ORORAD in PGD

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Computation of orographic parameters for surface radiation interaction : description of algorithm.

Technical note - v2.

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SSO in PGD

Subgrid orography is available in PGD, derived from the incoming DEM orographic data (SRTM, GTOPO or anyelse) to an intermediate resolution between the DEM resolution and the model resolution. This is called SubScale Orography (SSO).

Each model-scale gridpoint is divided into `NSSO` × `NSSO` subboxes, `NSSO` being computed as $floor(\Delta_{model}/\Delta_{DEM})$ and then constrained between 3 and 10 (cf. Fig. 1). The motivation for this reprojection of the DEM data to SSO is to make derivative quantities easier to compute, with a subscale orography aligned with the grid. It is used mainly for computing A/S and $h/2$ quantities used for orographic drag in SURFEX. This upper limit of 10 is set for memory reasons, but could be discussed. It leads to a 1:100 ratio for computing subgrid quantities that seems enough.

The computation of orographic parameters for surface radiation (hereafter *ororad parameters*) described in the following uses this SSO data whenever possible.

1 ORORAD new fields in PGD

Aspect-related fields are discretized into `NSECTORS` sectors of equal angle, sector 01 being centered on North, then rotating clockwise. `NSECTORS` has a default value of 8, but can be accessed in namelist block `&NAM_ZS`.

It is worth to be noted that some SSO fields are already present in PGD file : `SSO_STDEV` (standard deviation), `SSO_ANI` (anisotropy), `SSO_DIR` (aspect) and `SSO_SLOPE` (slope), computed according to Lott and Miller (1997) (in routine *sso.F90*). However, only `SSO_STDEV` and `SSO_SLOPE` are used for now in SURFEX, and it appears that `SSO_DIR` is inconsistent, its angles being comprised within [-90°, 90°] only. The computation of local derivatives $\partial h/\partial x$ and $\partial h/\partial y$ are somehow differently done, and the resulting field `SSO_SLOPE` is more smoothed than `AVG_SLO` (which seems a bit noisy, in turn).

Should not computations of `SSO_*` and new fields converge before entering an official SURFEX version ?

2 Local : Slope and Aspect

For these parameters, the SSO is used if all subboxes are filled for the gridpoint. Else, the parameter is computed at mesh-scale for the gridpoint.

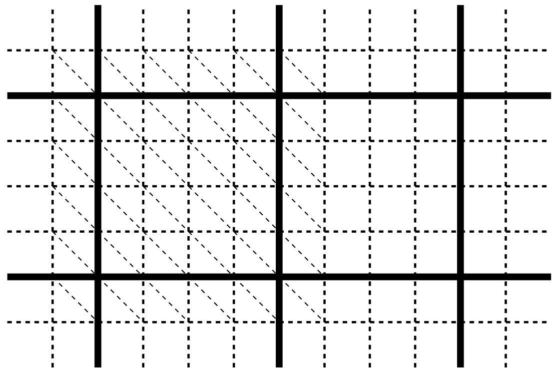

Figure 1: Model-scale gridpoint and its `NSSO` subboxing. Here `NSSO` $= 4$. The hatched subboxes are those used for computing subgrid derivatives.

Field Name	Significance	Unit	Scale of computation
`SVF`	SkyView Factor : fraction of incident radiation, reduced due to hemisphere obstruction by surrounding orography	$[0, 1]$	mesh/`NSECTORS`
`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)
`HMINS_DIR{ii}`	Sinus of the minimum horizon angle in direction ii	$[0, 1]$	mesh
`HMAXS_DIR{ii}`	Sinus of the maximum horizon angle in direction ii	$[0, 1]$	mesh

According to Rontu and Sattler (2013) and Lott and Miller (1997), for each subbox are computed:

$$K = \frac{1}{2}\Big(\frac{\partial h}{\partial x}\frac{\partial h}{\partial x} + \frac{\partial h}{\partial y}\frac{\partial h}{\partial y}\Big)$$

$$L = \frac{1}{2}\Big(\frac{\partial h}{\partial x}\frac{\partial h}{\partial x} - \frac{\partial h}{\partial y}\frac{\partial h}{\partial y}\Big)$$

$$M = \frac{\partial h}{\partial x}\frac{\partial h}{\partial y}$$

$$D = \sqrt{L^2 + M^2}$$

using a discretisation with its 4 neighbors (x^+, x^-, y^+, y^-).

Note that the $^-$ operator of Rontu and Sattler (2013) is not used here, as we are not computing a subgrid mean slope and aspect but slope and aspect on subboxes, to be aggregated further as fractions of the corresponding sector within the gridmesh.

The subbox aspect is computed as

$$\theta = \begin{cases} \arctan((D-L)/M) + \pi & \text{if } \frac{\partial h}{\partial x} > 0 \\ \arctan((D-L)/M) & \text{else} \end{cases}$$

to which is substracted $\pi/2$ for rotating reference to Y-axis, and $\vec{N}$ (the compass) to take into account the grid inclination to geographic North. The limit cases where $\frac{\partial h}{\partial x}$ or $\frac{\partial h}{\partial y}$ equals or tend to ± 0 (and so do the denominator M), are taken into account.

The subbox slope is computed as

$$s_m = \arctan(\sqrt{K + D})$$

A subbox contributes to the mean slope and fraction of the corresponding direction only if $s_m >$ `XFLATRAD`. Lower slopes are hereby considered flat. `XFLATRAD` has a default value of 0.0 rad but is actually accessible through namelist.

These parameters are computed in routine `fsso.F90`.

3 Neighborhood : SkyView Factor and shadowing

The SSO data is not used for the computation of horizon-line and SVF, for the combined following reasons :

- the added-value of using SSO for horizon computation is expected to be a second-order of these parameters, the horizon being already smoothed by the discretization in a few sectors, especially as the models refine their resolution.
- it is a time-consuming operation, whose cost grows as the square of the resolution with a fixed halo of horizon research. Going subgrid at sub-kilometer resolutions promise to be prohibitive, considering the computation time increment already observed at mesh-scale.
- Last, the longitude and latitude of SSO subboxes is not known within the PGD program and demands to be re-computed from interpolated projected coordinates, which adds complexity and once more computation time.

The horizon for a gridpoint is computed within a halo of neighboring gridpoints, halo whose radius `XHALORADIUS` can be set in `NAM_ZS` and defaults to 20000m (this is why the number of gridpoints used to scan horizon increases with the square of the resolution).

The aspect of each neighboring gridpoint[1] with regards to the center gridpoint is computed as

$$\theta_h = \arctan 2(\sin(lon_c - lon_n) * \cos(lat_n), \cos(lat_c) * \sin(lat_n) - \sin(lat_c) * \cos(lat_n) * \cos(lon_c - lon_n)),$$

[1] Actually, only those of higher elevation

(lon_c, lat_c) being the coordinates of the center point and (lon_n, lat_n) those of the neighboring point. The according elevation angle is computed as

$$l_h = \arctan((h_n - h_c)/\Delta),$$

h_c and h_n being respectively the elevations of the center and neighboring points, Δ the distance between them.

The horizon is then computed with a first discretization of 1°. Each neighboring gridpoint is projected on the intersecting 1°-sectors, considering its angular width, as illustrated on Fig. 2.

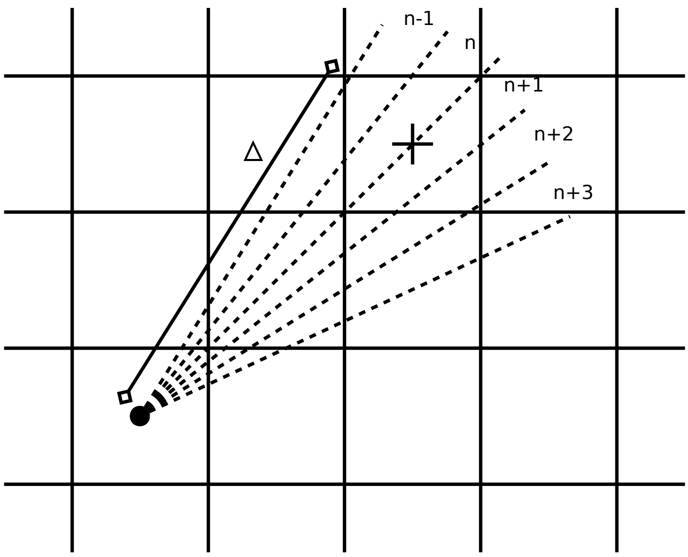

Figure 2: Projection of neighboring gridpoints on 1°-sectors. On this example, 4 sectors are impacted by the cross-marked gridpoint.

These 1°-sectors are then aggregated to min, max and average local horizon on `NSECTORS` sectors (`ZLHMIN, ZLHMAX, ZLHAVG`).

The SVF can be computed with 3 approaches, still using the average local horizon of each sector:

- 'Senkova': according to Eq. 15 of Senkova et al. (2007);
- 'Manners gridscale': according to Eq. 10-14 of Manners et al. (2012), using the gridscale local slope ($i ==$ `XSLOPE`) and aspect ($j ==$ `XASPECT`) to compute T_Φ;

- 'Manners subscale': computing a SVF for each fractional sector according to Eq. 10-14 of Manners et al. (2012), using the local fractional slope (i == `XSLOPE_DIR`) and aspect (j == *sector*) to compute T_{Φ}. Then, these fractional SVF are aggregated considering the fraction of each sector.

For 'Senkova' method, a comparative test using the 1° local horizon (instead of sectorial local horizon) showed very little difference in resulting SVF. Hence the cheaper solution has been retained.

These parameters are computed in routine `horizon_orog.F90`.

References

Rontu, L., and K. Sattler: Description of orography for a numerical weather prediction model, `https://hirlam.org/trac/attachment/wiki/VeryFineResolution/orodoc2013.pdf`, 2013.

Lott, F., and M. J. Miller: A new subgrid-scale orographic drag parameterization: its formulation and testing, Quart. J. Roy. Meteor. Soc., 123, 101-127, 1997.

Senkova, A. V., L. Rontu and H. Savijärvi: Parameterization of orographic effects on surface radiation in HIRLAM, Tellus A, 59, 279-291, doi: 10.1111/j.1600-0870.2007.00235.x, 2007.

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