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

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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
Land-cover (left) and Topography (right)

Central Andes
Daytime Climatology
TRMM Central Andes

Giovannettone and Barros, 2009
Nighttime Climatology
TRMM Central Andes

Giovannettone and Barros, 2009
Lowman and Barros, 2013, JGR-ES pending revisions
**Streaklines WLLJ***

**Start time [LST]**
- 7PM LST
- 7AM LST

**WRF 1.2 km resolution**
- 01/15-1000LST

**7PM LST DAYTIME**
- 7AM LST NIGHTTIME

**TRMM PFs**
- Barros, Nogueira and Sun, 2013, in prep

**Horizontal Projection**
- Andes Foreland Basin

**Andes Foreland Basin**
- Streaklines

**WLLJ**
- Starting points: z ≈ 1000 m

**Barros, Nogueira and Sun, 2013, in prep**
7PM LST
DAYTIME
WLLJ

1,000 m streaklines
7AM LST
NIGHTTIME
WLLJ

1,000 m streaklines
Start time: 7PM LST

Nighttime:
- Andes

Daytime:
- Starting point: 1st model level
Andes

Recall the PF gap

7PM LST

DAYTIME

Start time

[12, 15[

[9, 12[

[6, 9[

[3, 6[

[0, 3[

7AM LST

NIGHTTIME
Diurnal Cycle
- Dynamic Spatial Range
- Timing
- Convective Initiation

What is the role of Landcover?

7PM LST [DAYTIME]

7AM LST [NIGHTTIME]

Start time [LST]

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

Diurnal cycle

~ 4 days
~10 min

Van der Hoven, 1957
Lilly, 1989

Measurements near the tropopause

inverse energy cascade

2D turbulence

$\kappa^{-3}$

forward energy cascade

3D turbulence

$\kappa^{-5/3}$

Energy injection
LES Simulations of PBL- Convection Interactions

\[ z = 1.2 \text{ km} \]

moisture flux

filtered LES

C.H. Moeng, 2008 and 2009

nesting induced numerical moisture flux filtering??

Cold pool

Turbulence
Atmospheric Fingerprints of Evapotranspiration

Instability
mcpe (WLLJ-ADS-WLLJ-CTL)

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)

\[ E(k) \propto k^{-\beta} \]

Ivan, TC over Southern Appalachians
\[ \beta = 0.99 \ll 5/3 \]
Spectral gap energy injection, and inverse cascade

Madeira, Atmospheric River
\[ \beta = 1.75 \sim 5/3 \text{ Kolmogorov} \]

Nogueira, Barros and Miranda, NPG 2013
Sun and Barros, MWR 2012; QJRMS 2013
2D-3D Energy Transfers

\[
\frac{\partial q^2}{\partial t} + u \frac{\partial q^2}{\partial x} + v \frac{\partial q^2}{\partial y} + w \frac{\partial q^2}{\partial z} = \\
-2 \left( \tau_{xz} \frac{\partial u}{\partial z} + \tau_{yz} \frac{\partial v}{\partial z} \right) + P_b \\
- \frac{q^3}{B_1 l} + \frac{\partial}{\partial z} \left[ lqS_q \frac{\partial q^2}{\partial z} \right] + TB
\]

- Convection
- Turbulent Production
- Bouyancy Production
- Diffusion

Spectral gap energy transfer

PBL parameterization
YSU, MYJ,...

- Dynamic Spatial Range
  Local vs Remote Controls

- Need for Parameterizations
  \[ DNS \propto R^{9/4} \]
  \[ LES \propto R^{1.8} \]
  \[ PBLpar \propto R^{0.2} \]
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

- **Damping**
- **Dispersion**
  - phase speed error dependent on the wavenumber and grid resolution
  - shift in propagation for wavelength < 2-3 \( \Delta x \)
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 $\alpha$ 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

Night: 2:45 AM

Day: 5:45 PM

Giovannetonne and Barros, 2008
Yellow (10 LST : 15 UTC)

Orange (13 LST : 18 UTC)

7PM LST DAYTIME
Ts Sensitivity

Colder (more stable)  

Warmer (more unstable)

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