ICON Documentation: Parameterization of wind gusts

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January 19, 2015

1 Wind gusts

The gust parameterization of ICON consists of two components: turbulent gusts and convective gusts. The diagnosis of turbulent gusts has been taken over from the COSMO model (**??**). Turbulent gusts at 10 m above ground are derived from the turbulence state in the atmospheric boundary layer, using the absolute speed of the mean wind at 10 m above ground U_{10} and its standard deviation σ.

$$U_{10\,\mathrm{gust,turb}} = U_{10} + \alpha\,\sigma \tag{1}$$

Following **?**, the standard deviation σ can be approximated as

$$\sigma \approx 2.4\,u_*$$

with u_* denoting the friction velocity. Using the relationship $u_* = \sqrt{C_D}\,U_{10}$, where C_D denotes the drag coefficient for momentum, we arrive at

$$U_{10\,\mathrm{gust,turb}} = U_{10} + \alpha\;2.4\sqrt{C_D}\,U_{10} \tag{2}$$

The tuning parameter α has been estimated to $\alpha = 3\frac{1}{3}$. Note that for computing u_*, the mean wind speed at the lowest model level is used rather than U_{10}.

If an SSO parameterization is used, the wind speed directly above the top of the envelope layer computed in the SSO scheme is taken into account as well. Let k_{env} denote the level index the top of the envelope layer has at a given grid point. If $k_{\mathrm{env}} < nlev$, the turbulent gust is enhanced by taking

$$U_{10\,\mathrm{gust,turb}} = \mathrm{MAX}(U_{10}, U(k_{\mathrm{env}} - 1)) + \alpha\;2.4\sqrt{C_D}\,U_{10}\,. \tag{3}$$

This turned out to greatly reduce the systematic underestimation of gusts in mountainous regions.

Equation (2) asesses the gustiness in the boundary layer, however it does not take into account gusts due to strong convective events. Therefore, a convective contribution is added to the turbulent wind gusts in the presence of deep convection. The parameterization follows **?** where the convective gusts are simply estimated as proportional to the low level wind shear:

$$U_{10\,\mathrm{gust,conv}} = C_{conv}\max\left(0, U_{850} - U_{950}\right) \tag{4}$$

with the convective mixing parameter C_{conv} and $U_{850} - U_{950}$ the difference between 850 hPa and 950 hPa wind speeds. This contribution is computed only in regions where deep convection is active, as identified by the convection scheme (*ktype=1*). Thus, the total gustiness $U_{10\,\mathrm{gust}}$ becomes:

$$U_{10\,\mathrm{gust}} = U_{10\,\mathrm{gust,turb}} + U_{10\,\mathrm{gust,conv}} \tag{5}$$

The parameter $U_{10\,\mathrm{gust}}$ is computed every fast-physics time step and its 6-hourly maximum (preliminary) is written to disk.

1.1 Computation of U_{850} and U_{950}

The presence of topography and the fact that ICON uses a height based rather than a pressure based vertical coordinate, requires some care when implementing the convective contribution (4). In order to derive a sound estimate for $U_{850} - U_{950}$, we decided to

1. convert the 850 hPa and 950 hPa pressure levels into heights (above sea) by using the US Standard Atmosphere
2. compute the vertical level indices that matches best with those heights above ground, for each grid point. Wind speed is then evaluated at these level indices.

For the US Standard Atmosphere below 11 km height, one can derive the following expression for height z as a function of pressure p (**?**):

$$z = \frac{T_0}{\Gamma}\left[\exp\left(-\frac{R_d\Gamma}{g}\ln\frac{p}{p_0}\right) - 1\right] \tag{6}$$

with $\Gamma = -0.0065\,\mathrm{K/m}$ the tropospheric temperature gradient of the US standard atmosphere, $T_0 = 288.15\mathrm{K}$, $p_0 = 1013.25\,\mathrm{hPa}$ and the specific gas constant for dry air $R_d = 287.04\,\mathrm{J/(kg\,K)}$. For $p = 850\,\mathrm{hPa}$ and $p = 950\,\mathrm{hPa}$, we get $z = 1457.24\,\mathrm{m}$ and $z = 540.31\,\mathrm{m}$, respectively. In the following, those heights are interpreted as heights above ground, and for each grid point we search for the full levels that are closest to those heights and store the corresponding level indices termed k_{850} and k_{950}. For a particular horizontal grid point i, $U_{850} - U_{950}$ is then given by

$$U_{850} - U_{950} \approx \sqrt{u_{k_{850}}^2 + v_{k_{850}}^2} - \sqrt{u_{k_{950}}^2 + v_{k_{950}}^2} \tag{7}$$