# ORCHIDEE DEV Meeting

**06-Oct-2015**

# Testing Roughness Length ($z_0$) in LMDZOR

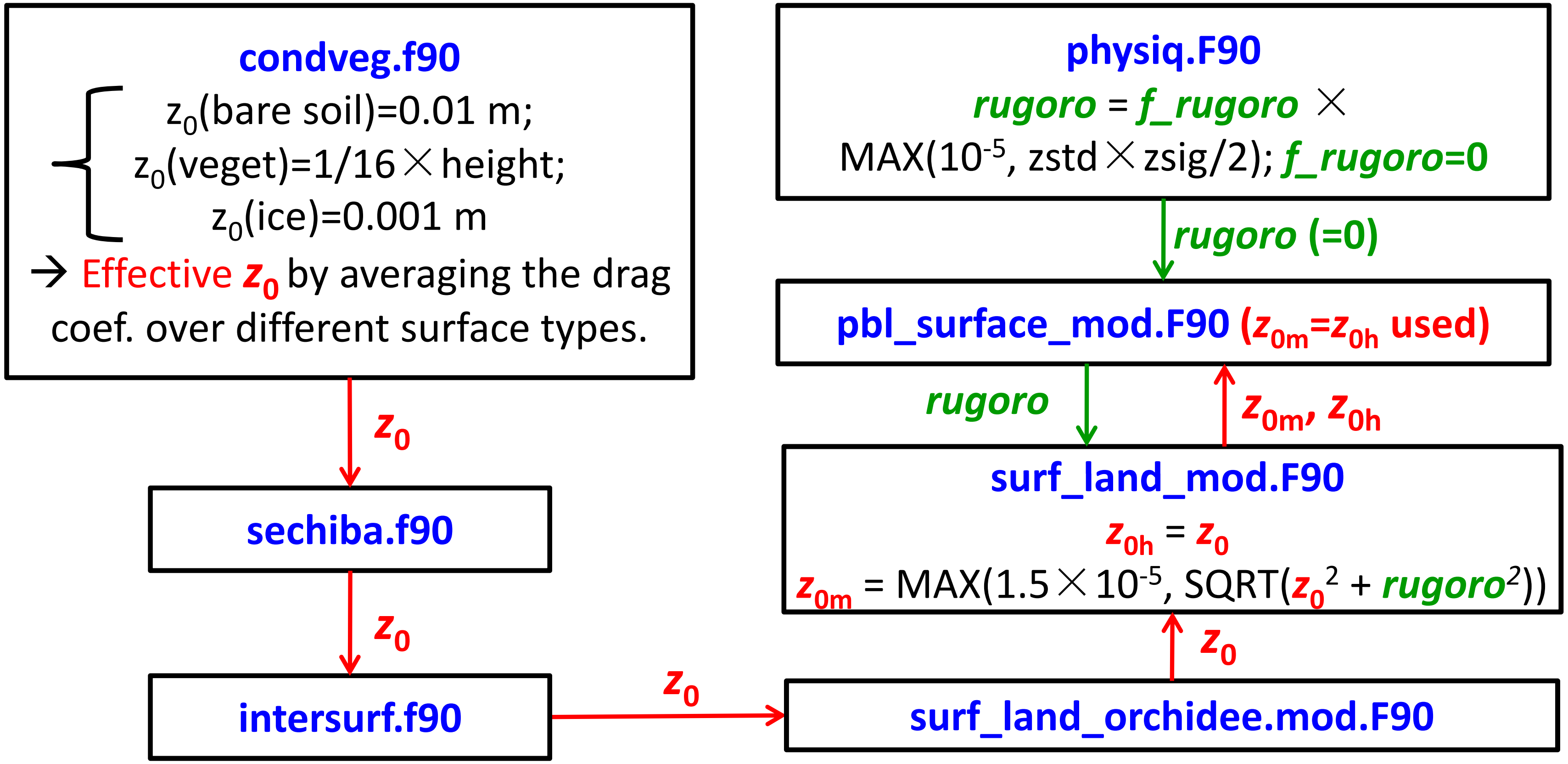
- **$z_0$ and its Sensitivity Test in LMDZOR.**
- **T2m and LE Bias in CMIP6 Simulations.**
- **Testing Zero Plane Displacement and von Kármán Constant.**

**Fuxing WANG**

# Roughness Length ($z_0$) in LMDZOR

## ORCHIDEE

## LMDZ



**condveg.f90**

$z_0$(bare soil)=0.01 m;
$z_0$(veget)=1/16 × height;
$z_0$(ice)=0.001 m

→ Effective $z_0$ by averaging the drag coef. over different surface types.

$z_0$

**sechiba.f90**

$z_0$

**intersurf.f90**

$z_0$

**physiq.F90**

*rugoro* = *f_rugoro* × MAX($10^{-5}$, zstd × zsig/2); *f_rugoro*=0

*rugoro* (=0)

**pbl_surface_mod.F90** ($z_{0m}$=$z_{0h}$ used)

*rugoro*

$z_{0m}$, $z_{0h}$

**surf_land_mod.F90**

$z_{0h}$ = $z_0$

$z_{0m}$ = MAX(1.5 × $10^{-5}$, SQRT($z_0^2$ + *rugoro*$^2$))

$z_0$

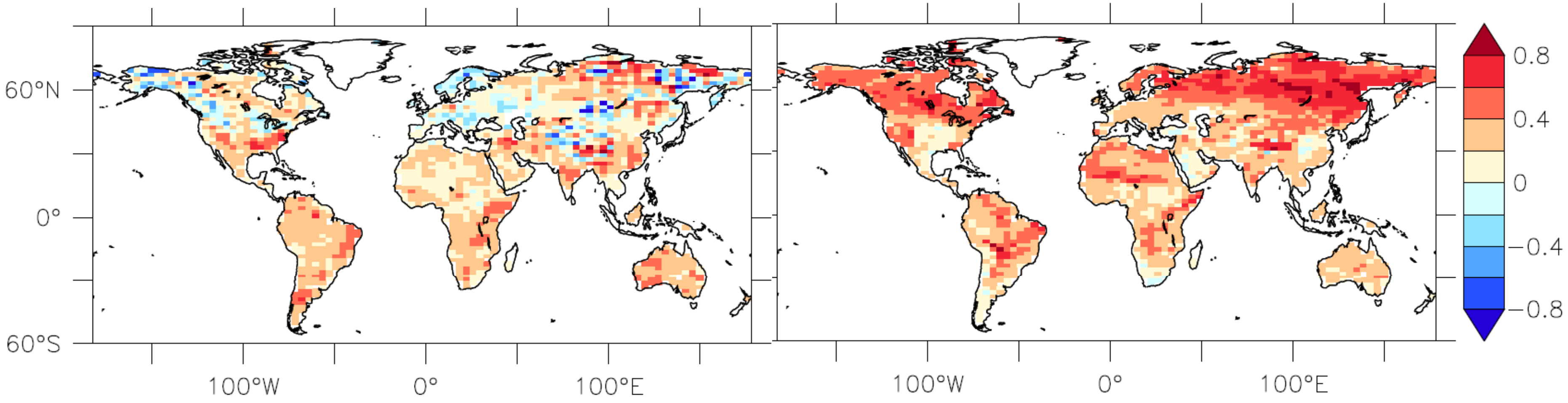
**surf_land_orchidee.mod.F90**

**$z_{0m}$ (pressure fluctuations) = $z_{0h}$ (molecular diffusion) ??**

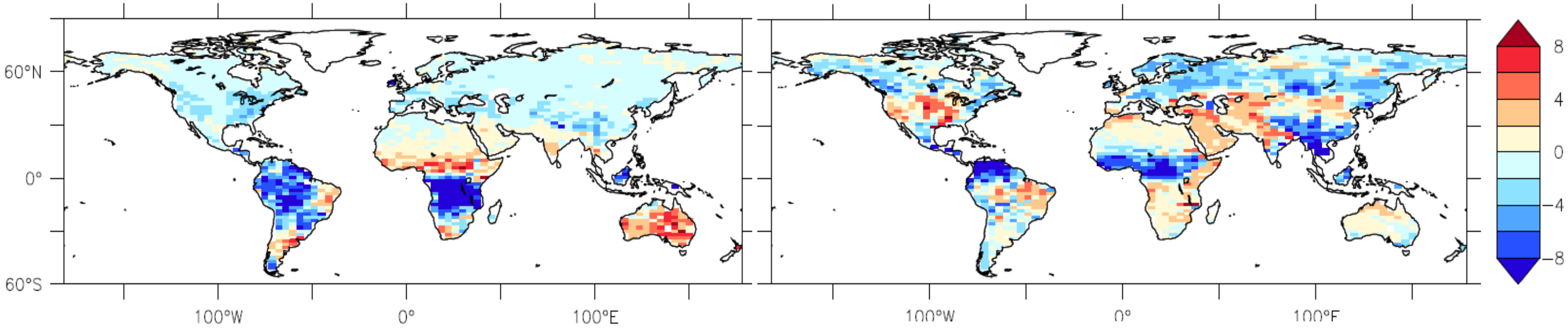
# Simple $z_0$ Tests ($z_{0h}=z_{0m}/10$) in LMDZOR

**CTL: $z_{0h} = z_{0m}$; EXP: $z_{0h} = z_{0m}/10$; ORC (CWRR); LMDZ (NPv3.2); 96×95×39; 1Y (nudged)**

**T2m, EXP – CTL: DJF** **T2m, EXP - CTL: JJA**



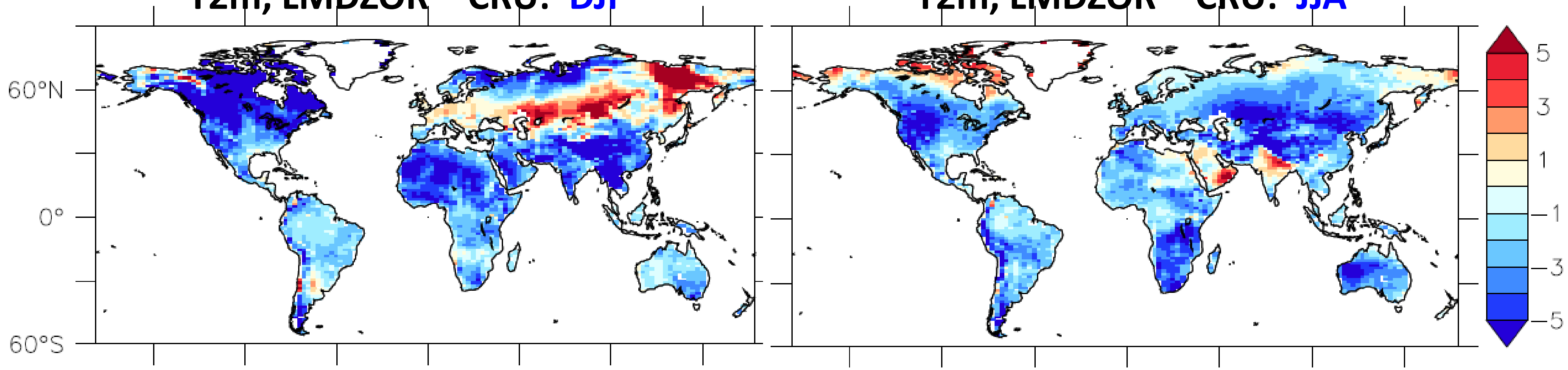
**LE, EXP – CTL: DJF** **LE, EXP - CTL: JJA**



***T2m* increases (LE decreases) with $z_{0h}$ decrease → Does it improves the simulation or not ??**

# T2m and LE Bias in CMIP6 Simulation

**ORC (CWRR): r2992; LMDZ (NPv5.17h): r2327; 144×142×79; 5Y climatology.**

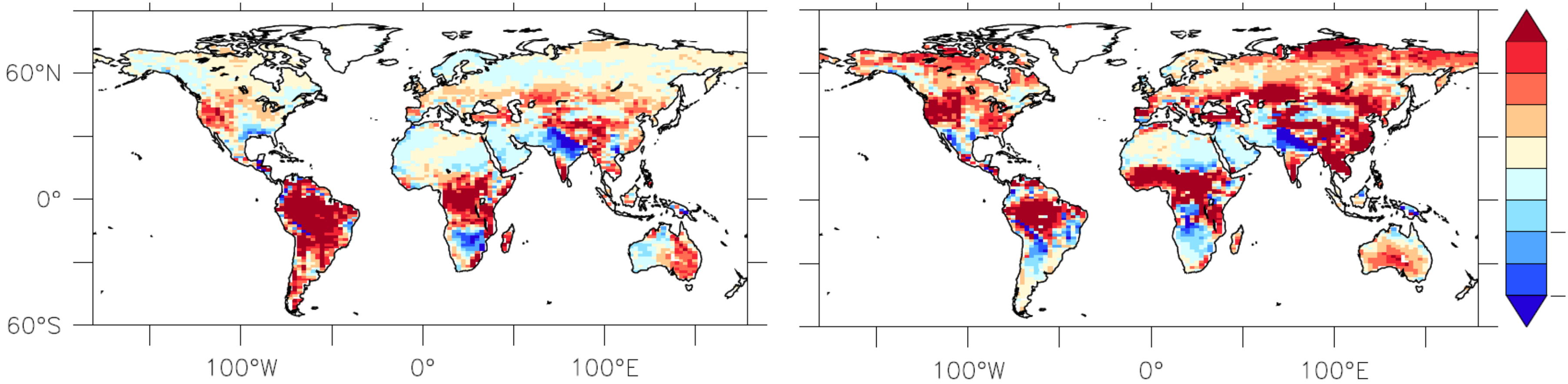


**T2m, LMDZOR – CRU: DJF**

**T2m, LMDZOR – CRU: JJA**

**LE, LMDZOR – landfluxEVAL: DJF**

**LE, LMDZOR – landfluxEVAL: JJA**



**(1) In LMDZOR, T2m underestimated (LE overestimated) over most regions;**

**(2) Lower $z_{0h}$ could eliminate part of T2m and LE bias.**

# More $z_{0h}$ Parameterizations

**$z_{0h} \neq z_{0m}$ in following models …**

| Model | z0h |
|---|---|
| ECHAM6 | z0h= z0m*$e^{(2\text{-}86.276z0m)0.375}$ |
| MetUM | z0h= α*z0m; α varies over different surfaces |
| CNRM,CLM4.5, ECMWF | z0h≠z0m |
| JMA | z0h= z0m/7.4 |
| Noah, SMHI | ln(z0m/z0h) = κB-1 |

**Two more schemes tested in LMDZOR:**

(1) **S02 proposed by Nicolas V.:** Su et al. [2001, JAM]; Su [2002, HESS].

**In red**: parameters need to calibrate.

$$kB^{-1} = \frac{kC_d}{4C_t\frac{u^*}{u(h)}(1-e^{-\frac{n}{2}})}f_c^2 + \frac{k\frac{u^*}{u(h)}\frac{z_{0m}}{h}}{C_t^*}f_c f_s + kB_S^{-1}f_s^2$$

$$\frac{z_{0m}}{h} = (1-\frac{d}{h})e^{-k\frac{u(h)}{u^*}}$$

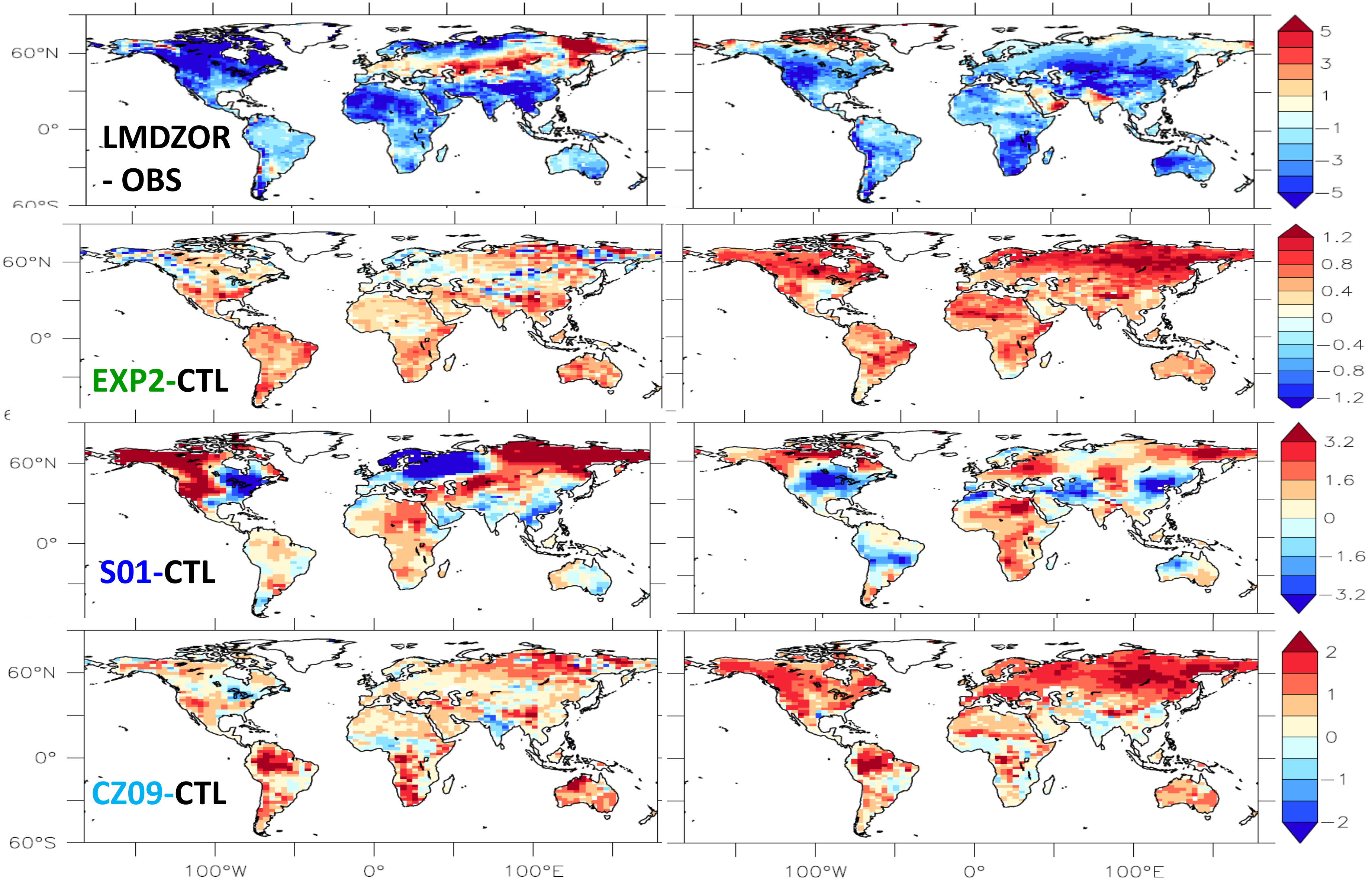
(2) **CZ09:** Chen and Zhang [2009, GRL, Noah 3.4.1]

$$\kappa B^{-1} = 10^{-0.4\times \mathrm{h}}\kappa Re_*^{1/2}$$

# Inter-Comparison of T2m in $z_0$ Tests (LMDZOR)

**CTL: $z_{0h} = z_{0m}$; EXP2: $z_{0h} = z_{0m}/100$; EXP3: S01; EXP4: CZ09.**

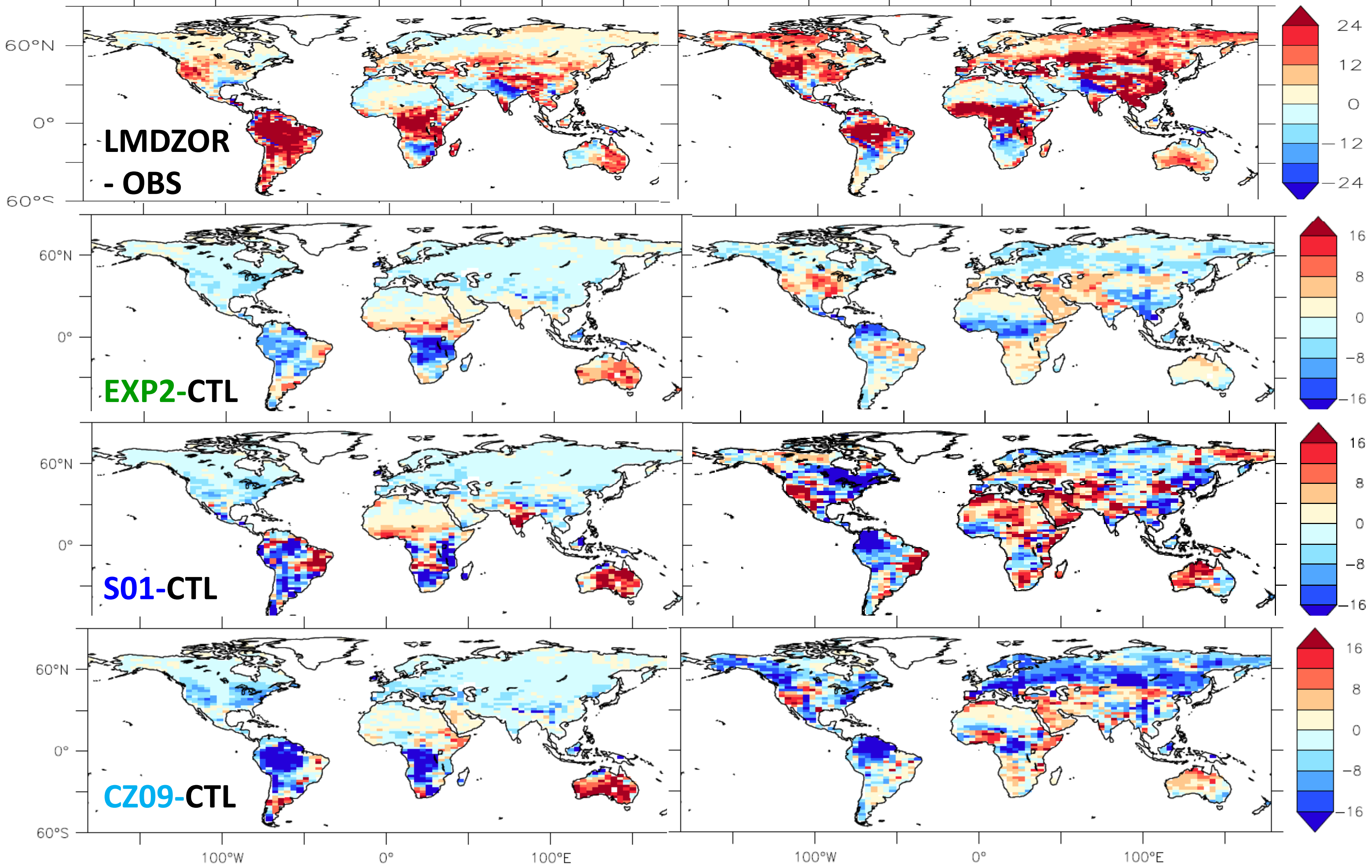
**T2m (K): DJF JJA**



# Inter-Comparison of LE in $z_0$ Tests (LMDZOR)

CTL: $z_{0h} = z_{0m}$; EXP2: $z_{0h} = z_{0m}/100$; EXP3: S01; EXP4: CZ09.

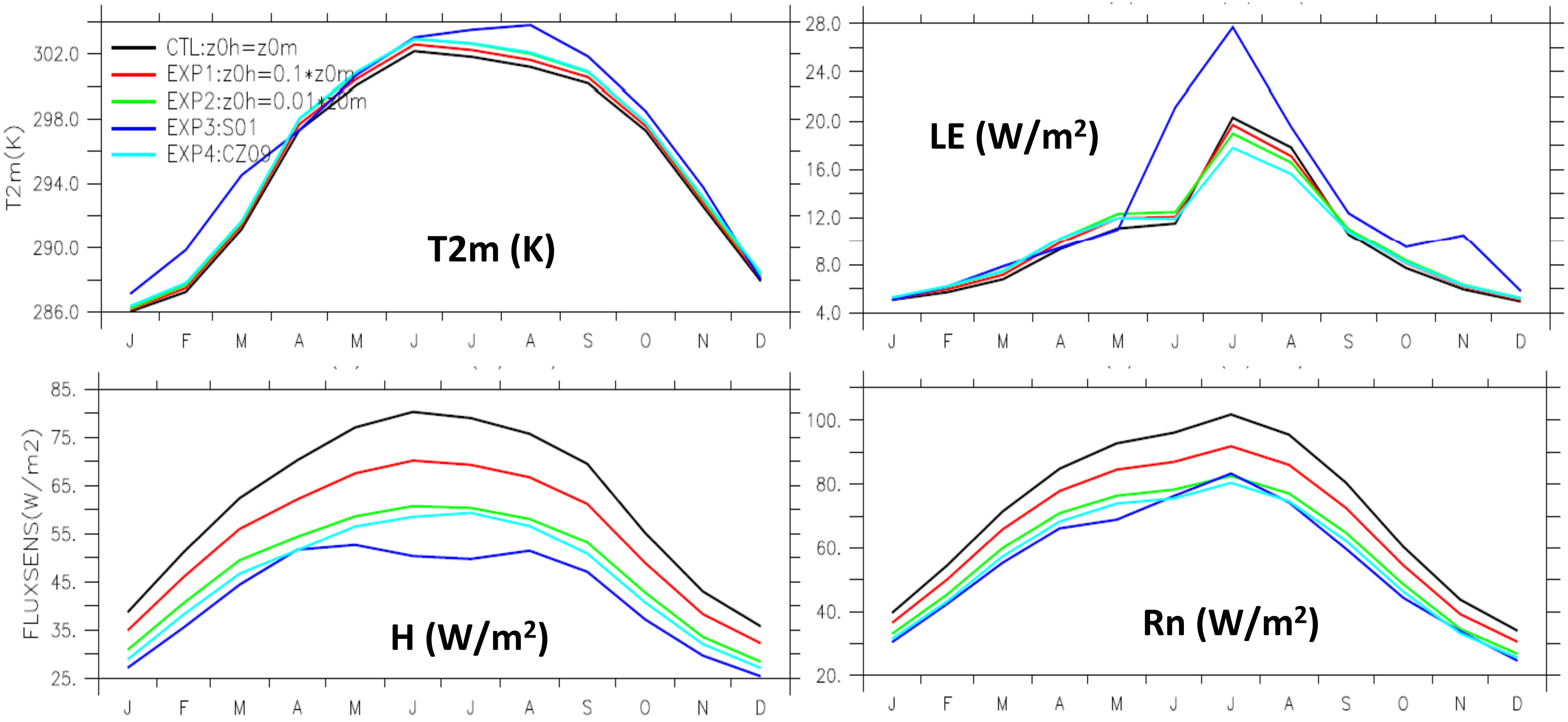
LE (W/m²): DJF JJA



# Seasonal Cycles (Sahara)

**CTL: $z_{0h} = z_{0m}$; EXP1: $z_{0h} = z_{0m}/10$; EXP2: $z_{0h} = z_{0m}/100$; EXP3: S01; EXP4: CZ09.**

**ORC (CWRR); LMDZ (NPv3.2); 96 × 95 × 39; 1Y (nudged).**

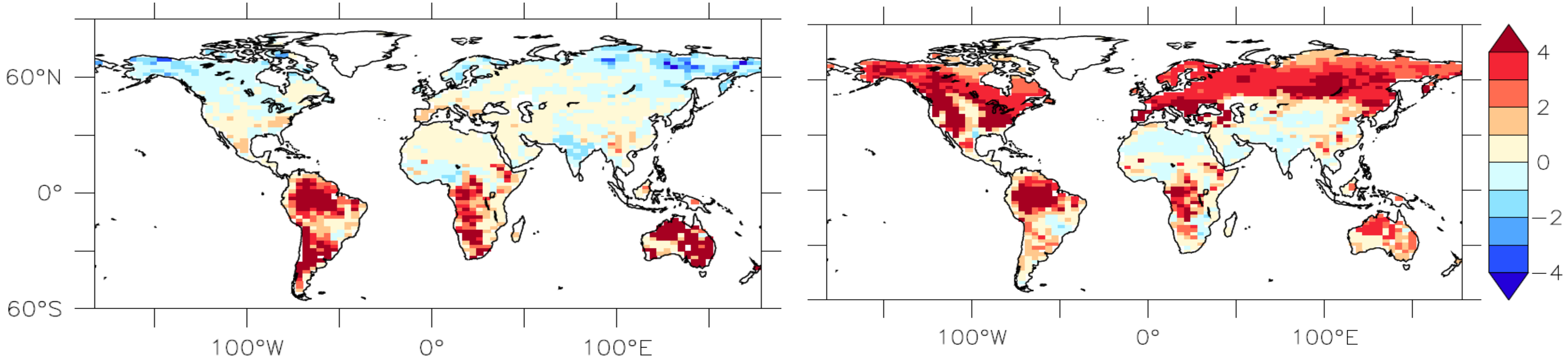


**T2m increases (H, Rn decreases) in all experiments over the Sahara.**

# Zero Plane Displacement (*d*) and von Kármán Constant (*κ*) in LMDZOR

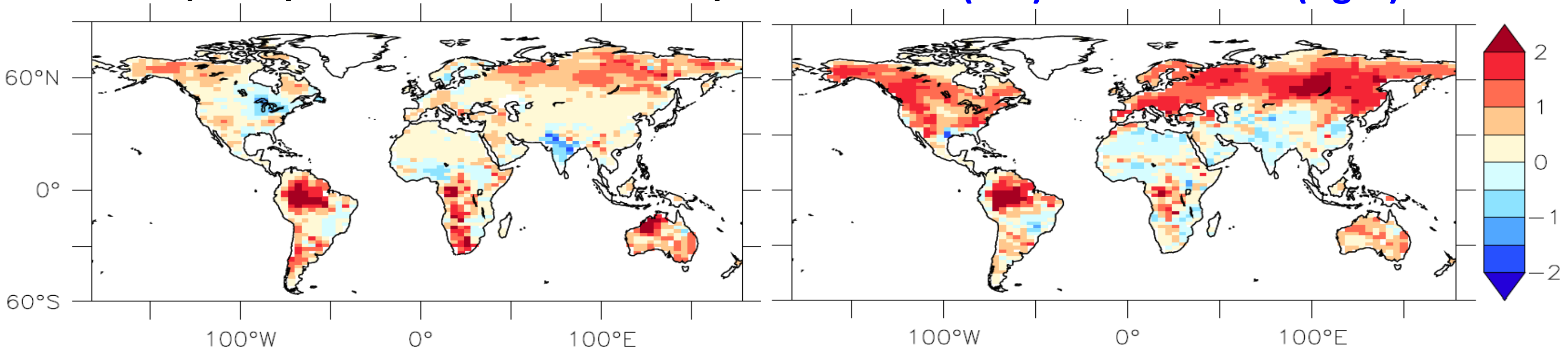
**(1) Question:** ***d*** **is calculated in ORC, but not used by LMDZ.**

**T2m, EXP (d included in LMDZ) – CTL: DJF (left) JJA (right)**



**(2) Question:** ***κ*** **= 0.4 in LMDZ, but** ***κ*** **= 0.35 in ORC. Inconsistent.**

**T2m, EXP (*κ* = 0.4 in ORC and LMDZ) – CTL: DJF (left) JJA (right)**



***d*** **included or** ***κ*** **consistent → T2m increase (most regions).**

# Conclusions

- **In general, $z_{0h} \neq z_{0m}$, but $z_{0h} = z_{0m}$ in LMDZOR.**
- **Different z0h parameterizations were tested in LMDZOR:**
  - 1. $z_{0h} = z_{0m}/10$; 2. $z_{0h} = z_{0m}/100$; 3. S01; 4. CZ09. (z0h<z0m in 3 and 4);
  - T2m increases (LE decreases) with the decrease of z0h;
  - These modifications compensate part of CMIP6 T2m and LE bias.
- **T2m in LMDZOR also influenced (increase) by:**
  - including zero-plane displacement in LMDZ; or
  - using consistent von Kármán Constant (=0.4).

***Thank You !***

- Presentation already stop from here.
- The slides hereafter might be facilitate later discussion.

# Formulas for S01

$$\frac{z_{0m}}{h} = (1-\frac{d}{h})e^{-k\frac{u(h)}{u^*}}$$

$$kB^{-1} = \frac{kC_d}{4C_t\frac{u^*}{u(h)}(1-e^{-\frac{n}{2}})}f_c^2 + \frac{k\frac{u^*}{u(h)}\frac{z_{0m}}{h}}{C_t^*}f_c f_s + kB_S^{-1}f_s^2$$

$$kB^{-1} = \ln(\frac{z_{0m}}{z_{0h}})$$

$$\zeta(z) = \int_0^z [\frac{C_d(z')\alpha(z')}{P_m(z')}]\,dz' \approx C_d \times LAI$$

$$\frac{u^*}{u(h)} = c_1 - c_2 e^{-c_3\zeta(h)}$$

$$n = \frac{\zeta(h)}{2\left[\frac{u^*}{u(h)}\right]^2}$$

$$\nu = 1.327\times 10^{-5}\frac{p_0}{p}\left(\frac{T}{T_0}\right)^{1.81}$$

$$\kappa B_S^{-1} = 2.46(Re_*)^{1/4} - \ln(7.4)$$

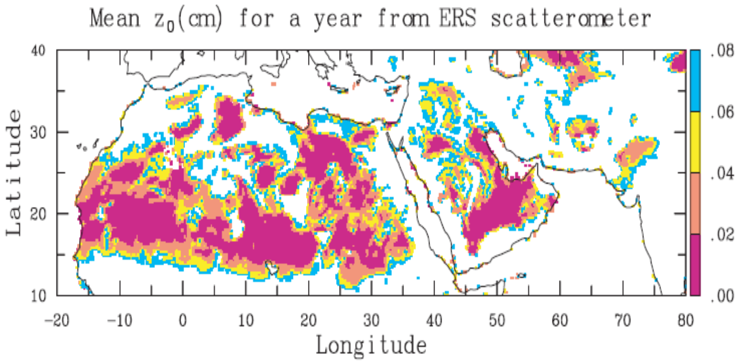
$$C_t^* = Pr^{-2/3}Re_*^{-1/2}$$

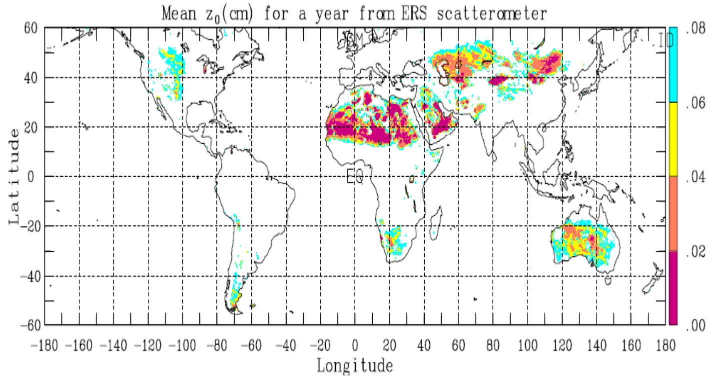
$$Re_* = \frac{z_{0m}u^*}{\nu}$$

$B^{-1}$: inverse Stanton number; $f_c$: fractional canopy coverage and $f_s$ is its compliment; $u$: wind speed (m/s); $u^*$ $(=\tau_0/\rho)^{1/2}$ :friction velocity, $\tau_0$: surface shear stress (kg/m/s$^2$), $\rho$:density of air (kg/m$^3$); $p$ and $T$: ambient pressure and temperature, $P_0$=101.3kPa, $T_0$ = 273.14K; $\nu$: fluid kinematical viscosity (m$^2$/s); $c_1$ (=0.320), $c_2$ (=0.264), $c_3$ (=15.1): model constants related to the bulk surface drag coefficient and to the substrate or soil drag coefficient $c_s$ as discussed by Massman [1997]; $\zeta(h)$: cumulative leaf drag area per unit planform area, $\zeta(h) \approx C_d \times$ LAI ; $C_d$: drag coefficient of the foliage elements assumed to take the value of 0.2 [Su, 2002]; $\alpha$: vertical leaf area density function; $P_m$: momentum shelter factor; $C_t$: heat transfer coefficient of the leaf. For most canopies and environmental conditions, $C_t$ is bounded as 0.005$N$ $\le C_t \le$ 0.075$N$ ($N$ : number of sides of a leaf to participate in heat exchange); $C_t$ = 0.01 currently (why ?). For bare soil, k$B_s^{-1}$ by [Brutsaert ,1982].

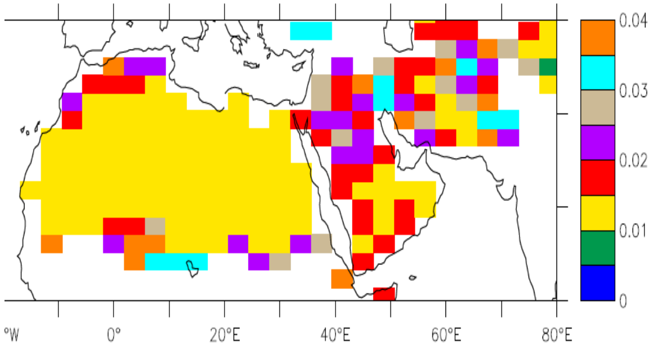
# $z_0$: ORC vs. Remote Sensing

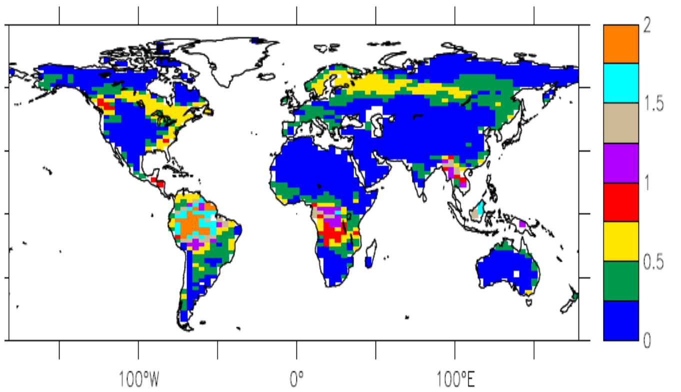
**$z_{0m}$ (in cm): RS**



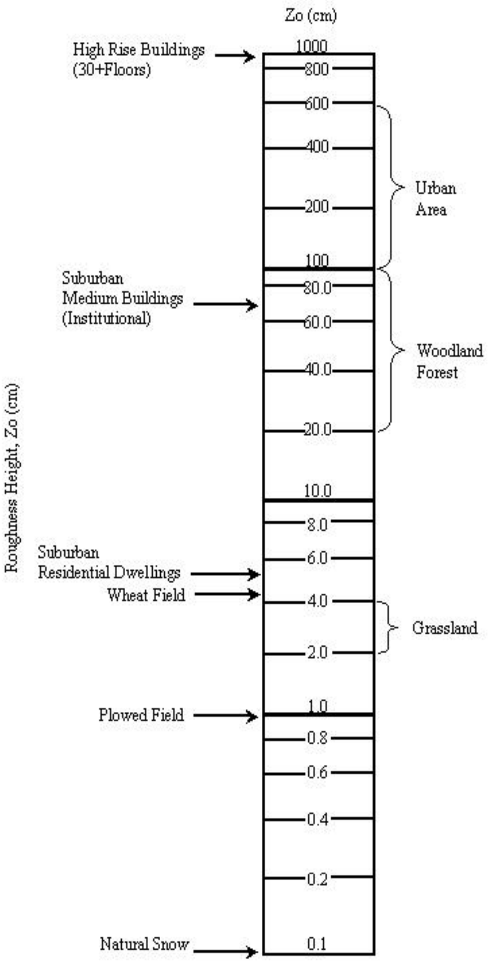


**$z_{0m}$=$z_{0h}$ (in m): LMDZOR**



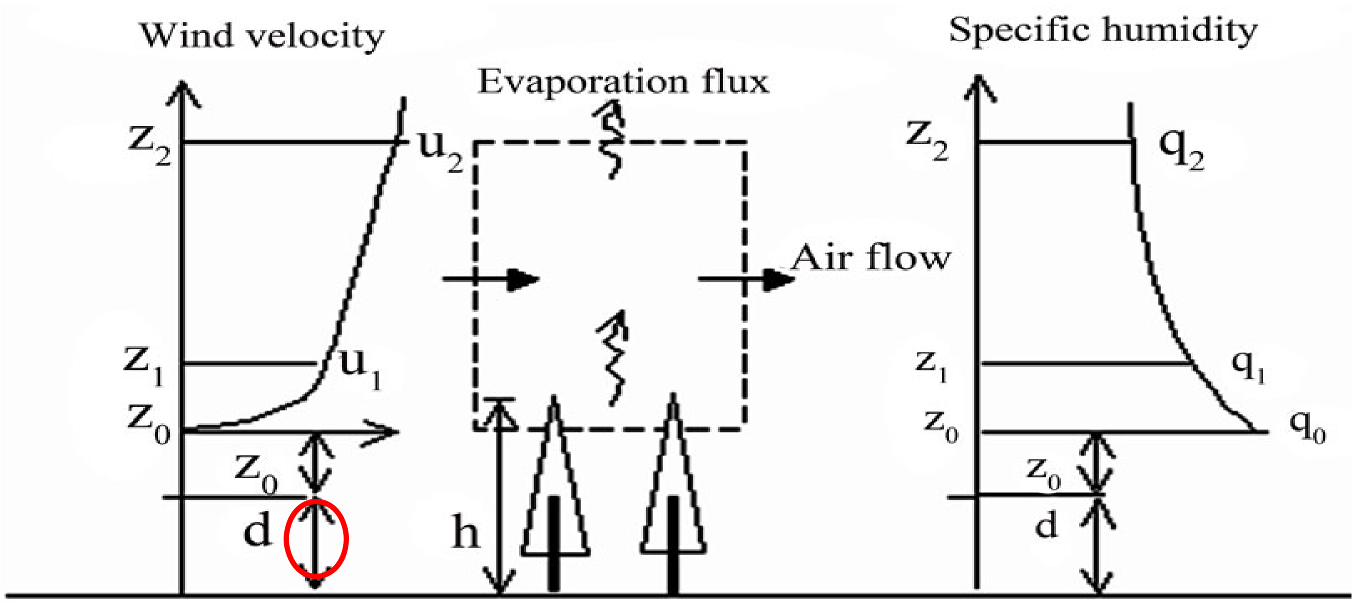


**from PNNL (in cm)**



***RS data only available over bare soil.*** **[*C. Prigent et al.*, 2005, JGR].**

# Zero Plane Displacement (*d*)



$$\mathrm{u} = \frac{u^*}{\kappa}[\ln\left(\frac{z-d}{z_{0m}}\right) - \Psi_m\left(\frac{z-d}{\mathrm{L}}\right) + \Psi_m\left(\frac{z_{0m}}{\mathrm{L}}\right)]$$

$$\theta_0 - \theta_z = \frac{\mathrm{P_r}\theta^*}{\kappa}[\ln\left(\frac{z-d}{z_{0h}}\right) - \Psi_h\left(\frac{z-d}{\mathrm{L}}\right) + \Psi_h\left(\frac{z_{0h}}{\mathrm{L}}\right)]$$

***d* not used by LMDZ (*i.e.*, *d*=0).**