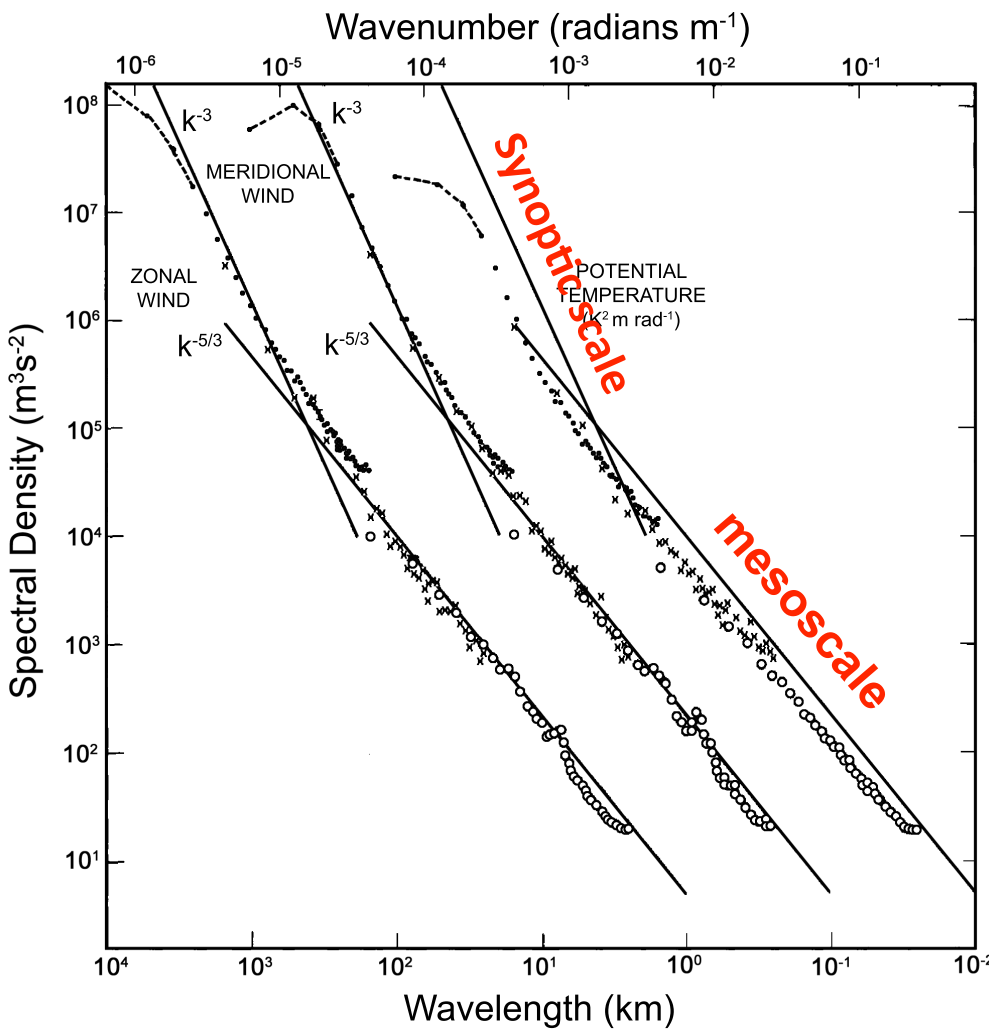
Contributions of moist convection and internal gravity waves to building the atmospheric "-5/3" kinetic energy spectra

Y. Qiang Sun[1], Richard Rotunno[2] and Fuqing Zhang[1]

[1] Penn State University
[2] NCAR

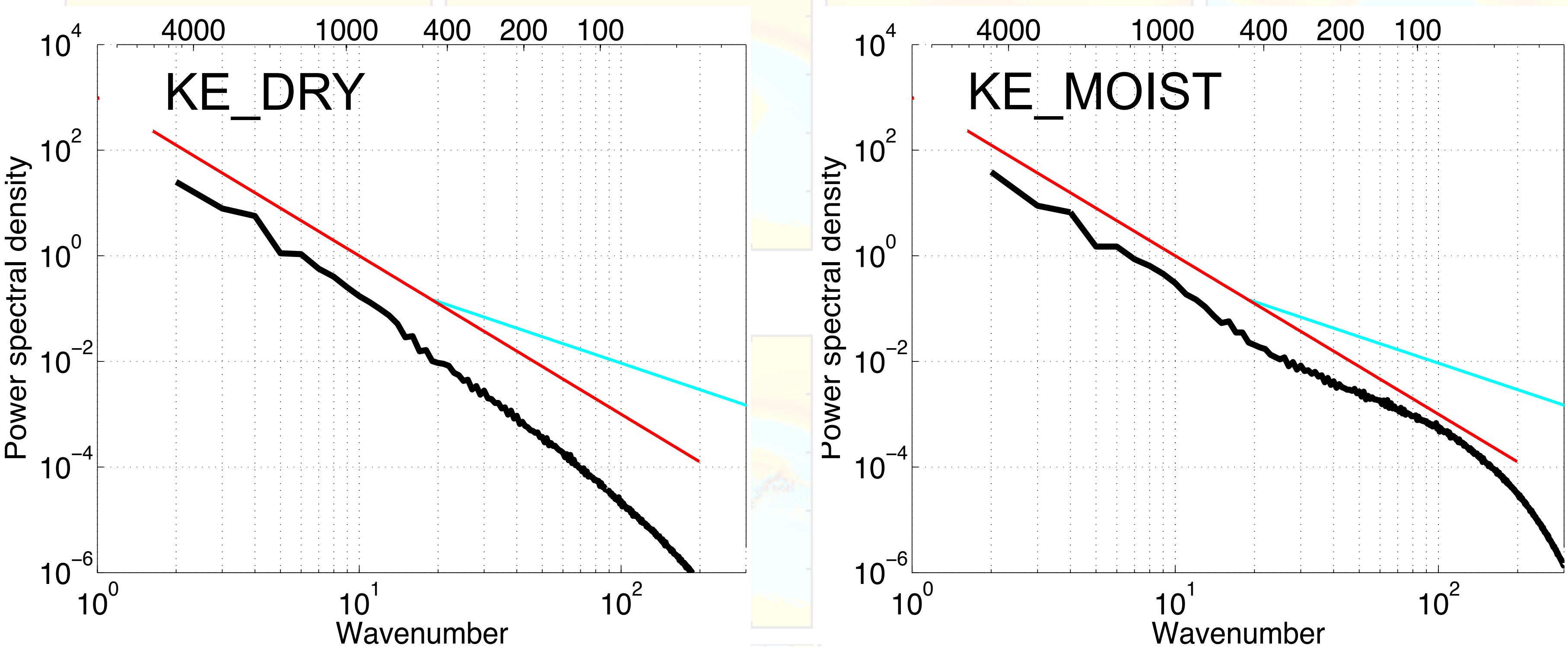
Power Spectra of Wind and Potential Temperature From Aircraft Measurements



Nastrom and Gage (1985)

Baroclinic wave simulations: Dry vs. Moist

Sun and Zhang (2016 JAS)

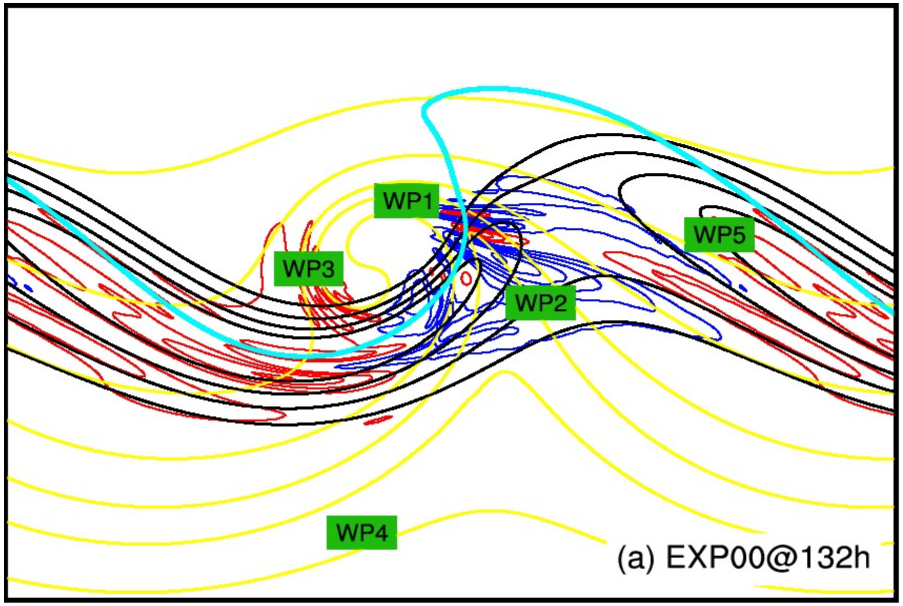


Simulated dry baroclinic Jets have a -3 slope, while moist experiments show a transition at mesoscale.

Gravity waves in baroclinic wave simulations: Dry vs. Moist

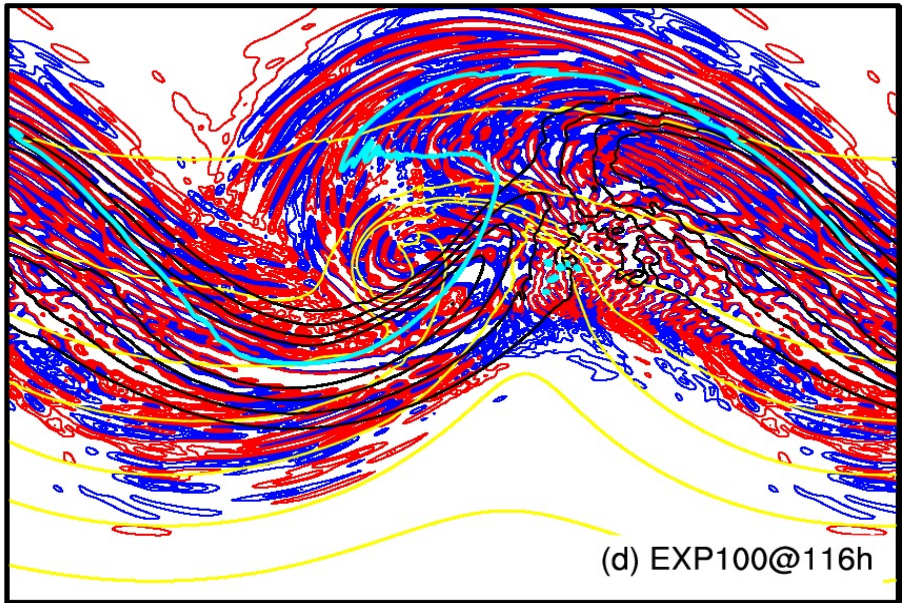
DRY

(Uccellini and Koch 1987; Zhang 2004 JAS)



MOIST

(Wei and Zhang 2014 JAS; 2015 JAMES)

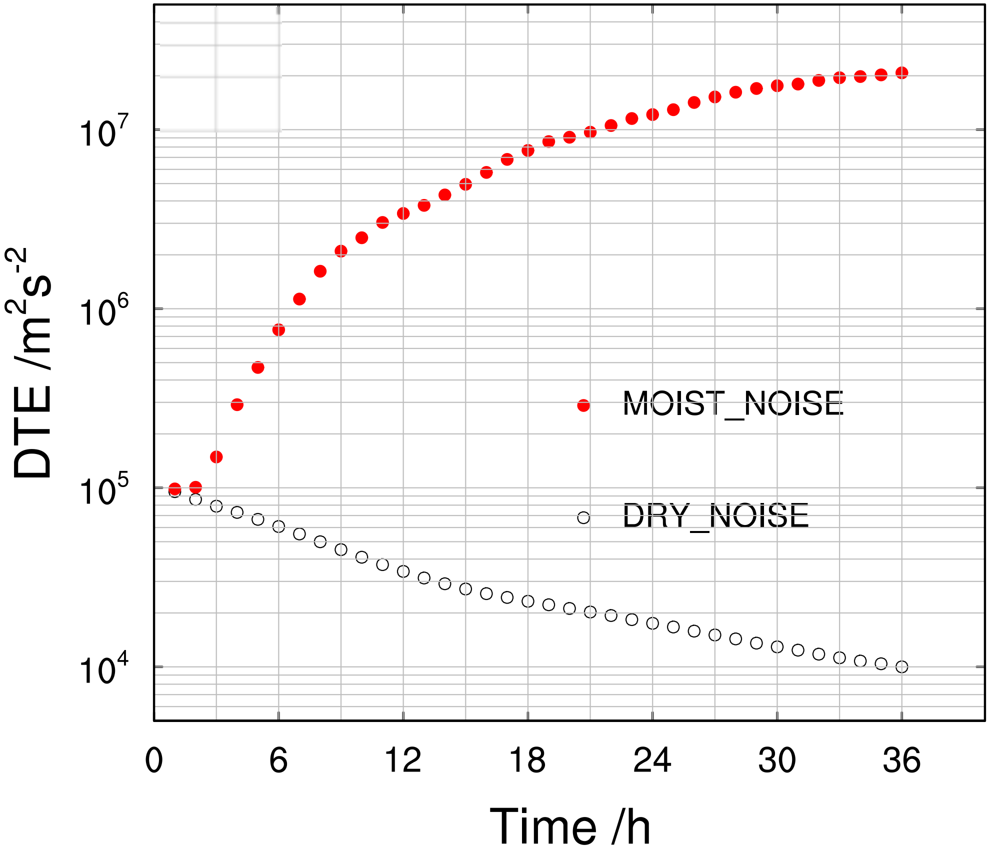


- ✓ Convection and gravity waves key to flatten the meso/small-scale spectral slope.
- ✓ Adjustment and gravity waves likely play a key role in the error propagation across scales, as hypothesized in Zhang et al. (2007 JAS).

Difference Total Energy (DTE) Growth: Dry vs. Moist

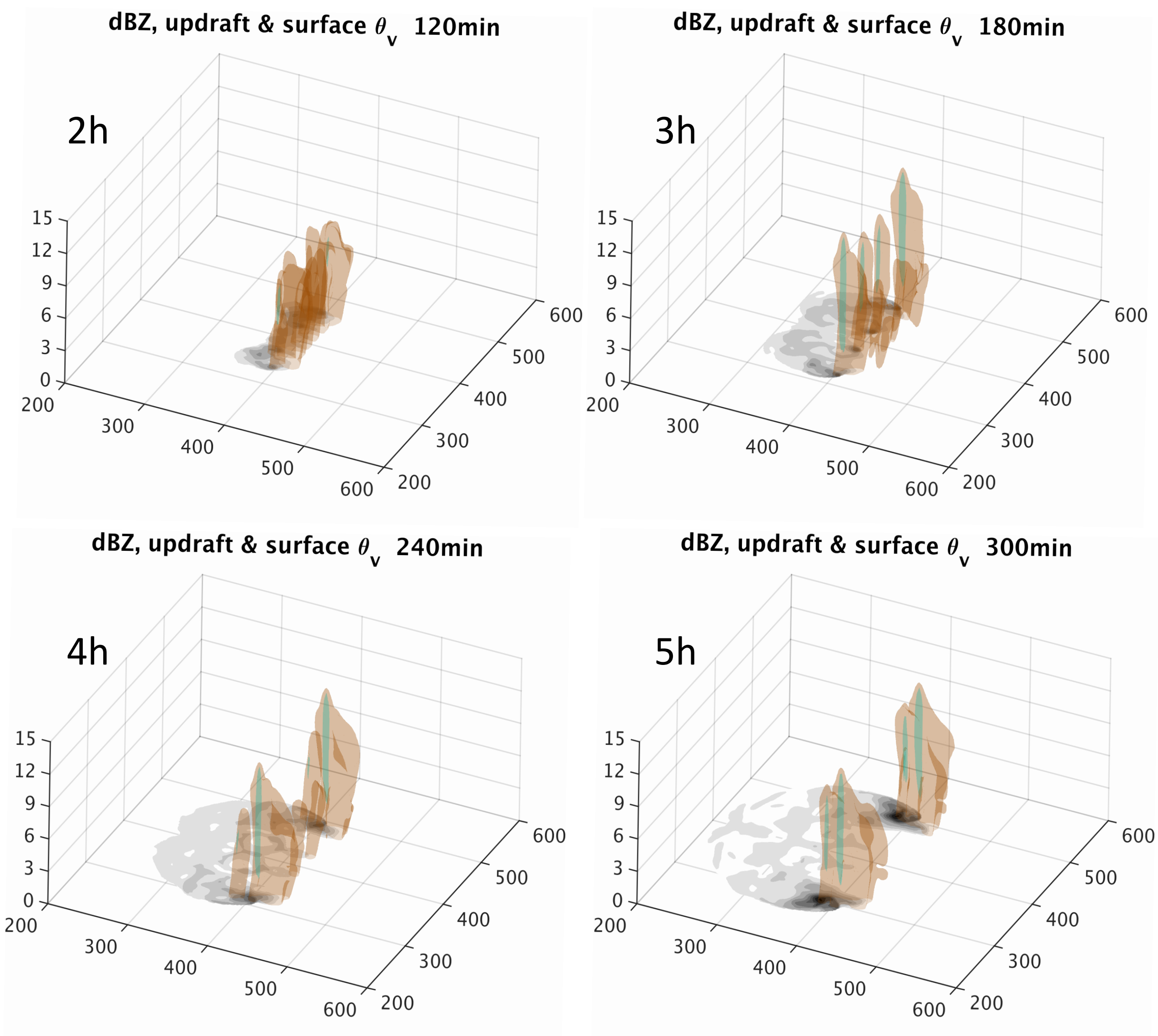
$$DTE = \frac{1}{2}\sum[(\delta u)^2 + (\delta v)^2 + \kappa(\delta T)^2]$$

Sun and Zhang (2016 JAS)

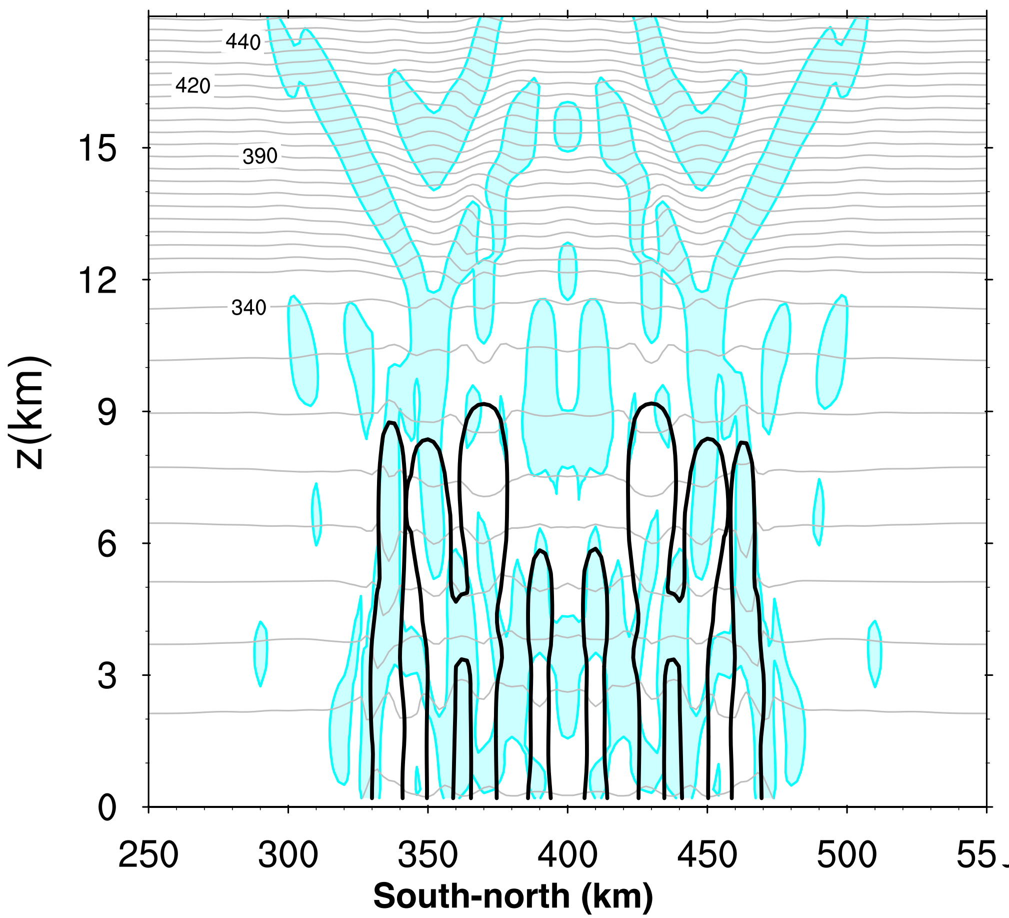


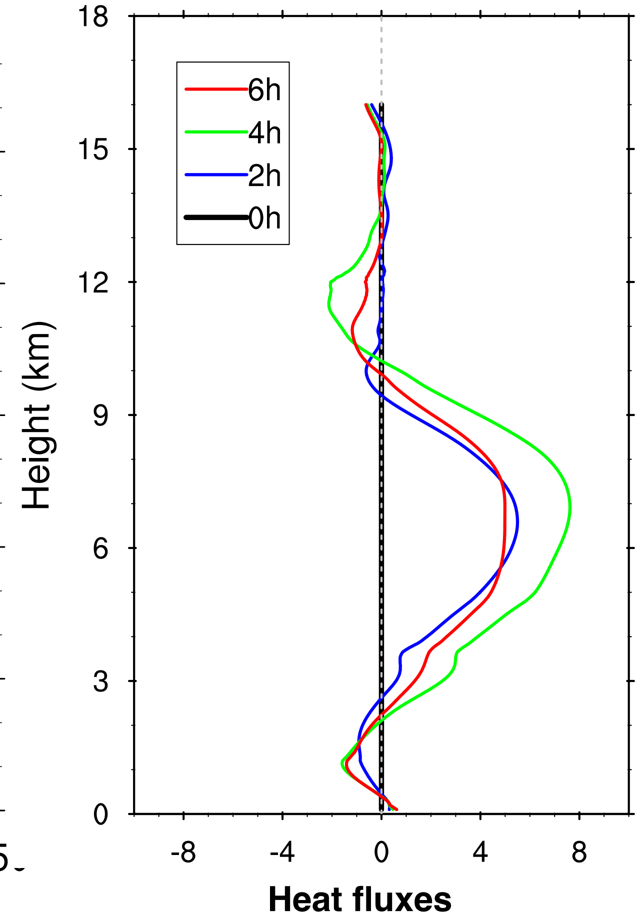
- ✓ Error growth behavior is possibly linked to the spectral slope.
- ✓ Implication of spectral slopes on intrinsic predictability consistent with previous study.

Time evolution of our simulated convective systems



Moist convection and gravity waves generated by convection

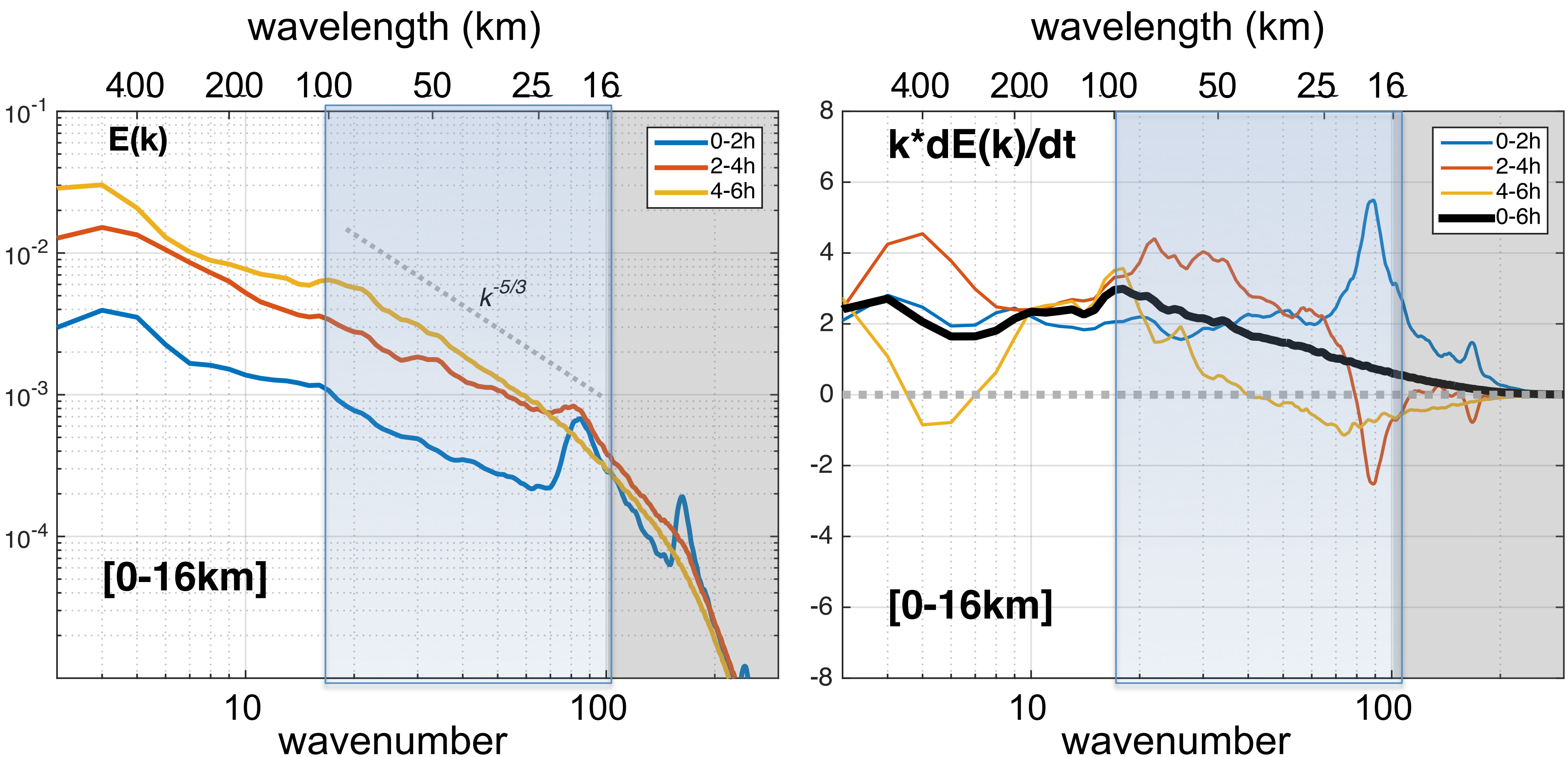




w > 0.1m/s, cyan; dbz > 25, black line;
potential temperature, gray

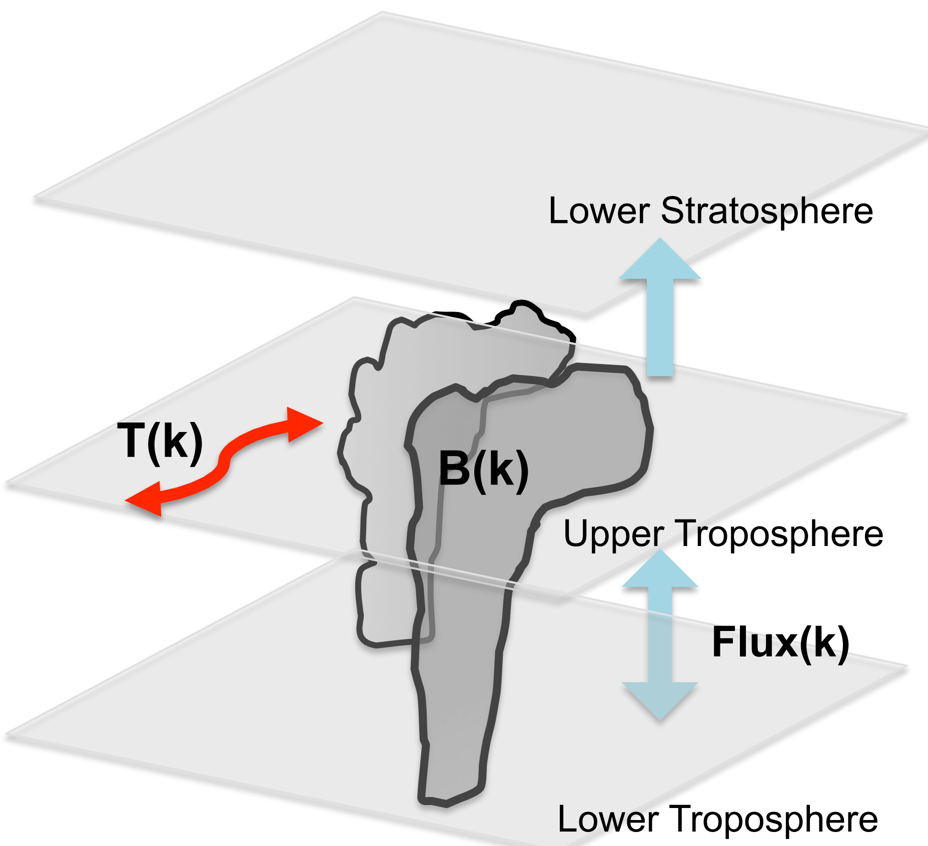
$w'T'$

Kinetic Energy Spectra in our Simulation



Spectra Budget Analysis for Kinetic Energy

$$\frac{\partial E(k)}{\partial t} = T(k) + B(k) + Flux(k) + D(k)$$

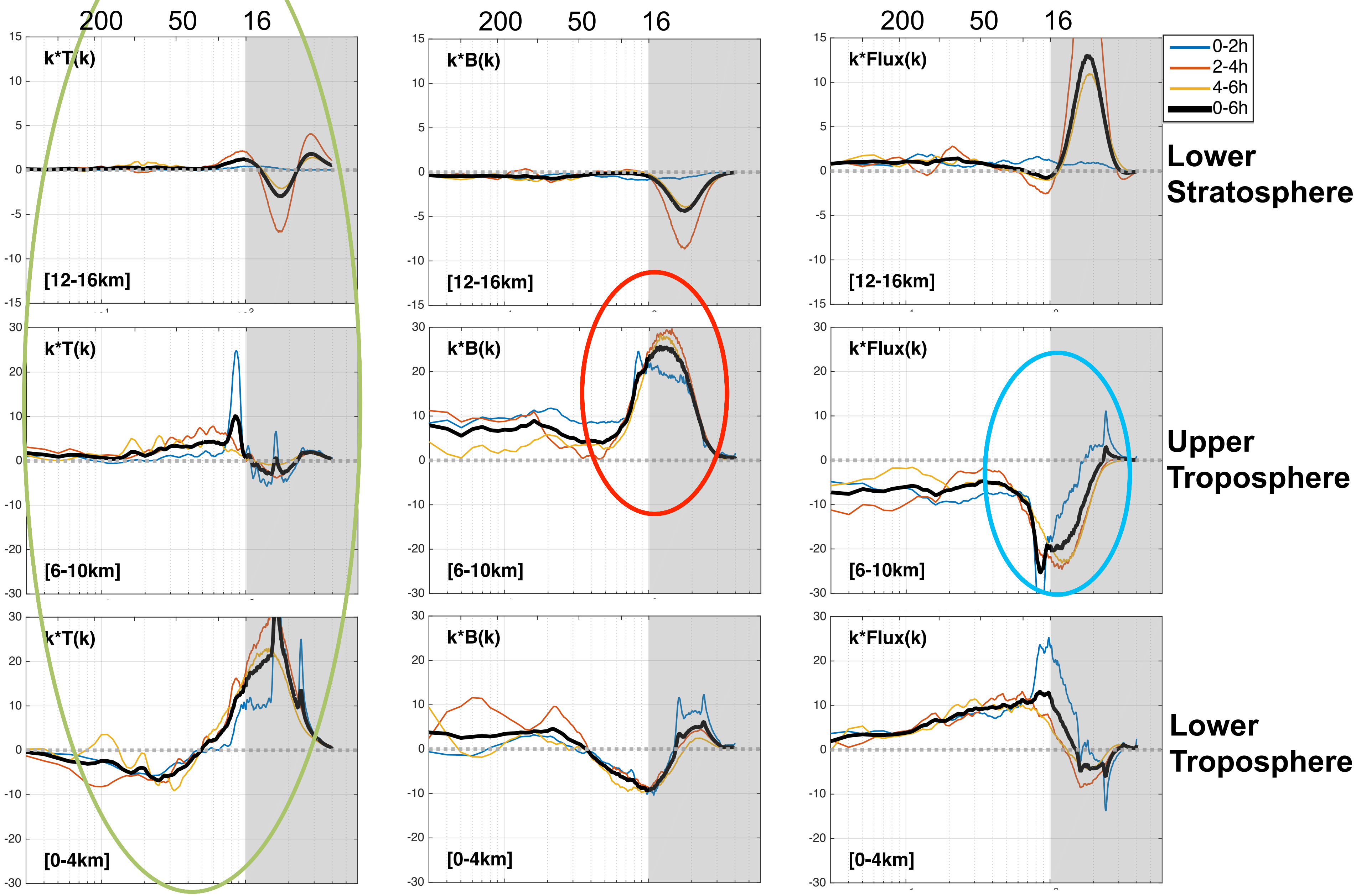


T(k): Energy transfer between different scales

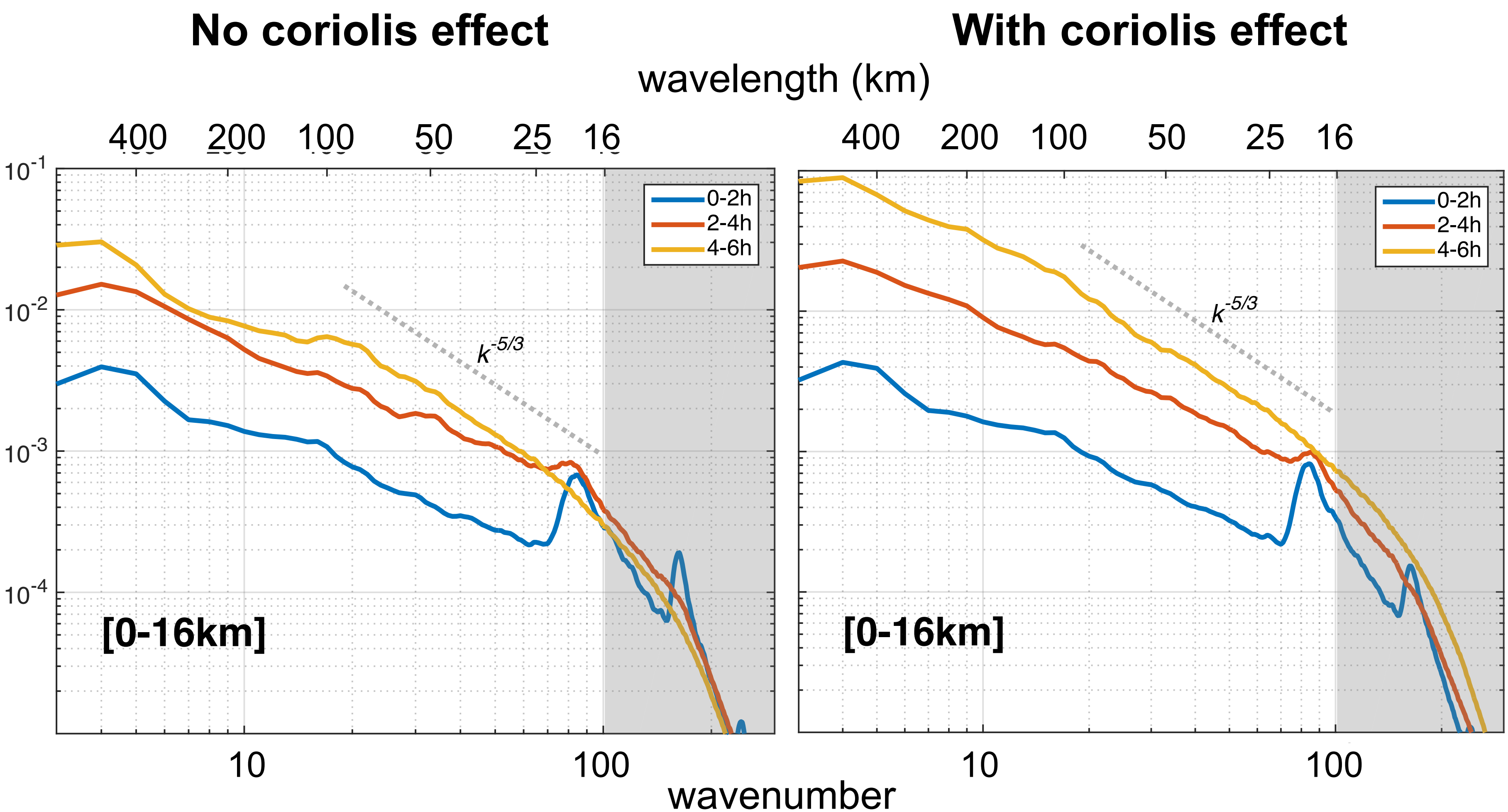
B(k): Energy converted from potential energy, buoyancy production

Flux(k): Energy exchange between different vertical levels, induced by convection and vertical propagating **gravity waves**

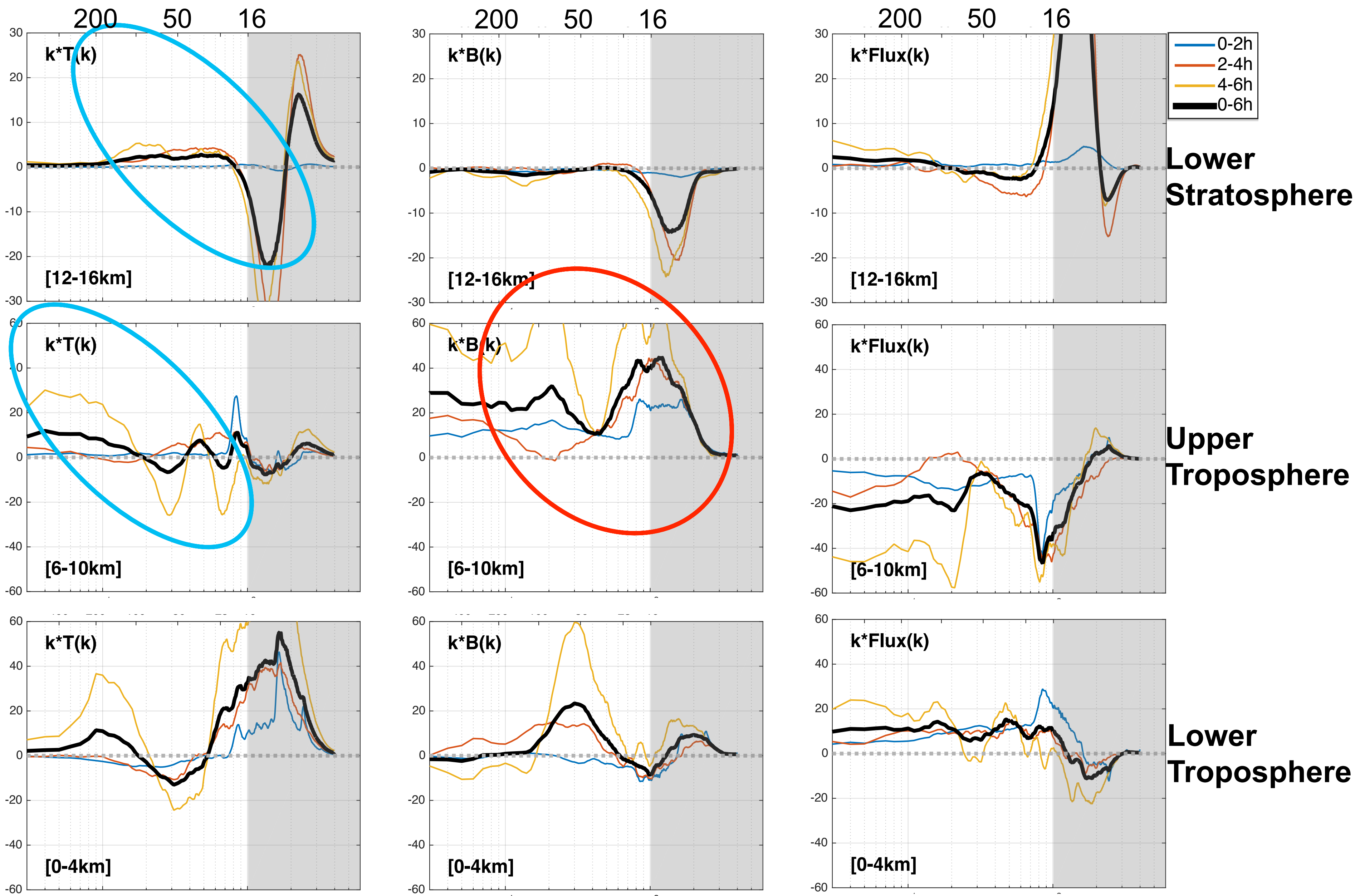
Spectra budget analysis at different levels



Kinetic Energy Spectra in Experiment with Coriolis effect



Spectra budget analysis at different levels (Coriolis experiment)



Concluding Remarks

- ❑ Moist convection and the gravity waves they generated are able to generate a background mesoscale kinetic energy spectrum with a -5/3 slope.

- ❑ Three physical processes actively contribute to the formation of the kinetic energy spectrum.

- ❑ Strong communications exist between different height levels, due to vertical energy fluxes induced by convection and the gravity waves.

- ❑ The classical cascade picture can not be applied to our simulation.