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

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

-15 dBz

-20 dBz

-17 dBz
What is the reflectivity threshold to detect precipitation from ground-based radars?

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

-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

\[ f_D = \frac{2v_z}{\lambda} \]

Cloud droplets

Doppler velocity [ms\(^{-1}\)]

Power [dB]
How to improve the detection?

- cloud radar Doppler (velocity) spectrum and skewness

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Cloud droplets

Drizzle

Doppler velocity \([\text{ms}^{-1}]\)

Power \([\text{dB}]\)
How to improve the detection?

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

\[ f_D = \frac{2v_z}{\lambda} \]

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

**Cloud droplets**

**Drizzle**

\[ SK > 0 \]
How to improve the detection?

- cloud radar Doppler (velocity) spectrum and skewness

\[ f_D = \frac{2v_z}{\lambda} \]

- Skewness turns negative when drizzle dominates the Doppler spectrum
How can we use skewness to detect drizzle in obs?
As $Ze$ increases, skewness changes sign, indicating growth of raindrops.
Principle of CLAssification of Drizzle Status Algorithm (CLADS)

(ACquistapace et al., 2019, JTECH)
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
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Simulated spectra and moments profiles

(rel distance from cloud top)
(diameter of the drop [µm])

PAMTRA

(credits for the bunny drawing: Dr. Pfitzenmaier)
Case study of the 17th June 2014: obs vs ICON-LEM
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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.
Is there a transition in the skewness in the model due to rain?

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

**Cloud water content Qc**
- Increase of Qc turns skewness negative
- Sk < 0

**ICON forward modeled skewness**
- Cloud droplet peak
- Sk > 0

**Height Spectrogram**
- 16:08:10
What controls the skewness signal in the model?

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

How can we use skewness to detect drizzle in obs?

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

Can we use skewness to evaluate LES models?

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

On what does the simulated skewness mainly depend?

**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
**Example: skewness mask of the CLADS algorithm**

**purple boxes**: pixels fullfilling the skewness criterion

**grey boxes**: pixels discarded.

**green boxes**: final selection of pixels from the mask.

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**Skewness bins > 0.3**

<table>
<thead>
<tr>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
<th>Value 5</th>
</tr>
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<tbody>
<tr>
<td>0.13</td>
<td>0.002</td>
<td>-0.28</td>
<td>0.524</td>
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</tr>
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**Skewness bins > 0.3 with at least 3 neighbours larger > 0.3**

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**Pixels selected by the mask**

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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).

INPUT
- SK noise threshold: +/- 0.3
- number of Neighbors (3)
- SK matrix
- ZE matrix
- VD matrix Below cloud base

SKEWNESS MASK

SPATIAL FILTERING

PRELIMINARY

DRIZZLE

CLASSES

NON DRIZZLE/ DRIZZLE GROWTH
0.3 > S_k > -0.3
At least 3 neighbors

DRIZZLE SEEDING
S_k > 0.3
At least 3 similar neighbors

DRIZZLE MATURE
S_k < -0.3
At least 3 similar neighbors

NON CLASS
All pixels between cloud base and top
Not selected by any mask

below cloud base

checks on
ZE and VD

Check Z_e gradient:
Grad_{Z_e} > 0
Grad_{Z_e} < 0

FINAL DRIZZLE

CLASSES

NON DRIZZLE
DRIZZLE SEEDING
DRIZZLE GROWTH
DRIZZLE MATURE
NON CLASS
PRECIPITATION

(From Acquistapace et al., 2018, JAS, under revision)
Skewness and reflectivity: range of the values in obs and model

**OBS**

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

Model resolution 150 m

- Green: Ice & liquid droplets
- Yellow: Ice (Ice & Snow & Graupel)
- Blue: Drizzle/rain & cloud droplets
- Red: Drizzle or rain
- Cyan: Cloud droplets

Time [h]

Height [km]
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 systematically smaller than in the ICON-LEM
Rain content ($Q_r$) 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 ($Q_r$) 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 $Q_r$ in determining the skewness behavior is negligible.
How to improve the detection?

\[ f_D = \frac{2v_z}{\lambda} \]

cloud radar Doppler (velocity) spectrum and skewness

one day of observations of a maritime liquid cloud

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

(From Kollias et al., 2011)
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)