CEOS WGCV Plenary Meeting 28

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Microwave Sensor Subgroup Report

25-29 February 2008
Sanya, Hainan Province
People's Republic of China

Microwave Sensor Subgroup Meeting ESA/ESTEC 22-23 January 2008

- Re-launch of the Microwave Sensor Sub-group
- ~20 attendees from across Europe and one from US
- Chance to (re-)establish “ground rules” and structure of the subgroup
- Encourage active participation in CEOS and CEOS/WGCV and hence GEO, GEOSS
- Key presentations invited from a number of leading experts
- Gauge interest, opinions, level of participation
- Assess major issues facing cal/val of microwave sensors

Agenda – MSSG Meeting 22-23 January 2008

1. Key presentations on microwave instruments
2. Review of the sub-group's terms of reference
3. Structure of the sub-group
4. GEO/CEOS Actions
5. Cal/Val Portal
6. GEO Tasks
7. Date and venue of next meeting
8. AOB

MSSG Meeting Presentations

- Radiometric Calibration and Validation of the Advanced Wind Scatterometer (ASCAT) aboard the Metop Satellite, J Wilson, Eumetsat
- Geophysical Calibration of Scatterometers, A Stoffelen, KNMI
- Absolute Calibration and other Measurement Accuracy Problems Related to Airborne Microwave Radiometer Systems , Niels Skou, DTU
- Calibration Approach for ESA's Forthcoming SMOS Mission, Y Kerr, Cesbio
- Potential for Calibration and Validation Activities of the Dome-C Area of Antarctica, M Drinkwater, ESA
- Challenges Facing the Calibration and Validation of CryoSat-2, S Laxon, CPOM
- Calibration of Ice Sounding Radars, S Gogineni, Kansas University
- Overview of the Use of Reflected Global Navigation Satellite System Signals for Remote Sensing, A Helm, GFZ
- Processing and Validation of the GPS Occultation Instrument, GRAS, on board the Metop Satellite, J Wilson, Eumetsat
- Some Statistical Issues Relating to the Calibration of the Significant Wave Height as Derived from Radar Altimeter Data, P Challenor, NOC

Microwave Sensor Subgroup

- **Mission**
  - To foster high quality calibration and validation of microwave sensors for remote sensing purposes. These include both active and passive types, airborne and spaceborne sensors.
- **Terms of Reference**
  - The objectives of the Microwave Sensors subgroup, beyond those of the WGCV, are to:
    - Facilitate international cooperation and co-ordination in microwave sensor cal/val activities by sharing information on sensor development and field campaigns
    - Promote accurate calibration and validation of microwave sensors, through standardization of terminology and measurement practices
    - Provide a forum for discussion of current issues and for exchange of technical information on evolving technologies related to microwave sensor cal/val

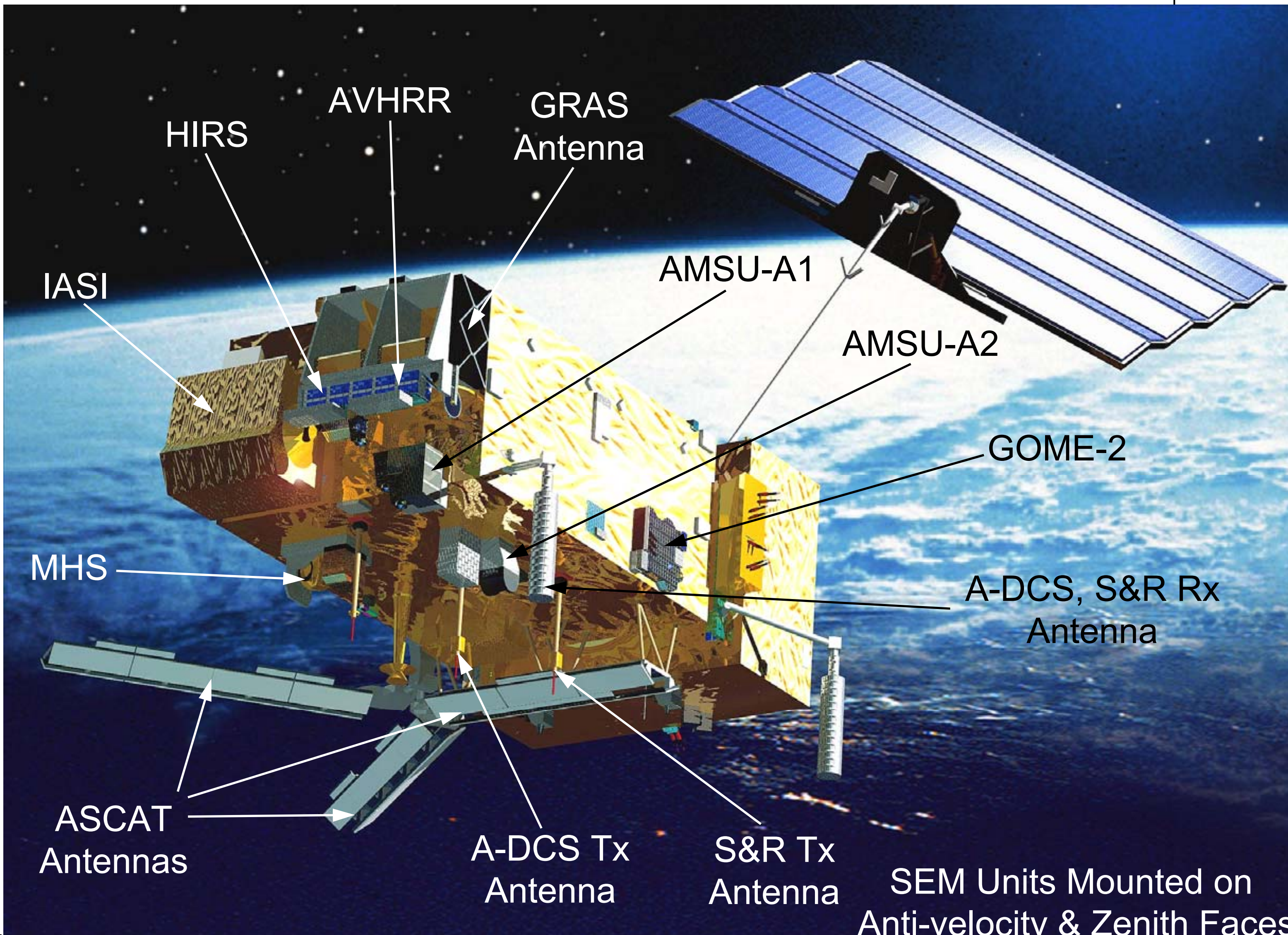
Microwave Sensor Subgroup
Previous Action Plan

- The plan of action for the subgroup is based on spaceborne microwave sensors
- The subgroup is concerned mainly with passive sensors at the present; however, it is envisioned that there will be a gradual increase of attention to active sensors, especially towards the end of the three-year period of this plan
- The subgroup will approach its objectives by starting from currently operating sensors, such as those flying aboard the DMSP and NOAA platforms, and extending to the next generation of sensors
- A focal point will be sensors aboard the EOS platforms of ESA, Japan, and the United States, as there will be both active and passive sensors covering a large part of the microwave spectrum

Microwave Sensor Subgroup
Revised Action Plan

- The plan of action for the subgroup is based on spaceborne microwave sensors and airborne microwave sensors where they support space missions
- The subgroup embraces all microwave sensors, both passive and active, with the exception of synthetic aperture radar
- The subgroup is concerned not only with the calibration and validation issues of currently operating (spaceborne) sensors but also with the next generation of sensors
- The subgroup is committed to supporting the general activities of CEOS WGCV and the tasks passed to it by GEO etc.
- Currently the intention is to meet at least once a year in order to communicate the latest findings amongst the members of the subgroup and to support the completion of tasks

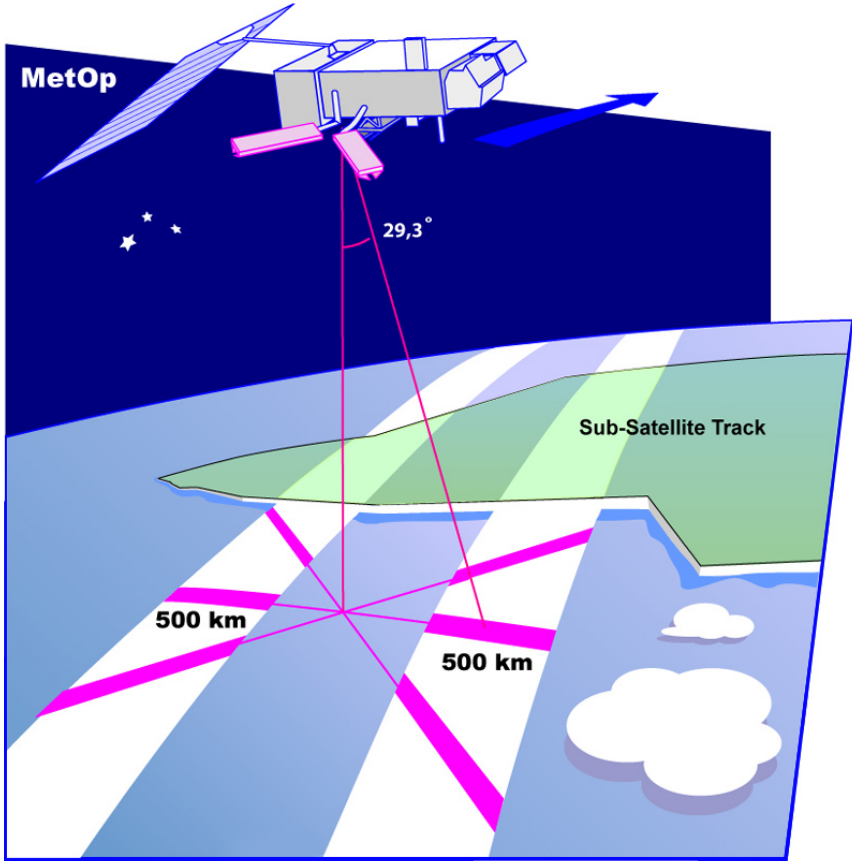
ASCAT on METOP



ASCAT

- Six antennas producing six beams
- Three beams observe left swath & three beams observe right swath
- Symmetrical beam configuration between left & right swaths
  - Fore Beam 45º
  - Mid Beam 90º
  - Aft Beam 135º - from satellite heading
- Each beam measures radar backscatter cross-section
- Follow-on from ERS-1 & ERS-2 AMI-SCAT
- Two 550km swaths (left & right) instead of single 500km Swath
- Different measurement techniques
  - ASCAT Long FM Pulse instead of
  - ERS Short Pulse
- Different RF power amplification
  - ASCAT SSPA instead of
  - ERS TWT
- ASCAT – excellent internal calibration & timeline

ASCAT Measurement Configuration



- Two 550km swaths with incidence angle range of 25° - 65°
- 3 fan beam antennas looking towards each swath
- Real-aperture radar
  - C-band (5.255GHz)
  - VV polarization

ASCAT Objectives

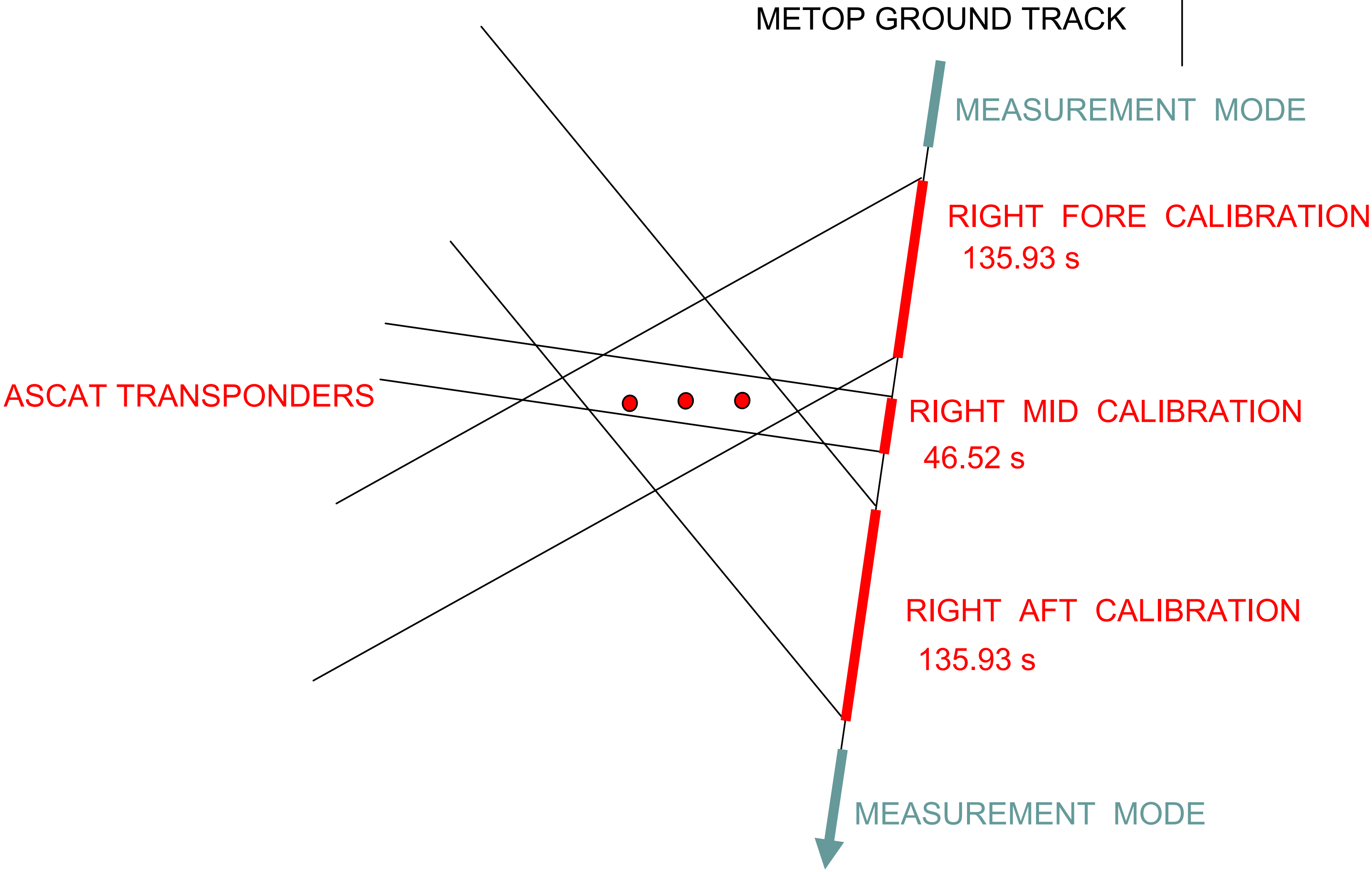
- Prime Objective
  - Measurement of Wind Speed and Direction over the Oceans (using CMOD5 Model)

- Secondary Objective
  - Also provides useful data for Ice & Land applications (e.g. Sea Ice Extent, Permafrost Boundary, Desertification, etc.)

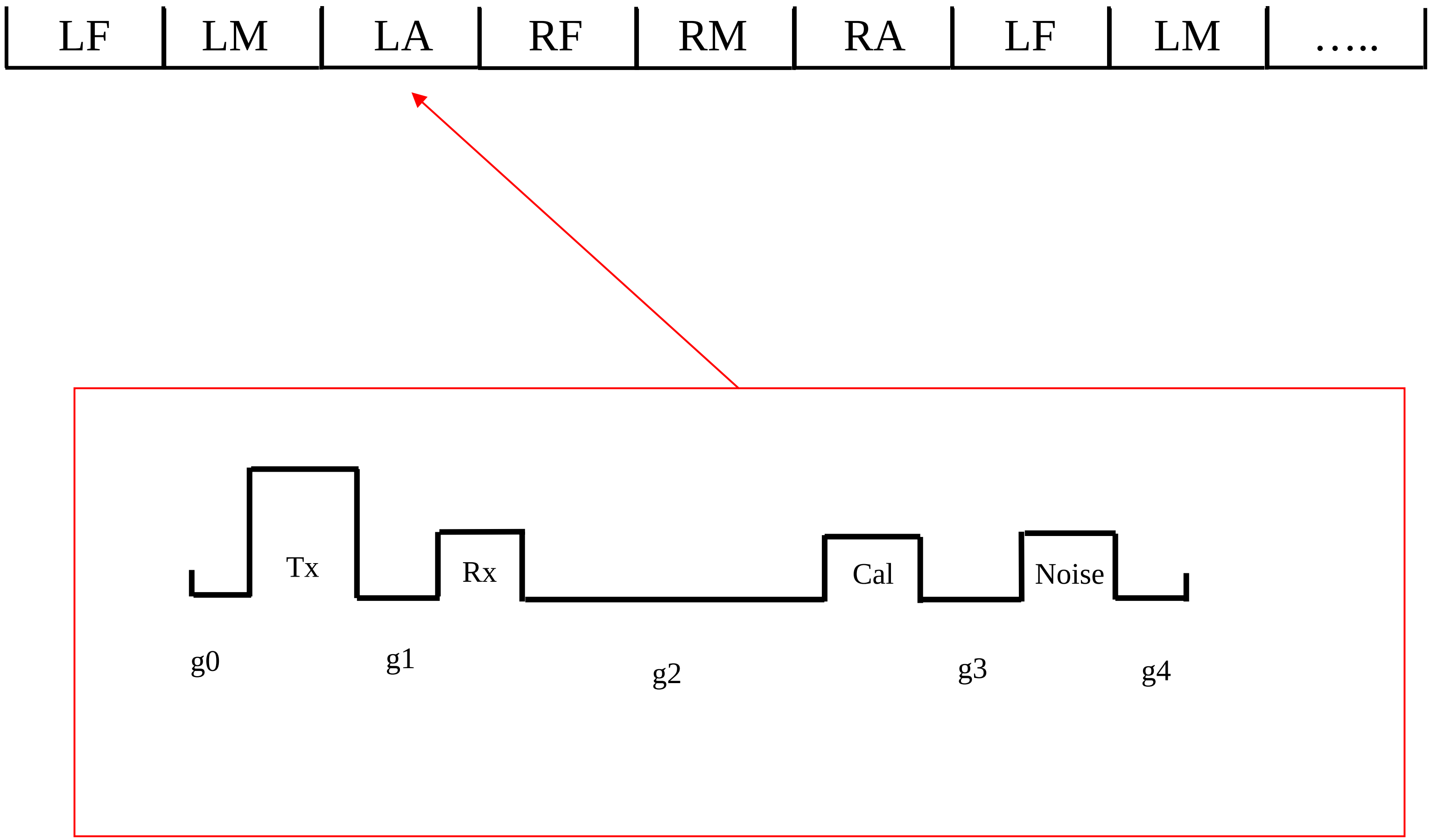
ASCAT Calibration

- The scientific value of the data is directly related to the quality of the radiometric calibration
- Therefore achieving, maintaining and demonstrating excellent radiometric calibration is of the utmost importance
- ASCAT calibration is performed using three active calibration point targets with internal time delays and with very accurately known point target cross-sections - the ASCAT transponders

ASCAT Calibration Pass



ASCAT
Calibration Timeline



ASCAT
Calibration Towers – Turkey

ASCAT Expected Performance

- The technique described can be used to determine and monitor the in-flight antenna one-way power gain patterns and their orientations

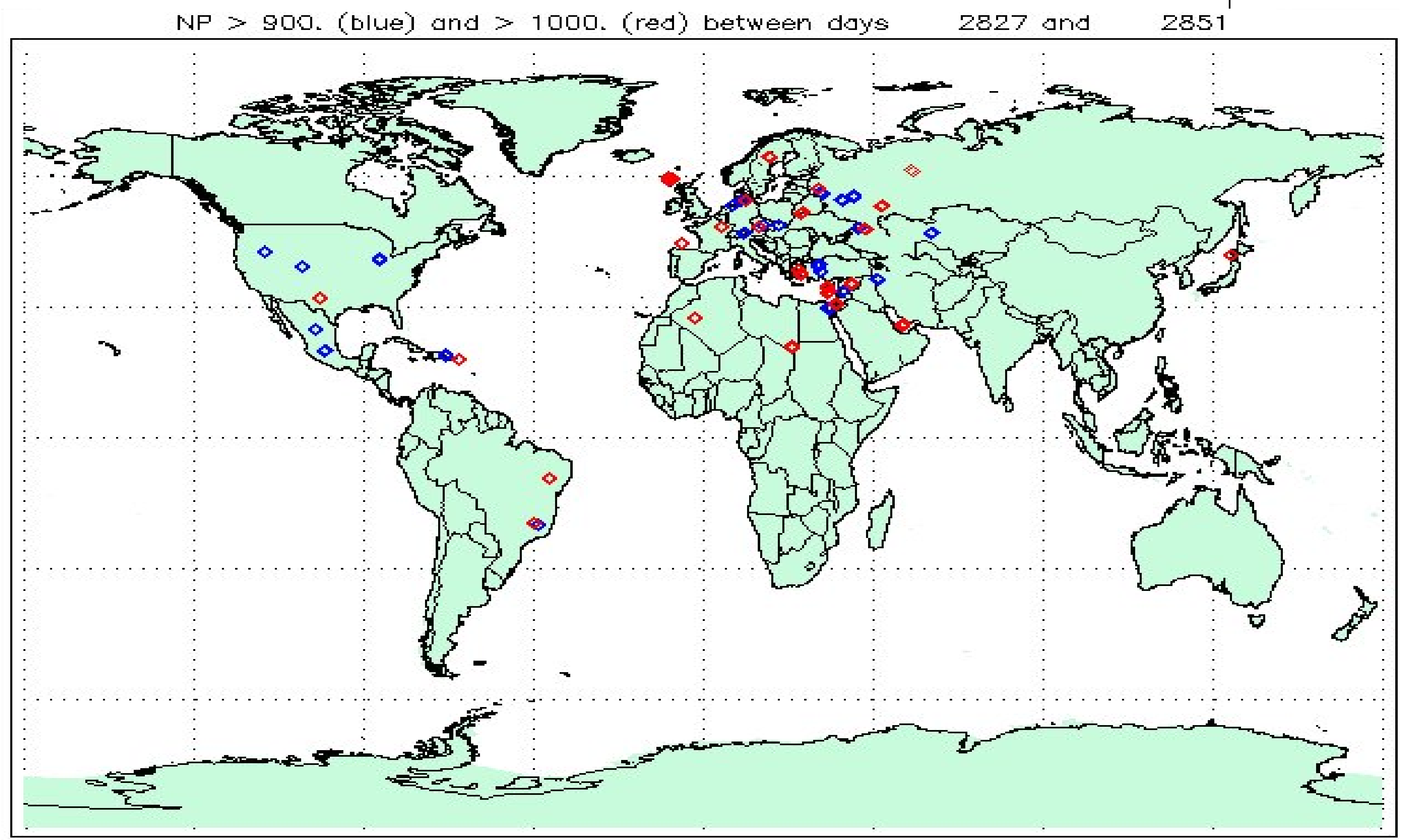
- Performance
  - Δ Gain ± 0.05dB
  - Δ Elevation Angle ± 0.08º
  - Δ Azimuth Angle, Δ Skew Angle ± 0.0025º

- Given good satellite, instrument and transponder performance, ASCAT may well be the best calibrated spaceborne radar ever [*sic*]

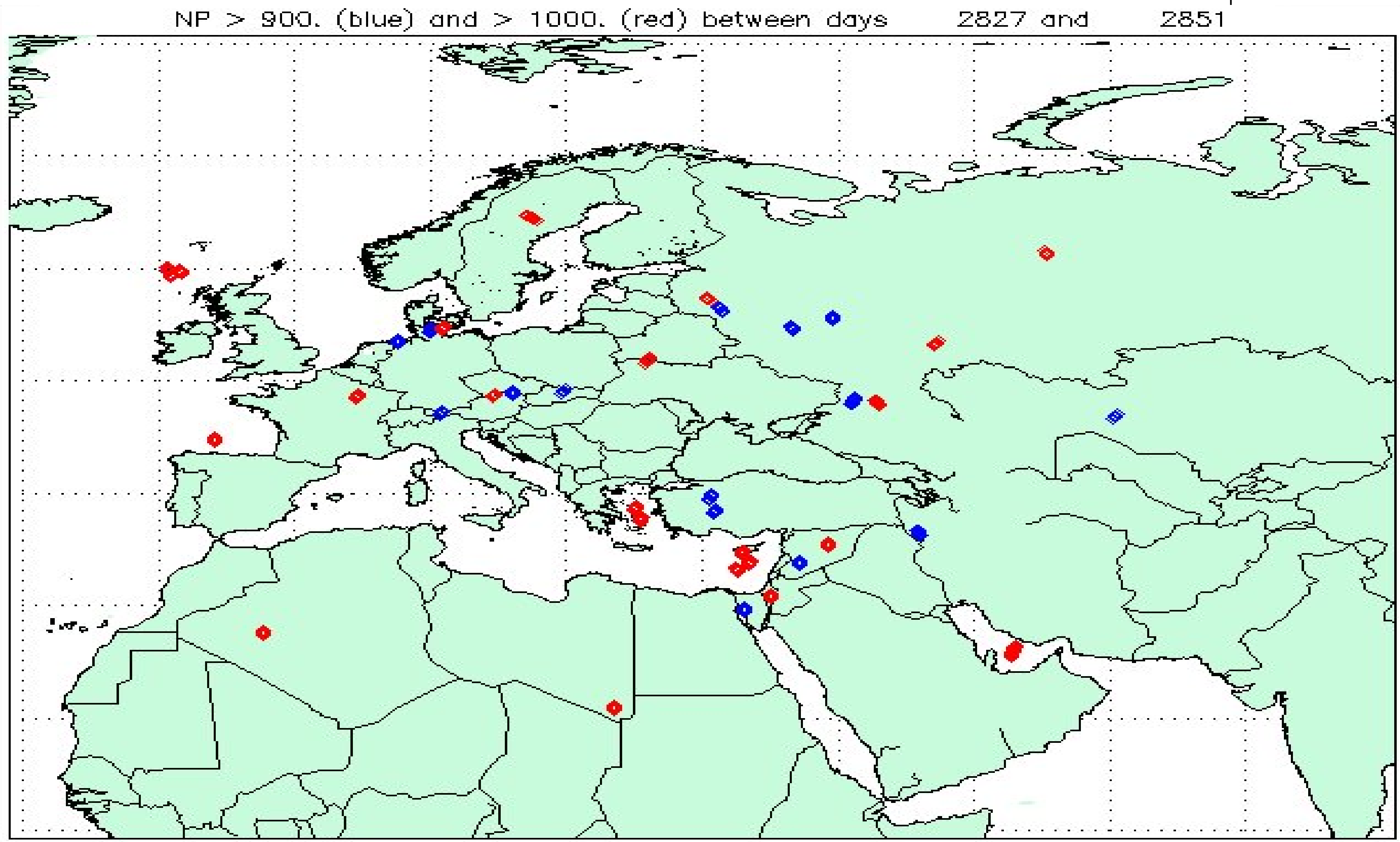
ASCAT Detected RF Interference

- ASCAT's calibration mode consists in part of taking noise measurements
  - Radar operated in "listen only" mode
  - Persistent high signal strengths over certain areas
  - Sources referenced to centre of radar beam therefore not geographically accurate although consistent
- Plots routinely produced by Eumetsat
  - Centre frequency 5.255GHz
  - Bandwidth ~200kHz

ASCAT RFI



ASCAT RFI – Europe



SMOS

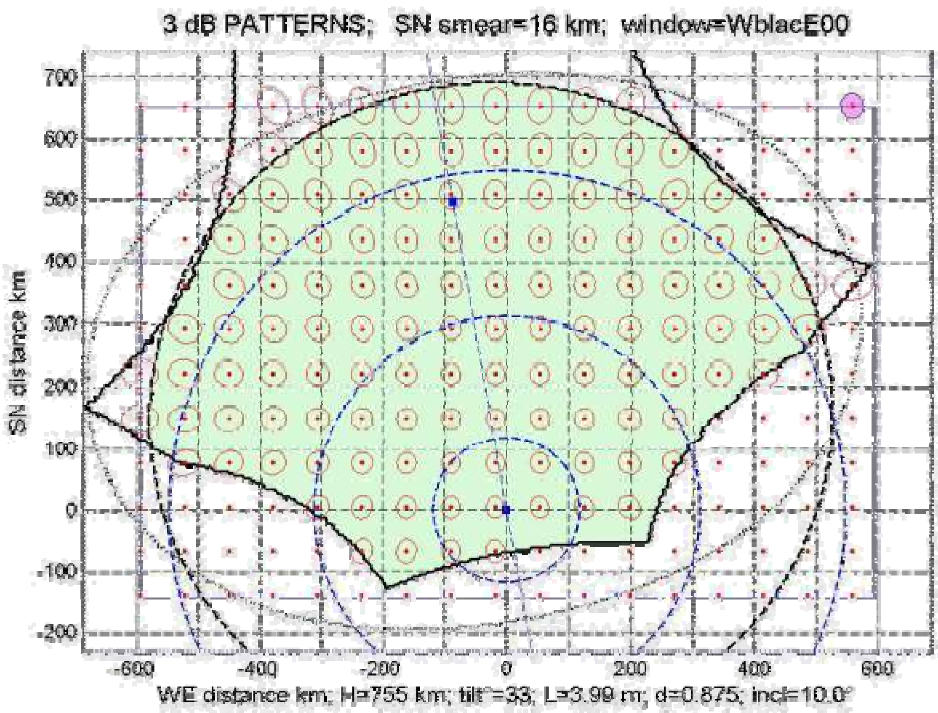
- Conclusions from PI Y Kerr (Cesbio)
  - SMOS will be the first mission to deliver global fields of soil moisture and sea surface salinity
  - It is an EXPLORER Mission
    - => new concept new instrument new measurements!
  - The challenge:
    - NO data exists, NO Algorithms exist
    - New ground is being broken
  - Requires extrapolation from higher frequency results and/or local ground measurements
  - Cal/Val is a challenge

SMOS Validation Summary

- Relatively easy over the oceans
  - Tie-in with Cal
  - Spatial and temporal stability
- Relatively impossible over land
  - Hydrologic modelling and data assimilation (Val and high levels)
  - Satellite data and algorithm inter-comparison
- Long term measurement networks
  - drifts, consistency, special events
- Field experiments
  - snapshots with high spatial resolution over footprint (!)

SMOS Footprint

- Each integration period, (2.4s) a full scene is acquired (dual or full pol)
- Average resolution 43km, global coverage
- A given point of the surface is thus seen with several angles
- Maximum time (equator) between two acquisitions: 3 days



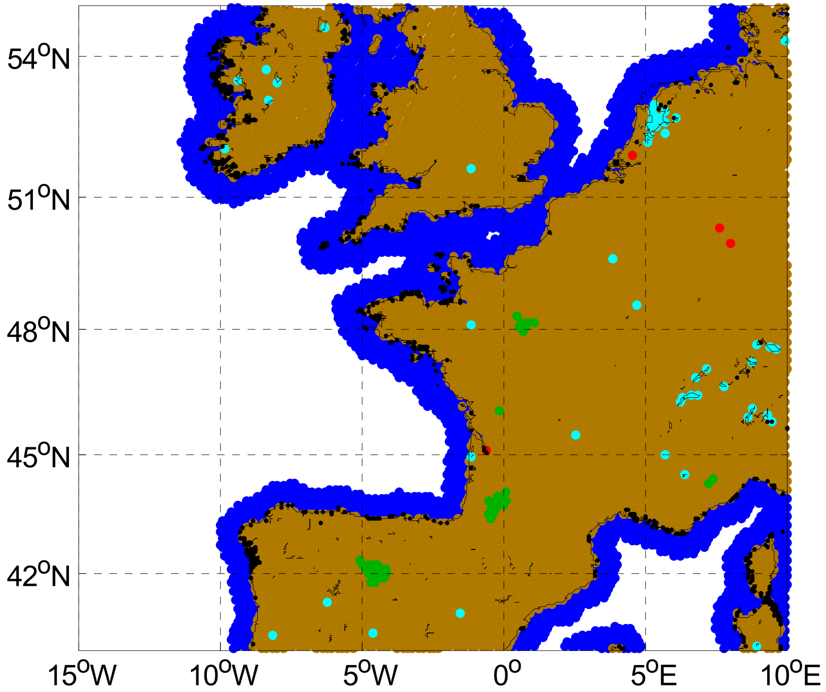
SMOS FOV; 755km, 3x6, 33°, 0.875λ

SMOS – Pure Pixels?

WA_DGG_exact

Colour code

- **Ocean**
- **Inland water body**
- **Rivers**
- **All others**
- **WA_DGG_nowater**



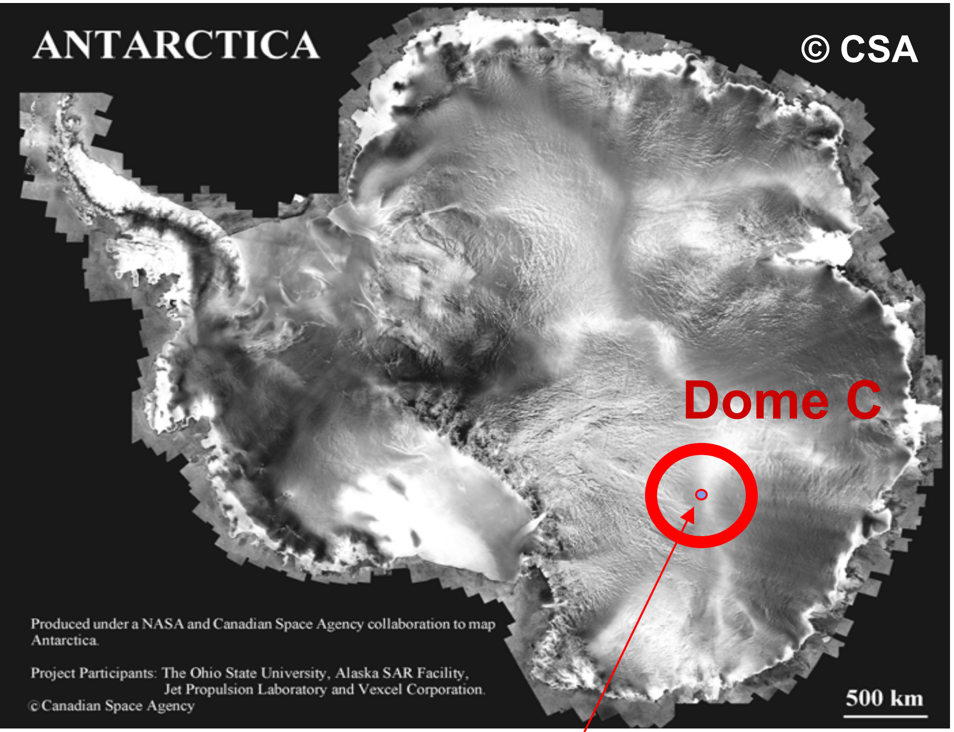
Cal/Val Requirements of Spaceborne Microwave Radiometers

- Detection of long-term climate trends using satellite radiometer data requires accurate calibration and validation of the observed signals (i.e. including absolute bias & drift corrections)
- The following are needed:
  - Internal (on-board calibration)
  - External (independent) calibration reference targets (to bracket the range of expected Tbs)
- Inter-satellite biases must be corrected during periods of mission overlap
- Verification of calibrated Tbs over time using external calibration database comprised of time-series data from reference sites (e.g. Dome-C)
  - Characterization of <1/day variations in performance requires sub-daily Tb's sampling (i.e. high-lat. sites advantageous for polar orbiting satellites)

Potential Large External Calibration Sites

- Sandy desert (e.g. Sahara)
  - Deep penetration depth, temporal stability of the Tb, underground structure TBD
- Rocky/mixed desert (e.g. Gobi)
  - Shallow penetration depth, azimuthal effects and vegetation TBD
- Rainforest (Amazon)
  - Volume scatter, effects of rain cells on the canopy equivalent moisture TBD
- “Stable” ocean areas
  - Effects of the wind/salinity at L-band TBD
- Antarctica
  - Dry atmosphere, large penetration depth & temporally stable, low azimuthal anisotropy

Dome-C – Location



Concordia Station (Dome C): 75.125 S, 123.25 E

- High-latitude sites offer frequent overpasses (on crossing orbits) of polar orbiters
- Light wind and uniform wind direction
  - Minimal variability in surface roughness effects on top of Dome-C
- Minimized surface anisotropy at C-/Ku-band on ridge lines and high elevation domes
  - Proved in ERS/NSCAT/QSCAT
- Location maximizes multi-azimuth/incidence “looks” with side- or forward-looking instruments

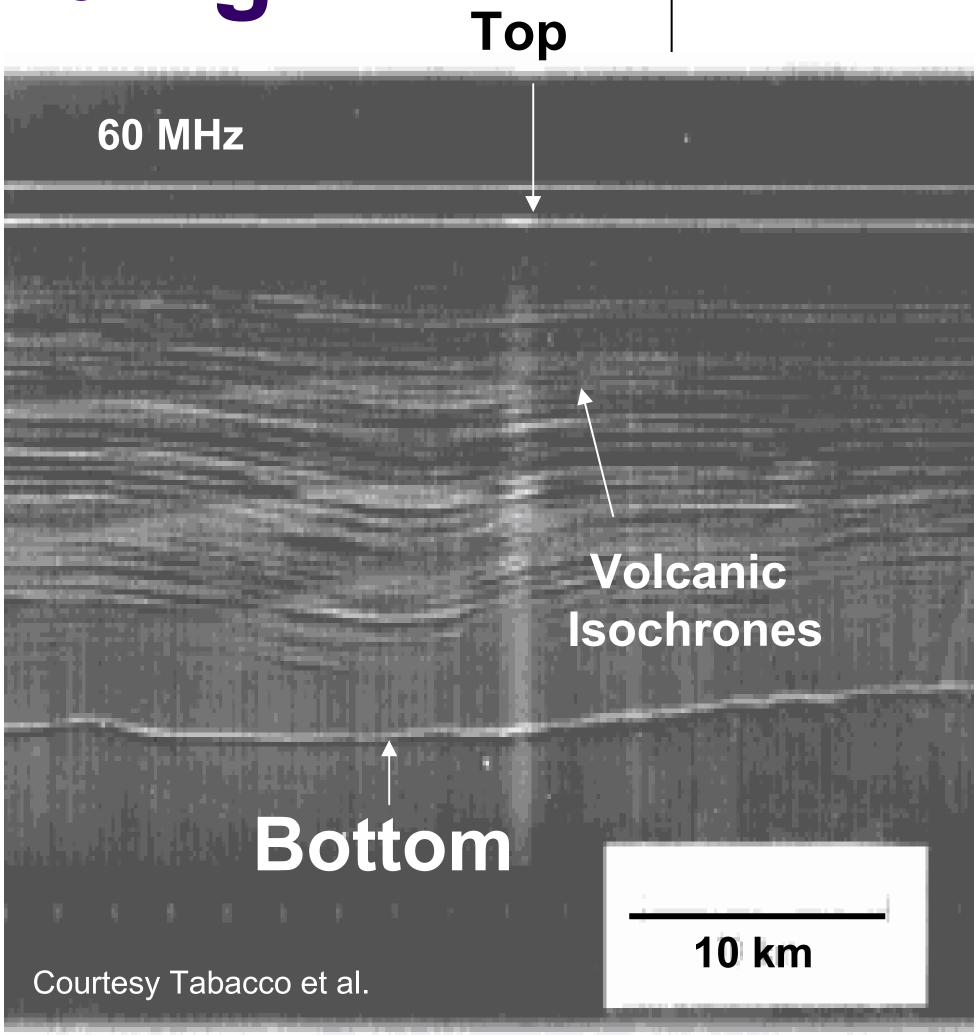
Dome-C
Concordia Station

Dome-C Characterization for Remote Sensing

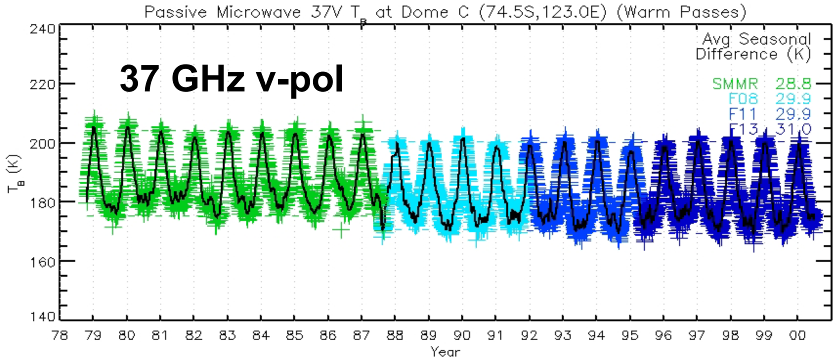
- Active microwave/UHF data
  - Radio Echo Sounding;
  - ERS-1/2 Wind Scatt;
  - ERS-1/2, Envisat, and Radarsat C-band SAR images
  - NSCAT/QSCAT(SeaWinds) Ku-band data
  - Radarsat SAR Mosaic (RAMP)
- Passive Microwave T_b time-series data
  - SMMR + SMMI historical 6/10/19/37/85 GHz data
    Spans 25 year period 1978 – present day
  - C-band radiometer on SMMR and AMSR

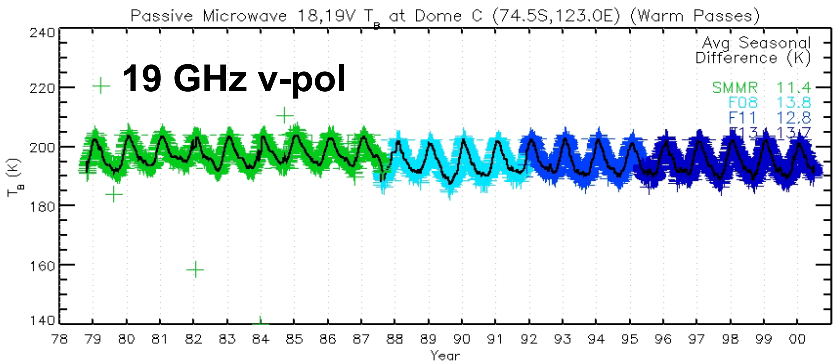
Dome-C
Radio Echo Sounding

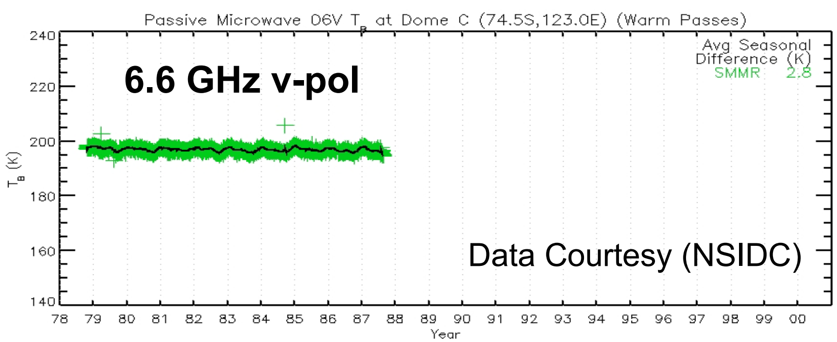
- Uniform layering to bottom
- Several km deep ice
- Penetration depth at L-band estimated to be of the order of several hundreds of metres to kms
  - Knowledge of loss part of complex permittivity poor at L-band
  - P-band (opposite) penetrates to bedrock
- Ice core properties serve as reference to e-m modelling



Dome-C T_b – Seasonal Cycle

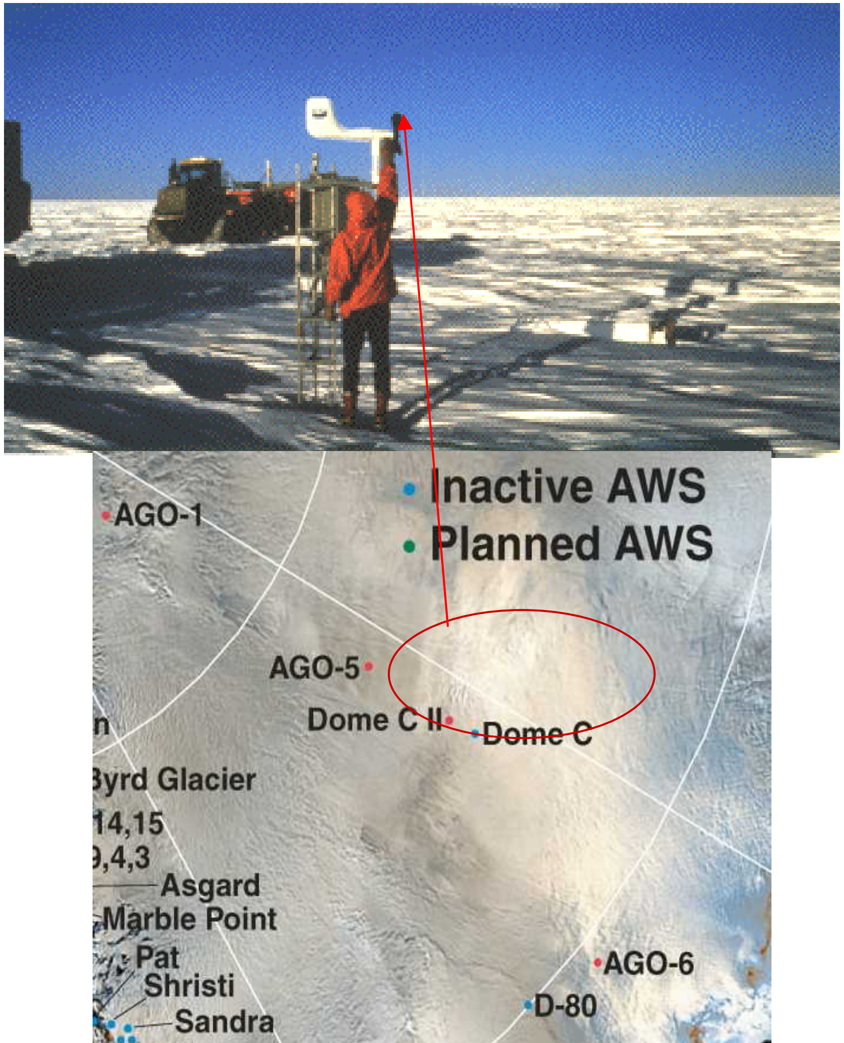






- Continuous >25 yr record of bi-polar microwave Brightness Temperature (T_b) from SMMR (green) + SSM/I (blue)+ AMSR (ADEOS-2 and EOS Aqua)
- Brightness temperature variations dominated by seasonal air temperature cycle (see: 37 & 19 GHz)
- Significant decay in amplitude with increasing microwave wavelength - due to greater transparency and penetration, and damped seasonal cycle with depth (down to 10m)
- Estimates indicate C-band emission from depths exceeding several metres
- Estimates imply L-band emission from a few hundred metres to kilometres depth

Dome-C – *In-Situ* Measurements



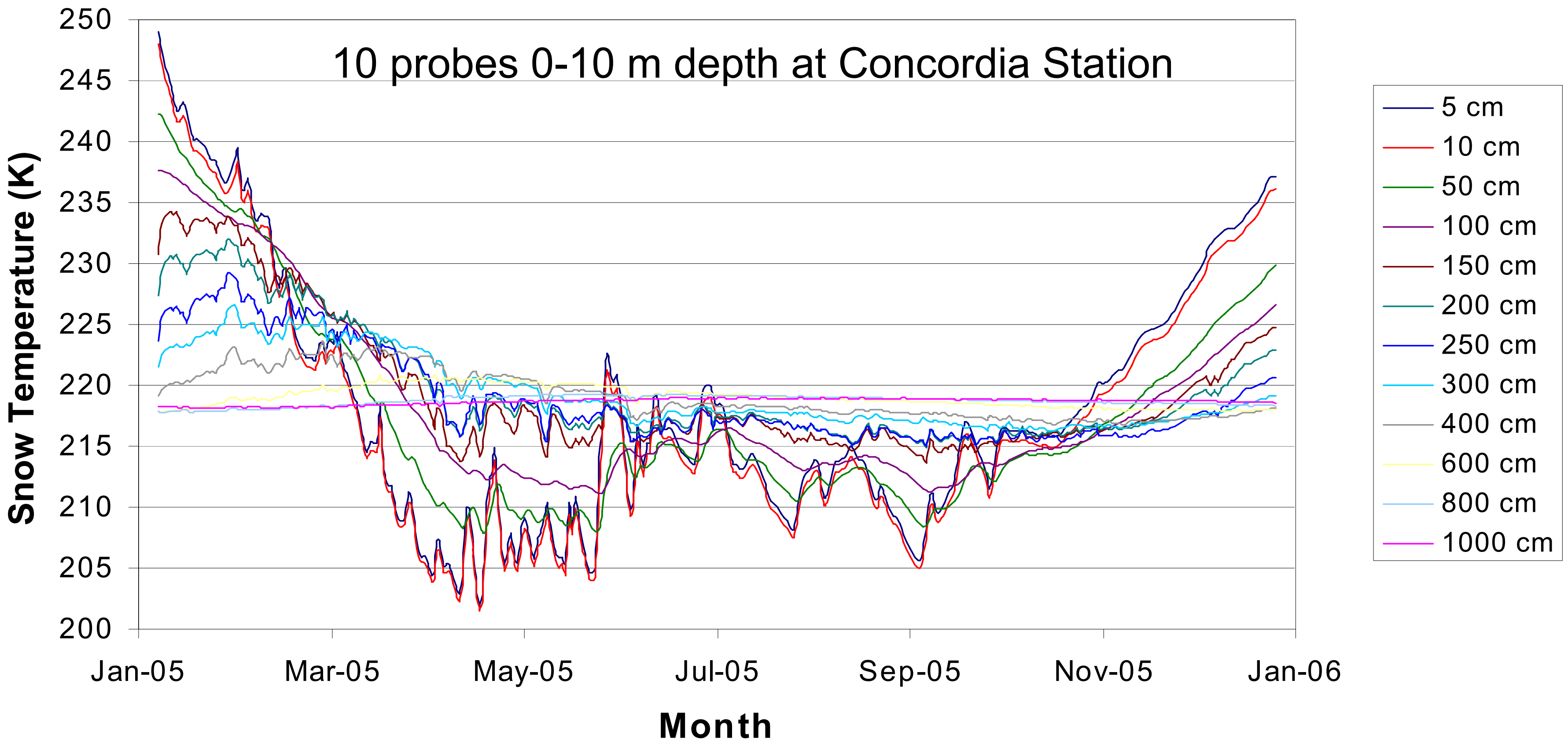
- Automatic Weather Station (AWS)
  - continuous record (> 10yrs)
- In-situ snow pit and EPICA ice core vertical profiles
  - Thermistor temperature depth profile
- Other DC tower-based activities
  - Optical BRDF ('02-03; '03-'04; '04-'05)
  - IR surface temp
  - GNSS(R) - TBC
  - Potential others: Scat??

Snow Measurements

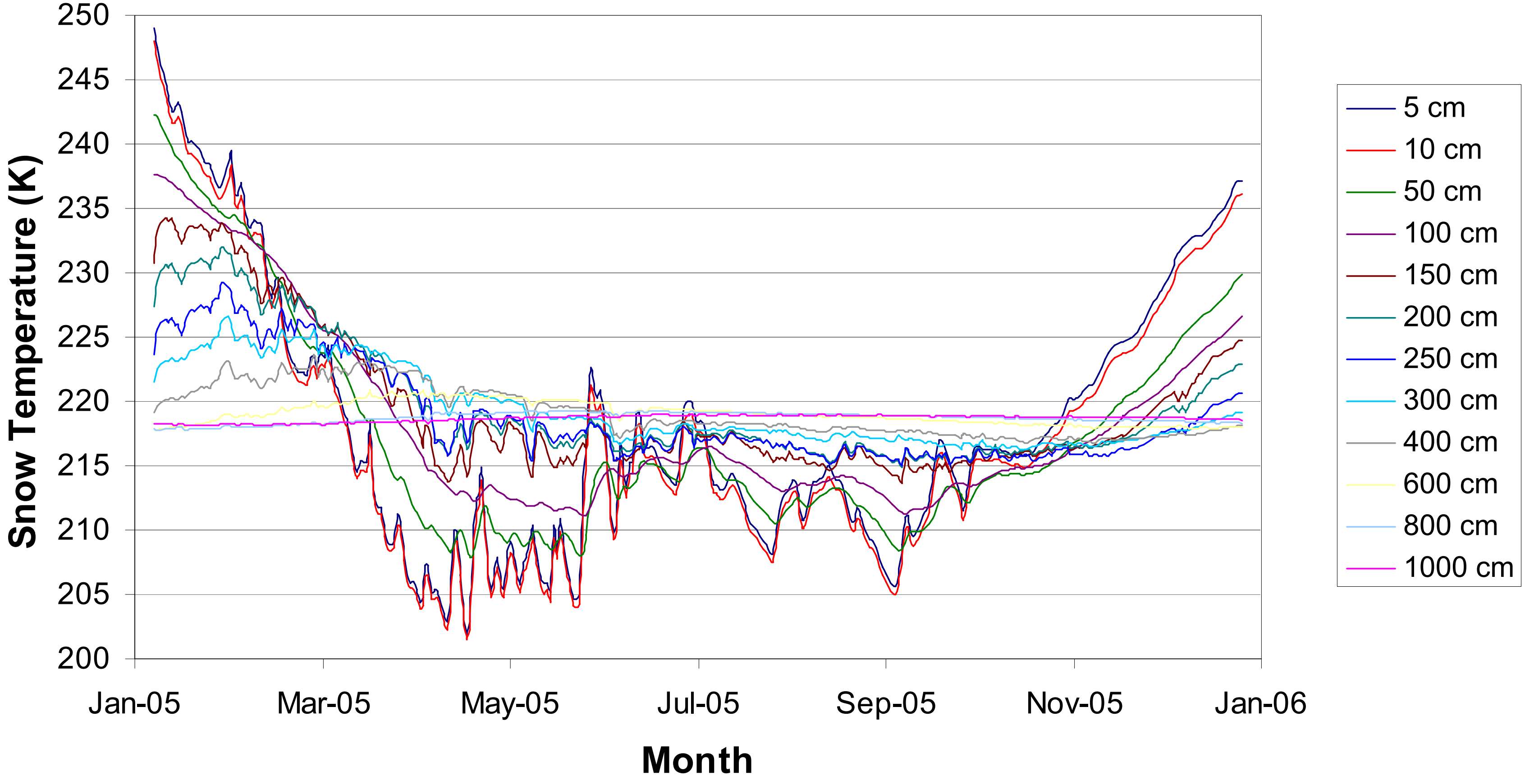
Snow Deposition:
Grain shape and size
Classification (precipitation, hoar, wind, etc.)

Snow layers:
Temperature
Hardness
Density
Grain shape and size
Dielectric Constant

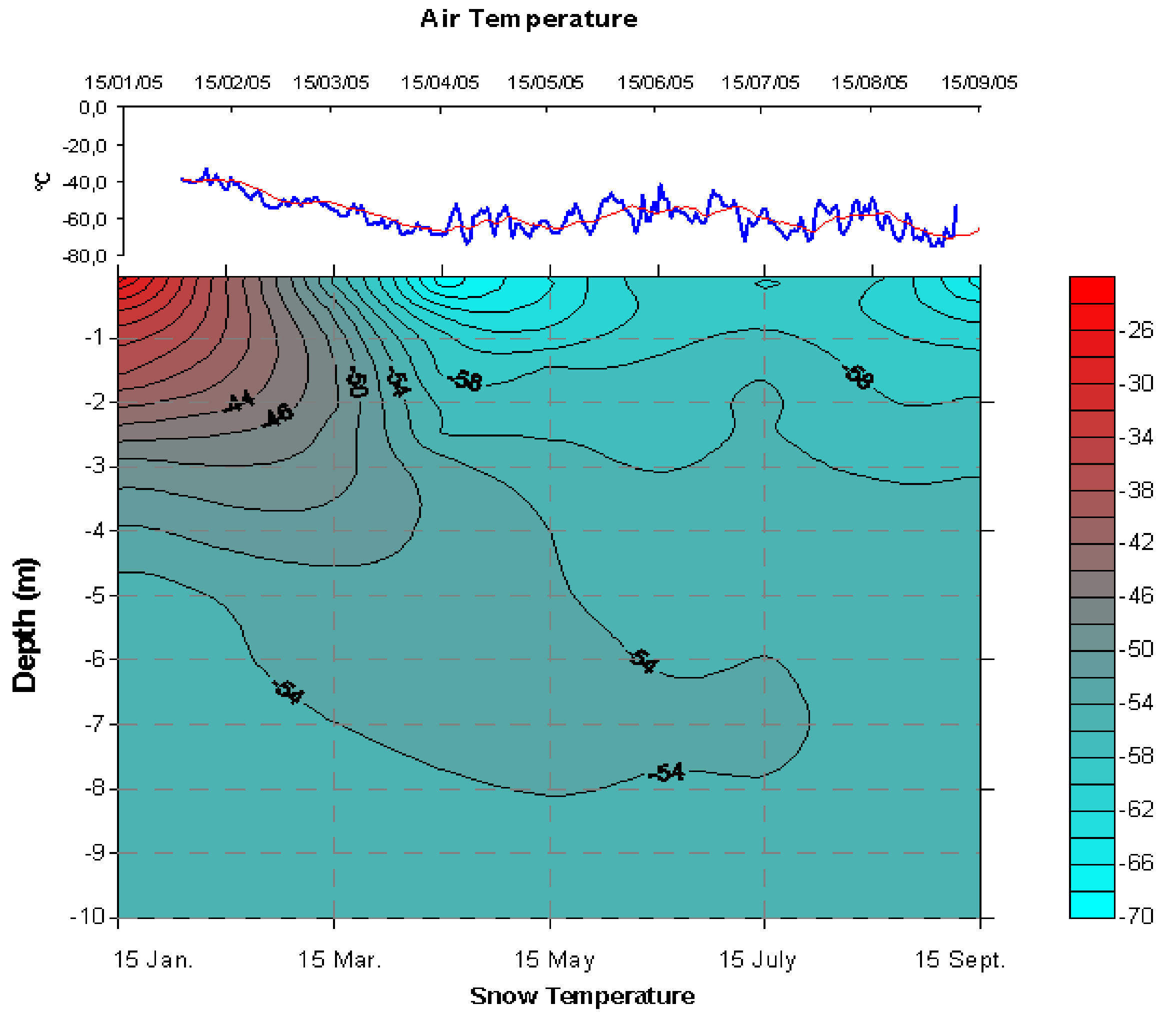
1 Year – Temperature of Snow



Temperature of Snow over One Year



Results – Snow Temperature

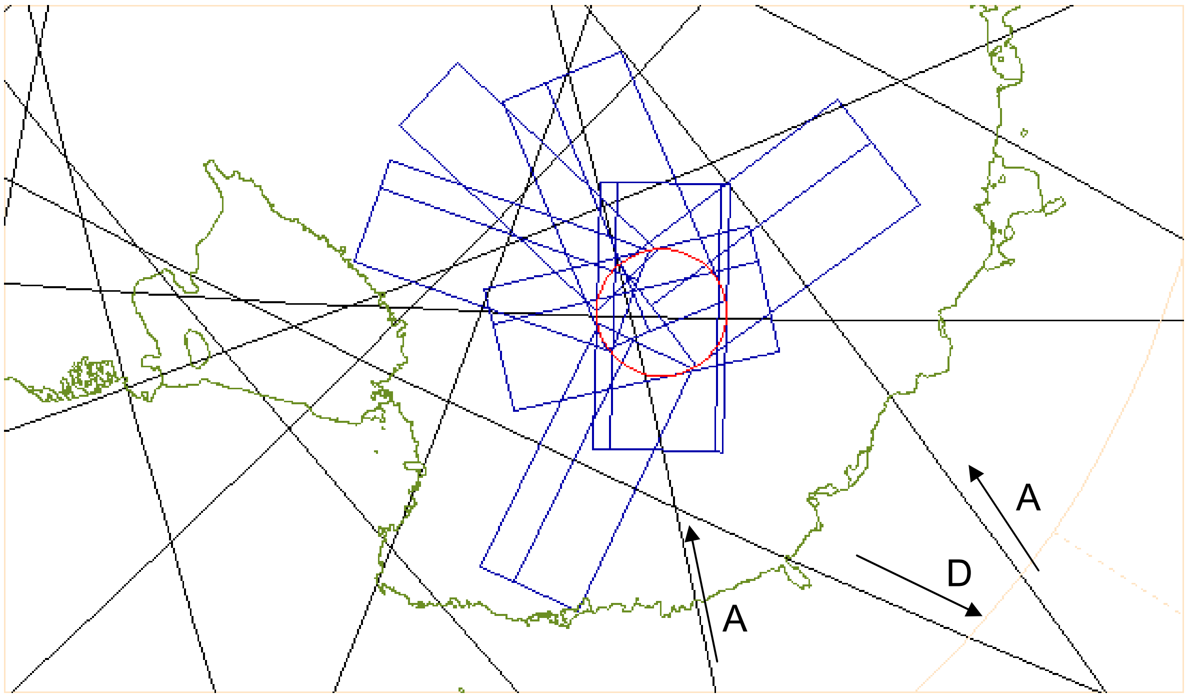


SMOS Calibration Issues

- Monitoring of the long term trend of the signal needed for
- Identification of long-term calibration drift or degradation of the system

- Need for an external target stable both temporally and spatially
  - Limited (monitored) temporal changes in the target structure and temperature
  - Geometry of observation shall have negligible impact
    - Azimuthal variations, heterogeneity on intra- and inter-footprint scale

Typically 2-7 Overlapping Passes per Day



SMOS swath overlap - over Concordia
500km diameter circle centred on DC
149-day repeat cycle (2144 orbits); Reference: 0.133500 deg, orbit 1; First orbit 1, Last orbit 14, Drift 0.000000

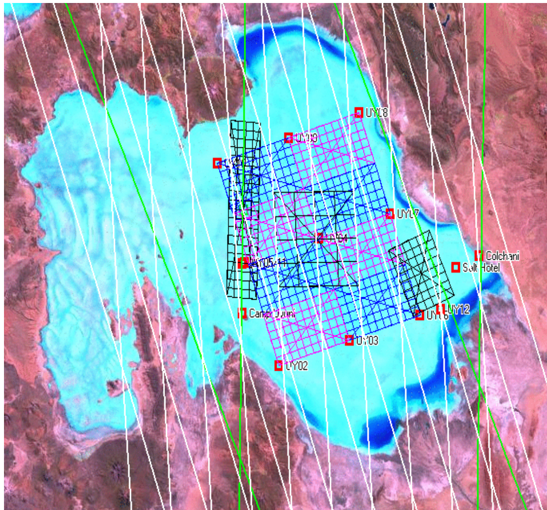
Future Issues/Interests

- Simulations of seasonal fluctuations of the L-band radiometric signals indicate annual amplitude of <0.5K
  - This will be confirmed in a year-round field campaign – 08/09
- Loss factor of snow / ice / firn at L-band is critical in controlling penetration of L-band signals
  - Requires firn measurements
- Effect of layering on de-polarization
  - EM model development
- Temporal survey of the ionosphere at high latitudes
  - Correlation with regional and global indices and with ancillary measurements
- Such a study may be valuable in preparation for SMOS cryosphere data exploitation

Other Opportunities

- Calibration and Validation possibilities exist for
  - CryoSat-2
  - ASCAT
- ADM-Aeolus mission (equipped with Doppler wind LIDAR)
  - ADM-Aeolus will measure tropospheric winds
  - Synergy aspects with surface lidar
- EarthCARE Mission

Inter-Satellite Calibration



Recommendations

- European organizations in particular, are generally not good at releasing data
  - Too often national and commercial interests block cooperation in data sharing
  - Subgroup calls for more openness in data policy
- Instrument cal/val plans as input to GEO-10 (best practices)
  - Can serve as inspiration to others
- Subgroup recommends to store cal/val plans in open repository (e.g. CEOS cal/val portal)
- Recommendation for cross-calibration of ASCAT, SeaWinds, Indian and Chinese scatterometers and check for overlap
  - Eumetsat to provide info to subgroup on all scatterometer missions

Follow up

- Second MSSG meeting should to be held preferably within the year
  - Consensus of opinion was that autumn 2008 would be a good time to reconvene
  - Venue: ESRIN and CESBIO were proposed – tbd

THANK YOU

Actions

- Definition of terminology for radiometers
  - A description of terms already exists for the MIRAS instrument on SMOS
    - To be used as a basis for all radiometers by extending to cover atmospheric sounders etc.
- Definition of terminology for each sensor
  - Scatterometers – extensive description exists for ASCAT
    - To be combined with SeaWinds and other descriptions
  - Altimeters – status of terminology not discussed at meeting
    - Should incorporate beyond Jason, Topex, RA-2 etc. also interferometric altimeters eg. CryoSat
  - Precipitation & Cloud radars
    - Tie up with Xcal group
  - Ice sounders
    - Terminology currently developing

Actions

- Best practices
  - Radar ice sounding and imaging
    - Draft list of best practices to be produced by S Gogineni (Kansas University)
  - Airborne RF campaigns
    - ESA's campaigns unit to provide guidelines