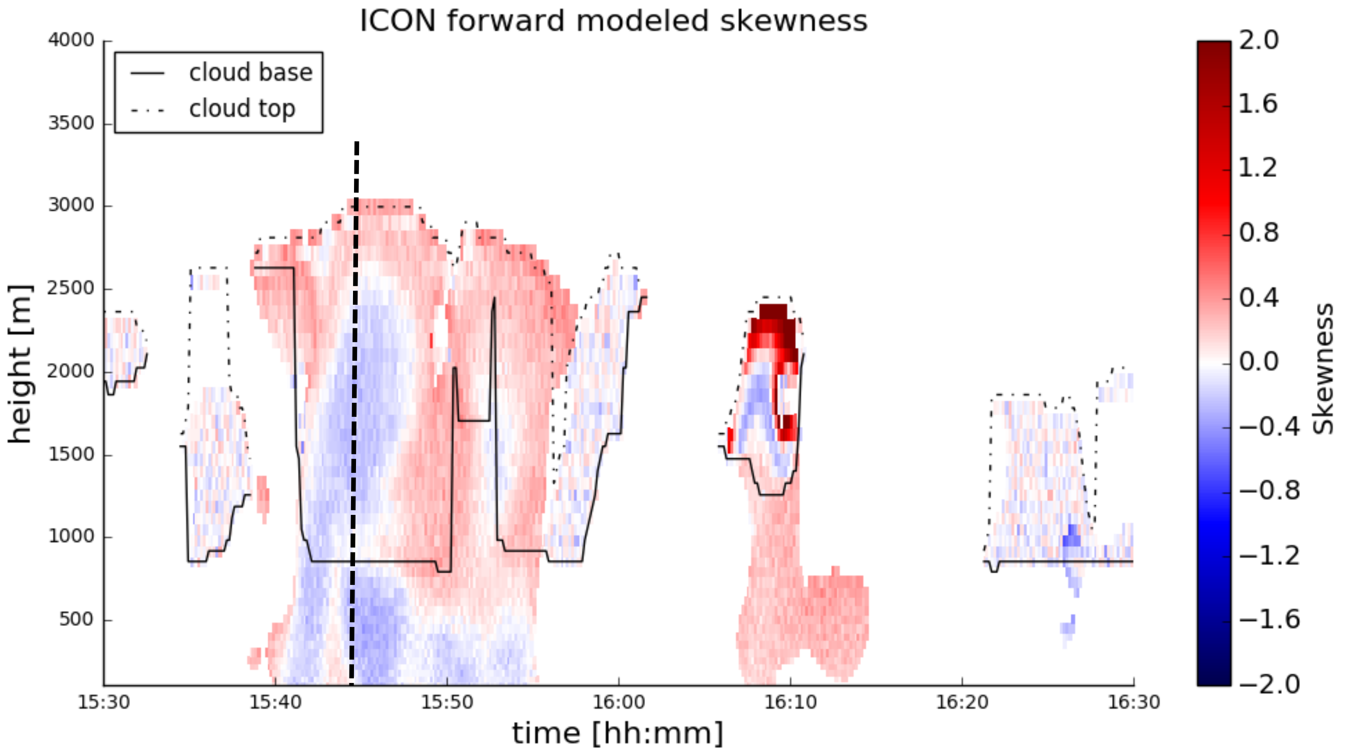
Raindrops growth →

In the skewness signal from the model, there is a transition from positive to negative values, but it is smaller than in the observations

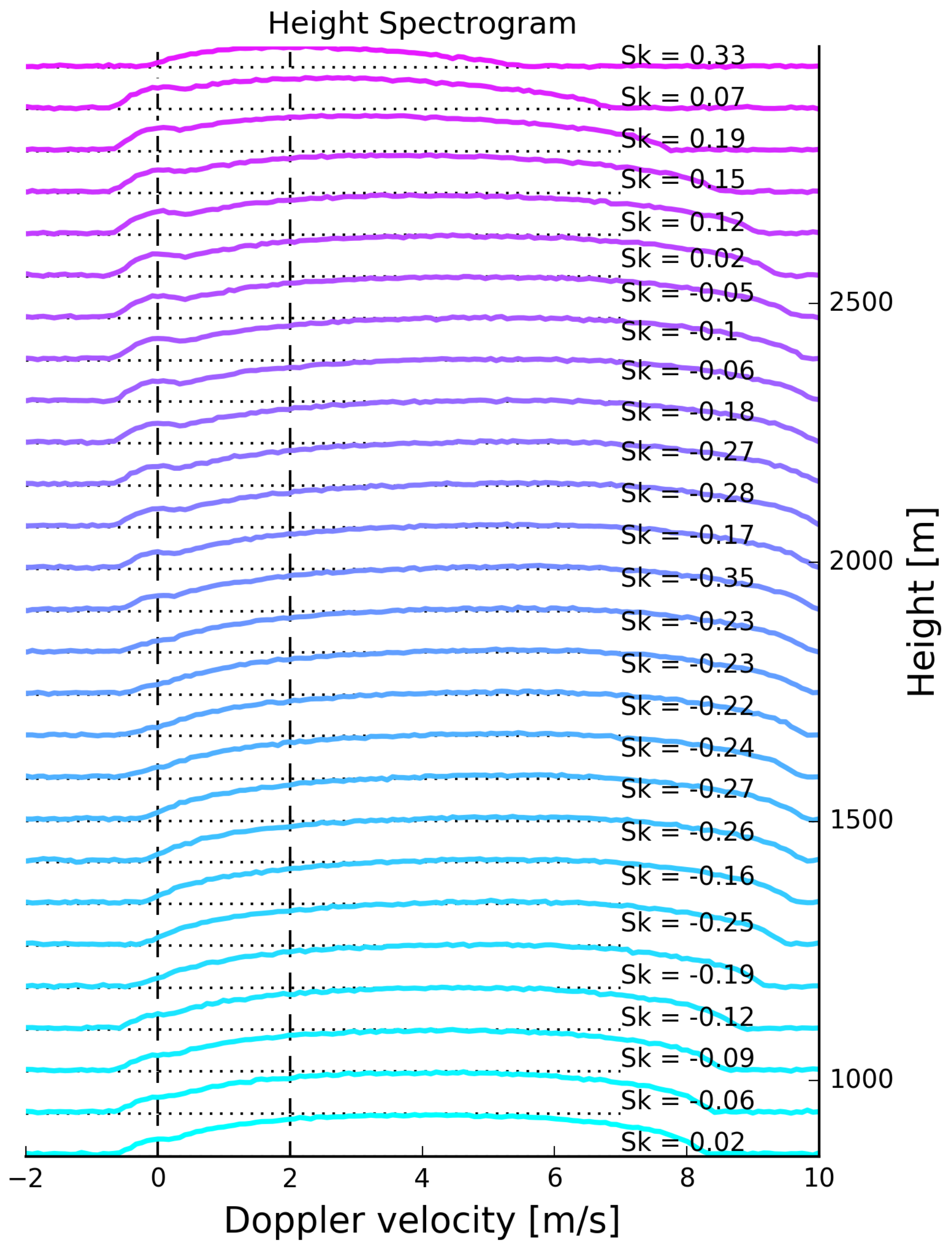
Comparing reflectivity distributions for each drizzle class



- Ze values in the observations are sistematically smaller than in the ICON-LEM

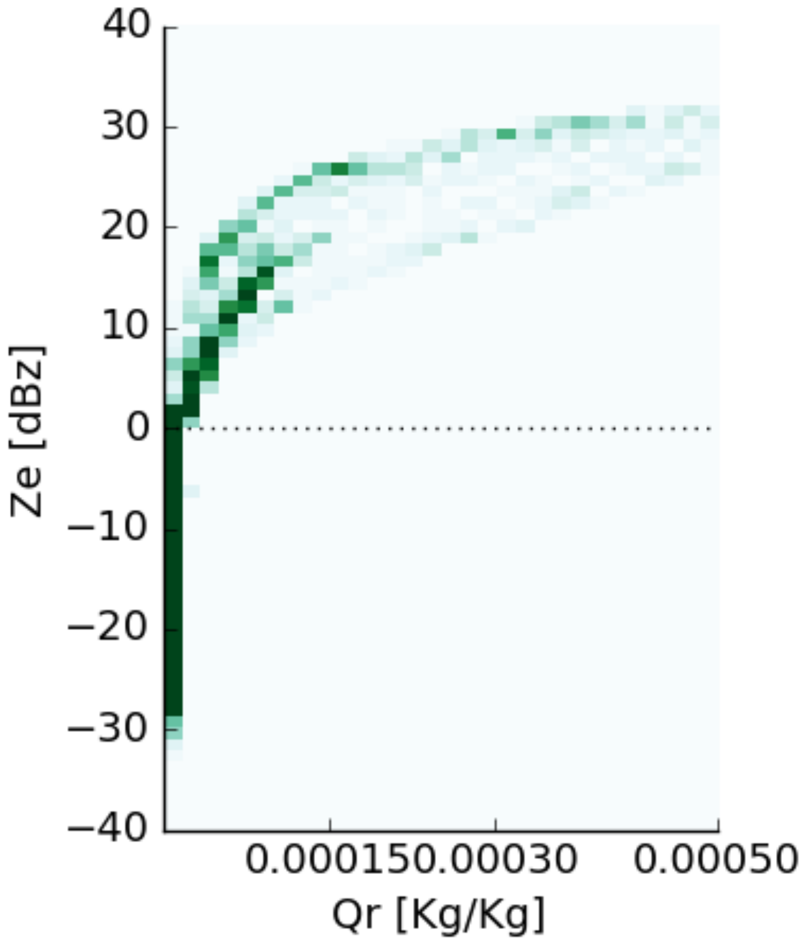


ICON forward modeled skewness
cloud base
cloud top
height [m]
time [hh:mm]
Skewness



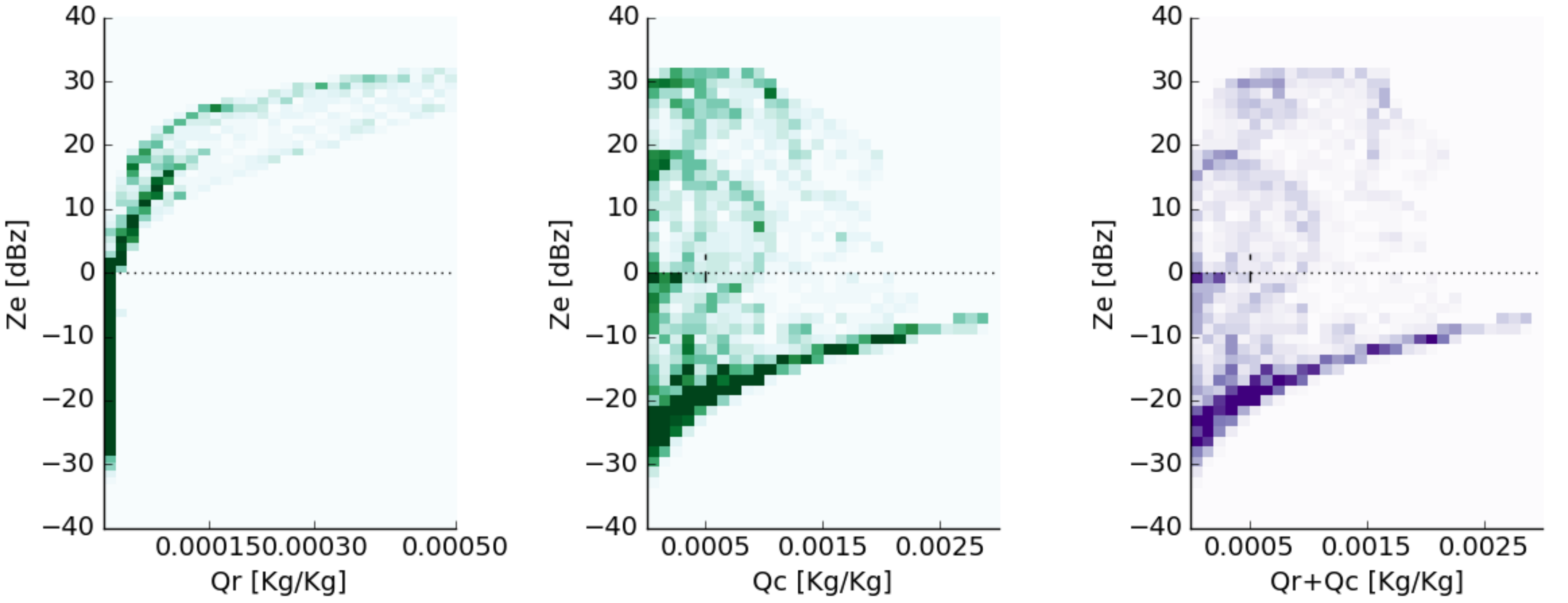
Height Spectrogram
Sk = 0.33
Sk = 0.07
Sk = 0.19
Sk = 0.15
Sk = 0.12
Sk = 0.02
Sk = -0.05
Sk = -0.1
Sk = -0.06
Sk = -0.18
Sk = -0.27
Sk = -0.28
Sk = -0.17
Sk = -0.35
Sk = -0.23
Sk = -0.23
Sk = -0.22
Sk = -0.24
Sk = -0.27
Sk = -0.26
Sk = -0.16
Sk = -0.25
Sk = -0.19
Sk = -0.12
Sk = -0.09
Sk = -0.06
Sk = 0.02
Height [m]
Doppler velocity [m/s]

What controls the skewness signal in the model?



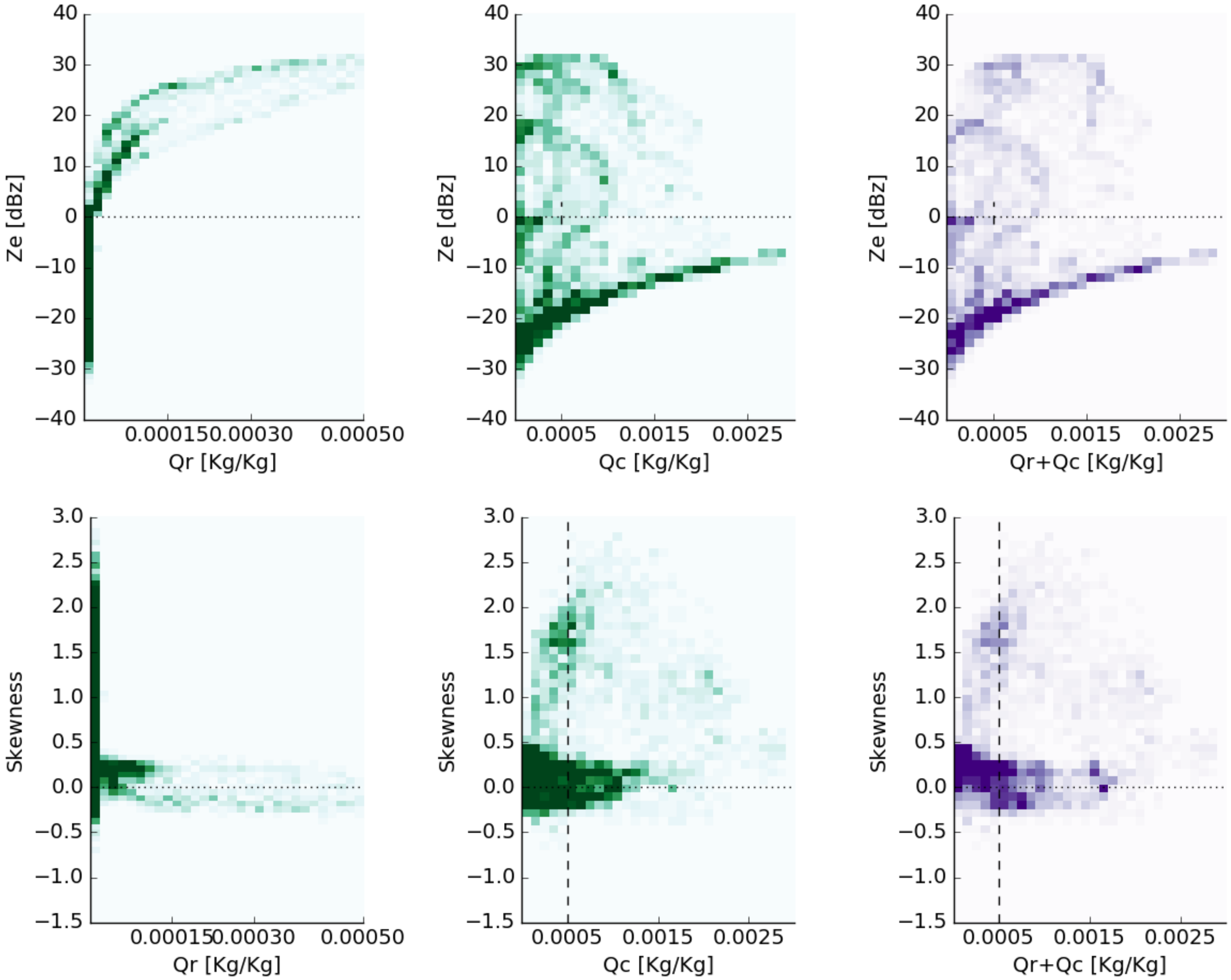
- Rain content (Qr) does not modify Ze for values of Ze < 0 dBz.
- Cloud content controls the behaviour of Ze for values of Ze between -30 and 0 dBz.

What controls the skewness signal in the model?



- Rain content (Qr) does not modify Ze for values of Ze < 0 dBz.
- Cloud content controls the behaviour of Ze for values of Ze between -30 and 0 dBz.

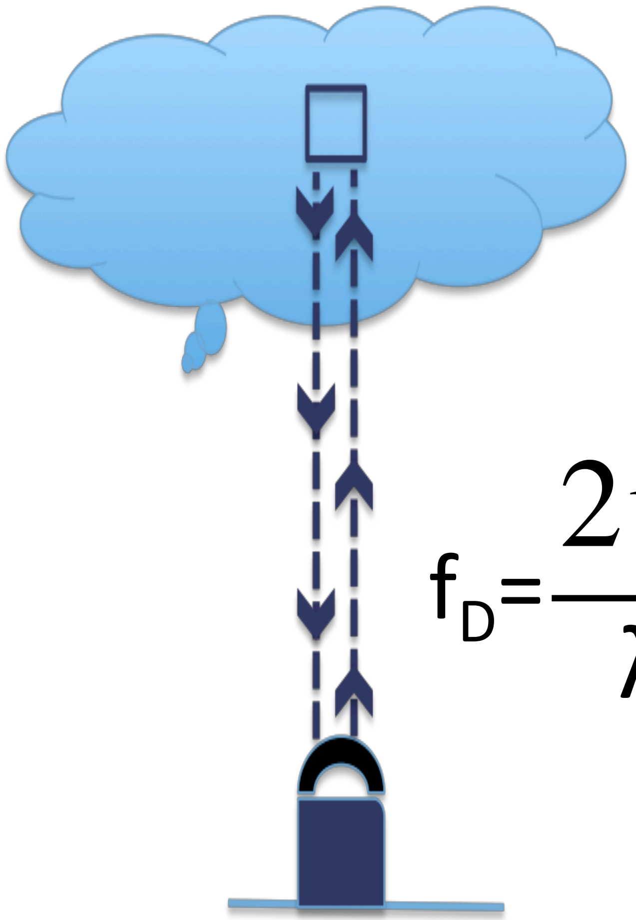
What controls the skewness signal in the model?



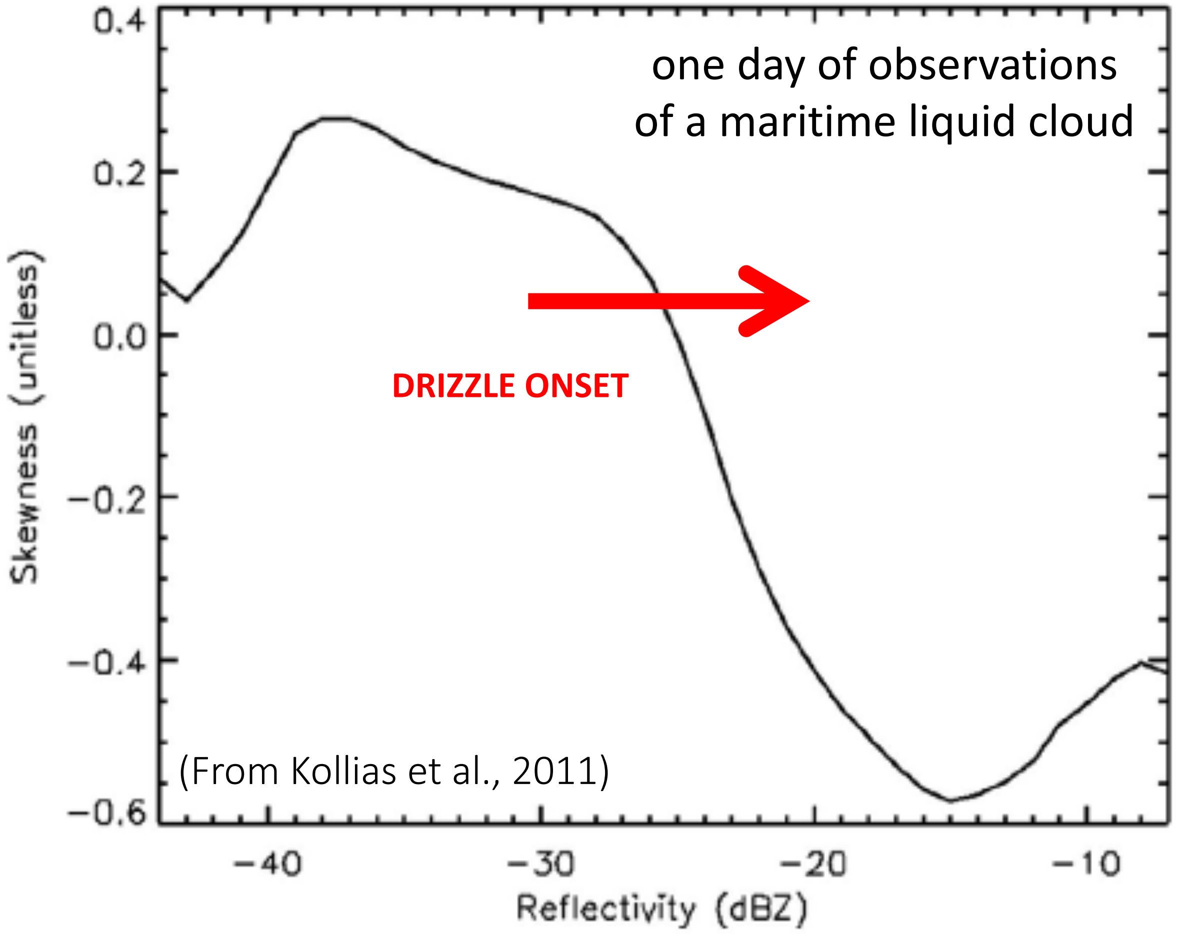
- Rain content (Qr) does not modify Ze for values of Ze < 0 dBz.
- Cloud content controls the behaviour of Ze for values of Ze between -30 and 0 dBz.
- Cloud content controls the behaviour of Sk
- The contribution of Qr in determining the skewness behavior is negligible.

How to improve the detection?

➔ *cloud radar Doppler (velocity) spectrum and skewness*



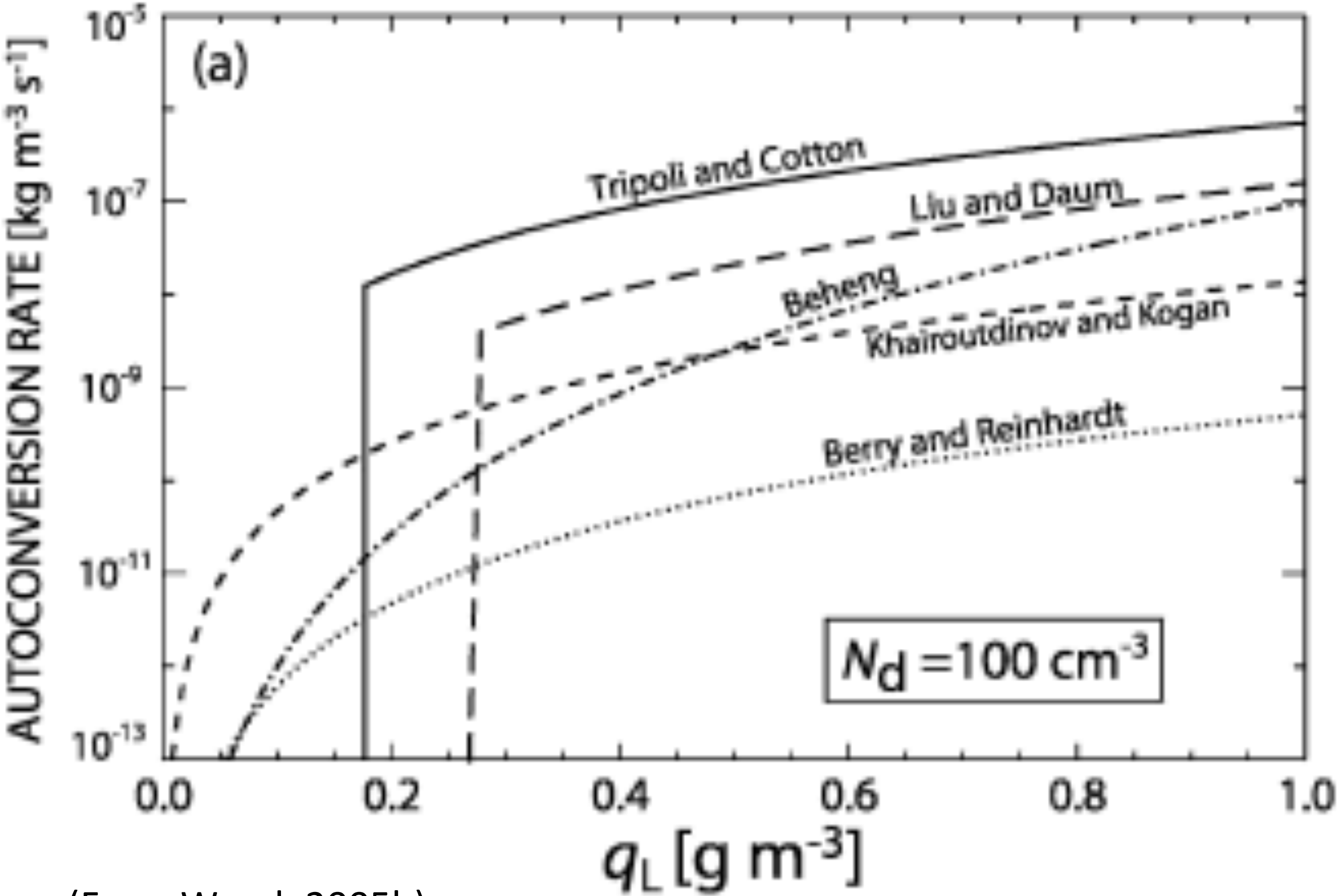
$$f_D = \frac{2v_z}{\lambda}$$



<u>skewness (SK)</u> : measures the degree of asymmetry of a given distribution

Why do we care of drizzle?

Drizzle is overestimated in global climate models (Stephens, 2010; Ahlgrimm, 2013)



q_L: liquid water content

(From Wood, 2005b)