Lead: Mike Ek (NWS/EMC)

1.0 Land Surface Model

1.1 State of the Science

The Land-Hydrology Team at NCEP/EMC is responsible for all aspects of land-hydrology in the NCEP operational regional and global weather and seasonal climate models. The state-of-the-art Noah land model accounts for the evolution of land states (surface/soil temperature, soil moisture, soil ice, canopy water and snowpack) and, with a surface-layer turbulence scheme, then calculates the exchange of heat, moisture, and momentum with the atmosphere, the bottom boundary condition for the atmospheric model (i.e. GFS). The Noah land model is in the NAM (short-range) and GFS (medium-range) NWP models at NCEP, where Noah depends on land data sets, some rather static such as vegetation and soil types, and others more dynamic such as surface albedo and plant phenology ("green vegetation fraction"), with land states updated via the proper representation of physical processes in the land. Assimilation of land states, specifically snow and soil moisture for the project here, will help to improve model performance via better initial land conditions.

1.2 Objectives

1.3 Milestones and Outcomes for Near-Term Objectives

The primary objective of the NGGPS project is to improve the representation of initial land states via the proper assimilation of land states such as snow and soil moisture into the Noah land model, a component in the GFS. Combined with a good physical model of the land-surface (i.e. Noah), this will then yield better fluxes (an improved boundary condition) for the atmospheric model (i.e. GFS).

- Satellite-based Land Data Assimilation in the NCEP Operational Global System
  - **Lead organization:** NCEP Environmental Modeling Center (EMC), Land-Hydrology Team (LHT)
  - **Activities:** Enable the existing NASA Land Information System (LIS) to serve as a Global Land Data Assimilation System (GLDAS) for GFS, with actual assimilation of snow and soil moisture states into GLDAS, thereby providing improved land initial conditions for GFS, with sufficient validation efforts to identify systematic biases to be addressed with further investigation and subsequent system improvements.
  - **Milestones and deliverables:** Assimilation of snow and soil moisture data into GLDAS
    - LIS upgrades for transition to NWS operational system
      - Gaussian grid implementation in LIS
      - Interface implementation between LIS/Noah and GFS
      - Implementation of model spin-up procedures and downscaling technique.
    - Land DA Tests for Transition to NWS Operational Systems
      - Assimilation tests of IMS SCA and AFWA SNODEP
      - Assimilation tests of SMOPS soil moisture products
      - Improved snow assimilation modules for Noah
      - Verification and validation of EnKF ensemble spread
    - III. Land DA Initialization Tests and Evaluation
      - Testing of improved Noah bundle upgrades within LIS

        - Testing of snow and soil moisture DA in coupled LIS and GFS
        - Evaluation against the operational system (control)
    - **Anticipated collaborating organizations:** NASA/GSFC Hydrology Sciences Branch, NWS Office of Hydrology (and National Water Center), National Center for Atmospheric Research/Research Applications Laboratory, NOAA/ESRL, and other agency and academic partners with collaboration via various national and international programs, such as GEWEX/GLASS land model development and benchmarking and land-atmosphere interaction projects.
    - **Priority (Low, medium, high):** High –improved land states/boundary conditions for GFS.
    - **Duration:** 2 years.
    - **Points of contact:** Primary: Michael Ek (NCEP/EMC LHT Lead) and Christa Peters-Lidard (NASA GSFC Hydrology Sciences Branch LIS Lead).

- Land data assimilation
    - **Lead organization:** NCEP Environmental Modeling Center (EMC), Land-Hydrology Team (LHT)
    - **Activities:** Ingest of land data sets (e.g remotely-sensed) for use in the Noah land model, NASA/LIS-based land data assimilation (soil moisture, snow, vegetation), improved land model physics, i.e. "Noah-MP" with dynamic vegetation, explicit canopy and carbon-based canopy conductance, multi-layer snowpack, with connections to hydrology models (ground water and river-routing to provide streamflow to the ocean). Account for freshwater lakes (i.e. use of the community "FLake" model).
    - **Milestones and deliverables:** Improved land data sets (new remote-sensing platforms), updates to GLDAS/LIS/Noah as required, improved land model physics and addition of new components (e.g."FLake"), with sufficient validation efforts to identify systematic biases to be addressed with further investigation and subsequent system improvements.
    - **Anticipated collaborating organizations:** NASA/GSFC Hydrology Sciences Branch, NWS Office of Hydrology (and National Water Center), National Center for Atmospheric Research/Research Applications Laboratory, NOAA/ESRL, and other agency and academic partners with collaboration via various national and international programs.
    - **Priority (Low, medium, high):** High –improved land states/boundary conditions for GFS.
    - **Duration:** 1.5-5 years.
    - **Points of contact:** Primary: Michael Ek (NCEP/EMC LHT Lead).

- Enhancing NCEP GFS Forecasts via Assimilating Satellite Soil Moisture and Snow Observations
    - **Lead Organization**: PI: Christopher Hain, University of Maryland, ESSIC/CICS, Co-I's Xiwu Zhan, NESDIS-STAR, NOAA, Michael Ek, NCEP-EMC, NOAA, Jicheng Liu, ESSIC, CICS, University of Maryland, Weizhong Zheng, I.M. Systems Group, NOAA, NCEP-EMC, Jiarui Dong, I.M. Systems Group, NOAA, NCEP-EMC, Li Fang, ESSIC, CICS, University of Maryland,
    - **Activities**: Develop a functional data assimilation system where LIS will be semi-coupled with the GFS at NCEP EMC
        - Prepare all relevant MW-based soil moisture and snow datasets for assimilation

        - Develop and test a semi-coupled system of GFS and the NASA Land Information System
        - Assimilate the MW-based soil moisture retrievals and snow product into the GFS using an ensemble Kalman filter initially over two seasonal study period
        - Perform extensive validation of all assimilation simulations against open-loop GFS simulations (no assimilation)
        - Document the new assimilation scheme and prepare a path for transition into operations at NCEP-EMC.
    - **Milestones and deliverables**:

      Year 1 Activities include:
        - Prepare all relevant data sets (SMAP/AMSR2/ASCAT for soil moisture and MODIS/VIIRS for snow) for assimilation
        - Prepare near-real-time (NRT) Green Vegetation Fraction (GVF) and deliver GFS results using NRT GVF
        - Collect all necessary observational data and in-situ SM observations from CRN and SCAN networks for validation task
        - Bias-correct SM retrievals prior to assimilation and deliver bias-corrected SM data set
        - Assess impact of the NRT GVF on GFS forecasts against current GFS operations and report the NRT GVF data impact assessment results
        - Development of a semi-coupled GFS/LIS System for assimilating remotely-sensed SM and snow products
        - Documents and reports of the findings

      Year 2 Activities include:
        - Test assimilation of remotely- sensed SM and snow products in semi-coupled GFS/LIS system and deliver data assimilation results for analyses
        - Evaluate the effectiveness and efficiency of the SM and snow assimilation approach and report data assimilation evaluation statistics
        - Collect feedbacks from NCEP GFS operations for implementation of the semi-coupled GFS/LIS system
        - Refine the semi-coupled GFS/LIS data assimilation utility for potential assimilation of remotely-sensed SM and snow products
        - Demonstrate the semi-coupled GFS/LIS system for parallel real time operational assimilation of remotely-sensed SM and snow products
        - Documents and reports of the findings of the whole project
    - **Anticipated collaborating organizations**: Jesse Meng, I.M. Systems Group, NOAA, NCEP-EMC
    - **Priority**: High
    - **Duration**: 05/01/2015 - 04/30/2017
    - **Points of contact**: Dr. Christopher Hain, chris.hain@noaa.gov

- Incorporation of near-real-time Suomi NPP Green Vegetation Fraction and Land Surface Temperature data into the NCEP Land modeling suite
    - **Lead organization:** Dr. Ivan Csiszar, NESDIS STAR, CO-PIs: Dr. Yunyue Yu, NESDIS STAR, Dr. Marco Vargas, NESDID STAR, Dr. Michael Ek, NCPEB EMC
    - **Activities:** Two main areas of focus

    - **(1)** The objective of assimilation and impact analysis of Green Vegetation Fraction (GVF) is to demonstrate that using the new near real-time VIIRS GVF instead of the operationally used AVHRR GVF climatology in NCEP NWP models will improve the performance of NOAA's operational environmental prediction suite. GVF non-dynamic climatologies present limitations such as that the annual cycle of vegetation is always represented in the same manner in models from year to year.
    - Task 1: Establishing a climatology baseline for weekly VIIRS GVF data
    - Task 2: Assessment of the impacts of weekly GVF on land surface and weather prediction models
    - **(2)** Promoting VIIRS Land Surface Temperature (LST) to produce a global gridded VIIRS LST dataset for NCEP forecast models (NAM, GFS, and NLDAS) at 0.036° and hourly resolution; and to evaluate the LSTs simulated from NAM, GFS, and NLDAS models using the gridded VIIRS LST products.
    - Task 1: Produce Global Gridded VIIRS LST data at 0.036° and hourly resolution for NCEP NAM, GFS, and NLDAS.
    - Task 2: Apply gridded VIIRS LST data to evaluate the model performance of NAM, GFS, and NLDAS.
- **Milestones and deliverables:**
    - Green Vegetation Fraction (GVF) Year 1: Task 1
        - May 2015 − April, 2016: acquire VIIRS GVF data product from CLASS or NDE PE-1 distribution zone
        - May 2015 − April, 2016: acquire AVHRR derived GVF data product from CLASS
        - August 2015 − September, 2015: develop software application to ingest GVF datasets (AVHRR and VIIRS), perform statistical analyses and implement data display tools.
        - October 2015 − March, 2016: perform statistical analysis to establish the relationship between GVF datasets (AVHRR and VIIRS) and the 5 year AVHRR derived monthly climatology currently used in NCEP models.
        - March 2016 − April, 2016: summarize results.
        - Year 2: Task2
        - May 2016 − June, 2016: select extreme weather events occurred during years 2014 and 2015 to use as case studies in the NWP simulations
        - July 2016 − Sept, 2016: incorporate the new VIIRS GVF data set into coupled model runs
        - Oct 2016 − February, 2017: demonstrate the impacts and utility of the high resolution, daily rolling weekly VIIRS GVF data set by comparing the surface energy budget using the VIIRS GVF to that using the current AVHRR derived GVF monthly climatology.
        - Oct 2016 − February, 2017: quantify the reduction of errors in temperature, humidity, wind speed forecasts, and the level of improvement in precipitation scores
        - March 2017 − April, 2017: summarize results.
    - Land Surface Temperature (LST) Year 1: Task 1
        - May − November, 2015: develop the methodology and software package to retrieve and match up LST from all four datasets, and then composite

all VIIRS granules on each day. Generate 24 hourly global gridded VIIRS LST files on each day in grib2 format at resolution of 0.036°.

- December, 2015 − May, 2016: on the weekly basis, download all VIIRS granule data including all VIIRS granule-level temperature and geo-location data, and run the software package to produce the continuous global gridded VIIRS LST data at 0.036° and hourly resolution.
- By the end of May 2016, generate the hourly global gridded VIIRS LST product at resolution of 0.036°.
- Year 2: Task2
- June − August, 2016: evaluate LST from NCEP NAM
- September − November, 2016: evaluate LST from NCEP GFS
- December, 2016 − February, 2017: evaluate LST from NLDAS
- March − April, 2017: summarize results.
- By the end of April 2017, the gridded VIIRS LST product can be utilized to assess the LST

- **Anticipated collaborating organizations:** Dr. Yihua Wu, IMSG and Dr. Weizhong Zhen, IMSG
- **Priority (Low, medium, high):** high
- **Duration:** 05/01/2015- 04/30/2017
- **Points of contact:** Dr. Ivan Csiszar, ivan.sciszar@noaa.gov

1.4 Milestones and Outcomes for Long-Term Objectives

A unified land data assimilation system (GLDAS/LIS/Noah) and land model ("Noah-MP") for all global systems operating under the NOAA Environmental Modeling System (NEMS), with hydrology components (groundwater and river-routing) allowing for connections to ocean models, as well as terrestrial and marine ecosystem models. Land and hydrology models may operate on grids that differ from each other, with the hydrology model at a typically finer resolution (order 1 km or less) than the land model (order 1-4 km) to accommodate better streamflow modeling, where both land and hydrology models underlie a coarser atmospheric model grid.