Coordinating Boundary Layer and Land-Atmosphere Research within NOAA

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With Contributions from the other NOAA Colleagues

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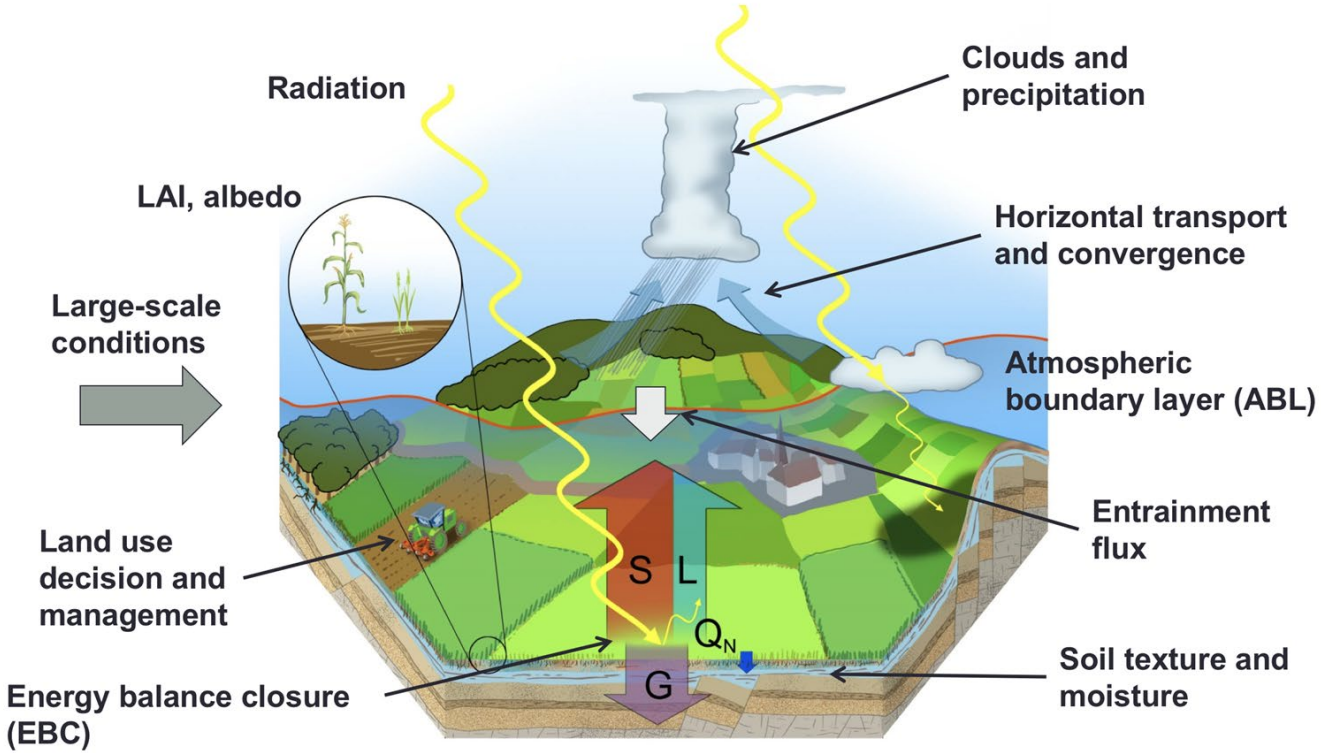
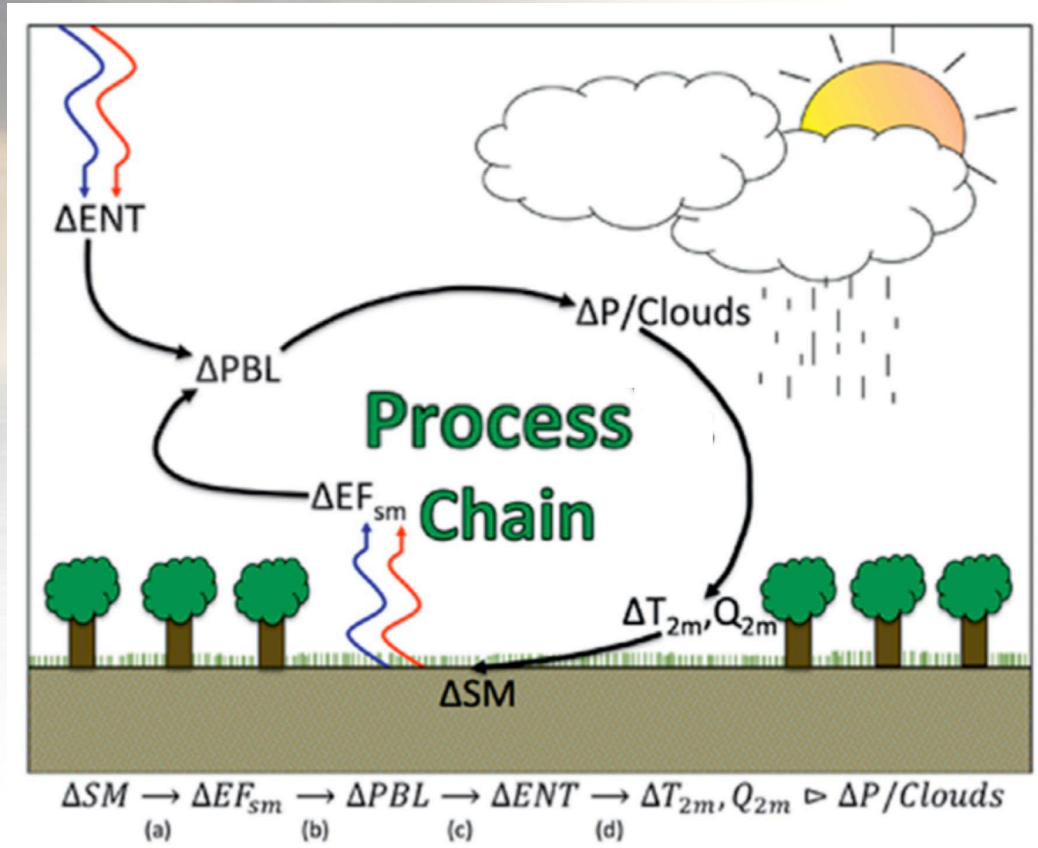
The Complexity of the Boundary-Layer System



Water and energy budgets are results of feedback processes in the LA system

Wulfmeyer et al BAMS 2018

A Simplified Land-Atmosphere Process Chain



Santanello et al BAMS 2017

Land-Atmosphere Feedback Has 2 Legs

$$\Delta P \Rightarrow \Delta SM \rightarrow \Delta Fluxes \rightarrow \Delta PBL \rightarrow \Delta P$$

Feedback loop: **Terrestrial leg** **Atmospheric leg**

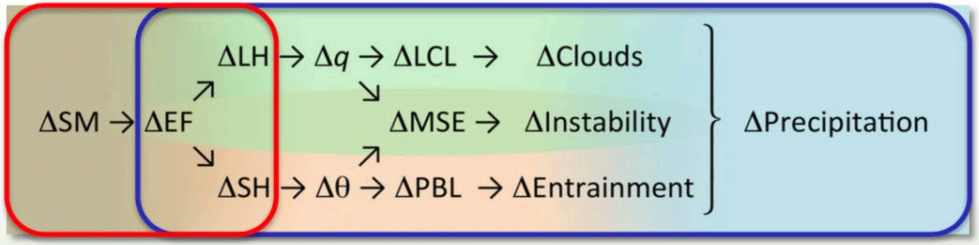
- Terrestrial – When/where/how does soil moisture (vegetation, snow, etc.) control the partitioning of net radiation into sensible and latent heat fluxes?

In many models, the coupling in the terrestrial leg is **too strong**

- Atmosphere – When/where do surface fluxes significantly affect boundary layer properties, clouds and precipitation?

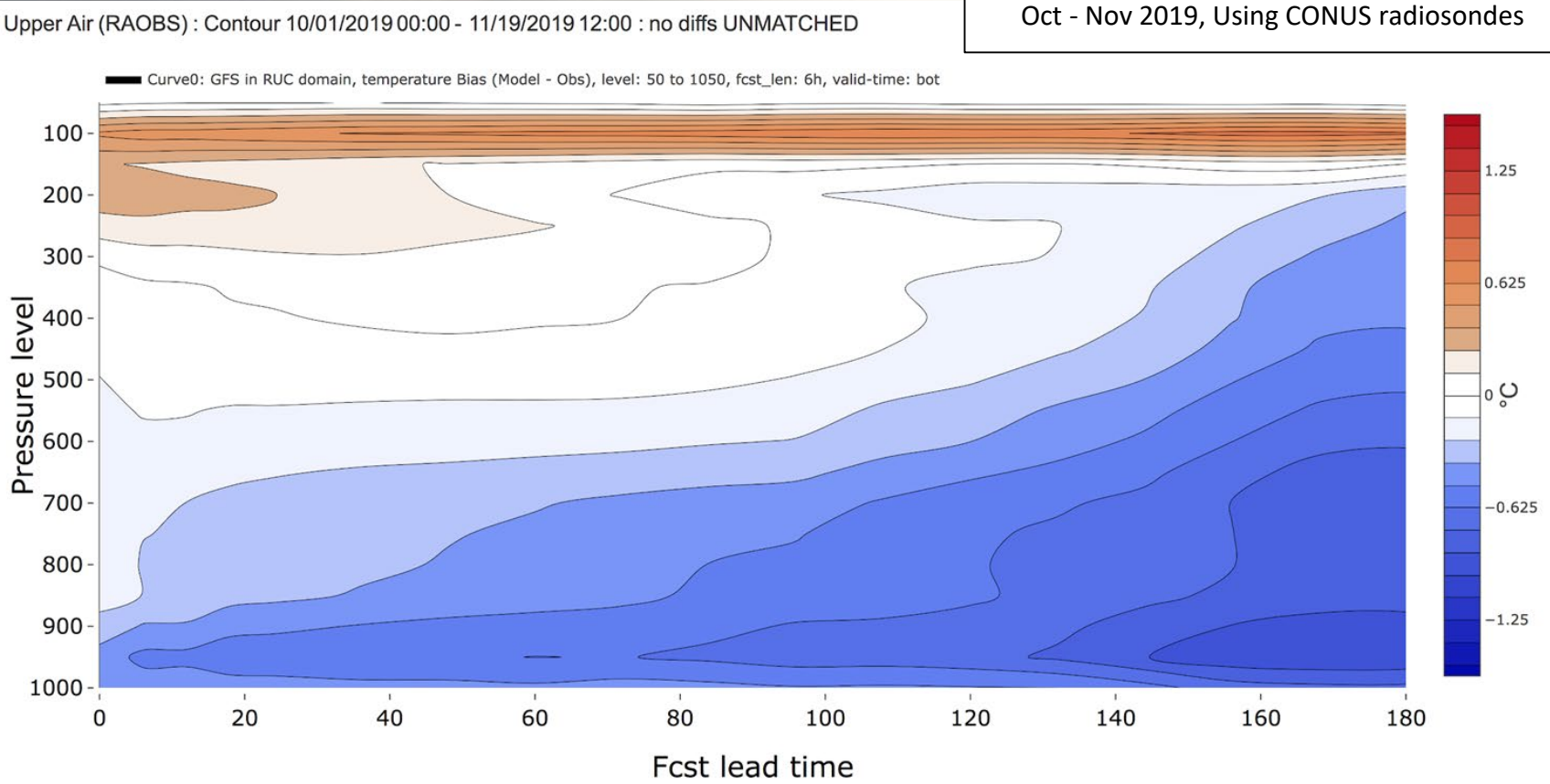
And the atmospheric leg is **too weak**

Process chains:



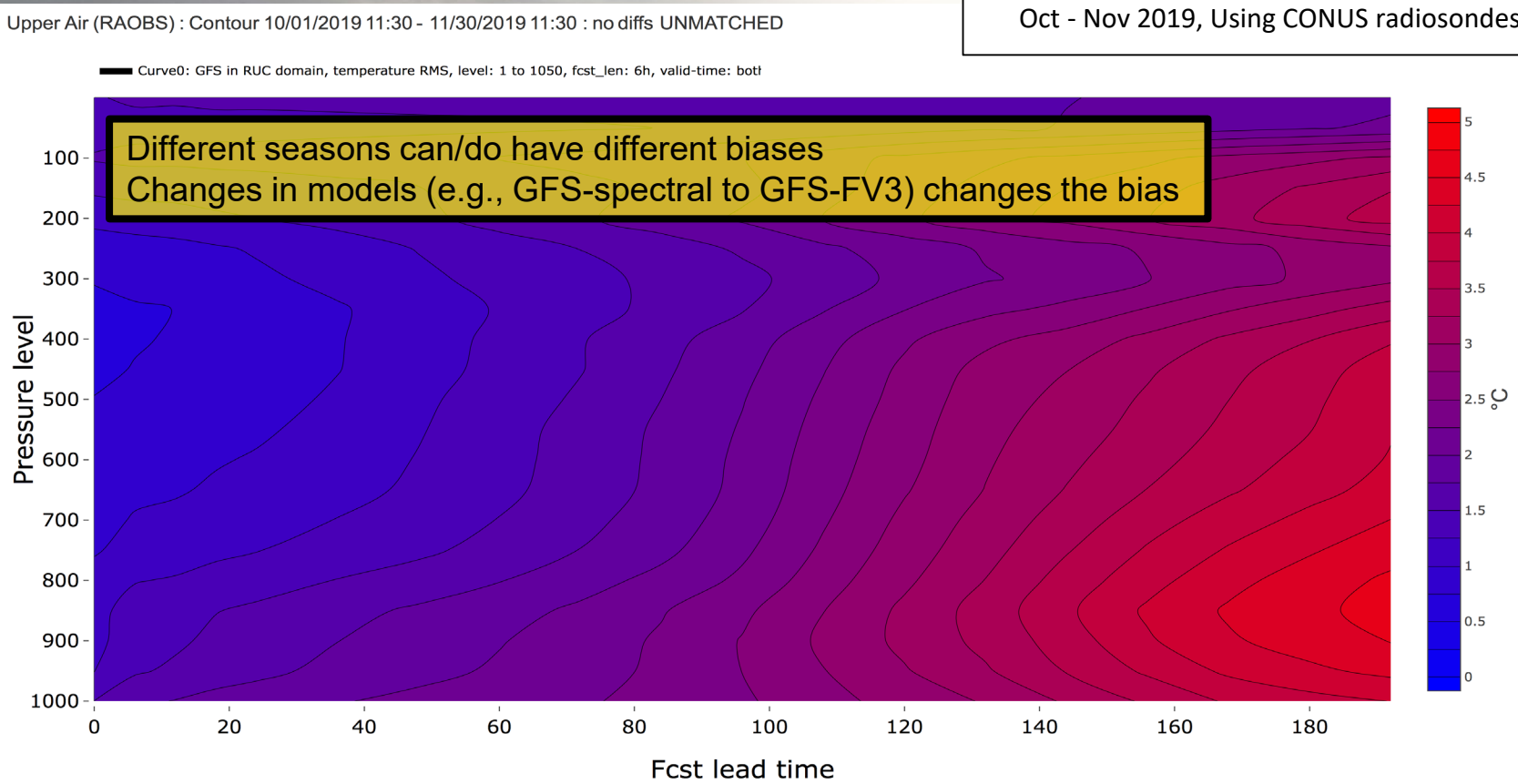
GFS Temperature Bias (out to 180 h)

Oct - Nov 2019, Using CONUS radiosondes



GFS Temperature RMS (out to 180 h)

Oct - Nov 2019, Using CONUS radiosondes



OAR Labs are Individually Addressing Portions of the PBL and Land-Atmosphere Problems

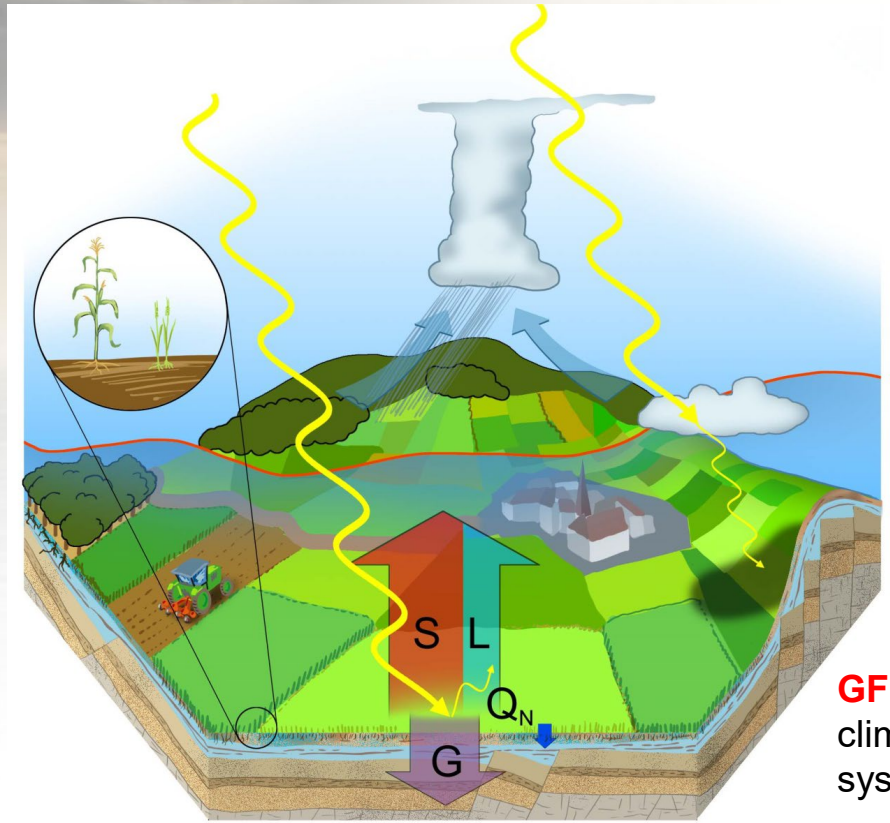
- ARL: relating surface heat fluxes to soil profiles (esp moisture), effects of surface inhomogeneities, impacts on dispersion and air quality (AQ)
- GML: shortwave and longwave radiative fluxes (upwelling and downwelling), interactions among radiation-aerosols-clouds, carbon cycle and AQ impacts
- CSL: turbulence and winds in the PBL, air chemistry and AQ, processes related to sources / dispersion / sinks
- PSL: turbulence, stability, and humidity in the PBL, clouds and precip, coupled DA, NWM
- GLERL: interaction btwn atmos, terrestrial hydrology, and lake processes
- GSL: improving LSM/surface layer/PBL schemes in operational HRRR (e.g., drag, mixing, subgrid-scale clouds), S2S modeling
- GFDL: seasonal to climate modeling, diurnal cycle, N and C cycles, representation of subgrid-scale inhomogeneities in the LSM and impacts on PBL
- NSSL: convective initiation, PBL impact on storms and vice versa, precipitation

OAR's Modeling Capability

GSL: operational mesoscale and storm-scale modeling, S2S modeling

PSL: Mesoscale and S2S modeling

ARL: Large-eddy simulation modeling and dispersion modeling



NSSL: Regional modeling (primarily towards severe Wx)

CSL: Large-eddy simulation, SCM, and regional modeling

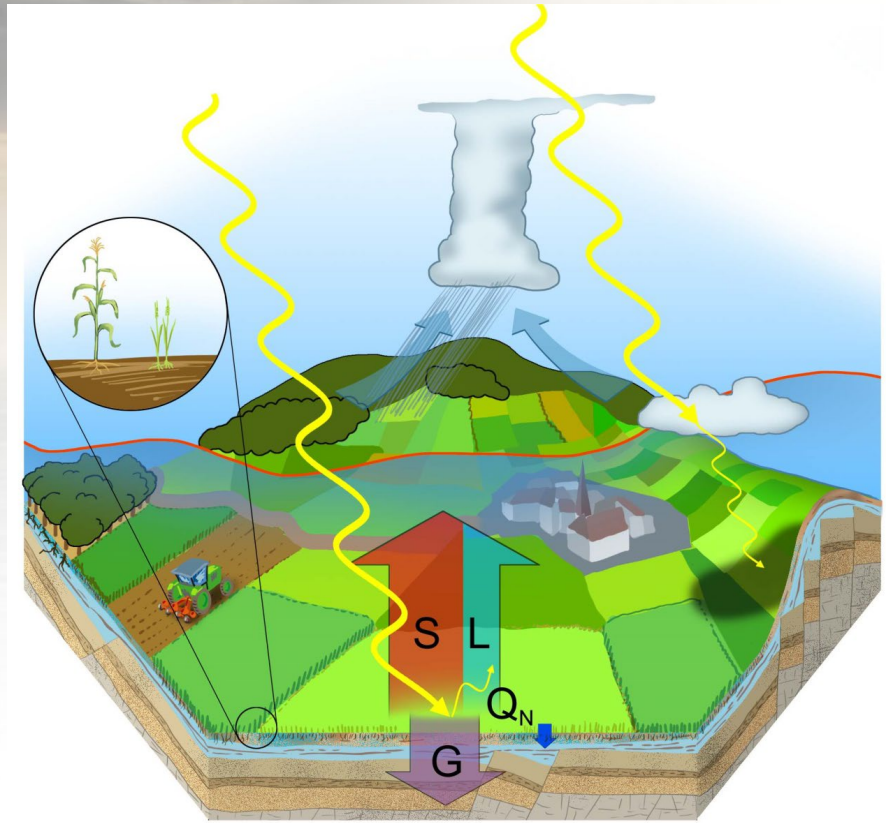
GML: Regional modeling (primarily towards carbon cycle)

GFDL: Seasonal and climate modeling (earth system modeling)

OAR's Observational Resources

PSL measures winds (10 radar wind profilers), temperature and humidity profiles (2 MWRs), surface met (20 stations), cloud properties (cloud radar), and precip (6 disdrometers)

ARL measures surface latent, sensible and ground fluxes (6 SEB stations) and periodic UAS flights to look at representativeness



NSSL measures profiles of temperature and humidity (2 CLAMPS), and precipitation (NOXP, disdrometers)

CSL measures wind and turbulence profiles with 5 Doppler lidars

GML measures radiative fluxes and cloud properties with SURFRAD and RADSYS systems

The Problem: L-A Research is Not Coordinated

- There is a strong need: improved forecasts (esp at all timescales) require better treatment of PBL and L-A interactions (this is an O2R driver)
- Each lab works (largely) independently to address its mission
- Instruments needed to study PBL and L-A interactions are dispersed among different OAR labs
- A cohesive science plan that integrates the activities of the different labs does not exist
- Organize some workshops with these objectives:
  - Identify a set of Qs and an obs + modeling plan that addresses PBL and L-A deficiencies
  - Prioritize locations where these datasets and modeling studies should occur
  - Commit: Deploy observations and modeling capability
- Side effect: these datasets will help each lab with its own mission
  - If you build it, they will come --- other Qs can be addressed outside the PBL and L-A focus

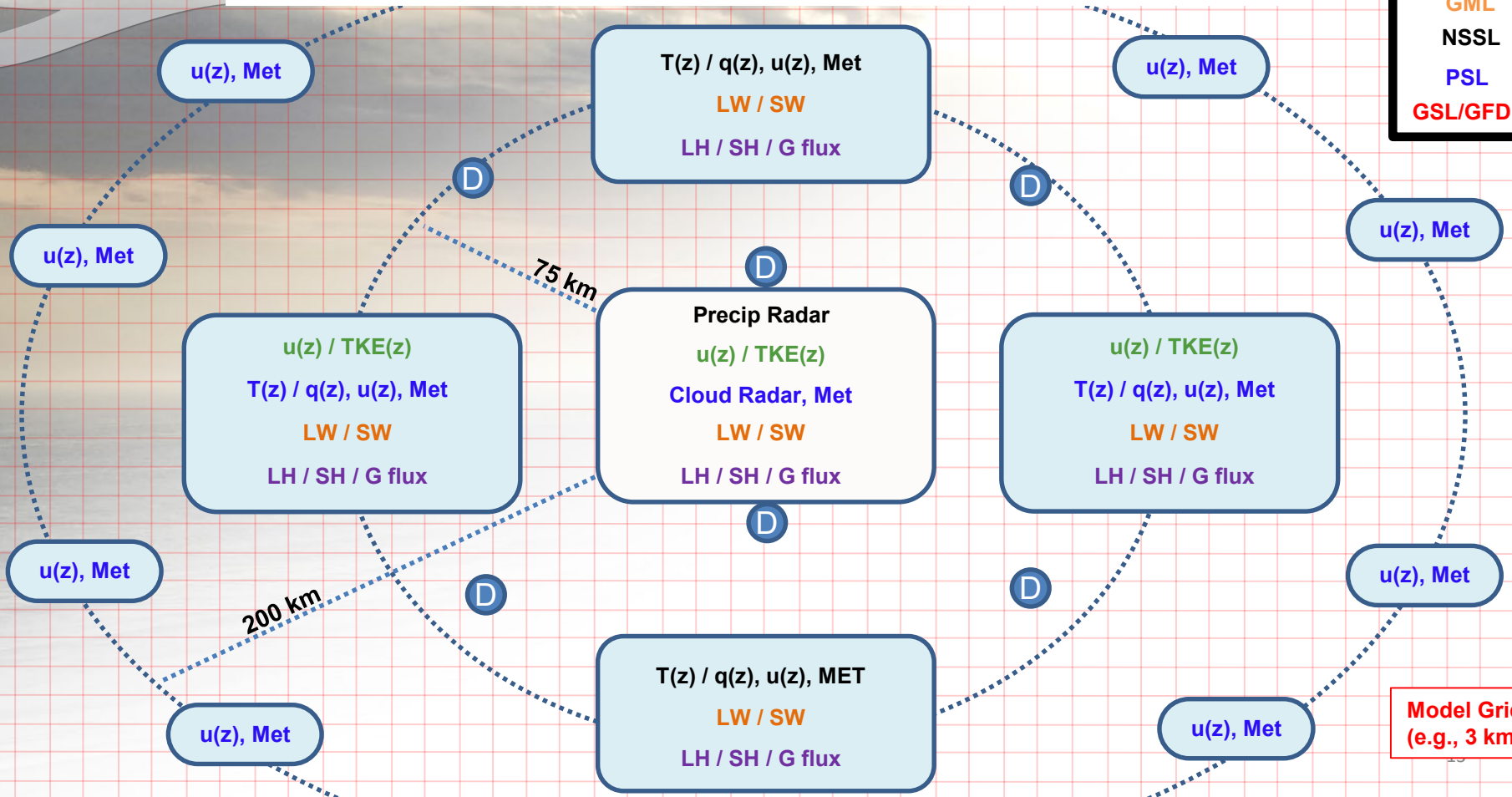
NOAA Bedrock-to-Boundary Layer Workshop

- First 2-day workshop at ESRL in April 2019
  - Reps from 8 of the 10 OAR labs, PMs from OAR HQ, and reps from NESDIS and EMC
  - Every lab was asked to describe their top ~3 scientific questions
  - Questions were discovered to organize around 4 different topical areas:
    - Surface inhomogeneities (5)
    - PBL evolution (6)
    - Entrainment and mixing (6)
    - Surface and subsurface processes (5)
- Planning to have 2nd workshop to continue the discussion (spring 2020)

Now fall 2020 due to COVID-19

  - Will focus on a subset of multi-lab overarching questions
  - Develop an implementation plan for integrated modeling/observation project
  - Identify if new instruments are needed and prioritize the acquisition (e.g., water vapor profilers)
  - Work with OAR HQ to move this effort forward
  - Integrate expertise from other agencies and universities
  - Scrubbed due to COVID-19 restrictions; online workshop in fall being considered

A Strawman Deployment Scheme

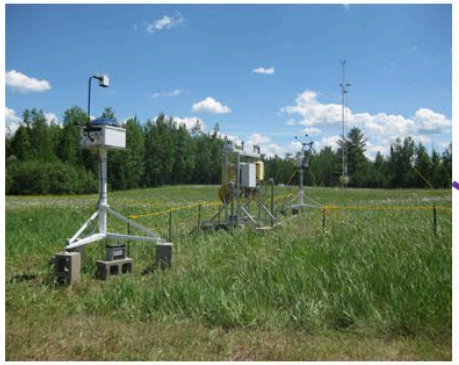


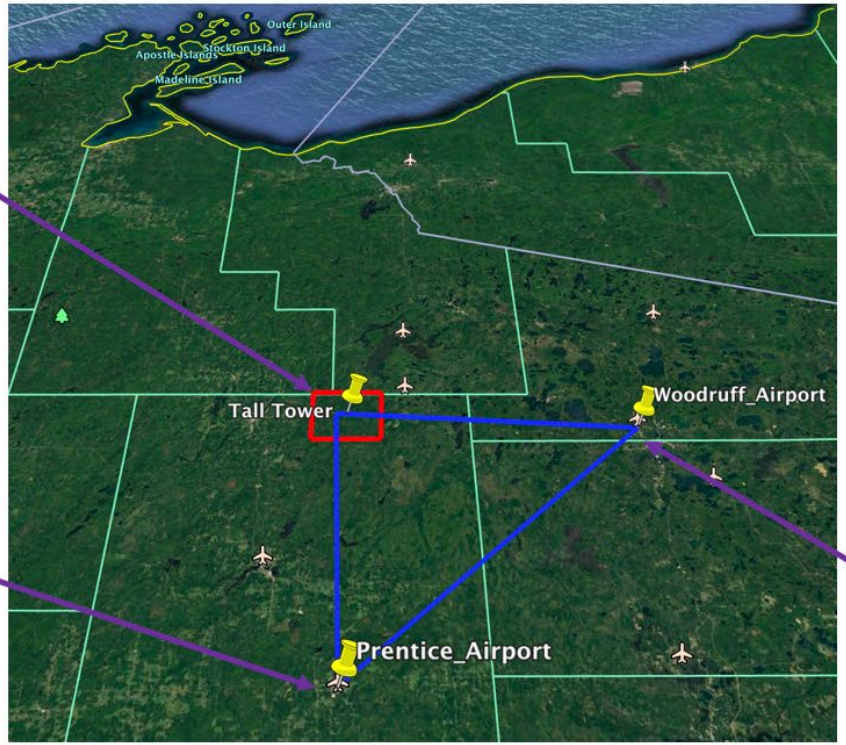
"CHEESEHEAD"

- OAR provided funding (FY19, FY20) for small multi-lab effort
- Decided to augment NSF-sponsored land-atmosphere study studying surface energy balance and atmospheric response over a heterogeneous northern forest region
  - More information from Ankur Desai shortly
- CHEESEHEAD is a multi-university, multi-national field campaign in northern WI from July to October 2019
- NOAA B2B effort augmented CHEESEHEAD by providing:
  - Thermodynamic and wind profiling obs to look at water vapor advection
  - Improved characterization of cloud-radiation interactions and radiative fluxes
  - Detailed UAS profiles and flight patterns to improve mapping of atmospheric heterogeneity
- 5 OAR labs participating: GSL, ARL, PSL, GML, and NSSL
- FY19 funding supported the collection of the data; FY20 support has enabled the analysis

Cloud – Radiation – Boundary layer forcing at CHEESEHEAD

This study evaluates the influence of surface heterogeneity on surface fluxes, boundary layer development, and cloud formation and their feedbacks to address inadequacies in land-atmosphere (LA) interactions within NOAA weather prediction systems.

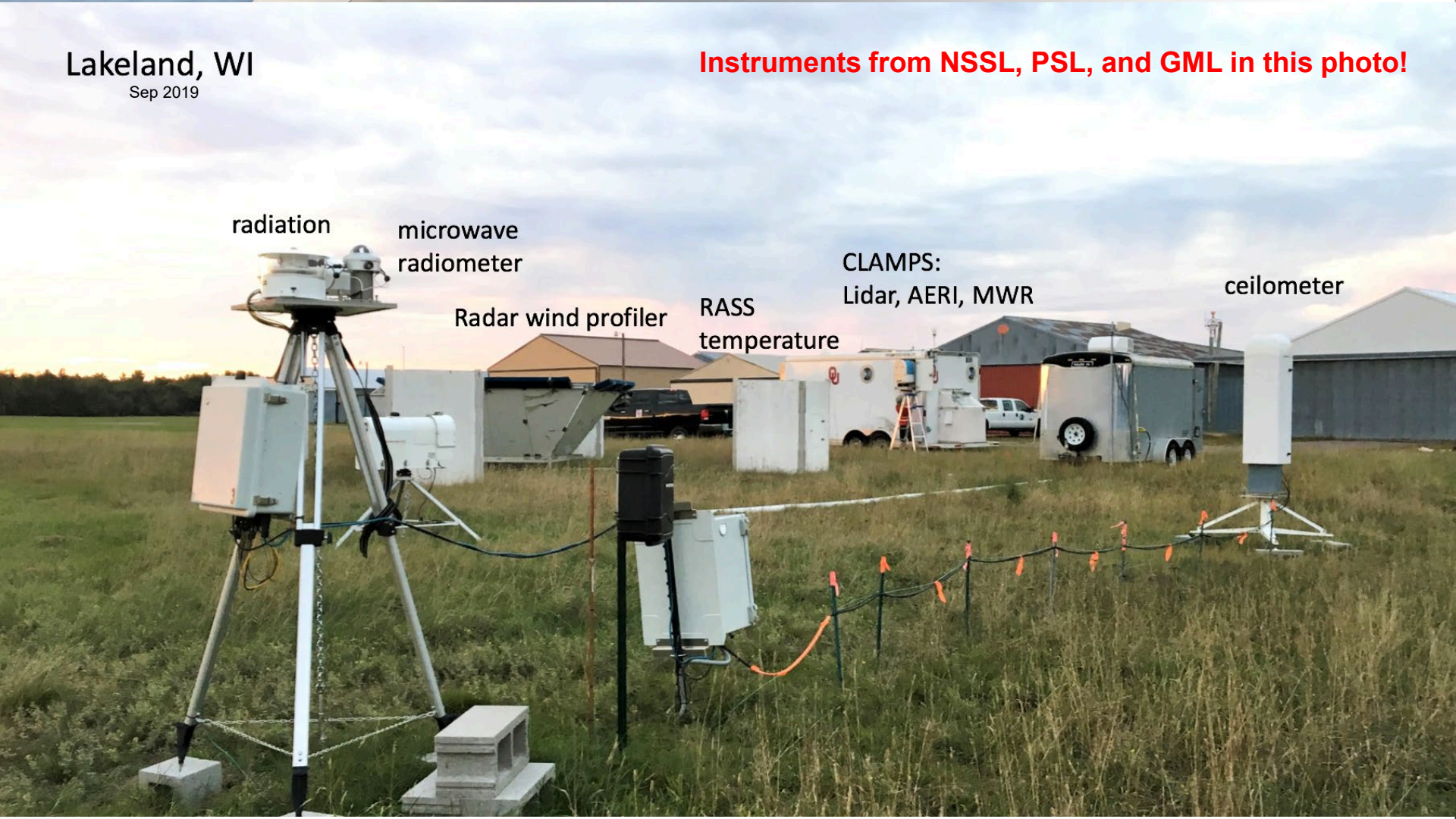




Tall tower site within a 10-km main CHEESEHEAD study area. Two sites located away from the main CHEESEHEAD site at the tall tower were desired to help characterize the larger scale spatial inhomogeneities.

Lakeland, WI
Sep 2019

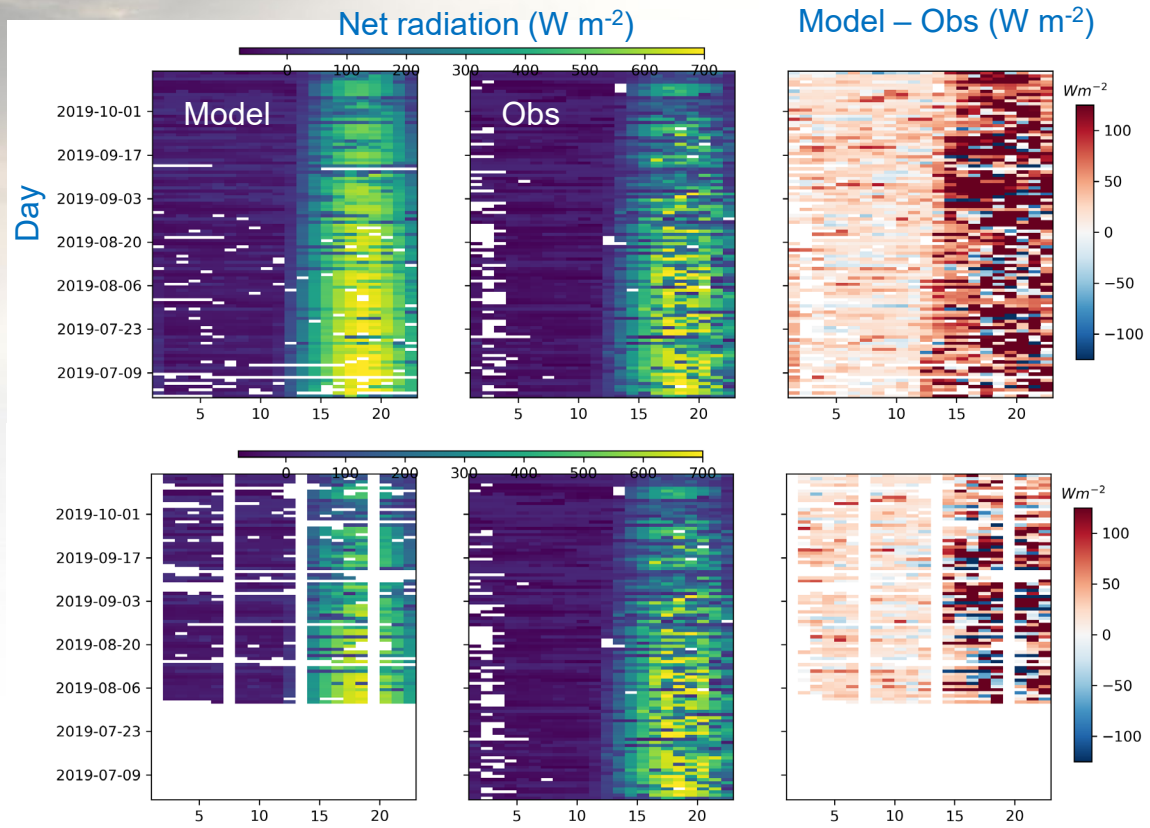
Instruments from NSSL, PSL, and GML in this photo!



Hovmöller-type evolution of net surface radiation (SWD-SWU+LWD-LWU) and turbulent heat fluxes (LHF, SHF)

HRRRv3 (operational), 6-hr lead forecast

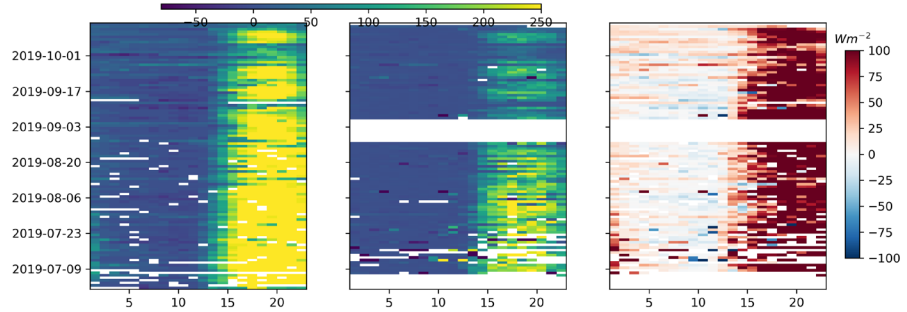
HRRRv4 (experimental), 6-hr lead forecast



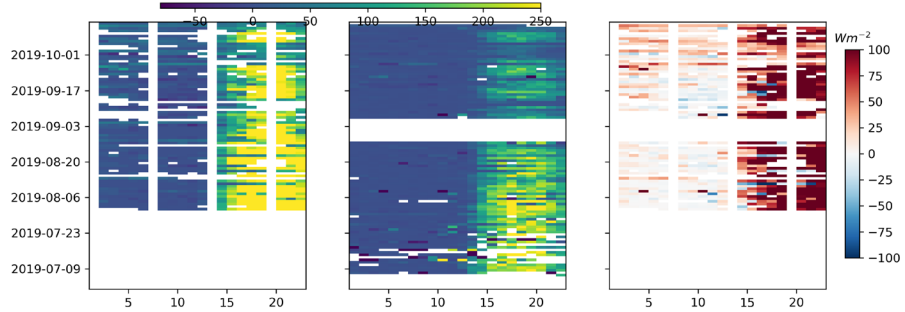
Courtesy Joe Sedlar (GML)

Hovmöller-type evolution of net surface radiation (SWD-SWU+LWD-LWU) and turbulent heat fluxes (LHF, SHF)

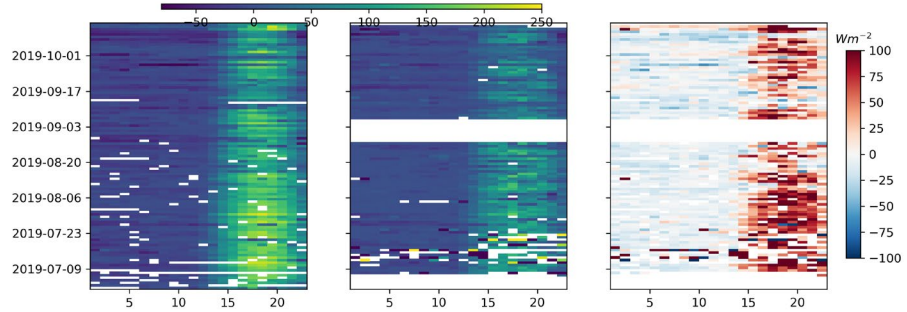
LHF - HRRRv3 (operational), 6-hr lead forecast



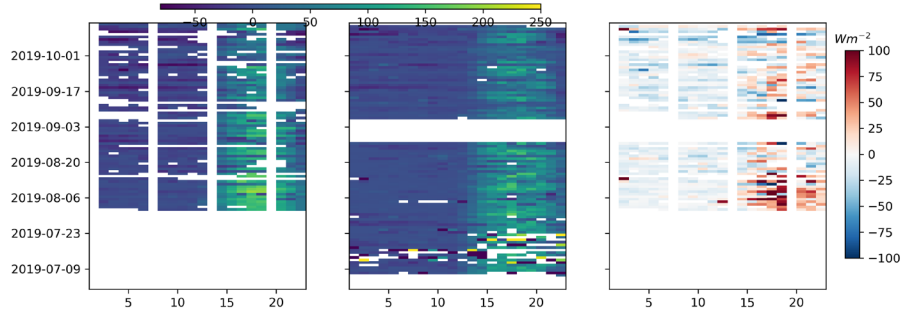
LHF - HRRRv4 (experimental), 6-hr lead forecast



SHF - HRRRv3 (operational), 6-hr lead forecast



SHF - HRRRv4 (experimental), 6-hr lead forecast



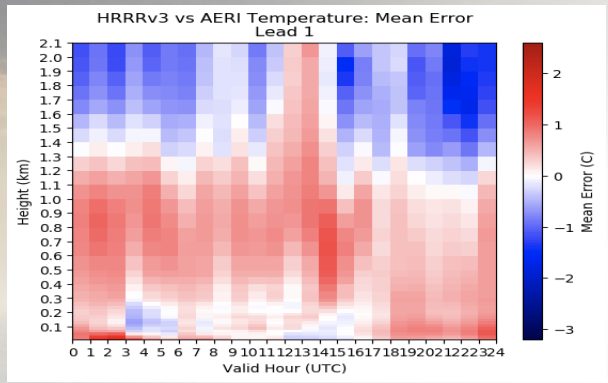
Courtesy Joe Sedlar (GML)

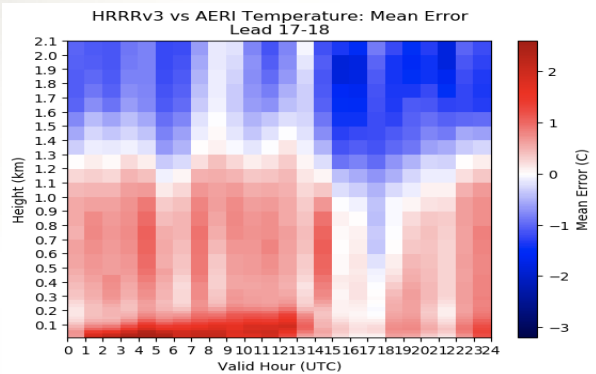
Evaluating the HRRR's Temperature Evolution

Forecast Hour:1

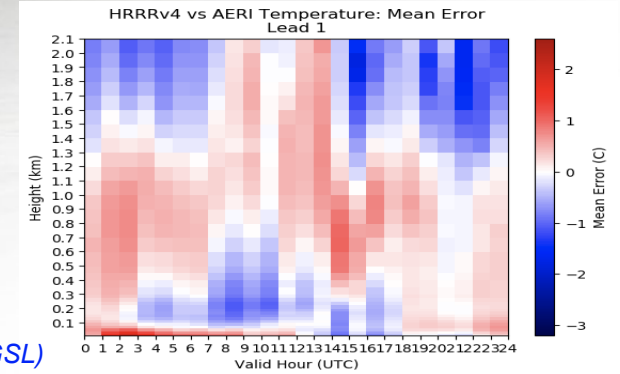
Forecast Hour:17-18

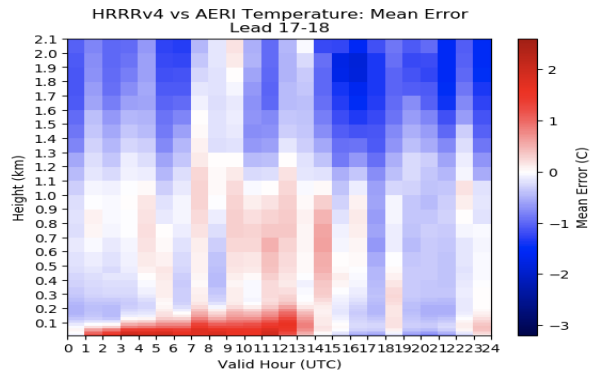
V3
(Currently operational)





V4
(Will be operational this summer)





Courtesy Dana Mueller (GSL)

Unified Forecast System

- NOAA is moving toward using the same forecasting system (i.e., dynamics core, physics, DA system) for weather forecasting at all scales
- Chose FV3 dynamic core; already operational in the global forecast model
- Work underway to incorporate FV3 into storm-scale regional model
- Desire unified physics schemes that work on all scales
- New working groups recently organized to work on merging efforts from different parametrization groups to create unified (a) convective and (b) PBL schemes
- B2B effort could contribute strongly to the development / evaluation of the unified PBL scheme

UFS
UNIFIED FORECAST SYSTEM

B2B Effort has Many Applications

- Improved physical understanding of the interacting processes
- Improved short term Wx, S2S, and climate prediction by improving physics
- Improved model initialization (short term forecasts)
  - Development of coupled DA systems
- Improved hydrologic prediction
- Air and water quality prediction
- NESDIS product validation
- Downstream impacts of these products on other NOAA line offices and other agencies
- Potential impact of new observation types by operational forecasters