NASA Weather Focus Area Workshop Report

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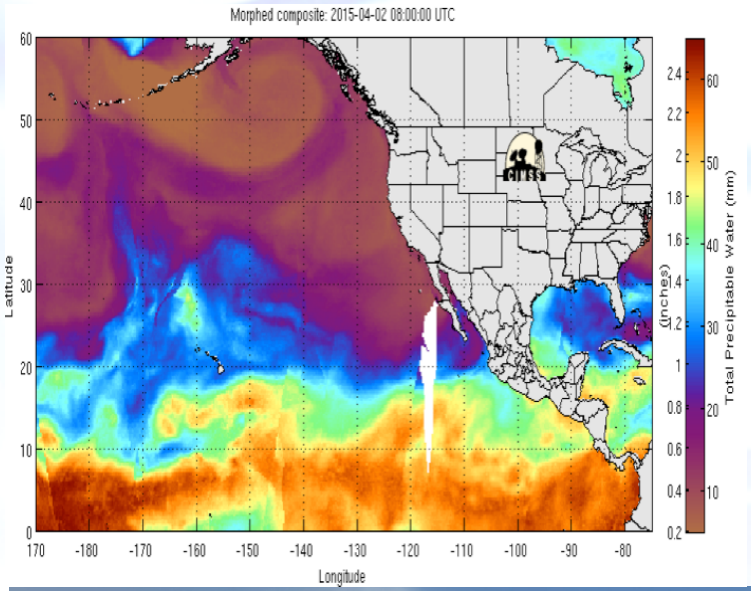
Motivation

This workshop serves as part of the advanced planning process for the NASA Weather Focus Area. **The purpose of the workshop is to gather NASA Weather Focus Area community leaders to identify the most challenging scientific research and development topics that can be uniquely addressed by the NASA Weather Focus Area using NASA's satellite, airborne, and surface observations, computational modeling and data assimilation systems, instrument (airborne and satellite) platforms, and high-end computing facilities.** Emphasis would be to use any new kind of observational, modeling, computational capabilities at present and planned for the future. Specific questions to be addressed:

1. What are the main scientific challenges in weather research (e.g., in fundamental understanding, model development, data assimilation, and research to operation or application transitions)?
2. What are the main opportunities in weather research using new satellite observations and suborbital field campaigns?
3. How can we leverage available NASA observations as well as new observing systems for weather research?
4. What measurements are urgently needed and can be made through future NASA missions?
5. What is NASA's unique role in weather research through the Weather Focus Area, relative to NOAA, NSF, and DOD?

Workshop on Scientific Challenges and Opportunities in NASA Weather Focus Area
April 7-9, 2015

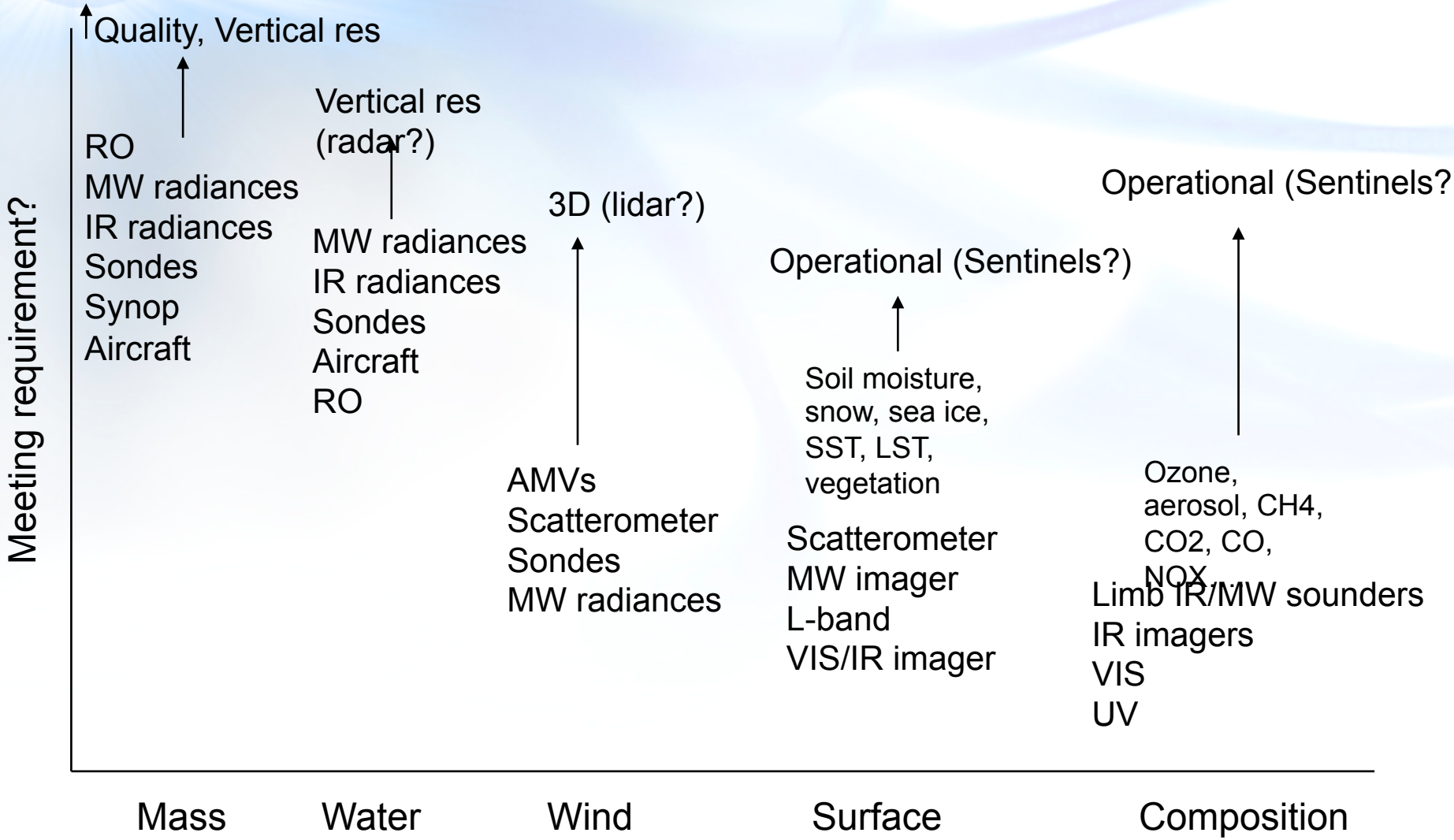
- About 80 people from from NASA HQ/ Centers, NOAA, DoD, FAA, OFCM, NGOs, academia, industry, and international organizations attended the two and a half days NASA weather focus area workshop.
- Top phenomena:
  - ✓ Extreme events
- Top observations:
  - ✓ high res wind profile obs in all weather
  - ✓ high res temp and moisture profiles
  - ✓ Atmosphere – Land fluxes
- Top system capability development
  - ✓ advanced DA (including coupled)
  - ✓ high res global models
  - ✓ OSSE



Field Campaigns

- Science:
  - Field campaigns observations have been critical for improving the fundamental understanding of convection, tropical storm structure impact of aerosols on tropical storms, etc.
  - They have been important for model validation and sub-grid scale parameterizations in mesoscale models and GCM's.
  - The most challenging measurements are less than a few km and minutes. But these are often the most important for dynamical and microphysical process studies.
- NASA has had a long history of coordinated field campaigns with other Agencies. This leveraging has shown to be very important in producing top quality science.
- NASA instrument technology developments along with unique aircraft have have provided new measurement capabilities that define NASA's role in weather field campaigns.
- Weather covers many different possible targets but some high impact areas affecting U.S. that have been neglected:
  - Severe storms
  - Coastal storms (both U.S. coasts)
  - Winter storms

Satellite Observations
5D coverage (3D space + Time + Parameters)



What is needed?

- Are research missions prototypes for future operational missions or “one offs” to improve scientific understand of processes?
- If prototype we need to recognise
  - Need for longer missions so operational centres are interested and develop capability
  - Forward thinking about real time data delivery
  - Forward thinking about how to address the gap from research prototype to operational mission, given the timescales
  - Where are the gaps, given operational plans, other agency plans
    - 3D Wind e.g. Doppler wind lidar
    - Surface e.g. L-band
    - Vertical resolution e.g. radar
    - High temporal “all-sky” observations e.g. Geo MW
    - Atmospheric composition e.g. IR + MW limb sounders

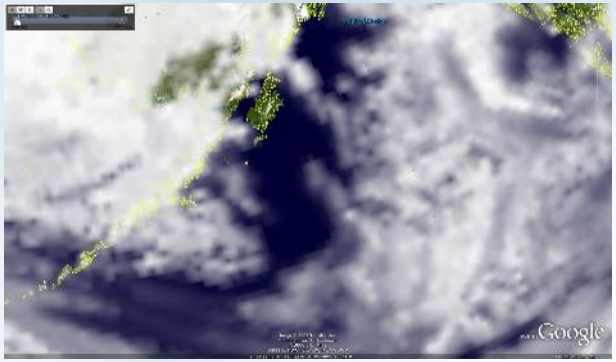
Technology

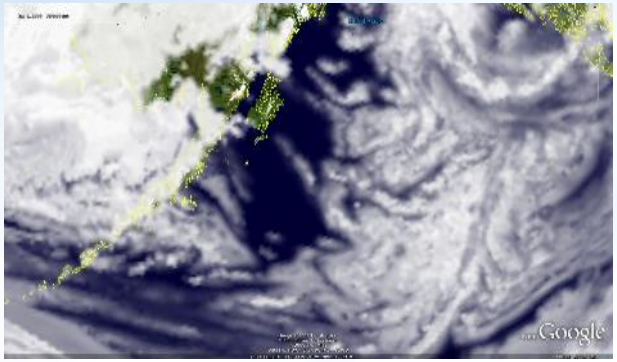
- ESTO has currently ~$50M of investments in instrument and information technologies related to Weather Focus area science measurements.
- These technologies once matured would enable new and/or enhance existing measurements in Weather Focus area using wide range of platforms that include cubesat, microsat, smallsat, and traditional size satellites.
- Constellation of small instruments would provide higher spatial and temporal resolution of measurement. These observations, when assimilated into high resolution weather models, would enhance short-term and severe weather forecasting.

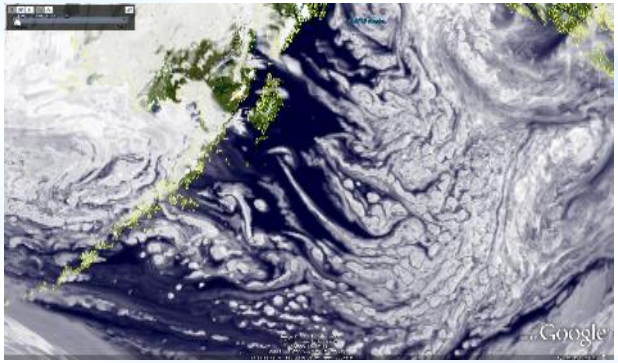
Visit us at http://esto.nasa.gov for more information on ESTO's investments in Earth science technologies

Increasing Global Forecast Resolution

Current Operations | **Cloud-Permitting** | **Cloud-Resolving**







Requirement	Current Operations	Cloud-Permitting	Cloud-Resolving
Number of Cores	100's -> 1,000's	300,000	10,000,000
Resolution	27 KM -> 13 KM	10 KM to 3 KM	1 KM or Finer
Number of Racks	1 Rack	234 Racks	7,800 Racks
Total Power	20 KW	4.7 MW	100 MW

Compute capability to generate a 5-day forecast every 6-hours.
Assuming current compute technology (Intel SandyBridge), the computer needed to run a cloud-resolving model does not exist today and would require entirely too much power. A different approach is needed – adoption of low-power highly parallel processors.

Recommendations (1)

- **Recommendation on OSSEs:** The Weather Focus Area should take ownership of a NASA Earth Science OSSE capability for assessing the impact of measurements and measurement systems on the ability to answer weather and related science questions. In this way, mission systems trade studies can be done against impact and cost for satellite missions and technology development. Serious consideration should be given to increasing NASA and NOAA interagency collaborations, including evolving the current shared OSSE elements into a common unified infrastructure.

- **Recommendation on wind measurements:** Global measurements of the spatio-temporal (four-dimensional) evolution of large-scale horizontal wind vectors are urgently needed. It is important to avoid all or nothing strategies for the three-dimensional wind vector measurements, as important progress is possible with less than comprehensive observing strategies. Some additional trade studies may still be needed to design the most cost-effective strategy for wind measurements (based on lidar, radar, and atmospheric motion vectors) from satellites and airborne flights.

Recommendations (2)

- **Recommendation on temperature and humidity measurements:** Continuous investment in temperature and humidity measurements is needed, particularly focusing on higher spatial and temporal resolution, and synergistic measurements involving multiple instruments, different platforms (geosynchronous, low earth orbit, and airborne), and different types of satellites (including small-sat and cubesat). Better measurements from space of the temperature, water vapor, and wind in the boundary layer are needed, in particular to estimate more accurately from space ocean/land surface turbulent fluxes that are closely coupled to boundary layer and convection processes.

- **Recommendation on cloud and precipitation measurements:** Continuous investment in cloud and precipitation measurements is needed, particularly focusing on higher spatial and temporal resolution, and synergistic measurements involving multiple instruments (e.g., radar, radiometer, and lidar observations), different platforms (geosynchronous, low earth orbit, and airborne), and different types of satellites (including small-sat and cubesat). Particularly relevant to these measurements is the estimate of the vertical velocity.

Recommendations (3)

- **Recommendation on modeling:** Global high-resolution modeling (convective permitting with grid sizes of 1-5 km) should be pursued as an essential contribution to the broad national and international modeling activities and to NASA mission planning. This involves the research support of dynamic core, physical processes, software engineering, and high-performance computing. Research on and development of other high-resolution models (e.g. mesoscale, cloud resolving and large-eddy simulation models) also need to be pursued in parallel.

- **Recommendation on data assimilation:** NASA should collaborate closely with operational and research centers and support research on cutting-edge assimilation issues such as: hybrid ensemble-based 4D-Var, all-sky radiance assimilation, assimilation of properties related to clouds and radiation, land surface emissivity, coupled DA of the atmosphere-ocean-land-ice system, and DA evaluation metrics.

Recommendations (4)

- **Recommendation on computing:** NASA should match the supercomputing capability and capacity with the growth in a sustained, high-resolution modeling capability directed at using all observations to their fullest extent in weather prediction and at planning for new global observations. Enhanced data-distribution techniques (e.g., storage proximal analytics) are also needed for data access and discovery.

Partnership and Uniqueness

- **Partnership:** These science questions and recommendations require NASA to work closely with other agencies, academia, the private sector, and international partners, including the leverage of existing partnerships such as the National Earth System Prediction Capability (ESPC) and Joint Center for Satellite Data Assimilation (JCSDA) as well as joint satellite missions with international partners.

- **Unique Role:** At the same time, NASA has a unique role in weather research (as reflected by the above science questions and recommendations) through the Weather Focus Area, relative to its partners. NASA is the only agency in the U.S. with the capability to develop new technologies and satellite missions for the above measurements. This also requires NASA's leadership role in OSSEs.

Thank You!