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Climate data downscaling using ALADIN

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15th ALADIN workshop, Bratislava, Slovakia; 10 June 2005

Acknowledgements: Manfred Dorninger, Theresa Gorgas; Jure Cedilnik

Motivation

- Climate (change) impact research requires high-resolution data
- Use ALADIN for dynamical downscaling of global climate datasets
  - ERA40-Analyses (1999; 1981-1990)
  - ECHAM5-Simulations (1981-'90; 2041-'50)

-> Results from different experiments for 1999

Experimental setup …

- ‘Perfect boundary’ conditions (ERA40 analyses)
- ALADIN 25t3, LINUX-cluster, ifort 8.1
- (old) LACE domain, 12km, 41 levels
- Sequence of daily initialized 30h forecasts
  - No climate-run (yet!)
- Single-step, one-way nesting (120km -> 12km)*
- 6h coupling

-> Applicability of ALADIN for this research?

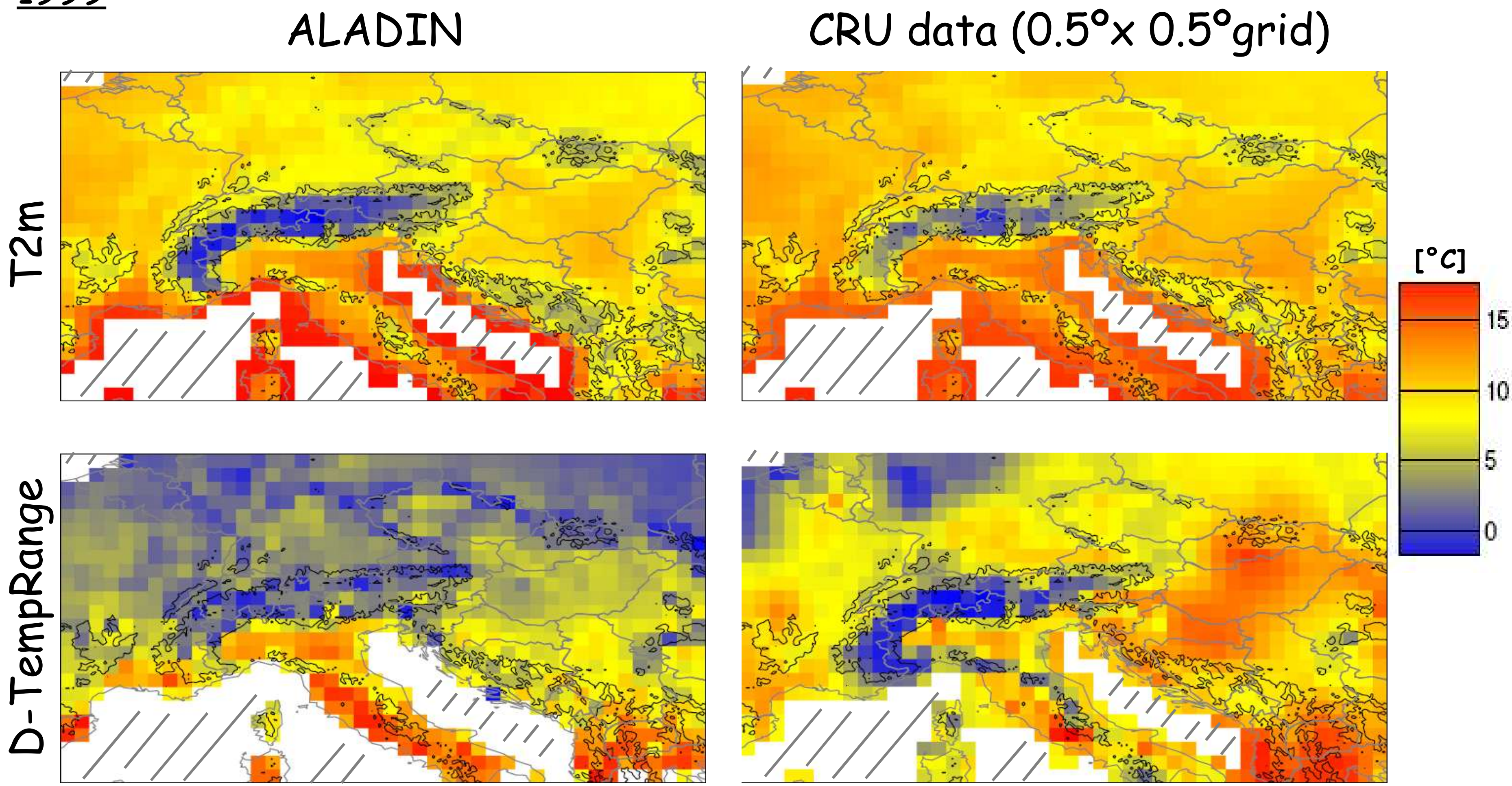
-> Potential problems for ‘climate applications’ ?

-> Model setup ?

* (Beck et al. 2004 investigate the feasibility of the single-step approach)

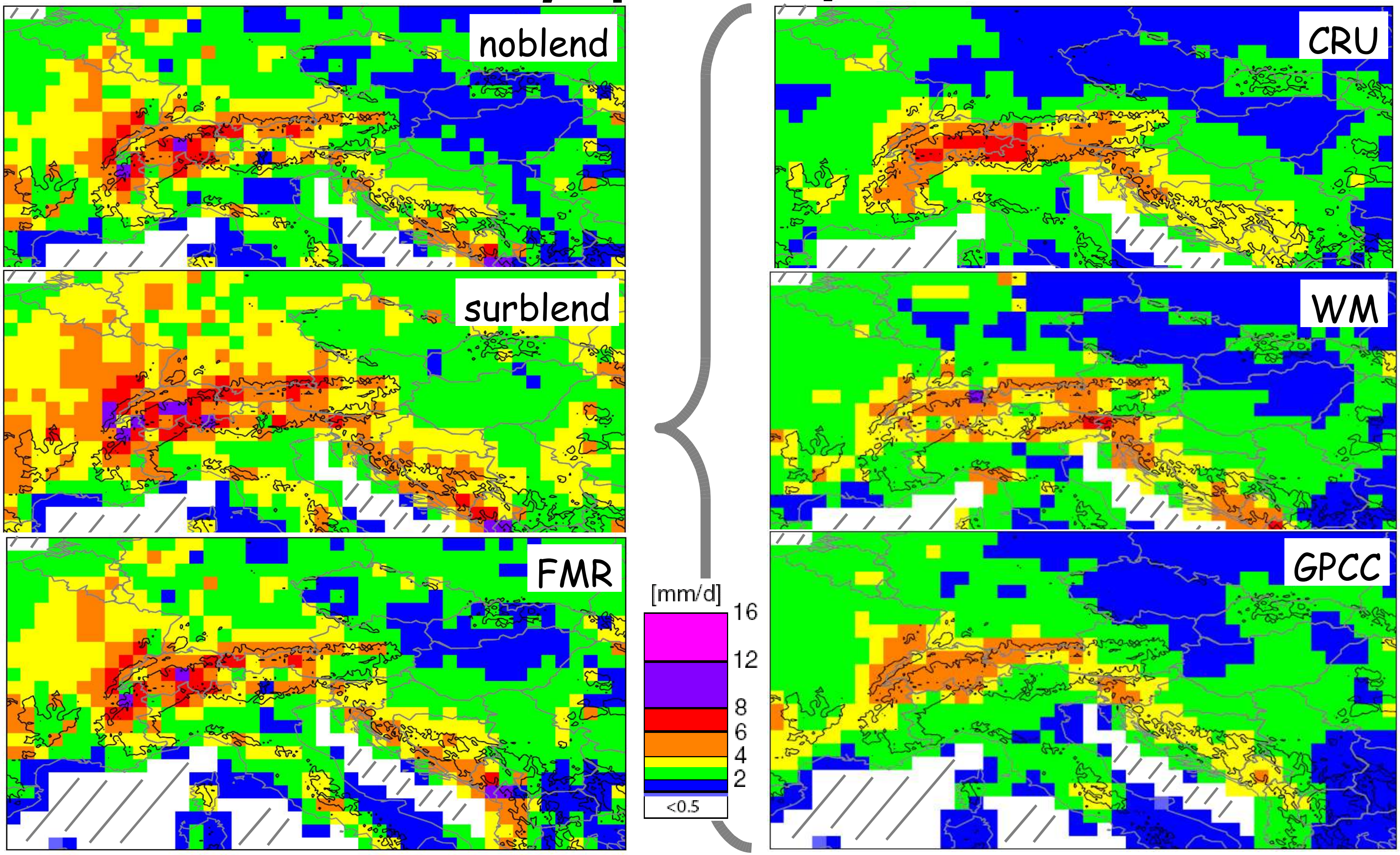
Annual mean temperature #1

1999



-> ALADIN - CRU: Negative temp-bias ~ -1° (up to -5° locally)
-> Large underestimation of diurnal-temperature-range -> cloud cover?

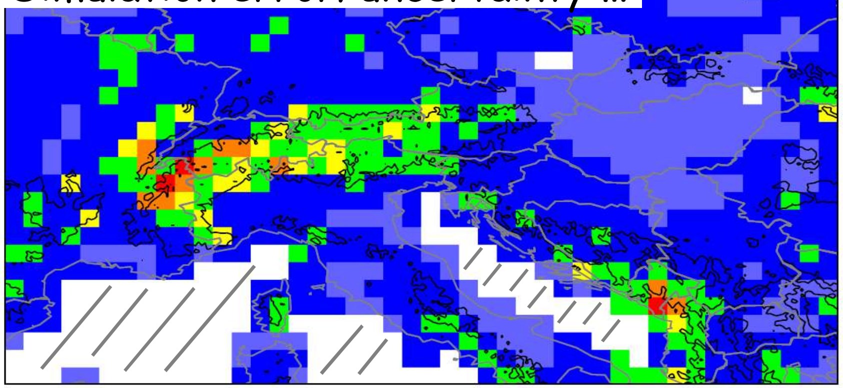
Mean daily precip for 1999



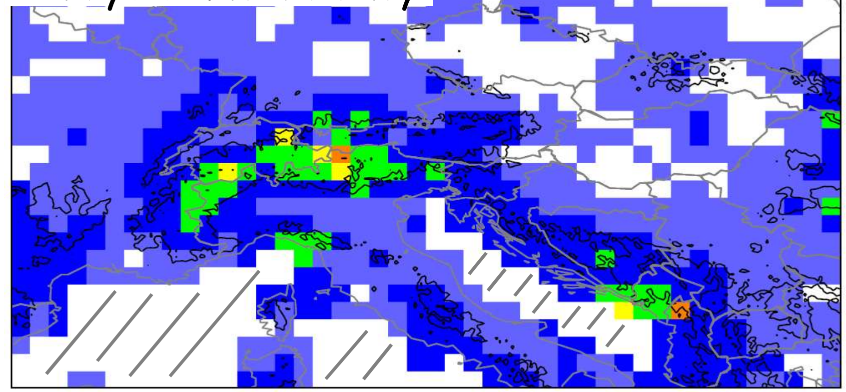
-> Similar performance compared to precipitation datasets …

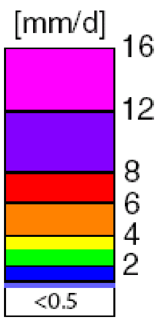
Evaluation uncertainty?

Simulation error/uncertainty …



Analysis uncertainty





RMS of <u>monthly</u> grid point estimates for 1999

… for three 0.5°x 0.5° datasets

- CRU Mitchell et al. (2003)
- GPCC http://gpcc.dwd.de
- Willmott and Matsuura (2001)

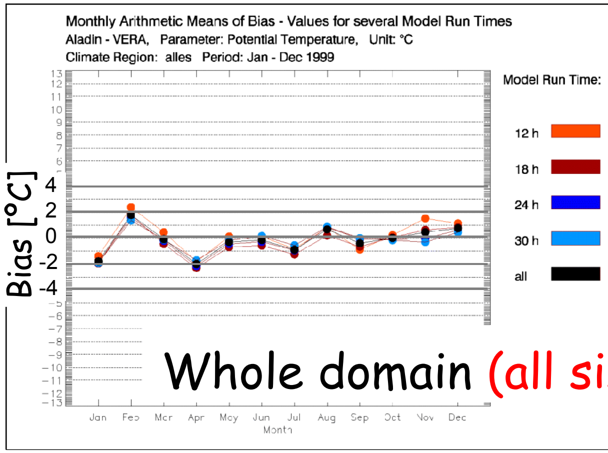
-> Similar spatial structures -> Careful interpretation of results!

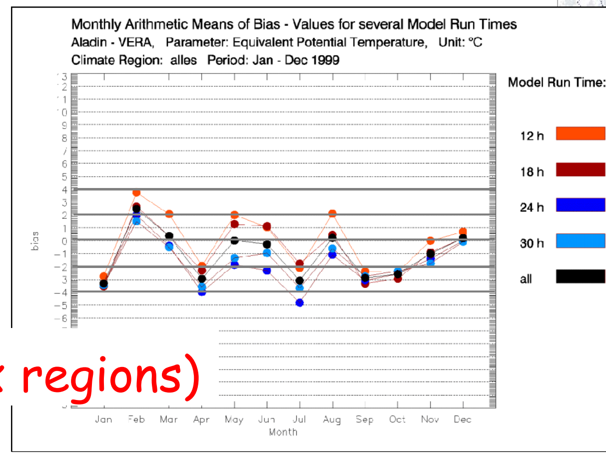
-> ALADIN - GPCC: Positive bias ~0.5-1.0 mm/d (locally: up to 5 mm/d)

High-resolution comparison

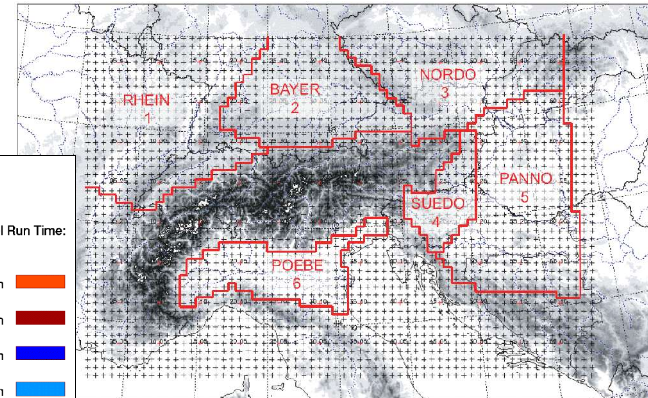
Pot. temp

Equiv. pot. temp

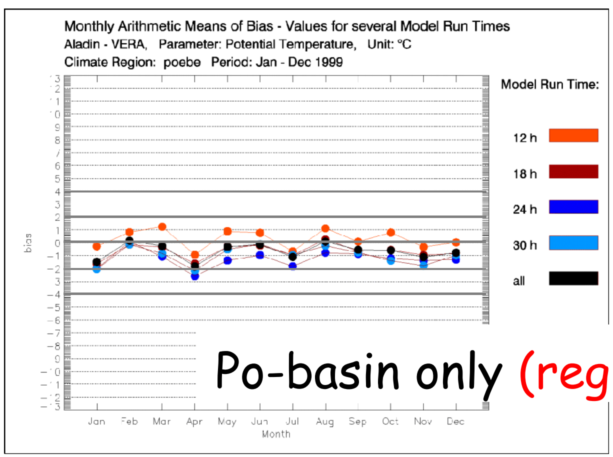


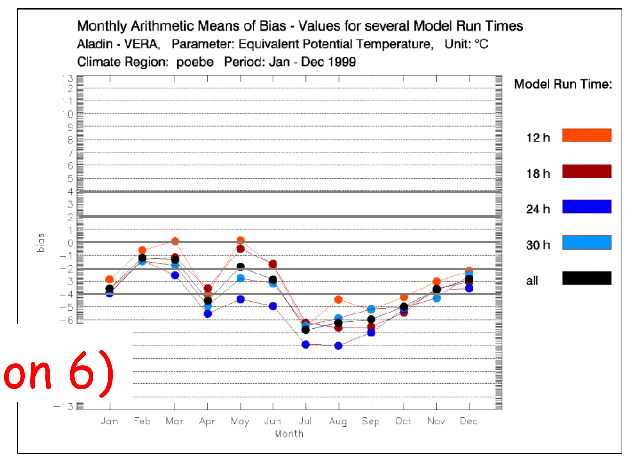


Whole domain (all six regions)



'ALADIN – Analysis'





Po-basin only (region 6)

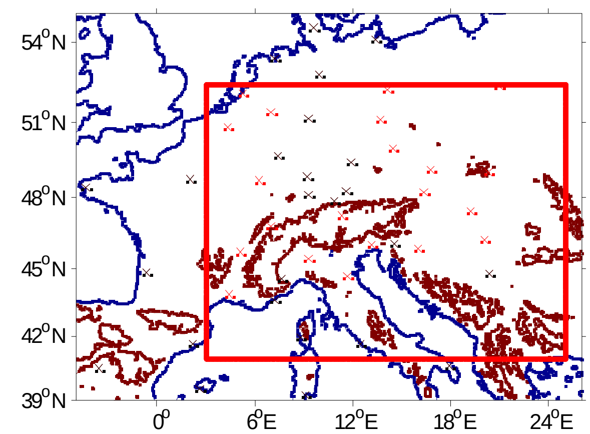
-> Dry-bias in Po-basin

? ERA40

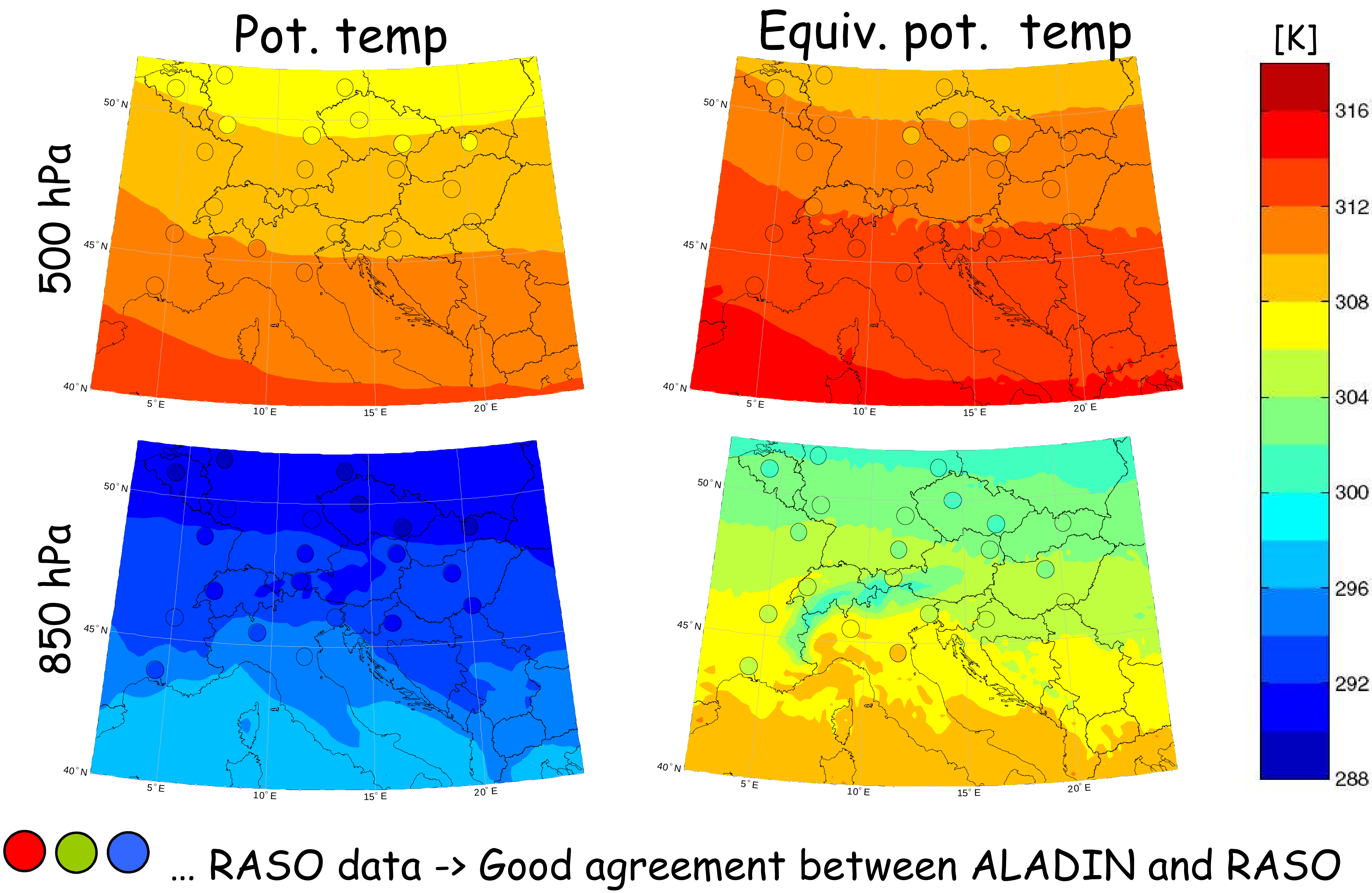
Upper-air parameters?

-> Comparison against RASO data

CALRAS dataset (Haeberli 2003)

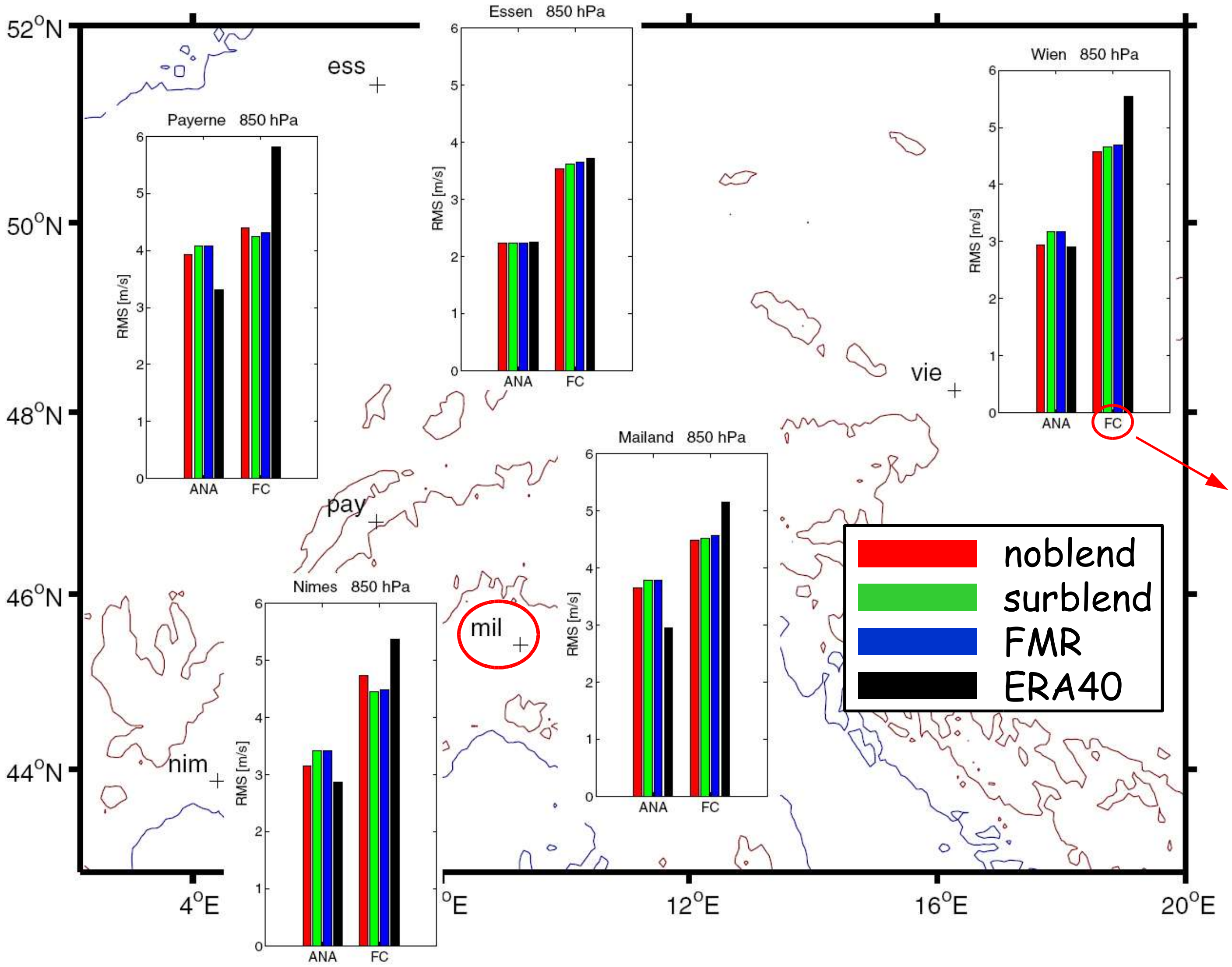


Annual mean temperature #2



... RASO data -> Good agreement between ALADIN and RASO

RMSE windfield 850hPa



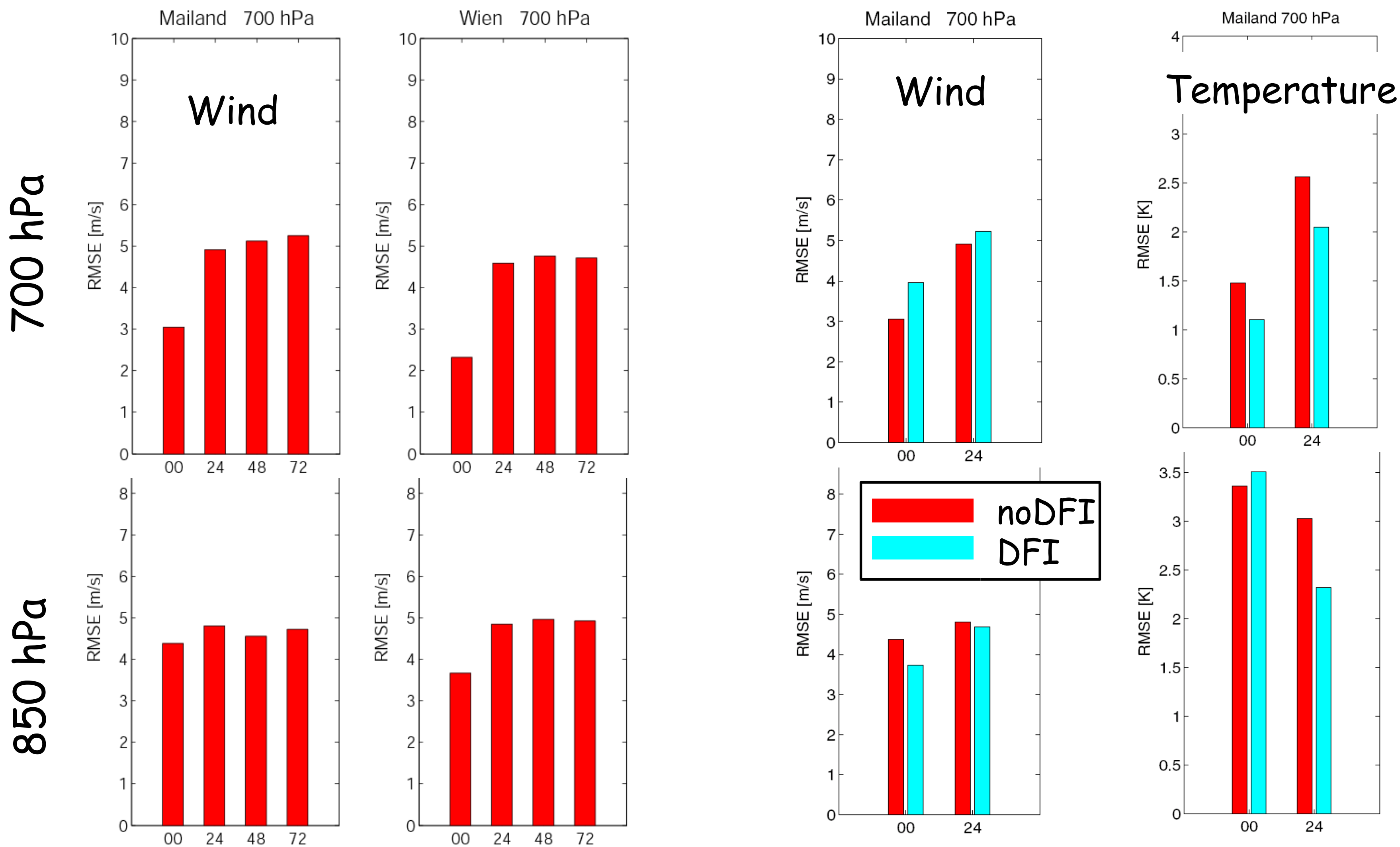
- ALADIN profiles
- ERA40 profiles

- CALRAS soundings

24h forecast !

$$\mathrm{MSE} = \overline{(\mathbf{v}_M - \mathbf{v}_C)^{\mathrm{T}}(\mathbf{v}_M - \mathbf{v}_C)} = \overline{(\mathbf{v}_M - \mathbf{v}_C)^2} = \overline{\mathbf{v}_M}^2 + \overline{\mathbf{v}_C}^2 + \overline{\mathbf{v}_M'^2} + \overline{\mathbf{v}_C'^2} - 2\,\overline{\mathbf{v}_M} \cdot \overline{\mathbf{v}_C} - 2\,\overline{\mathbf{v}_M' \cdot \mathbf{v}_C'}$$

Saturation of error growth?



Summary & outlook

- ALADIN performs pretty well ☺
- Overestimation of precipitation (?)
  - But also: substantial analysis uncertainty!
- Underestimation of diurnal temp.range
- Good performance for upper-air parameters
  - No systematic error-growth (compared to RASO)

- Next task: 10y-simulations (ERA40 & ECHAM5)
- Dynamical downscaling promising
  - Comparison with ALADIN-climate-run ?

Dynamical downscaling

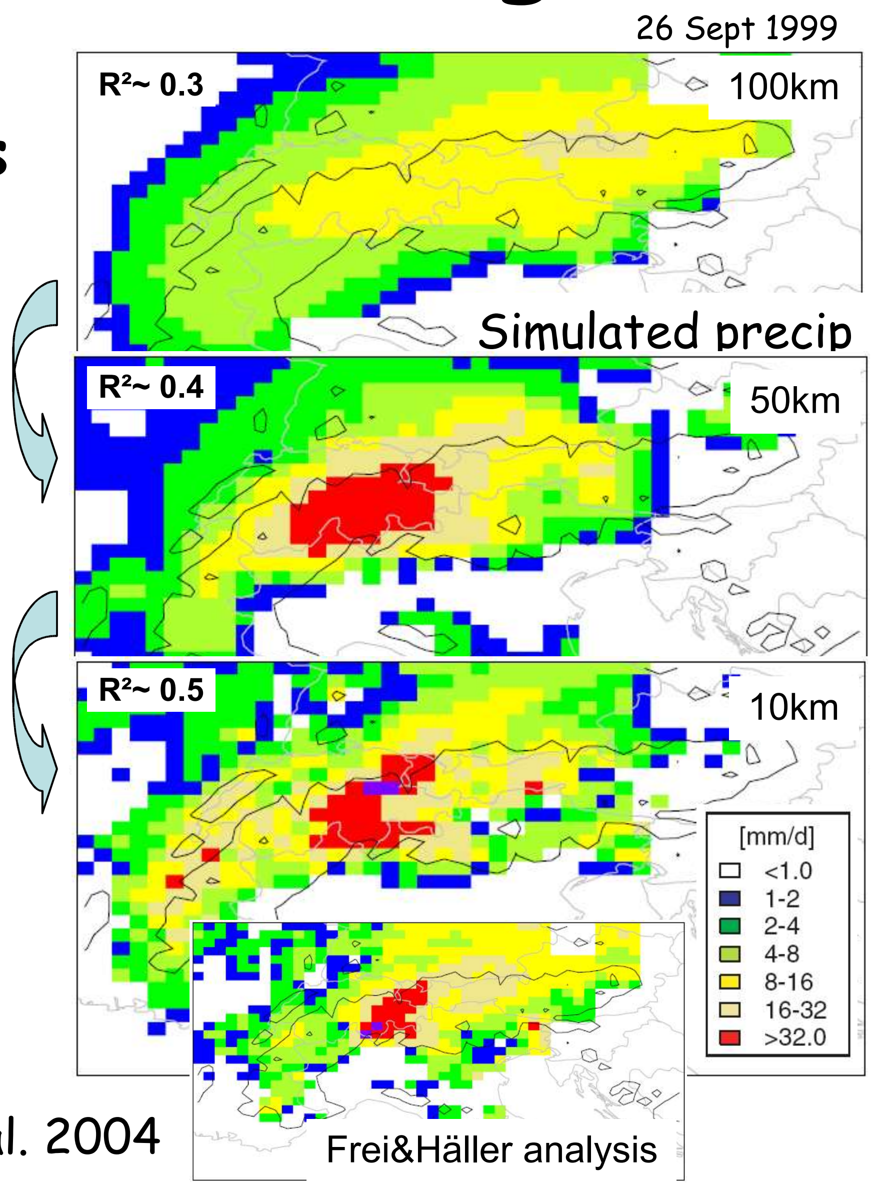
Sequence of short integrations

- Avoid additional, systematic errors ?
- Easy to implement on basis of NWP setup

but:

? spinup/adjustment problem

? 'Memory' of surface fields



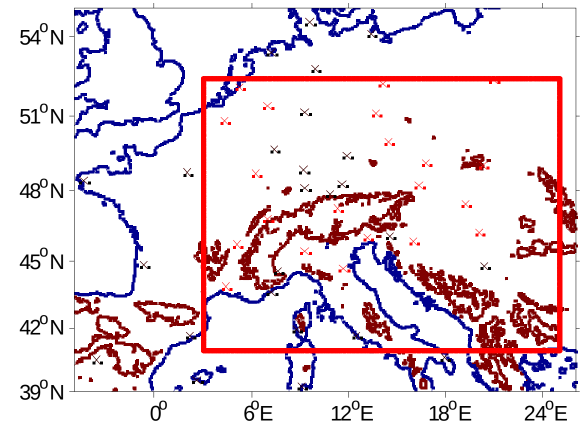
Promising results for precipitation:
Pan et al. 1999, Qian et al. 2003, Beck et al. 2004

-> Precipitation pattern influenced by flow aloft

-> Investigation of lower-tropospheric wind field

- Comparison with RASO data

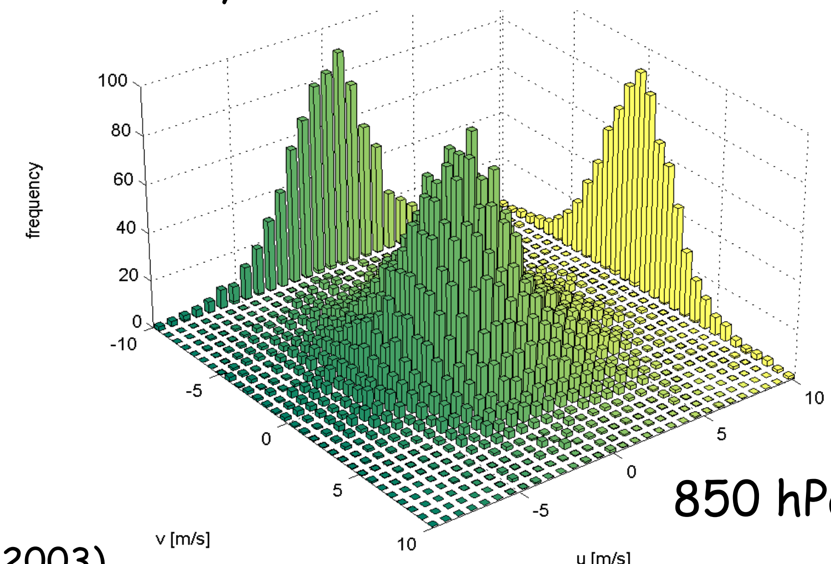
  CALRAS* dataset



Red × indicate stations used

- 'Area-to-point' comparison
  - Simulated profiles
  - Representative ?

u, v differences for 1999

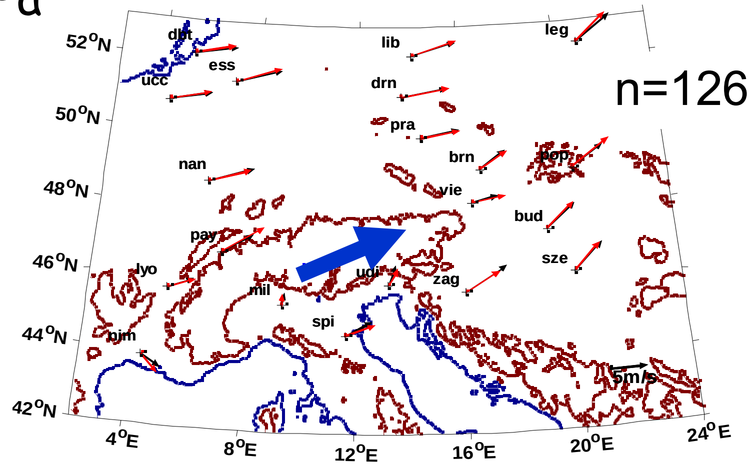


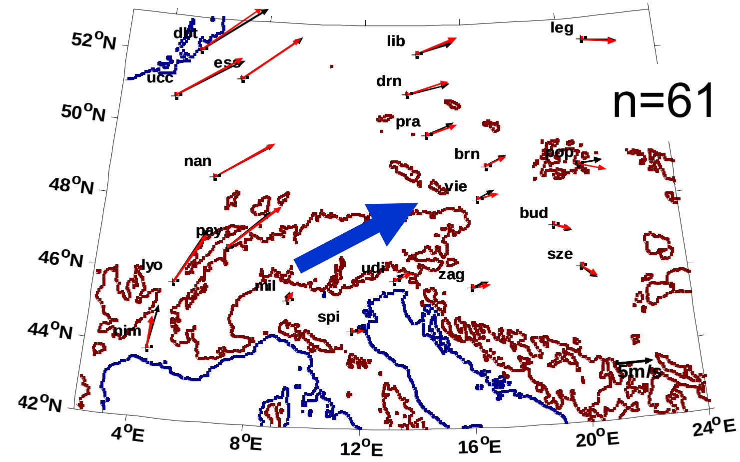
850 hPa

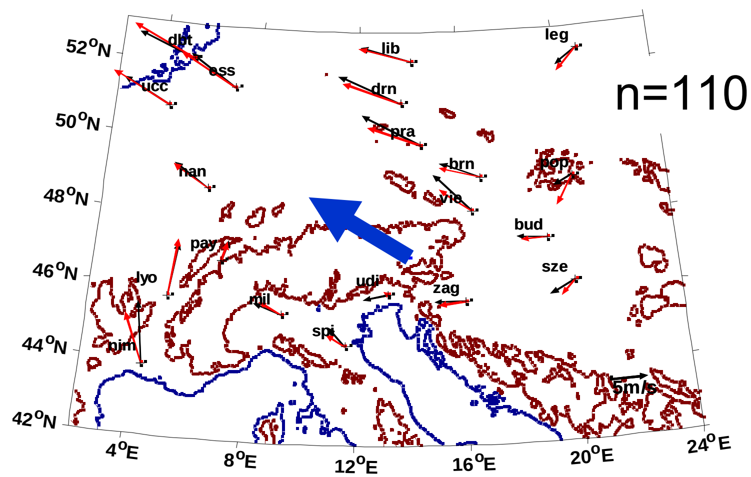
- Systematic deviations?
  - Simulation minus CALRAS

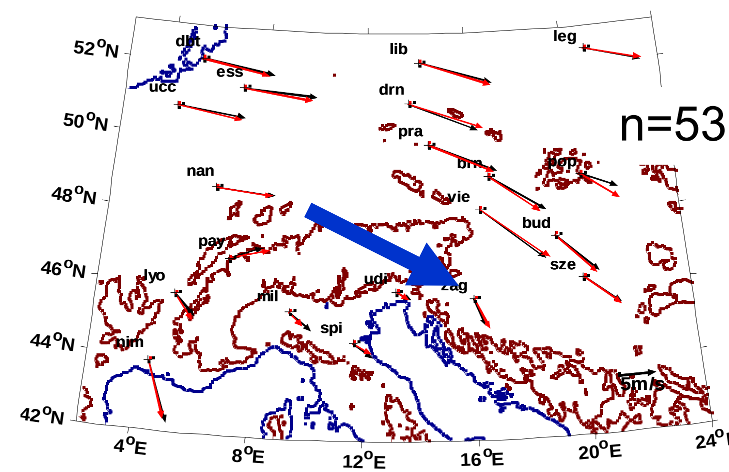
*The Comprehensive ALpine RAdioSonde dataset (Häberli 2003)

850 hPa

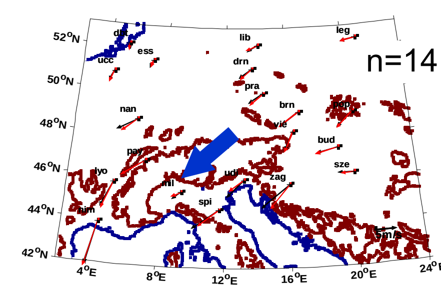








→ CALRAS wind → ALADIN wind



-> Clusters of daily RASO data and corresponding days from model simulation

Wind field evaluation

$$\mathrm{MSE} = \overline{(\mathbf{v}_M - \mathbf{v}_C)^{\mathrm{T}}(\mathbf{v}_M - \mathbf{v}_C)} = \overline{(\mathbf{v}_M - \mathbf{v}_C)^2} =$$

$\overline{(\ldots)} \equiv$ mean over time

$$= \overline{\mathbf{v}_M}^2 + \overline{\mathbf{v}_C}^2 + \overline{\mathbf{v}_M'^2} + \overline{\mathbf{v}_C'^2} - 2\,\overline{\mathbf{v}_M} \cdot \overline{\mathbf{v}_C} - 2\,\overline{\mathbf{v}_M' \cdot \mathbf{v}_C'}$$

$\mathbf{v} = \overline{\mathbf{v}} + \mathbf{v}'$

$$\delta = \overline{\mathbf{v}_M} - \overline{\mathbf{v}_C}$$

$$\beta = \mathrm{acos}\left(\frac{\overline{\mathbf{v}_M} \cdot \overline{\mathbf{v}_C}}{|\overline{\mathbf{v}_M}||\overline{\mathbf{v}_C}|}\right)$$

Pay	RMSE [m/s]	δ [m/s]	β [^{o}]
A1	4.4	1.0	5
A2	4.3	0.3	27
A3	4.2	0.2	26
mA1	4.1	0.6	3

-> Payerne, 850 hPa

- Investigation of flow patterns

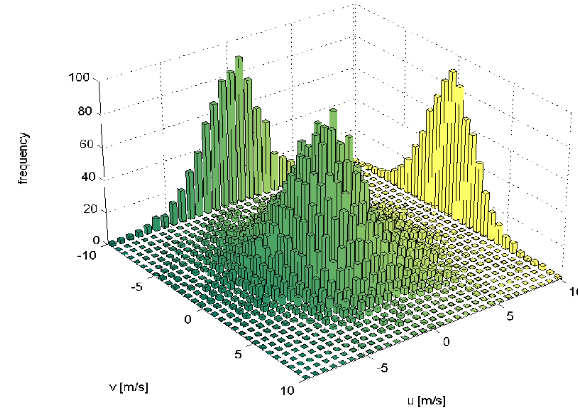
  -> Cluster analysis of daily windfields

'Distance measure': RMSE of RASO stations at 4 levels for days s and t

$$\mathrm{d}_{s,t} = \sqrt{\overline{(\tilde{\mathbf{v}}_s - \tilde{\mathbf{v}}_t)^2}}$$

$\overline{(\ldots)} \equiv$ mean over 20 stations and 4 levels

… other approaches



- Systematic deviations?
  - Freq. distribution of difference vectors
- Climatology of simulated flow-patterns
  - Cluster analysis of daily windfields
  - Comparison of RASO & model clusters