AROME-SURFEX
orographic parametrizations

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with thanks to
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Contents

Introduction: schemes and principles
Ororad: calculating slopes and horizons
Orotur: method and variables
Next steps
Ororad

To account for slope, shadow and sky view effects on short- and longwave radiation at the surface:

\[
\frac{\partial T}{\partial t} = -\vec{v} \cdot \nabla \zeta T - \zeta \frac{\partial T}{\partial \zeta} - \frac{1}{c_p} \left( \frac{g}{p_s} \frac{\partial F_r}{\partial \zeta} + \frac{g}{p_s} \frac{\partial F_t}{\partial \zeta} + F_c \right)
\]

\[F_{rs} \sim g_1(\text{orography}(x,y,t)), \ g_2(\text{radiation flux}(x,y,z,t))\]

Orotur

To account for the impact of the subgrid-scale orography on the surface layer momentum fluxes:

\[
\frac{\partial \vec{v}}{\partial t} = -\vec{v} \cdot \nabla \zeta \vec{v} - \zeta \frac{\partial \vec{v}}{\partial \zeta} - \frac{1}{\rho} \nabla \zeta p - \nabla \zeta \Phi - f \vec{k} \times \vec{v} - \frac{g}{p_s} \frac{\partial \vec{r}}{\partial \zeta}
\]

\[\vec{T}_s \sim f_1(\text{orography}(x,y)), \ f_2(\text{flow}(x,y,z,t))\]
but how to describe the subgrid-scale orography properties in a NWP model?
Principles

1. Average the fluxes, not orography
   e.g. net SW radiation

\[ S_{\text{net}} = \left[ \delta_{sl} \delta_{sh} - \alpha \delta_{sv} \sin(h_s) \right] S_{\downarrow \text{dr},0} \]
\[ + \left[ (1 - \alpha) \delta_{sv} \right] S_{\downarrow \text{df},0}. \]

- small-scale orography features have been condensed to grid-scale slope, shadow and sky view factors

How to derive them optimally?
## Variables

### Table 1. Orography-related parameters within grid resolution

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Principles

2. Mind the physics of scales
Principles

3. KISS: keep it simple, stupid

Integrated into the NWP model in runtime?

Preprocessed?

Postprocessed?
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Introduction: schemes and principles
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Fraction of SE slopes

Mean maximum SE slope

external for cy38

grid-scale by cy43 PGD
Fraction of an maximum SE slopes SE slope

SRTM* point of ca.100m

Sector of 45 deg (SE) from one SRTM point

Harmonie gridsquare of 1.5km

*SRTM = Shuttle Radar Topography Mission https://www2.jpl.nasa.gov/srtm/
Calculations for each SRTM point, statistics for each gridsquare
Calculations for each SRTM point, statistics for each gridsquare

Maximum slope among 8 neighbours for each SRTM point:
- slope direction → pick to own direction sector (e.g. SE) within each gridsquare
- slope angle → calculate mean maximum slope of each sector within gridsquare
Using gridsquare average $h$ results in a different variable, explicit slope
Orography gradient correlation

tensor

\[ H_{ij} = \frac{\partial h}{\partial x_i} \frac{\partial h}{\partial x_j} \]

ellipsoid within each gridsquare
Eigenvalues of the tensor

Principal axis → direction with respect to model grid

Mean subgrid-scale slope

Asymmetry factor (form of the ellipsoid)
3a) Subgrid tensors within the grid-squares → slope and directional fraction

\[ H_{ij} = \frac{\partial h}{\partial x_i} \frac{\partial h}{\partial x_j} \]
All three methods are already available somewhere in SURFEX

1) Import fine-resolution slopes → read and average in PGD physiography generation: ororad experiments in cy38

2) Use mean elevation: alternative for ororad in cy43

3) Calculate tensor for SSO: originally for gravity wave parametrizations in the atmospheric model IFS-ARPEGE → ALADIN → SURFEX orographic drag

3a) Subtensors: alternative for ororad in cy43
Fraction of SE slopes

srtm-external for cy38

Fraction of SE slopes

subgrid-scale by cy43 PGD

Mean maximum SE slope

Mean maximum SE slope
Calculation of local horizon around each SRTM point, statistics for each gridsquare.
Calculation of local horizon angle around each SRTM point by scanning one-degree direction angles in 8 sectors. Statistics for grid-scale sky-view and shadow factors KISS?
Result: local horizon around each SRTM point

Observed horizon (grey shaded area) and calculated local horizon angles (blue dots and green circles) around the Alpine station St. Leonhard/Pitztal, Austria.

Blue dots are in SRTM grid, green circles estimated for NWP gridpoint (2500m)

Red and blue lines show the path of the sun at the winter (blue) and summer (red) solstice.
Sky view factor based on subgrid/grid-scale local horizon

“Senkova” subgrid-scale by external program

“Manners” subgrid-scale by external program

“Senkova” grid-scale by cy43 PGD

“Manners” subgrid-scale by cy43 PGD

Note the different colour scales!
There are different possibilities and the results differ. However, the sky view factor is averaged from the local horizon angles of different directions that makes it quite smooth in grid-scale.

Manners = slope of the starting point is taken into account when calculating the sky view factor. This is more correct, but the result depends on definition of the slope.

Senkova = starting point is assumed flat. This is more approximate.
Ororad sensitivities

MUSC cy38 experiments over Krasnaya Polyana, Sochi

A longwave example: the effect of orography is larger than the difference between radiation schemes

MUSC cy43 experiments over Krasnaya Polyana: influence of different orofields

- LWD differences seem to be larger than in the cy38 experiments (different input atmosphere, too)
- SWD (global radiation) differences are due to the diffuse radiation
- 43seocf and 43se use same orofields but the results differ (to be explained soon ...)

Orofields come from:
- 38es: external senkova, cycle38
- 38em: external manners, cycle38
- 43se: explicit slopes in PGD, cycle 43
- 43ma: subgrid slopes in PGD, cycle 43
- 43seocf: explicit slopes in PGD, cycle 43
MUSC cy43 experiments over Krasnaya Polyana: influence of different orofields

- Minor differences in slope factor
- Shadow factor influences in the afternoon/early morning only
- Sky-view factors differ except between 43se and 43seocf

Orofields come from:
- 38es: external senkova, cycle38
- 38em: external manners, cycle38
- 43se: explicit slopes in PGD, cycle 43
- 43ma: subgrid slopes in PGD, cycle 43
- 43seocf: explicit slopes in PGD, cycle 43
MUSC cy43 experiments over Krasnaya Polyana: influence of different orofields

- Tsurf and energy balance differences are correlated (as expected)
- Cloud interactions! 43Seocf uses different microphysics than the others- no OCND2
- Low clouds may be unrealistic in MUSC but such sensitivities may appear also in 3D!

Orofields come from:
- 38es: external senkova, cycle38
- 38em: external manners, cycle38
- 43se: explicit slopes in PGD, cycle 43
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Orotur

In this study, a simplified version of the HIRLAM smallest-scale orographic turbulence parametrization (Rontu, 2006), hereafter referred to as orotur, was tried in HARMONIE. The suggested scheme is another realization of the Wood et al. (2001) idea of handling the non-separated sheltering effect. The surface value of the subgrid-scale orographic stress $\tau_{os}$ (horizontal momentum flux in the surface layer given in units of Pa) is related to the subgrid-scale orography variance $\sigma_{sso}^2$, multiplied by the turbulent stress $\tau_{ts}$

$$\tau_{os} = C_o \sigma_{sso}^2 \tau_{ts},$$  \hspace{1cm} (1)

where $C_o$ is the subgrid-scale orography drag coefficient and $\tau_{ts}$ denotes the turbulent surface stress $\tau_{ts} = \rho_s w' v'$. $\rho_s$ stands for the air density at the surface, overline denotes average over a gridsquare and $w'$ and $v'$ are deviations of the vertical and horizontal wind components from the average, respectively. Finally, the total stress $\tau_{tot}$ is obtained as a sum of the orographic and turbulent components

$$\tau_{tot} = \tau_{os} + \tau_{ts} = (1 + C_o \sigma_{sso}^2) \tau_{ts}$$  \hspace{1cm} (2)

The coefficient $C_o = C_{oo} V_{oo}^2 / (V_{nlev}^2 + V_{oo}^2)$, where $V_{nlev}$ denotes the lowest model level wind speed, $C_{oo} = \alpha / \Delta x^2$, $\alpha$ and $V_{oo}^2$ are tunable constants (in the first trials set to 100 m$^2$ and 8 m$^2$/s$^2$, respectively) and $\Delta x$ denotes the model’s horizontal resolution (grid size in metres). The idea behind the wind scaling was to increase the drag on the weakest winds by accounting for the surface layer wind shear. Inclusion of $\Delta x^2$-scaling was done in order to roughly relate the orography variations to the steepness of subgrid-scale slopes in each gridsquare.
Variables

Only one orovariable is used for orotur: the subgrid-scale standard deviation of surface elevation

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Any other variable, characterizing surface elevation variations, might do as well:

Slope angle?
Sky view factor?
Wind speed (m/s) as a function of height (m, y-axis) and time (x-axis) for Krasnaya Polyana from MUSC experiments initiated at 06~UTC the 8th of February 2014 with enhanced wind forcing. Values of the enhanced experiment on the left, difference from the reference (no orotur) on the right.
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Next steps within cy43

Checking and optimizing the code in cy43 → SURFEX 9 →→ cy45

ORORAD

• Compare external v.s. subtensor slopes, local horizon and skyview factor
• Do not use slopes based on grid-average sfc elevation

Model-observation intercomparison
• Over Alps using global SW radiation observations

OROTUR

• Testing, tuning, choosing basic orovariable
• Study the interactions with surface layer turbulence parametrizations and their roughness definitions

Model-observation intercomparison
• Find an area with representative wind observations, downscale model wind towards point observations
Thank you for your attention!