IPWG Land Surface Focus Group

Primary aim: act as a forum for individual research questions that are meant to facilitate the transition from research to operations

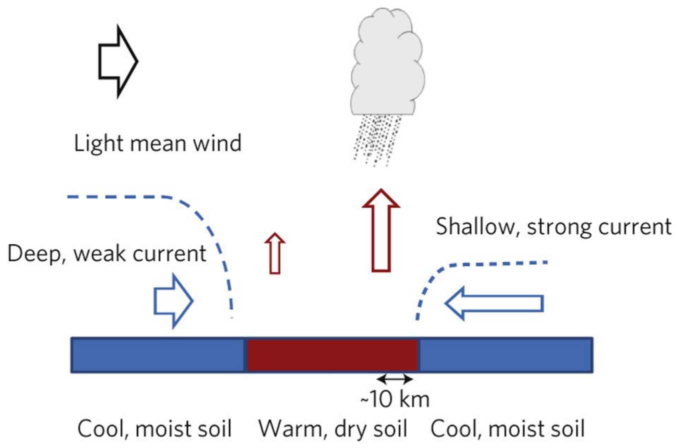
Co-chairs: Sarah Ringerud (GSFC) and Joe Turk (JPL)

Who are we?

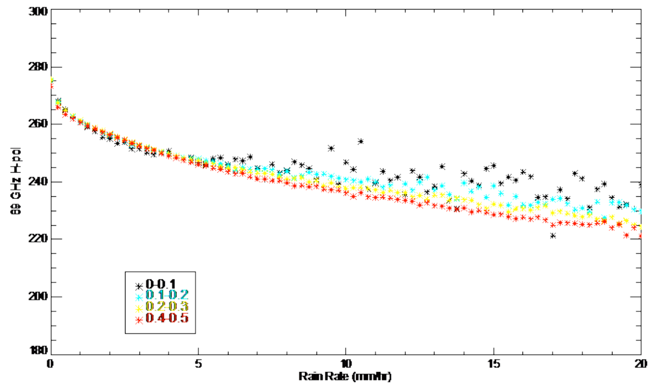
- Participation from space agencies, modeling centers, academia
- Areas of expertise:
  - Algorithm development
    - Microwave, IR, imagers, sounders
    - Detection and quantification over various surfaces
    - Machine learning
  - Modeling
    - hydrological modeling, global model data assimilation (all-sky), coupled modeling, radiative transfer modeling
  - Land-Atmosphere Interaction
    - Precipitation characteristics, orographic precipitation
  - Validation
    - Efforts stratified by surface type
    - Field campaigns
  - Data Fusion
  - Estimating Uncertainty
- Meet virtually, mainly through NASA PMM LSWG seminars

Why do we care about the land surface?

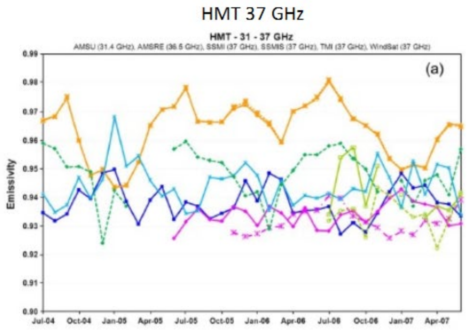
- Decades of work investigating soil moisture pre-conditioning and convective initiation (trigger)
  - Surface properties clearly related to precipitation occurrence
  - Precipitation (observable) character?
- Surface emission in microwave needed for physical retrievals, data assimilation, radiative transfer modeling
  - Estimates often disagree

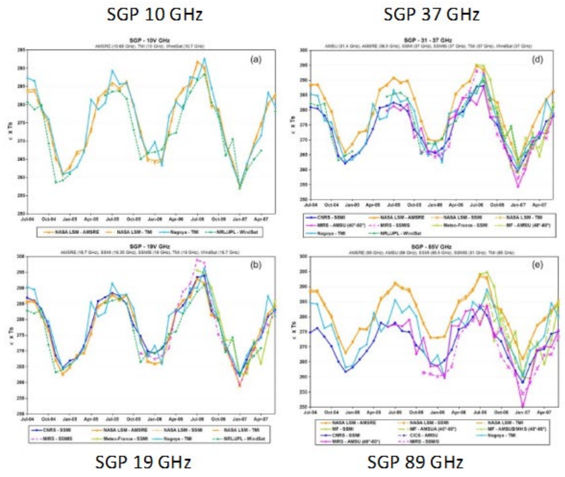


Taylor et al. 2011



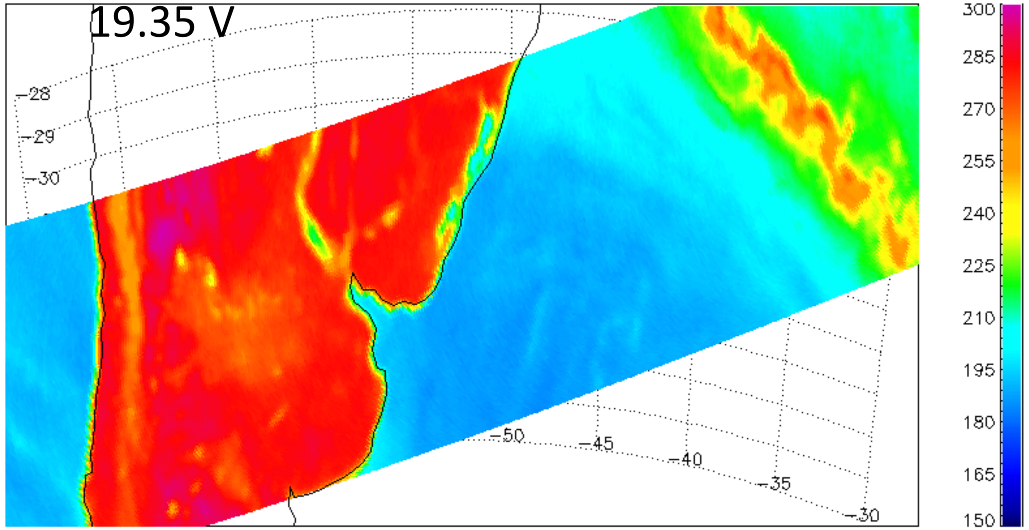
Ferraro et al. 2012

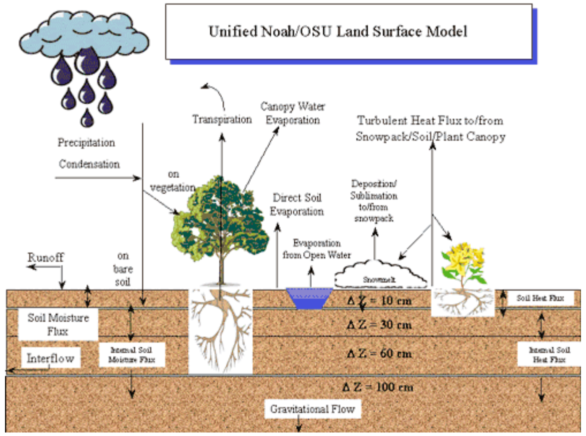




Land surface emissivity in the microwave

- Large and highly variable contribution to upwelling radiation
- Sensitive to many variables
  - Frequency, polarization, and incidence angle
  - Dielectric and roughness properties of soil and vegetation
  - Standing water or snow can cause very large instantaneous changes
- Challenging to model, difficult to validate, requires many assumptions and input surface parameter datasets
  - NCEP CRTM (LandEM), ECMWF (CMEM)
  - Bottom-up – don't need clear sky





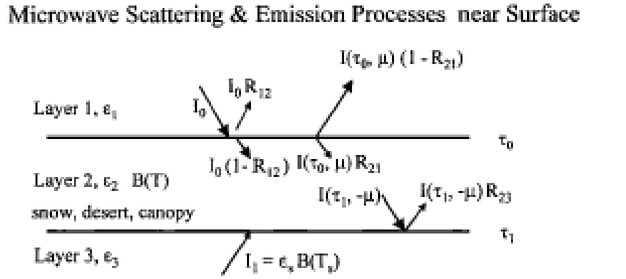
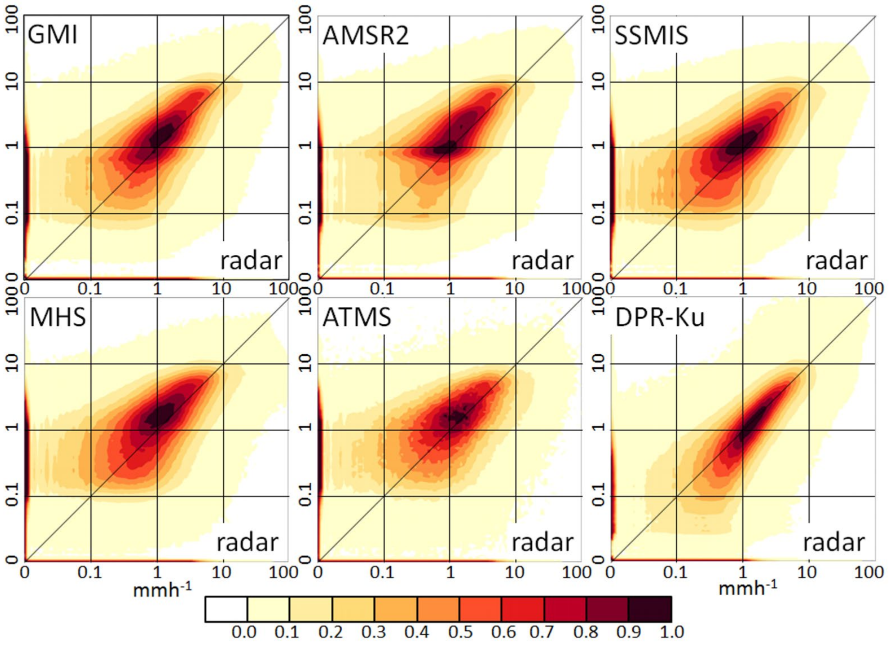


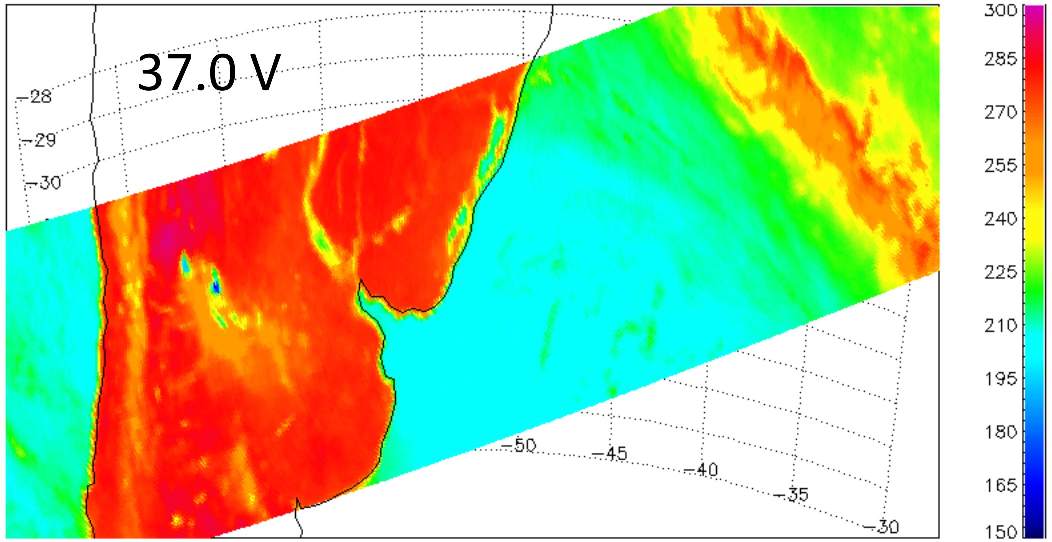
Figure 1. A schematic diagram of radiative transfer process for scattering and emission material on land surface.

Passive Precipitation Retrieval Over Land

- High land surface emissivity makes hydrometeor absorption signal difficult to distinguish – basically limited to scattering/precipitation rate relationships



KIDD ET AL. 2017: Normalised density scatterplots of the V05 GPROF and DPR-Ku precipitation products versus surface radar data over the United States region; all products are compared at a nominal resolution of 15x15km (note that zero values are plotted along the x and y axes)



Calculations from 1 year of retrievals over non-snow land surfaces (Ku rain rate over GMI footprint area):

0-1 mm/hr: 73% of raining footprints
: mean ku: .30, mean GPROF: .49 (+63%)

1-5 mm/hr: 23% of raining footprints
: mean ku: 2.1, mean GPROF: 2.3 (+8%)

5-10 mm/hr: 3% of raining footprints
: mean ku: .6.72, mean GPROF: 5.39 (-20%)

10+ mm/hr: 1% of raining footprints
: mean ku: 19.67, mean GPROF: 7.62 (-61%)

Member Highlights/Interests and Avenues of Investigation

Precipitation area detection using MWI Surface Emissivity and Fraction of Water

Kazumasa Aonashi (Kyoto University, JAXA/EORC)

Shoichi Shige (Kyoto University)

- An algorithm was developed that uses the MWI surface emissivity (EsEPC) estimated by the EPC method of Turk et al (2014).
- For TB166v, (TB/Ts) was used as a substitute for EsEPC.
- For coastal precipitation area detection, we used fraction of water within the FOV of each channel using the method of Mega and Shige (2016).
- This method gives precipitation area fraction closer to the DPR observations than the previous algorithm.

Future direction：

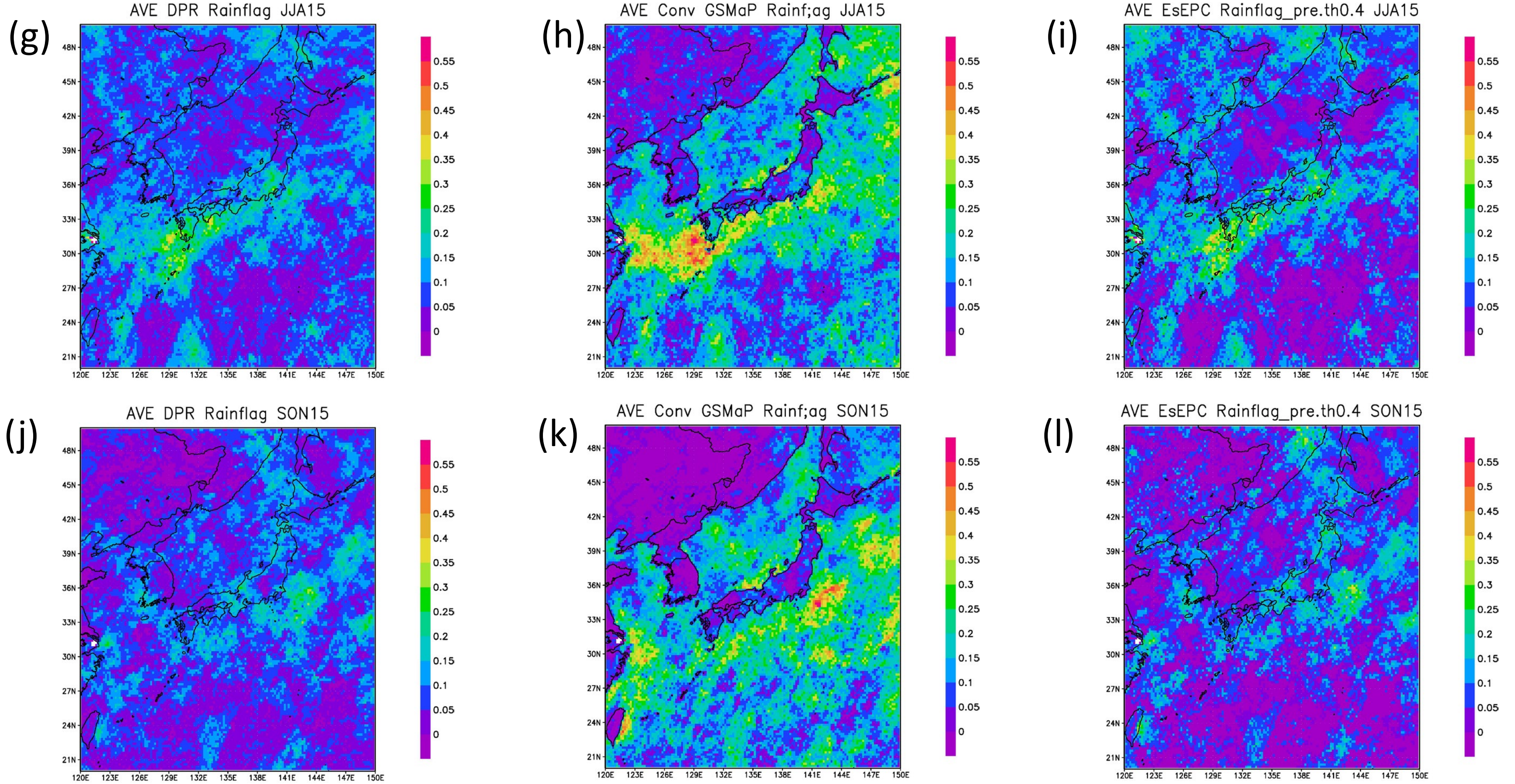
- Avoid 10GHz RFI
- Introduction of classes of land surface conditions (desert, forest, etc.) to apply to the whole globe
- Improvements for topographic precipitation

Preliminary Results：3-month mean of Precip area fraction for pixels without snow cov or sea ice 2015

DPR rainflag | Conv. GSMaP | Algorithm of the present study

JJA2015

SON2015



Soil moisture-precipitation feedbacks

Research line at the eoLab (Univ. Coimbra) Vasco Mantas

Assessing the role of antecedent soil moisture and land cover characteristics over precipitation.

Causality studies being conducted in Africa and Peru, along with the development of enhanced land cover masks.

In situ point data analysed, now starting event/spatial (satellite-only) analysis.

Project Gradients (Peru) will enable dense instrumentation network of Andean watershed.

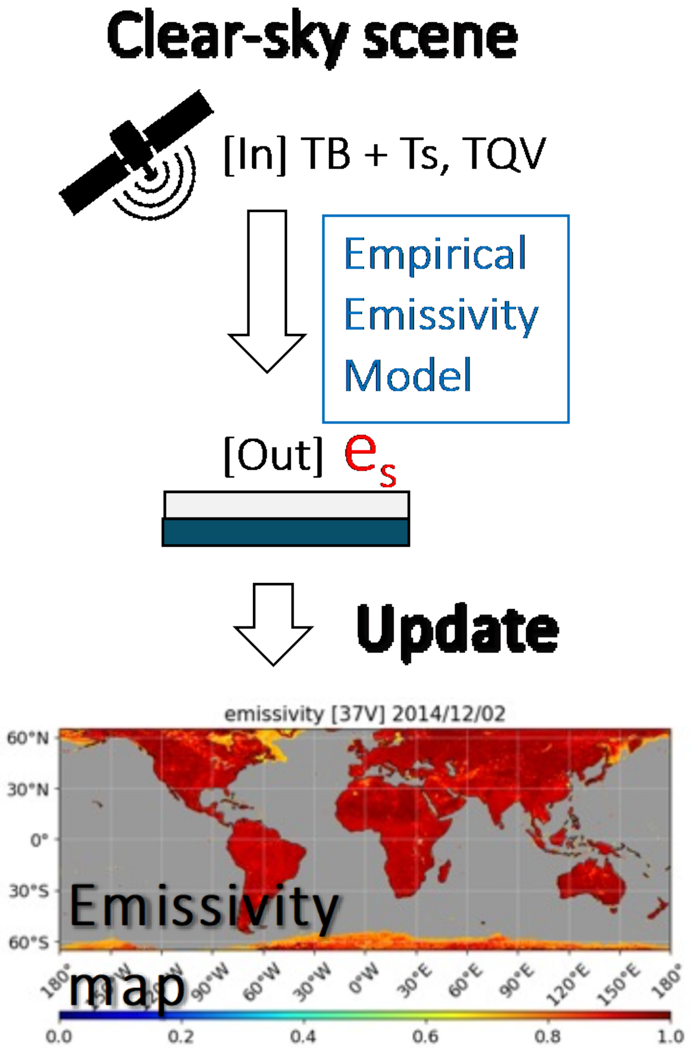
GRADIENTS

Dynamic surface emissivity atlas

Nobuyuki Utsumi

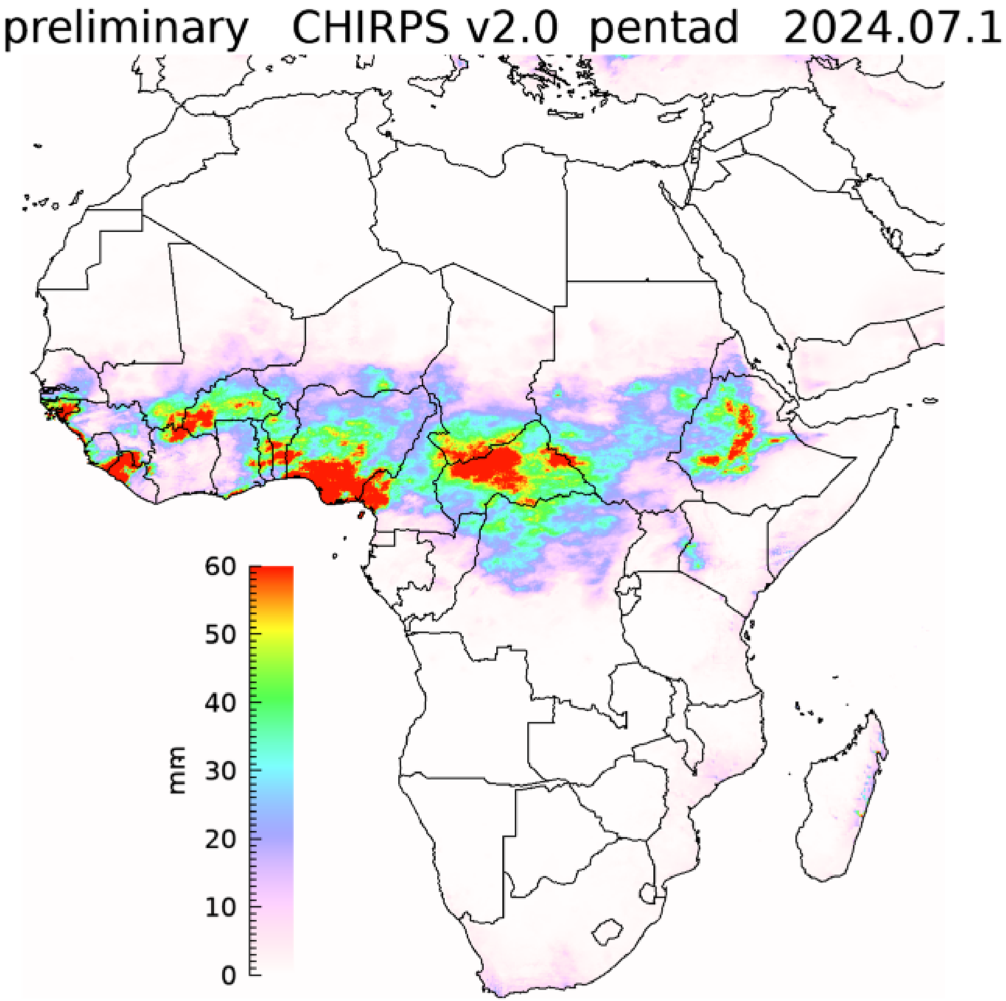
GMI-based empirical emissivity model

Updates with each clear-sky overpass



Climate Hazards Center

- Pete Peterson
- Working on next version of CHIRPS and CHIMES
  - Serve early warning needs and monitor food security



Data Assimilation

- Alan Geer
- ECMWF all-surface assimilation
- Looking at sea ice using new machine learning and data assimilation approach

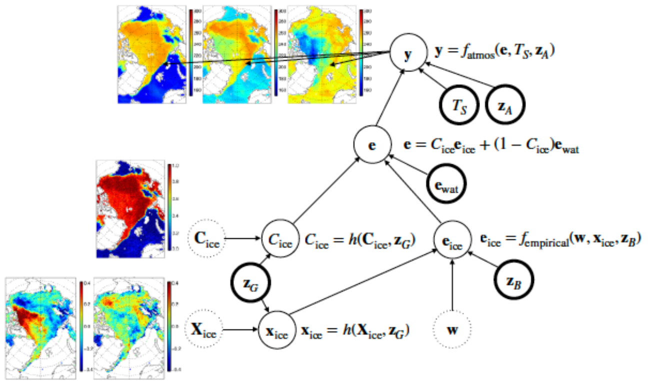


Figure 1. Simplified overview of the hybrid empirical-physical training network, for a single day and a single multi-channel observation. Circles represent variables that are trainable (dotted), dependent (thin solid), or fixed (thick solid). Arrows indicate dependencies and equations give the functional form of these dependencies. The meaning of the variables is explained in the text. Colour maps illustrate, for the Arctic, the observations (top); sea ice concentration (middle) and empirical sea ice properties (bottom) for 7th November 2020; full size extended versions, along with full explanatory details, can be found later in Figs. 2, 9 and 6 respectively.

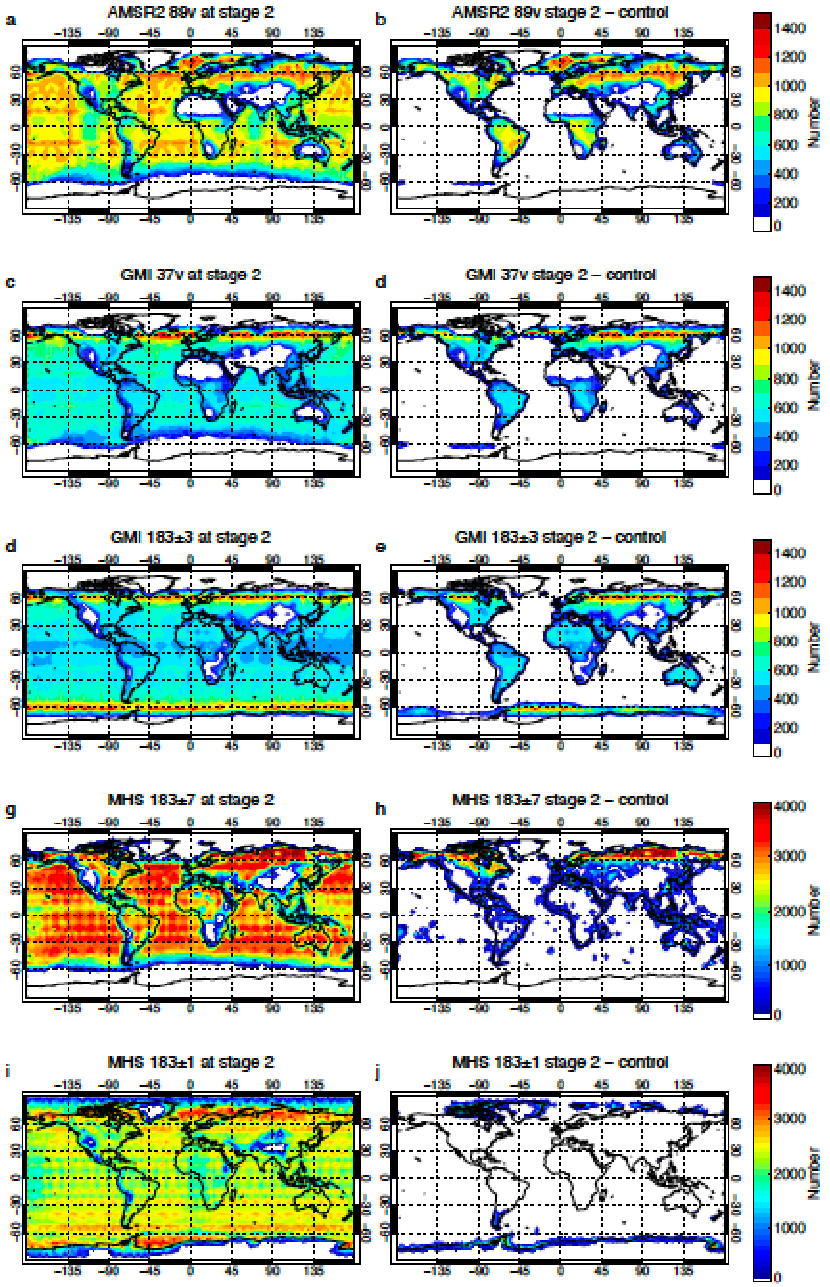


Figure 20: Number of observations (left) actively assimilated in the Stage 2 experiment; (right) the increase compared to control; per 4° latitude box, in July 2019. Selected channels and instruments.

"Hybrid" Retrieval with Dynamic Surface Constraints

- Use surface state to inform the retrieval
- First Pass: OE output from Munchak et al. scheme
  - Use retrieved emissivity to determine snow cover
  - Areas of convergence assumed precip-free
- Bayesian Retrieval where indicated by Normalized Error Parameter
  - Experiment with cutoff value
- Use GPROF database, organized/constrained with **retrieved** parameters
  - Use recent precipitation-free retrieved emissivity at 19 GHz as retrieval constraint (+search below)
  - Interpolate retrieved TPW as retrieval constraint (+search above)

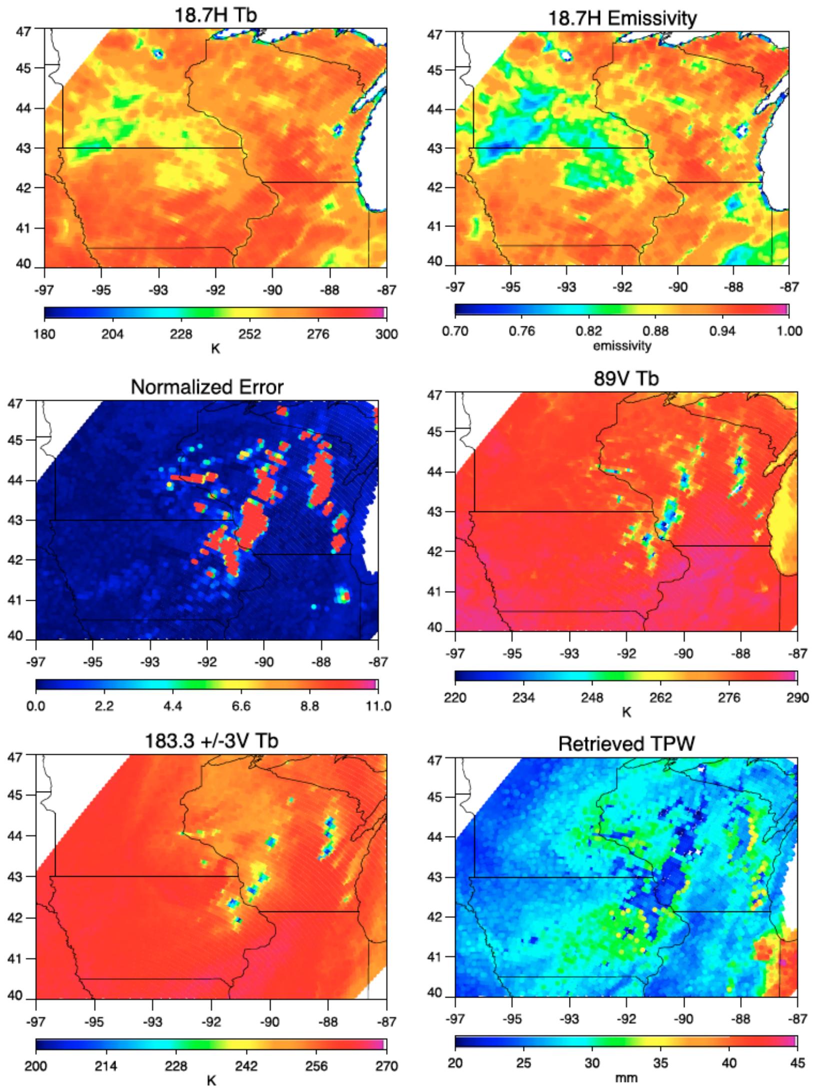


FIG. 3. Observed and retrieved parameters from a GMI overpass on 4 Jun 2016. (top left) Observed Tb and (top right) retrieved emissivity at 18.7 GHz. (middle left) The normalized error parameter from the OE retrieval and (middle right) the observed 89V Tb. (bottom left) Observed Tb at 183 ± 3GHz alongside (bottom right) retrieved TPW.

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Hybrid Retrieval Global Results

NASA

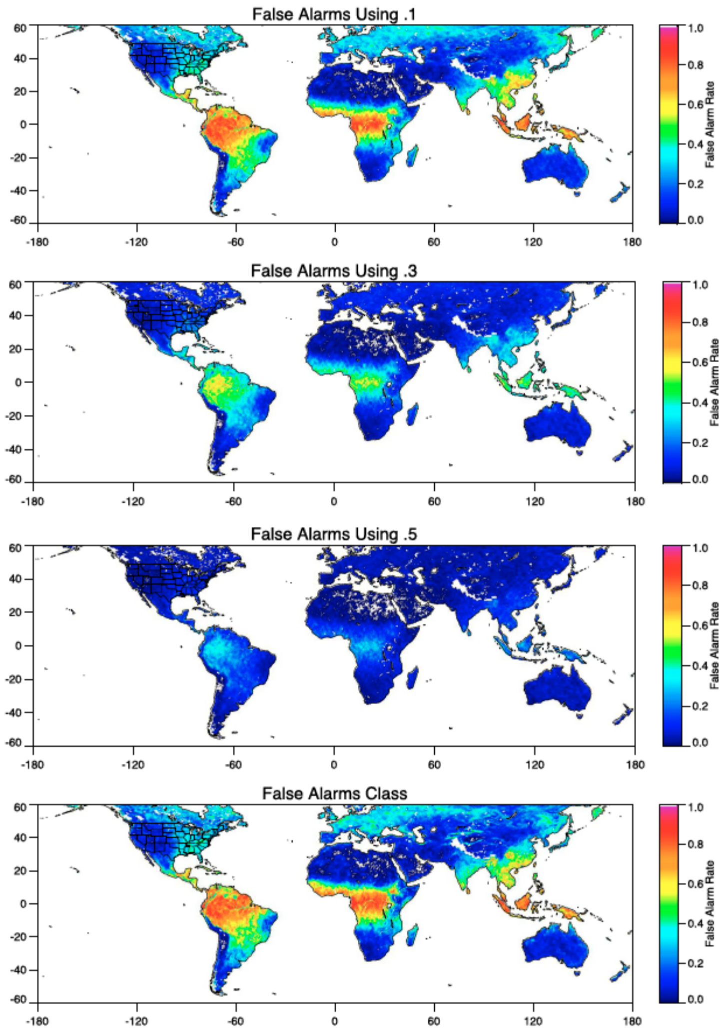


FIG. 9. Ratio of retrieval false alarms (not detected by the active radar) to all observations for the 1-yr period September 2015–August 2016. (bottom) Results using the GPROF classification scheme; (top three rows) results using the hybrid retrieval with several values of normalized error parameter cutoff defining locations for the Bayesian retrieval.

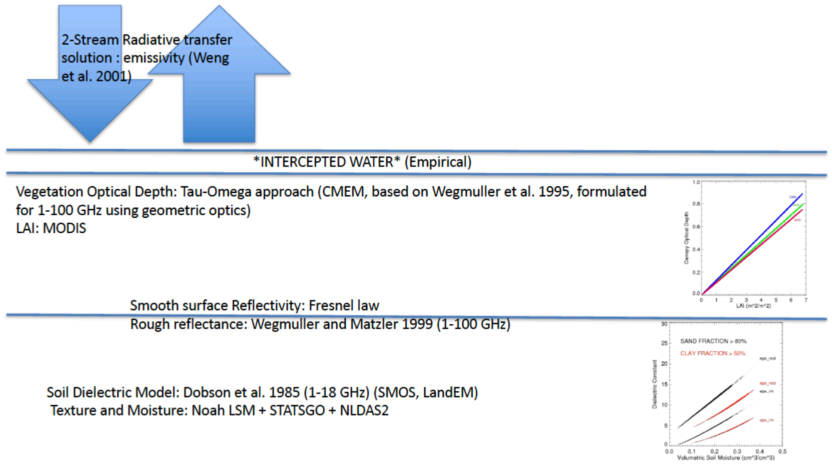
False alarms decrease significantly using the hybrid technique along with dynamic surface constraints.

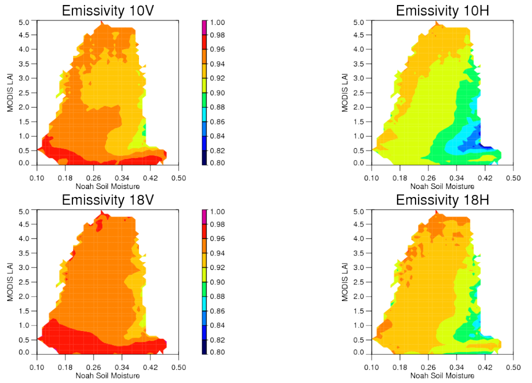
Probability of false detection minimization along with maximized POD occurs at 0.3 on average where false alarms are decreased by half, but this may vary by surface and/or environmental conditions.

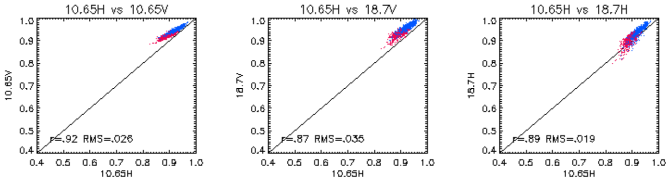
Semi-Empirical Emissivity Model

- Retrieved emissivity is the standard – but a value is required in precipitating conditions (high chi-sq)
  - Particularly important in generating best database for future retrievals that may use ML
- A method for emissivity estimation that makes use of best info from models, retrievals
- Physical model for 10 GHz emissivity
  - Required inputs: soil type, soil moisture, surface temperature, LAI, antecedent precipitation
  - This is where physical model and retrievals agree
- Empirical model uses observed covariance relationships to map to other frequencies
  - Bytheway and Kummerow 2010
- Adapt for GPM, others

10 GHz Physical Model (based on operational schemes)







5 years of clear sky AMSR-E retrievals, over 2 million pixels

Noah-NLDAS2 surface temperature + ERA-Interim atmosphere (MODIS confident-clear)

Plane-parallel Eddington radiative transfer scheme

Retrieved emissivities strong function of soil moisture, particularly at lower frequencies, and LAI, particularly at higher frequencies

Emerging themes

- Field is moving to smaller, high frequency, cross-track instruments (with some key exceptions). We will lose sensitivity to the surface and to warm rain. What effect will this have on remote sensing of precipitation over land? Can we start to quantify some of the resulting uncertainties as a function of surface type?

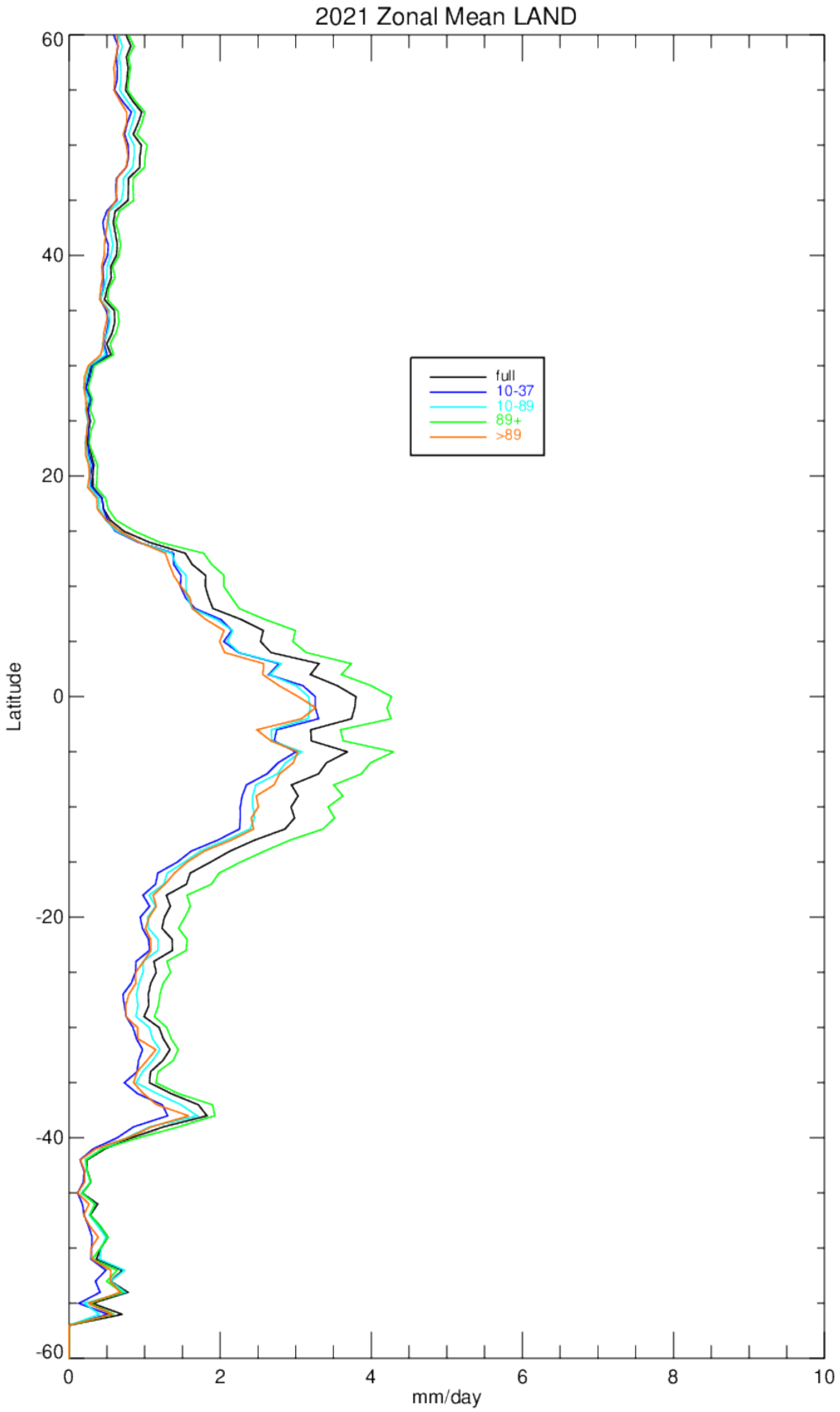
- How are surface characteristics (soil moisture, vegetation, etc.) and precipitation characteristics linked?

- Where are we as a field currently in terms of surface emissivity modeling and retrieval, specifically for land surfaces and snowpack? This can also include radiative transfer modeling. This is of great importance for data assimilation as well as algorithm development. It’s important to note this question includes the quality and availability of input parameters for these models on the global scale.

- What available information content are we not taking advantage of? GEO has great potential and is underutilized for example.

Gaps, Needs, Synergies

- Microwave emissivity
  - Modeling and retrieval community cooperation needed here
  - Important synergy here with PBL community
    - Exploring hyperspectral microwave technology
- New missions and industry moving away from lower microwave frequencies
  - Quantify what the loss of this information content related to the surface means for precipitation retrieval



International Earth Surface Working Group (IESWG)

Clara Draper (NOAA) and Samantha Pullen (UK Met Office) - Co-chairs

- Current IESWG ToR ratified by CGMS WG-II:
- https://docs.google.com/document/d/1RfslzrLyEMy7pK_DgQT8FAqVLCTOtFh2/edit

- The IESWG was approved as a probationary CGMS working group, acknowledging its
- distinctive blend of data assimilation and Earth surface modeling expertise, aimed at
- maximizing the utilization of present and upcoming observations.

- The IESWG has a distinct vocation towards earth surface data assimilation, observation
- operators and modelling developments that can advance coupled land-atmosphere
- assimilation in numerical weather prediction and climate/environmental reanalyses.

- The three main topical areas in the IESWG are:
  - Snow ice and cryosphere-atmosphere interaction
  - Vegetation and land-atmosphere fluxes
  - Soil moisture, river-discharge and water cycle

- **Can IPWG identify areas of interaction and exchange with IESWG?**

Westcoast Hyperspectral Microwave Sensor Intense Experiment (WHyMSIE)

- Through a NOAA BAA, the Conical Scanning Millimeter-wave Imaging Radiometer Hyperspectral (CoSMIR-H) will fly on an aircraft in 2024, will provide airborne validation of the hyperspectral architecture
- AMPR will also fly
- WHyMSIE field campaign ER-2 range rings showing the amount of on-station flight time available and key ground-based sites.
- WHyMSIE will cover a comprehensive ensemble of surface types (ocean regimes, complex terrain/land regimes) and weather scenarios (all-sky, cloudy, precipitating)
- PoR satellite sensors under-flights: SNPP and JPSS ATMS.

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DOE ARM SGP

- Supplemental launches in addition to standard 00 and 12 UTC radiosondes
- Surface classification and skin temperature are key variables measured, critical for microwave retrievals

- The SGP flight plan (that will look something like this ^) will be flown 1-2 times

NOAA NWS

- In communication with Jordan Gerth, site preferences have been modified to concentrate on NWS RAOB sites on the path to-and-from ARM SGP (8 NWS radiosondes total per ARM SGP flight) and initial cost estimates have been provided
- KOUN (University of Oklahoma Westheimer) has been added to the site list, but would only launch once during an ARM SGP flight plan due to this being a site that uses helium
- Next steps: as flight plans are developed, Jordan will coordinate with field offices, and basic SOPs for launches will be developed

Instrumentation of interest at ARM SGP:

• **Radiosondes (SONDE):** supplement the twice daily launches with additional radiosondes to be launched when the ER-2 is overhead (PRIMARY REQUEST)

Ancillary Instrumentation:

•**Surface Meteorology Systems (MET):** Atmospheric moisture, Atmospheric pressure, Atmospheric temperature, Horizontal wind, Precipitation, Aerosol absorption, Aerosol extinction, Cloud fraction, Cloud ice particle, Ice water content, Liquid water content, Longwave broadband downwelling irradiance, Ozone Concentration, Planetary boundary layer height, Sea surface temperature, Shortwave broadband total downwelling irradiance, Soil characteristics, Soil moisture, Soil temperature, Surface condition, Surface skin temperature, Visibility

•**Ground Radiation (GNDRAD):** Longwave broadband upwelling irradiance, Shortwave broadband total upwelling irradiance, Surface skin temperature

•**Infrared Thermometer (IRT):** Longwave broadband upwelling irradiance, Longwave narrowband brightness temperature, Longwave narrowband radiance, Surface skin temperature

•**Atmospheric Emitted Radiance Interferometer (AERI):**

•**Raman Lidar (RL):** Aerosol scattering, Atmospheric moisture, Atmospheric temperature, Backscatter depolarization ratio, backscattered radiation, cloud base height

•**High Spectral Resolution Lidar (HSRL):** depolarization allow for discrimination between ice and water clouds

•**Micropulse lidar (MPL)**: Aerosol backscattered radiation, Aerosol extinction, Aerosol optical depth, Backscatter depolarization ratio, Backscattered radiation, Cloud base height, Cloud fraction, Cloud top height, Hydrometeor phase, Lidar polarization, Radar polarization, Radar reflectivity

•**Doppler Lidar (DL):** Atmospheric turbulence, backscatter depolarization ratio, backscattered radiation, horizontal wind, lidar doppler, radar doppler, vertical velocity

•**Ceilometer (CEIL):** Backscattered radiation, cloud base height

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Moving forward

- Review paper (meta-analysis) focused on microwave emissivity for land and snow surfaces
  - Modeling/data assimilation and retrieval interests
- Continue sharing work and knowledge through seminars
- Identify additional areas for collaborative efforts
  - Identify and advertise funding opportunities
  - Collaborate with PBL efforts – WHyMSIE