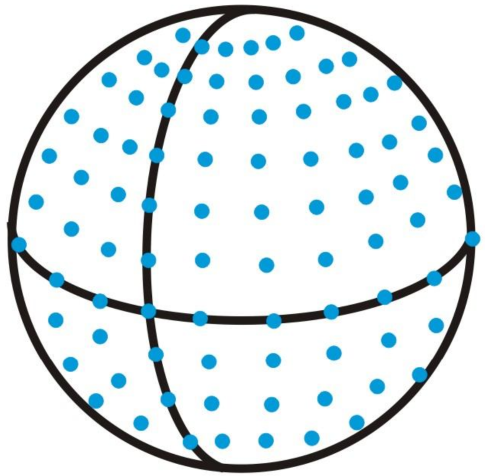
ABL - Current Problems & Advancements

Is the **warm bias** in regional climate simulations influenced by the **PBL** parameterization?

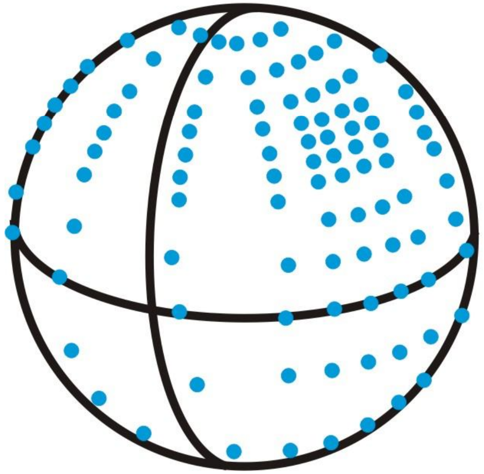
Ivan Güttler,
Zagreb, 25. 2. 2010.

Dynamical downscaling: a broader look

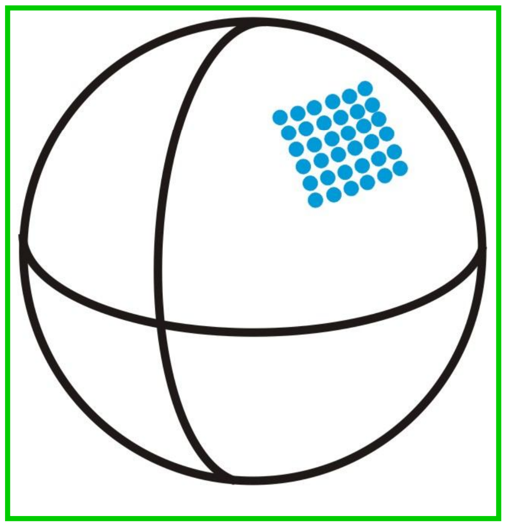
GCM



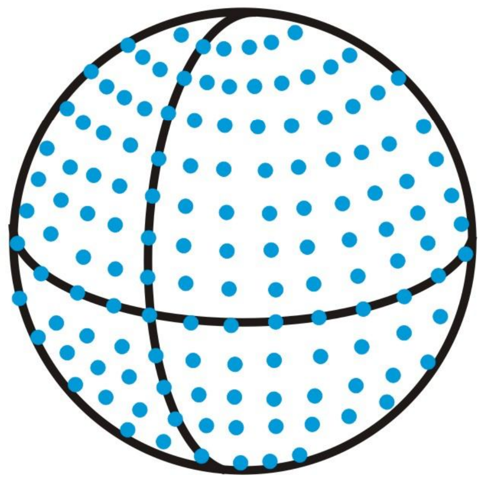
GCM: a changing spatial step



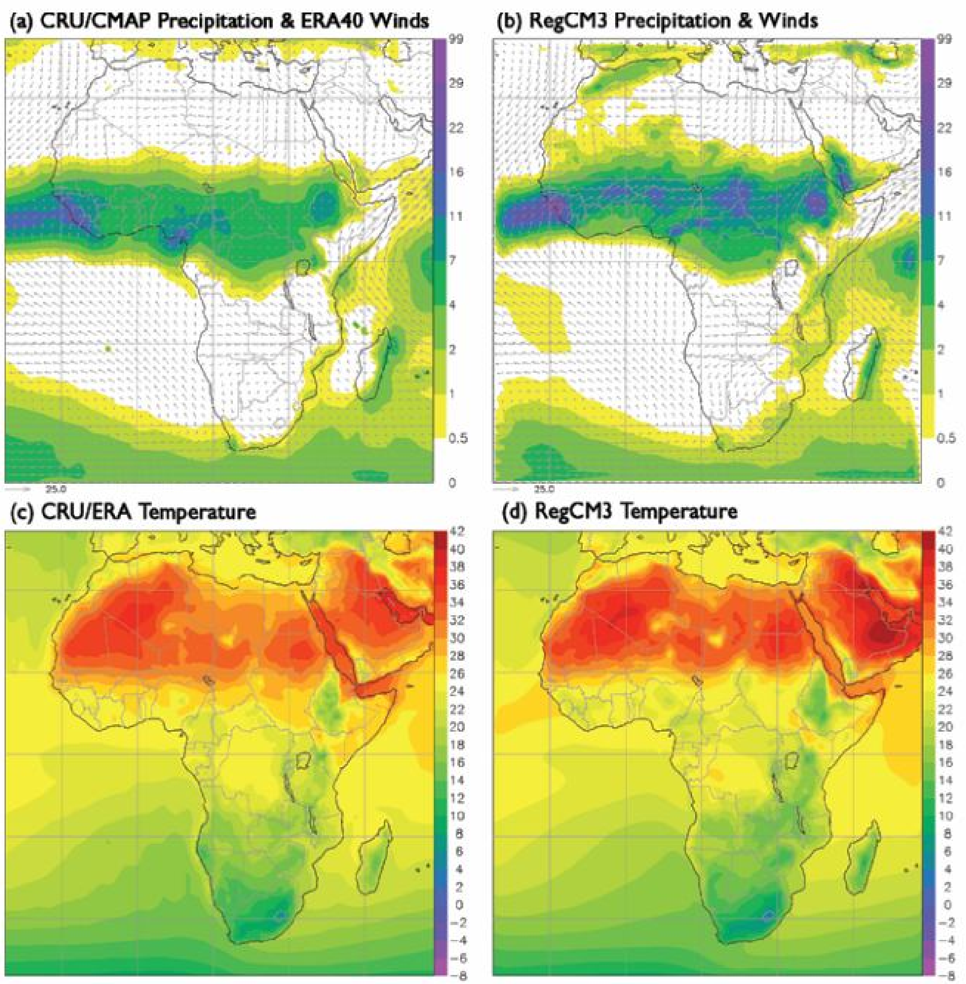
RCM



GCM: a smaller spatial step



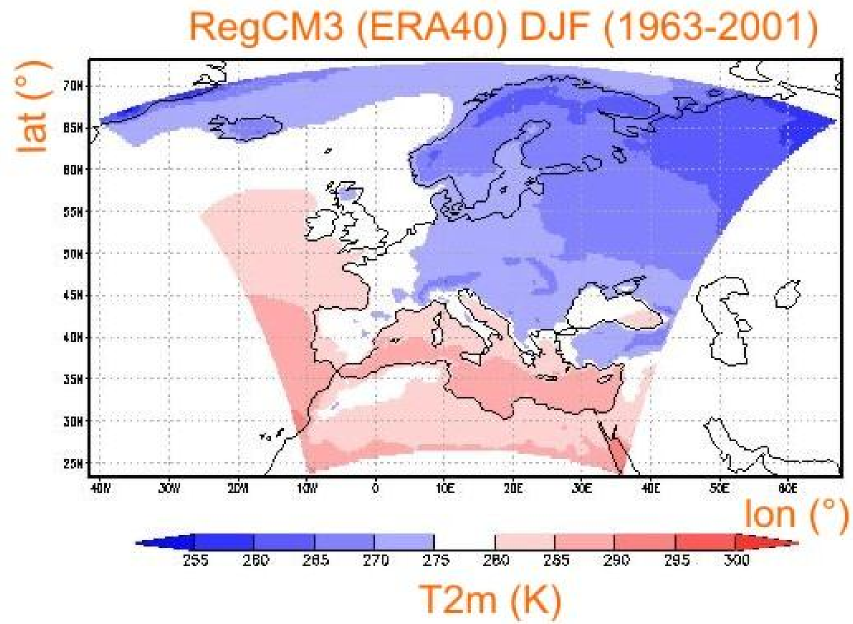
Which RCM? RegCM3

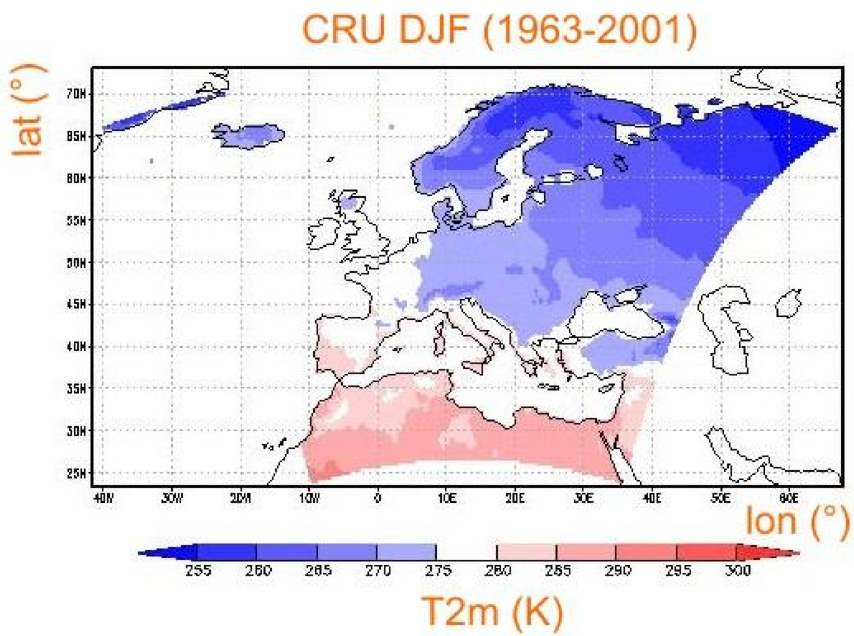


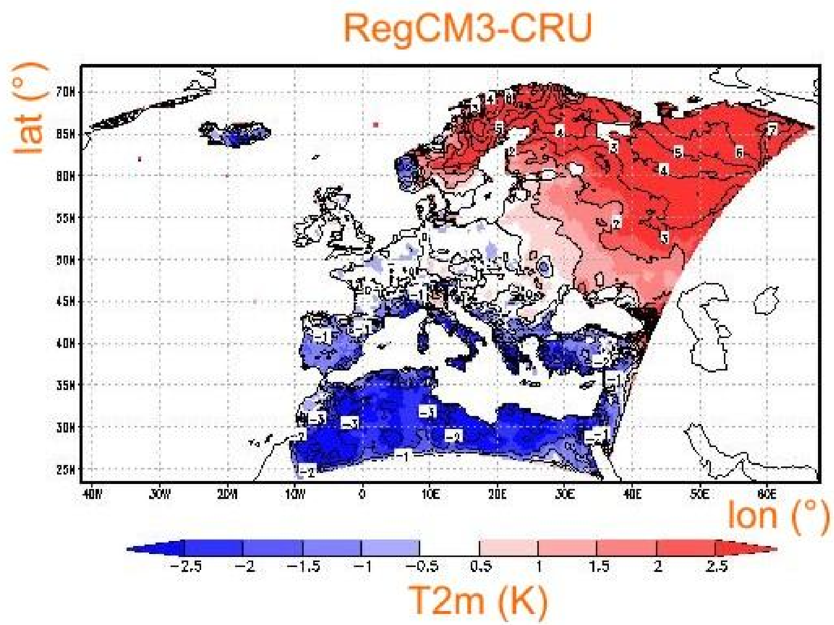
Dynamics	MM5 (hydrostatic) Grell et al. (1994)
Radiative transfer	CCM3 Kiehl et al. (1996)
Boundary layer	Nonlocal, counter gradient Holtslag et al. (1990)
Land surface	SUBBATS Giorgi et al. (2003)
Convective precipitation	MIT (Emanuel 1991) Anthes-Kuo, Grell (1993)
Resolvable precipitation	SUBEX Pal et al. (2000)
Aerosols and chemistry	Solmon et al. (2006) Zakey et al. (2006)

adapted from Pal et al., 2007, *Bull. Amer. Meteor. Soc.*

A challenge: The Warm Bias in RegCM3







... similar for only one year and RegCM3 (ERA Interim).

RegCM3 PBL scheme: a broader look

Local

$$\overline{u'w'} = -K_m \frac{\partial u}{\partial z}$$
$$\overline{w'\theta'} = -K_h \frac{\partial \theta}{\partial z}$$

First-order

$$K_m = l_m^2 \frac{\partial U}{\partial z} f_m(Ri)$$
$$K_h = l_m l_h \frac{\partial U}{\partial z} f_h(Ri)$$

Higher-order

$$K_m = c_m \sqrt{e}\, l_m f_m(Ri)$$
$$K_h = c_h \sqrt{e}\, l_h f_h(Ri)$$
$$\frac{\partial e}{\partial t} = -\overline{u'w'}\frac{\partial u}{\partial z} - \overline{v'w'}\frac{\partial v}{\partial z} \cdots + \frac{g}{\theta_{ref}}\overline{w'\theta'} - \frac{\partial \overline{w'e}}{\partial z} - \epsilon$$

Nonlocal

$$\overline{u'w'} = -K_m \frac{\partial u}{\partial z}$$
$$\overline{w'\theta'} = -K_h \left(\frac{\partial \theta}{\partial z} - \gamma_\theta\right)$$

$$K_m = k w_t z \left(1 - \frac{z}{h}\right)^2$$
$$K_h = K_m$$
$$\gamma_\theta = C \frac{\overline{w\theta_0}}{w_t h}$$

adapted from Holtstag et al., 1990. , *Mon. Wea. Rev.* and Cuxart et al., 2006. , *Boundary-Layer Meteorol.*

K(z) above PBL: Blackadar scheme

$$Ri = \frac{g}{\theta(\sigma_1)} \frac{\Delta\theta / \Delta z_\sigma}{(\Delta u / \Delta z_\sigma)^2 + (\Delta v / \Delta z_\sigma)^2}$$

$$Ri_c = A \left(\Delta z_{\sigma/2}\right)^B, \; A = 0.257, \; B = 0.175$$

$$K_m = K_h = K_q = K$$

$Ri < Ri_c$

$$K(z) = 1 \text{ m}^2\text{s}^{-1} + \left[\sqrt{\left(\frac{\Delta u}{\Delta z_\sigma}\right)^2 + \left(\frac{\Delta v}{\Delta z_\sigma}\right)^2} + \epsilon \right] (Ri_c - Ri) \left(1600 \text{ m}^2\right)$$

$Ri \geq Ri_c$

$$K(z) = 1 \text{ m}^2\text{s}^{-1}$$

$\propto l^2$

$K(z)$ inside PBL: Holtslag scheme

$$Ri_B = \frac{g}{\theta} \frac{\Delta\theta\Delta z}{(\Delta u)^2 + (\Delta v)^2} = \frac{gz(\sigma)}{\theta(10\text{ m})} \frac{[\theta - \theta(10\text{ m})]}{u^2 + v^2}$$

$$Ri_{BC} = 0.25$$

$$h = z \text{ when } Ri_B(z) = Ri_{BC}$$

$$Q_{VH} = Q_H + 0.61 \cdot \theta(\sigma_1) \cdot Q_q$$

$$K_m = k w_t z \left(1 - \frac{z}{h}\right)^2 \qquad L = -\frac{\theta(10\text{ m}) u_*^3}{gk\left(Q_{VH} + \epsilon\right)}$$

$Q_{VH} \leq 0$ stable and neutral conditions

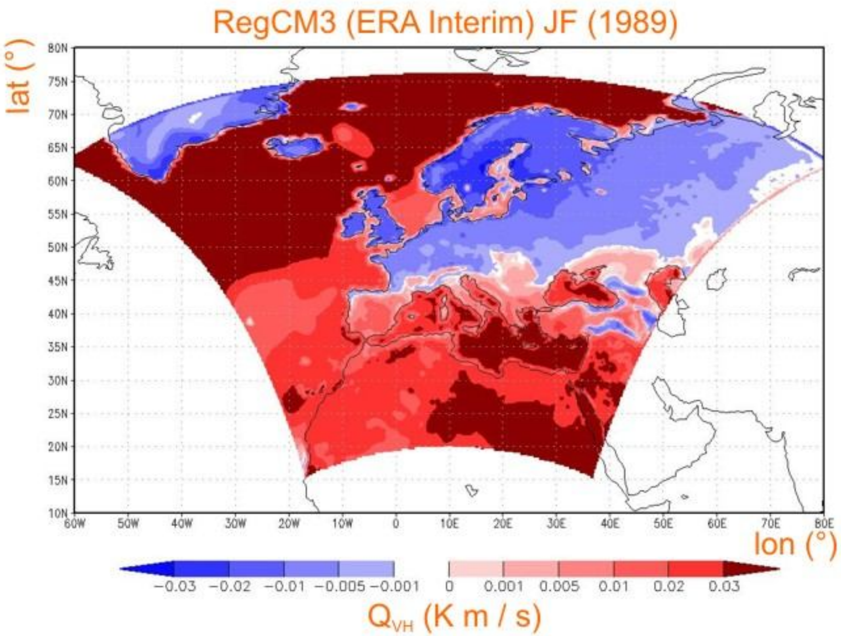
$$\frac{z}{L} \leq 1 \qquad w_t = u_* / \left(1 + 5\frac{z}{L}\right)$$

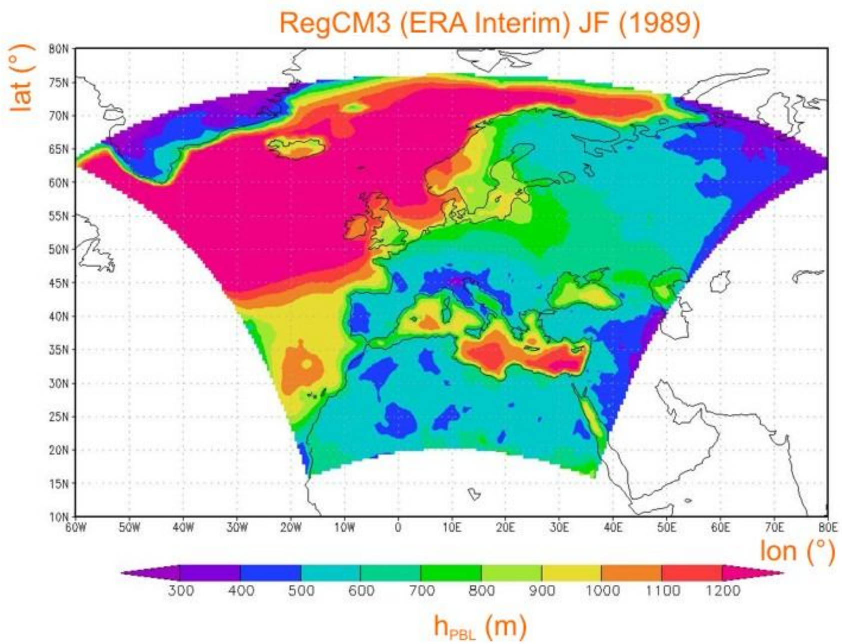
$$\frac{z}{L} > 1 \qquad w_t = u_* / \left(5 + \frac{z}{L}\right)$$

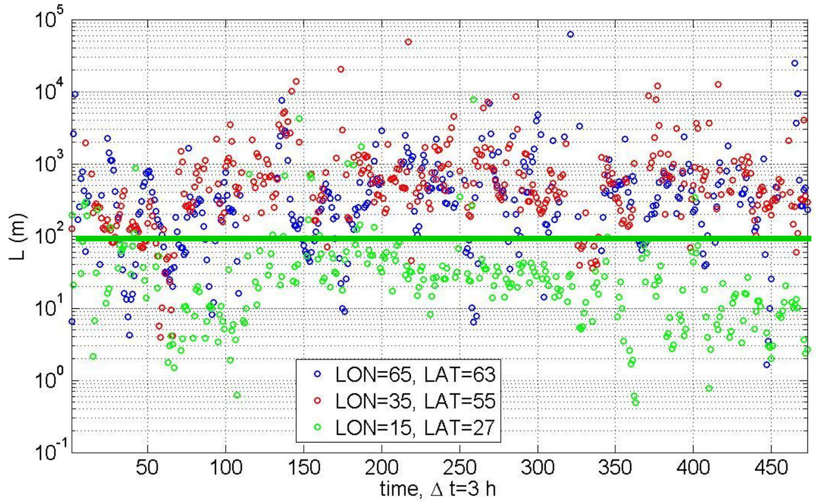
$Q_{VH} > 0$ unstable conditions

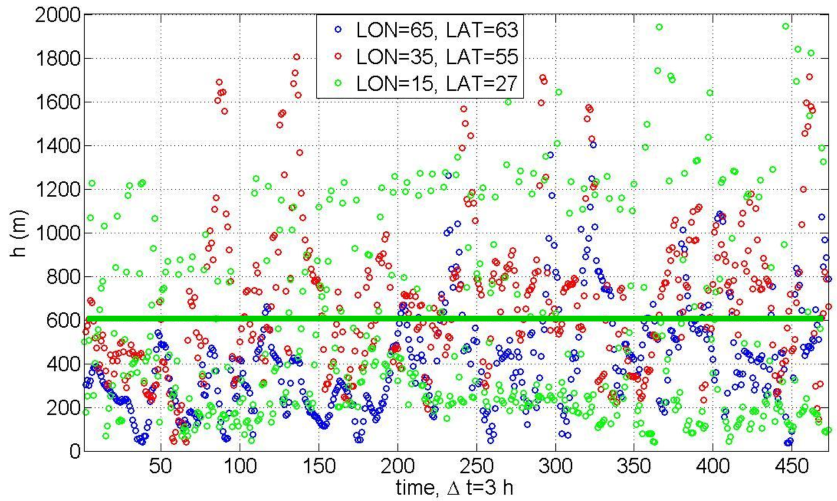
...

Default simulation: Q_{VH} and PBL height fields

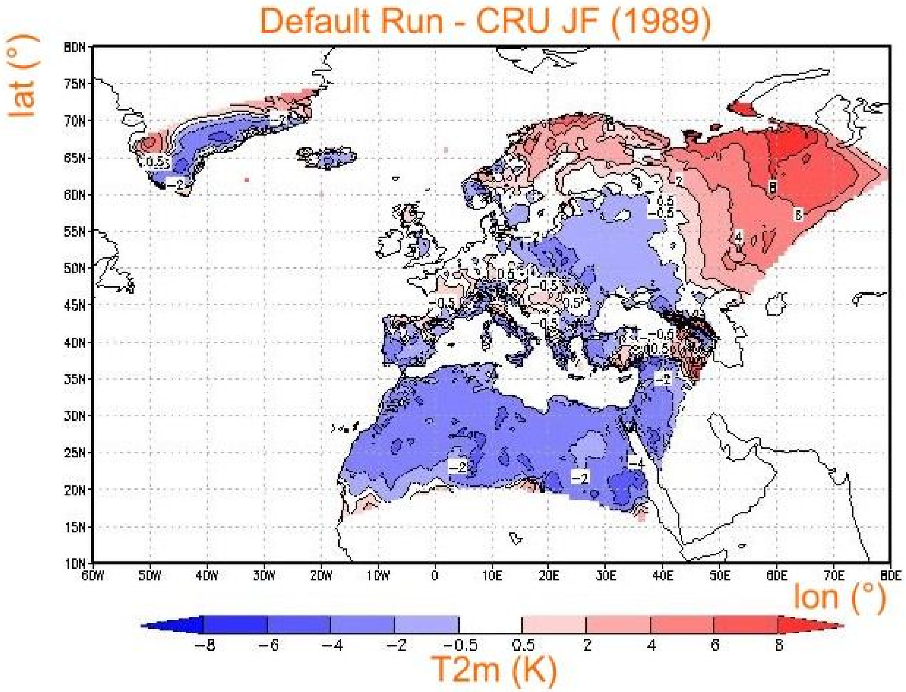






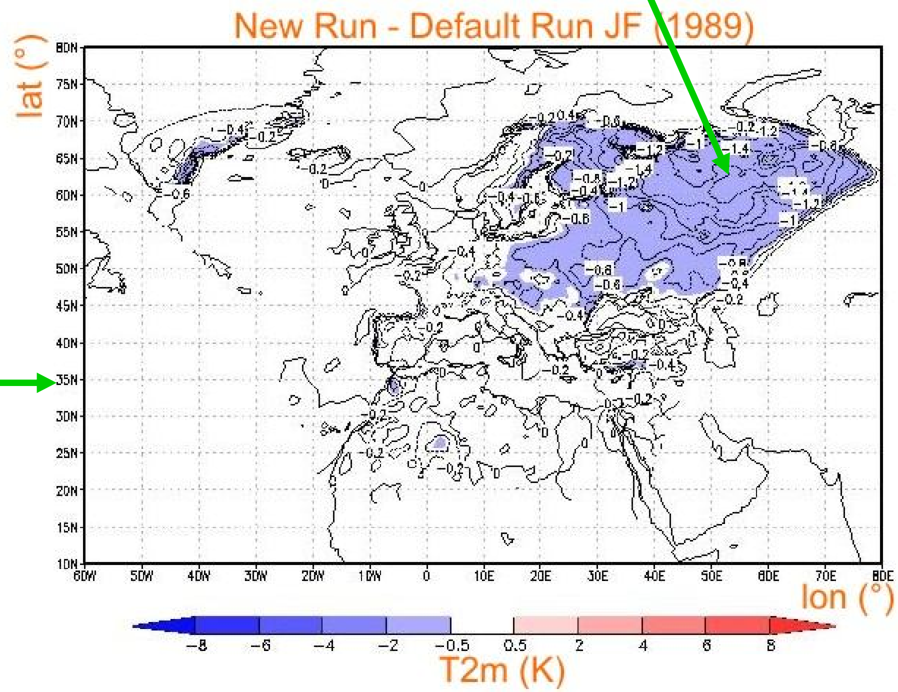


The "quick fix" approach

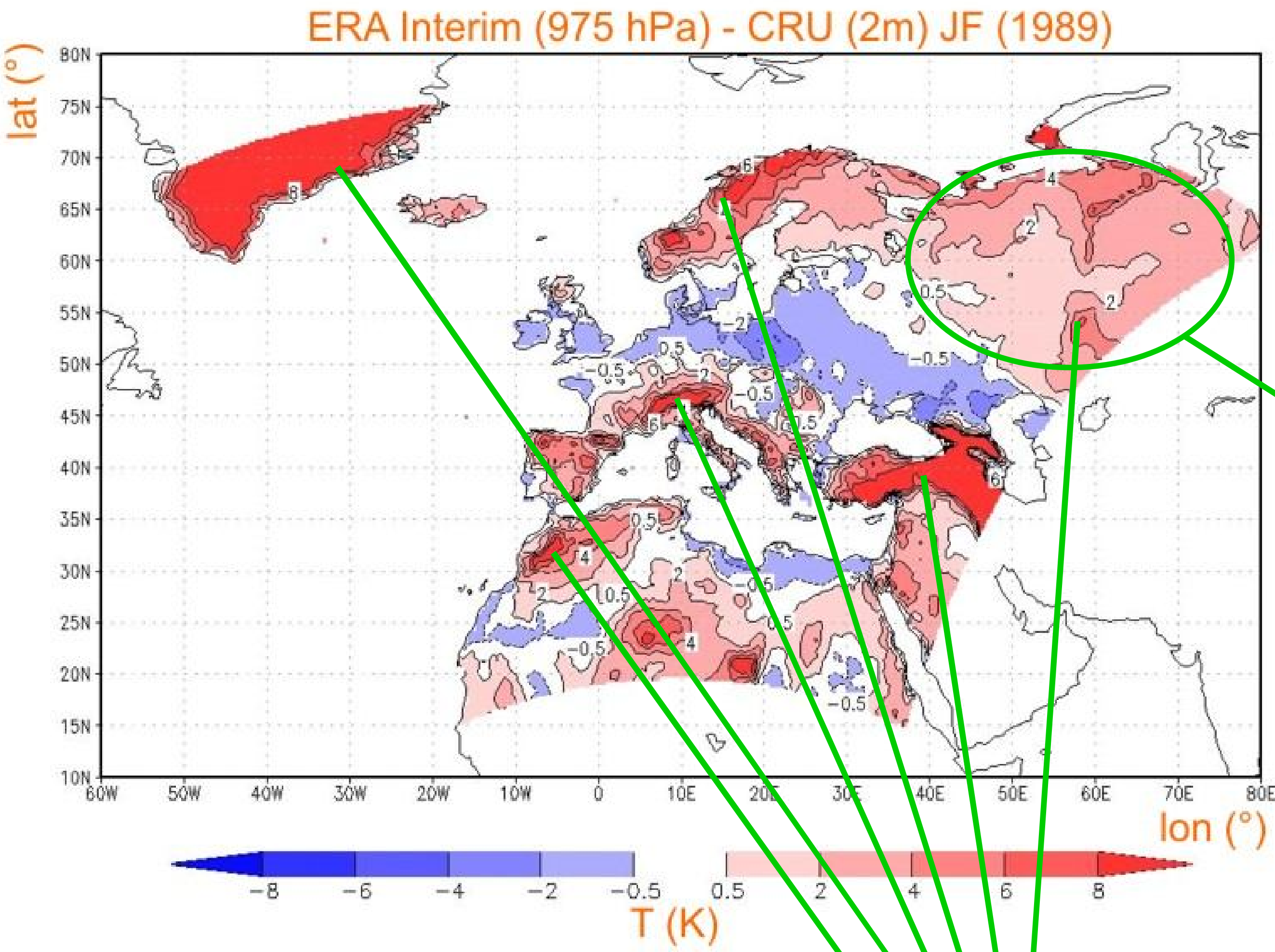


$$
\begin{aligned}
h &< 600 \text{ m} \\
L &> 100 \text{ m} \\
K_h &= 0 \text{ m}^2/\text{s}
\end{aligned}
$$

Only ~1 K reduction in bias



A step before using RegCM3: ERA Interim vs CRU



Only rough comparsion

Possibly triggers even higher bias

975 hPa surface passing through topography

Summary

1. RegCM3 has challenges/problems in high latitudes during winter.

2. There is initial difference between the forcing data and the CRU data.

3. “Quick fix” approaches can reduce bias only to some extent.

What is **Your** experience with similar challenges?

Literature

Cuxart, J., A.A.M. Holtslag, R.J. Beare, E. Bazile, A. Beljaars, A. Cheng, L. Ek. M. Conangla, F. Freedman, R. Hamdi, A. Kerstein, H. Kitagawa, G. Lenderink, D. Lewellen, J. Mailhot, T. Mauritsen, V. Perov, G. Schayes, G.J. Steeneveld, G. Svensson, P. Taylor, W. Weng, S. Wunsch, K.M. Xu, 2006: Single-column model intercomparison for a stably stratified atmospheric boundary layer. *Boundary.-Layer Meteorol.*, **118**, 273-303

Holtslag, A., E. De Bruijn, and H.L. Pan, 1990: A High Resolution Air Mass Transformation Model for Short-Range Weather Forecasting. *Mon. Wea. Rev.*, **118**, 1561-1575.

Pal, J.S., F. Giorgi, X. Bi, N. Elguindi, F. Solmon, X. Gao, S.A. Rauscher, R. Francisco, A. Zakey, J. Winter, M. Ashfaq, F.S. Syed, J.L. Bell, N.S. Diffenbaugh, J. Karmacharya, A. Konaré, D. Martinez, R.P. da Rocha, L.C. Sloan, and A.L. Steiner, 2007: Regional Climate Modeling for the Developing World: The ICTP RegCM3 and RegCNET. *Bull. Amer. Meteor. Soc.*, **88**, 1395–1409

Abbrevations

GCM: Global Climate Model

RCM: Regional Climate Model

CRU: Climatic Research Unit

ERA-40 / ERA-Interim: ECMWF re-analysis