Parameterization of orographic effects on surface radiation in AROME

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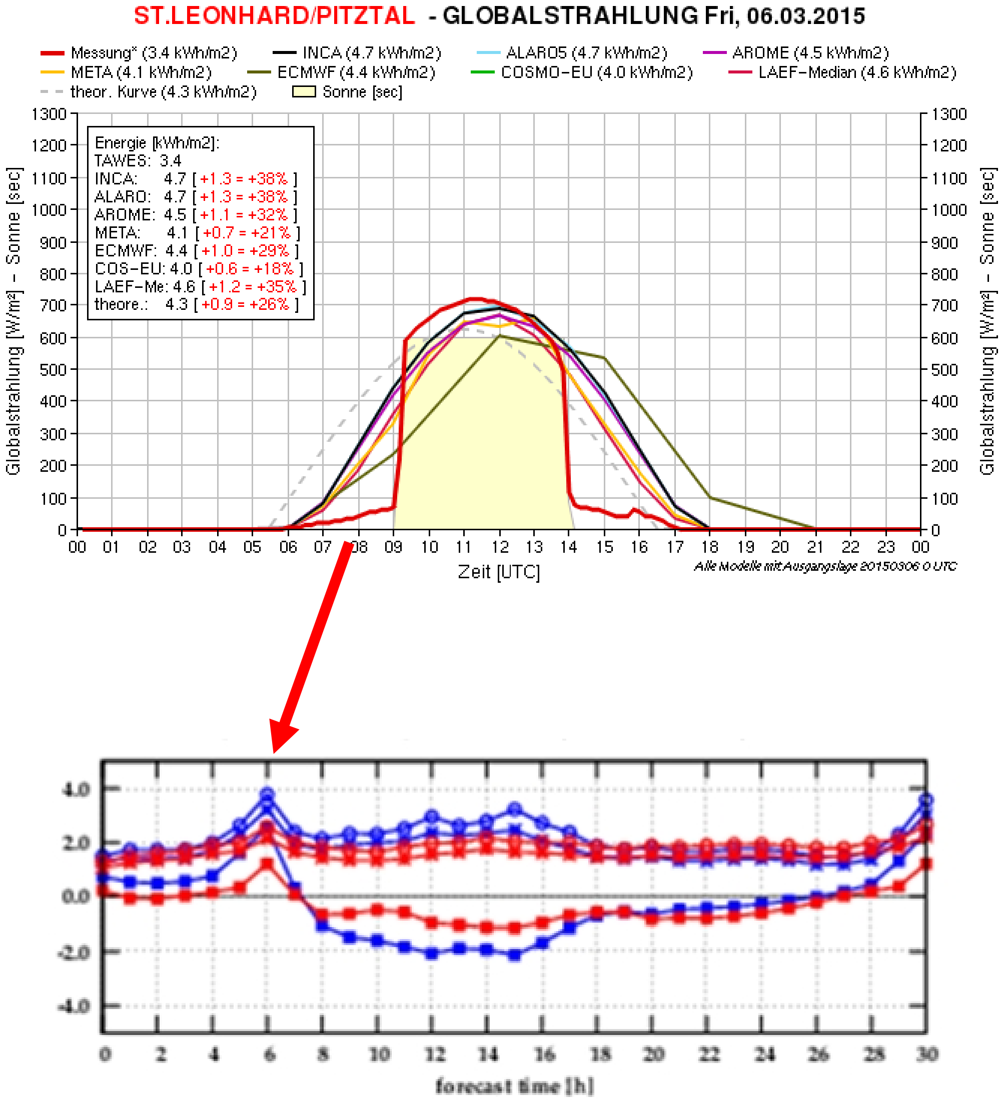
Content

- Motivation
- Method and implementation
- Case study (1D + 3D)
- Outlook

Motivation



Pitztal / Tyrol / Austria

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Objectives/Method

- Webmeeting in February 2014 to coordinate efforts and resources (ZAMG, MF, FMI, LACE); common workplan:

1. Objectives

i. Derive the orographic parameters necessary for radiation calculations, based on high-resolution surface elevation source data
i. Implement the orographic radiation parametrizations for short-wave and (SW) and long-wave (LW) radiation fluxes
ii. Study the sensitivity and validate the parametrizations with respect to the primary (radiation fluxes, temperature) and secondary(convection, low stratus in valleys, local circulations etc.) effects in different model resolutions.

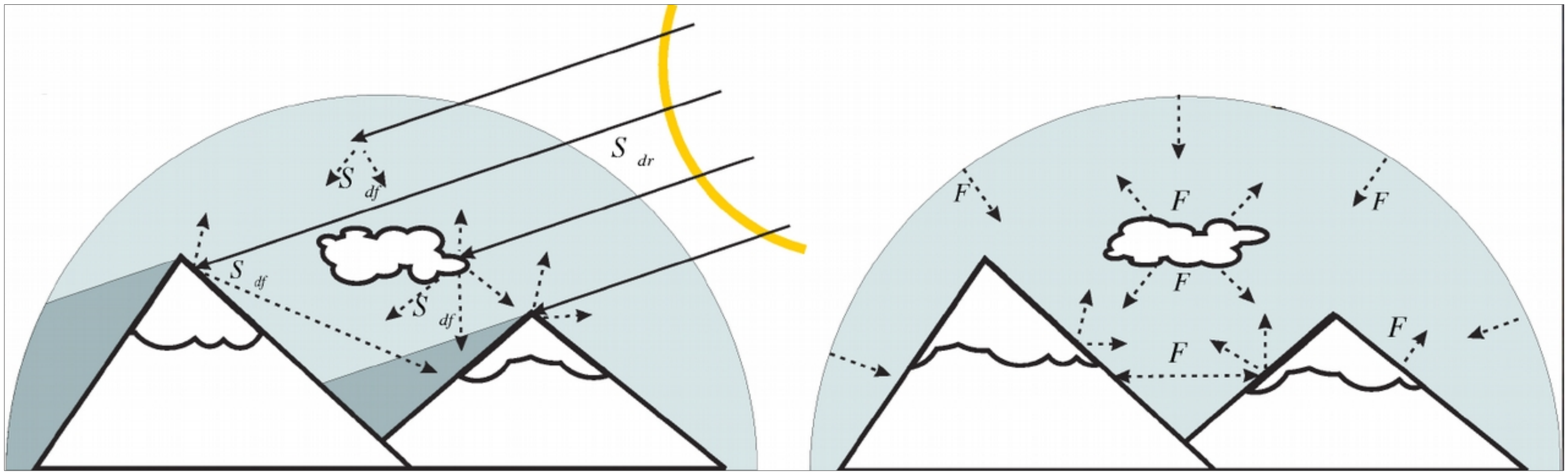
- ororad parameterization was already implemented in HIRLAM
  -> use existing tools for preparation of oro parameters
  -> implementation in PGD later
- available via SURFEX (for AROME, ALARO, ..)
- LACE financed stay of Clemens at MF + local work at MF+FMI+ZAMG

Müller and Scherer, 2005: *„A Grid- and Subgrid-Scale Radiation Parametization of Topographic Effects for Mesoscale Weather Forecast Models.“ (Monthly Weather Review, 133)*

Senkova et al., 2007: *„Parameterization of orographic effects on surface radiation in HIRLAM“, Tellus 59A)*

Modification of radiation fluxes at the surface

short wave radiation (SW) long wave radiation (LW)



taking into account:

- SW direct: shadowing of direct solar radiation by orography
- SW direct: angle/direction of slope with respect to sun
- SW diffusive: reduced fraction of sky visible
- LW: reduced fraction of sky visible

➡ basic orographic factors: **sky view factor, slope aspect, shadow fraction**

Shadow fraction (SW)

Basically we need:

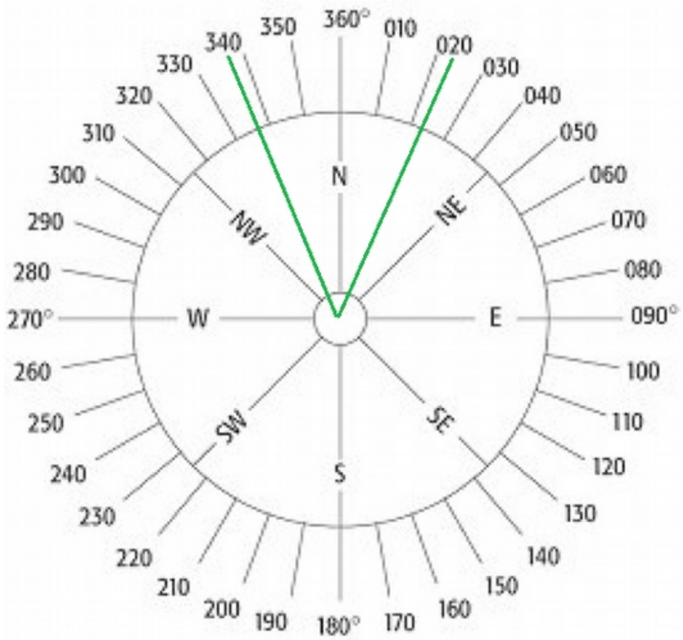
- δ_{SH} = 0 for solar angle h_s < horizontal angle h_h
- δ_{SH} = 1 for $h_s > h_h$

Extension: As we use high resolution DEM we introduce sectors for different directions seen from the grid point (e.g. i=1,...,n=8 for N,NE,....,NW)

- we need $h_{h,max}$ and $h_{h, min}$ for each sector
- $\delta_{SH,i}$ = 0 for solar angle h_s < horizontal angle $h_{h,i,min}$
- $\delta_{SH,i}$ = 1 for solar angle h_s > horizontal angle $h_{h,i,max}$
- used to solve equation

$$\delta_{sh,i} = A_i \sin(h_s) + B_i$$

- yielding fields Ai and Bi
- values for $\delta_{SH,i}$ ranging from 0 to 1



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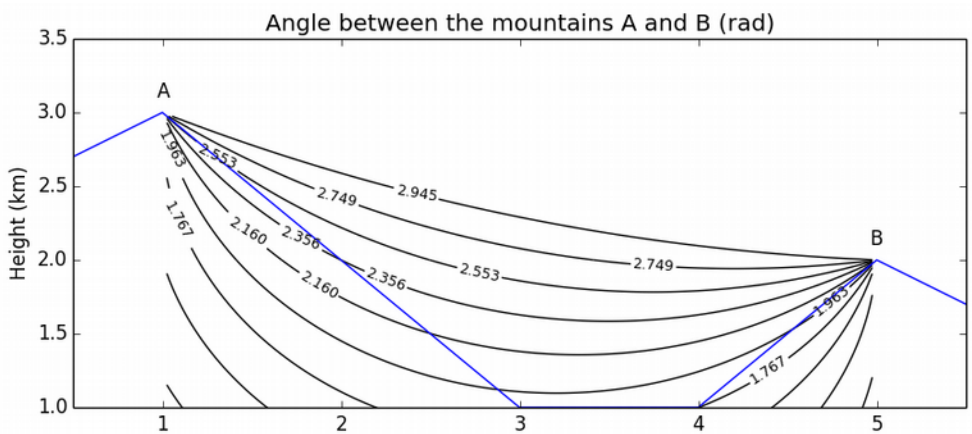
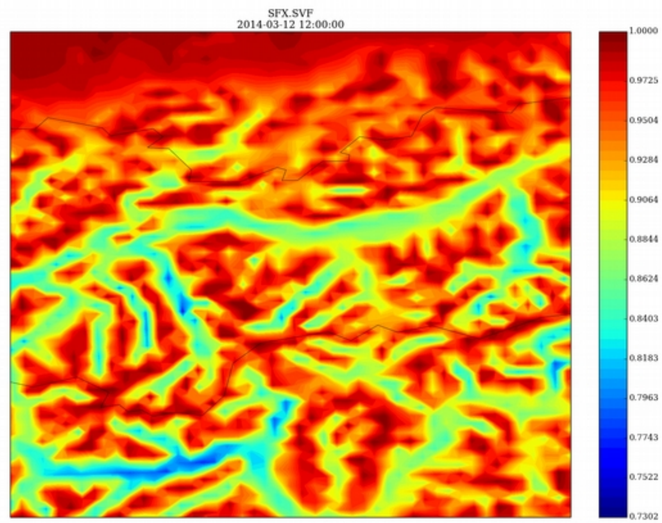
Sky view factor (SW and LW)

- fraction of sky visible at a grid point (integral over horizon)
- δ_{SV} ranging from 0 to 1 (flatland)

$$\delta_{sv} = 1 - \frac{1}{2\pi} \int_0^{2\pi} \sin[h_h(\theta)]\, \mathrm{d}\theta. \qquad \delta_{sv} \approx 1 - \frac{\sum_{i=1}^{8} \sin(h_{h,i})}{8}.$$

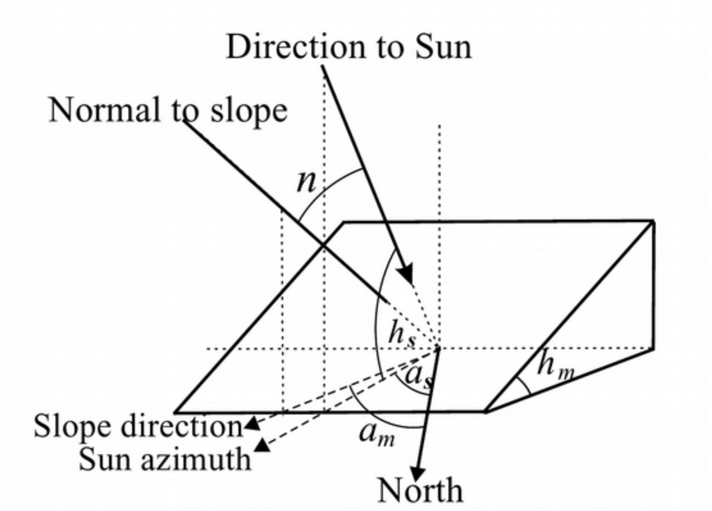




Slope aspect (SW)

- information about direction of slope (based on subgrid information)

- sector approach:
  - mean slope angle $h_{m,i}$
  - azimut angle of sector $a_{m,i}$
  - solar azimut a_s
  - solar height angle h_s



- fraction f_i (range: 0-1) for each sector direction
- δ_{SL} would be 1 if all (sub)grid slopes heading perpendicular to sun

$$\delta_{sl} = \sin(h_s) + \cos(h_s) \sum_{i=1}^{8} f_i \tan(h_{m,i}) \cos(a_s - a_{m,i})$$

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PGD and implementation aspects

new fields in PGD:

Field Name	Significance	Unit	Scale of computation
SVF	SkyView Factor : fraction of hemisphere seen from the gridpoint	[0, 1]	mesh
SLOPE	Slope angle	radians	mesh
ASPECT	Aspect with regards to geographic North, clockwise	radians	mesh
AVG_SLO	Subgrid average slope angle	radians	subgrid (SSO)
FRAC_DIR{*ii*}	Fraction of subgrid orography in direction *ii*	[0, 1]	subgrid (SSO)
SLOPE_DIR{*ii*}	Average slope of subgrid orography in direction *ii*	radians	subgrid (SSO)
SHADA_DIR{*ii*}	A-factor for orographic shadowing in direction *ii*	radians	mesh
SHADB_DIR{*ii*}	B-factor for orographic shadowing in direction *ii*	radians	mesh

first implementation:

- *external pre-processing (using HR orographic data)*
- *aggregation in PGD (sector mean, etc.)*

-> MF: moved to PGD (partly using mesh oro, partly intermediate SSO [subscale oro])

new namelist switches for SURFEX:

LSHAD=.TRUE. (general switch to activate orographic radiation)
LDSL=.TRUE. (activate effect related to slope aspect)
LDSH=.TRUE. (... shadow fraction)
LDSV=.TRUE. (... sky view factor)

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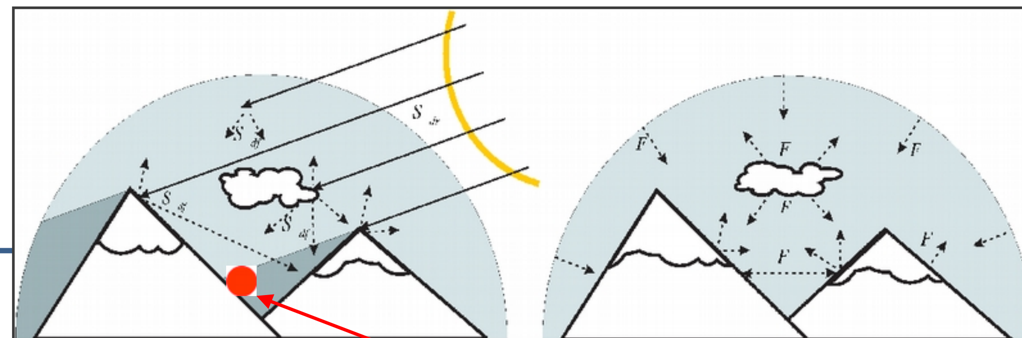
1D sensitivity tests (Laura)

- single-column HARMONIE/MUSC experiments to see the order of magnitude of the impacts on radiations fluxes, surface temperature, etc.
- sensitivity studies, not for direct comparison with observations
- offers possibility to play around with artificial orographic parameter setups, code modifications, etc.



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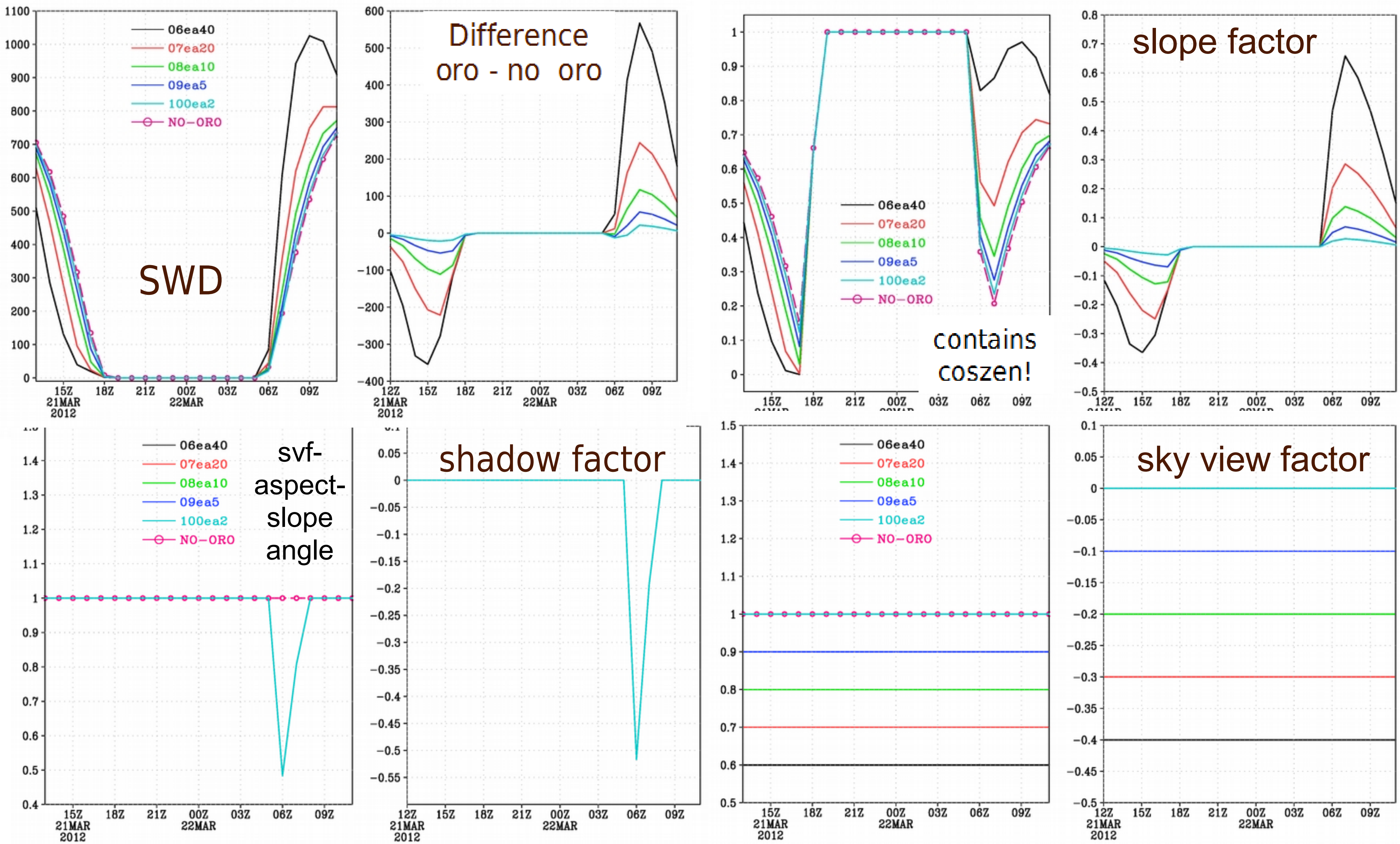
Experiment setup:

- 24h integration using clear sky conditions
- IFS radiation scheme
- eastern slope with shadowing mountain in the east
- diagnosed parameters: surface temperature, (global) radiation

1D sensitivity tests (Laura)



3D Case studies / setup

AROME domain & setup:

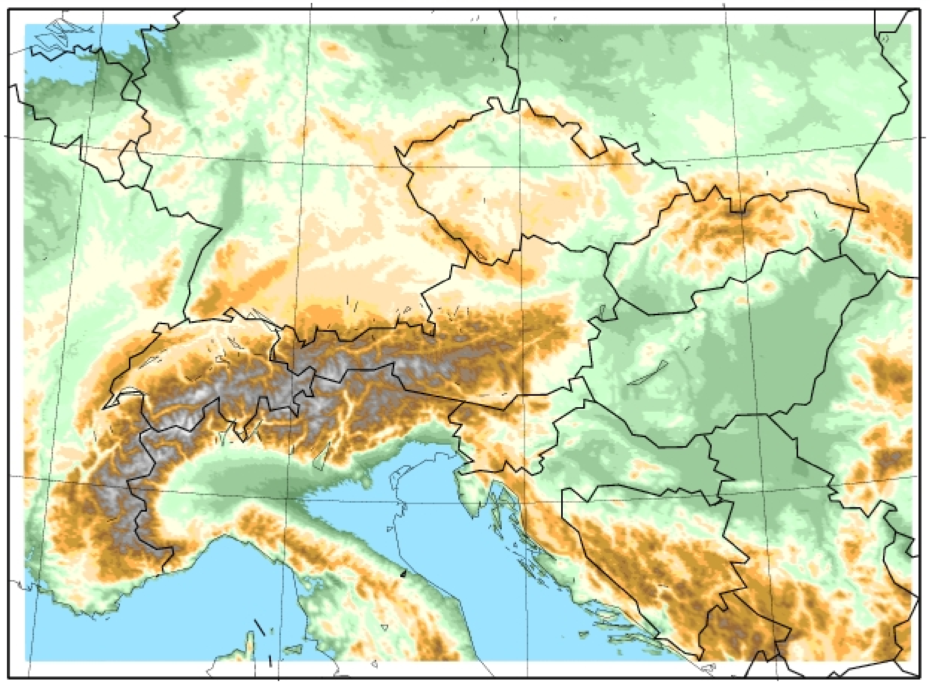
- 2.5km resolution (600 x 432)
- 90 levels
- code modifications based on cy38t1
- time step 60s

3 weather situations:

- clear sky condition
- low stratus / fog case
- moderate local convection

5 model runs:

- reference without ororad
- only shadowing
- only slope effects
- only sky view factor effect
- all three effects combined



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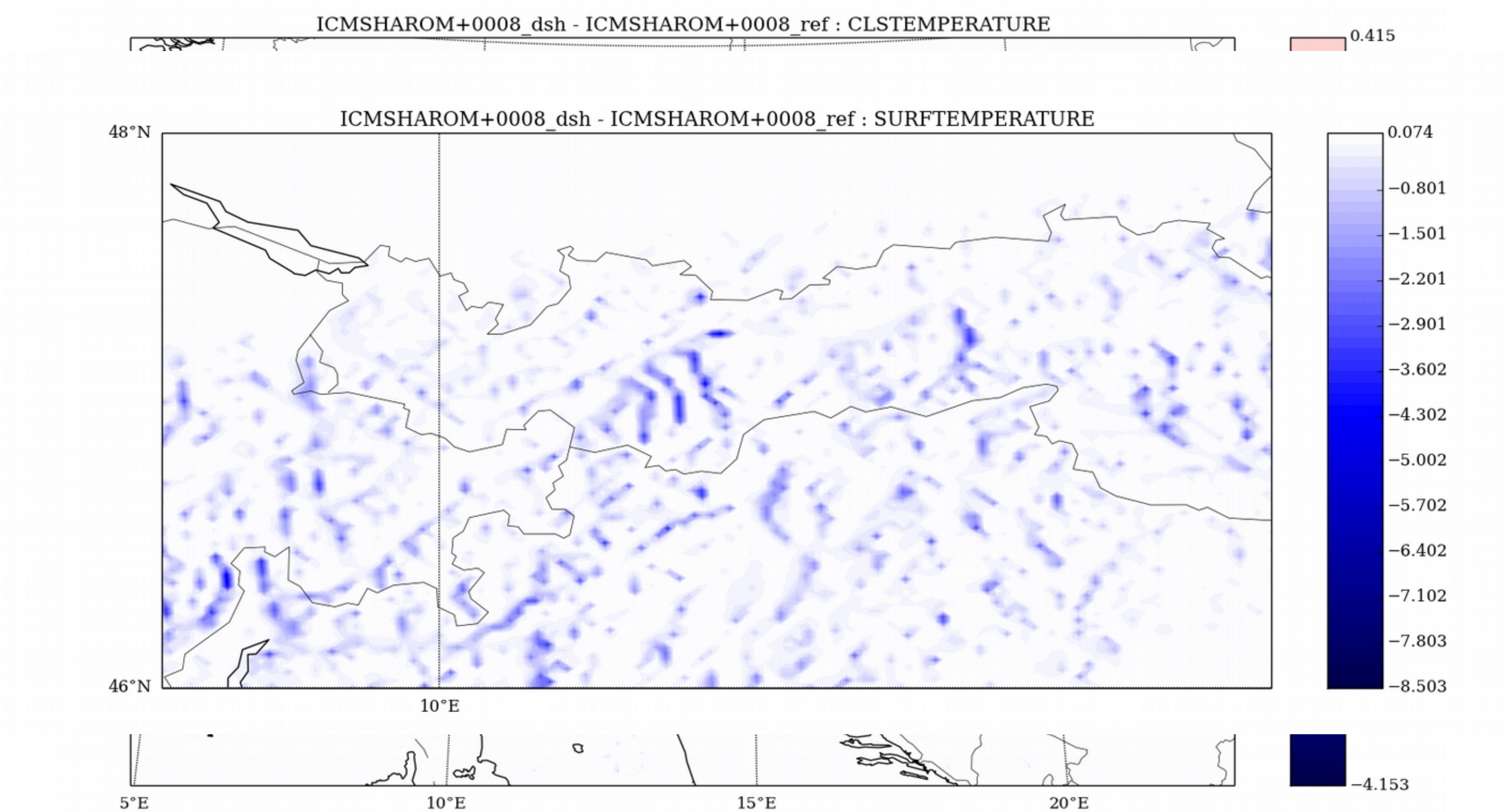
Clear sky, LSH = .T. , T2m/Tsurf (diff ororad – no_ororad)



shadowing effect as expected for t2m/tsurf: cooler valleys(N-S) with respect to reference

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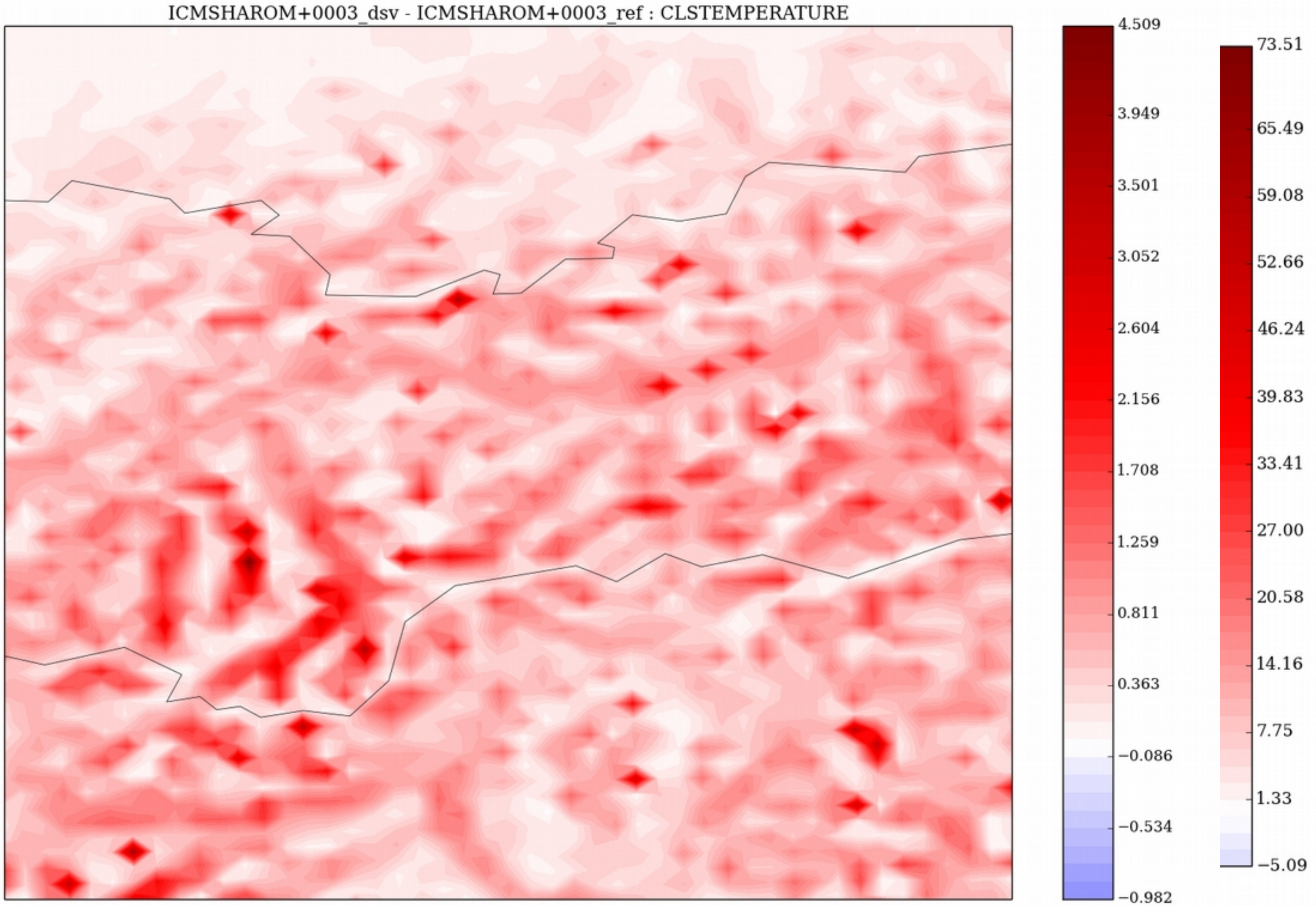
Clear sky conditions, LSV = .T., LW radiation / T2m



increased downward LW radiation due to limited sky view; warming effect (in valley)

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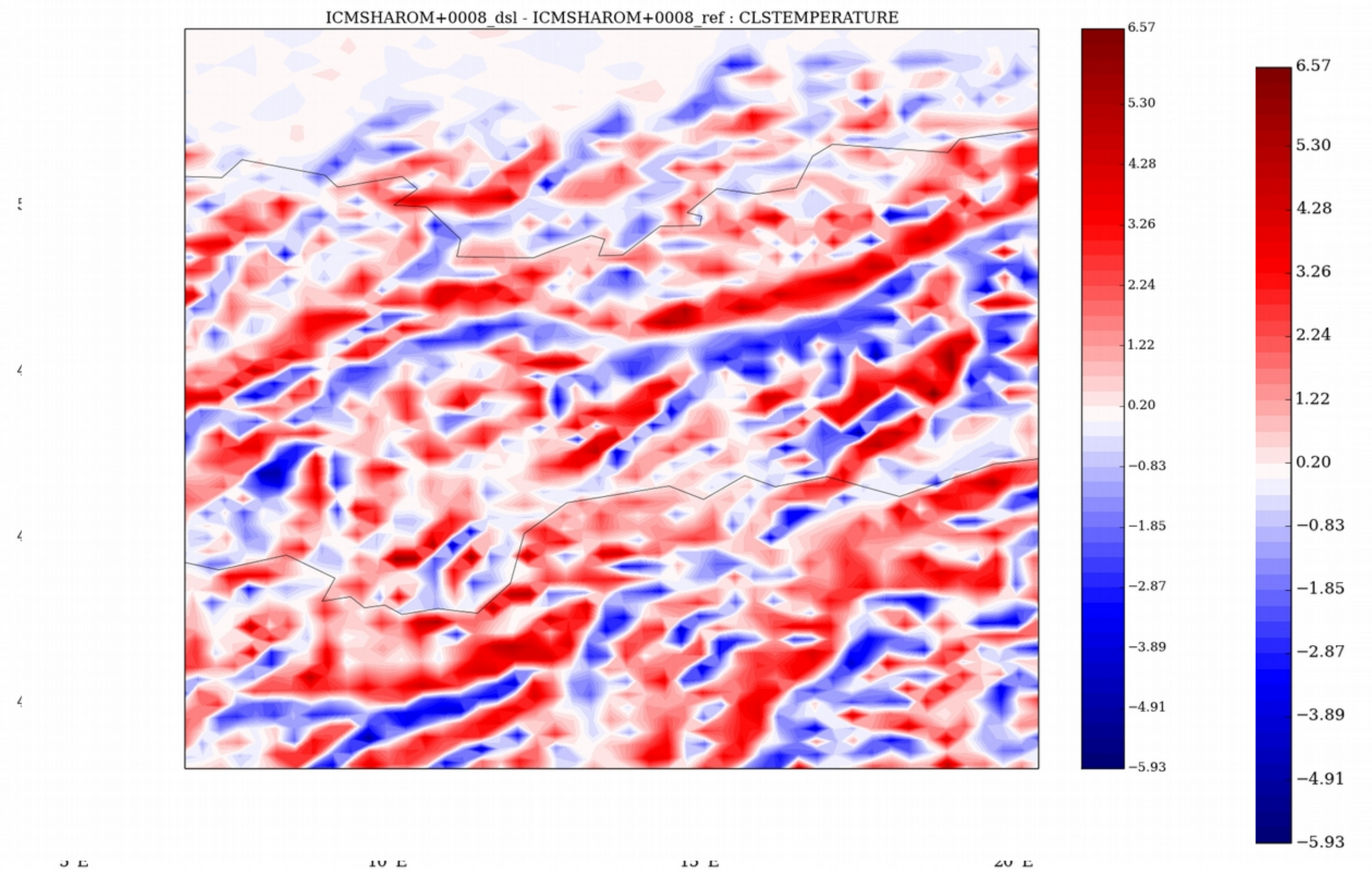
Clear sky conditions, LSL = .T.



warmer slopes (directed to sun), colder slopes in the shadow

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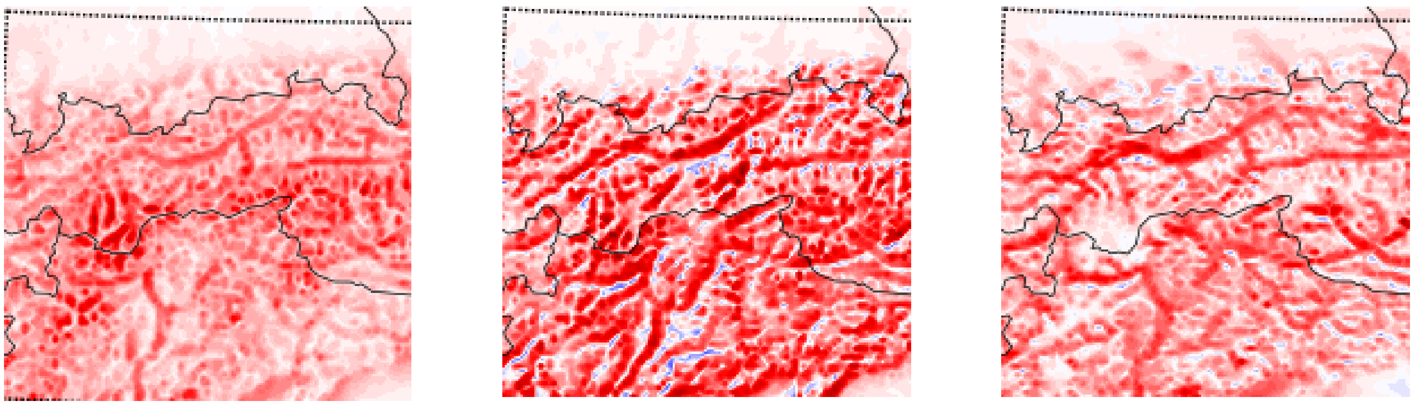
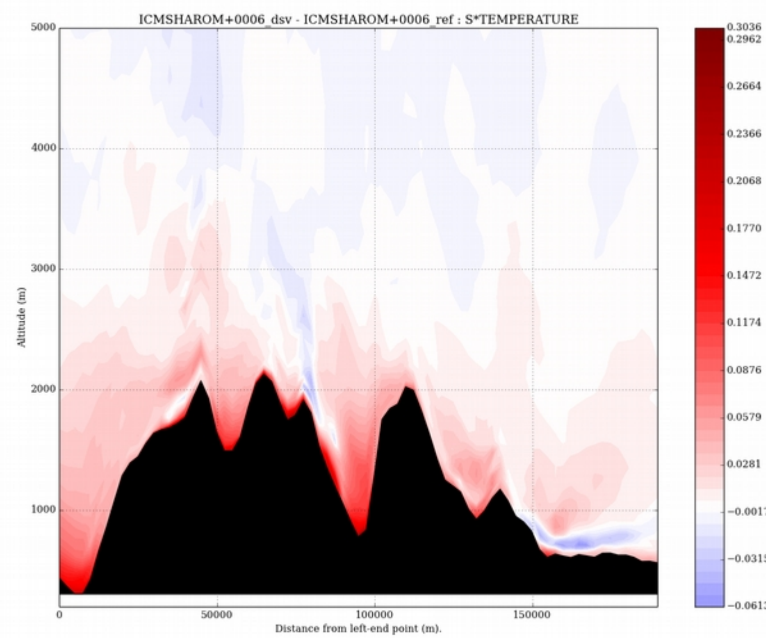
Clear sky conditions, all effects

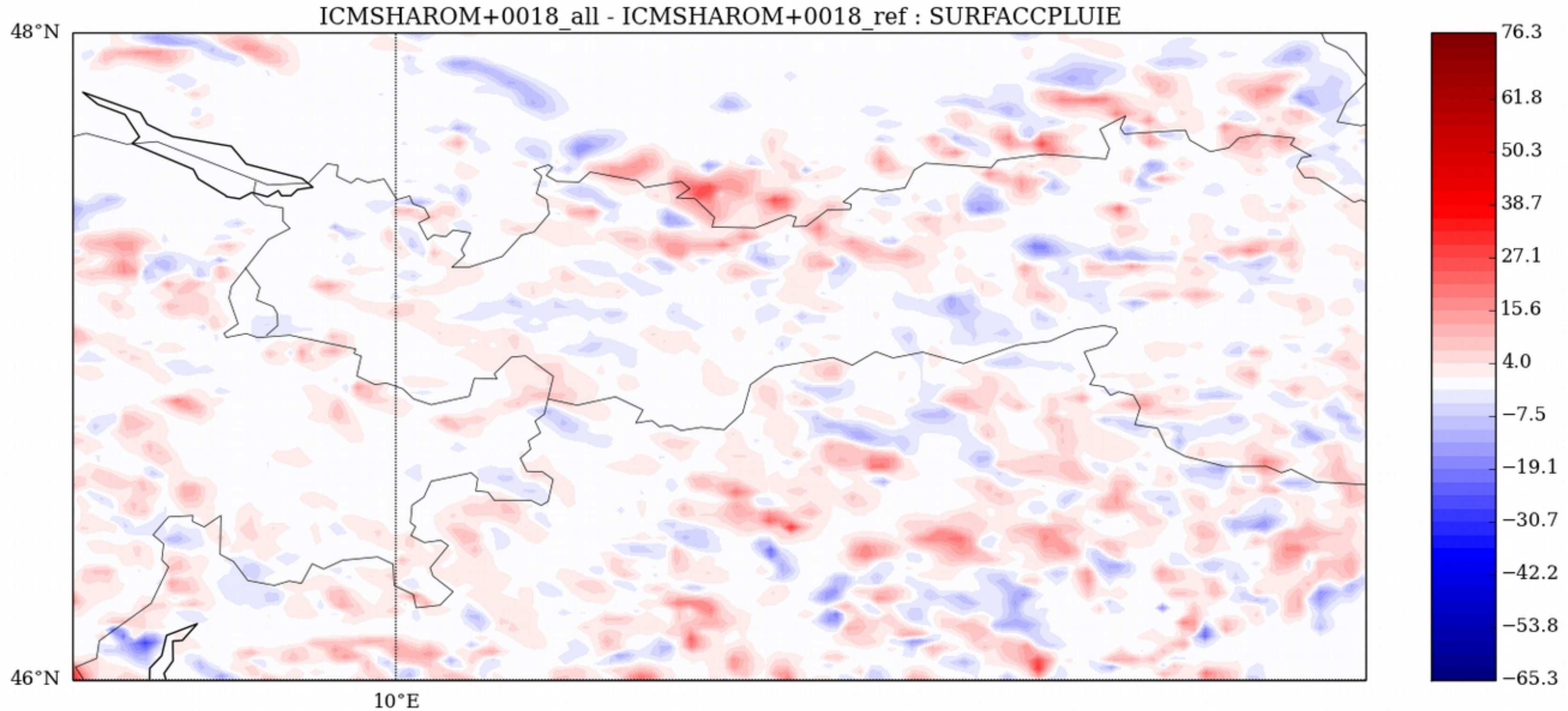
3 UTC **8 UTC** **12 UTC**



- sky view factor dominating during
- slope effect dominating during day
- shadowing effect active for short p
- overall warming effect (sky view fa
- 3D effects not clear



Local convection, all effects, precipitation



- local convection over orography during summer highly unpredictable
- ororad seems to be able to displace of convection (not surprising)

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Summary and Outlook

- parameterization of orographic effects on (surface) radiation coded within SURFEX
- preparation of relevant orographic fields included into PGD
- effects seen for simple cases (clear sky 3D + 1D) suggest that scheme is doing the right thing (T2m,Tsurf,etc.), but 3D effects not fully clear
- 1D and 3D tests

<u>Next steps</u>:

- validation of orographic parameters still an issue (e.g. sky view factor)
- 3D+1D tests to be continued (simplified + extended), better understanding of effects necessary, radiation fluxes every time step, etc.
- LACE research stay of Martin Dian (SK) in Vienna in April/May
- extended verification using radiation + temperature observations in Alpine region
- perform tests over longer period to quantify mean effect on scores

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