# GPM in complex terrain: evaluation in the Swiss Alps

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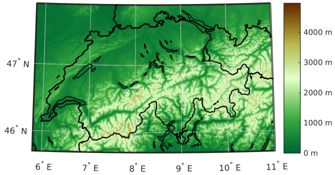
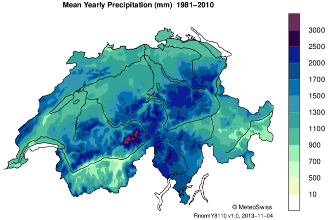
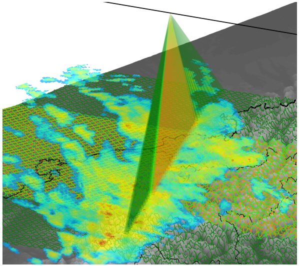
# Outline

# GPM in the Swiss context



Ku only   Ku & Ka   Ka only

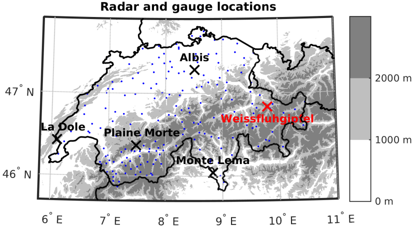
Product evaluated: precipRateESurface

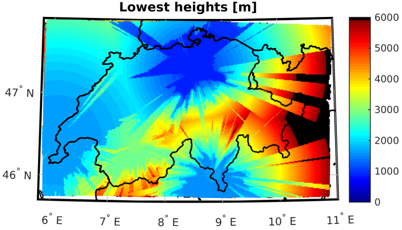
Mar. 9$^{\mathrm{th}}$ 2014 $\rightarrow$ Feb. 29$^{\mathrm{nd}}$ 2016.

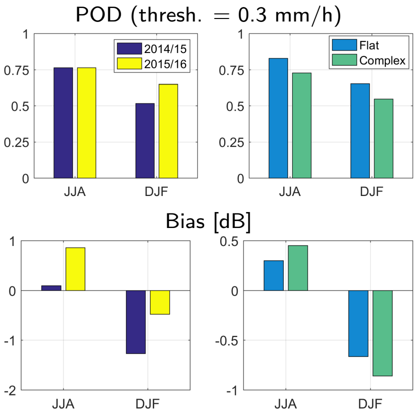
| | Ku only | Ku & Ka | Ka only | Total unique |
|---|---|---|---|---|
| No. of overpasses | 528 | 393 | 392 | **530** |
| With precip | 327 | 193 | 188 | **332** |

# Reference data

Ground-level precip. rate from MeteoSwiss operational radar network (1 $km^2$ - 5 min)

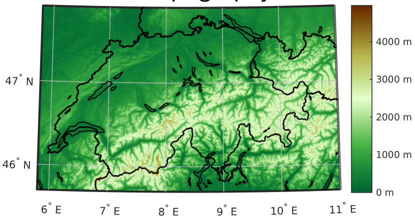


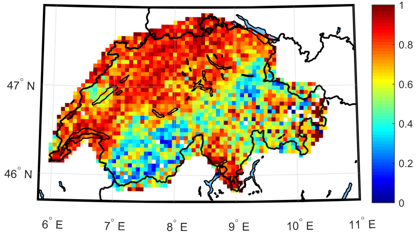



# Performance across Switzerland

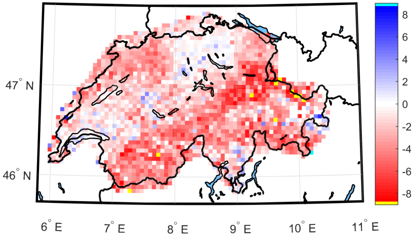
Topography



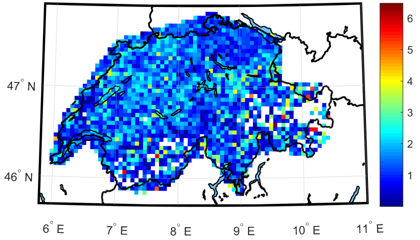

Heidke Skill Score (R $\geq$ 0.15 mm hr$^{-1}$)



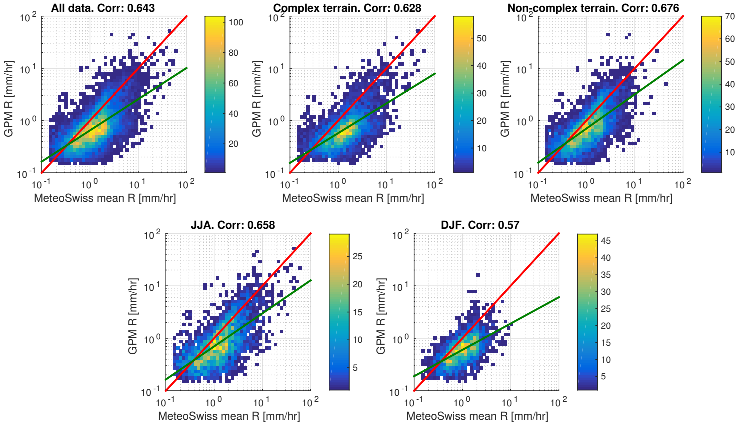

BIAS [dB]




MADM



# Global scatterplots

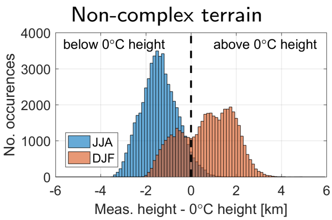


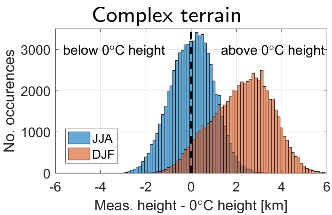

## GPM estimates appear influenced by both

- terrain complexity;
- seasonality.

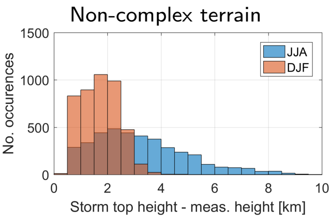
# Why worse in complex terrain and in winter?

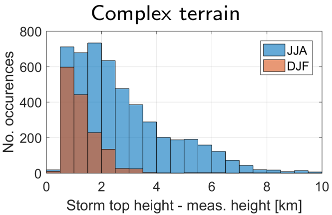
## Phase matters




## Vertical extent matters



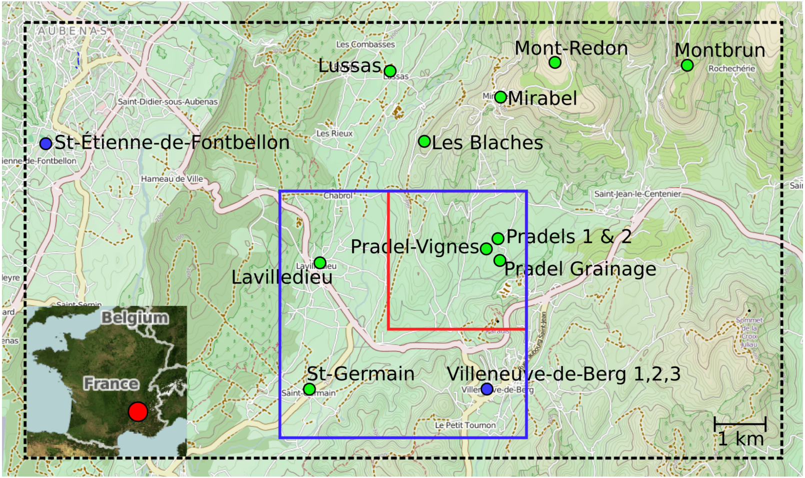




(Speirs et al., JHM, in revision)

1. GPM in the Alps
2. **DSD variability within GPM footprint**
3. MASC image classification
4. Conclusions

# Instrument network in Ardèche, France

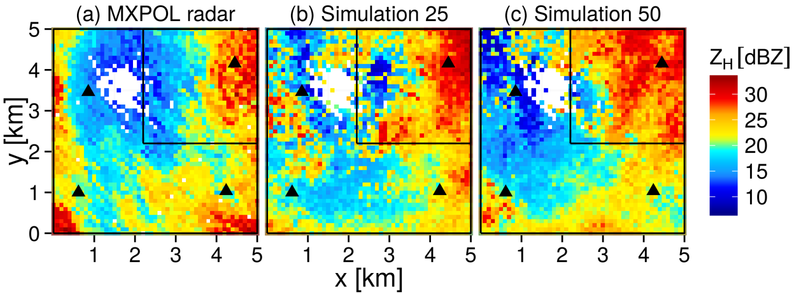
Maps ©Thunderforest (CC BY-SA), map data ©OpenStreetMap (ODbL)




OTT Parsivel ● 1st gen. ● 2nd gen.

2.8x2.8 $km^2$ 5x5 $km^2$

# Stochastic simulation outputs




- 100 m resolution over 5×5 $km^2$ region (typical GPM DPR footprint).
- 100 realisations per time step.
- Each realisation is equally likely, none the most likely.
- More realistic, non-smooth fields.

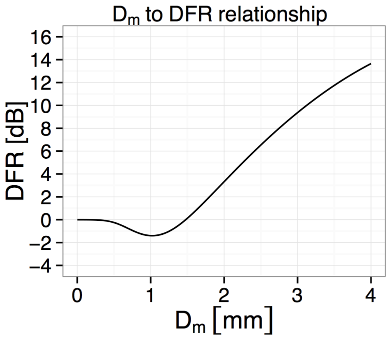
(Raupach and Berne, QJRMS, 2016)

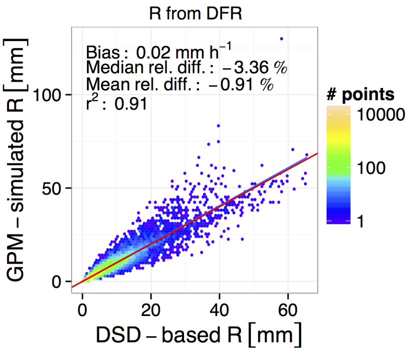
# GPM dual-frequency estimation

- The areal DSD is estimated by a normalised gamma model.

$$N(D) = N_w \frac{6}{4^4} \frac{(4+\mu)^{\mu+4}}{\Gamma(\mu+4)} \left(\frac{D}{D_m}\right)^{\mu} \exp\left[-(4+\mu)\frac{D}{D_m}\right]$$

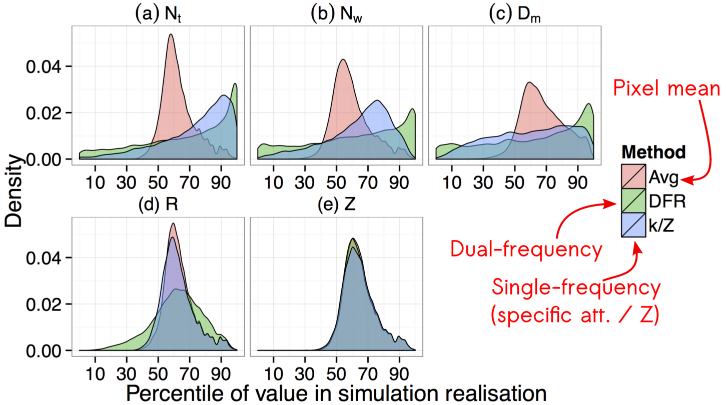
- Dual frequency ratio (DFR) $\rightarrow$ $D_m$ [mm] $\rightarrow$ $N_w$ [mm$^{-1}$ m$^{-3}$]. $\mu = 3$.



# GPM DSD estimation

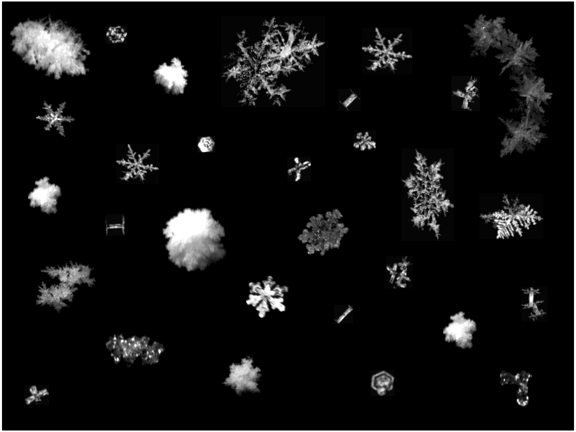
Low-order moments usually above median sub-grid value




Errors are primarily a result of error in determination of $D_m$.

(Raupach and Berne, JHM, 2016)

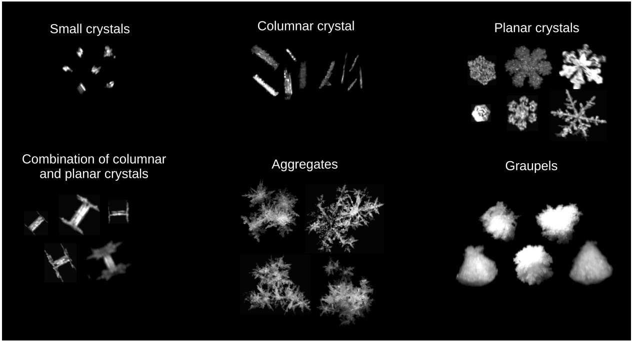
# Examples of snowflakes pictured by the MASC



- Variability of shape, size, etc.
- Human eye/brain can distinguish and group pictures.
- Huge number of pictures → we need an automatic classification.

# Output of classification scheme (1)

- Started with 10 main categories taken from Magono and Lee (1966).
- Removed classes rarely observed (germ of snow, comb. of planar crystals).
- Added aggregates and small crystals.
- Merged similar classes (col. - needles ; plates / sectored plates / dend.).



# Output of classification scheme (2)

Complementary information : Riming degree and melting or not.

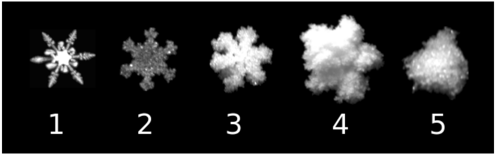
## Riming degree

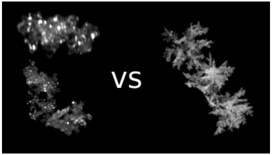
- Continuous value in general...
- Here: ordinal value from 1 to 5.

(adapted from *Mosimann et al. 1994*)

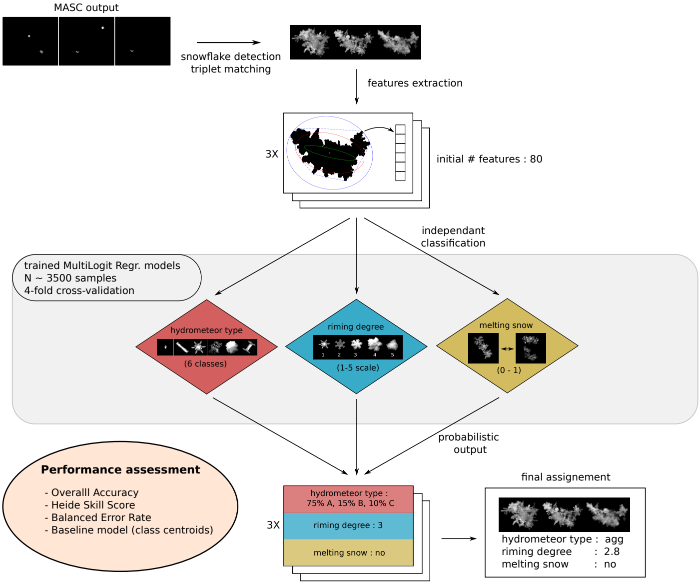
## Melting snow

- Cont. value in general...
- Here: boolean (dry / melting).



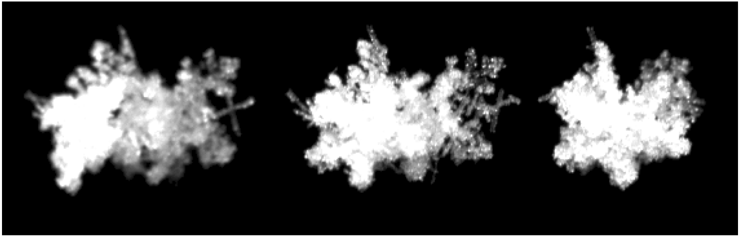



# Summarising flowchart



# Application to Masc stereoscopic images

Example 1:

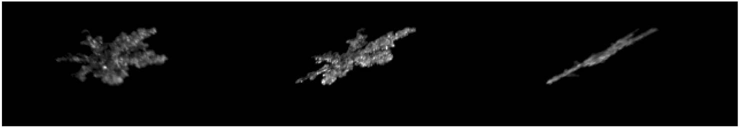


| | | |
|---|---|---|
| >99% aggregate<br><1% others<br>Riming = 3.0<br>Dry | 83% aggregate<br>16% planar crystal<br><1% others<br>Riming = 3.5<br>Dry | 48% aggregate<br>32% planar crystal<br>20% graupel<br>Riming = 4.1<br>Dry |

$\Rightarrow$ Dry, "heavily rimed to graupel-like" aggregate.

# Application to Masc stereoscopic images

Example 2:



| | | |
|---|---|---|
| 65% planar crystal<br>30% aggregate<br>5% others<br>Riming = 2.2<br>Dry | 71% planar crystal<br>26% aggregate<br>3% others<br>Riming = 2.5<br>Dry | ~97% columnar crystal<br>3% planar crystal<br>~0% others<br>Riming = 2.0<br>Dry |

$\Rightarrow$ Dry, moderately rimed planar crystal.

# Summary and perspectives

## Summary

- GPM surface precip product is globally **underestimated** in the Alps.
- **Worse in complex terrain and winter** $\leftarrow$ phase and vertical extent.
- **Similar behavior** for MS, NS and HS product.
- DSD retrieval good for $R$ and $Z$, but **bias** for $D_m$ and low-order moments.
- Method to **automatically classify** pictures from **MASC** (and others).

## Future work

- Influence of hydrometeor types on GPM estimates.
- Influence of clutter contamination in complex terrain.
- Statistics about geometry of snowflakes in the Alps (and Antarctica).

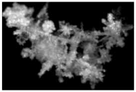
# Thank you for your attention!

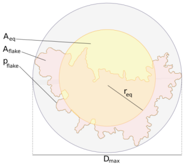
MeteoSwiss operational radar at La Plaine Morte

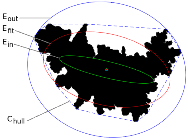
# Geometric descriptors

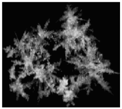
## Descriptors based on the B&W silhouette

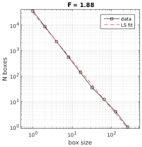
- Basic: $D_{max}$, Area A, Perimeter P, $R_{eq}$, number of holes...
- Shape complexity: Fractal dimension, complexity index, skeleton...
- Form: Ellipse fits (aspect ratio, orientation), circumscribed circle (compactness), convex hull, encompassing rectangle...
- Rotational symmetry features: based on distance to centroid calculations.

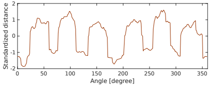


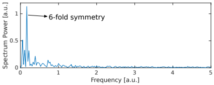




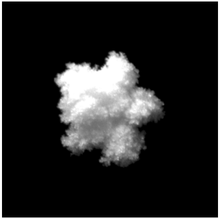



# Textural descriptors

## Descriptors based on shades of colour

- Global: Mean brightness, ,contrast, interpixel variability, ...
- Local: Mean local variability, mean range intensity, mean laplacian, ...
  $\rightarrow$ based on a moving window operator.
- Haralick features (14 features based on the grayscale co-occurrence matrix).



$\leftarrow$ brighter

higher local var. $\rightarrow$