Modified Antarctic Mapping Mission-2

RADARSAT-1 Antarctic Mapping Project

Project Requirements Document

April 25, 2000

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NASA, CSA, ASF, GSFC, Wallops, JPL, VEXCEL, OSU

Introduction

This document defines the science goals, mission objectives, mission requirements and operational requirements to support the second Antarctic Mapping Mission (AMM-2) which is part of the RADARSAT-1 Antarctic Mapping Project (RAMP). The document includes activities to be conducted by the team members including NASA, Canadian Space Agency, ASF, JPL, Vexcel, GSFC, WFF, OSU, ERIM, and the Antarctic Mapping Planning Group.

AMM-2 consists of three phases: the planning phase; the second Antarctic Imaging Campaign (AIC-2); and the data processing and delivery phase. The follow-on activity (AMM-3) is briefly discussed as well.

I. AMM-2 Science Goals

Ice Sheet Kinematics and Mass Balance

1) How are the interior ice sheet and ice sheet margin changing?

2) How are internal boundaries, such as the southerly limits of melt facies, changing?

3) What are the velocities and strain rates for different flow regimes (ice streams, interior ice sheet, ice shelves)?

4) What is the mass discharge from major drainage basins?

5) Where are grounding lines located and have they moved?

Ice Sheet Dynamics and Ice Streams

1) What are the morphologies and dynamic properties of Antarctic Ice Streams?

2) What portion of the Antarctic Ice Sheet is drained by ice streams?

3) How are ice sheet properties correlated with the glacier bed?

II.– AMM-2 Mission Objectives

1) **Produce high-resolution image mosaics** of Antarctica north of –80 degrees for change detection measurements and studies to understand the response of the ice sheet to climate change.

2) **Measure the surface velocity field** over coherent and/or trackable areas of the ice sheet north of –80 degrees for ice dynamics studies and for exploring the time varying nature of dynamical processes.

III. AMM-2 Science Requirements

Image Mosaic

Science Product	Accuracy	Spatial Resolution	Contribution to Measurement Objectives
2nd image mosaic of area north of –80 degrees	100 m absolute geolocation 1 dB relative and 2 dB absolute radiometric accuracy	25 m	Flow variations Mass balance Non-steady flow Calving Flux
Coherence mosaic of area north of – 80 degrees	100 m absolute geolocation	200 m	Flow styles surface physical properties

Velocity

Science Product	Velocity Accuracy Requirement	Grid Spacing	Contribution to Measurement Objective
Velocity field over coherent and/or trackable areas north of –80 degrees	1 m/yr (slow flow) 10% (fast flow) speed accuracy, 5 degrees in direction	5 km grid	Flow Styles Flow Variation Balance Velocity
Selected Study Areas (e.g., East and West Antarctic Ice Streams, Lambert Glacier)	5 % in speed, 5 degrees in direction	1 km grid	Mass Balance Ice Dynamics Nonsteady flow Calving Flux
Grounding Line Velocities north of –80 degrees	20% in speed, 10 degrees in direction	500 m grid within 20 km of the estimated grounding line	Grounding Lines

The following requirement pertains to both velocity and image products.

Image mosaics and velocity fields should be **snapshots** of Antarctica. Data acquisitions should be accomplished over a minimum period of time.

IV. AMM-2 Mission Requirements

1) Two complete cycles of ascending and descending images. A third, partial cycle of ascending and descending images over high slope areas.

2) Maximize spatial coverage and spatial coherence.

4) Mapping must occur during the same time period as AIC-1

5) Post-mission satellite ephemeris absolute accuracy of better than 200 m (prior to GCP refinement).

6) Radiometric calibration accuracy 1 dB relative; 2 dB absolute

7) Nominal baseline separation between 0 and 300 m for standard beams. Nominal baseline separation between 0 and 800 m for fine beams.

8) Post mission baseline knowledge better than 1 m (satellite navigation and GCPs)

9) Use beams EL1, ST1, ST2, ST6 and F1 (ST3, 4, 5 and 7 are contingency options)

10) Acquire pre-mission data to test processors, validate verification tools, evaluate data links, and acquisition strategy

11) Acquire data in AGC mode

12) Ground and velocity control points distributed across Antarctica

13) Near real time verification of acquired data coverage

14) Near real time verification of InSAR success rate.

15) Distribute test data within 1 month of the end of the acquisition phase of the mission

16) Receive first calibrated, Single Look Complex (SLC) data within 6 months of the end of the acquisition phase of the mission and all SLC data within 10 months of the acquisition phase of the mission

17) Process all image and coherence data to a mosaic within 16 months of the acquisition phase

18) Process all SLC data to velocity products within 3 years of acquisition

19) Map products supported by additional data (e.g. projection information, incidence angle, azimuth, and ASF image ID(Vexcel)).

20). The map product will be in the SSMI Polar Stereographic projection (Vexcel).

21) Maintain an archive of valued-added products, (e.g. GCPs, DEM).

22) Coordinate with other complementary programs (GLAS, ENVISAT, GRACE)

23) 25 m image products will be available to NASA/CSA approved investigators. 125 m image products and velocity products will be to any user.

V.– Pre-mission Test Data Requirements

1. Data to verify assumptions in acquisition plan (EL1, ST1,2,6 and F1 Insar pair, SLC data) and to test InSAR validation tools

2. Data to verify operational readiness of active radar transponder

3. Data to verify data links (e.g. McMurdo to ASF via TDRSS link, GAT/PAS to ASF)

VI.– AIC-2 Data Acquisition Strategy and Contingency Options

1) September – October 2000 northmode acquisitions

2) September- October 2001 northmode acquisitions for contingency

3) Select and schedule beams to maximize spatial coverage and coherence

4) Ascending and descending coverages

5) Maximize fine beam coverage in support of InSAR high priority study areas.

6) Develop a satellite navigation plan to optimize baseline

7) AMM-2 data shall be downlinked to North Hemisphere ground receiving stations.

8) Data downlink to the McMurdo Ground Receiving Station will be maximized.

9) McMurdo Ground Receiving Station will be capable of acquiring simultaneous real time and OBR downlinked data.

10) Acquisitions over important glaciologic features are a higher priority than complete InSAR coverage.

11) Acquisition of gaps in AIC-1 INSAR higher priority than areas already covered during AIC-1

12) Acquisition of gaps in ERS Tandem coverage higher priority than areas covered during the Tandem mission

13) Minimize the complexity of the acquisition plan (EL1, ST1, ST2, ST6 and F1 beams)

14) Minimize the impact on other users while meeting mission objectives.

VII.– Mission Success Criteria

1) Complete image coverage of Antarctica north of –80 degrees latitude.
Sufficient observations to support double differencing insar analysis of the entire area of Antarctica north of –80 degree latitude.

2) Based on the recent record of orbit maintenance and in view of the approaching solar maximum, the InSAR criteria is that 75% of the planned InSAR data will have an acceptable baseline. The goal remains to achieve 100% successful acquisition over MAMM2 and 3.

VIII.– RAMP AMM Operational Requirements

1) JPL will create a pre mission, test data acquisition plan

2) ASF must acquire and process test data to support verification of the acquisition strategy and to validate verification tools. This includes at least one InSAR pair each of F1, EL1 and ST1, 2 6 data. Test data will be provided to JPL and OSU for further analysis.

3) ASF shall acquire and process data over the McMurdo Antarctic Transponder to verify operational readiness

4) ASF and or JPL shall receive and process test data from McMurdo over the TDRSS link to verify operational readiness in support of data quality verification activities

5) JPL and GSFC will develop a satellite navigation plan for optimizing baselines. The plan will be submitted by the Joint Technical Team.

6) GSFC/Wallops will conduct satellite tracking activities both pre and during mission

7) JPL shall create a mission acquisition plan and provide same to CSA

8) CSA and ASF will develop detailed mission operations plans

9) CSA will provide JPL with mission planning rules

10) CSA will provide means for User Request File input to the MMO both prior to and during the mission.

11) CSA will manage satellite operations and mission planning activities in accordance with the CSA/NASA approved acquisition plan, provide the science team with information on mission progress, receive replanning information from the science team, and provide ASF with data calibration information complementary to the ASF calibration plan.

12) ASF must acquire, receive, record and duplicate all RAMP raw data either received directly by ASF or other ground receiving stations.

13) ASF must support activities of other ground receiving stations by verifying data transmission linkages (e.g. PAS/GAT data transfer to ASF, supplying expendable products as needed

14) ASF should be prepared to use either ASF receiving antenna in the event of ground station failures

15) ASF shall generate Scan Results File (or comparable information) within 10 minutes of acquisition at ASF; scanning priority is ranked by the oldest data on hand.

16) ASF shall immediately transmit scan results files to RAMP mission planning computers.

17) MGS will transmit Data Quality Monitoring (DQM) results to ASF within 12 hours of acquisition.

18) ASF shall have on site expertise for interpreting scan results and DQM files during AMM.

19) ASF shall request, receive and process select data from MGS for verification purposes during the mission.

20) Gatineau and Prince Albert signal data sent to ASF to arrive within 2-days after acquisition.

21) ASF will make quick look products of 10% of the data available within 30 minutes of acquisition.

22) ASF shall write, maintain, and implement a calibration plan for RAMP data

23) ASF will provide science team with a Work area (phones, desks, internet, workstation) to support science team. ASF will also provide image processing tools for image inspection and interferometric processing and selected AMM full resolution data (high-res display, create histograms, inspect individual pixel values, interpolate geographic location of interior pixels from 4-corner points, inspect coherence maps and interferograms).

24) ASF near real time processing requirements include: 2 minutes/day of data to level zero products for distribution to JPL, Vexcel, OSU; quick-look process 10% of the AMM-2 data for distribution to the science team.

25) CSA will provide a work area (desks, phones, internet) to support replanning team activities.

26) JPL will provide near real time analysis of baseline separations

27) JPL and OSU will be prepared to measure coherence on selected SLC pairs received from ASF or, in the case of JPL, directly from MGS via the TDRSS link.

28) CSA shall provide JPL and ASF with an updated SPA configuration file optimized for planning over Antarctica

29) CSA Science team will advised CSA and NASA on mission progress towards meeting science objectives.

IX. RAMP Requirements for ASF Processor
(See also RAMS Functional Requirements Document)

1) single-look complex imagery

2) calibrated data with look up table or equation to convert digital numbers to backscatter coefficient

3) Processor shall not introduce geometric errors greater than 100 m and distortions greater than 50 m in 100 km

4) Data products to be delivered to BPRC on DLT tapes (uncompressed and at highest density allowed by device).

5) Data processed/provided in RAMP requested order.

6) Radiometrically calibrated data (1 dB relative, 2 dB absolute)

7) Process standard, extended low, and fine 1 beams

8) Detailed formatting requirements are contained in the Vexcel functional requirements document

X. Modified Antarctic Mapping Mission -2
Support Requirements for Prince Albert and Gatineau Satellite Stations

The Modified Antarctic Mapping Mission, a joint CSA, and NASA project will be undertaken in fall 2000. The goal of this mission is to acquire data to be used for mapping, as well as interferometric studies of the antarctic continent. The mission has been defined to start no earlier than 3 September, 2000, and will last for three consecutive, 24-day cycles.

Identified below are requirements, as specified by NASA and CSA, for support at the Gatineau and Prince Albert Satellite Stations. It is anticipated that the requirements will emulate the support provided during AMM-1.

1) CCRS will provide on-site resources (desk, telephone, etc.) for one NASA identified staff person. This person will be responsible for data quality assessment, logistics of tape shipments, coordination with NASA for any issues.

- NASA will be on-site for the duration of the first cycle, plus 7 days (31 days)
- Additionally, NASA will be on-site for the first week of the third cycle (7 days)

2) CCRS will record data to Sony ID-1 media, for delivery to ASF.

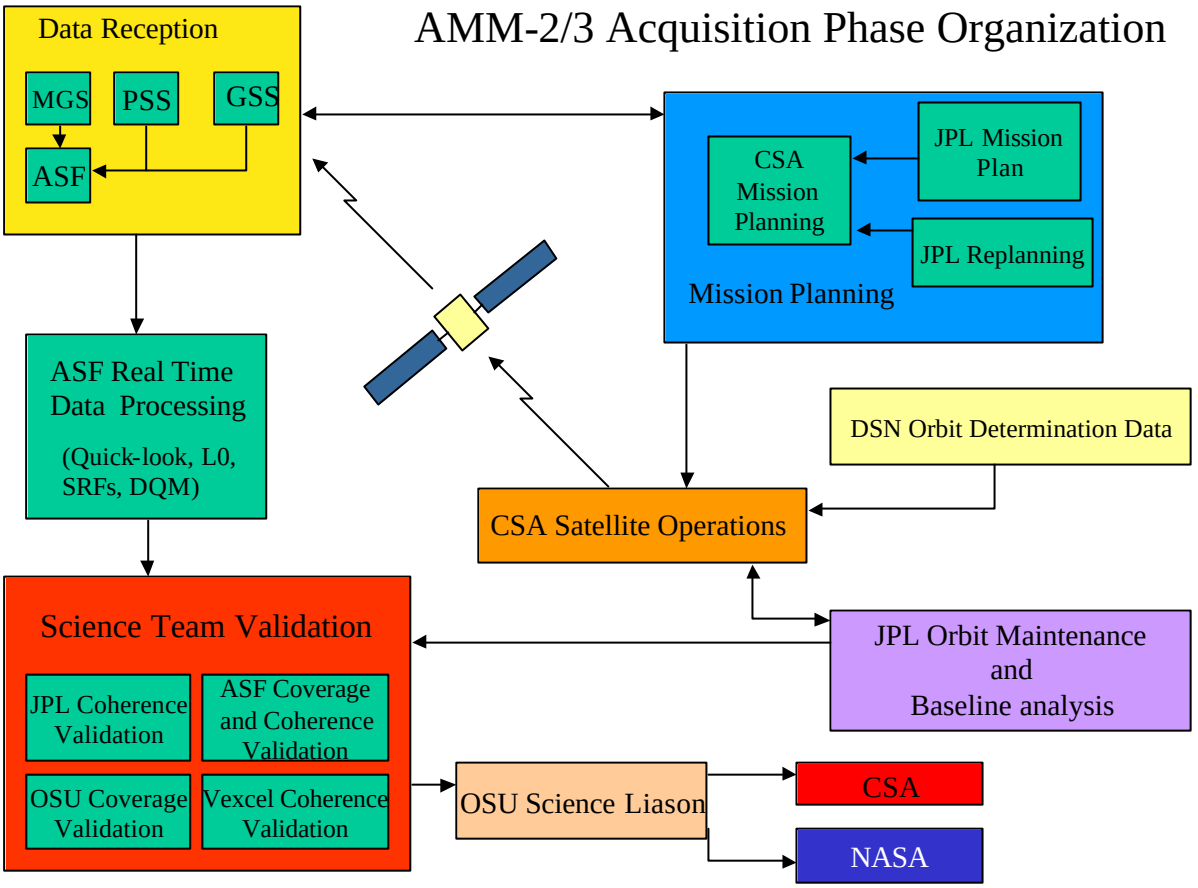
3) CCRS will provide access to the Fast-Scan systems at each station, for use in data quality and coverage assessment.

4) CCRS will support a delivery time of 7 days when NASA staff is not on-site (cycles 2 and 3). Logistics of shipping (account numbers, addresses, etc.) will be provided by NASA.

Appendix 1

AMM-2 Mission Responsibilities Chart

Team Member	Pre-mission	Mission	Post Mission
BPRC	Science Team Coordination Compile available velocity, GCP and DEM data Science requirements Mission Requirements Participate in rehearsals	Replanning guidance Support staff deployed to receiving facilities Liaison with CSA and NASA	Mosaic production Velocity Products Science Team Coordination
ASF	Acquisition Scheduling (WOS) repair and deploy transponders Data validation tools Calibration Plan Mission Ops Plan Processor Upgrades Participate in rehearsals	receive and validate all data monitor mission progress by: verify acquisitions against acquisition plan generate demonstration products contingency planning coordinate on-site science team	Calibrated image data in SLC format within 4 months of mission. limited SLC data within 1 month of mission for system validation Final product distribution
Vexcel	Functional Requirements Processing system development	replanning guidance	System Delivery System validation Sustaining engineering
JPL	Acquisition Plan Burn Strategy Participate in rehearsals	Replanning Teams (ASF and CSA) Baseline monitoring Coherence verification Science Team (ASF)	Participate in science team validation activities
GSFC/ WFF	Ground Station Preparations (MGS, SGS, ASF)		
ERIM	Velocity Control Point Plan	VCP acquisition	VCP delivery to OSU


AMM-2/3 Acquisition Phase Organization
Data Reception
MGS
PSS
GSS
ASF
CSA Mission Planning
JPL Mission Plan
JPL Replanning
Mission Planning
ASF Real Time Data Processing
(Quick-look, L0, SRFs, DQM)
DSN Orbit Determination Data
CSA Satellite Operations
Science Team Validation
JPL Coherence Validation
ASF Coverage and Coherence Validation
OSU Coverage Validation
Vexcel Coherence Validation
JPL Orbit Maintenance and Baseline analysis
OSU Science Liason
CSA
NASA

Appendix 2

AMM Test Data Plan

1.0 Test Data Objectives

Test data are necessary for the following AMM activities:

1) validate mission planning concepts (e.g. southerly reach)
2) verify coherence-related performance of F1 beams
3) develop InSAR data processing tools
4) verify data links
5) verify feasibility of swath vs frame processing (stability of doppler centroid)
6) verification of baselines computed dynamically with those computed with interferometry

2.0 Data Requests

The following data can l be used to support those activities. Requests are in priority order:

2.1 Test F1 coherence over a bright region of Antarctica (Wilkes Land)

a) Two acqusitions sets separated by the 24 day repeat cycle for use in interferometric analysis.
b) 3 adjacents F1 swaths which cover the target area, each swath should be at least 3 frames long
c) Target area is: 72.5 S and 155 E

2.2 Test EL1 reach, sensitivity and coherence (WAIS)

a) Two acquisition sets separated by the 24 day repeat cycle for use in interferometric analysis.
b) 3 adjacent EL1 swaths which cover the target area, each swath should be at least 3 frames long.
c) Target area is: 80S 140 W

2.3 Test F1 coherence over a dark region (Law Dome)

a) Two acqusitions sets separated by the 24 day repeat cycle for use in interferometric analysis.
b) 3 adjacents F1 swaths which cover the target area, each swath should be at least 3 frames long
c) Target area is: 70S 120 E

2.4 Test F1 coherence over a medium bright region (QML) (OBR Required)

a) Two acqusitions sets separated by the 24 day repeat cycle for use in interferometric analysis.
b) 3 adjacents F1 swaths which cover target area, each swath should be at least 3 frames long
c) Target area is: 72.5S 5E

2.5 Test El1 reach, sensitivity and coherence (EAIS) (OBR Required)

a) Two acquisition sets separated by the 24 day repeat cycle for use in interferometric analysis.
b) 3 adjacent EL1 swaths which cover the target area, each swath should be at least 3 frames long.
c) Target area is: 80S 20W

Total data volume is estimated to be about 22 minutes over two cycles.

3.0 Data links

A combination of real time downlink data and OBR data are identified. These data can be used to verify the various data links.

4.0 Processing Requirements

Data should be processed to level zero products. Products should be sent to OSU and JPL on DLT tape.

Appendix 3

Mission Planning Requirements

1.0 Acquisition Planning Constraints

The following tables are requirements subsets from the main body of the Antarctic Mapping Mission 2/3 mission requirements document. The subsets pertain to requirements levied on acquisition and mission planning. They should be used as a guide to developing the mission acquisition plan.

I. AMM-2 Mission Requirements Related to Acquisition Planning
1) Two complete cycles of ascending and descending images. A third, partial cycle of ascending and descending images over high slope areas.
2) Maximize spatial coverage and spatial coherence.
4) Mapping must occur during the same time period as AIC-1
7) Nominal baseline separation between 0 and 300 m for standard beams. Nominal baseline separation between 0 and 800 m for fine beams.
9) Use beams EL1, ST1, ST2, ST6 and F1 (ST3, 4, 5 and 7 are contingency options)

VI. AIC-2 Data Acquisition Strategy and Contingency Options
1) September – October 2000 northmode acquisitions
2) September- October 2001 northmode acquisitions for contingency
3) Select and schedule beams to maximize spatial coverage and coherence
4) Ascending and descending coverages
5) Maximize fine beam coverage in support of InSAR high priority study areas.
6) Develop a satellite navigation plan to optimize baseline
7) AMM-2 data shall be downlinked to North Hemisphere ground receiving stations.

8) Data downlink to the McMurdo Ground Receiving Station will be maximized.

9) McMurdo Ground Receiving Station will be capable of acquiring simultaneous real time and OBR downlinked data.

10) Acquisitions over important glaciologic features are a higher priority than complete InSAR coverage.

11) Acquisition of gaps in AIC-1 INSAR higher priority than areas already covered during AIC-1

12) Acquisition of gaps in ERS Tandem coverage higher priority than areas covered during the Tandem mission

13) Minimize the complexity of the acquisition plan (EL1, ST1, ST2, ST6 and F1 beams)

14) Minimize the impact on other users while meeting mission objectives.

2.0 Acquisition Planning Scenarios

Given these requirements, we require an optimized mission plan based on experience from AMM-1 and the capabilities of the satellite system and ground network. Our approach is to investigate differenct scenarios and contingency options. For each scenario, we require information on:

Total SAR on time
Total OBR vs Real Time downlink
Total number of swaths
Total number of on/off cycles
Misstion Duration
SAR Ontime per day
Acquisitions per day
Schedule of Downlinks into each ground recieving station

2.1 Nominal Plans

We recommend the following scenarios for further investigation:

1) Maximize InSAR opportunities : EL1, ST1, ST2, F1. These plans will assume no special orbit maintenance and worst case conditions for solar drag.

2) SAR OnTime and Acquisitions Optimized for Science and Resource Efficiency: This plan should utilize EL1, ST1, ST2, ST6, F1 beams with an acquisition schedule

based on the coverage map shown in figure 1. This plans will assume that specialized orbit maintenance strategies will be implemented.

3) Image Mapping Only: EL1, ST1, ST2, ST6. This is a contingency plan designed to meet the first objective of complete image mapping. Utilizing standard beams only is desirable.

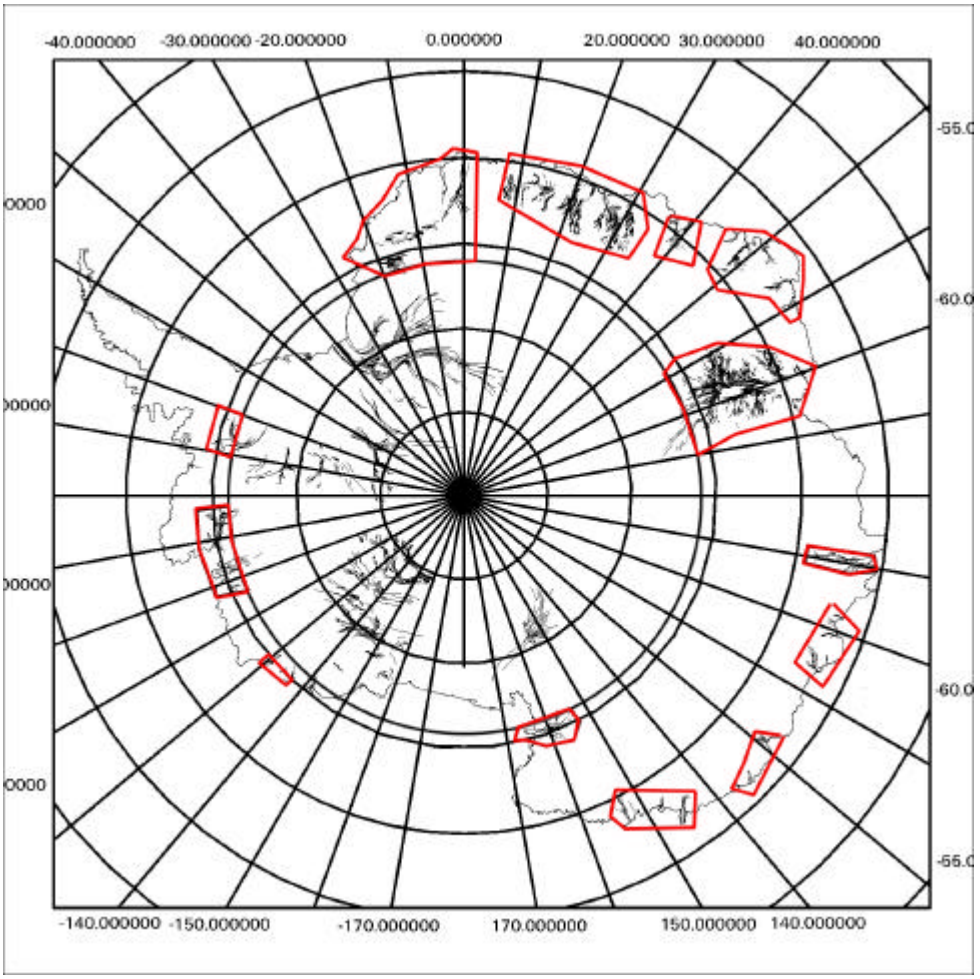


Figure 1. High priority locations for F1 coverage

4) Double differencing coverage: The OSU digitial elevation model of Antarctica will be used to subtract surface topography effects from the InSAR data in regions where slopes are less than 1 degree. In higher slope areas the DEM may be less accurate. Therefore, there is a requirement for a third cycle of acquisitions that acquire data for a double differencing calculation (Figure 2)

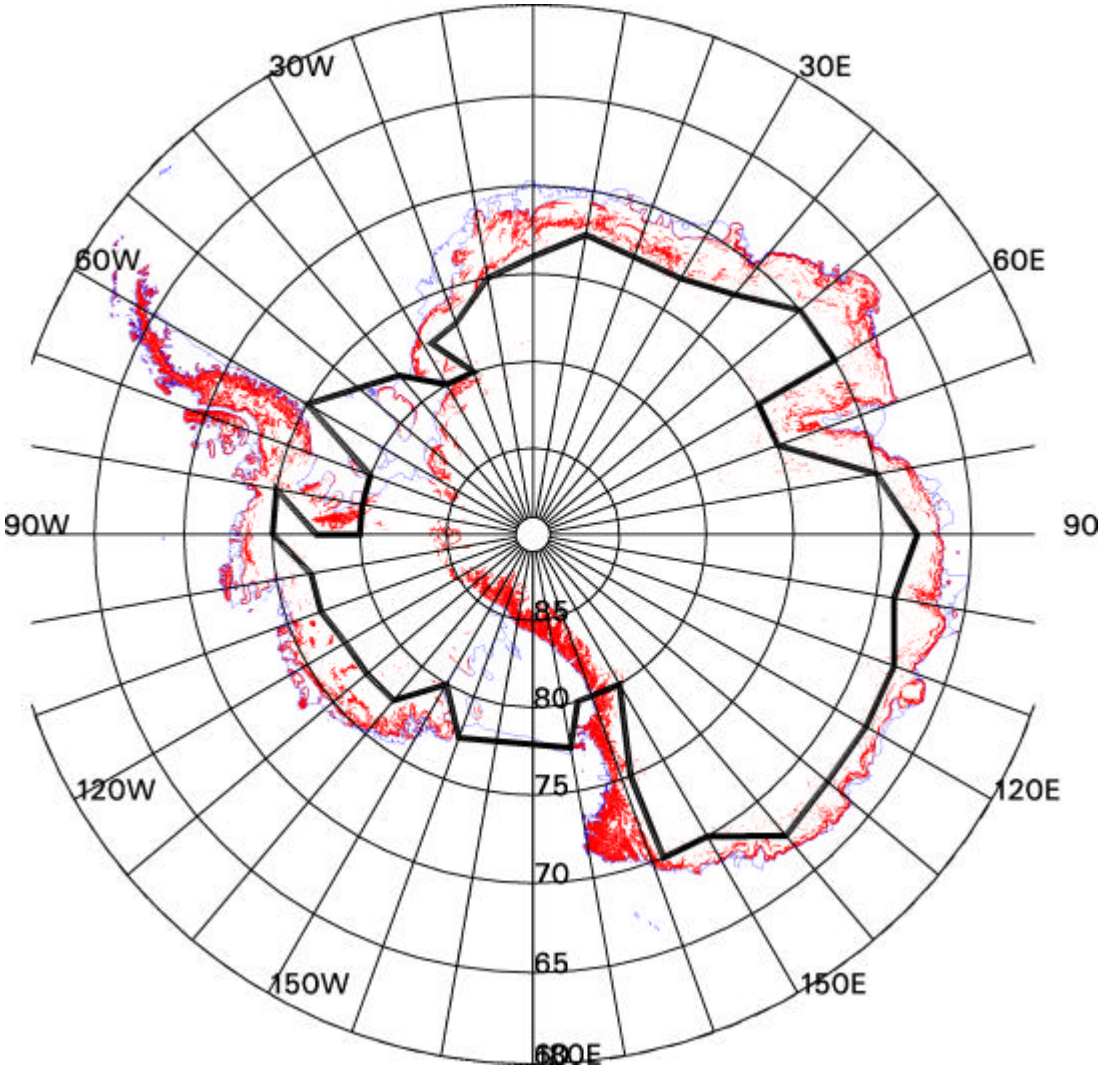


Figure 2. Surface slopes greater than 1 degree (red) and polygon showing the limits of double differencing coverage.

2.2 Contingency Plans

Contingency planning criteria are listed in table VI. In the event that only partial coverage of the Antarctic north of –80 degress is possible, the highest priority targert areas are shown in figure 3.

Contingency planning should also investigate:

1) Loss of a Ground Receiving Station
2) Loss of OBR
3) Loss of a beam
4) Solar wind variability and complications in orbit maintenance
5) Satellite and ground network anomalies

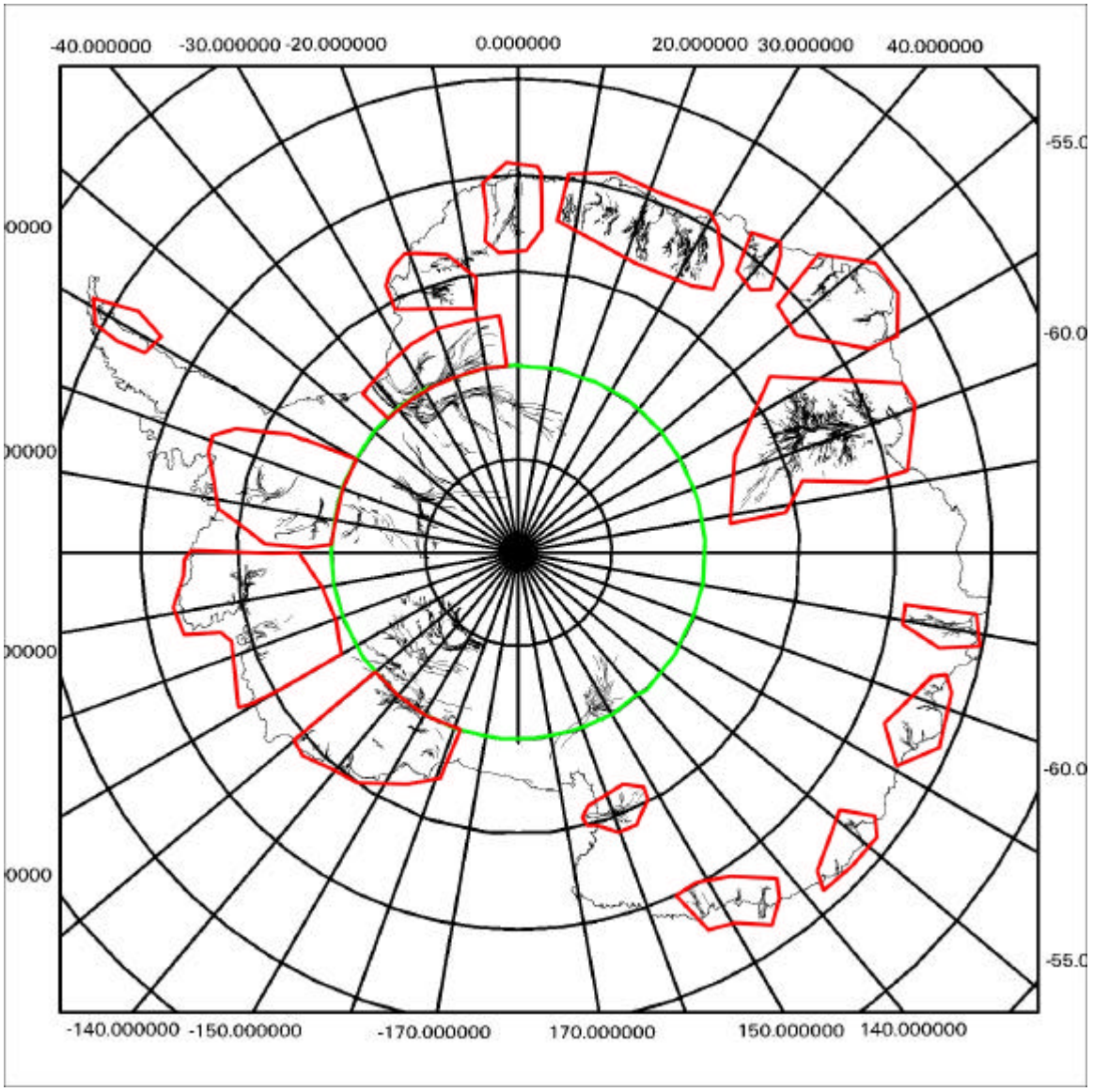


Figure 3. High priority target sites for use in replanning exercises