IMPACT OF NUMERICAL DIFFUSION, CONVECTION AND TURBULENCE PARAMETERISATION ON LAKE BREEZE OF SMALL LAKES IN 1 KM SIMULATIONS IN NORTH-EAST GERMANY

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Lake Breeze and Land-Lake Wind

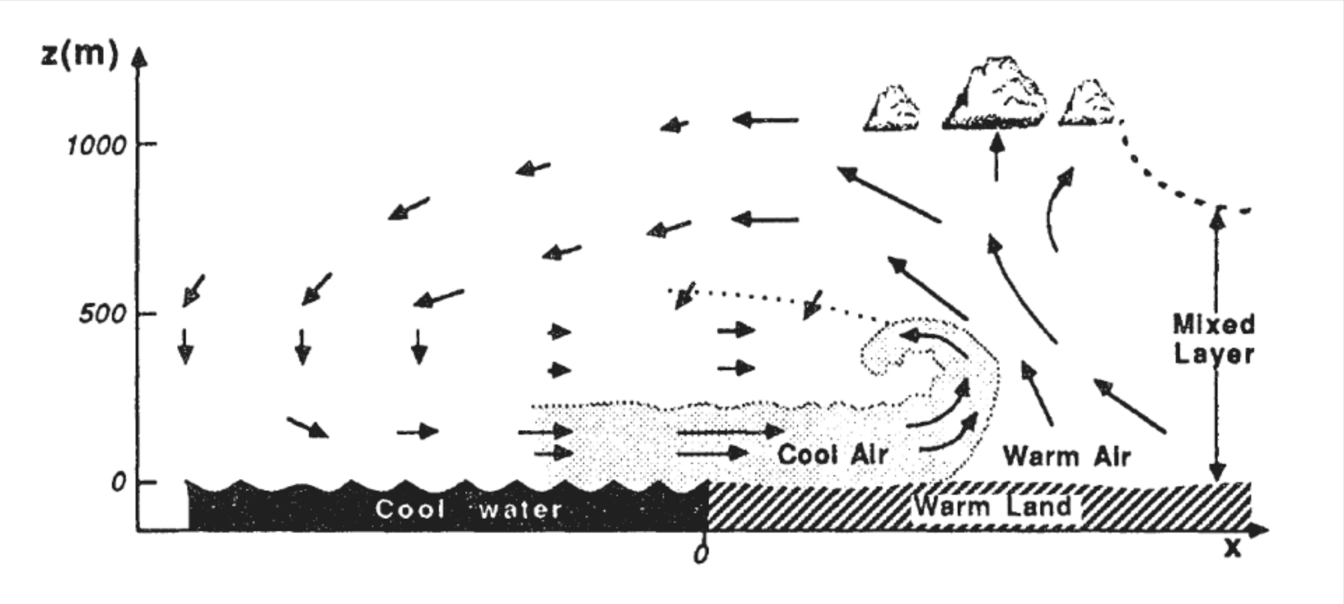


Image: Vertical cross section of Land Sea wind. Source : Lyons (1975) and Ogawa, et al., 1986

- Phenomenon
  - intermittent meso-scale stabilization of the atmosphere in the PBL
  - Physical mechanism: Different heat capacity of land and lake → differential heating of air → pressure gradient at the surface → convection over land → pressure gradient at top of the PBL → reversal flow → Land-Lake Wind
- Typical Scale:
  - Big Lakes/Sea (D > 100 km) due to balance of friction and forcing
  - Small Lakes (D < 20 km): limited by lake size

Studies on climate impact of lakes and oceans considered

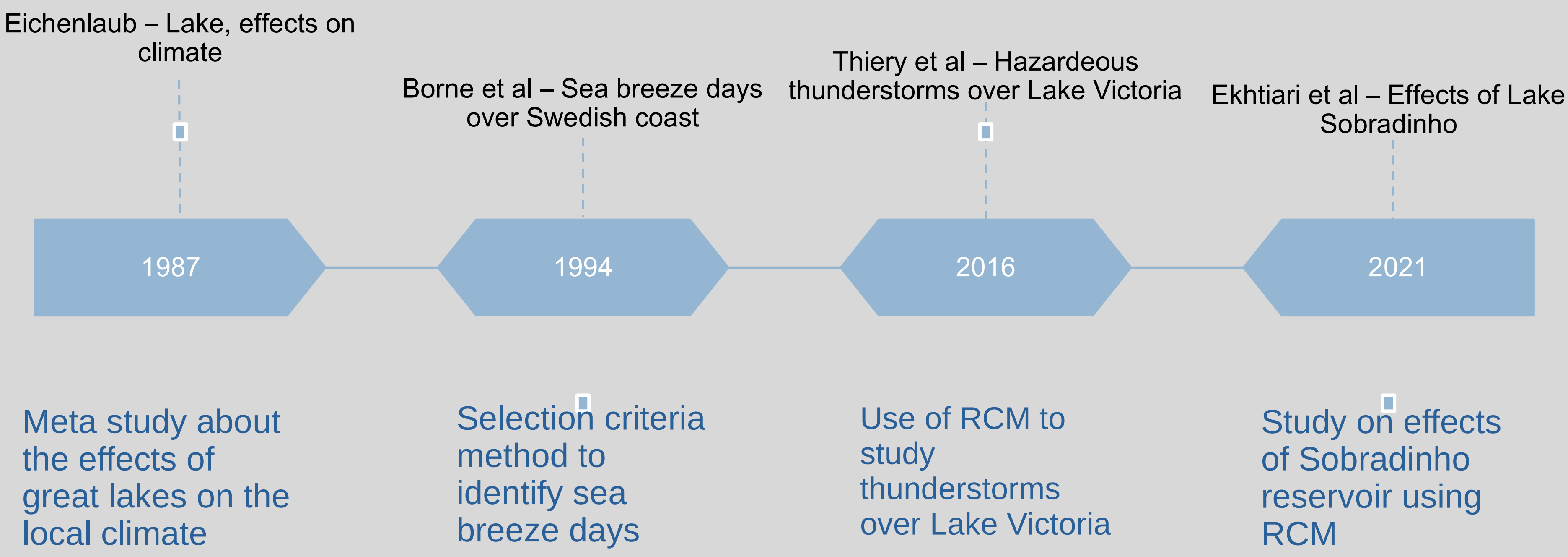


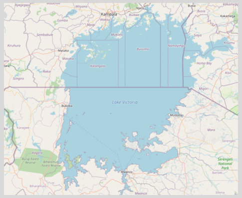
Image : Some studies on the impact of oceans and lakes on the local climate

Selection of sea breeze days using filters (Borne et al, 1994) 0.

Table : Comparing filters from Borne et al and filters used in this study

Borne filter	SL filter	Purpose of filter
$\Theta_{geostrophic} < 90°$	-	Direction does not change much
$\Delta V_{geostrophic} < 6$ m/s	-	Speed does not change much
$V_{geostrophic} < 11$ m/s	-	LLW spatial scale too small for geostrophic wind
$T_{land} - T_{sea} > 3°$ C	$T_{land} - T_{lake} > 3°$ C	Differential surface heating
$\Delta\Theta_{surface} > 30°$	$\Delta\Theta_{surface} > 30°$	Near surface wind phenomenology
$peak(\Theta_{surface})/Avg(\Theta_{surface}) > 6$	$\Delta w_{surface} > 0.2$ m/s	Replaced by vertical velocity

Lakes and their representation in different models

Name of Lake	Lake shape	Surface area (km^2)	Horizontal grid resolution in model (km)
Lake Victoria		59,947	7
Sobradinho reservoir		4,214	2
Lake Mueritz		117	2.8 and 1
Lake Cottbus East		19	1

Images from open street maps and LEAG (for Cottbus)

Model Domain

Domain:
COSMO-DE:
421 x 461x50 Grid points – CDE (0.025 °)
COSMO-LAU:
301 x 401x80 Grid points - LAU (0.01 °)

h_{max} = 22 km

Müritz Region: 271 qkm lake surface

Lausitz Region: 258 qkm lake surface

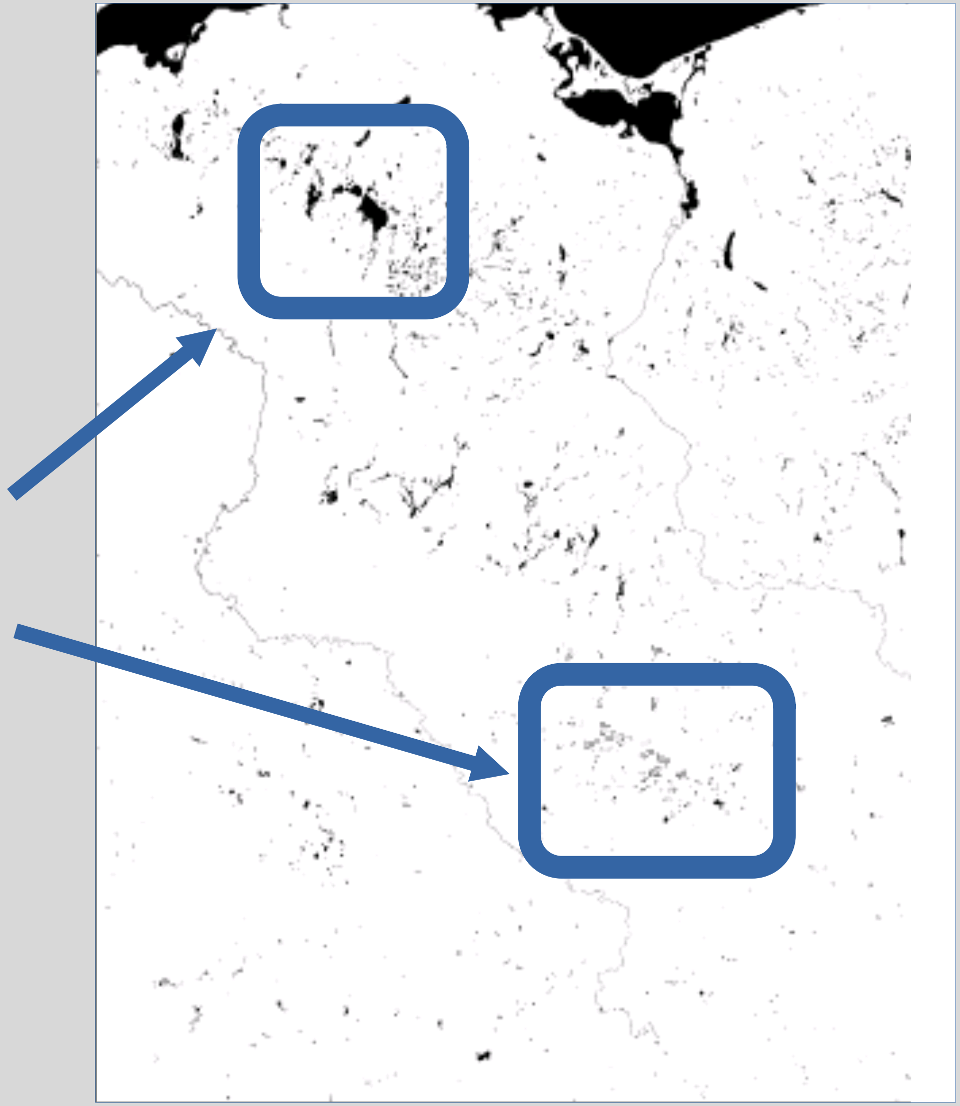
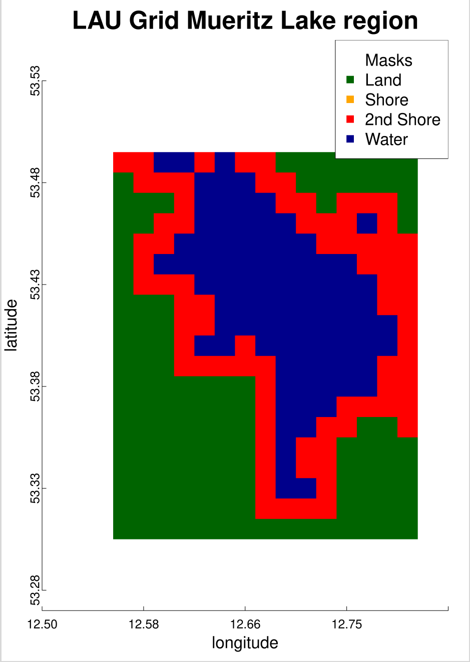


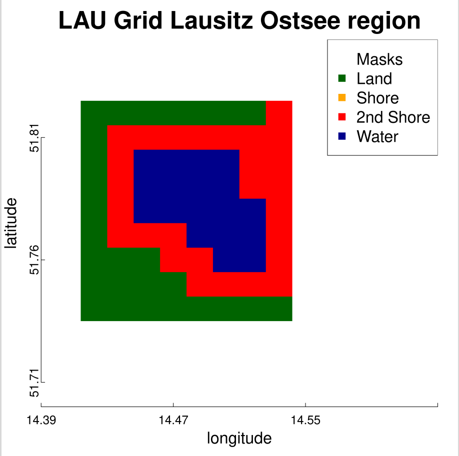
Image : Domain (FR_LAND,LAU065)
White = Land , Black = Water

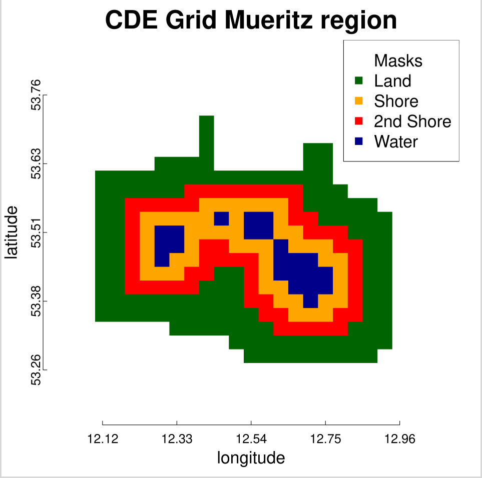
Masks used

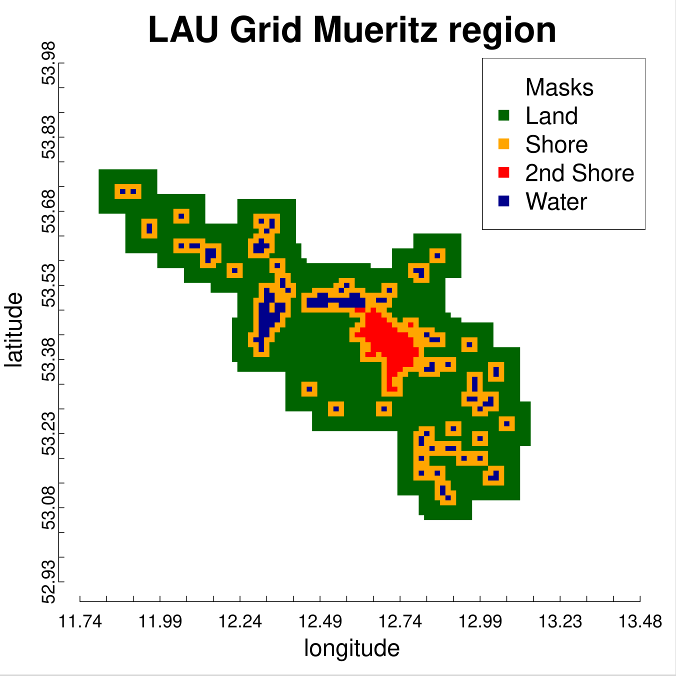


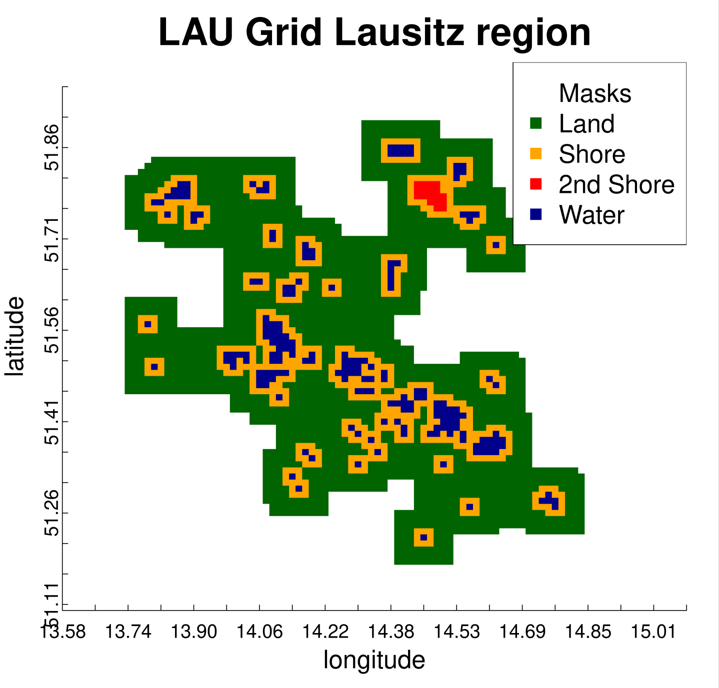
Mueritz Region: MU
Mueritz Lake: ML
Lausitz Region: LA
Lausitz Lake E: LO

XXG - all
XXL - land
XXW - water
XXS - shore
XX2 - 2nd shore









Model configurations

Model chain: ERAINT -> TEU -> CEU (0.065) -> CDE (0.025) -> LAU (0.01)

	Sim. Time		Refer.	oarse	Time Invariant Data				Interpolation parameterisations				
							Modifications						
SIM-ID	START	END	Conf.	grid data	Land Use	SOIL Type	ALL	LAU	NZ	t_ skin	itype_ aerosol	llbc_ smooth	lbalance_ pp
CEUA11	1.2000	12.2014	CEU	TEU005	G00	FAO			40	T	1	F	F
CEUA12			CEU011	TEU006									F
CDE011	1.2000	12.2014	CDE	CEU011	G00	FAO			50	T	1	F	T
CDE012			CDE011	CEU012									T
CDE014			CDE011	CEU012									
LAU001	11.2005	12.2006	NEG	CDE012	G00	FAO			60	T	1	F	F
LAU002	1.2006	12.2006	LAU001	CDE012	ECO	HWSD							
LAU003	11.2005	12.2006	LAU001	CDE012									
LAU004	11.2005	12.2006	LAU001	CDE012		HWSD							
LAU005	11.2005	12.2006	LAU001	CDE012	G09	HWSD							
LAU044	11.2005	12.2006	LAU005				ST9	FL1900	80	F	2	T	T
LAU045			LAU044					FL1900-2050					
LAU055	11.2005	12.2006	LAU044			FAO		FL1900-2050					
LAU064	1.2006	12.2006	LAU044										
LAU065	1.2006	12.2006	LAU044					FL1900-2050					
LAU071	1.2006	12.2006	LAU044		G00	FAO		FL1900-2050					
LAU075	1.2006	12.2006	LAU044			FAO		FL1900-2050					
LAU085	11.2005	12.2006	LAU044					FL1900-2050					
LAU164	11.2009	12.2010	LAU044										
LAU165	11.2009	12.2010	LAU044					FL1900-2050					
LAU175	11.2009	12.2010	LAU044			FAO		FL1900-2050					

Standard configurations: CEU011(=COSMO-EU), CDE011 (= COSMO-DE) 2000-2014, LAU001/LAU002 (2006)

Optimised configurations: LAU065, (LAU064: no lakes in Lausitz, LAU075: FAO soil, LAU164,LAU165, LAU175: 2010 instead of 2006)

Model configurations

Model chain: ERAINT -> TEU -> CEU (0.065) -> CDE (0.025) -> LAU (0.01)

SIM-ID	Simulation Time		REFCON	Modifications of REFCON						
	START	END		IBC: rlwidth /crltau /nrfac	DYNNUM: adv. pres. dif.	Convection: itype_/hinc_ conv / entr_sc	Turbulence: c_Smag /tur_len	tkhmin /tkmmin	Surface: rlam_h /rat_sea	itype_ evsl/root /h-cond /albedo
CEUA11	1.2000	12.2014	CEU	83333/1/5	C3p2d0.1	0/0.0667/0.0002	0.03/500	0.35/0.40	0.5249/9	3/1/2/3
CEUA12			CEU011		S4p4d0.0					
CDE011	1.2000	12.2014	CDE	50000/1/10	C5p2d0.1	3/0.0694/0.0003	0.03/150	0.35/0.40	0.5249/20	2/1/1/3
CDE012			CDE011		S4p4d0.0		0.00/			
CDE014			CDE011		S4p4d0.0		0.00/			
LAU001	11.2005	12.2006	LAU	13333/1/10	C5p2d0.1	3/0.0277/0.0003	0.03/150	0.35/0.40	0.5249/20	2/1/1/2
LAU002	1.2006	12.2006	LAU001							
LAU003	11.2005	12.2006	LAU001		S4p4d0.0		0.00/			
LAU004	11.2005	12.2006	LAU001		S4p4d0.0		0.00/			
LAU005	11.2005	12.2006	LAU001		S4p4d0.0		0.00/			
LAU044	12.2005		LAU002	20000/2/10	S4p4d0.0	- / - / -	0.10/	0.01/0.01	1.0000/20	2/2/2/4
LAU045	01.2006		LAU044							
LAU055			LAU044							
LAU064	11.2005	12.2006	LAU044				0.10/900			
LAU065	1.2006	12.2006	LAU064							
LAU066	11.2005	12.2006	LAU064						0.5000/20	
LAU067	11.2005	12.2006	LAU064						0.2500/20	
LAU075	1.2006	12.2006	LAU064							
LAU085	1.2006	12.2006	LAU064		C5p2d0.1		0.03/150	0.35/0.40		
LAU164	11.2009	12.2010	LAU064							
LAU165	11.2009	12.2010	LAU065							
LAU175	11.2009	12.2010	LAU075							

Intermediate configuration LAU044: S4p4d0.0 dynamics and numerics+no minimum turbulent transport, , no convection param., higher Smagorinsky coeff., higher rlam_h
Optimised configurations LAU065: tur_len=900m

Results

Signal to Noise Ratio

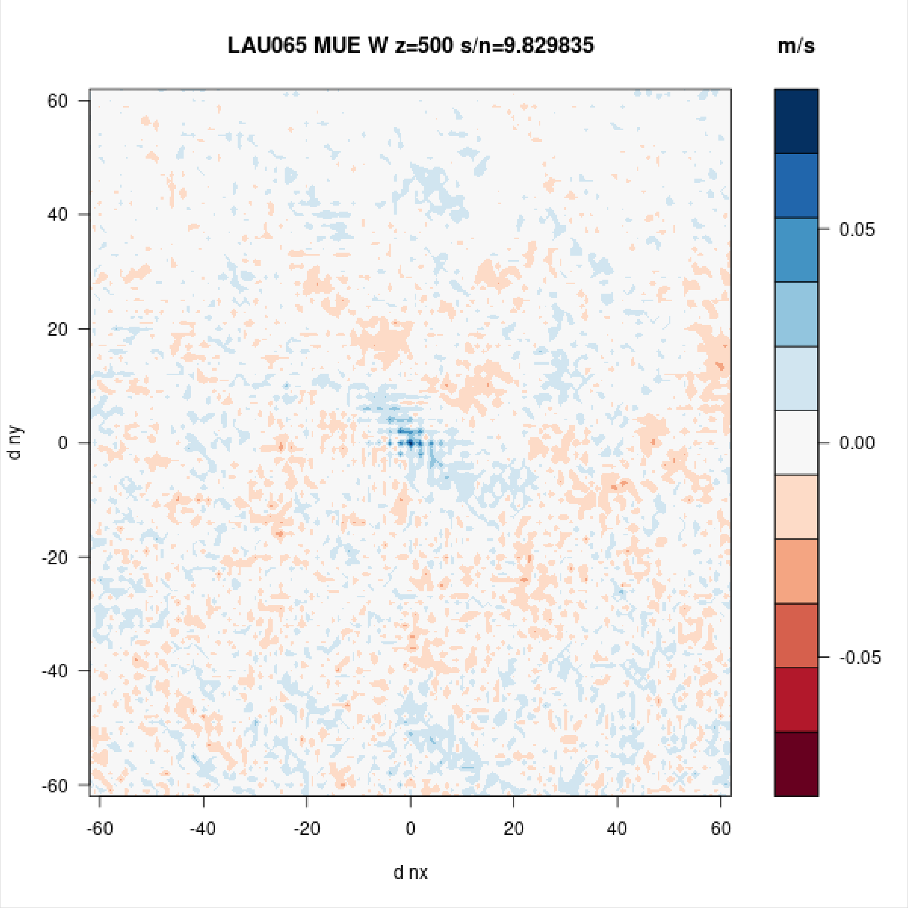
Signal to noise ratio

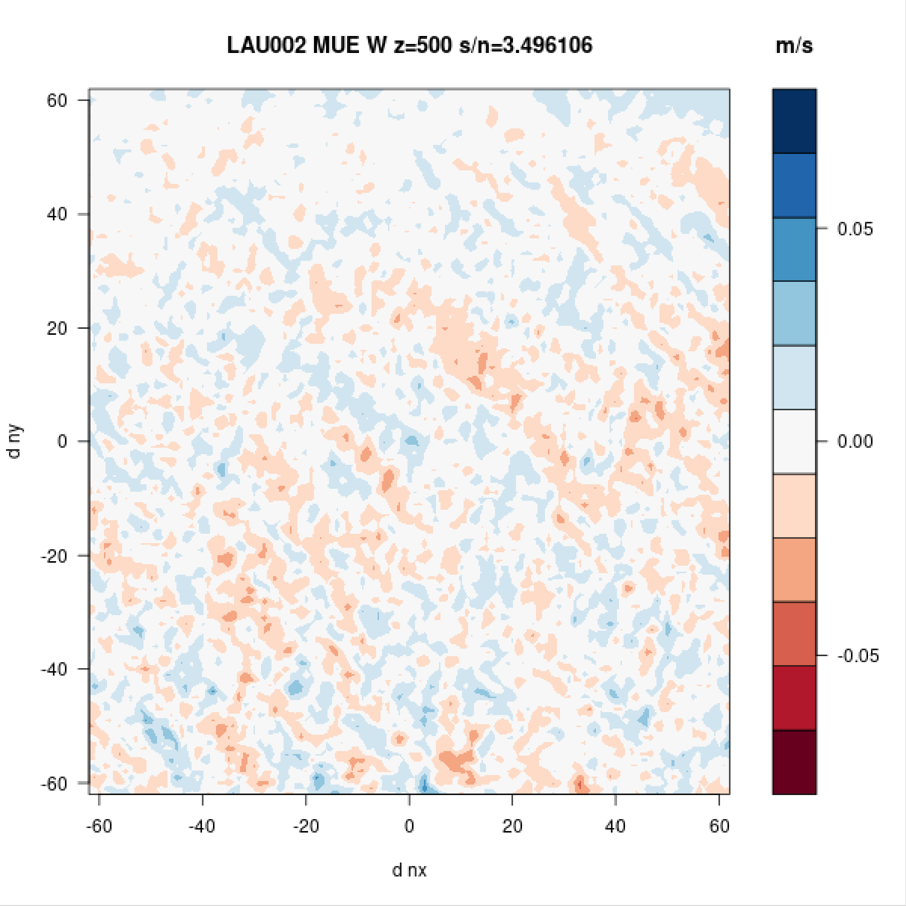
$$
\begin{aligned}
StN_W &= S_W(s,w,k_m)/N_W(s,w,k_m) \quad \text{with} \\
S_W(s,w,k_m) &= \overline{\left(\widetilde{W(i,j,k_m)}^{7,13} - \widetilde{W(i,j,k_m)}^{7,0}\right)}^{s} - \overline{\left(\widetilde{W(i,j,k_m)}^{7,13} - \widetilde{W(i,j,k_m)}^{7,0}\right)}^{w} \\
N_W(s,w,k_{max},N) &= \frac{1}{(2N+1)^2}\sqrt{\sum_{l=-N,n=-N}^{N,N} S_W(s,w,k_m,l,n)^2}
\end{aligned}
$$

Signal function $S_W(s,w, km)$: mean over shore (s) minus mean over water (w) points of the difference between july mean at 13h and 0h of vertical velocity W. k_m *is the level* of maximum vertical velocity W *over shore*.

Noise function $N_W(s,w, km,N)$ is the $L2$ norm of signals for masks shifted by up to $\pm N$ grid points. (Signal at an arbitrary position)

Results – Signal to noise ratio





Signal function for region Müritz in dependency on the number of points d nx, d ny by which masks are shifted in direction x and y for the optimised simulation LAU065 and the standard configuration simulation at 0.01° resolution LAU002.
StN is given in the header of the figure.

Summary StN Results

MUE	**CDE011**	**3.8**	**CDE012**	**4.8**	**Non dissipative dynamics and numerics → better StN**
MUE	**LAU064**	**9.67**	**LAU065**	**9.82**	**No large scale effect due to small lakes**
MUE	**CDE011**	**3.84**	**LAU002**	**3.5**	**No improved StN due to grid resolution**
MUE	**LAU045**	**7.6**	**LAU065**	**9.8**	**tur_len=900m → better StN**
MUE	**LAU075**	**9.0**	**LAU065**	**9.8**	**HWSD instead of FAO soil type → better StN**
MUE	**LAU085**	**6.7**	**LAU065**	**9.8**	**Non dissipative dynamics and numerics → better StN**
LAU	**LAU045**	**6.4**	**LAU065**	**6.8**	**tur_len=900m → better StN**
LAU	**LAU075**	**5.9**	**LAU065**	**6.8**	**HWSD instead of FAO soil type → better StN**
LAU	**LAU085**	**4.8**	**LAU065**	**6.8**	**Non dissipative dynamics and numerics → better StN**

- Higher grid resolution not necessarily improves StN
- Improved simulation of Lake Breeze of small lakes is achieved by
  - grid resolution of the lake by 4 points (or more)
  - Non dissipative dynamics and numerics
  - turbulence parameterisation optimized for dynamics and numerics (horizontal and vertical)
  - Higher resolution soil types

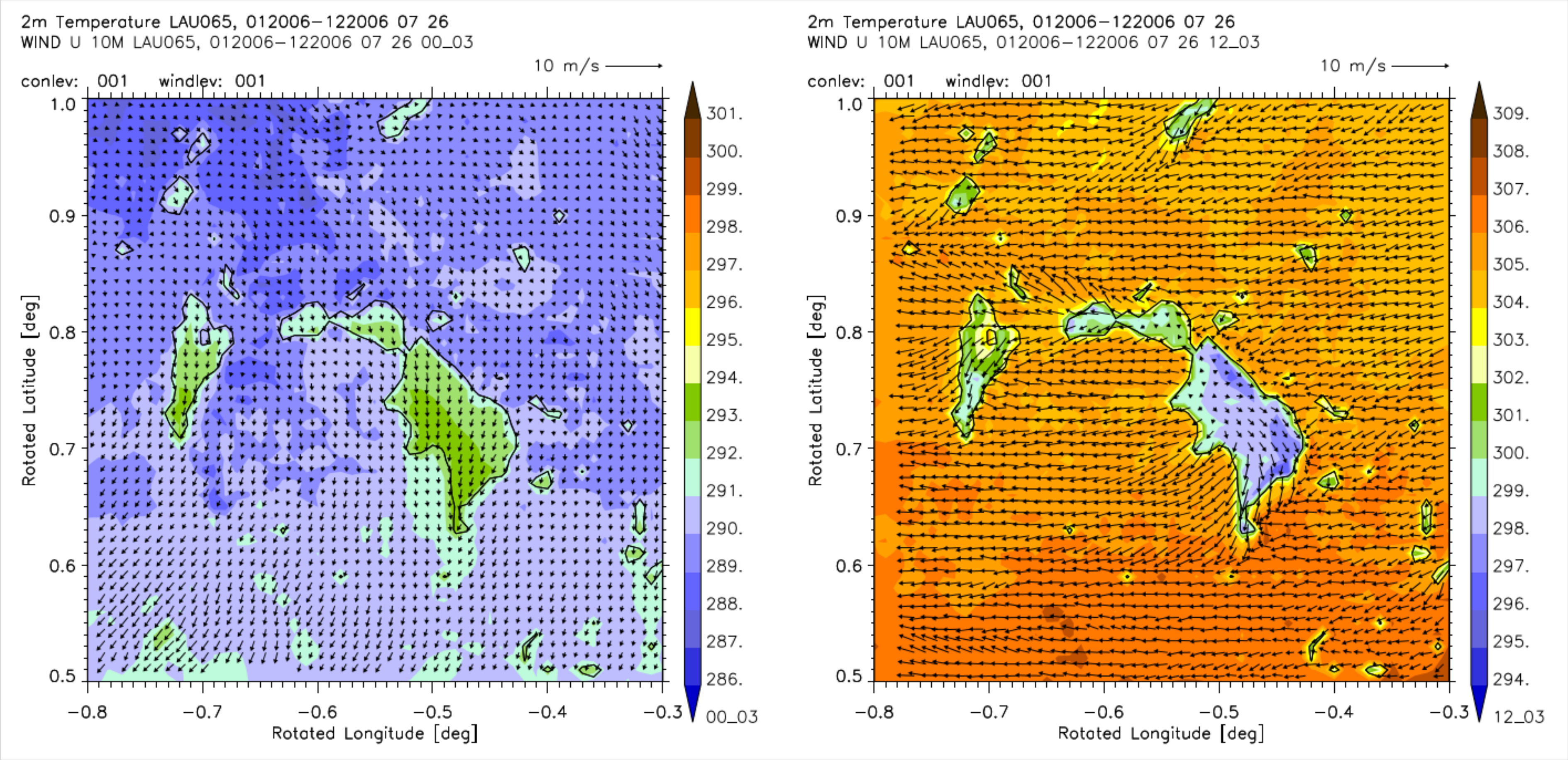
Results

Case Study 26th July 2006

Lake Breeze day

Lake Müritz, T2M/V10M, 26. July 2006

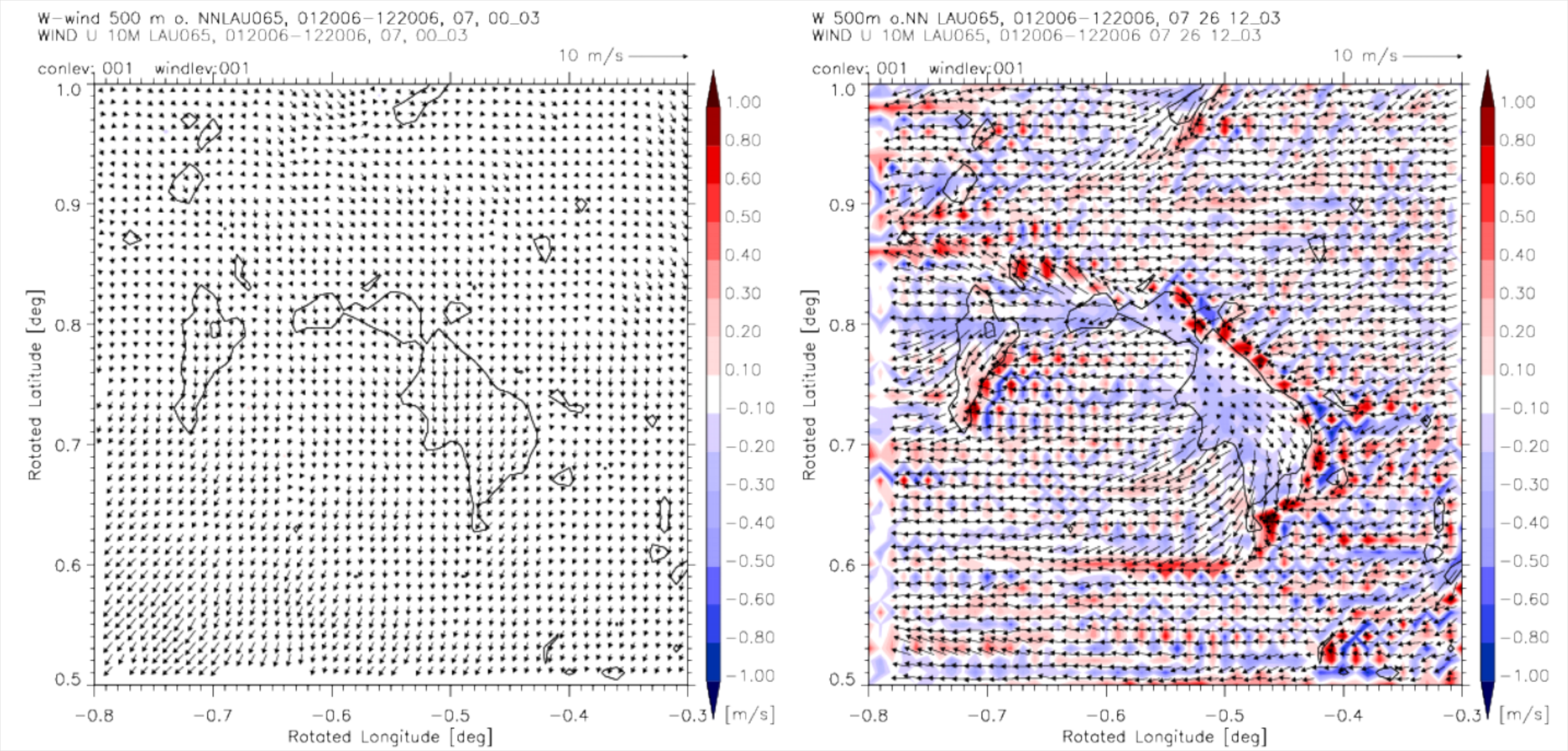
LAU065, 00 h LAU065, 12h



Lake Breeze phenomenon: v_g=3.2 m/s, dT=6.9 K, d Theta=100°. No Lake Breeze during night, radial wind over lake during the day, Cooling in shore region

Lake Müritz, W / V10M, 26. July 2006

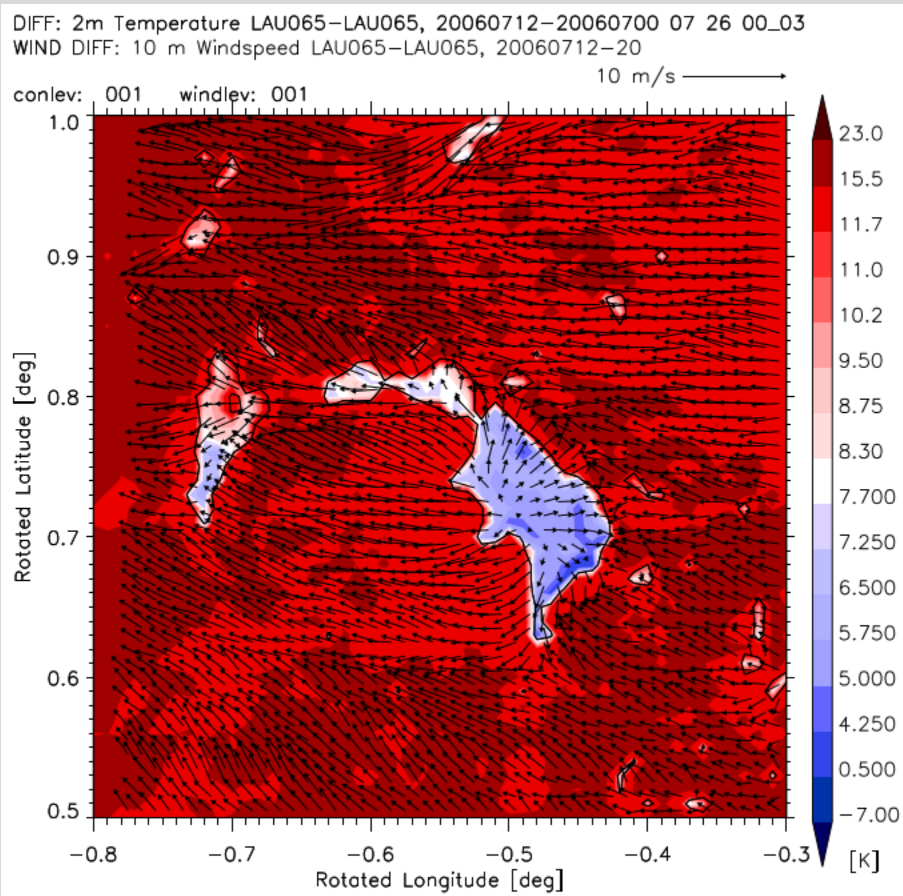
LAU065, 00 h LAU065, 12h



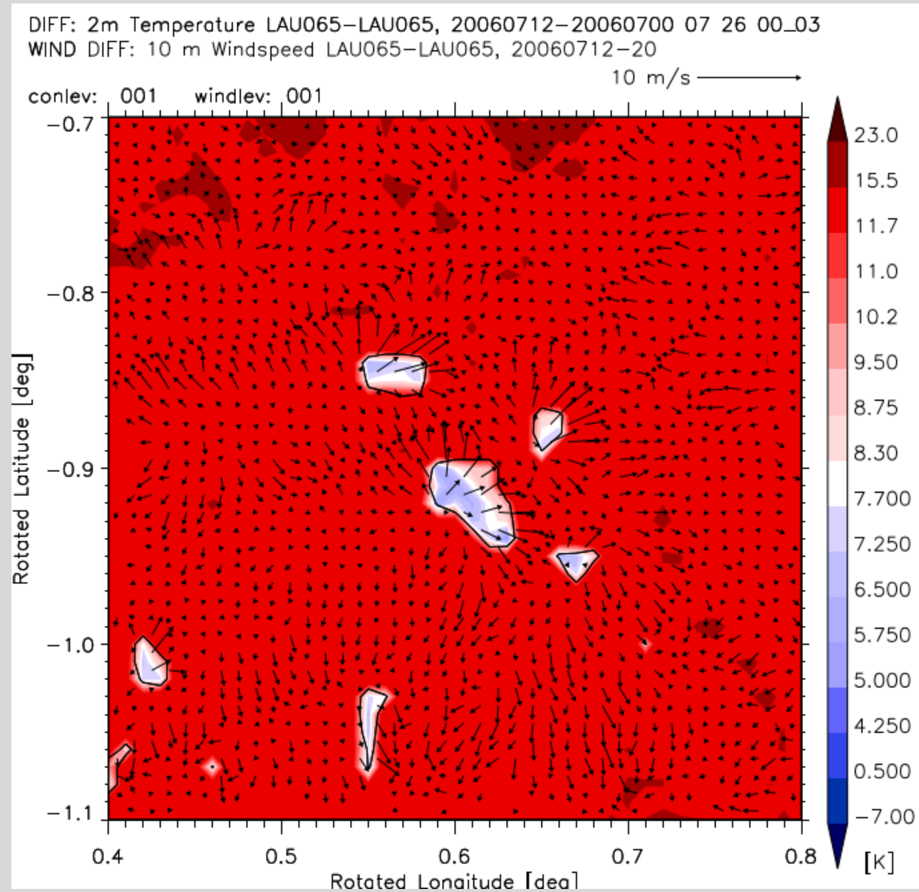
Lake Breeze phenomenon: v_g=3.2 m/s, dT=6.9 K, d Theta=100°
No vertical wind during night, Updrafts at eastern shore during day and downdrafts over lake.

Lake Breeze Effect, T2M / V10M, 26. July 2006

Lake Müritz
LAU065, 12h - 00 h



Lake Lausitz East
LAU065, 12h – 00 h

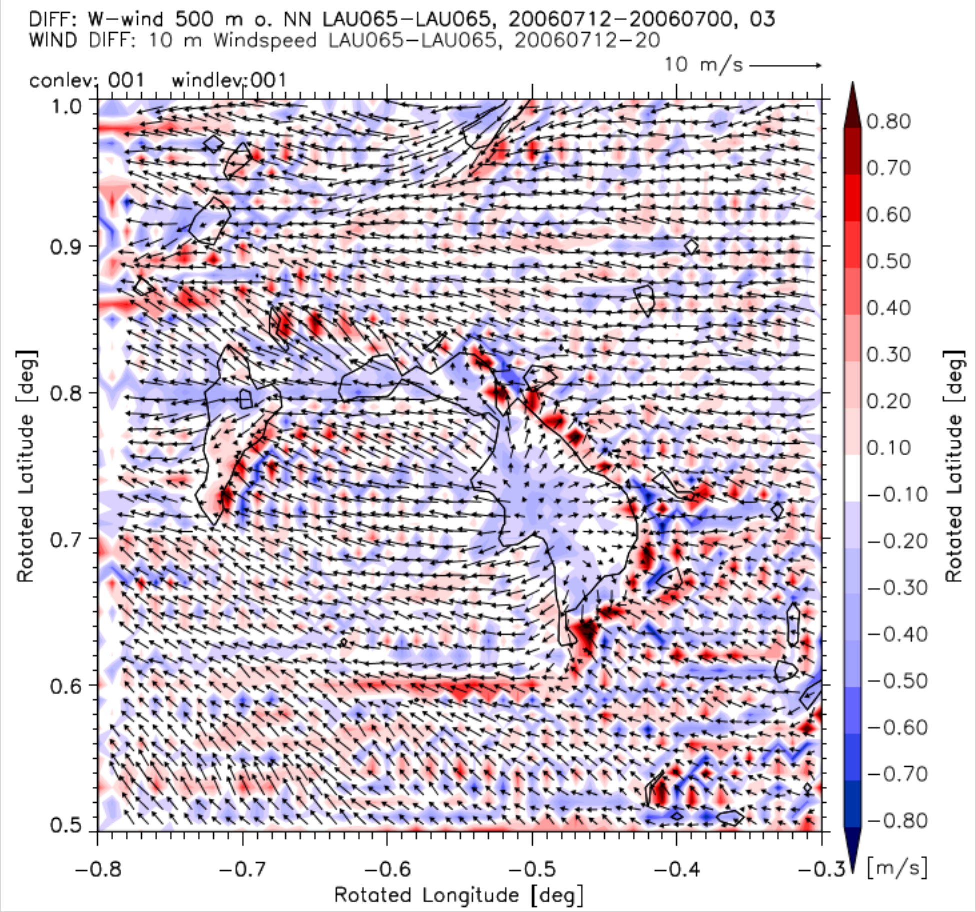


Lake Müritz:	Radial wind of up to 3 m/s simulated at dT2M=6.9 K
Lake Lausitz East:	Radial wind of up to 2 m/s simulated at dT2M=6.2 K

Lake Breeze Effect, W / V10M, 26. July 2006

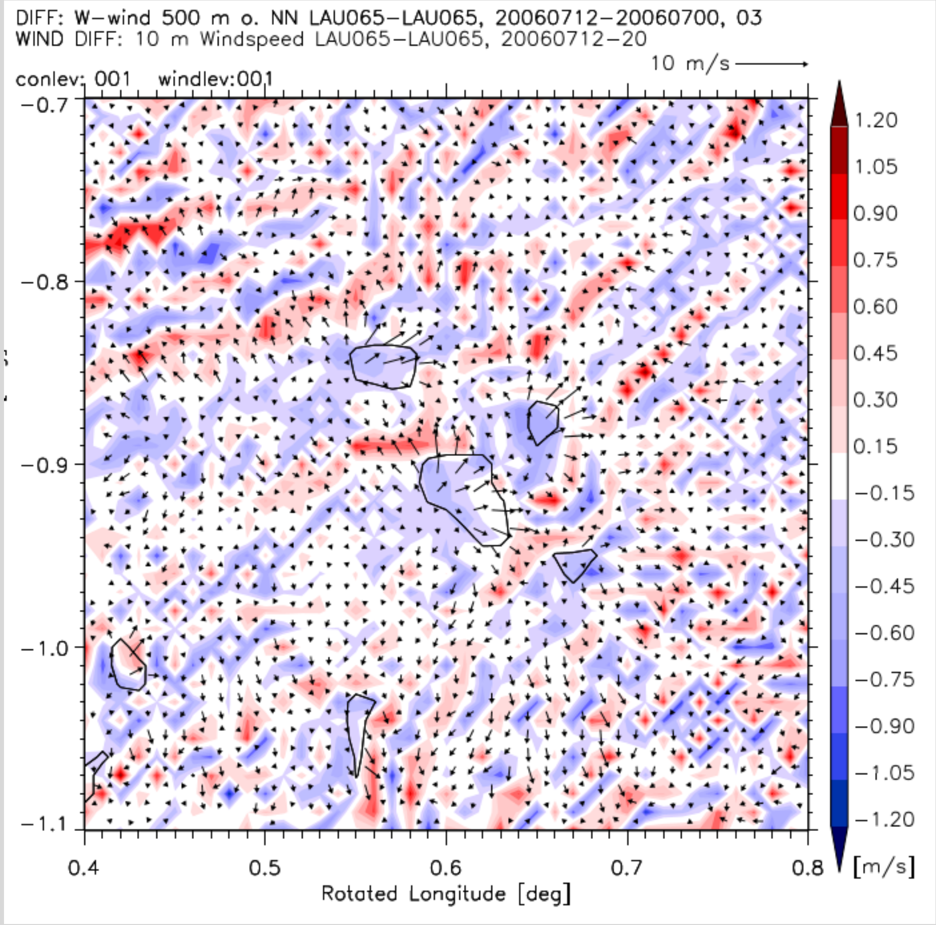
Lake Müritz

LAU065, 12h - 00 h



Lake Lausitz East

LAU065, 12h – 00 h



Lake Müritz: Updrafts of 1-2 m/s simulated upwind and downdrafts over lake

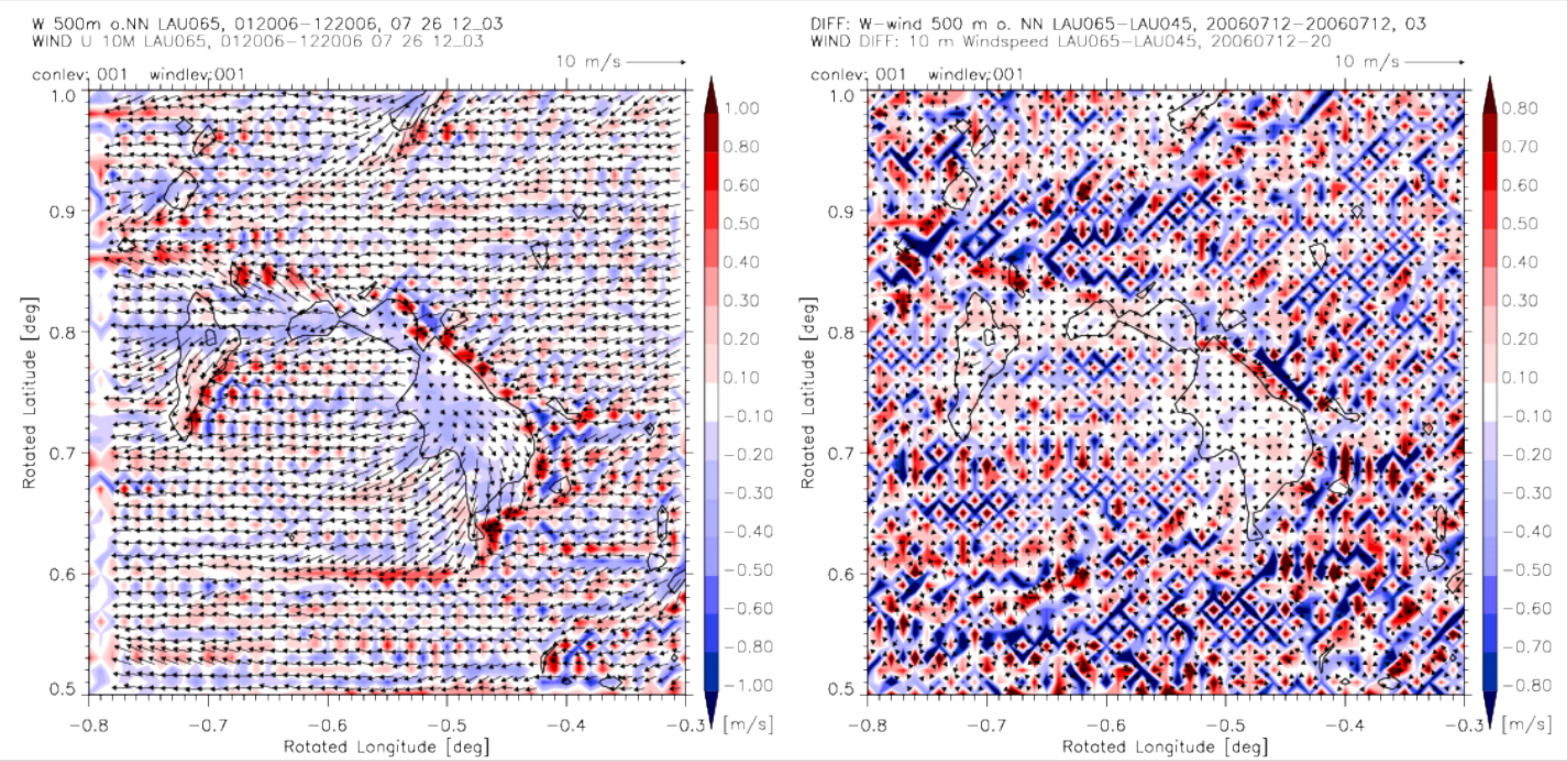
Lake Lausitz East: Updrafts of 0.5-1 m/s simulated upwind and downdrafts over lake

More intensive small scale turbulence in the Lausitz at 2-5 km scale

Lake Müritz, W500m / V10M, 26. July 2006

LAU065, 12h — LAU065 - LAU045, 12h

tur_len — 900 m — 900 m – 150 m

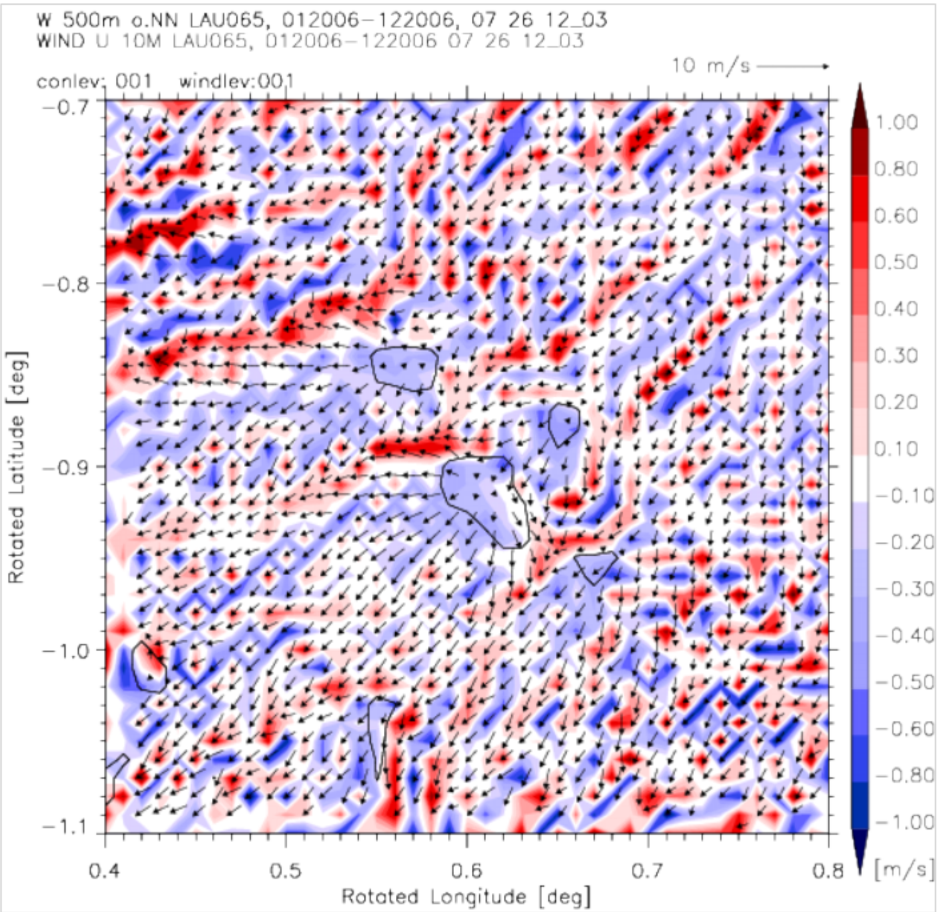


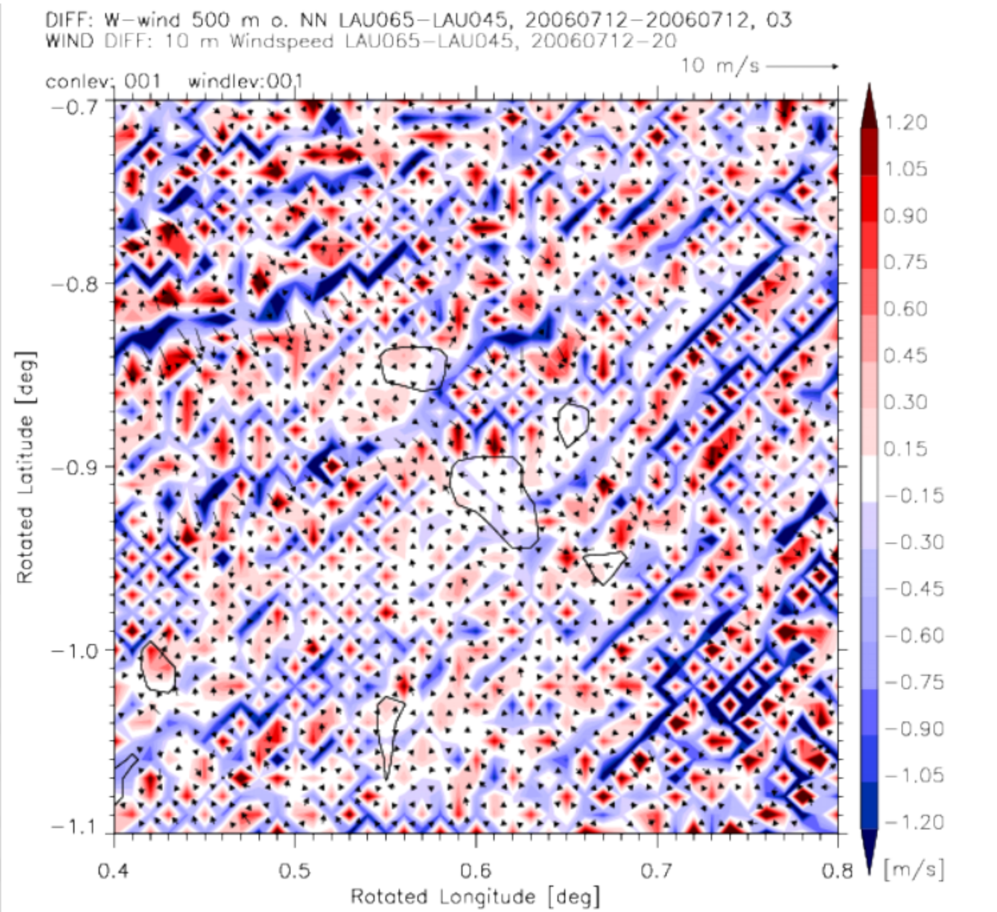
Impact of tur_len: Noise at 2dx scale removed by tur_len=900m close to grid scale.

Lake Lausitz, W500m / V10M, 26. July 2006

LAU065, 12h — LAU065 - LAU045, 12h

tur_len 900 m — 900 m – 150 m



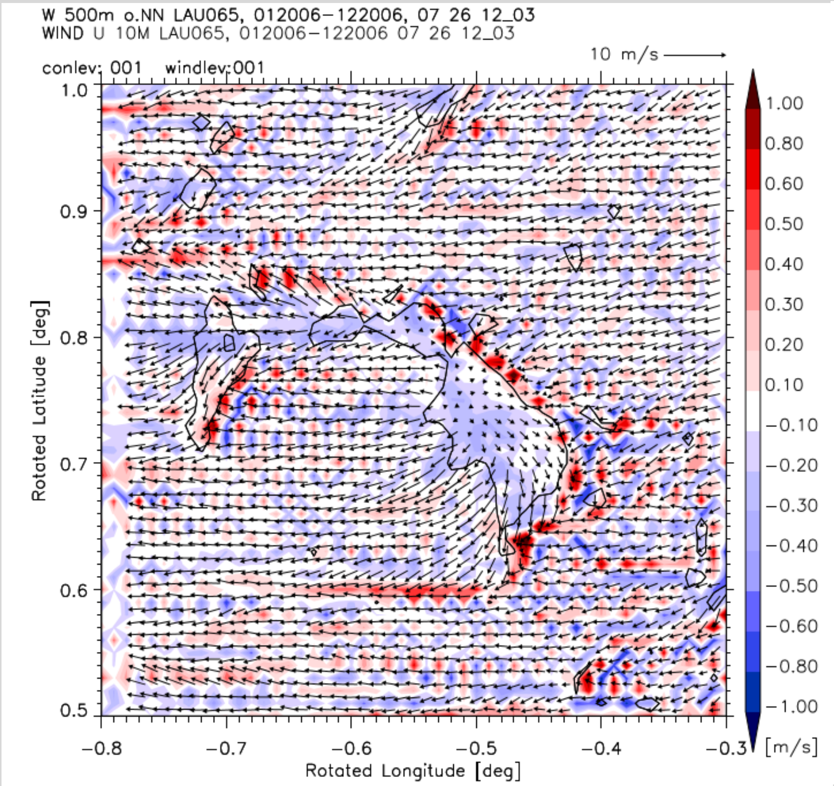


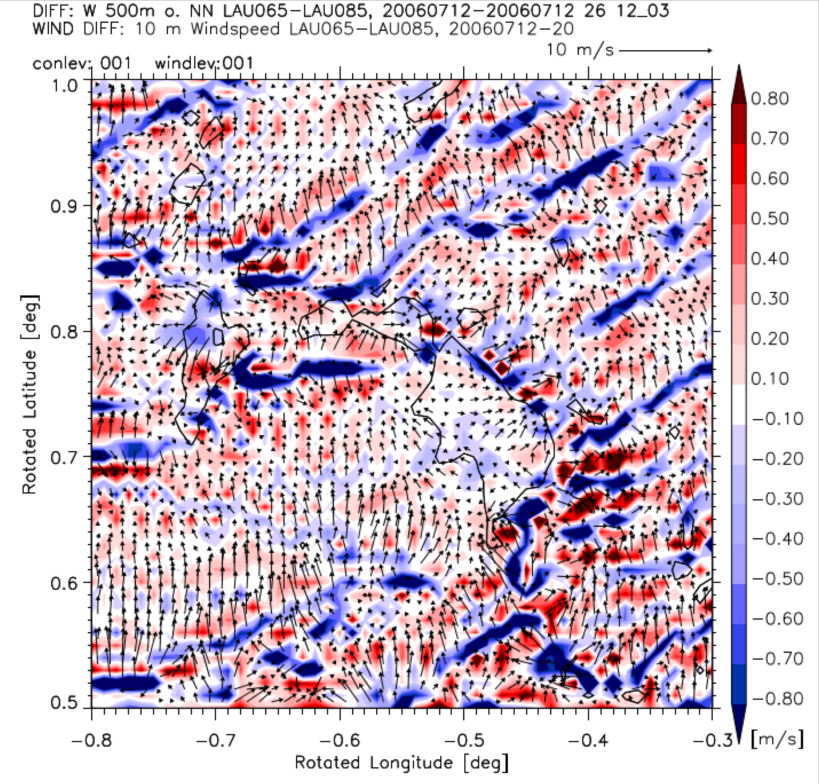
Impact of tur_len: Noise at 2dx scale removed by tur_len=900m close to grid scale.
No suppression of small scale turbulence !!!

Lake Müritz, W500m / V10M, 26. July 2006

LAU065, 12h — LAU065 - LAU085, 12h

numerics S4p4d0.0 — S4p4d0.0 – C5p2d0.1

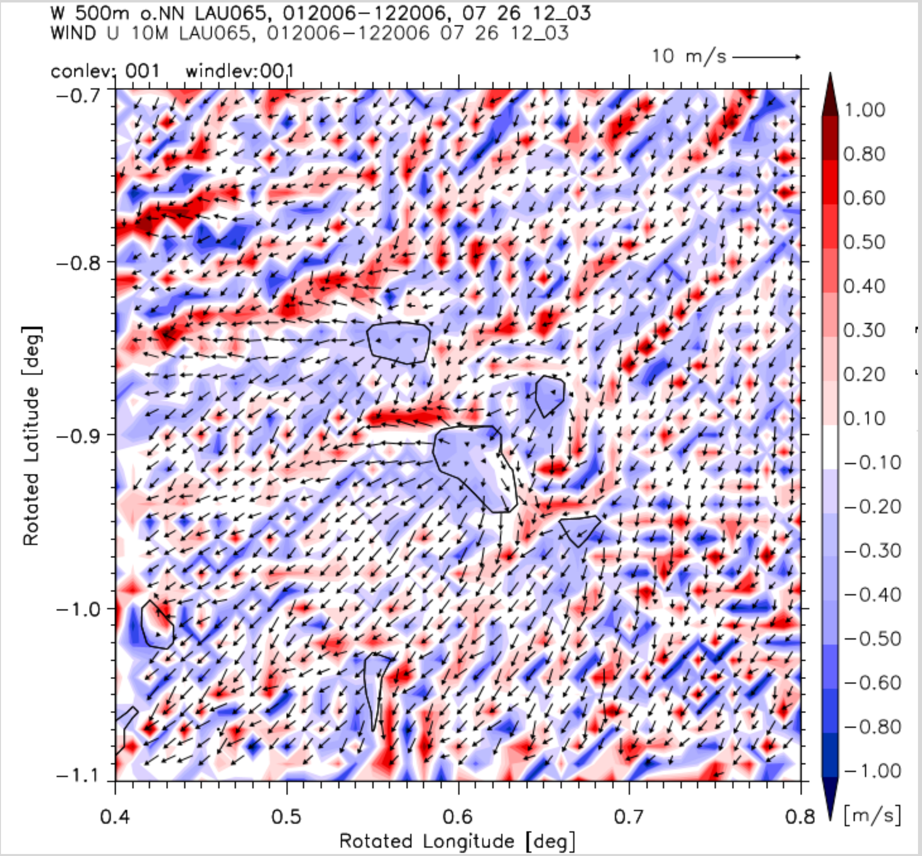


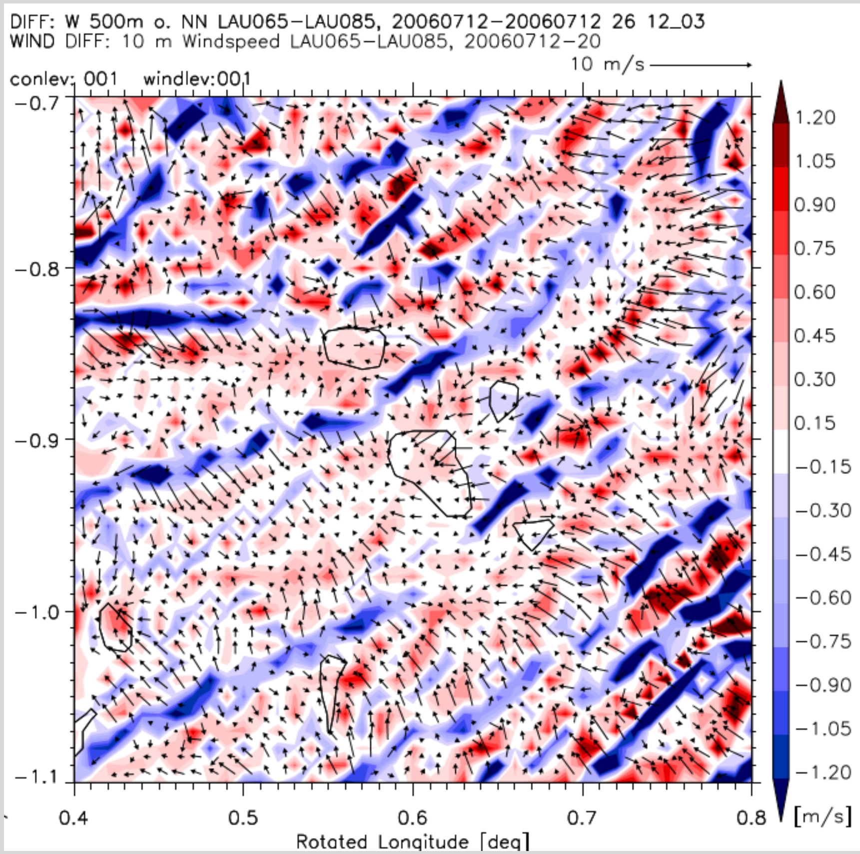


Impact of dynamics and numerics: Implicite and explicite numerical diffusion in COSMO 5th order adv. 2nd order fast waves and hd_corr_in=0.1 suppresses vertical mixing at scales dominated by numerical diffusion. The stabilization of the atmosphere occurs at scales not affected by numerical diffusion (approx. 8 dlon/dlat). The streaks in LAU085 are most probably not a physical but a numerical effect.

Lake Lausitz, W500m / V10M, 26. July 2006

	LAU065, 12h	LAU065 - LAU085, 12h
numerics	S4p4d0.0	S4p4d0.0 – C5p2d0.1





Impact of dynamics and numerics: The Lausitz region is a more continental site. Higher surface temperatures are found than in Müritz. Thus the atmosphere is more unstable. The convective rolls might be due to insufficient horizontal resolution. They convective rolls have a larger space scale and are more intensive in LAU085.

Summary and Conclusions

- A configuration for COSMO is developed, which significantly improves the simulation of meso-scale dynamics in the PBL
- The phenomenon of Land-Lake Wind, is found to have maximum strength at optimum forcing and minimum disturbance (not shown)
- Optimum configuration is found for maximum Land-Lake Wind of small lakes
- The optimum configuration is characterised by
  - Non-dissipative dynamics and numerics
  - No convection parameterization
  - Strength of horizontal Smagorinsky, vertical TKE turbulence parameterisation and resistance to turbulent fluxes at the surface adjustet such that the Land-Lake Wind of small lakes is as strong as possible

- Comparison of results with station observations remains for further studies.

Thank you for your attention

Any questions ?

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