LoCo Updates

Joe Santanello & Ahmed Tawfik

…on behalf of the LoCo WG

2017 GLASS Panel Meeting
15 May 2017

GLASS17 – LoCo Updates

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- **Benchmarking**

Current Working Group Members:

Joseph Santanello (lead)
Alexis Berg
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Trent Ford
Pierre Gentine
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LoCo Publicity

What is the Coupling Metrics Toolkit?

The Coupling Metrics Toolkit (CoMeT) brings together many commonly used land-atmosphere coupling metrics into a single, standardized set of Fortran 90 modules. Calculate everything from soil moisture retention over time, to the link between convective initiation and surface properties are available.

What is a 'Coupling Metric'?

Land-atmosphere coupling has come to mean quite a few things. Within the context of the Coupling Metrics Toolkit (CoMeT), land-atmosphere interactions follow the paradigm outlined by the **Local Land-Atmosphere Coupling** (LoCo) Project as part of the Global Land-Atmosphere System Study Panel (GLASS) efforts under the Global Water and Energy Exchanges Project (GEWEX). Here land-atmosphere coupling metrics are intended to quantify process relationships between the land surface and atmosphere and attempt answer questions such as: 1) Do changes in soil moisture promote changes in cloud cover or precipitation? 2) Are positive or negative feedbacks produced by soil anomalies? By addressing these questions, improvements can be made to model processes and ultimately increase predictability of impactful phenomena, such as drought and where convection is likely to be triggered.

Goals

Enable quick, early, and broad adoption of the latest and most useful land-atmosphere coupling metrics.

Apply to Data

Take the fortran 90 module of choice and write a wrapper code around it which calls the CoMeT modules. This way specific metrics can be calculated for existing model output, reanalysis, or observations.

Portable

All metrics are available in a format readily portable and called from NCAR Common Language

List of Available Metrics

Convective Triggering Potential

Evaluates morning atmospheric profiles to determine whether dry or wet soils are more likely to trigger convection

Heated Condensation Framework

Assess the atmospheric background state with respect to convective initiation and identifies local versus non-locally triggered moist convection

Mixing Diagrams

Uses the diurnal covariation of temperature and humidity to quantify heat and moisture fluxes into the planetary boundary layer

Relative Humidity Tendency

Returns the contribution of surface energy fluxes, dry air entrainment, heat entrainment, and boundary layer growth to changes in top of boundary layer relative humidity

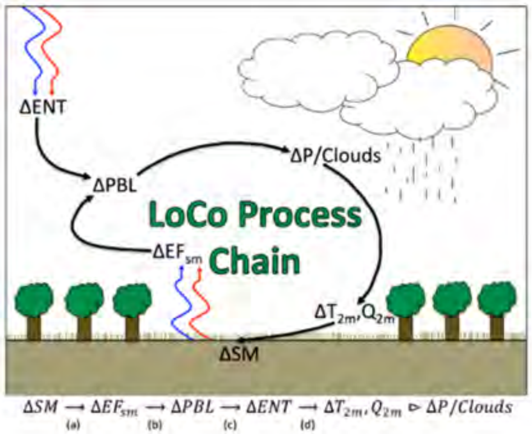
http://www.coupling-metrics.com/

LOCO

Local Land-Atmosphere Coupling (LoCo) Project

- LoCo Working Group
- LoCo Working Group Publications

The original structure of the GEWEX Global Land/Atmosphere System Study (GLASS) was designed to support four modes of land-surface modeling: (1) local-scale off-line; (2) large-scale off-line; (3) local-scale coupled; and (4) large-scale coupled (van den Hurk et al., 2011). To date, each of these has been addressed through organized, community-wide intercomparison studies, such as the Project for the Intercomparison of Land Surface Parameterization Schemes (PILPS), the Global Soil Wetness Project (GSWP), and the Global Land-Atmosphere Coupling Experiment (GLACE), with the exception of local land-atmosphere coupling (LoCo). The LoCo Project has instead evolved and, in recent years, gained momentum through process-level modeling and observational studies that focus on the development and application of coupling diagnostics. This has lead to the development of the Coupling Metrics Toolkit (CoMeT), which is a set of fortran modules containing the most widely used coupling diagnostics.



The equation above emphasizes that the impact of SM anomalies (ΔSM) on cloud development and subsequent precipitation (ΔP) depends on the sensitivities of: (a) the surface fluxes (EFsm) to SM; (b) PBL evolution to surface fluxes; (c) entrainment fluxes at the PBL-top (ENT) to PBL evolution; and (d) the collective feedback of the atmosphere (through the PBL) on ambient weather (2-meter temperature and humidity). As a result, there are numerous pathways composed of positive and negative feedback loops inherent in this chain. Equation 1 has omitted the role that additional inherent and external factors (e.g., canopy interception and large-scale convergence) can play in modulating the strength of each link, and therefore must be addressed in LoCo studies as well.

http://www.gewex.org/loco/

LoCo 'Cheat Sheets'

Table 2. L-A coupling metrics; "Y" and "N" answer: Can the method be applied to land states, surface fluxes, near surface atmospheric or PBL variables? Are they strictly local in space or time? Are they primarily statistical (Stat) metrics or are they based upon physical processes (Phys)? Full documentation of these metrics with references can be found at: http://cola.gmu.edu/dirmeyer/Coupling_metrics.html.

Name	Land State	Surf. Fluxes	Near Surf.	PBL	Local Space	Local Time	Type
Two-Legged Metrics	Y	Y	Y	Y	Y	Y	Stat
Mixing Diagrams	N	Y	Y	Y	N	Y	Phys
LCL Deficit	N	N	Y	Y	Y	Y	Phys
Betts Relationships	Y	Y	Y	Y	Y	N	Stat
Priestley-Taylor Ratio	N	Y	Y	Y	Y	Y	Phys
Heated Condensation Framework	N	Y	Y	Y	Y	Y	Phys
CTP-HI_{Low}	N	N	N	Y	Y	Y	Phys
Notaro's Feedback parameter	Y	Y	Y	Y	Y	N	Stat
Conditional Correlation	Y	Y	Y	Y	Y	N	Stat
Soil Moisture Memory	Y	N	N	N	Y	N	Stat
Granger Causality	Y	Y	Y	Y	N	N	Stat
P-T metrics	N	N	Y	N	N	N	Stat
Zeng's Gamma	Y	Y	Y	N	Y	Y	Stat
Coupling Drought Index	Y	N	Y	N	Y	N	Phys
Bulk Recycling Ratio	N	Y	N	Y	N	N	Phys

http://cola.gmu.edu/dirmeyer/Coupling_metrics.html

LoCo Publications

L-A Summer School Book Chapter

Metrics of Land-Atmosphere Coupling

Paul A. Dirmeyer, George Mason University, USA
Kirsten L. Findell, NOAA Geophysical Fluid Dynamics Laboratory, USA
Joseph A. Santanello Jr., NASA Goddard Space Flight Center, USA

Abstract: A variety of quantitative metrics to estimate the degree of feedback of land surface states on the overlying atmosphere, weather and climate are reviewed. The metrics described are designed to elucidate processes operating within the surface water and energy cycles and are applicable at various spatial and temporal scales. The pathway for feedbacks involves the effects that land surface states have on fluxes of heat and moisture from land to atmosphere, how those fluxes affect the temperature and humidity in the lower atmosphere, which impact the daily growth of the turbulent, well-mixed planetary boundary layer, ultimately influencing the formation of clouds and incidence of precipitation. Some metrics are applicable only to the results of numerically-based computational models, but many can be calculated from observations in the natural world. Challenges to future research in this field are also discussed.

Keywords: Water cycle, energy cycle, soil moisture, precipitation, clouds, land surface, climate.

Introduction

While the direct impact of atmospheric processes (e.g., rainfall) on the land surface state are easily recognizable, the many temporal and spatial scales connecting the land surface and the atmosphere make it difficult to concisely characterize the impact that the land surface has on the evolution of the planetary boundary layer (PBL) and the overlying atmosphere, especially the impact of soil moisture on subsequent precipitation. The partitioning of available energy into latent and sensible heat fluxes is the primary mechanism by which land surface contributions to the atmosphere are controlled, and yet evapotranspiration (ET) rates vary widely between different vegetation species, and depending on soil water and water intercepted by the vegetation canopy. In addition, ET is dependent on incoming radiation and the humidity deficit of the near-surface atmosphere. There is also evidence that plant species vary widely in their response to environmental stressors, with grasslands and forests displaying opposing coping strategies to deal with heat wave events (Teuling et al., 2010). Forest stands tend to close stomata, conserve water and transpire less during high temperature events, while grasslands maximize ET until groundwater reserves are depleted. These process-specific and species-specific behaviors lead to varying and time-dependent impacts of the land surface on the atmosphere, indicating the degree of complexity

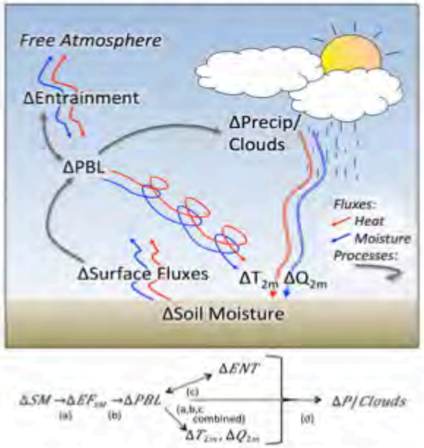


Figure 1: Schematic of the Local Coupling (LoCo) process chain.

Volume #, Publication Year, <Community URL>, ISSN #

COMMON GROUND

GEWEX NEWS

GEWEX is a Core Project of WCRP on Global Energy and Water Exchanges

WCRP World Climate Research Programme · WMO · IOC · ICSU International Council for Science

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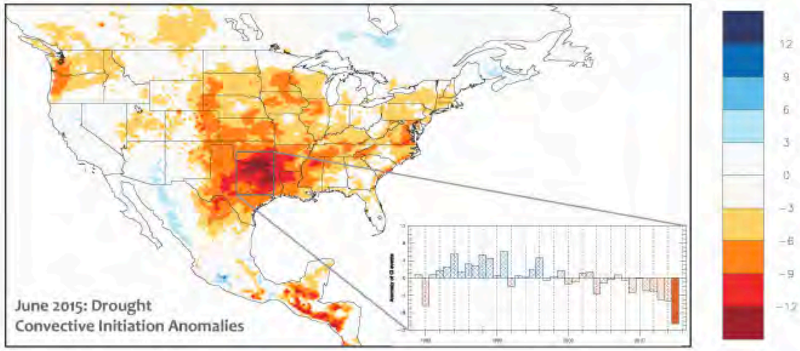
GLASS-LoCo Project is Developing Land-Atmosphere Coupling Metrics and Diagnostics



The map above shows the anomaly in surface-triggered convective initiation (CI) events during the summer of 2015 when a heat wave occurred. There are 6-12 fewer days with surface-triggered CI in the build-up and during the heat wave. The inset shows a time series of CI anomalies to put the 2015 heat wave in perspective. Overall, the strong connection between heat waves and surface-triggered convection demonstrates that from a Local Land-Atmosphere Coupling (LoCo) viewpoint, metrics such as the "Heated Condensation Framework" (used here; Tawfik et al., 2015) allow for local-scale processes to be put into the perspective of broader synoptically forced events, such as heat waves. See article by M. Ek et al. on page 9.

Also Inside

LoCo Publications

BAMS Proposal Accepted

Land-Atmosphere Interactions: The LoCo Perspective

Authors: Joseph A. Santanello, Paul Dirmeyer, Craig Ferguson, Kirsten Findell, Ahmed Tawfik, and the LoCo Working Group

Land-atmosphere (L-A) interactions are critical in determining the Earth's surface water and energy balance. They control cloud and precipitation feedbacks that lead to the persistence of hydrological extremes such as drought. Despite their importance, L-A interactions have been difficult to observe and quantify in weather and climate models due to their inherent complexities. Furthermore, a complete understanding of L-A processes requires interdisciplinary approaches and expertise that transcend traditional research paradigms and communities.

To address these issues, the international Global Energy and Water Exchanges project (GEWEX) Global Land-Atmosphere System Study (GLASS) has supported 'L-A coupling' as one of its core themes for over a decade. Under this initiative, several successful land surface and global climate modeling projects have identified hotspots of L-A coupling and helped quantify the role of land surface states in climate predictability.

Subsequently, the local L-A coupling ('LoCo'; Santanello et al., 2011) project was formed to examine L-A interactions at the process level while focusing on the observability and validation of these processes in models. LoCo has produced an array of L-A coupling diagnostics for various applications and scales, and has motivated a growing number of (particularly young) scientists from around the world.

This article will provide an overview of the LoCo effort over the last decade, including diagnostic and model applications, along with scientific and programmatic developments and challenges. The importance of satellite retrieval and model-data fusion (e.g. assimilation, calibration, and benchmarking) will also be discussed, as will plans for field campaigns and community model evaluation projects.

WG Publications

- **Satellite**
- **Roundy, J. K.,** and **J. A. Santanello**, 2017: Utility of Satellite Remote Sensing for Land–Atmosphere Coupling and Drought Metrics, J. Hydrometeor., 18, 863-877.

- **SGP Coupling**
- Phillips, T., S. Klein, H-Y Ma, Q. Tang, S. Xie, I. Williams, M. Torn, **J.A. Santanello**, D. Cook, 2017: Using ARM Observations to Evaluate Climate Model Simulations of Land-Atmosphere Coupling on over the U.S. Southern Great Plains. J. Geophys Res., under review.

- **GCM and LULCC**
- **Findell, K**., et al., 2017: The impact of historical land use/land cover change on regional climate extremes. Nature Comm., under review.
- **Berg**, **A.**, B. Lintner, K. Findell, A. Giannini, Soil moisture influence on seasonality and large-scale circulation in simulations of the West African Monsoon, *Journal of Climate,* **30**, 2295–2317, doi: 10.1175/JCLI-D-15-0877.1
- **Berg**, **A.**, K. Findell, B. Lintner, A. Giannini, et al., Land-atmosphere feedbacks amplify aridity increase over land under global warming, *Nature Climate Change*, **6**, 869-874 (DOI: **10.1038/nclimate3029**).
- Chen, L., **P. A. Dirmeyer, A. Tawfik** and D. M. Lawrence, 2017: Sensitivities of land cover-precipitation feedback to convective triggering. *J. Hydrometeor.*, (in revision).
- Chen, L. and **P. A. Dirmeyer**, 2017: Impacts of land use/land cover change on afternoon precipitation over North America. *J. Climate*, **30**, 2121-2140, doi: 10.1175/JCLI-D-16-0589.1.
- **Tawfik, A. B.**, D. M. Lawrence, and **P. A. Dirmeyer**, 2017: Representing sub-grid convective initiation in the Community Earth System Model. *J. Adv. Mod. Earth Sys*., (in revision).
- Nair, U., R. Pielke, M. Shepherd, **J. Santanello**, et al., 2017: Brown Ocean Effect on the Louisiana August 2016 Extreme Flooding Event. Submitted to *Nature Climate Change* (May 2017).
- **Tölle, M. H**., S. Engler, H.-J. Panitz, 2016: Impact of abrupt land cover changes by tropical deforestation on South-East Asian climate
- and agriculture, Journal of Climate, 30, 2587-2600, DOI: 10.1175/JCLI-D-16-0131.1

- **Cloud/Radiative Coupling**
- **Betts, A.K**., R. Desjardins, A.C.M. Beljaars and **A. Tawfik** (2015). Observational study of land-surface-cloud-atmosphere coupling on daily timescales. *Front. Earth Sci. 3:13*. http://dx.doi.org/10.3389/feart.2015.00013
- **Betts, A.K**. and **A.B. Tawfik** (2016) Annual Climatology of the Diurnal Cycle on the Canadian Prairies. *Front. Earth Sci. 4:1*, 1-23. doi: 10.3389/feart.2016.00001.
- **Betts, A.K**., **A.B. Tawfik** and R.L. Desjardins (2017): Revisiting Hydrometeorology using cloud and climate observations. *J. Hydrometeor., 18*, 939-955, http://dx.doi.org/10.1175/JHM-D-16-0203.1

WG Publications

- **PBL Observations**
- **Wulfmeyer, V.**, et al., 2015: A review of the remote sensing of lower-tropospheric thermodynamic profiles and its indispensable role for the understanding and the simulation of water and energy cycles. Rev. Geophys. **53**, 819–895, DOI:10.1002/2014RG000476.
- **Wulfmeyer, V.**, et al., 2016: Determination of convective boundary layer entrainment fluxes, dissipation rates, and the molecular destruction of variances: Theoretical description and a strategy for its confirmation with a novel lidar system synergy. J. Atmos. Sci. **73**, 667-692, DOI:10.1175/JAS-D-14-0392.1.
- Milovac, J., K. Warrach-Sagi, A. Behrendt, F. Späth, J. Ingwersen, and **V. Wulfmeyer**, 2016: Investigation of PBL schemes combining the WRF model simulations with scanning water vapor differential absorption lidar measurements. J. Geophys. Res. Atmos. **121**, 624–649, DOI:10.1002/2015JD023927.
- Knist, S.,, **V. Wulfmeyer**, et al., 2016: Land-atmosphere coupling in EURO-CORDEX evaluation experiments, J. Geophys. Res. Atmos. **122**, 79-103, DOI:10.1002/2016JD025476.

- **Soil Moisture, ET, and Irrigation**
- **Dirmeyer, P. A**., and S. Halder, 2016: Sensitivity of surface fluxes and atmospheric boundary layer properties to initial soil moisture variations in CFSv2. *Wea. Fcst*., **31**, 1973-1983, doi: 10.1175/WAF-D-16-0049.1.
- Kumar, S. V., **P. A. Dirmeyer**, C. D. Peters-Lidard, and R. Bindlish, 2017: Information theoretic evaluation of satellite soil moisture retrievals. *Remote Sens. Env*., (submitted).
- **Lawston, P., J. Santanello** et al., 2017: Assessment of Irrigation Physics in a Land Surface Modeling Framework using Non-Traditional and Human-Practice Datasets. *HESS*, accepted.
- Kolassa J., **Gentine P**., Prigent C., Aires F., (2017), Soil moisture retrieval from AMSR-E and ASCAT microwave observation synergy: Product presentation and synergy, *Remote Sens Env.*
- **Gentine P., Chhang A.,** Rigden A., Salvucci G., (2016), Evaporative fraction estimates using weather station data and boundary layer theory, *Geo Res Letters*
- Creakier N.Y, Puma M.J., Cook B.I., **Gentine P**., Nazarenko L. and Kelly M., (2016), Ocean-Atmosphere interactions modulate irrigation's climate impact, *Earth Sys Dyn*
- Merlin O., et al. **Gentine P**., (2016), Modeling soil evaporation efficiency in a range of soil and atmospheric conditions: A downward approach based on multi-site data, *Water Resources research,* doi: 10.1002/2015WR018233

- **Weather**
- **Dirmeyer, P. A.,** and S. Halder, 2017: Application of the land-atmosphere coupling paradigm to the operational Coupled Forecast System (CFSv2). *J. Hydrometeor*., **18**, 85-108, doi: 10.1175/JHM-D-16-0064.1.
- **Gentine P**., **Garelli A.,** Park S., Nie J. ,Torri G., Kuang Z., (2016), Role of surface heat fluxes underneath cold pools, *Geophysical Research Letters,* 43 (2), 874-883

WG Publications

- **Surface Layer**
- ***McColl K.**, Katul G., van Heerwaarden C., **Gentine P**., Entekhabi D., (2017), Role of large eddies in the breakdown of the Reynolds analogy in an idealized unstable atmospheric surface layer, *Quarterly Journal of the Royal Meteorological Society.*
- **Cheng Y.,** Sayde C., Selker J., **Gentine P.,** (2017), Failure of Taylor's hypothesis in the atmospheric surface layer and its correction, *Geo Res Letters,* doi: 10.1002/2017GL073499

- **Biosphere/Vegetation**
- **Green J.,** Konings A., Kolassa J., Alemohammad H., Entekhabi D., **Gentine** P., Hotspots of biosphere-atmosphere feedbacks, (2017), *Nature Geo*
- Konings A., Williams P., **Gentine P**., (2017), Sensitivity of grassland productivity to aridity controlled by stomatal and xylem regulation, *Nature Geo*; doi:10.1038/ngeo2903
- **Lemordant L.,** Drobinksy P., Stefanon M., Fatichi S., **Gentine P.,** CO_2 fertilization could mitigate heat waves and exacerbate summer dryness in future climate, *Geo Res Letters*, doi: 10.1002/2016GL069896
- Konings A., **Gentine P**., Global variations in Ecosystem-scale Isohydricity, (2016), *Global Change Biology,* doi: 10.1111/gcb.13389

LoCo WG Proposals

- Santanello, J. et al.: **Investigating the Utility of SMAP Observations for Local Land-Atmosphere Coupling (LoCo) Studies**. Science Utilization of SMAP, 3 years (2017-2020).
  - LIS, NU-WRF, SMAP, LSM calibration
  - Coupling WRF-SCM to LIS, SCM calibration

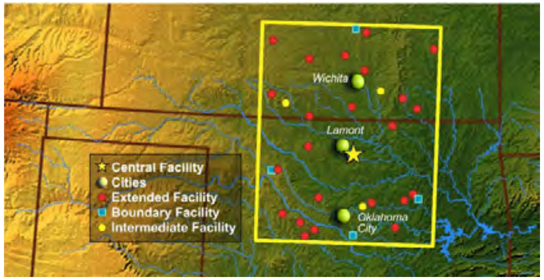
- Ferguson, C. et al.: **The Role of Soil Moisture in Weather Predictability**. Science Utilization of SMAP, 3 years (2017-2020).
  - LIS, NU-WRF, HTESSEL coupling to LIS
  - SMAP DA (coupled DA)

SGP/Field Campaign Updates

- Enhanced Soundings for Local Coupling Studies (ESLCS)
- New soil moisture network
- CSLAEX
- LAFE field campaign

LoCo-SGP Testbed

- Based on community feedback and through collaboration between **LoCo, ARM, and the NASA NEWS program**, a new data product called **ARM Best Estimate (ARMBE) - Land** has been produced for the SGP Central Facility (Lamont, OK).



- PI: Shaocheng Xie, Lawrence Livermore National Laboratory
- Data Product Name: ARMBELAND - Critical soil quantities for describing land properties Product Type: ARM Evaluation Products
- **Date Range of Product: 01/01/1994 - 12/31/2012**
- Data Directory Location: http://iop.archive.arm.gov/arm-iop/0eval-data/xie/armbe-eval/armbeland/

- Currently, the ARMBE-Land contains the following quantities:
  - * **Soil temperature measured from CO2FLX, EBBR, and SWATS**
  - * **Soil moisture content measured from CO2FLX, EBBR and SWATS**
  - * **Soil heat flux from CO2FLX, EBBR**
  - * **CO2 flux from CO2FLX**
  - * **CO2 density from CO2FLX**
  - * **Friction velocity from CO2FX**
  - * **Photosynthetic photon flux density (PAR) from CO2FX**

Data availability:

- Quantities from CO2FLX : 2003-2012
- Quantities from EBBR: 1994-2012
- Quantities from SWATS: 1996-2012

- Work has begun on a 2-D gridded (variational analysis) product over the broader ARM SGP network, which will include all the fields relevant for land-atmosphere coupling studies as well as sub-grid scale variability. Delivery of this product is expected by early 2014.

PBL Initiatives

- Decadal Survey
- NASA Science Task Group
  - AIRS/CALIPSO highlight
  - A-Train Poster
- GCOS/ECV Initiative
- DICE-LoCo
- LIS-SCM

NRC Decadal Survey White Papers

The Importance of Routine Planetary Boundary Layer Measurements over Land from Space

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1 Introduction

The planetary boundary layer (PBL) is the lower part of the atmosphere in which we live, and which is coupled to the land surface where plants perform photosynthesis and most pollutants are emitted. The PBL controls surface fluxes as well as the temperature range and concentration of gases (water vapor, CO_2, pollutants), aerosols, and chemical constituents that humans and ecosystems experience. In addition, the turbulence in the PBL and its coupling with free-tropospheric conditions controls convective initiation, cloud coverage as well as pattern and intensity of precipitation. The PBL is thus a critical layer in the atmosphere, but is still not optimally represented both in current weather and climate models as well as in observations.

The Boundary Layer Gap over Land and Importance of Improved Retrieval from Space

Lead: Joseph A. Santanello, Jr. (NASA-GSFC; Code 617); joseph.a.santanello@nasa.gov
Co-lead: Volker Wulfmeyer (University of Hohenheim); volker.wulfmeyer@uni-hohenheim.de
NASA-GSFC: David Whiteman, Dong Wu, and Joel Susskind
Community: Aaron Boone (Meteo-France), Paul Dirmeyer (GMU), Michael Ek (NCEP), Craig Ferguson (SUNY), Pierre Gentine (Columbia), Benoit Guillod (Oxford), Zhanqing Li (UMCP), Benjamin Lintner (Rutgers), David Turner (NOAA-NSSL), Chiel van Heerwaarden (Wageningen), and Yunyan Zhang (DOE)

Executive Summary

Importance: The planetary boundary layer (PBL) is a critical region of the lower atmosphere for our understanding of the Earth as a system and the interaction with the land surface across all scales and phenomena. The present performance of weather and climate models clearly demonstrates that advances in the understanding of land-atmosphere (L-A) interactions and the diurnal evolution of the PBL must come first before we can expect improvements in simulations of the Earth system with respect to clouds and precipitation. The PBL, however, remains a major gap in our observational suite and is therefore a limiting factor in process studies and applications to models. ***The NRC and NASA have, in fact, acknowledged that PBL observations, particularly from space, are essential to improving weather and climate services to society as well as filling the gaps in process-level understanding [1,2,3].*** Even so, there is very little attention or planning (short or long-term) in place for improving lower tropospheric thermodynamic sounding from space.

-2007 Decadal Survey – PBL not mentioned at all
-Submitted multiple white papers to 2017 DS (see above)
-2017 DS due at the end of the year – hearing promising things (e.g. PBL recognized as critical and '**transformative**' – yet a major challenge)

*NASA-GSFC Science Task Group Funded (FY17):

Impact and Improvement of Planetary Boundary Layer (PBL) Retrieval from Space

Joe Santanello (**617**/Lead), Will McCarty (**610.1**/Deputy)

- PBL retrieval over land remains a significant gap in our suite of Earth observational suite and water and energy cycle understanding.
- This STG will quantify the potential benefits and challenges related to improved retrieval of PBL properties based on current and next-generation satellite technology.
- Specifically, the STG will act to:

a) **Survey and evaluate current space-based approaches for PBL remote sensing (inc. advanced IR, lidar, GPS-RO, GEO, MISR).**

b) **Quantify the specific impact of PBL information on weather/climate modeling and process-level understanding.**

c) **Determine the long-term instrument and mission strategy that can achieve these goals for both Earth and Martian PBLs**.

GCOS/ECV

- Global Climate Observing System (WMO)
- GCOS/WCRP Panel for Climate (March 2017)

- **Action : Water vapour profiles in low tropical troposphere**
- Action: develop a strategy for measuring low troposphere water vapour profiles from space
- Benefit: vertically resolved water vapor in lower troposphere
- Who: WCRP GC and space agencies
- Time-frame: ongoing
- Performance indicator: definition of a three years mission concept for a space water vapour lidar
- Annual cost:
- ======================================
- Atmospheric water vapour plays a fundamental role in many processes critical to both weather and climate. In particular, deep convection and clouds in the lower tropical troposphere over the ocean are intimately connected to the vertical profile of water vapour. The absolute humidity in the marine boundary layer (i.e below 950 hPa) determines the convective potential, and the surface evaporation. The vertically resolved structure of water vapour (between 950 and 650 hPa) influence the distribution of deep convection, the pattern and amount of cloudiness in the lower troposphere, as well as its response to other perturbations, such as from aerosols. Because tropical cloudiness and convection are so intimately linked to water vapour understanding how it changes with warming is crucial, not just for understanding convection, but also for the circulation of the tropics and how both change with climate warming.
- Advancing our understanding of weather and climate will require measurements of water vapor at higher vertical resolution than is available from current sensors, particularly in the lower troposphere. Despite this crucial need, no satellite missions are currently planned which could overcome the limitations of sensors currently flying.
- ======================================
- **Geophysical variable: Water vapour profiles below 600hPa**
- Horizontal resolution: 10km
- Vertical resolution: 300m
- Temporal resolution: instantaneous
- Timeliness:
- Uncertainty: 3%
- Stability:

DICE-LoCo

- Martin and Adrian are planning 3 core DICE papers:
  - 1) Experimental design overall results
  - 2) Stages 1-2: physics and uncoupled vs. coupled
  - 3) Stage 3: sensitivity to boundary conditions/coupling strength
- Santanello and Ek: "The Diurnal Land-Atmosphere Coupling Experiment (DICE): Application of LoCo Diagnostics"
  - Focus on standard mixing diagram suite of metrics
  - Ensemble spread indicative of coupling sensitivity
  - On hold until we see the DICE core papers above

GLASS17 – LoCo Updates

→ **Connection to GLASS community projects**

Observations should be brought to bear on current GLASS efforts:

A) **SMAP** – Launched February 2015.
Data available this summer
9km soil moisture product every 2-3 days
SMAP call for proposals (May)

B) **PBL Profiling** – Still a ‘gap’ in Earth Observations
COSMIC GPS-RO proposal
ESA abstract (Oct 2015)
NASA WG on PBL missions

GLASS17 – LoCo Updates

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A) **SMAP** – Launched February 2015.
Data available this summer
9km soil moisture product every 2-3 days

***SMAP proposal funded:**
"Investigating the Utility of SMAP for LoCo Studies"
-LSM vs. SMAP initialization of coupled (NU-WRF) models
-LSM Calibration using SMAP
-Coupling of LIS to SCM (WRF-SCM) for sensitivity and calibration of LoCo process-chain

GLASS17 – LoCo Updates

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***Decadal Survey White Papers:**

RFI1: “The Importance of Routine Planetary Boundary Layer Measurements over Land from Space”

RFI2: “The Boundary Layer Gap over Land and Importance of Improved Retrieval from Space”

LoCo-CMIP6 Connection

- Dear Bart and Hyungjun (Cc Joe),
-
- There has been some discussion within the LoCo group of the ability to analyze the surface flux budget and to calculate land-atmosphere coupling metrics from the diagnostics requested in CMIP6. After looking at the requested diagnostics listed at http://clipc-services.ceda.ac.uk/dreq/index.html, we think it would be useful if some extra diagnostics could be added. At the outset, I should say that we appreciate that it is late in the day and that it may not be possible to make these additions now, but we believe that the addition of these diagnostics would enhance our ability to analyze the runs. We think also that, at this stage, any new diagnostics could be requested only under Tier 3 (discretionary). We also understand that diagnostics have to be requested through a MIP, so I am contacting you as those coordinating LS3MIP.
-
- We are interested in two experiments, the standard CMIP6 runs, referred to as DECK and HISTORICAL and the runs within LS3MIP.
-
- 1.) In the standard runs, the diagnostics are fairly complete, but there does not appear to be any measure of boundary layer depth, so we would like to request that the netCDF variable "armosphere_boundary_layer_thicknesss" should be added to the diagnostic group 3hr to be sampled synoptically. This group currently contains 23 variables, so we would be asking for an increase of 4% in the data volume.
- 2.) In LS3MIP itself the diagnostics are less complete and we would like to add the following variables to be sampled every 3 hours to the LFMIP runs to diagnose land-atmosphere coupling:
- a. "Surface upwelling shortwave radiation" sampled as a time-mean.
- b. "Surface upwelling longwave radiation" sampled as a time-mean.
- c. "Surface upwelling clear-sky shortwave radiation" sampled as a time-mean.
- d. "Surface upwelling clear-sky longwave radiation" sampled as a time-mean.
- e. "Surface downwelling clear-sky shortwave radiation" sampled as a time-mean.
- f. "Surface downwelling clear-sky longwave radiation" sampled as a time-mean.
- g. "Surface upward sensible heat flux" sampled as a time-mean.
- h. "Surface upward latent heat flux" sampled as a time-mean.
- i. "Surface temperature" sampled synoptically
- j. "Atmospheric boundary layer thickness" again sampled synoptically.
- (So in summary the first 8 variables are to be sampled as time averages and the last two synoptically.) On a 1x1 degree grid, making the standard assumption of 2 bytes per value, representing 50% compression of a 4-byte real, the data volume would be 3.78 Gb per year (360 points EW x 180 points NS x 8 values per day x 365 days per year x 2 bytes per value x 10 variables). Compression to land points would reduce that to about 1.1 Gb per year, but this form of compression does not seem to be included in the accounting on the CMIP6 websites. According to Table 1 of the paper on LS3MIP, http://www.geosci-model-dev.net/9/2809/2016/, the total proposed length of the LFMIP runs is 2891 years, so on a full grid this would give 11 Tb, or 3.3 Tb if compressed to land points. Alternatively, the data volume could be compared with what is already requested with 3-hourly sampling in table A4 of the paper. There are already 15 variables here, so we would be asking for an increase to a total of 25.
-
- Please could you let me know whether there is any chance of including these diagnostics in the simulations.
-
- Many thanks,
-
- John Edwards

LIAISE Campaign (Iberia)

- LoCo Input
  - Paul
    - Deploy instruments that can remain indefinitely for continuity measurements.
  - Volker
    - Need to iron out instrument synergy and ground-based profilers.
    - Possible synergy with a campaign in Southern France in 2018 w/Meteo-France.
  - Joe
    - Possible lessons learned from LAFE this summer in terms of instruments, requirements, synergy, and scientific questions.
    - Lessons learned from SGP (and Pierre's DTS) activities – what are gaps?
  - Pierre
    - Aircraft MW measurements
    - Surface roughness with mobile EC
    - He can provide high-res veg stress mapping

LoCo Benchmarking

PALS/Benchmarking – SSG looking ahead to distributed (spatial) benchmarking. We need to look ahead to vertical/coupled benchmarks (beyond offline).

> Mike discussed ideas w/Joe. Need to continue with GLASS discussion.

LoCo-CORDEX Connection

LUCAS Project (Land Use & Climate Across Scales)

- LUCAS uses an ensemble of regional simulations at 3 km over Europe
- Include some assessment of L-A coupling from the ensemble
- Are there efforts to coordinate?

End of Updates

- Big picture material from GLASS16 follows for reference

Status of LoCo

- Galvanized young scientists to look at process-level metrics of SM-P connections; generated suite of LoCo metrics
- Metrics vary in inputs, scale, and components of the process-chain (some suited for diurnal cycles, some for global models, etc.)
- Established need for observational testbeds to establish how complimentary these metrics are and their hierarchy
- Has led to many larger initiatives (observationally):
  - SGP Testbed and NASA Unified WRF (LIS-WRF) coupling
  - Collaboration with DOE to enhance obs from SM-PBL
  - Decadal Survey white papers and ‘PBL from space’ effort
- Recently failed (ASR), submitted (MAP), and funded (SMAP) proposals:
  - LoCo metric intercomparison
  - Satellite retrieval of LoCo metrics

Challenges of LoCo

- We have helped to unify the definition in the literature, but 'coupling strength' is still thrown about loosely and with a variety of implications (a lot of them not even truly ‘coupling’ related)

- Single, unifying metric of coupling strength still does not exist and may never exist

- One thing to say, ‘model is too strongly coupled’ (e.g. GLACE, Precip is too sensitive to SM)

- Another thing to be able to say ‘why, and where is that coupling too strong in the parameterizations’

- The challenge we have is how to translate *easily implementable metrics* to the model developers

Future of LoCo

- LoCo WG breakout session – help assess where we are and where we need to go
  - AGU annual session on L-A Interactions (this year focused on remote sensing)
- Continue to push for SGP-type metric intercomparison and improved L-A observations (PBL) w/RHPs
- Define what is missing/challenges (scale, heterogeneity, radiation, clouds/precip, carbon) and how to address them
- Discuss potential way to better interface with the model developers
- 3-Pronged Approach?
  - a) Continue to follow and broaden the science and WG participation
  - b) Engage and entrain the operational/model development community
  - c) Consider a more formal GLASS-type MIP – but don't force it!

Future of LoCo – Ideas (Craig)

(1) take leadership in LUMIP and LS3MIP activities so far as in applying the suite of LoCo metrics (perhaps written into our NASA MAP?) (If Sonia will allow?).

(2) be involved in the GHP-GLASS integration of water management in models and quantify how humans are perturbing natural process coupling and the associated consequences

(3) establish transfer functions between coupling strength and tangible quantities like rainfall and runoff, drought S-A-D, and heating (also our MAP proposal?)

(4) work with Mike Ek to respond to a future NCEP R2O solicitation

(5) work for U.S. RHP to establish a network of enhanced sites for LoCo studies (can we apply your LIS-SCM over the 17 NYS Mesonet enhanced sites as a starting point)?

(6) consider an explicit LoCo session at AGU or AMS in an effort to rebuild visibility or alternatively, dissolve back into GLASS?

Future of LoCo

3-Pronged Approach?

- a) Continue to follow and broaden the science and WG participation
  - No problems here: snow, geology, carbon, LULCC, momentum, radiation, fluorescence, monsoon – will evolve naturally
- b) Engage and entrain the operational/model development community
  - Ahmed and Craig – convective schemes + observing networks
- c) Consider a more formal GLASS-type MIP – but don't force it!
  - Synthesize what we have now in terms of metrics and message
    - Craig's roadmap
    - What can we entice modelers with? Simple is often better
    - What are the variable and obs requirements – doable?
    - Leverage off existing MIPs: LoCo-Plumber, LoCo-DICE, LoCo-CMIP