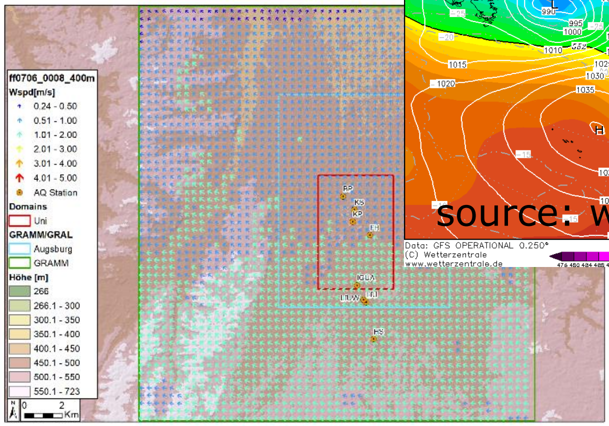
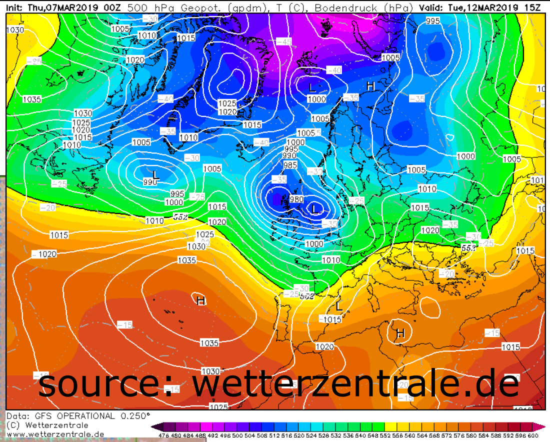
Development & Application of a Multi-Scale Flow Field Analysis System for Complex Terrain

Ulrich Uhrner, Johannes Werhahn, Raphael Reifeltshammer & Renate Forkel

Introduction

- For dispersion good representation of flow important at **local scale**
- **Initialisation & BC** still major challenge
  - **Complex terrain**
  - Catabatic conditions
- Typically only few wind measurements available
- **Use regional model for Init & BC**
  - optionally use available surface measurements





- Model & Approach
- Impact of model orography
- Data flow regional/local
- Results complex terrain
- Results alpine foreland
- Summary

regional e.g. WRF

- Global (ECMWF ERA-INTERIM)
- Multi-nesting Δx,y 25/5/1 km
- smallest Domain 130 km x 142 km
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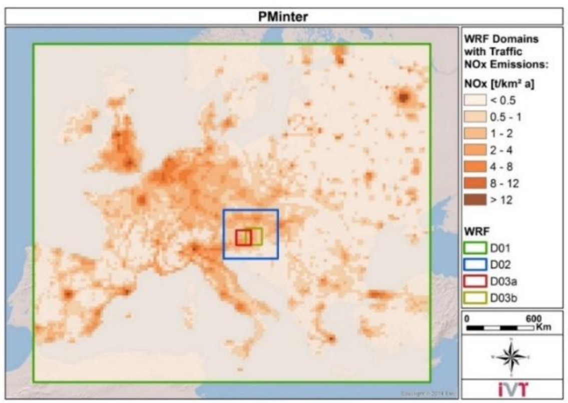
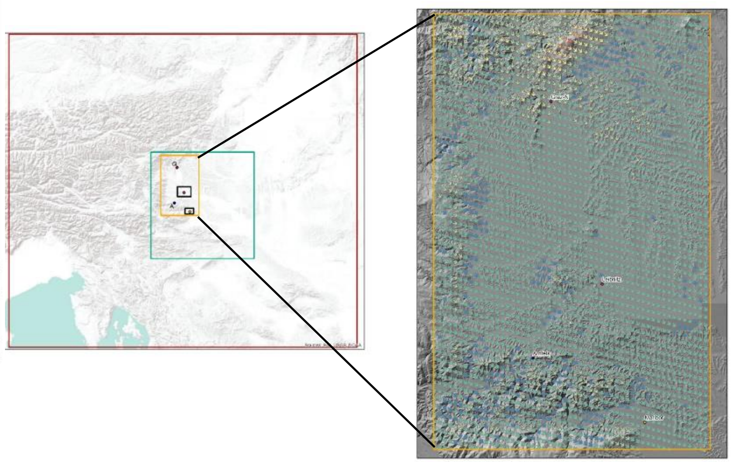
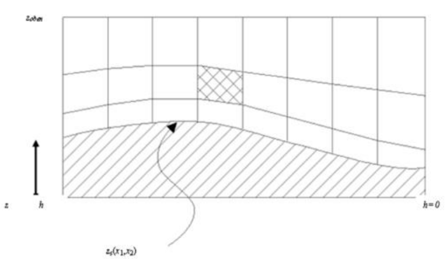
local GRAMM

- SIMPLE algorithm (Patankar & Spalding, 1972)
- Δx,y 50m – 300m
- Prognostic non-hydrostatic



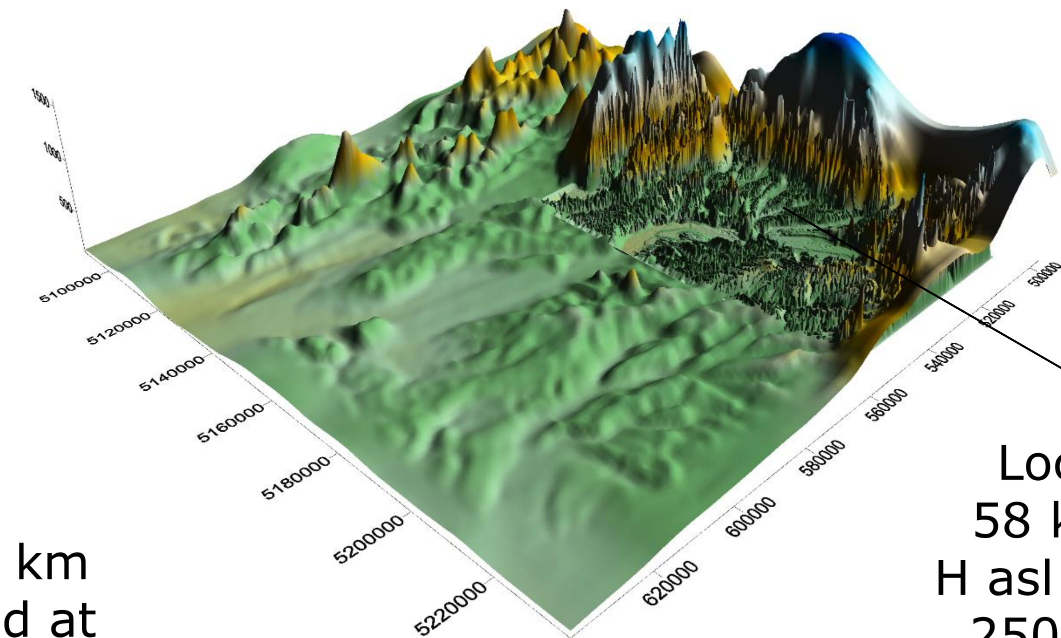




58 km x 90 km
Δx,y 250m

January 2010: low WS & frequent Inversions – tricky!

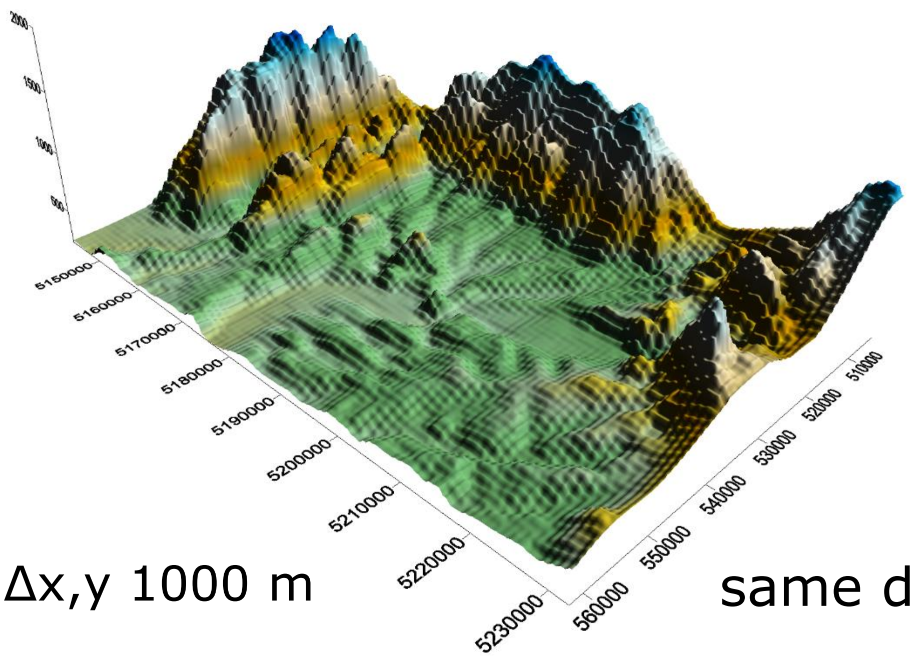
Different model orography & complex terrain implications

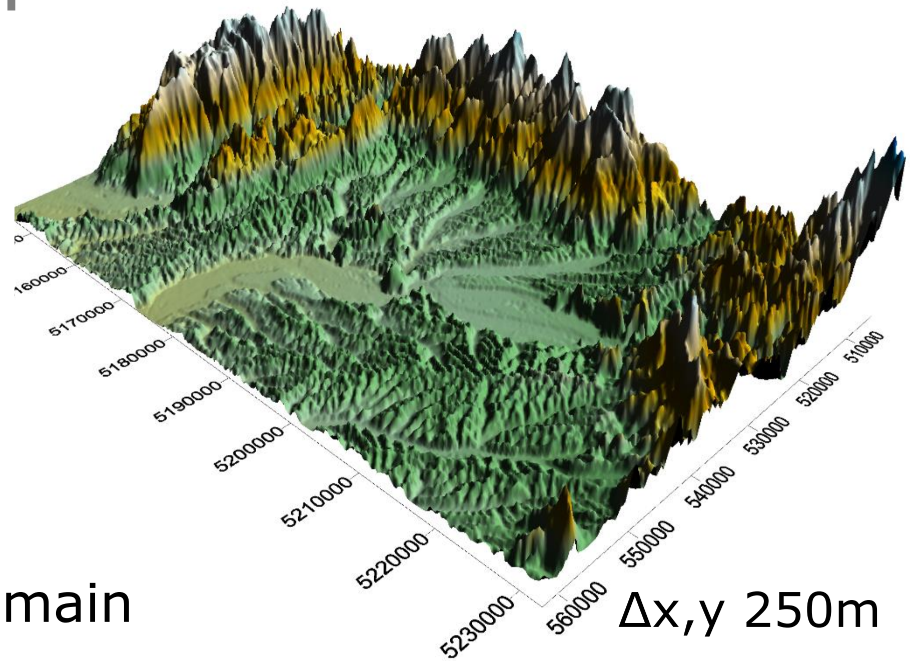


Domain
140 km x 145 km
H asl processed at
1 km x 1 km

Local domain
58 km x 90 km
H asl processed at
250 m x 250 m

Different model orography & complex terrain implications





Δx,y 1000 m same domain Δx,y 250m

finer, detailed & ragged orography → implications on flow:

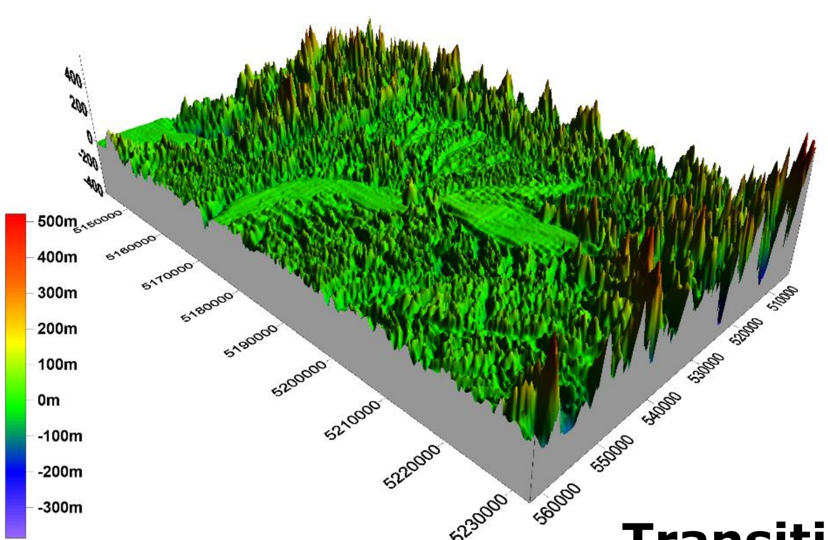
- steeper slopes → more drag
- vertical velocity (lift force, vortices)
- wind direction (drainage, vortices)

➢ Large difference in Δx,y → strong impact on flow

Difference model orography

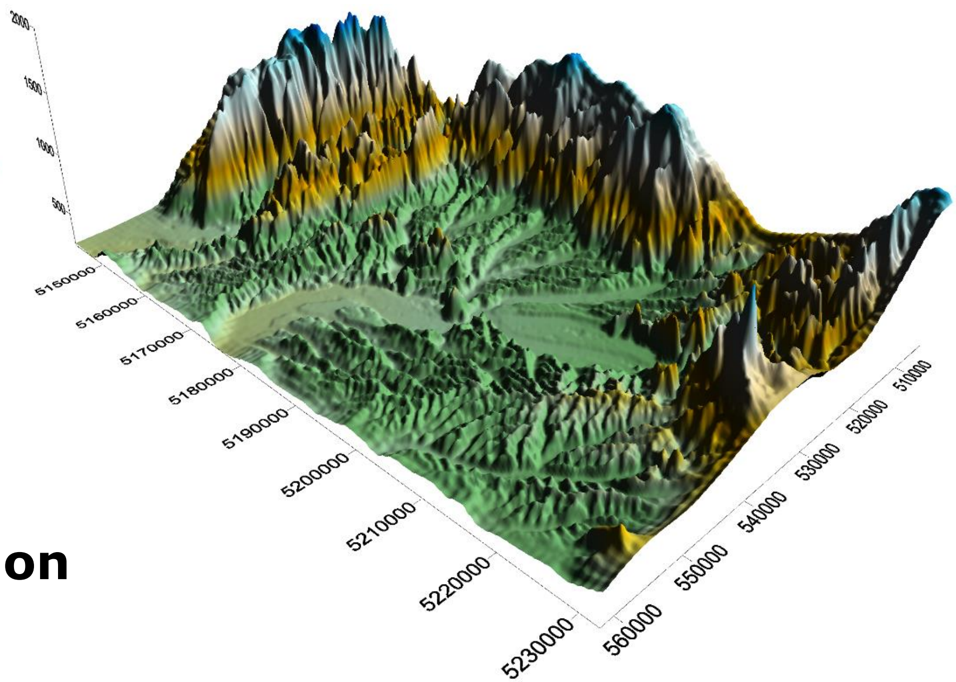
Problematic zone near model domain boundaries, - either

- „smart“ domain choice & smoothing/levelling off
- Create **hybrid orography transition zone**
  boundary: regional orography – core: local HR orography
  → may allow arbitrary domain choice

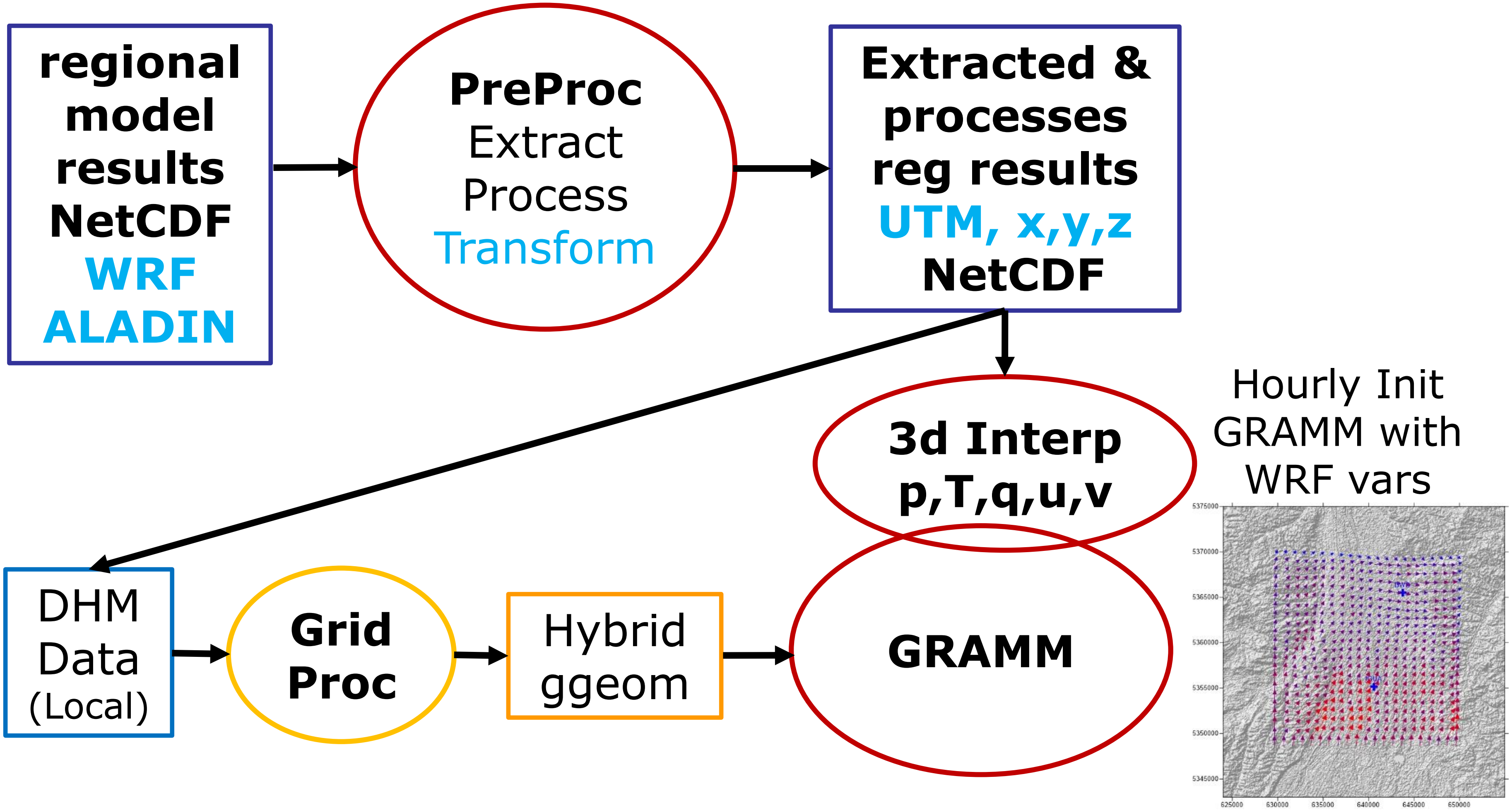


Dif Orogr
Local–Regional

Transition zone

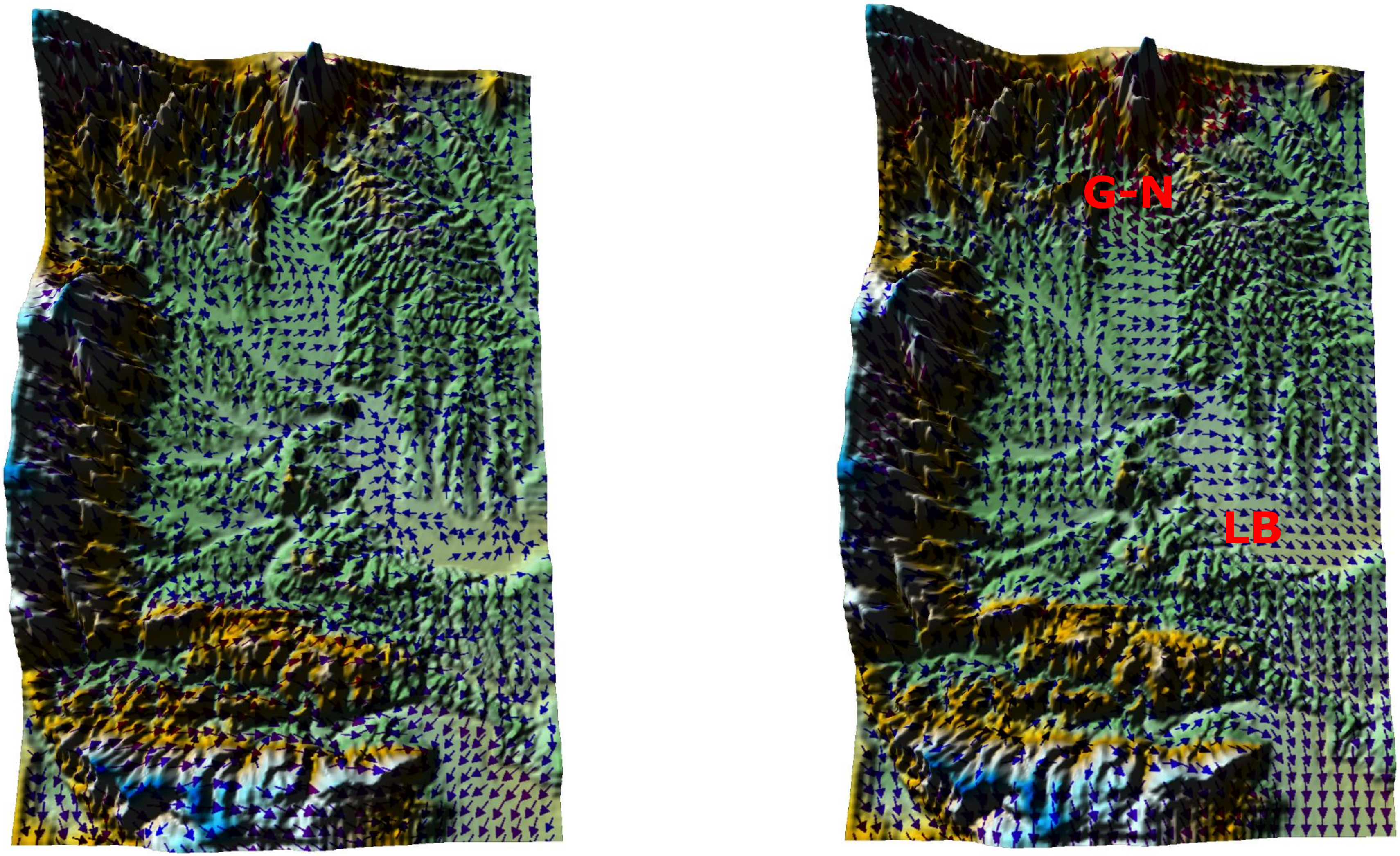


Data Flow regional-local & NetCDF

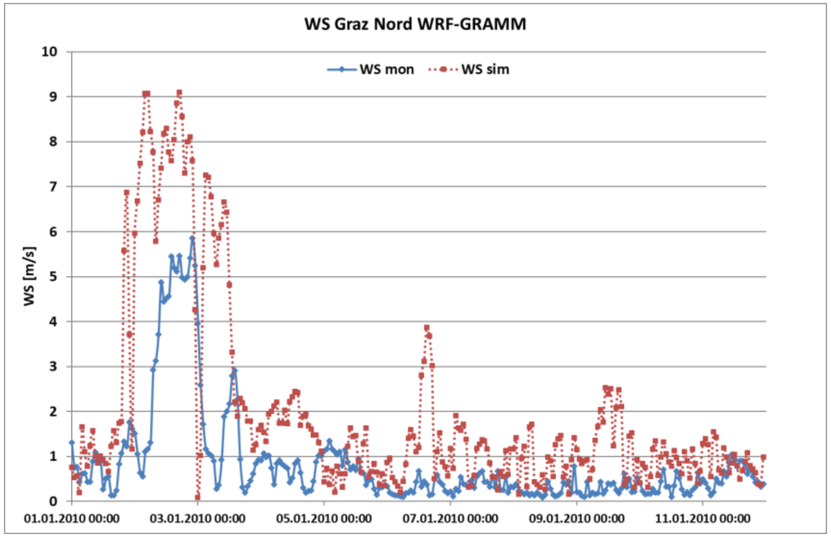


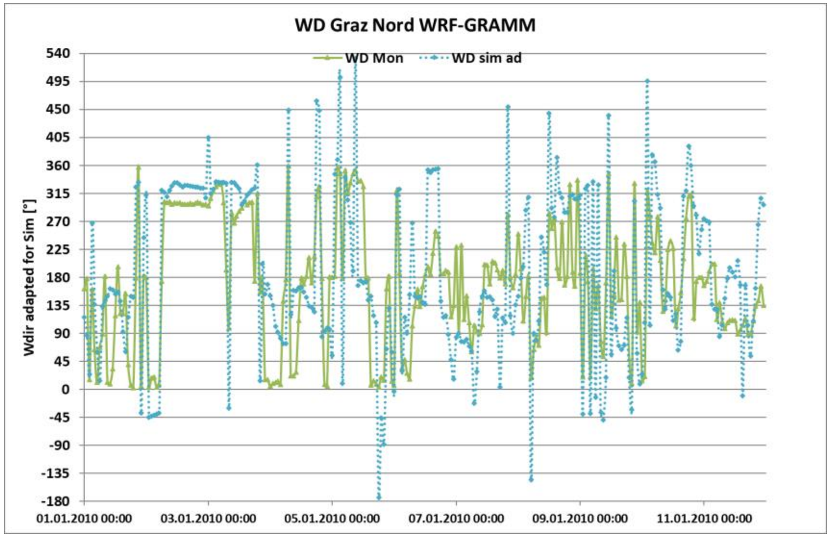
Common Data Format (NetCDF), machine independent, open data standard

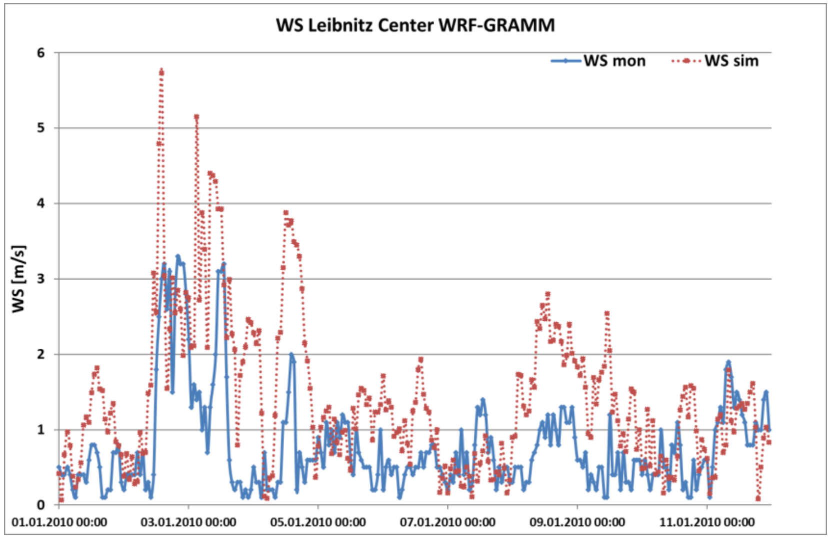
Flow field WRF-GRAMM

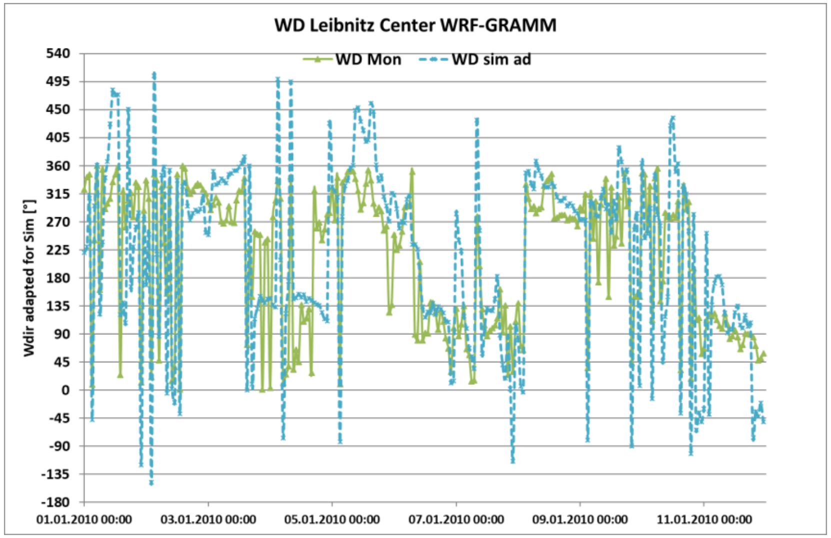


WS & Wdir WRF-GRAMM

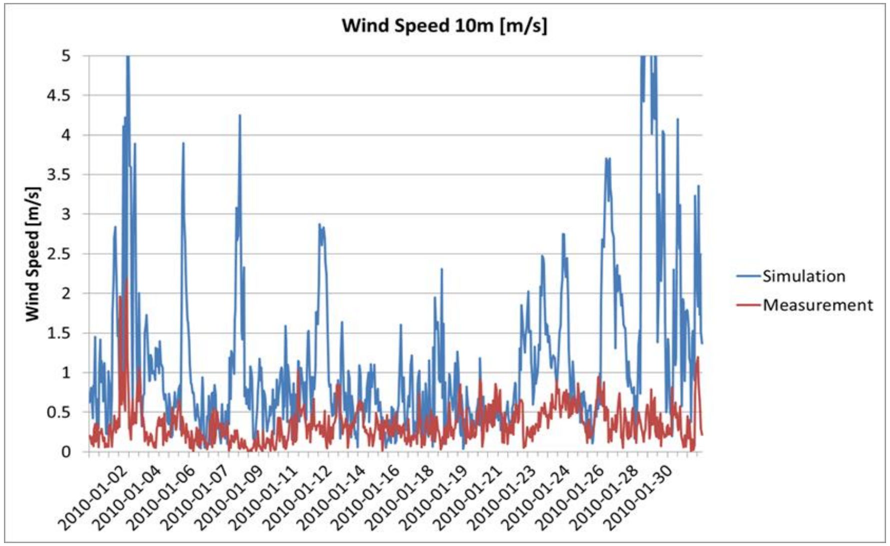


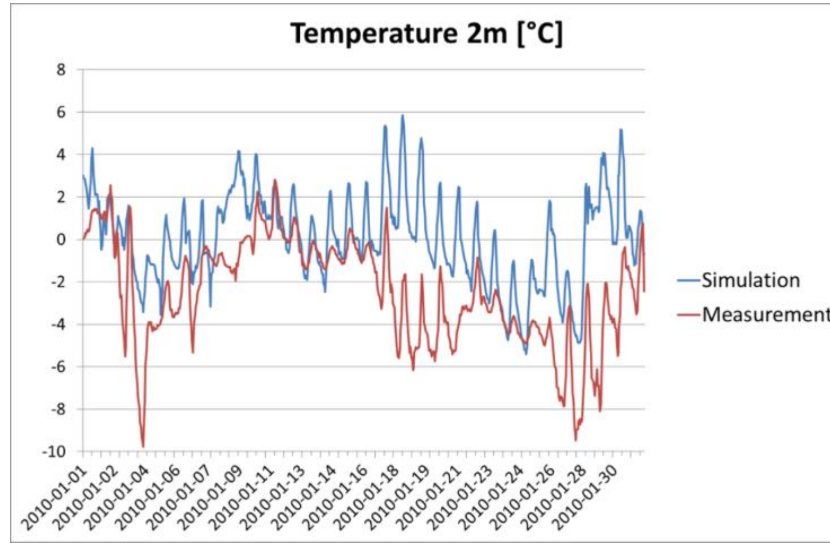






By measurements modified initialisation





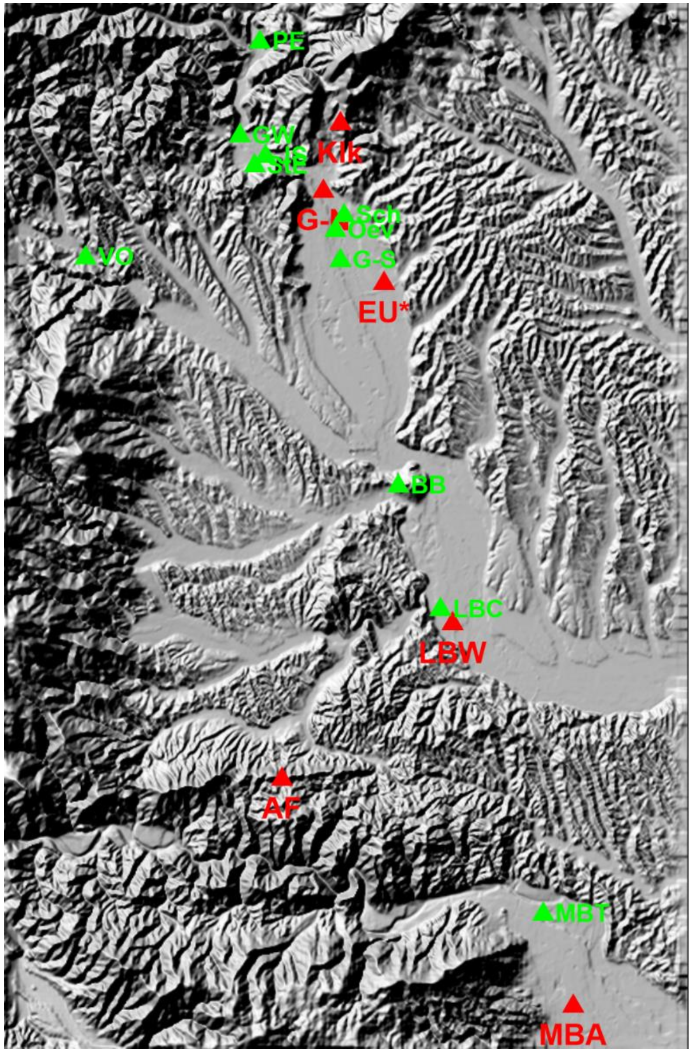
- Reg models substantial deficiencies in complex terrain, i.e. low WS conditions in valleys strong T inversions not captured
- Modified cond‵ initialisation using Wind & T sfc measurements

$$|(u_{sim} - u_{mon})/u_{mon}| > crit \quad \&\& \quad |(v_{sim} - v_{mon})/v_{mon}| > crit$$

WS ≤ *0.8 m/s crit* = 1   *0.8 m/s* < *WS* ≤ *1.5 m/s crit* = 0.5

WS ≥ *1.5 m/s crit* is set to 0.25

By measurements modified initialisation

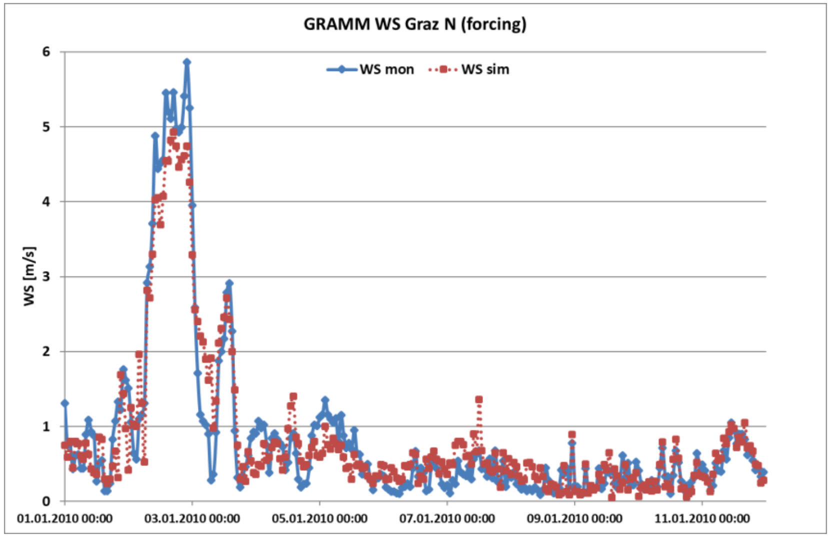


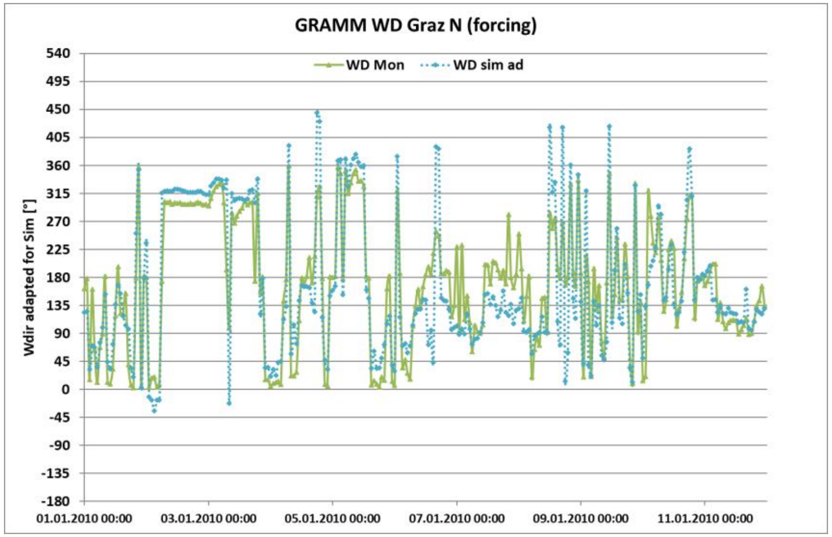
- Vertical weighting profiles: near ground $W_{mon}=1/W_{RM}=0$ at $H_{max\ peak}$ $W_{mon}=0/W_{RM}=1$

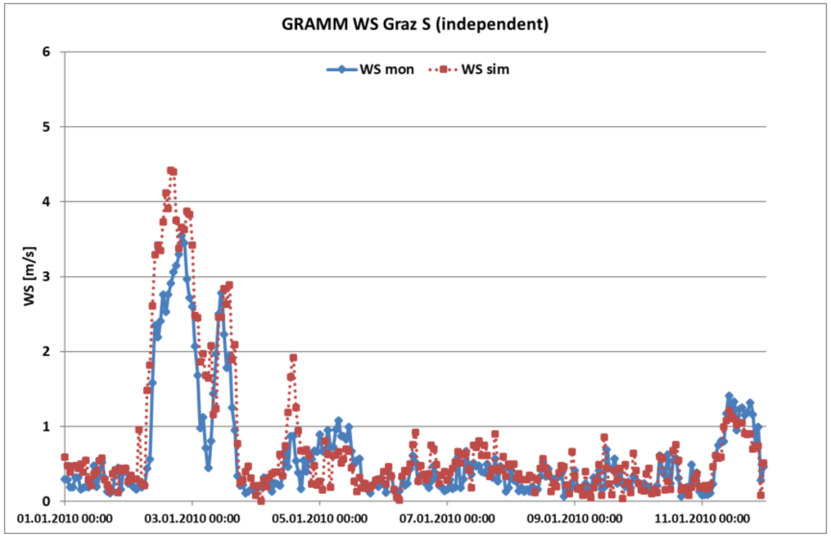
$$zwgt_{i,j,k} = 1 - \Delta z_{i,j,k}/(H_{max\ peak} - H_{min})$$

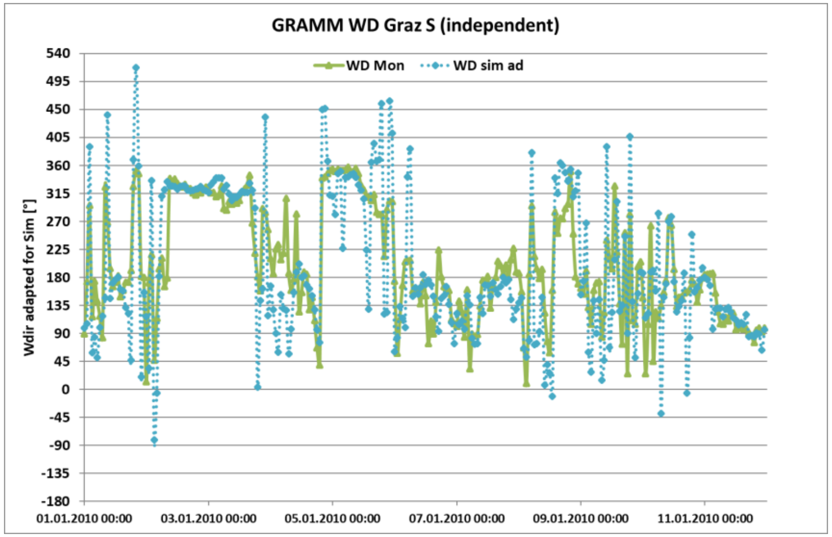
- 6 selected forcing stations
- Localized horiz Wgt (1/R crit)
- Correction for T_{sfc} & T-profile
- further stations used for independent validation

GRAMM WS & Wdir with WRF/Monit init

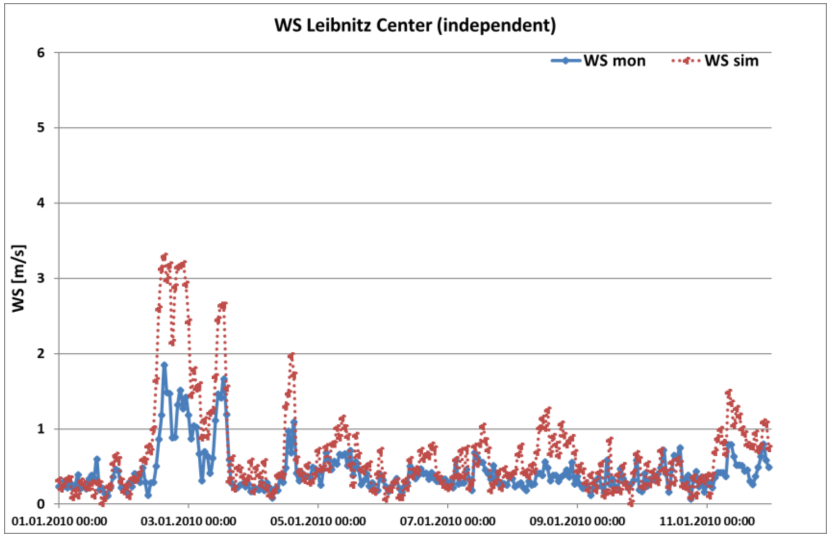


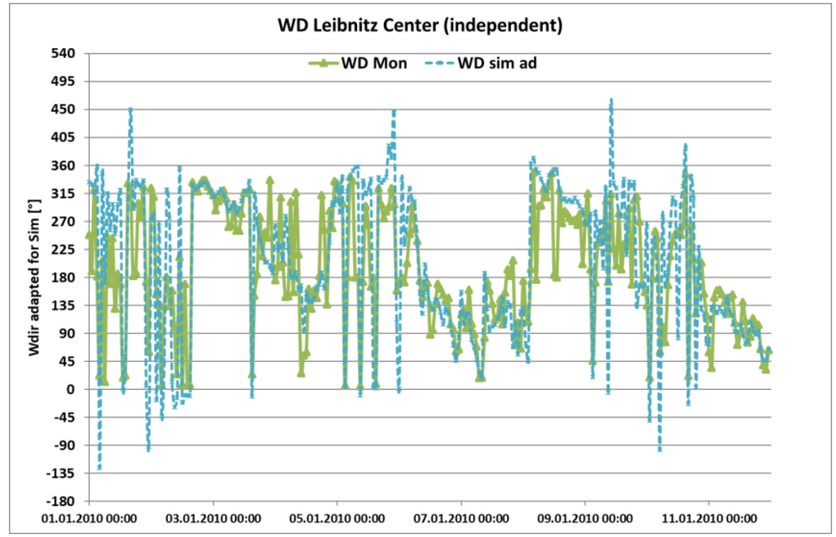


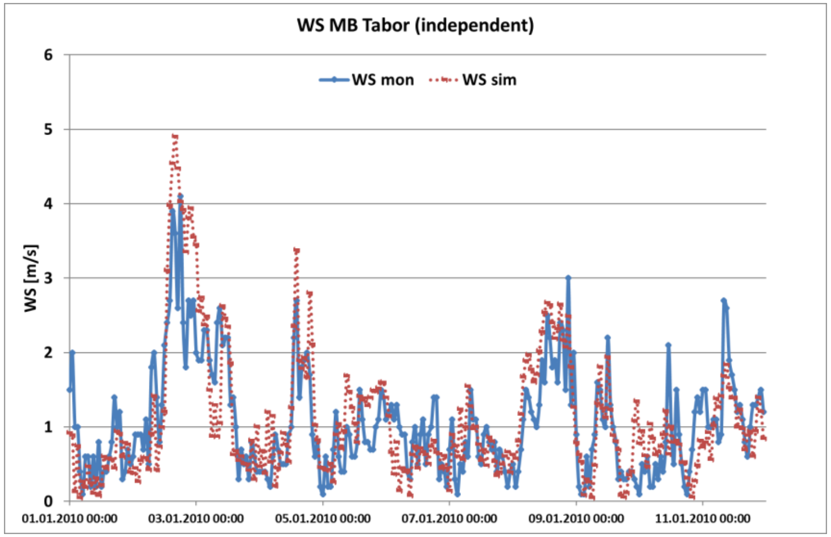


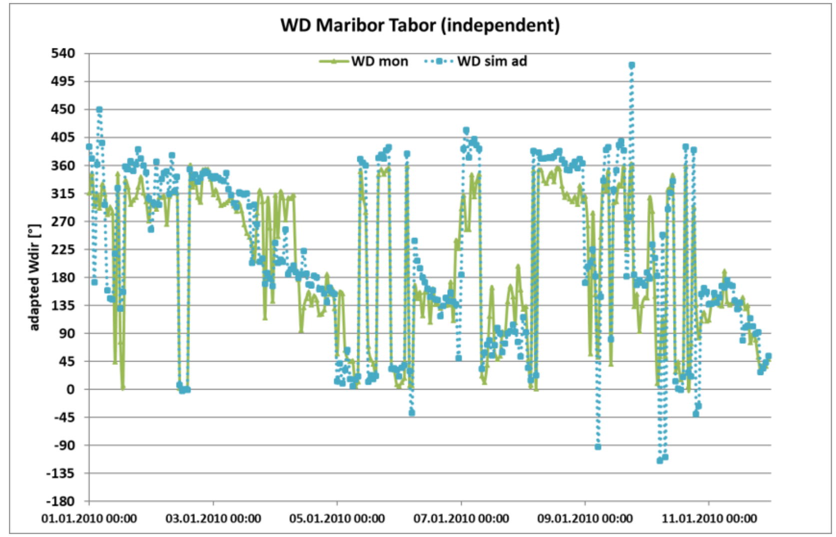


GRAMM WS & Wdir with WRF/Monit init

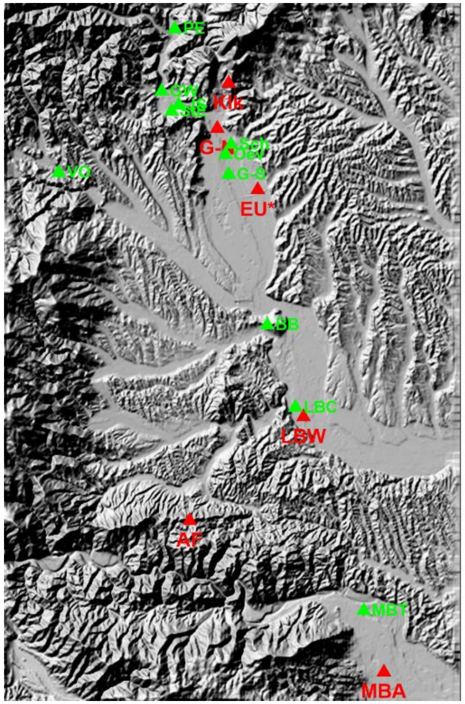


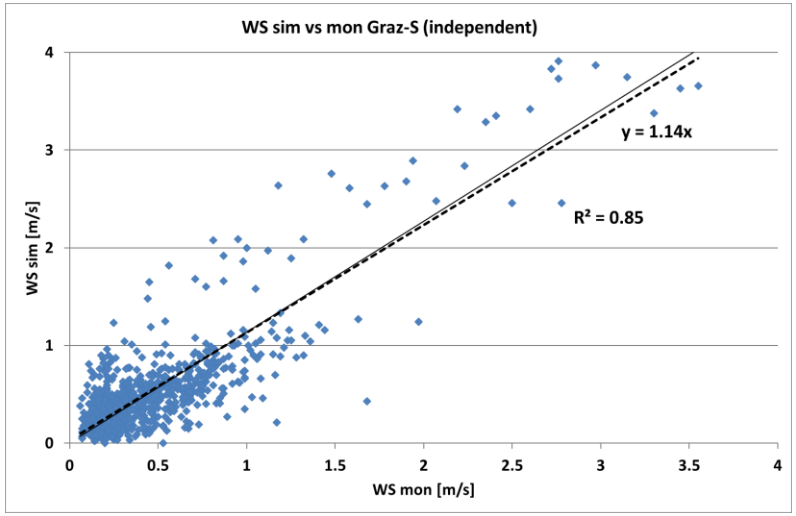




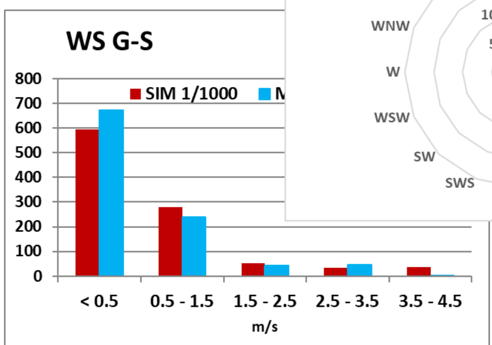


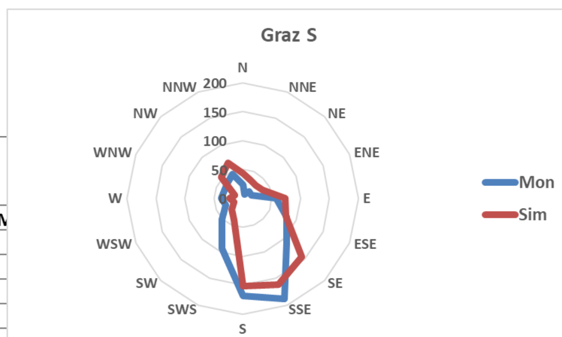
Further validation





Stat	R^2	m
MB-T	0.48	0.85
BB	0.54	0.66
LB-C	0.67	1.54
Dlbg	0.22	2.24
VO	0.76	0.94
G-S	0.85	1.14
G-Sbg	0.76	0.52
G-Oe	0.60	1.42
Peg	0.63	0.78
StrK	0.70	0.93
J-S	0.69	0.69

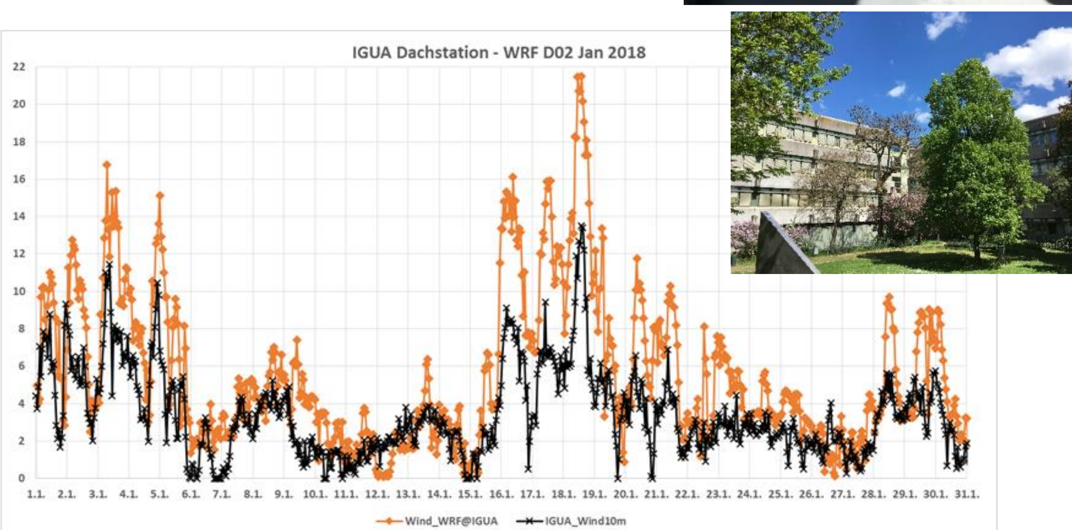


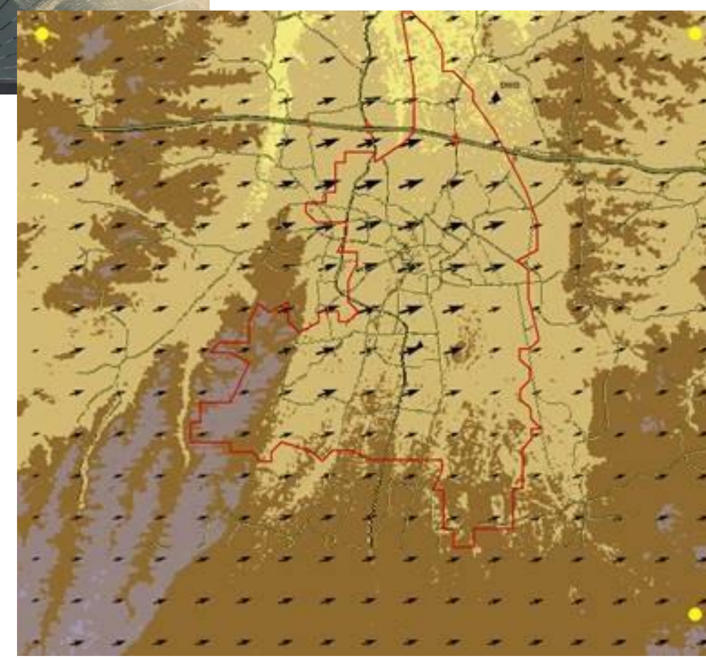


Stat	R^2	m
MB-A	0.92	0.91
LB-W	0.90	0.86
G-N	0.88	0.89
EU*	0.92	0.93
Klk	0.73	0.78
Arnf	0.72	0.76

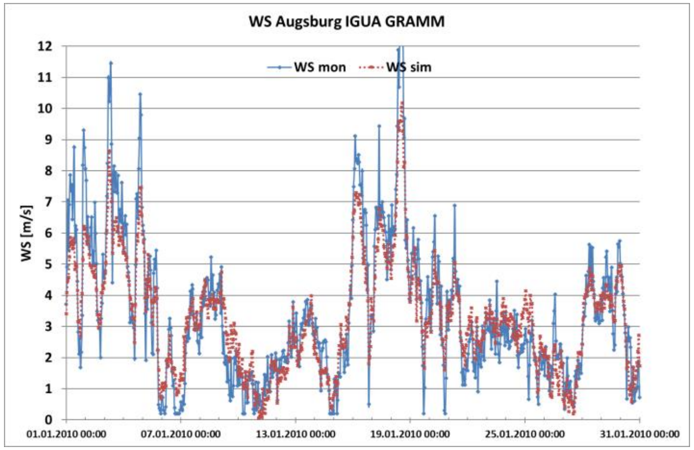
Simulations Augsburg Jan 2018

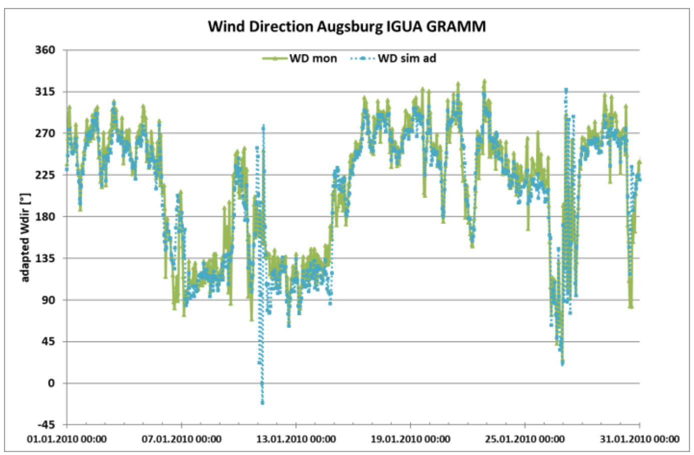
6h NCAR 0.25° Analysis
WRF 1x Nesting
Δx,y D2 ~2.3km

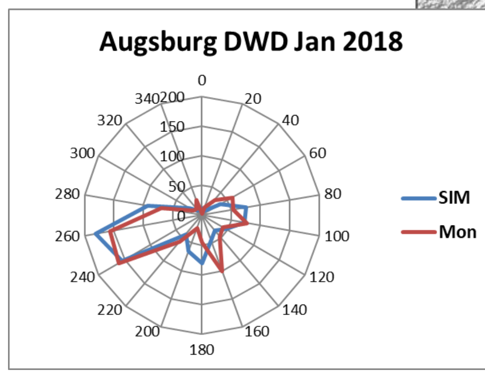


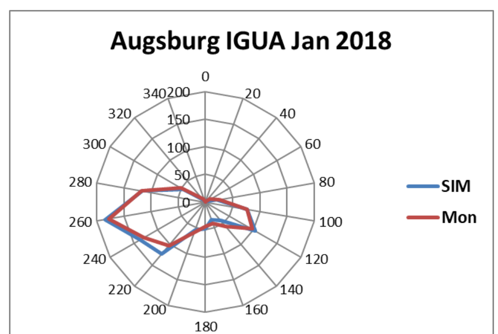


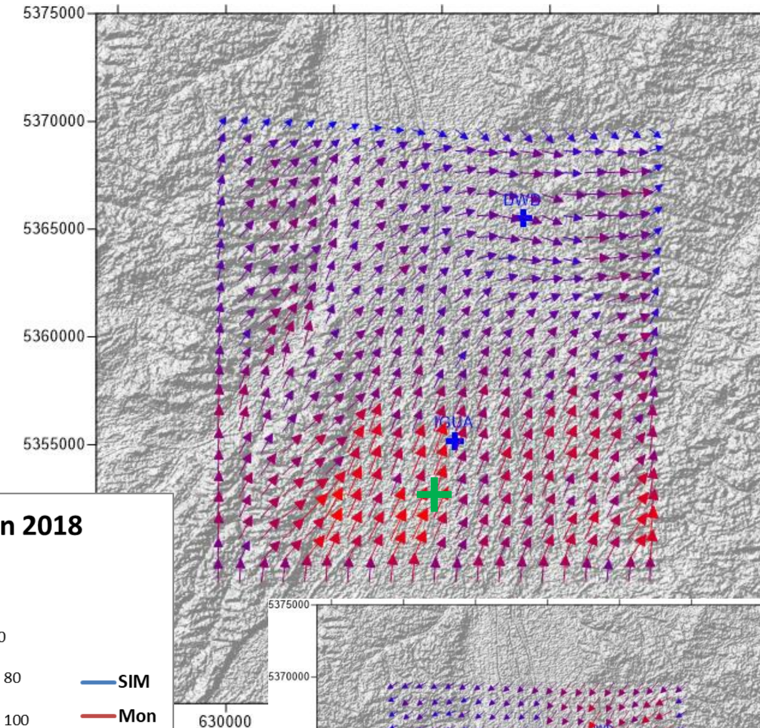
Augsburg Jan 2018

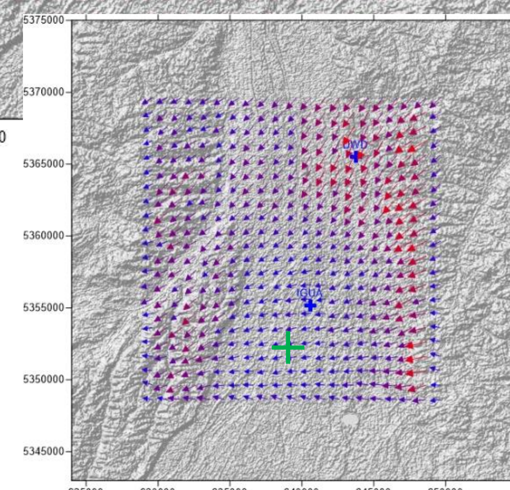






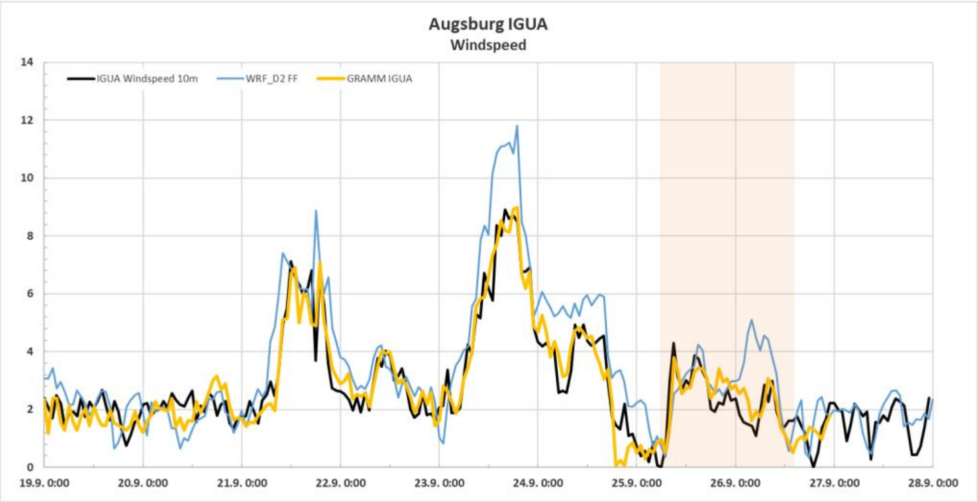


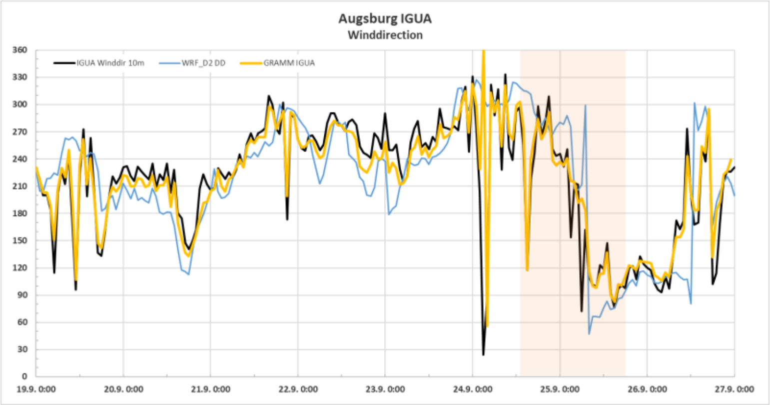


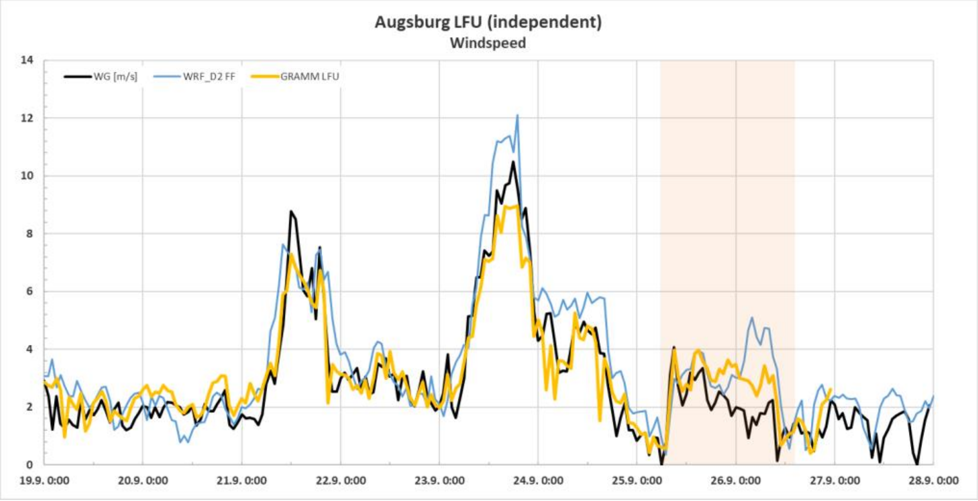


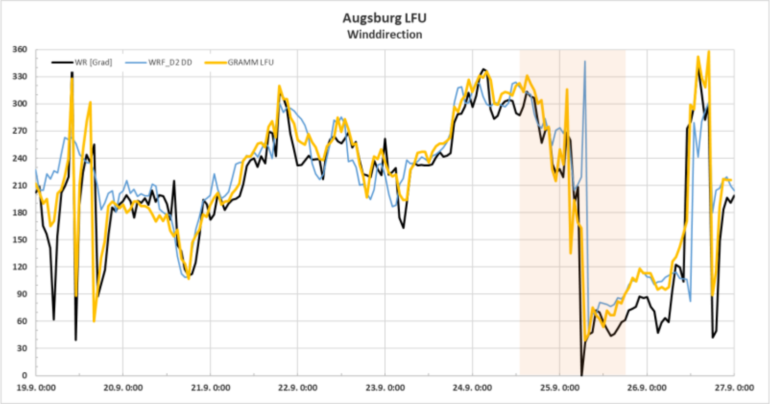
21km x 22km
Δx,y = 100m

Augsburg 19.09.-27.09.18









Summary

- Efficient WRF-GRAMM coupling implemented
- Overall, in complex terrain good representation of mountain and valley wind systems
- WRF-GRAMM reduced significantly excess momentum, improved representation of WS & WD
- modified initialisation using measurements - good results obtained (reanalysis mode)
- In hilly terrain (Augsburg) better WRF performance → very good WRF-GRAMM results