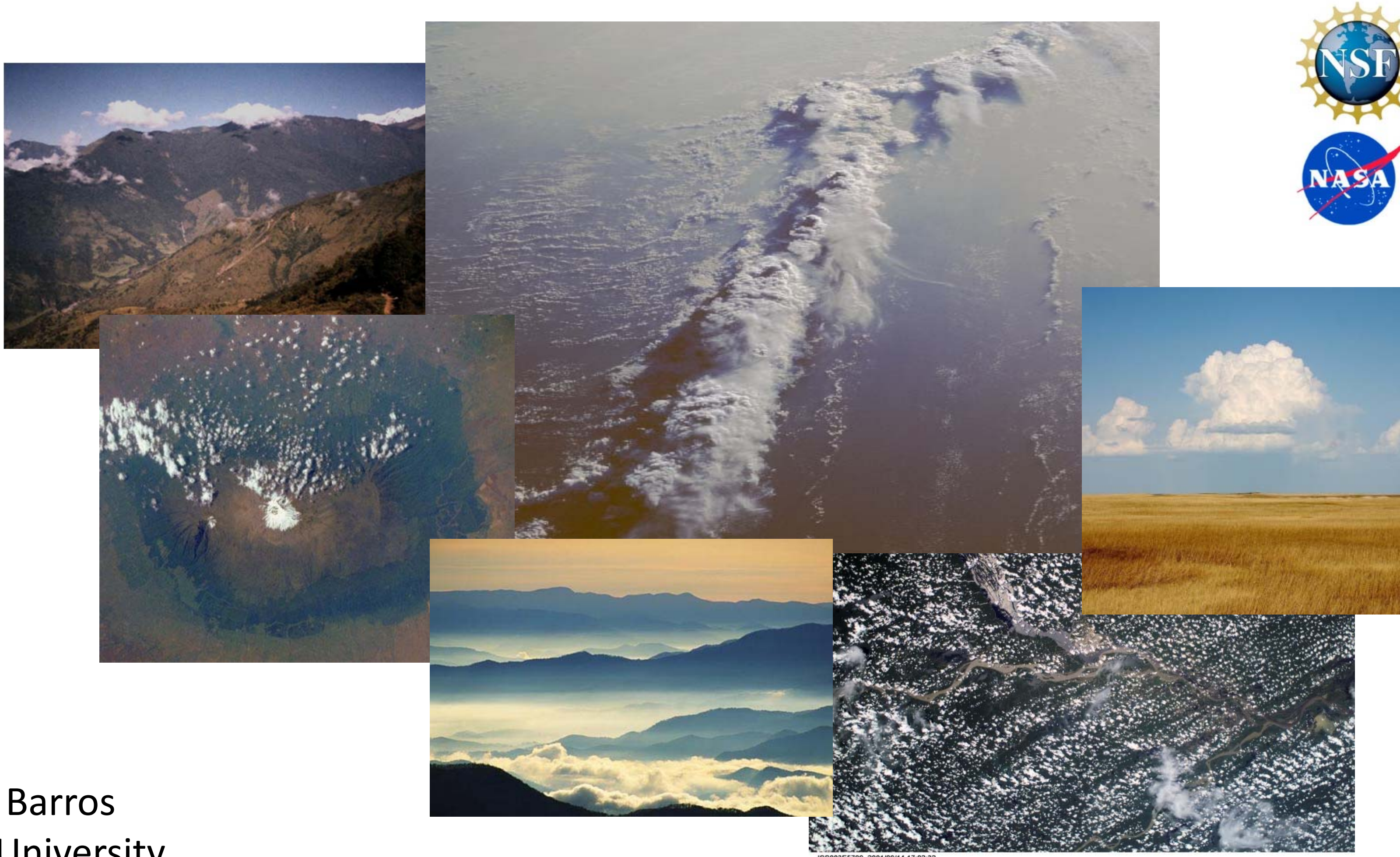
Emergent Pathways of Predictability :
– The Diurnal Cycle and the Role of Landform and Landcover on the Organization of Moist Processes at Multiple Scales



Ana P Barros
Duke University
Shanti Bushan, Jessica Erlingis, Miguel Nogueira, Xiaoming Sun, Lauren Lowman

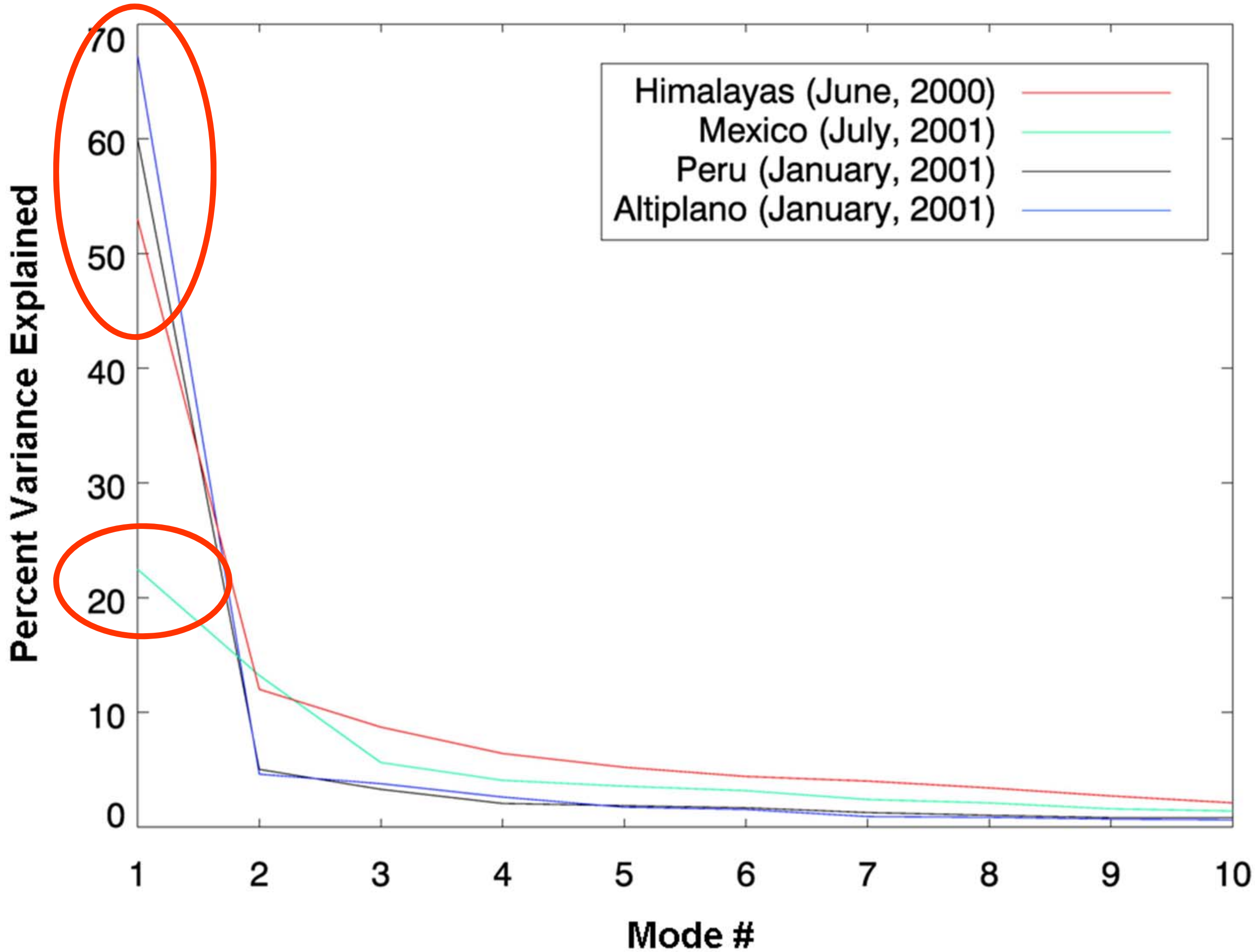
Diurnal Cycle and Land-Atmosphere Interactions

❑ The Space-Time Organization of Clouds and Precipitation

Observations in Mountainous Regions
Understanding the Roles of Landform and Landcover
Predictability Challenges – Hydrometeorological Regimes
Dynamic Range
Superstructures
Convective Initiation

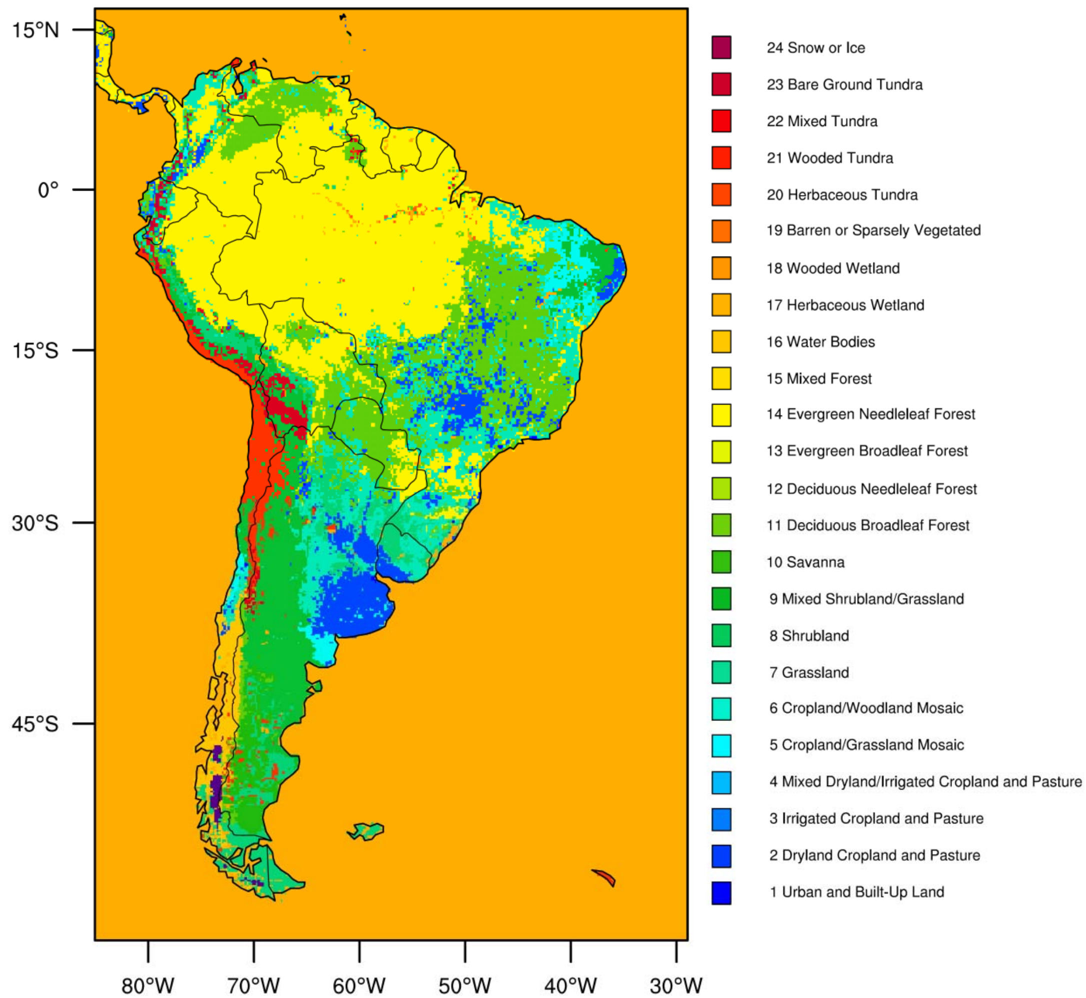
Clouds and Orography

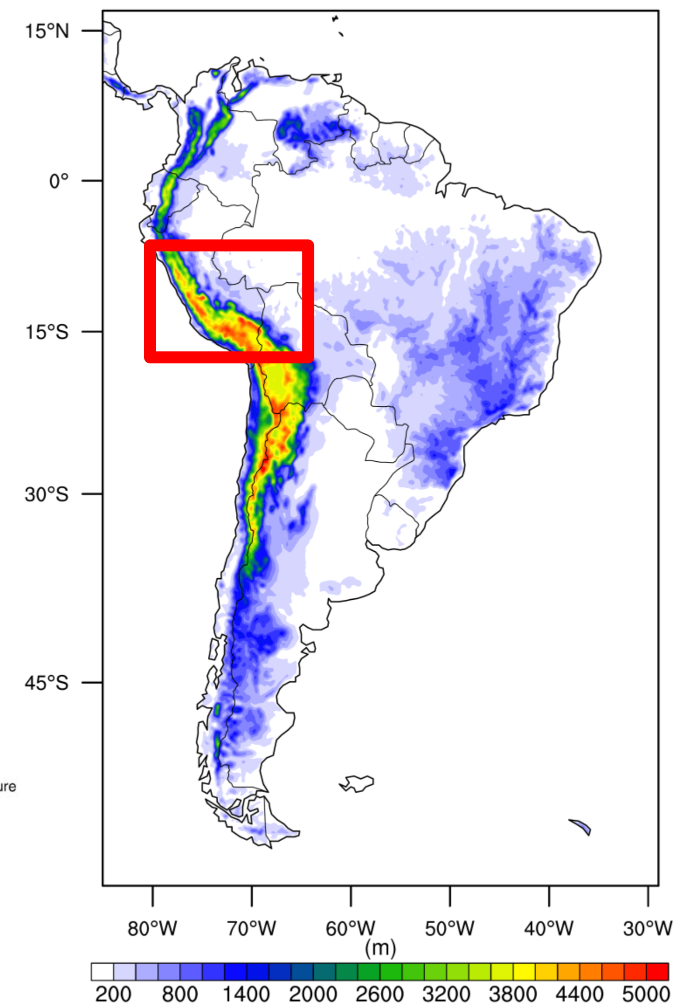
1st Principal Component of Cloudiness (IR Brightness)



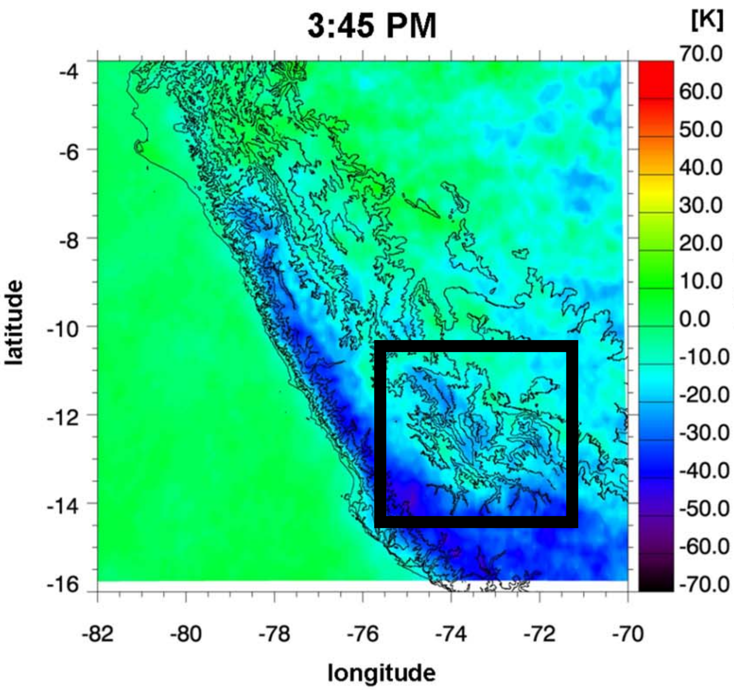
Barros et al. 2004 NHESS; Giovannetone and Barros, JHM, 2008 and 2009; Shrestha and Barros, ACP, 2010

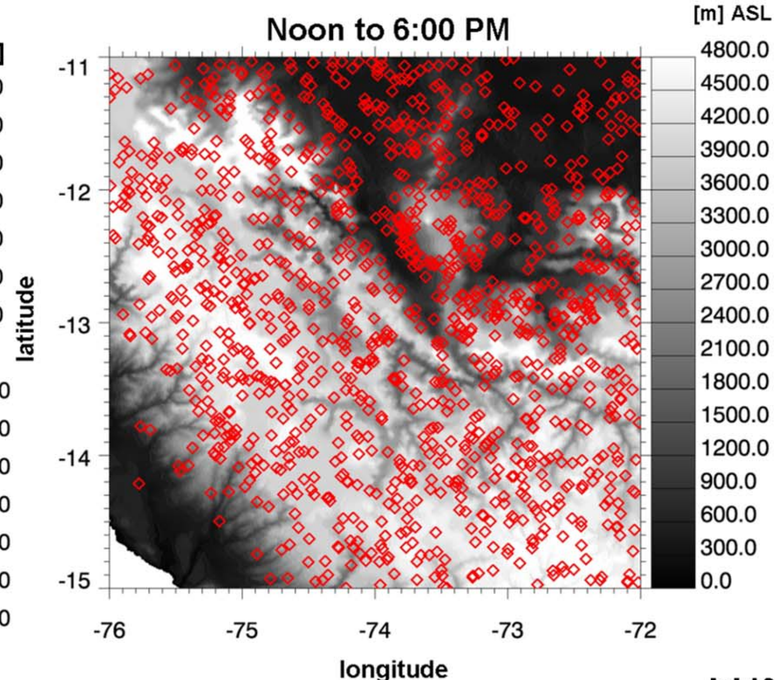
Central Andes





Land-cover (left) and Topography (right)

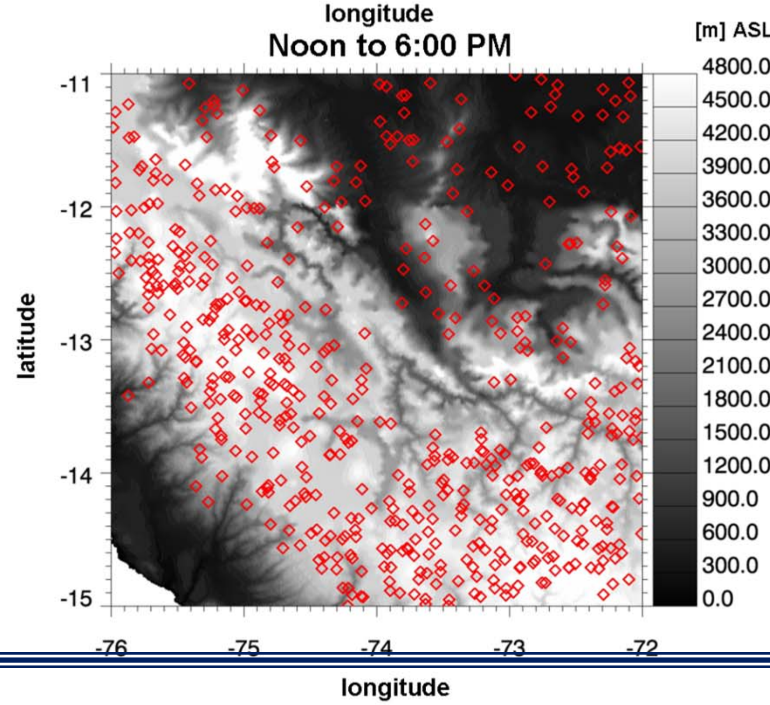




Warm Rain

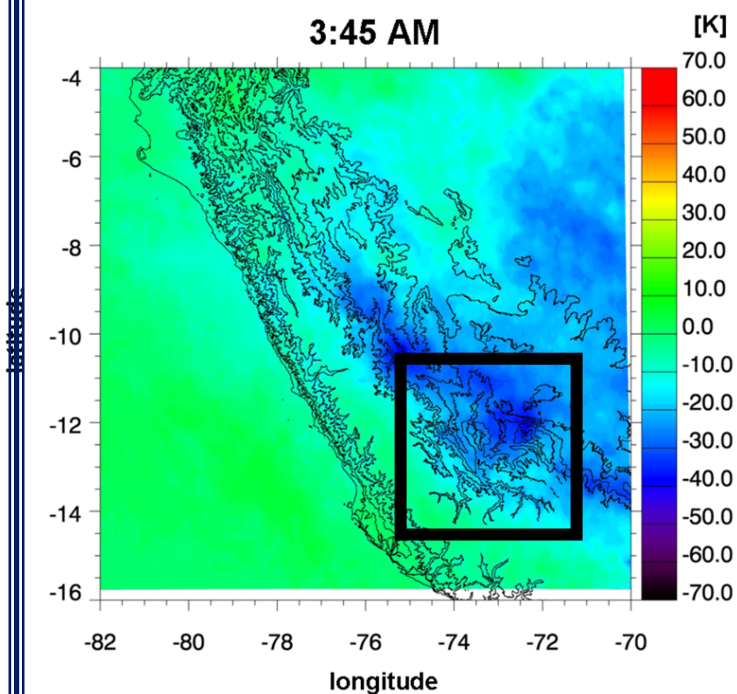
Daytime Climatology

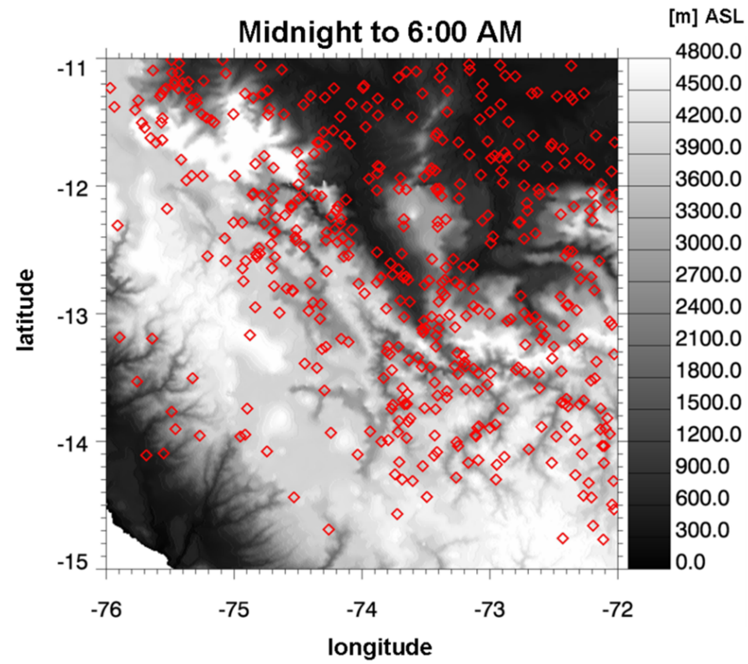
TRMM Central Andes



Deep Convection

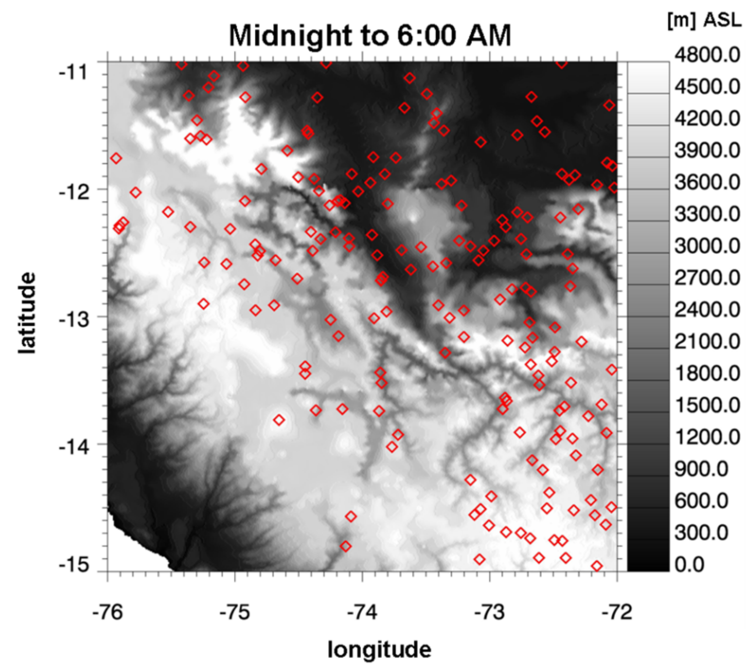
Giovannettone and Barros, 2009





Warm Rain

Note valley alignment



Deep Convection

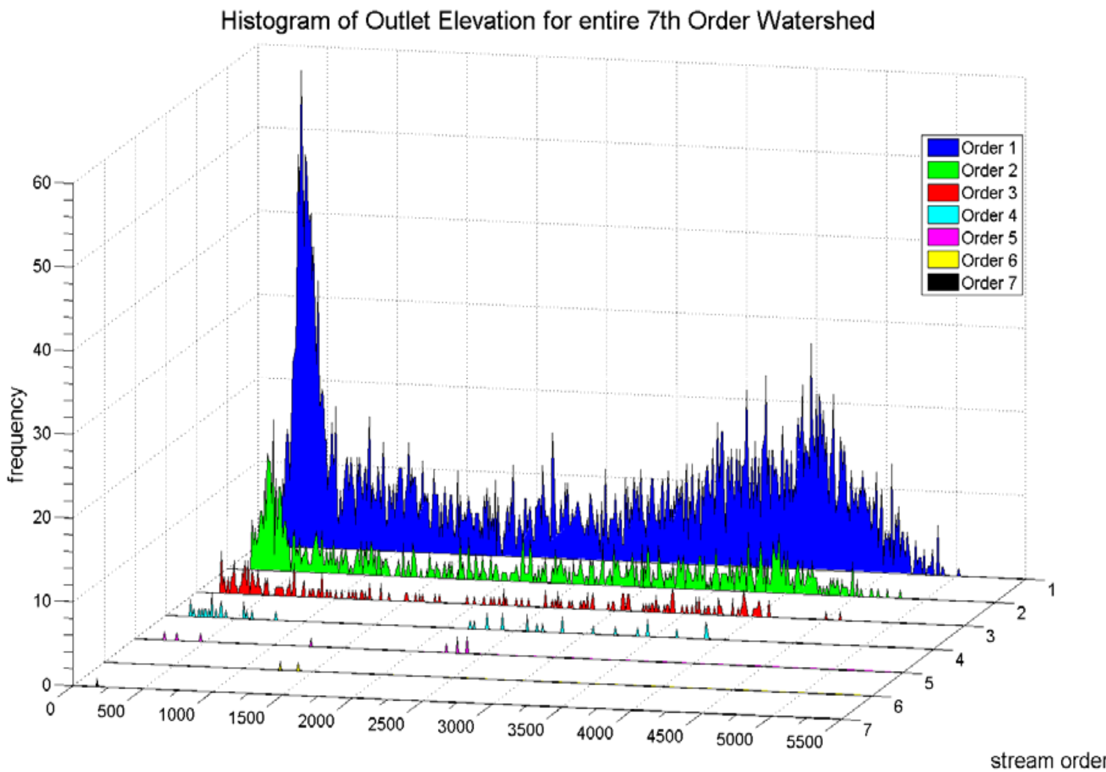
Nighttime Climatology

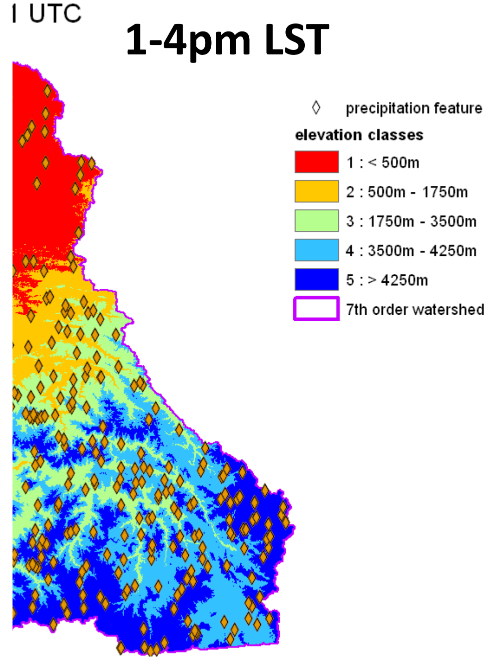
TRMM Central Andes

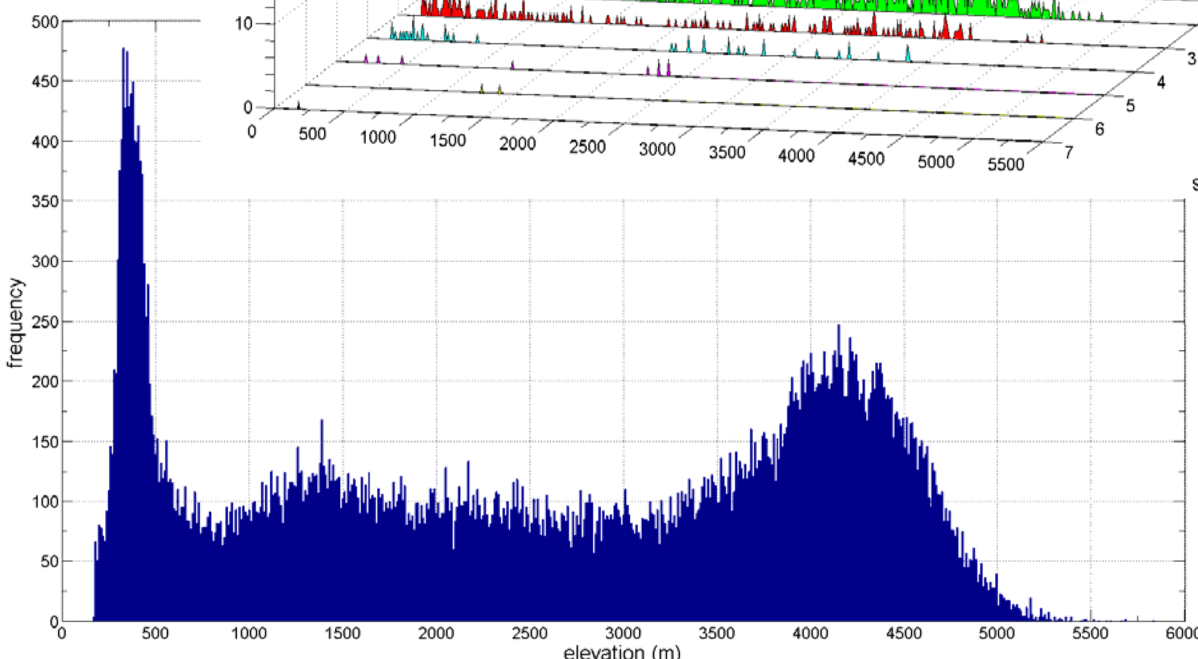
Giovannettone and Barros, 2009

Prec ... or January 1998-2010

l UTC



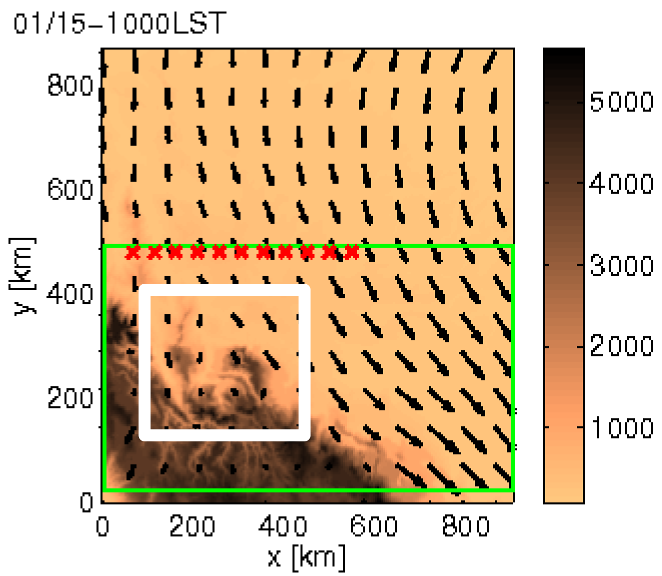


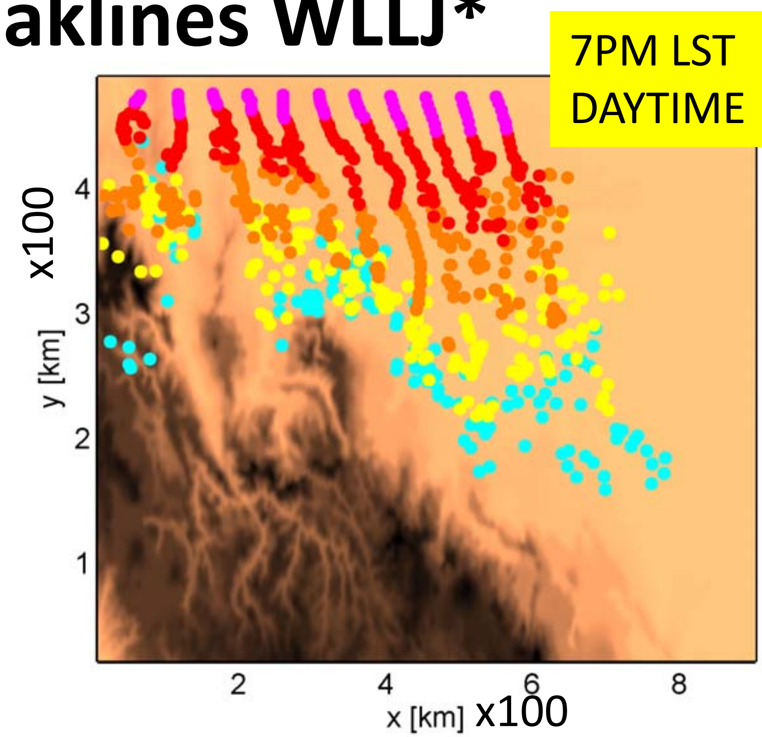


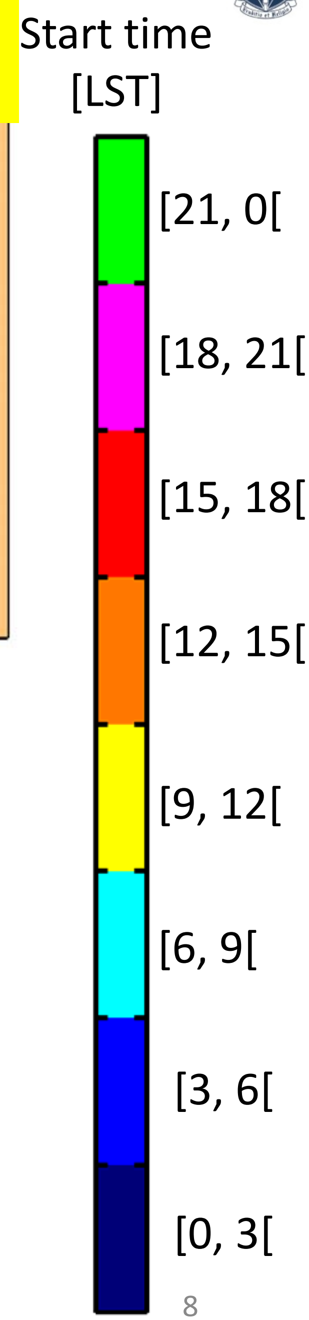
Lowman and Barros, 2013, JGR-ES pending revisions

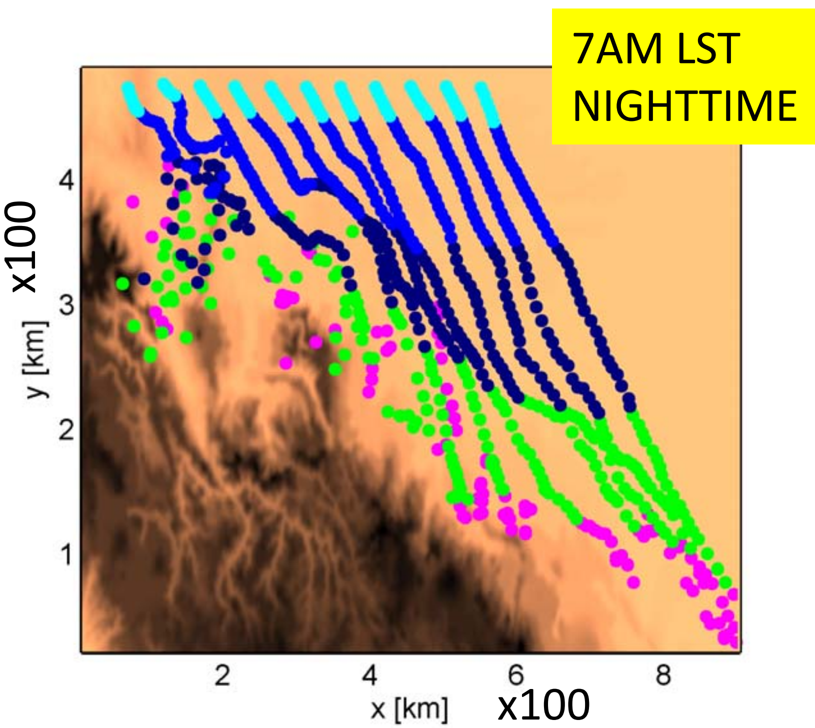
Streaklines WLLJ*

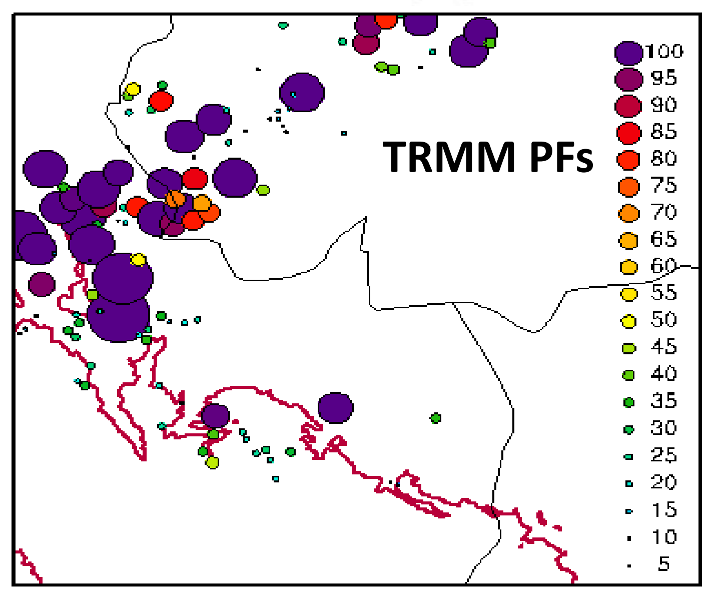
WRF 1.2 km resolution



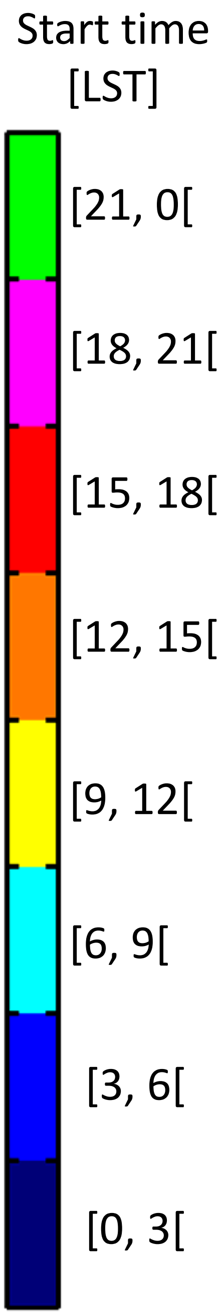


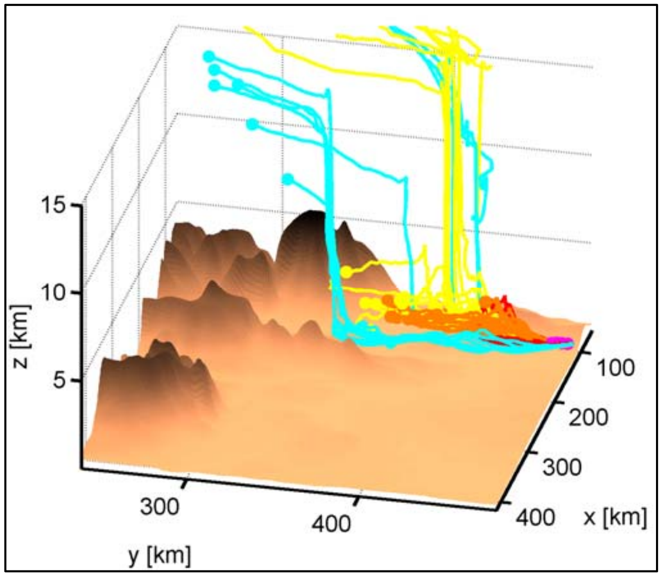


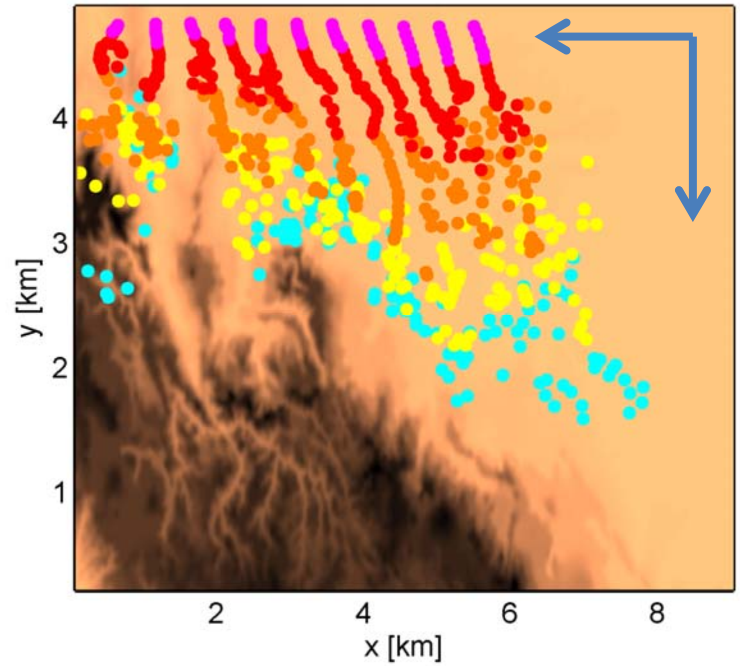


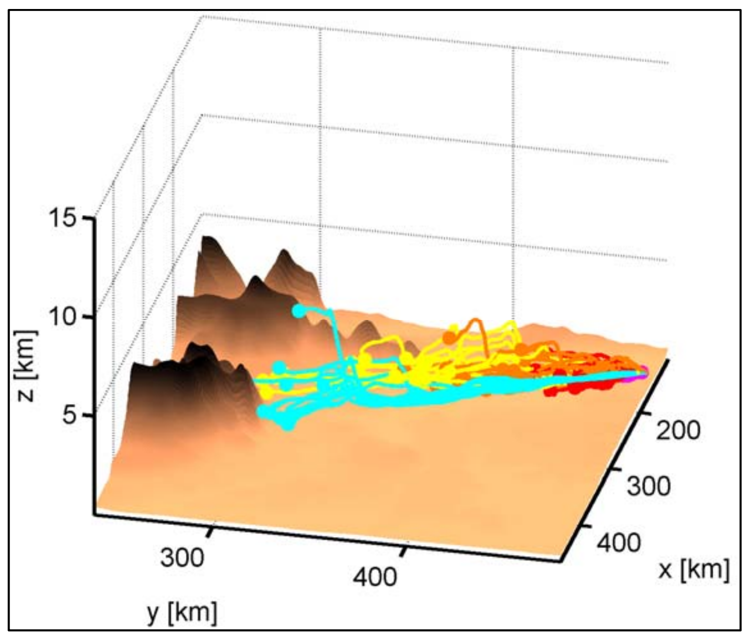


Barros, Nogueira and Sun, 2013, in prep









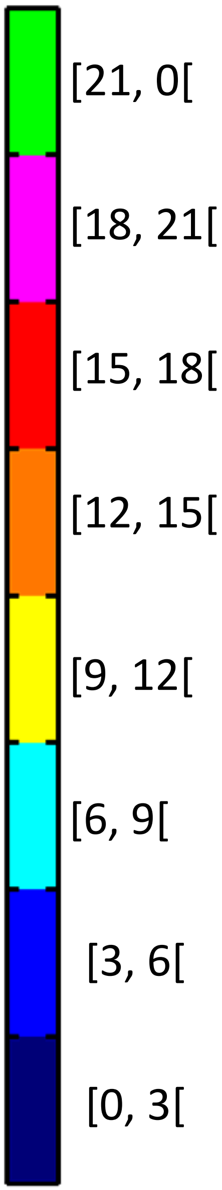
7PM LST

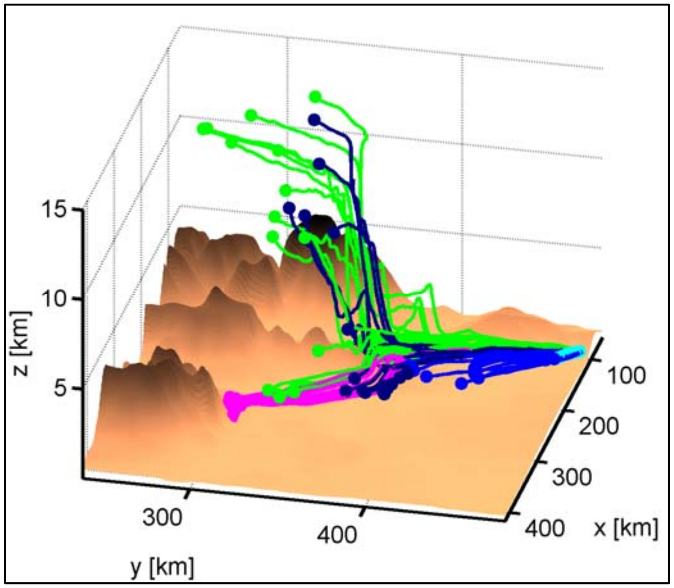
DAYTIME

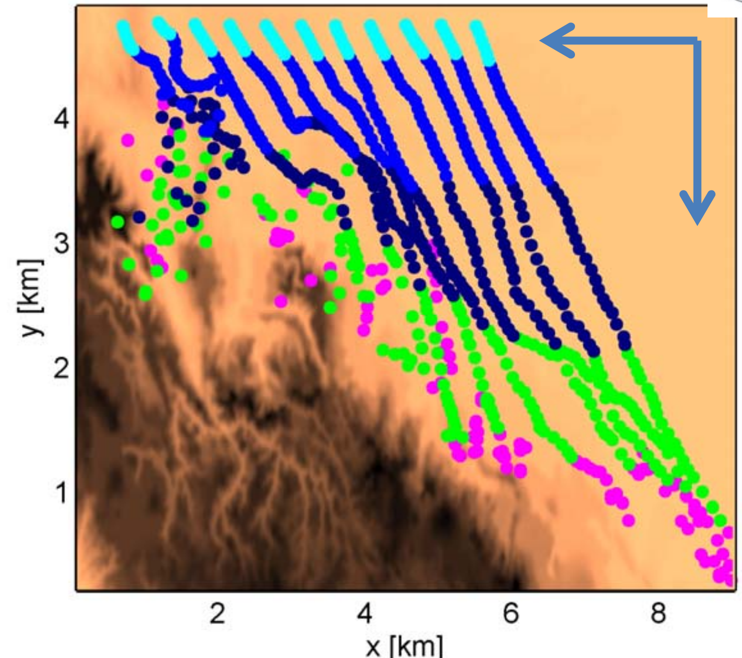
WLLJ

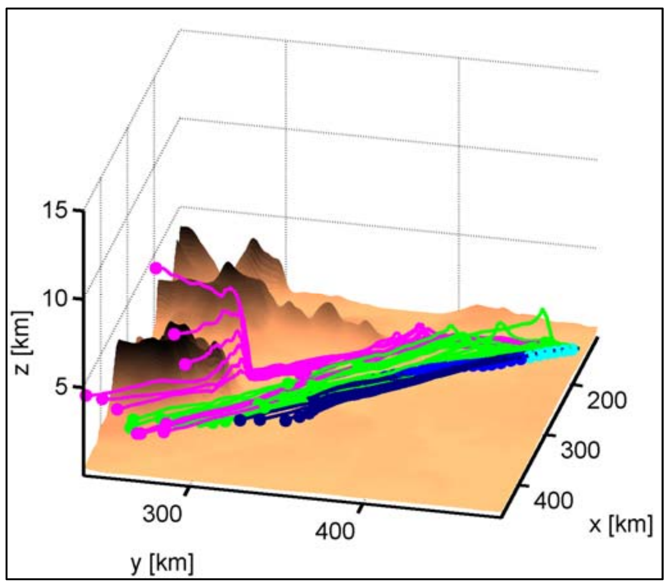
1,000 m streaklines

Start time [LST]







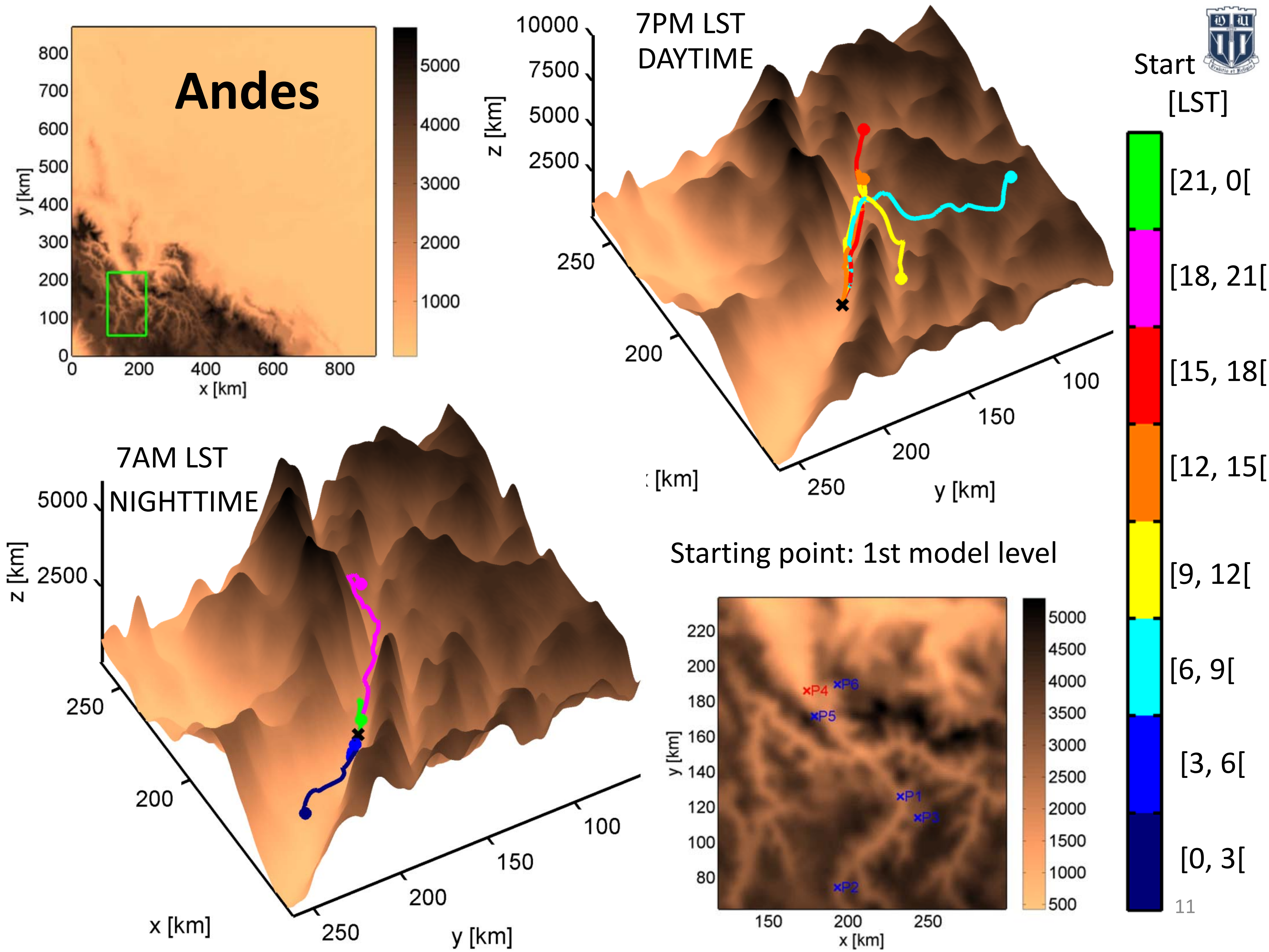


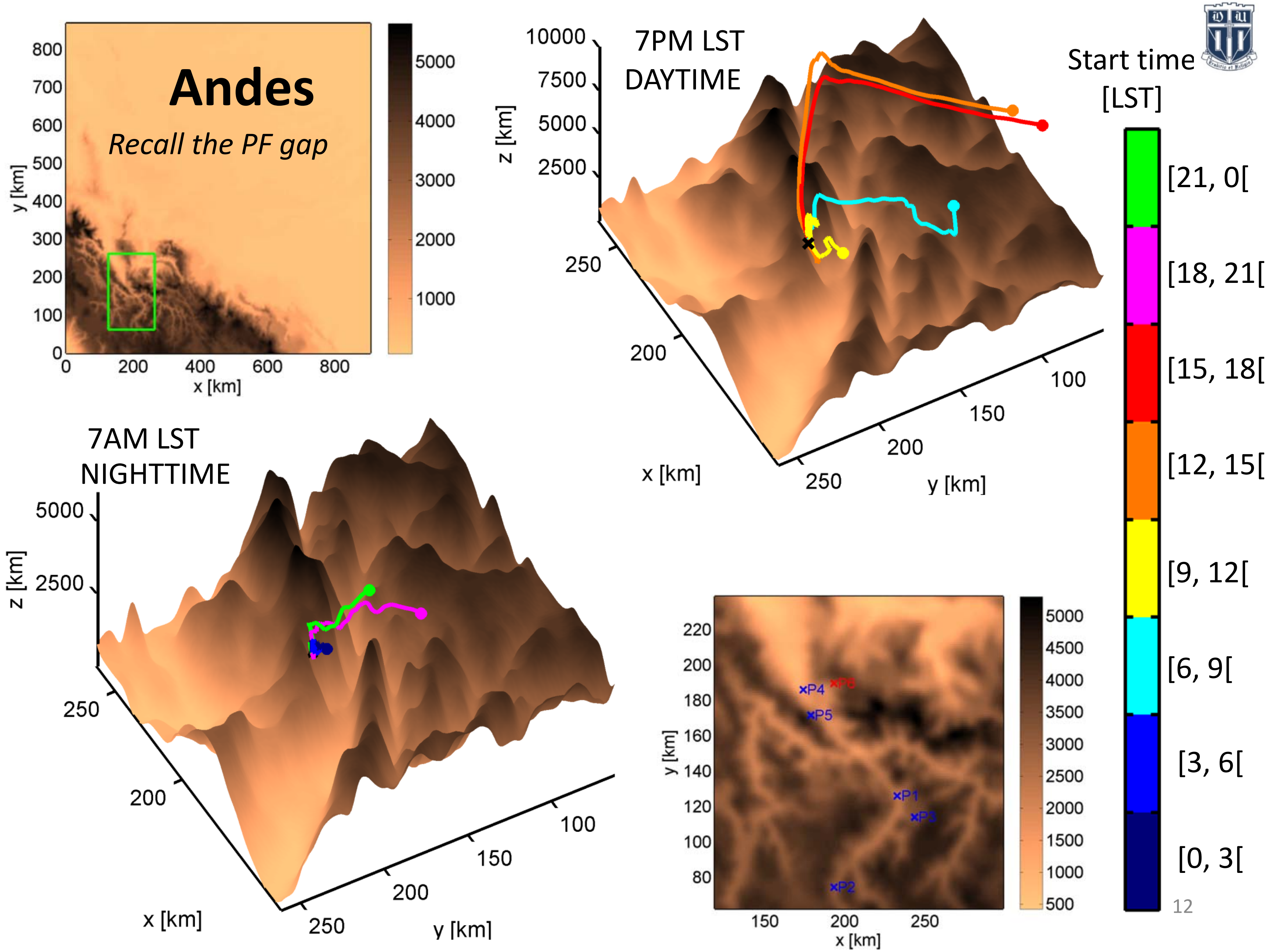
7AM LST

NIGHTTIME

WLLJ

1,000 m streaklines


Andes
y [km]
x [km]
7PM LST
DAYTIME
z [km]
y [km]
7AM LST
NIGHTTIME
z [km]
x [km]
y [km]
Starting point: 1st model level
P1
P2
P3
P4
P5
P6
y [km]
x [km]
Start
[LST]
[21, 0[
[18, 21[
[15, 18[
[12, 15[
[9, 12[
[6, 9[
[3, 6[
[0, 3[



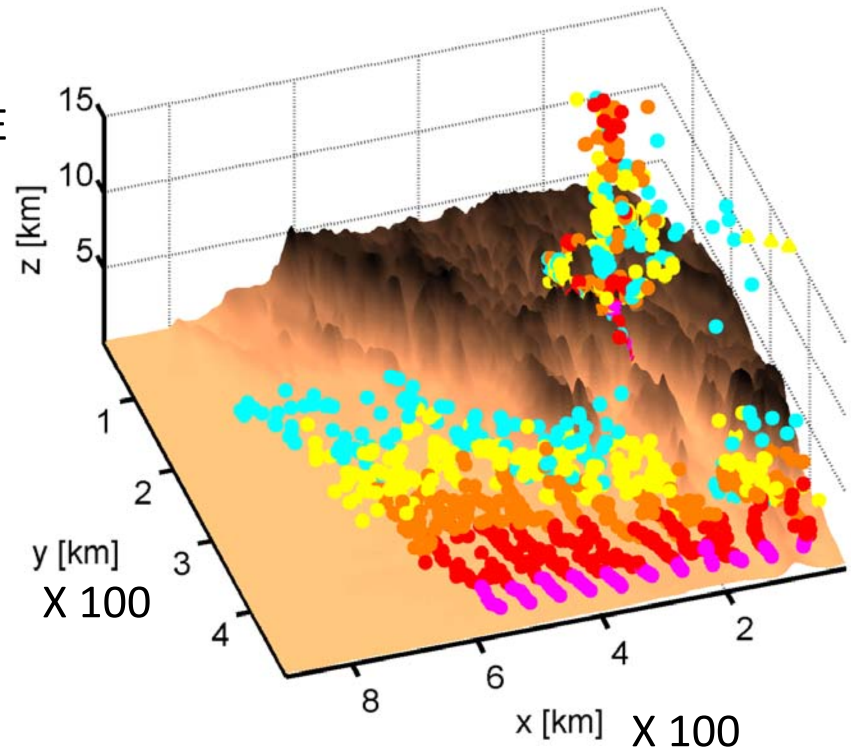
Andes
Recall the PF gap
y [km]
x [km]
800
700
600
500
400
300
200
100
0
5000
4000
3000
2000
1000
7PM LST
DAYTIME
z [km]
10000
7500
5000
2500
250
200
100
150
200
250
x [km]
y [km]
Start time
[LST]
[21, 0[
[18, 21[
[15, 18[
[12, 15[
[9, 12[
[6, 9[
[3, 6[
[0, 3[
7AM LST
NIGHTTIME
5000
2500
P1
P2
P3
P4
P5
P6
4500
3500
2500
1500
500
220
180
160
140
120
80
150

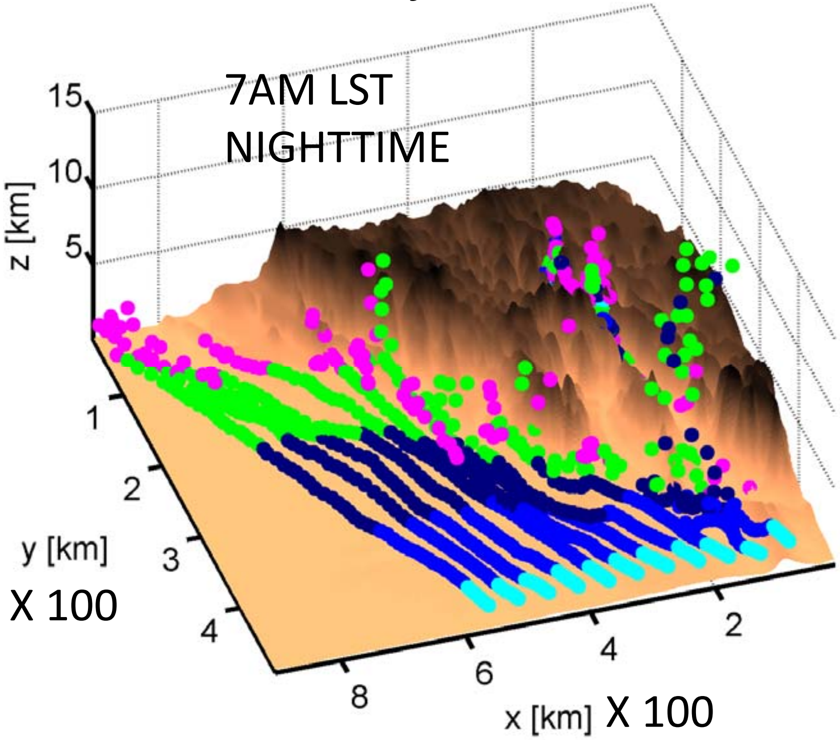
Diurnal Cycle

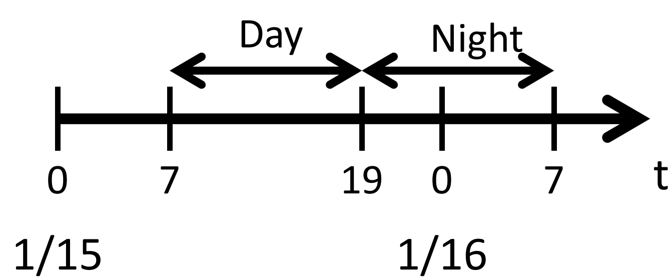
- ❑ Dynamic Spatial Range
  nesting precipitation gap
- ❑ Timing
- ❑ Convective Initiation

What is the role of Landcover?

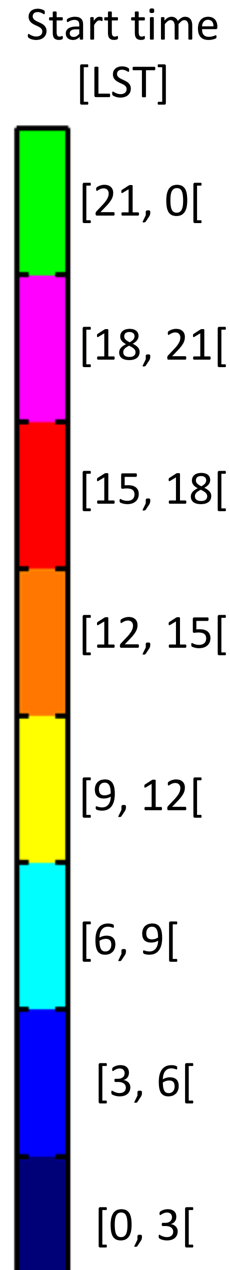
7PM LST
DAYTIME







SALLJEX, 2003



Diurnal Cycle and Land-Atmosphere Interactions

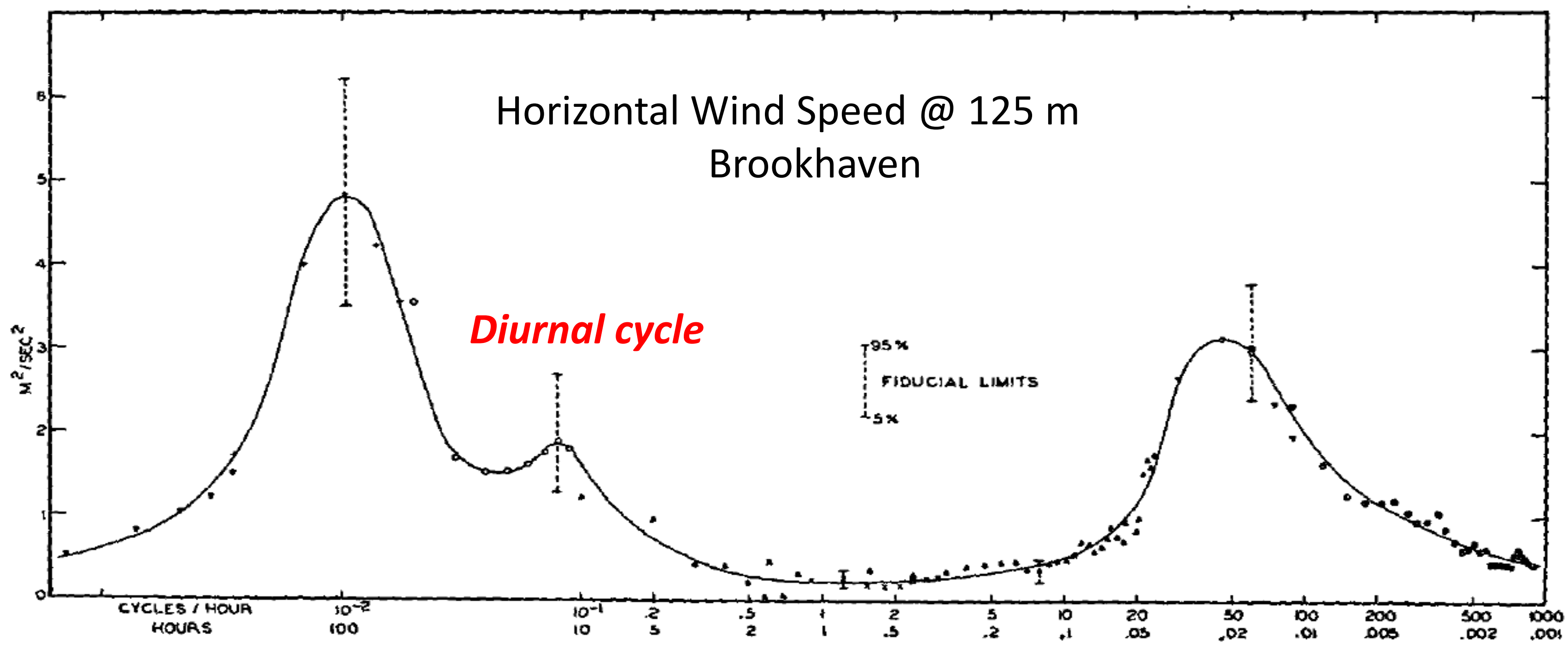
❑ Multiscale Interactions and Scaling Behavior

- Land-Atmosphere Interactions are "Wall Processes"
- Universal vs Local Scaling
- Modeling Challenges
  - Numerical Physics vs Resolved Physics
  - Resolution
  - Parameterizations

❑ Evaluation, Verification, Skill, Reproducibility and Metrics

Horizontal Wind Speed @ 125 m
Brookhaven

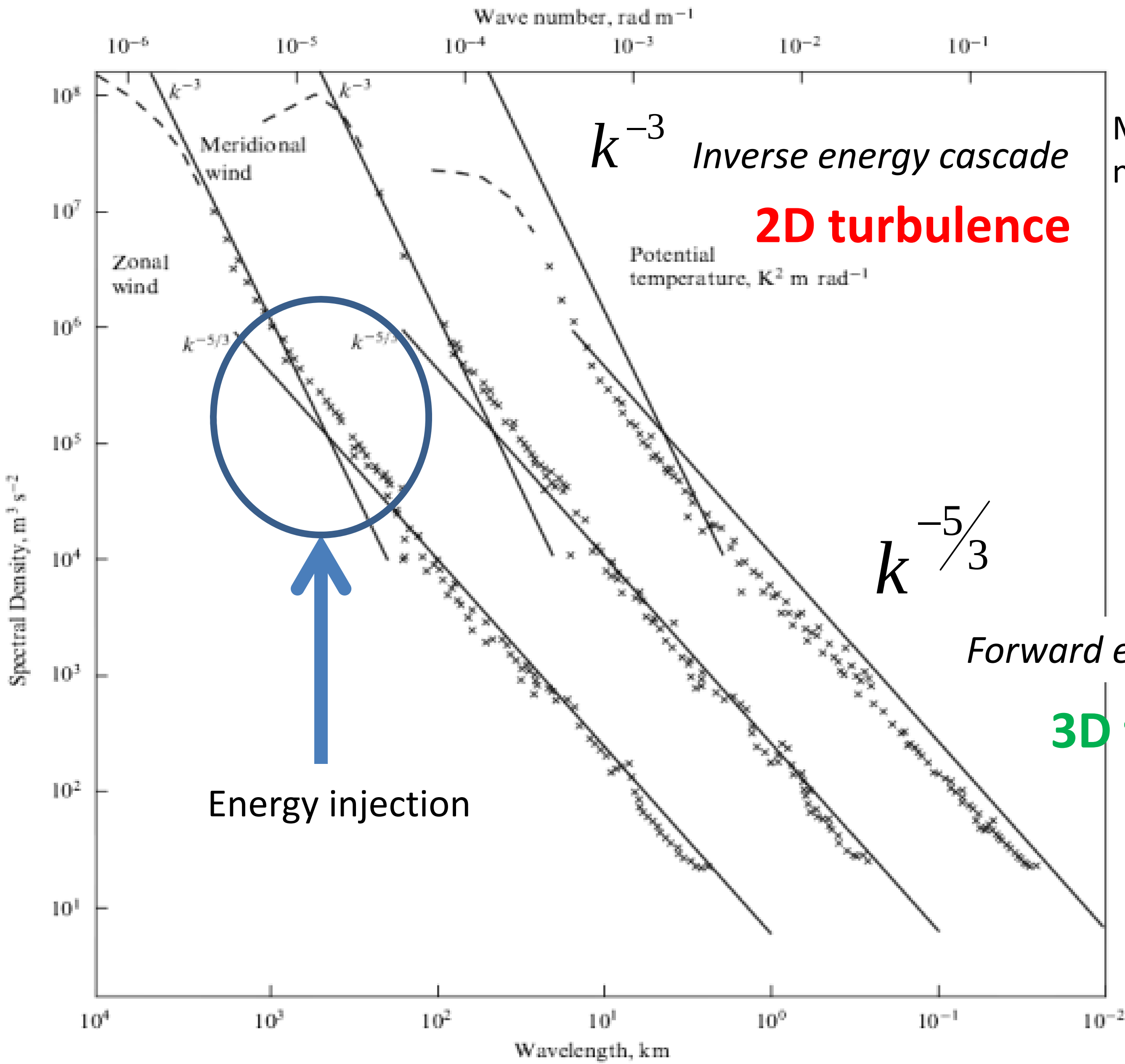
V×V



~ 4 days

~10 min

Van der Hoven, 1957



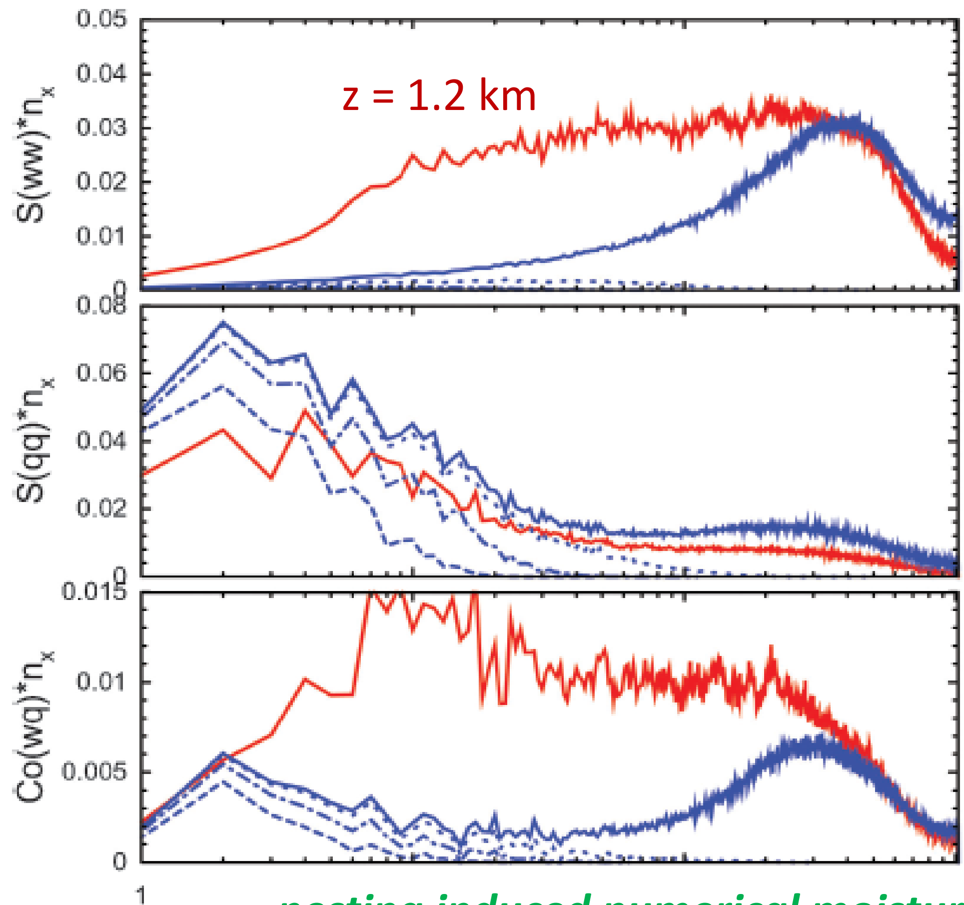
Measurements near the tropopause

Forward energy cascade

3D turbulence

Lilly, 1989

LES Simulations of PBL- Convection Interactions



moisture flux

nesting induced numerical moisture flux filtering??

Cold pool

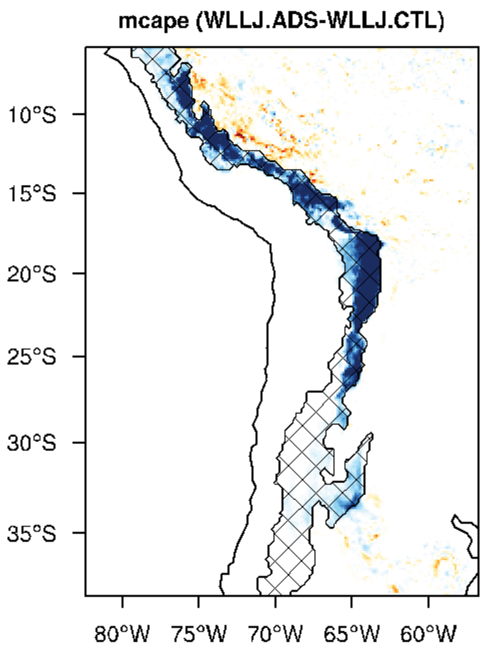
Turbulence

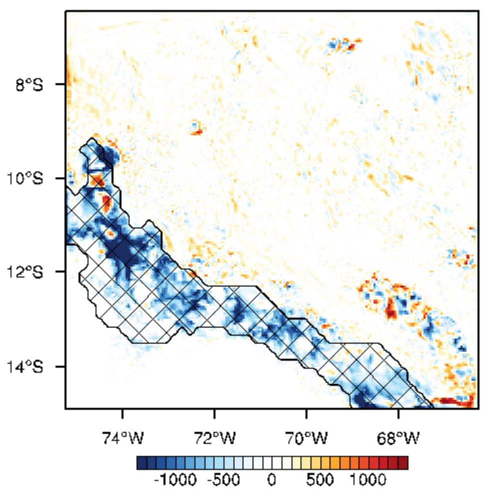
Filtered LES

C.H.Moeng, 2008 and 2009

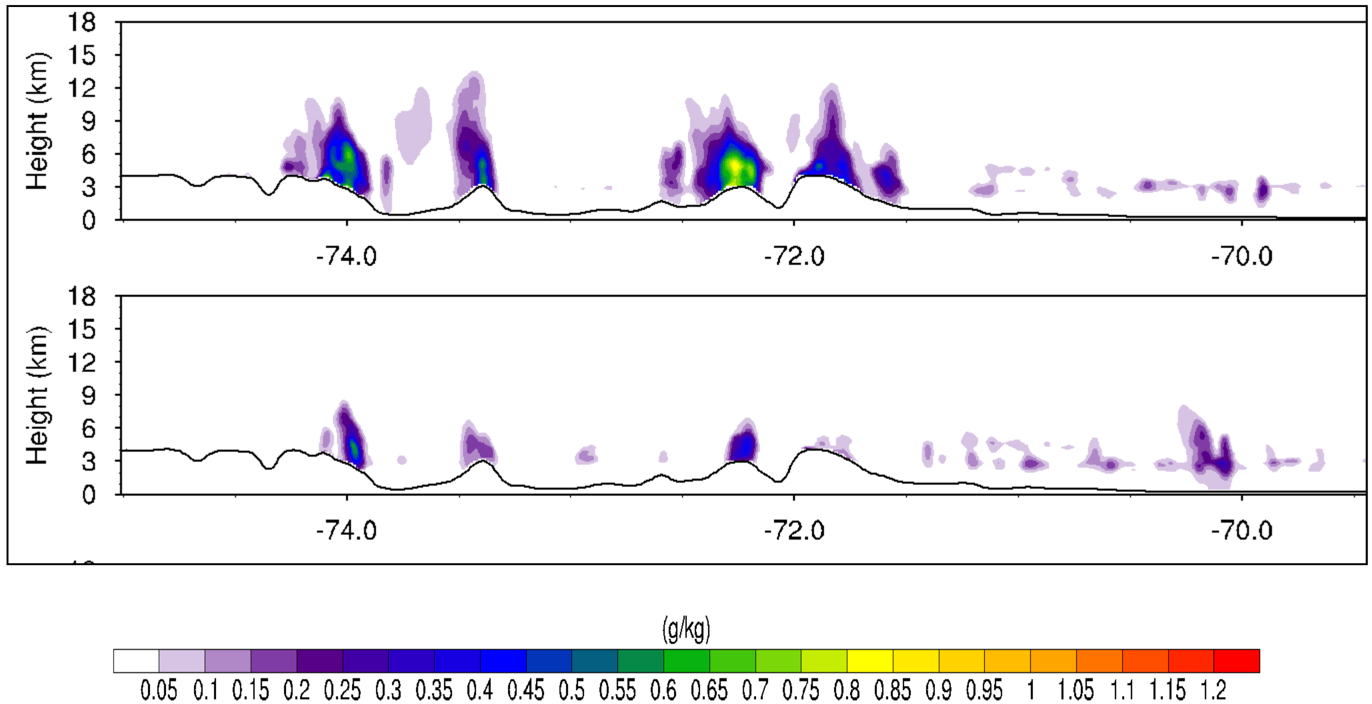
Atmospheric Fingerprints of Evapotranspiration

Instability





Clouds



Cloud contents (g/kg)

daytime average hydrometeors except rainwater

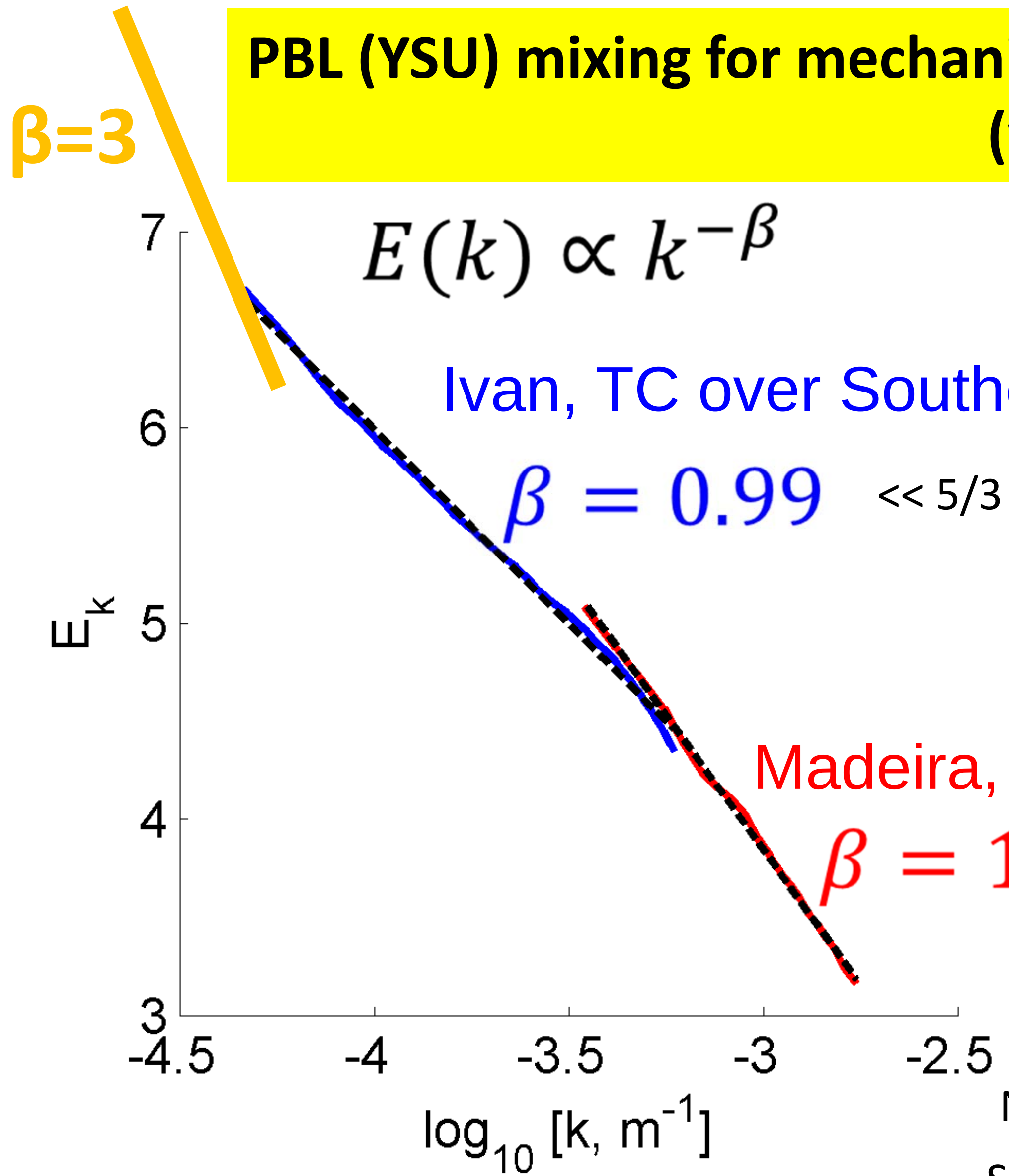
Convection diagnostics (13:00 PM, LST)

Sun and Barros, 2013, JAS, tbsub.

Cloud Water Mixing Ratio Scaling

WRF Ensemble

PBL (YSU) mixing for mechanical turbulence is too low (weakly stable conditions)



Spectral gap energy injection, and inverse cascade

Nogueira, Barros and Miranda, NPG 2013

Sun and Barros, MWR 2012; QJRMS 2013

2D-3D Energy Transfers

$$\frac{\partial q^2}{\partial t} + \underbrace{u\frac{\partial q^2}{\partial x} + v\frac{\partial q^2}{\partial y} + w\frac{\partial q^2}{\partial z}}_{Convection} =$$

$$\underbrace{-2\left(\tau_{xz}\frac{\partial u}{\partial z} + \tau_{yz}\frac{\partial v}{\partial z}\right)}_{Turbulent\ Production} + \underbrace{P_b}_{\substack{Bouyancy\\ Production}} \underbrace{- \frac{q^3}{B_1 l} + \frac{\partial}{\partial z}\left[lqS_q\frac{\partial q^2}{\partial z}\right]}_{Diffusion} + \mathbf{TB}$$

Spectral gap energy transfer

PBL parameterization

YSU, MYJ,…

- ***Dynamic Spatial Range***
  Local vs <u>Remote</u> Controls

- Need for Parameterizations

$$DNS \propto \Re^{9/4}$$

$$LES \propto \Re^{1.8}$$

$$PBLpar \propto \Re^{0.2}$$

Attribution and Artificial Scaling Behavior

Recall Linear Advection

$$\frac{\partial q}{\partial t} + u\frac{\partial q}{\partial x} = D\frac{\partial^2 q}{\partial x^2} + S(q)$$

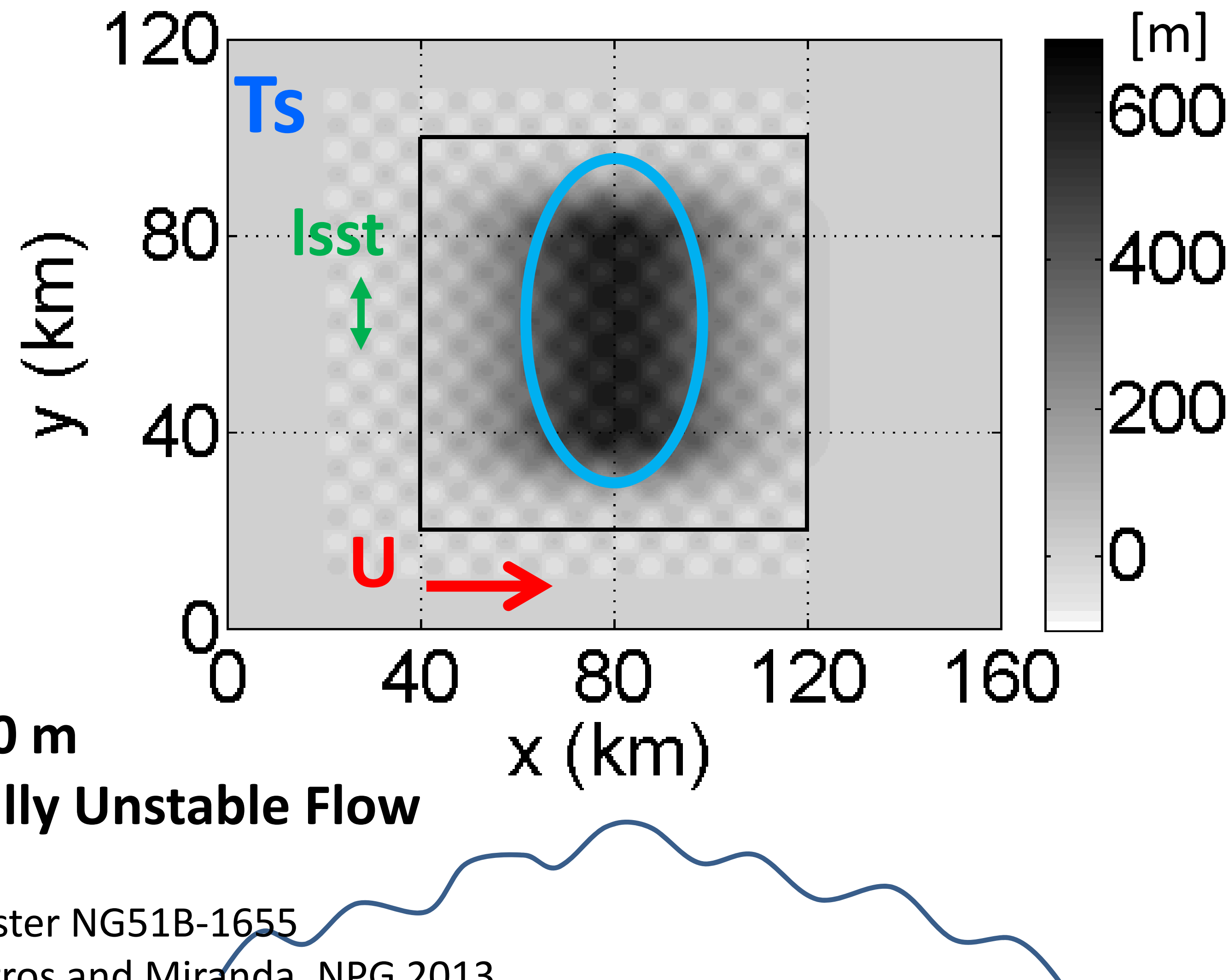
- Numerical wavenumber is always smaller than the physical wavenumber

❖ ***Timing***
Convective Initiation

❑ Damping
❑ Dispersion
  – **phase speed error dependent on the wavenumber and grid resolution shift in propagation for wavelength < 2-3 Δx**

Shallow Orographic Convective Precipitation

Population of 3D Idealized Simulations



WRF @ 250 m

Conditionally Unstable Flow

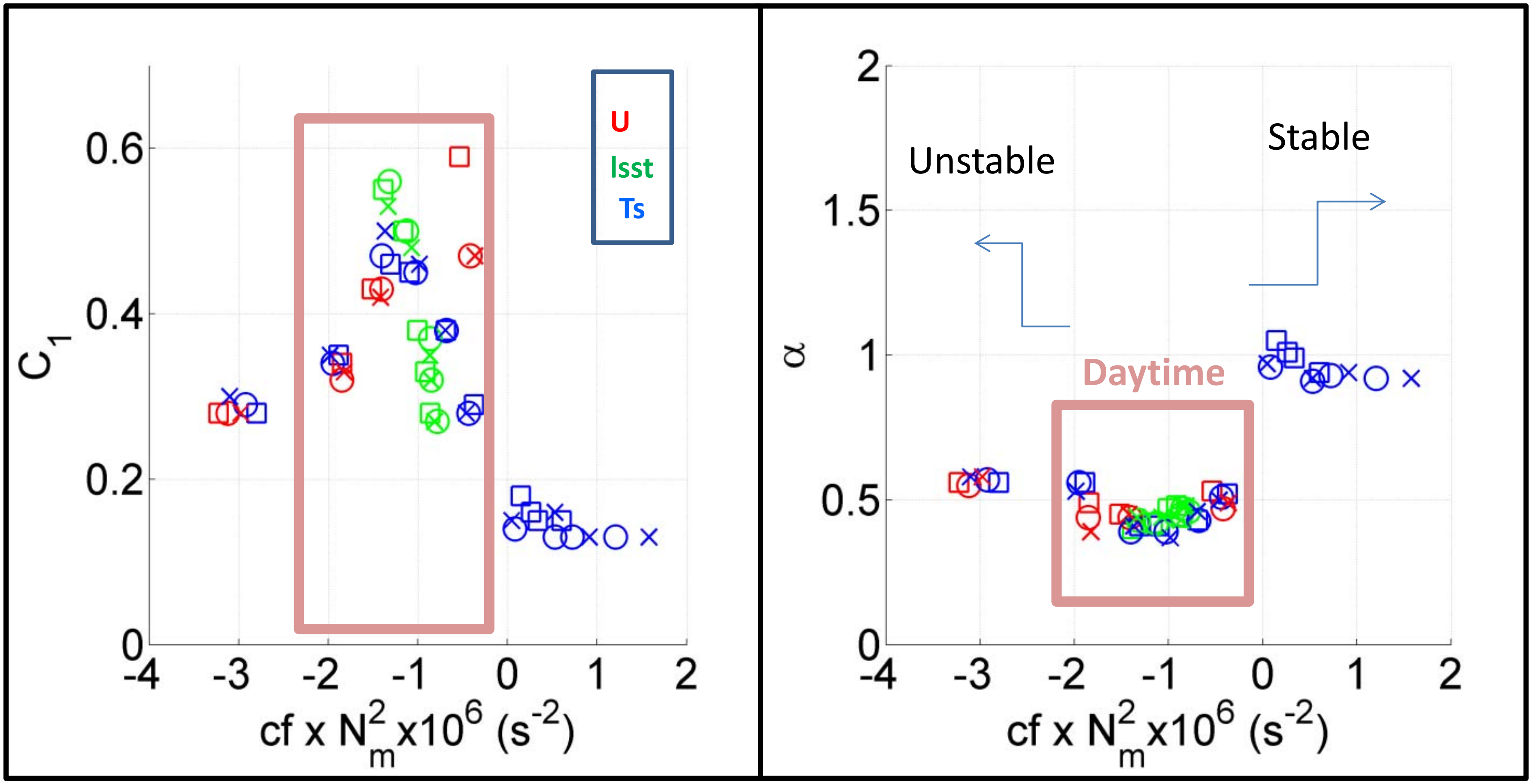
AGU 2011 Poster NG51B-1655

Nogueira, Barros and Miranda, NPG 2013

"Realized Moist Instability"

= cloud fraction × Brunt-Väisälä frequency

a) Higher α indicates lower frequency of large magnitude fluctuations;
b) Higher C_1 implies higher intermittency



Nogueira, Barros and Miranda, NPG 2013

Challenges

- Resolve Processes at Correct Location in Phase-Space

  Phase and Morphology, and **Forcing**

  Understand nonlinear interactions between

  resolved physics and numerics

  observations and physics

- 2D – 3D turbulence transitions

  Direct and **Inverse** Cascades

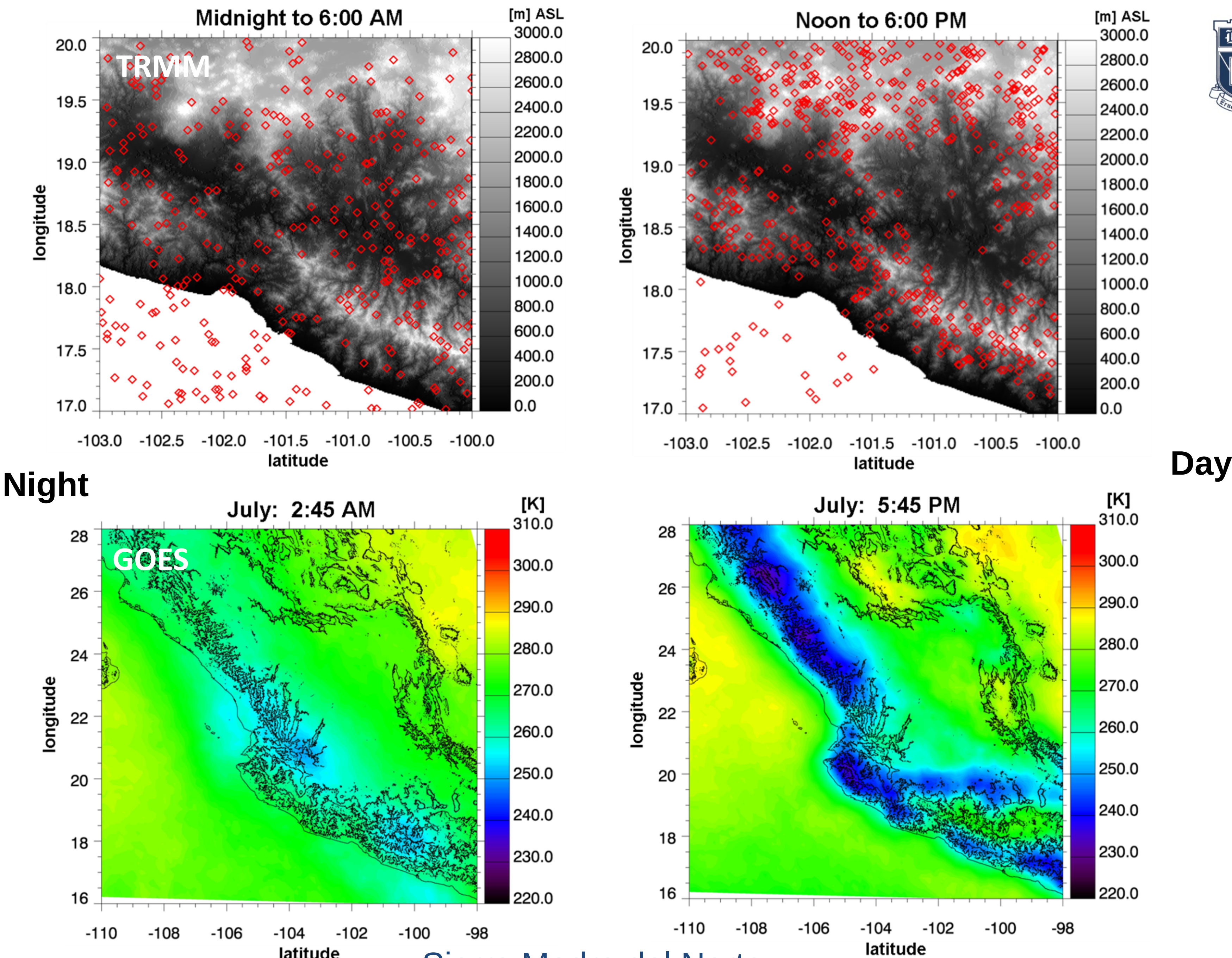
- Parameterizations that Preserve Scaling Behavior

  Dynamically

- Nesting (Dynamical/Static) – "Teleconnection" Scales?

  Lagrangian Streakline Analysis wrt **Storm Initiation** Environment

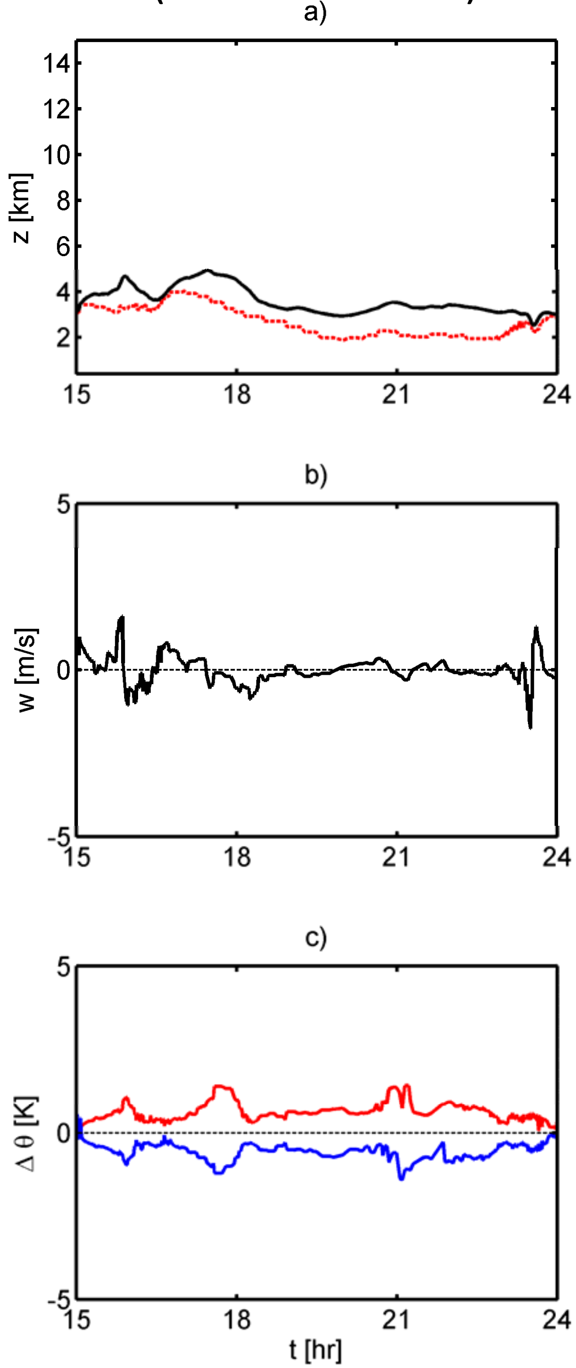

Thank you

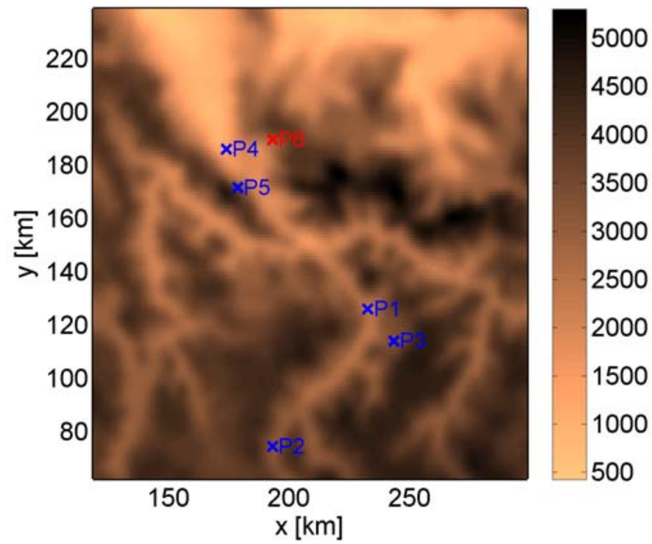


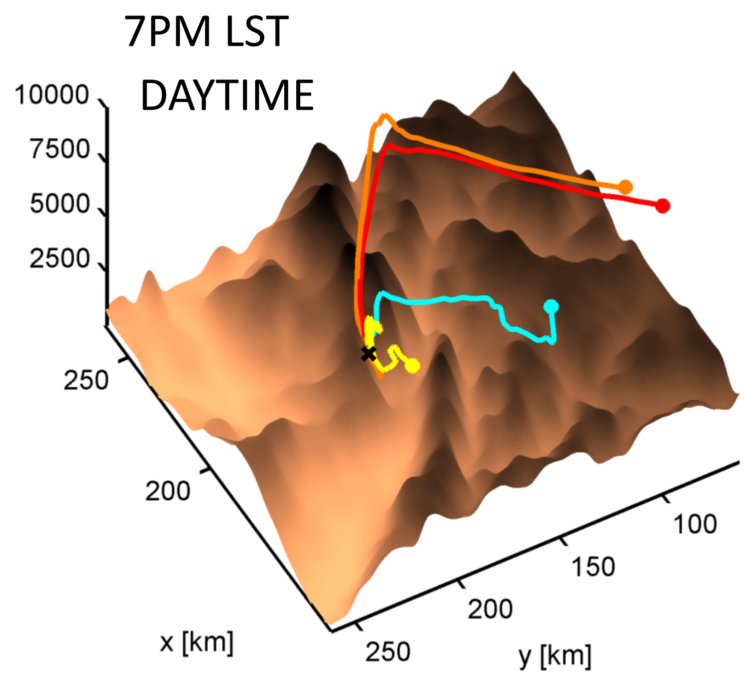
Sierra Madre del Norte

Giovannetonne and Barros, 2008

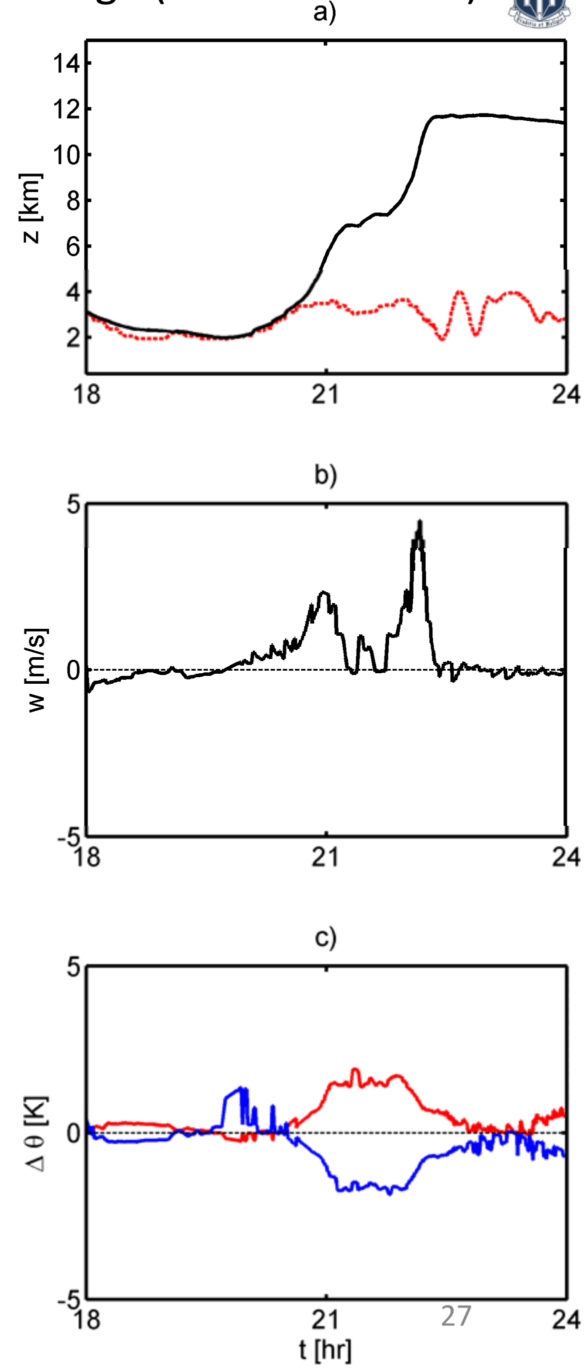
Yellow (10 LST : 15 UTC)







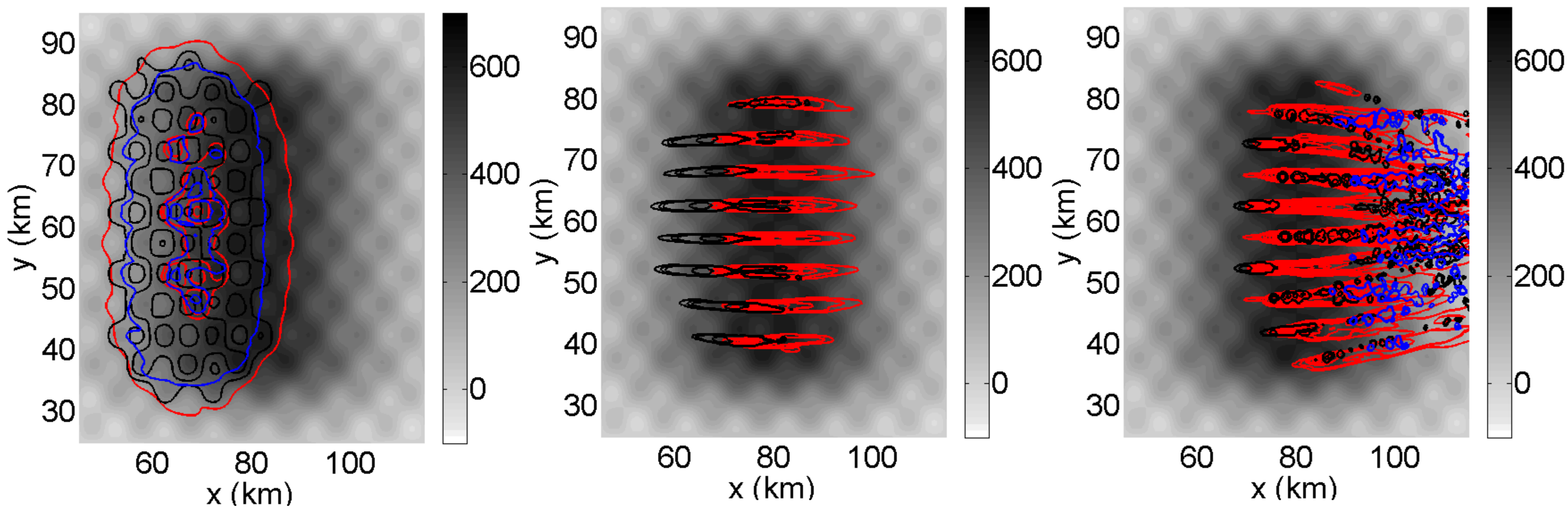
Orange (13 LST : 18 UTC)



Ts Sensitivity

Colder
(more stable)

Warmer
(more unstable)



Poster NG51B-1655, Nogueira et al.
2011Nogueira, Barros and Miranda, NPG 2013