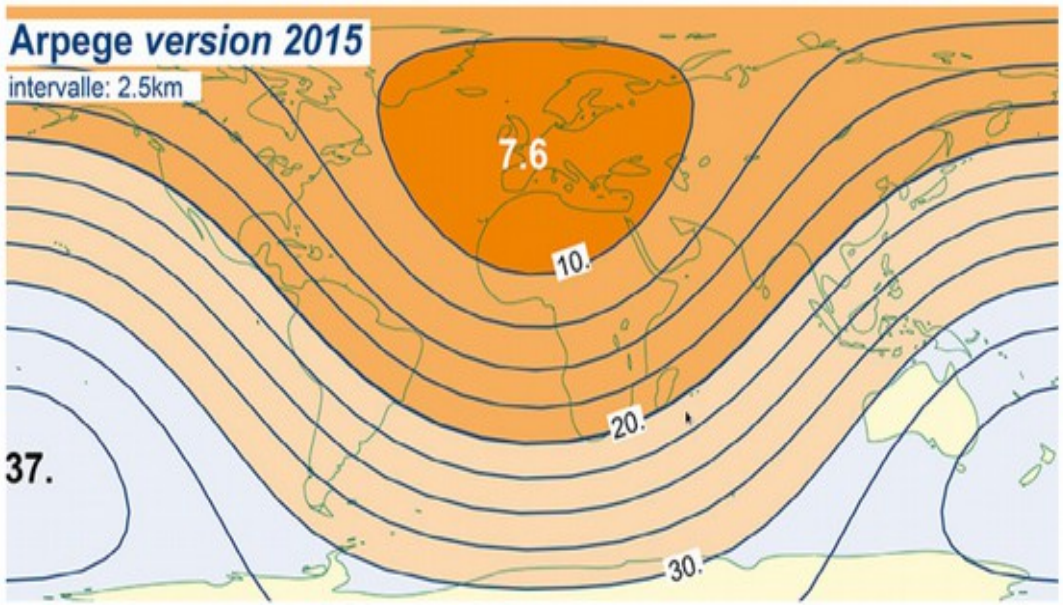
Parametrizations of sub-grid orography effects in global and regional models at Météo-France. Sensitivity studies to parametrizations and horizontal resolution.

François Bouyssel
CNRM-GAME

ECMWF/WCRP/WWRP workshop on drag processes and their links to large-scale circulation, 12-15 September 2016, Reading

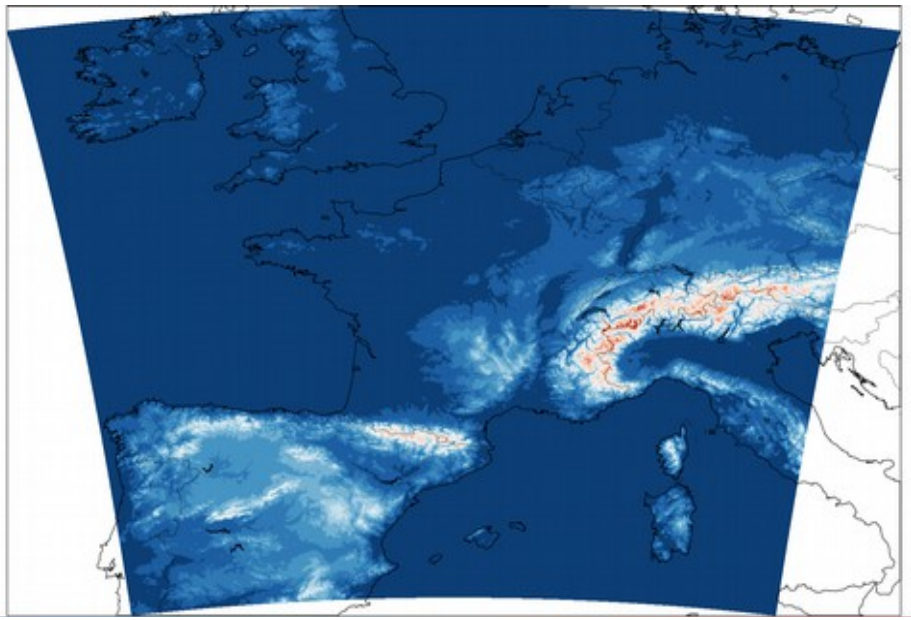
Global Arpege and LAM Arome models

Numerical models used both for operational weather forecasting and climate studies (deterministic and ensemble systems)



Nouvelle résolution horizontale (en km) du modèle Arpege en version « déterministe »

ARPEGE *Deterministic*	**TI1198c2.2 L105 (7.5km on W Europe)** 4DVar (6h cycle): **TI149c1L105** & **TI399c1L105** 5 forecasts per day up to 114h



AROME-France *Deterministic*	**1.3km (1536 x 1440 pts)** **L90: from 5m to 10hPa** 3DVar (**1h cycle**) 5 forecasts per day **up to 42h**

Physical packages

	Targeted physics for hydrostatic scales (ARPEGE NWP and Climat)	Operational physics of convective scale model (AROME NWP and Climat)
Surface	SURFEX (Masson et al., 13): surface modelling platform	
Radiation	RRTM (Mlawer, 97) + SW6* (Fouquart 80, Morcrette 01)	
Turbulence	1.5 order scheme prognostic TKE (Cuxart et al., 00)	
Mixing length	Non local, buoyancy based (Bougeault-Lacarrère, 89)	
PBL thermals	New scheme PCMT (5 prog. var) (Piriou et al., 07) and (Gueremy, 11)	PMMC09 (Pergaud et al., 09)
Clouds	PDF based: (Smith, 90) **or** (Bougeault, 82)	
Microphysics	Bulk scheme with 4 prog. var. (Lopez, 02)	Bulk scheme** 5 prog. var. (Pinty and Jabouille, 98)
Convection	New scheme PCMT (5 prog. var) (Piriou et al., 07) and (Gueremy, 11)	x
Subgrid orographic effects (GWD, blocking, etc.)	Catry-Geleyn (08)	x

Sub-grid scale orography parameterizations in Météo-France models

	Enhanced orography	Effective roughness length	Subgrid orography scheme (GWD, blocking, lift, etc.)
ARPEGE Climat	NO	Georgelin et al., 1994	Boer et (1984), with modifications Catry et al. 2008
ARPEGE NWP	YES (mean+$\sigma\Gamma$)	Georgelin et al., 1994	Boer et (1984), with modifications Catry et al. 2008
AROME	NO	Georgelin et al., 1994	NO

SSO scheme

- Surface drag for the wave part (Boer et al., 1984)
- Anisotropy effects (following Phillips, 1984)
- Deposition effects (following Lindzen, 1981)
- Wave trapping
- Form drag part (Lott et Miller, 1997)
- Lift effect

F	inverse Froude number
F_c	critical F value (=0.5)
τ	total surface stress
τ_{lin}	surface stress from the linear theory
C_d	drag coefficient

$$F < F_c \quad \tau = \tau_{lin}$$

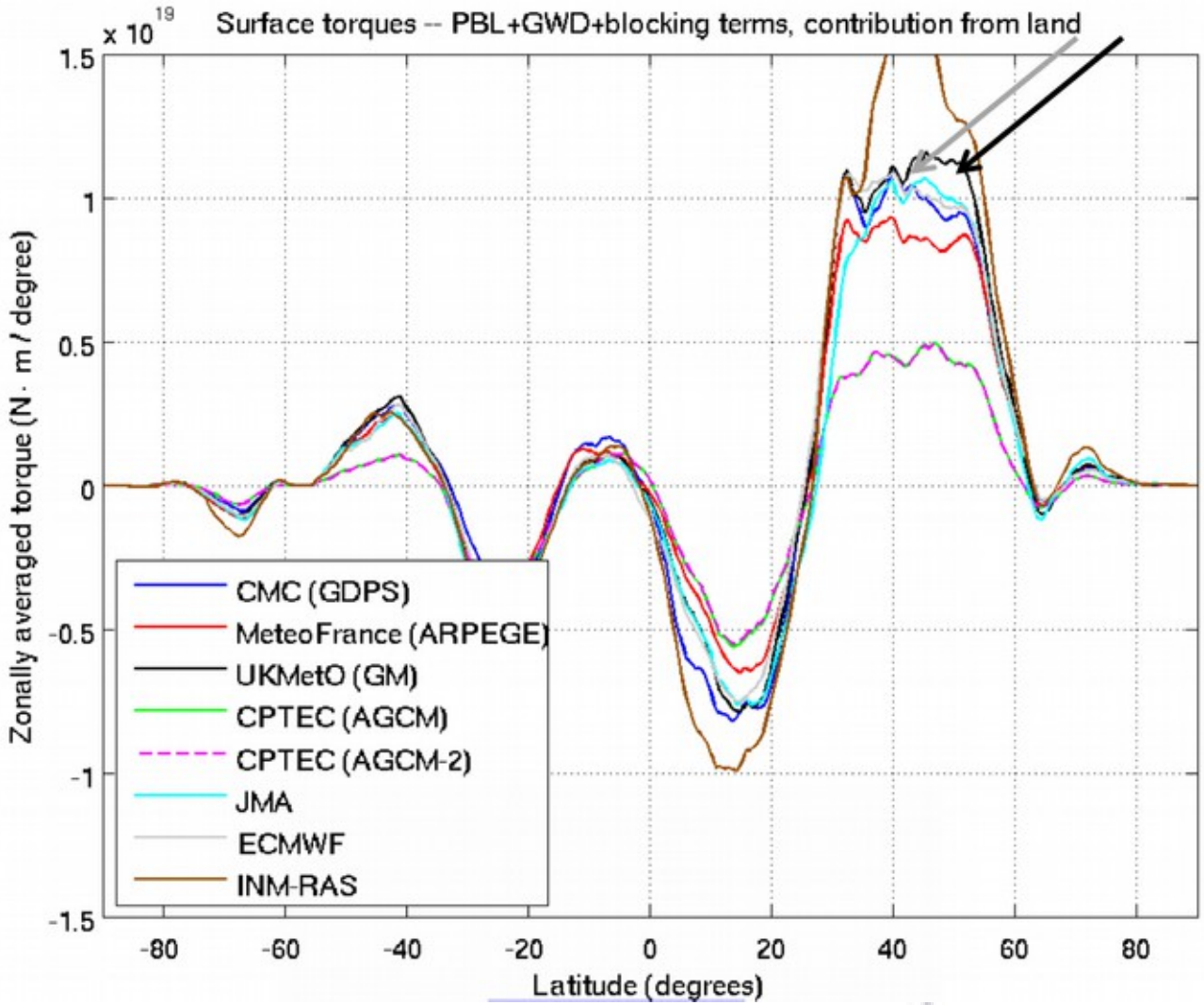
$$F > F_c \quad \tau = \tau_{lin} \frac{F_c}{F}\left(1 + C_d\left(1 - \frac{F_c}{F}\right)\right)$$

CATRY, B, JF GELEYN, F BOUYSSEL, J CEDILNIK, R BROZKOVA, M DERKOVA, and R MLADEK. 2008: A New Sub-grid Scale Lift Formulation in a Mountain Drag Parameterisation Scheme. Meteorologische Zeitschrift 17 (2): 193–208

WGNE DRAG-project

WGNE DRAG-project, torque inter-comparison Step0-24 January 2012

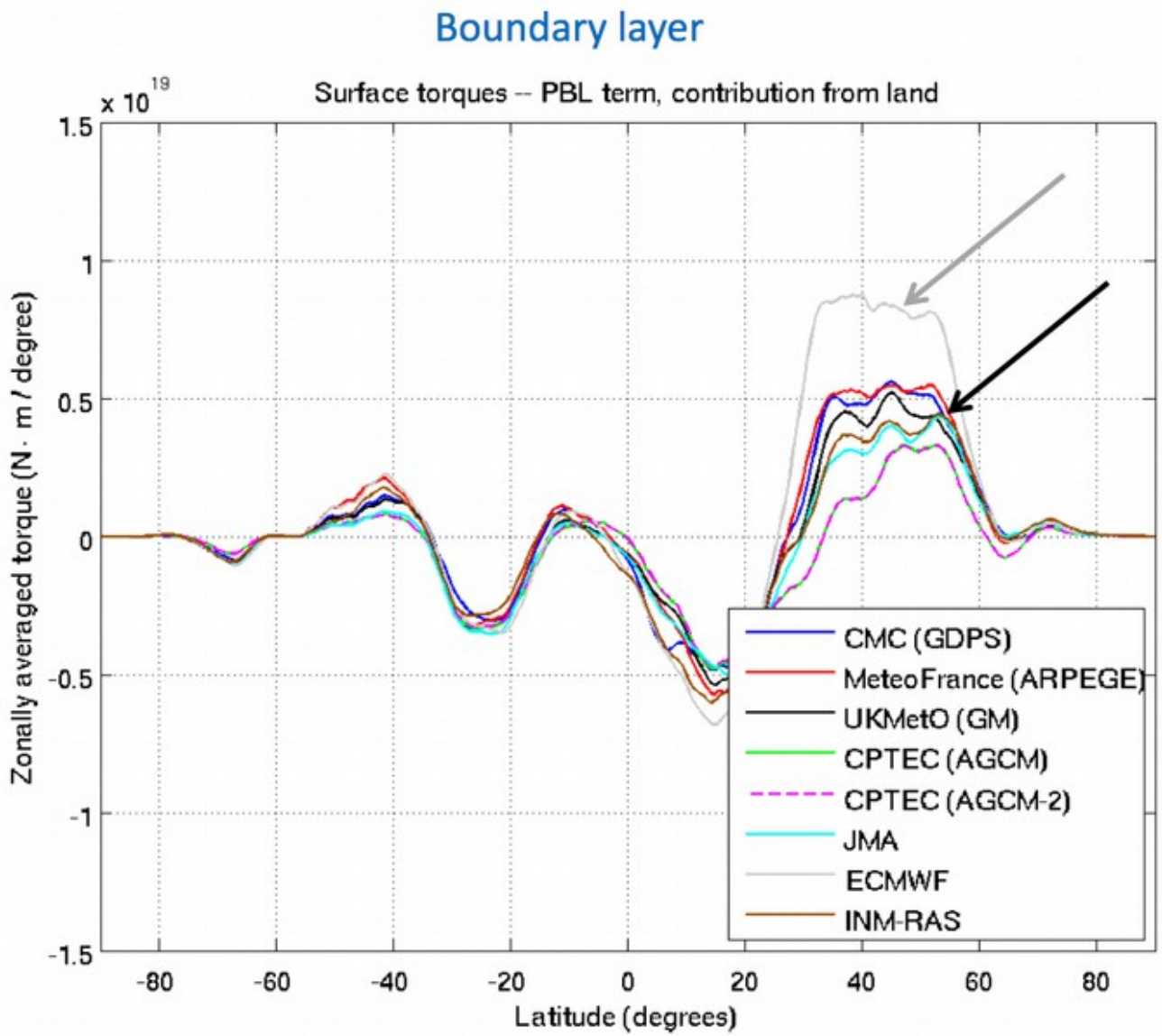
Boundary layer + subgrid orography



(Ayrton Zadra)

WGNE DRAG-project

WGNE DRAG-project, torque inter-comparison Step0-24 January 2012



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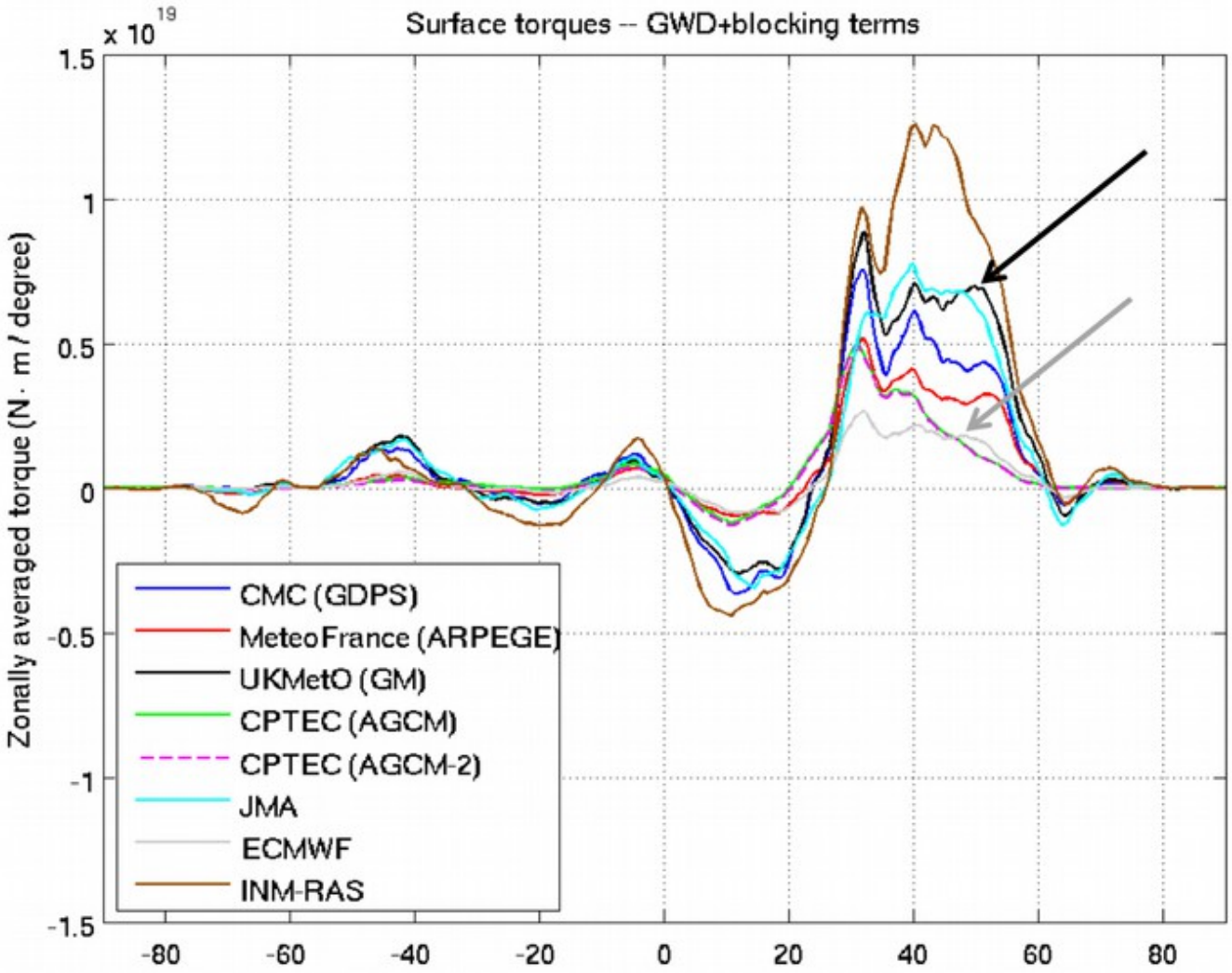
WGNE DRAG-project

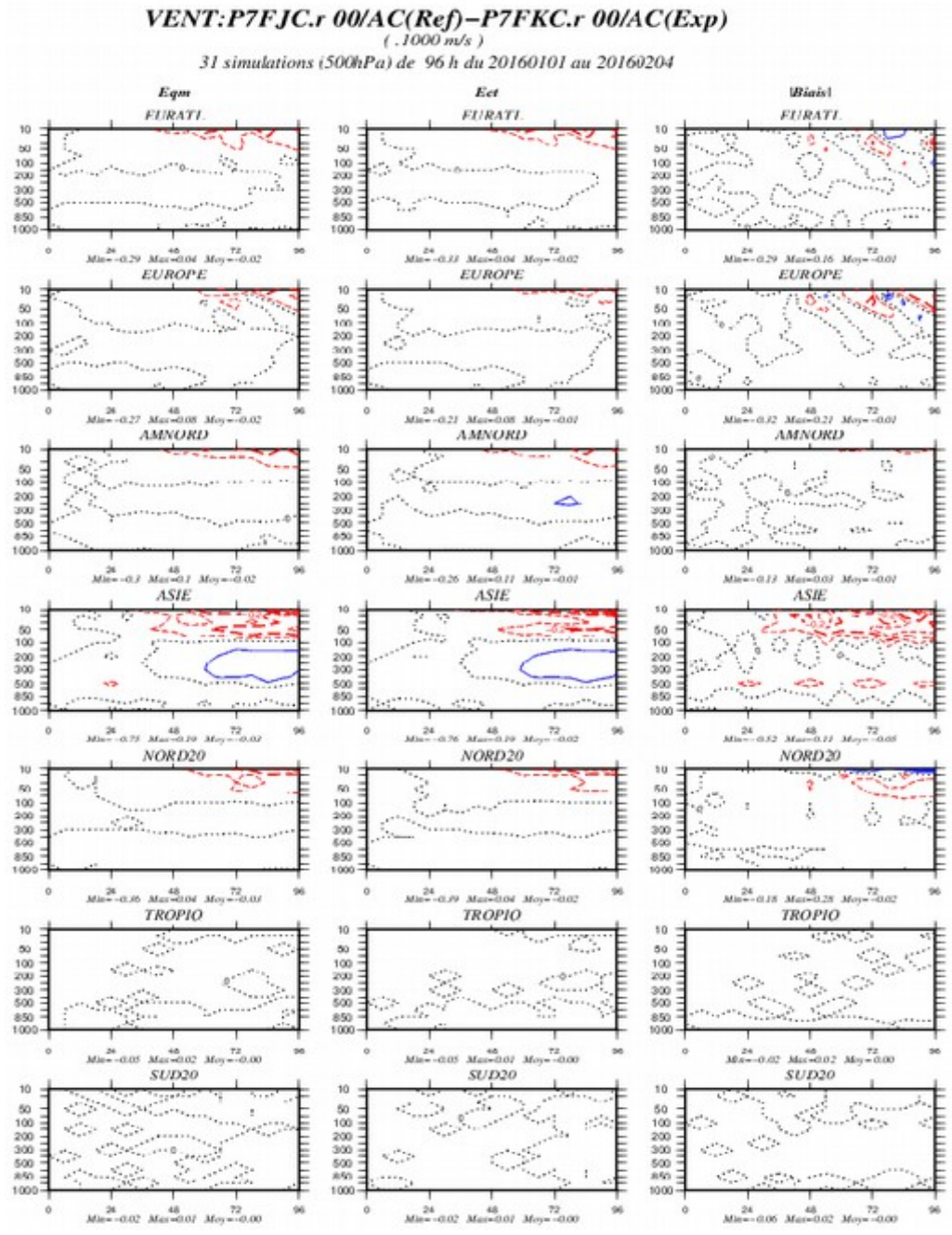
WGNE DRAG-project, torque inter-comparison Step0-24 January 2012

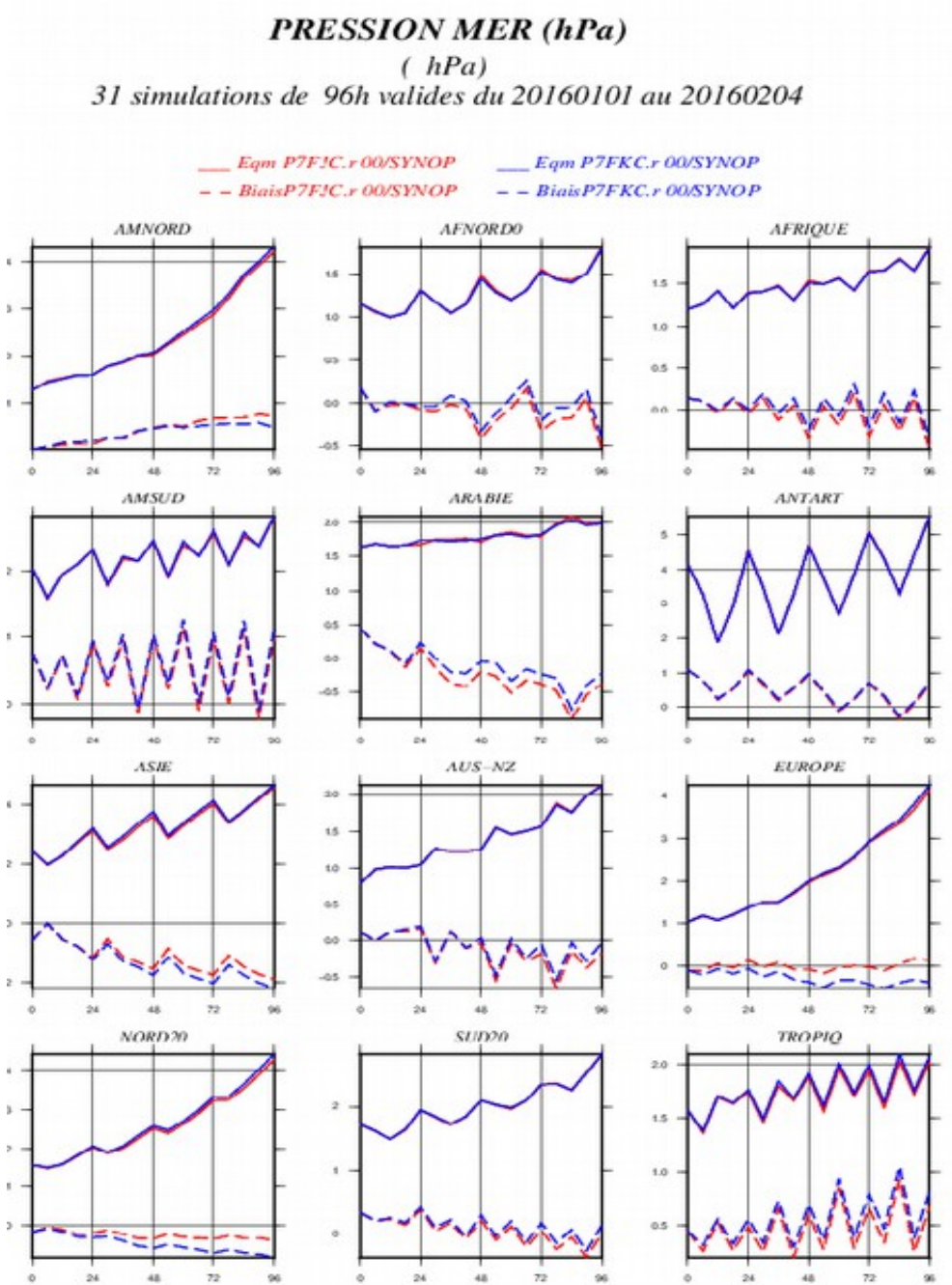
subgrid orography



(Ayrton Zadra)

Impact of turning-off the SSO scheme





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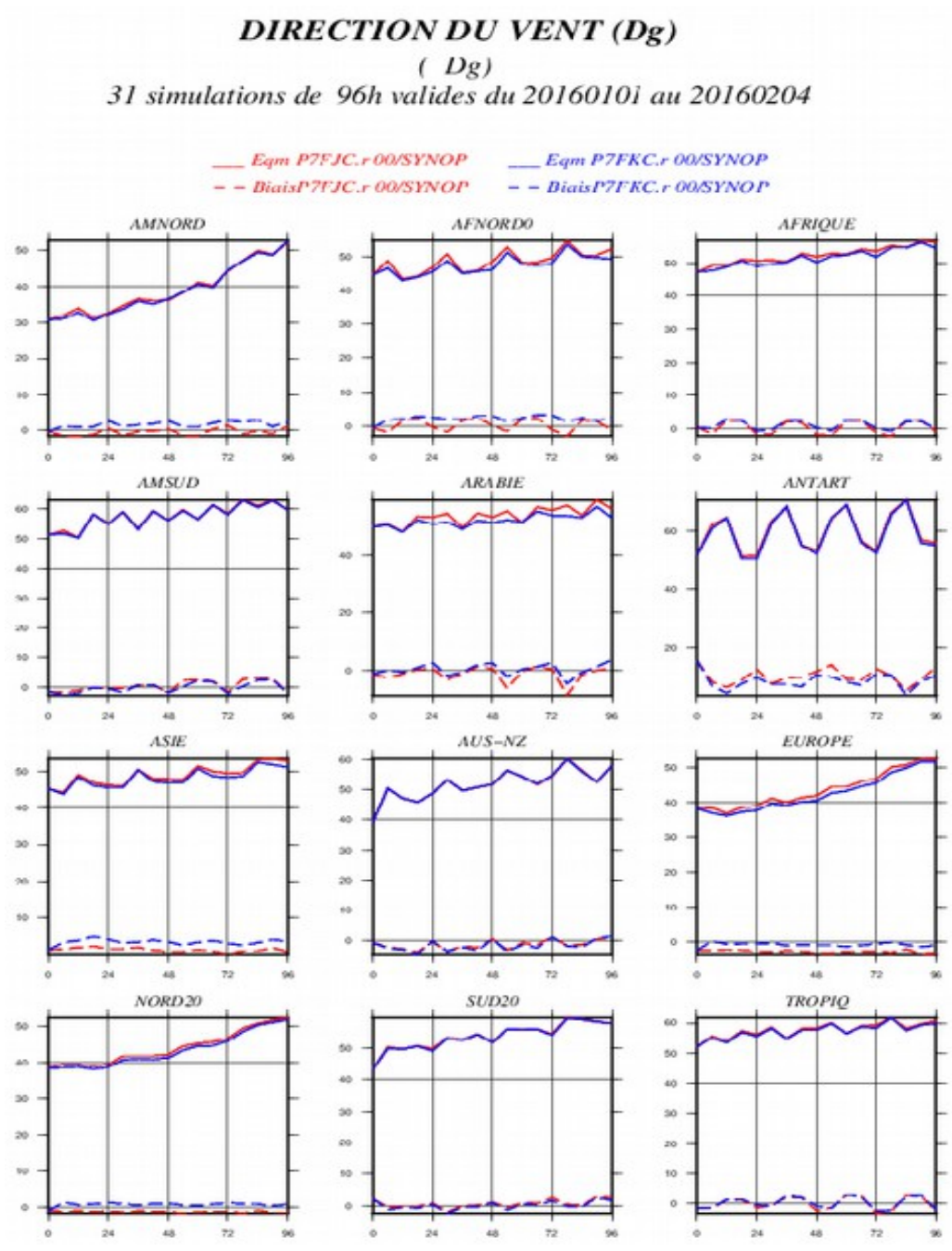
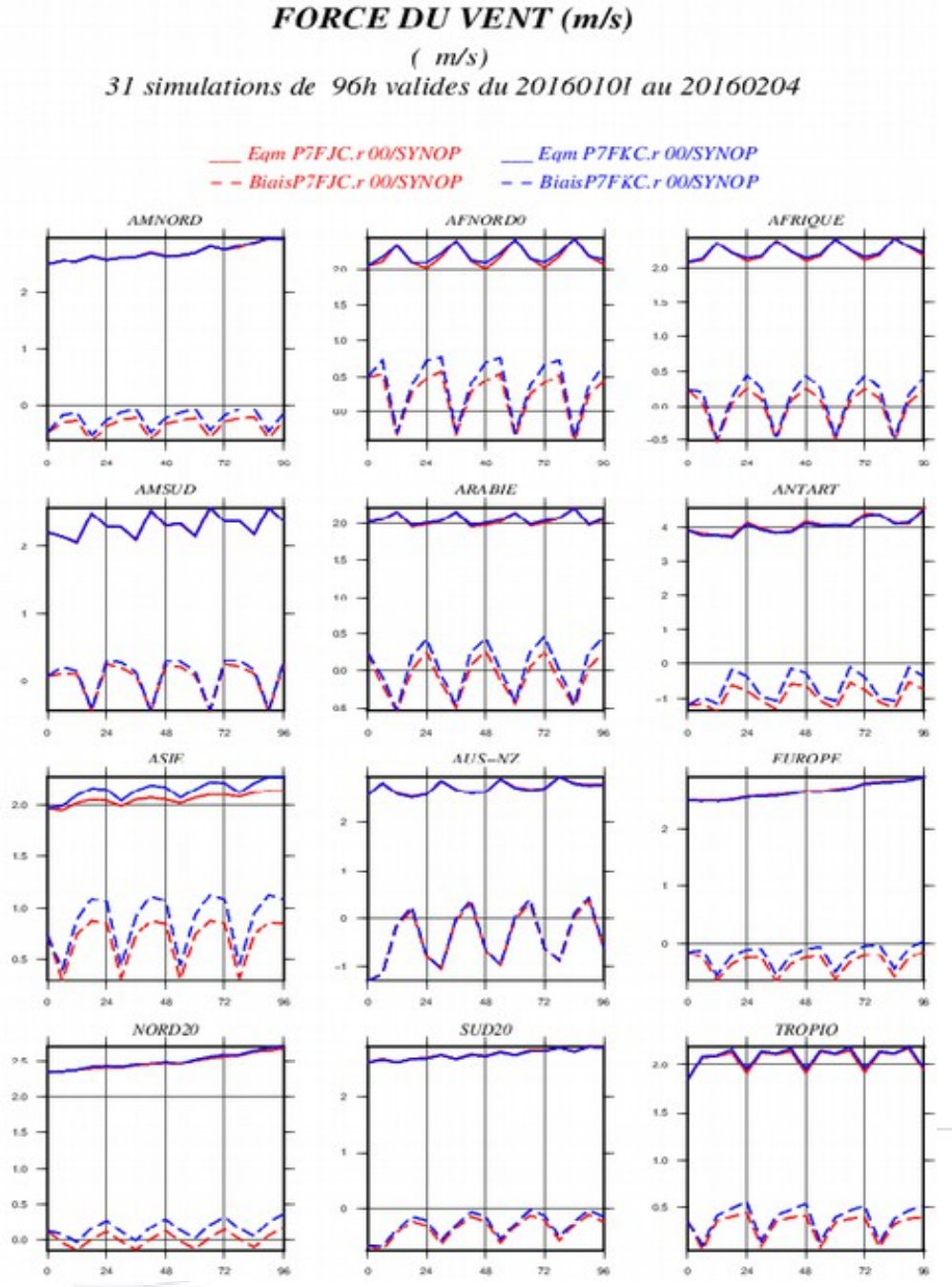
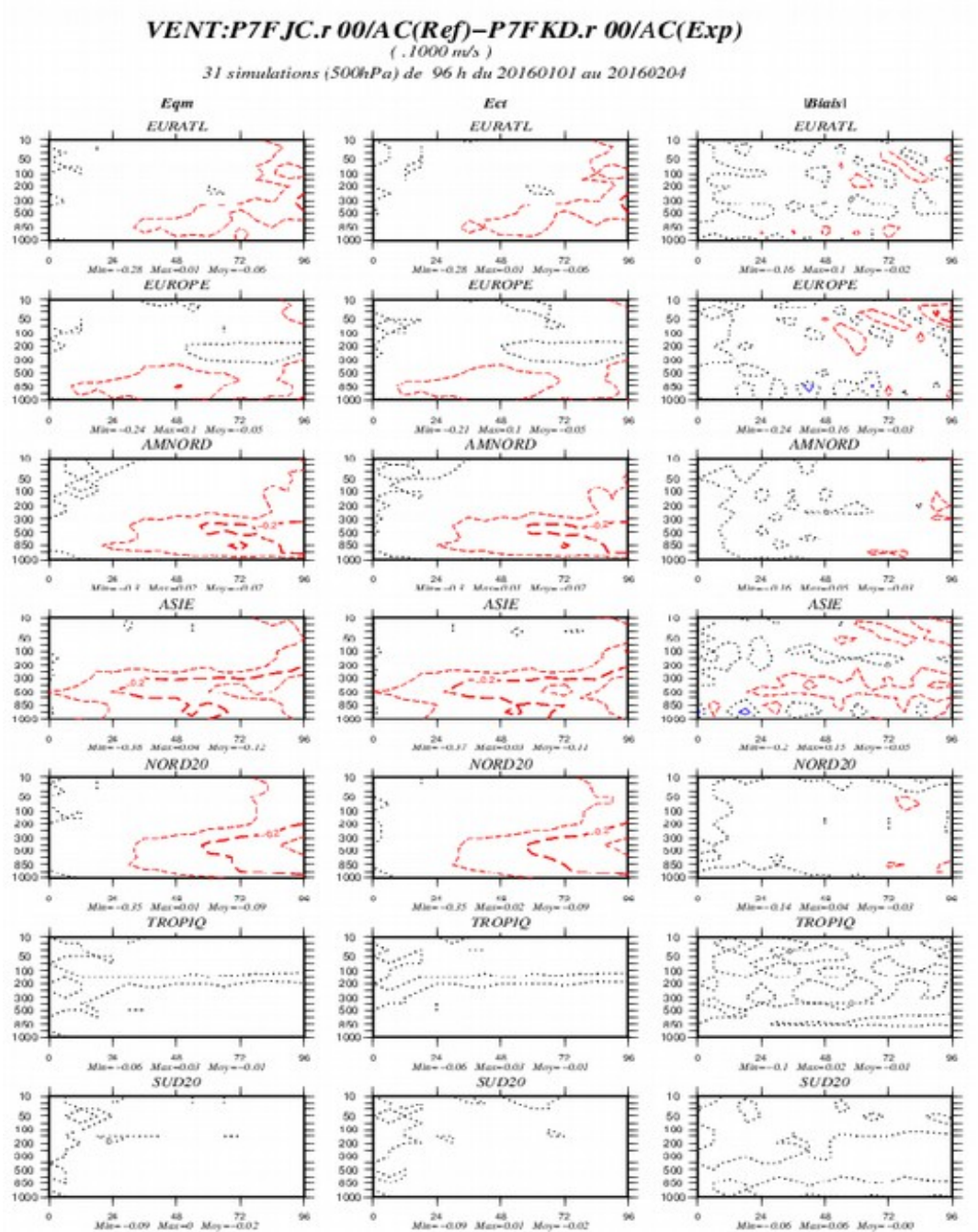
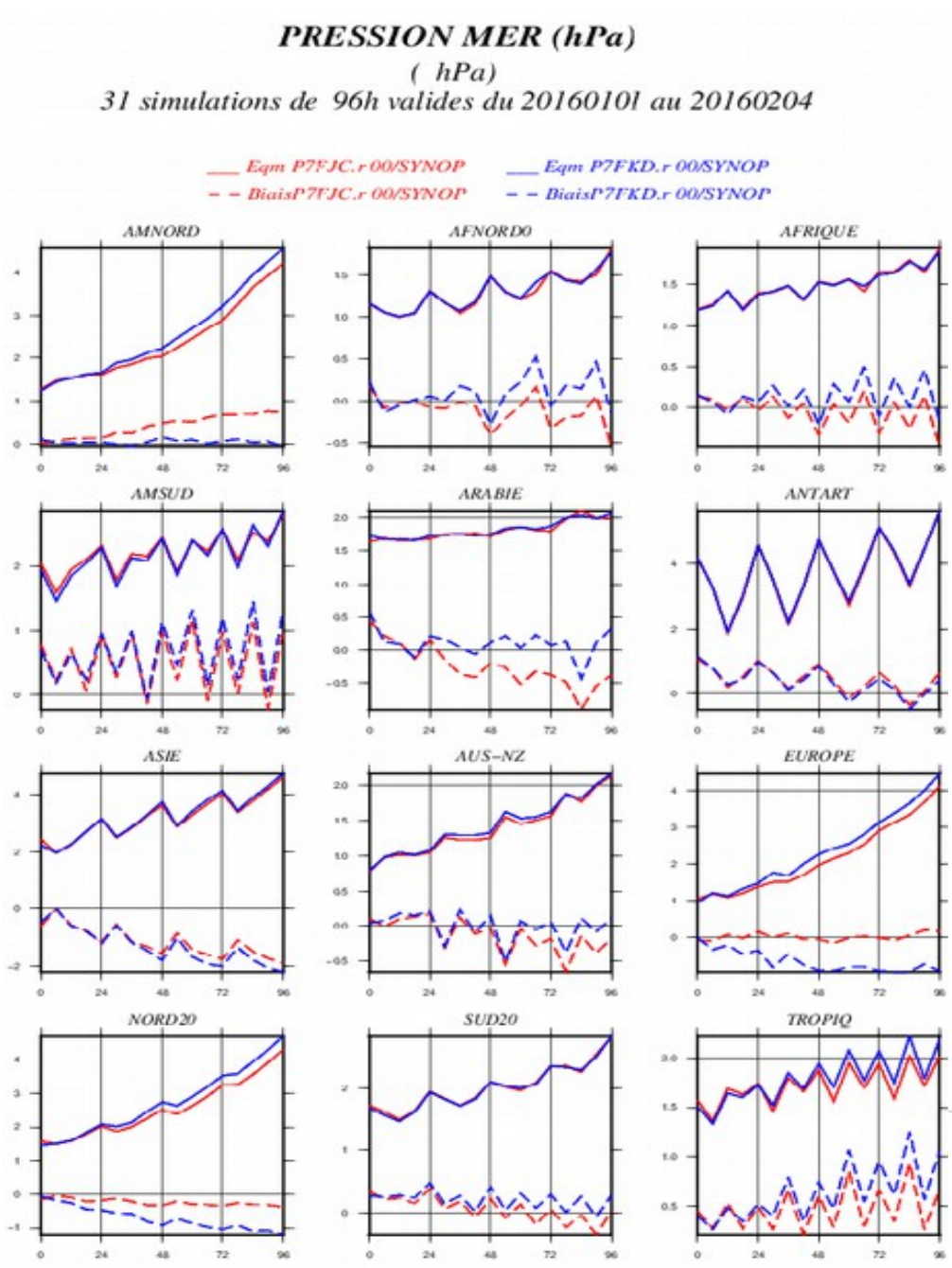




Impact of removing envelop orography





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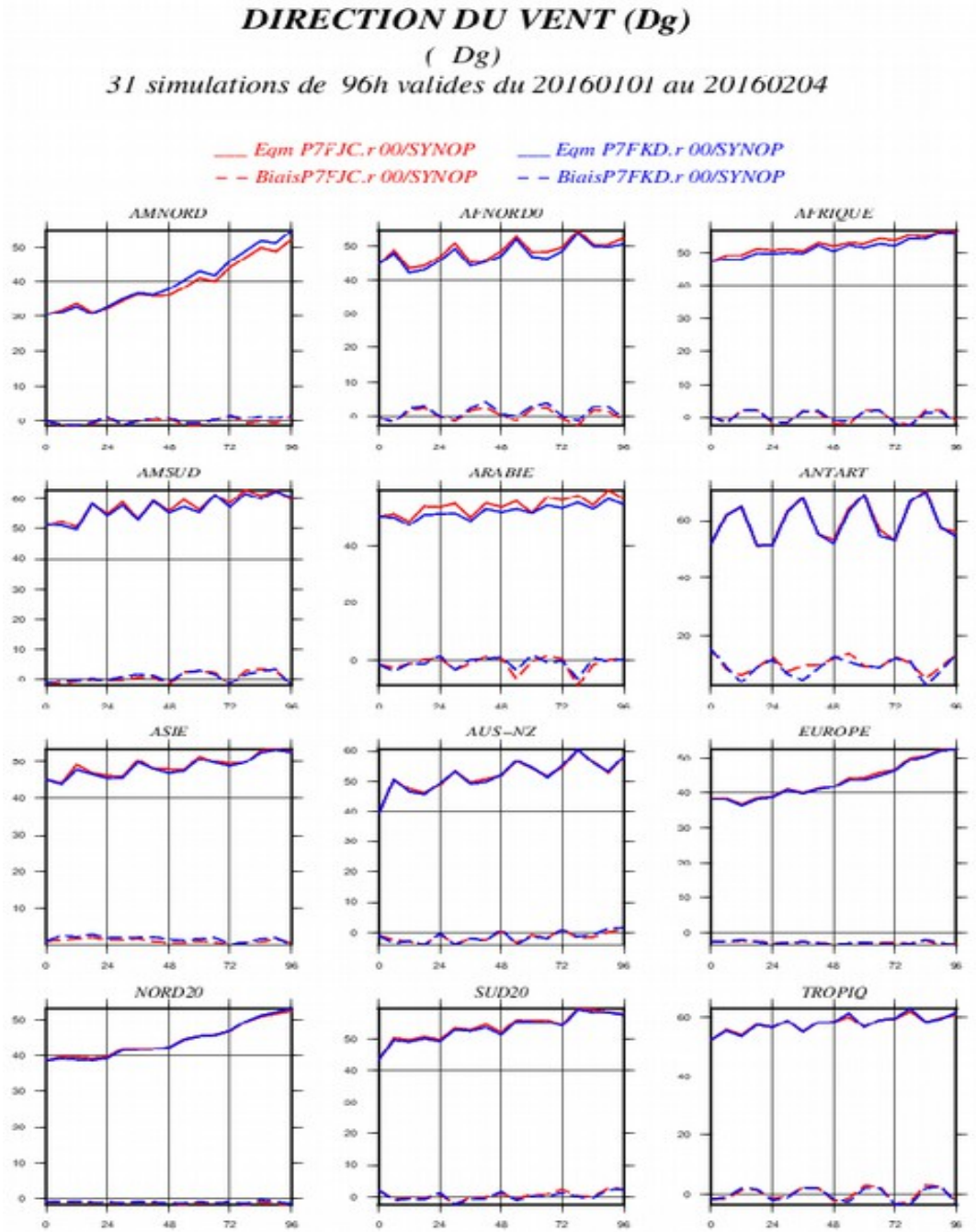
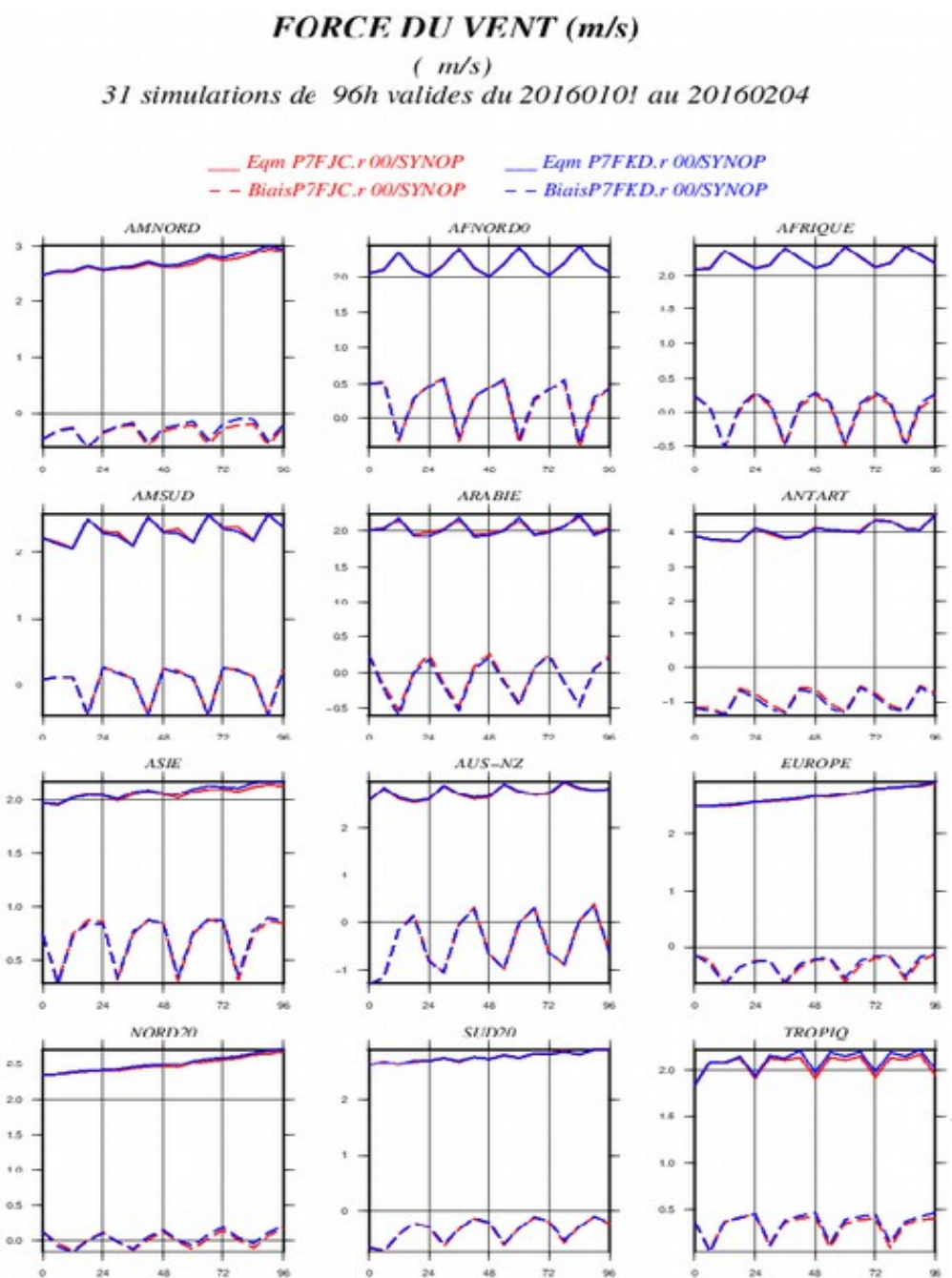
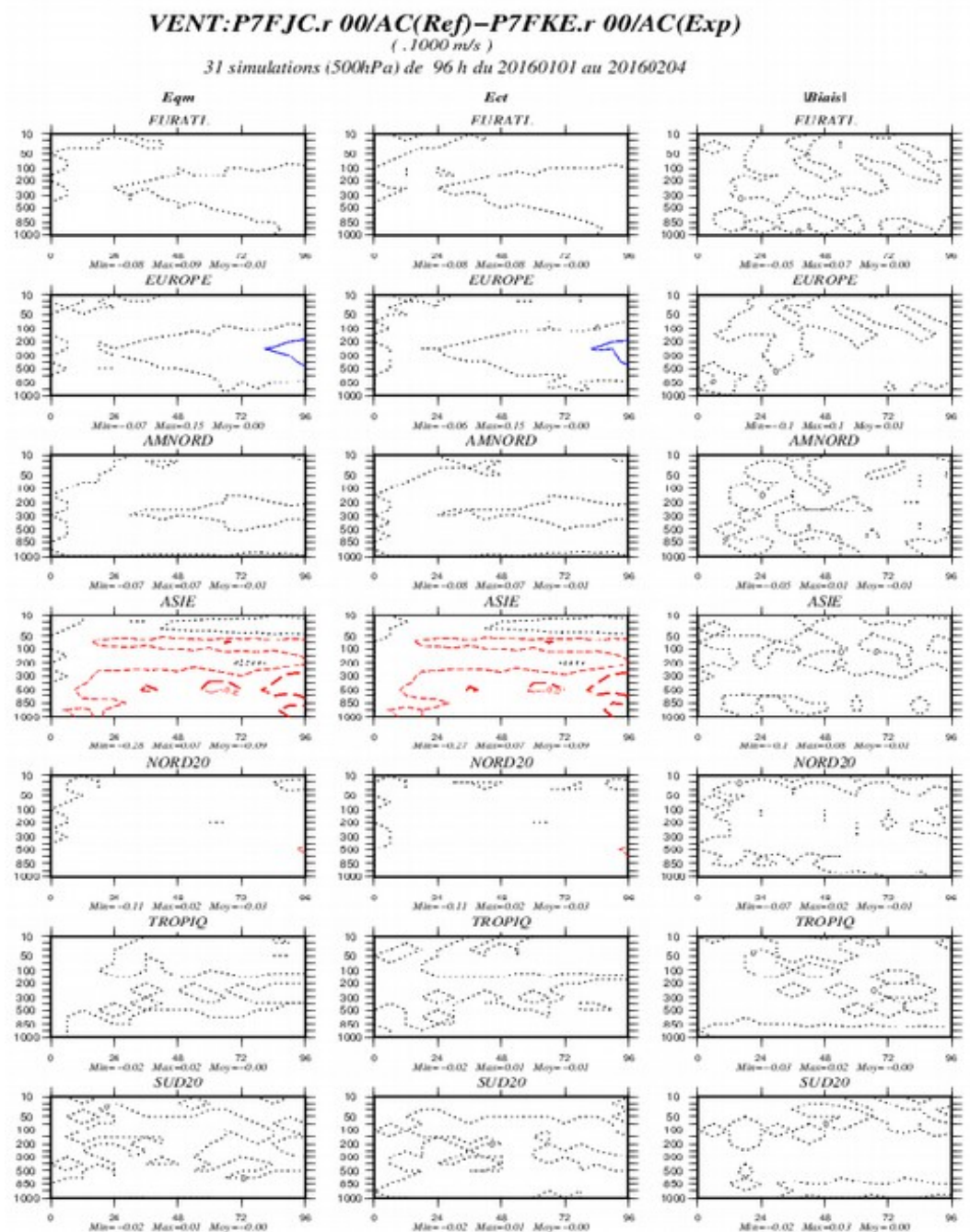
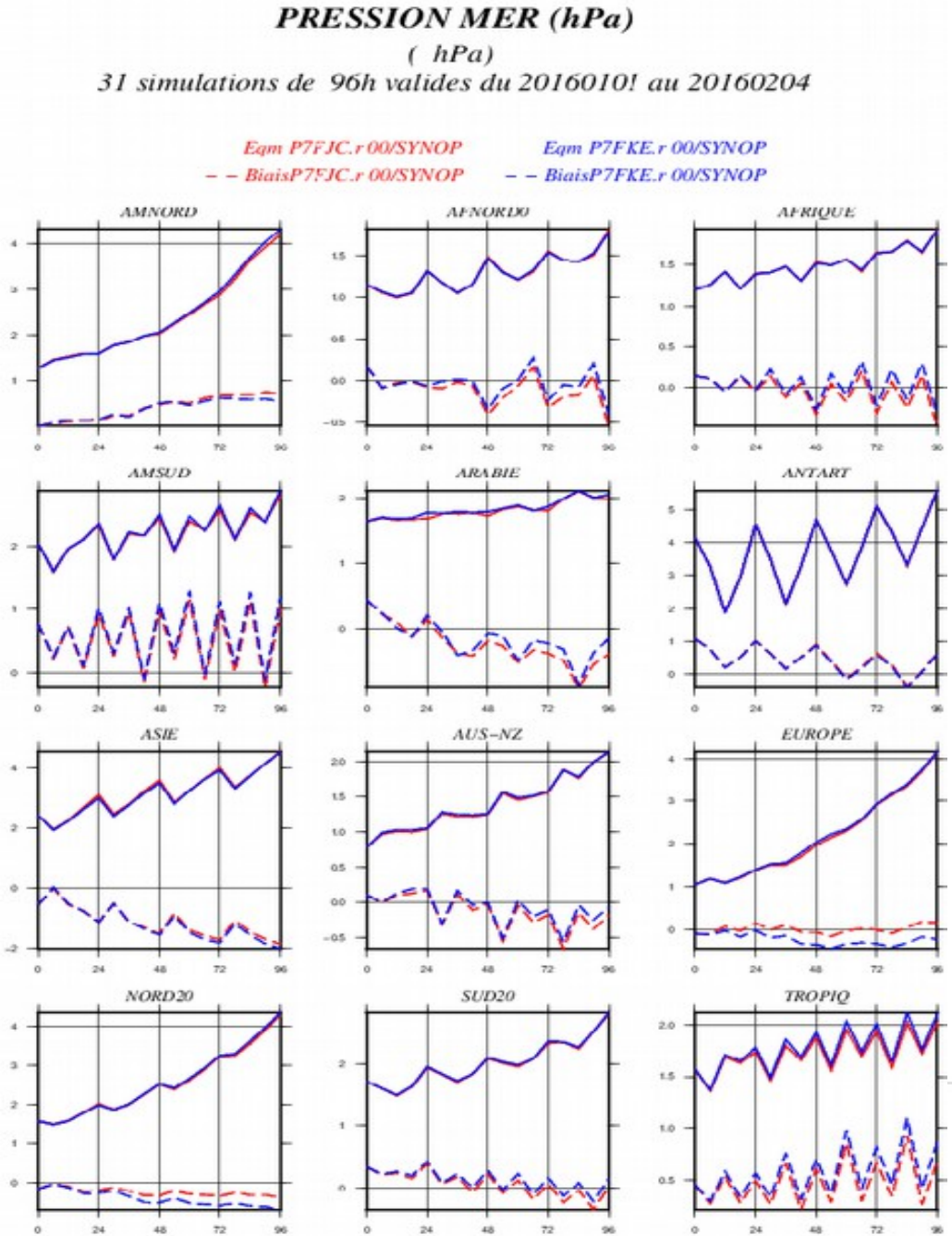


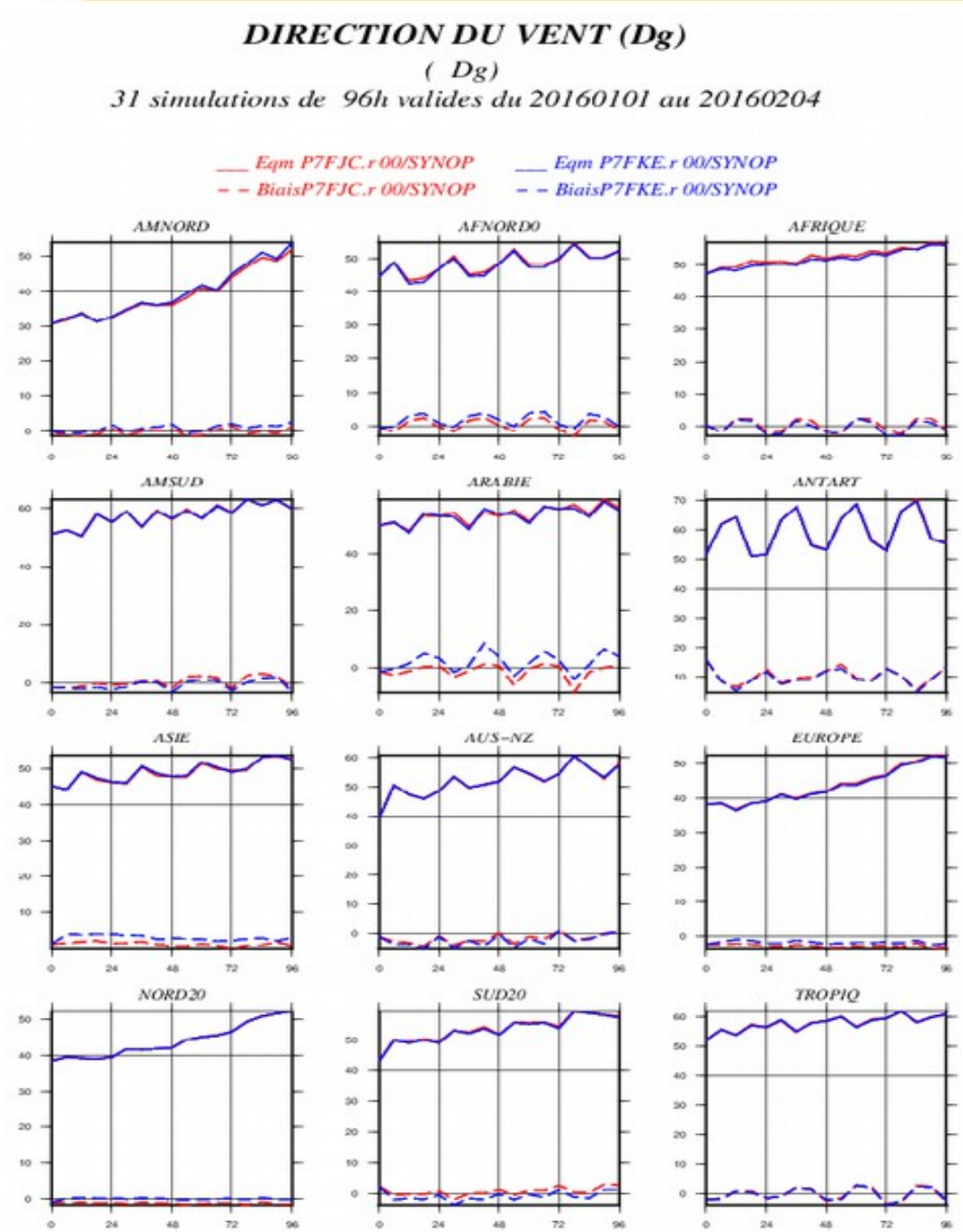


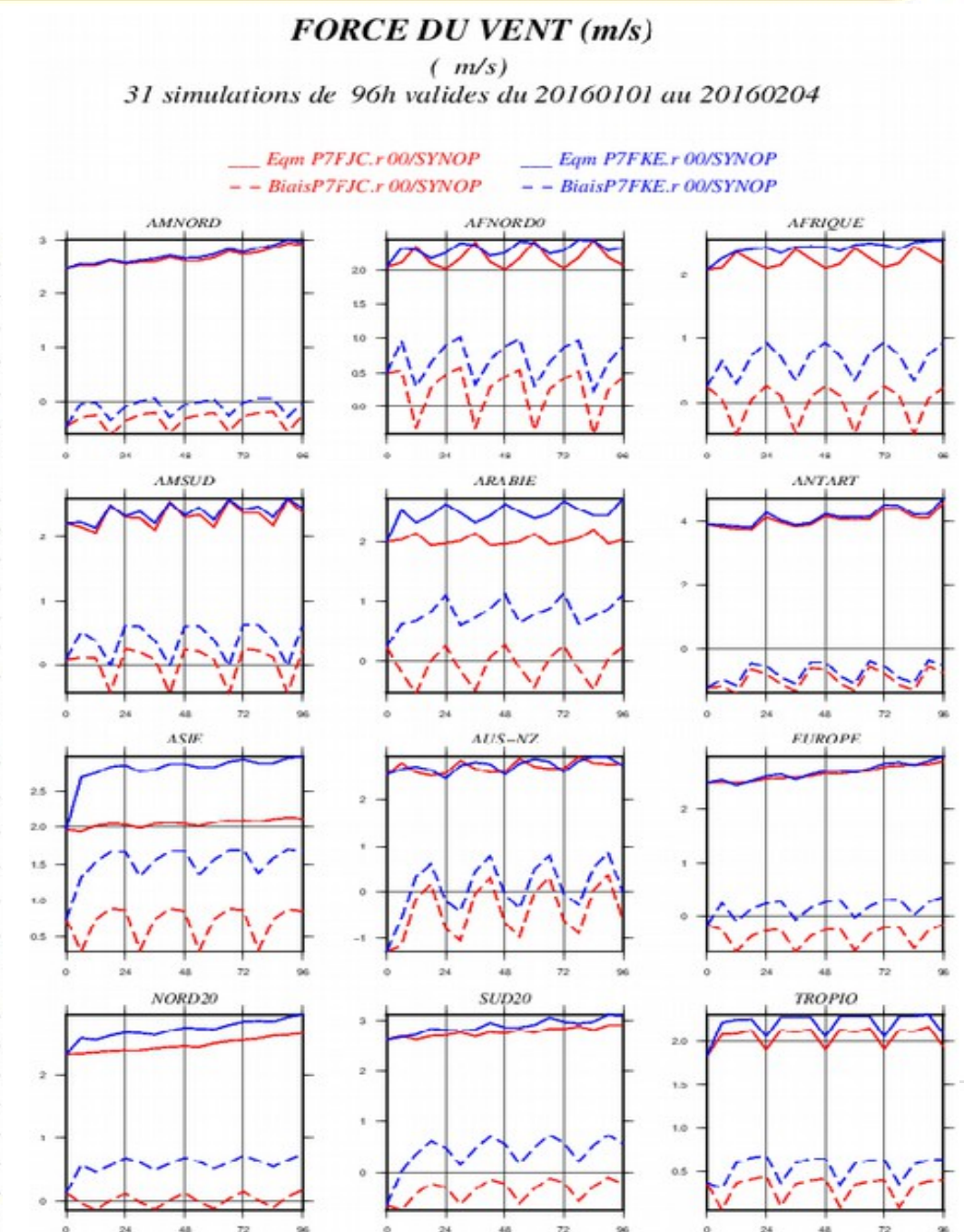
Impact of removing effective roughness length





Impact of removing effective roughness length

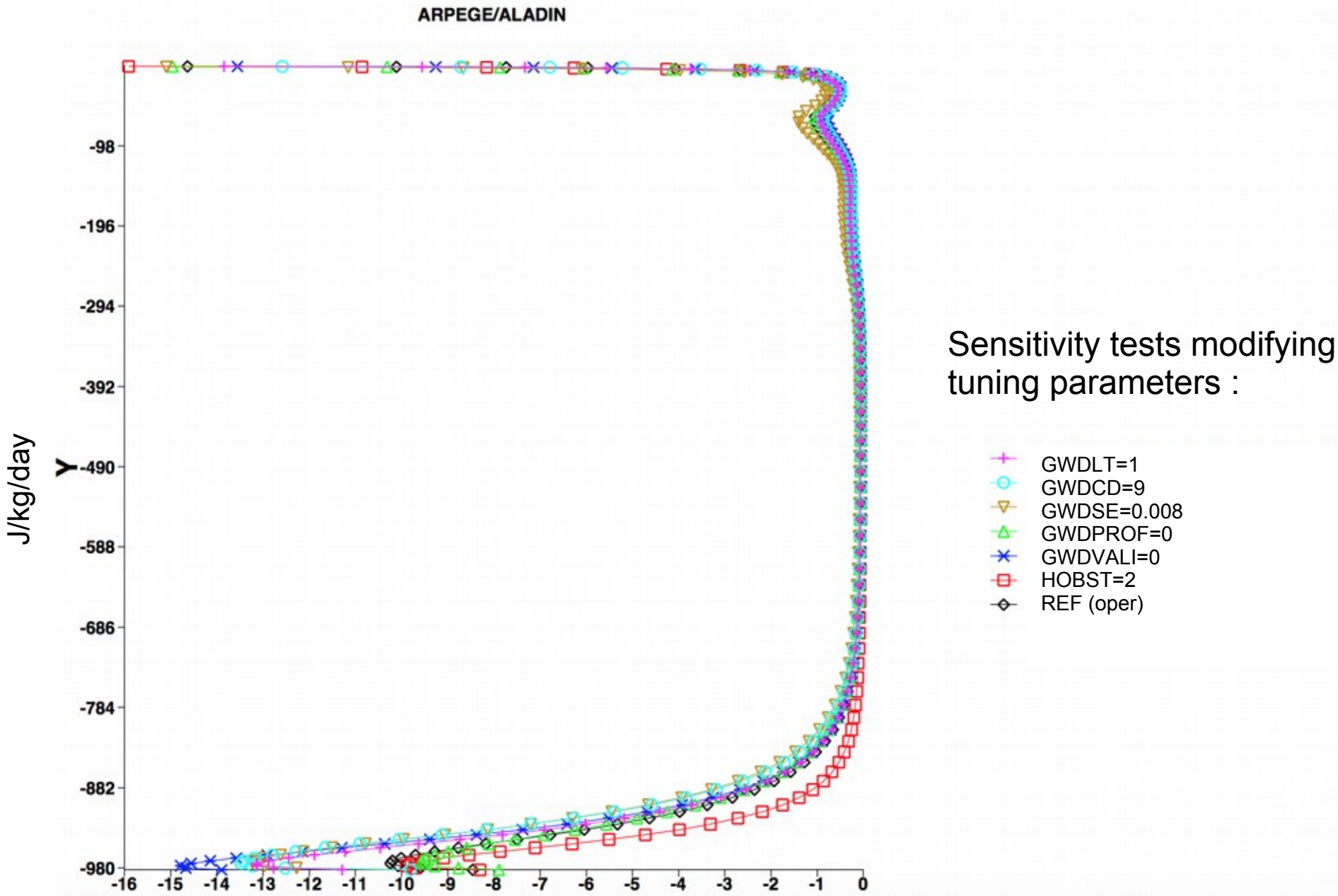




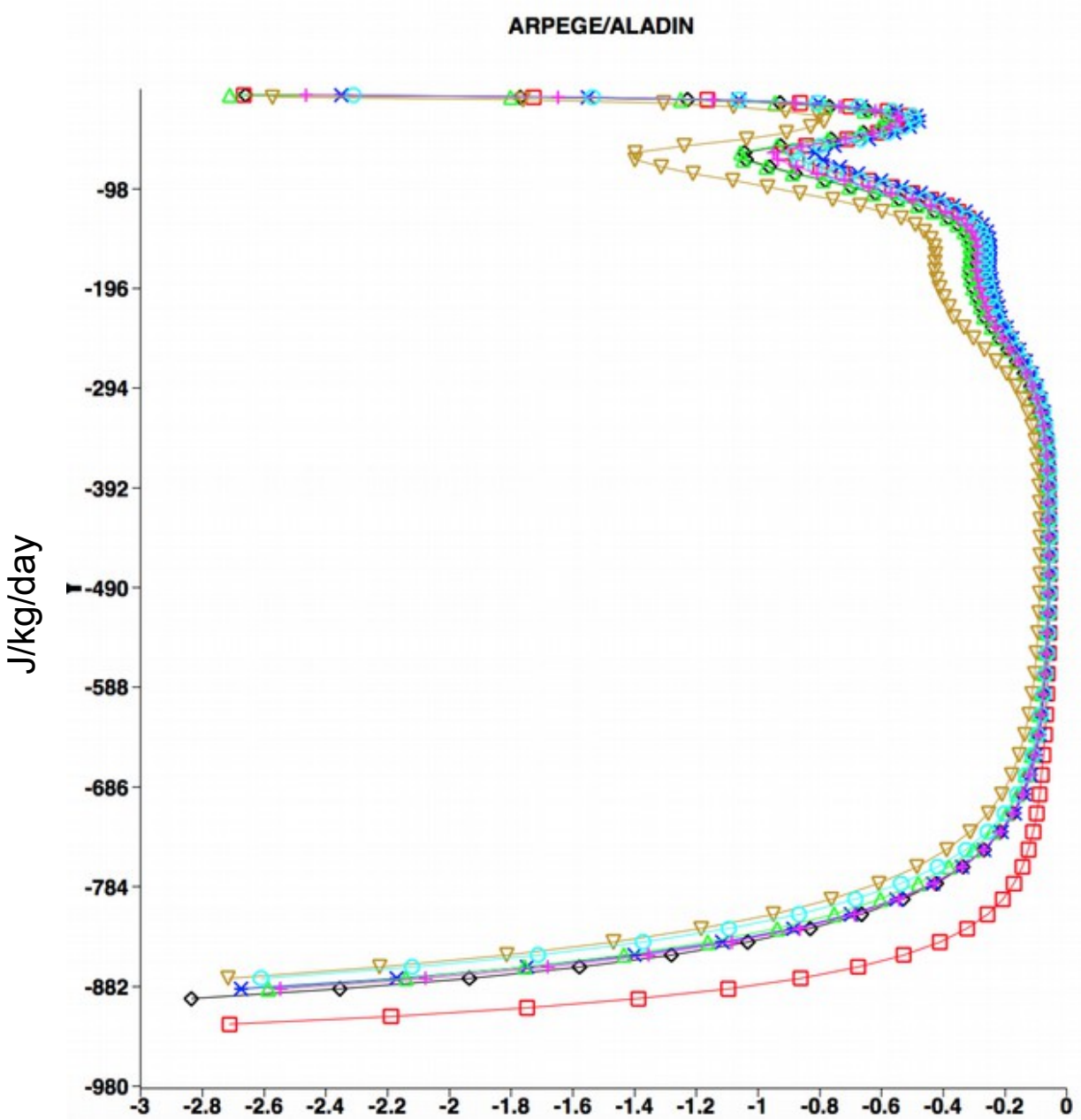
Tuning parameters in SSO scheme (gravity waves, blocking, lift, etc.)

	PNT	CLIMAT
FACTOR FOR THE ST. DEV. OF OROG. FOR G.W.D. "WALL" (“HOBST”)	3.0	3.5
ASPECT RATIO TYPE COEFF. AT THE SURF. FOR THE G.W.D. (“GWDSE”)	0.0035	0.003-0.006
INVERSE CRITICAL HEIGHT FOR THE G.W.D. (“GWDBC”)	2.0	2.0
DRAG COEFFICIENT FOR FOR THE LOW LEVEL G.W.D. (“GWDCD”)	5.4	5.4
VALLEYS DECOUPLING COEFF. FOR THE G.W.D. (“GWDVALI”)	0.5	0.5
MOUNTAIN SHAPE COEFF. FOR THE G.W.D. (“GWDPROF”)	1.0	1.0
RESONNANCE COEFFICIENT FOR THE G.W.D. (“GWDAMP”)	0.6	0.6
SURFACE LIFT COEFF. FOR THE G.W.D. (“GWDLT”)	0.0	1.0

Global tendency on Kinetic Energy due to SSO scheme (Jan 16)



Global tendency on Kinetic Energy due to SSO scheme (Jan 16)



Sensitivity tests modifying tuning parameters :

- GWDLT=1
- GWDCD=9
- GWDSE=0.008
- GWDPROF=0
- GWDVALI=0
- HOBST=2
- REF (oper)

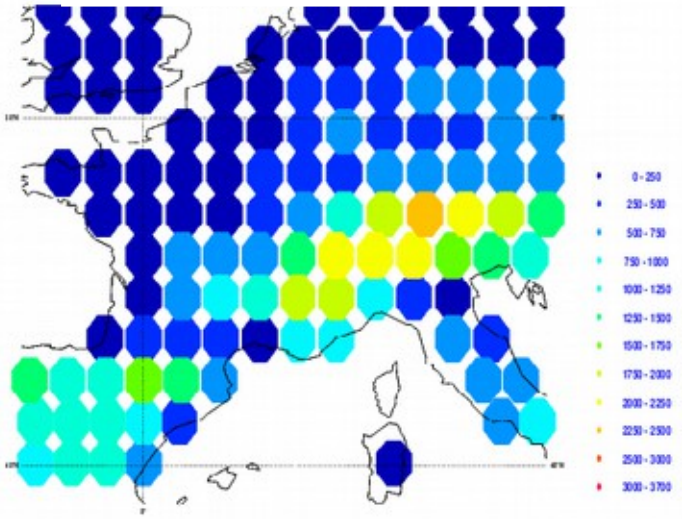
Dependency to horizontal resolution

ARPEGE global forecasts with operational physics done on January 2016, initialized from operational analysis, using stretching capability. Comparison of simulations spatially over Western Europe and averaged horizontally over a rectangular domain centered over the Alps :

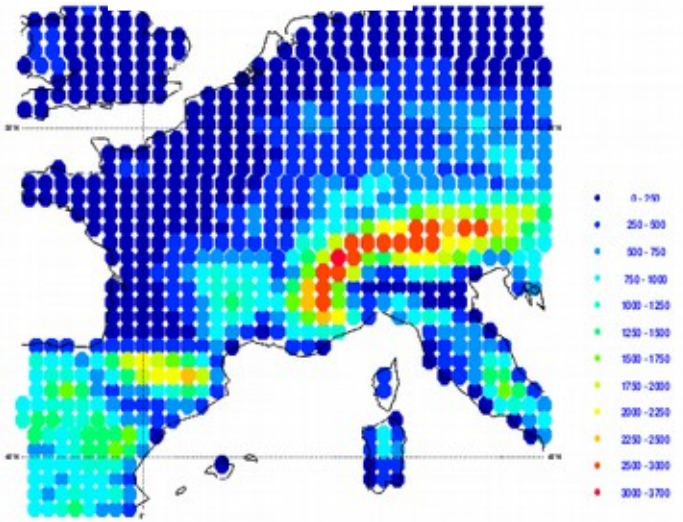
- T149c1L105 (~135 km)
- T399c1L105 (~ 50 km)
- T1199c1L105 (~ 16 km)
- T1198c2.2L105 (~ 7.5 km)
- T1198c8L105 (~ 2 km) - *turning off SSO scheme*

Mean orography

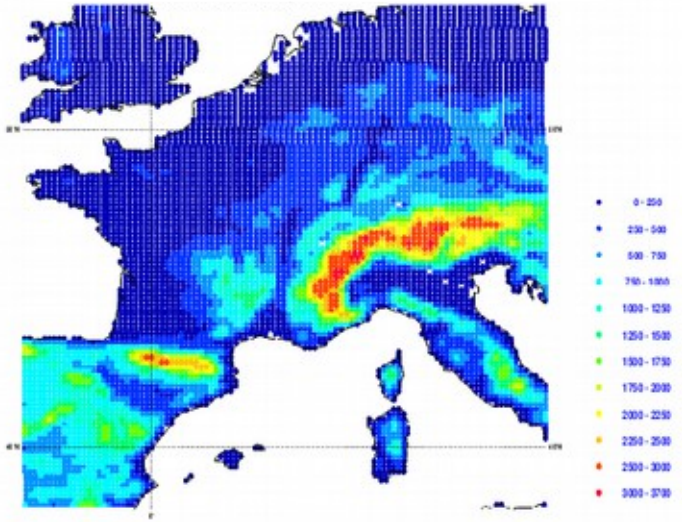
T149c1L105 (~135 km)



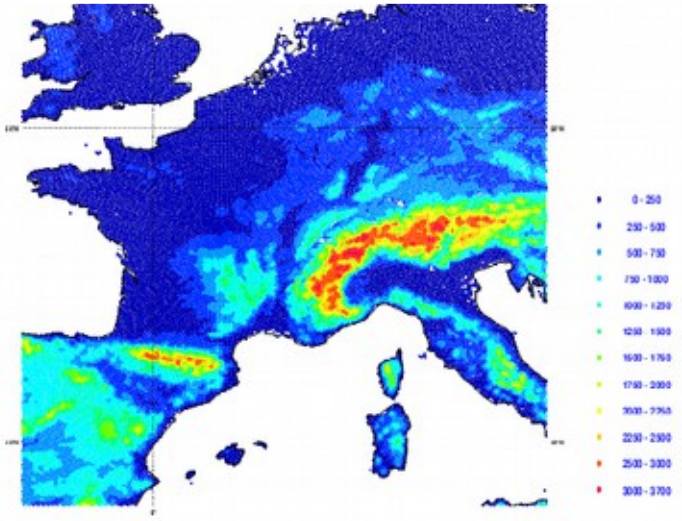
T399c1L105 (~50 km)



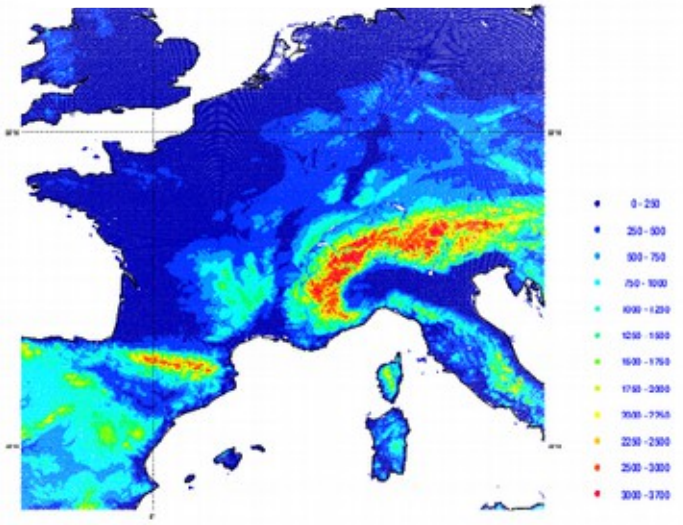
T1199c1L105 (~ 16 km)



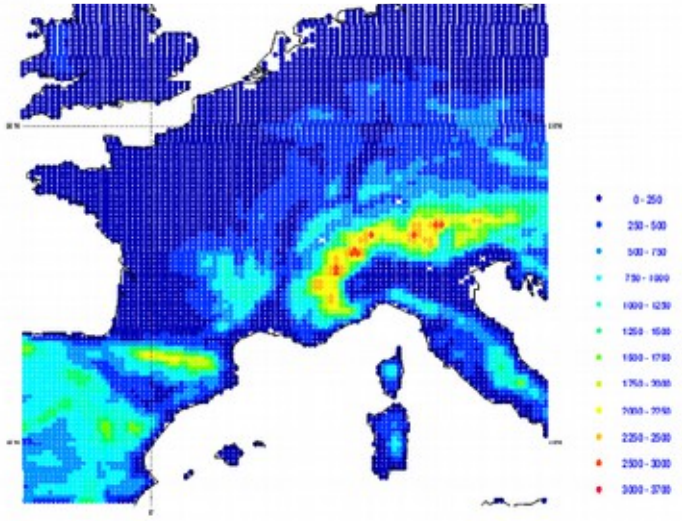
T1198c2.2L105 (~ 7.5 km)



T1198c8L105 (~2km)

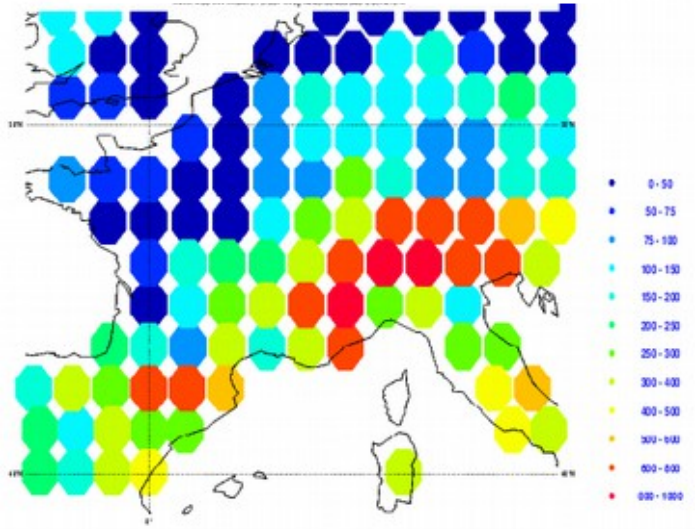


T1199c1L105NE (~ 16 km)

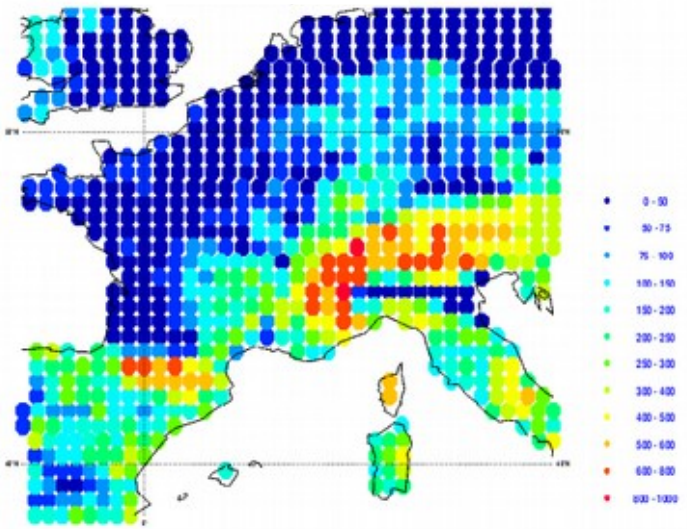


Standard deviation of orography

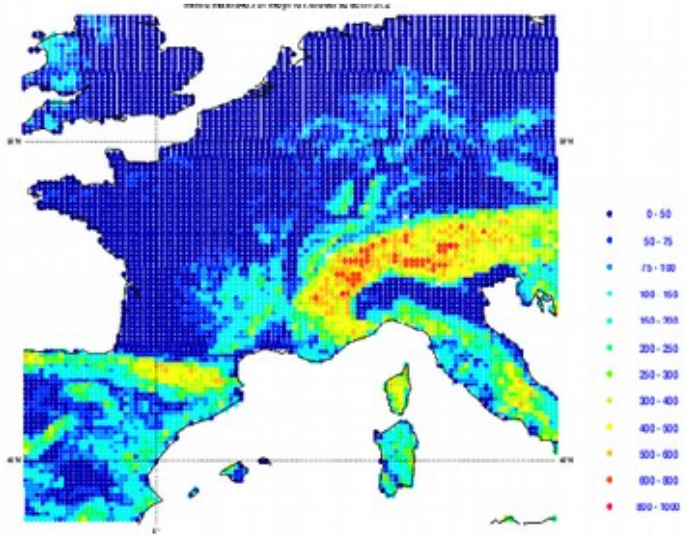
T149c1L105 (~135 km)



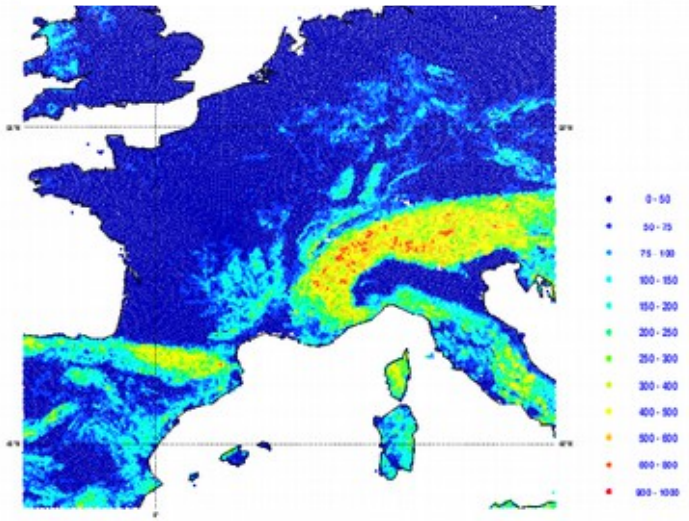
T399c1L105 (~50 km)



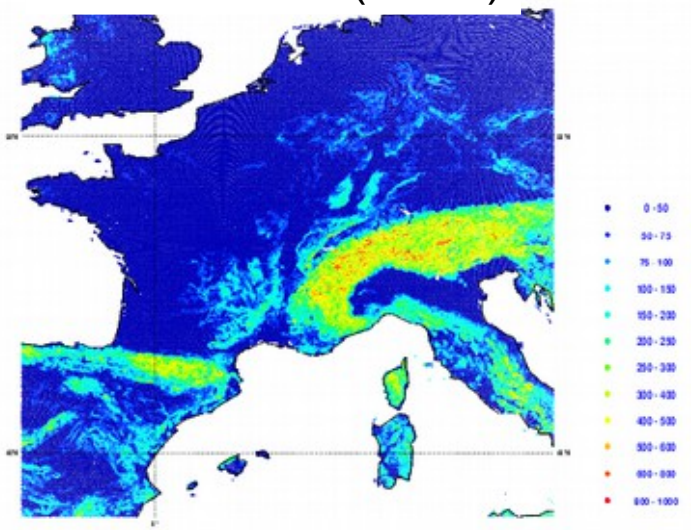
T1199c1L105 (~ 16 km)



T1198c2.2L105 (~ 7.5 km)

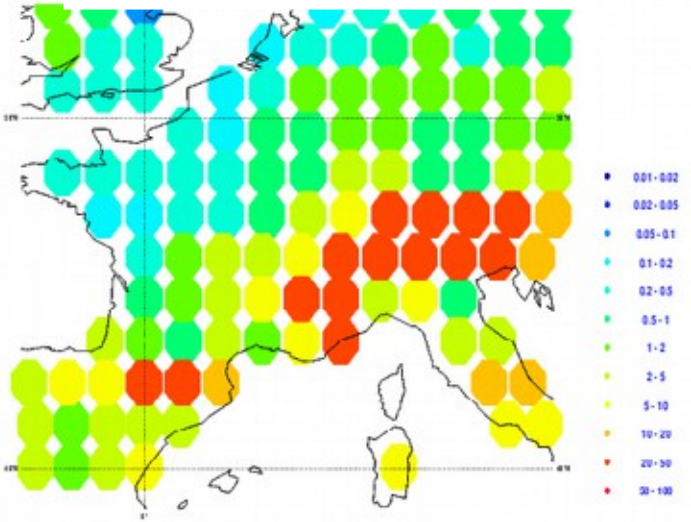


T1198c8L105 (~2km)

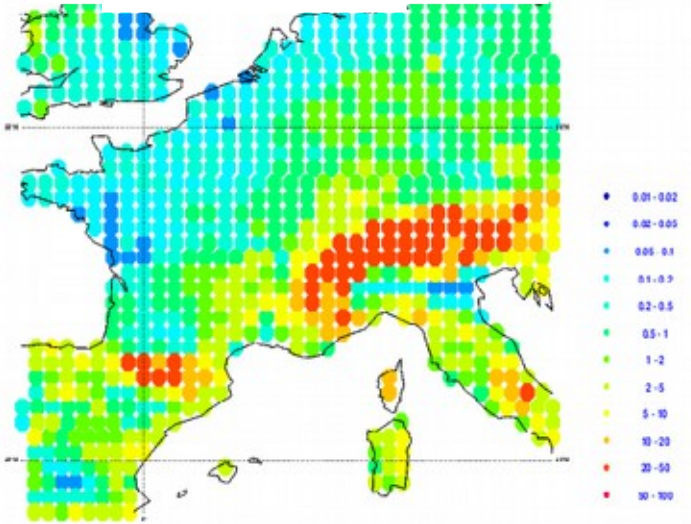


Dynamical roughness length

T149c1L105 (~135 km)



T399c1L105 (~50 km)



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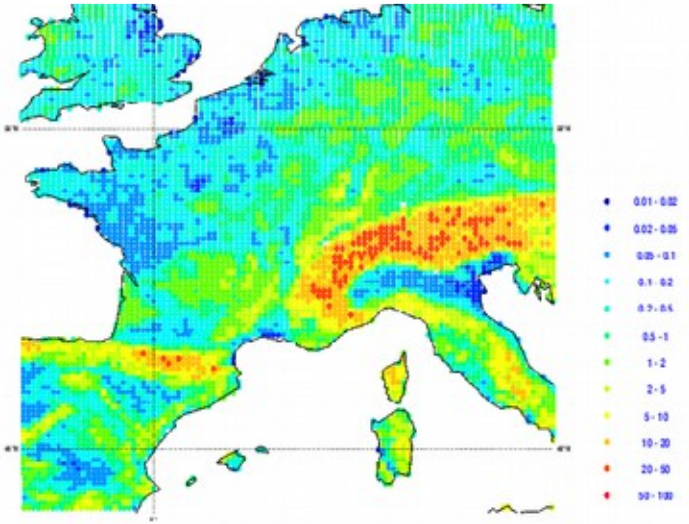
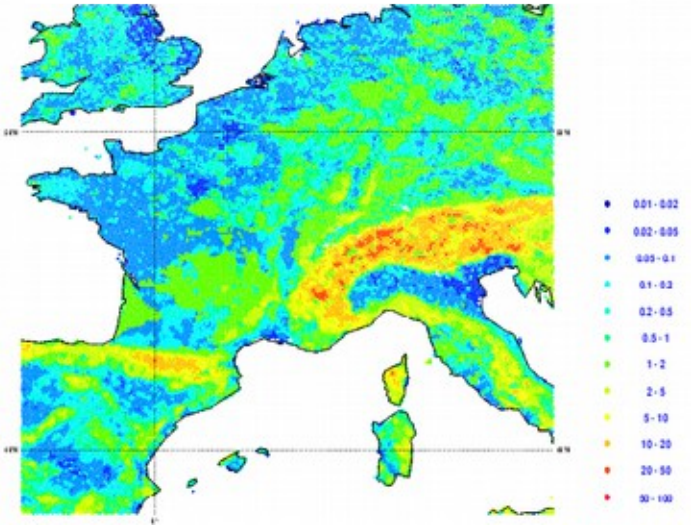
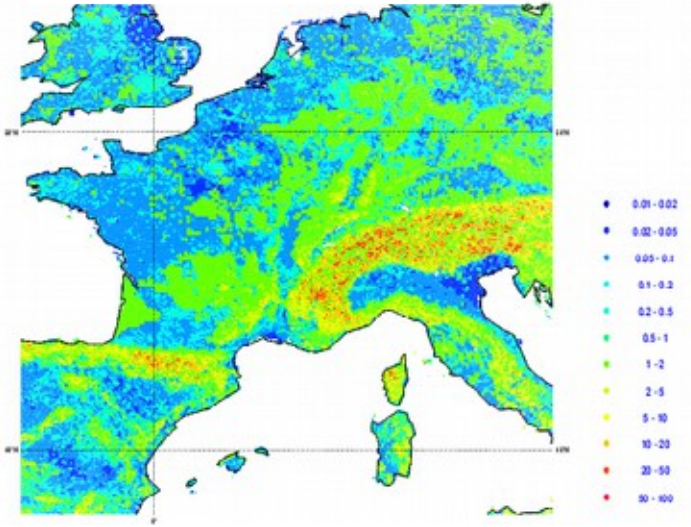


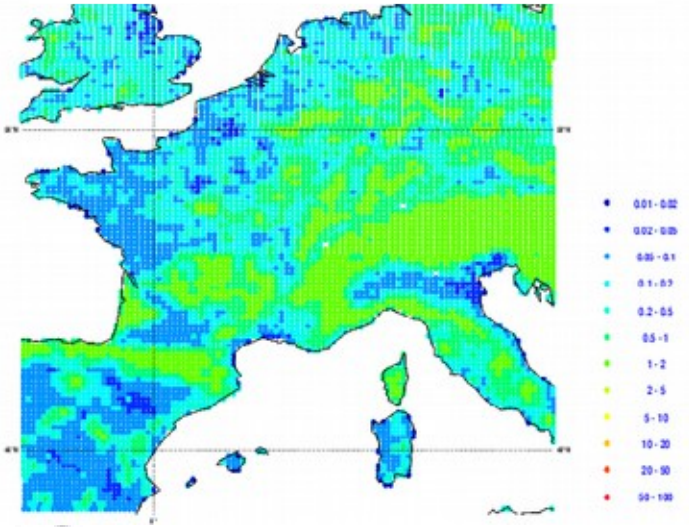
T1198c2.2L105 (~ 7.5 km)



T1198c8L105 (~2km)

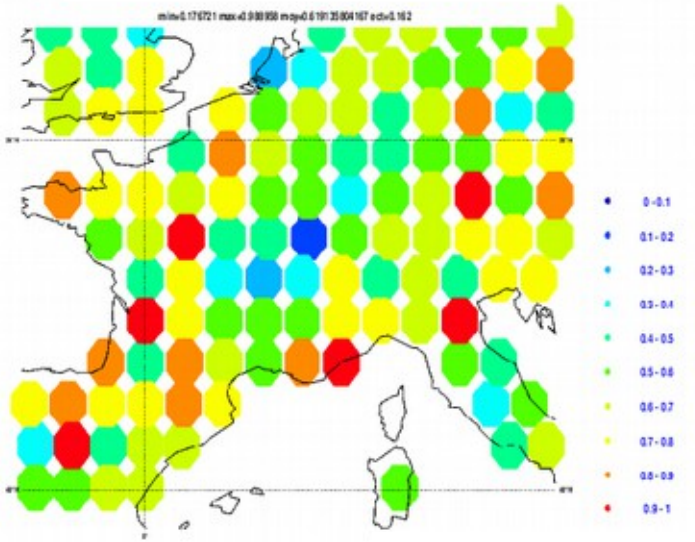


T1199c1L105NF (~ 16 km)

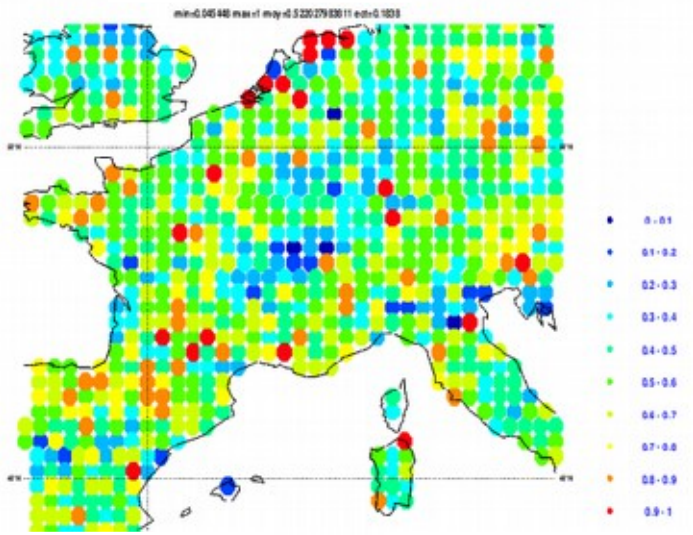


Anisotropy

T149c1L105 (~135 km)



T399c1L105 (~50 km)



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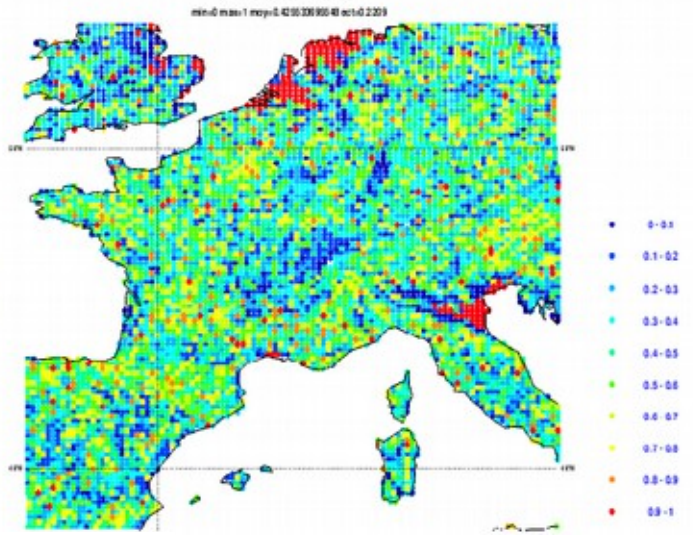
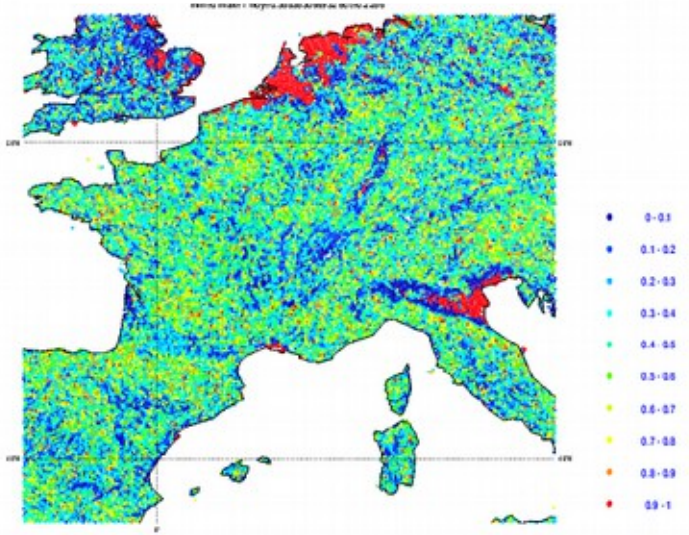
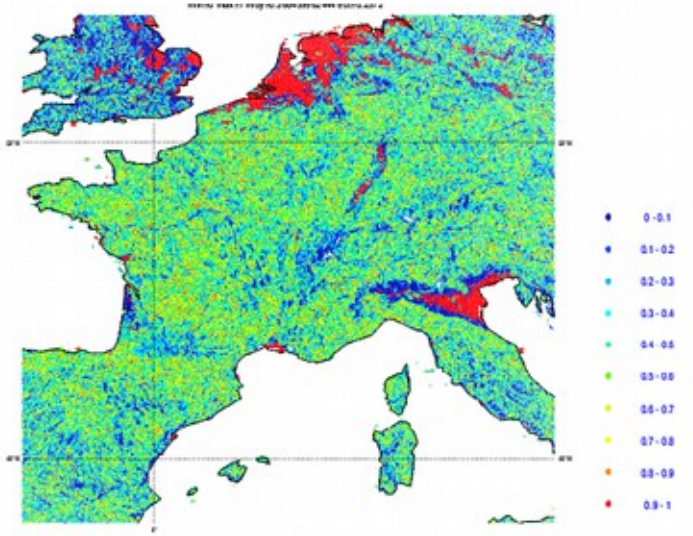


T1198c2.2L105 (~ 7.5 km)

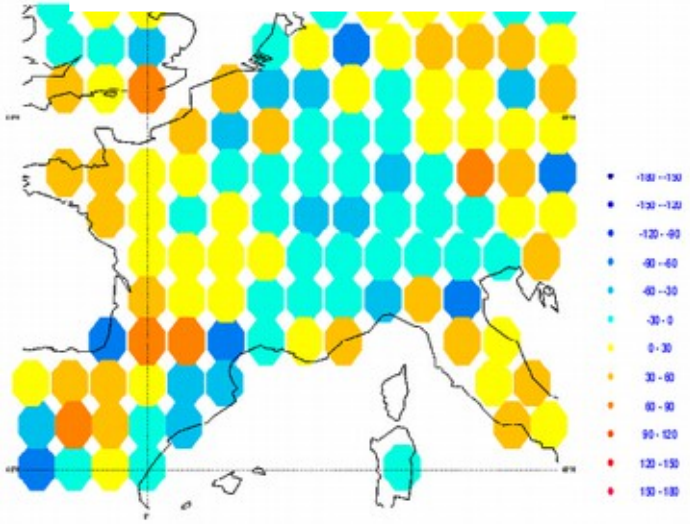


T1198c8L105 (~2km)

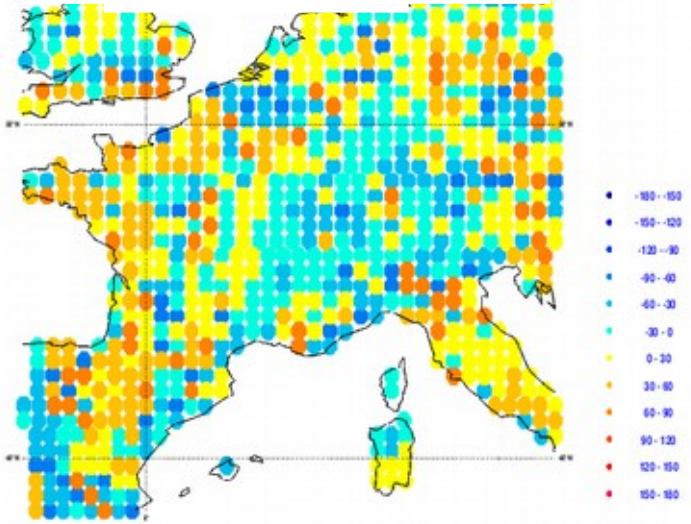


Directionality

T149c1L105 (~135 km)



T399c1L105 (~50 km)



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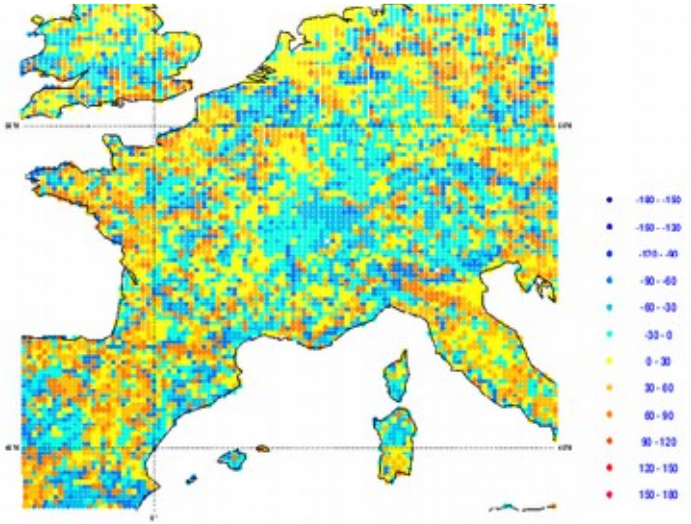
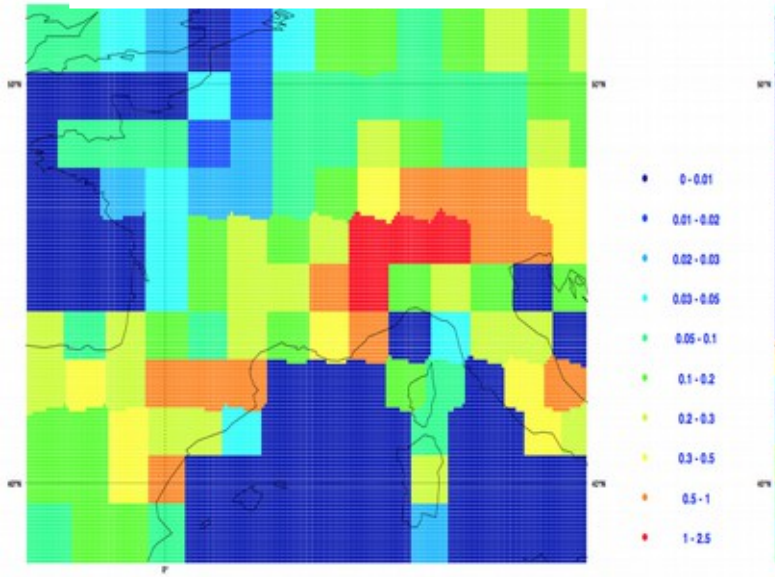
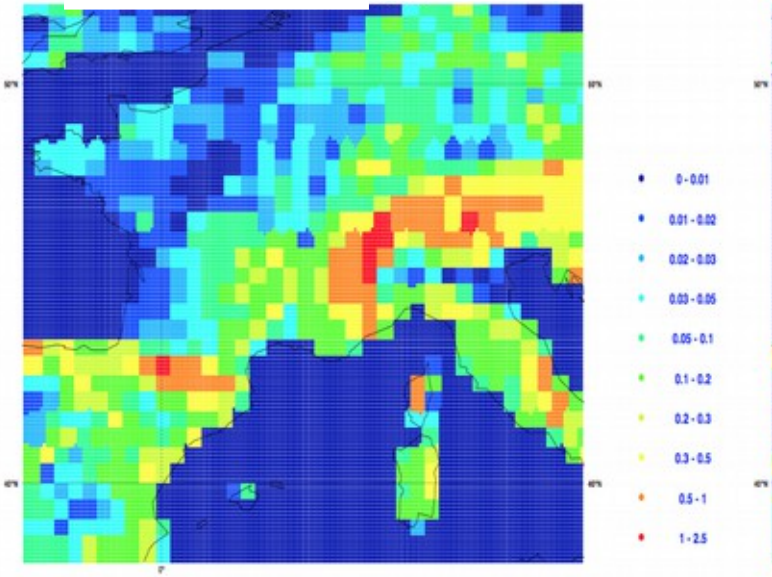


SSO surface drag

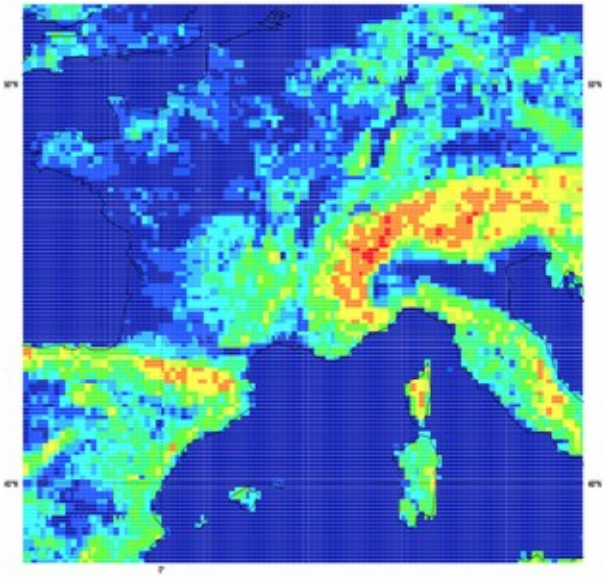
T149c1L105 (~135 km)



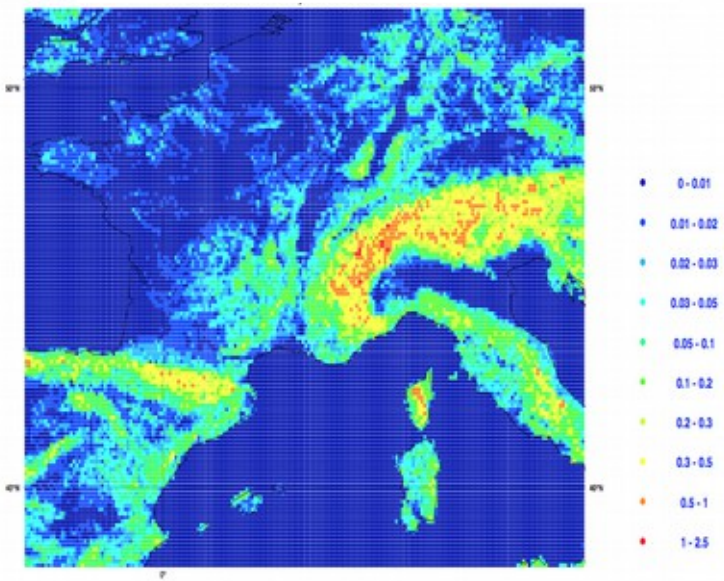
T399c1L105 (~50 km)



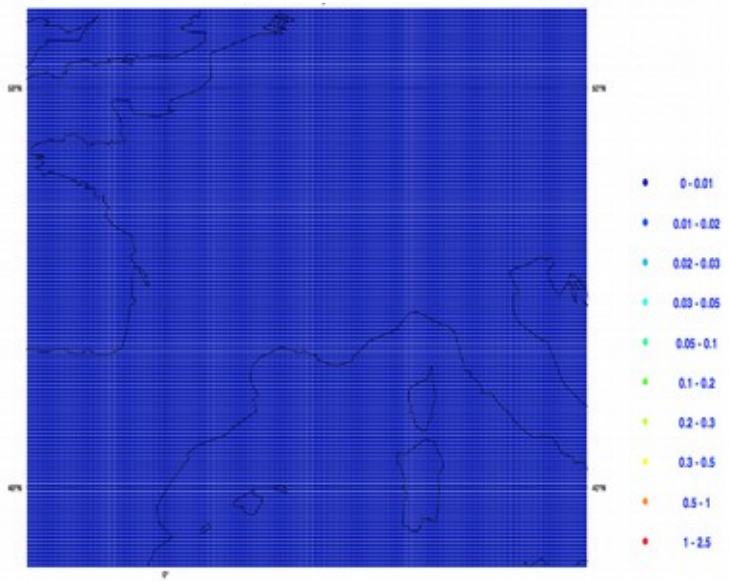
T1199c1L105 (~ 16 km)



T1198c2.2L105 (~ 7.5 km)

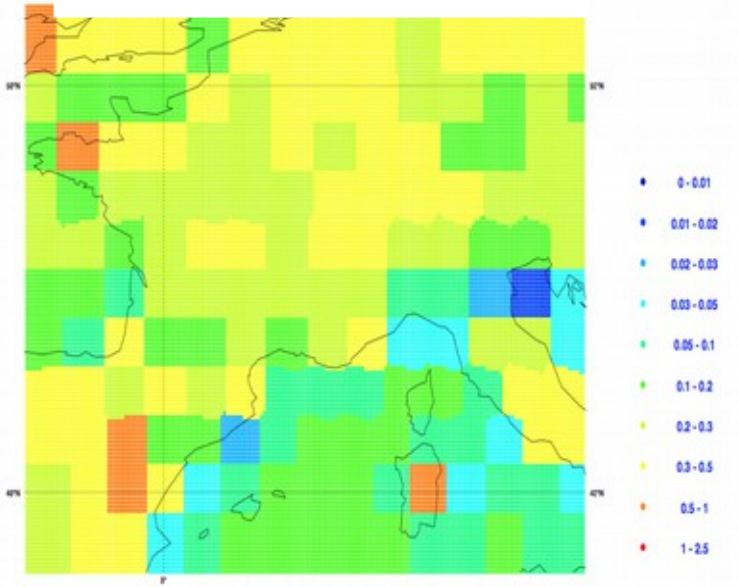


T1198c8L105 (~2km)

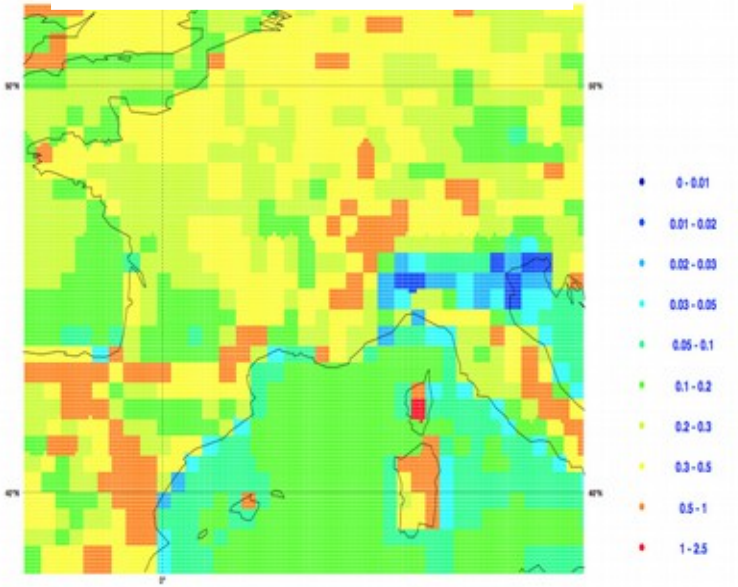


Sub-grid turbulence surface drag

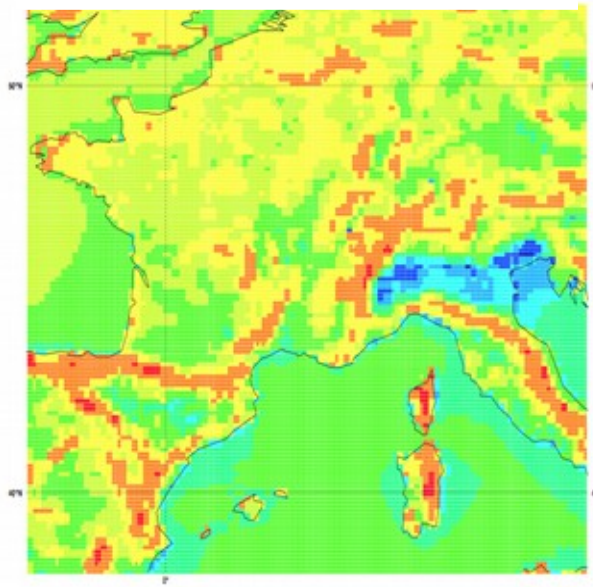
T149c1L105 (~135 km)



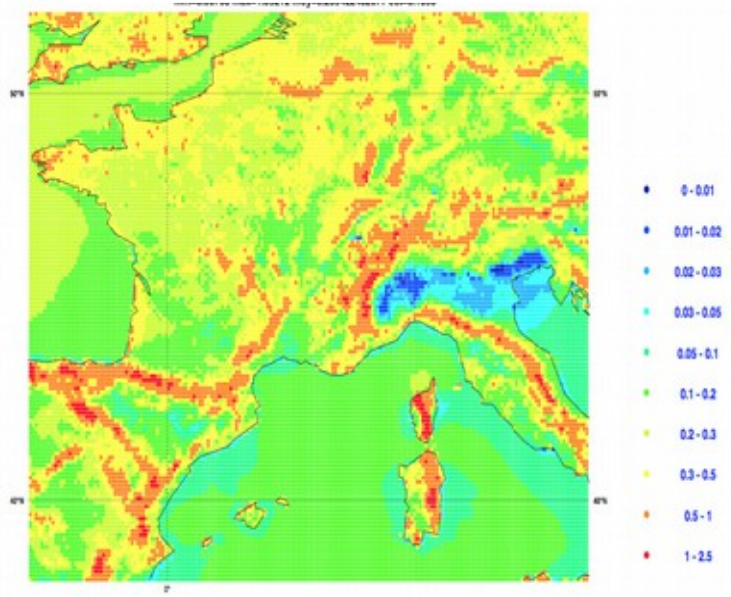
T399c1L105 (~50 km)



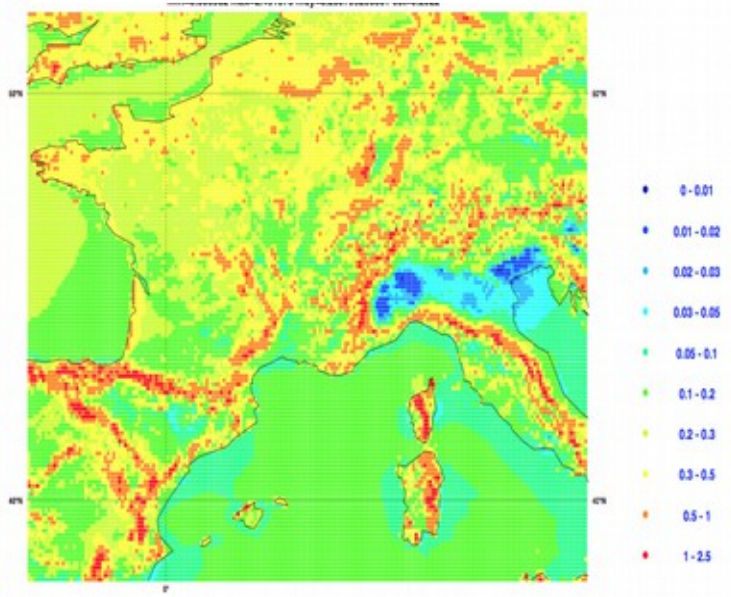
T1199c1L105 (~ 16 km)



T1198c2.2L105 (~ 7.5 km)

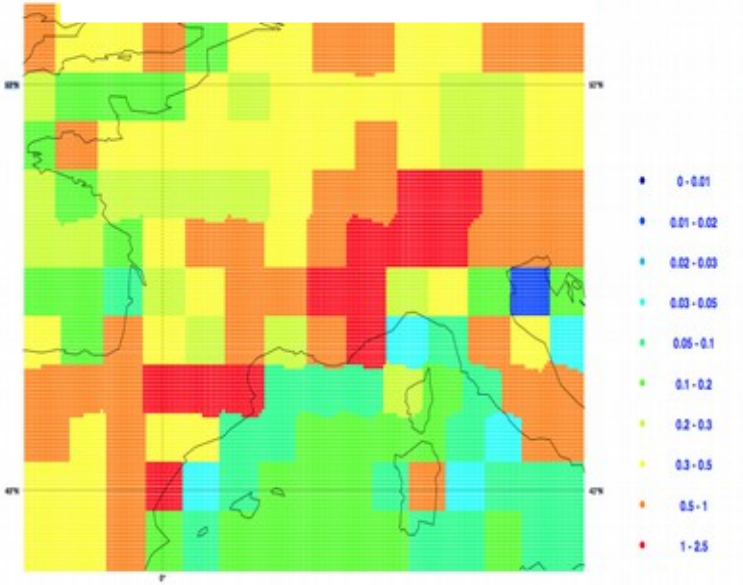


T1198c8L105 (~2km)

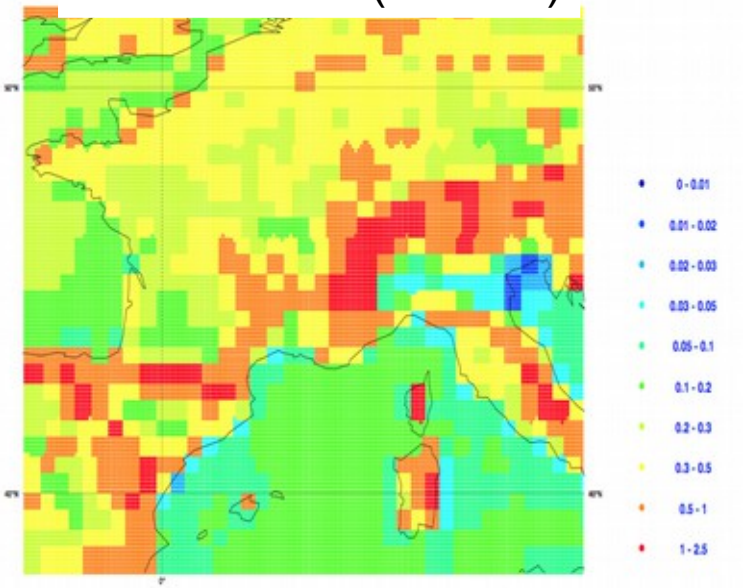


Total parameterized surface drag

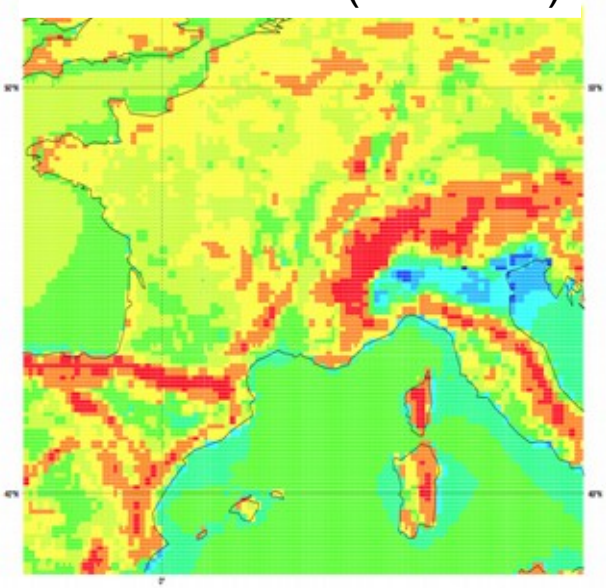
T149c1L105 (~135 km)



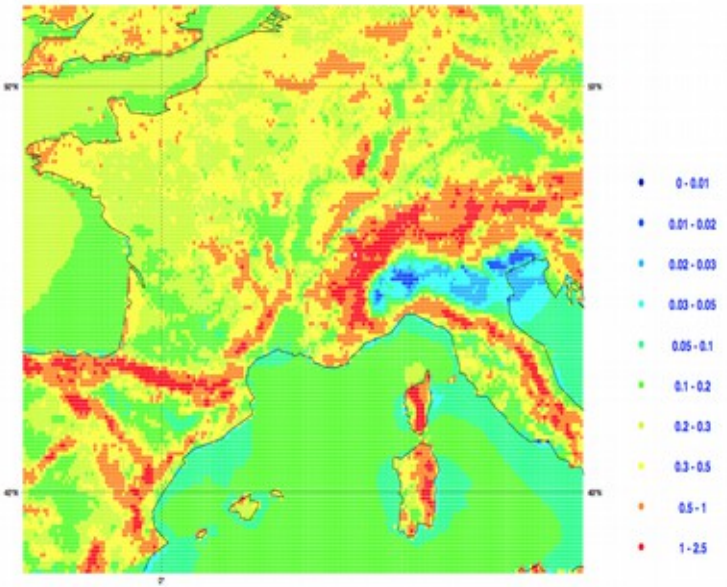
T399c1L105 (~50 km)



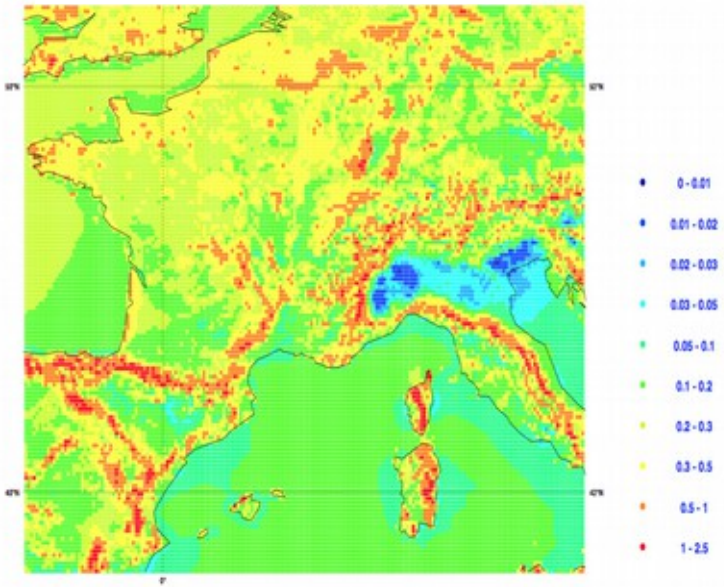
T1199c1L105 (~ 16 km)



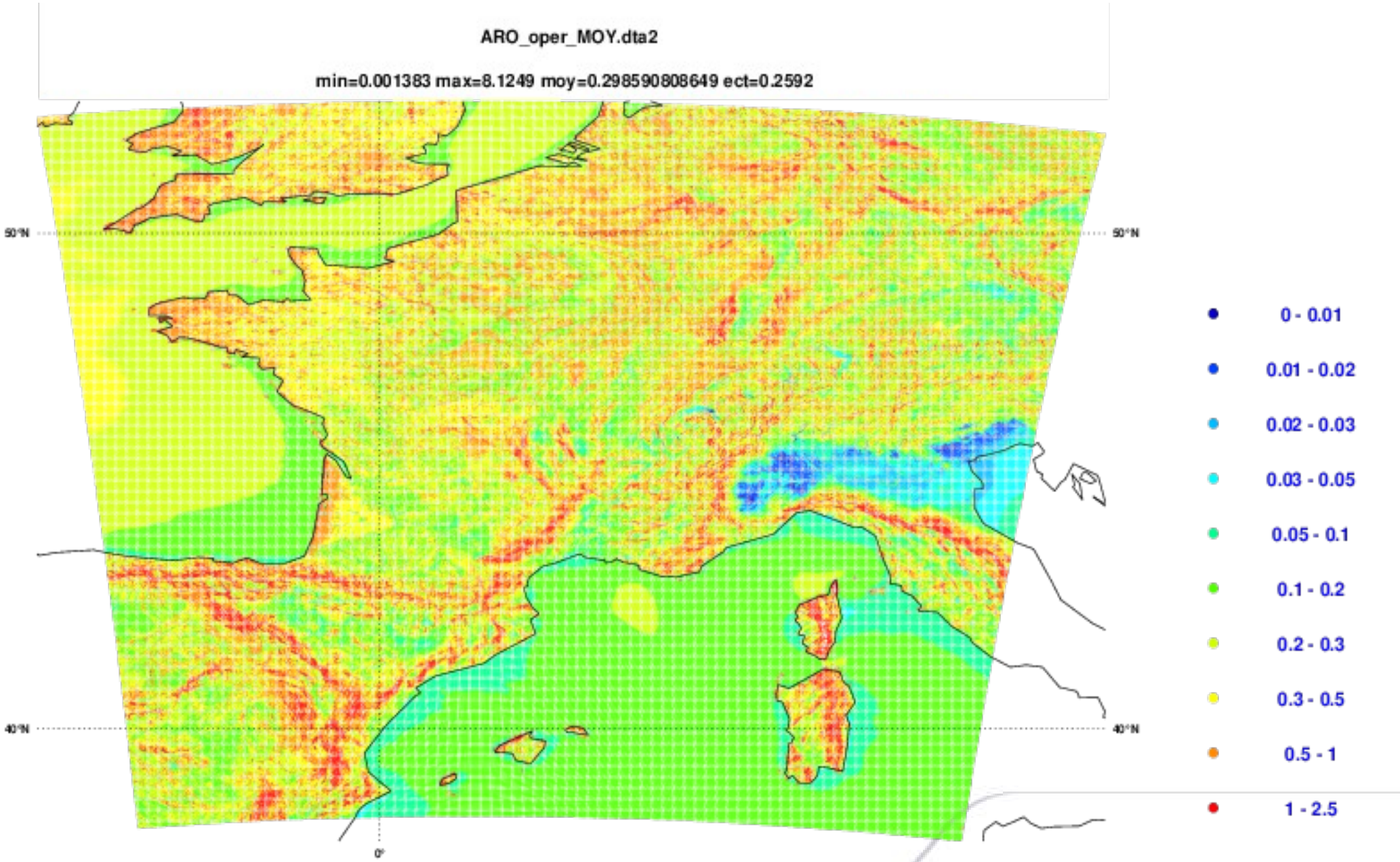
T1198c2.2L105 (~ 7.5 km)



T1198c8L105 (~2km)

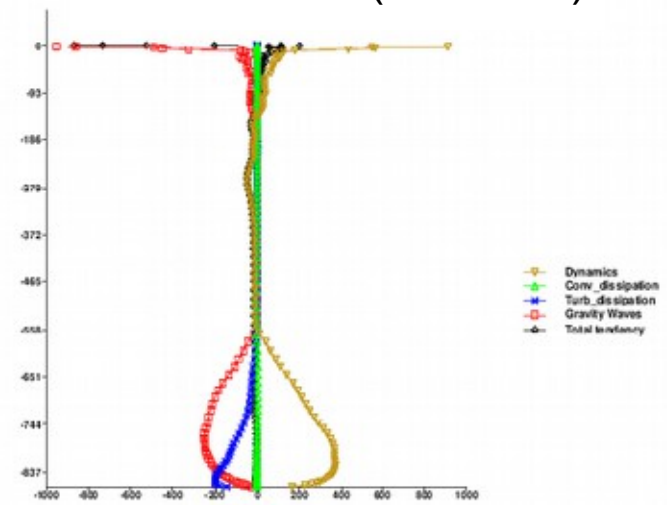


Surface turbulent drag in Arome-France (1.3km)

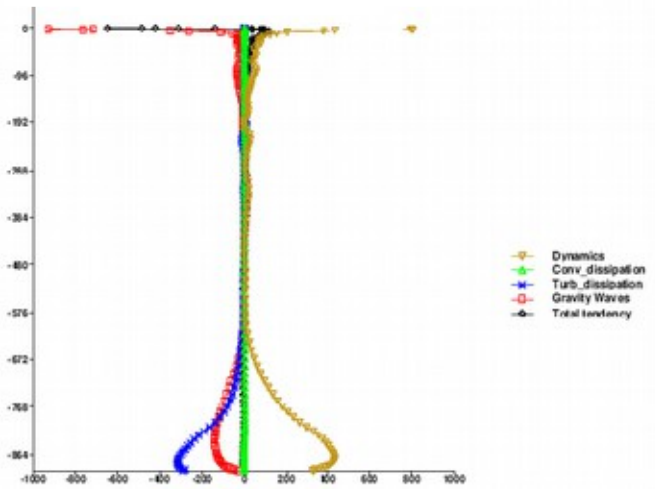


Kinetic energy budget over "Alps domain"

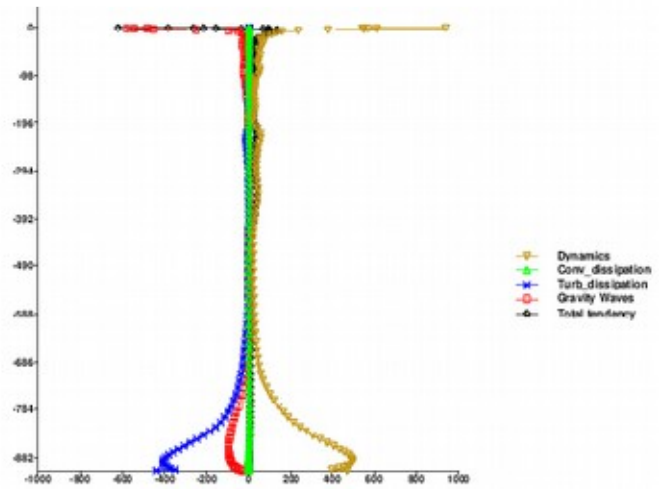
T149c1L105 (~135 km)



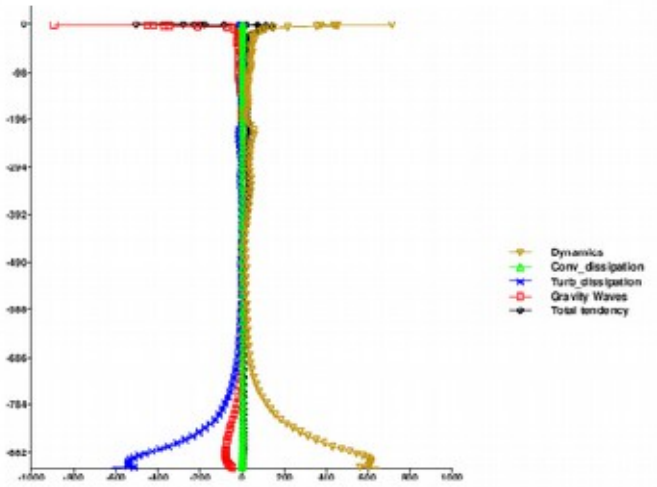
T399c1L105 (~50 km)



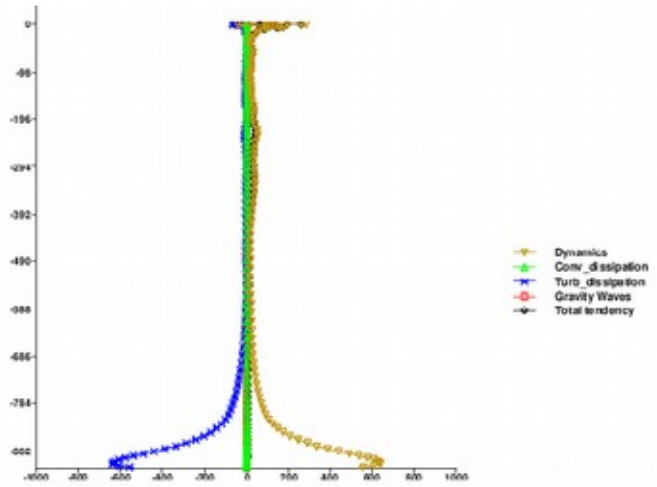
T1199c1L105 (~ 16 km)



T1198c2.2L105 (~ 7.5 km)



T1198c8L105 (~2km)



Conclusions

- Sub-grid orography effects are important to parameterize in NWP and climate models at current resolutions
- Difficult to constrain SSO and turbulence parameterizations (compensating errors, several parameters to tune)
- Still struggling to remove enhanced orography in global NWP Arpege model. Automating tuning ? Improving blocking and/or lift parameterizations ?
- Wish to continue investigations using high resolution simulations for improving SSO scheme in global models. What is the best methodology ?