Report from stay in Ljubljana : 5 May - 31 May 2013

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Contents

Abstract

The current version of turbulent scheme TOUCANS has been implemented in to local cycle CY36t1. Influence of mixing length on quality of wind forecast was tested in implemented TOUCANS scheme. The analyses in case studies shows improvement of wind forecast when using mixing length based on TKE, which does not overestimate mixing in situation with strong wind. However the change in turbulent mixing leads to cold bias in 2 meter temperature forecast.

Also diagnostic of wind gust computed from TKE was examined. The "default" TKE based wind gust diagnostic tends to underestimation, so a modification of the formula was proposed (in order to account for skewness of the wind gust distribution) and tested in one month winter period in Slovenia.

1 TOUCANS implementation

1.1 TOUCANS

TOUCANS (Third Order moments (TOMs) Unified Condensation Accounting and N-dependent Solver (for turbulence and diffusion)) is a compact turbulence parametrisation. TOUCANS integrates several ideas in turbulence parametrization: no existence of critical Richardson number Ri_{cr}, anisotropy of turbulence, prognostic treatment of Turbulence Kinetic Energy (TKE), Third Order Moments (TOMs) parametrisation, and parametrisation of shallow convection.

No existence of Ri_{cr} and anisotropy of turbulence are ensured by the shape of stability functions ϕ_3, χ_3. These are taken either from CCH02 turbulent scheme [3] (with modifications) or from Quasi-Normal Scale Elimination (QNSE) [11] (with fit 'extended' for $Ri < 0$).

Prognostic treatment of TKE is adapted from pTKE [5] turbulent parametrisation (adapted version called as eTKE).

Usage of TKE as prognostic variable enables computation of TKE dependent mixing lengths L. In TOUCANS are available five different settings for mixing length computation.

1.2 TOUCANS implementation

TOUCANS has been implemented in to cycle CY36t1. The technical details of TOUCANS scheme are presented in this subsection.

1.2.1 Turbulence scheme

The schemes with prognostic TKE (pseudo-TKE and TOUCANS) are turned on with LPTKE=.TRUE., otherwise the Louis scheme is used. TOUCANS is turned on by LCOEFKTKE=.TRUE. .

LPTKE	.TRUE.		.FALSE.
LCOEFKTKE	.TRUE.	.FALSE.	-
Scheme:	TOUCANS	pseudo-TKE	Louis scheme

1.2.2 TOUCANS emulation

We have 4 possibilities. A system versus B system and QNSE versus CCH02 system:

Switch	.TRUE.	.FALSE.
LCOEFK_QNSE	QNSE scheme	CCH02 scheme
LCOEFK_CCH02A	A system	B system

The choice of turbulence scheme is connected with degrees of freedom . In the code we use these four:

Parameter	Parameter name	CCH02 A	CCH02 B	QNSE A	QNSE B
C_3	C3TKEFREE	1.183	1.183	1.39	1.39
Ri_{fc}	ETKE_RIFC	0.1865	0.1865	0.377	0.377
$\nu \equiv (C_K C_\epsilon)^{\frac{1}{4}}$	NUPTKE	0.5265	0.477	0.504	0.4643
C_ϵ	C_EPSILON	0.8709	0.7148	0.798	0.6772

pseudo-TKE pseudo-TKE is controled by one degree of freedom ν (NUPTKE). The default value is 0.52.

1.2.3 Mixing lengths

The calculation of mixing length l_m is not restricted to 'classical' computation of z-dependent mixing length (parameter CGMIXELEN='AY', or default CGMIXLEN='Z'; difference is in PBL height computation):

$$l_{m/h} = \frac{\kappa z}{1 + \frac{\kappa z}{\lambda_{m/h}} \left[\frac{1+\exp\left(-a_{m/h}\sqrt{\frac{z}{H_{pbl}}}+b_{m/h}\right)}{\beta_{m/h}+\exp\left(-a_{m/h}\sqrt{\frac{z}{H_{pbl}}}+b_{m/h}\right)} \right]}. \quad (1)$$

(κ is Von Kármán constant, z is height, $a_{m/h}$, $b_{m/h}$ and $\lambda_{m/h}$ are tuning constants and H_{pbl} is PBL height)
, but we can also use mixing lengths dependent on TKE (e) L:

- modified Bougeault and Lacarrère (1989) approach:
  $L_{BL}(e) = \left(\frac{L_{up}^{-\frac{4}{5}} + L_{down}^{-\frac{4}{5}}}{2} \right)^{-\frac{5}{4}}$
  $L_{up}(e)$ ($L_{down}(e)$) - upward(downward) mixing distances
- $L_N = \sqrt{\frac{2.e}{N^2}}$ for stable regimes (N is Brunt-Väisälä Frequency)

thanks to the conversion relation:

$$L = \frac{\nu}{C_K} l_m. \quad (2)$$

5 new appropriately combined mixing lengths are available in the code:

Parameter CGMIXELEN	$Ri > 0$	$Ri \leq 0$
EL1	L_{BL}	L_{BL}
EL2	L_{BL}	$\min\left(\sqrt{L_{BL}\,L_{GC}}, L_{BL}\right)$
EL3	$\min(L_N, L_{max})$	L_{GC}
EL4	$\frac{L_{GC}\,L_N}{\sqrt{L_{GC}^2+L_N^2}}$	L_{GC}
EL5	$\min(L_{BL}, L_N)$	L_{BL}

L_{max} - upper limit for mixing length in stable stratification;

L_{GC} is (1) converted to TKE type mixing length.

The dependence of mixing length L on TKE can be tuned by the parameter TKEMULT (by default TKEMULT=1): $L(e) \to L(\text{TKEMULT}.e)$

1.2.4 Shallow convection

Shallow convection can be parametrised:

1. with parametrisation after Geleyn 1987 (Ri^*)
2. with new 'moist' Ri based on Pascal Marquet's moist entropy potential temperature θ_{s1}: Ri^{**}
3. computing 'moist' Ri from SCC (Shallow Convection Cloudiness) after [10]: Ri_m , or
4. using two Richardson numbers (hybrid mode): Ri_m for computation of source terms in TKE equation, and Ri_{s1} (directly connected to θ_{s1}) for computation of stability functions in turbulent diffusion

Switch	.TRUE.	.FALSE.
LCOEFK_THS1	Ri^*	Ri^{**}
LCOEFK_RIH	hybrid Ri_m, Ri_{s_1}	only Ri_m
LCOEFK_RIM	Ri_m from ext. SCC	Ri_m from SCC from $Ri^{*/**}$

The 'sharpness' of on and off switching of shallow convection parametrisation by Ri^{**} is controlled by ETKE_RIFC_MAF. The default value is ETKE_RIFC_MAF=0.5. Higher value makes the transition from $Ri < 0$ to $Ri > 0$ less steep.

Moist AntiFibrillation (AF) scheme can be turned off by setting XDAMP=0.0. The default value is XDAMP=1.0.

Ri_{s1} and Ri_m have moist AF turned off by construction and are not influenced by XDAMP.

1.2.5 Third Order Moments (TOMs)

TOMs parametrisation is turned on by LCOEFK_TOMS=.TRUE. .

It is possible to tune individual TOMs terms by multiplying factors (default values are 1.0):

TOM term	Multiplying parameter
$\overline{w'^3}$	ETKE_CG01
$\overline{w'^2\theta'}$	ETKE_CG03

1.2.6 Security

The limitation for τ against too small values is set by ETKE_BETA_EPS : $\tau = \tau + \text{ETKE\_BETA\_EPS}\,\Delta t$. The default value is 0.02.

The limitation for τ against too large values is set by ETKE_GAMMA_EPS : $\tau = \frac{\tau}{1+\text{ETKE\_GAMMA\_EPS}\,\frac{\tau}{\Delta t}}$. The default value is 0.03.

2 Mixing length testing

Influence of mixing length on quality of wind forecast was tested in implemented TOUCANS scheme Two "typical" winter syndromes were chosen for this purpose:

1. Forecast gives too strong south-west wind in north-east of Slovenia in situation with stable stratification near surface:
   (a) case **14.12.2012 00:00 + 34h** - false alarm for strong south-west wind in north-east of Slovenia.
   (b) case **24.12.2012 00:00 + 36h** - strong south-west wind in north-east of Slovenia.
2. Forecast onset of Bora wind with low intensity is too early in south-west of Slovenia:
   (a) **28.12.2012 00:00 + 20h** - too early forecaster onset of Bora wind with low intensity in south-west of Slovenia.
   (b) **01.02.2012 12:00 + 30h** - Bora wind with high intensity in south-west of Slovenia.

The model settings in these experiments were set to default values except for the mixing lengths (and except in Figs. 12 and 13) where all six possible (AY, EL1–5) mixing lengths were tested. For better orientation only the most relevant results will be presented in Appendix A in the form of figures.

In both situations the usage of mixing length based on TKE qualitatively improves the forecast, it reduces the forecaster wind speed in 1.(a) (see Fig.5 and Fig.6) and delays the onset of Bora wind in 2.(a) (see Figs. 33, 34, and 35). Also the introduction of TKE based mixing length does not significantly deteriorate the quality of wind forecast in "counter cases" (see Subsection A.2 and A.4).

The improvement of wind forecast is caused by the overestimation of mixing due too large mixing length AY. The problem originates in diagnostic of PBL height dependent on Richardson number. In chosen cases is such diagnostic very inaccurate (PBL height over 10 km) and leads to erroneous vertical profiles of mixing length (see Figs. 9, 19, and 28). Too strong mixing then leads to too strong downward transport of momentum.

The change in turbulence mixing (with usage on TKE based mixing lengths) affects also mixing of heat and moisture and leads to cold bias (smaller cold bias is already present for AY mix. length) of 2 meter temperature forecast. However the inversion of temperature which appears by usage of EL1-5 is confirmed by observations, so the error in 2 meter temperature forecast could be related also to other schemes of the model.

The TKE based mixing length produce less mixing (than AY) near surface in studied experiments. A tuning parameter TKEMULT can be used to adjust the scheme (see Figs. 12 and 13).

3 Wind gust diagnostics

Wind gust G diagnostics based on TKE was tested in the implemented TOUCANS scheme. The "old" method is based on friction velocity u_* (in the code in ACHMT subroutine) (dependent on bulk Richardson number and wind near surface) [12]:

$$G = U + \text{FACRAF}\, u_*, \tag{3}$$

where FACRAF is tuning constant.

The TKE based method (in the code in AROCLDIA subroutine) relates TKE to the wind gust[12]:

$$G = U + \text{FACRAF}\,\sqrt{\text{TKE}}, \tag{4}$$

Both methods were tested in one month period in winter (December 2012, 28308 data points - observation versus forecast). The friction velocity based method (LRAFTKE=.FALSE.) shows underestimation of wind gust (see Figs. 1, 3 and 4). The "default" ($G - U \sim \sqrt{\text{TKE}}$) TKE based method tends to underestimate wind gusts with lower intensity. So a modification of this method was performed by changing the exponent of TKE in Eq. (4). It appears that lower values of TKE exponent (probably $1/4$ is optimal) enable to introduce skewness (which is not considered in [12]) in to distribution of $G - U$ and this helps better TKE based diagnostic of wind gust (see Figs. 1-4).

Further testing of the modified diagnostic should be performed to confirm increased skill of this approach.

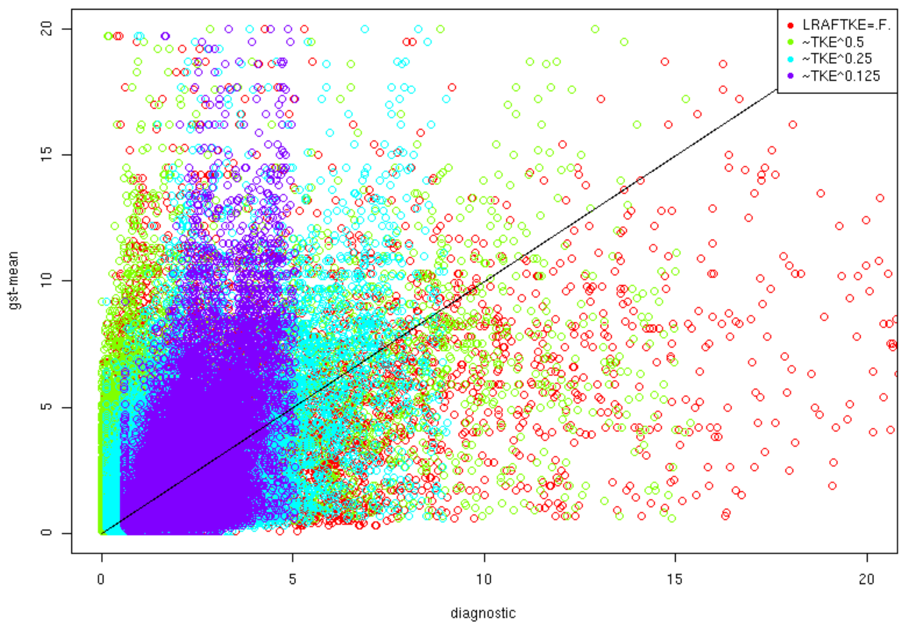

Figure 1: Scatter-plot of observed gust wind - observed mean wind versus diagnostic of this difference by : friction velocity (LRAFTKE=.FALSE.) or by TKE diagnostics; for December 2012 in Slovenia - 28308 points.

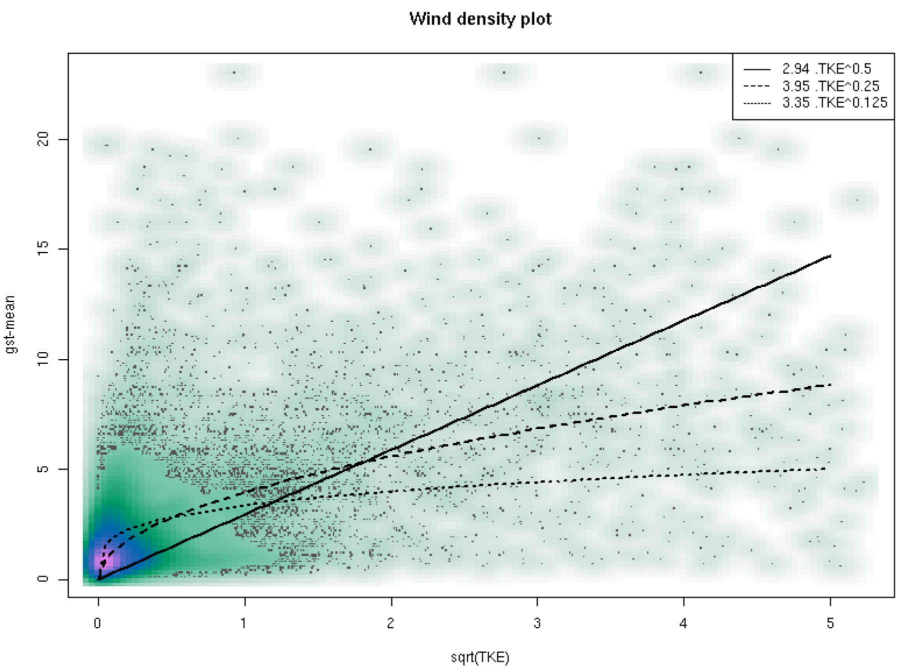

Figure 2: Density plot of observed gust wind - observed mean wind versus square root of TKE. Lines are fitting curves.

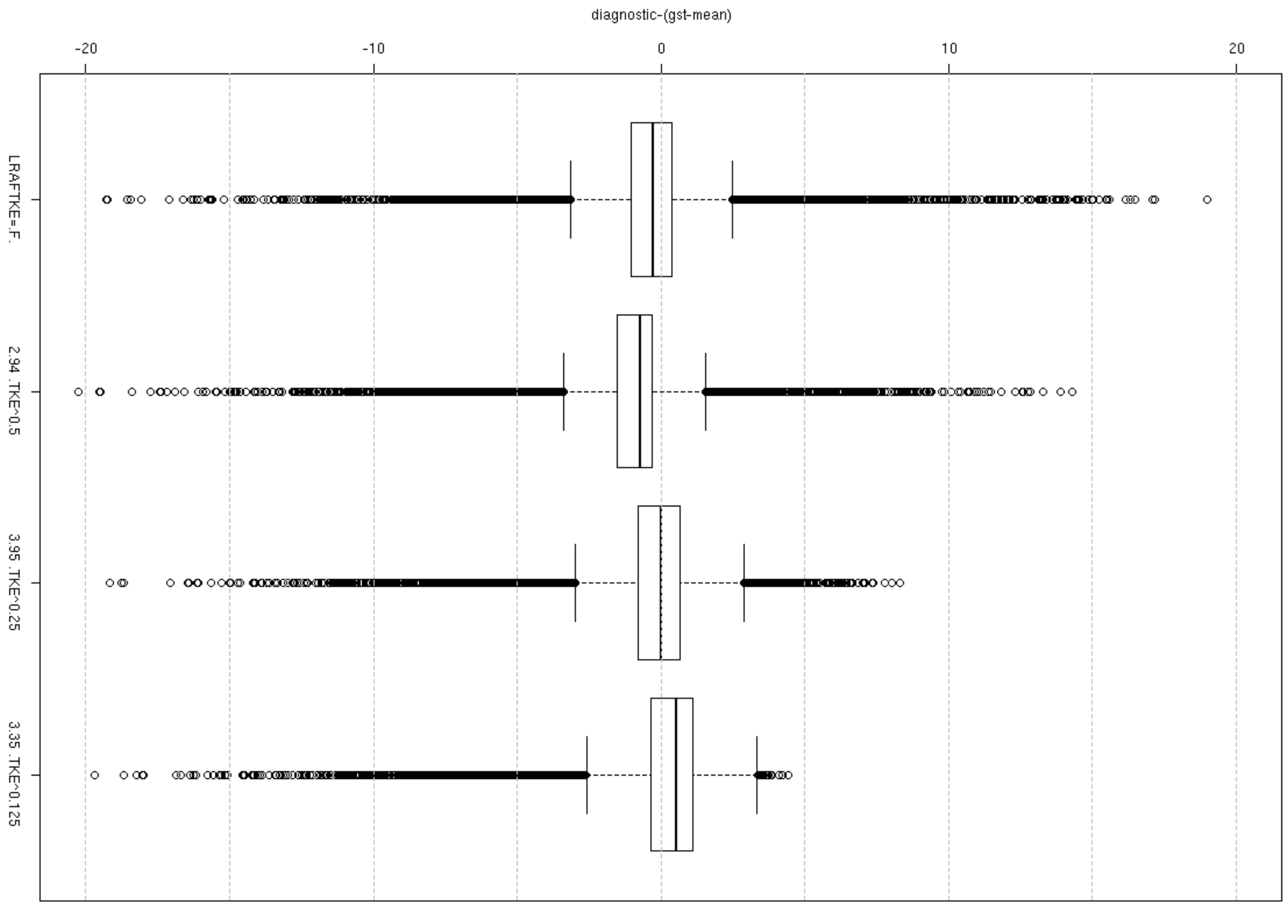

Figure 3: Box-plots of difference between diagnosed and observed gust wind - mean wind.

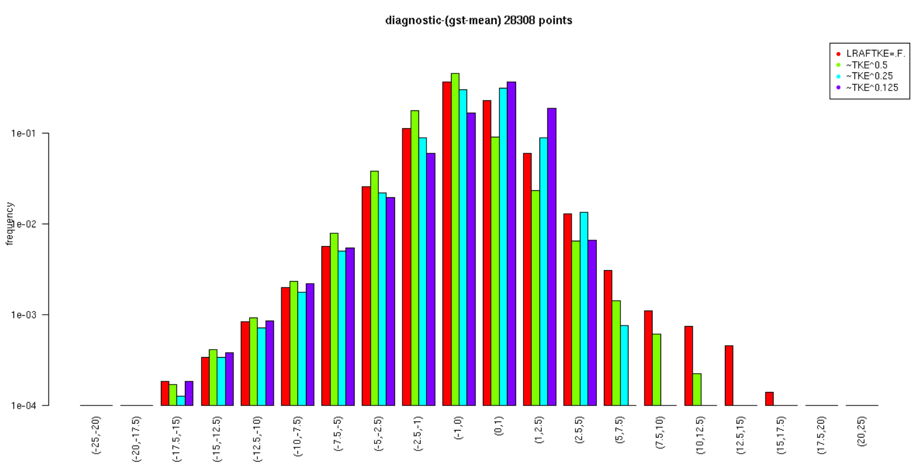

Figure 4: Histogram of difference between diagnosed and observed gust wind - mean wind.

A Appendix: Mixing length testing - case studies

List of Figures

A.1 False alarm for south-west wind - 14.12.2012 00:00 + 34h

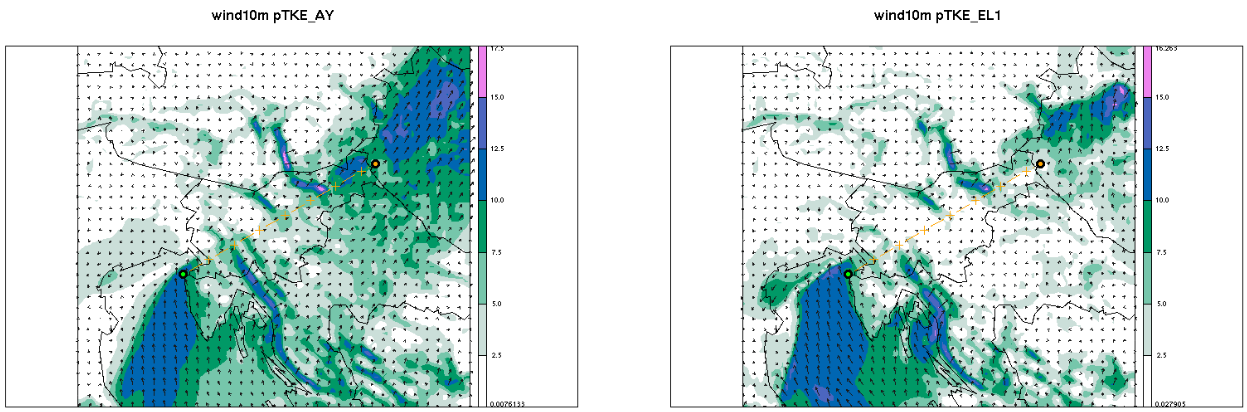

Figure 5: Wind forecast for 14.12.2012 00:00 + 34h with AY (left) mixing length, and EL5 (right) mixing length. Orange line indicates position of verticall cross section (green circle start, orange circle end of cross section) in Figs. 7-13.

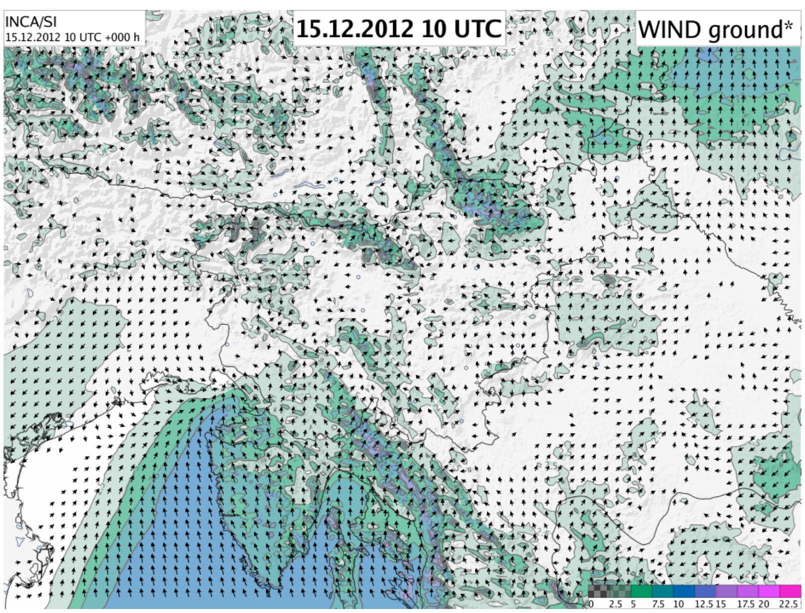

Figure 6: INCA 10 m wind analysis for 15.12.2913 at 10 UTC.

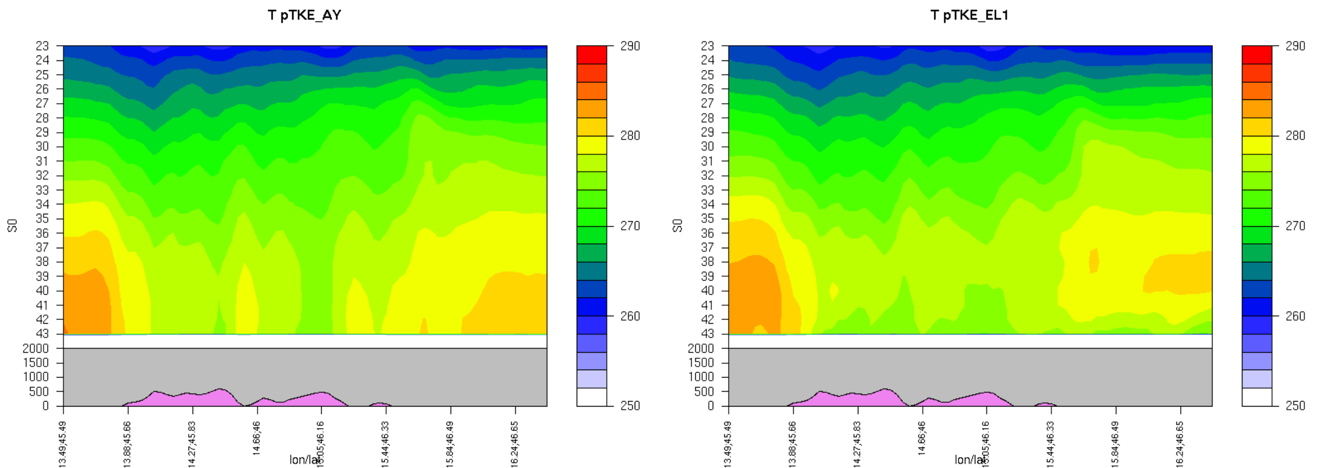

Figure 7: Vertical cross section (according to Fig. 5) of temperature forecast on 14.12.2012 00:00 + 34h with AY (left) mixing length, and EL5 (right) mixing length. Vertical coordinate is model level. Lower part of the graphs displays model orography in [m].

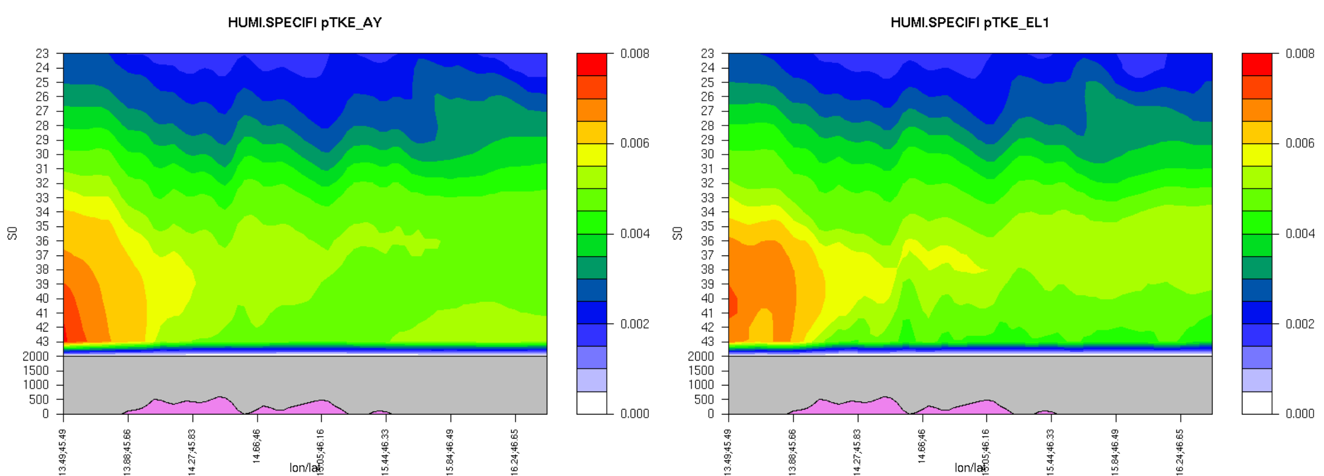

Figure 8: Same as Fig. 7 but for specifique humidity.

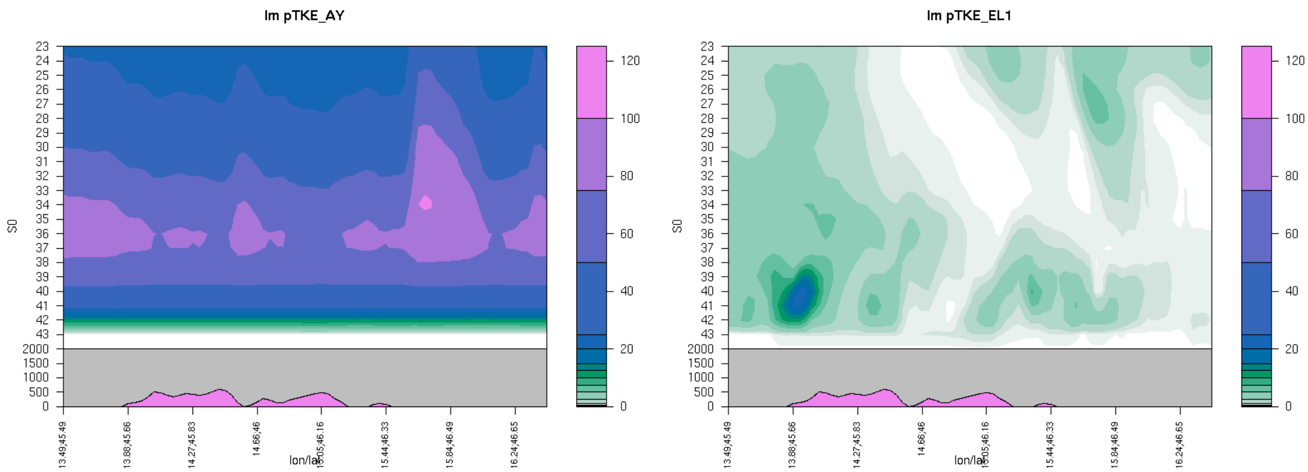

Figure 9: Same as Fig. 7 but for mixing length l_m (in case of EL1-5 converted with Eq. (2)).

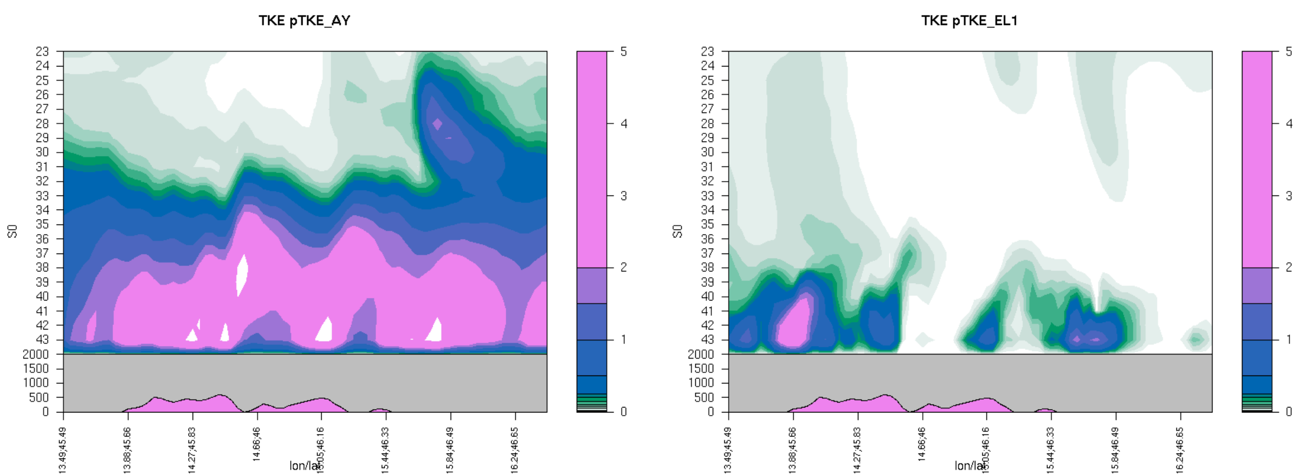

Figure 10: Same as Fig. 7 but for TKE.

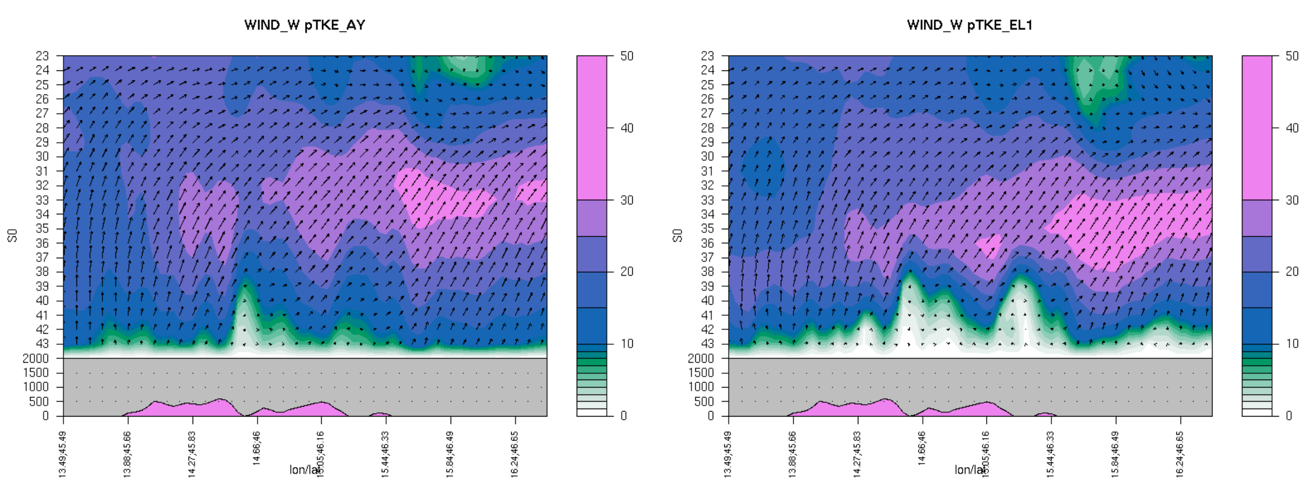

Figure 11: Same as Fig. 7 but for wind.

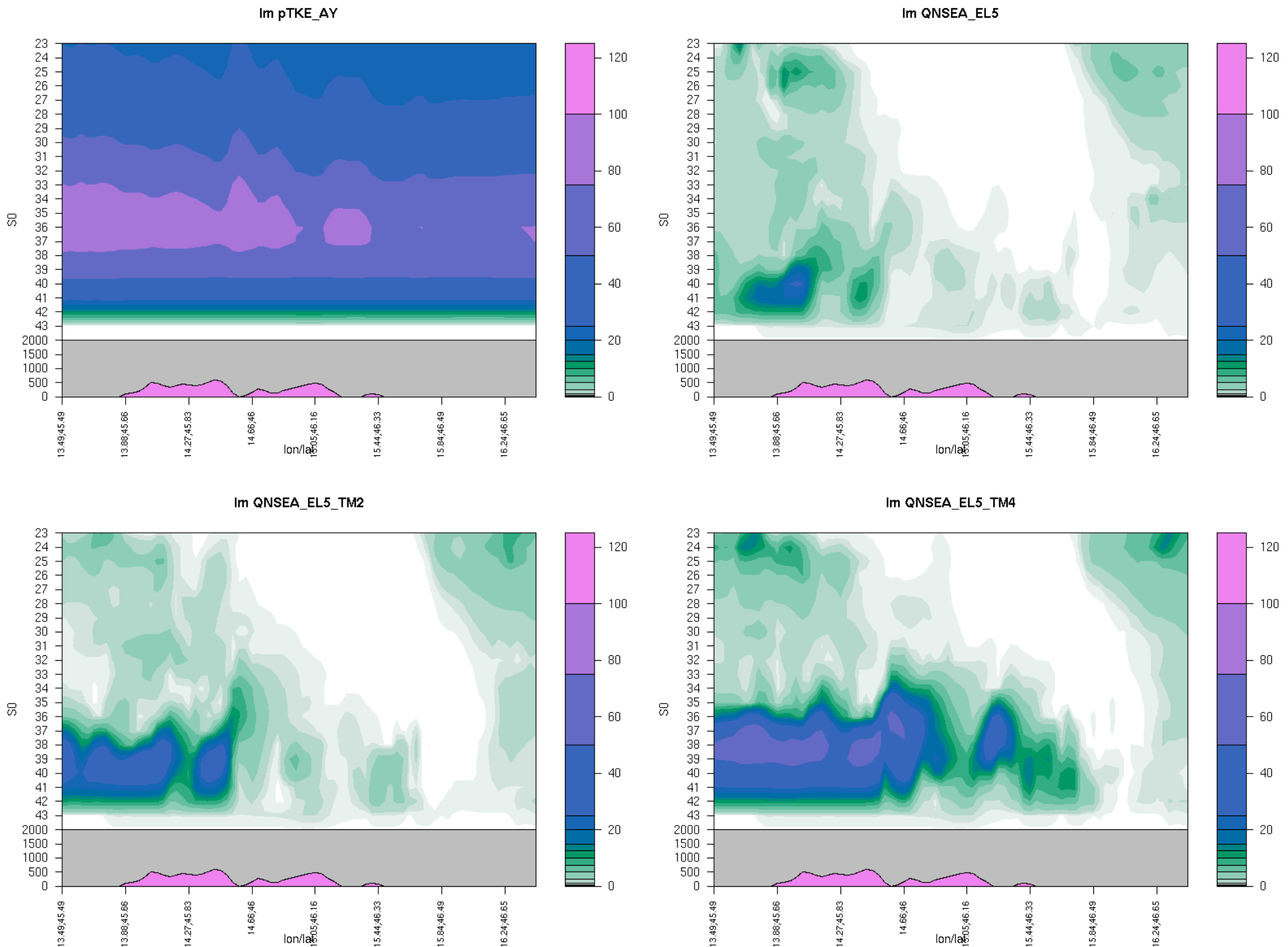

Figure 12: Same as Fig 7 but for mixing lengths l_m, and model settings are following: pTKE_AY: pTKE scheme with AY mixing length, QNSEA_EL5: QNSE scheme emulated in A system with EL5 mixing length, QNSEA_EL5_TM2: same as QNSEA_EL5 but with TKEMULT=2, QNSEA_EL5_TM2: same as QNSEA_EL5 but with TKEMULT=4

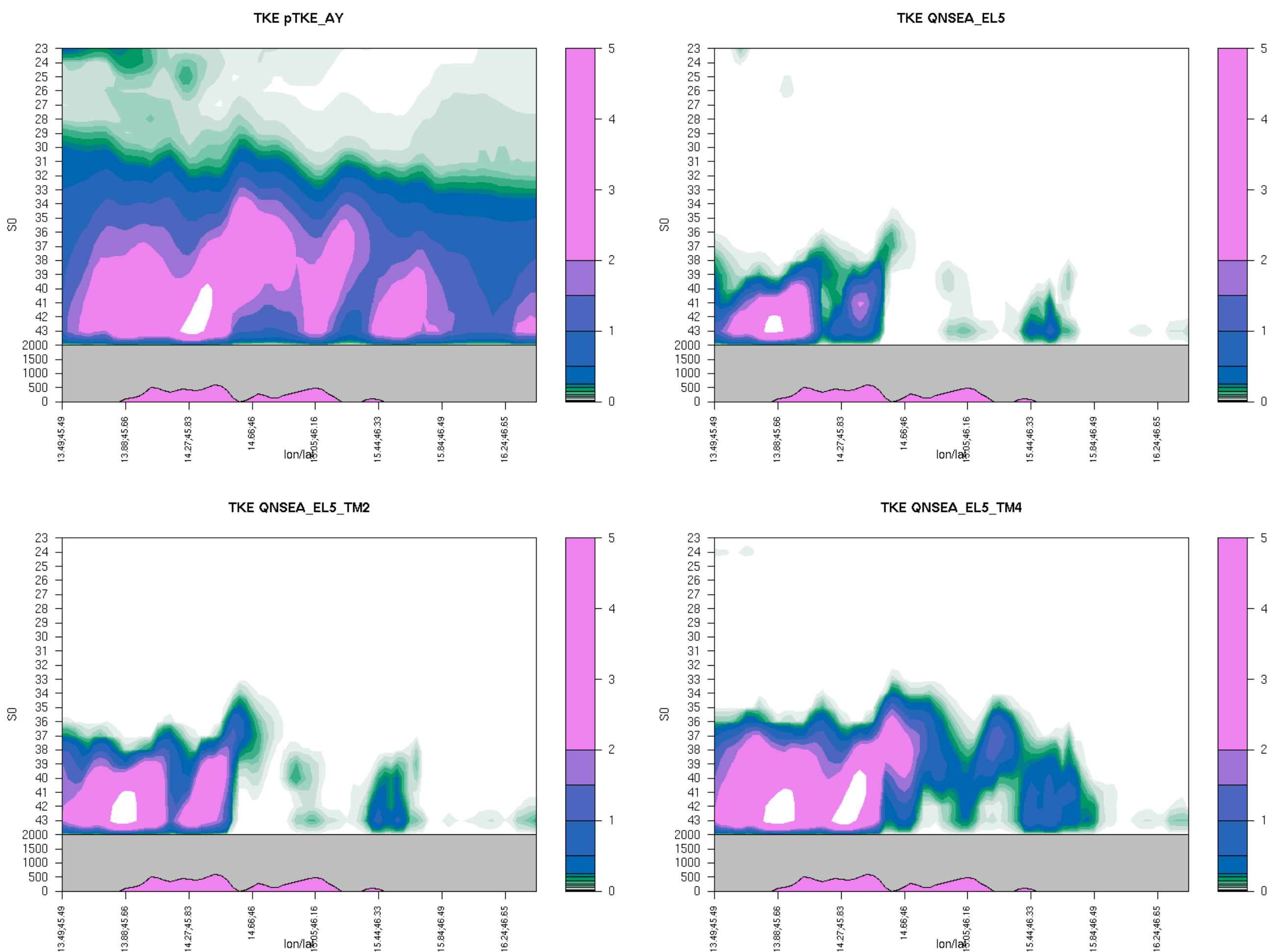

Figure 13: Same as Fig. 12 but for TKE.

A.2 Strong south-west wind - 24.12.2012 00:00 + 36h

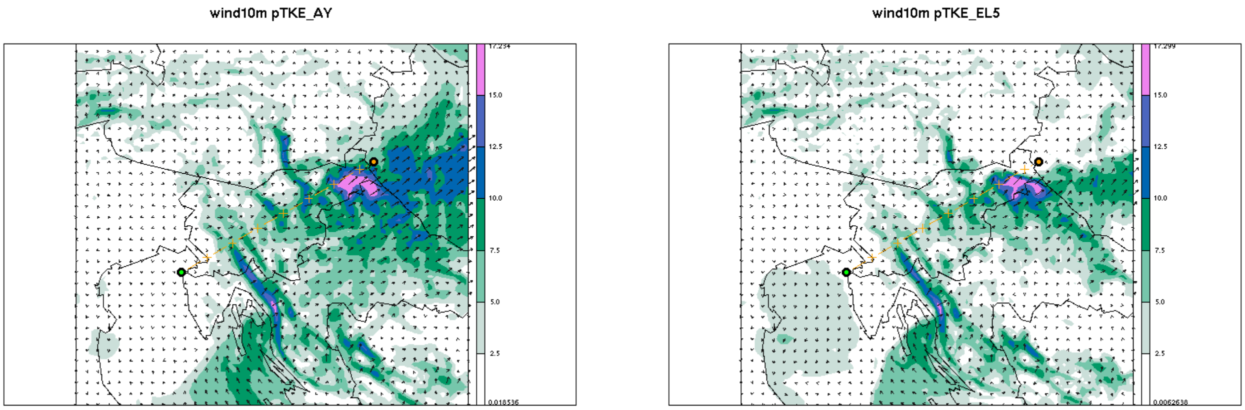

Figure 14: Same as Fig. 5 but forecast for 24.12.2012 00:00 + 36h and with EL5 on the right picture.

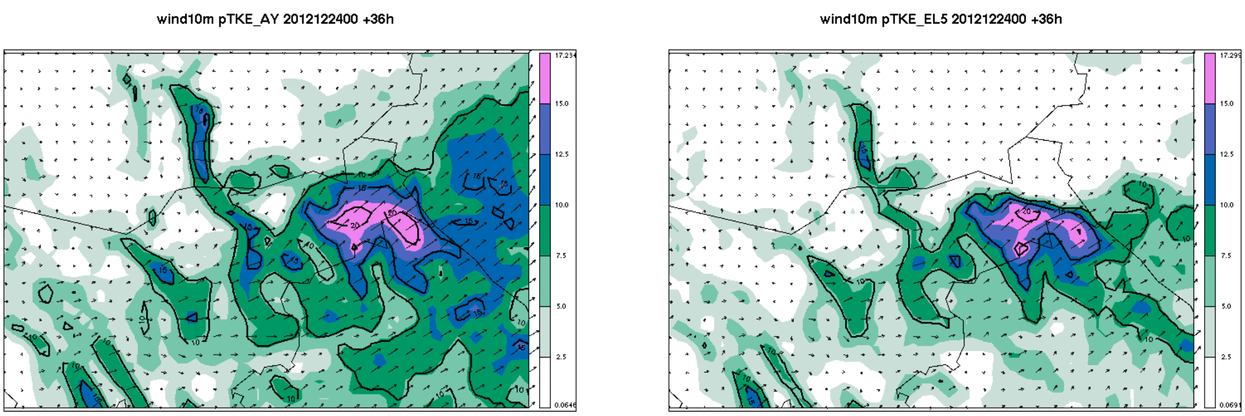

Figure 15: Same as Fig. 14 but zoomed.

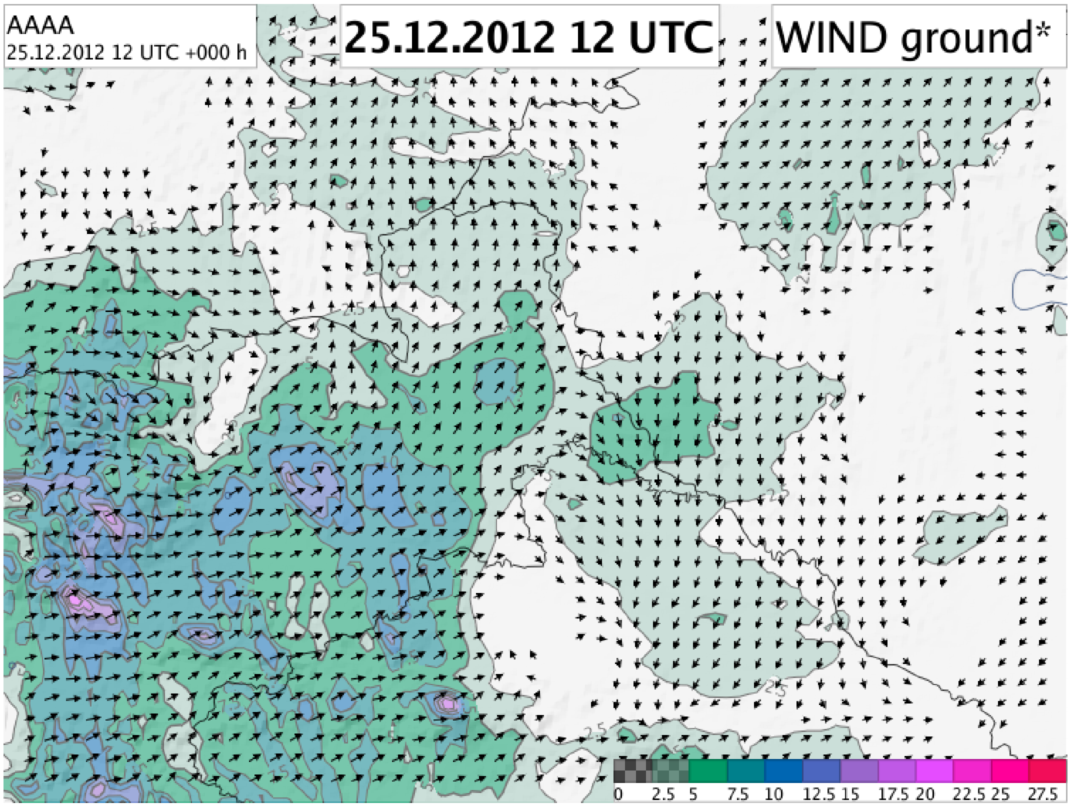

Figure 16: Same as Fig. 6 but analyses for 24.12.2012 00:00 + 36h.

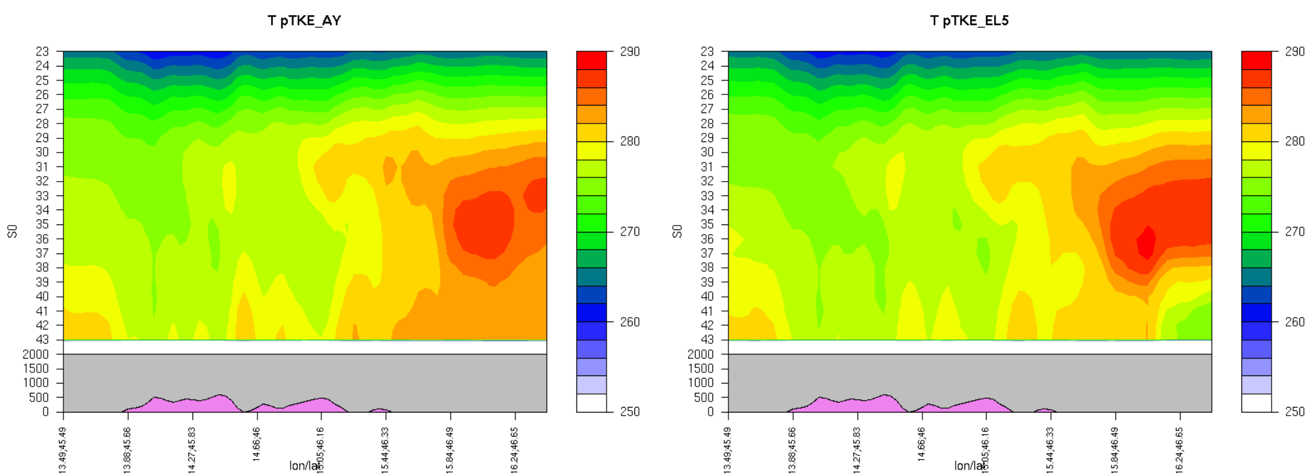

Figure 17: Same as Fig. 7 but forecast for 24.12.2012 00:00 + 36h.

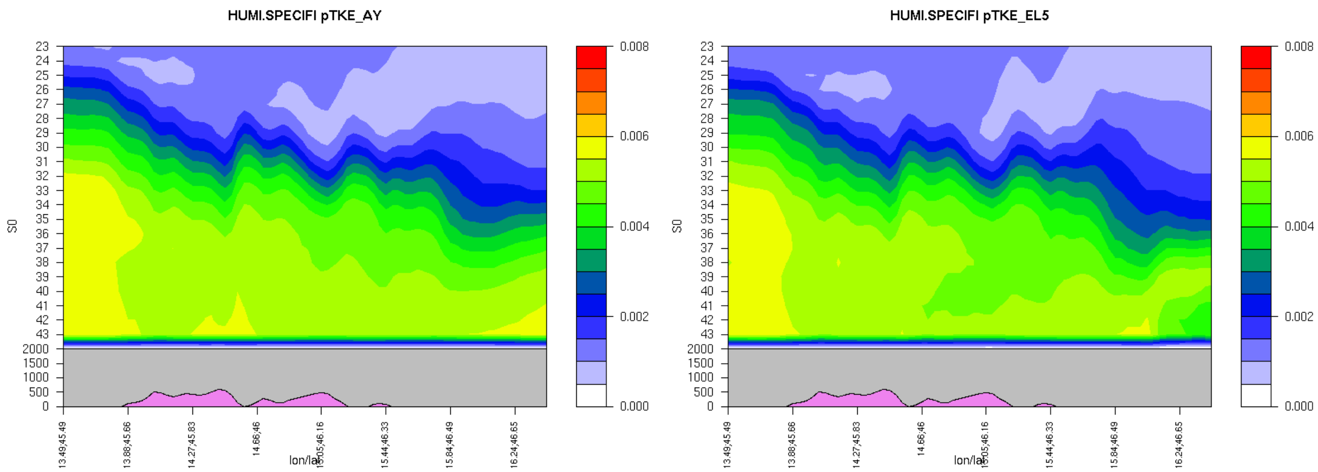

Figure 18: Same as Fig. 17 but for specifique humidity.

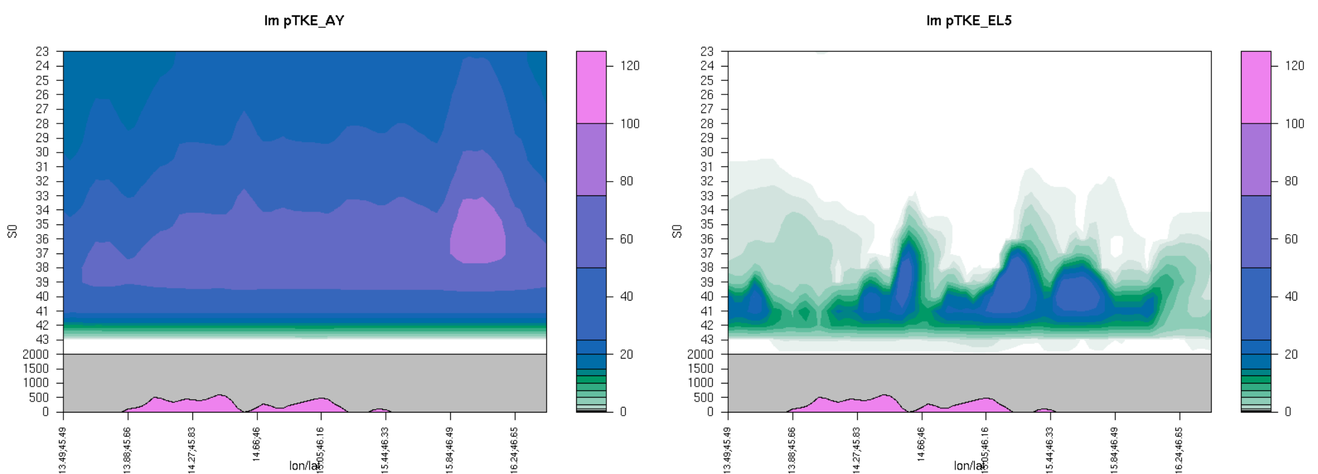

Figure 19: Same as Fig. 17 but for mixing length l_m (in case of EL1-5 converted with Eq. (2)).

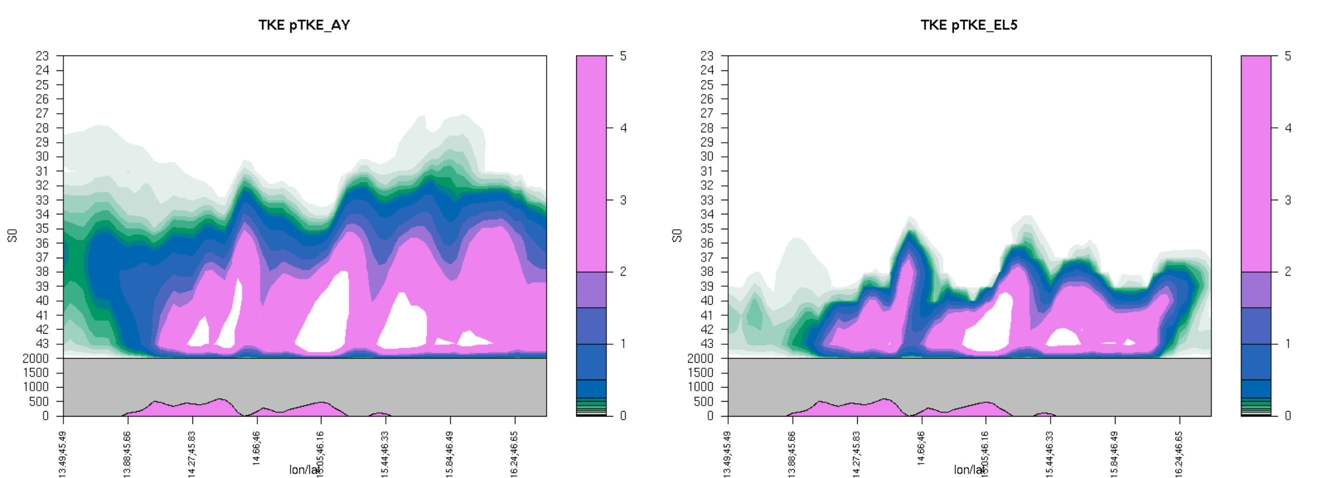

Figure 20: Same as Fig. 17 but for TKE.

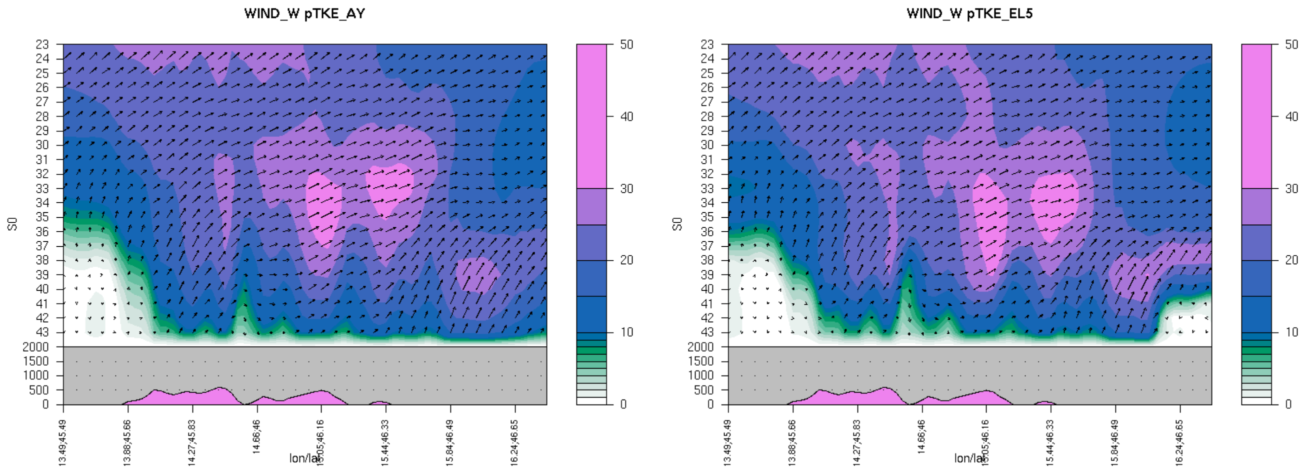

Figure 21: Same as Fig. 17 but for wind.

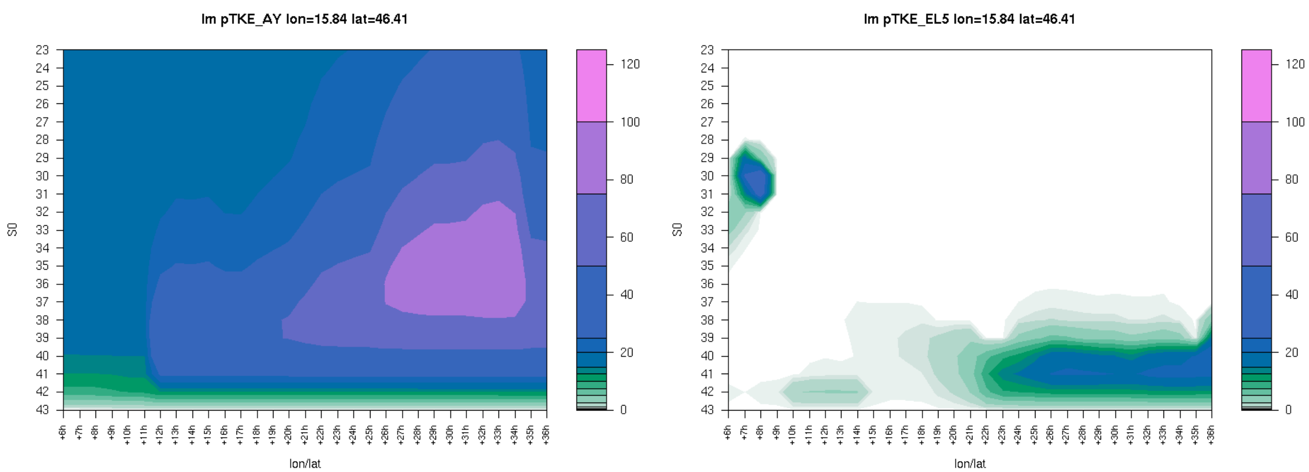

Figure 22: Time cross section(24.12.1012 00:00 from +06 till +36) of mixing length forecast for grid point near Ptuj with AY (left) mixing length, and EL5 (right) mixing length.

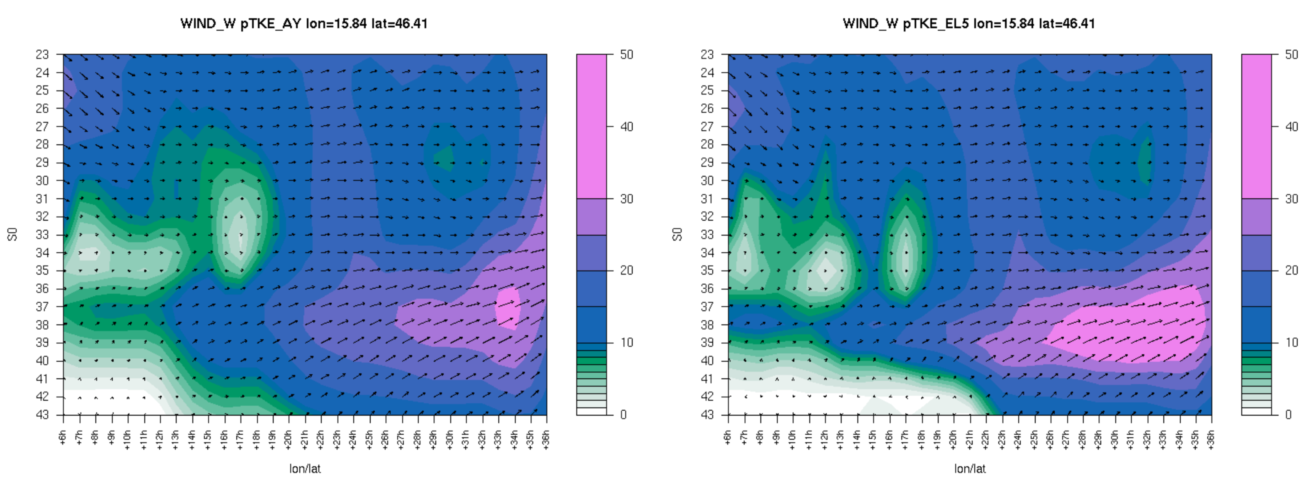

Figure 23: Same as Fig. 22 but for wind.

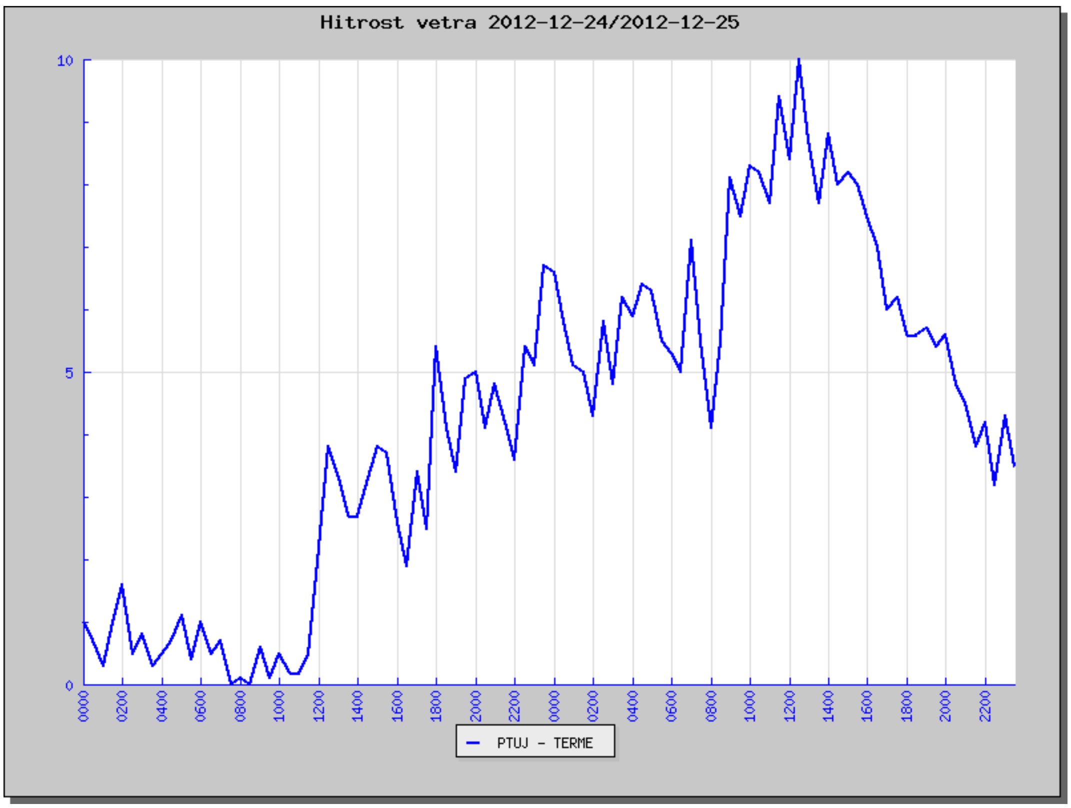

Figure 24: Measurement of wind velocity at station Ptuj (data every half an hour for 24. and 25. 12 2012).

A.3 'Early Weak Bora' case - 28.12.2012 00:00 + 20h

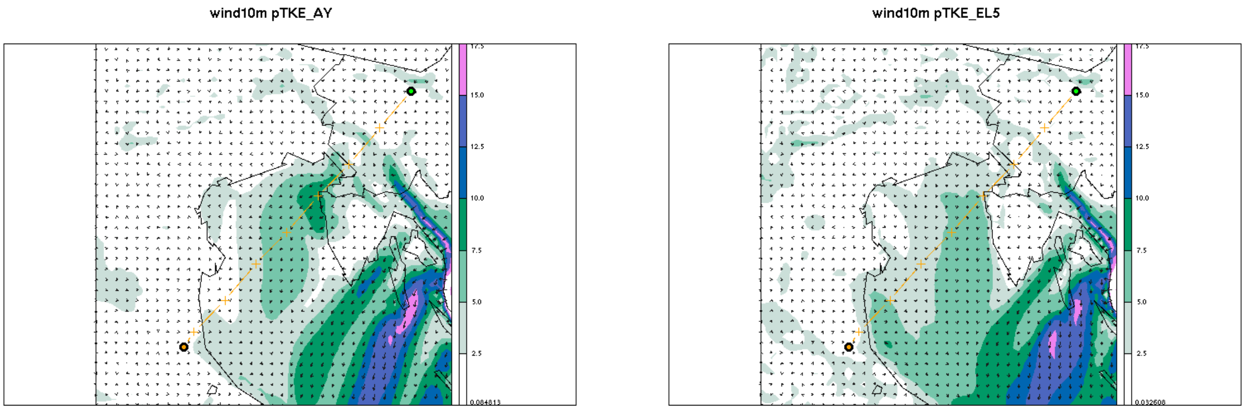

Figure 25: Same as Fig. 14 but forecast for 28.12.2012 00:00 + 20h.

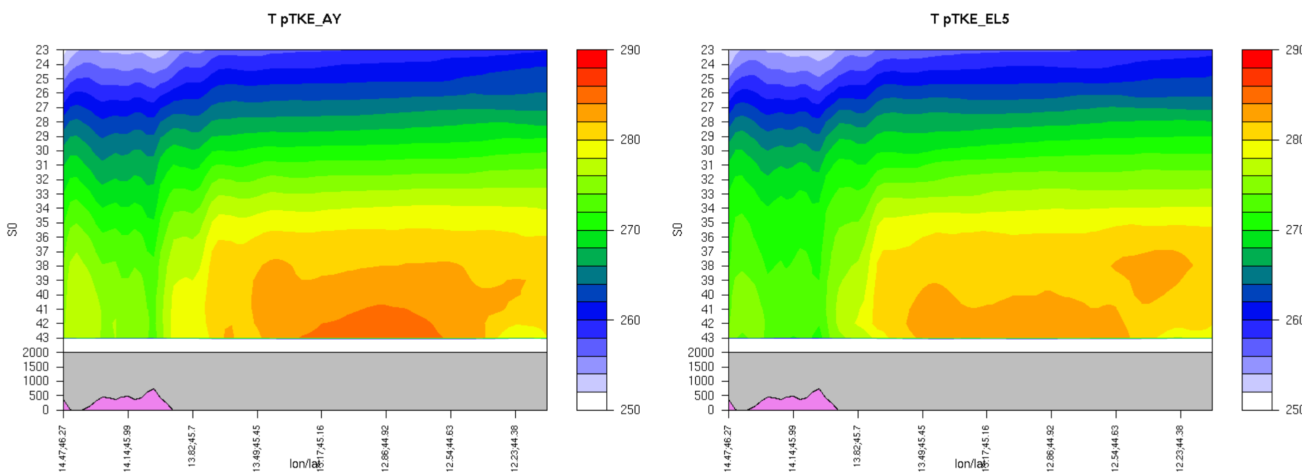

Figure 26: Same as Fig. 17 but forecast for 28.12.2012 00:00 + 20h and vertical cross section according to Fig. 25.

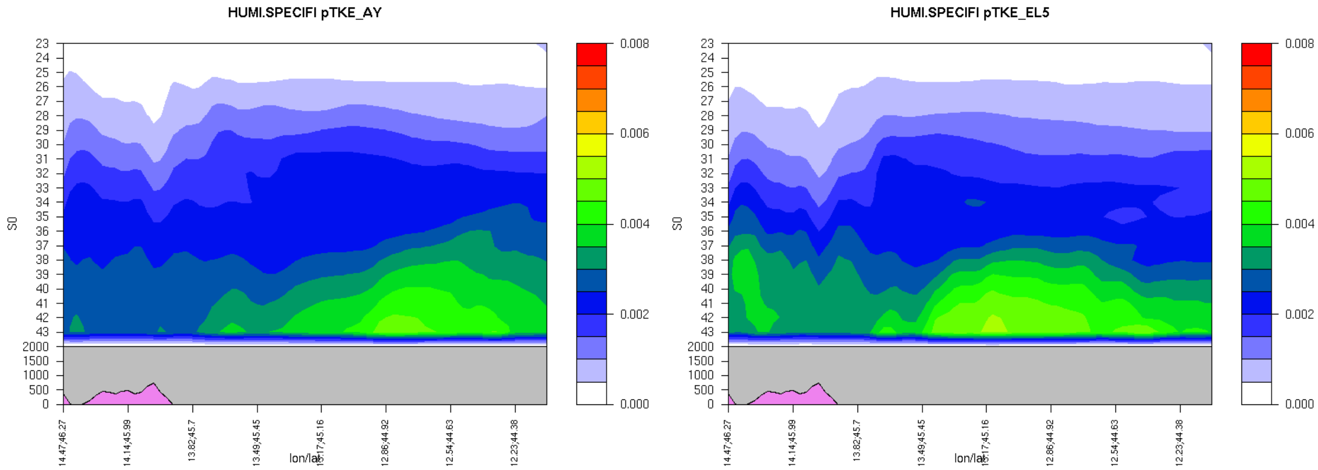

Figure 27: Same as Fig. 26 but for specifique humidity.

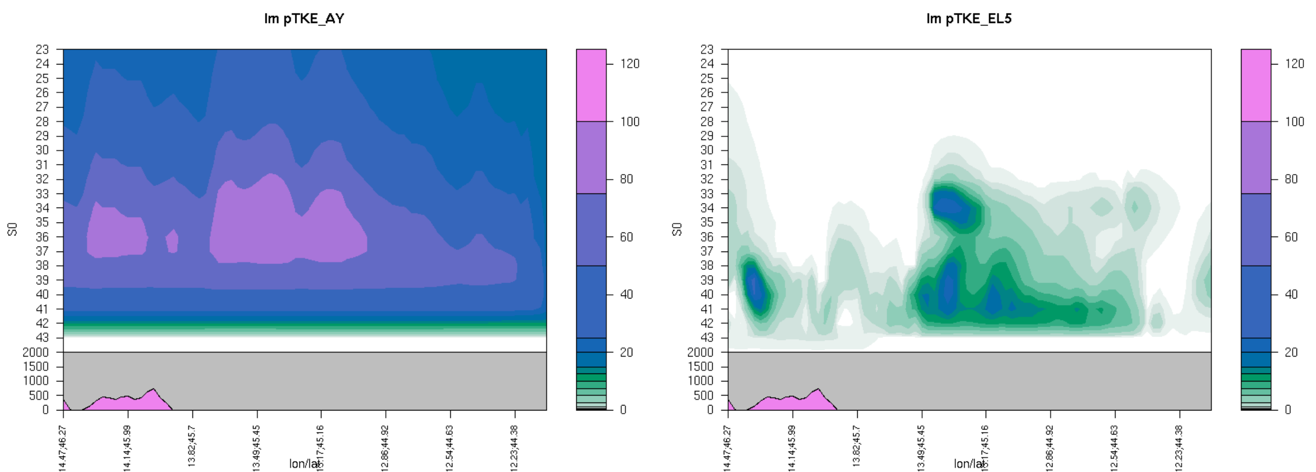

Figure 28: Same as Fig. 26 but for mixing length l_m (in case of EL1-5 converted with Eq. (2)).

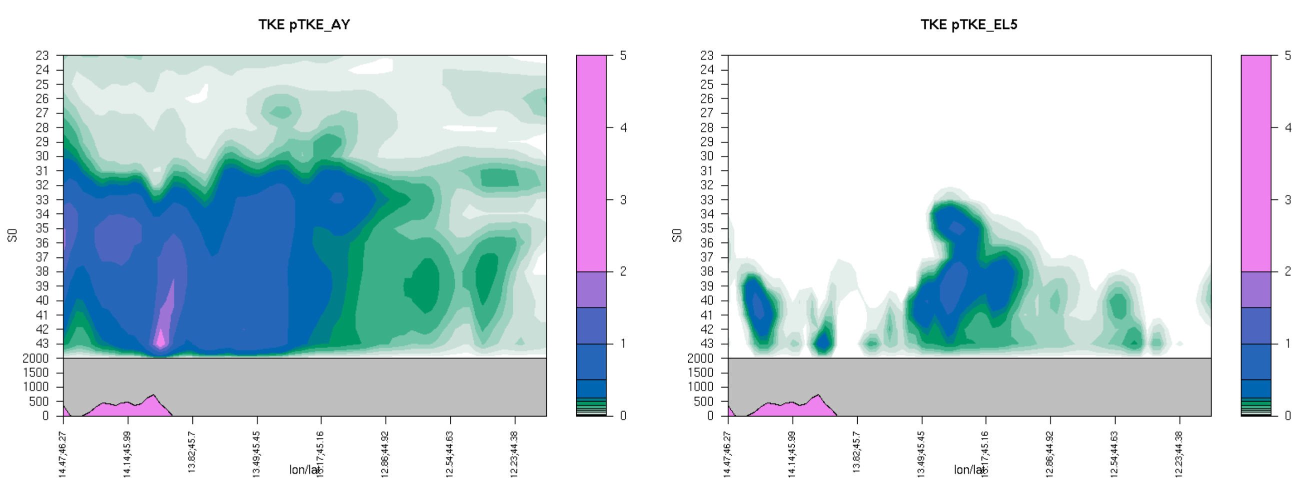

Figure 29: Same as Fig. 26 but for TKE.

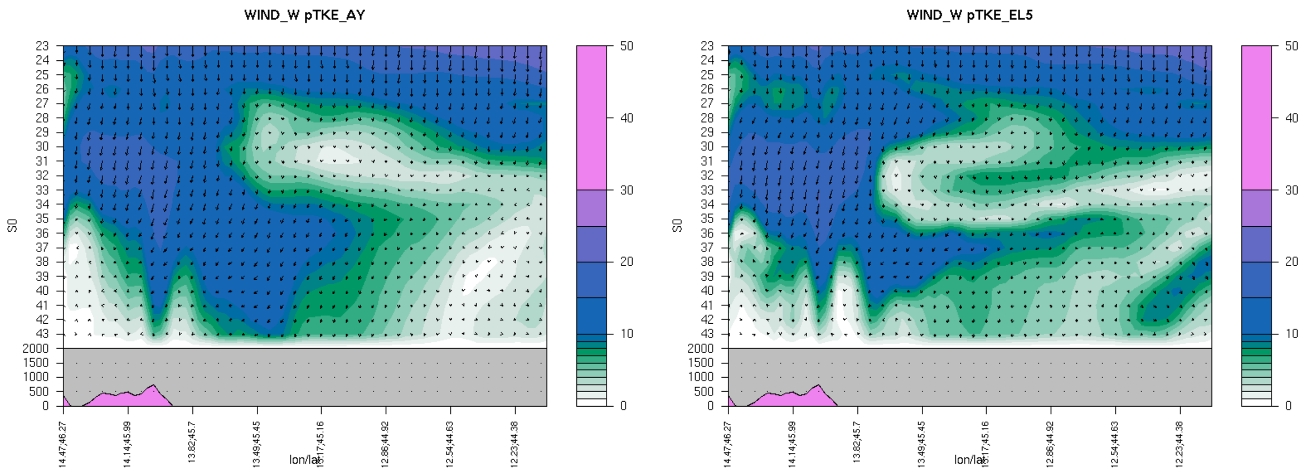

Figure 30: Same as Fig. 26 but for wind.

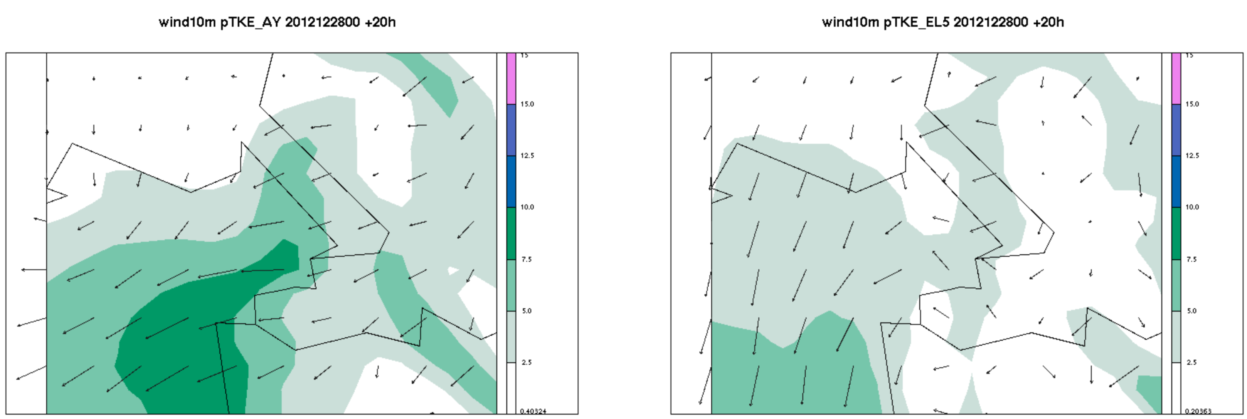

Figure 31: Same as Fig. 30 but zoomed.

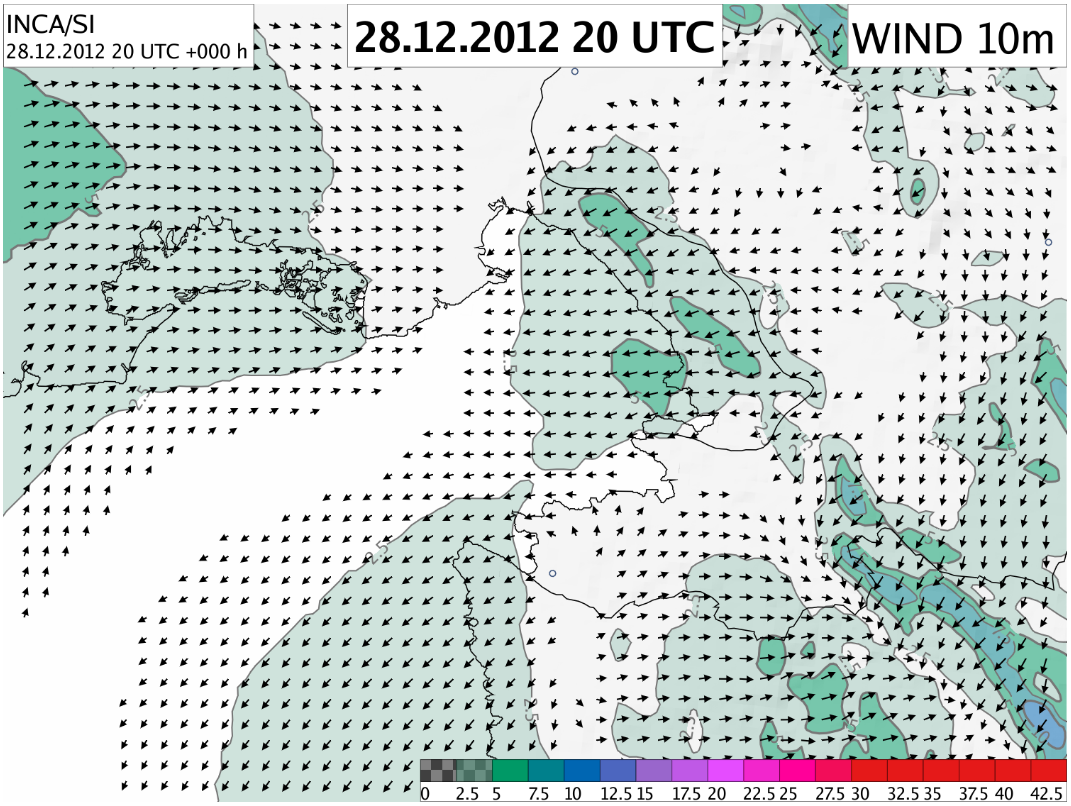

Figure 32: Same as Fig. 6 but analyses for 28.12.2012 00:00 + 20h.

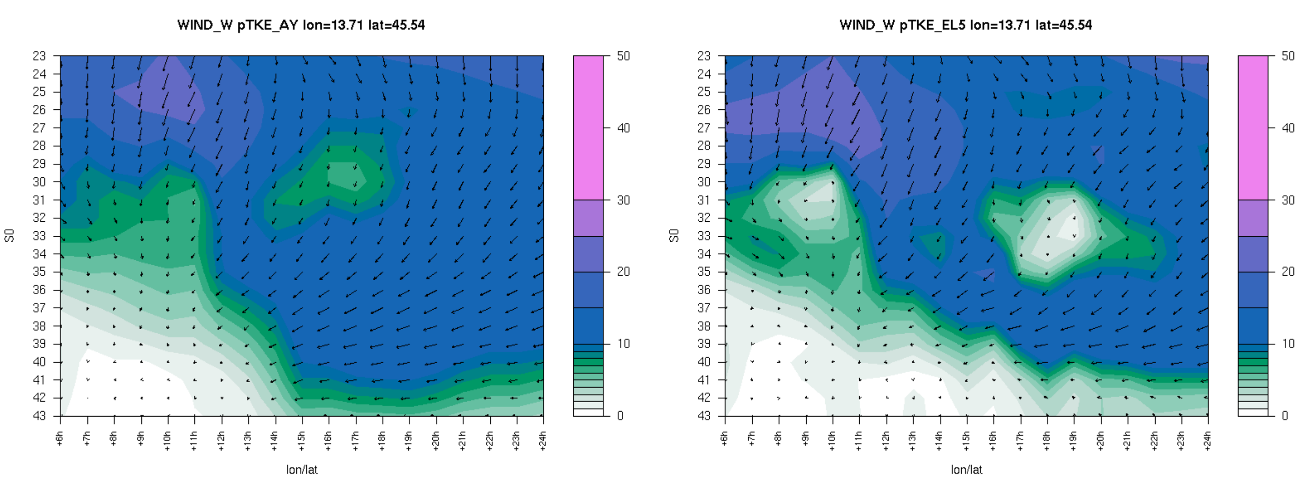

Figure 33: Time cross section (28.12.2012 00:00 from +06 till +24) of wind forecast for grid point near Koper with AY (left) mixing length, and EL5 (right) mixing length.

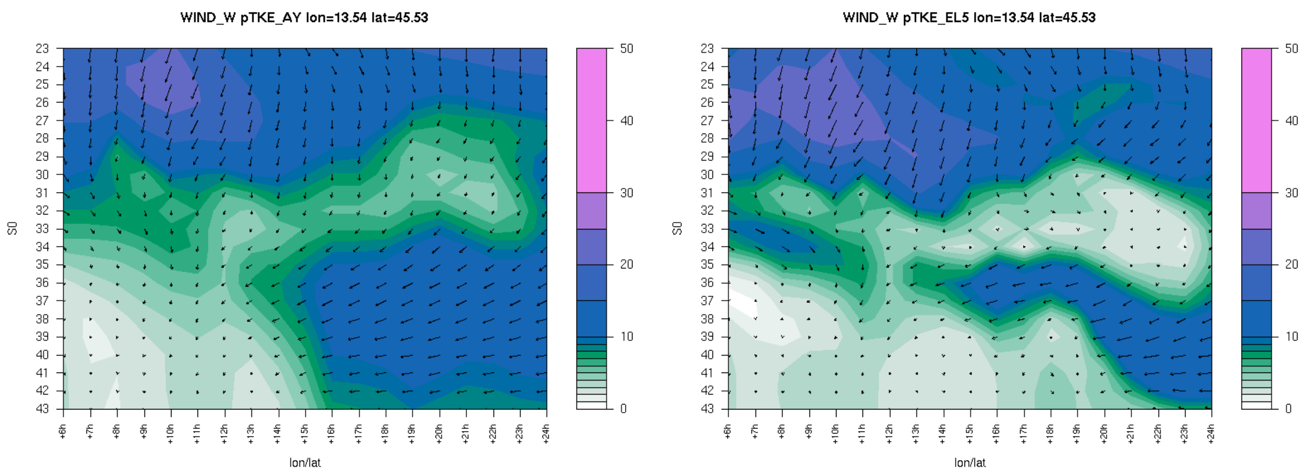

Figure 34: Same as Fig. 33 but for grid point near Piran

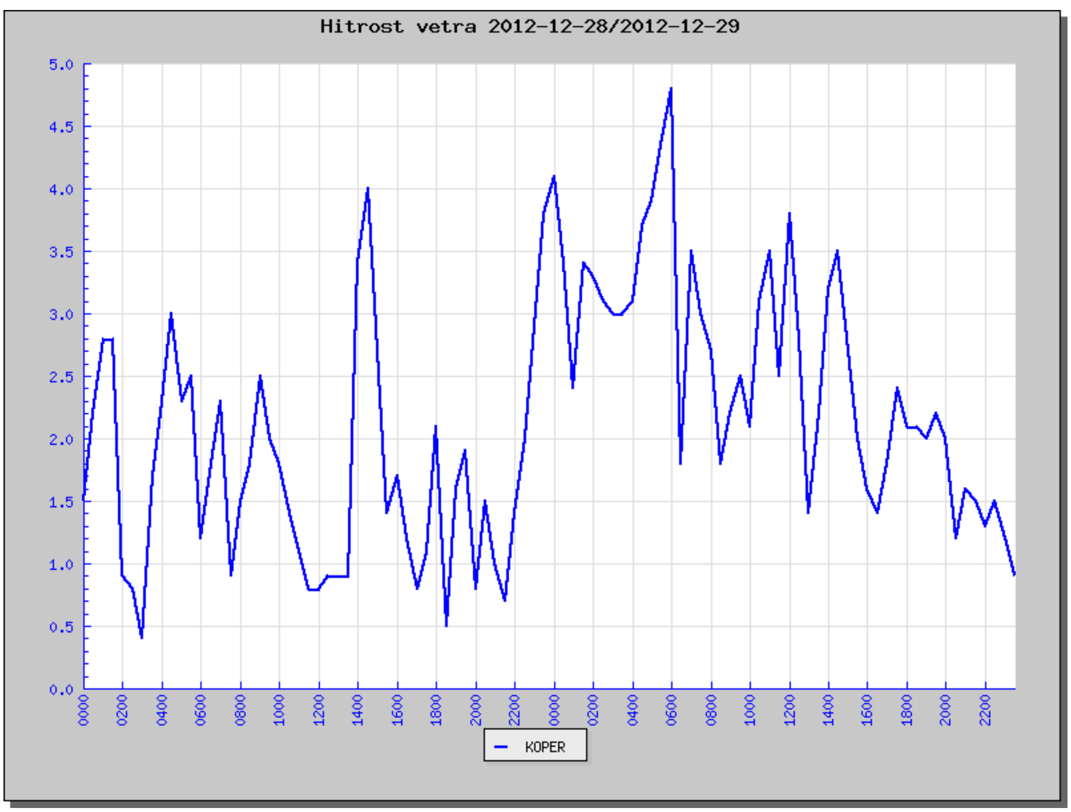

Figure 35: Measurement of wind velocity at station Koper (data every half an hour for 28. and 29. 12 2012).

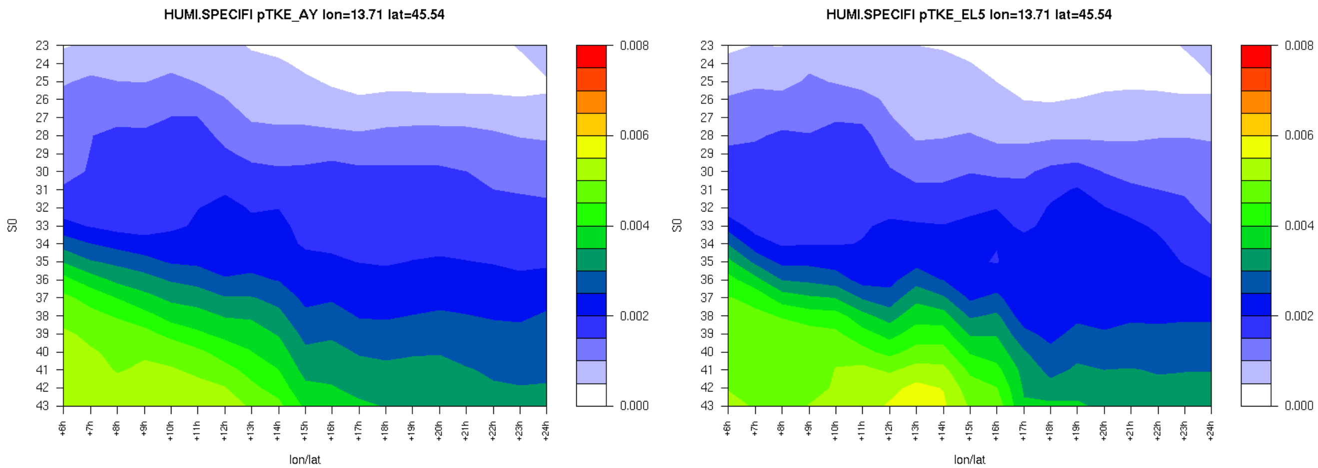

Figure 36: Same as Fig. 33 but for specifique humidity.

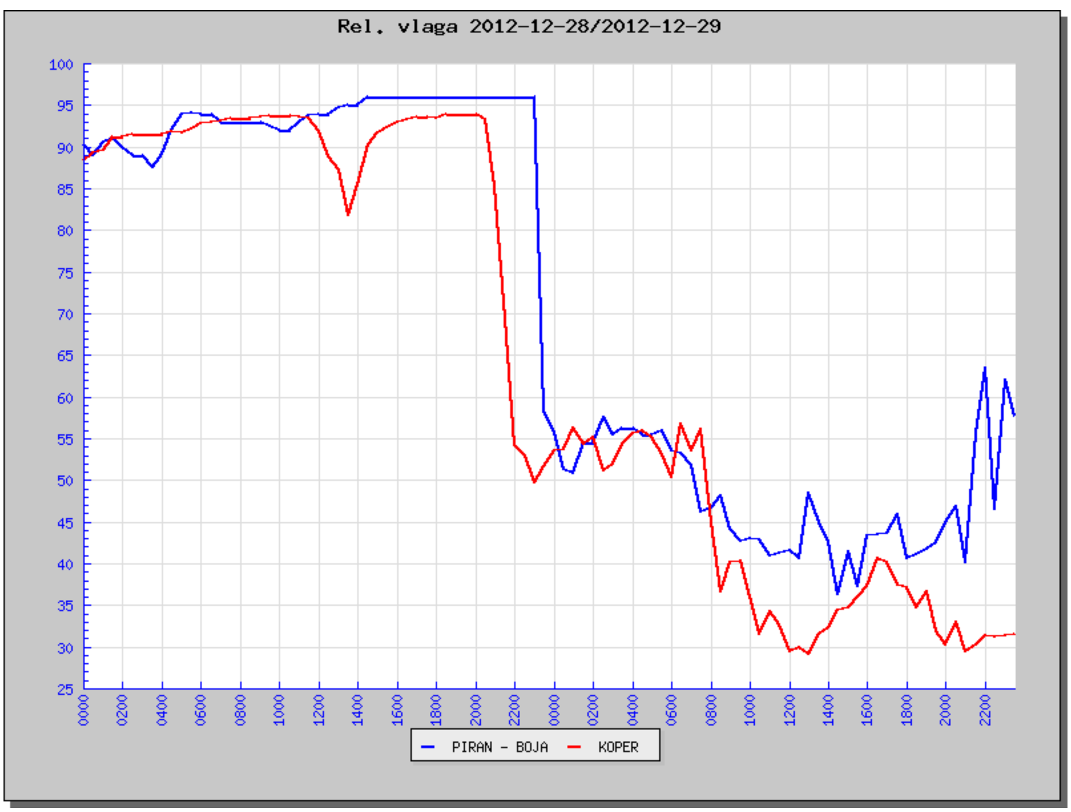

Figure 37: Measurement of relative humidity on stations Koper and Piran (data every half an hour for 28. and 29. 12 2012).

A.4 'Strong Bora' case 01.02.2012 12:00 + 30h

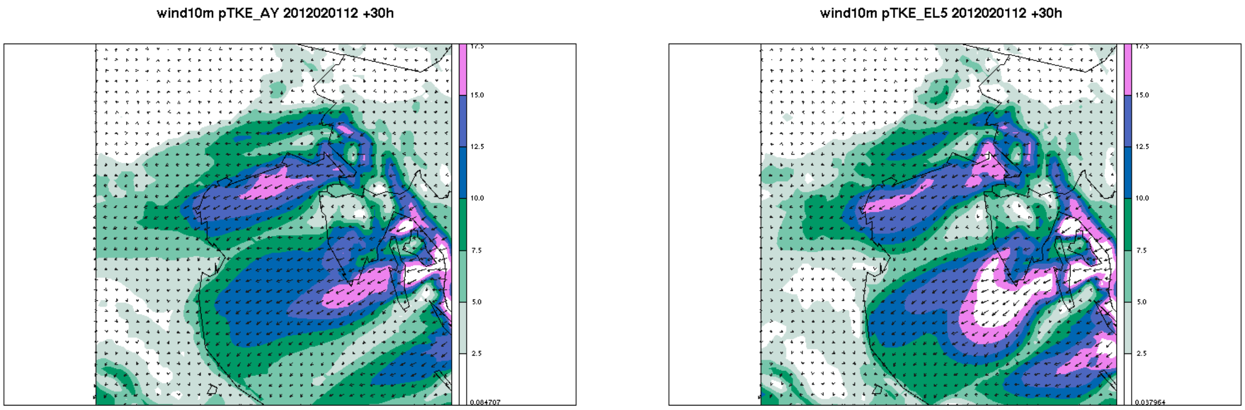

Figure 38: Same as Fig. 14 but forecast for 01.02.2012 12:00 + 30h.

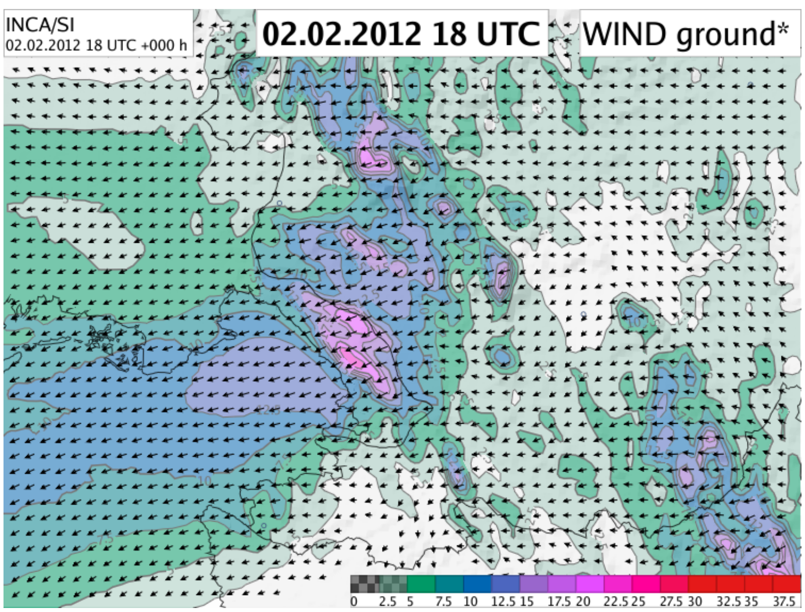

Figure 39: Same as Fig. 6 but analyses for 01.02.2012 12:00 + 30h.

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