Hands-on

Doppler spectra analyis with peako peakTree

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SPP 2115

image generated using stable diffusion

PEAKO and peakTree: toolkit for detecting and interpreting peaks in cloud radar Doppler spectra

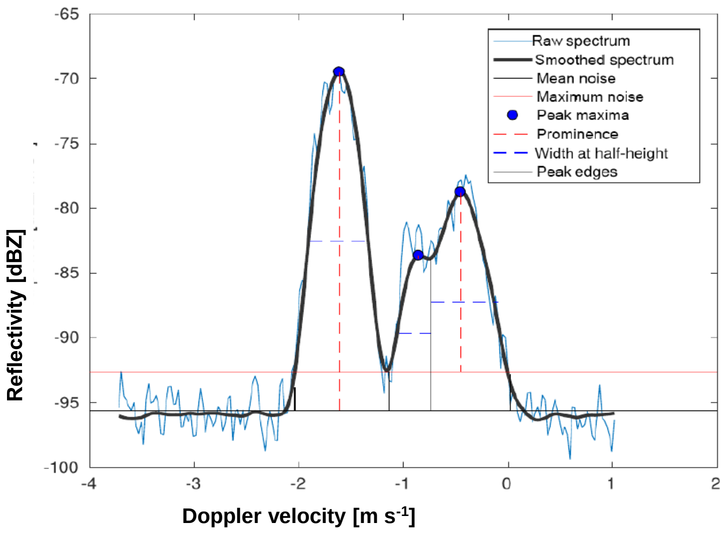
1. **Peak identification (or peak finding)** — PEAKO
   Locate the boundaries of a (sub)peak
2. **Peak structuring** — peakTree
   Identify the arrangement of the (sub)peaks
3. **Peak interpretation**
   Categorize and interpret the peaks

PEAKO overview

PEAKO is a supervised radar Doppler spectrum peak finding algorithm. It finds the optimal parameters <u>for detecting peaks</u> in cloud radar Doppler spectra based on user-generated training data.

<u>PEAKO is used to:</u>

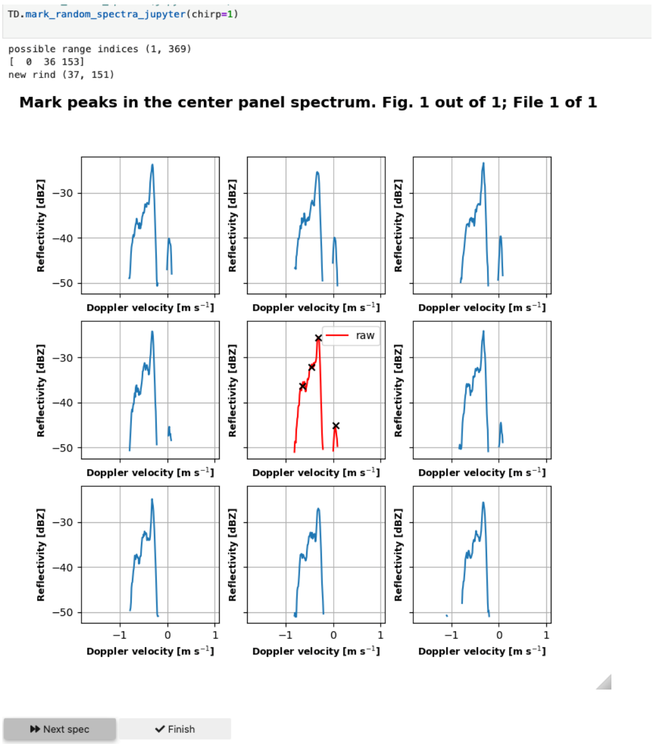
- create labeled data (peaks marked by a user in cloud radar Doppler spectra), which are used for training and testing the learned function
- train the algorithm using the labeled data to obtain the optimal parameter combination for peak detection
- test the performance of the learned function
- detect peaks in cloud radar Doppler spectra using the learned function for new data sets



PEAKO: creating training data

- GUI prompts you to mark peaks in a cloud radar Doppler spectrum
- neighboring spectra in time/ range are displayed around the center panel
- new: (for this workshop) version compatible with jupyter lab

- Be picky!
- skip marking spectra that have Doppler folding or ghost echoes/ other artifacts



PEAKO: training

Calculation of a similarity measure: Determine maximum overlapping area of peaks marked by user ★ and detected by algorithm ● for a certain parameter combination.

- → **determine area under each peak**
- → **“peak edge“: saddle point between merged peaks or Doppler bin, where spectrum power < max. noise floor**
- → **sum up matching peak areas, subtract deviating peak areas**

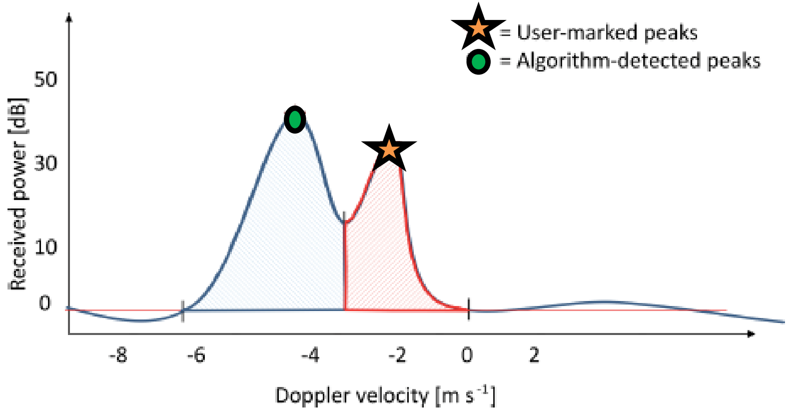


Figure 3. Schematic to visualize how the similarity measure to compare user-marked and algorithm-found peaks in Doppler spectra: areas of matching peaks are summed up (blue hatched area), and the areas of mismatched peaks (red hatched) are subtracted.

Fig. adapted from Kalesse et al., 2019

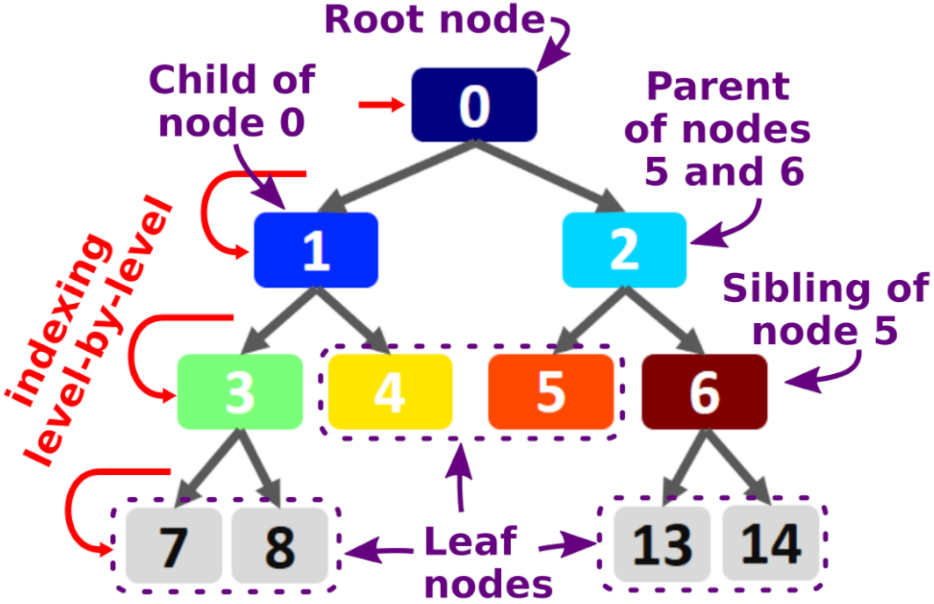
PEAKO result

- netcdf file with all parameter combinations and similarity
- result.txt with the three „best“ combinations

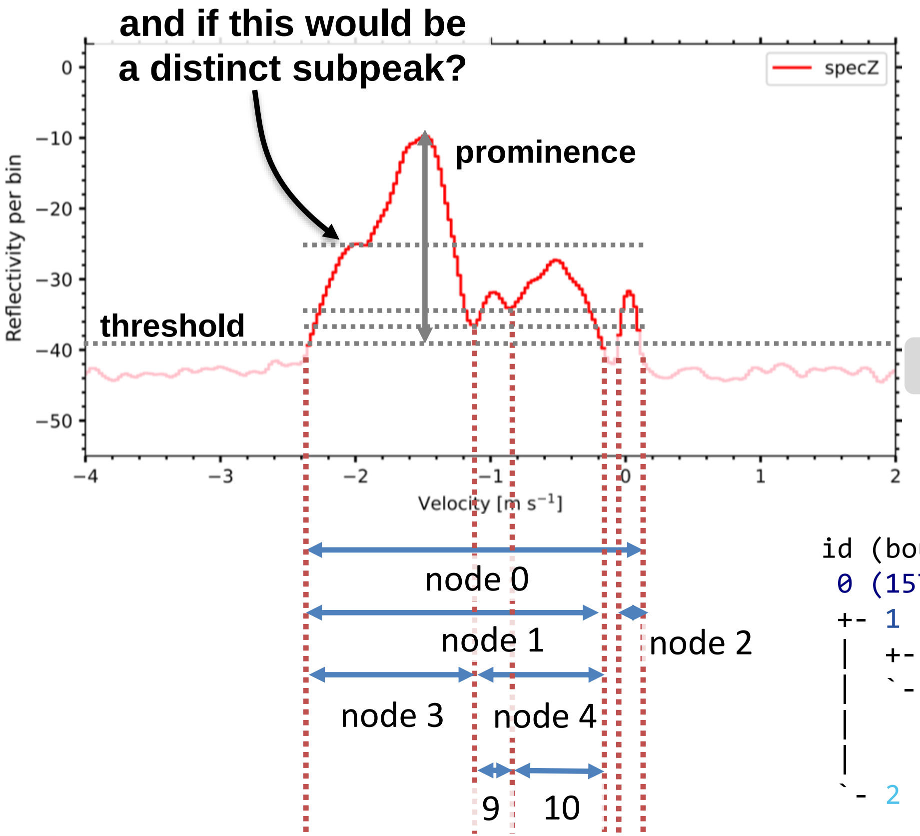
→ peako can be applied using these parameters to obtain peak locations in other cloud radar Doppler spectra files (stand-alone)

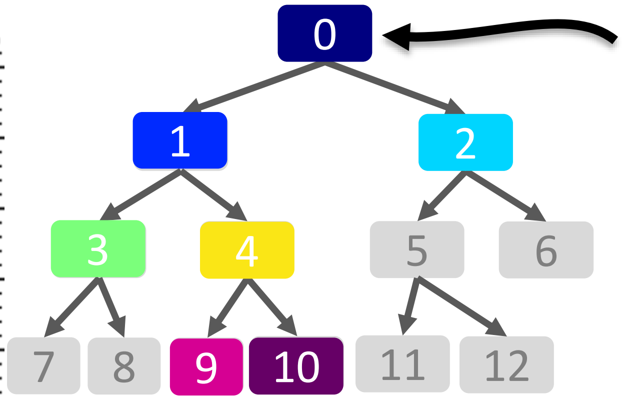
→ or: peak finding parameters can be input to peakTree

peakTree: Peak structuring with binary trees



Represent (sub-)peaks as nodes in a binary tree





node 0 is equal to 'traditional' moments

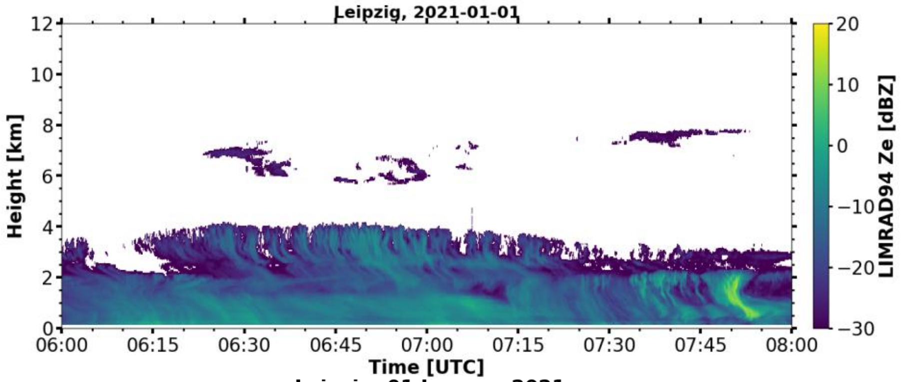
$$i_{\text{left child}} = 2\, i_{\text{parent}} + 1$$

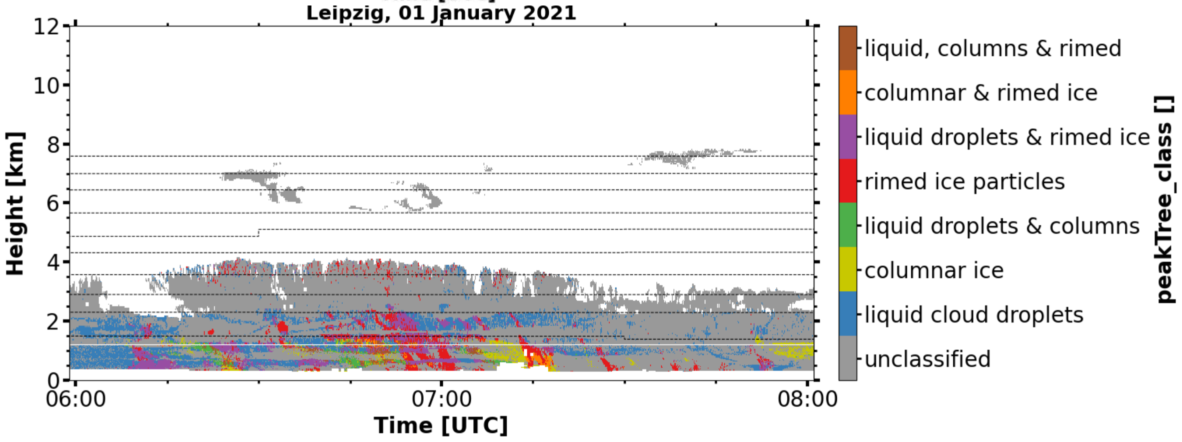
$$i_{\text{right child}} = 2\, i_{\text{parent}} + 2$$

$$i_{\text{parent}} = \left\lfloor \frac{i_{\text{child}} - 1}{2} \right\rfloor$$

```
id (bounds)                  Z       v      σ      γ   thres. prom.
 0 (157, 260)           |   0.98, -1.52, 0.22,  2.54, -40.0, 30.3
 +- 1 (157, 249)        |   0.96, -1.52, 0.20,  2.09, -40.0, 30.3
 |   +- 3 (157, 209)    |   0.85, -1.55, 0.14, -1.41, -36.5, 26.8
 |   `- 4 (209, 249)    | -14.97, -0.61, 0.21, -0.57, -36.5,  9.2
 |       +- 9 (209, 220)| -22.54, -0.95, 0.06,  0.18, -34.1,  2.2
 |       `-10 (220, 249)| -15.74, -0.55, 0.14, -0.22, -34.1,  6.8
 `- 2 (254, 260)        | -25.26,  0.03, 0.04, -0.02, -40.0,  8.3
```

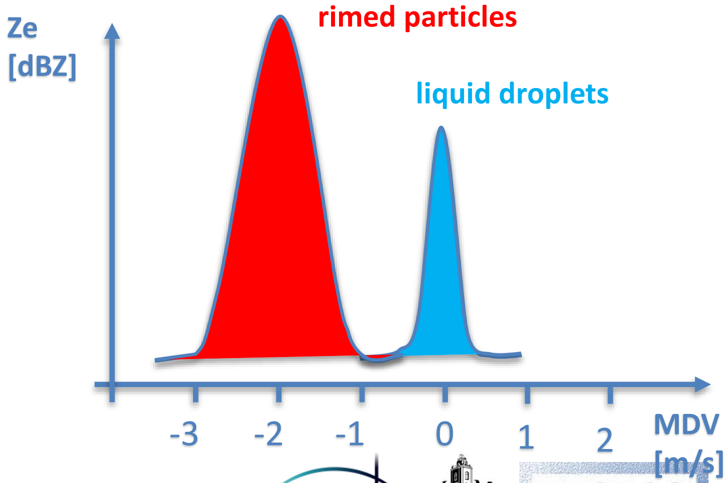
peak-based hydrometeor classification





assigning hydrometeor types based on peak properties

- liquid: low MDV, low Ze, low LDR
- columnar ice: low Ze, high LDR
- rimed particles: falling more than 1.5 m/s faster than another slower-falling peak



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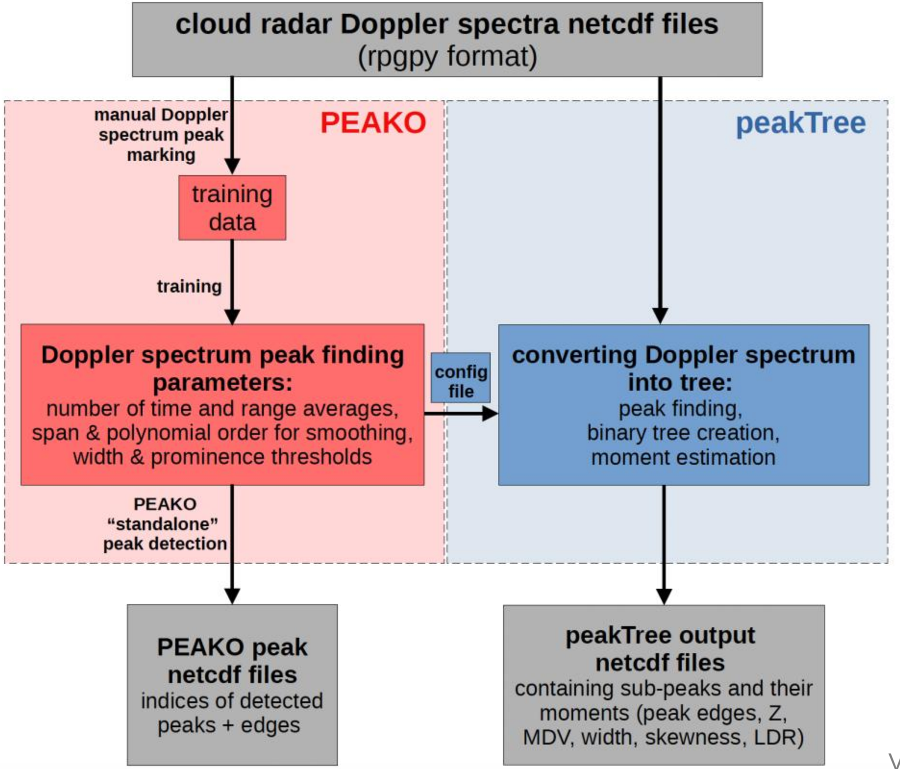
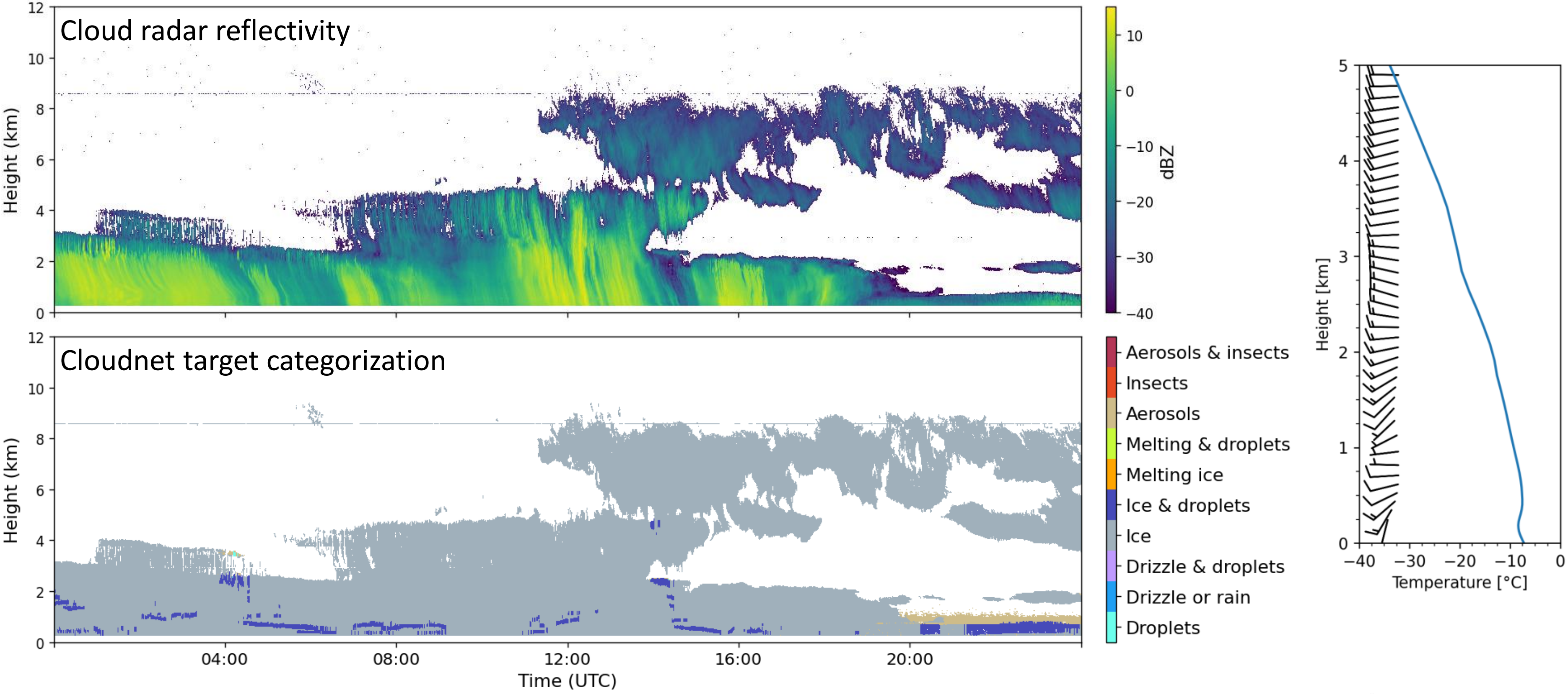
work flow



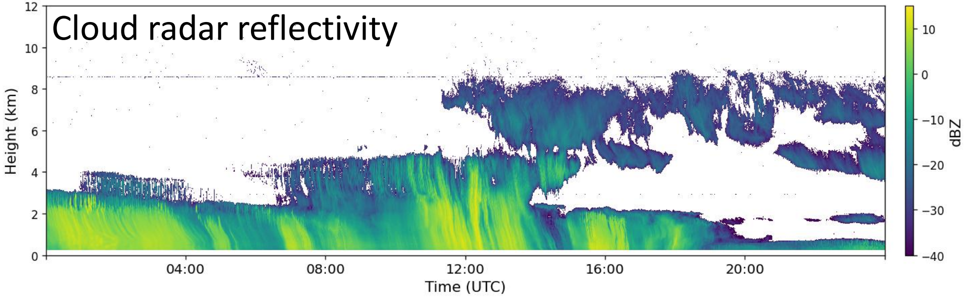
Vogl and Radenz et al., 2024

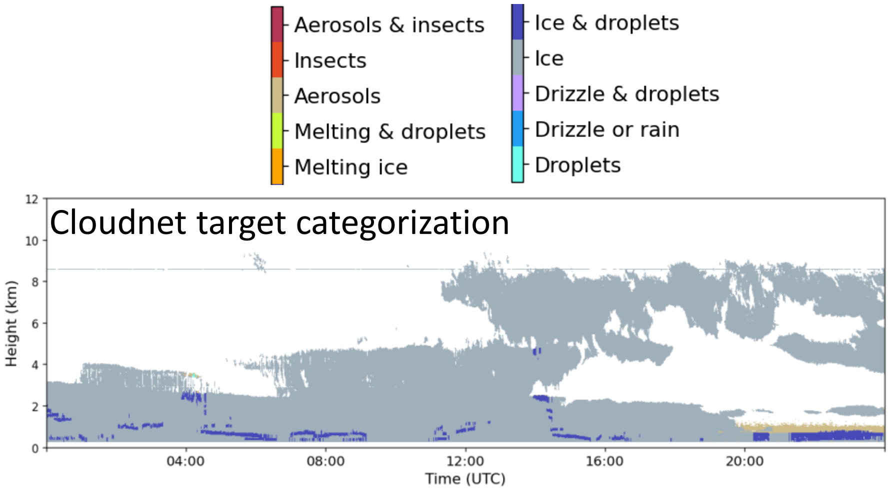
Hyytiälä 14 January 2024

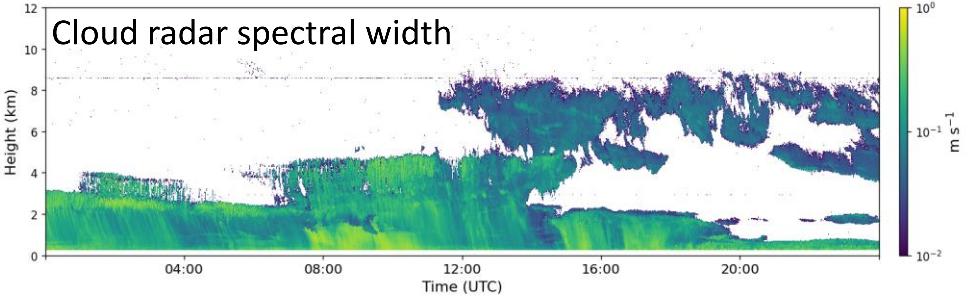


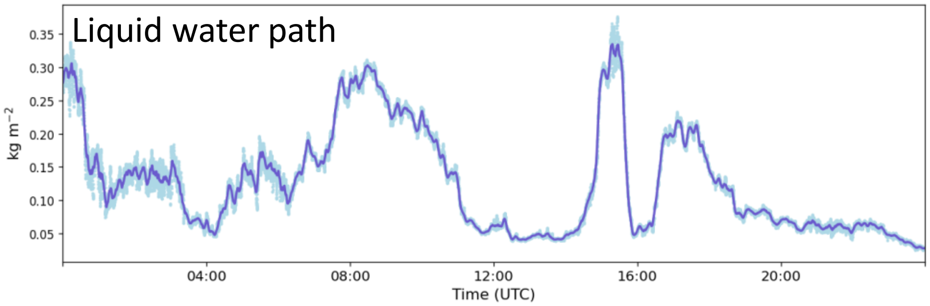
https://cloudnet.fmi.fi/search/visualizations?site=hyytiala

Hyytiälä 14 January 2024









https://cloudnet.fmi.fi/search/visualizations?site=hyytiala

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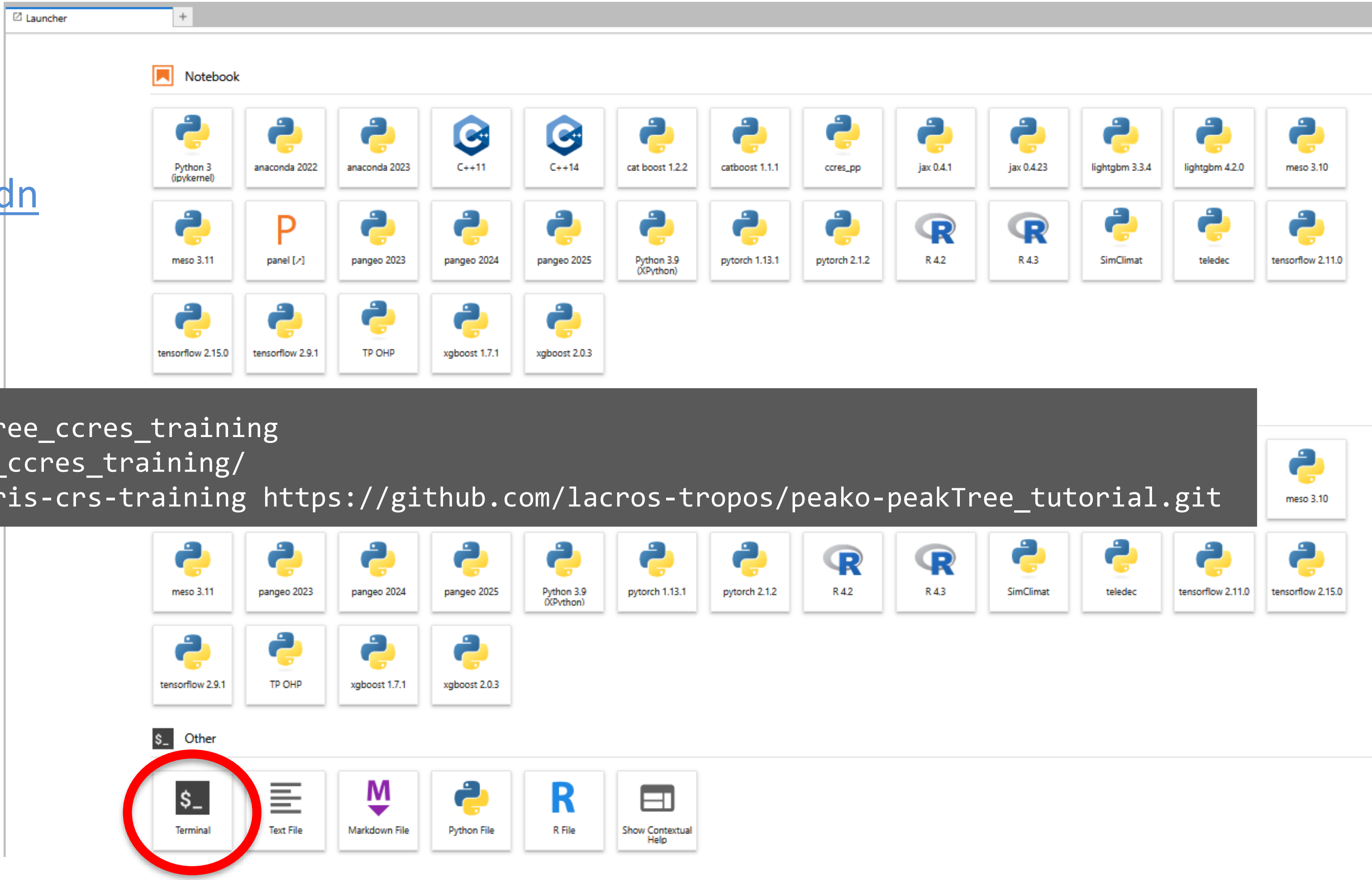
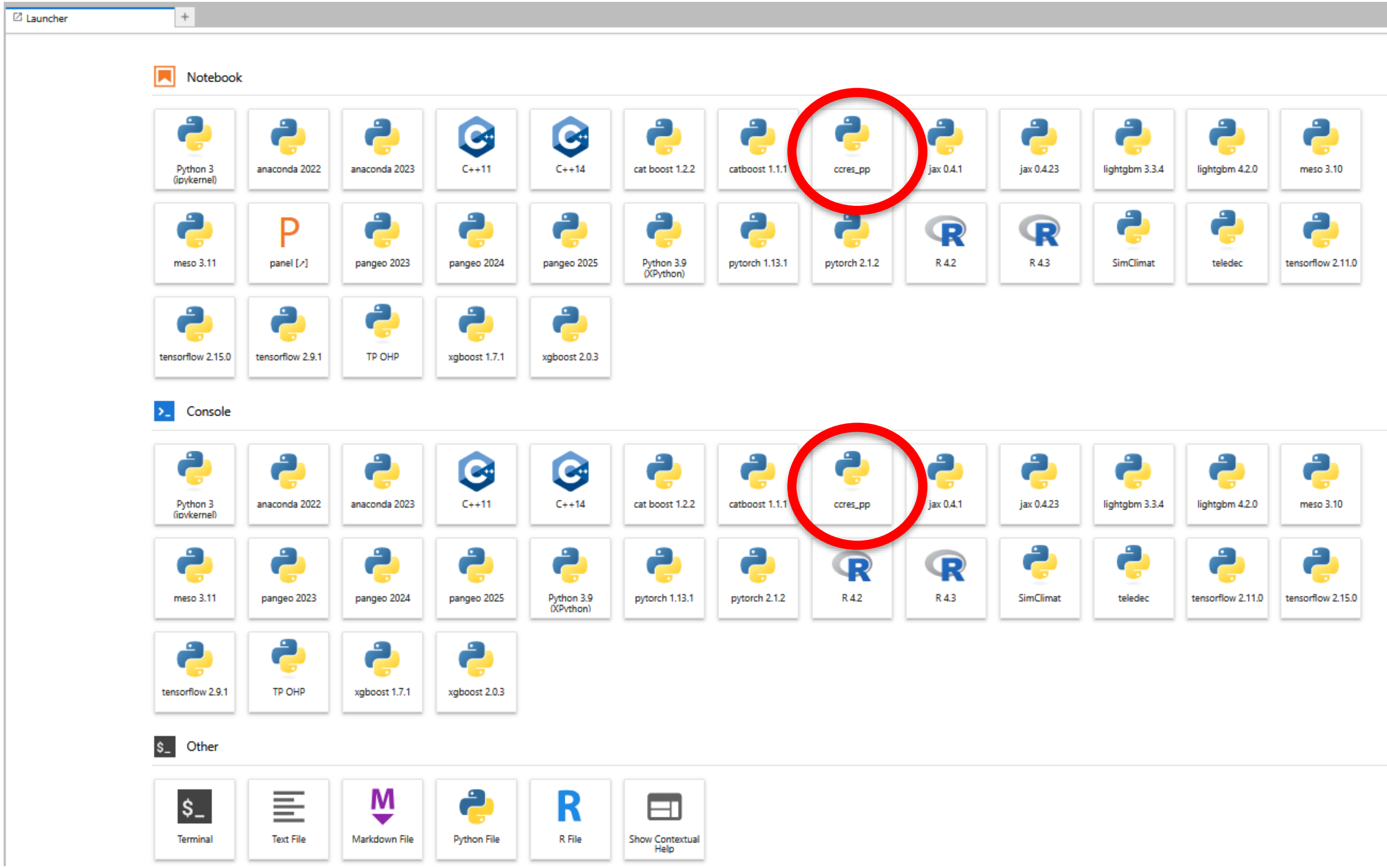
https://t1p.de/tv6dn




```
~$ mkdir peakopeaktree_ccres_training
~$ cd peakopeaktree_ccres_training/
~$ git clone -b actris-crs-training https://github.com/lacros-tropos/peako-peakTree_tutorial.git
```

Hands-on


Launcher
Notebook
Python 3 (ipykernel)
anaconda 2022
anaconda 2023
C++11
C++14
cat boost 1.2.2
catboost 1.1.1
ccres_pp
jax 0.4.1
jax 0.4.23
lightgbm 3.3.4
lightgbm 4.2.0
meso 3.10
meso 3.11
panel [↗]
pangeo 2023
pangeo 2024
pangeo 2025
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pytorch 1.13.1
pytorch 2.1.2
R 4.2
R 4.3
SimClimat
teledec
tensorflow 2.11.0
tensorflow 2.15.0
tensorflow 2.9.1
TP OHP
xgboost 1.7.1
xgboost 2.0.3
Console
Python 3 (ipykernel)
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anaconda 2023
C++11
C++14
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catboost 1.1.1
ccres_pp
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jax 0.4.23
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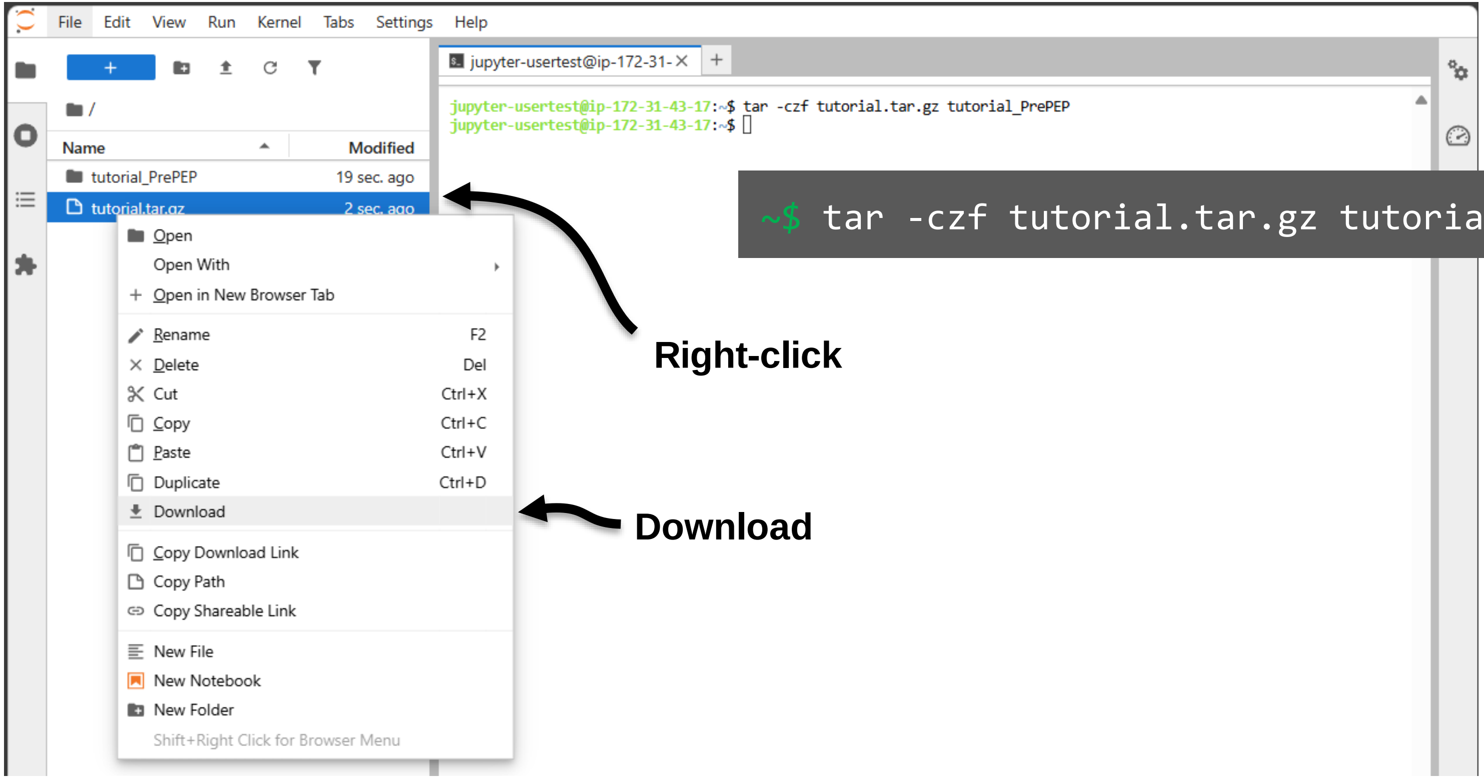
lightgbm 4.2.0
meso 3.10
meso 3.11
pangeo 2023
pangeo 2024
pangeo 2025
Python 3.9 (XPython)
pytorch 1.13.1
pytorch 2.1.2
R 4.2
R 4.3
SimClimat
teledec
tensorflow 2.11.0
tensorflow 2.15.0
tensorflow 2.9.1
TP OHP
xgboost 1.7.1
xgboost 2.0.3
Other
Terminal
Text File
Markdown File
Python File
R File
Show Contextual Help

Backup

Backup your materials




```
~$ tar -czf tutorial.tar.gz tutorial_PrePEP
```

Right-click

Download

From real atmospheric and cloud properties to radar spectrum

- **Ideal (undisturbed, separated and unbiased) spectral components**

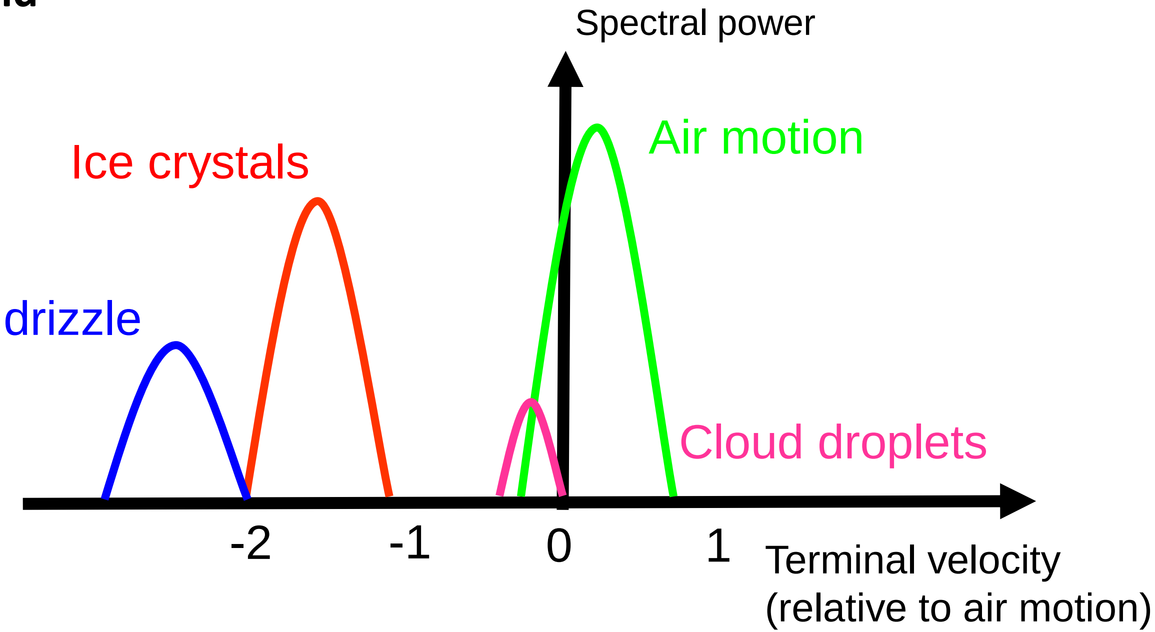


Fig. P. Seifert

From real atmospheric and cloud properties to radar spectrum

Real (biased and broadened) spectral components

- **terminal fall velocities sufficiently separated**
- **small turbulence broadening**

→ Doppler spectrum with seperated peaks

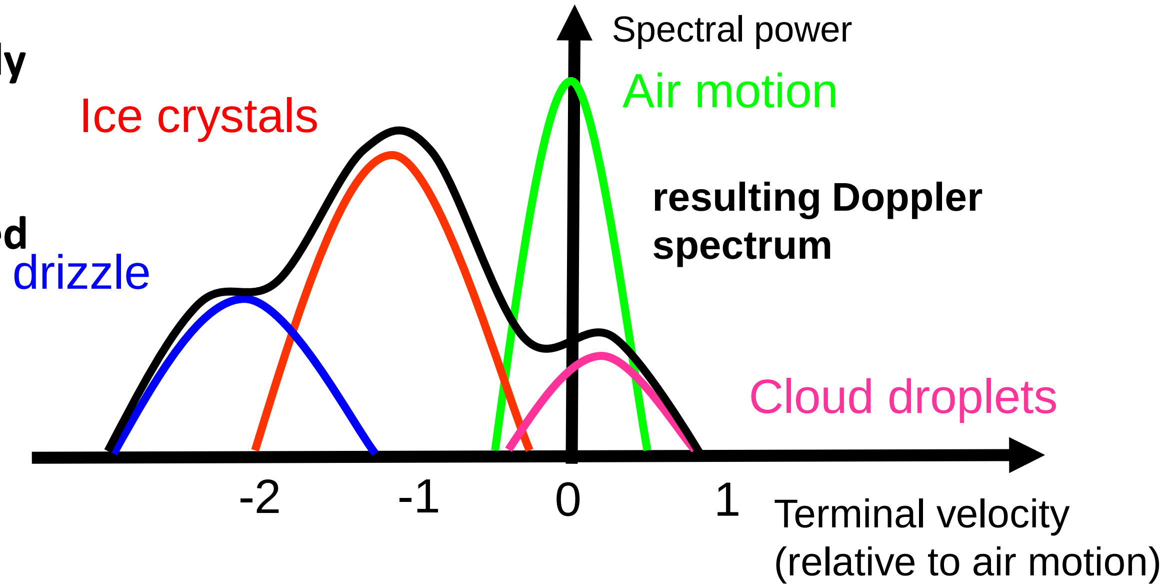
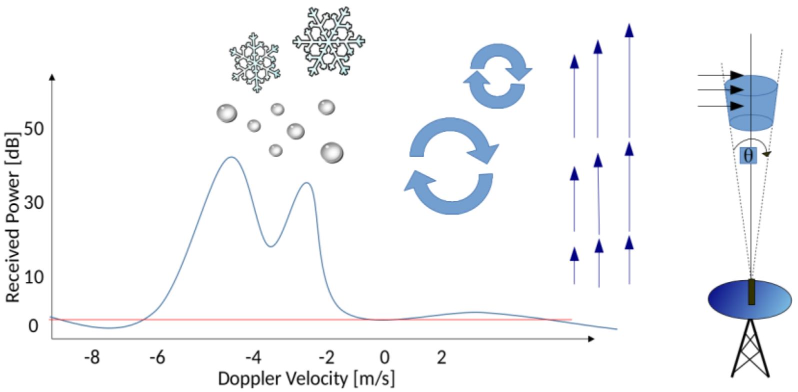


Fig. P. Seifert

spectrum width

- radar beam width component σ_B
  - radar beam is slightly divergent → small horizontal component in the radial (Doppler) velocity
  - for radars not pointing vertically, σ_B has also a dependence on zenith angle
- broadening due to radial wind shear σ_S
  - wind shear perpendicular to the radar beam → function of beam width and range
  - vertical shear of the vertical wind → function of range gate height

$$\sigma^2 = \sigma_{DSD}^2 + \sigma_T^2 + \sigma_S^2 + \sigma_B^2$$



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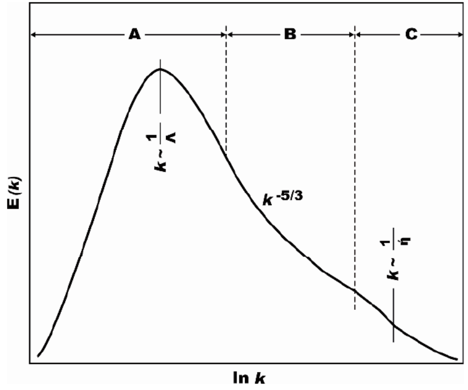
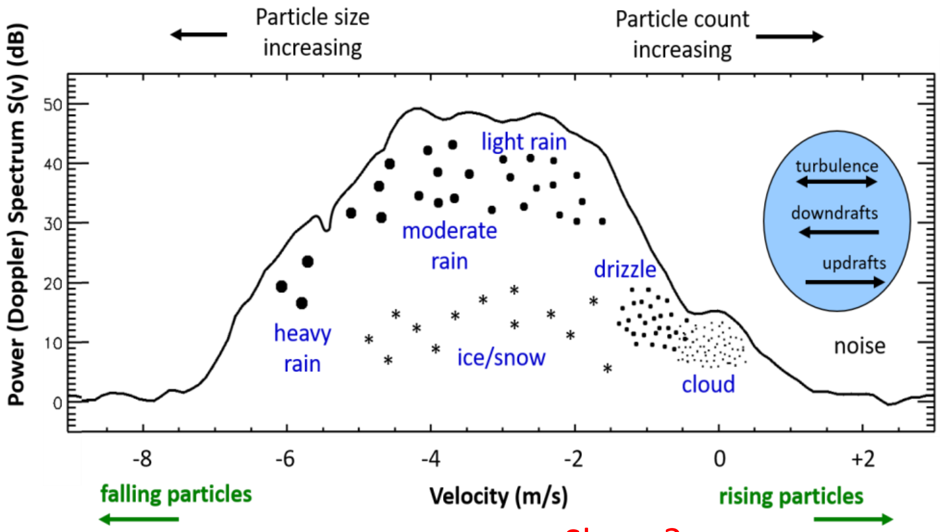
spectrum width

- Turbulence broadening σ_T
  - Turbulence is atmospheric motion due to stochastic movement of turbulence elements (eddies) around a mean state
  - Length scale probed by the radar: from 0.5*λ up to the size of the sampling volume, also taking into account the dwell time (i.e. large eddies passing through the sampling volume during the dwell time)

Kaimal & Finnigan (1994): schematic of turbulent energy plotted against the wave number k
A: range of energy production
B: inertial subrange
C: dissipation range



From Doppler radar moments to Doppler radar spectra



Shape?

- **Historically: storage of first 3 moments of the Doppler spectrum:**
- **Reflectivity Z_e [dBZ], mean Doppler velocity V_{dop} [m s^{-1}], spectrum width σ [m s^{-1}]**
- **Nowadays: extended electronic storage → whole Doppler spectrum**

For „fingerprinting“ of microphysical growth processes in mixed-phase/drizzle clouds: cloud radar Doppler spectra offer big information content.

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