The Role of the Edwards Plateau and Balcones Escarpment in Texas in Modulating August Precipitation:
The Importance of Soil Type Contrast

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References

1. **Hu, X.-M.**, and M. Xue (2016), Influence of synoptic sea breeze fronts on the urban heat island intensity in Dallas-Fort Worth, Texas, *Mon. Wea. Rev.*, doi:10.1175/MWR-D-15-0201.1.
2. **Hu, X.-M.**, M. Xue, and R. A. McPherson (2017), The Importance of Soil-Type Contrast in Modulating August Precipitation Distribution near the Edwards Plateau and Balcones Escarpment in Texas, *J. Geophys. Res.*, doi:10.1002/2017JD027035 .
3. **Hu, X.-M.**, M. Xue, R. A. McPherson, E. Martin, D. H. Rosendahl, and L. Qiao (2018), Precipitation dynamical downscaling over the Great Plains, *J. Adv. Modeling Earth Systems*,10.1002/2017MS001154

Impact of Mountainous Terrain

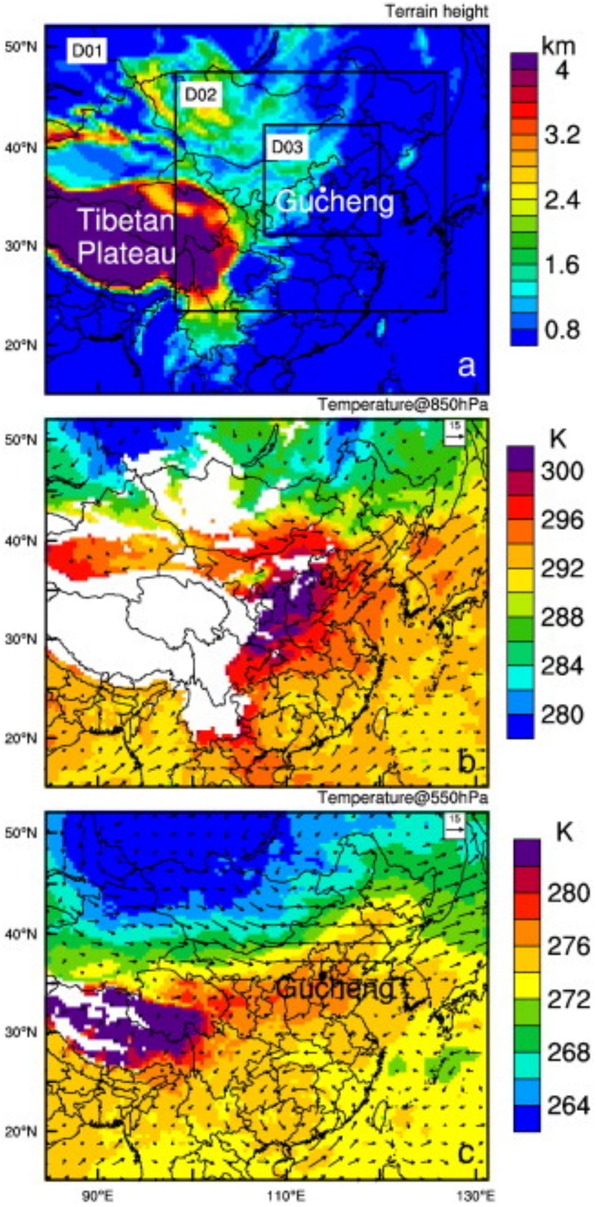
1. Mountain effects under dry conditions
2. Mountain effects under wet conditions

North China Plain, heat source

Terrain height

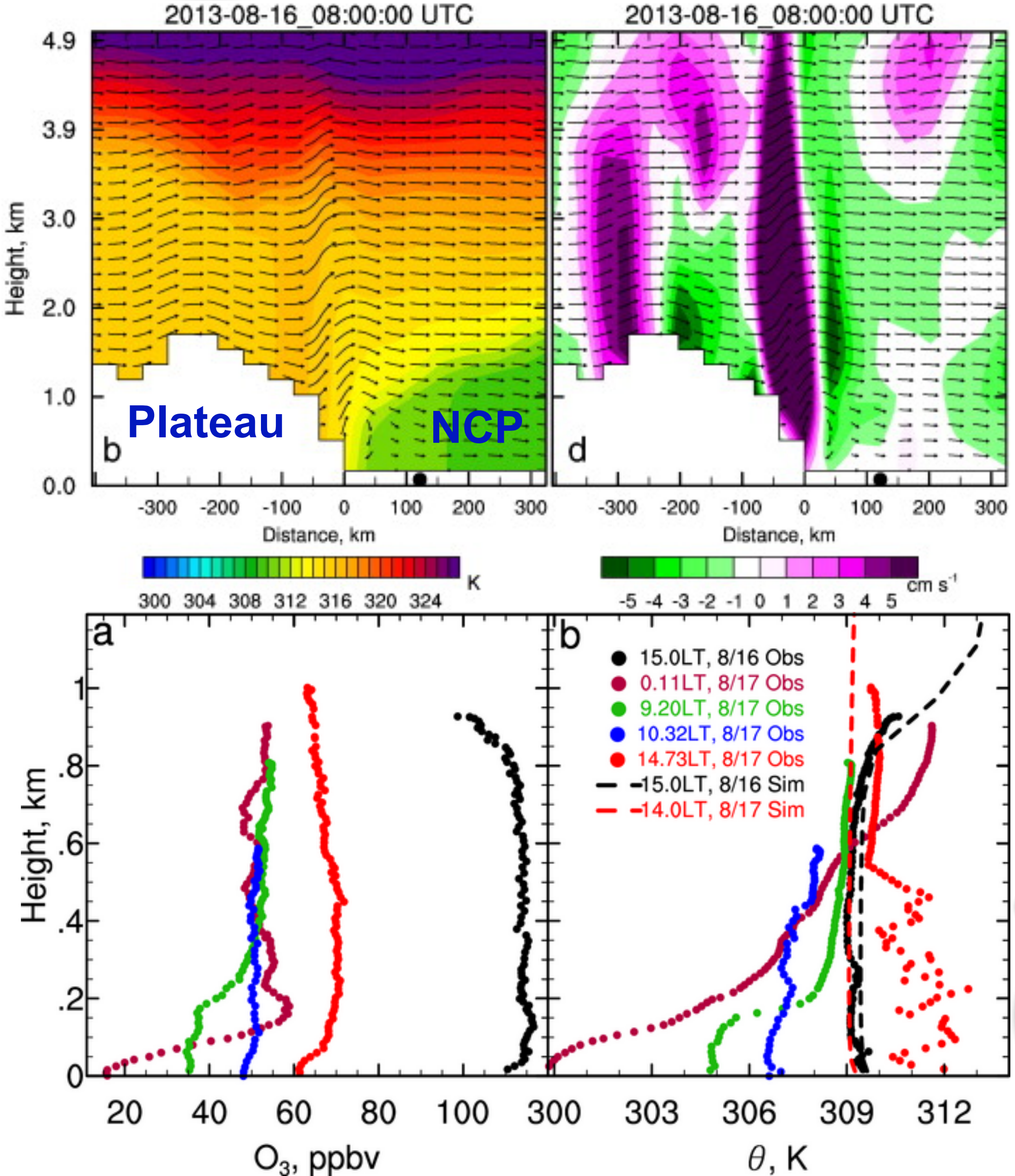
T@850hPa

T@550hPa



The Plateau acts as a heated source in Summer (Hu et al., 2014, STE)

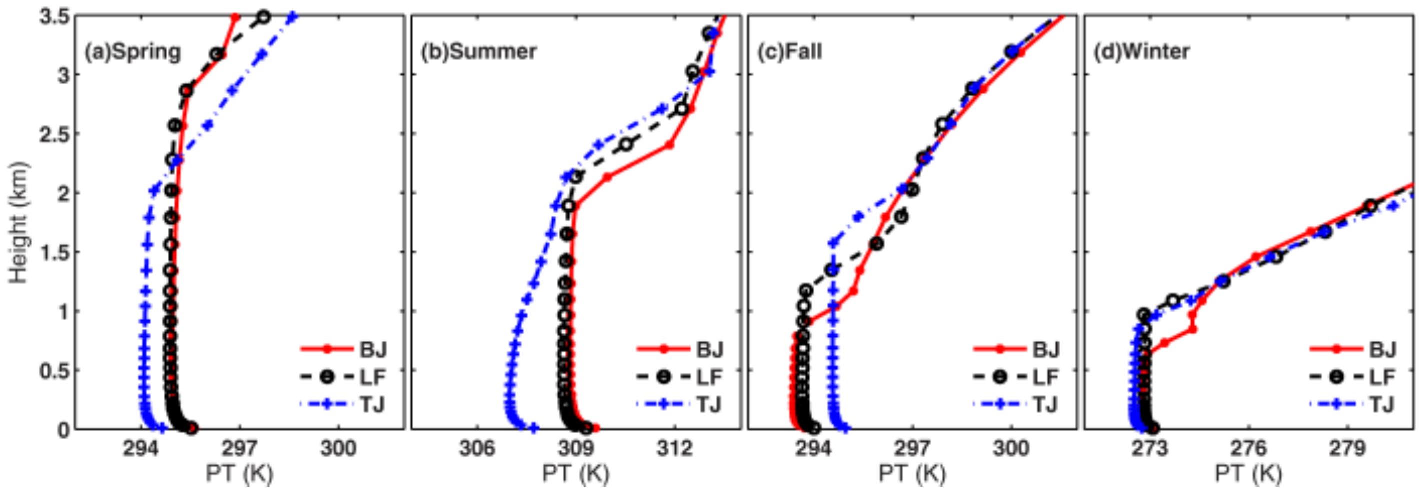
Impact of Mountain-Plain solenoid on boundary layer

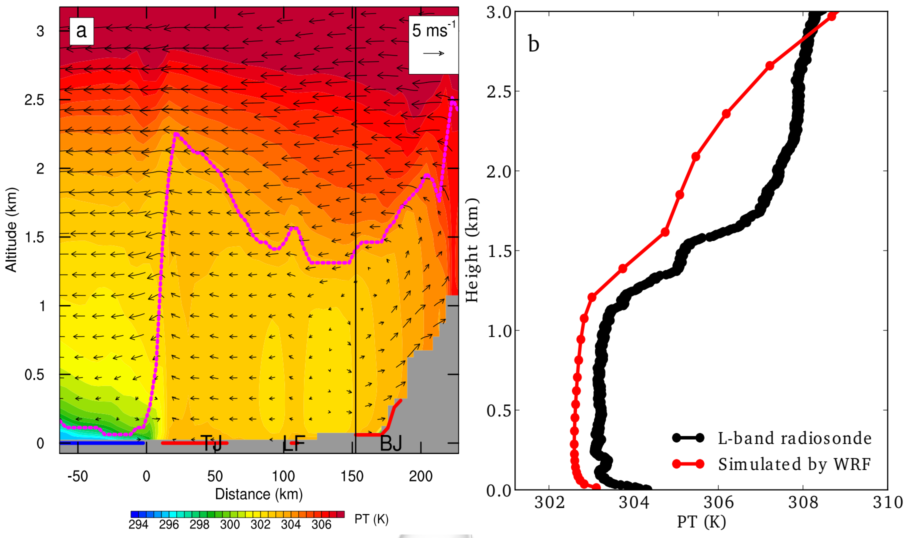


Mountain-Plain solenoid suppress boundary layer development and enhance air pollution (Hu et al., 2014, STE)

Impact of thermal effects on boundary layer

Seasonal study for the Beijing-Tianjin-Hebei region





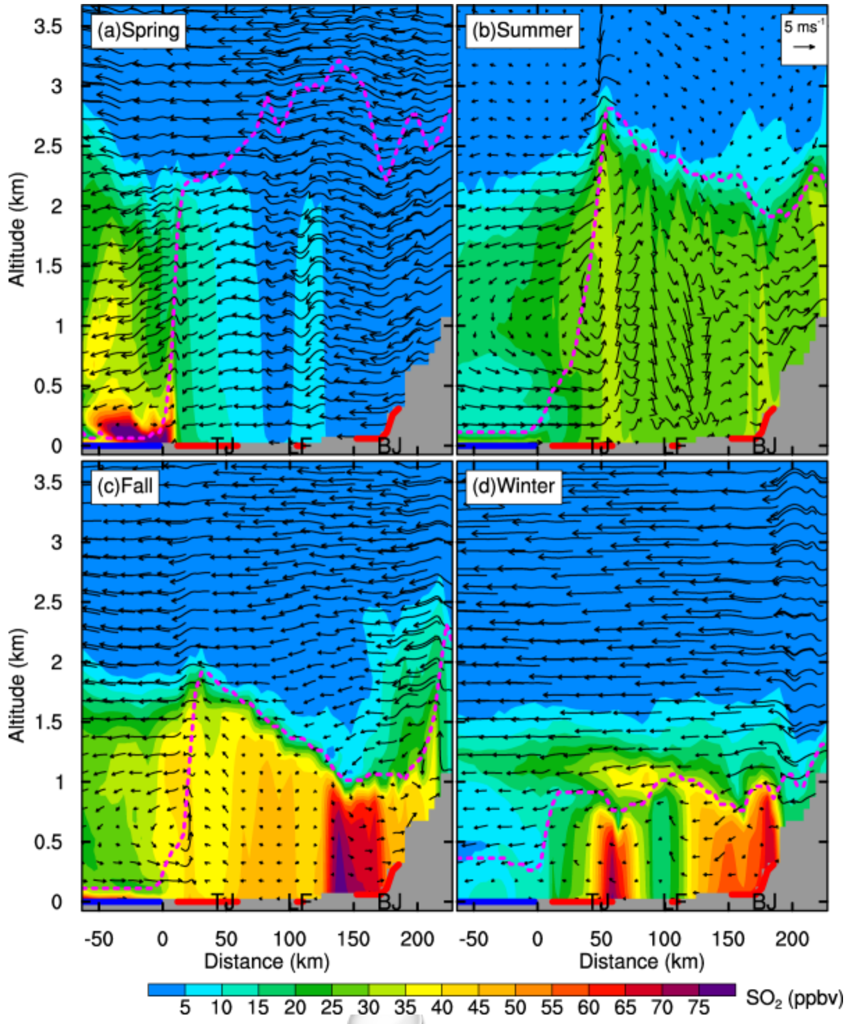
Thermal effects of Plateau partially lead to PBL height spring > summer > fall > winter

Miao and Hu et al. (2015, *JAMES*)

12 September 2010 simulated by WRF and observed by the L-band radiosonde.

Impact of thermal effects

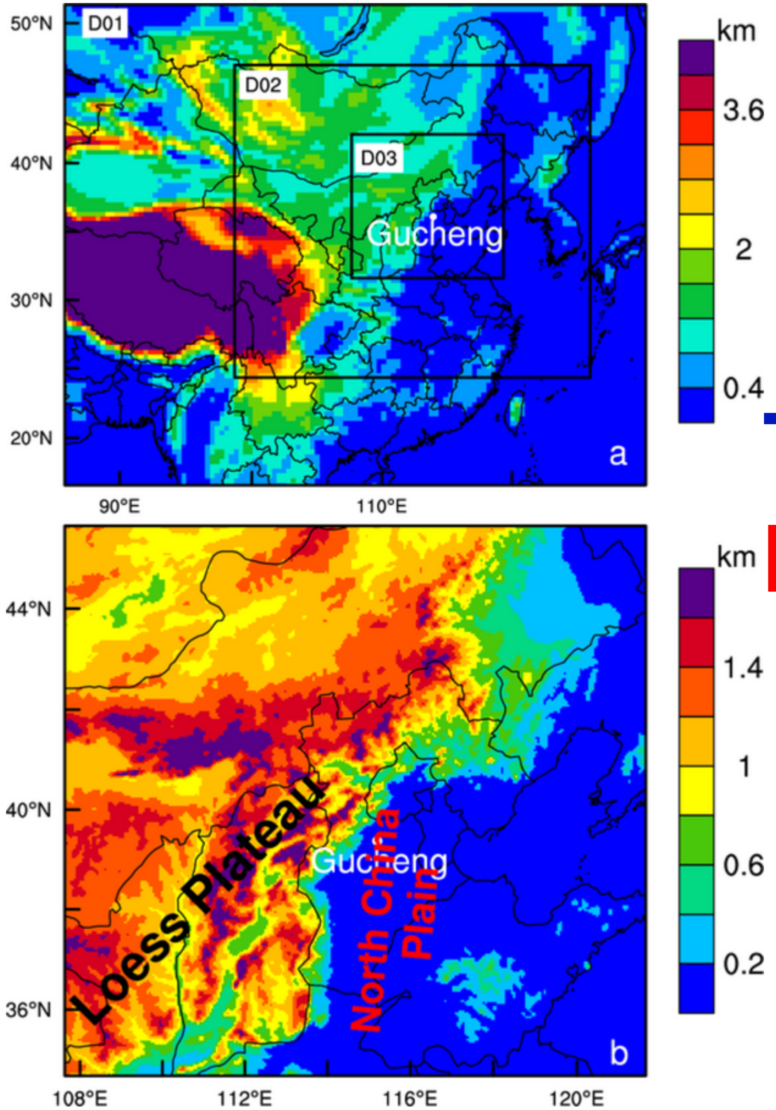
Seasonal variation of pollutants in the boundary layer



Thermal effects of Plateau partially lead to frequent haze events in Fall and Winter

Miao and Hu et al. (2015, *JAMES*)

Effects of Loess Plateau



Thermal (active*) effect

Dynamic (passive) effect

Dynamic effect of Loess Plateau

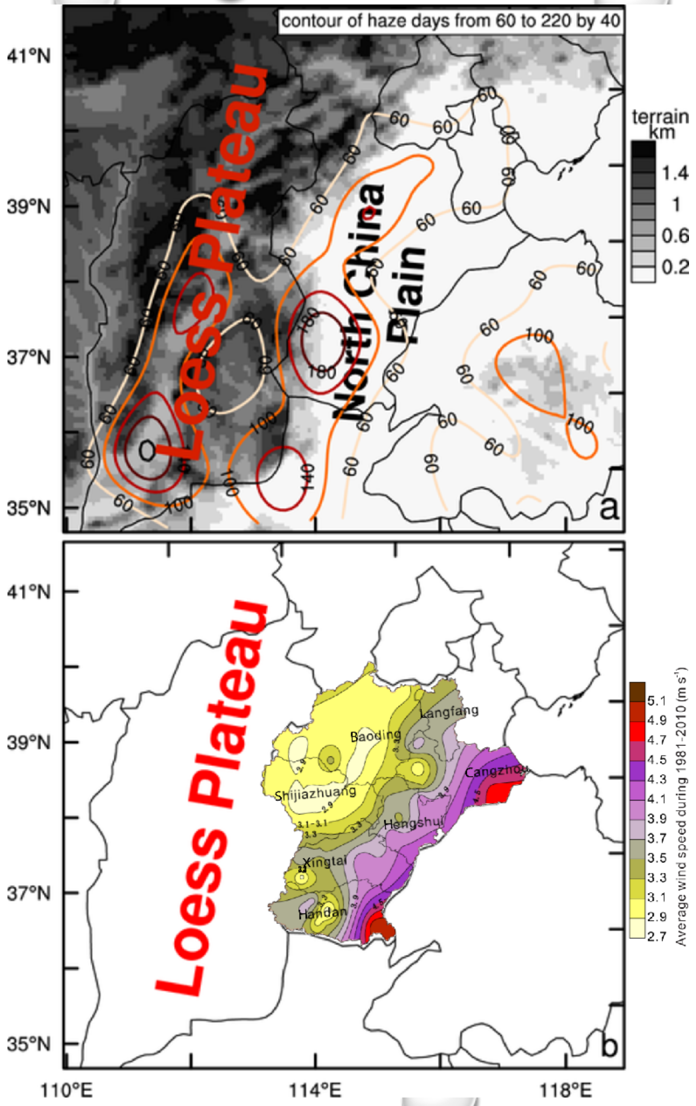
Hu, Li and Xue (2016a, BLM)*

– Identify the dynamic effects of Loess Plateau

– Investigate the impact of such effects on air quality in the North China Plain (NCP)

*Hu, X.-M., et al. (2016a), The Formation of Barrier Winds East of the Loess Plateau and their Effects on Dispersion Conditions in the North China Plains, *Bound.-layer meteor.*, DOI:10.1007/s10546-016-0159-4 .

Spatial distribution of haze days & wind speed



Weak winds in the west of NCP (Fu et al. 2014) **lead to** more frequent haze events in this region (Wu et al. 2014)

Fu GQ et al. (2014) The distribution and trends of fog and haze in the North China Plain over the past 30 years. Atmos Chem Phys 14:11949–11958.
Hu, X.-M., et al. (2016), The Formation of Barrier Winds East of the Loess Plateau and their Effects on Dispersion Conditions in the North China Plains, *Bound.-layer meteor.*, DOI:10.1007/s10546-016-0159-4 .
Wu D et al. (2014) The long-term trend of haze and fog days and the surface layer transport conditions under haze weather in North China. Acta Sci Circumst 34:1–11

Develop a slab model to simulate winds in NCP

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} + fv - g\frac{\partial h}{\partial x} - \phi_x \,, \qquad (1)$$

$$\frac{\partial v}{\partial t} = -u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} - fu - g\frac{\partial h}{\partial y} - \phi_y \,, \qquad (2)$$

$$h = -\tau H\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right), \qquad (3)$$

$$\frac{\partial C}{\partial t} = -u\frac{\partial C}{\partial x} - v\frac{\partial C}{\partial y}\,, \qquad (4)$$

C is the concentration of a passive pollutant

$H \approx 1$ km

h is the perturbation height of the layer top,
representing the pressure perturbation caused by mountain blocking and subsequent flow rising

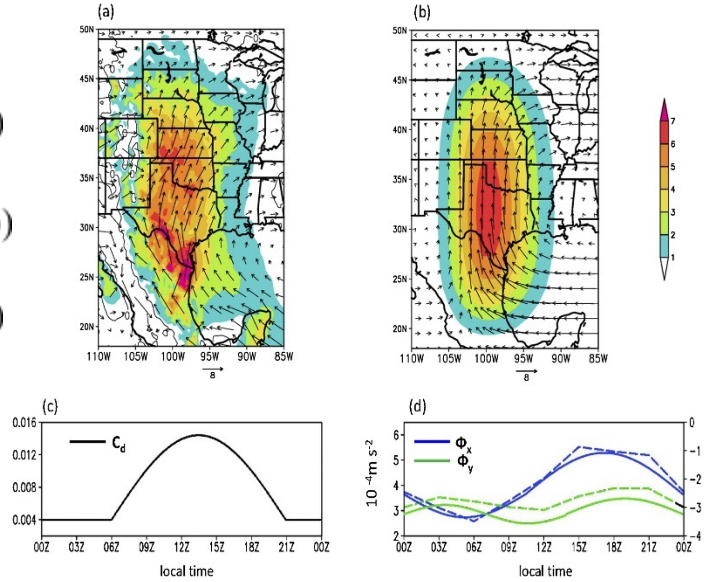
A slab model based on Pu and Dickinson (2014)

Pu and Dickinson (2014, JAS)

$$\frac{\partial u}{\partial t} = fv - g\frac{\partial h'}{\partial x} - \varepsilon u - \phi_x, \qquad (1a)$$

$$\frac{\partial v}{\partial t} = -fu - g\frac{\partial h'}{\partial y} - \varepsilon v - \phi_y, \qquad (1b)$$

$$h' = -\tau H\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right), \qquad (1c)$$



Hu (2016, BLM)

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} + fv - g\frac{\partial h}{\partial x} - \phi_x, \qquad (1)$$

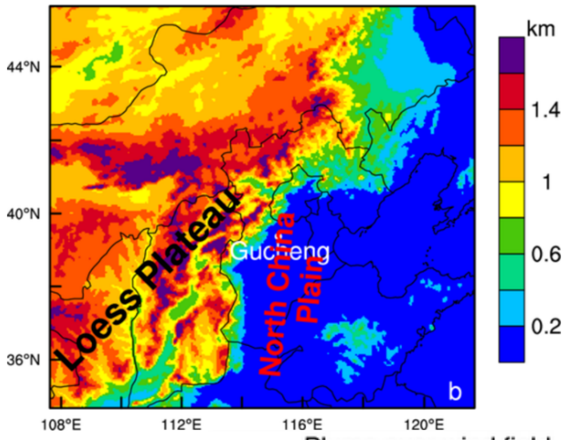
$$\frac{\partial v}{\partial t} = -u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} - fu - g\frac{\partial h}{\partial y} - \phi_y, \qquad (2)$$

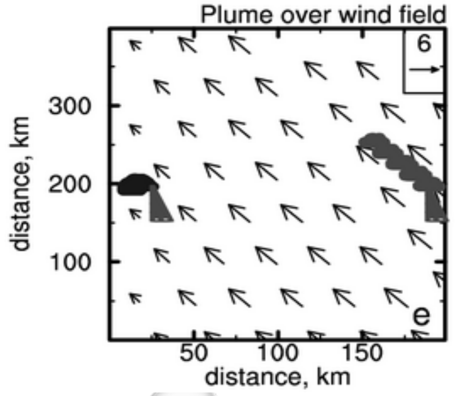
$$h = -\tau H\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right), \qquad (3)$$

$$\frac{\partial C}{\partial t} = -u\frac{\partial C}{\partial x} - v\frac{\partial C}{\partial y}, \qquad (4)$$

1. Removed friction
2. Added advection
3. Added pollutants

Model configuration of the slab model





$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} + fv - g\frac{\partial h}{\partial x} - \phi_x , \quad (1)$$

$$\frac{\partial v}{\partial t} = -u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} - fu - g\frac{\partial h}{\partial y} - \phi_y , \quad (2)$$

$$h = -\tau H\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right), \quad (3)$$

$$\frac{\partial C}{\partial t} = -u\frac{\partial C}{\partial x} - v\frac{\partial C}{\partial y}, \quad (4)$$

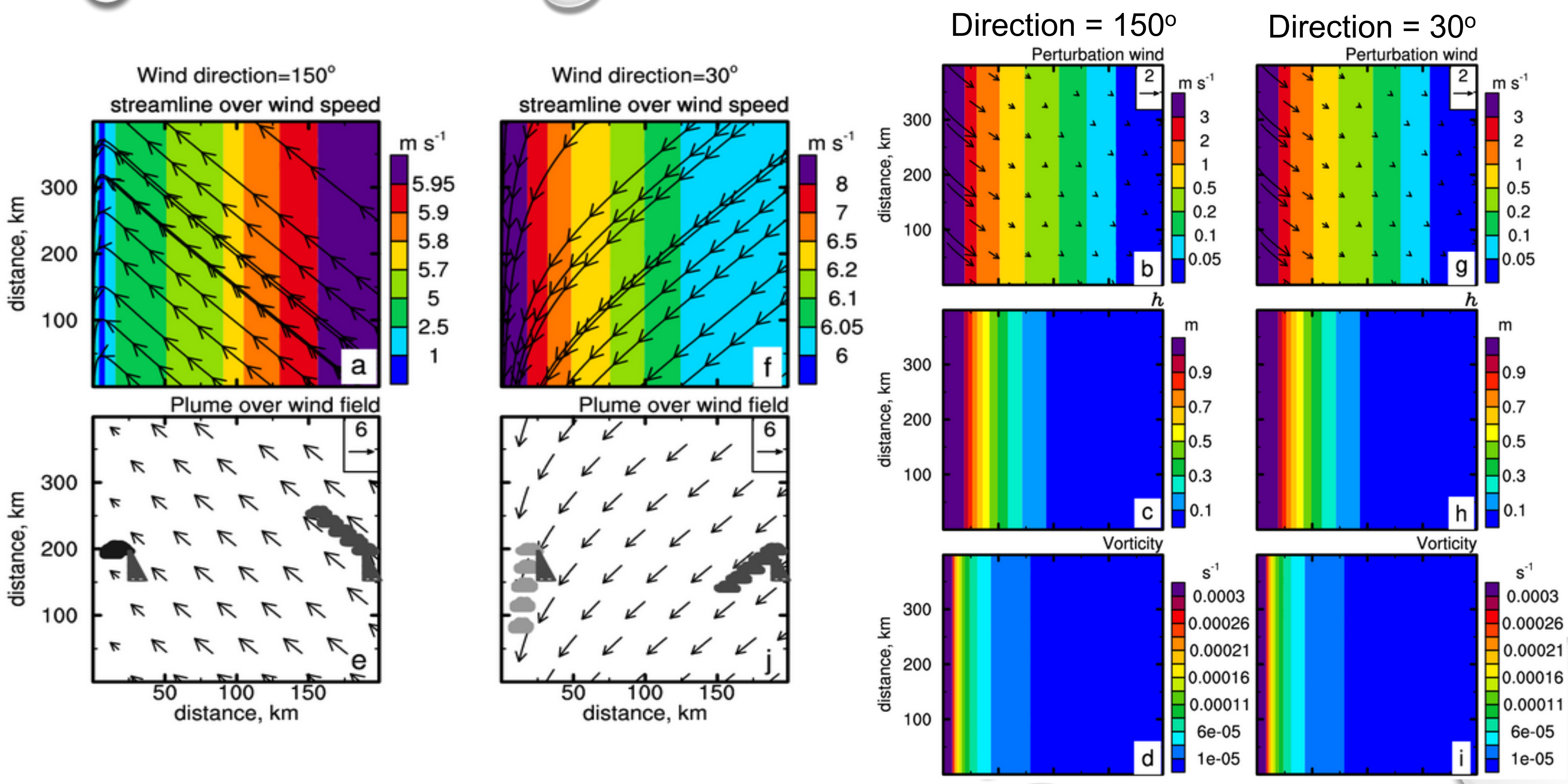
Domain: 400kmx400km

Boundary condition: slip-wall in west boundary
open condition in east

Ambient wind: 150^{o}C (southeasterly)
30^{o}C (northeasterly)

Geopotential gradient: constant

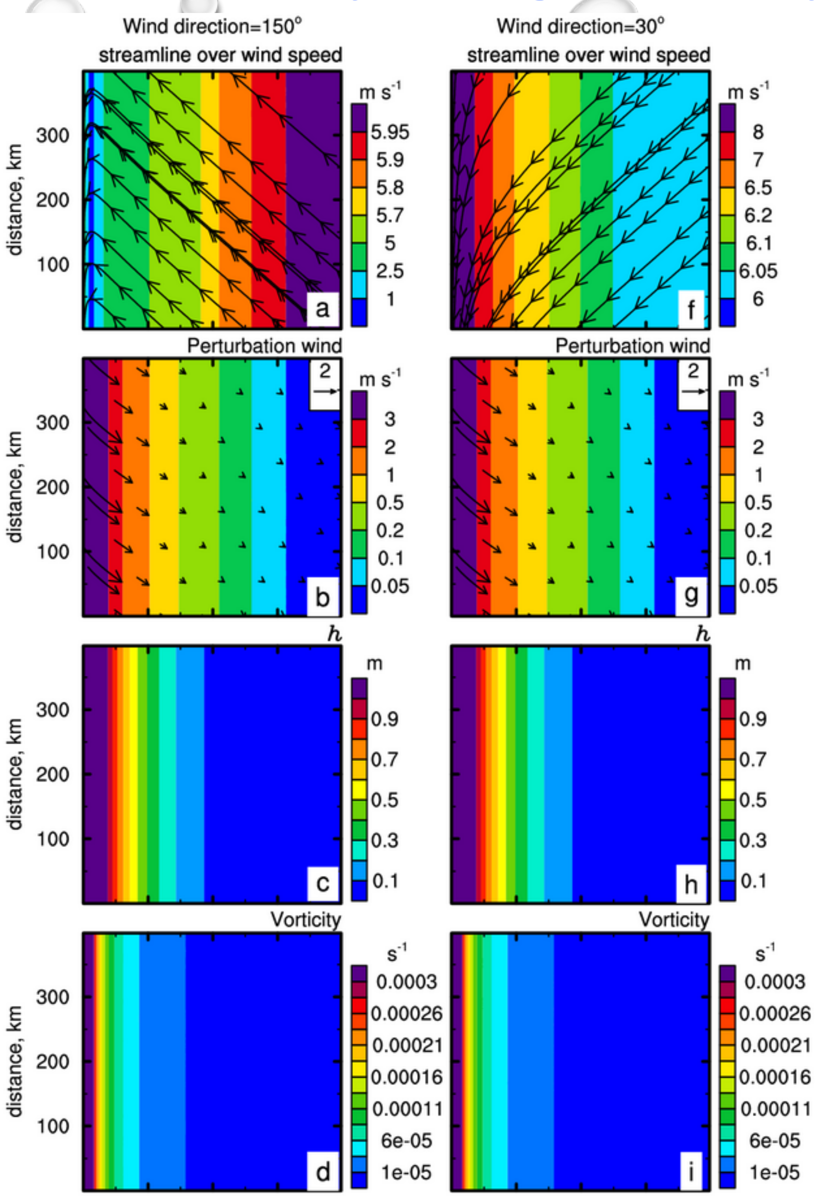
Simulated winds in NCP under 2 conditions



Same perturbation winds lead to different spatial distribution of wind speed.

- **Weak wind region for 150°C, leading to poor dispersion!**
- Barrier jet for 30°C, good dispersion!

Use vorticity budget to explain cyclonic turning of wind



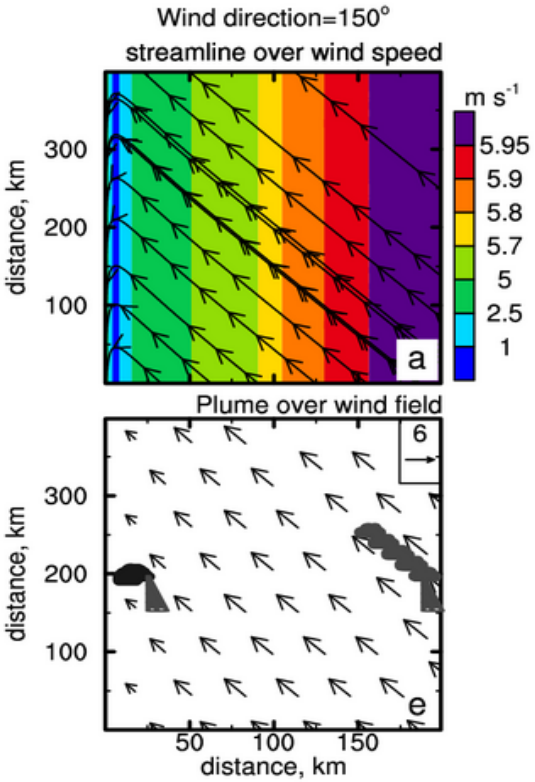
$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} + fv - g\frac{\partial h}{\partial x} - \phi_x\,, \quad (1)$$

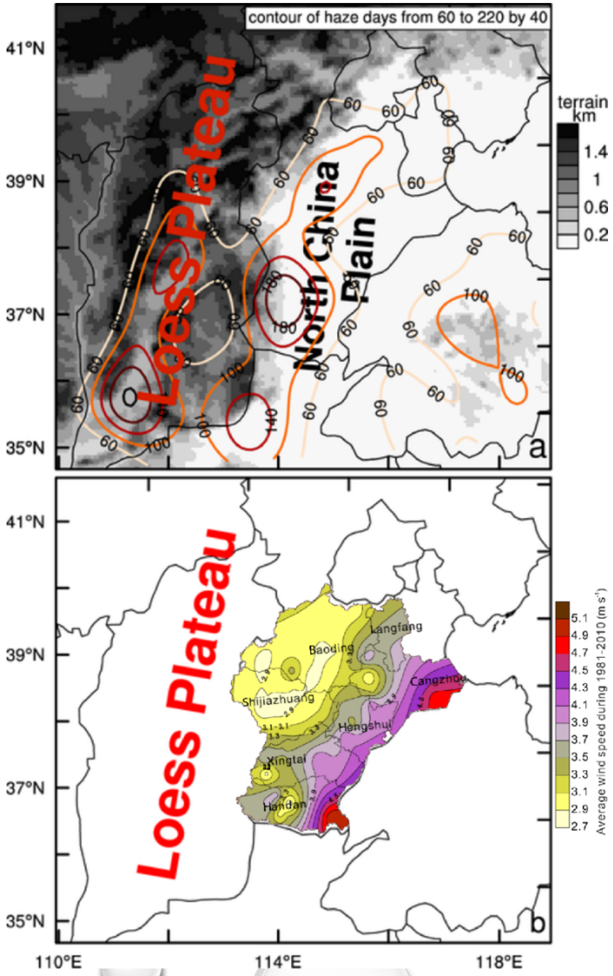
$$\frac{\partial v}{\partial t} = -u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} - fu - g\frac{\partial h}{\partial y} - \phi_y\,, \quad (2)$$

Taking ∂/∂x of Eq. 2 and subtracting ∂/∂y of Eq. 1 gives the rate of relative vorticity

$$\frac{\partial \zeta}{\partial t} = -u\frac{\partial \zeta}{\partial x} - v\frac{\partial \zeta}{\partial y} - (\zeta + f)\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right)$$

Impact on air quality in NCP





Weak wind region for southeasterly winds, leading to poor dispersion!

Conclusions for NCP

1.The Mountain-Plains Solenoid (MPS) circulation suppresses the mixed layer, exacerbating air pollution over the NCP

2.Thermal effects lead to seasonal variation of boundary layer and pollutants (more haze in fall and winter)

3.A one-layer slab model is developed to investigate the wind field in the North China Plain (NCP)

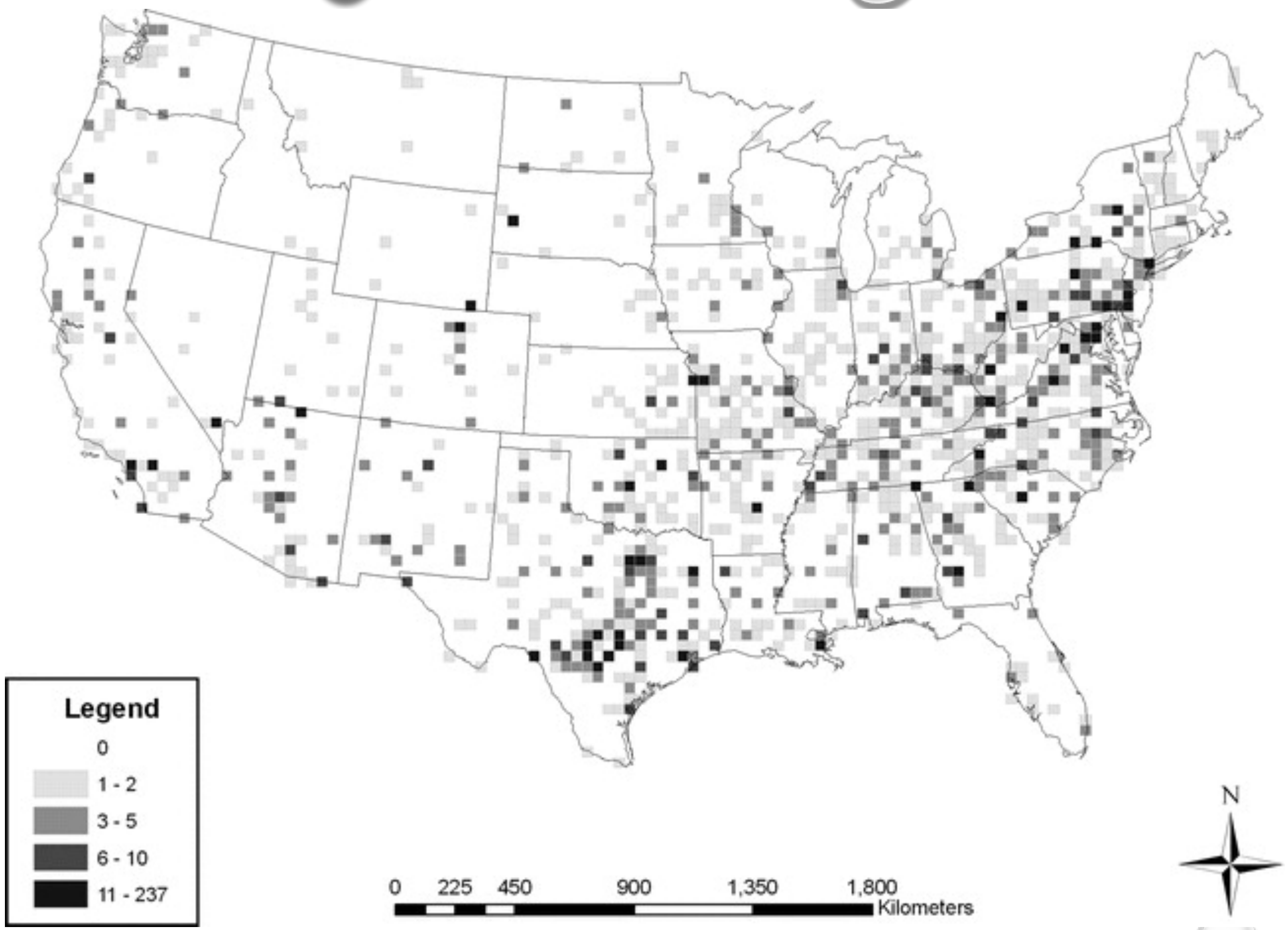
4. Dynamic modification by the Loess Plateau leads to barrier wind formation in the NCP

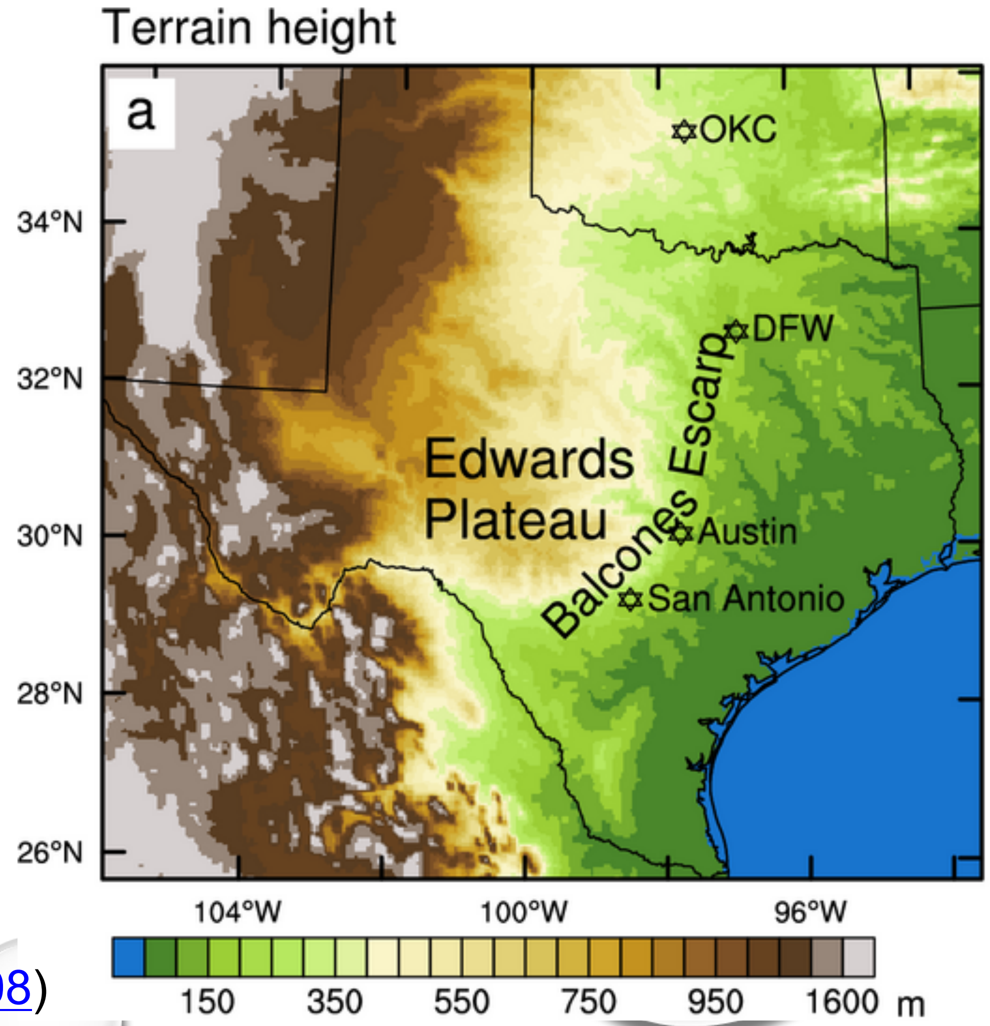
5. Barrier wind formation reduces the wind speed in the western part of NCP, leading to poor dispersion condition and exacerbating air pollution.

Impact of Mountainous Terrain

1. Mountain effects under dry conditions
2. Mountain effects under wet conditions

Flood Region along the Balcones Escarpment

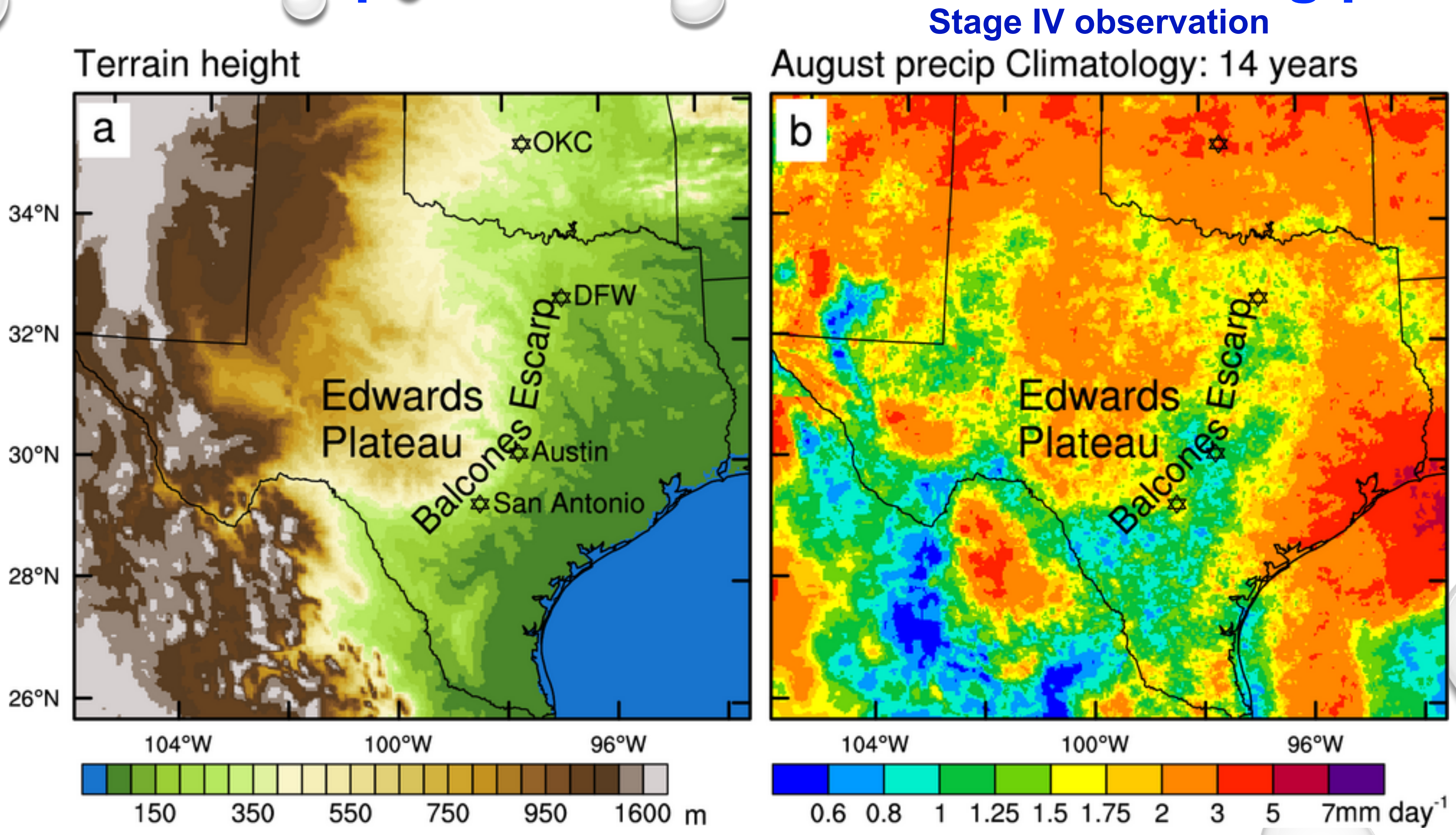




Tallies of all **flood fatalities** from 1959 to 2005 (Ashley & Ashley, 2008)

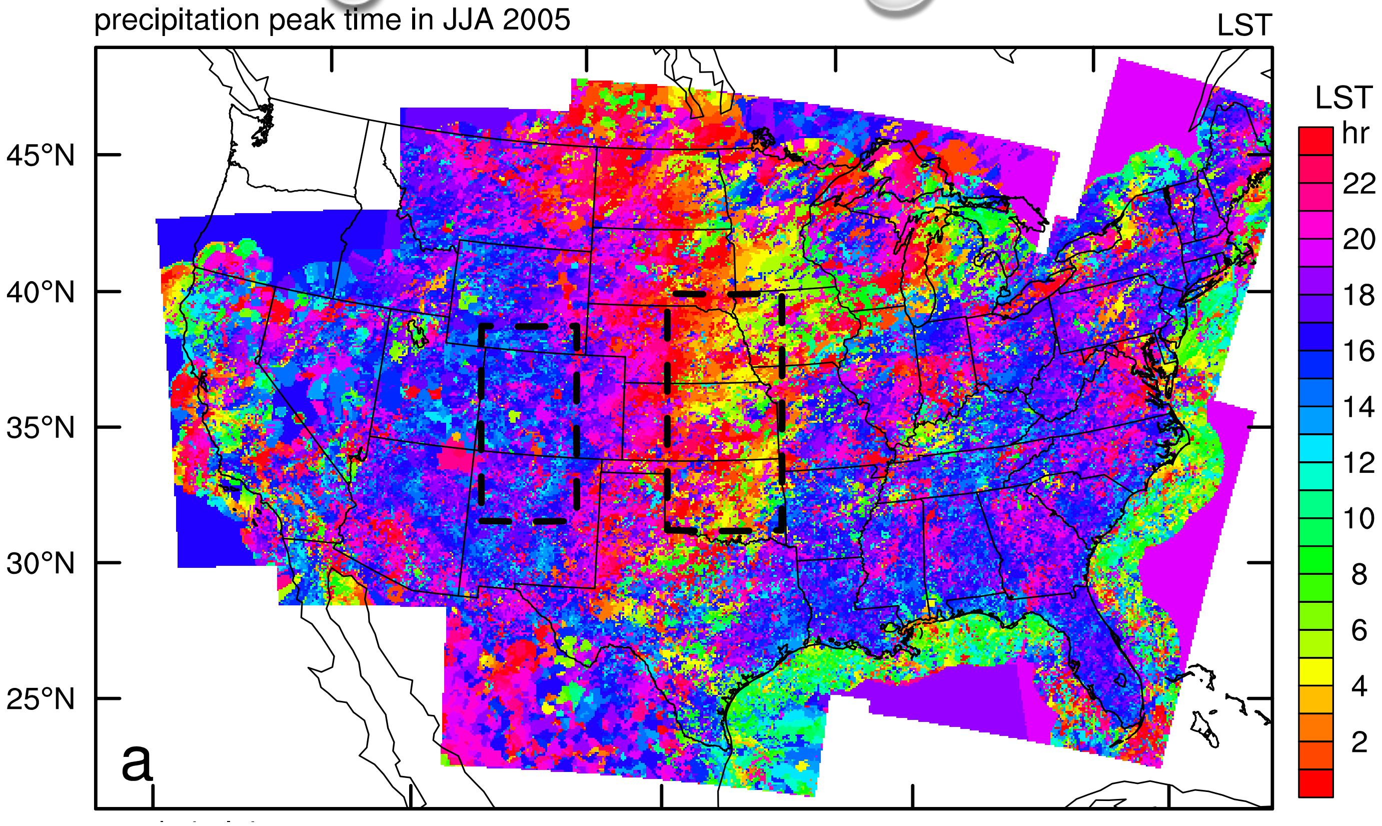
hydrologic effects of the Balcones Escarpment are well known,
the meteorological impacts of the Edwards Plateau and Balcones Escarpment are not well understood

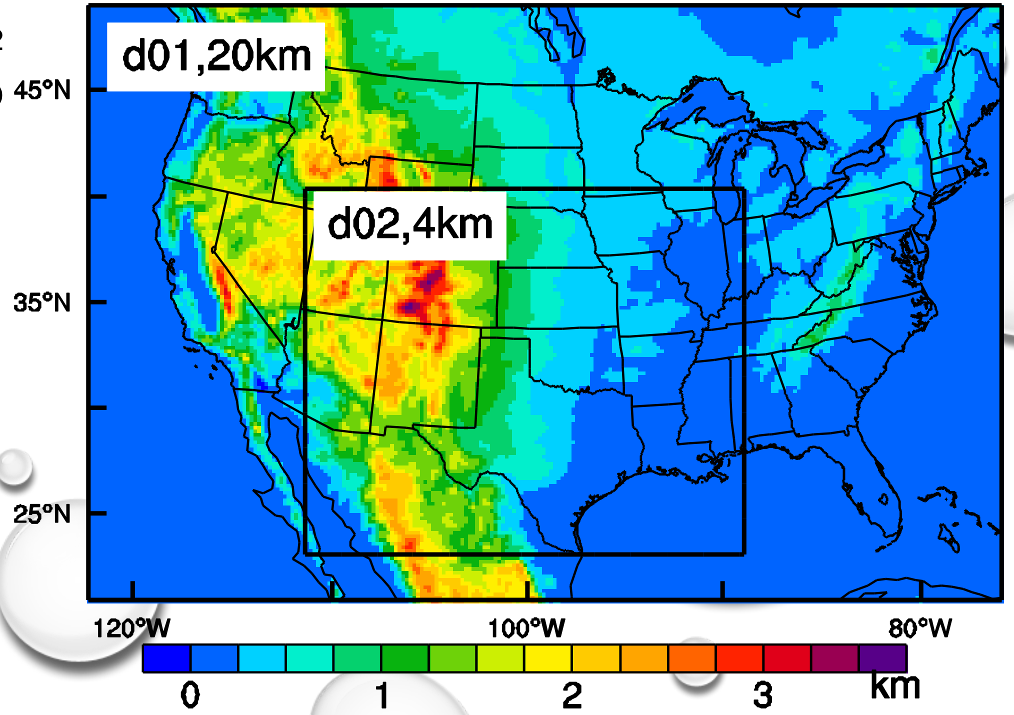
The Escarpment and Plateau modulate Aug precipitation



Thermal effect?
Dynamic effect?

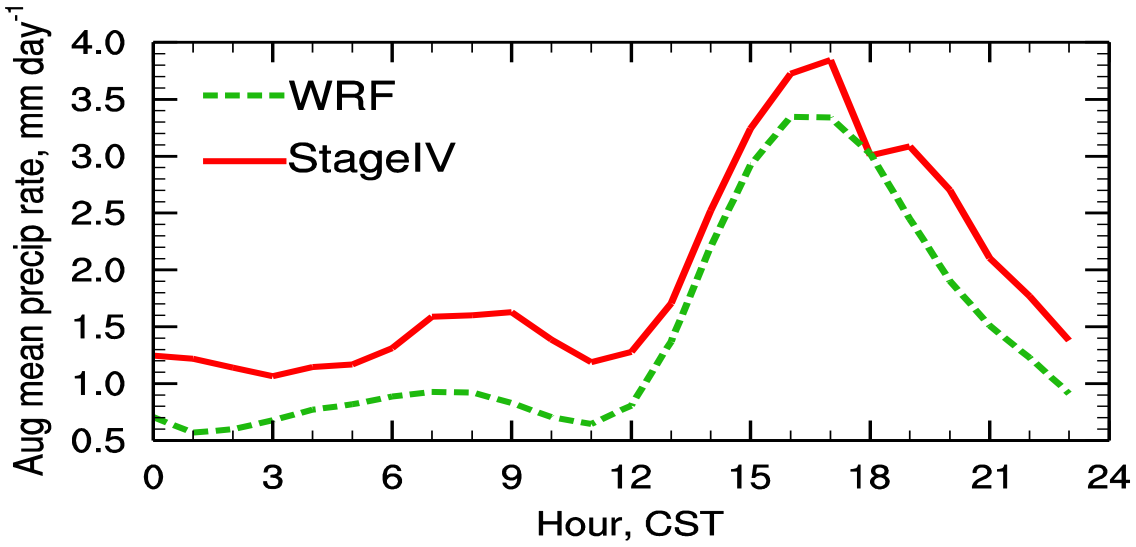
Configuration of dynamic downscaling with the Weather Research and Forecasting (WRF) model

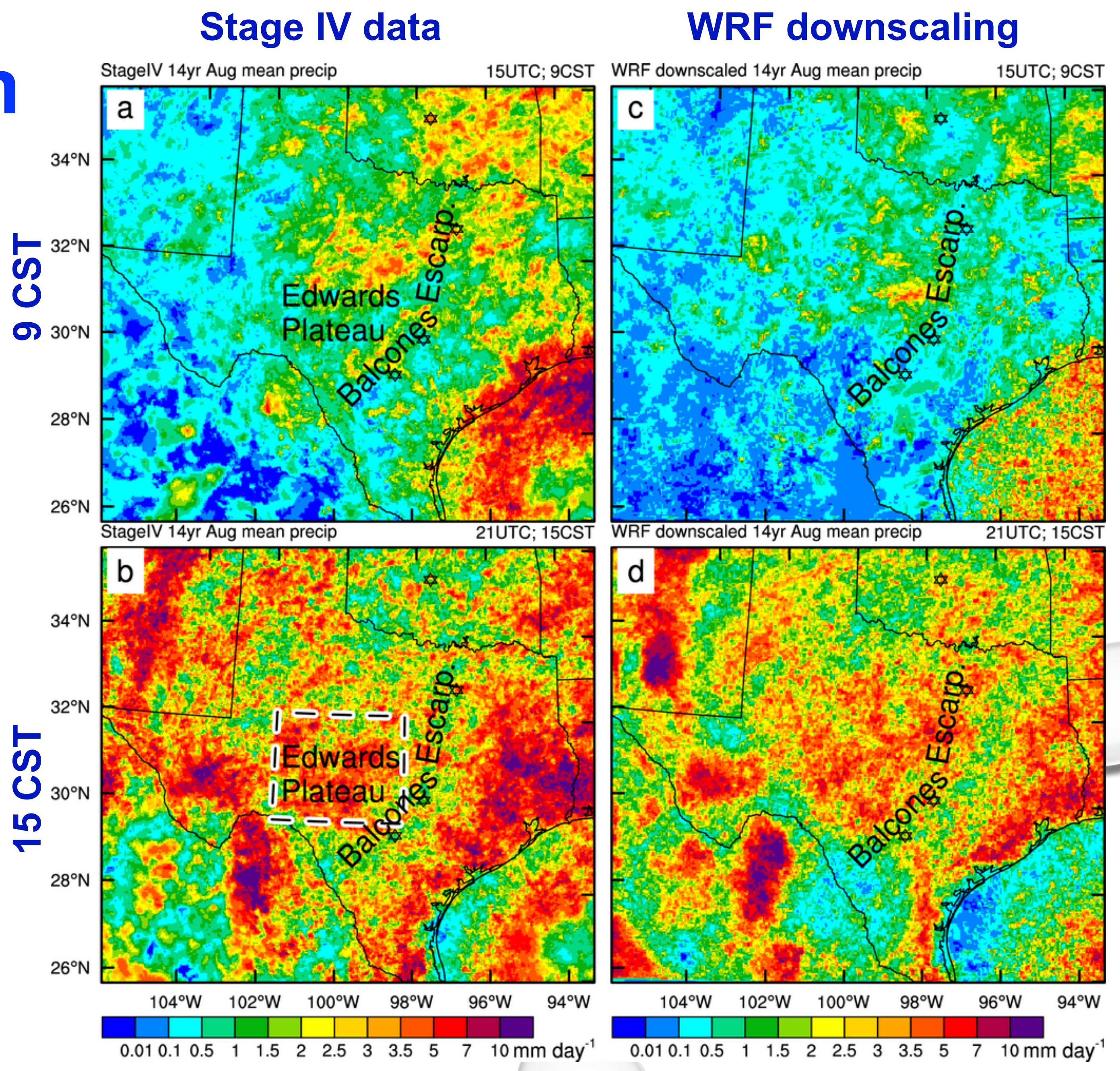




Difficulty of precipitation downscaling in the region
Spectral nudging and convection-permitting are critical

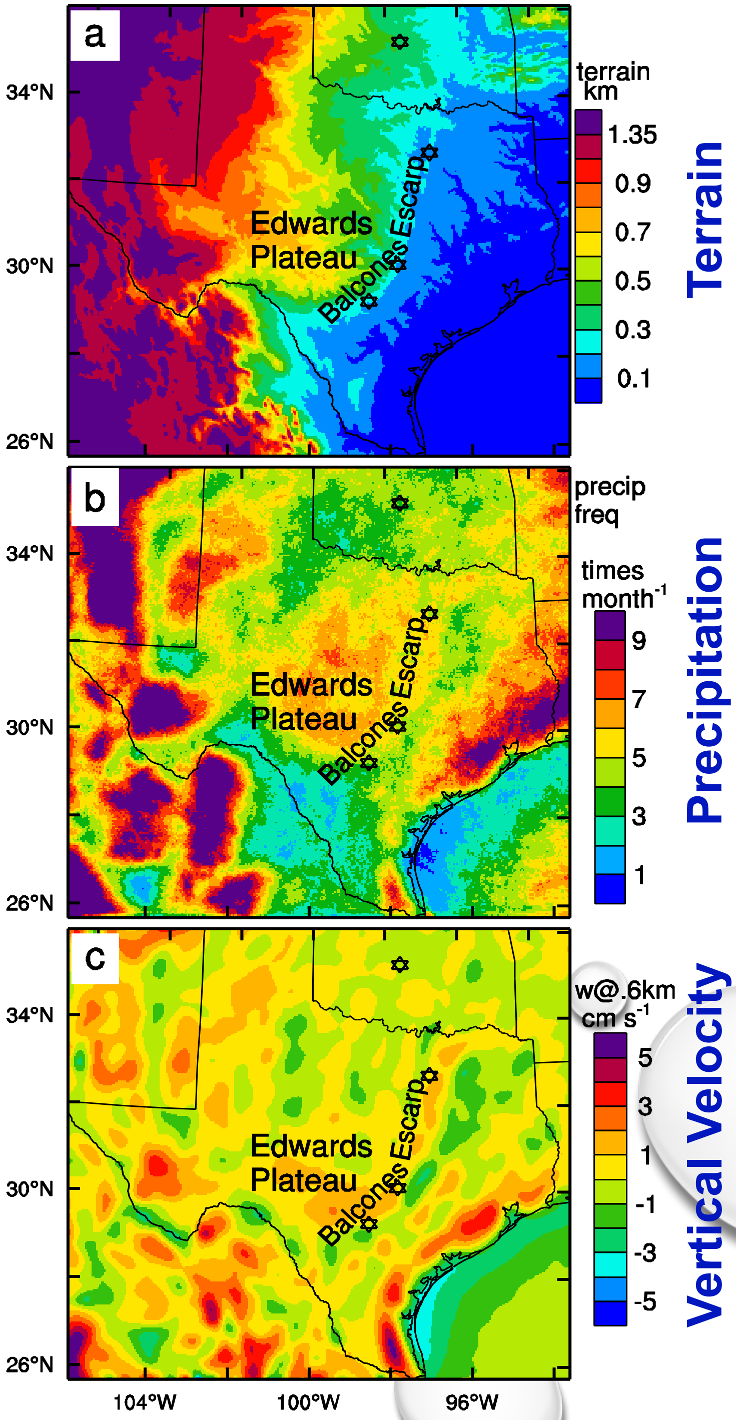
Precipitation evaluation





WRF downscaling nicely captures the spatial and temporal distributions.

Likely causes: enhanced upward motion

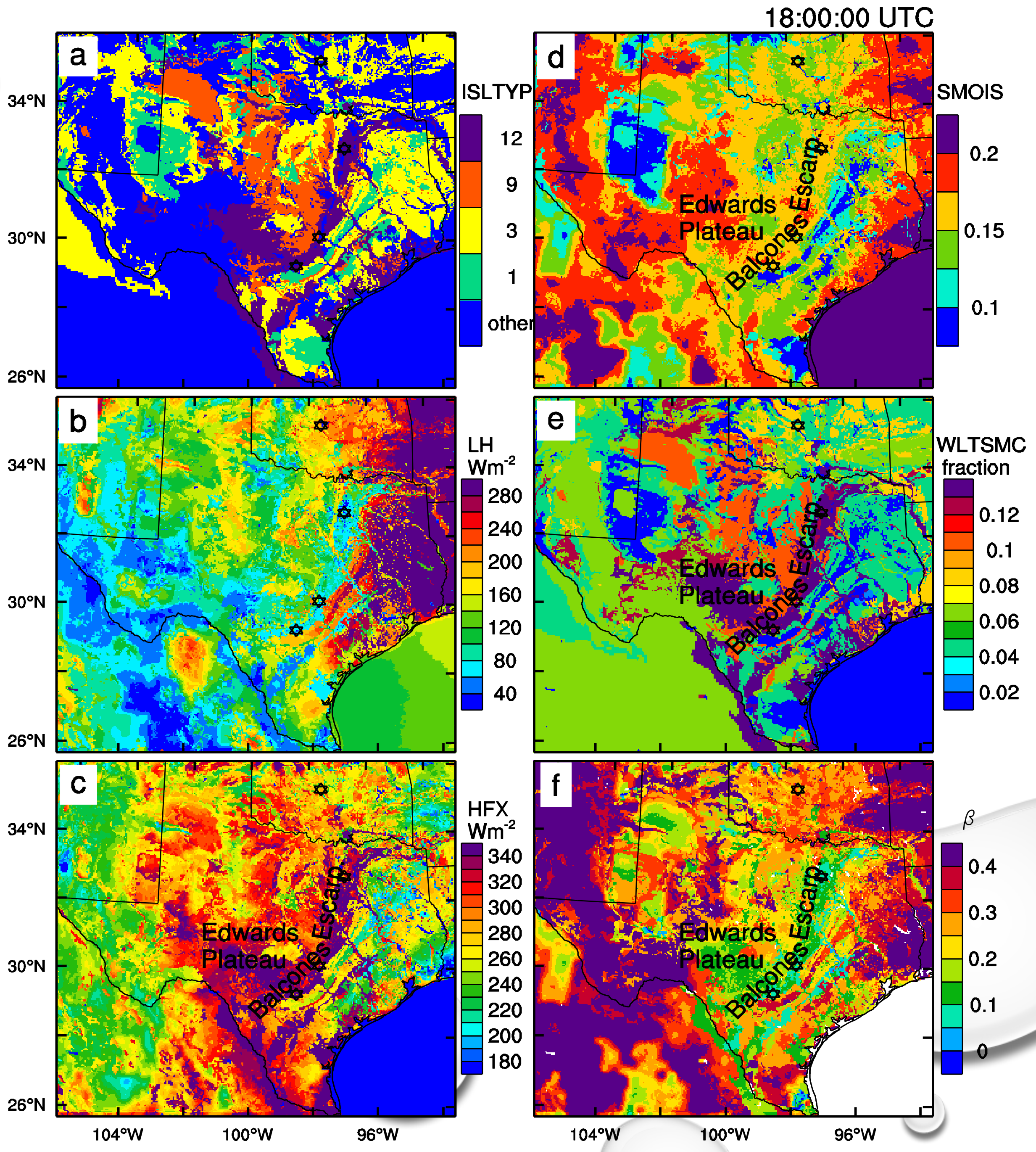


Precipitation is well aligned with the upward motion.

due to terrain height gradient or other factors?

Likely causes: soil types

Soil category	Soil description
1	Sand
3	Sandy Loam
9	Clay Loam
12	Clay

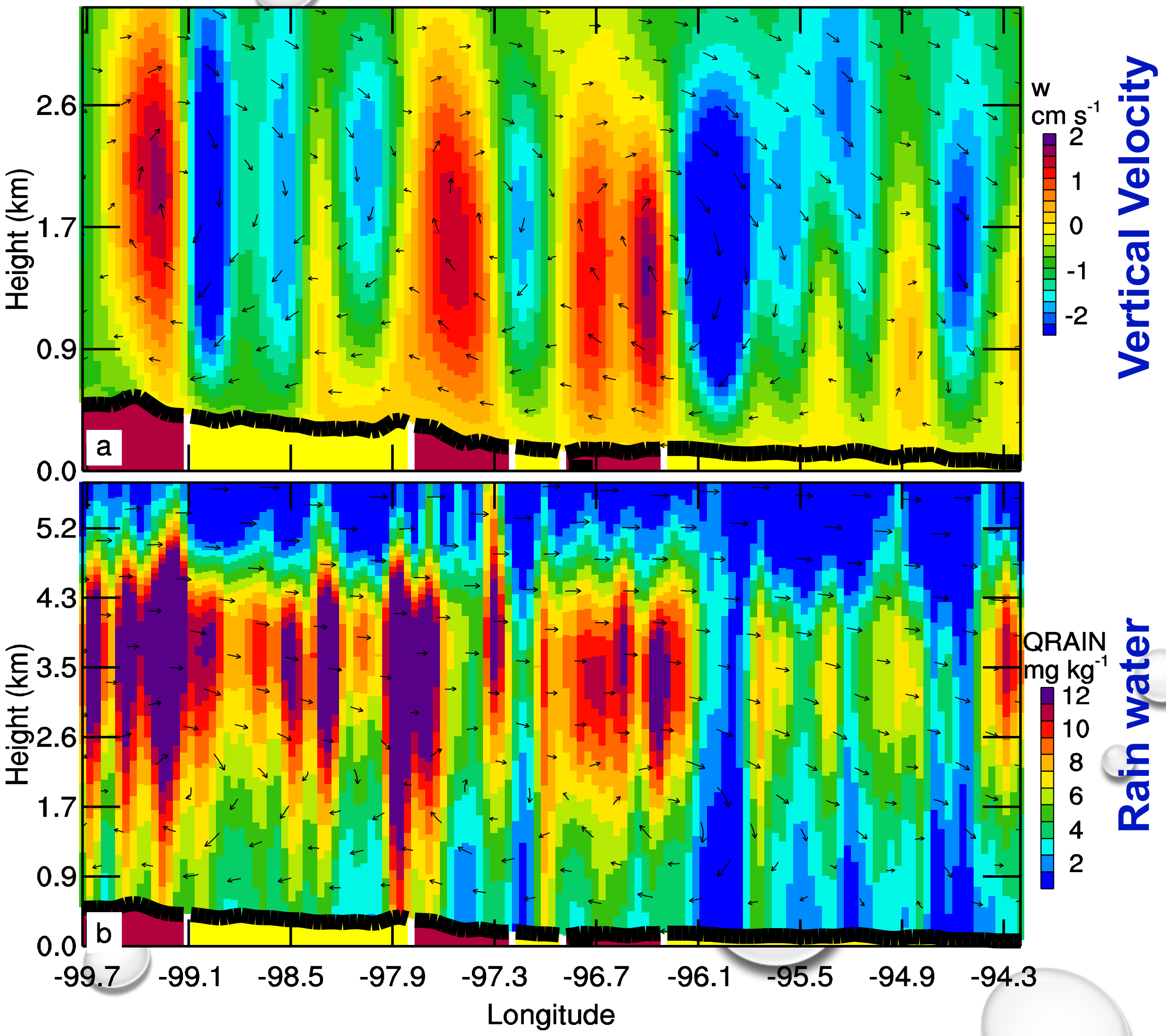


Over the Escarpment and Plateau: fine-textured clay => slow capillary motion => suppressed latent heat fluxes.

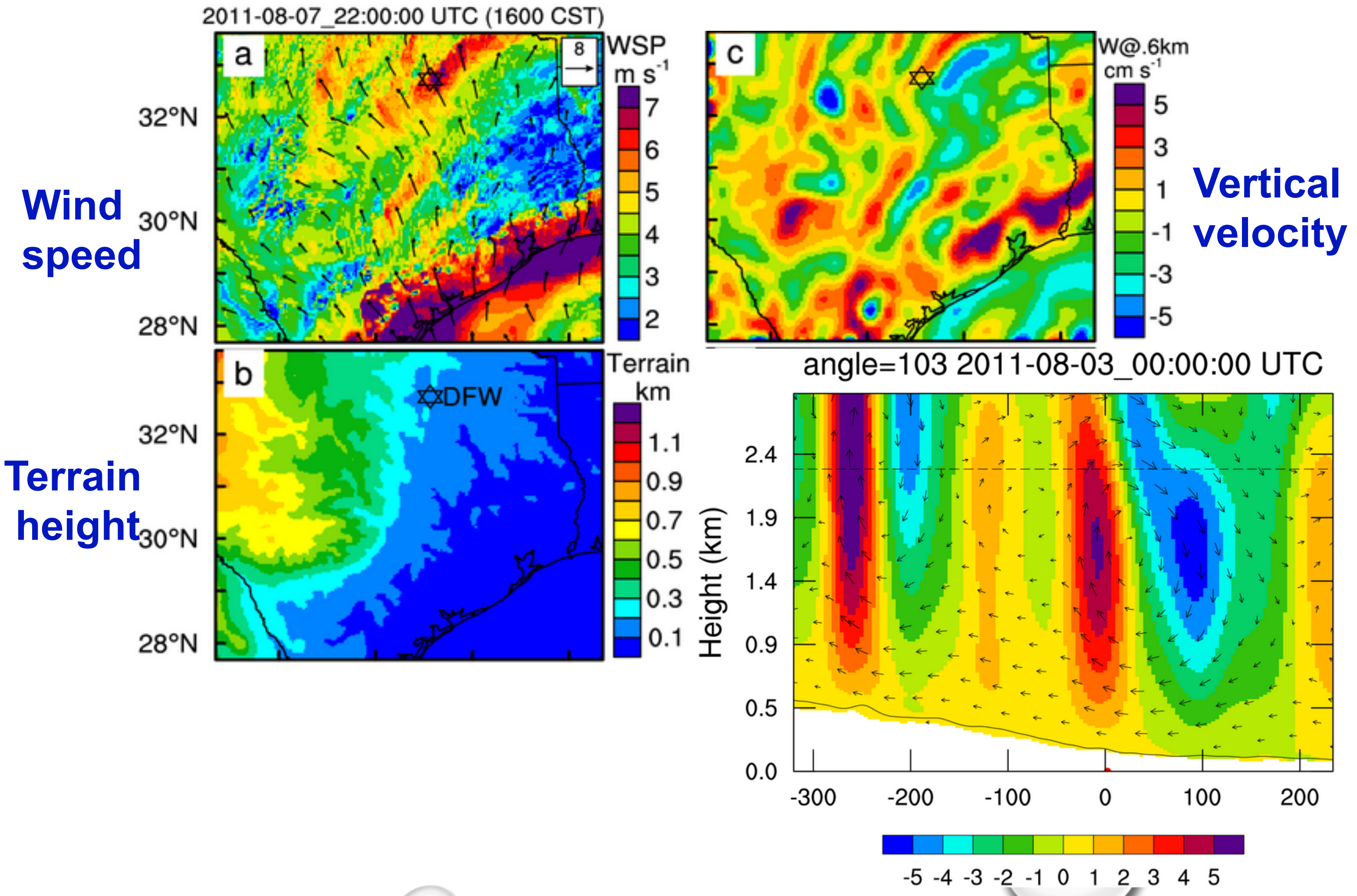
In contrast, sand over the coastal plain is coarse textured

Clay enhanced vertical motion

Brown: Clay



Mountain-Plain Solenoid induced the wind maximum band?



Hu and Xue (2016) noticed the wind maximum band along the Balcones Escarpment in summer afternoon

Further confirmation: sensitivity simulations

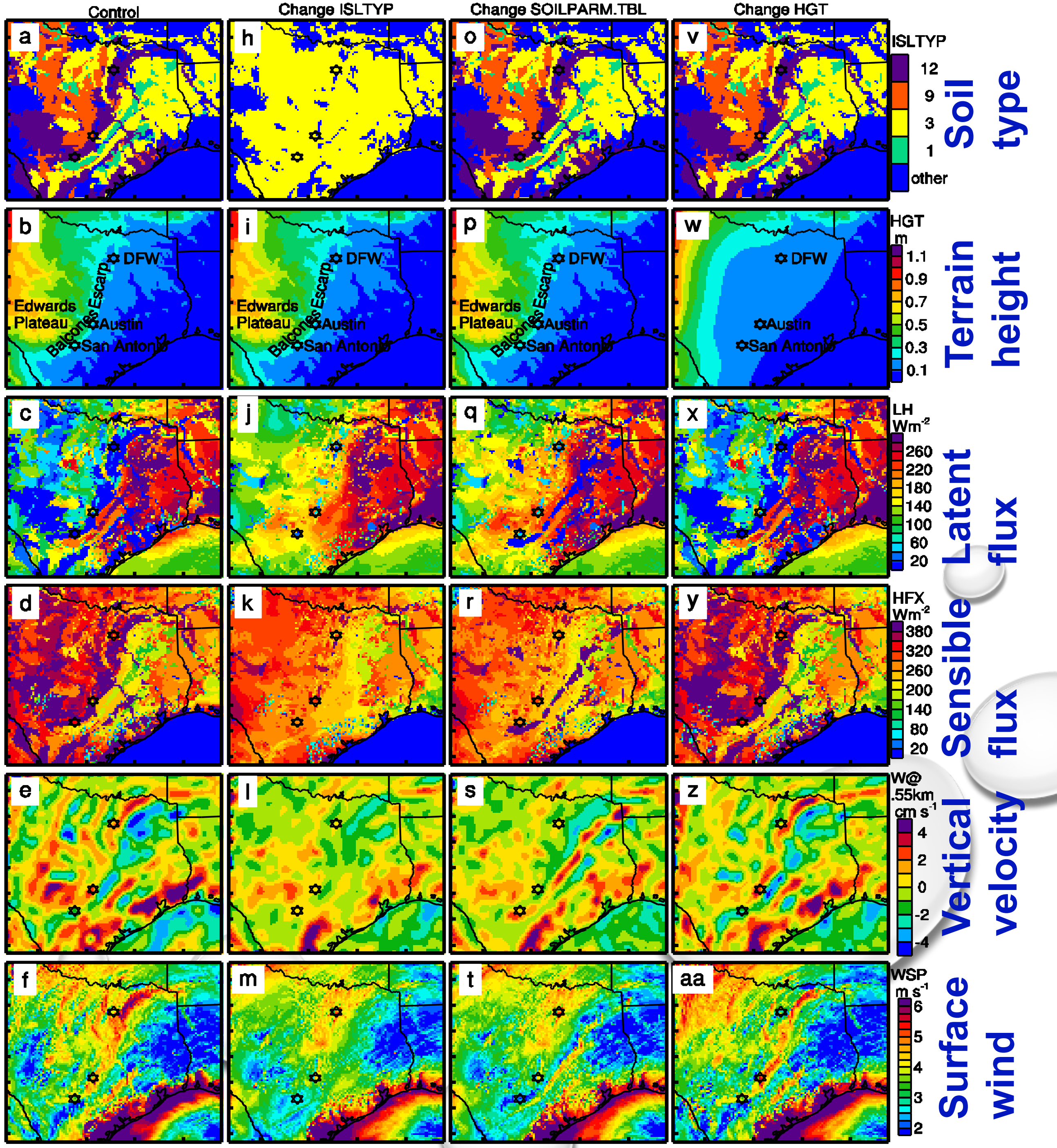
#	Simulation	configuration
1	Control	as in Hu and Xue [2016]
2	Change ISLTYP	Change the soil type in most Texas to sandy loam (type 3), see Fig. 9h
3	Change SOILPARM.TBL	Switch the DRYSMC and WLTSMC* between clay-based soil types (9 and 12) and sand (1)
4	Change HGT	Remove the terrain in most Texas (Fig. 9w)

Different soil textures are reflected in moisture availability parameter

$$\beta = \frac{\Theta - \Theta_w}{\Theta_{ref} - \Theta_w}$$

Θ_w wilting point soil moisture (WLTSMC)

Soil category	Soil description	DRYSMC	WLTSMC
1	Sand	0.01	0.01
3	Sandy Loam	0.047	0.047
9	Clay Loam	0.103	0.103
12	Clay	0.138	0.138



Conclusions

1. Plateau and escarpment enhance precipitation, not due to mountain-plain solenoid circulation, but due to **soil type differences**.

2. Clay tends to retain soil moisture, thus enhancing sensible heat fluxes and triggering upward motions.

3. The upward motion and compensating downward motion lead to the soil-type circulation breezes.