General and common WG3-Task

"Consolidation of the Surface-to-Atmosphere Transfer (ConSAT):

according to a dynamically adapted list of actions
being the base of past and (maybe) future PTs

Current topic:

Better overall treatment of surface roughness (R) in the tiled model
(around the packages 'turbdiff', 'turbtran' and 'terra')

According to 3 (new) theoretical concepts: GBLA, STIC and ISuP

Current contributor: Matthias Raschendorfer (DWD)

Other thematically involved people:

Jürgen Helmert, Martin Köhler, Ekaterina Maschulskaja, Dimitrii Mironov,

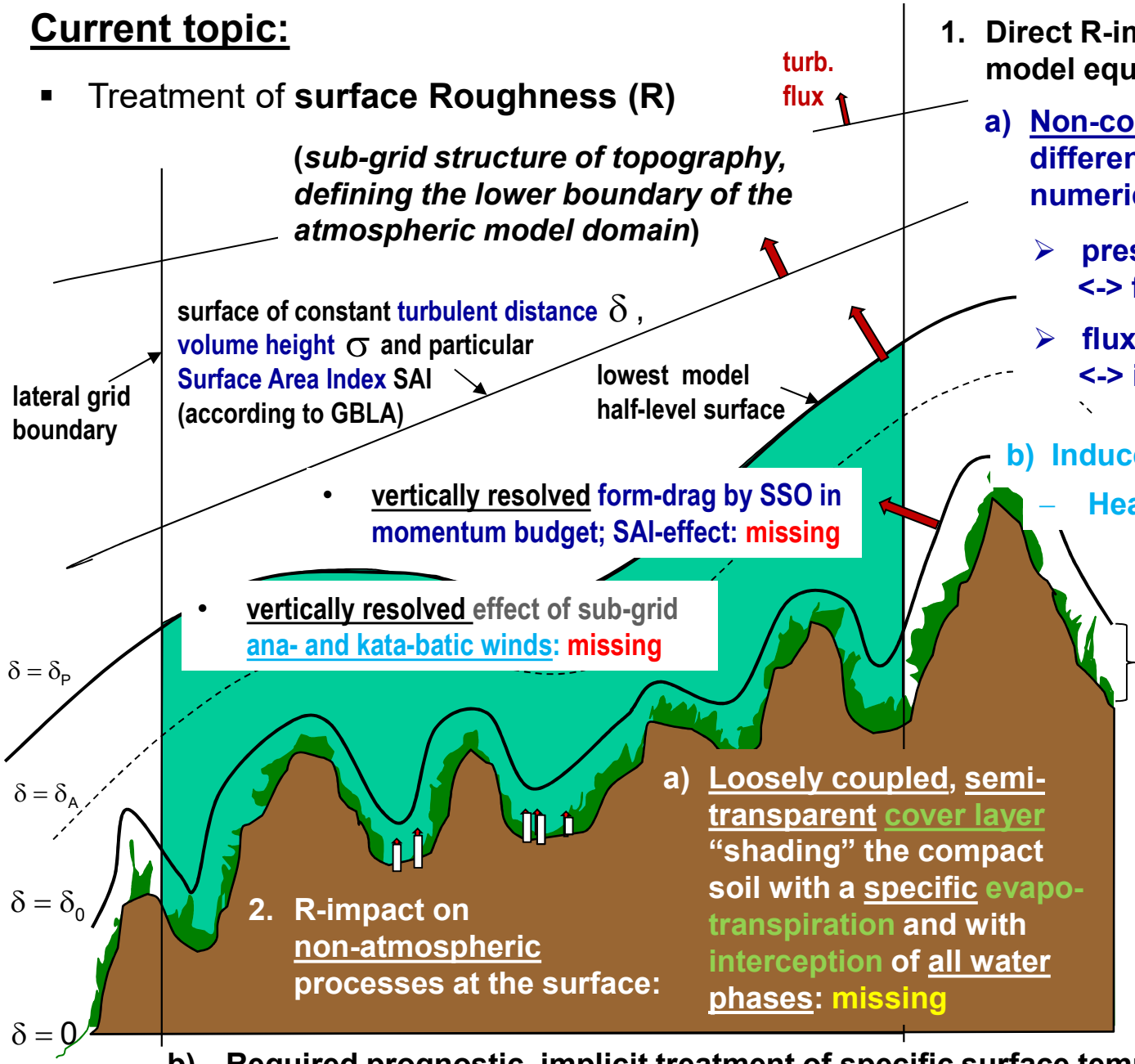
Daniel Reinert, an-Peter Schulz, Günther Zängl (DWD),

Contributors to the PP/PTs: CITTA, SAINT and VAINT, …?

ICON-projects: ICON_land/seamless/c ?

Current topic:

- Treatment of **surface Roughness (R)**



1. Direct R-impact to atmospheric model equations:
   a) Non-commutativity of spatial differentiation and inherent numerical averaging
      - pressure gradient <-> form drag by blocking
      - flux divergence <-> increased surface area (SAI)
   b) Induced sub-grid heterogeneity:
      - Heating or cooling of slopes

- vertically resolved form-drag by SSO in momentum budget; SAI-effect: missing
- vertically resolved effect of sub-grid ana- and kata-batic winds: missing

2. R-impact on non-atmospheric processes at the surface:
   a) Loosely coupled, semi-transparent cover layer "shading" the compact soil with a specific evapo-transpiration and with interception of all water phases: missing
   b) Required prognostic, implicit treatment of specific surface temperatures for R-Elements, compact soil and a partial snow-cover: missing

R-layer by small-scale land-use:
- Vertically not resolved
- Part of CF transfer layer

- Increased R-length by inter-tile variation of Land Use: missing
- Shear by non-turbulent sub-grid wind induced by SSO: missing

- **ConSAT-development distributed over 3 code "branches"**

  I. **In recent ICON-branch 'mrprep' (focus of current activity):**

  - **So far mainly related to the atm. subdomain ('turbdiff', 'turbtran' and interfaces): Issue 1**
    - **Thermal SSO effects (TSSO): SGS kata/anabatic circulations considered; substitutes old "circulation term" [completely revised version]**
    - **Tile-Variation mode of Land-use Roughness (TVLR): Additional surface R by change of Land-Use from tile to tile [new issue]**
    - **Surface-Layer Shear-Amplification (SLSA): Additional wind-shear in surface layer due to the impact of Non-Turbulent Circulations (NTC) [new issue]**
    - **Dynamical Surface Smoothing by Snow (DSSS): Snow-sinking of Land-use R**
    - **Consolidation of water budget [new issue]:**
      - **Deposition fluxes of liq.-water and ice-particles considered in 'terra'**
      - **Unphysical upward non-grad. surf.-flux of liq.-water at diffusion mode in quasi-conserved scalar variables (lexpcor=T) no longer possible**
    - **Major optimization, correction and cleaning of entire turbulence code: All new development as switchable options; speed-up of about 7% with oper. config.**
  - **Quite large interconnected development; recently merged with current ICON-master**
    - **Is being absorbing all the remaining development of the other 2 branches**

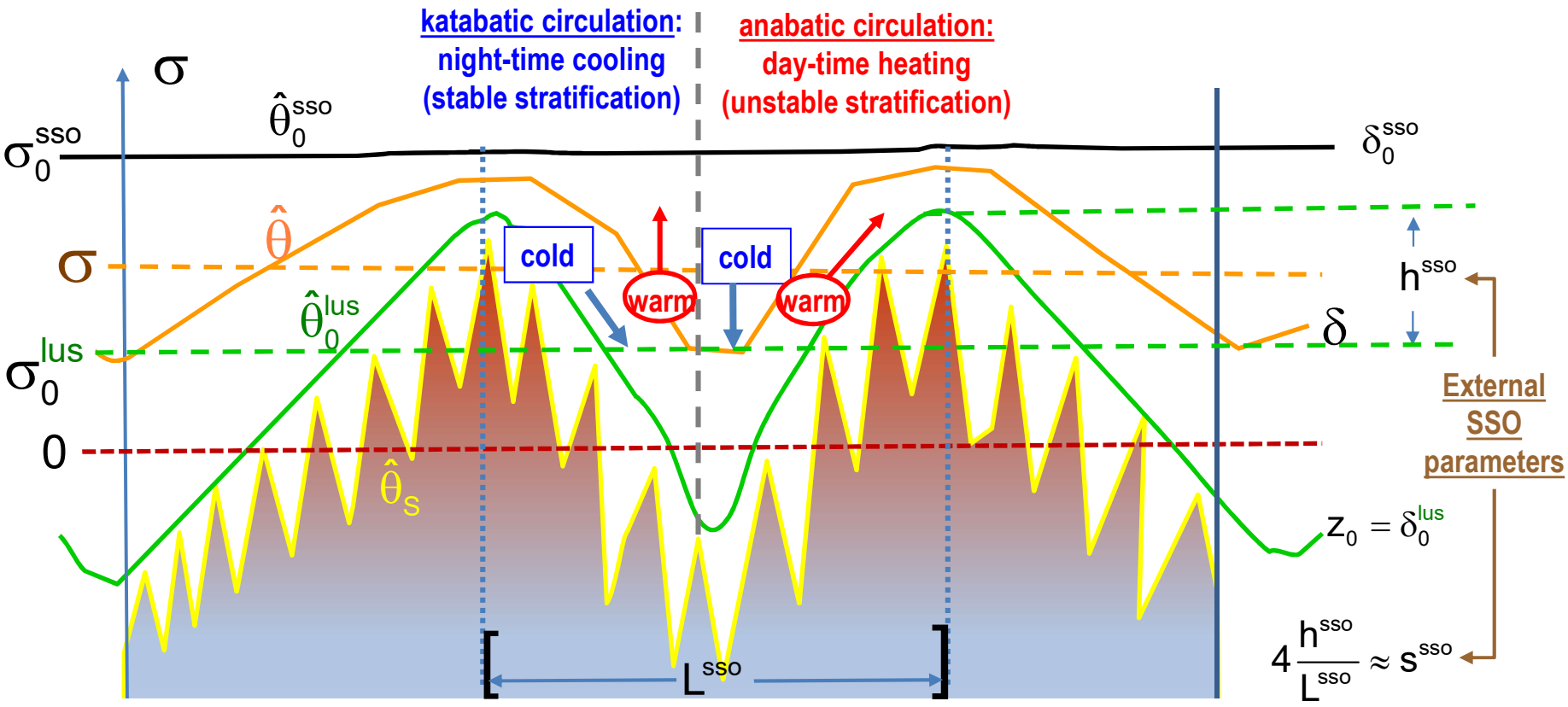
II. In older ICON-branch 'mrsurf' (currently inactive):

- More related to the non-atm. subdomain ('terra', 'turbtran' and interfaces): Issue 2b
  - Major 'terra' revision (incl. interfaces) with implicit treatm. of surface temperatures (IST)
    - ➢ various necessary adaptations and corrections around surface processes
  - Includes heat-equation of á fully implicit coupled ml<->sl fractional snow-cover above soil
    - ➢ Prepared for new ml snow-hydrology, e.g. from 'snowpolino'
  - Solves significant numerical problem with oscillating surface temperatures
    - ➢ Necessary prep. for a conceptually and numerically clean R-Cover impl. (s. III.)
  - Abstains from the introduction of major additional physical content
    - ➢ This ought to be introduced by an extension towards an R-Cover impl. (s. III.)

III. In old private COSMO development version (currently inactive): Issue 2a

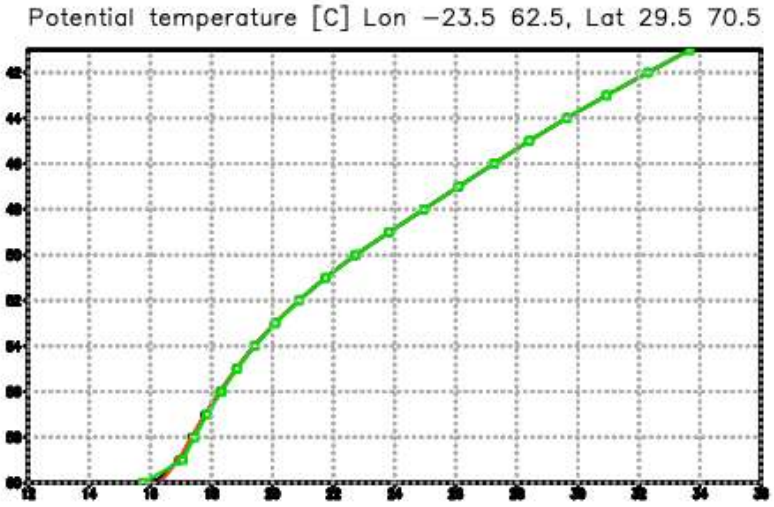
- More related to the non-atm. Subdomain (mainly 'terra'):
  - Prototype of a R-Cover scheme (canopy treatment)
    - still without IST-development and ignoring snow at all
  - Large impact on evapo-transpiration
    - ➢ significant improvement of T2m and Td2m daily cycle with test case

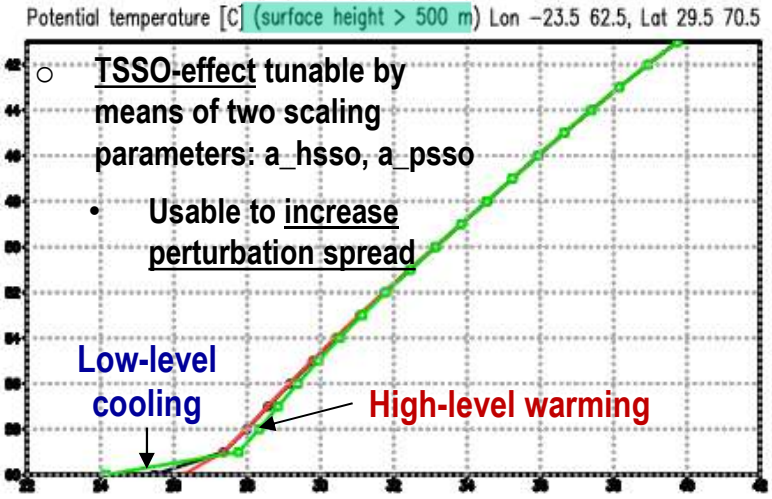
About the Thermal effect of SSO (TSSO):



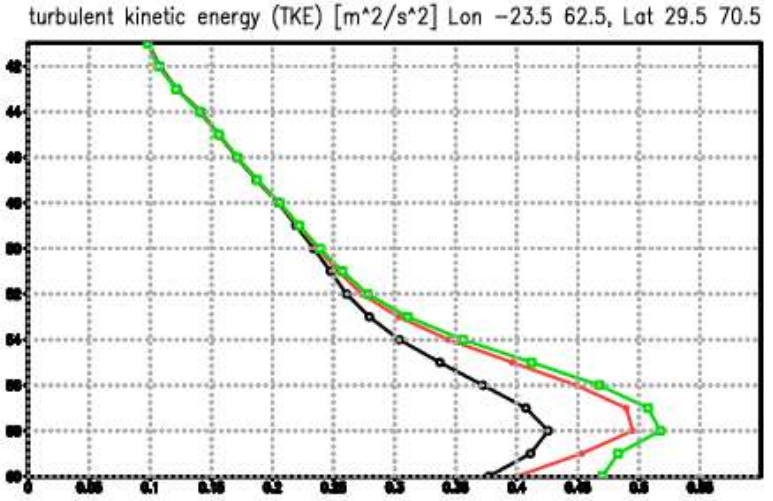
- **STIC-approach** for **TKE-Production** and the related **upward heat flux by NTC**:
  - Forcing **L-scale pressure gradient** based on estimated **L-scale std. dev.** $\left|\Delta\hat{\theta}_{v}{}^{z}{}_{|L}\right|$ along **horizontal surfaces** provides **buoyant CKE-production**, using h^{sso} and s^{sso}
    - **TKE-source** by additional **shear-forcing: increased downward turbulent heat flux**
    - **Buoyant NTC heat-flux** $\overline{\bar{\rho}|_L \hat{w}|_L'' \hat{\theta}|_L''}^{\delta}$: **low-level cooling** and **high-level warming**

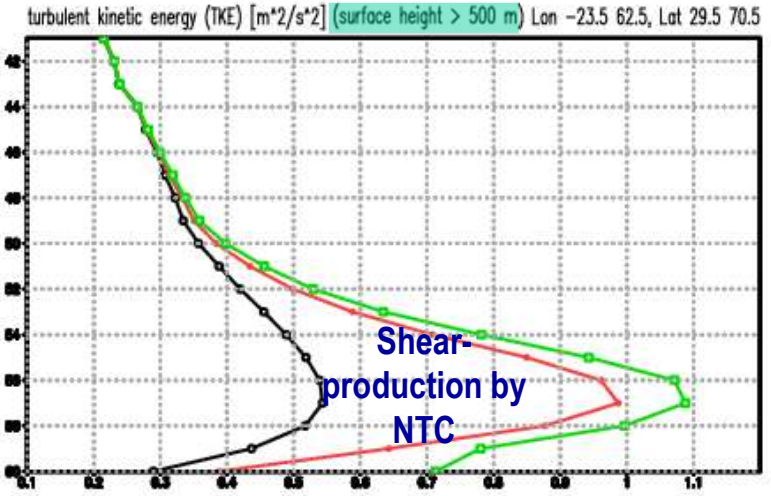
Mean profiles with katabatic effect





- **TSSO-effect tunable by means of two scaling parameters: a_hsso, a_psso**
  - **Usable to increase perturbation spread**



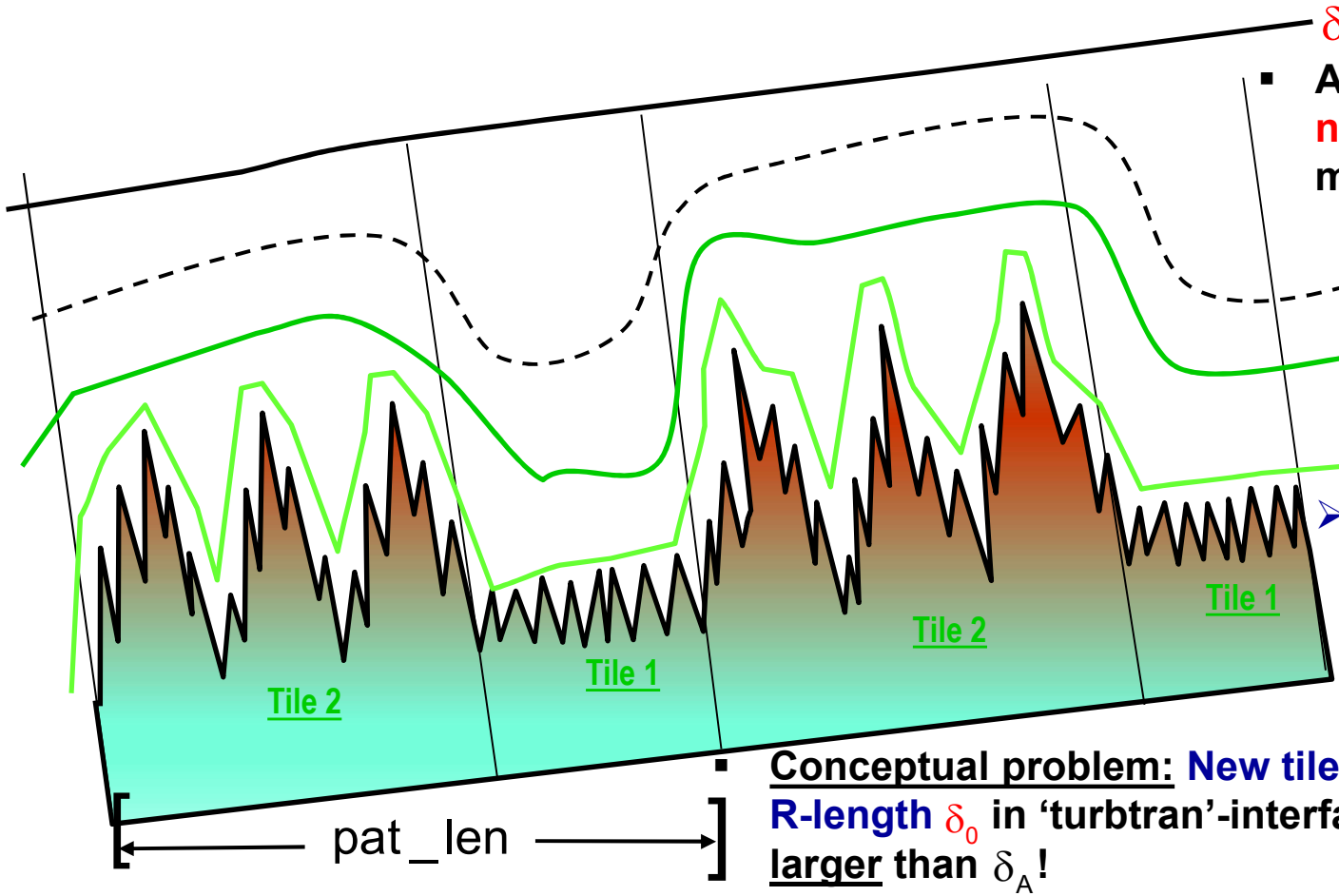


out_ic02−prp5−rout out_ic02−prp5−a_hsso=1−lcirflx=F out_ic02−prp5−a_hsso=1−lcirflx=T−p_hsso=0.1

Reference test-case used for whole development:

or time=03Z20SEP2020 or hour=3hr

About the Tile Variation of Land use Roughness (TVLR):



- Additional **SSO-like TVR** **not considered** in the model

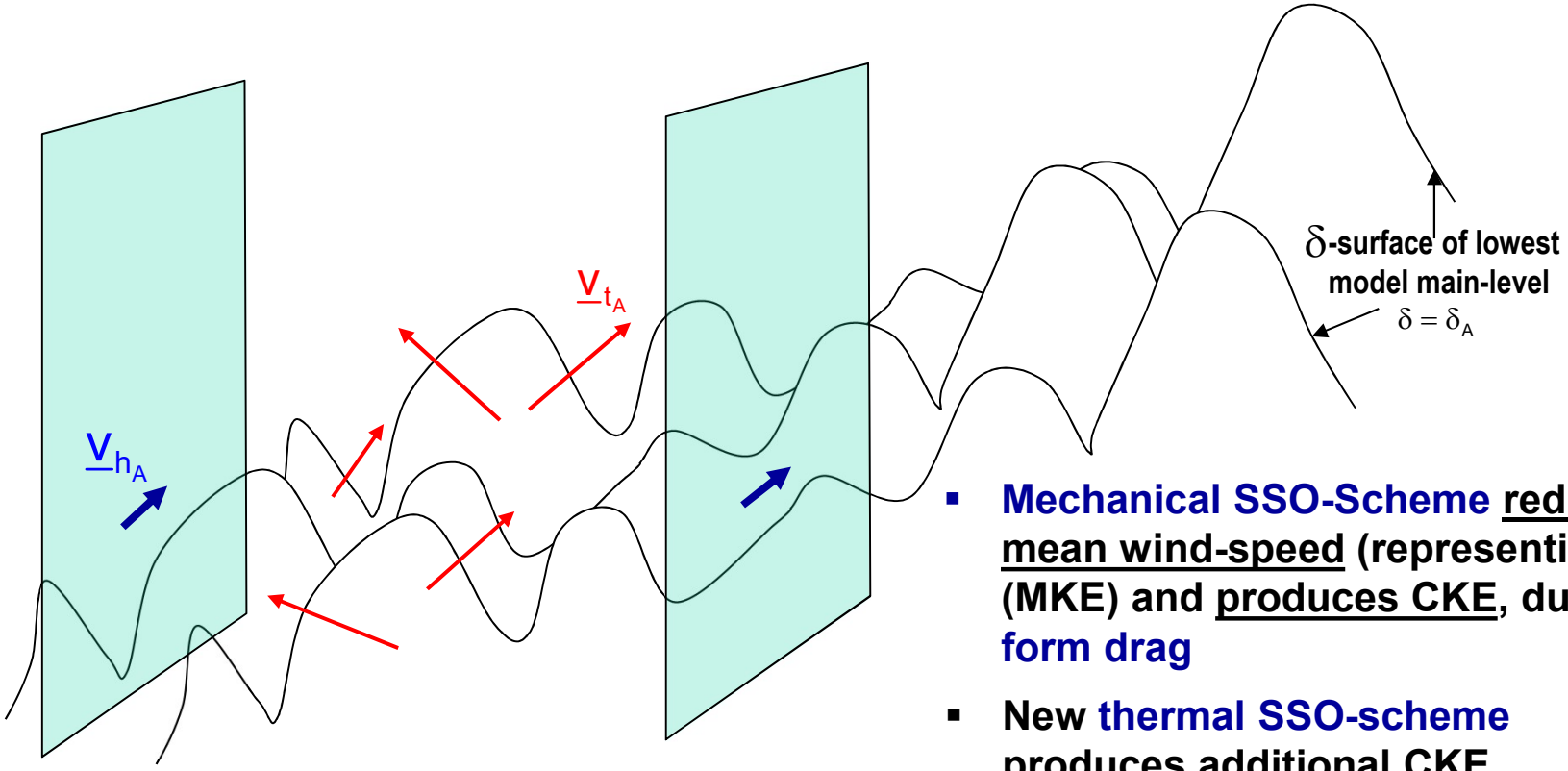
➢ **Momentum coupling** with surface and **wind shear-forcing** for turbulent transfer **too weak**

- **Conceptual problem:** **New tile-aggregation** of **overall R-length** δ_0 in 'turbtran'-interface may become even **larger** than δ_A!

➢ **Solution:** TMod in 'turbtran' **still applied at** δ_0^i **for each tile i**, but with **reduced transfer-resistance for momentum** and accordingly **more shear-forcing** by applying **wind speed from an associated higher level**

❖ **Required some substantial reformulation in ICON-turbtran**

About Surface-Layer Shear Amplification (SLSA) by the action of NTCs:



- **Mechanical SSO-Scheme reduces mean wind-speed (representing (MKE) and produces CKE, due to form drag**
- **New thermal SSO-scheme produces additional CKE**

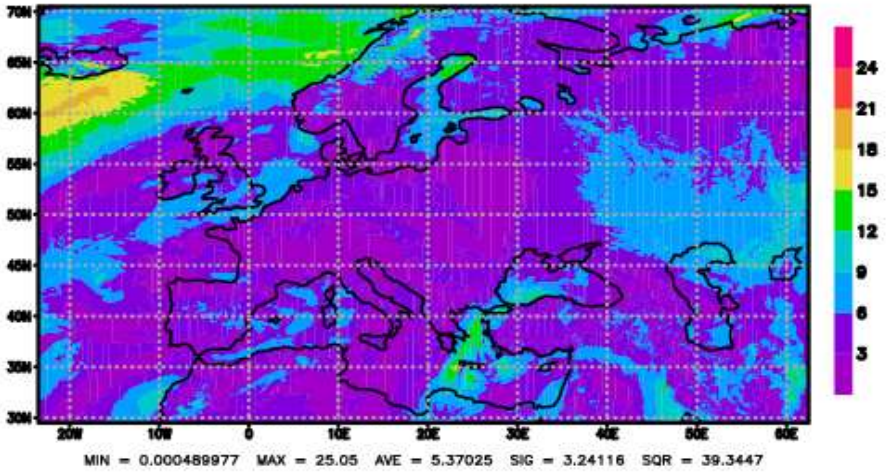
➢ **Locally averaged, tangent non-turbulent wind-vector $\underline{V}_{t_A}$ at the lowest model level (representing MKE + CKE) may be much larger than grid-scale averaged horizontal wind-vector $\underline{V}_{h_A}$.**

➢ **Driving wind shear for transfer scheme systematically underestimated!**

❖ **SLSA-impact introduced into ICON-turbtran by estimation of $v_{t_A} := |\underline{V}_{t_A}|$ and defining the transfer layer (between $\delta = \delta_A$ and $\delta = 0$) as a CFL for v_t**

Horiz. wind speed at 10m [m/s]

out_ic02-prp5-rout



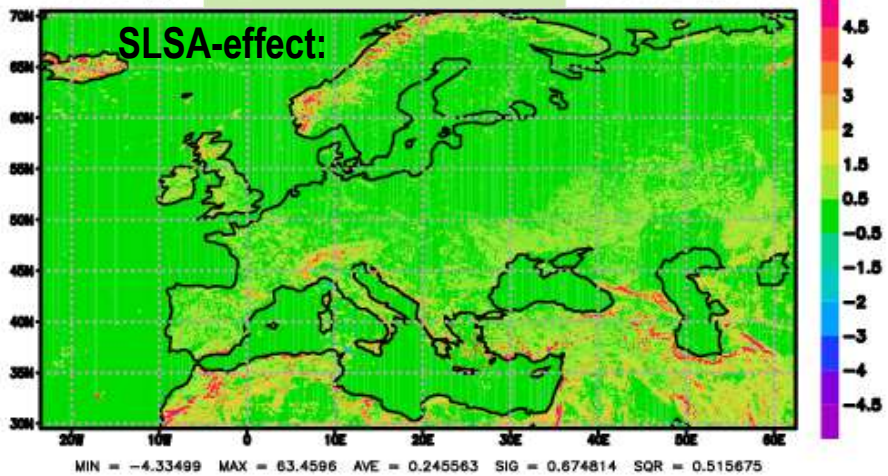
MIN = 0.000489977 MAX = 25.05 AVE = 5.37025 SIG = 3.24116 SQR = 39.3447

- **TVLR-effect tunable by means of two scaling parameters: rtil_var and pat_len**
- **SLSA-effect tunable by means of the scaling parameters: rsur_shr**

❖ **New parameters may be usable to <u>increase perturbation spread</u>!**

out_ic02-prp5-rsur_sher=0.5-imode_10m_diag=2 – out_ic02-prp5-rout

SLSA-effect:



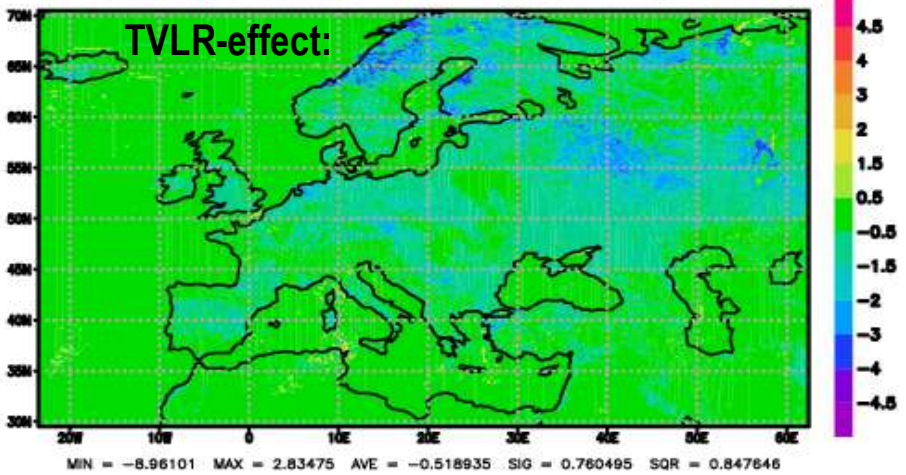
MIN = -4.33499 MAX = 63.4596 AVE = 0.245563 SIG = 0.674814 SQR = 0.515675

❖ **Increased 10m-wind** at places with high wind-speed and large SSO-roughness

pat_len=100m

out_ic02-prp5-rtil_var=1.0 – out_ic02-prp5-rout

TVLR-effect:



MIN = -8.96101 MAX = 2.83475 AVE = -0.518935 SIG = 0.760495 SQR = 0.847646

❖ **Reduced 10m-wind** at places with high wind-speed and large tile-variation of roughness

Reference test-case used for whole development:

or time=12Z20SEP2020 or hour=12hr

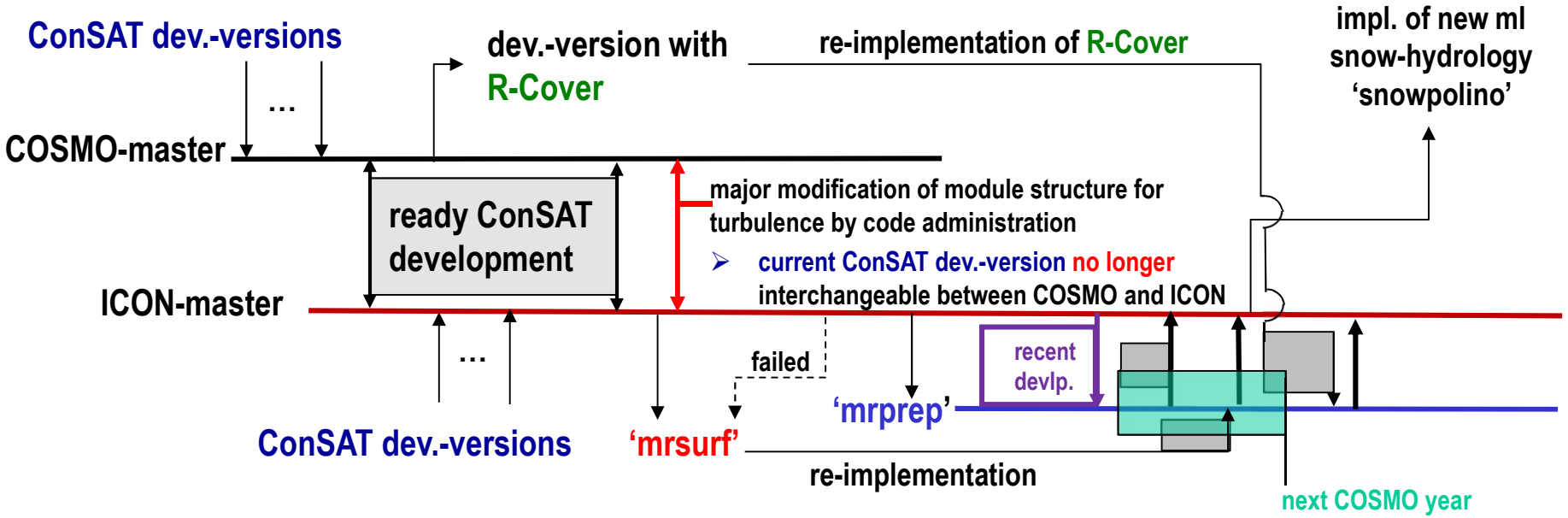
Next development steps:

- **Extensive Testing and Tuning:**
  - **Buildbot-tests, adaptations after gate-keeper control, merge into 'master'**
  - **Getting 'mrprep' into 'master' as soon as possible**
  - **Estimation of optimal parameter configuration, verification and further revision**
    - **with particular consideration of new external SSO data**
    - **employing data from particular field experiments (TeamX)**

- **Some further related ConSAT development:**
  - **SAI-effect on turbulent fluxes (in 1st and 2nd order eq.) for SSO-layer and grid-scale slopes**
    - **Sai-dep. closure parameters and turbulent distance δ (as funct. of volume height σ)**
    - ➢ **Contribution to simulation at hector-metric resolution**
  - **Consideration of full SGS diffusion by NTCs for all properties**
  - **…**

- **Related development (so far) apart from ConSAT:**
  - **Consideration of surface slopes by SSO or GS orography for radiation calculation**

Previous and upcoming course of ConSAT-implementations:



And now, let‘s have a look at the anabatic winds in the Greek mountains!