Future perspectives of SAR polarimetry with applications to multi-parameter fully polarimetric pol-sar remote sensing & geophysical stress-change monitoring with implementation to natural disaster assessment and monitoring within the "*Pacific Ring of* Fire" by implementation of polar & equatorially orbiting satellite sensors

Wolfgang-Martin Boerner[1 -7]

In coordination with

Yoshio Yamaguchi[2], **Akinobu Sato**[2], **Roichi Sato**[2], **Hiroyoshi Yamada**[2]; **Alberto Moreira**[3], **Gerhard Krieger**[3], **Andreas Reigber**[3], **Irena Hajnsek**[3], **Kostas Papathanassiou**[3] ; **Katsumi Hattori** [4], **Josaphat Tetuko Sri Sumantyo**[4], **Kun-Shan Chen**[5], **Chih-Yuan Chu**[5], **Chih-Tien Wang**[5], **Jong-Sen Lee**[5] ; **Enrico Paringit**[6]; **Roberto Heru Triharjanto**[7], **Mahmud Raimadoya**[7]

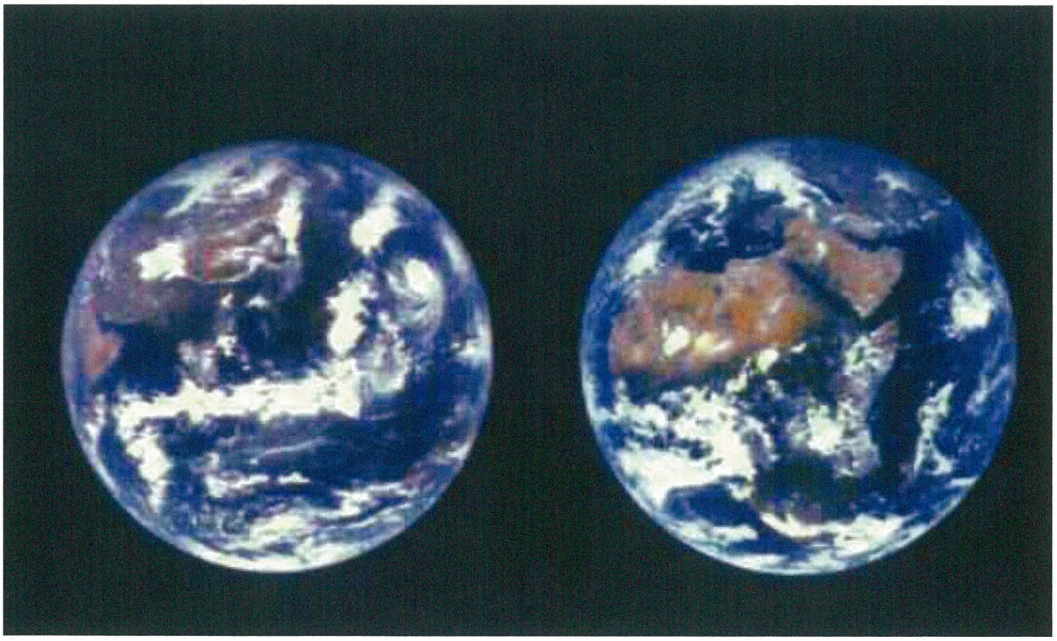
1 University of Illinois at Chicago, UIC-ECE/CSN, Chicago, IL/USA
2 Niigata University, Electronic Information Engineering, Ikarashi, Niigata, Japan
3 DLR-HR, Oberpfaffenhofen, Bavaria, Germany
4 Chiba University, Earthquake Research Center & CEReS, Chiba, Japan
5 National Central University, NCU-CSRSR/MRSL, Jhongli, Taoyuan, Taiwan ROC
6 UPD-GE, Diliman, Quezon City, Metro-Manila, Philippines
7 LAPAN, Jakarta; BAC-CEE/RAWG, Jalan Meranti Dramaga Campus, Bogor, Java, Indonesia

UIC University of Illinois at Chicago Communications, Sensing & Navigation Lab ECE Electrical and Computer Engineering

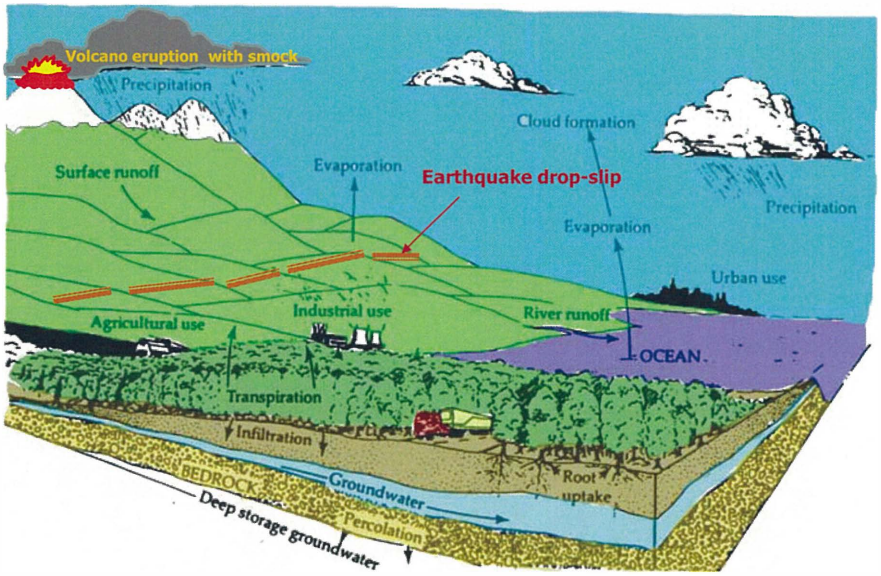
Exploitation of fully polarimetric Satellite POLSAR modes for natural hazard detection and subsequent disaster reduction of SE-Asian/Pacific earthquakes, volcano eruptions and taiphoons – Japan, *Taiwan, Philippines and Indonesia*

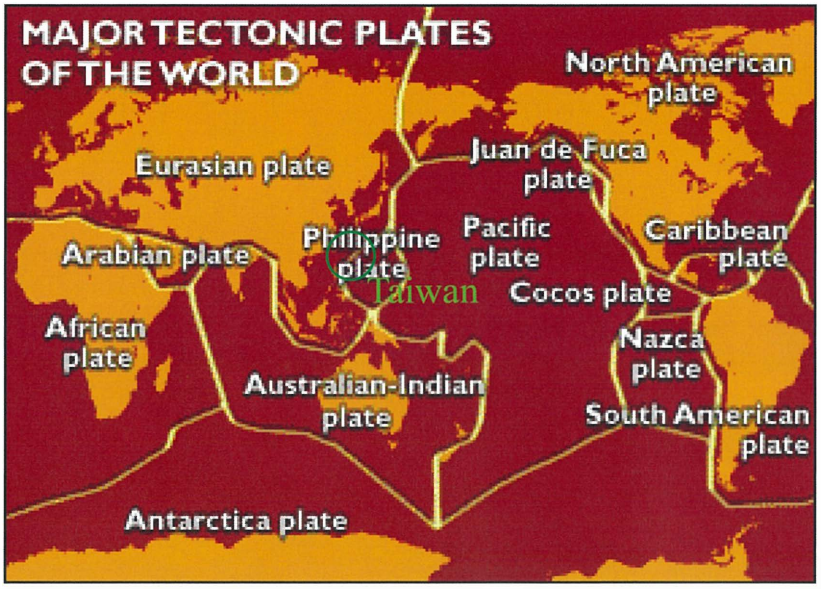
Abstract: The outstanding performance capabilities of the three Satellite POLSAR sensors are well established; and in this exposition the exploitation of the fully polarimetric ALOS-PAL=PPL=SAR mode is demonstrated by implementing the NIIGATA-UNIVERSITY four-scatterer SAR image decomposition with coherency-matrix rotation proving the superior imaging capabilities of the fully polarimetric SAR modes not only for the ALOS-PALSAR L-Band and similarly to the S-Band, C-Band and X-Band. The novel fully polarimetric POL-SAR image processing techniques are then applied to natural hazard detection and subsequent disaster reduction of taiphoons with land-slides, volcano eruptions with plume aftereffects & landslides, and of earthquakes with drop-slips experienced within the SE-Asian/Pacific Ring-of-Fire including next to Japan in Taiwan, the Philippines and Indonesia, promoting equatorially orbiting Single and TanDEM L-/S-/X-Band POLSAR sensor deployment.


Apollo 11: 1969 July 16 - 24



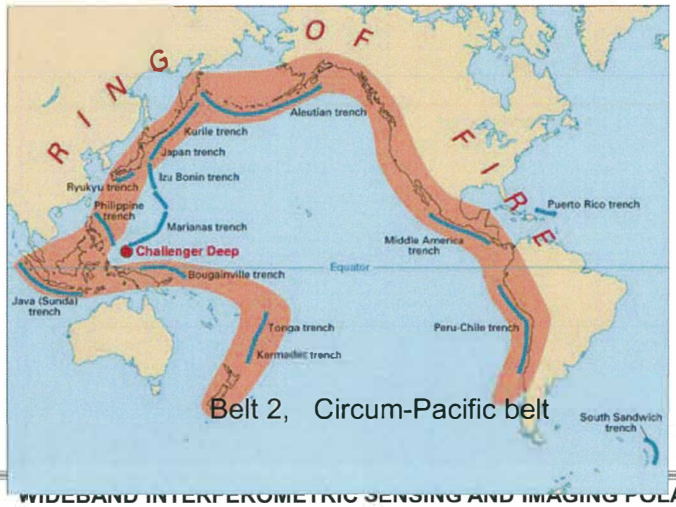
Hydrologic cycle with volcanologic & seismic activity



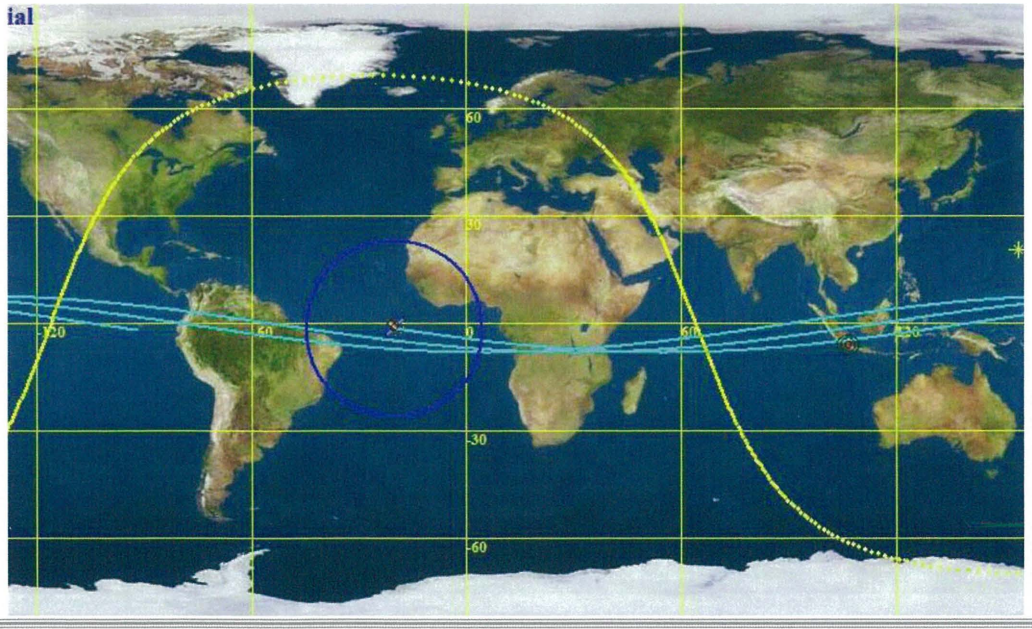


From BBC news site

The terrestrial tectonology: Alfred Wegener's tectonic plate theory and the two major seismic belts



LAPAN-A2 ORBIT PROFILE
(14 pass per 24 hr / orbit time 100 minutes and stay above horizon at about 10 minutes)



TUB-LAPAN-ORARI ORBIT PROFILE
(14 pass per 24 hr / orbit time 100 minutes and stay above horizon at about 10 minutes)

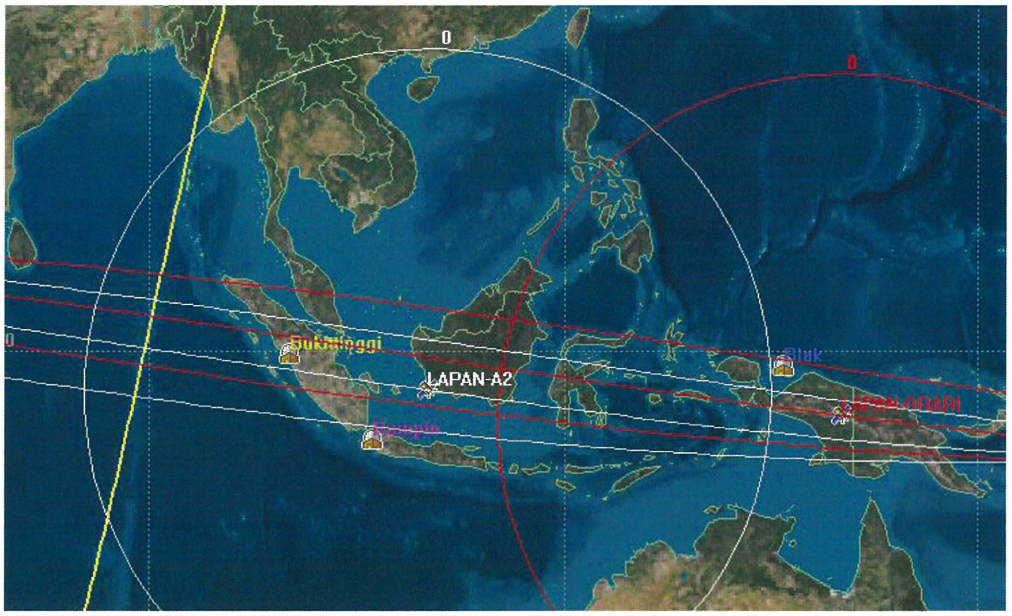
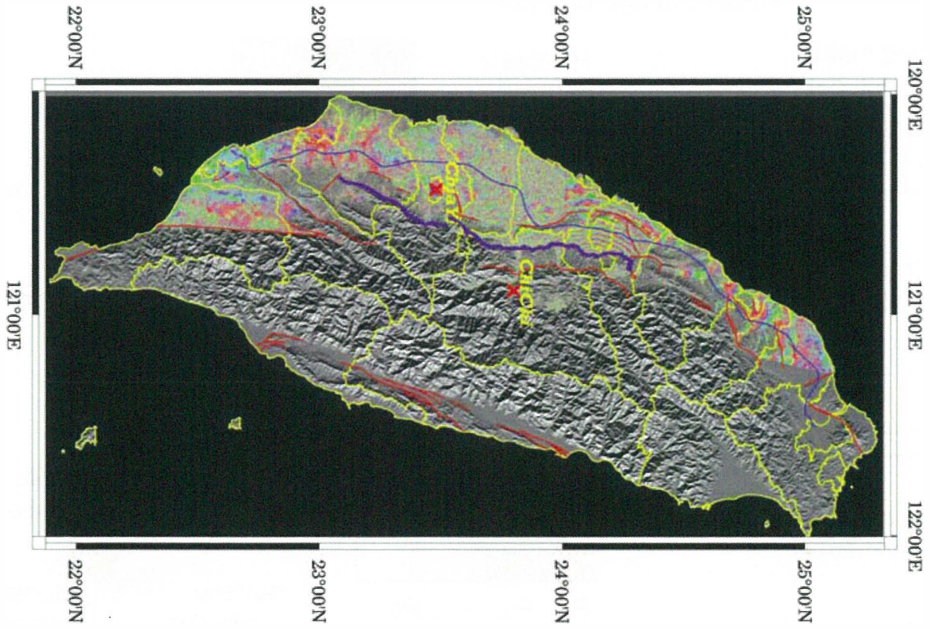


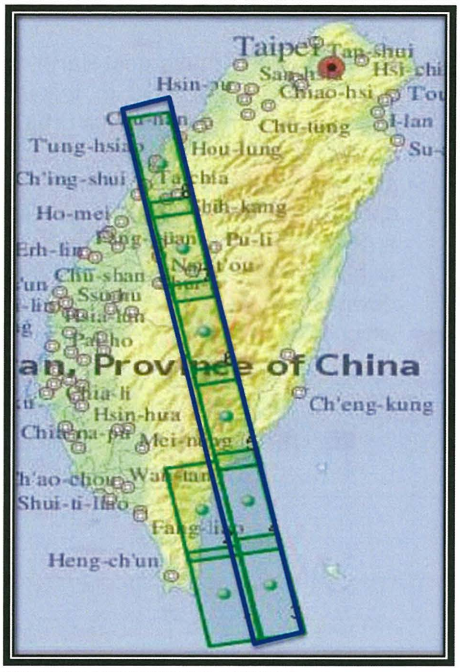
Table 1. Comparison of High-Level Parameters			
Parameter	**PALSAR**	**RADARSAT-2**	**TerraSAR-X**
Orbit: LEO, circular	Sun-synchronous	Sun-synchronous	Sun-synchronous
Repeat Period (*days*)	46	24	11
Equatorial Crossing time (*hrs*)	22:30 (ascending)	18:00 (ascending)	18.00 (ascending)
Inclination (*degrees*)	98.16	98.6	97.44
Equatorial Altitude (*km*)	692	798	515
Wavelength (*Band*)	23 cm (*L*)	5.6 cm (*C*)	3 cm (*X*)
Fully polarimetric mode	Yes	Yes	Yes

ALOS is one of the largest Earth observing satellites ever developed, at 3850 kg. It is in a near-exact 45-day repeat sun-synchronous orbit, 690 km altitude above the equator. The active phased array SAR antenna is obliquely Earth-facing, aligned with the spacecraft velocity vector. The solar array is arranged at right angles to the orbit plane, consistent with the near-mid-day orbit phasing. The X-band down-link must be shared with optical instruments, which constrains SAR operation times.

Table 1. Selected PALSAR Mode Parameters

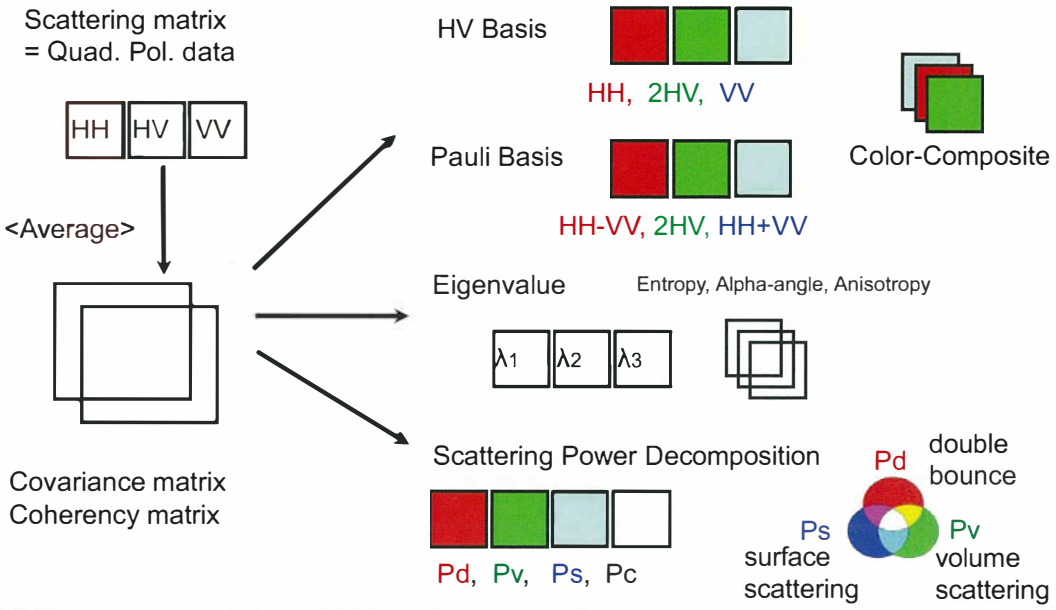
Mode (selected)	Resolution (m)	Swath (km)	Looks	Polarization
Standard, stripmap	20 x 10	70	2	HH or VV
Fine	10	70	1	HH or VV
ScanSAR (5-beam)	~ 100	350	8	HH or VV
Dual polarization	(as above)	(as above)	(as above)	(HH, HV), (VV, VH)
Quad-pol	30 x 10	30	2	Full polarization

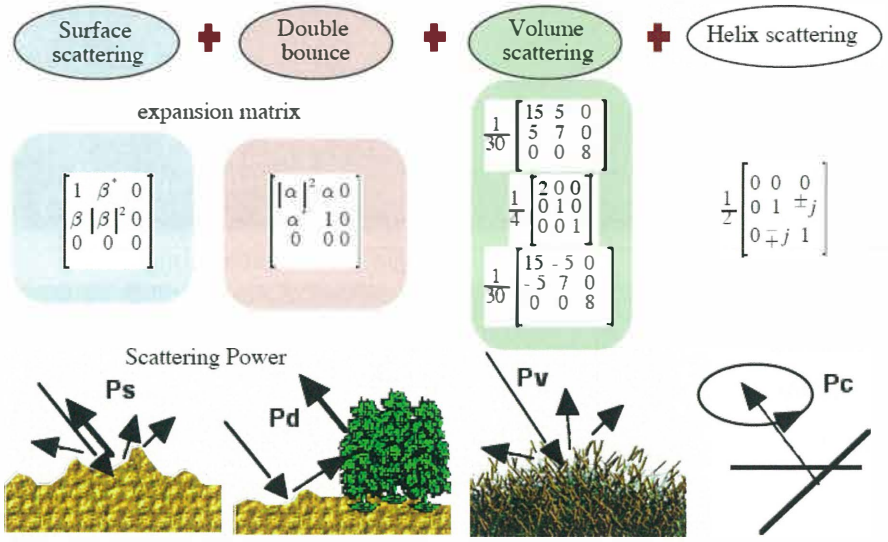




3.4.5.6.7.8
Polarimetric mode
Incident angle :23.1°
Date:2009/05/01
Path:442
Frame:430(3),440(4)
450(5),460(6)
470(7),480(8)

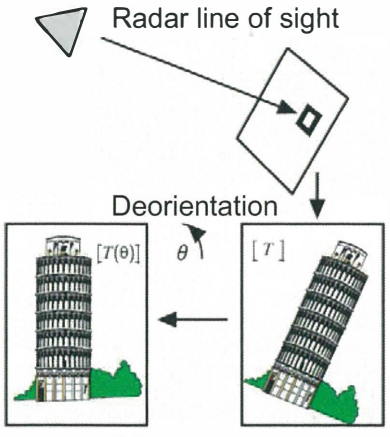
POLSAR image analysis





The four-component decomposition of scattering powers Ps, Pd, Pv, and Pc

4-compornent scattering power decomposition algorithm using rotated coherency matrix



Rotation of imsge

Taiwan

23.703N
120.875E

PASL110090501
14242009070200
02

Pd
Ps Pv
Niigata University

©METI, ERSDAC

2009/5/1

Google earth optical image

Scattering power decomposition (Pd, Ps, Pv)

UIC University of Illinois at Chicago Communications, Sensing & Navigation Lab ECE Electrical and Computer Engineering

Scattering power decomposition

Pd

Ps Pv

Niigata University

Pauli-basis

Taiwan

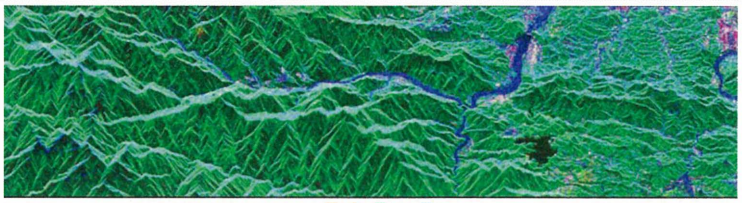
23.703N

120.875E

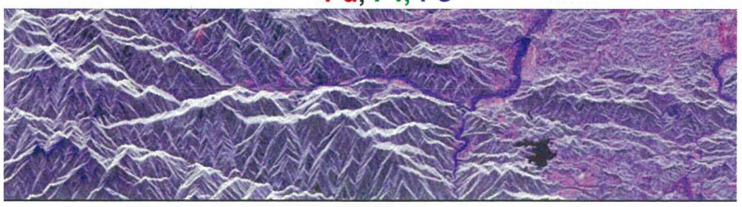
HV-basis

2009/5/1

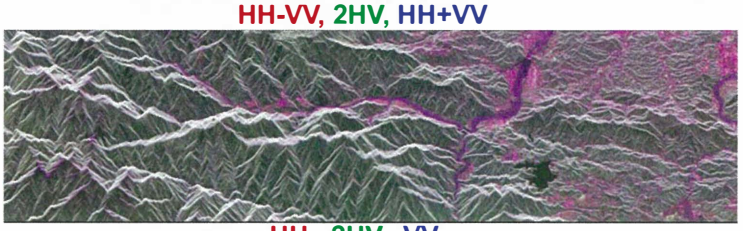
PASL1100905011424200907020002



Pd, Pv, Ps



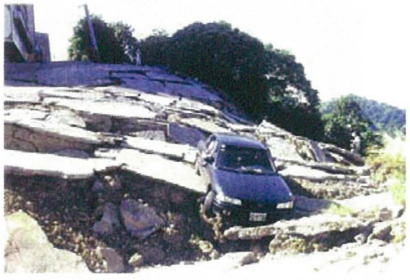
HH-VV, 2HV, HH+VV



HH, 2HV, VV

UIC University of Illinois at Chicago Communications, Sensing & Navigation Lab ECE Electrical and Computer Engineering

The destruction along the Cheleng-Pu fault caused by the Chi-Chi earthquake of 1999 September 21



Scattering power decomposition

Pd

Ps Pv

Niigata University

T33 Rotation

Pauli-basis

Taiwan

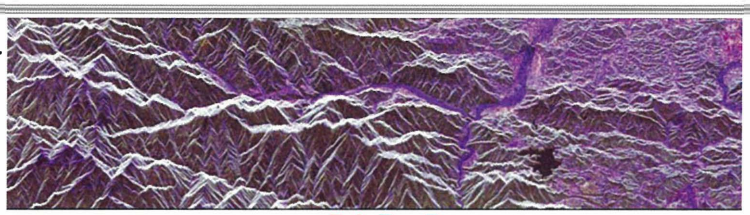
23.703N
120.875E

HV-basis

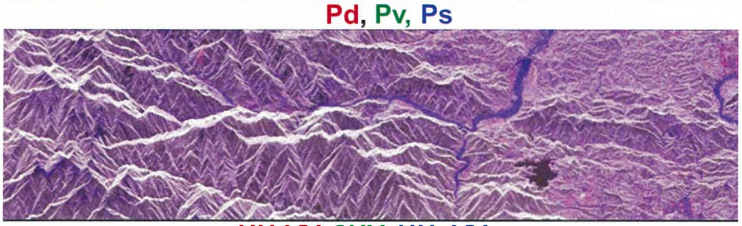
2009/5/1

PASL1100905011424200907020002

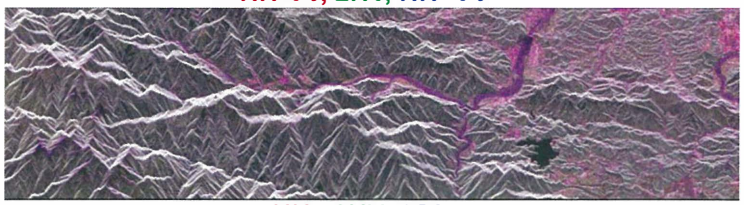
©METI, ERSDAC



Pd, Pv, Ps



HH-VV, 2HV, HH+VV



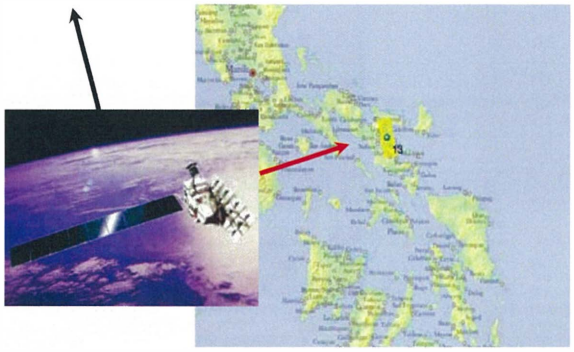
HH, 2HV, VV

UIC University of Illinois at Chicago Communications, Sensing & Navigation Lab ECE Electrical and Computer Engineering

ALOS-PALSAR Polarimetric Mode

Philippines

Ascending



13.501N
123.551E

2009/5/30

Data no.
ALPSRP178330
260

© METI, JAXA

Yoshio Yamaguchi

Niigata University

Mt. Mayon – The pearl of the Orient

Philippines

13.498N
123.561E

2010/1/15

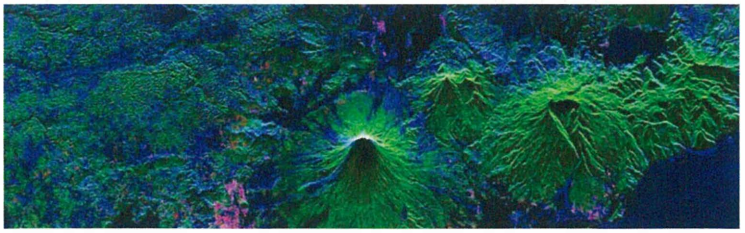
Data no.
ALPSRP211880260

Scattering power
Decomposition

Pd
Ps Pv
Niigata University

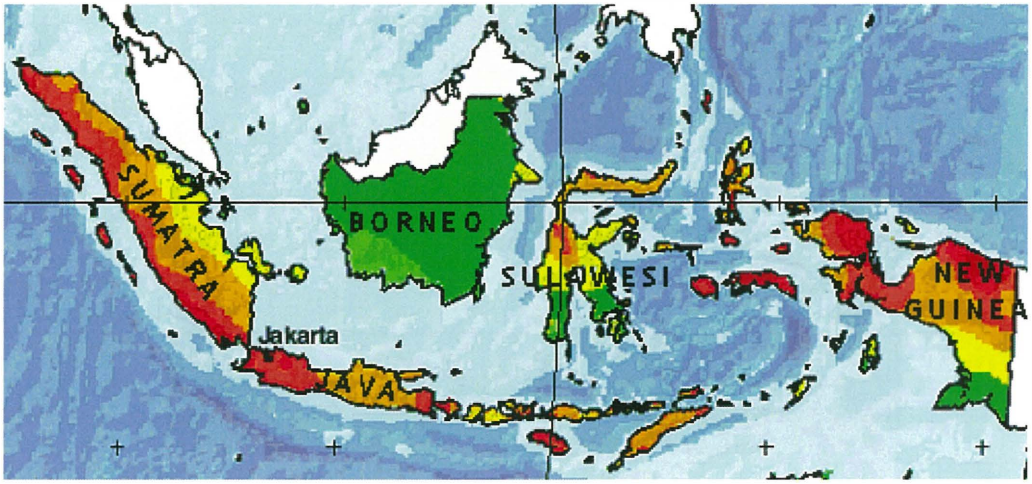
Mt. Mayon

Google Earth optical image



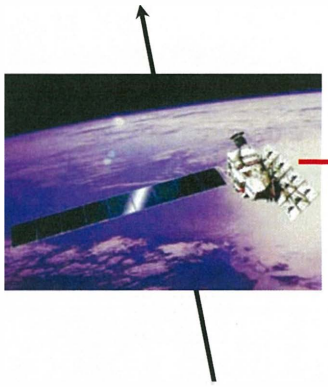
Decomposed image (Ps, Pd, Pv) with rotation 2*12 window

South-East Asia



ALOS-PALSAR Polarimteric Mode

Ascending



Indonesia

2007/3/10

Data no.
ALPSRP059887030
ALPSRP059887040

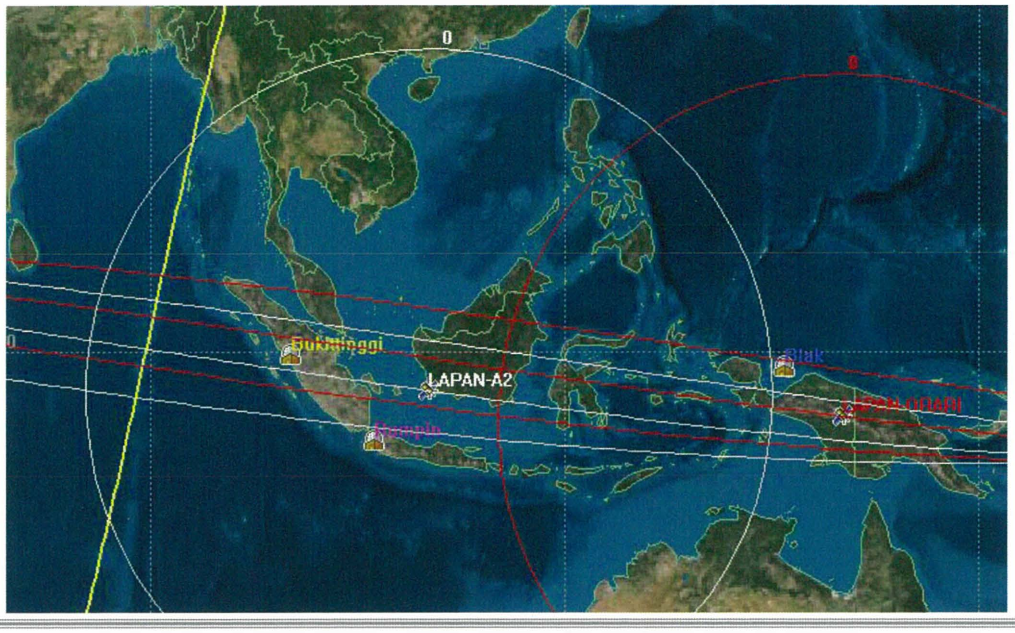
2009/3/15

Data no.
ALPSRP167247030
ALPSRP167247040

Yoshio Yamaguchi

Niigata University

TUB-LAPAN-ORARI ORBIT PROFILE
(14 pass per 24 hr / orbit time 100 minutes and stay above horizon at about 10 minutes)



Indonesia

−7.942N
112.870E

2007/3/10

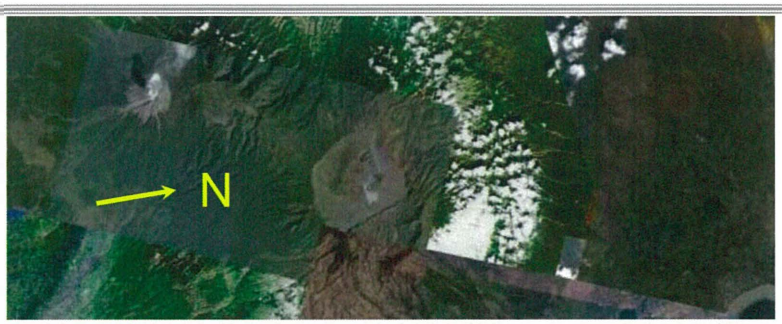
ALPSRP059887030-P1.1__A

©JAXA, METI

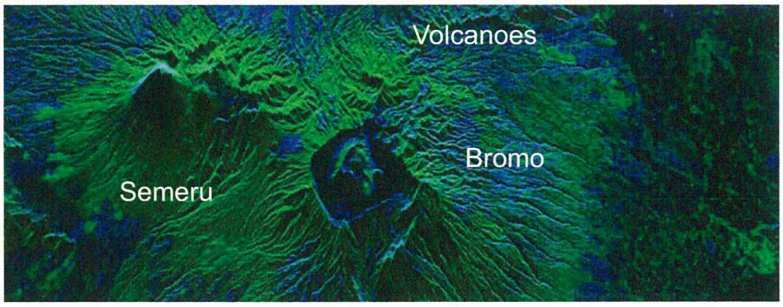
Scattering power
Decomposition

Pd
Ps Pv

Niigata University



Google earth optical image



Decomposed image (Ps, Pd, Pv)

Mount Semeru puffs steam behind a cloud of sulphur gas from Mount Bromo in the Tengger caldera on Java.

Scattering power decomposition

Pd

Ps Pv

Niigata University

2007/3/10

Pauli-basis

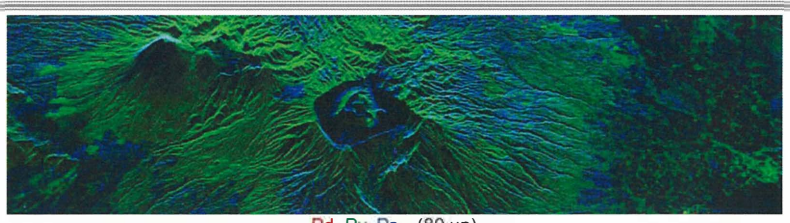
−7.942N

112.870E

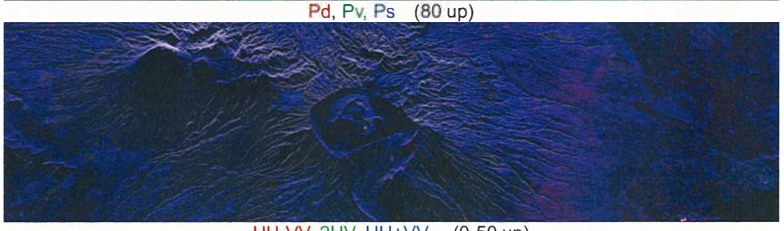
HV-basis

Indonesia

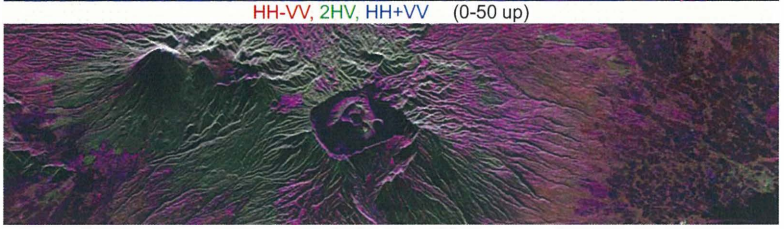
ALPSRP059887030-P1.1__A



Pd, Pv, Ps (80 up)



HH-VV, 2HV, HH+VV (0-50 up)



HH, 2HV, VV (50 up)

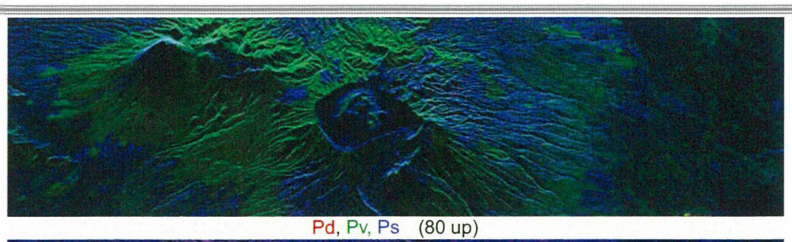
Scattering power decomposition

Pd
Ps Pv
Niigata University

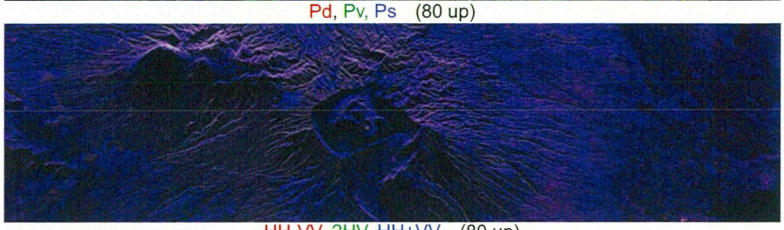
2007/3/10

T33 Rotation

Pauli-basis



Pd, Pv, Ps (80 up)



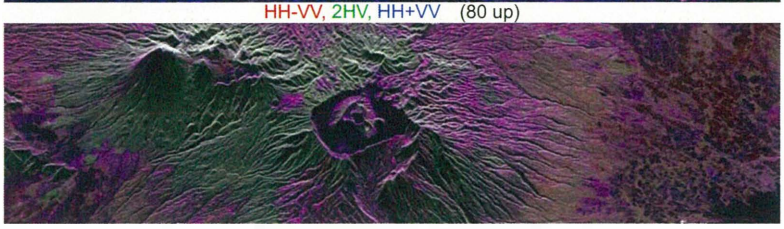
HH-VV, 2HV, HH+VV (80 up)

HV-basis

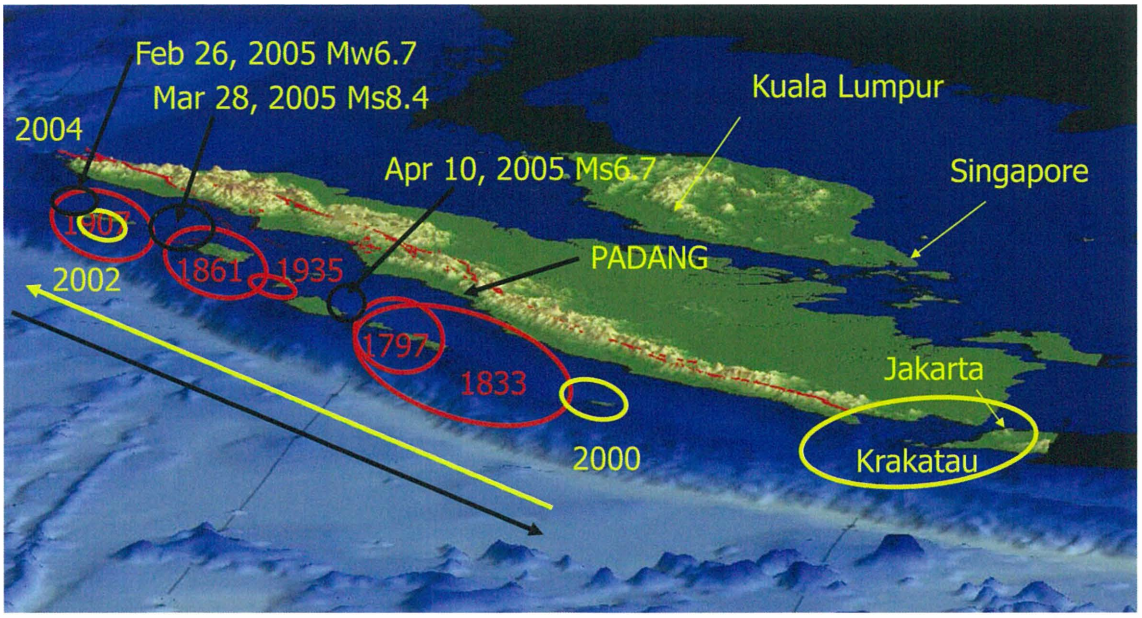
Indonesia
-7.942N
112.870E

ALPSRP059887030-P1.1__A

©JAXA, METI



HH, 2HV, VV (50 up)



A flurry of ruptures have occurred since 2000

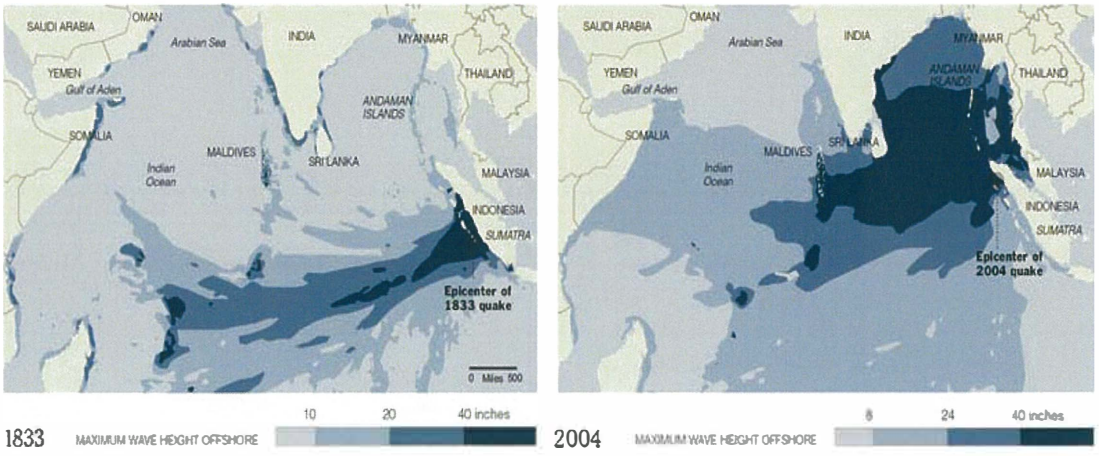
From Simkin and Fiske, 1983

Krakatau

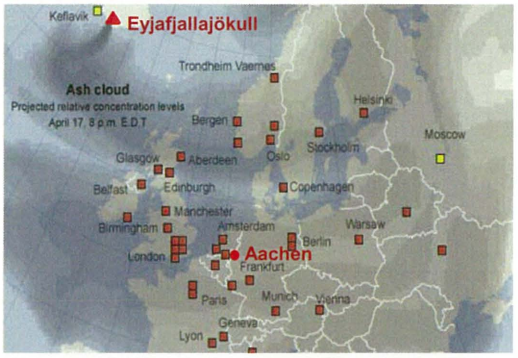
8/26/1883

Next major eruption within 20 years

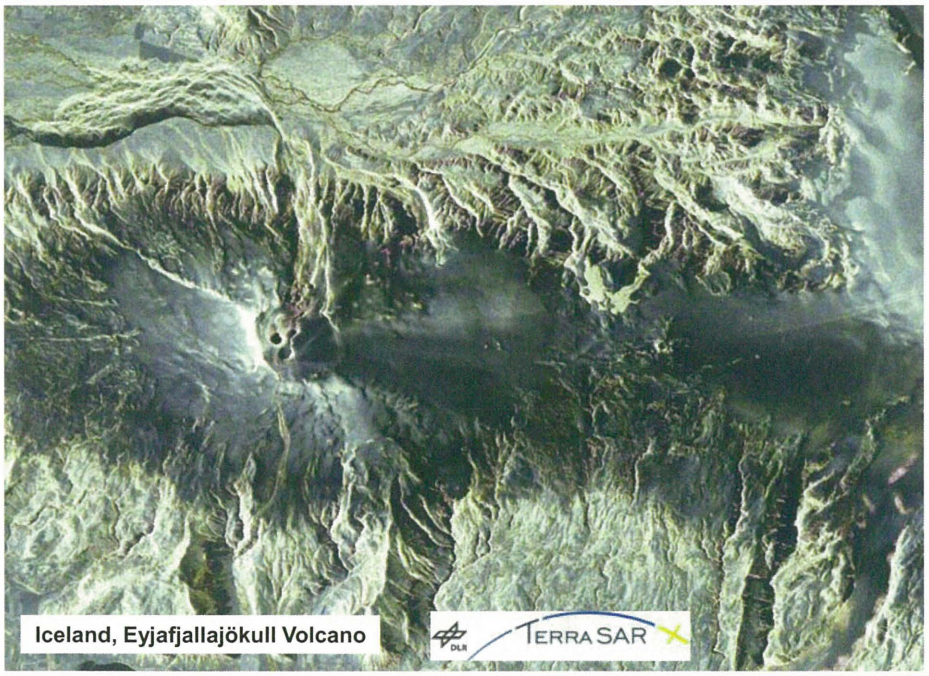
Indian Ocean Tsunamis: 1833 & 2004

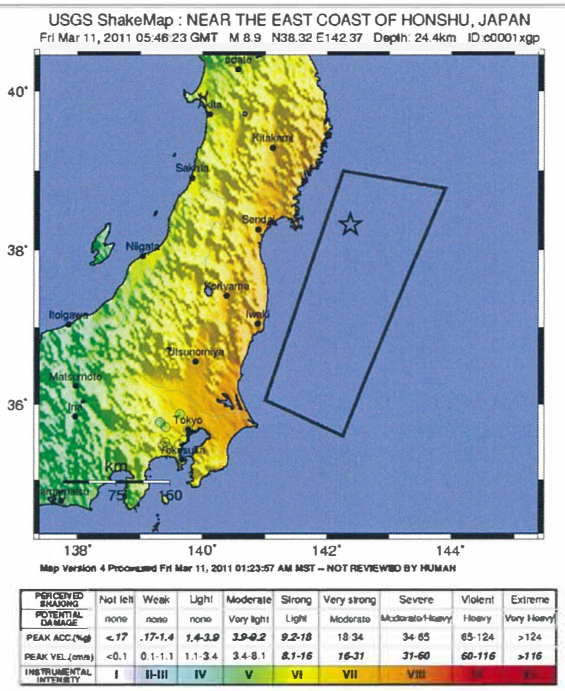


Hannah Fairfield/The New York Times, Science Section, January 4, 2005



Iceland, Eyjafjallajökull Volcano





Off-Tohoku M9 Seaquake & Tsunami 110311

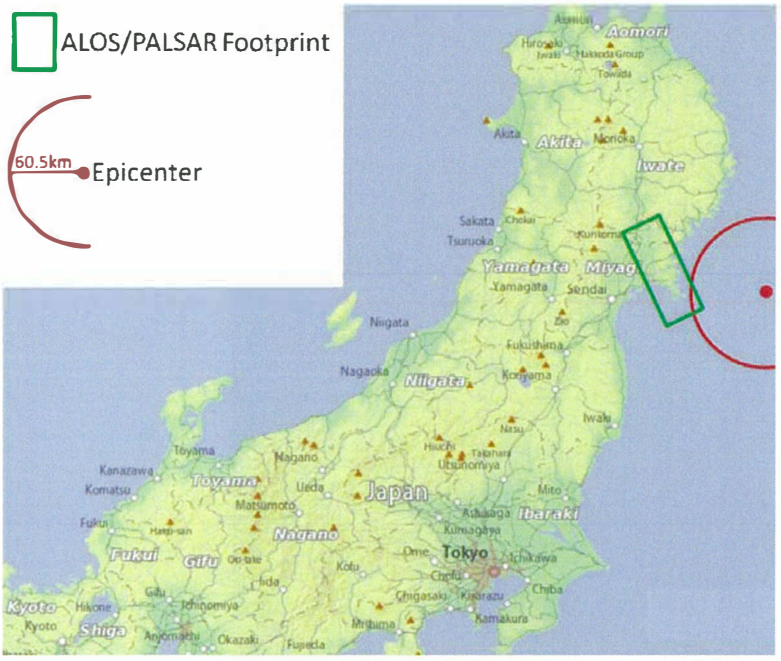
Friday, March 11, 2011 at 05:46:23 UTC
Friday, March 11, 2011 at 02:46:23 PM at epicenter
Epicenter
38.322°N, 142.369°E

110311-Tsunami
OFF-TOHOKU-COASTAL-DISATER
Map-book, 2011 March/April

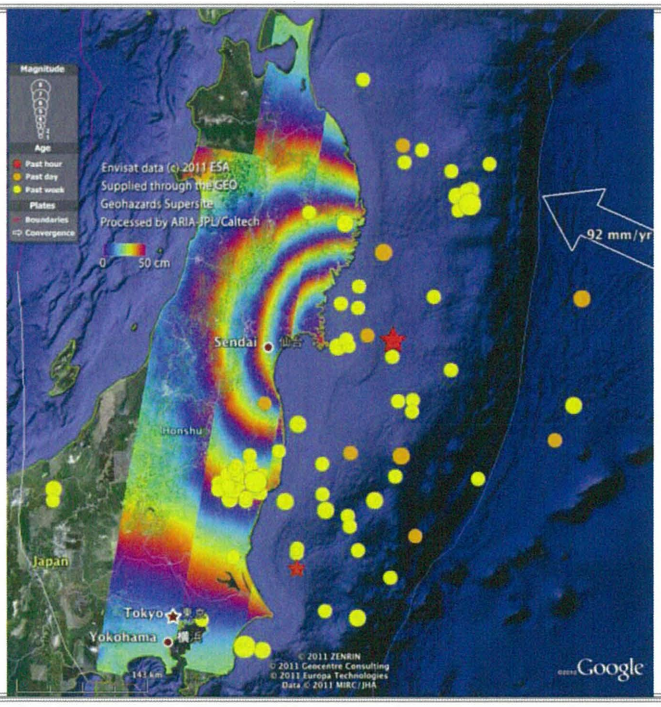
Clearly interpreting the Japanese

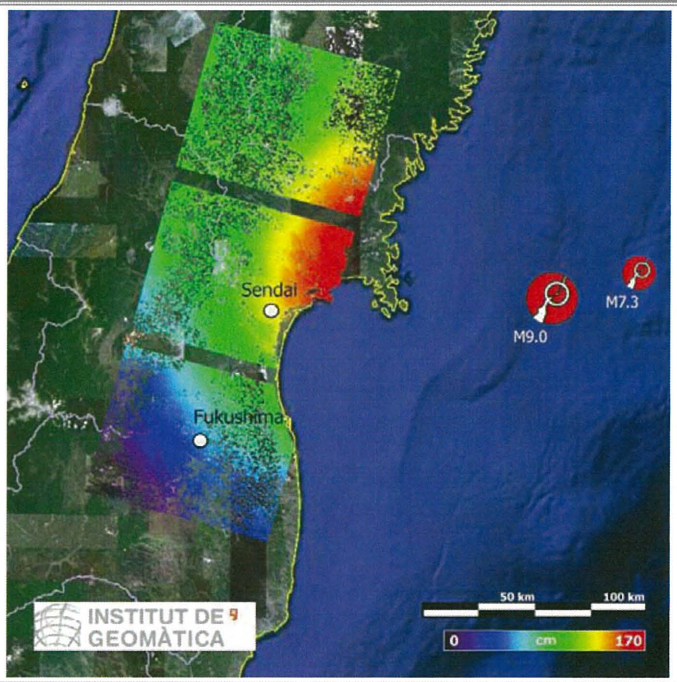
Expression Tsu-nami 津波
= Harbor-wave

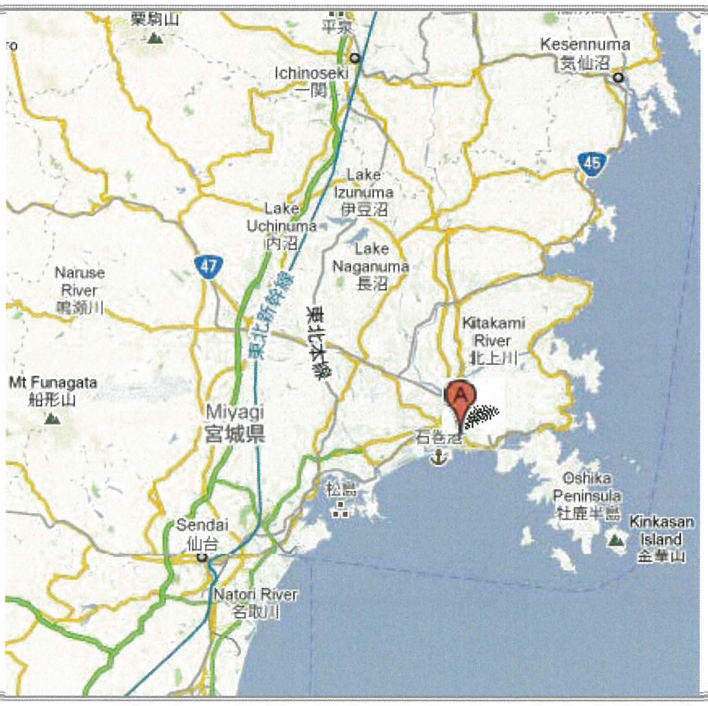
Note that every harbor along the affected Eastern Off-Tohoku coastal corridor was severely damaged by the incoming and outgoing tsunami water-walls



Off-Tohoku 9.0 Earthquake with Super-Tsunami



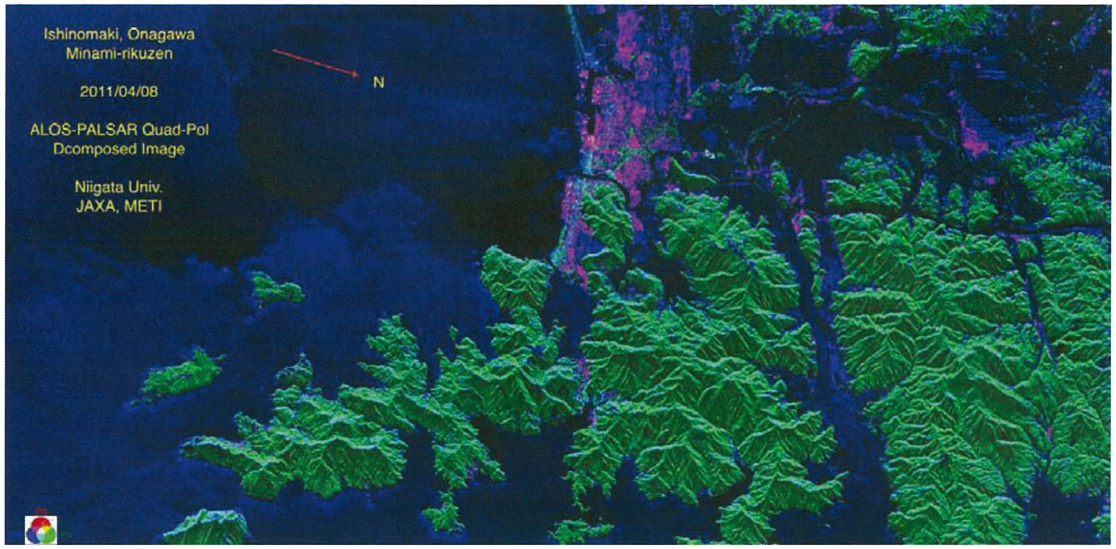




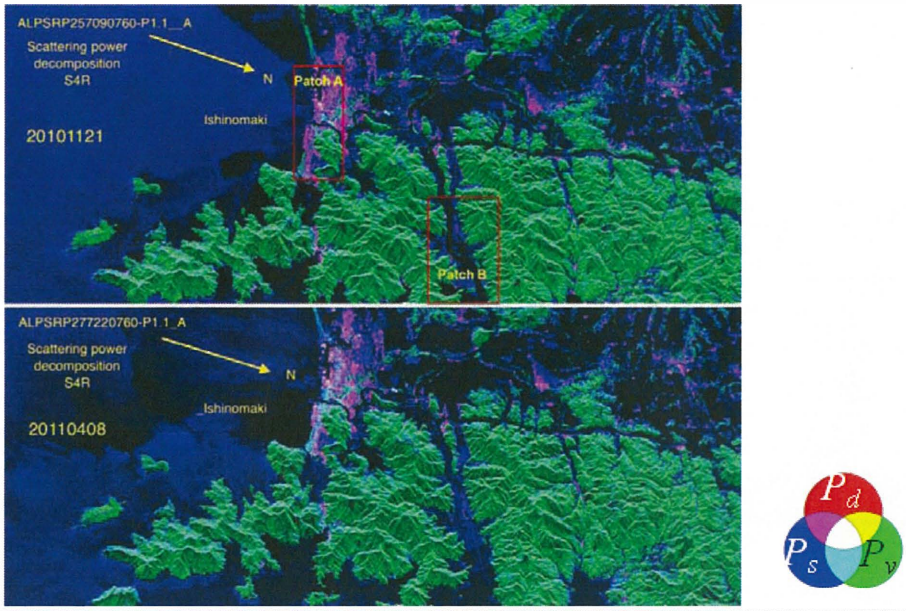
Ishinomaki harbor
38*25'N, 141*18'E

Destruction of City and Harbor of Ishinomaki by 110311 Tsu-nami (Harbor-Wave)

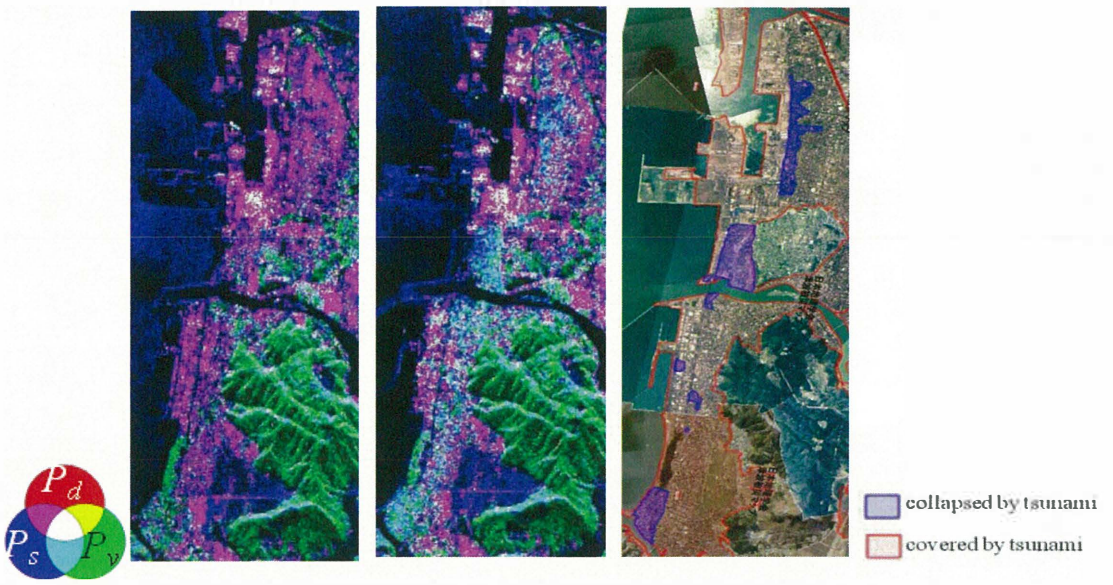
Off-Tohoku M9 Seaquake & Tsunami 110311



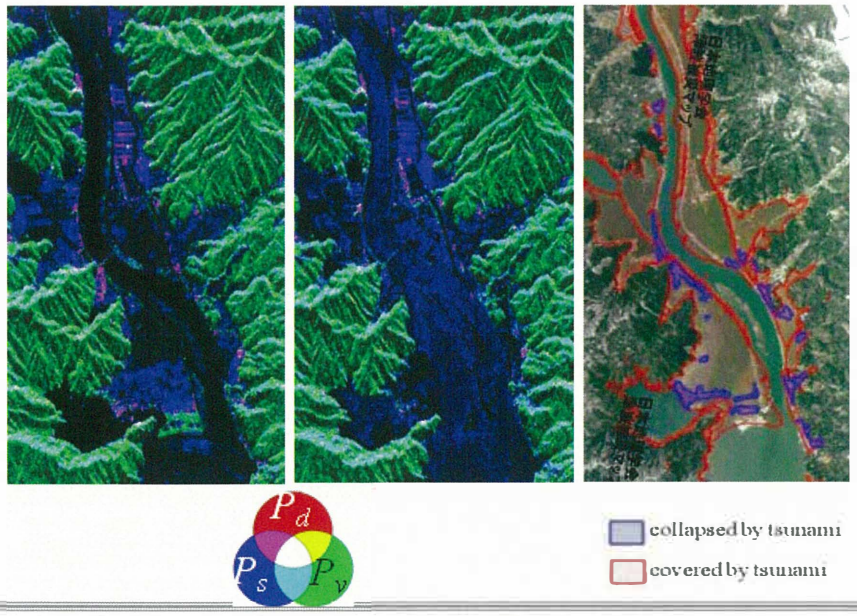
Off-Tohoku M9 Seaquake & Tsunami 110311

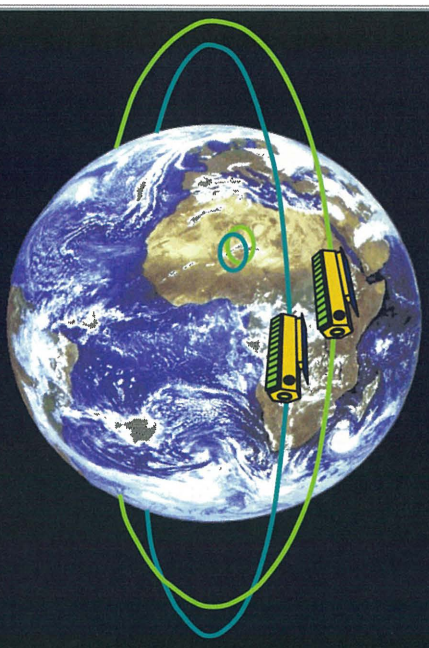


Off-Tohoku M9 Seaquake & Tsunami 110311



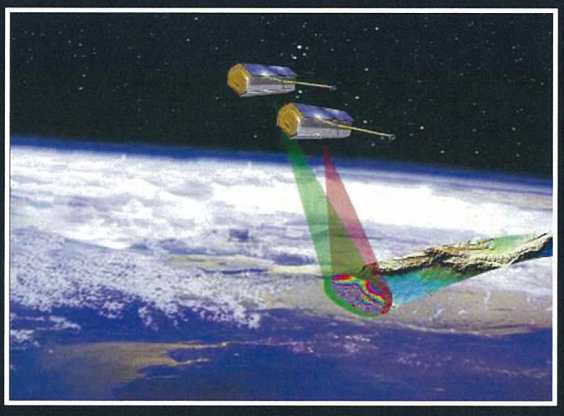
Off-Tohoku M9 Seaquake & Tsunami 110311



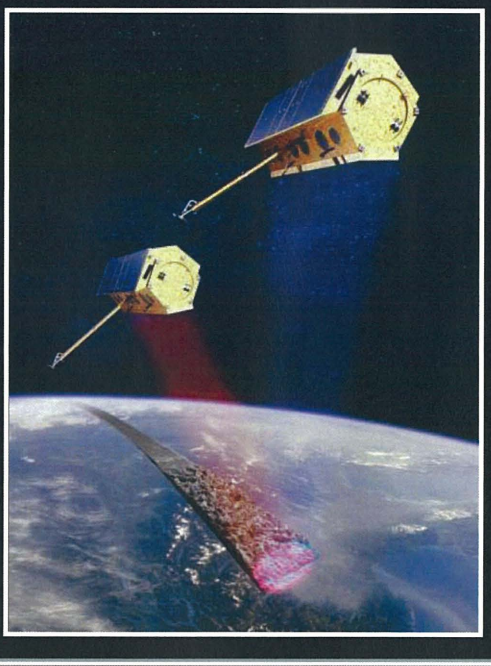


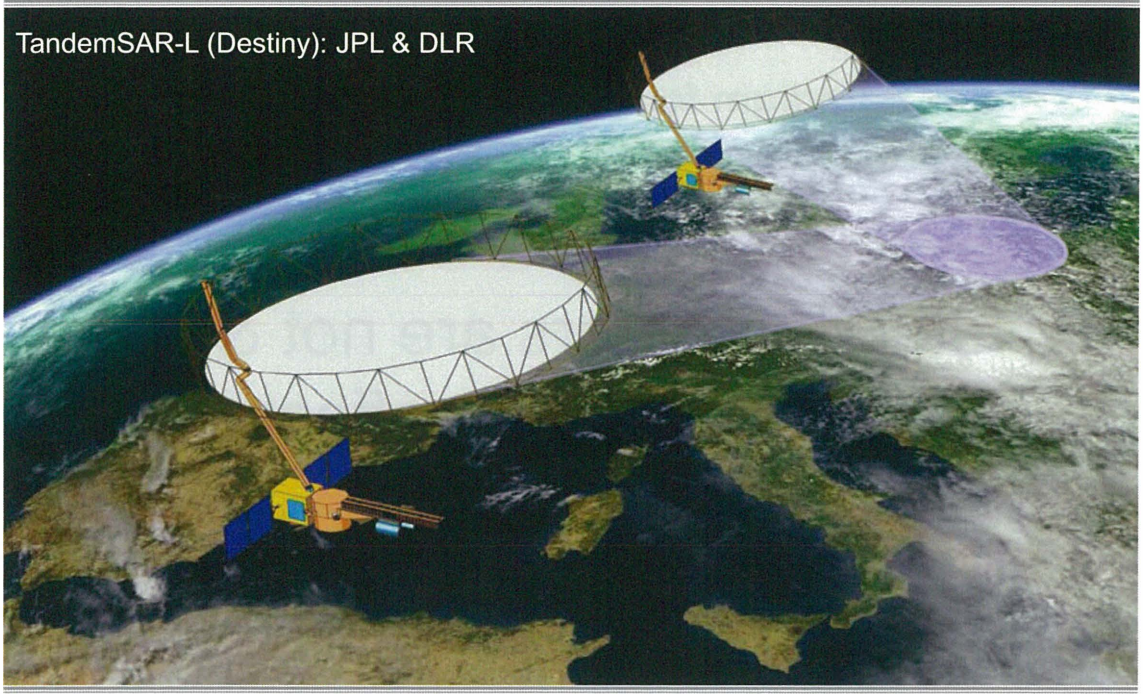
Global Monitoring of Bio-, Geo-, Cryo- and Hydrosphere processes with hith temporal and spatial resolution.
(Prof. A. Moreira – POLINSAR09)

Radar Interferometry



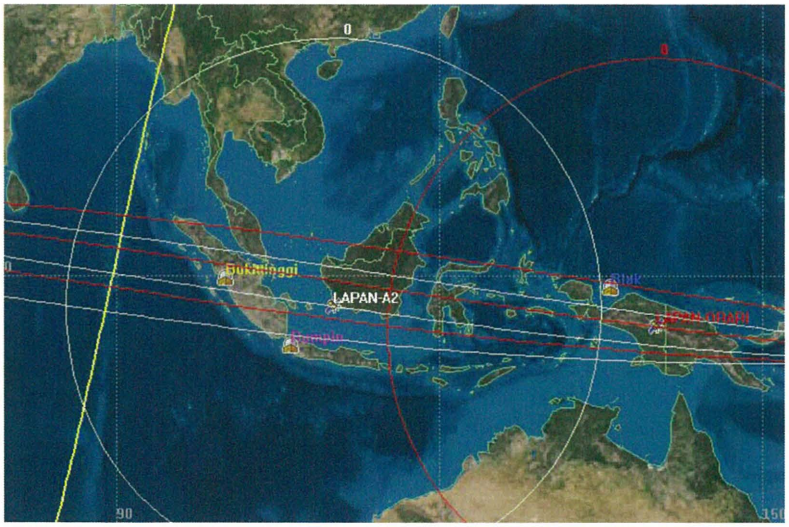
TerraSAR – X (1 & 2)
(2010)
PoI – InSAR Sensors
TanDEM-X





TUB-LAPAN-ORARI ORBIT PROFILE

(14 pass per 24 hr / orbit time 100 minutes and stay above horizon at about 10 minutes)



Major Paradigm for Remote Sensing from Air and Space of the Terrestrial Covers:

"Natural hazards are inevitable! Natural disasters are not & how can we reduce aftereffects?"

Accomplished with the aid of fully Polarimetric POLinSAR Sensors at Very High Resolution and all pertinent bands:

ACQUISITION OF NEW BANDS FOR PASSIVE & ACTIVE SENSING

• Deep earth sounding	ULF - LF
• Ground penetrating radar	LF - VHF
• Mineral resource exploration	HF - UHF
• Biomass and vegetative cover estimation	HF – EHF (P/L/C-Band)
• Man made surface structure monitoring	HF – EHF (C/X/K-Band)
• Atmospheric passive remote sensing	cm – sub-mm

◇ We need to put our act together as the global remote sensing community and request from ITU/WMO the protection of the "fundamental natural resource: the e-m spectrum", and for providing the spectral bands for us to fulfill our professional duties as

"The Remote Sensing Pathologists and Radiologists of Earth and Planetary Covers"

Table - EESS (active) Frequency Bands between P-band and Ka-band (Huneycutt)

IEEE Band Designation	Frequency Band (MHz)	Bandwidth (MHz)	Allocation Status
P-band	432-438	6	Secondary (WRC'03)
L-band	1215-1300	85	Primary (WRC'97)
S-band	3100-3300	200	Secondary (WRC'97)
C-band	5250-5570	320	Primary (WRC'97)
X-band	8550-8650	100	Primary (WRC'97)
X-band	9300-9900	600	Primary (WRC'97, WRC'07)
Ku-band	13250-13750	500	Primary (WRC'97)
Ku-band	17200-17300	100	Primary (WRC'97)
K-band	24050-24250	200	Secondary (WRC'97)
Ka-band	35500-36000	500	Primary (WRC'97)

F-SAR technical characteristics (Reigber)

	X	C	S	L	P
RF [GHz]	9.6	5.3	3.25	1.325	0.35/0.45
Bw [MHz] PRF	760	400	300	150	100/50
[kHz] PT [kW]	5	5	5	10	10
Rg res. [m] Az	2.5	2.2	2.2	0.9	0.9
res. [m]	0.2	0.4	0.5	1.0	1.5
Rg cov. [km]	0.2	0.3	0.35	0.4	1.5
Sampling	12.5 (at max. bandwidth)				
Channels Data rate	8 bit real, 1000MHz				
	4	2	2	2	1
	247 MByte/s (per channel)				

FOUNDATIONS AND RELEVANCE OF MODERN EARTH REMOTE SENSING & ITS APPLICATIONS BY IMPLEMENTING SPACE-BORNE POL-IN-SAR

Conclusions:

The Electromagnetic **Vector (Polarization) Wave** Spectrum:
A Natural Global Treasure

Terrestrial Remote Sensing with POLinSAR for
The *Diagnostics of the Health of the Earth*