Remote Sensing Platforms

SD 534 Remote Sensing Systems

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Overview

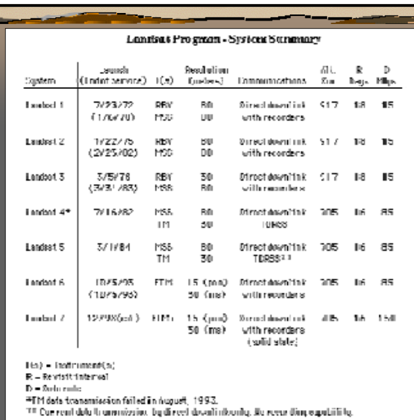
1. Optical Platforms
2. Meteorological Satellites
3. Passive Microwave Radiometers
4. Active Radar Platforms
5. GRACE

1. Optical Platforms

- LANDSAT
- SPOT

LANDSAT

- Designed by NASA to provide regular near global earth coverage
- Orbits are near polar, sun synchronous
- Repeat cycles: 14 orbits each day; revisits every 16 to 18 days
- Whiskbroom sensor



Landsat Program - System Summary

System	Launch (End of service)	I(s)	Resolution (meters)	Communications	Alt. Km	R Days	D Mbps
Landsat 1	7/23/72 (1/06/78)	RBV MSS	80 80	Direct downlink with recorders	917	18	15
Landsat 2	1/22/75 (2/25/82)	RBV MSS	80 80	Direct downlink with recorders	917	18	15
Landsat 3	3/5/78 (3/31/83)	RBV MSS	30 80	Direct downlink with recorders	917	18	15
Landsat 4*	7/16/82	MSS TM	80 30	Direct downlink TDRSS	705	16	85
Landsat 5	3/1/84	MSS TM	80 30	Direct downlink TDRSS**	705	16	85
Landsat 6	10/5/93 (10/5/93)	ETM	15 (pan) 30 (ms)	Direct downlink with recorders	705	16	85
Landsat 7	12/99(est.)	ETM+	15 (pan) 30 (ms)	Direct downlink with recorders (solid state)	705	16	150

I(s) = Instrument(s)
R = Revisit interval
D = Data rate
*TM data transmission failed in August, 1993.
** Current data transmission by direct downlink only. No recording capability.

LANDSAT 1, 2, 3 - Payload

- RBV (Return Beam Vidicon):
  - Blue/green, red, I/R bands (Bands 1, 2, 3)
  - 80 m resolution
  - Single instantaneous picture
  - High cartographic accuracy
- MSS (Multispectral Sensor):
  - First global digital multispectral images
  - Blue/green (0.5-0.6), red (0.6-0.7), red and near IR (0.7-0.8) and near IR (0.8-1.1)
  - 6 bit data

LANDSAT 4, 5

- Designed to travel 8 days out of phase so that coverage is available at least every 8 days
- Payload
  - MSS scanner (as for Landsat 1, 2, 3)
  - TM (thematic mapper): improvement over MSS; scanning mirror, 8 bit data; captures data in both directions of oscillating mirror

LANDSAT 6, 7

- LANDSAT 6 – launched October, 1993
  - Did not achieve orbit
- LANDSAT 7
  - Payload: Enhanced Thematic Mapper Plus (ETM+)
- ETM+: 8 channels in total

ETM+ Channels (μm)

1) 0.45 - 0.52, 30m
2) 0.52 - 060, 30m
3) 0.63 - 069, 30m
4) 0.76 - 0.90, 30m
5) 1.55 - 1.75, 30m
6) 10.4 - 12.5, 60m
7) 2.08 - 2.35, 30m
8) 0.50 - 0.90, 15m

Araona Crater

- Suspected crater impact; Amazon forest region
- 8 km wide; 3 m deep
- Occurred ~20,000 years ago

SPOT (Satellite Pour l'Observation de la Terre)

- Joint venture between France, Sweden, and Germany
- First commercial remote sensing satellite
- Carried pair of sensors to view either side
- Used pushbroom technology (a satellite first!)
- Repeat pattern of 26 days; pointable optics allow same area to be viewed every 4 or 5 days (different angles)
- Near polar, sun synchronous
- Altitude: 832 km; Period: 101 minutes

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SPOT Satellites Launched

Satellite	*Launch Date*	*Current State*
SPOT 1	Feb/86	Decommissioned: 12/31/90
SPOT 2	Jan/90	Still Operational (mostly!)
SPOT 3	Sept/93	Stopped Functioning 1996
SPOT 4	Mar/98	Still Operational
SPOT 5	May/2002	Still Operational

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SPOT Payload

- Both multispectral (20x20 m) and panchromatic (10x10 m) modes
- Dynamic range of 8 bits
- Swath of 60km
- Unable to sense in upper-mid and thermal IR ranges (CCD limitation)

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SPOT Example

- 10 metre panchromatic SPOT image
- Agricultural fields in a gridded format

A. Crop in mid-harvest
B. Bowtie: combine patterns
C. Surface salt (use of ground water irrigation)

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2. Meterological (Weather) Satellites

- Operate in VIR
- Primary purpose: weather prediction and monitoring
- Difference from earth resource satellites? Resolution on order of kms as opposed to 10 or 100s of metres
- Consider two here: AVHRR and GEOS

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AVHRR

- AVHRR – Advanced Very High Resolution Radiometer
- Resolution of 1.1 km (at best)
- Can download in real-time, or store onboard and transmit at a later time
- Also used to monitor ocean temperatures, snow cover, flood monitoring, regional soil moisture, wildfire mapping, fire detection, volcanic eruptions, etc.

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AVHRR – Temporal Coverage

Satellite Number	Launch Date	Ascending Node	Descending Node	Service Dates
TIROS-N	10/13/78	1500	0300	01/30/80
NOAA-6	06/27/79	1930	0730	11/16/86
NOAA-7	06/23/81	1430	0230	06/07/86
NOAA-8	03/28/83	1930	0730	10/31/85
NOAA-9	12/12/84	1420	0220	05/11/94
NOAA-10	09/17/86	1930	0730	Present
NOAA-11	09/24/88	1340	0140	09/13/94
NOAA-12	05/14/91	1930	0730	12/15/94
NOAA-14	12/30/94	1340	0140	Present
NOAA-15	05/13/98	1930	0730	Present
NOAA-16	05/04/02			Present
NOAA-17	06/24/02			Present
NOAA-18	05/20/05			Present

- NOAA-B launched May 29, 1980, failed to achieve orbit. NOAA-13 launched August 9, 1993, failed due to an electrical short circuit in the solar array.

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AVHRR – Spectral Range

Band	*Satellites: NOAA-6,8,10*	*Satellites: NOAA-7,9,11,12,14,15*	*IFOV*
1	0.58 - 0.68	0.58 - 0.68	1.39
2	0.725 - 1.10	0.725 - 1.10	1.41
3	3.55 - 3.93	3.55 - 3.93	1.51
4	10.50 - 11.50	10.3 - 11.3	1.41
5	band 4 repeated	11.5 - 12.5	1.30
	(micrometers)	(micrometers)	(milliradians)

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- AVHRR image of Alaska
- Downloaded 1984
- Half of Great Bear Lake is visible in lower right

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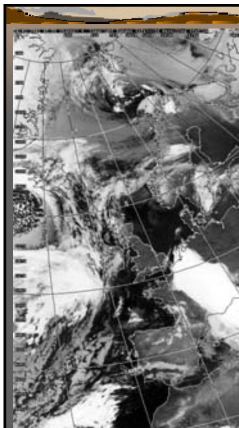

- Channel 4 AVHRR covering England and European mainland
- Note overlays used to identify land/ocean boundaries and mark lines of longitude and lattitude

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GOES – Geostationary Operational Environmental Satellite

- Satellites launched by NOAA / NASA work in concert with similar satellites launched by USSR, ESA and Japan
- Provide geostationary coverage ie. Orbiting around ~36,000 km
- Resolution varies as a function of wavelength

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GOES Imager Characteristics

Band (μm)	Spatial Resolution at Nadir (km)
0.55 – 0.75	1
3.80 – 4.00	4
6.50 – 7.00	8
10.20 – 11.20	4
11.50 – 12.50	4

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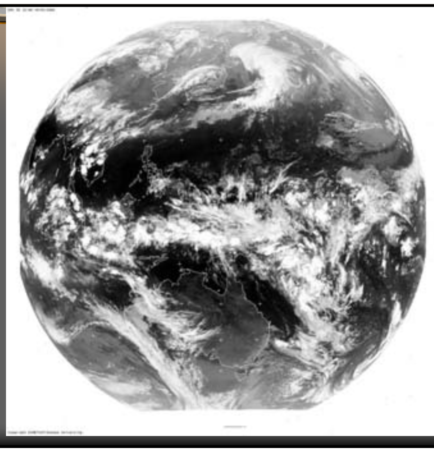

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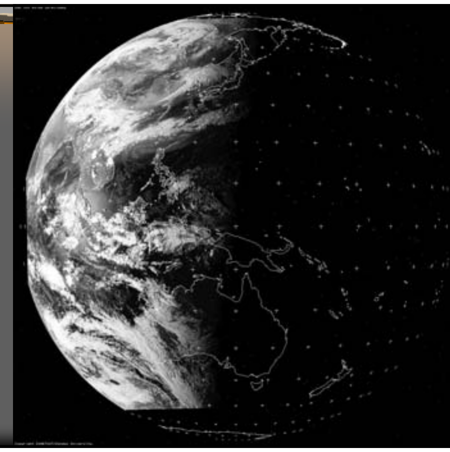

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3. Passive Microwave Radiometers

- SSM/I
- TMI (Tropical Rainfall Measuring Mission) (N/A)
- AMSR (Advanced Microwave Scanning Radiometer) (N/A)

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SSM/I (Special Sensor Microwave / Imager)

- Measures emissivity (passive sensor)
- Polarized receptions (V or H)
- Conical scan
- Swath: 1400km

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SSM/I Channels

Channel	Frequency (GHz)	Resolution (km)
19V	19.35	70x45
19H	19.35	70x45
22V	22.235	60x40
37V	37.0	38x30
37H	37.0	38x30
85V	85.5	16x14
85H	85.5	16x14

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SSM/I Data Products

- Raw data converted into sensor data records (SDRs) and environmental data records (EDRs)
- SDRs: calibrated, ground referenced, antenna pattern corrected brightness temperatures
- SDRs used to compute EDRs
- EDRs: quantitative parameters eg. Cloud water, rain rate, surface wind, soil moisture, sea ice information, water vapour content, precipitation amount

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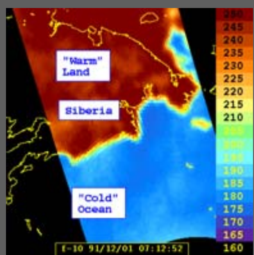
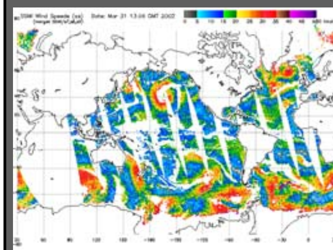
SSM/I SDR Example



- Based on "brightness temperature" ie. emissivity
- Siberia in December
- Land should be "colder" than open ocean, but not in the 19GHz range! ie. Land has higher emissivity

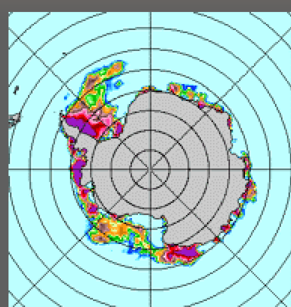
SSM/I EDR Example



- Derived wind velocities using multiple SSM/I bands
- Experimentally derived equation to generate wind speeds

SSM/I Antartica Temporal Sea Ice Concentrations

- Jan/96 to Dec/96 progressive changes in sea ice concentrations
- Red/Blue: highest/lowest ice concentrations



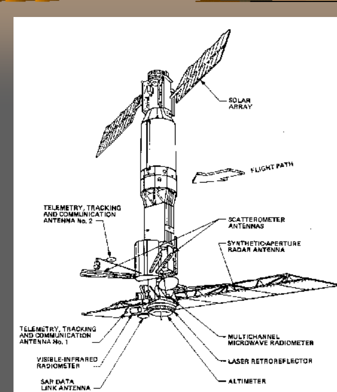
4. Active Radar Platforms

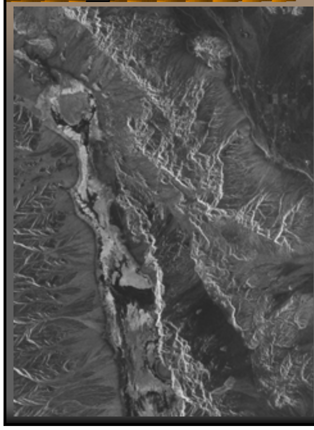
- SEASAT
- ERS-1, ERS-2
- RADARSAT

Seasat

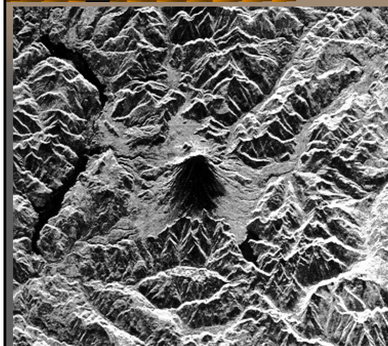
- First satellite carrying SAR sensor
- Launched 1978; failed 99 days later
- Also carried a radar altimeter, scatterometer, microwave radiometer, and VIR radiometer
- SAR operated at 1.275 GHz (L-band, 23.5 cm) to generate a 100km swath at 25m resolution
- Nominal incidence angle of 20 degrees

SEASAT - Satellite Platform





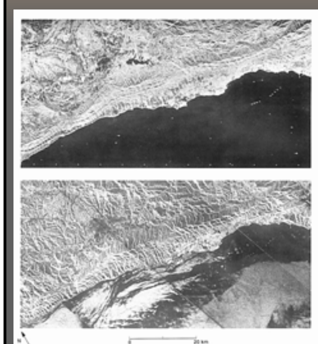
SEASAT image of Death Valley



Mount St. Helens, WA
JPL SEASAT SAR Image
Aug. 13th 1978

Seasat image of Mount St. Helens

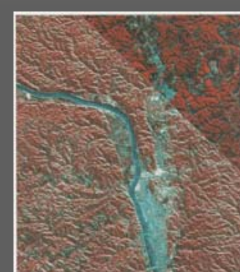
Variation of SAR Incidence Angle



- Large look angles, such as SIR-A's 47 degrees, reduce the effect of topography and enhance the sensitivity to surface roughness (top)
- SAR imaging radars with small look angles, such as SEASAT, enhance the topography at the expense of surface roughness (bottom)

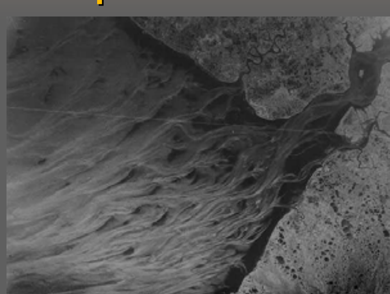
SEASAT - Coregistration

- LANDSAT alone in dark red in top right
- SEASAT and LANDSAT coregistered elsewhere
- Note enhanced relief in coregistered region



SEASAT: L-band penetration

- Sediment deposits at mouth of Kuskokwim River (southwest Alaska) captured by penetration of L-band signal into the water



ERS-1, ERS-2

- ERS-1 launched in 1991; ERS-2 launched 1995
- Each carried the following major instruments:
  - Active Microwave Instrument (AMI) (includes a SAR)
  - Radar Altimeter (RA)
  - Along-Track Scanning Radiometer (ATSR)
  - Global Ozone Monitoring Experiment (GOME – ERS-2 only)

ERS-1, ERS-2 SAR

- C-band sensor, VV mode
- Steep, fixed angle of incidence (23 degrees)
- Resolution: 30 m
- Swath: 80 – 100 m
- Sun synchronous, near polar, near circular orbit

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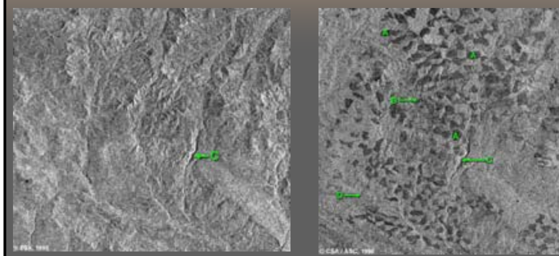
ERS-1 Versus RADARSAT



- RADARSAT Fine mode (43 46 degrees) (right) displays deforested areas; 8 m resolution displays roadways, pipelines as well
- Why can't ERS-1 (left) note the deforested regions? VV versus HH? Or is this a function of incidence angle?

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RADARSAT-1

- Canadian owned and operated SAR satellite
- Operates in C-band (5.6 cm; 5.3 GHz), HH
- Launched in 1995; expected lifespan of 5 years
- Designed to support timely data delivery
- Scenes commercially available for $3,000 U.S.

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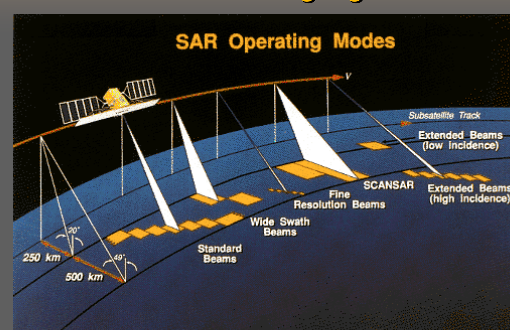
RADARSAT-1 Imaging Modes



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RADARSAT-1 Imaging Modes

Mode	*Nominal Resolution (m)*	*No. of Positions/ Beams*	*Swath Width (km)*	*Incidence Angle (degrees)*
Fine	8	15	45	37- 47
Standard	30	7	100	20 - 49
Wide	30	3	150	20 - 45
ScanSAR Narrow	50	2	300	20 - 49
ScanSAR Wide	100	2	500	20 – 49
Extended (H)	18 – 27	3	75	52 – 58
Extended (L)	30	1	170	10 - 22

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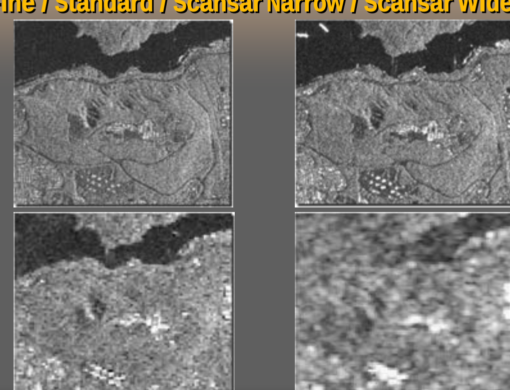
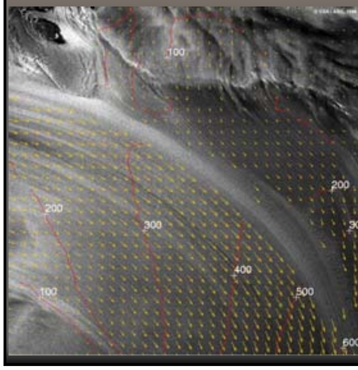
Fine / Standard / Scansar Narrow / Scansar Wide



RADARSAT-1 – Glacier Ice Movement



- Ice motion on Antartica glacier
- Variations in velocities can be determined using repeat coverages of the same area

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RADARSAT-1 – Ship Detection

- "Ocean Monitoring Workstation", produced at the CCRS, is an automated system that uses RADARSAT to locate ships

RADARSAT-1 – Rice Crop Monitoring

- False colour composite RADARSAT imagery
- Combined one standard and two fine mode images

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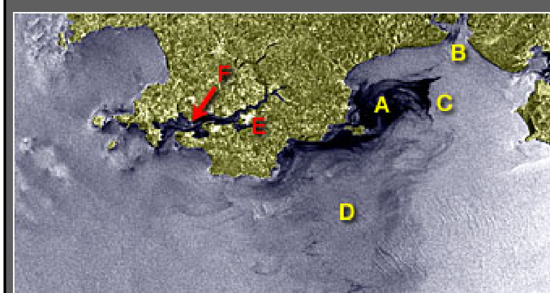
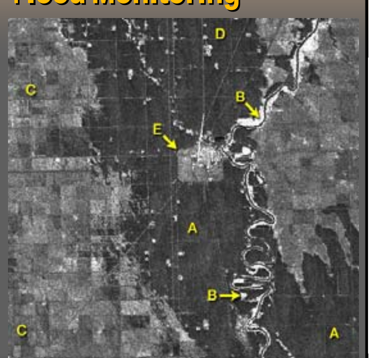
RADARSAT-1 Oil Spill Monitoring

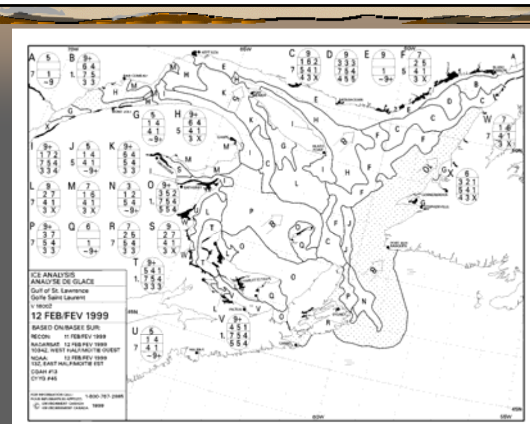
- Oil floats on water creating a smoother surface than surrounding water

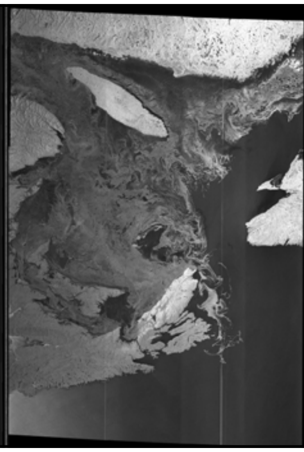


RADARSAT-1 – Flood Monitoring

- Red River, MN
- Smooth, standing water appears dark (A)
- Brighter areas are not flooded
- Corner reflectors (trees and water) appear at (B)
- Town of Morris not flooded (E)







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SAR Sea Ice Classification

- Why? Navigation and environmental monitoring
- "Holy Grail" of Remote Sensing/Computer Vision problems
- Many scientists have tried to find solutions
- Problems? Speckle, incidence angle, ice variations, insufficient resolution, need to account for tone, texture, and shape (just like the operator!)

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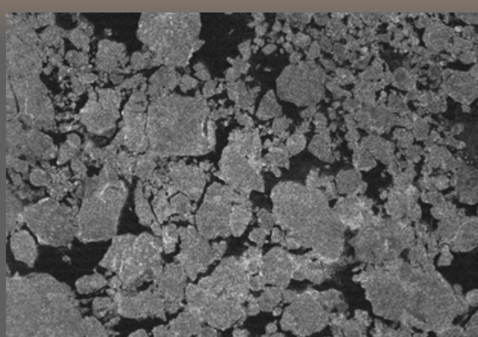

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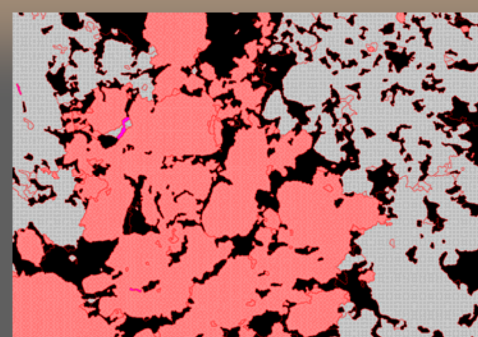

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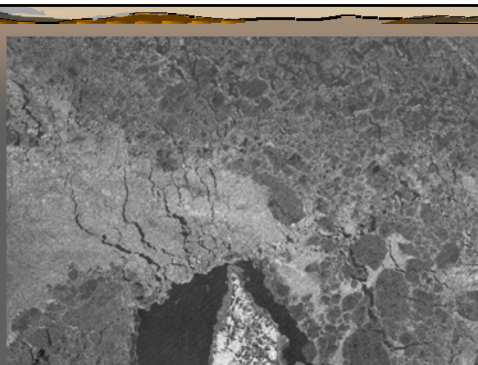

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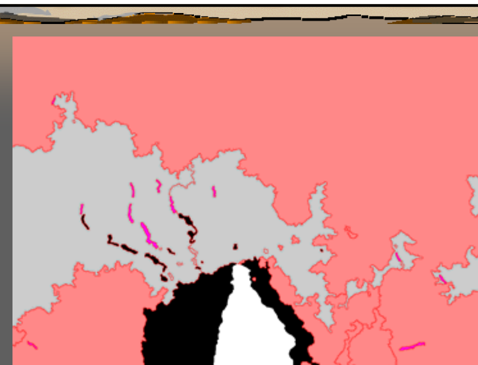

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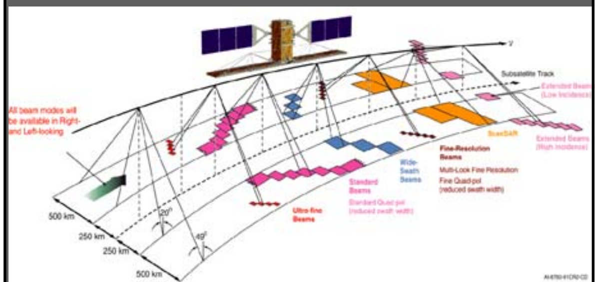
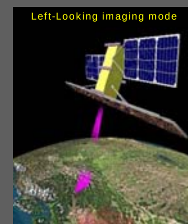
RADARSAT-2: Imaging Modes

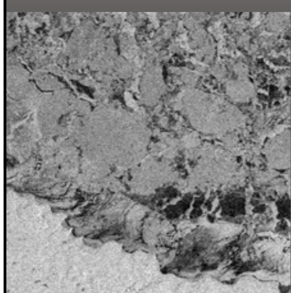


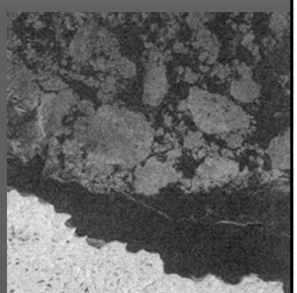
RADARSAT 2: Right and Left Looking

- More frequent revisits
- Faster response to emergency situations



RADARSAT-2 HH vs HV



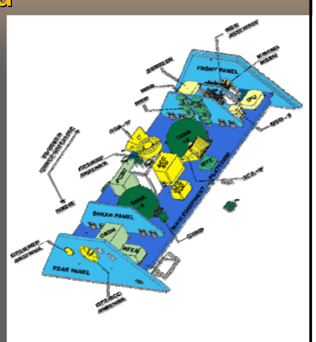


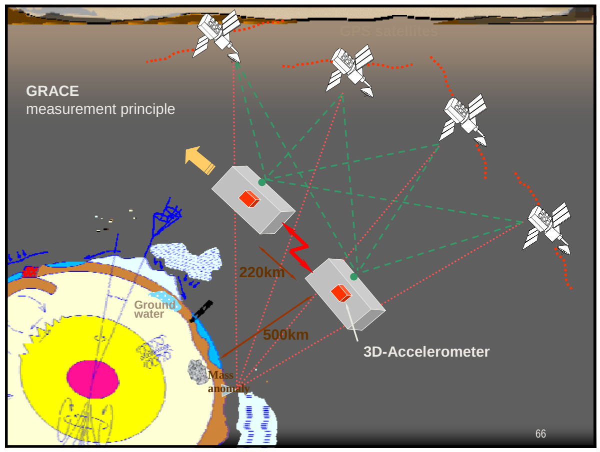
Satellite Gravimetry

- GRACE: Gravity Recovery and Climate Experiment (launch 2002)
- Two identical satellites separated by ~220km along track
- Slides courtesy of Prof. Fotopoulos (U. of Toronto)

GRACE - Payload

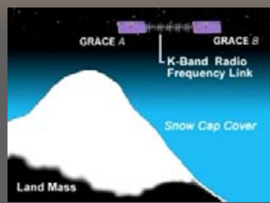
- accelerometers
  - detect non-gravitational acceleration acting on SVs and remove from satellite-to-satellite distance
- GPS receivers
  - 24 dual frequency channels
  - precise time tagging of the measurements for inter-SV range change
  - absolute positions of SV
- laser corner-cube reflector assembly
  - enables tracking by ground based lasers
- two STAR Cameras
  - orientation sensing (attitude control)
- Litton Gyro and actuators
  - 3-axis stabilized, nearly Earth-pointed orientation so that K-band antennas are pointed precisely at each other
- K-band microwave ranging
  - for inter-satellite tracking





Gravity and Mass Change

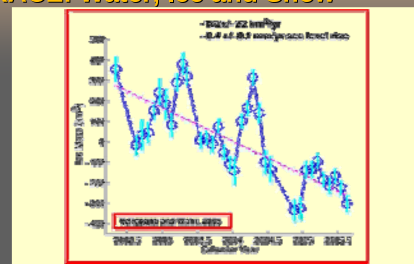
- Earth's gravity field reflects the composition and structure of the planet
- Changes in the gravity field are caused by the redistribution of mass **within** the Earth and **on** (water mass) or **above** its surface (atmosphere)
- Observations of spatio-temporal variations in Earth's gravity field place constraints on models of global mass variability and temporal exchange among the land, ocean and atmosphere
- Earth's global gravity field described in terms of the shape of the geoid (equipotential surface roughly approximating MSL over oceans)



courtesy of: CSR/NASA

- GRACE travels over areas of snow & ice sheets
- change in mass/gravity recorded
- combine with in-situ measurements & other data
- determine if areas are growing/shrinking
- input for climate change and sea level change

GRACE: Water, Ice and Snow



GRACE Measurements Show Mass Loss in Greenland

- ice mass loss in Greenland observed from GRACE (2002-2005)
- contributes to 0.4mm/yr to global sea level rise → climate change

The End

Good luck on your final exams!