Land-atmosphere feedbacks in a high-resolution RCM: sensitivity to the land-surface forcing

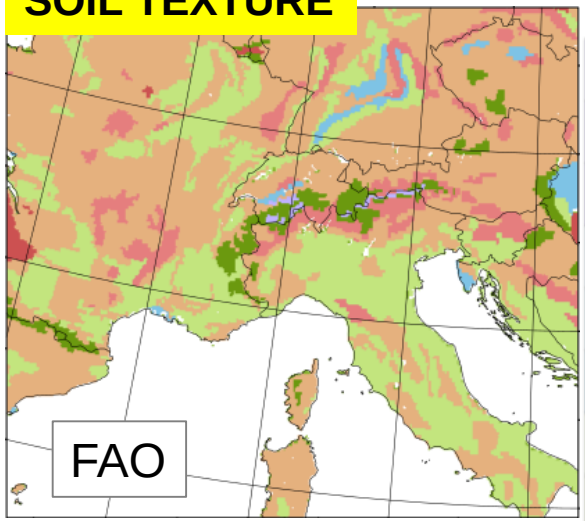
Josipa Milovac[1,2]
milovacj@unican.es
Klaus Görgen[3], Jesús Fernández[1], Kirsten Warrach-Sagi[2], Álvaro Lavín Gullón[4], Joachim Ingwersen[2], and Volker Wulfmeyer[2]

[1]University of Cantabria, Santander, Spain; [2]University of Hohenheim, Stuttgart, Germany; [3]Research centre Juelich, Juelich, Germany; [4]Institute of Physics, Santander, Spain

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD co-funded by FEDER/ERDF EU funds
SIGNIA CGL2016-79210-R
MULTI-SDM CGL2015-66583-R BES-2016-078158
UC UNIVERSIDAD DE CANTABRIA
IFCA Instituto de Física de Cantabria CSIC

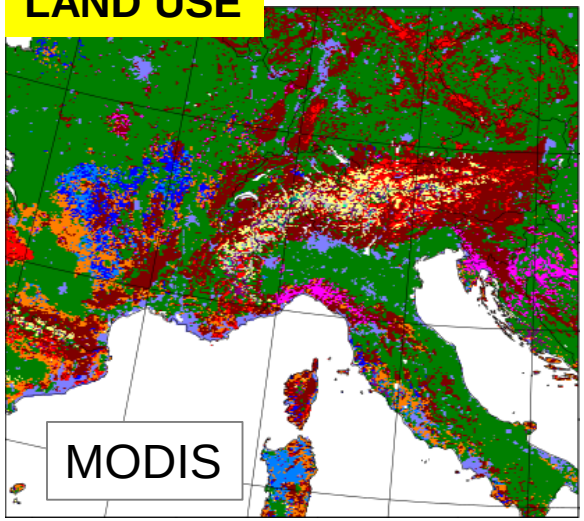
Land-surface forcing

SOIL TEXTURE



- Other(land-ice)
- Bedrock
- Water
- Organic Material
- Clay
- Silty Clay
- Sandy Clay
- Clay Loam
- Silty Clay Loam
- Sandy Clay Loam
- Loam
- Silt
- Silt Loam
- Sandy Loam
- Loamy Sand
- Sand

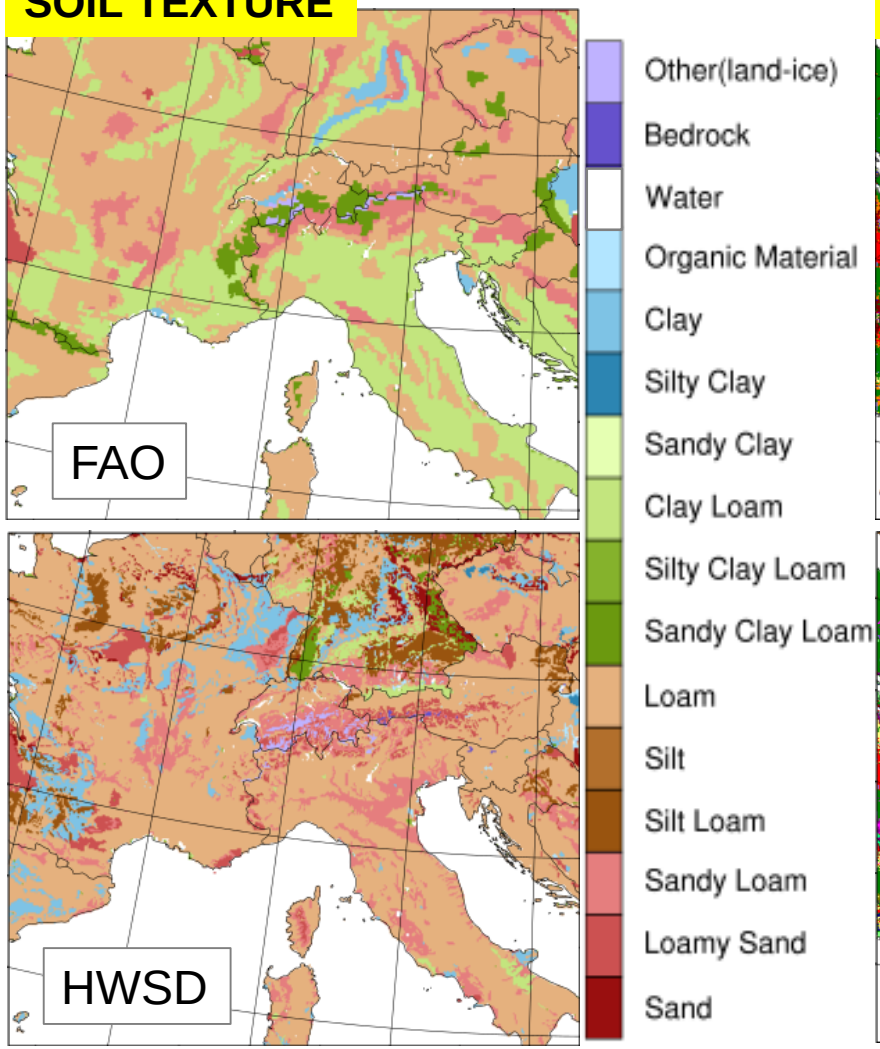
LAND USE



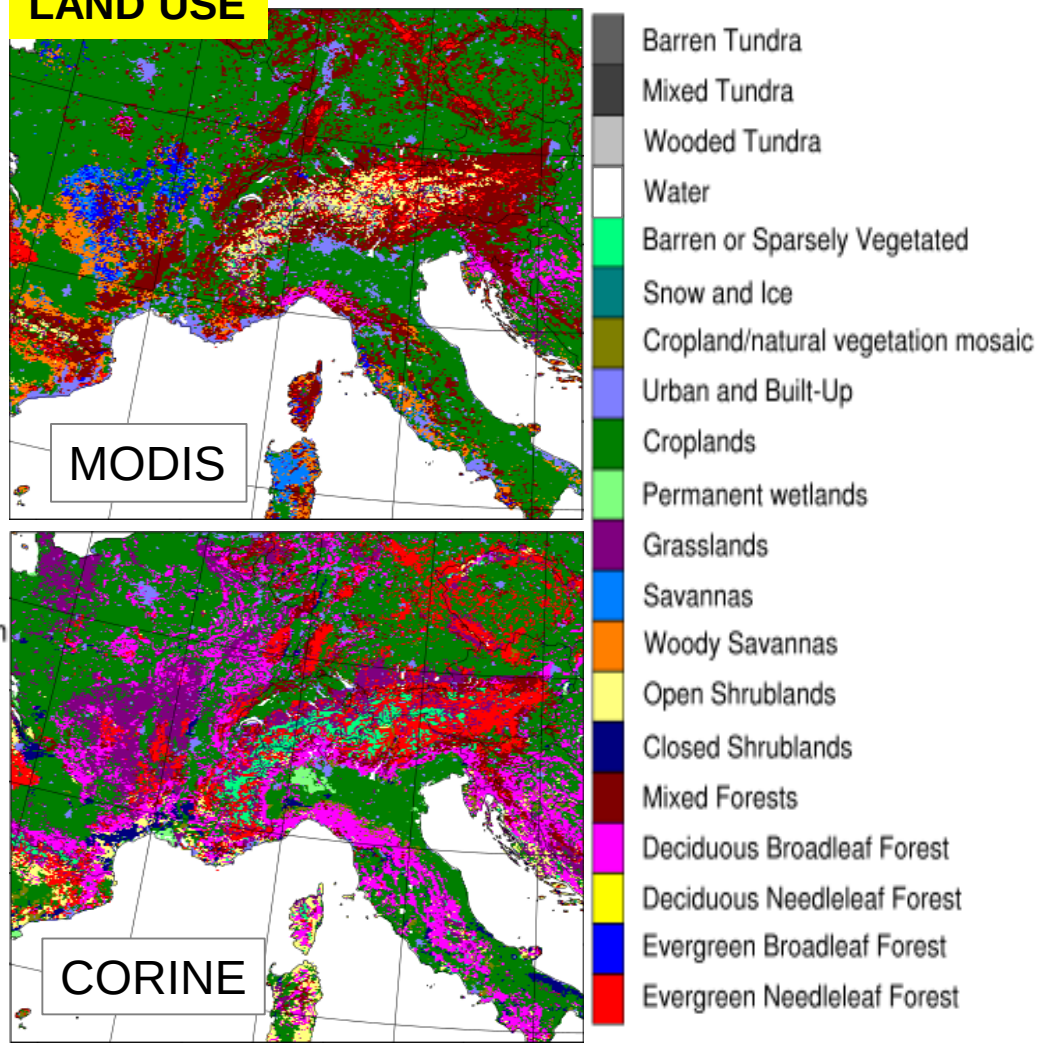
- Barren Tundra
- Mixed Tundra
- Wooded Tundra
- Water
- Barren or Sparsely Vegetated
- Snow and Ice
- Cropland/natural vegetation mosaic
- Urban and Built-Up
- Croplands
- Permanent wetlands
- Grasslands
- Savannas
- Woody Savannas
- Open Shrublands
- Closed Shrublands
- Mixed Forests
- Deciduous Broadleaf Forest
- Deciduous Needleleaf Forest
- Evergreen Broadleaf Forest
- Evergreen Needleleaf Forest

Land-surface forcing

SOIL TEXTURE



LAND USE

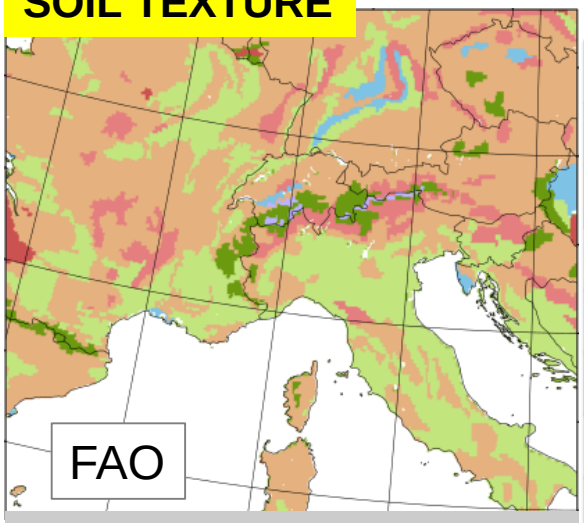


Milovac et al. 2014a
Milovac et al. 2014b

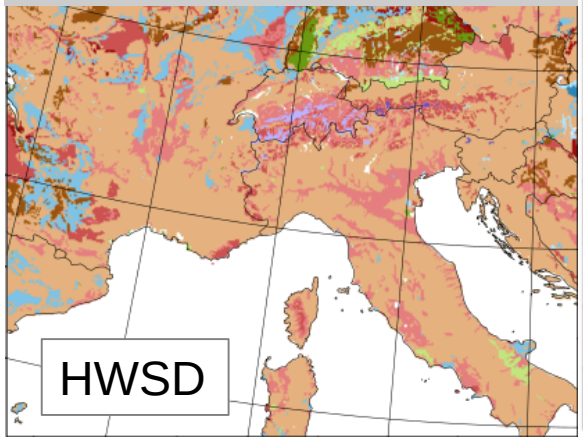
Contact person:
Hans-Stefan Bauer, hans-stefan.bauer@uni-hohenheim.de

Motivation

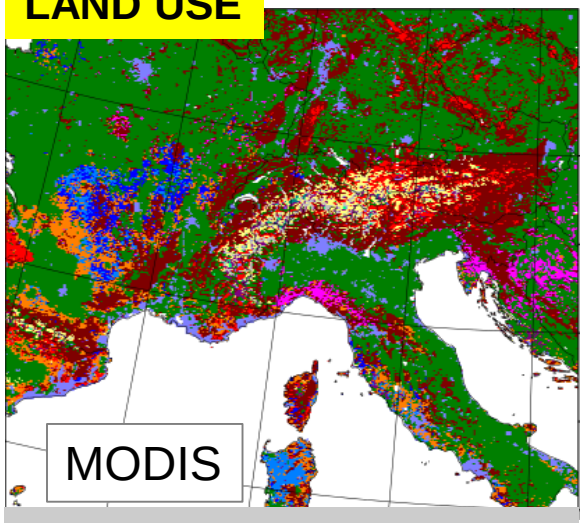
SOIL TEXTURE



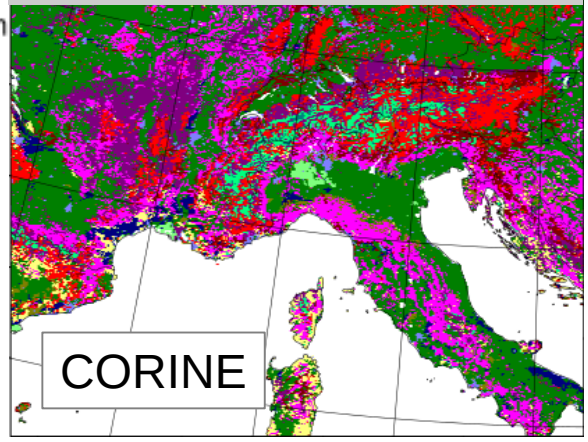
58.4% difference



LAND USE



51.9 % difference



Milovac et al. 2014a
Milovac et al. 2014b

Contact person:
Hans-Stefan Bauer, hans-stefan.bauer@uni-hohenheim.de

Objectives

SQ1:

Sensitivity of WRF to LS static data

SQ2:

Sensitivity of WRF to LS & BL sophistication

SQ3:

Sensitivity of WRF to season

Experimental design

SQ1:

Sensitivity of WRF to LS static data

4 simulations with various land surface forcing

1. CORINE-HWSD (**CH**)
   WRF-FPS setting
2. CORINE-FAO (**CF**)
3. MODIS-HWSD (**MH**)
4. MODIS-FAO (**MF**)
   WRF default setting

SQ2:

Sensitivity of WRF to LS & BL sophistication

2 WRF model configurations

1. More sophisticated: MYNN PBL, NOAHMP LSM (**UHOH**)
2. Less sophisticated: YSU PBL, NOAH LSM (**FZJ**)

SQ3:

Sensitivity of WRF to season

2 case studies

Coppola, E., Sobolowski, S., Pichelli, E. et al. Clim Dyn (2018)

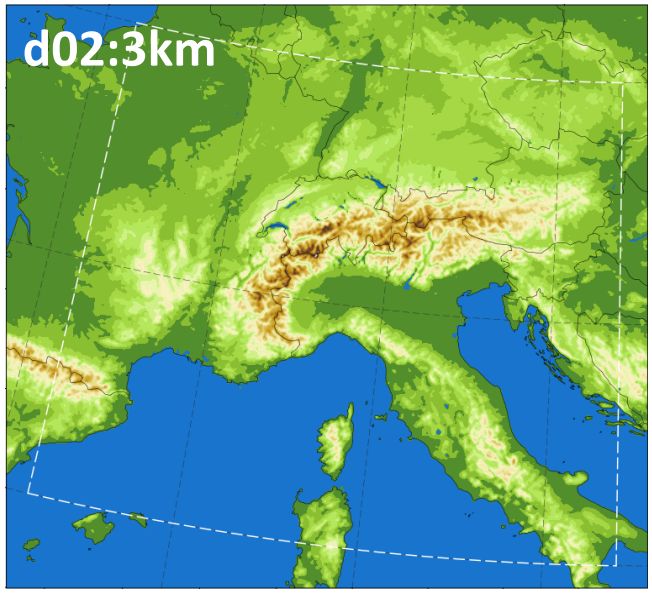
1. **Summer case** (Austria, 1.6.-1.7.2009)
2. **Fall case** (Foehn, 1.10.-7.11.2014)

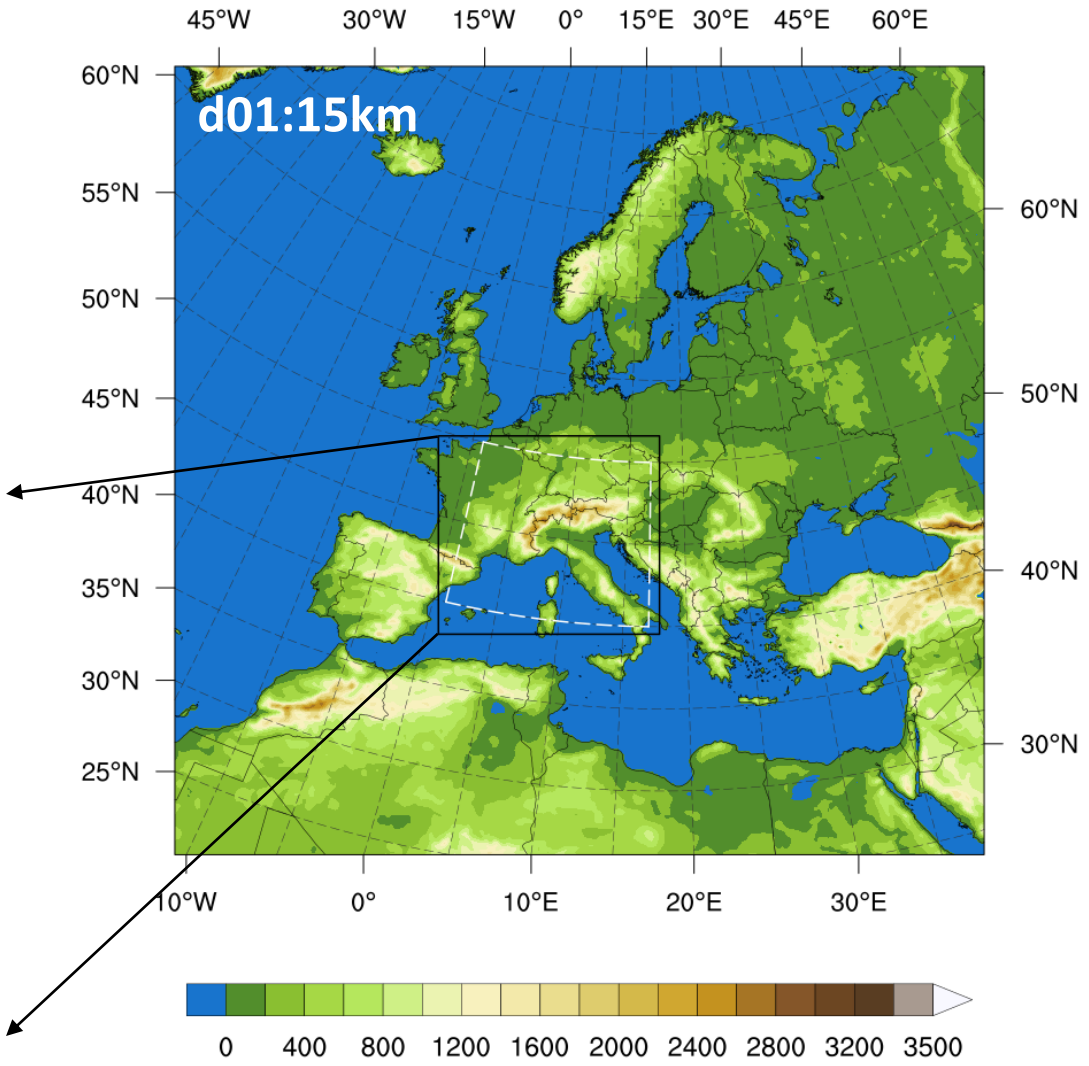
8-member ensemble for 2 case studies

Experimental domain

WRF version 3.8.1

- WRF-CORDEX FPS Domain
- 15 km to 3 km one-way nesting
- Forcing: ECMWF ERA-Interim
- Simulations ~1 month long

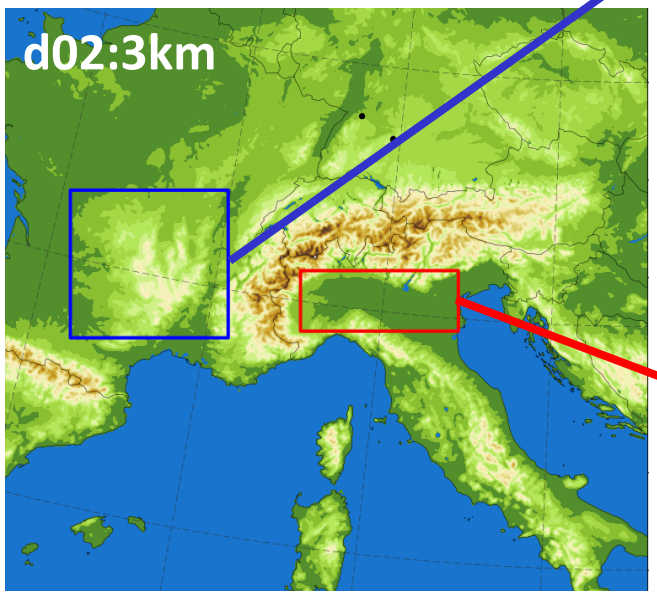




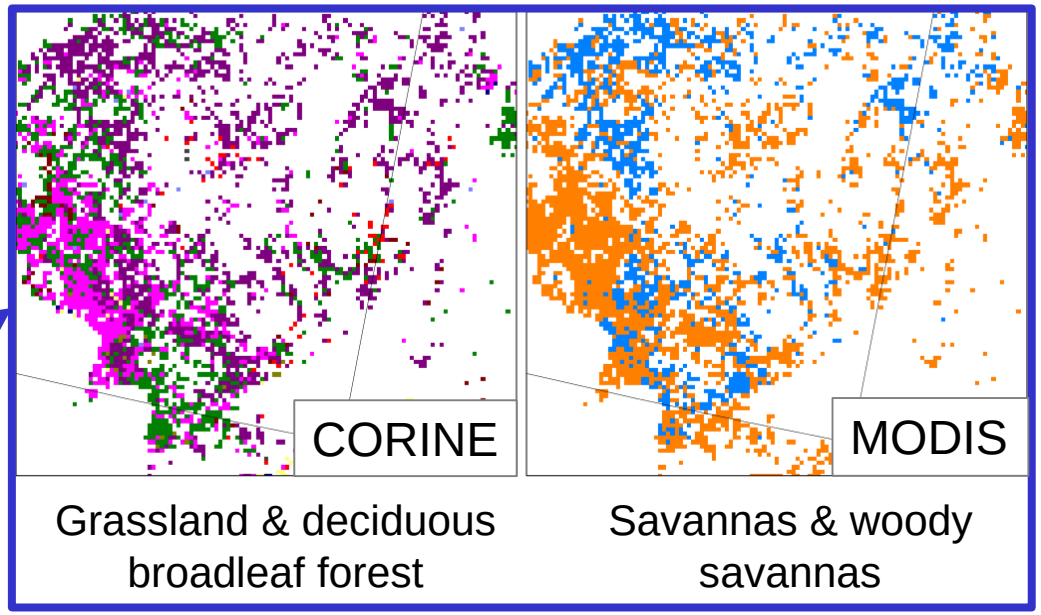
Analysis approach

2 analysis regions

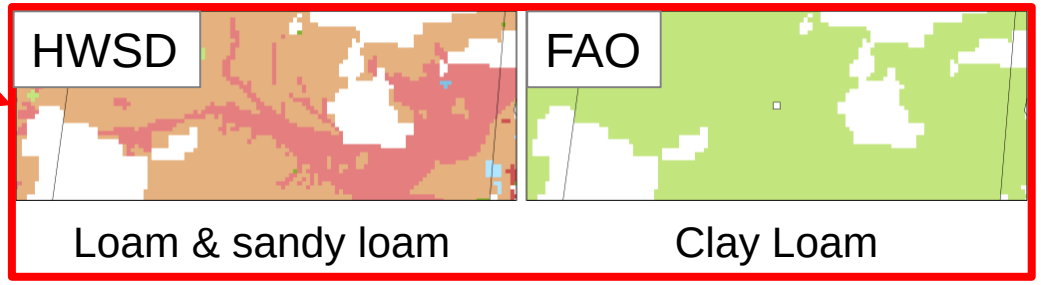
- **ST region:** Sensitivity to **ST changes** (79% grids change)
- **LU region:** Sensitivity to **LU changes** (77% grids change)



Sensitivity to LU changes

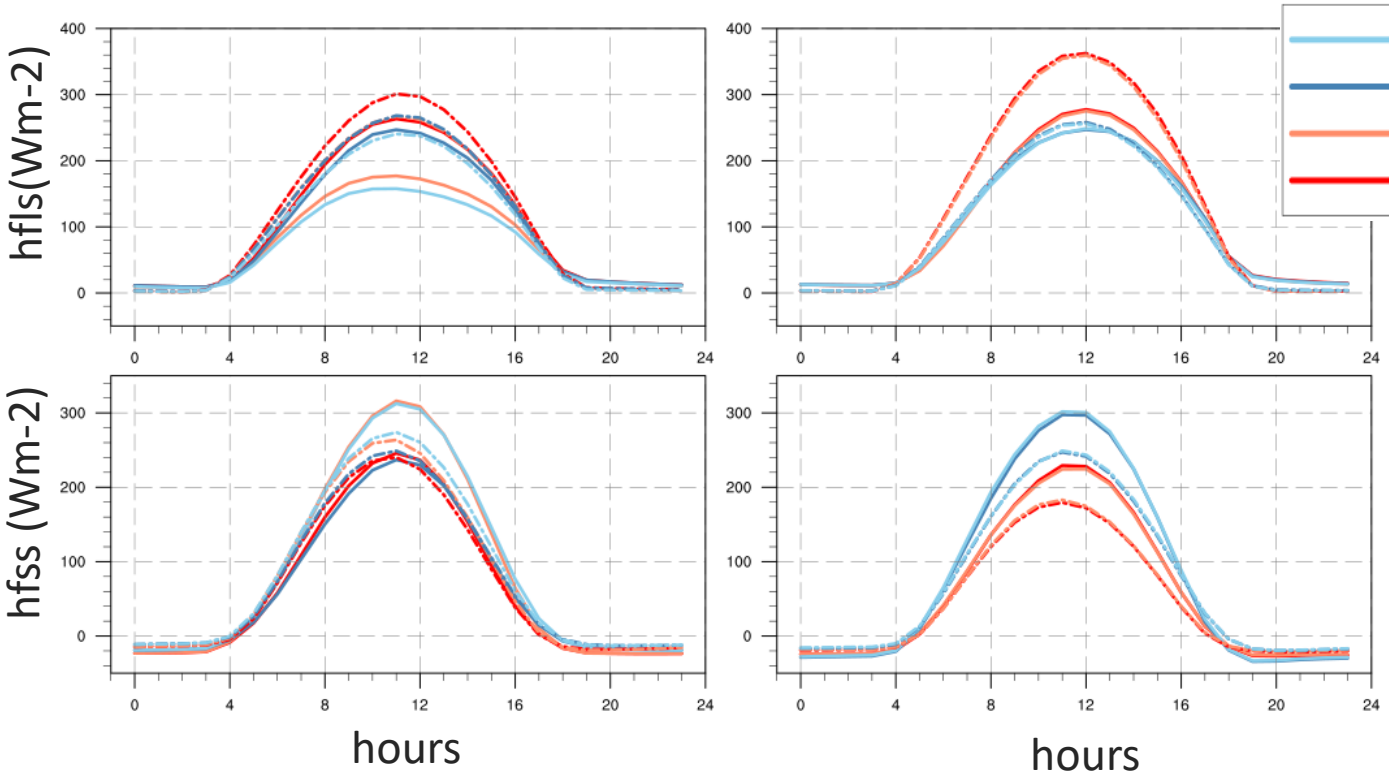


Sensitivity to ST changes



Diurnal cycles: Summer case

Sensitivity to ST changes **Sensitivity to LU changes**

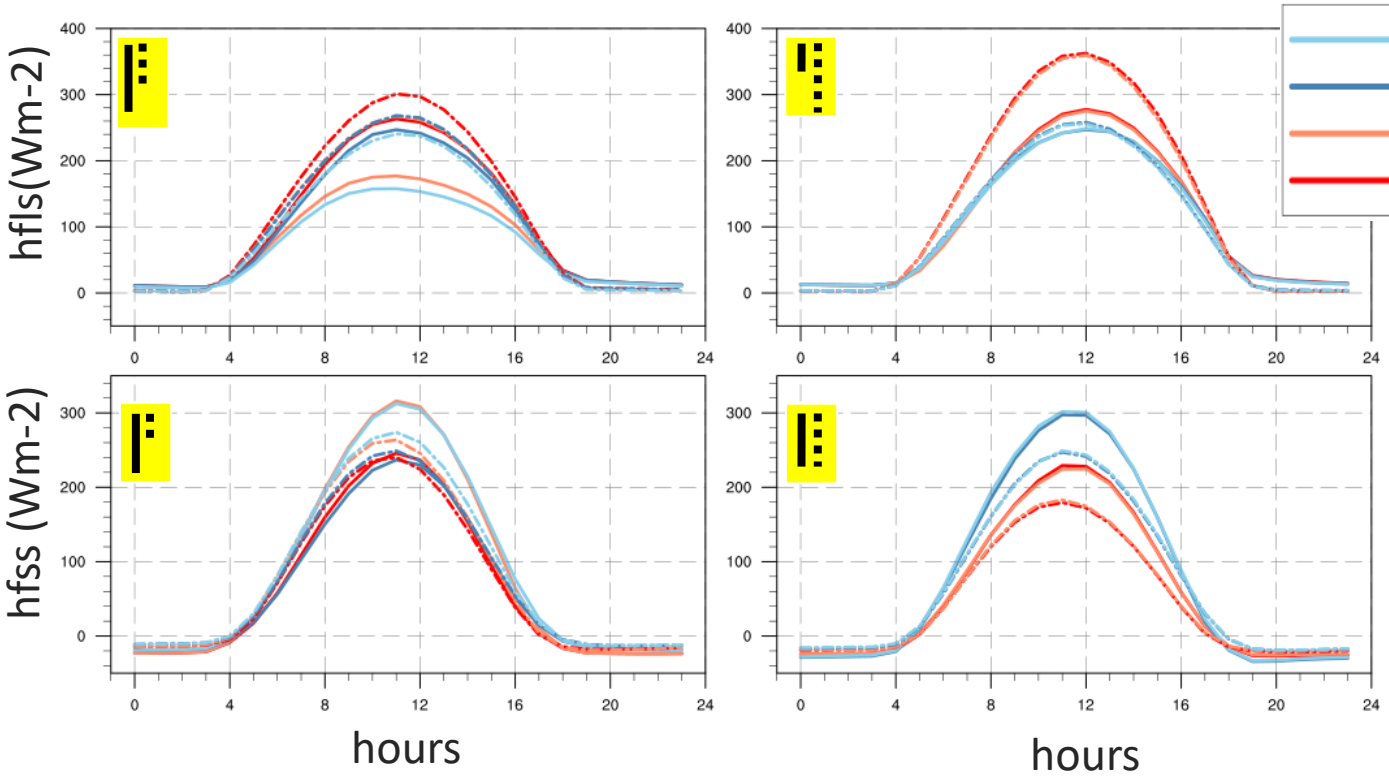


UHOH (more sophisticated: NOAH-MP+MYNN)

FZJ (less sophisticated: NOAH+YSU)

Diurnal cycles: Summer case

Sensitivity to ST changes | **Sensitivity to LU changes**

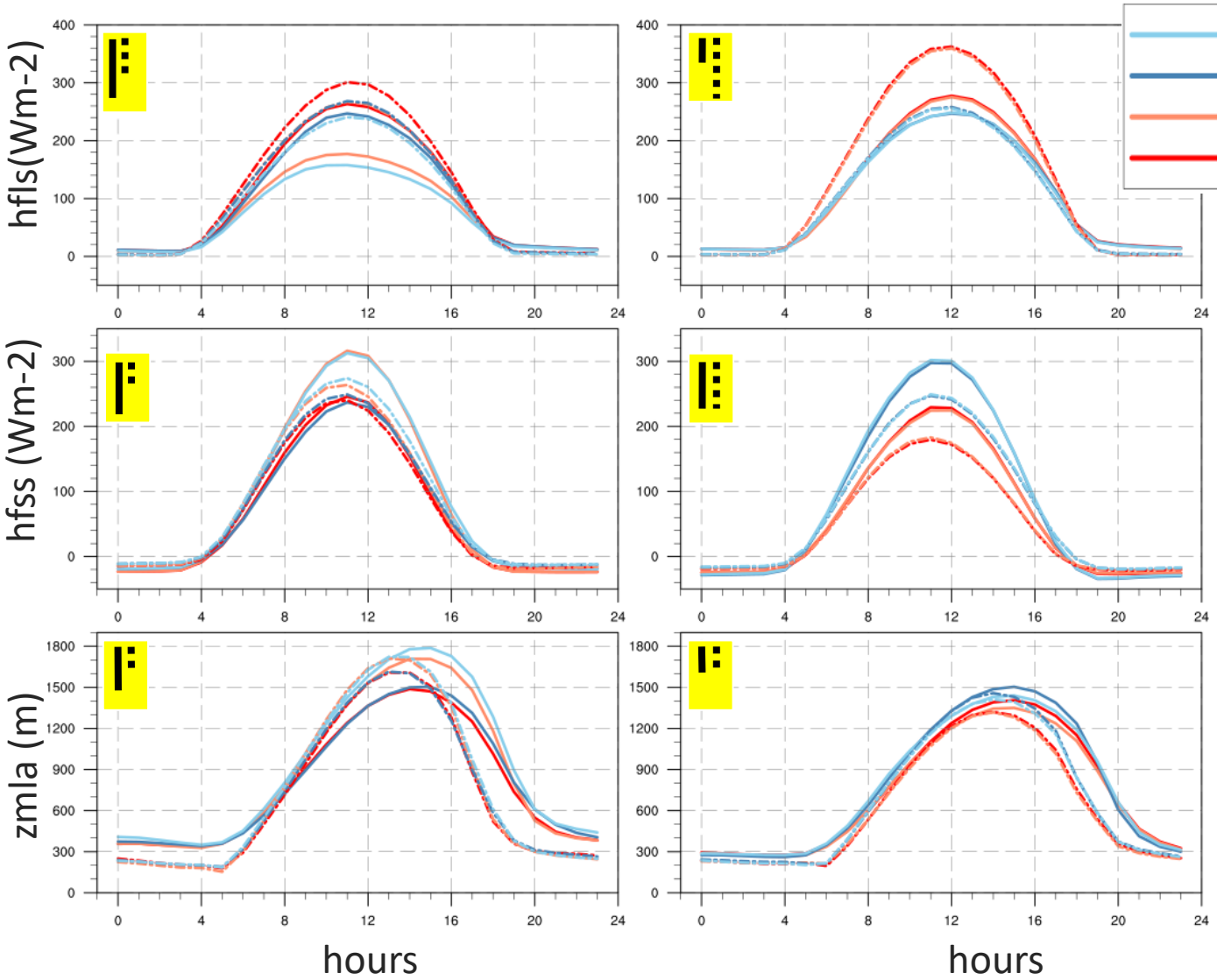


UHOH (more sophisticated: NOAH-MP+MYNN)

FZJ (less sophisticated: NOAH+YSU)

Diurnal cycles: Summer case

Sensitivity to ST changes **Sensitivity to LU changes**

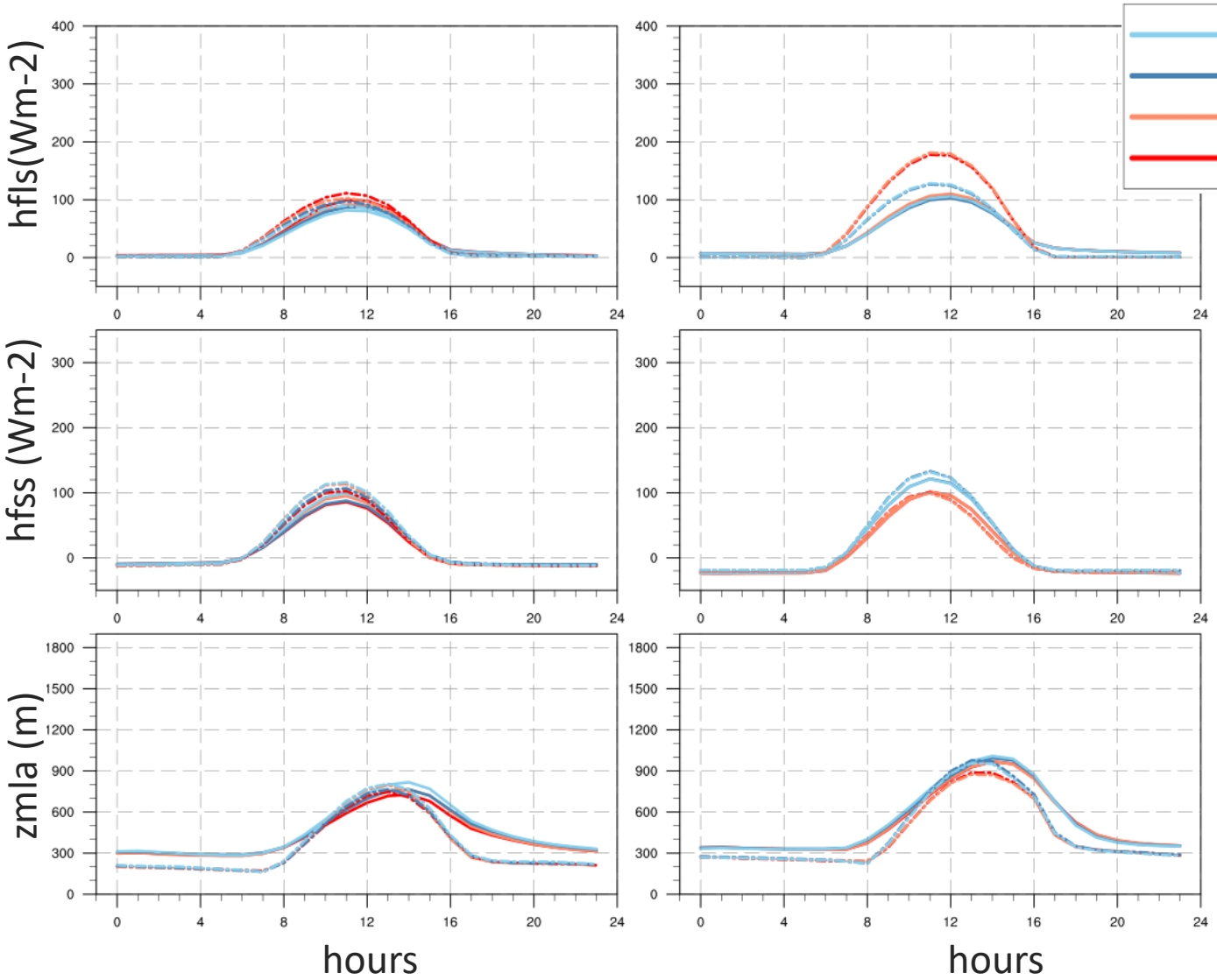


UHOH (more sophisticated: NOAH-MP+MYNN)

FZJ (less sophisticated: NOAH+YSU)

Diurnal cycles: Fall case

Sensitivity to ST changes **Sensitivity to LU changes**

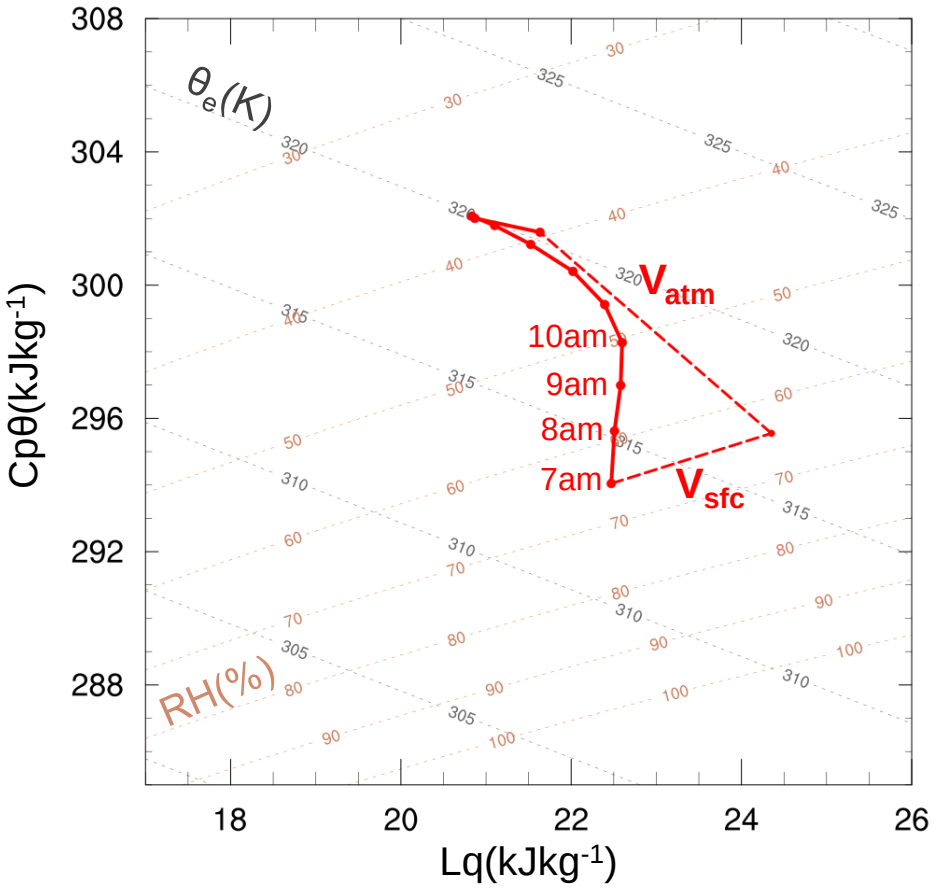


UHOH (more sophisticated: NOAH-MP+MYNN)

FZJ (less sophisticated: NOAH+YSU)

LA feedbacks: Methodology

Mixing Diagram: Well mixed **PBL** can be represented with **near surface humidity** and **temperature**

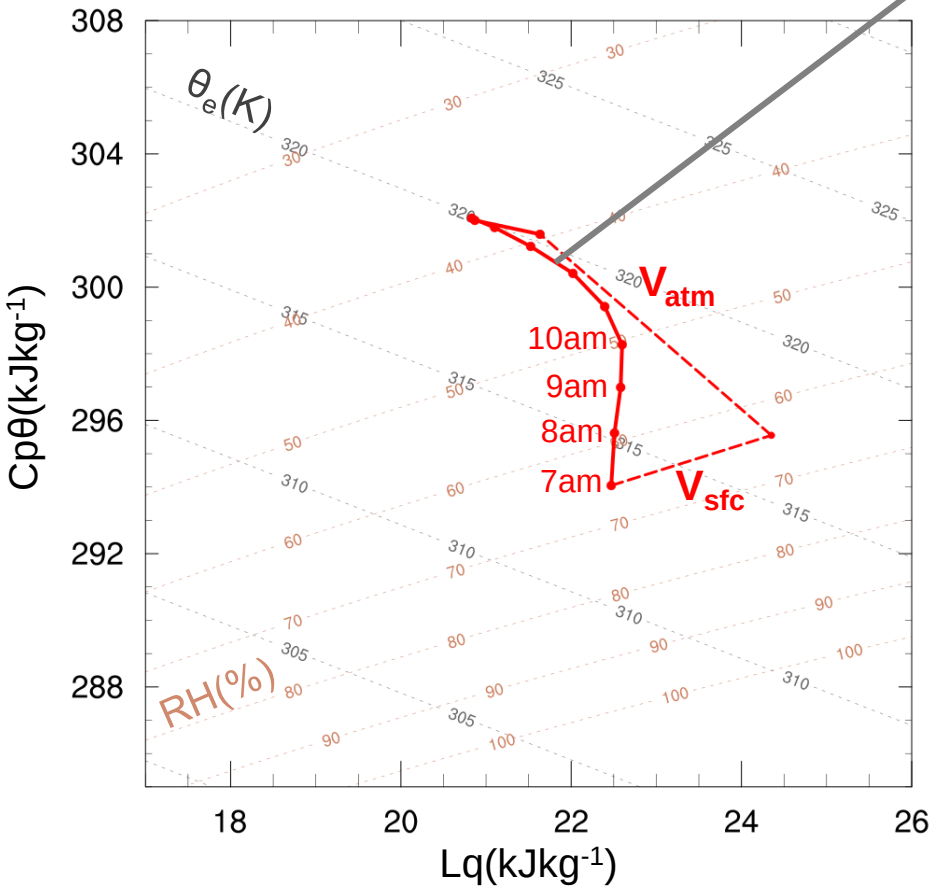


Santanello et al.(2009)J. Hydrometeor, 10, 577–599. doi:10.1175/2009JHM1066.1

LA feedbacks: Methodology

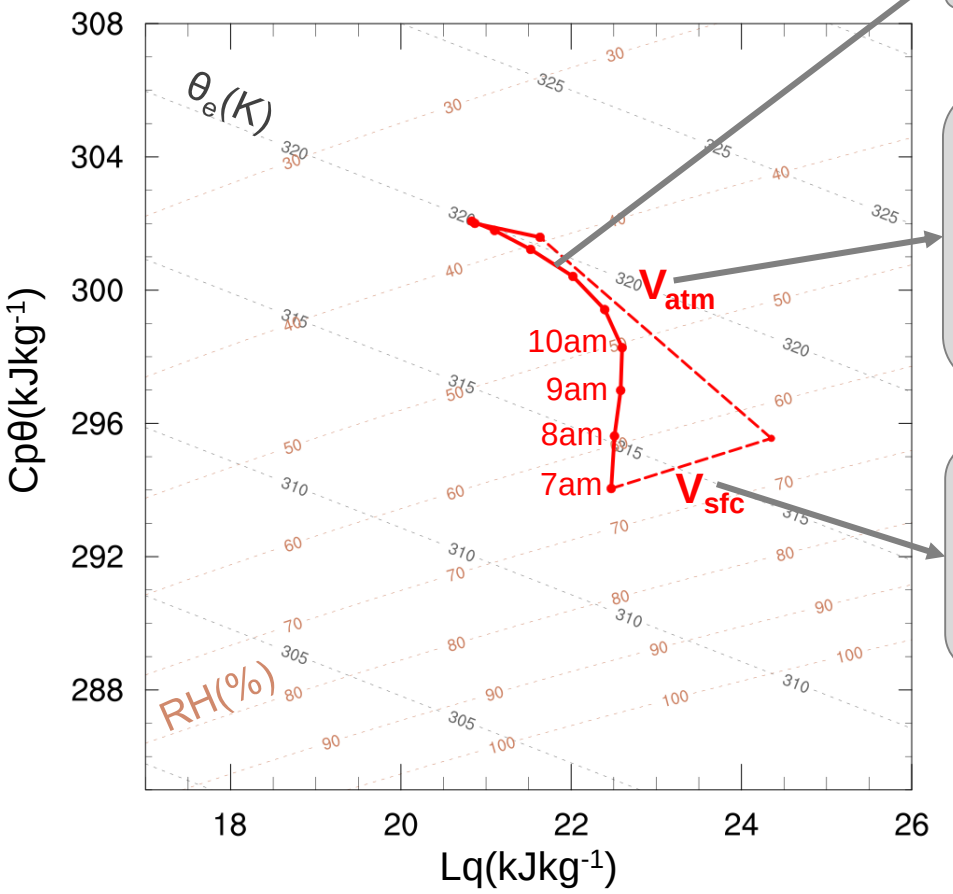
Mixing Diagram: Well mixed **PBL** can be represented with **near surface humidity** and **temperature**

Daily coevolution of moisture and heat

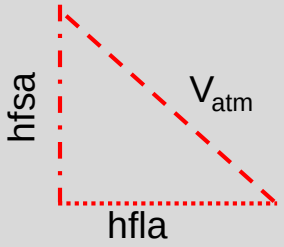


LA feedbacks: Methodology

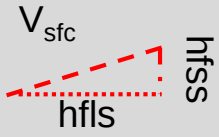
Mixing Diagram: Well mixed **PBL** can be represented with **near surface humidity** and **temperature**



Daily coevolution of moisture and heat



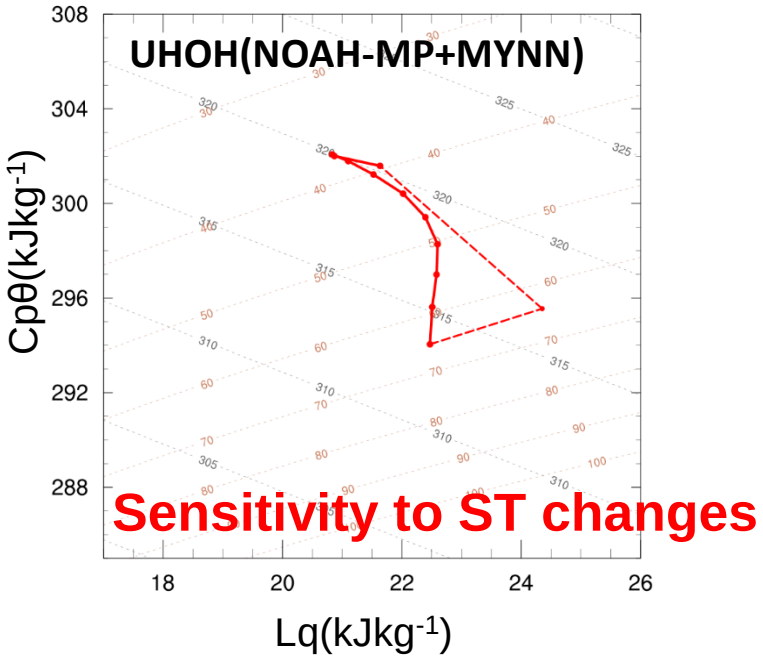
Quantifies the impact of advective and entrainment fluxes (from the diagram)



Quantifies the impact of surface fluxes (from model output)

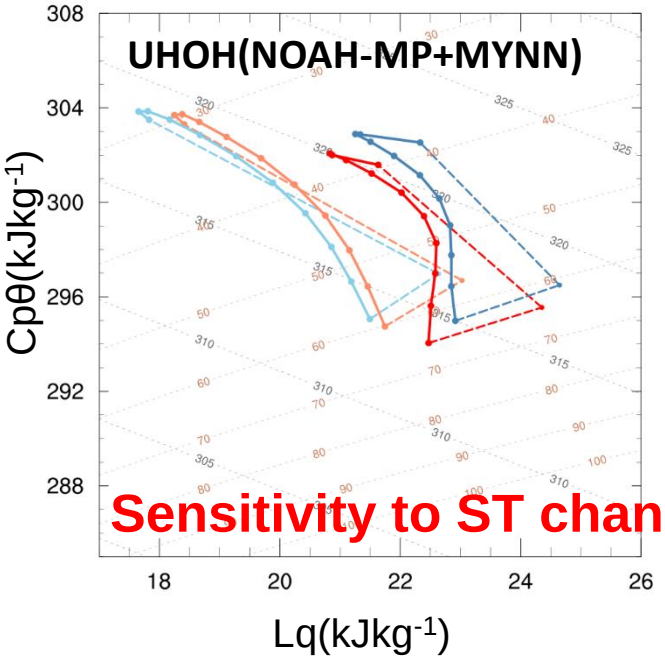
Santanello et al.(2009)J. Hydrometeor, 10, 577–599. doi:10.1175/2009JHM1066.1

Mixing diagrams: Summer case



Sensitivity to ST changes

Mixing diagrams: Summer case

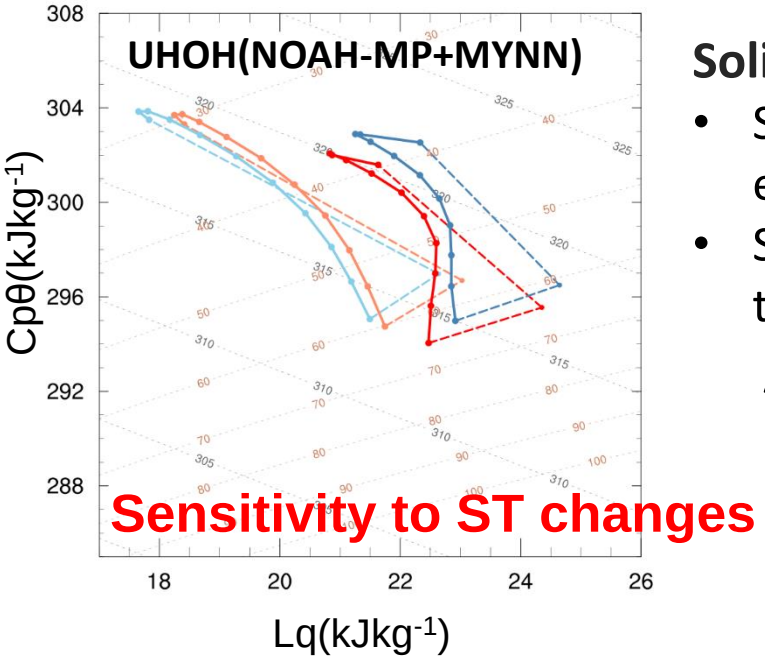


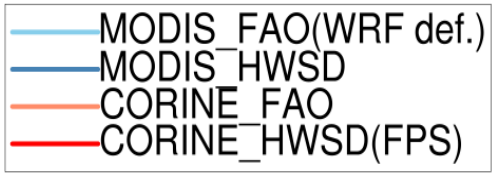
Solid lines:

- Sensitivity to changes in **ST** evident (colors)
- Stronger PBL drying with FAO than with HWSD (line shapes)

MODIS_FAO(WRF def.)
MODIS_HWSD
CORINE_FAO
CORINE_HWSD(FPS)

Mixing diagrams: Summer case





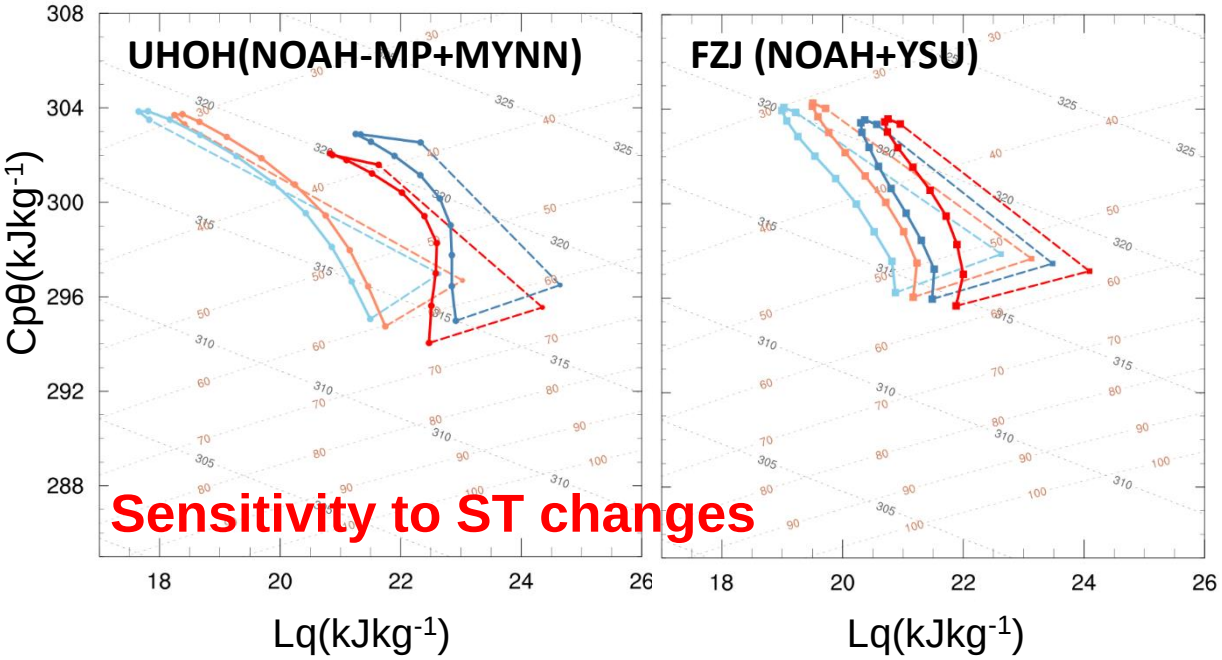
Solid lines:

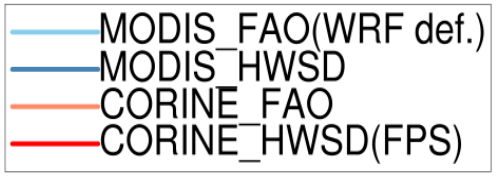
- Sensitivity to changes in **ST** evident (colors)
- Stronger PBL drying with FAO than with HWSD (line shapes)

Atmospheric vector V_{atm} :

- More atmospheric drying than surface moistening with FAO

Mixing diagrams: Summer case

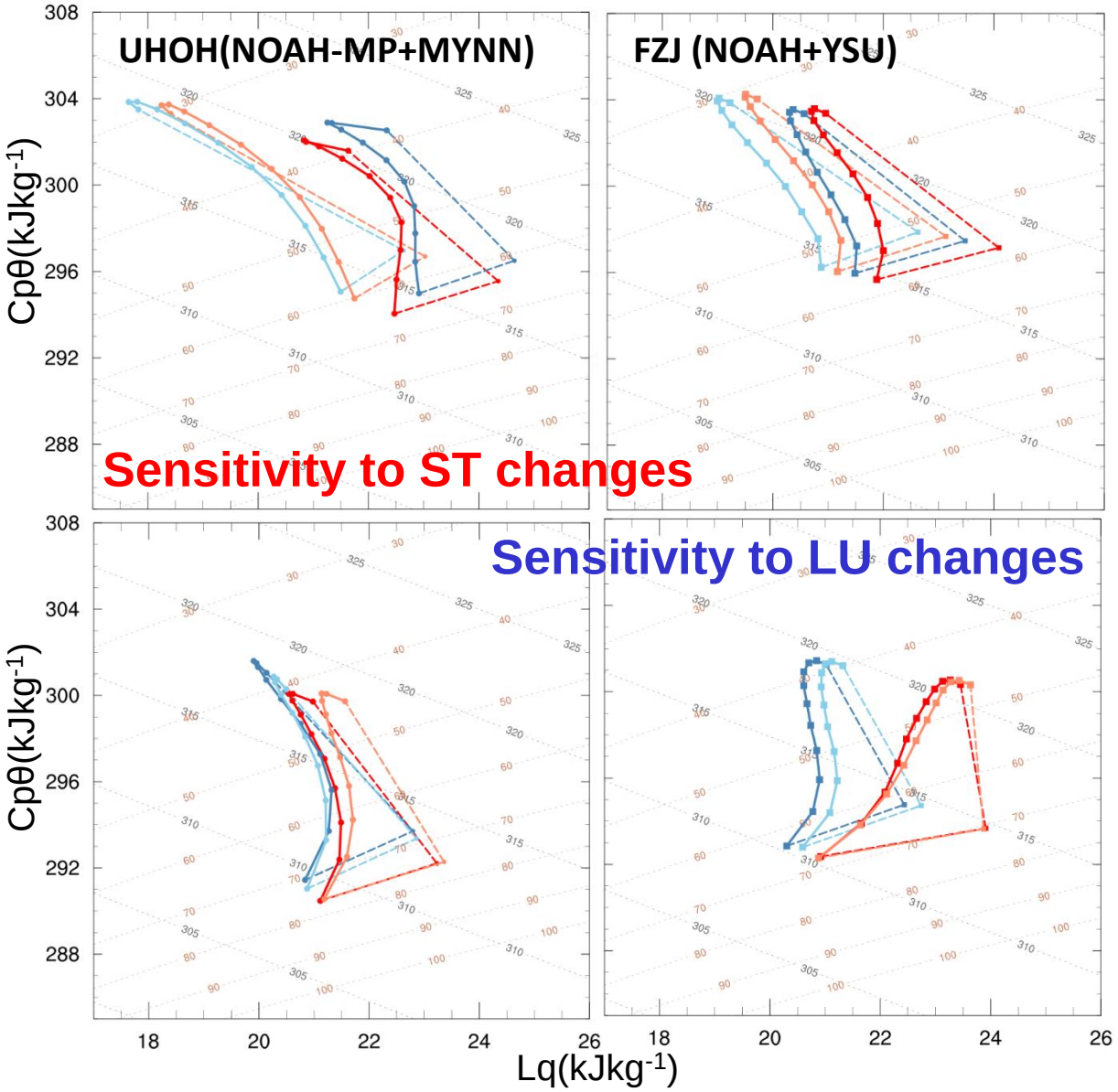




Solid lines:

- Effects of the **ST** changes on PBL evolution in FZJ not as pronounced as in UHOH

Mixing diagrams: Summer case



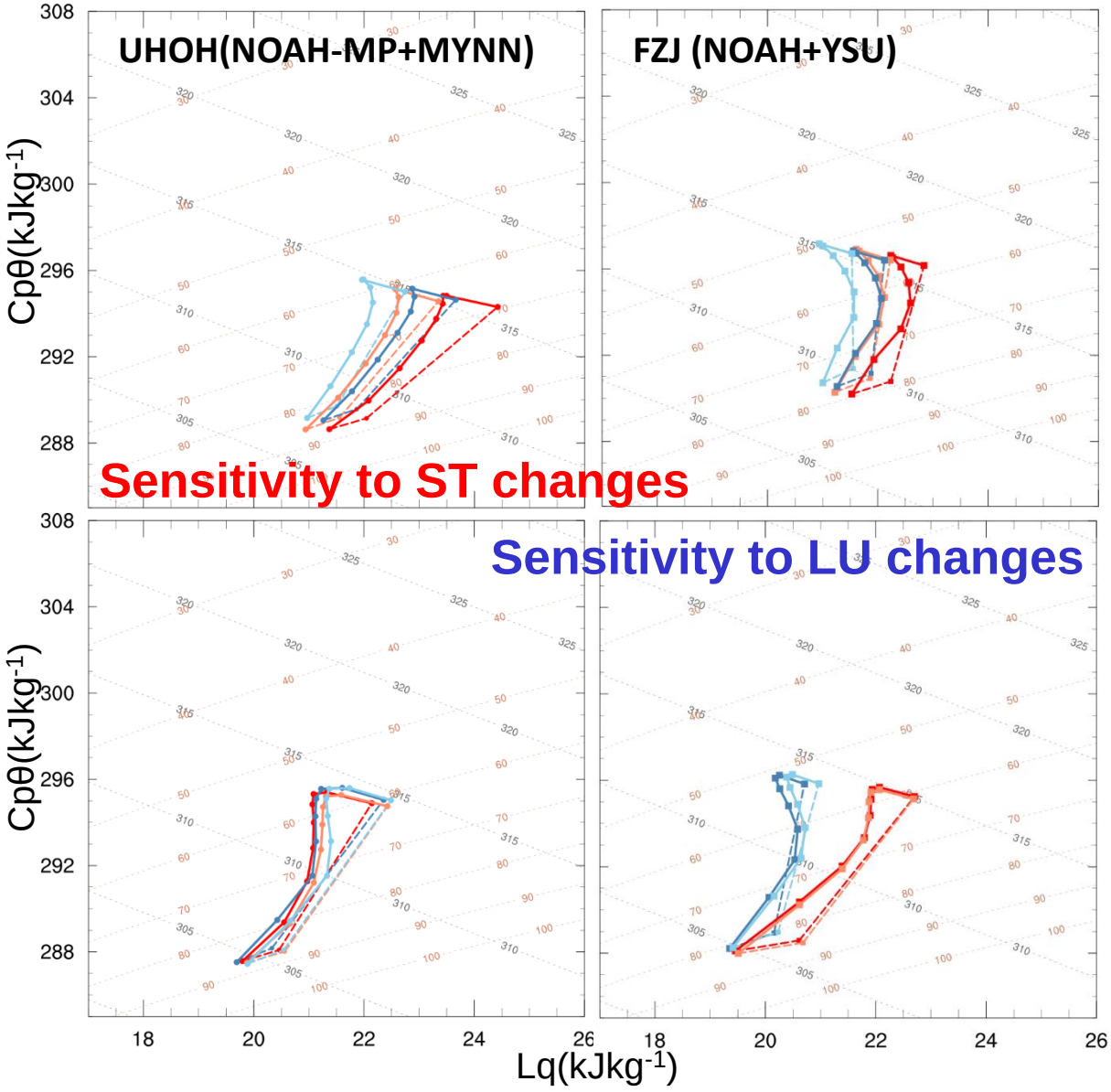
Solid lines:

- Effects of the **LU** change on the PBL evolution clearly evident in FZJ simulations.

Surface vector V_{sfc}:

- Strong moistening with CORINE in FZJ due to higher hfls than with MODIS

Mixing diagrams: Fall case



Solid lines:

- Effects of the LU and **ST** changes not as evident as for the summer case
- **FZJ** more sensitive to **LU** changes than UHOH

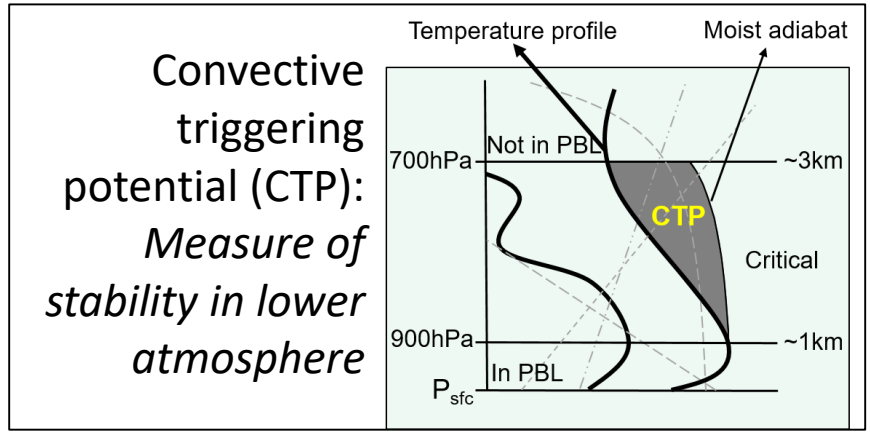
Atmospheric vector V_{atm}:

- Atmospheric impact on the PBL evolution significantly larger than the impact from the surface

Convection indices: CTP

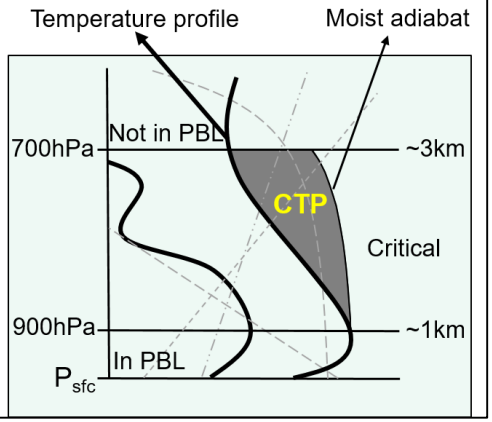
- Calculated from the morning profiles for the days without morning precipitation
- UHOH model configuration only

Convective triggering potential (CTP): *Measure of stability in lower atmosphere*

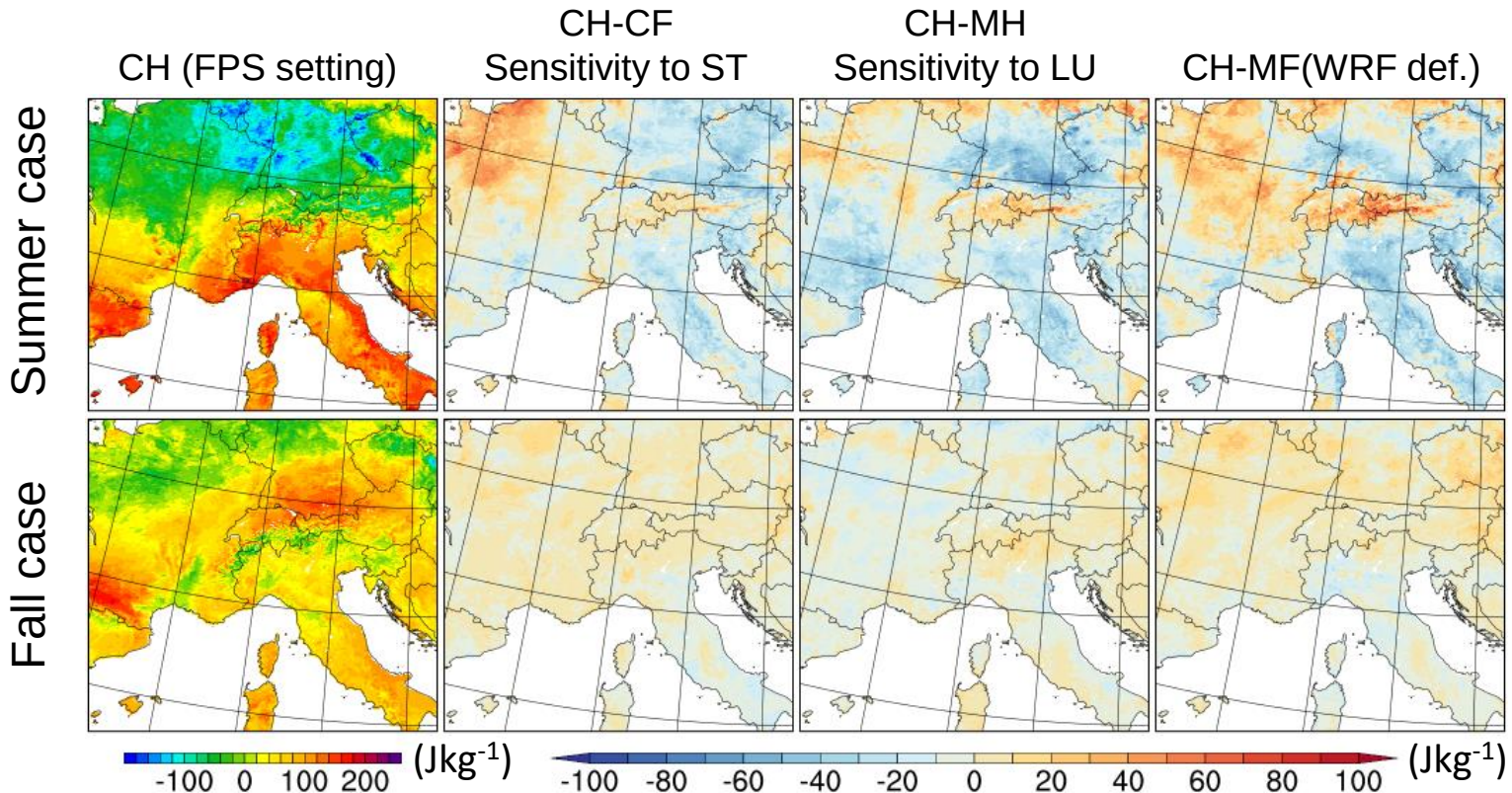


Convection indices: CTP

Convective triggering potential (CTP): *Measure of stability in lower atmosphere*



- Calculated from the morning profiles for the days without morning precipitation
- UHOH model configuration only

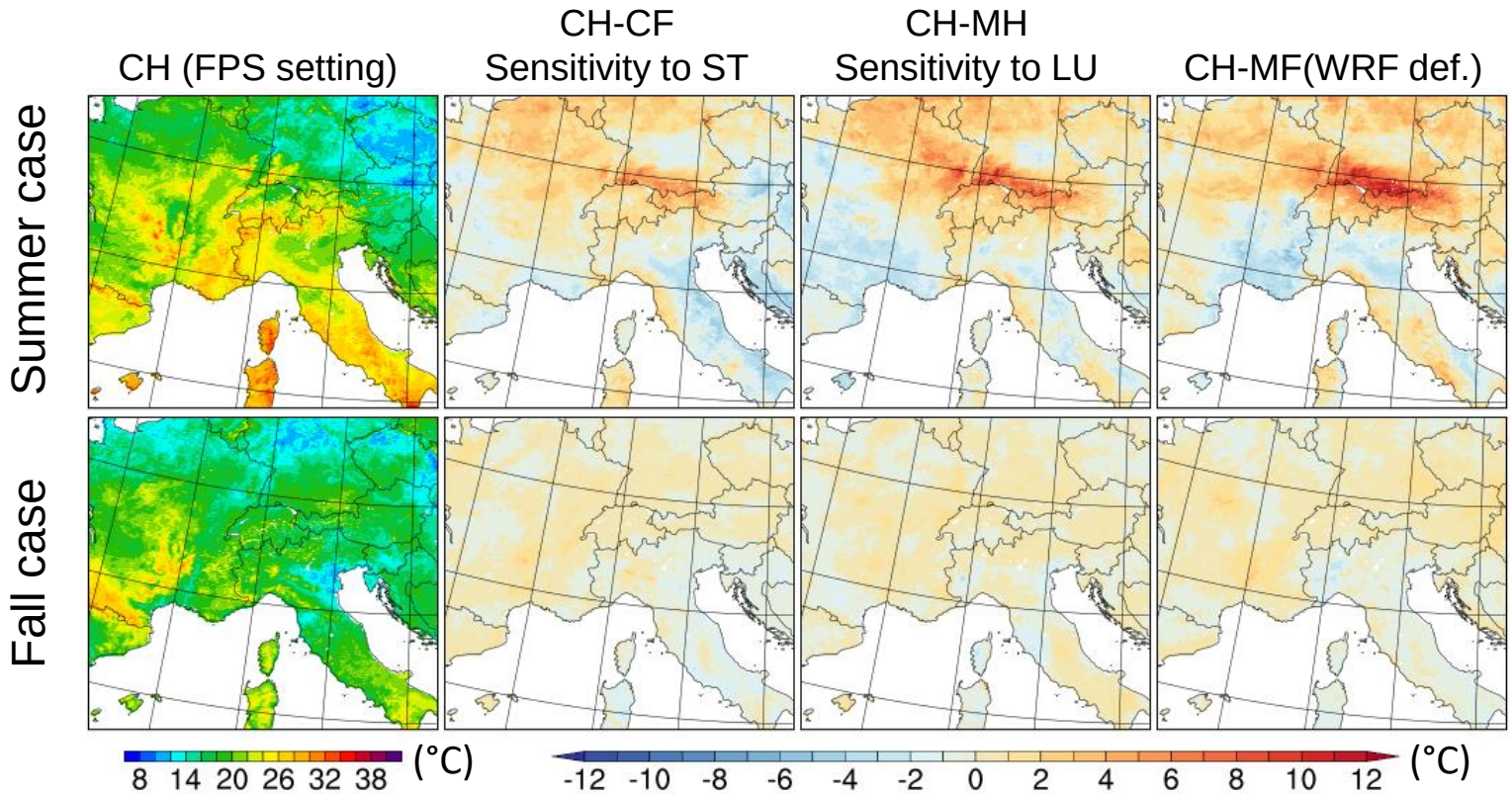


Evidently stronger impact of the land surface changes in the summer case

Convection indices: HI_{low}

Humidity Index at low levels: $HI_{low} = (T_{950} - T_{d950}) + (T_{850} - T_{d850})$

- Calculated from the morning profiles for the days without morning precipitation
- UHOH model configuration only

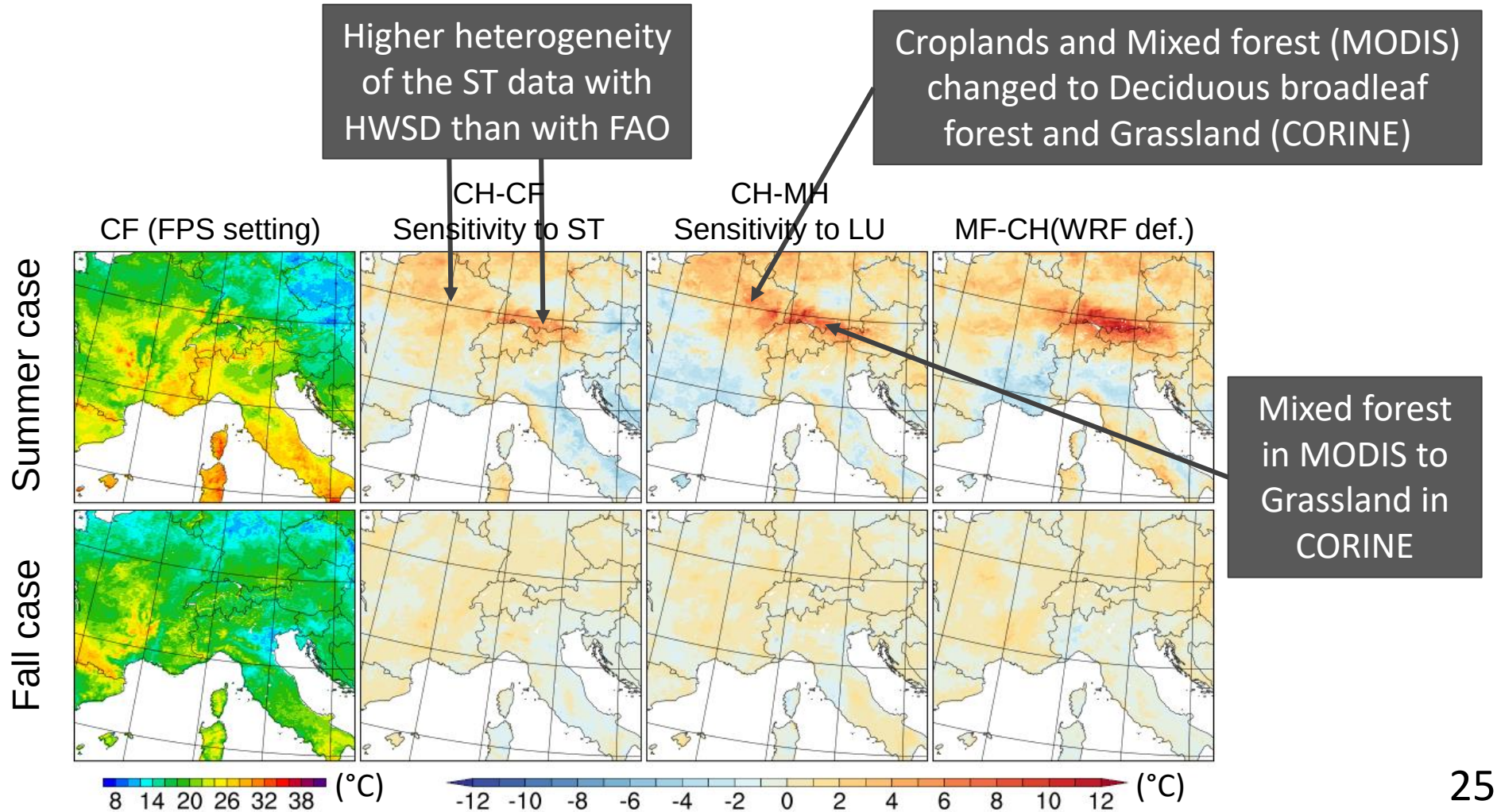


Convection indices: HI_{low}

Humidity Index at low levels: $HI_{low} = (T_{950} - T_{d950}) + (T_{850} - T_{d850})$

Higher heterogeneity of the ST data with HWSD than with FAO

Croplands and Mixed forest (MODIS) changed to Deciduous broadleaf forest and Grassland (CORINE)



Mixed forest in MODIS to Grassland in CORINE

Preliminary conclusions

2 LU maps | 2 ST maps | 2 WRF configs. | 2 case studies

8 CP simulations for 2 cases ~**1 month** periods

Dry days **(Mixing Diagram)**

Convective indices **(CTP, HI_{low})**

SQ1: Sensitivity of WRF to land surface static data

- Evident impact of ST and LU changes on the model output: surface variables, PBL evolution, atmospheric stability and humidity in the lower atmosphere
- Strength of the sensitivity to a specific change depend on the model configuration

SQ2: Sensitivity of WRF to the configuration

- Less sophisticated FZJ (NOAH+YSU) configuration more sensitive to LU changes, and more sophisticated UHOH (NOAH-MP+MYNN) more sensitive to ST changes in representing PBL evolution

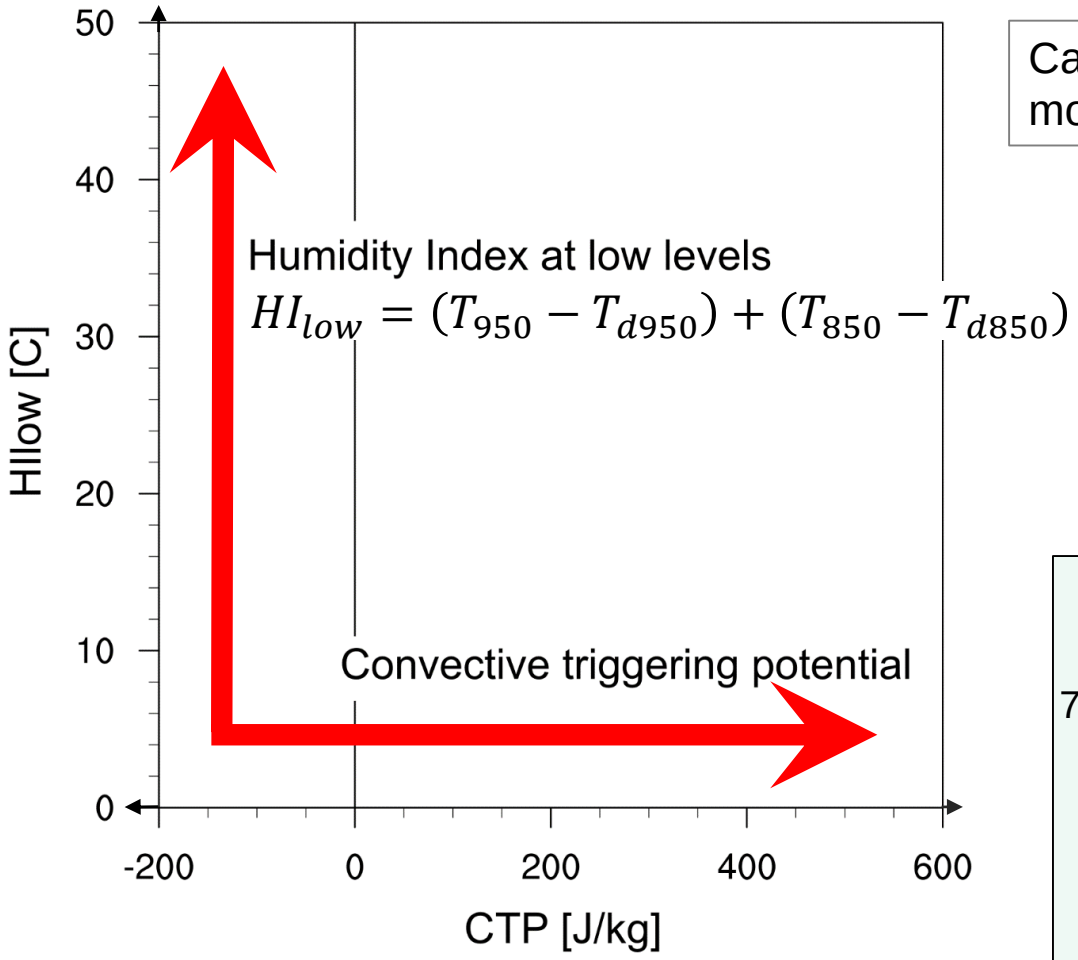
SQ3: Sensitivity of WRF to season

- Sensitivity of WRF higher to the land surface changes in the summer case

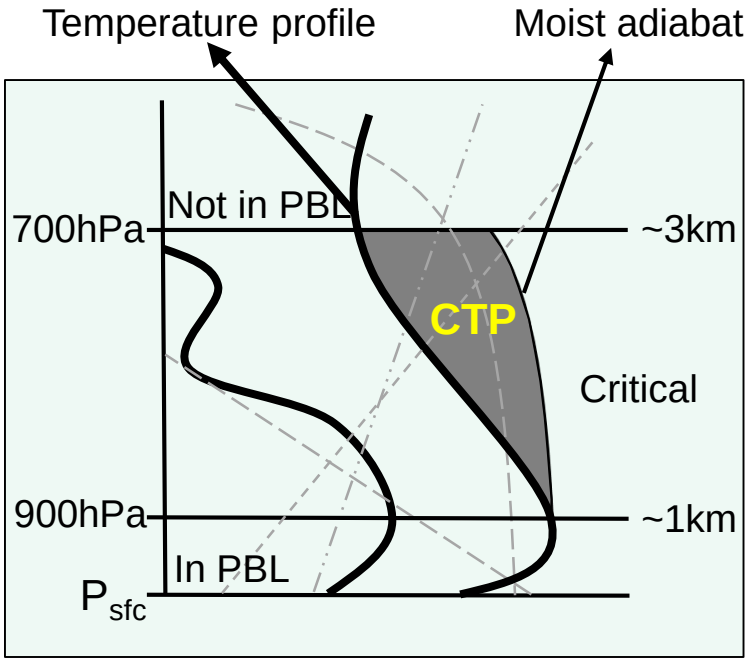
Thank you for your attention

co-funded by FEDER/ERDF EU funds
CGL2016-79210-R
MULTI-SDM
CGL2015-66583-R
BES-2016-078158

Convection: CTP-HI$_{low}$

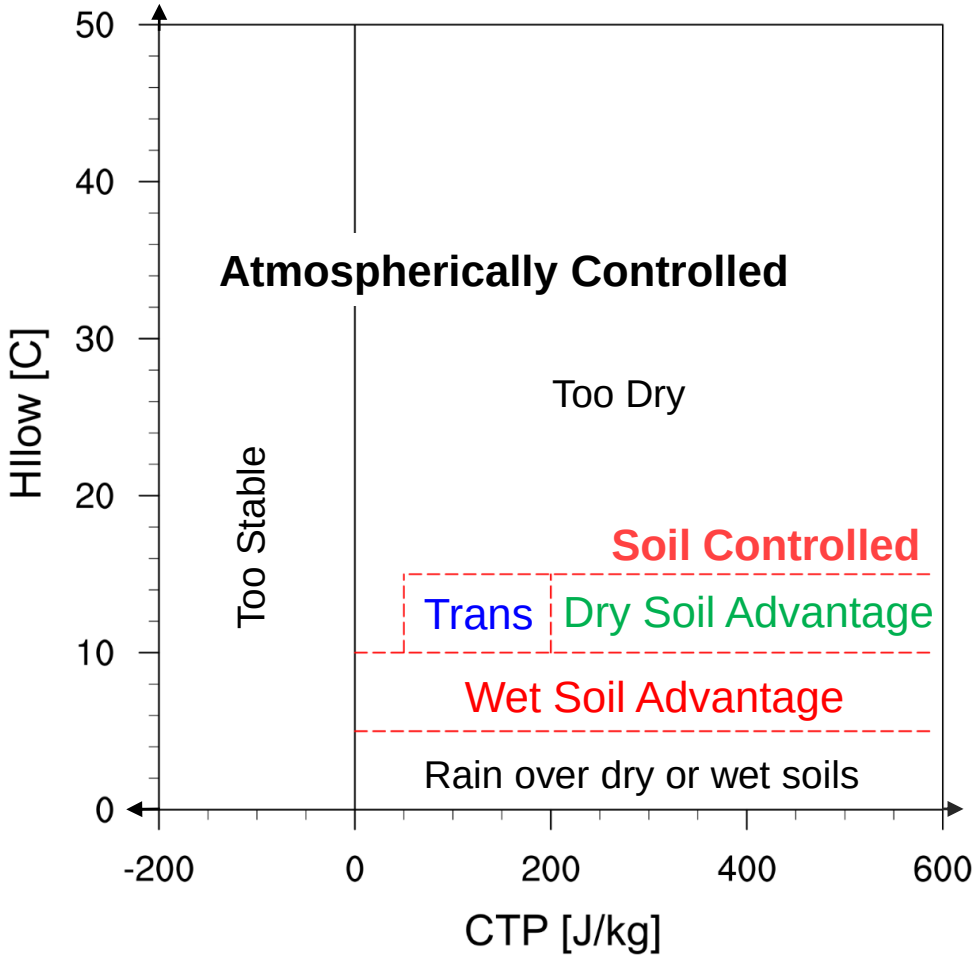


Calculated from early morning heat and moisture profiles



Findell, K.L. & E.A. Eltahir (2003), J. Hydrometeor., 4, 552–569, https://doi.org/10.1175/1525-7541(2003)004<0552:ACOSML>2.0.CO;2

Convection: CTP-HI_{low}



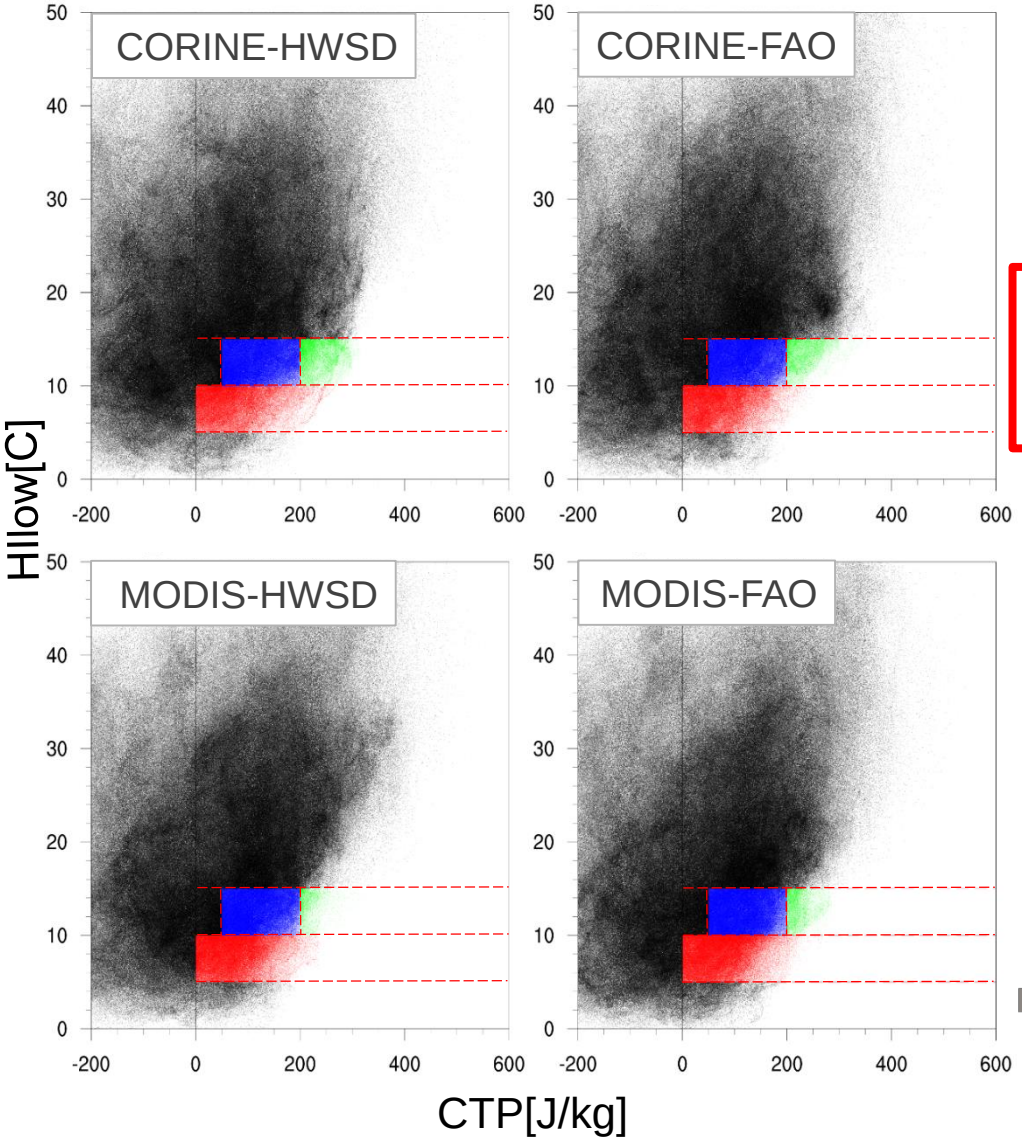
$CTP\text{-}HI_{low}$ regimes:

1. **Atmospherically controlled (Atm)**
(Too stable to rain; too dry to rain; rain everywhere)
2. **Dry soil advantage (DSA) – negative feedback**
(rain favoured over dry soils)
3. **Wet soil advantage(WTA) – positive feedback**
(rain favoured over wet soils)
4. **Transition regions (Trans)**
(positive and negative feedbacks possible)

Findell, K.L. & E.A. Eltahir (2003), J. Hydrometeor., 4, 552–569, https://doi.org/10.1175/1525-7541(2003)004<0552:ACOSML>2.0.CO;2

d02:CTP-HI$_{low}$

d02: 01.6.-01.07.2009



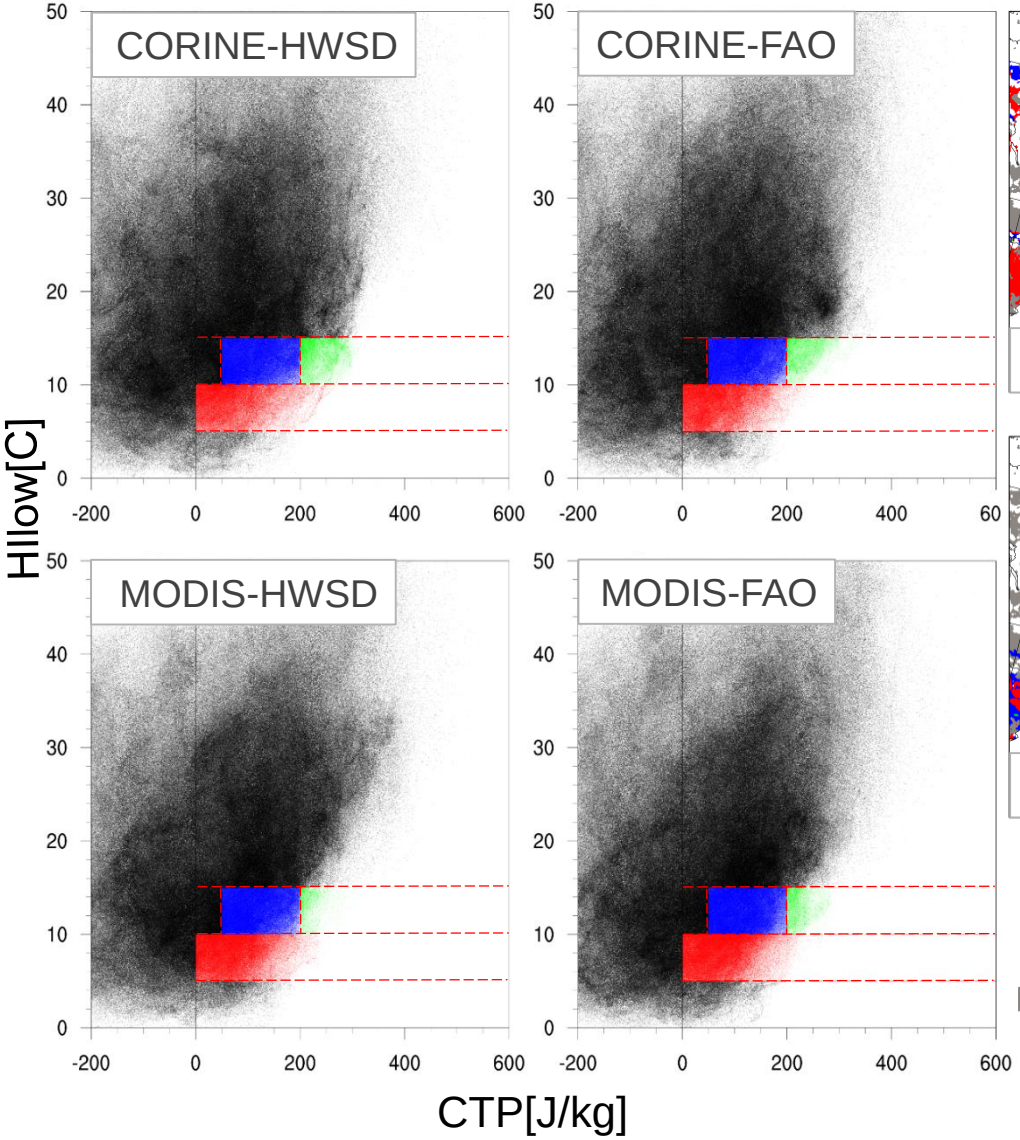
Area fraction

(%)	Atm.	WSA	Trans	DSA
CH	88.5	4.0	6.6	0.9
CF	88.6	4.4	6.4	0.6
MH	87.0	5.5	7.2	0.3
MF	86.3	5.7	7.5	0.5

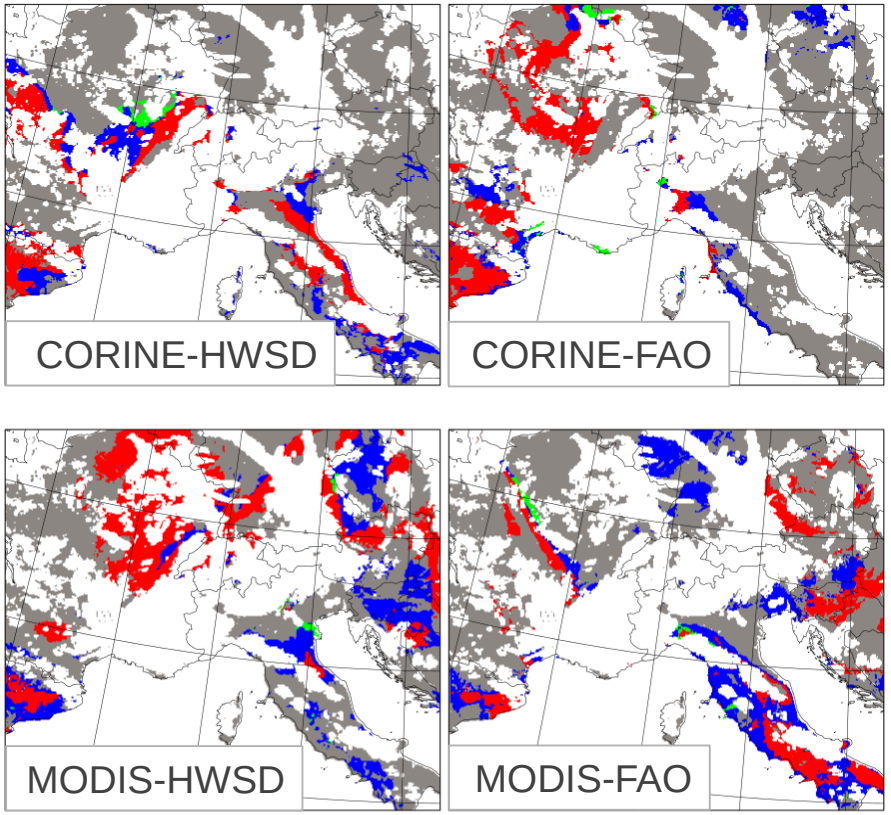
Higher sensitivity to LU changes

d02:CTP-HI$_{low}$

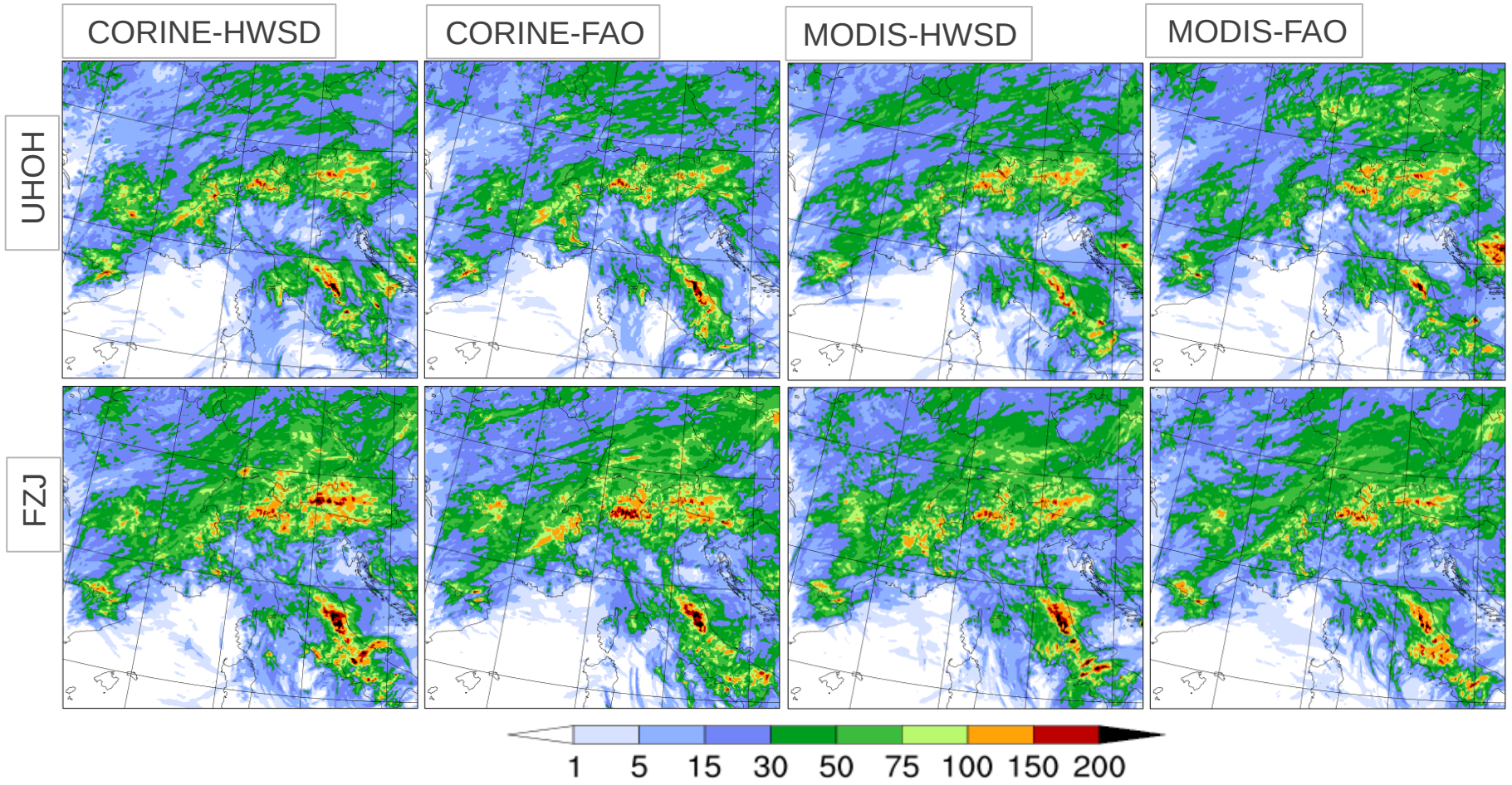
d02: 01.6.-01.07.2009



27.06.2009

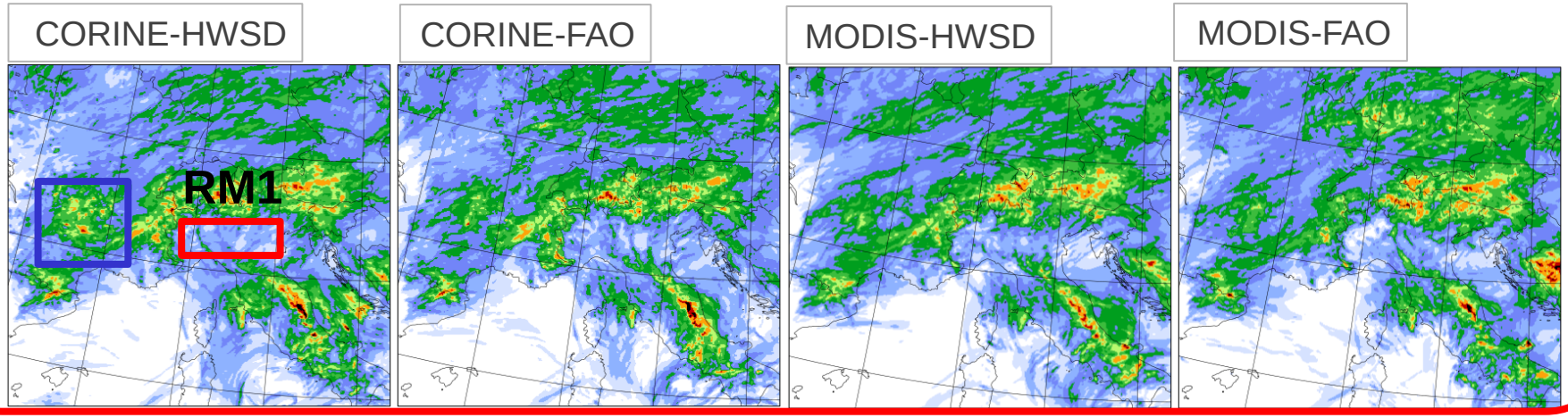


Afternoon Precipitation

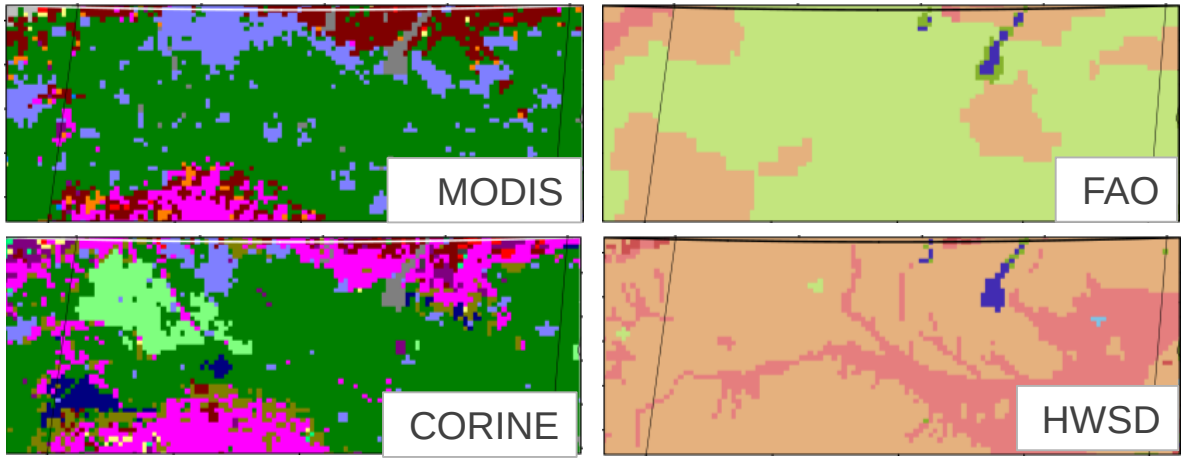


UHOH: MYNN + NOAH-MP
FZJ: YSU + NOAH

Dry days



Surface forcing maps for the limited region:



RM1

- Major changes: **Croplands** and **Mixed Forest** in MODIS into **Permanent Wetlands** and **DB Forest** in CORINE.
- 75% of **clay-loam** in FAO into 50% **loam** and 25% **Sandy Loam** in HWSD

Sensitivity to LS forcing

Averages for RM1 over 30-day period, 1.6.2009 - 1.7.2009