Small-scale variability of alpine precipitation

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ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Motivation

Variability of precipitation

- Drop size distribution (DSD) is crucial for the intepretation of weather radar measurements.
- Influence of DSD variability at radar subgrid scales is not well known.

⇒ **Characterize DSD variability at small scales**.

Mountain precipitation

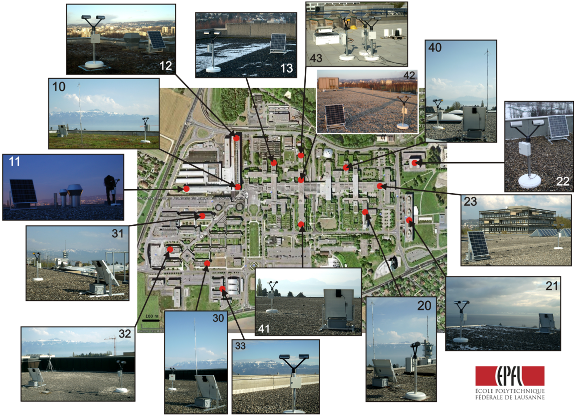
- Complex patterns + frequent snowfall.
- Limited data because measurements in difficult conditions.

→ **Investigate alpine precipitation using polarimetric radar**.

Exp. approach: Network of disdrometers

Parsivel

Optical disdrometer.
DSD + fall speed.



- 16 identical instruments (Parsivel) over $\sim 1 \times 1$ km^2 (radar pixel).
- Temporal resolution of 30 s + real-time access to data.

(Jaffrain et al., WRR, 2011)

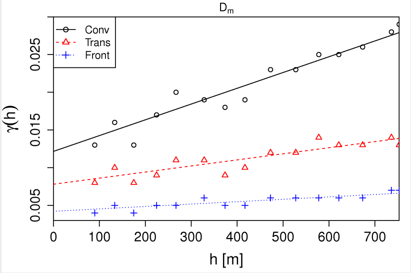
DSD variability within a radar pixel

Spatial structure of D_m

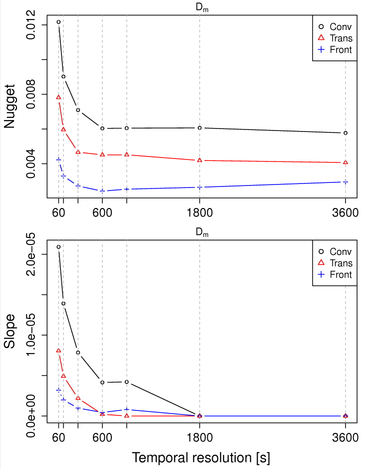
Quantified by the variogram γ

$$\gamma(h) = \frac{1}{2}\mathrm{E}\left\{[D_m(x+h) - D_m(x)]^2\right\}$$

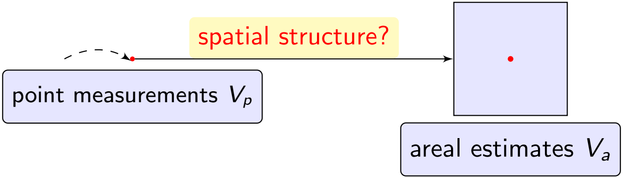
where x is a position vector and h is a separation vector.



Evolution of the parameters of the variogram in time



Spatial representativity of point measurement?



spatial structure?

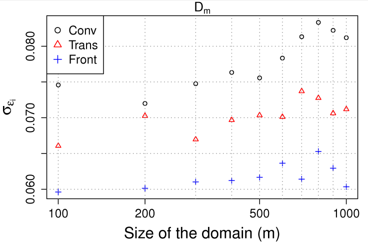
point measurements V_p

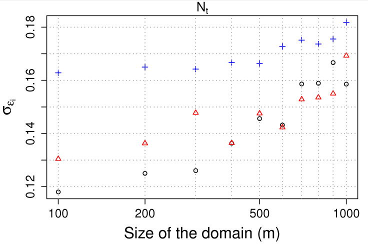
areal estimates V_a

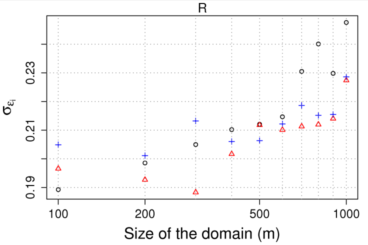
Stochastic simulation approach

- 1000 2D-fields are generated for each type of rainfall
- Simulated fields are constrained by:
  - * the observed spatial structure (variograms)
  - * the average of the quantity of interest
- Relative extension error: $\epsilon = \dfrac{V_p - V_a}{V_a}$

Evolution of σ_ϵ with domain size







Stochastic approach: Simulation of DSD fields

- Geostatistical framework (e.g., Chilès and Delfiner, 1997). Structure is characterized using the **space-time variogram**:

$$\gamma(h,\tau) = \frac{1}{2}\mathrm{E}\left\{[Z(x+h,t+\tau) - Z(x,t)]^2\right\}$$

- DSD is assumed to follow a **Gamma distribution**:

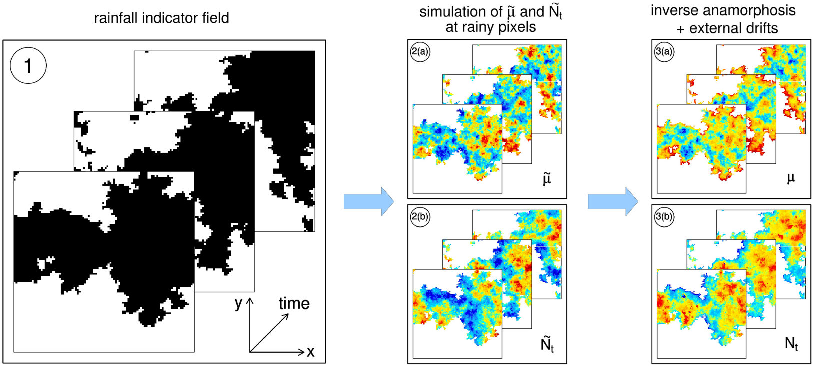
$$N(D) = \alpha N_t D^{\mu} \exp(-\Lambda D)$$

  In subsequent illustrations, we assume $\Lambda = f(\mu)$ (but not mandatory).
  $\rightarrow$ DSD field = bivariate random field (N_t,μ).

- Take advantage of existing **fast Gaussian field simulation** algorithms (conditional or unconditional sequential simulation).

- Hence need for a **Gaussian anamorphosis** technique (Leuangthong and Deutsch, 2003).

Space-time DSD simulator

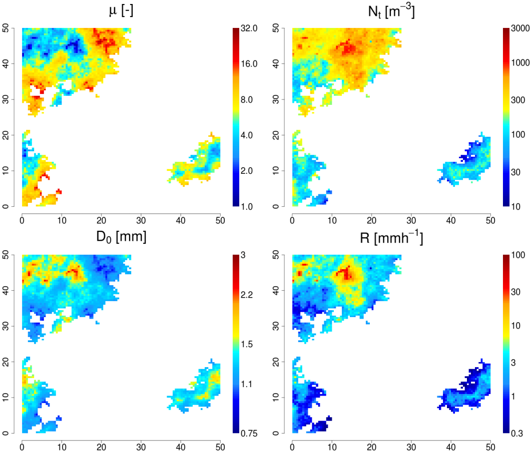


(Schleiss et al., WRR, 2009; Schleiss et al., JHM, in press)

Illustrations

Parameterization

- Meteo Swiss radar data: space-time structure of the indicator function, advection and anisotropy.
- Disdrometer data: space-time structure of N_t and μ.



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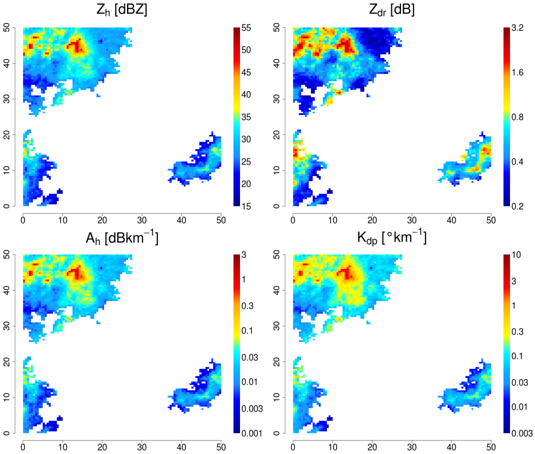
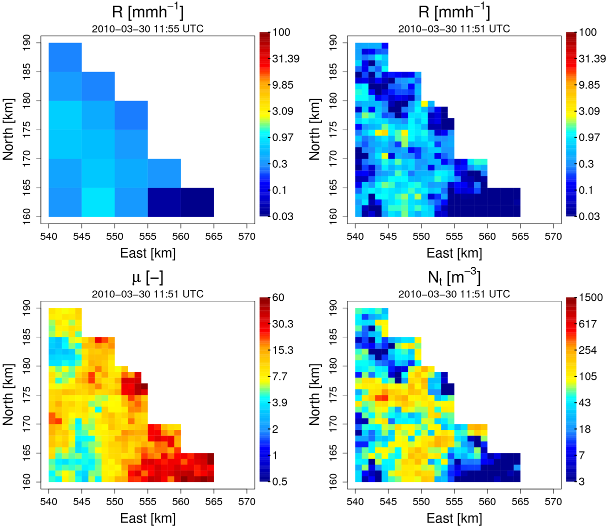


Disaggregation in space and time



Mobile X-Band Polarimetric Radar: MXPol

Manufacturer

ProSensing, USA.

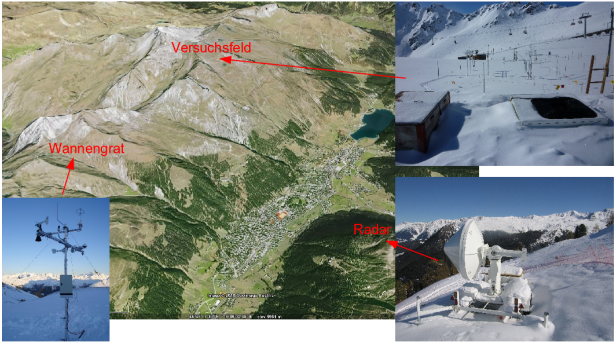
Field campaign suitability

- Trailer / Power generator.
- Tested in difficult conditions.

Specifications

- 3dB beam width: 1.45°.
- Simultaneous H and V transmission.
- Up to 15 m range resolution.
- Up to 2000 range gates.

Field campaign in Davos



Collaboration with SLF (M. Lehning).

Radar

MXPol, alt. 2133 m.

Wannengrat

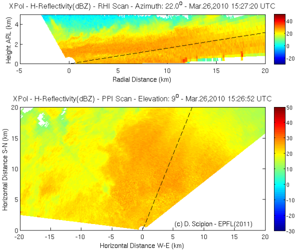
20 weather stations.

Versuchsfeld

Video-disdro, daily snow height and density.

- Radar (and other instruments) deployed from Sep. 2009 to June 2011.
- Collect unique data set about alpine precipitation: $\sim$ **100 precip events** $\sim$ **2500 h** (50% snow, 25% rain, 25% mixed)

Snow event - March 26th 2010

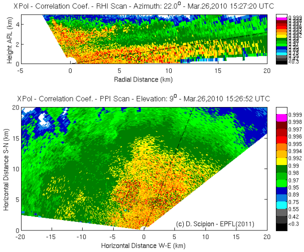

XPol - H-Reflectivity(dBZ) - RHI Scan - Azimuth: 22.0° - Mar.26,2010 15:27:20 UTC

XPol - H-Reflectivity(dBZ) - PPI Scan - Elevation: 9° - Mar.26,2010 15:26:52 UTC

(c) D. Scipion - EPFL(2011)

Z_h

ρ_{hv}


XPol - Correlation Coef. - RHI Scan - Azimuth: 22.0° - Mar.26,2010 15:27:20 UTC

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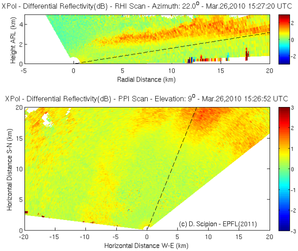
XPol - Differential Reflectivity(dB) - RHI Scan - Azimuth: 22.0° - Mar.26,2010 15:27:20 UTC

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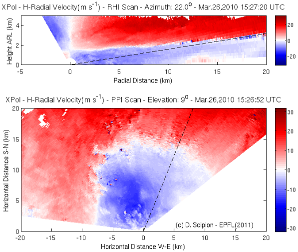
Z_{dr}

V_h


XPol - H-Radial Velocity(m s^{-1}) - RHI Scan - Azimuth: 22.0° - Mar.26,2010 15:27:20 UTC

XPol - H-Radial Velocity(m s^{-1}) - PPI Scan - Elevation: 9° - Mar.26,2010 15:26:52 UTC

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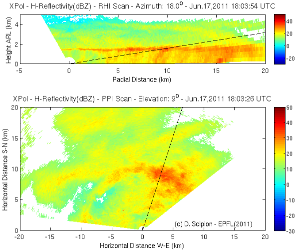
Mixed event - June 17th 2011

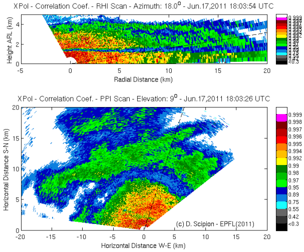

XPol - H-Reflectivity(dBZ) - RHI Scan - Azimuth: 18.0° - Jun.17,2011 18:03:54 UTC

XPol - H-Reflectivity(dBZ) - PPI Scan - Elevation: 9° - Jun.17,2011 18:03:26 UTC

(c) D. Scipion - EPFL(2011)

Z_h

ρ_{hv}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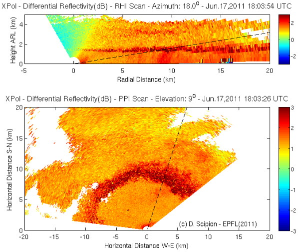
XPol - Differential Reflectivity(dB) - RHI Scan - Azimuth: 18.0° - Jun.17,2011 18:03:54 UTC

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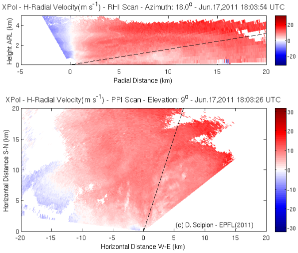
Z_{dr}

V_h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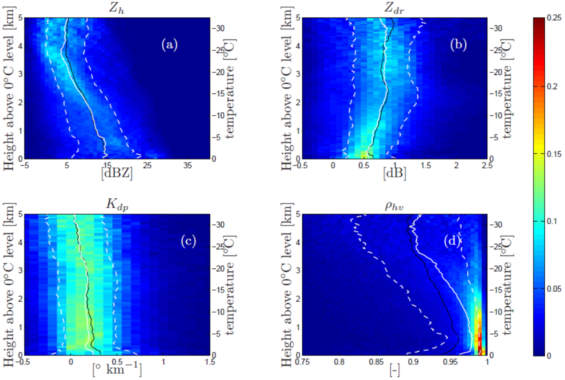
Microphysics of snowfall

Distributions of polarimetric radar variables / height above 0°C



- Below -20°C: **pristine/polycrystalline ice crystals**.
- -20 to -15°C: **Dendrification** (increase in Z_{dr}, K_{dp} and Z_h).
- -15 to 0°C: **Aggregation** (decrease in Z_{dr}, increase in Z_h).

Conclusions

LTE → variability of precipitation at small scales in alpine context

- **Small-scale variability of DSD**
  - Experimental and simulation approaches.
  - Can be significant over radar pixel.
- **Polarimetric radar measurements in the Alps**
  - Unprecedented high-resolution data of precipitation in alpine regions.
  - Information about dominant microphysical processes.

Possible links with GPM

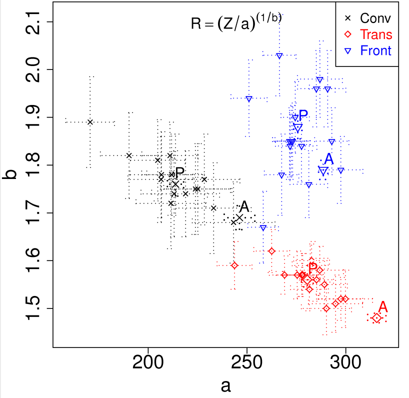
- DSD: data are available (daily files, contact alexis.berne@epfl.ch); variability features could be useful for error structure.
- Alpine precip: radar data will be soon available (once QC finished); analyses of snowfall radar signatures are going on.
- MXPol and disdrometers involved in HyMeX campaign → see next talk!

Thank you for your attention!

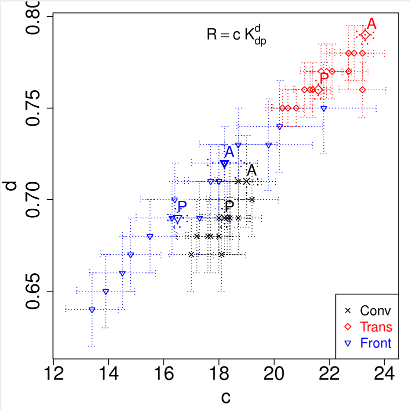
Davos, 9 Dec. 2009

Influence on radar power laws

$R - Z$ power law



$R - K_{dp}$ power law



C-band, 1min

Processing algo. based on Ext. Kalman Filt.

Obs. and state vectors

$$\mathbf{o}(i) = \begin{bmatrix} \Psi_{dp}(i) \\ \Psi'_{dp}(i) \\ \tilde{Z}_h^m(i) \\ \tilde{Z}_v^m(i) \\ -45.5 \\ -43.2 \\ 0 \\ 0 \end{bmatrix} \qquad \mathbf{s}(i) = \begin{bmatrix} \Phi_{dp}(i) \\ \Phi'_{dp}(i) \\ \tilde{Z}_h(i) \\ \tilde{Z}_v(i) \\ \tilde{K}_{dp}(i) \end{bmatrix}$$

- Non-linear relations
- Gaussian distributions (work with log)

→ **Extended Kalman Filter**

Observation model

$$\begin{aligned}
\Psi_{dp}(i) &= -2\Delta r 10^{\tilde{K}_{dp}(i)/10} + \Phi'_{dp}(i) + \delta_{hv}(i) \\
\Psi'_{dp}(i) &= +2\Delta r 10^{\tilde{K}_{dp}(i)/10} + \Phi_{dp}(i) + \delta_{hv}(i) \\
\tilde{Z}_h^m(i) &= -0.245\Phi_{dp}(i) - \tilde{Z}_h(i) \\
\tilde{Z}_v^m(i) &= -0.206\Phi_{dp}(i) - \tilde{Z}_v(i) \\
-45.5 &= 1.23\tilde{K}_{dp}(i) - \tilde{Z}_h(i) \\
-43.2 &= 1.15\tilde{K}_{dp}(i) - \tilde{Z}_v(i) \\
0 &= \Phi'_{dp}(i) - \Phi_{dp}(i) - 2\Delta r 10^{\tilde{K}_{dp}(i)/10} \\
0 &= 0.674\left(\tilde{Z}_h(i) - \tilde{Z}_v(i)\right)^{1.63} - \delta_{hv}(i)
\end{aligned}$$

Propagation model

$$\begin{aligned}
\mathbf{s}^{(-)}(i+1) &= \mathbf{s}^{(+)}(i) \\
\Phi_{dp}^{(-)}(i+1) &= \Phi_{dp}^{\prime(+)}(i) \\
\Phi_{dp}^{\prime(-)}(i+1) &= \Phi_{dp}^{\prime(+)}(i) + \Delta r 10^{\tilde{K}_{dp}^{(+)}(i)/10}
\end{aligned}$$

Application to radar measurements

X-band polarimetric radar deployed in the Swiss Alps
Rain event on August 12 2010 (radar + disdrometer)