Surface-atmosphere interactions and the boundary layer

Keynote Speakers: Boone, A. - Demott, C.

Oral Presentations:

Barlage, M. - Dayon, G. - Diallo, I. - Findell, K. - Fu, R. - Gulizia, C. - Huang, J. - Rumbold, H. - Svensson, G. - Winkler, M. - Xue, Y.

Poster Presentations:

Ardilouze, C. (SU86) - Brody, M. (SU80) - Brunke, M. (SU85) - Demirdjian, R. (SU99) - Ek, M. (SU94) - Fall, Ch. (SU84) - Garcia Rosales, A. (SU 89) - Kalina, E. (SU102) - Lee, J. (SU98) - Li, D (SU90) - Lock, A. (SU 95) - Lundgren, K. (SU93) - Ryu, K. (SU83) - Salvucci, G. (SU92) - Sarangi, C. (SU81) - Schackelford, K. (SU91) - Tjernström, M. (SU87) - Werapitiya, G. (SU96), - Wulfmeyer, V. (SU105) - Yang, F. (SU101) - Yin, Z. (SU88) - Zhang, C. (SU104) - Zhang, M. (SU82)

Keynote Speakers

How close is close enough? The role of bulk surface fluxes in regulating tropical clouds and circulations

Charlotte DeMott – Colorado State University

Surface fluxes regulate the exchange of energy, moisture, momentum, gases, and particulate matter between the ocean and atmosphere. They play an essential role in setting the Earth's global energy balance. Climate and forecast models, reanalysis products, and satellite-based surface flux retrievals all estimate surface latent and sensible fluxes using bulk surface flux algorithms that convert inputs of surface temperature and near-surface wind speed, temperature, and humidity to a flux via an empirically estimated bulk transfer coefficient. Biases in surface fluxes can thus originate from biases in the bulk inputs, as well as the bulk flux algorithms.

While many studies have examined bulk input biases as sources of surface flux bias in climate and forecast models, sources of bias rooted in bulk flux algorithms have received less attention. In this talk I will first introduce a simple method of diagnosing both input and algorithm sources of bias. For the remainder of the talk, I will demonstrated the consequences of algorithm biases that are revealed by replacing a model's original bulk flux algorithm with the COARE3.5 bulk flux algorithm, which well-replicates direct covariance flux measurements across a wide range of conditions. Implications for the Madden-Julian oscillation, the eastern Pacific ITCZ, and the EUREC4A/ATOMIC region will be highlighted.

Overview of the Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) Project Field Campaign

Aaron Boone – CNRM Meteo-France/CNRS

The understanding of the impact of anthropization and its representation in models have been inhibited due to a lack of consistent and extensive observations, but in recent years, land surface and atmospheric observation capabilities have advanced. The overall objective of the Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) project is to improve the understanding and prediction of land-atmosphere-hydrology interactions in a region characterized by strong surface heterogeneity mainly owing contrasts between the natural landscape and intensive agriculture. The study region is located over the Pla d'Urgell region within the Ebro basin in NE Spain. This area was selected since it is a significant European breadbasket region. The consensus of current climate projections predicts a significant warming and drying over this region in upcoming years. Thus there is an urgent need to improve the prediction of the potential changes to the regional water cycle since water resources are limited.

Here we present an overview of the intense phase of the LIAISE observational campaign, which took place in July, 2021 when land surface heterogeneity was at a maximum. A network provided continuous measurements of the surface energy and water budget components for multiple representative land cover types, including irrigated surfaces, along with detailed surface biophysical measurements from the leaf to field scale. Surface fluxes at the field scale were made using scintillometer configurations over 3 of the sites. Lower atmospheric measurements were obtained from tethered balloons, lidar, UHF profilers, frequent radio-sounding releases, UAVs and several aircraft. Finally, airborne instruments measured solar induced florescence, surface temperature over several spectral bands and soil moisture over a transect cutting across the rain-fed and irrigated areas. The main outcome of this project is to provide the underpinnings for improved understanding and models leading to better water resource impact studies for both the present and under future climate change.

Go to Top

Oral Presentations

Boundary Layer Wind Balances and their In uence on Equatorial Sea-Surface Temperatures

Marius Winkler – Max-Planck-Institut für Meteorologie

At the equator, over the ocean, pressure gradients in the atmosphere are strongly coupled to the surface temperature of the ocean. Pressure gradients drive winds, which in turn exert stress on the ocean surface, leading to equatorial upwelling, and bringing cold deep water to the surface, which in turn have an influence on pressure gradients; this is a feedback loop. At the same time, besides pressure gradients in the atmosphere, vertical momentum fluxes and horizontal eddies are a source of the winds and maintain near equatorial surface winds. A momentum budget at the atmospheric boundary layer allows us to calculate the individual contributions defining the wind. We see that the magnitudes and contributions of pressure gradient term,

nonlinear advection terms, Coriolis term, acceleration term as well as surface drag and vertical turbulent flux are strongly dependent on direction and region. In previous literature such as Lindzen and Nigam (1987), the Rayleigh friction model is used to represent the boundary layer wind balance. Studies like Deser (1993) improved this model into an anisotropic Rayleigh friction model where the x- and y-direction of the surface drag in the momentum balance within the boundary layer were considered separately. Over the years, this approach has been widely used to analyze reanalysis data. Deser, supported by Chang and Zebiak (2000), provides a plausible explanation for the anisotropy of the friction coefficients based on the larger scale dynamics of the winds. We, on the other hand, turn our attention to the individual components defining the wind. Apart from the Rayleigh friction model, we try to find an explanation for their role via their individual contributions. In particular, we examine the vertical momentum flux, which can be interpreted as surface drag at the atmosphere-ocean interface and acts as a counterpart for pressure gradient, advection terms, Coriolis and acceleration term in the vertical direction up to the top of the atmosphere boundary layer.

Towards a more accurate model, two strong feedback mechanisms are hypothesized: one by which a stronger vertical flux of momentum leads to colder surface temperatures which stabilizes the boundary layer and reduces the downward momentum flux. Another whereby stronger winds at the equator maintain larger near equatorial surface temperature gradients, which drive off-equatorial zonal winds, whose momentum is carried by eddies to help maintain the winds. This is a tightly coupled system that is not well represented in existing climate models. To adequately represent the small-scale nonlinear terms within the momentum budget and thus explain the winds well, a fine resolution is needed. We have performed global, full year, coupled storm and eddy resolving (2.5 km-5 km grid spacing and 90 height levels) simulations, called ICON Dyamond runs, to study the dynamics of the wind. Since these runs have only now become feasible, and with the prospect of runs with even finer resolution, which will also be available to us in the near future, we hope to better understand how the interplay of turbulent momentum fluxes and sea-surface temperature influence the pattern of convection and the structure of the global tropics.

Demonstrating the impact of modelling coupled irrigation over regional and global domains

Heather Rumbold, presented by Adrian Lock – Met Office

Irrigation is the application of water to the land with the aim to maintain plant productivity (in particular for crops), when water supply is low. There are many different methods in which water is applied; for example, bringing in water via pipes from rivers, canals and reservoirs into sprinklers, drip and flood irrigation systems. In addition human decisions can manage the water application through water resource restrictions and government licensing. This results in huge spatial and temporal heterogeneity which is an ongoing challenge to simulate in land surface models.

The application of irrigation will change the radiation budget of the land surface by increasing latent heat flux and cooling the surface temperatures through the increase in soil moisture. These effects increase the net radiation at the surface, directing that energy into additional latent heat flux, which can enhance the land surface interactions with the atmospheric boundary layer.

The aim of this study is to demonstrate and understand the impact of irrigation on the terrestrial water fluxes, surface energy fluxes and atmospheric fields, with a focus over the LIAISE campaign area of NE Spain. The JULES irrigation code has been coupled to the Unified Model (UM) at version 12.0. The work here has run the UM regional nesting suite over a 2.2km domain around North-eastern Spain using a newly generated irrigated fraction ancillary based on land cover classes from the ESA Climate Change Initiative (CCI) dataset.

Early results show that the impact of using the coupled irrigation scheme is an increase in soil moisture over the areas mapped by the ancillary. This has led to beneficial impacts on latent heat fluxes, land surface (skin) temperatures and screen temperature and humidity. The colder, wetter irrigated surface suppresses boundary layer growth and sets up a circulation, increasing the potential for convective activity and clouds downwind of irrigated areas. Future work is planned to evaluate the land surface and boundary layer fully using the ground-based and airborne observations collected during the LIAISE field campaign. The global impacts will also be assessed by performing global NWP case study runs and a 20 year climate simulation. This will focus in on the larger scale impacts of irrigation.

Go to Top

Enhancing UFS Land Model Development Using Hierarchical Testing

Michael Barlage – NOAA/NWS/EMC

A collaborative effort is currently underway to develop NOAA's next generation Unified Forecast System (UFS) framework. Within the UFS, there are multiple major earth system components, including atmosphere, oceans, and land. UFS applications span local to global domains and predictive time scales from sub-hourly to seasonal. These wide-ranging applications pose challenges and provide opportunities for the development and evaluation of UFS land components. This presentation will discuss on-going efforts in addressing and coordinating a land evaluation framework and land model physics advances. Models lacking proper coupled land-atmosphere behavior will underperform at all temporal and spatial scales, and will be prone to systematic biases in temperature, humidity and precipitation. The overarching initial UFS land goal is to ensure equal, and achieve superior, model performance compared to the baseline UFS land model, the Noah land surface model (LSM).

To facilitate UFS community engagement and accelerate R2O transition, a hierarchical testing approach is being developed that involves a spectrum of LSM-only simulations, a single-column coupled land-atmosphere modeling system, and coupled simulations both without and with a prognostic ocean. This approach is used to isolate and quantify the impacts of individual components before systematically increasing complexity and inherently introducing non-linear, difficult to track interactions. This provides a direct pathway for candidate models to diagnose problem areas in the model process chain, which enables identification of specific parameterizations that are the source of poor model performance. The evaluation framework is being extended beyond traditional meteorological validation to land process metrics that focus on the interactions between land and the atmosphere.

Global Precipitation Experiment (GPEX): Concept and Status

Jin Huang – NOAA Climate Program Office

When, where, and how much precipitation will occur, and in what form, are of critical importance to every person, business, and water resource manager. These and other users need those answers for the next few hours, months, seasons, and decades. Although temperature forecasts have generally improved greatly over the last few decades, precipitation forecasts beyond a few days have not. Climate models have huge uncertainties in regional precipitation projections as indicated by the recently issued IPCC AR6 report. One fundamental reason for the lack of improvement in precipitation prediction and projections is that today's global coupled models do not accurately capture the physical processes critical to precipitation, resulting in persistent biases that are as large as the real precipitation signal they are trying to produce. The sources and limits of precipitation predictability are still not well understood.

The Global Precipitation Experiment (GPEX) is aimed at reducing model biases in global coupled models using an integrated observations and modeling strategy and targeting priority processes and phenomena that are key to enhancing precipitation predictability and improving precipitation predictions and projections. GPEX requires a long-term and coordinated global commitment. It is envisioned that GPEX will be a multi-year project with national and international participation and collaboration. GPEX includes three major research components with user engagement throughout the entire process to guide future research needs and requirements for improvements:

1) Predictability and Process Studies to advance understanding of precipitation predictability sources and limits; and improve processes key to global and regional precipitation distributions and variability, and the representations of the processes in coupled models. This will be achieved through process studies of intensive and innovative field campaigns and hierarchical model experiments.

2) Optimizing observations and datasets (including satellite, radar and in-situ) for prediction initialization, evaluation and process understanding. This includes enhancement of existing observation networks, applications of new observing technologies to fill in observation gaps in key regions, targeted observations focusing on specific high impact events, and integrated datasets for process understanding and process-level model diagnosis.

3) Improving global coupled model systems: This includes improved physics, high-resolution modeling, and novel approaches to represent processes critical to precipitation (e.g., applications of AI/ML) in global coupled models, development of coupled data assimilation capability, and creative numerical configurations.

The concept of GPEX has been discussed within the agencies of US CLIVAR and USGCRP/US GEWEX (e.g., NOAA, DOE, NSF, and NASA) and with international CLIVAR and GEWEX. GPEX is supportive to U.S. agencies' priorities and can leverage agencies' capabilities, for example, NOAA's Precipitation Prediction Grand Challenge (PPGC), DOE's research areas in integrated water cycle, high latitudes, NSF foundational science and NASA's space based Earth system observations. The World Climate Research Program (WCRP) is enthusiastic about GPEX and has adopted GPEX as a cross-WCRP activity and a potential new WCRP Lighthouse Activity.

The discussions in the Pan-GASS conference will engage the broader research communities towards the development of a GPEX Science Team. The feedback from the conference participants will inform the GPEX planning and help coordinate ongoing and future field campaigns, modeling experiments, analyses of observations/datasets, and improvements to model biases and uncertainties in predictions and projections.

Go to Top

Impact of an interactive vegetation scheme on seasonal forecast

Gildas Dayon – Météo-France

Processes governing land-atmosphere interactions have a flawed representation in dynamical seasonal forecast systems. In particular, the vegetation evolution is generally prescribed, following an annual climatology for example. However, vegetation is involved in the climate mean state and interannual variability, due to the impact on the surface water and energy budgets through the canopy transpiration and albedo. Furthermore, the time scale of vegetation evolution is slower than atmospheric processes, which could be an asset for atmospheric predictability considering the persistence of anomalous leaf area index initial states.

While recent efforts on land sources of seasonal predictably have mostly focused on soil moisture and its initialization, the impact of a better representation of the vegetation evolution on seasonal forecast skill is yet to be explored.

In the framework of the European project H2020-CONFESS, we investigate the extent to which a dynamic vegetation scheme influences the simulated climate variability as well as the seasonal forecast skill. The study relies on two sets of historical simulations (AMIP-type experiments) and two sets of retrospective seasonal forecasts carried out with the CNRM-CM6.1 coupled model.

In both approaches, the reference set has a fixed prescribed vegetation seasonal cycle, and the second set uses an interactive vegetation module with plant photosynthesis and respiration parameterized for each vegetation type.

Among the presented results, a particular focus is set on extreme drought events occurring during boreal spring and summer. Preliminary conclusions from this study will contribute to pave the way to the next generation of operational seasonal forecast systems in the context of the European Copernicus Climate Change Services (C3S) program.

Land-atmosphere feedbacks, heatwave predictability, and changing seasonal moisture availability

Kirsten Findell – GFDL/NOAA

Surface flux partitioning during daylight hours is to first order determined by moisture and energy availability at the surface. Atmospheric conditions—moisture deficits near the surface, exchange rates governed by winds and turbulence, stability and humidity of air entrained by the growing boundary layer—create further constraints on surface flux determination. These fluxes are the key conduit connecting the land with the boundary layer and the overlying atmosphere. Constraints on the latent heat flux, in particular, arise through moisture limitation and/or energy limitation, and create a highly non-linear relationship between soil moisture and surface latent heat flux.

Here we apply and extend a new global framework which uses local climatological aridity and the probability distribution function (PDF) of daily soil moisture to understand how these constraints and boundary layer-mediated processes impact the behavior of daily latent and sensible heat fluxes, and how those fluxes, in turn, impact near-surface temperature and precipitation in a changing climate. This framework is a guide to understanding vulnerabilities to heat waves and drought, opening the door to improved predictions of these extremes. The framework also reveals model-specific behaviors and biases that can be helpful for model development purposes. We extend this framework to seasonal time-scale land-atmosphere feedbacks to help explain how land-atmosphere coupling impacts the variability of regional-scale wet and dry seasons in a changing climate.

Land-atmosphere coupling processes impact local and regional temperature and precipitation on time scales ranging from minutes to seasons to years. Improved understanding of the inherent non-linearities of and constraints on these interactions can contribute to improved predictions of temperature and precipitation across time scales.

Local and remote land-atmospheric interaction in determining warm season rainfall and its predictability over US Great Plains

Rong Fu – UCLA

Warm season droughts have disproportionally strong impacts on agriculture, water resources and wildfires both over the United States (US) and worldwide. Yet, we cannot predict them on seasonal or longer time scales because of their limited connection to sea surface temperature anomalies. Increasingly, the research community looks at land-atmosphere interaction as another promising source of the predictability for warm season droughts. Most previous studies have been focused on local coupling through the impact of land surface on the atmospheric boundary layer (ABL), which, in turn, influences rainfall. By comparison, much less effort has been made to understand the impact of the moisture above the ABL on local land-atmosphere coupling and the remote influence of land surface wetness on warm season rainfall elsewhere. In this presentation, we will provide observational evidence to show that the atmospheric humidity above the ABL has a significant influence on local land-atmosphere coupling, especially under dry soil conditions. Thus, such an influence needs to be considered in determining the impact of local land-atmosphere coupling on rainfall predictability under drought conditions. We will also show that the soil moisture anomaly over the Southwest US in spring is a leading contributor to moisture transport anomalies over the northern and central US Great Plains, which in turn, influence summer rainfall in the latter region.

Go to Top

On the remote effects of spring Tibetan Plateau land surface temperature on African summer monsoon development

Ismaila Diallo – Pennsylvania State University, Department of Meteorology and Atmospheric Science

Recent observational and modeling studies have demonstrated the substantial influence of the Tibetan Plateau (TP) spring land surface temperature (LST) and subsurface temperature (SUBT) on global summer monsoon precipitation, highlighting the potential application of LST/SUBT on sub-seasonal to seasonal prediction (S2S) precipitation prediction. In this study, we employ the National Centers for Environment Prediction – Global Forecast System/Simplified Simple Biosphere model version (GFS/SSiB2) to investigate the potential role of the late spring cold LST anomaly over the TP on the early summer 2003 above normal rainfall conditions in the African monsoon region. Numerical experiments indicate that the colder (below normal) May LST over the TP may contribute to the wet conditions of 2003 over the whole West African (WAF) region, with the LST reproducing about 25% and 37% of observed above-normal rainfall anomaly over Gulf of Guinea region and the whole WAF region, respectively. Furthermore, the results show that the imposed cold LST/SUBT over the TP produces an increase of easterly wave activities in the 3-5 days regime associated with a northward shift of the African Easterly Jet, leading to a widespread increase of the African monsoon precipitation. The present study demonstrates that the spring TP land surface temperature anomaly could be a new source of S2S predictability for more skillful S2S prediction of the African summer monsoon precipitation.

Spring Land Temperature in Tibetan Plateau Enhances Global-Scale Summer Precipitation Prediction – The GEWEX/LS4P Phase I Experiment

Yongkang Xue – University of California, Los Angeles

Sub-seasonal to seasonal (S2S) prediction, especially the prediction of extreme hydroclimate events such as droughts and floods, is not only scientifically challenging but has substantial societal impacts. The Global Energy and Water Exchanges (GEWEX)/Global Atmospheric System Study (GASS) has launched an initiative called "Impact of initialized Land Surface temperature and Snowpack on Sub-seasonal to Seasonal Prediction" (LS4P. Xue et al., 2021. https://ls4p.geog.ucla.edu/), as the international grass-roots effort to introduce spring land surface temperature (LST)/subsurface temperature (SUBT) anomalies over high mountain areas as a crucial factor that can lead to significant improvement in precipitation prediction through the remote effects of land/atmosphere interactions. Because of the high elevation of the Tibetan Plateau (TP), its significant areal coverage and the comprehensive field measurements by the Third Pole Environment and related projects that span more than a decade, the LS4P Phase I focuses on the first order effects most related to TP land temperature. LS4P focuses on process understanding and predictability, hence it is different from, and complements, other international projects that focus on the operational S2S prediction. The year 2003, when extreme summer drought/flood occurred in East Asia after a very cold spring in the TP, is the focal case. More than forty groups worldwide have participated in this effort.

Observational data for Tibetan Plateau spring surface temperatures show a lag correlation with observed summer precipitation in several regions. This relationship cannot be reproduced by current global models due to significant errors in producing observed Tibetan Plateau surface temperature. After introducing surface 2-meter air temperature observations for an innovative land temperature initialization over the TP in LS4P Phase I experiment, new results from multi-models have established the observed causal relationship between the cold Plateau spring land temperature and summer precipitation in several regions of the world. The areas with a significant June precipitation impact from multi-model results due to the TP May cold temperature, that are also consistent with the observations, are defined as hot spots. The simulated TP land surface temperature anomaly produces the largest impact in the Yangtze River Basin, North America, and Central America, which corresponds to about 42%, 44%, and 51% of observed precipitation anomaly for these three regions, respectively. For these hot spots, only a couple of models among the total of 16 models produce anomalies that are different in sign compared to the observations. For the hot spots in tropical regions, such as the Sahel, East Africa, and northern South America, model uncertainties are relatively large.

The TP land surface temperature influence is underscored by an observed out-of-phase oscillation between the Tibetan Plateau and Rocky Mountain surface temperatures. It has been identified that the impact on the large-scale climate dynamics is manifested as a downstream wave train linking the TP to North America. The Tibetan land temperature effect on the global S2S is also compared with the sea surface temperature effect. The multi-model results demonstrate for the first time that high mountain land temperature could be a new source of S2S precipitation predictability, and its effect is probably as large as the more familiar effects of ocean surface temperature. The multi-model results show that SST and high mountain LST have some common hot spot regions, but they also consist of different hot spot regions over globe.

The LS4P will launch the Phase II experiment in the second half of 2022, and the community is welcome to join the project (contact email: yxue@geog.ucla.edu). The LS4P Phase II will focus on the Rocky Mountain LST/SUBT effect and the interaction between TP and Rocky Mountain surface temperature anomalies and their impacts. In addition to the global model, regional climate model downscaling and regionally refined model within global model in S2S prediction will be conducted. The effects of snow and aerosols in snow in high mountains on S2S prediction will also be explored in the LS4P Phase II.

Reference

Xue, Y., Yao, T., Boone, A. A., Diallo, I., Liu, Y., Zeng, X., Lau, W. K.-M., Sugimoto, S., Tang, Q., Pan, X., van Oevelen, P. J., Klocke, D., Koo, M.-S., Lin, Z., Takaya, Y., Sato, T., Ardilouze, C., Saha, S. K., Zhao, M., Liang, X.-Z., Vitart, F., Li, X., Zhao, P., Neelin, D., Guo, W., Yu, M., Qian, Y., Shen, S. S. P., Zhang, Y., Yang, K., Leung, R., Yang, J., et al., 2021:
Impact of Initialized Land Surface Temperature and Snowpack on Subseasonal to Seasonal Prediction Project, Phase I (LS4P-I): Organization and Experimental design, Geosci. Model Dev., 14, 4465–4494, https://doi.org/10.5194/gmd-14-4465-2021

Go to Top

Understanding ENSO teleconnections and processes in the La Plata basin using river discharge as precipitation proxies with Regional Earth System model RegIPSL

Carla Gulizia – Centro de Investigaciones del Mar y la Atmosfera (CIMA/CONICET-UBA), UMI IFAECI/CNRS-IRD-CONICET-UBA, DCAO/FCEN (University of Buenos Aires)

Regional Earth System Models (RESM) are state-of-the-art modelling platforms which open new possibilities for regional climate modelling exhibiting higher robustness and complexity than standard atmospheric alone RCMs, since they are based on the dynamical coupling of specific models for each component of the climate system. The RegIPSL is the RESM of the 'Insitute Pierre Simon Laplace' that couples: WRF (atmosphere), ORCHIDEE (land) and NEMO (ocean) throughout the NEMO coupler, using XIOS for the I/O tasks. For the first time, RegIPSL has been used to perform a 30-year (1990-2019) long climate simulation (WRF, ORCHIDEE only) for the entire South American continent at 20 km horizontal resolution forced and nudged to ERA5 reanalysis.

The La Plata basin (LPB) is the fifth largest basin in the world, and the second in South America, after the Amazon basin. Extreme events in the LPB can produce significant socio-economic impacts and these took place mainly during El Niño-Southern Oscillation (ENSO) warm and cold conditions. The aim of this process-oriented study is to understand how the ENSO conditions (El Niño, La Niña and neutral) modulate different atmospheric mechanisms that produce the wet and dry extremes in the river discharges of the LPB and how these interact with the local processes. River discharge data is used as being a more suitable variable for risk assessment and water resources management as well as a proxy for actual precipitation due to the lack of a dense and long term precipitation time series over the continent.

In order to assess RegIPSL model response to the El Niño-Southern Oscillation (ENSO), we first evaluate the representation of key atmospheric variables as simulated in the RegIPSL, using ERA5 as reference, for the composites of El Niño, La Niña and Neutral events, respectively, during the studied period. We also compare observed and simulated river discharges at different locations of the main rivers of the La Plata basin (Paraná, Paraguay Uruguay), known to be influenced by ENSO, for different ENSO conditions (El Niño, La Niña and neutral). Particular ENSO events such as the extreme La Niña 1999/2000 and El Niño 2015/2016 are analyzed exhaustively to further understand the ENSO teleconnections evolution during each event.

Preliminary results indicate that though the RegIPSL underestimate precipitation and thus, the river discharges at the studied locations, the benefit of this 20-km simulations is the physical consistency within the model output variables contributing to a better understanding of the atmospheric dynamics and interactions in the LPB river basin during an El Niño and La Niña event, respectively.

YOPPsiteMIP: The YOPP site model inter-comparison project

Gunilla Svensson – Stockholm University

Although the quality of weather forecasts in the polar regions is improving, it still lags behind the quality of forecasts in lower latitudes. Arctic regions pose specific challenges related to processes which are historically difficult to model (stable boundary layers, mixed-phase clouds, and atmosphere-snow-ice coupling). Moreover, so far there has been relatively little effort to evaluate processes in weather models using in-situ datasets from the terrestrial Arctic and Antarctic, compared to the situation in mid-latitudes.

The YOPP site inter-comparison project (YOPPsiteMIP) is addressing this gap by producing Merged Observatory Data Files (MODFs) and Merged Model Data Files (MODFs), bringing together observations and forecast data at polar meteorological observatories in a format designed to facilitate process-oriented evaluation. This legacy project of the World Meteorological Organization's Year of Polar Prediction (YOPP), is an international effort bringing together forecasters, observationalists and data scientists from multiple institutions. The presentation will outline muti-model-multi-site results from the project, focussing on identifying and highlighting common causes of forecast error in surface and near surface weather parameters.

Suggestions for further model intercomparison studies using YOPP dataset will also be discussed.

Go to Top

Poster Presentations

SU80 – A Proposed Central Asian Regional Hydroclimate Project linking Hydroclimate and Atmospheric Dynamics to Air and Water Quality

Michael Brody – George Mason University

The Central Asian region is a land locked region with strongly varying topography and climatic zones that is already affected strongly and negatively by a changing climate. It is an underrepresented and poorly studied area within the framework of the World Climate Research Programme and GEWEX. Most GEWEX Regional Hydroclimate Projects (RHPs) focus on hydroclimate but can be broader in scope. Since air quality is already a major human health issue in this region it makes sense to incorporate air quality, and not just water resources, into a RHP research endeavor. However, to this date air quality has not been a significant part of the GEWEX research agenda and hence in this presentation we explore the potential pathways to link atmospheric dynamics and processes as well as land atmosphere interactions and hydroclimate processes to air and water quality issues. This is crucial as both air quality and clean freshwater availability are important societal drivers. As such a Central Asian RHP could support a more inclusive GEWEX agenda both in terms of regional representation as well as in research foci.

SU81 – Aerosol-associated enhancement in fogginess over North India: Observations and Modelling

Chandan Sarangi – Indian Institute of Technology Madras

Frequent fog events form in a high aerosol-laden environment over the Indo-Gangetic Plain, causing widespread day-to-day disruptions to the public sectors, leading to substantial economic losses. Although previous modeling studies have illustrated strong associations of aerosols with fog intensity, their observational evidence is rare. We used active remote sensing observations to identify the fog layer over the IGP and observed many instances of the co-existence of fog layer and aerosol above fog. Interestingly the aerosol transport also strengthens over the central and east IGP. The co-located samples of fog and AOD denote a non-linear increase in the fog layer's top height (and hence thickness) associated with higher AOD loading. Further, numerical experiments revealed that the elevated aerosol's scattering and absorption of the incoming shortwave radiation can strengthen the inversion conditions and stabilize the boundary layer leading to shallower PBL height. Furthermore, the solar dimming at the surface results in suppression of surface temperature by 5°C and increases the RH by 20%. These can promote supersaturation conditions, leading to increased fog droplet number concentrations, causing the fog to deepen. Therefore, we present unprecedented and robust observational and modelling evidence of aerosol-fog interaction over IGP by influencing the fog-boundary layer thermodynamics via a combination of aerosol radiative and thermodynamical effects.

SU82 – Assessing the Land-Atmosphere Interactions in the Unified Forecast System

Man Zhang – CIRES/University of Colorado and NOAA/Global Systems Laboratory

The Unified Forecast System (UFS) is a comprehensive, community-developed Earth modeling system, designed as both a research tool and as the basis for NOAA's operational forecasts. To improve the skill of operational forecast models, NOAA recently funded the UFS-Research-to-Operations (R2O) Project with goals of developing modeling innovations suitable for R2O transition and broadening the access and usage of the UFS. The UFS-R2O physics subproject enables physics developers and scientists to actively engage in the development process and ensures the improvements will be properly implemented in the UFS. The Developmental Testbed Center (DTC), which has the overarching goal of making the R2O pipeline more efficient, participates in this process by conducting Testing and Evaluation (T&E) of physics innovations.

Surface fluxes, which are essential components of the water and energy budgets, govern the interactions between the land and the atmosphere. In this presentation, we will showcase the DTC T&E activity using NASA's Phase 2 of the North American Land Data Assimilation System (NLDAS-2) dataset, Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) atmospheric observatories observations, and NOAA's Soil Moisture Operational Products System (SMOPS) datasets. The gridded hourly NLDAS-2 data provide an excellent way to evaluate the model errors and biases of surface heat fluxes over the contiguous United States (CONUS) for long-term averages. The ARM SGP observations are suitable to evaluate the diurnal change of model surface fluxes at individual stations in the SGP. The gridded, satellite-based SMOPS data allow for global evaluations of soil moisture.

To evaluate the performance of physics innovations in the UFS, retrospective experiments with physics updates in the Global Forecast System (GFS) convection and planetary boundary layer (PBL) schemes, as well as the land surface model, were conducted by the UFS physics developers. To better understand and inform how the updated physics interacted in establishing the surface states, process-based assessment tools to quantify the effect of surface forcing on near-surface variables were developed in the DTC. Our results indicate a problematic Bowen ratio over the eastern CONUS region in the GFS v16 and misrepresentations of the soil temperature and moisture states, the lifting condensation level, and the PBL height of convective PBL (CPBL) in the UFS. This study provides insight into model strengths and deficiencies and suggests the importance of physical processes that represent clouds and their role in the land-atmosphere interactions.

Go to Top

SU83 – Boundary Layer Interactions Explain Observed Patterns of Soil Moisture-Precipitation Interactions across the Conterminous United States

Kyoungho Ryu – Boston University

Changes in land surface moisture state alter the exchange of fluxes between land and the atmosphere and result in changes in the state of heat and moisture in the lower part of the atmosphere. Evaporative Fraction (EF), defined as the fraction of Latent Heat Flux to the available surface energy, represents such surface changes in the Surface Energy Balance framework. Given the framework and a boundary layer model, it is feasible to study how the atmosphere responds to land surface moisture state changes. Here we demonstrate that a simplified atmospheric boundary layer model can produce similar patterns of land-atmosphere interactions to that found empirically from remotely sensed soil moisture and ground-based precipitation data. The comparison of land-atmosphere interactions is indirect. It is made between two sensitivity analyses: 1) the sensitivity of vapor flux at cloud-base to surface evaporative fractions (EF) around their equilibrium value in the boundary layer model and 2) the sensitivity of precipitation probability to soil moisture perturbations in the empirical model. In the first sensitivity analysis, we applied equilibrium evaporative fraction between the land and the top of the boundary layer to estimate evapotranspiration across the United States. We find consistent results between the two approaches, with positive interactions in the western and negative interactions in the eastern of the United States. Results indicate surface moisture state changes result in the different tendencies of shallow cloud formation depending on location. The different evolutions of the boundary layer, and in particular the interaction of the boundary layer height and the lifting condensation level, explain the resulting patterns. Analyzing the sensitivity of fluxes to perturbations of evaporative fraction around the equilibrium evaporative fraction enhanced our understanding of hydrology-related issues in regions where in-situ measurements are not available.

SU84 – Characteristics of the diurnal rainfall cycle in relation to deep convection using a dense network of rain gauges in western Dakar

Cheikh Fall – University Cheikh Anta Diop of Dakar

West African monsoon system has a strong diurnal cycle drived by the daily migration of the Intertropical discontinuity. This variability affected the westward propagation of the mesoscale convective systems and local thunderstorms observed during the afternoon hours.

The LPAOSF (Laboratoire Physique de l'Atmosphère et de l'Océan Siméon-Fongang) raingauges network acquired during the African Multidisciplinary Monsoon Analysis (AMMA) campaign is used to investigate characteristics of rainfall diurnal cycle. This network is located over extreme western Senegal and consists of 36 raingauges installed in three subzones named nothern zone, southern zone, and high-density zone in order to have a spatial coverage centered on the NASA S-band dual Polarimetric (NPOL) radar located at Kawsara (-17.09804°W, 14.65654°N) during AMMA field campaign.

The diurnal cycle and intra-seasonal variation of the rainfall amount, frequency and intensity, and durations are analyzed using rainfall data from a dense network of 18 rain gauges over in the peanut basin in Senegal, during the 2007-2015 period. Results show that the mean rainfall amount and frequency peaks are observed around 1800 GMT for the whole season, while the intensity peak occurred between 1300 and 1400 GMT. Rainfall intensity indicated the strongest spatial variability compared to rainfall amount and frequency. Most of the rainfall events had a short lifetime between 1 and 3 hours (up to 80%). These short rainfall events contribute up to 75% of the total rainfall over this region. However, the heavy rainfall are much longer with a lifetime between 4 and 5 hours, the intraseasonal variability of rainfall diurnal cycle indicate a strong variability between the start and end of the monsoon season. Indeed, rainfall events occur between 1200 and 1400 GMT during the installation phase of the West African Monsoon (WAM) in June-July. During the active phase of the WAM (August-September). These results have important implications on the nowcasting early warning system over western Sahel and will contribute on the improvement of the parametrization of convection in the numerical weather prediction model.

SU85 – Characterizing boundary layer turbulence using ACTIVATE observations over the Western North Atlantic Ocean: Implications for model evaluation and development

Michael Brunke – University of Arizona

Boundary layer turbulence is derived from high temporal resolution meteorological measurements from research flights over the western North Atlantic Ocean from deployments of ACTIVATE. Frequency distributions of various turbulent quantities reveal stronger turbulence during the winter flights than in summer and for cloud-topped than in cloudless boundary layers. Minimum turbulent kinetic energy is most often within cloud from observations in winter and summer, whereas it is mostly produced below cloud in both seasons by a global model turbulence parameterization. Bivariate frequency distributions are generally binormal, validating a key assumption in higher-order turbulence/shallow convection parameterizations used by some global models. Turbulence simulated by global models using such parameterizations, though, is not as strong as observed, suggesting that the higher-order parameterization of turbulence using in Earth system models still requires further improvement.

Go to Top

SU86 – Climate model precipitation bias over continents in summer: in-line mitigation strategy and impact on seasonal prediction skill

Constantin Ardilouze – CNRM, Université de Toulouse, Météo France, CNRS, Toulouse, France

Soil moisture is a well-known source of summer potential predictability at the monthly to seasonal time scale, especially over regions of intense land-atmosphere coupling. However, improving soil moisture initialization in dynamical forecast systems leads to increased temperature and precipitation prediction skill over fewer regions than one could expect. This limitation could originate from model precipitation biases, prone to rapidly spoil the soil moisture anomalies present in the land surface initial conditions. In particular, dry summer biases over the Great plains of North America are a common feature in many CMIP5 and CMIP6 climate models, also found in dynamical forecast systems.

In order to make the most out of soil moisture as a source of prediction skill, we implemented a method to reduce the precipitation bias throughout the CNRM-CM6-1 climate model integration in forecast mode. The precipitation flux intercepted by the land surface is corrected at each time step. The correction consists in applying a multiplicative factor to the simulated precipitation feeding the land component of the climate model. This method leads to a considerably reduced precipitation and 2-meter temperature seasonal bias over Europe and North America. It also reduces the bias in number of days with significant precipitation, although less markedly. Results on the model mean climate for evapotranspiration, root zone water content and run-off are presented, as well as the ensemble spread. Finally, we discuss the beneficial impact of the method on summer temperature forecast skill over the US Great plains with respect to a baseline hindcast, in contrast with results found for Europe.

SU87 – Confronting the ECMWF/IFS with data from the Central Arctic

Michael Tjernström – Stockholm University

Numerical weather prediction of climate models are rarely evaluated for the central Arctic other than very superficially, simply because detailed data are hardly ever available. The data set from the Arctic Ocean 2018 (AO2018) expedition on the Swedish research icebreaker Oden provides a possibility to do just that, and in this presentation we will take advantage of th extensive observations to take a hard look at the vertical structure of the lower atmosphere, how that is related to clouds and how it affects the surface energy budget - in the model and in reality - for forecasts out to three days over about a month in late summer, early autumn and in particular the transition in between.

The results reveal some good things and some problematic things. The winds have only smaller biases and the wind direction is really good in the model; while the surface pressure is actually drifting away from reality, the pressure gradient seems to be OK. The whole boundary layer temperature is, however, biased high and this gets worse as the temperature starts to drop when the surface freezes in early autumn. Before that, the boundary-layer temperature is help back by the constraint on the surface temperature by the snow melt but is still biased warm. There is also a substantial diurnal cycle in the modelled boundary-layer temperatures that does not appear in reality; when the surface is melting the surface temperature is stuck at the melting point, essentially prohibiting a diurnal cycle and later, when the temperature drops below freezing the sun is so low on the horizon that there is no forcing of a diurnal cycle. A positive bias in the boundary layer moisture just follows the warm bias. One could think that the warm bias has to do with the coupling to the sea ice, but an analysis of the surface energy fluxes indicate that it is the atmosphere that insists on trying to warm the surface; not the other way around. On top of the too warm boundary layer there is a layer of a substantial cold bias, while the mid-troposphere is slightly too warm but not very much. Interestingly, mean errors in the vertical profiles of cloud presence and temperature are is nicely anti-correlated. On top of the too warm boundary layer, the cold bias corresponds to where there is too much clouds while the slightly too warm mid troposphere has too little clouds; the cloud water paths are also too large.

Putting the pieces together, the IFS seems to exaggerate cloudiness, and this error has a preferred vertical structure, with too deep and water laden clouds in the lower troposphere leads to a too warm boundary layer with too much cloud top cooling around 2-3 km; hence the cold bias there. It is also quite clear that the temperature error above the boundary layer gets worse with cloud liquid water path.

It is unclear what causes the cloud overestimation, but one hypothesis is an overly active mid-level convection scheme, well functioning in the extratropical weather systems, is poorly adopted to the Arctic and feeds the too deep clouds with boundary layer moisture. This leads to an temperature error with a vertical structure (warm bias below cold bias) that aided by the the diurnal cycle structure triggers even more mid-level convection that feeds more clouds, larger temperature error and so on and so forth.

This type of analysis of model errors would have been impossible if we did not have access to vertical profiles of clouds and thermodynamic structure along with surface fluxes, and can serve as a model for how to usefully evaluate models with field campaign data, going beyond the traditional evaluations of surface pressure, 2-meter temperature and 10-meter winds.

Go to Top

SU88 – Daytime-only-mean data can enhance our understanding of land-atmosphere coupling
Zun Yin – GFDL-NOAA, Princeton University
A primary concern of land-atmosphere (L-A) interactions is the evolutionary process between the land surface and the planetary boundary layer during daylight hours. However, many relevant studies have been conducted with time series of entire-day (24 hour) mean values due to the lack of sub-daily data. It is unclear whether the inclusion of nighttime data in these daily averages alters the results or obscures L-A interactive processes. To address this question, we generated daytime-only-mean (D) and entire-day-mean (E) daily data based on the ERA5 (5th ECMWF reanalysis) hourly product, and evaluated the strength of L-A coupling through the two-legged metrics, which assess the L-A coupling strength through two segments: the impact of the land state on surface fluxes (the land leg), and the impact of surface fluxes on the atmospheric state (the atmospheric leg). The results demonstrate that the spatial pattern differences of strong L-A coupling regions between the D- and E-based diagnoses can be as large as 67% (median 20.7%), though they strongly depend on the season and the region. Additionally, we described two phenomena that may result in false L-A diagnoses based on the E. One is an advection-dominant climate regime in tropical hyper-arid regions that leads to a unique negative false correlation between the sensible heat flux and the PBL growth. The other is that the soil moisture and sensible heat flux coupling may be substantially overlooked in some regions of Western Hemisphere due to associated period segmentation for entire day (a night and the following day). Both circumstances may disturb the signal of L-A coupling if entire-day-mean data is used. To improve our knowledge of L-A interactions, we call attention to the urgent need for more high frequency data for relevant diagnoses. We propose two approaches to resolve the dilemma of huge storage for high frequency data: (1) integration of L-A metrics in Earth System Model outputs, and (2) production of daily datasets based on different averaging algorithms.

SU89 – Diagnostic Evaluation of Instability necessary for Severe Convective Storms through use of the Lapse rate tendency equation
Alan Garcia Rosales – Central Michigan University
Severe Convective Storms (SCS) regularly produce produced damaging hail, intense wind gusts, and other damage worldwide. Consequently, a broad understanding of the processes and dynamics that govern deep convective development and organization on a global scale is crucial for both assessments of the present hazard and future climate change scenarios. However, these broad-scale model and reanalysis datasets do not provide a simple framework to diagnose whether the generation of instability that drives convective processes is being reliably resolved. To address this limitation we use the lapse rate tendency equation, which can be used to identify regions of effective sources, sinks, and transport of instability. The horizontal and vertical lapse rate advection rate gradients terms considerably affect the calculation of the lapse rate tendency. In this study, we explore the global spatial distribution of these terms using the Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2), which is the latest atmospheric reanalysis of the modern satellite era produced by NASA's Global Modeling and Assimilation Office (GMAO). Preliminary results show that the lapse rate tendency provides a useful diagnostic framework to assess the generation of instability.

SU90 – Diurnal variations of the planetary boundary layer height and the lifting condensation level from aircraft observations
Dan Li – Boston University
Low-level clouds are strongly dependent on the relative positions of the planetary boundary layer height (PBLH) and the lifting condensation level (LCL). However, measurements of the PBLH and the LCL at the diurnal scale are still lacking. Utilizing commercial aircraft measurements, we derive a 10-year, hourly dataset for PBLH and LCL at 54 major airports over the Contiguous United States (CONUS). At diurnal scales, this dataset allows us to study the growth of the PBL and how it interacts with LCL, especially during the daytime when flights are abundant. Combining measurements of cloud cover, we can quantify whether the observed low-level clouds are coupled with the surface or not. At longer (e.g., seasonal) time scales, it allows us to characterize the probability of PBLH crossing LCL in the daytime (i.e., the number of days with PBLH higher than LCL in the daytime within a season). This probability is then compared to the number of rainy days, the amount of rainfall, as well as the soil moisture values from SMAP to understand seasonal (and inter-annual) variability of land-atmosphere coupling strength. The comparison between different airports over CONUS also allows us to understand the role of background climate on land-atmosphere coupling.

Go to Top

SU91 – Equatorial Indian Ocean surface rain layer feedbacks to the atmospheric boundary layer
Kyle Shackelford – Colorado State University
Surface freshening via precipitation can act to stabilize the upper ocean, forming a rain layer (RL). RLs inhibit subsurface vertical mixing and alter air-sea fluxes. This process has been studied using both observations and idealized simulations. The ocean modeling study presented here first uses a 1D, surface-forced ocean model, the General Ocean Turbulence Model (GOTM), to investigate characteristics of equatorial Indian Ocean RLs. The GOTM simulations involve forcing a 2D array of GOTM columns with realistic output from an existing regional atmospheric simulation. RL feedback to the atmospheric is evaluated through analysis of RL-induced modification to sea surface temperature (SST), which reveals a prolonged reduction of SSTs within RLs. A second 2D

array simulation with identical atmospheric forcing to that in the first, but with rainfall set to zero, is conducted to evaluate the role of rain temperature and salinity stratification in maintaining cold SST anomalies within RLs. Comparison between the RAIN and NO-RAIN simulations indicate that SST reduction within rain layers persist on time scales longer than the associated precipitation event. Approximately one-third of the SST reduction within RLs can be attributed to rain effects, while the remainder is attributed to changes in atmospheric temperature, humidity, and wind speed. Results from the GOTM experiments also show that prolonged RL-induced SST anomalies sharpen SST gradients that have been linked to surface wind convergence and initiation of atmospheric convection. Fully coupled ocean-atmosphere simulations are conducted to further explore the influence of RL-generated SST gradients on atmospheric convection. Preliminary results from these coupled simulations are presented here.

SU92 – Evaporative fraction based on weather data for a cloud-topped boundary layer at diurnal equilibrium

Guido Salvucci – Boston University

A method for estimating evaporation (ET) from net solar radiation and early morning temperature, humidity, pressure is proposed. The method is demonstrated with approximately 100,000 site-days of fluxnet data (with one set of parameters) over a range of land cover and climate conditions. The method rests on two approximations: 1) Mixed layer humidity (q) is on average the same at the start and end of boundary layer growth; and 2) The humidity lapse rate is small and proportional to early morning humidity, except above the lifting condensation level (LCL) where a sharp jump (also proportional to early morning humidity) occurs. The approximations are based on the absence of moisture sinks below the LCL and negligible convergence. With these approximations, a unique value of daily-constant evaporative fraction (EF) yields an equilibrium diurnal cycle of predicted q, for which entrainment of dry air and cloud mass fluxes of humidity balance ET. Enforcing equilibrium with budget terms calculated from weather data and a cloud-topped mixed layer model estimates EF. Under simplifying conditions, EF depends mainly on two dimensionless variables related to the LCL and maximum mixed layer height. Performance at daily, seasonal, and interannual scales will be presented.

SU93 – FESSTVaL: Field Experiment on sub-mesoscale spatio-temporal variability in Lindenberg – the campaign, first results and data availability

Kristina Lundgren – Universität Hamburg, presented by Daniel Klocke – Max-Planck-Institut für Meteorologie

The field campaign FESSTVaL (Field Experiment on sub-mesoscale spatio-temporal variability in Lindenberg) was carried out by 16 institutions from May to August 2021 in the surroundings of the Meteorological Observatory Lindenberg – Richard-Aßmann-Observatory of the German Meteorological Service (DWD). The project aims at an improved understanding of the initiation and interaction of cold pools and wind gusts in the summertime convective boundary layer. Such weather phenomena can cause great damage, but are, however, difficult to capture by conventional surface networks due to their small-scale nature.

Unique to this campaign is the deployment of a high-density near-surface measurement network made of 80 ground-level stations for measurements of temperature, pressure complemented by 19 automatic weather stations as well as a dense network of soil moisture measurements. An X-band radar and several energy balance stations were also used. The surface network was augmented by a network of vertical profiling instruments including nine Doppler lidar systems for measurements of the wind profile and turbulence variables up to an altitude of several kilometers, four microwave radiometers, and measurement flights with unmanned and remotely-controlled aircraft. As a supplement to these measurements, the project investigates the gain of a citizen science measurement network.

This presentation will shed light on the 4D structure and evolution of cold pools associated with a strong convective event as viewed by the different sensors. The cold pool observations will be compared to forecasts and to large-eddy simulations conducted for that particular case. Overall, the results of the project will serve to improve the representation of such small-scale processes in numerical weather prediction and to define new measurement strategies. The data products of the campaign are treated under the FAIR principle and are made available via a platform at the Integrated Climate Data Center of the University of Hamburg.

Go to Top

SU94 – Improving Earth System Models via Hierarchical System Development

Michael EK – NCAR

Hierarchical System Development (HSD) is an effective approach to efficiently connect the Research-to-Operations/Operations-to-Research (R2O2R) process, with the ability to test small elements (e.g., physics subroutines) of an Earth System Model (ESM) first in isolation, then progressively connecting the elements with increased two-way interaction between ESM components and HSD steps. System in HSD is end-to-end in that it includes data ingestion and quality control, data assimilation, modeling, post-processing, and verification. The HSD includes Single Column Models (SCMs; including individual physics elements within the SCM), Limited-Area Atmosphere-only Models, all the way up to complex fully-coupled global ESMs with components for atmosphere/chemistry/aerosols, ocean/waves/sea-ice, land-hydrology/snow/land-ice, and biogeochemical cycles/ecosystems. Although an ESM subset (i.e. atmosphere-land and specified ocean conditions) has traditionally addressed Numerical Weather Prediction (NWP) needs, we assert that the R2O2R process may be improved by more fully utilizing the complexity spectrum inherent with the HSD approach. Datasets for use in the different tiers of the HSD are obtained from observational networks and field programs, ESM output, or idealized conditions, e.g. a constant background flow to simplify physics interactions, or extreme winds or instability to "stress-test" system components across the HSD steps, among other options. The requirements for advancing from one HSD step to the next are appropriate verification metrics/benchmarks of ESM performance, many of which are at the physical process level. It's important to note that this process is concurrent and iterative such that more complex HSD steps can provide information to be used at simpler HSD steps, and vice versa. The HSD approach can also help increase understanding of spatial and temporal dependencies in model physics where there is a need for consistency in model solutions between higher-resolution/limited-area short-range, global medium/extended-range and subseasonal-to-seasonal time scales, as well as at longer-term climate time scales. The Common Community Physics Package (CCPP) is designed to lower the bar for community involvement in physics testing and development through increased interoperability, improved documentation, and continuous support to the developers and the users. Together, the CCPP and the corresponding CCPP SCM, both developed at the Developmental Testbed Center (DTC), provide a software infrastructure that is an enabling tool to efficiently connect some of the HSD steps. GEWEX activities that address improving our understanding and modeling of Earth system processes very much fit within the HSD approach, and include land model benchmarking ("PLUMBER"), boundary-layer processes ("GABLS"), land-atmosphere interaction ("LoCo"), and the use of observations from (future) GEWEX Land-Atmosphere Feedback Observatory (GLAFO) sites. The use of CCPP in the HSD approach will be illustrated and discussed through the use of examples from DTC projects.

SU95 – Improving our understanding of land-surface and boundary-layer coupling using the LIAISE observational campaign

Adrian Lock – Met Office, UK

Land surface-atmosphere interactions play a critical role in the development of the boundary layer. Studies have shown that these interactions are strongest in semi-arid regions where there is both a sensitivity of the surface fluxes to the soil moisture profile, and a sensitivity in the atmosphere to these surface fluxes. However, our knowledge of the dominant processes that control these interactions is still limited and is further complicated by significant heterogeneity in the land surface. Here we present an observation and modelling framework to improve the understanding of the role of land surface-atmosphere interactions and the impact of surface heterogeneity (which is further enhanced by anthropization mainly through irrigation) on boundary layer evolution.

The LIAISE (Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment) observational campaign deployed a network of six eddy-covariance flux sites, representative of a range of Mediterranean land cover types, including irrigated and naturally rainfed regions. Here we focus on a 2-week Special Observational Period during July 2021 when intensive observations were made, including radio soundings, tethered balloon profiles and Doppler/Raman Lidar profiles. A protocol is developed from that used by DICE (Diurnal land/atmosphere Coupling Experiment). Sonde observations and ERA5 will be used to diagnose large-scale atmospheric forcing that can then be applied in large-eddy and single-column model simulations. Our methodology for assessing the impact of land/atmosphere feedbacks begins by assessing the individual components constrained by observational data and then identifies changes due to coupling. This international modelling intercomparison will initially examine irrigated and natural semi-arid domains but will go on to explore how the regional spatial heterogeneity impacts on boundary layer development and evolution.

Go to Top

SU96 – Insight Into Cold Air Outbreak Surface Wind Speed Through Remote Sensing, Perturbed Parameter Ensembles And Global Storm Resolving Models.

Geethma Werapitiya – University of Wyoming

The global climate system, which we study through global climate models (GCMs), acts to transport, distribute, and circulate heat around the globe through the atmosphere and oceans. A part of this global transport of heat is forced by the surface winds that drive the exchange of momentum, aerosol, water vapor, and heat between the atmosphere and ocean. We utilize wind speed from the microwave Multi-sensor Advanced Climatology (MAC) dataset to examine coupling between convective cloud and precipitation processes, synoptic state, and surface winds in cold air outbreaks (CAOs) and to evaluate the representation of ocean surface winds in this regime in GCMs and The Community Atmosphere Model version 6 (CAM6) Perturbed Parameter Ensemble (PPE). Surface winds in CAOs drive the largest exchanges of sensible and latent heat flux on Earth in western boundary currents. Surface wind speed in this regime is underestimated by GCMs relative to observations from MAC-LWP. The magnitude of this underestimate scales with the frequency of mesoscale cellular convection as predicted by CAO index. We examine three potential mechanisms to explain this model behavior: cold pool formation driving downdrafts that enhance surface wind speed, wind enhancement tied to small convection induced circulations and surface convergence, and poorly-resolved temperature gradients in cyclone cold sectors. We evaluate parametric and structural sources of model bias in the context of these mechanisms. The CAM6 PPE varied 45 parameters from the convection, radiation, microphysics, and aerosol schemes in 250 ensemble members- allowing insight into a broad array of parametric sources of uncertainty. We evaluated structural uncertainty- with a particular focus on model resolution- by examining lower resolutio in CMIP6 models (horizontal resolution Δx~100km), HighResMIP models

(Δx~12-25km), and global storm-resolving DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains (DYAMOND) simulations (Δx~5 km). We characterize different contributions to CAO wind speed bias in models resulting from model structural and parametric configuration and offer suggestions for reducing this bias.

Go to Top

SU98 – Land-atmosphere coupling in global fully coupled storm-resolving simulation

Junhong Lee – Max Planck Institute for Meteorology

The land is a key component of the climate system as it interacts heavily with water and energy cycles through surface latent and sensible heat fluxes. As a result of efforts to understand the role of the land surface for the climate system, many preceding studies have shown that there are hot spots regions where land and atmosphere are strongly coupled. While most of the past studies agreed that soil moisture-temperature coupling is of negative sign, there is a discrepancy in the coupling between soil moisture and precipitation. On the one hand, studies using coarse-resolution global climate models reported positive coupling. On the other hand, studies using single-column or limited-area cloud-resolving models found the possibility of negative or inconclusive coupling. Differences are generally thought to be the result of unresolved surface heterogeneity and the use of parameterized convection at coarse resolution, but the use of limited domains may also spuriously affect the coupling at high resolution. In this study, we explore the strength of land-atmosphere coupling using the output of a global fully coupled storm-resolving simulation. The simulation was conducted with the ICON model with a grid spacing of 5 km for one year. To determine the coupling strength, we compute coupling metrics, such as correlation coefficient, and analyse the results using the evapotranspiration regime based on the classical conceptual framework of Budyko. First results show that the global full coupled storm-resolving simulation successfully captures coupling strength derived from the FLUXNET dataset. In addition to this, evapotranspiration regimes are also reproduced.

SU99 – Latent Heat Flux Influence on Idealized Extratropical Cyclones, Atmospheric Rivers, and the Conveyor Belt Model

Reuben Demirdjian – Naval Research Laboratory

An analysis of the latent heat flux influence on the accumulated precipitation associated with an idealized extratropical cyclone and atmospheric river using the Coupled Ocean-Atmosphere Mesoscale Prediction System is presented. There are two distinct precipitation regions found to be strongly influenced by the latent heat flux, referred to as the primary maximum and the cold-frontal precipitation. A substantial reduction by approximately 30 mm (35%) and 15 mm (75%) is observed in the accumulated precipitation of the two regions respectively when the latent heat flux is switched off everywhere at 96 h – the starting time of most rapid cyclone deepening. The source of this reduction is investigated by systematically controlling the latent heat flux in three cyclone sectors, which are the warm, baroclinic, and high latitude sectors. The precipitation in the primary maximum is most strongly controlled by the baroclinic sector which experiences strong positive latent heat flux due to its cool, dry environmental air. This demonstrates the fundamental role of surface fluxes outside of the warm sector in generating extreme precipitation in extratropical cyclones. In contrast, the precipitation in the cold-frontal zone is most strongly controlled by the warm sector which experiences a moderate amount of positive latent heat flux into the already warm and moist boundary layer air. The results underscore the crucial role of latent heat flux and boundary layer processes in precipitation forecasting thereby demonstrating the need for accurate initial conditions of the air-sea temperature contrast, surface level winds and moisture to properly simulate air-sea interactions.

SU101 – On the Development and Evaluation of Atmospheric Model Physics in Particular the Gravity-Wave Drag Parameterization for the Unified Forecast System Applications

Fanglin Yang – NOAA/NCEP/EMC

NOAA is collaborating with the US weather and climate science community to develop the next generation fully coupled earth system modeling capability for both research and operational forecast applications across different temporal and spatial scales. This presentation will first introduce major changes and updates of atmospheric model physics which are targeted for both the global and regional models for short and medium-range weather forecasts and subseasonal to seasonal predictions. Strategies are developed to first test individual physics parameterizations in atmospheric-only forecast experiments in the aforesaid applications and then to further evaluate and improve the parameterizations in the integrated earth system modeling applications to reduce model systematic biases and improve model prediction skills. Significant efforts are made to unify physics parameterizations for all applications to speed up the transition of research to operation (R2O) and to reduce the cost of operational systems maintenance. The second part of the presentation will focus on the R2O of one particular physics scheme, the gravity wave drag parameterization. A new suite of subgrid-scale orographic drag and nonstationary gravity wave drag parameterizations jointly developed by NOAA OAR and NWS scientists was tested and evaluated for the Unified Forecast System global applications. This presentation will discuss the optimization of the various components of the drag suite and the interplay between them and other physics parameterizations, and the challenge of integrating a new and scientifically sound scheme into operational forecast systems of which key performance metrics used by NWS forecasters must be maintained and improved.

Go to Top

SU102 – Single-Column Modeling of Land-Atmosphere Feedbacks in the Global Forecast System Physics
Evan Kalina – NOAA/Global Systems Laboratory, presented by Man Zhang – CIRES/University of Colorado and NOAA/Global Systems Laboratory
Single-Column Models (SCMs) facilitate hierarchical testing of model physics without the significant computing resources required for high-resolution, three-dimensional regional or global model runs. In this study, we use the Common Community Physics Package (CCPP) SCM to evaluate Planetary Boundary Layer (PBL) processes and land-atmosphere interactions in the operational Global Forecast System version 16 (GFS v16) physics suite. For the evaluation, 16 warm-season cases from the Large-Eddy Simulation (LES) Atmospheric Radiation Measurement Symbiotic Simulation and Observation (LASSO) campaign in Lamont, Oklahoma were selected. The SCM cases were first run with prescribed surface heat fluxes to remove the impact of coupled feedbacks between the land surface and the atmosphere. Composites across the 16 cases demonstrate that the SCM results are, on average, 0.5 °C warmer and 0.5 g/kg drier than the LES runs, and the near-surface layer in the SCM is considerably more unstable. Time-averaged vertical profiles of temperature, specific humidity, and wind speed tendencies from the physics schemes suggest that the PBL scheme contributes to the warmer, drier result through extensive vertical mixing of the PBL. When the Noah Land-Surface Model (LSM) is used in place of prescribed surface heat fluxes, the SCM PBL warms by about another 0.5 °C. This additional warming is caused by deficient shallow cumulus development near the PBL top, which leads to excessive insolation at the surface. The increased insolation also rapidly dries the soil due to large daytime latent heat fluxes from the surface to the atmosphere. These results illuminate the processes that contribute to a known low-level warm, dry bias in the operational GFS v16 over the central United States in the warm season. The opportunity for new physics development to improve upon these biases will also be discussed.

SU104 – The E–ε Planetary Boundary Layer Parameterization Scheme
Chunxi Zhang – IMSG at NOAA/NWS/NCEP/EMC
The turbulence kinetic energy (TKE) and TKE dissipation rate (ε) based 1.5-order closure planetary boundary layer (PBL) parameterization scheme (E–ε, EEPS) was implemented into the Weather Research and Forecast (WRF) model and the Unified Forecast System (UFS). Both TKE and ε are treated as tracers which are advected in the model dynamics. The cloud-top radiative cooling driven turbulence is included for the boundary layer capped by stratocumulus. The EEPS scheme along with other PBL schemes were evaluated over the stratocumulus dominated southeast Pacific (SEP) and over the Southern Great Plains (SGP) where strong PBL diurnal variation is common. The simulations by these PBL parameterizations are compared with various observations from two field campaigns: the Variability of American Monsoon Systems Project (VAMOS) Ocean–Cloud–Atmosphere–Land Study (VOCALS) in 2008 over the SEP and the Land–Atmosphere Feedback Experiment (LAFE) in 2017 over the SGP. Results show that the EEPS and Yonsei University (YSU) schemes perform comparably over both regions, while the Mellor–Yamada–Nakanishi–Niino (MYNN) scheme performs differently in many aspects, especially over the SEP. The differences among the PBL schemes in simulating the PBL features over the SGP are relatively small. More than 25 tropical cyclones (TCs) in the North Atlantic basin were selected to evaluate the EEPS scheme in one of the UFS applications, e.g., the Hurricane Analysis and Forecast System (HAFS). Results show that the EEPS scheme outperformed the baseline TKE-based moist eddy-diffusivity-mass-flux (TKE-EDMF) scheme for weak to moderate TCs in terms of track, intensity, and size forecasts. The EEPS scheme, however, had worse performance for some strong TCs, such as hurricane Dorian and Laura. The EEPS scheme tended to have a degraded relationship between maximum wind speed and minimum sea level pressure for strong TCs compared to observations. Future development of the EEPS scheme will focus on improvement upon those issues.

Go to Top

SU105 – The GEWEX Land-Atmosphere Feedback Observatory (GLAFO)
Volker Wulfmeyer – University of Hohenheim

We present and discuss the GEWEX Land-Atmosphere Feedback Observatory (GLAFO), which is one of the projects of the Global Land-Atmosphere System Studies (GLASS) Panel (see https://www.gewex.org/panels/global-landatmosphere-system-study-panel/glass-projects).

The GLAFO will observe the relevant processes and variables with respect to mass, energy, water, and momentum transport with unprecedented spatial and temporal resolutions, from bedrock to the lower troposphere encompassing the atmospheric boundary layer (ABL). Thus, a GLAFO will be designed that all relevant feedback loops between the subsurface, vegetation, and the atmosphere can be characterized. By observing profiles of the mean, the gradient, and the turbulent fluctuations (if applicable) of all relevant variables, including surface and entrainment fluxes, advection, as well as the evolution of key variables in the other compartments of the critical zone (such as ground-water levels, soil moisture, and vegetation processes), from the diurnal cycle, via seasonal/annual to ideally climatological time scales, unprecedented data sets will be provided for the study of land-atmosphere (L-A) feedbacks.

The GLAFO project has the following scientific goals:

1. Understand the L-A feedback chains over the regimes of temperature, soil, and snow conditions as well as vegetation properties and ABL evolutions in the context of large-scale forcings
2. Study and quantify the effects of land use and land cover changeLUCC on regional weather and climate
3. Contribute to advanced simulations and predictions of extreme events
4. Provide the basic knowledge and methodologies for evaluating future bio-geoengineering efforts
5. Climate monitoring
6. Verification of current operational and future advanced weather, climate, and Earth system models down to the turbulent scales
7. Data assimilation impact studies towards operational assimilation of GLAFO data

The measurements will be realized through the synergistic use of in-situ instruments and ground-based scanning active remote sensing systems. This approach was pioneered during the Land Atmosphere Feedback Experiment (LAFE) performed at the ARM Southern Great Plains (SGP) site of the US Atmospheric Radiation Measurement (ARM) project in August 2017 (Wulfmeyer et al. BAMS 2018, DOI:10.1175/BAMS-D-17-0009.1). We present the GLAFO hierarchical design considering of different levels of complexity as well as the potential of the current observatories and observational networks to be extended to GLAFO sites towards a global GLAFO network.

The scientific potential will be substantiated by measurements of the Land-Atmosphere Feedback Observatory (LAFO) of the University of Hohenheim (see https://lafo.uni-hohenheim.de/en), which can be considered as a prototype for the GLAFOs. Simultaneous profiles of latent and sensible heat fluxes, turbulent kinetic energy, momentum, variances as well as gradients and means of wind, temperature, and moisture will be presented in combination with surface fluxes and vegetation and soil measurements. It will be demonstrated that this data set can be applied for tests and developments of turbulence parameterizations as well as the derivation of advanced feedback metrics.

Consequently, the GLAFO concept complements the measurements of existing observatories and addresses the need to improve and to verify the next generation of numerical weather prediction, air pollution, and climate models operating from the convection to the turbulence permitting scales, as well as the need to observe and understand climate change and the impact of extreme events in all climate zones.

Go to Top