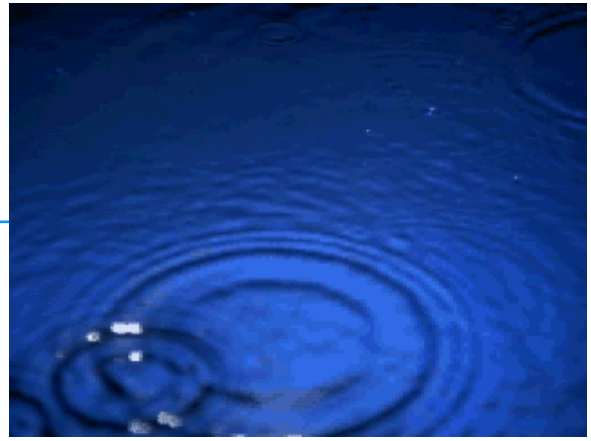
Global Precipitation Measurement (GPM)



GPM Ground Validation (GV) Strategy:

Proposed measurements and opportunities for synergy with ARM at the SGP and other sites

November 9, 2006

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Global Precipitation Mission: Overview

Building on the success of TRMM, GPM will be a reference standard for Global precipitation measurement

Broader capabilities (constellation of satellites with frequent global sampling) and thus broader applicability

GPM will launch:

<u>GPM core satellite</u>

- *Dual frequency radar (14 & 35 GHz)*
- *Microwave imager (10-183 GHz)*

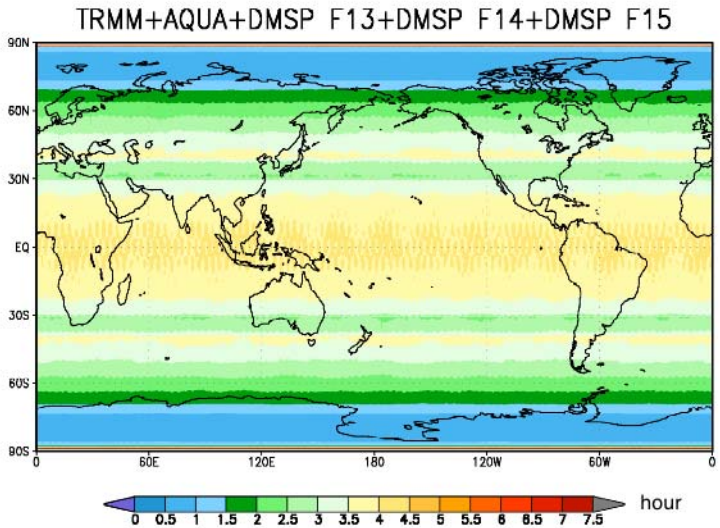
<u>"Wild Card" microwave satellite</u>

Constellation satellite (with a microwave imager) to maximize the coverage and sampling by the GPM core and constellation satellites

GPM will attain "global" coverage

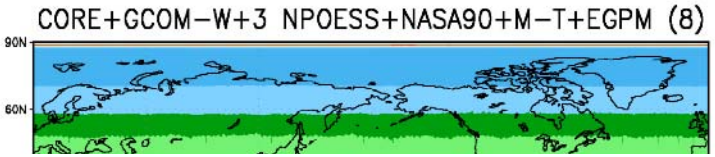
GPM science requirement: 3h revisit time over 80% of globe

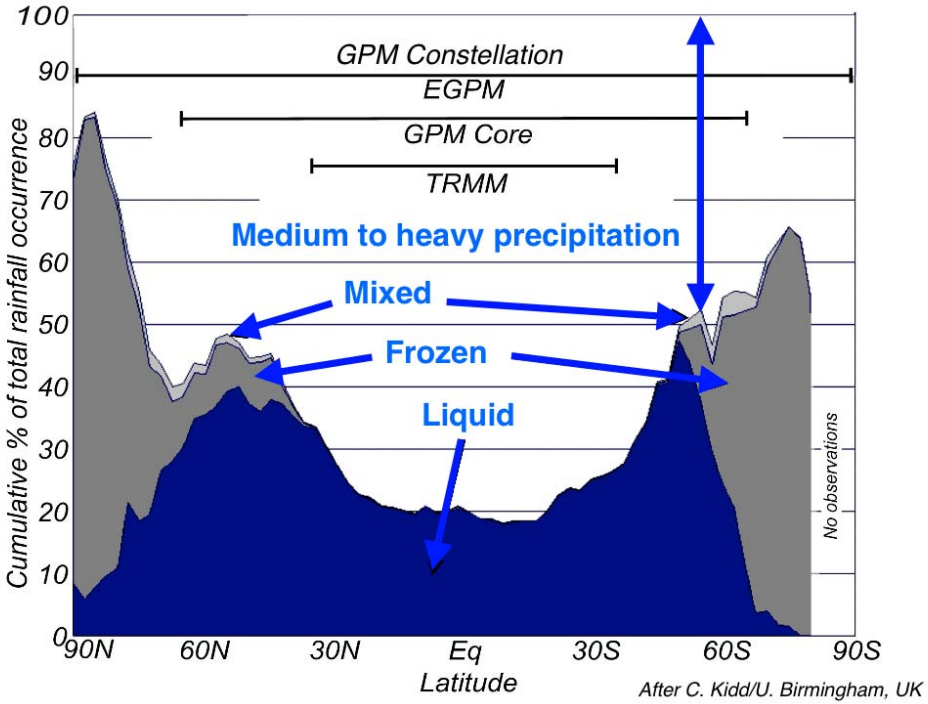
Current:
(≤ 3h over 34.6% of globe)



TRMM, Aqua
F13, F14, F15

Expected GPM-Era:
(≤ 3h over 100% of globe)





…but that brings new measurement and validation challenges.

Detection of light rain (<0.5 mm/h) and snow requires increased radar sensitivity than TRMM/PR and HF (> 90 GHz) radiometer channels

The Scope of GPM

- ***GPM, by design, will have the responsibility to address a broad complement of science and operational issues***
  - *Improved precipitation measurement capability*
  - *Water/energy cycle variability*
  - *Climate prediction*
  - *Weather prediction*
  - *Hydrometeorological prediction*

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

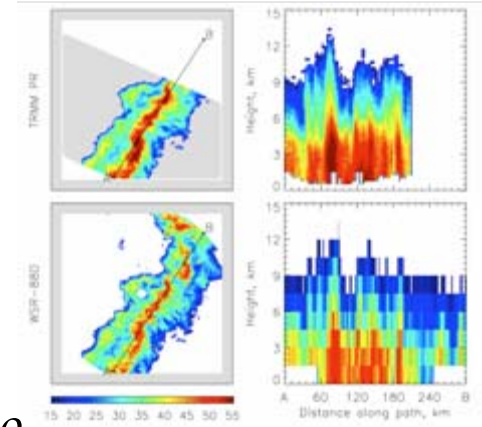
- ***Increased reliance on microwave retrievals will require their improvement, particularly over land***
  - *Development of physically-based over-land microwave retrievals in frozen precipitation and light rain will require characteristics of land surface (e.g., μw emissivity) to be quantified*
  - *A coupled land-atmosphere cloud resolving model (CRM), with satellite simulation capability, will be key in implementing and validating physically-based passive microwave retrievals*
- ***These extensive objectives will necessarily broaden the validation effort beyond just validating surface rain rate***
  - *Surface + hydrologic measurements, cloud model validation*

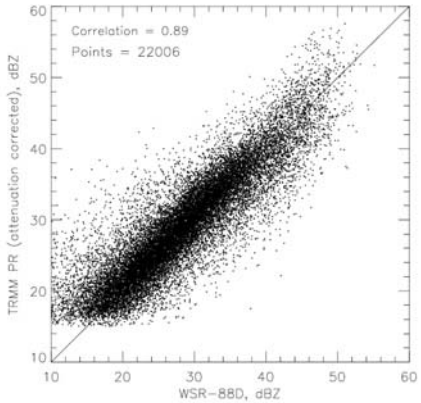
New Challenges for GPM Ground Validation

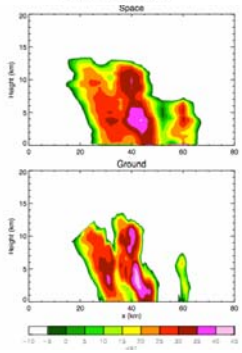
- ***GPM will have high expectations for accuracy of its products***
  - *Possibly higher than current surface-based instantaneous measurements of rainfall*
- ***Validation strategy must meet those challenges***
  - *Development of comprehensive validation approach for GPM ground validation*
- ***An outline for the strategy has been drafted by the GPM GV Advisory Panel, led by C. Kummerow and W. Petersen***
  - *R. Adler, A. Barros, R. Bras, V. Chandresekar, R. Cifelli, L. Donner, R. Ferraro, J. Fuentes, G. Heymsfield, G. Huffman, G. Skofronick-Jackson, S. Klein, C. Peters-Liddard, B. Meneghini, W. Olson, G. Petty, M. Ralph, S. Rutledge, M. Shepard, E. Smith, S. Sooroshian, M. Steiner, W.-K. Tao, T. Wilheit, E. Wood, S. Yuter. E. Zipser*
- ***Implementation of GV Strategies for GPM, based on guidance from the above advisory panel, is accomplished by the GPM GV Study Team***
  - *E. Amitai, V. Chandrasekar, R. Cifelli, K. Gage, J. Gerlach, M. Grecu, T. Lang, B. Martner, B. Meneghini, B. Morris, S. Nesbitt, W. Olson, W. Petersen, H. Pryor, S. Rutledge, A. Tokay, C. Williams, D. Wolff, S. Yuter*

The Validation Strategy

- ***Overall objectives for validation***
  - *(1) Quantitative assessment of the rainfall uncertainties from the core satellite*
  - *(2) Collection of data required to advance current empirical radiometer retrievals over land towards a physical approach*
- ***The sobering reality:*** *The satellite overpasses a particular location capable of making most the measurements required too infrequently to perform direct physical validation*
- ***This motivates a two-pronged validation effort:***
  - *Statistical validation (satellite measurables + rain rates)*
    - *Use many distributed sites leveraging value-added "national map"-type products (e.g. NOAA Q2)*
      - *Polarimetric NEXRADs will be coming on line by GPM launch*
  - *Physical validation (algorithm physics)*
    - *Few sites, with enhanced measurement capabilities, to address algorithm issues*
      - *These sites will contain research-quality, retrieval algorithm-targeted validation measurements*

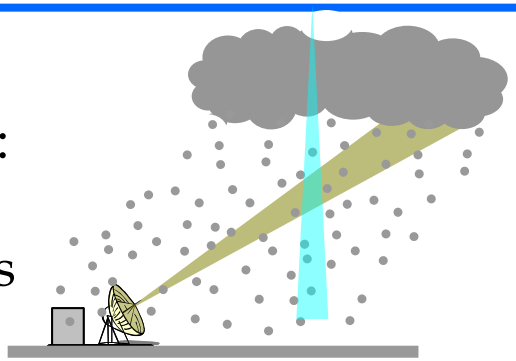






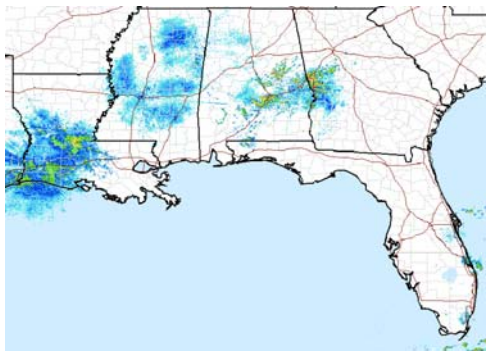
3 Scales of Measurement for GPM GV

Physical Validation: Field Campaigns



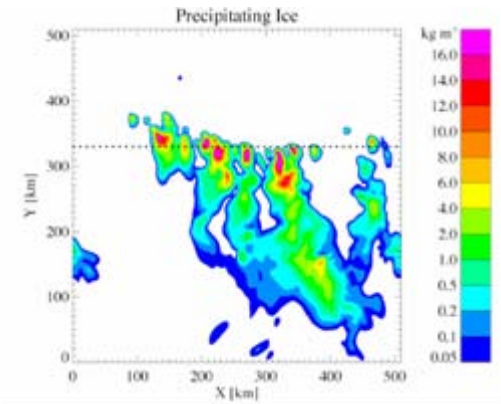
- *From individual hydrometeors to radar/aircraft ensembles*
- *Timescales up to two years for extended observing periods (EOPs), 1-2 months for intensive observing periods (IOPs)*

Statistical Validation: The National Network



- *Measurements on the order of radar networks*
- *Individual radars with radii of 150-300km; networks with large regional to continental coverage*
- *Leverage polarimetric NEXRAD upgrade over US*

Satellite Simulation



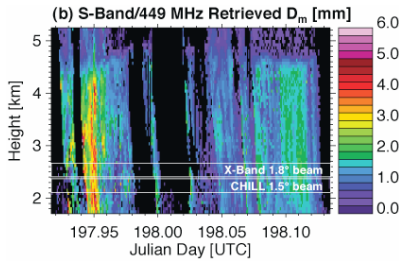
- *Integrate measurements with radiative transfer models across all scales of GV measurement: from the earth-surface to top of the atmosphere*
- *Possibility of expansion to global scale*

Physical validation site objectives

- ***Core and constellation satellite validation (land + ocean)***
  - *Operate long-term field campaigns with EOPs and IOPs with deployable instrumentation*
  - *EOPs: Polarimetric NEXRAD network + multi-frequency scanning radar, ground instrumentation*
  - *IOPs: Aircraft multi-parameter radar, radiometers, and microphysical instrumentation*
  - *Meteorological observations (including frequent soundings)*
- ***Use "Satellite Simulator Models" to quantify uncertainties in GPM products***
  - *Development of end-to-end radiative transfer model, field observations and model data as input*
- ***CRM validation activities***
  - *Initialization (soundings, heat and moisture budgets, CCN and IN)*
  - *Validation*
    - > *Kinematic and dynamic cloud structures (soundings and Doppler/polarimetric radar)*
    - > *Statistical relationship between simulated/observed microwave Tb vs. surface rainfall (aircraft, scanning polarimetric radar, vertically pointing Doppler radars)*
    - > *Microphysical properties over the life cycle of clouds (aircraft and ground based remote sensing, ground-based in situ sampling)*
    - > *Latent heating structures (sounding arrays, scanning polarimetric Doppler radars)*
- ***Coupled CRM-LSM and closure of the water cycle***
  - *CRM validation activities, plus*
    - > *Land surface water and energy budget terms*
    - > *Surface water fluxes (e.g. streamflow)*
    - > *State variables such as soil moisture and temperature profiles, groundwater levels and land cover, vegetation properties, and soil properties.*

GPM GV Pilot studies

- ***GPM Front Range Pilot Project (Colorado - Summer 2004)***
  - *Test of physical validation site framework with multi-instrument ground-based measurements*
  - *Demonstrated the utility of X-Band measurements in using polarimetric rainfall retrievals as low as 2 mm h^{-1} (Matrosov et al. 2006)*
  - *Identified 3 GHz and 449 MHz Doppler profilers as ideal frequency pair for DSD retrieval (Williams et al. 2005, AMS radar conference)*
  - *Highlighted utility of profilers and 2D video distrometers (2DVD) in determining radar uncertainties (Nesbitt et al. 2005, AGU)*

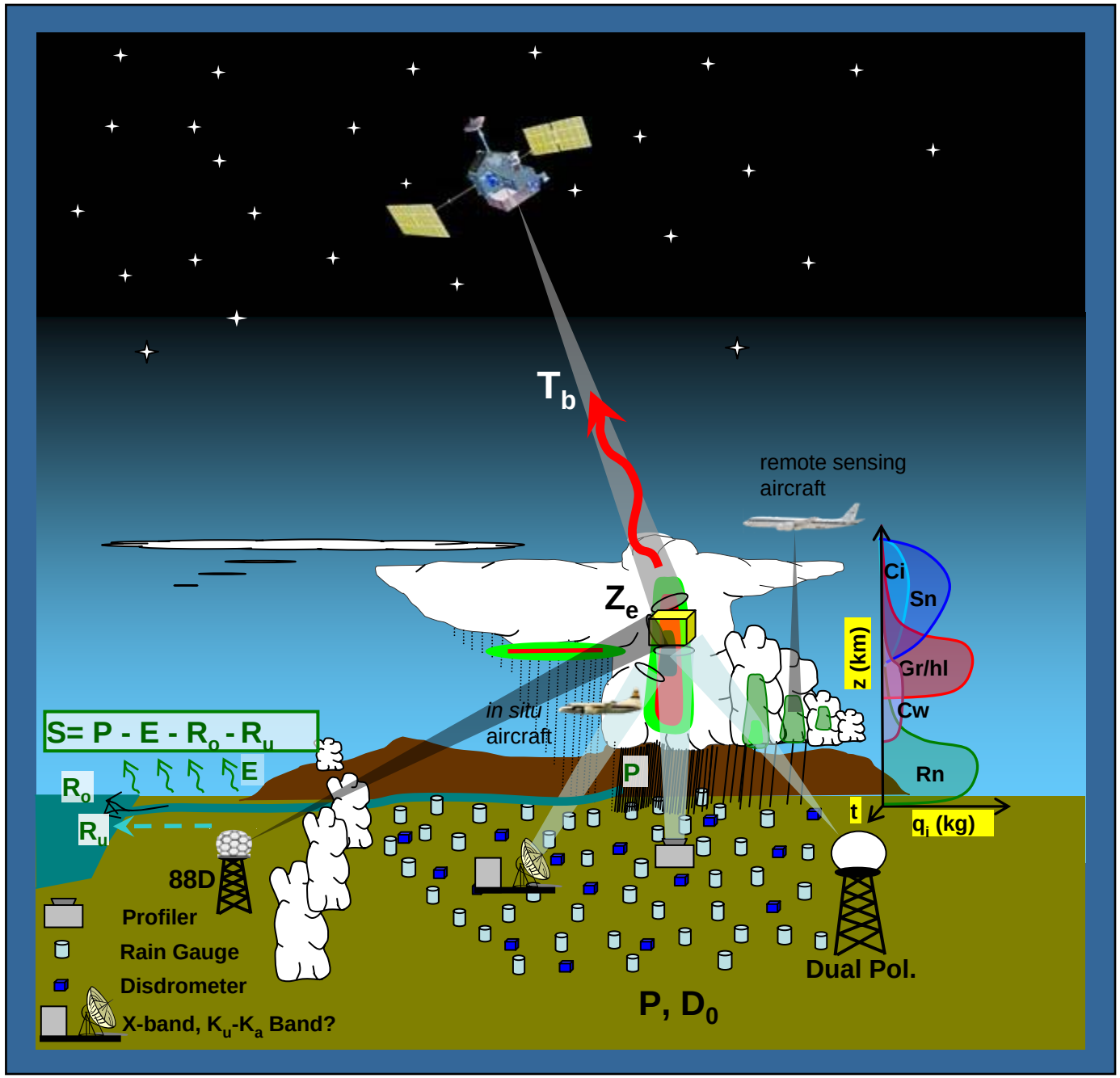


- ***GPM Contribution to Canadian Calipso/CloudSat Validation Project (near Toronto, Ontario - January 2007)***
  - *Template for cold season validation study*
  - *Planned deployment of U. Mass. Advanced Multi-Frequency Radar (K_u-K_a-W Band) polarimetric Doppler scanning radar, alongside C-Band polarimetric radar measurments made by Environment Canada*
  - *Assess 2DVD performance in heavy/blowing snow regime*
  - *Leverage simultaneous aircraft remote sensing and in situ measurements as opportunity to test template for GPM cold season winter validation site*

Physical Validation Site Notional Implementation Plan

- ***Notional ground-based instrument suite provided by NASA GPM***
  - *X-band and/or K_u-K_a dual polarization radar (NASA procurement) - depending on availability at sites (e.g., ARM-SGP AVA or CASA)*
  - *S-band dual polarization radar (NASA "lease" of existing research radar for subset of warm season EOPs)*
  - *2-frequency Doppler radar profiler (NASA procurement)*
  - *Disdrometer and gauge network (NASA procurement)*
  - *All instrumentation planned to be deployable for EOPs*
  - *Instrument operations costs include personnel, spare parts, licenses, etc.*
- ***Aircraft***
  - *Supplement the process study "product packages" during IOPs*
  - *Provide detailed atmospheric radiometric and microphysical measurements during specified IOPs*
- ***Aircraft instrument observations***
  - *TBD Radar/Radiometric observations*
  - *TBD Microphysical observations*
  - *Coupling of high altitude remote sensing aircraft and low altitude in situ aircraft the working template*

GPM Physical validation IOP working template

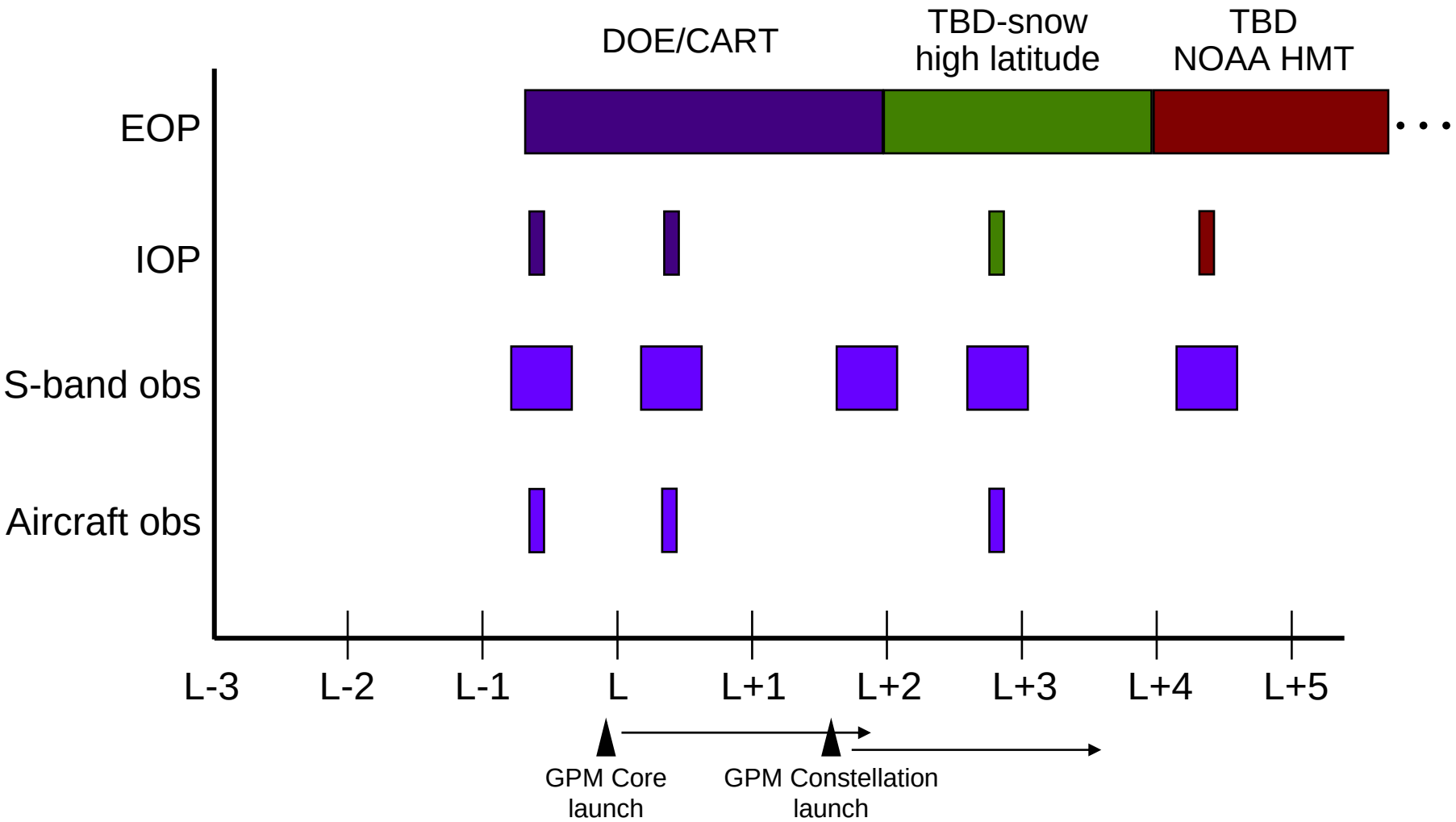


- ***Precipitation Process Studies and Integrated Science conducted as a series of Extended & Intensive Observation Periods (EOPs and IOPs), presented as years relative to launch (L)***

EOP	IOP	Location	Purpose
L-.5 to L+2	L -.5	DOE-CART/SGP pre-launch	Precipitation processes
	L+1	DOE-CART/SGP post-launch	Precipitation processes
L+2 to L+4	L+3	TBD-snow/mixed-phase	Precipitation processes/hydrology
L+4 to L+6	L+5	TBD-NOAA HMT (or equivalent)	Integrated hydrology

- ***Study site locations leverage off of operational agency sites: e.g., DOE CART/SGP and NOAA HMT. Assumptions:***
  - *Initial deployment and operations support of GPM GV instrumentation at CART/SGP*
  - *Extended operations (EOPs) with NASA-provided X- or K- band radar, profiler, disdrometers/gauges; and non-NASA instrumentation leveraged from existing facilities*
  - *Intensive operations (IOPs) with NASA-provided S-band research radar when required (meteorology) and aircraft*

Notional Sequence of EOPs and IOPs



GPM SGP Validation EOP Template

S-Band Polarimetric Doppler Radar

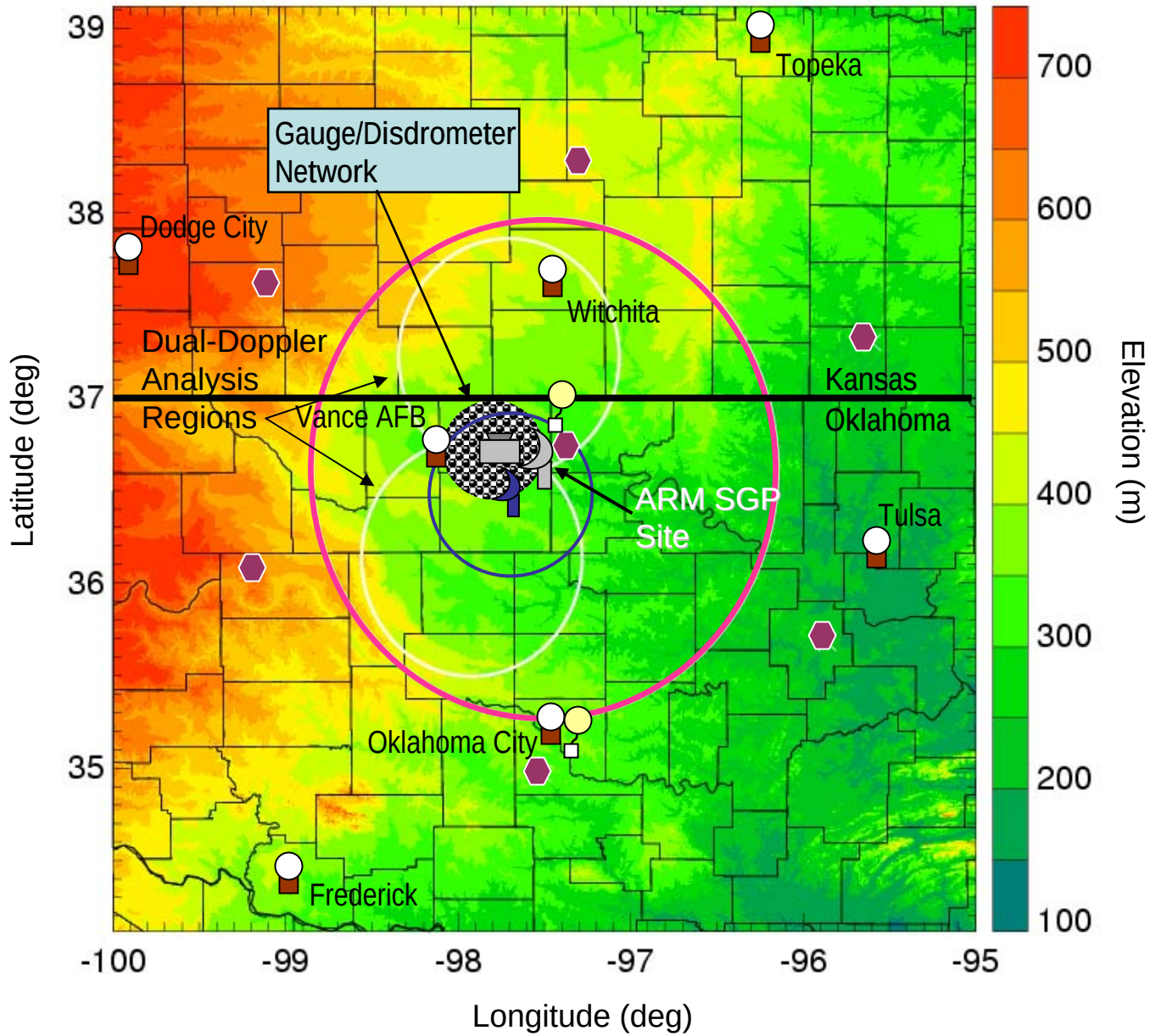
X-Band and/or K_u - K_a Band Polarimetric Doppler Radar

Existing NEXRAD S-Band Doppler Radar

Existing Radiosonde Site

Existing Wind Profiler

Precipitation Profiler



Why GPM EOP at SGP would be mutually beneficial

- ***Proposed infrastructure provided by GPM would augment what is already a world-class observing facility***
- ***Extensive existing measurements at and around SGP greatly benefit GPM measurement requirements***
  - *Location close to existing resources for validating CRMs*
    - > *Existing CART sounding site(s) and NOAA profiler network, cloud and atmospheric state measurements*
  - *Hydrologic Applications*
    - > *Will identify potential instrumented & instrumentable watersheds for hydrologic applications*
- ***GPM would provide ARM with a long-term research quality precipitation dataset, and augment current remote sensing capabilities at the CART site***
  - *Potential for coordinating instrument deployments and IOPs*
- ***Staff expertise, instrument procedures, history at SGP site would provide keystone for potential GPM implementations at SGP***
- ***The GPM project wishes to keep an open dialogue on potential CART implementations and cost sharing opportunities for our mutual benefit***