L-band SARs and what's for the future
– Joint Study between DLR & JAXA-

日独連携による合成開口レーダーと期待する地球物理量

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JAXA, EORC

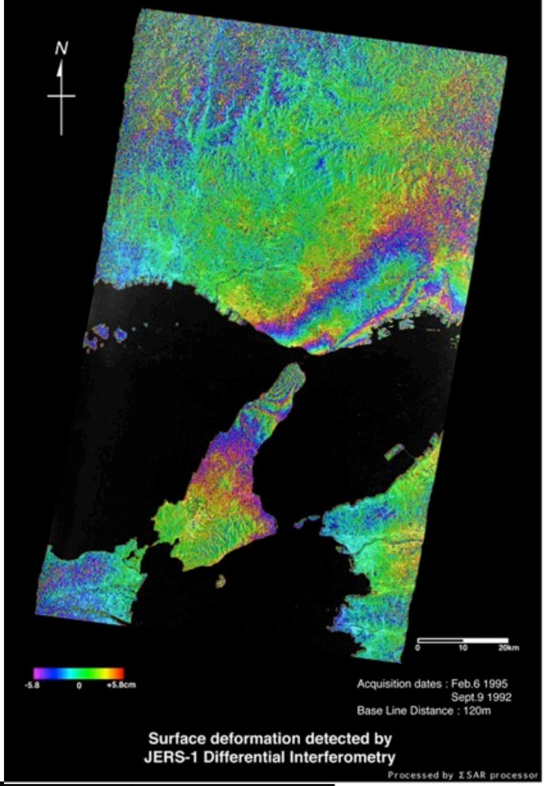
京都大学防災研究所特定研究集会「SARが切り拓く地球人間圏科学の新展開」
Aug. 22-23, 2013

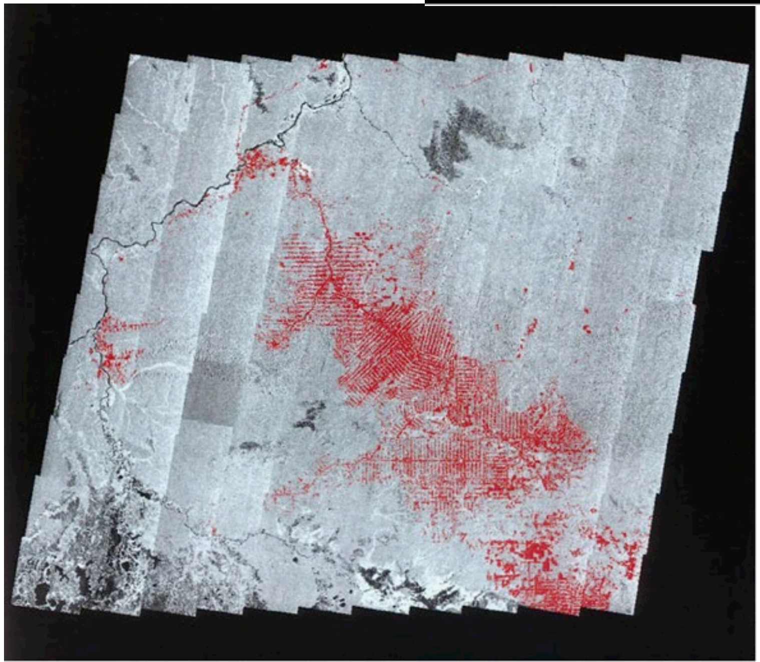
Japanese Earth Resources Satellite -1 (JERS-1)

1992~1998

- Instruments

1)OPS(8 bands)
2)SAR(L HH)：
3)MDR（Mission Data recorder）
4)MDT（Mission Data transmitter）

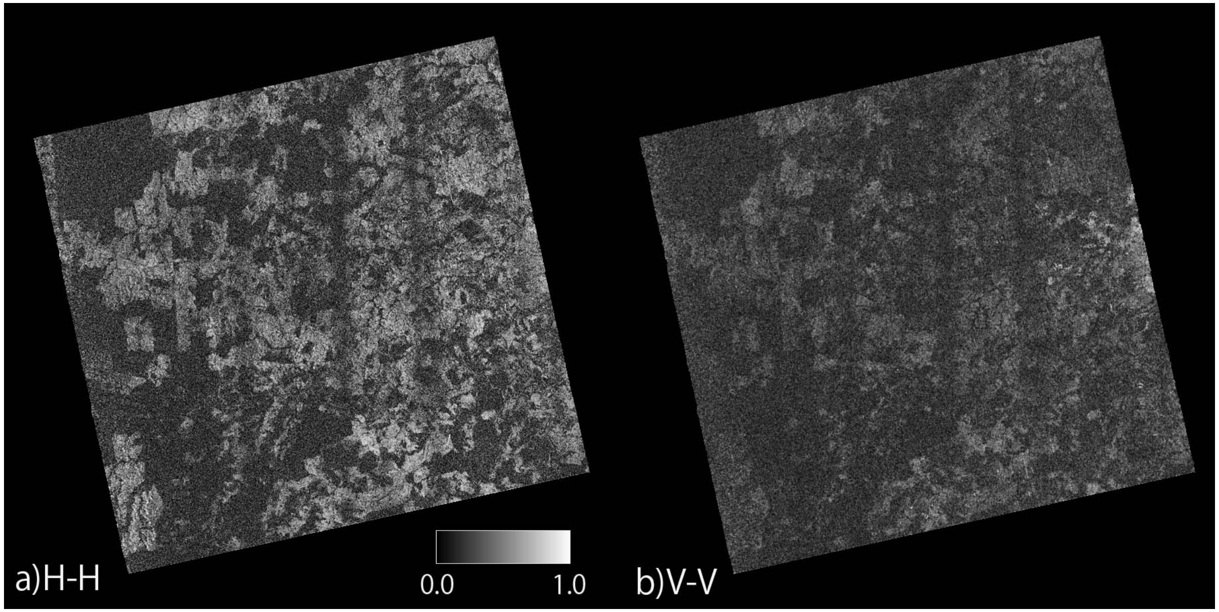


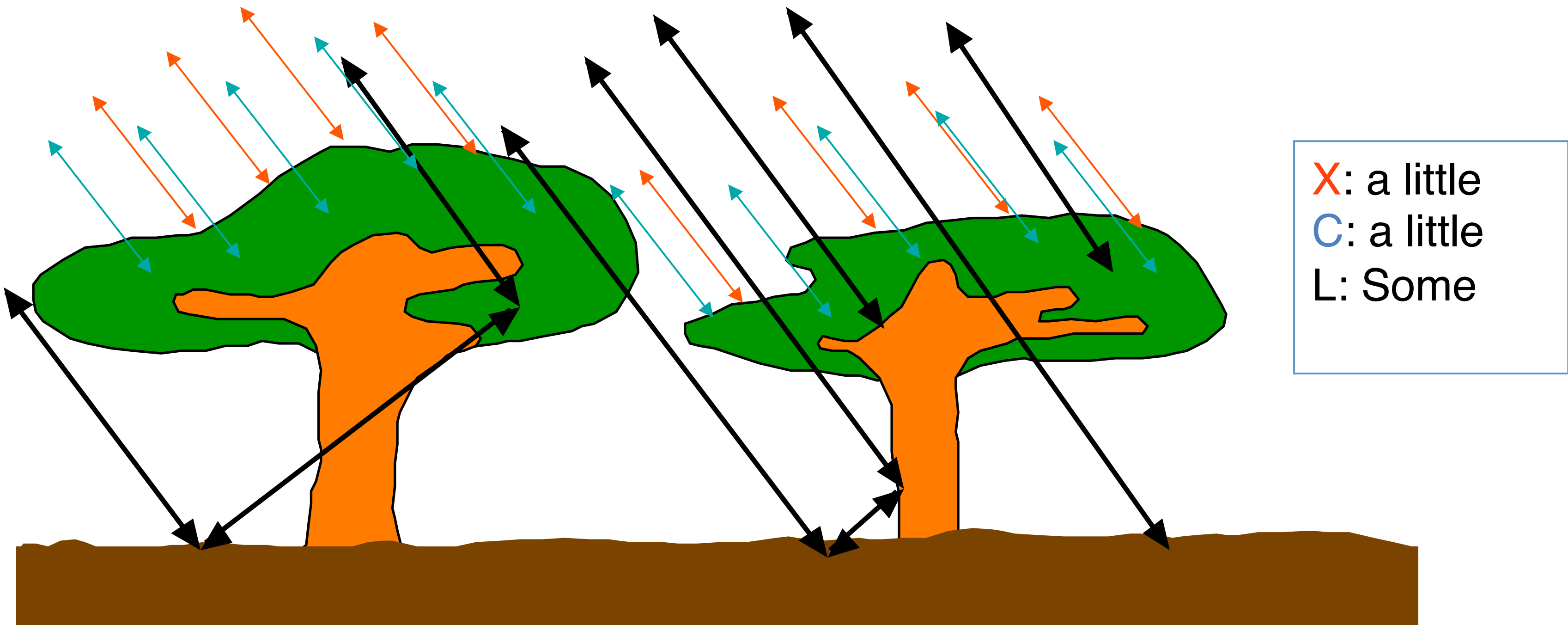


- Total data (at EOC)

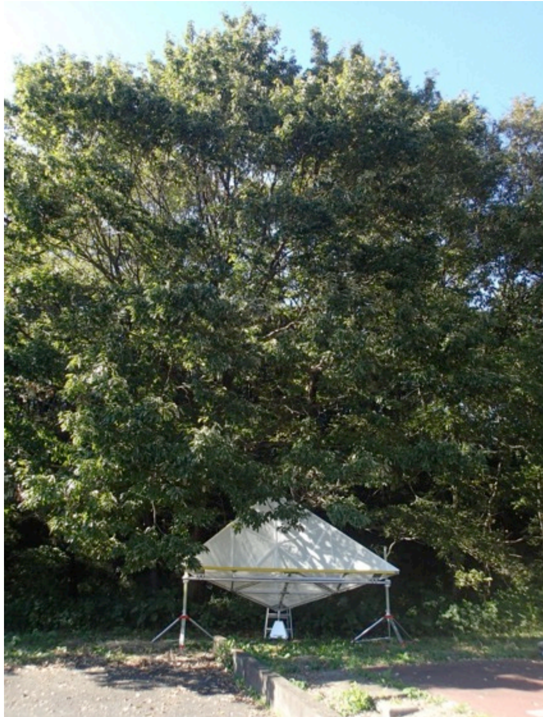
SAR：707,393 scenes(97%)
OPS：335,619 scenes(63%)

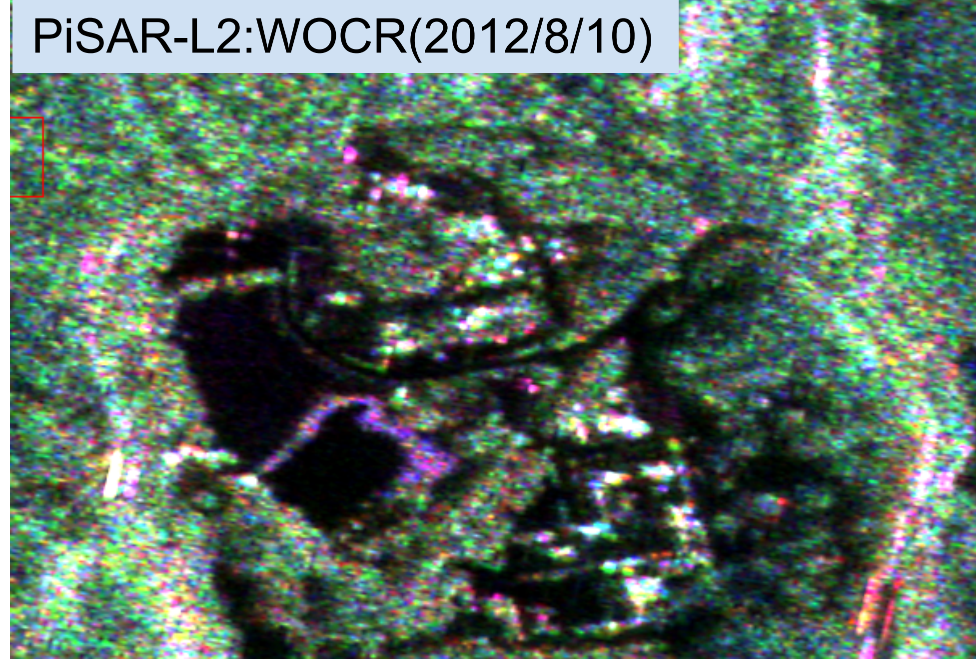
L-band SAR and Penetration/Interferometry/Polarimetry

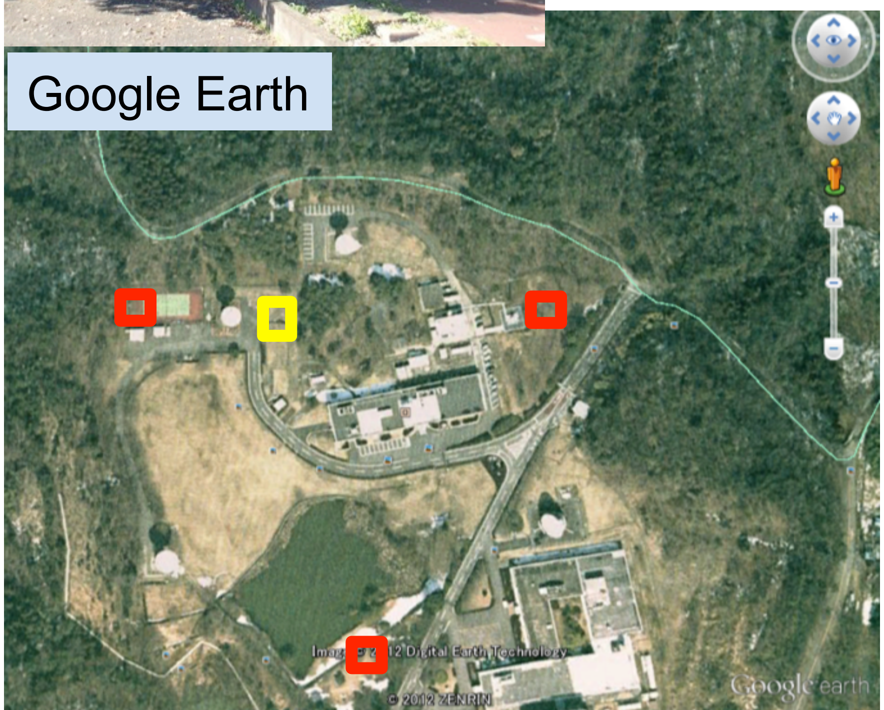


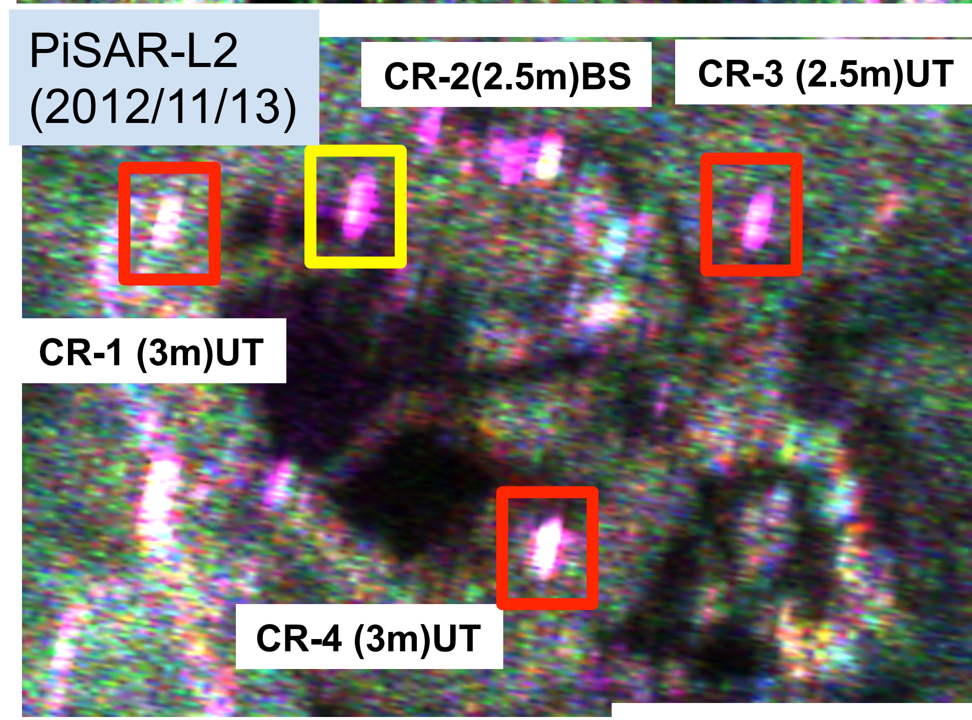


Ground Photo









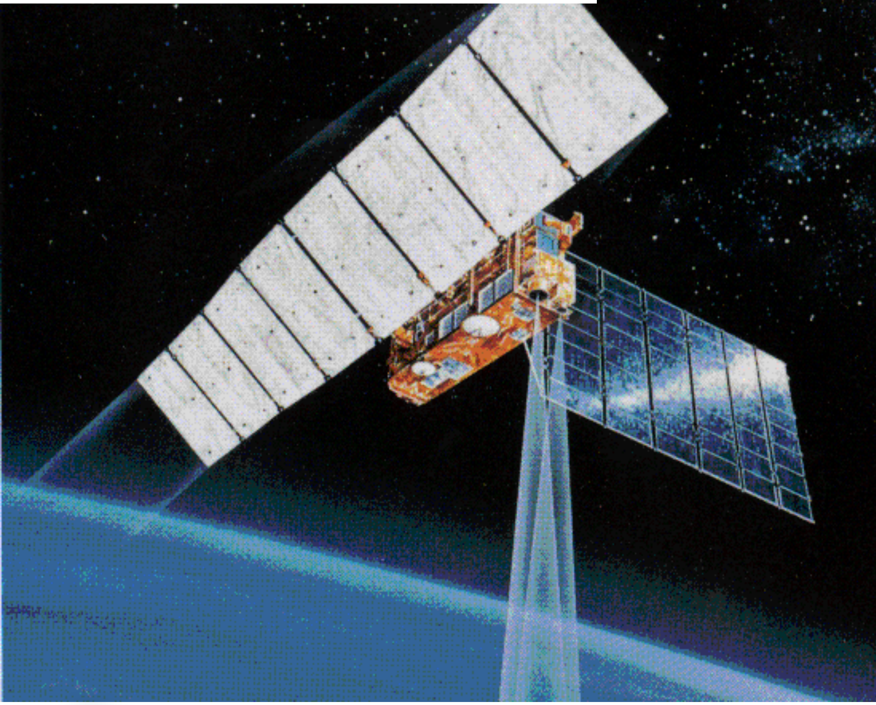
R: HH G: HV B: VV

JAXA's SAR history

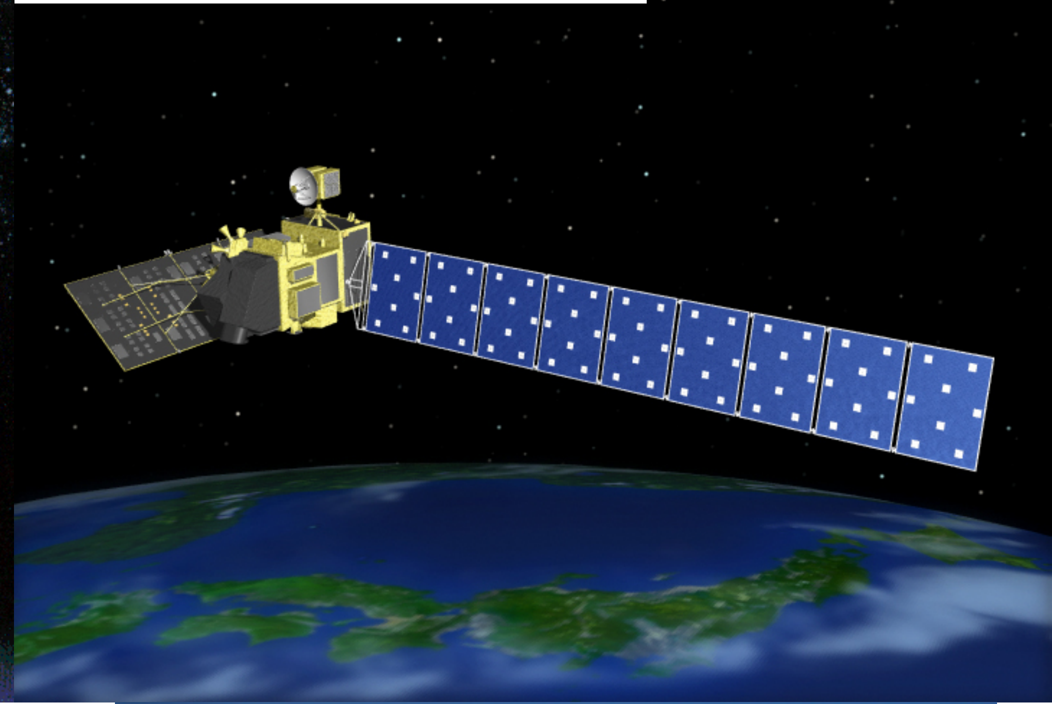
- JERS-1/SAR : 1992/2/11-1998/10/12
- Pi-SAR-L:1997/11/M-2011/11/E
- ALOS/PALSAR:2006/1/24-2011/4/22
- Pi-SAR-L2:2012/4/17-
- ALOS-2/PALSAR-2:2013/11/7-
- ALOS-followon:201? or 2020

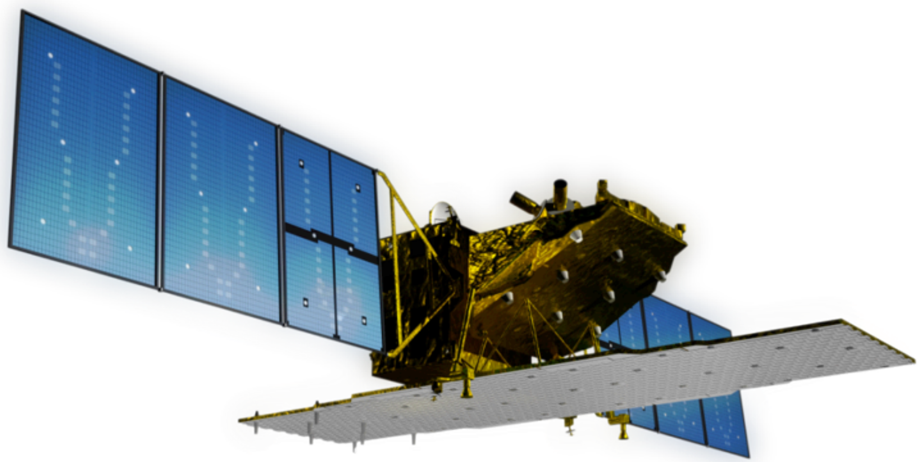
- All L-band, of large Duty SAR for global Observation, heritages from 1990 for solid Earth and Biospheric observation. Application (including disaster) and the science are the main objectives.

JERS-1/SAR (1992-1998)



ALOS/PALSAR(2006-2011)





ALOS-2(2014~)

Pi-SAR-L(1998~2011)
Pi-SAR-L2(2012~)

Sat.	JERS-1	Pi-SAR-L	ALOS/ PALSAR	Pi-SAR-L2	ALOS-2/ PALSAR-2
Resol. (m:Az-Rg)	5-10	0.8-3.0	4.5-5	0.8-1.72	1-1.72
NESZ(dB)	-18	-35	-34(-23)	-54(-35)	?(-30)
Polarization	HH	Quad	HH+HV Quad(E) ScanSAR(HH)	Quad	HH+HV Quad ScanSAR(HH+HV)
Revisit/ Off-nadir	44D 35.1	NA 7-60	46D 7.7-50.8	NA 7-60	14D 7-70
Mode(swath)(km)	Strip(75)	Strip(15)	Strip(70) Scan(350)	Strip(20)	Spot(25) Strip(50) Scan(350/490)

Comparison among L-C-X

	L(23cm)	C(5.6cm)	X(3.0cm)
Resolution	<85MHz	<TBD	<500MHz
Penetration	Much	less	less
Observables	Forest covered surface	Surface scattering	Surface scattering
Forest	sensitive	Less sensitive	less-sensitive
Agriculture	Less sensitive	Medium sensitive	sensitive
Ocean	Sensitive	Sensitive	Sensitive
Coastal erosion	Sensitive (sometimes coast invisible)	Sensitive	Sensitive
DinSAR	Very sensitive with longer time	Sensitive only in urban	Sensitive only in urban
Disaster	Effective use of Pol + InSAR	Effective	Effective

Frequency sensitivity of the SAR

Frequency	Advantages(disadvantages)
P-band	High penetration through the vegetation (Lower Bandwidth)
L-band	Adequate signal penetration through the vegetation depending on the polarization increases the radar sensitivity using the amplitude data, interferometry, and Polarimetry. →High InSAR coherence (depending in the polarization) →Tree height and 3D measurement using PolInSAR→Challenge →Deformation Monitoring (Earthquake, Volcano, subsidence) →Disaster monitoring and land use monitoring using PolSAR →Forest Monitoring (Clear-cut, FNF, Biomass) →Bandwidth is 85MHz narrower than C-X bandwidth →ionospheric disturbance →Frequency allocation issue with GPS satellite
C-band	High resolution and highly sensitivity for smaller vegetation Weaker signal penetration > lower InSAR coherence
X-band	High resolution and highly sensitivity for smaller vegetation Weaker signal penetration > lower InSAR coherence nor PolSAR

L-band Radar Remote Sensing

- Imaging under All weather Observation
- Accurate Geometry > GIS
- Accurate Radiometry
- Interferometry > CCD, Deformation
- Polarimetry > Classification/Disaster
- PolInSAR > 3D structure

Researches using ALOS/PALSAR

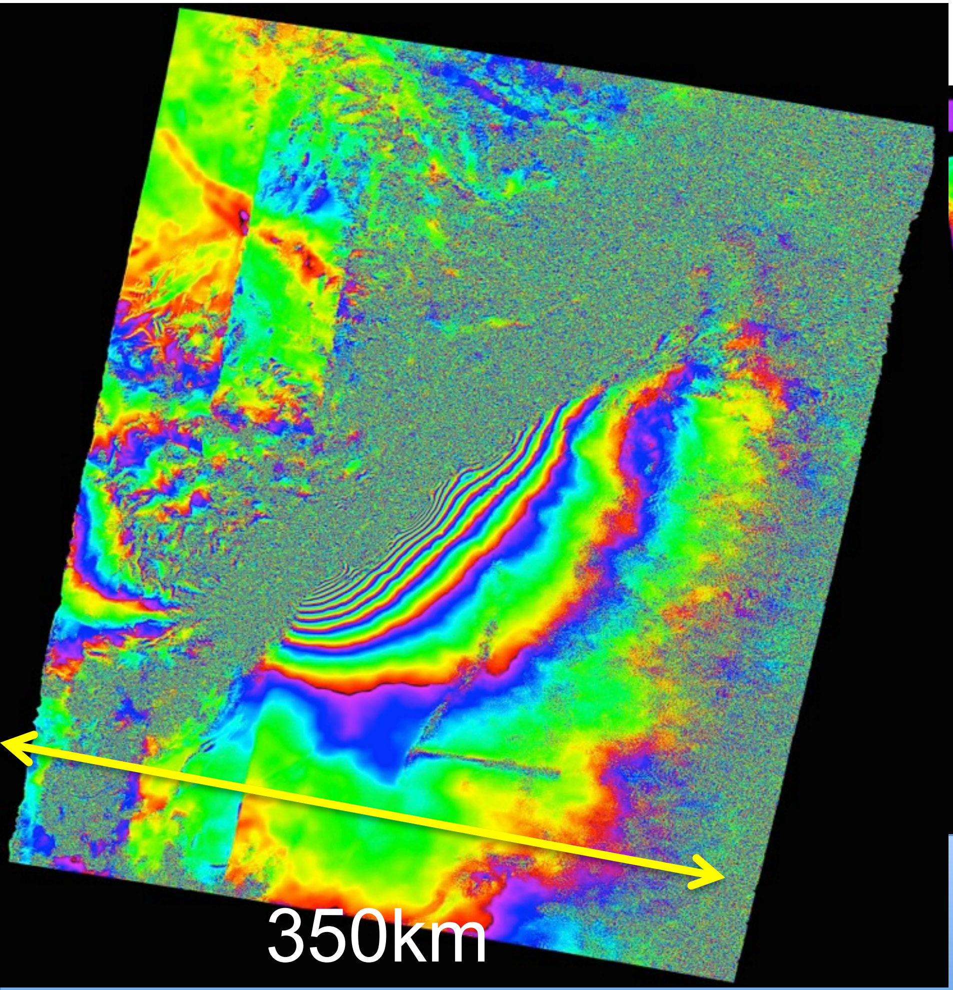
- Oil Spill
- Fire scare
- Flooding
- Land Slide (Flash water and Slow moving)
- Change Detections(CCD, ICCD)
- Subsidence (DinSAR)
- Volcano
- Earthquake (DinSAR)
- Forest, REDD+, Wetland
- Illegal Logging Monitoring
- Rice Paddy Monitoring
- Polar Ice Movement/ Glaciers(Antarctica and North Polar region)
- Drift Ice monitoring
- Coastal Erosions
- Ocean Wind Speed distribution
- Marine surveillance(Debris, etc.)
- Land inflation/subsidence monitoring for resource/Oil spill
- Map by Ortho-rectification
- DSM generation (InSAR)
- Ionospheric Disturbances
- Radio Frequency Interference
- Soil Moisture

3. Interferometry and Deformation

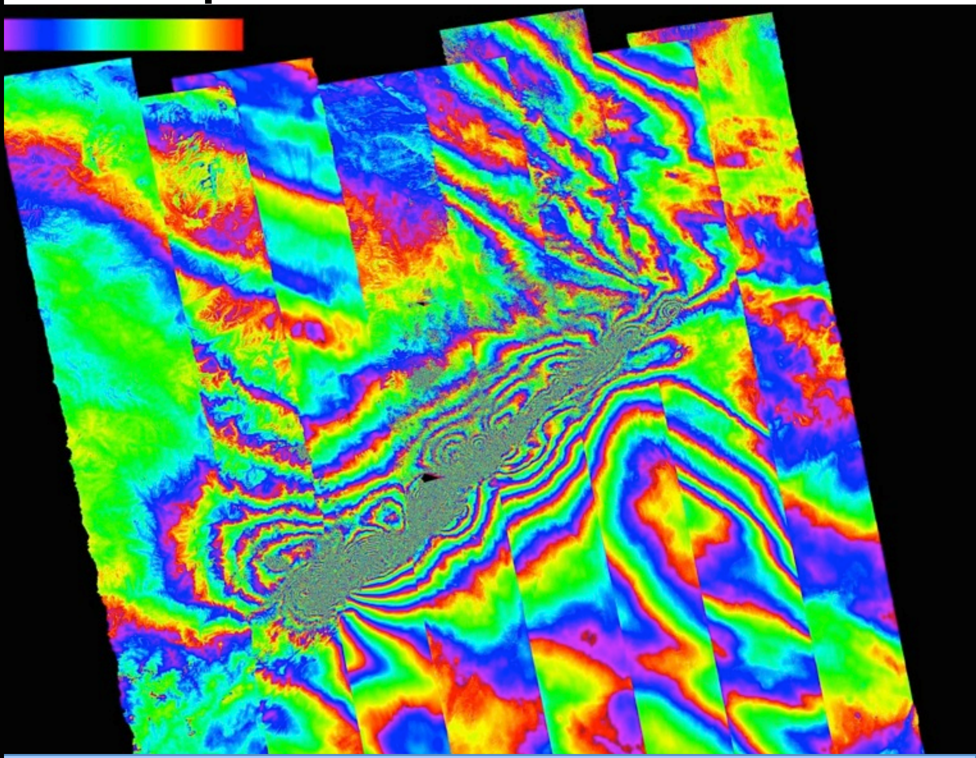
- Deformation monitoring (Seismic)
- ScanSAR interferometry
- Subsidence monitoring

四川省大地震、2008年5月12日

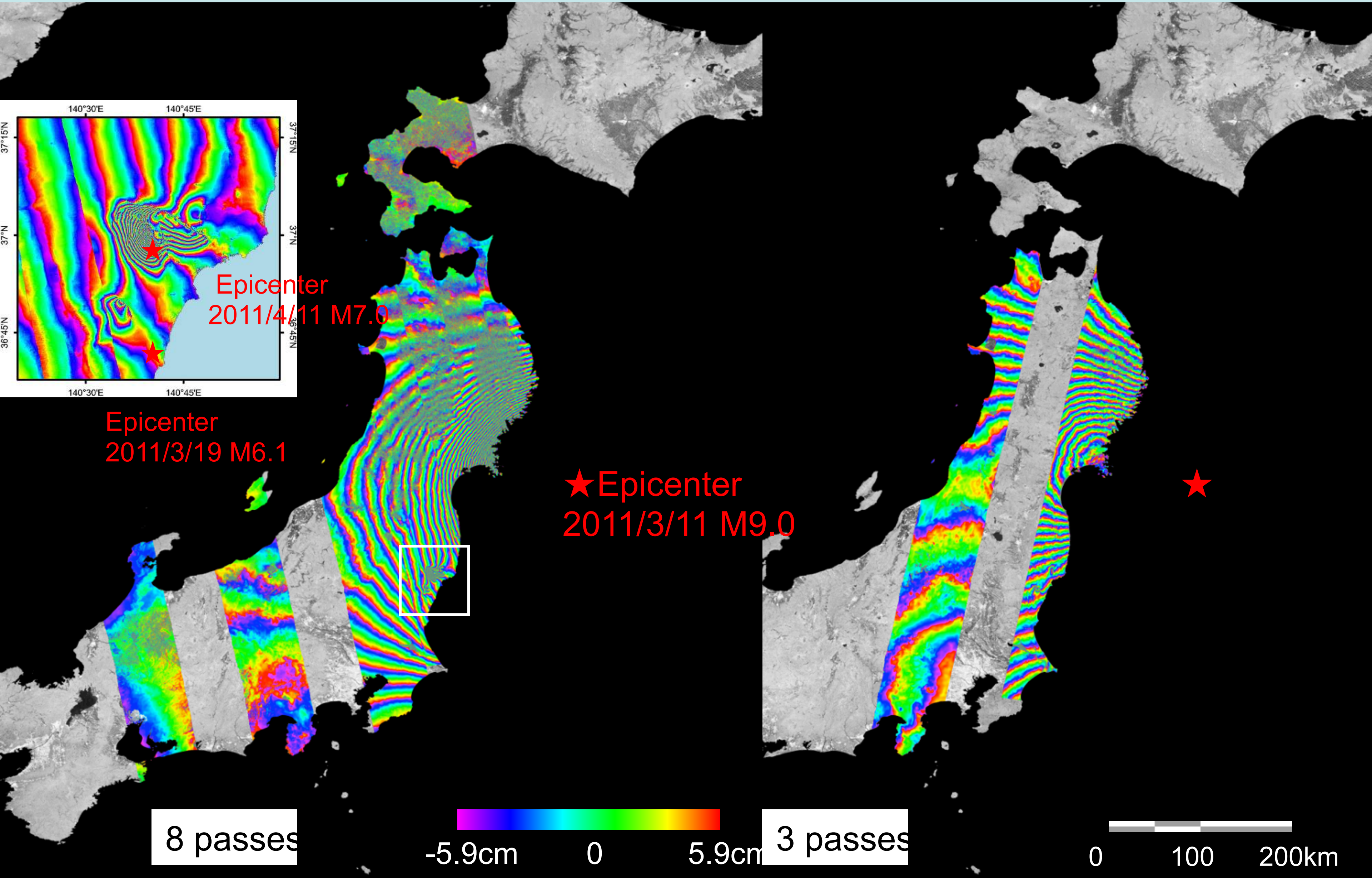
ScanInSAR



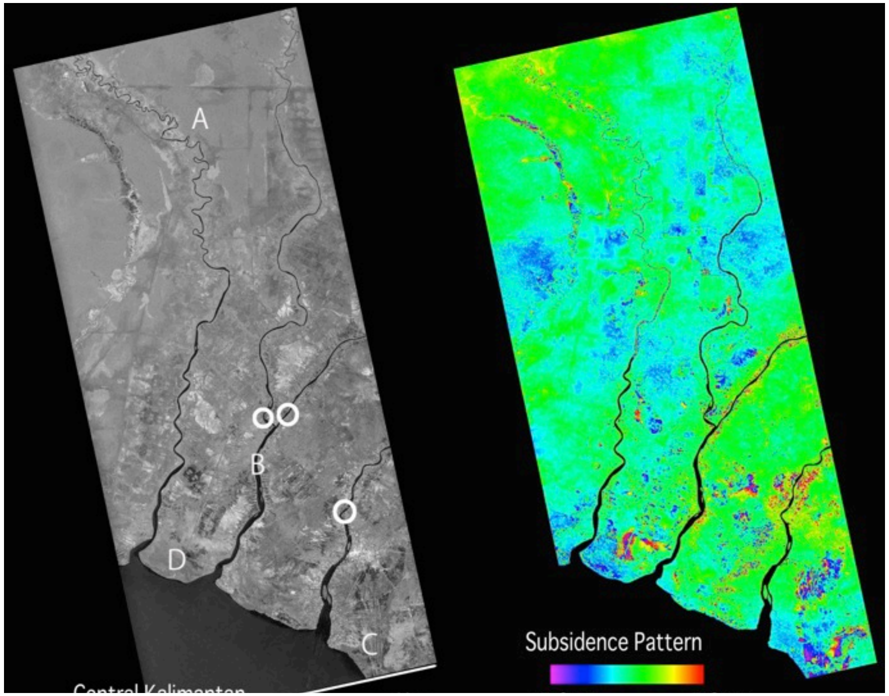
Strip SAR x 8

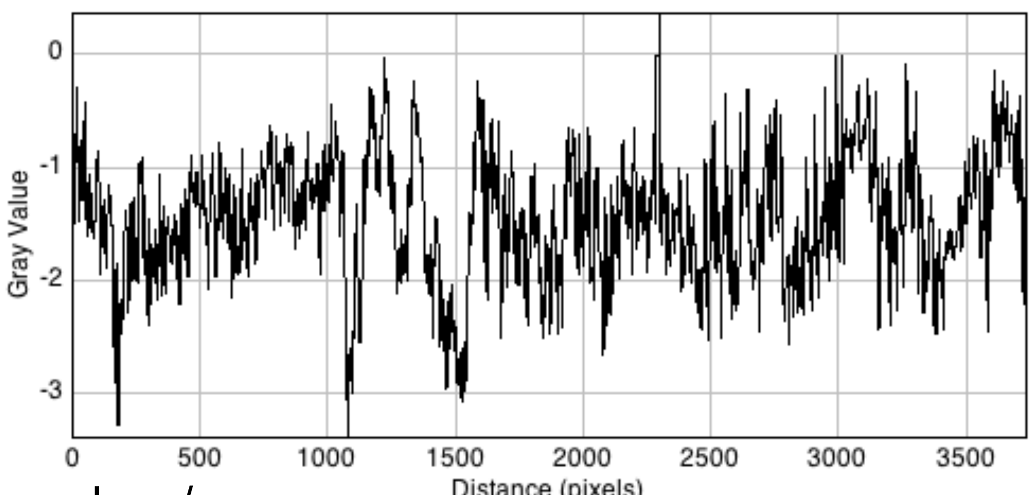


PALSARによる地殻変動解析（PALSAR DinSAR for Tohoku-Oki Earthquake）

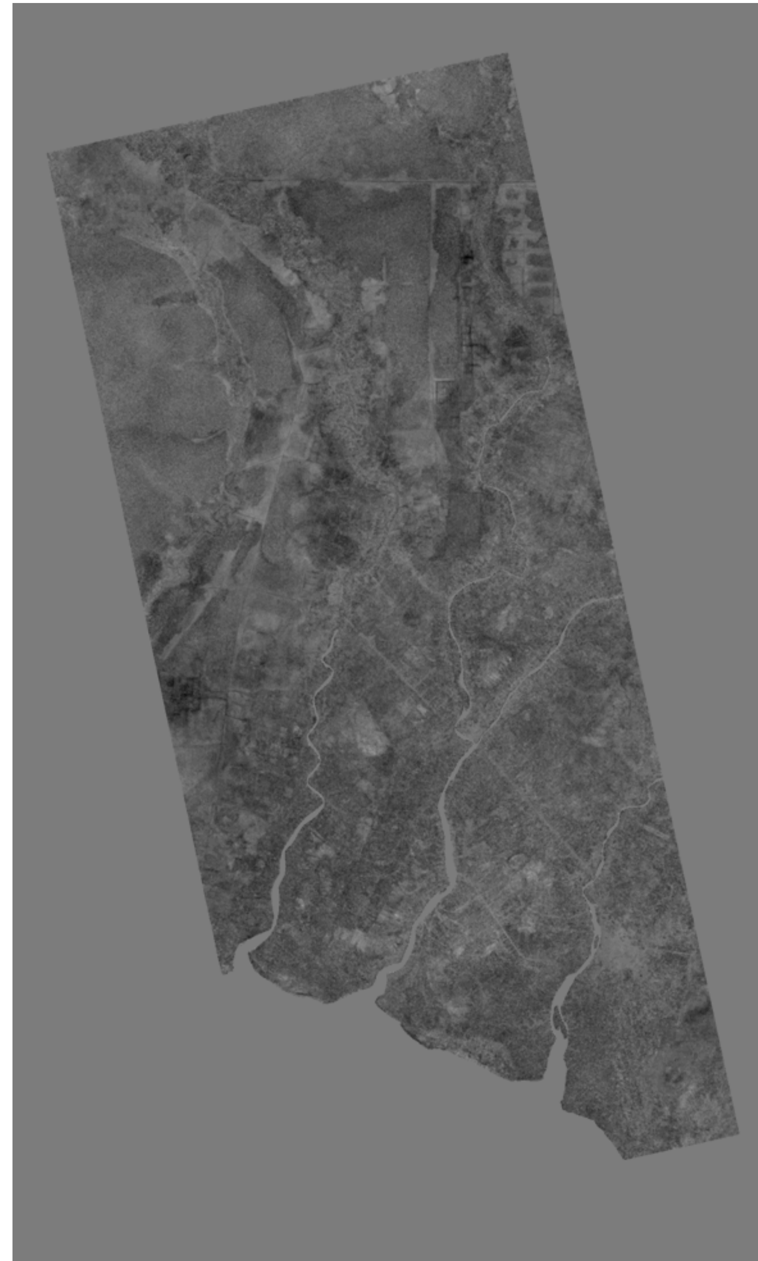


Subsidence of the peatland





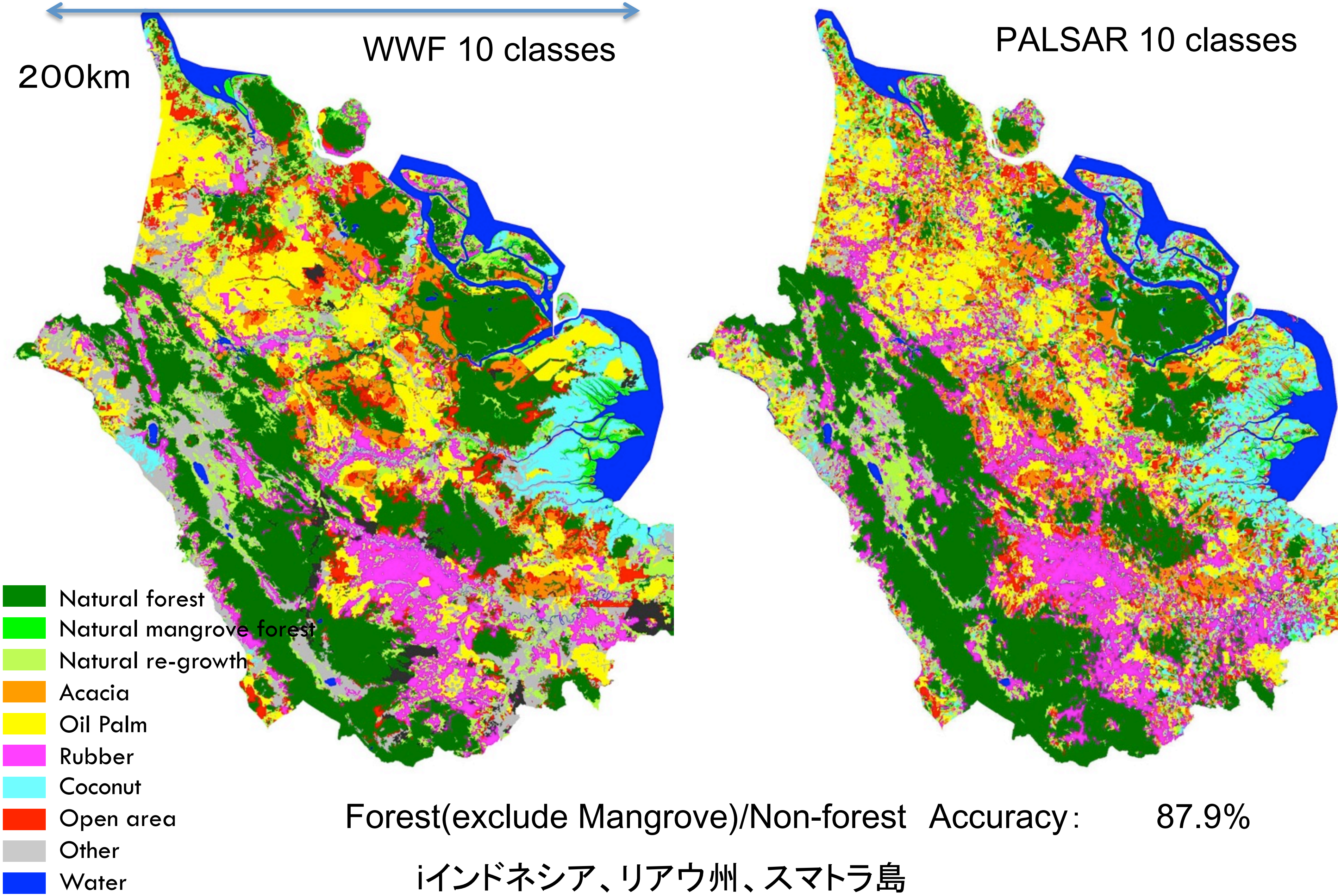
Speed cm/year



3. Forest Monitoring

- Deforestation monitoring
- Illegal Logging monitoring
- LULUCF classification
- REDD+
- Mangrove Watch

Land Use Classification in Riau, Sumatra（土地利用分類）



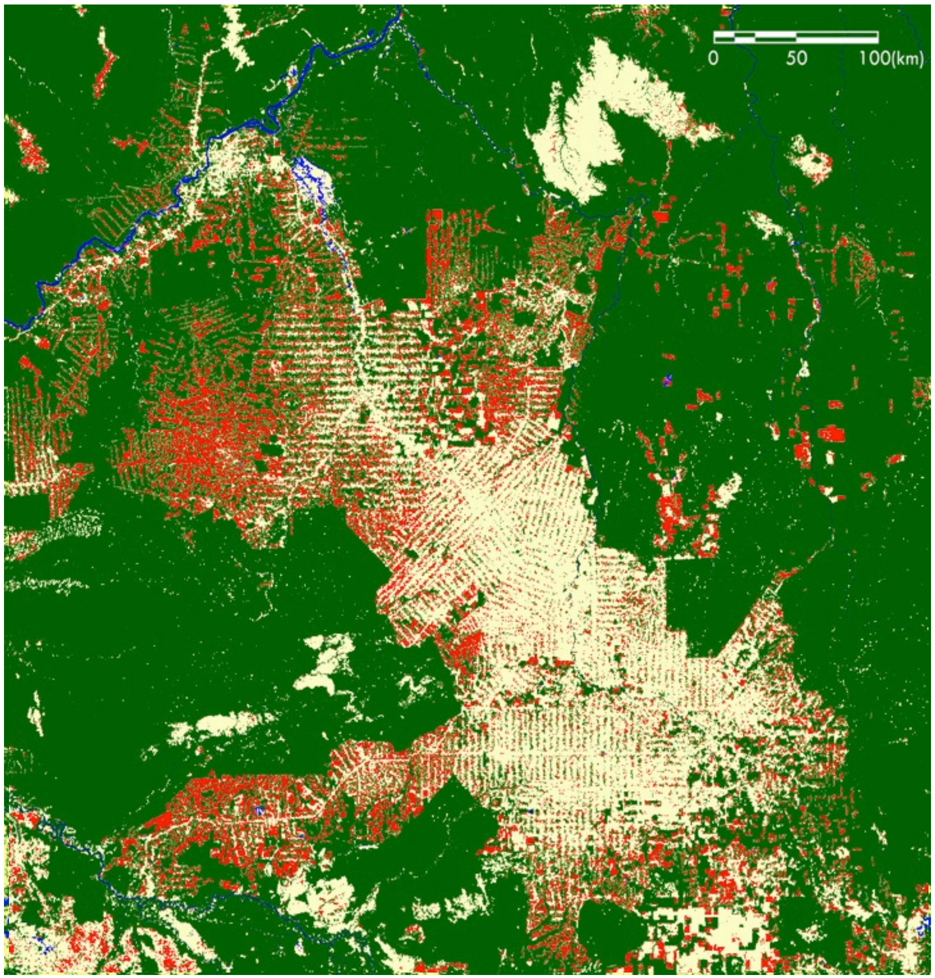
Forest(exclude Mangrove)/Non-forest Accuracy: 87.9%

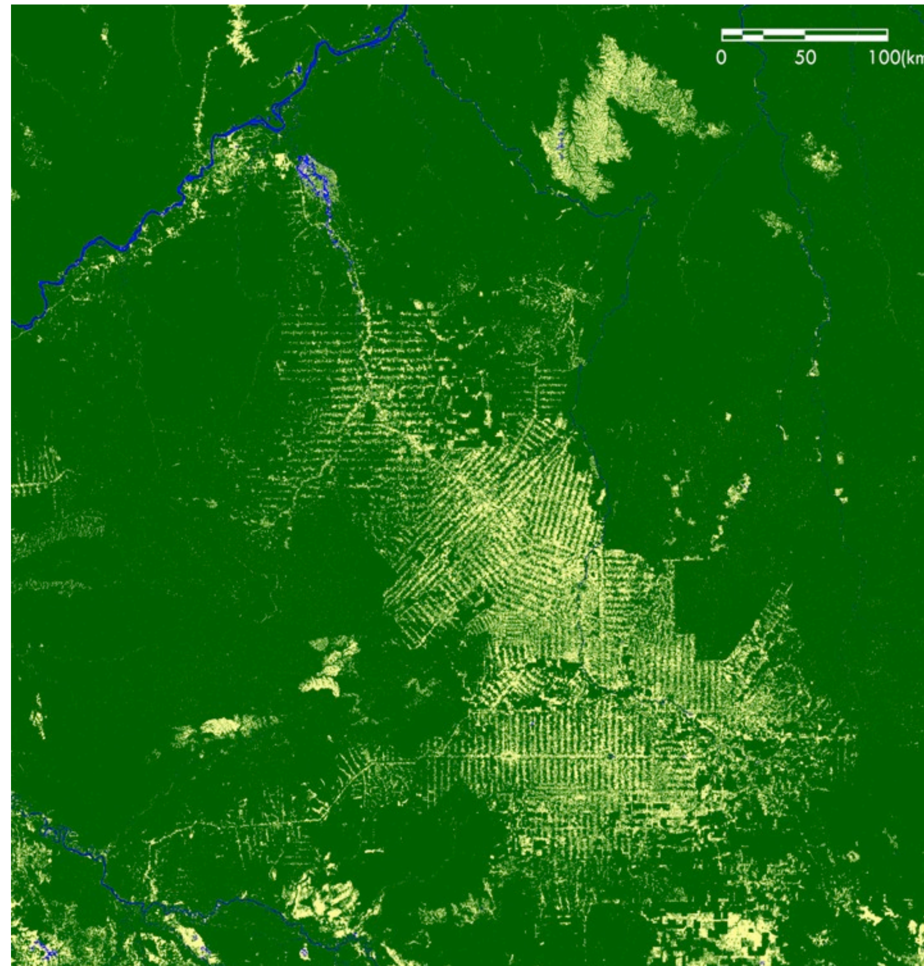
iインドネシア、リアウ州、スマトラ島

2009年 (ALOS/PALSAR)

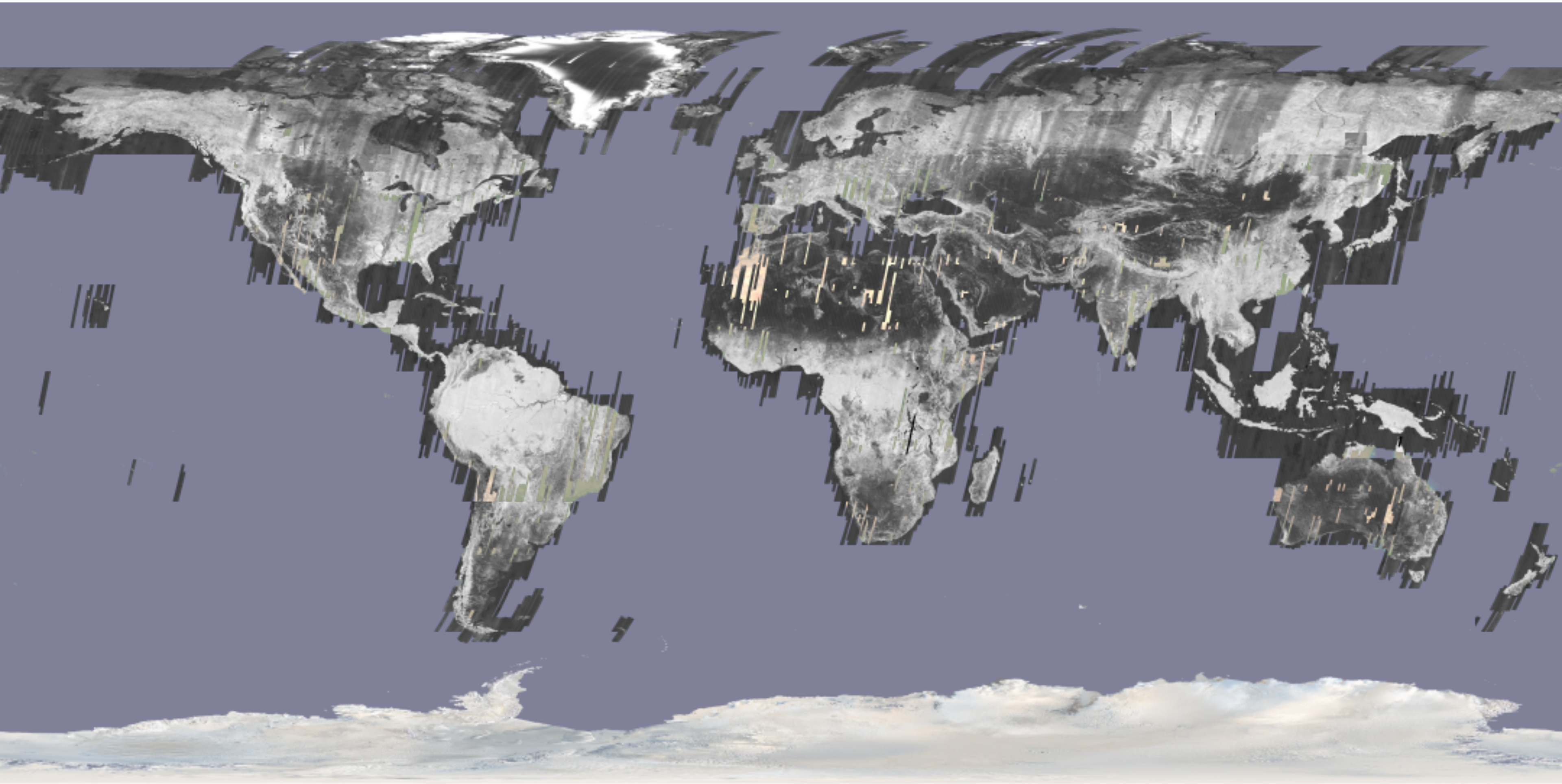
13年

1996年 (JERS-1/SAR)





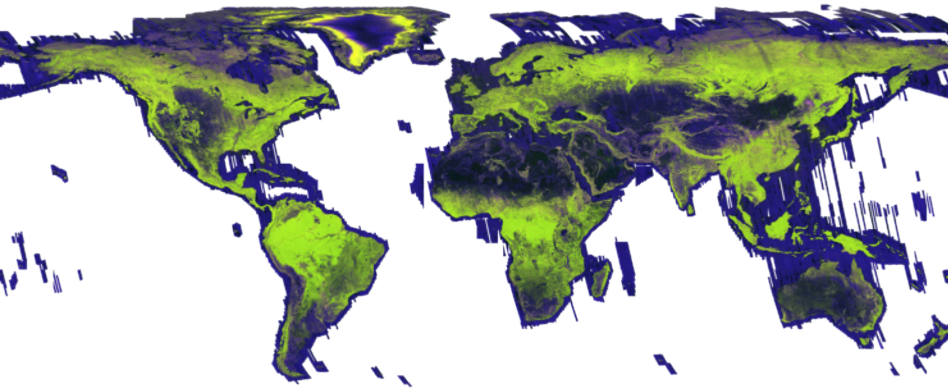
JERS-1 SAR Mosaic data (HH)



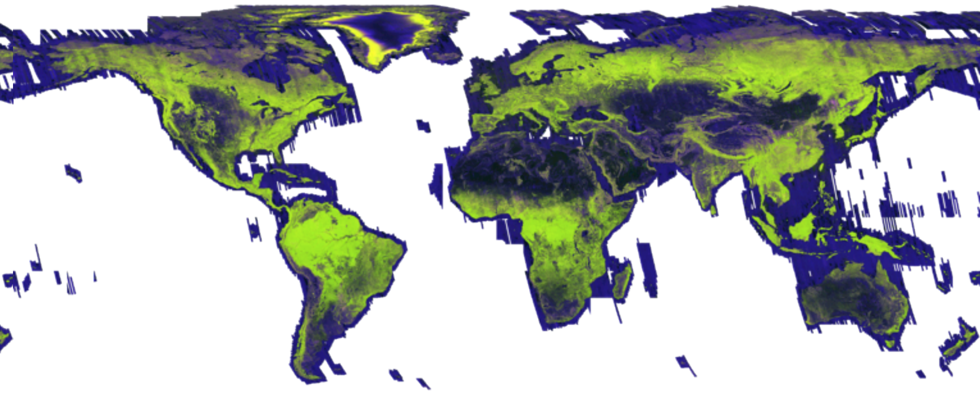
1992-1998

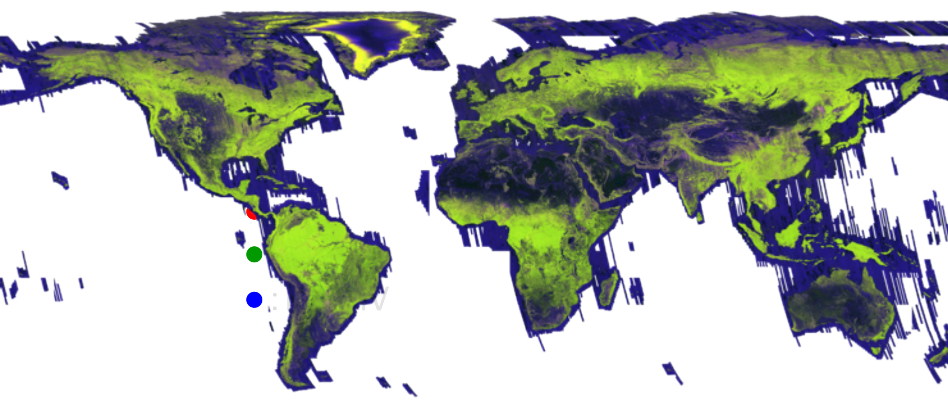
PALSAR 25m Mosaic RGB Composite Image

2007

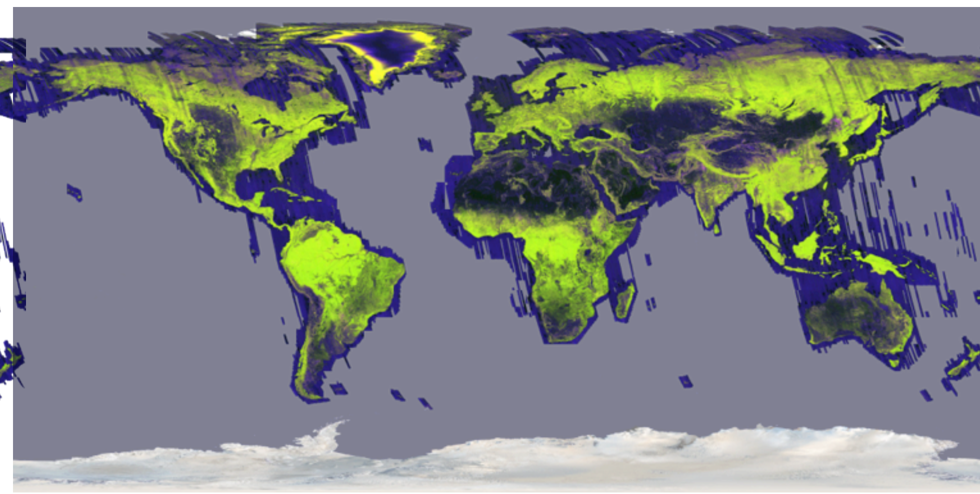


2008



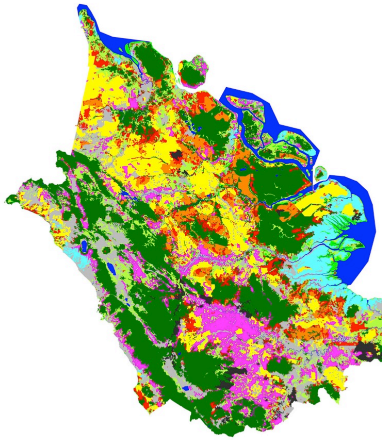


2009

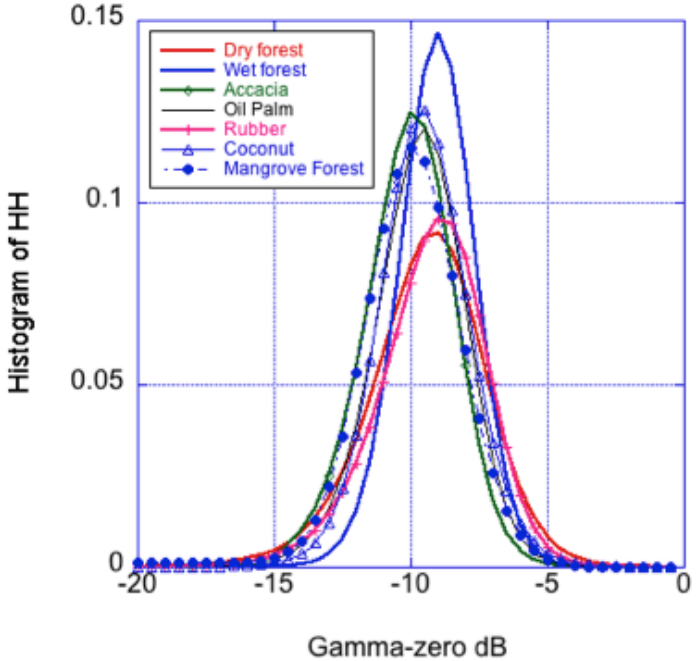


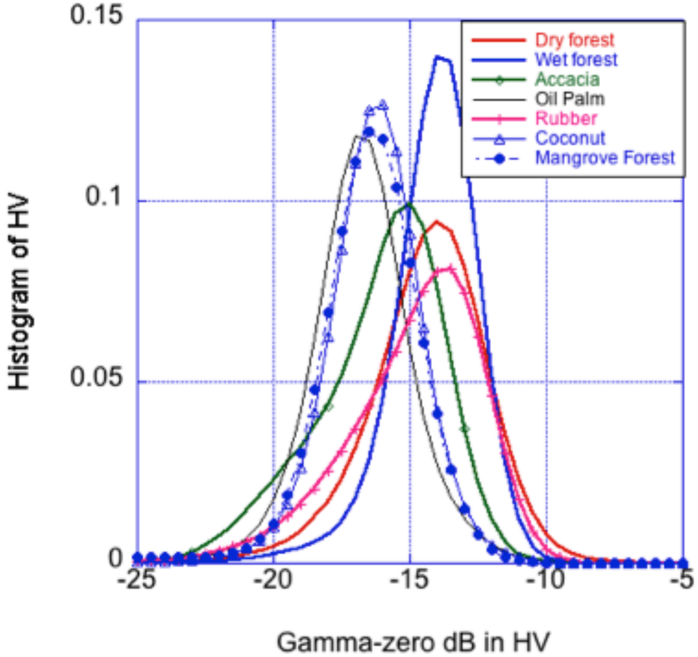
2010

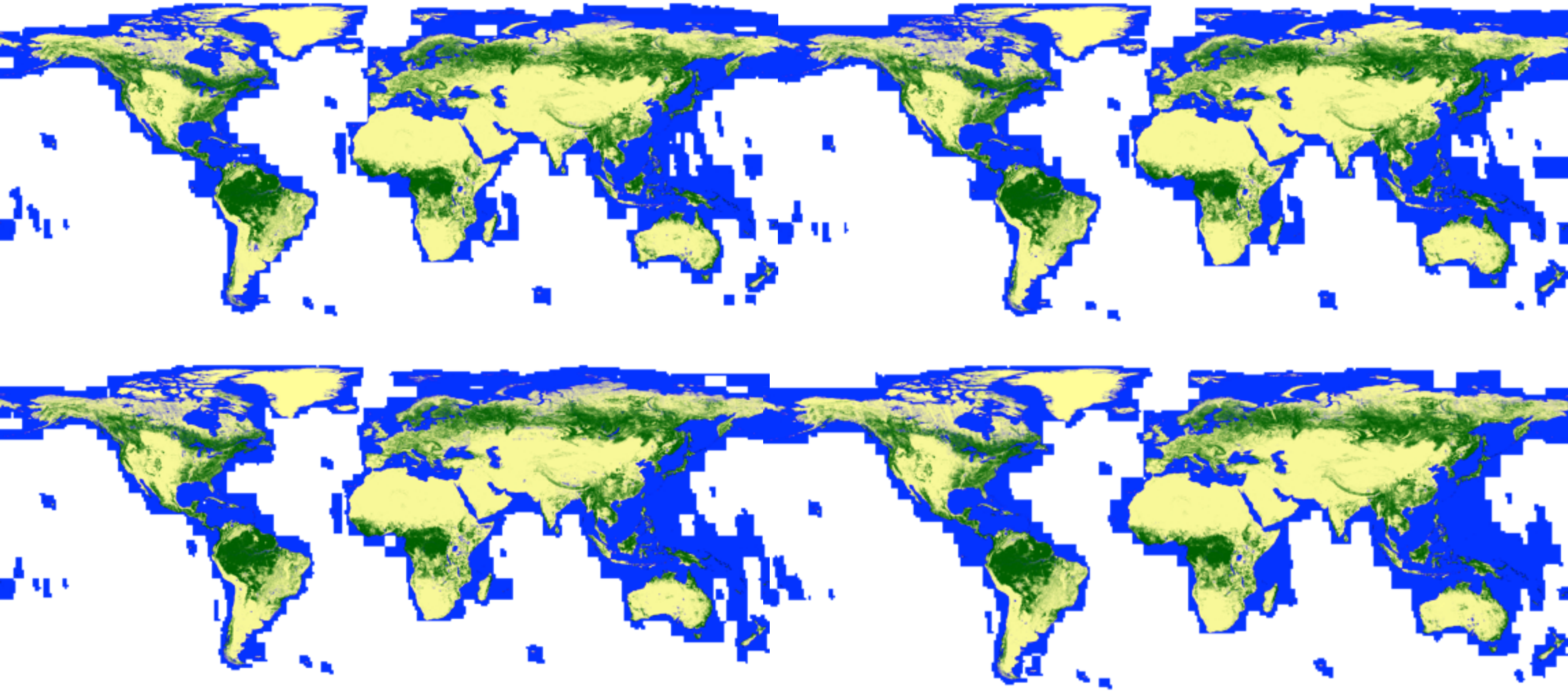
Land Use sensitivity of polarizations



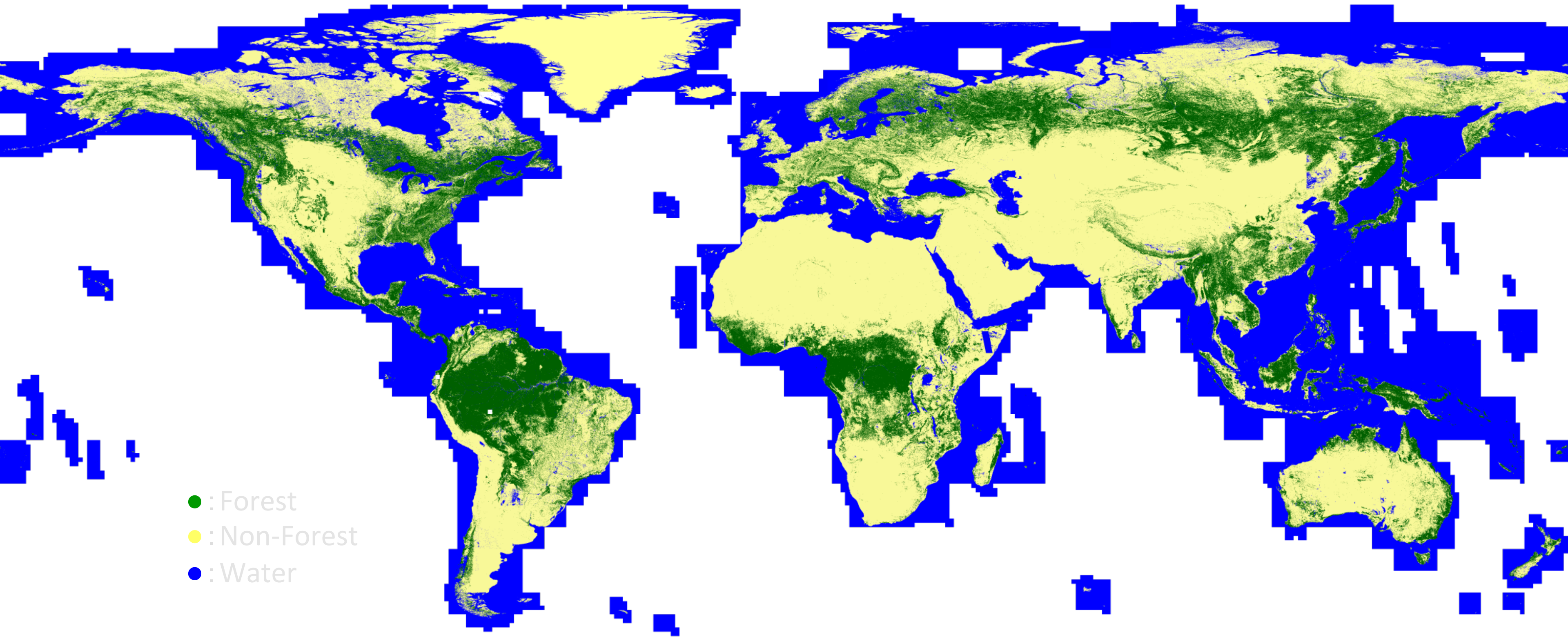
HV much more sensitive than HH



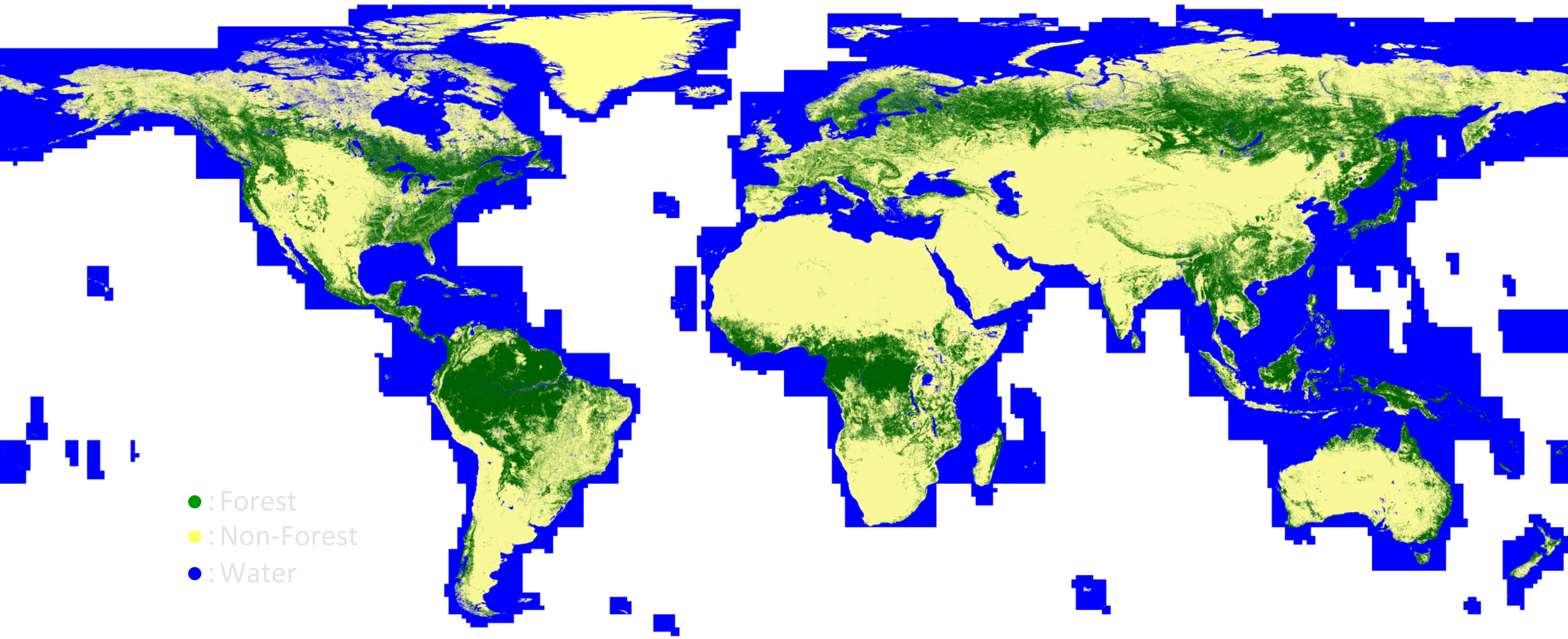




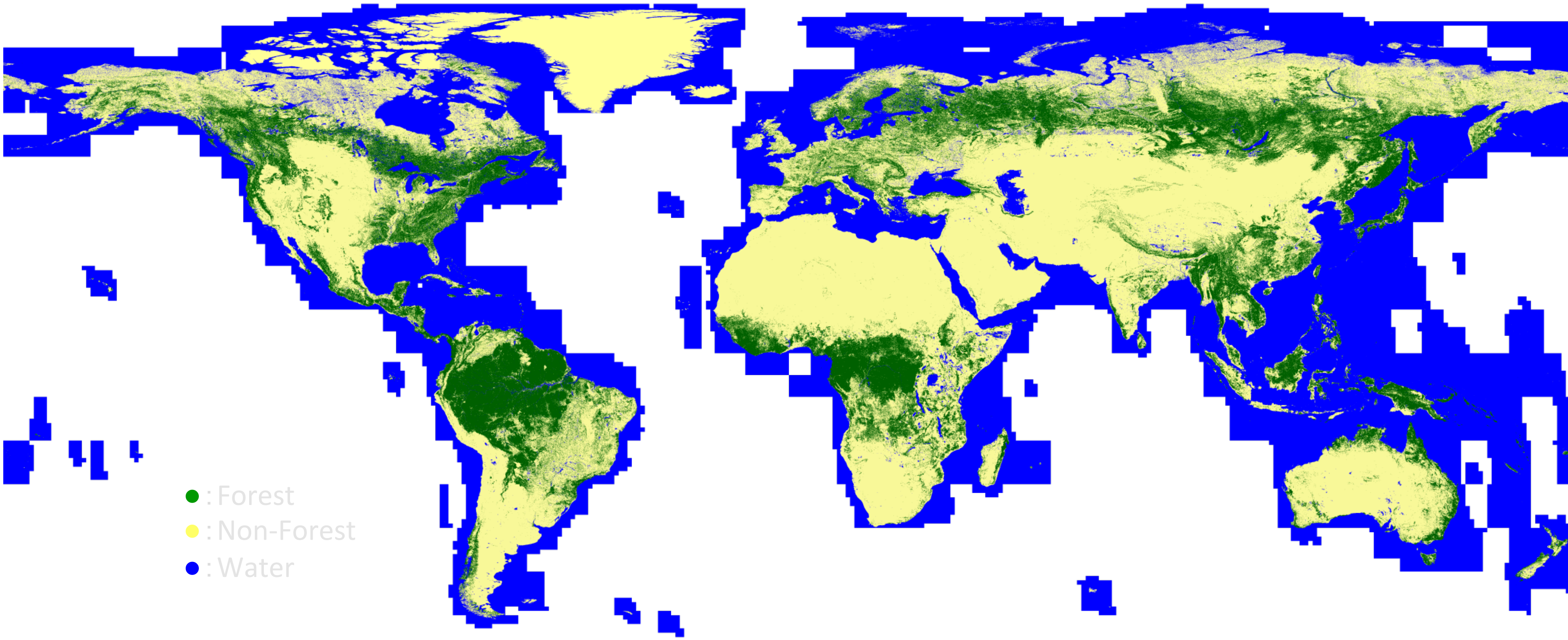
PALSAR 25m Mosaic 2007
Forest/Non-Forest Map, (produced in 2013, Feb.)



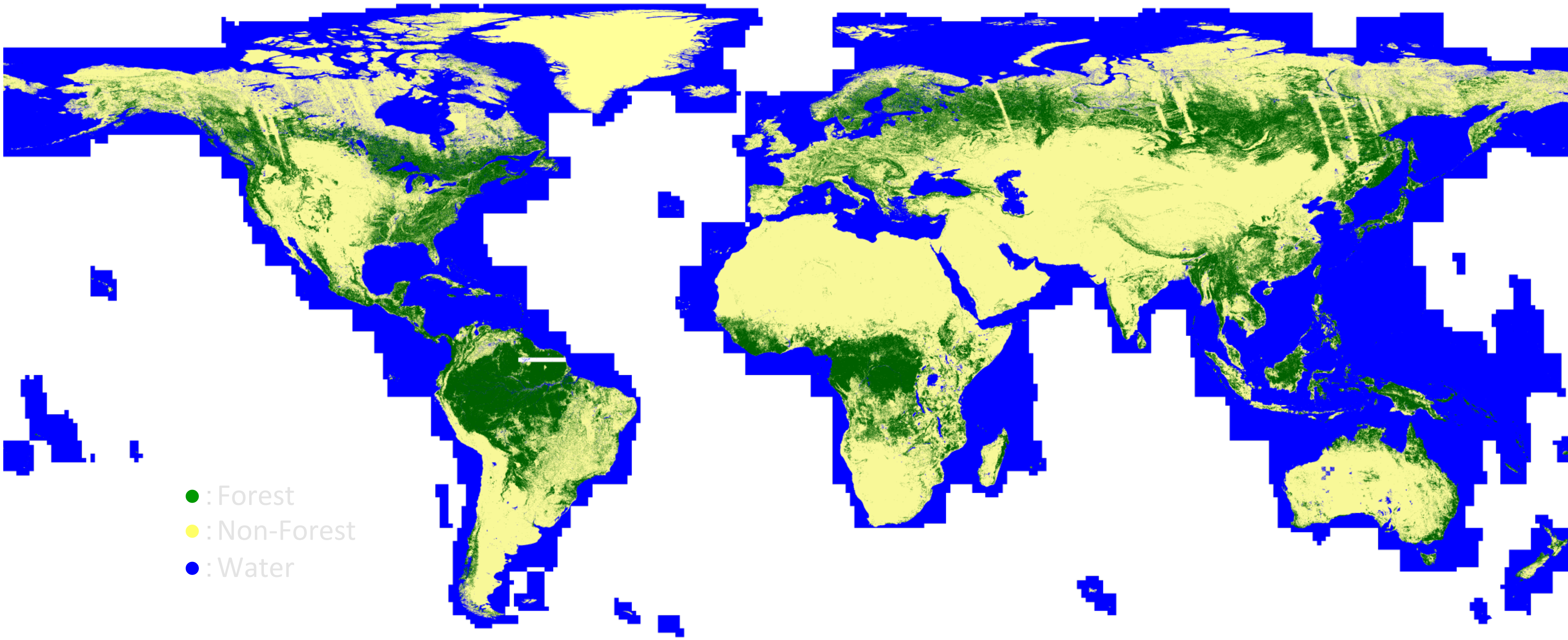
PALSAR 25m Mosaic 2008
Forest/Non-Forest Map, (produced in 2013, Feb.)



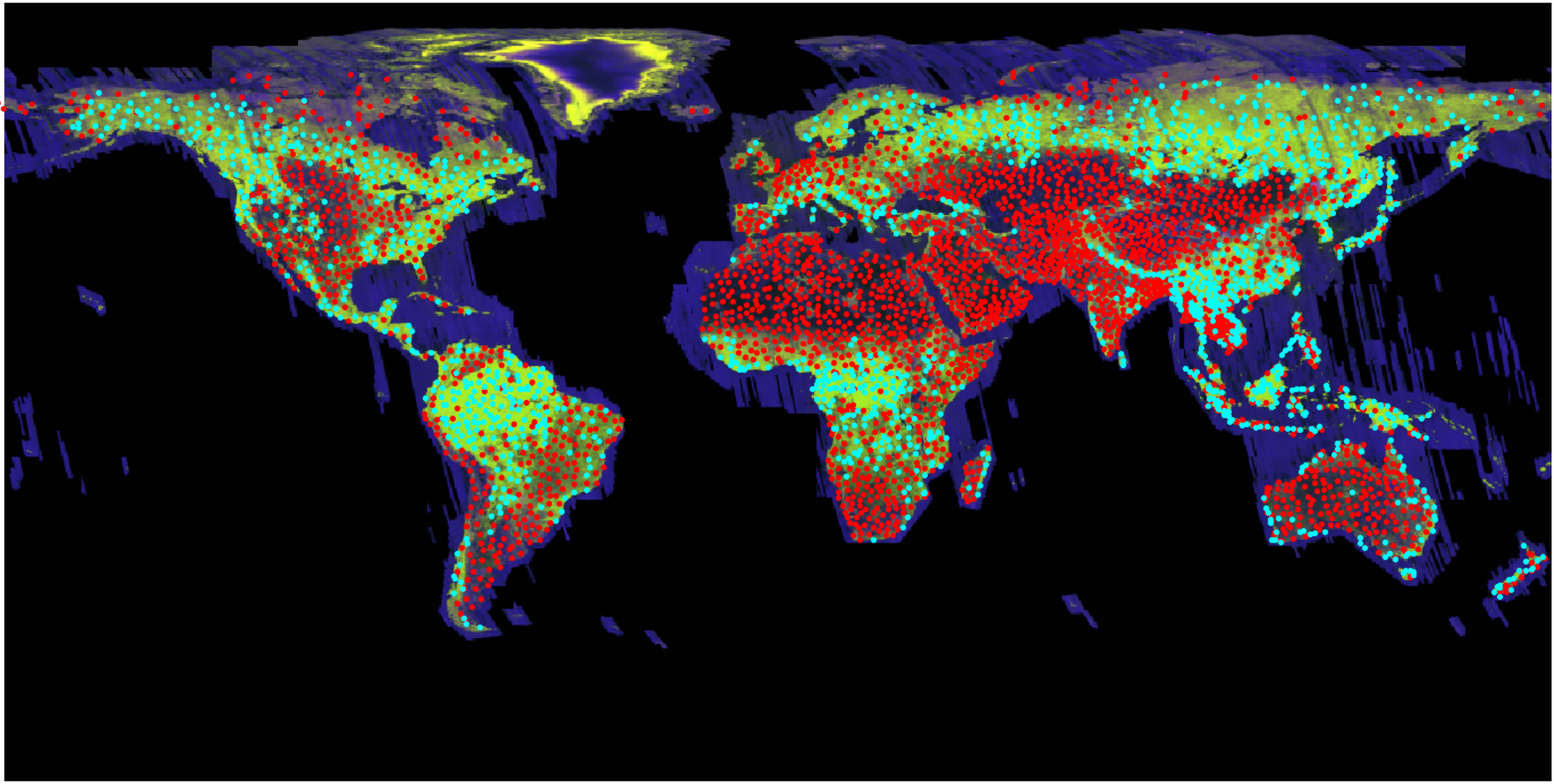
PALSAR 25m Mosaic 2009
Forest/Non-Forest Map, (produced in 2013, Feb.)



PALSAR 25m Mosaic 2010
Forest/Non-Forest Map, (produced in 2013, Feb.)



Validation Using the GE images



Accuracy measure of the FNF using the database

Year	GE	DCP
2007	90.40	88.10
2008	90.28	84.10
2009	89.95	87.40
2010	90.20	88.60
Mean	**90.20**	**87.05**

Note: GE>4000 points, DCP>2000 points

Accuracy Assessment (1/3) – PALSAR vs. FRA

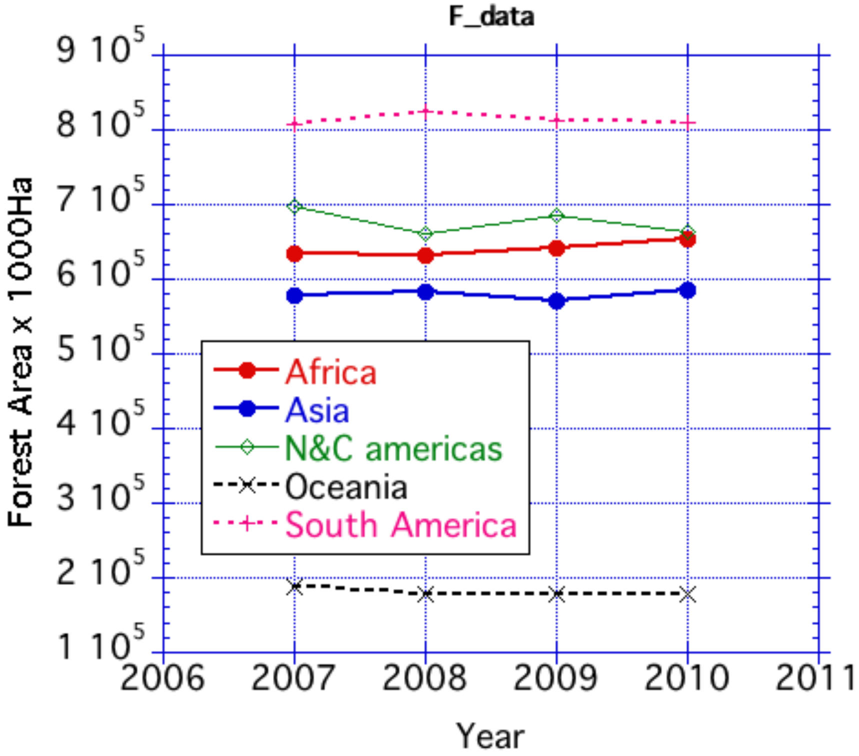
	2008		
Product	PALSAR(2008) [1000ha]	FRA(2005) [1000ha]	Relative Error (±) [%] (PALSAR vs FRA)
Africa	630,650	691,369	−8.78%
Asia	583,615	584,049	−0.07%
Europe	1,007,734	1,009,462	−0.17%
North and Central America	660,443	705,183	−6.34%
Oceania	177,026	196,745	−10.02%
South America	825,212	874,158	−5.60%
Total	**4,535,687**	**4,759,534**	**−4.70%**

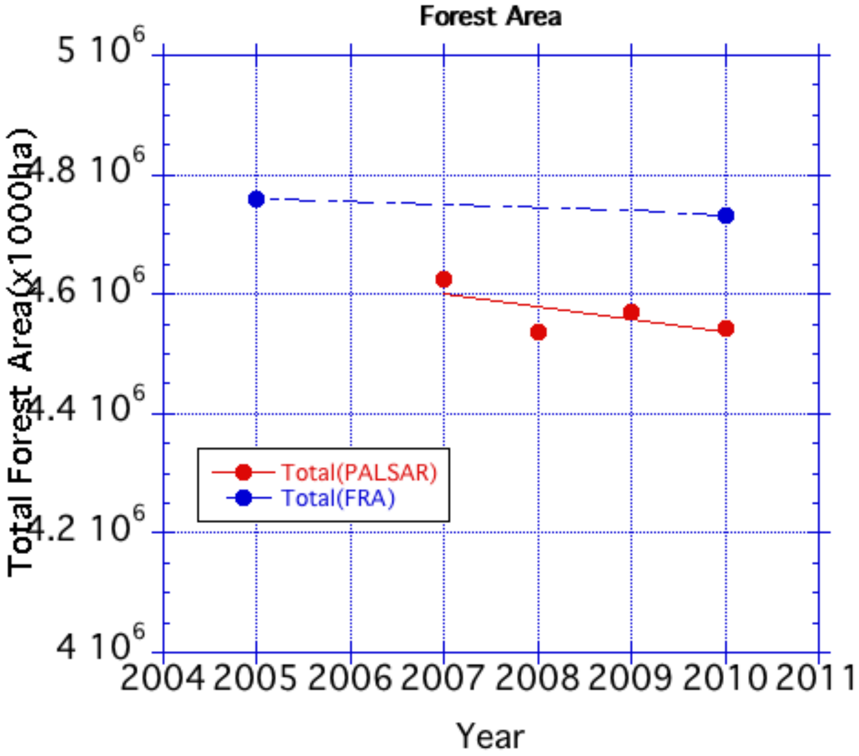
Accuracy Assessment (2/3) – Time Series

	PALSAR(2007) [1000ha]	PALSAR(2008) [1000ha]	PALSAR(2009) [1000ha]	PALSAR(2010) [1000ha]	FRA(2005) [1000ha]	FRA(2010) [1000ha]
Africa	635734	630650	642222	653925	691369	674318
Asia	583800	583615	575862	592854	584049	592513
Europe	1026132	1007734	999182	987224	1009462	1013297
North and Central America	697116	660443	686048	663862	705183	705281
Oceania	187538	177026	177597	179115	196745	191385
South America	807790	825212	813203	811082	874158	856269
Total	**4625874**	**4535687**	**4571128**	**4541520**	**4759534**	**4731523**

Accuracy Assessment (3/3) – Time Series

Temporal Change of the Forest Areas

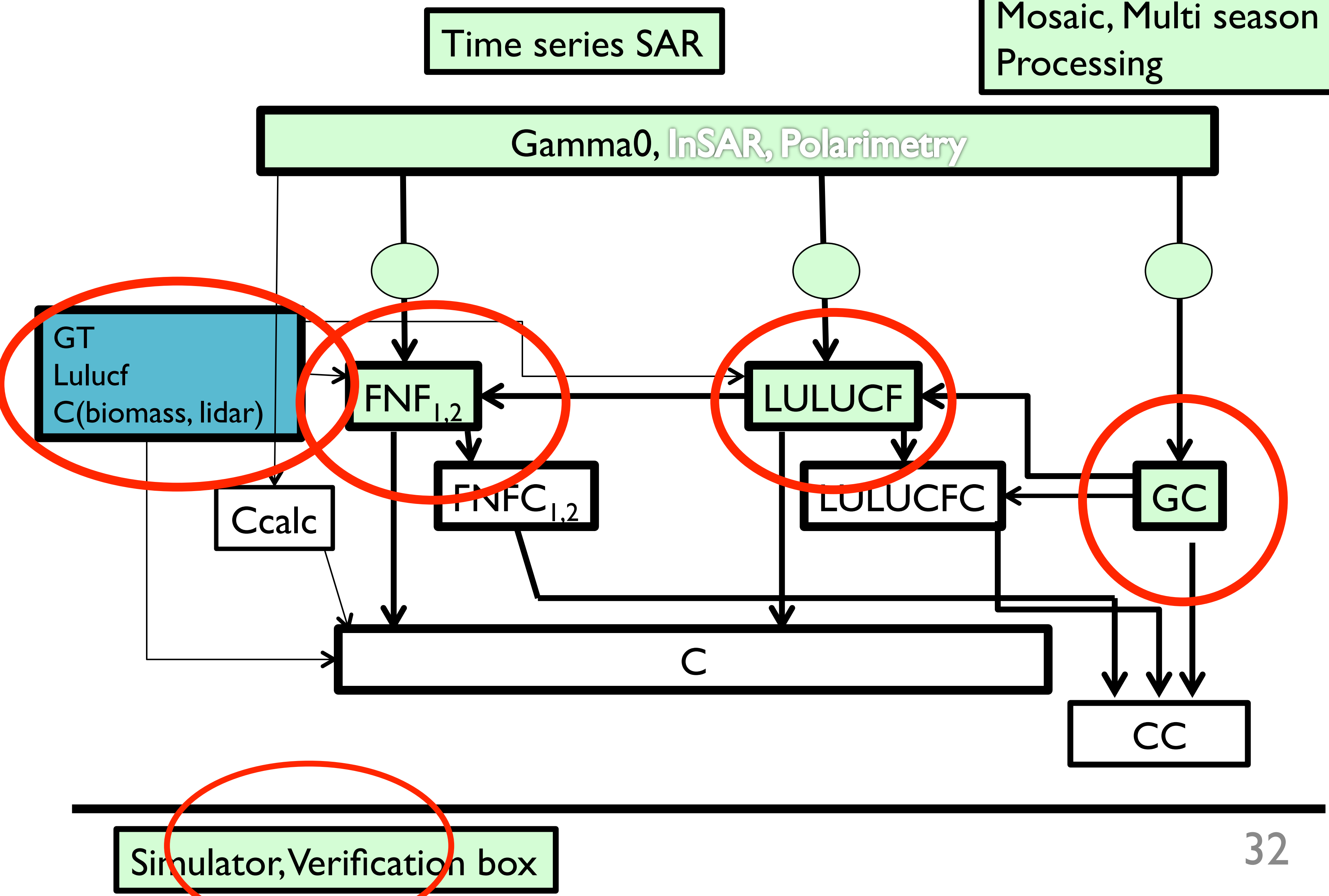




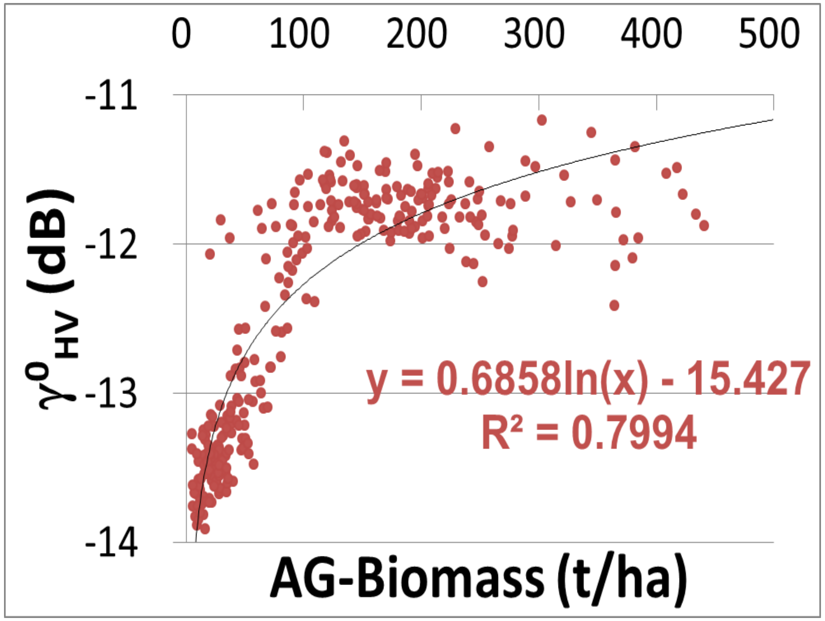
Forest area is decreasing.

JAXA-MRV

Basic Information
Ortho, Slope
Mosaic, Multi season
Processing



Biomass estimation from γ^0_{HV}（3月時点）



- Natural forest only
- Biomass data

  Obtaion from (LiDAR)–(field plot)

  PALSAR data

  2007, 2008, 2009, 2010年
- Resolution 3.6 ha

	Simple mean	All biomass	Biomass < 100 tons/ha	Biomass ≥ 100 tons/ha
Average(tons/ha)	120.5	128.7	38.7	218.2
RMS Error (tons/ha)	104.9	80.4	31.8	109.8
RMS Error (%)	87.1	63.1	82.1	50.3

Good accuracy, if AG-biomass - γ^0 is available

Biomass estimation from γ^0_{HV}（最新版）

- Natural forest only
- Biomass data

  Obtaion from (LiDAR)-(field plot)

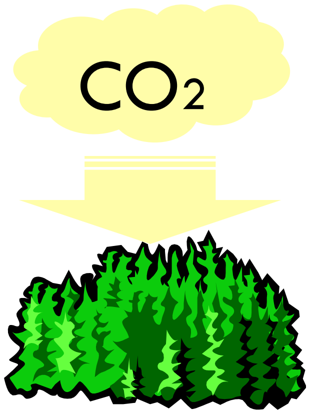
  PALSAR data

  2007, 2008, 2009, 2010年

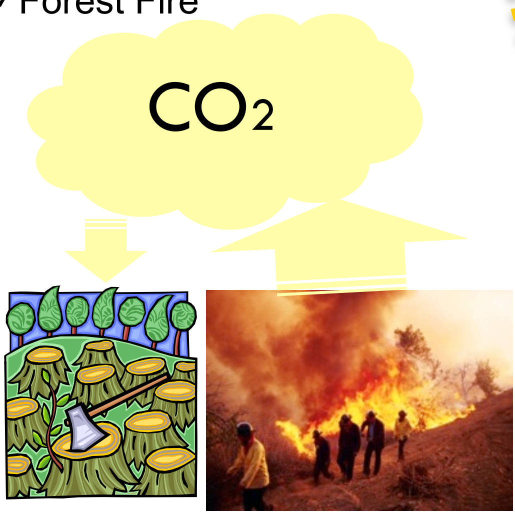
Method		AG-biomass (tons/ha)	Std. Dev.[1]/ RMS error[2] (tons/ha)	Std. Dev. (%)
Simple Average		218.0	**99.1**[1]	45.4
Use AG-biomass - γ^0	total		**62.8**[2]	
	< 100 tons/ha		**13.2**[2]	
	>100 tons/ha	223.4	**67.0**[1]	30.0

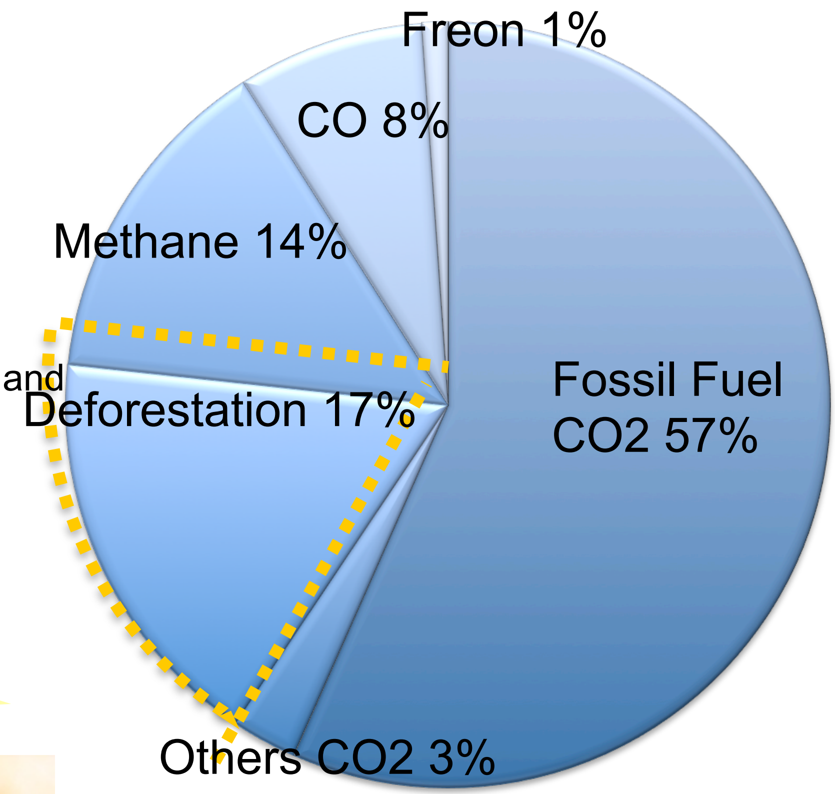
Good accuracy, if AG-biomass - γ^0 is available

World Green House Gas Emission from the Land



Deforestation
- ✓Conversion of agricultural land
- ✓Illegal Logging
- ✓Forest Fire



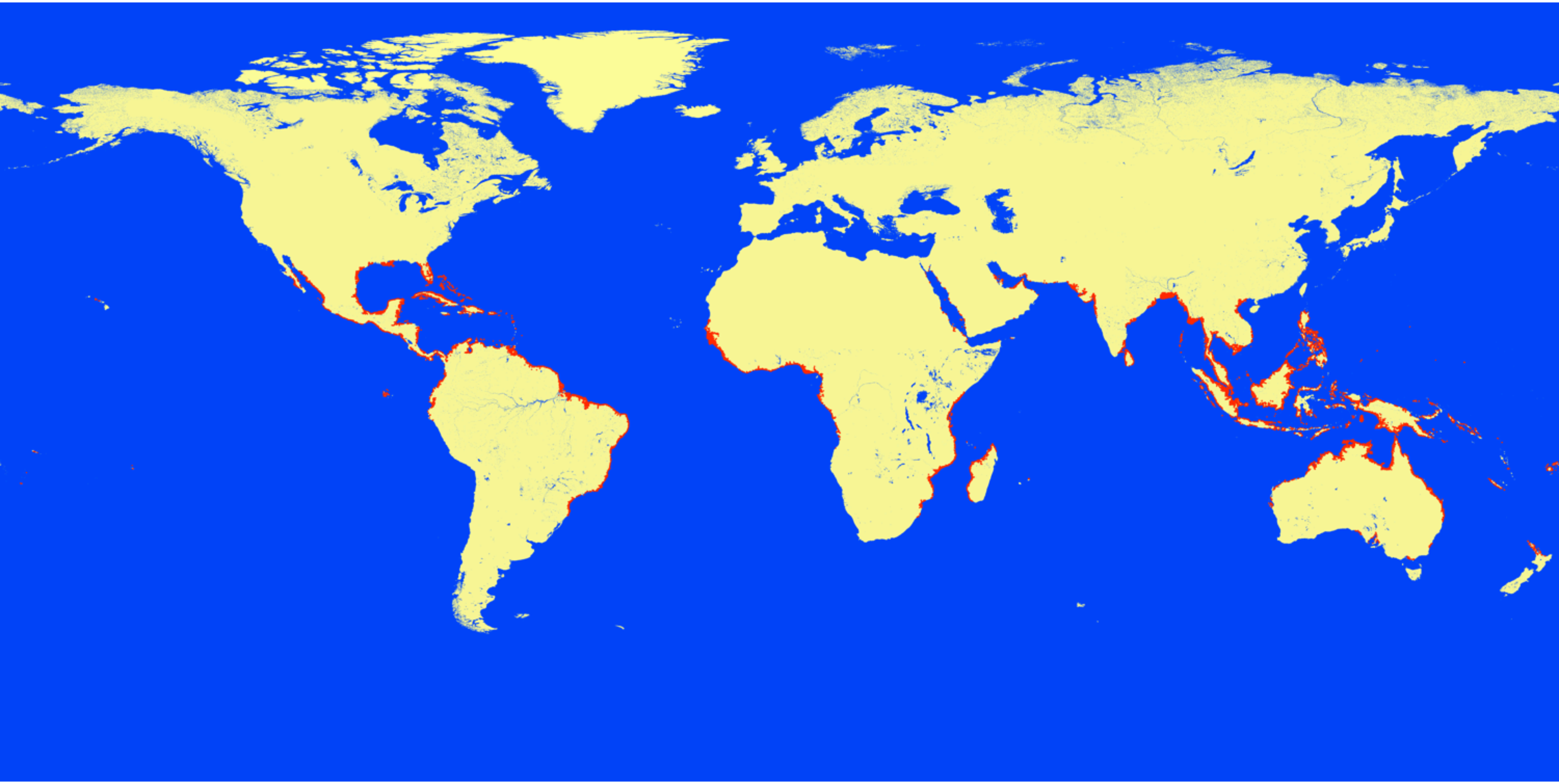


（Intergovermental Panel on Climate Change, 2004）

Industries

Transportation

Global Mangrove distribution from PALSAR2010



4. Disaster Application

- Land Slide Monitoring using the Polarimetry
- Flooding Area Detection using the InSAR coherence and phase
- Oil spill detection
- Comparison between Pi-SAR-L2 and High-resolution optical images at the Tohoku disaster.

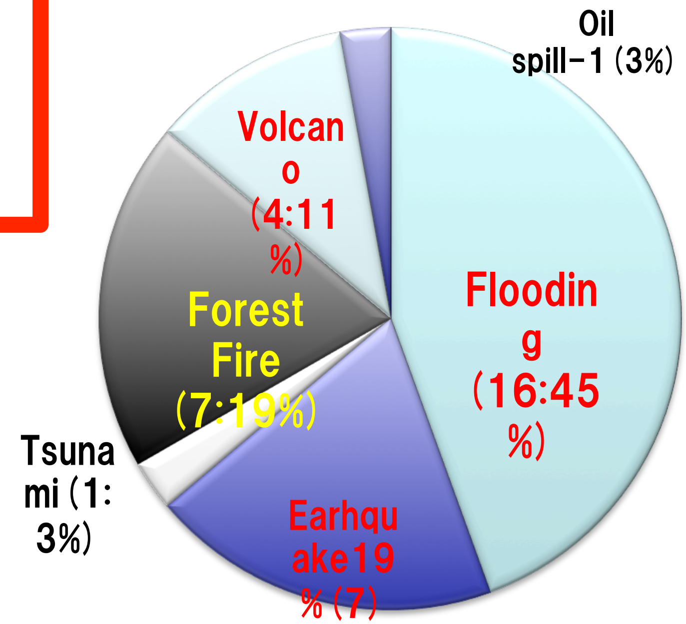
Problem definition

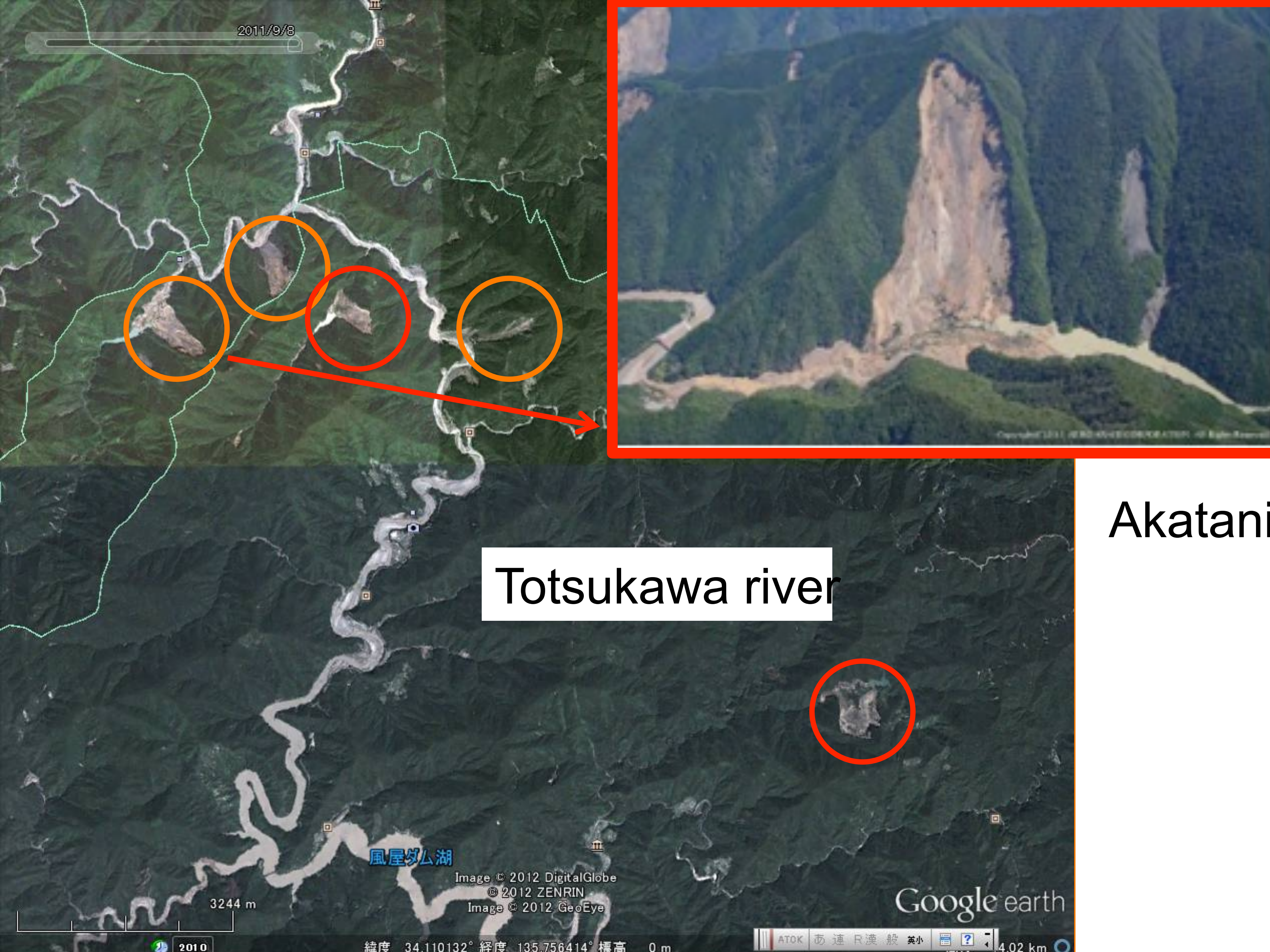
Water related disaster covers 40% of all the disasters

1. **Flooding**
2. **Large scale landslide in the mountain**

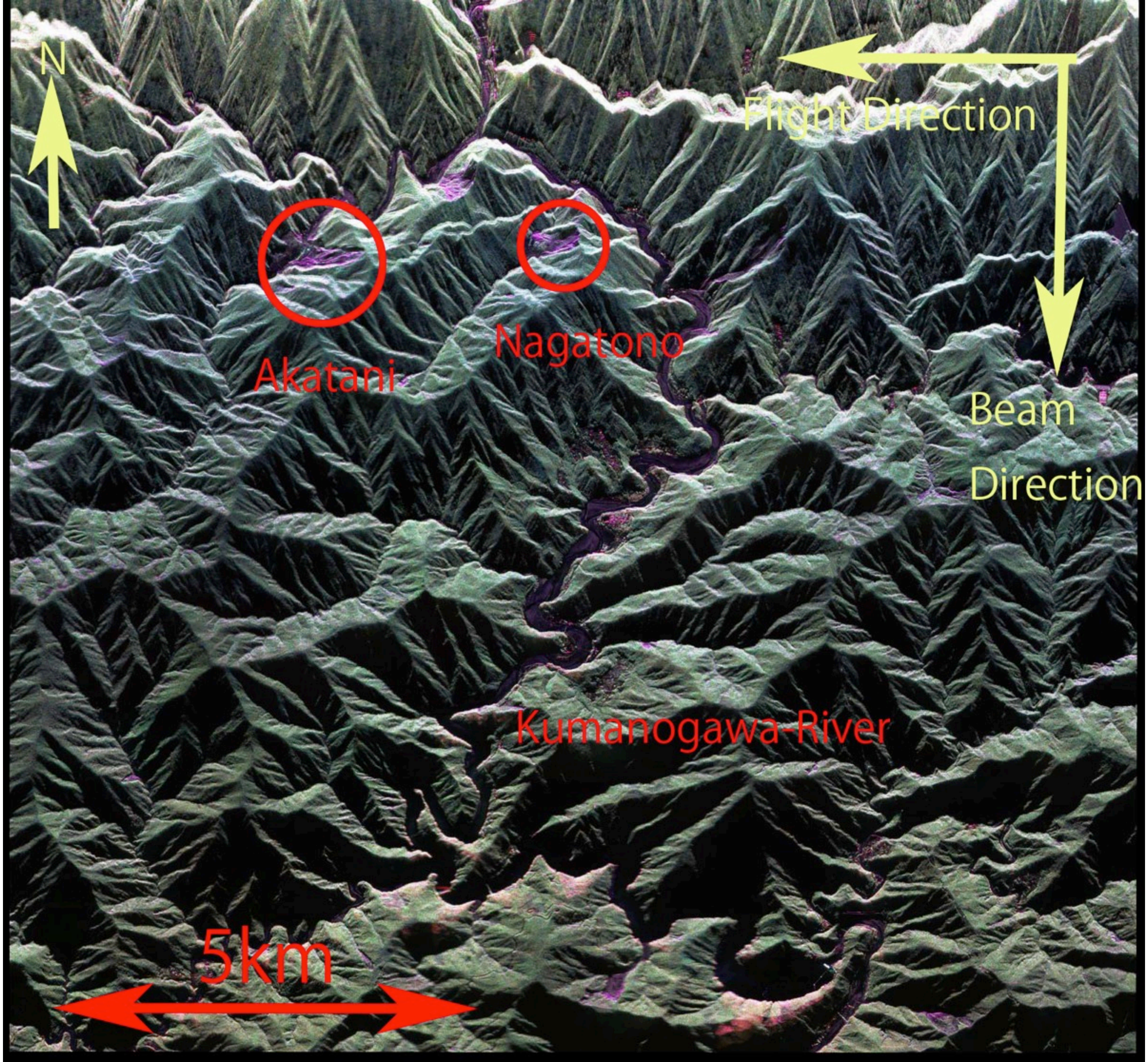
What are the best Parameters detecting these events by SAR (L-X) ?

Frequency of the emergency Observation-disaster – from International Charter Call 2008




2011/9/8
Totsukawa river
風屋ダム湖
Image © 2012 DigitalGlobe
© 2012 ZENRIN
Image © 2012 GeoEye
3244 m
2010
緯度 34.110132° 経度 135.756414° 標高 0 m
Google earth

Akatani



N
Flight Direction
Beam
Direction
Akatani
Nagatono
Kumanogawa-River
5km

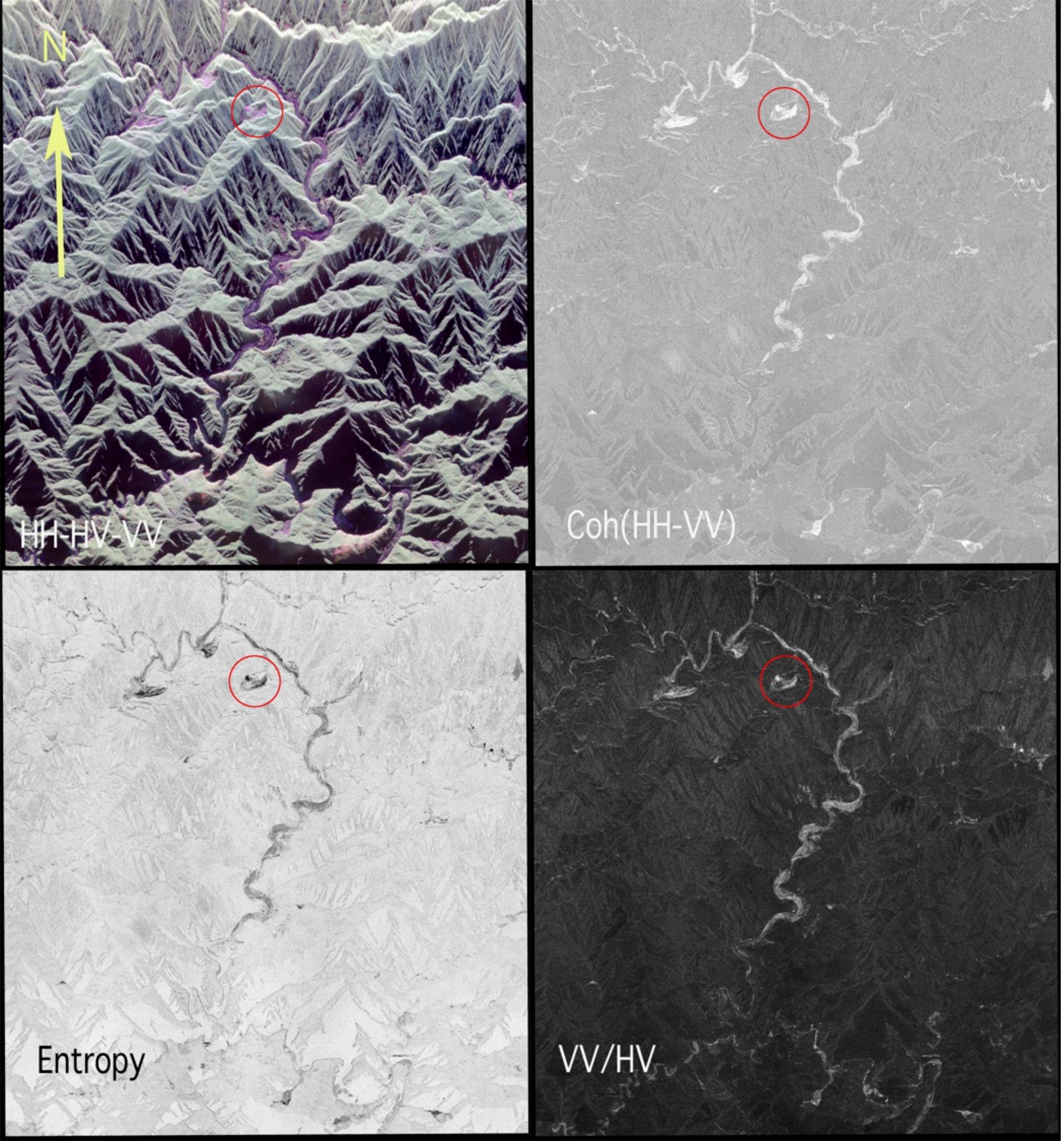
Parameters for evaluation

Event: Highly steep mountain is landslide and rough surface are visible.
Points：1)Surrounding area is rough surface and2) time variation occurs

parameter	Expression
Color merging	HH(R) + HV(G) + VV(G)
Correlation	Correlation of HH-VV, HV-VH
Decomposition	Ps+Pd+Pv (Freeman-Durden)
Entropy-Alpha	Randomness and phase
Power ratio or difference	HH/HV, HH/VV, VV/HV, or HH-VV, etc.
Single Pol Image	HH, HV, or VV

Which parameter is optimum?

Which frequency is optimum?



Totsukawa-mura, June 19, 2012
Nagatono area in red circle

Pi-SAR-L2

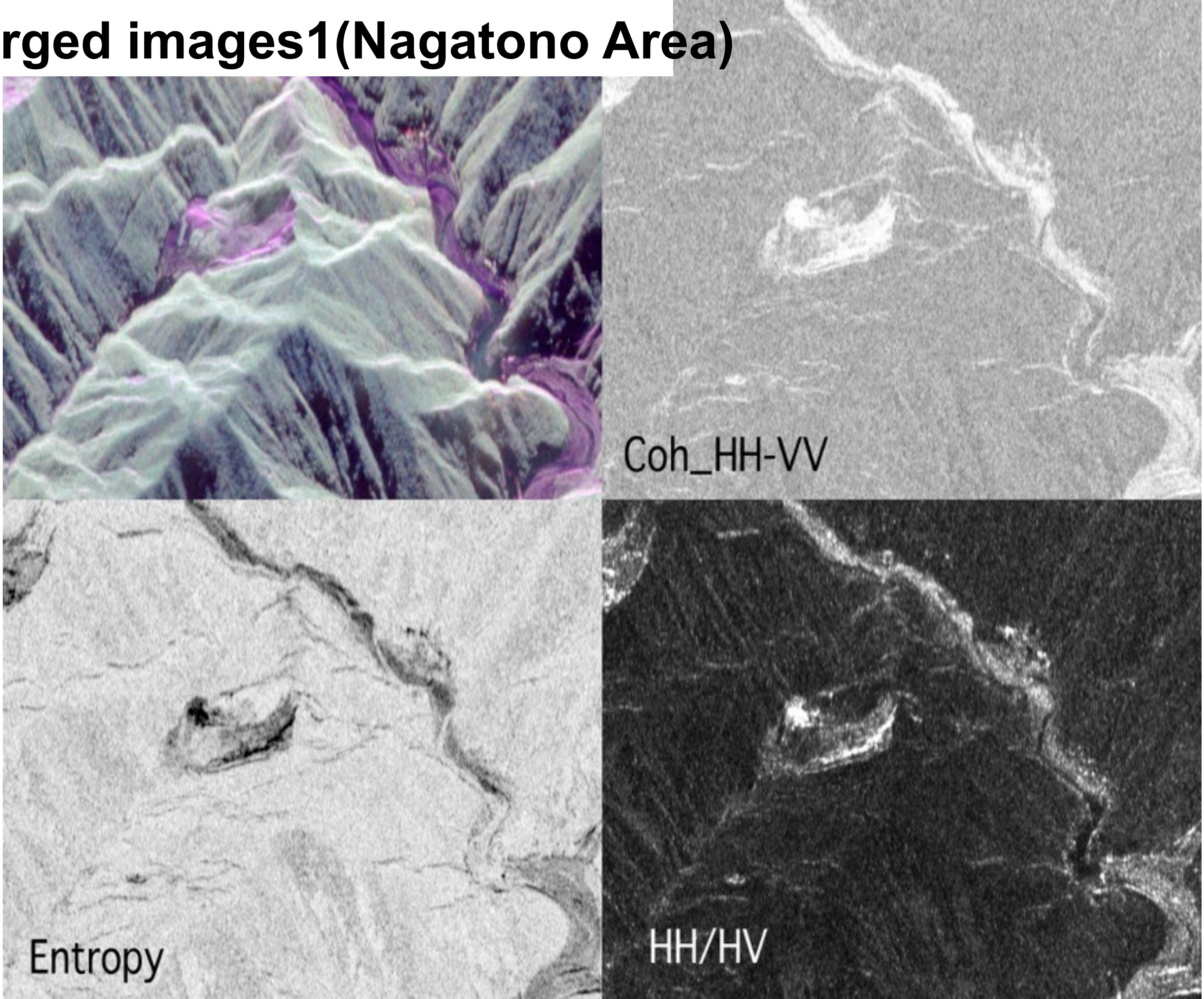
Among combinations, the most effective parameters are selected.

Three color images

- HH-VV Coherence
- Entropy
- Ratio of VV/HV(HH/HV)

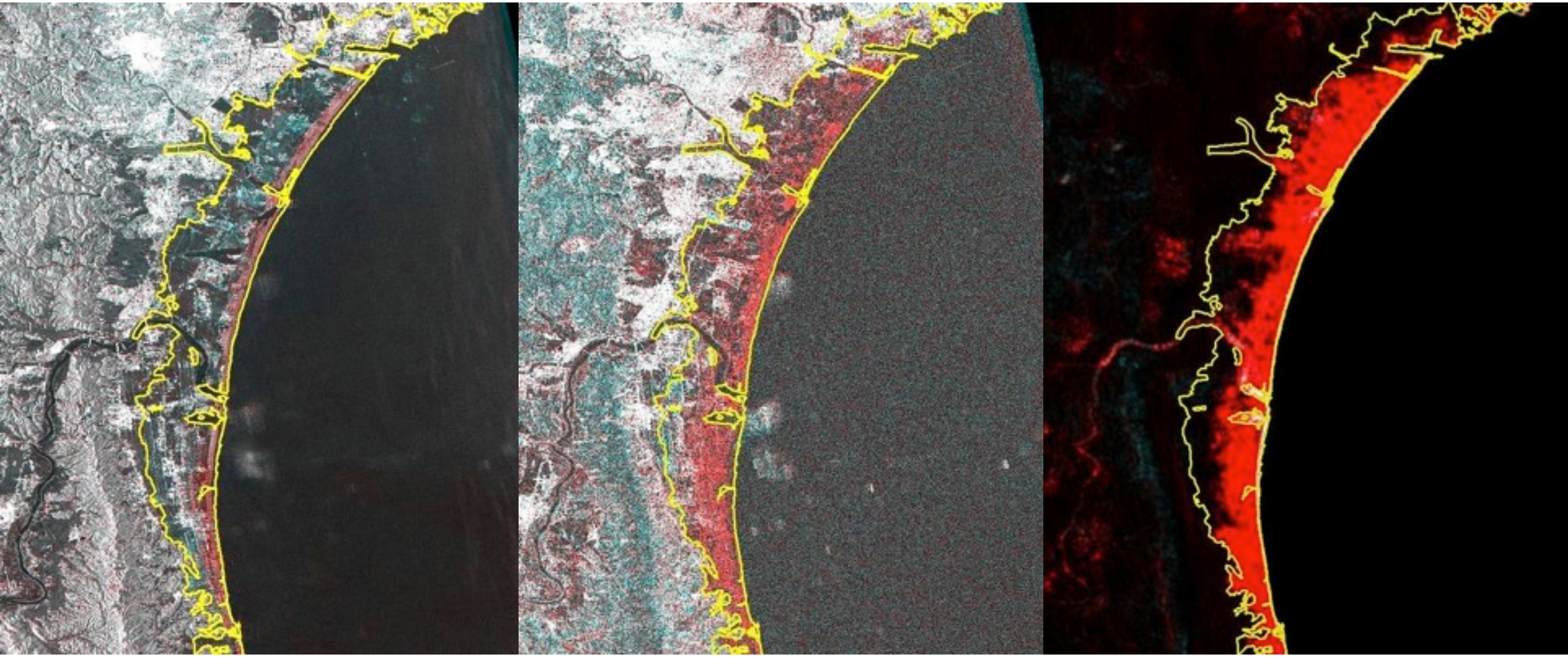
Pi-SAR-L2

Enlarged images1(Nagatono Area)



Coherence and SAR image at Kyushu Flooding

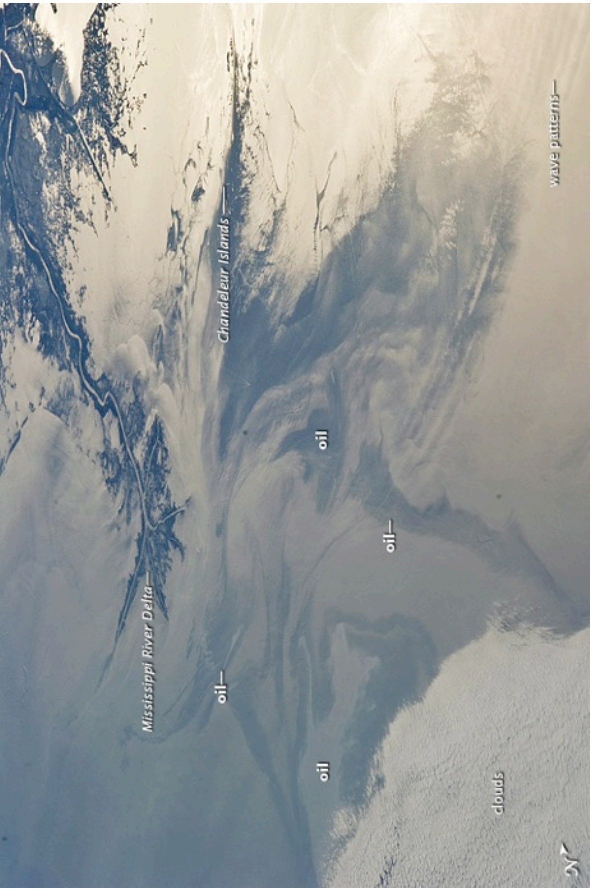
3) Estimation of the flooded area by InSAR phase

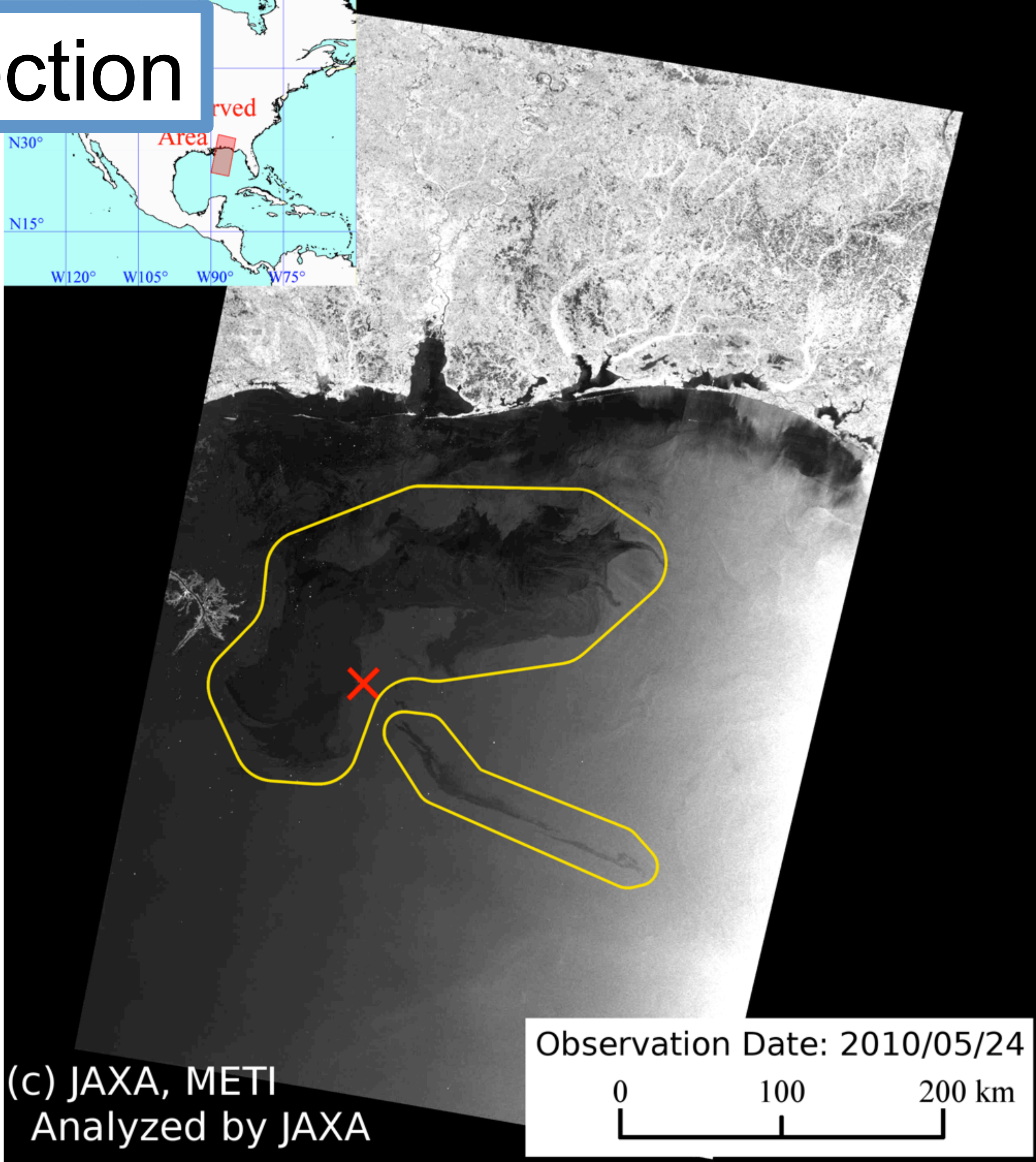


•SAR image shows red for coastal forest lost area.
•InSAR coherence and phase variance show red for coastal area without water.

（Note）water covered polygon referred to GSI of 2011/12/09

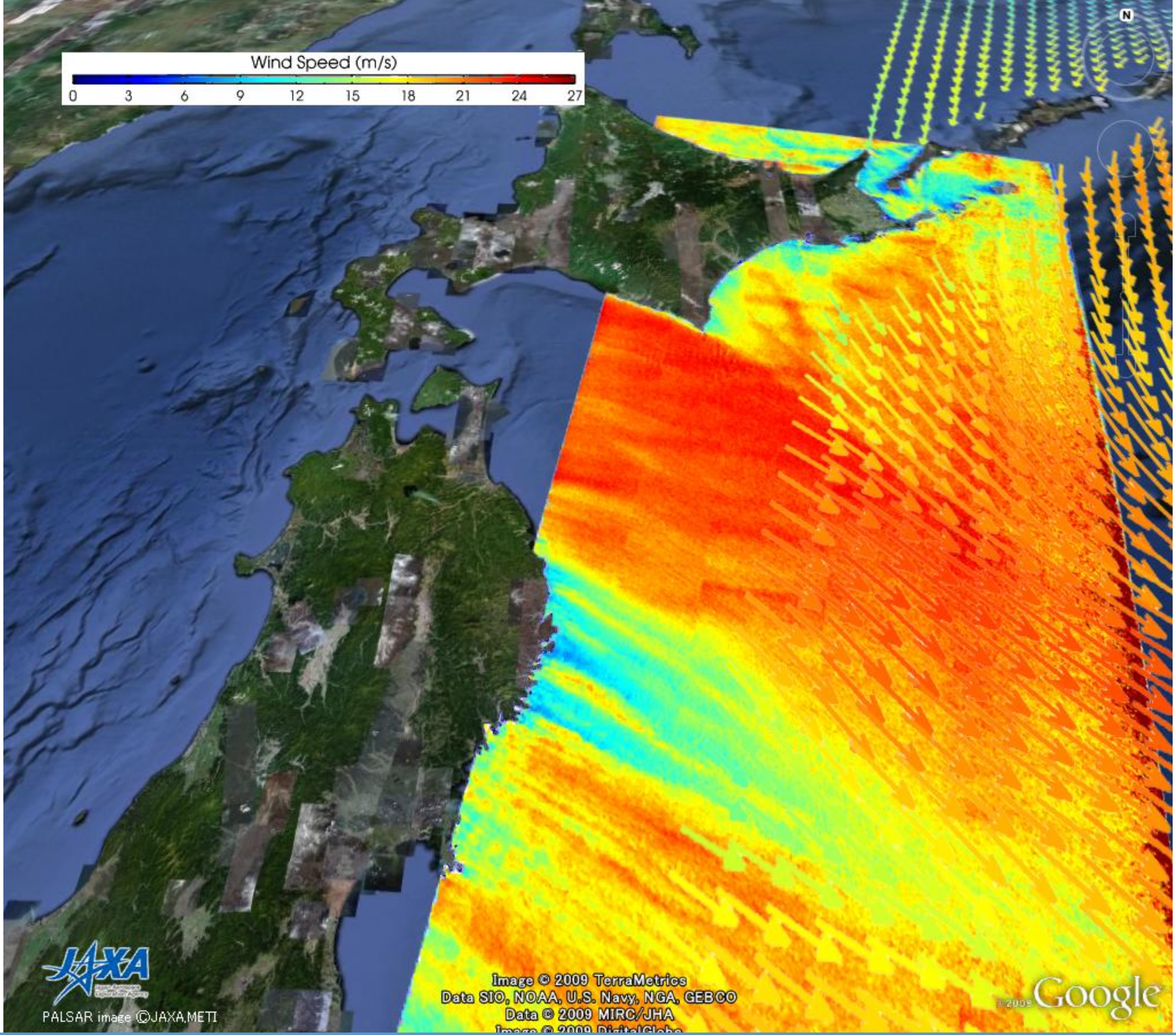
Oil Spill Detection





3. Ocean Application

- Wind speed measurement
- Sea Ice monitoring

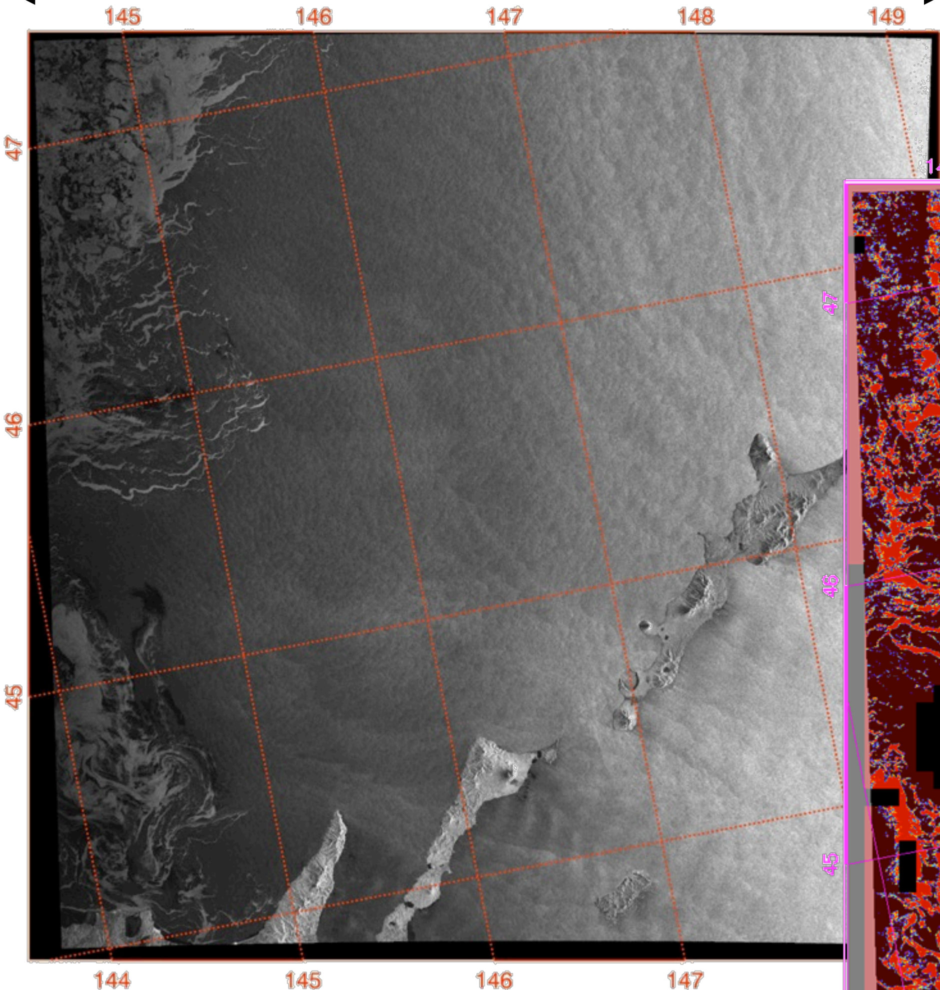


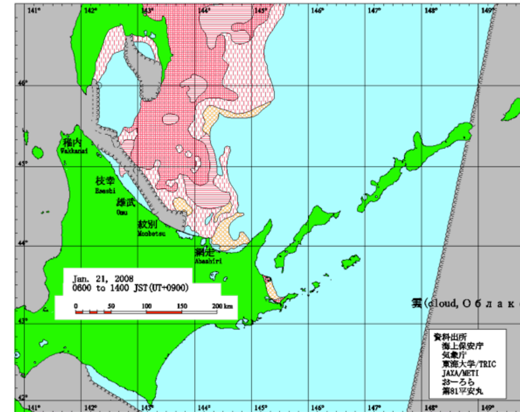
Wind Speed Measurement Using the PALSAR/ScanSAR off coast of Tohoku

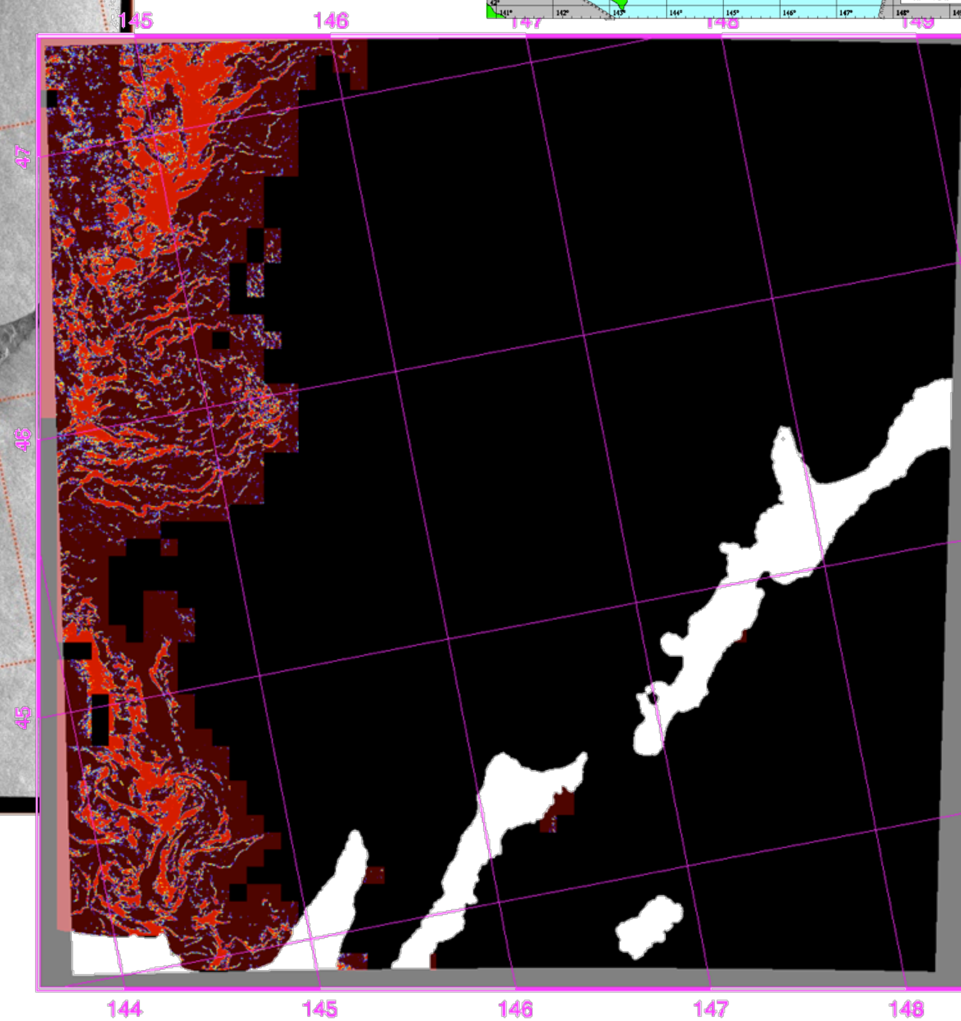
PALSARの流氷マップ(1/21/2008)

ScanSAR Image

ALOS/PALSAR (ScanSAR)-350km

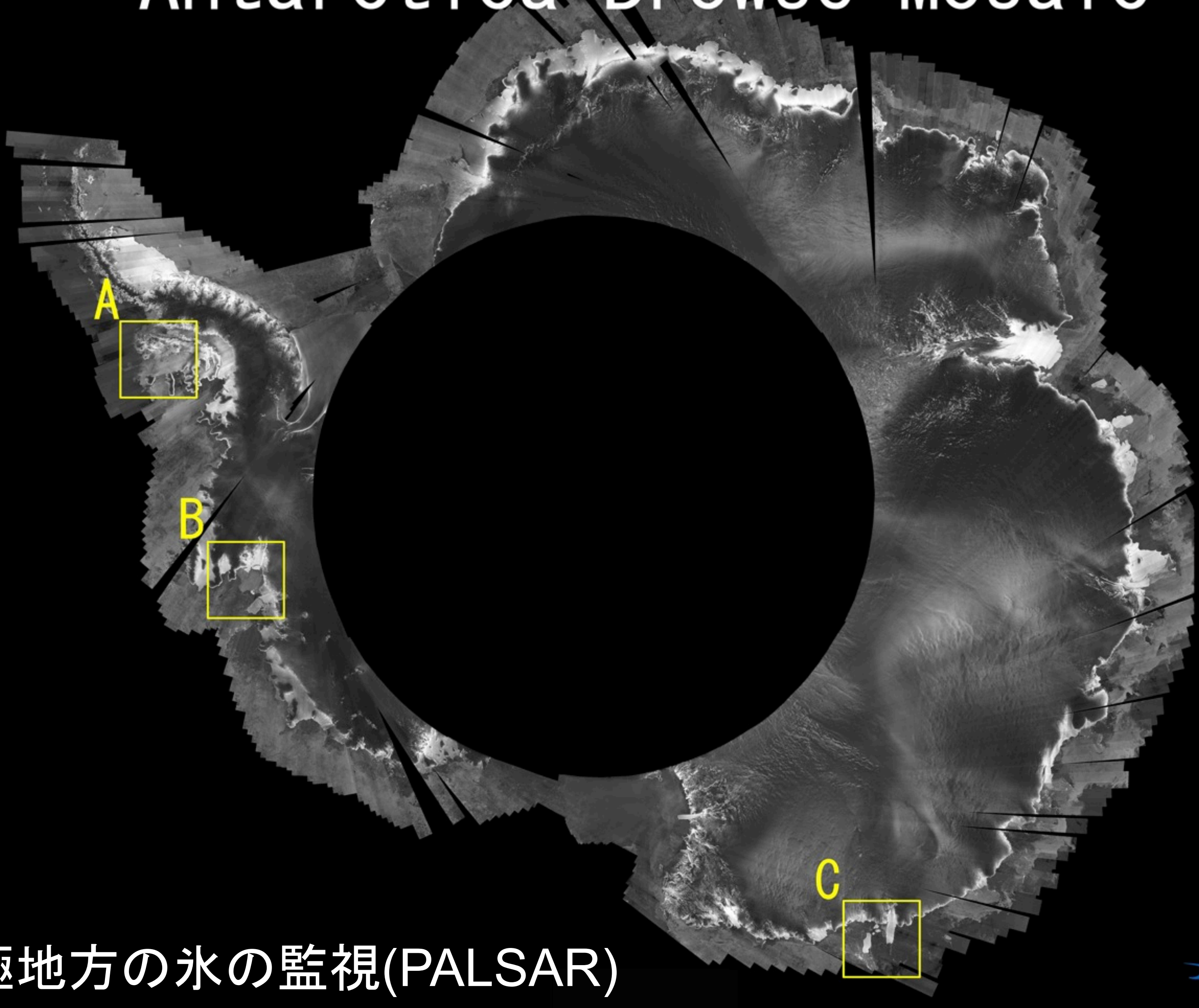






Sea Ice concentration map

Antarctica Browse Mosaic



極地方の氷の監視(PALSAR)

3. Coastal Erosion Monitoring

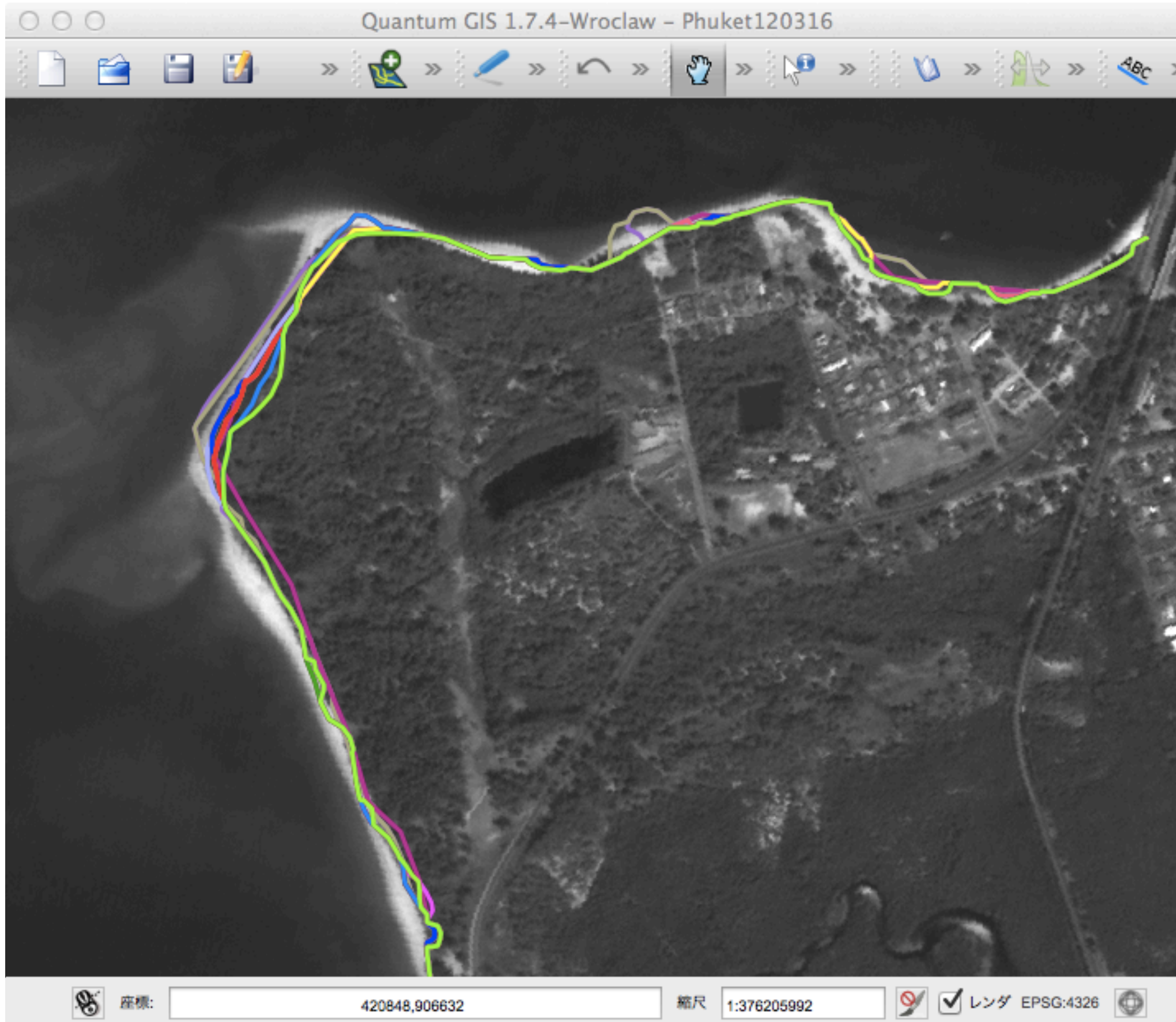
- Thailand case study

Coastline Changes at Phuket by ALOS/PALSAR (2007-2010)

Sai kaew beach

- Big fluctuation due to strong wind and wave. Also by tidal current.

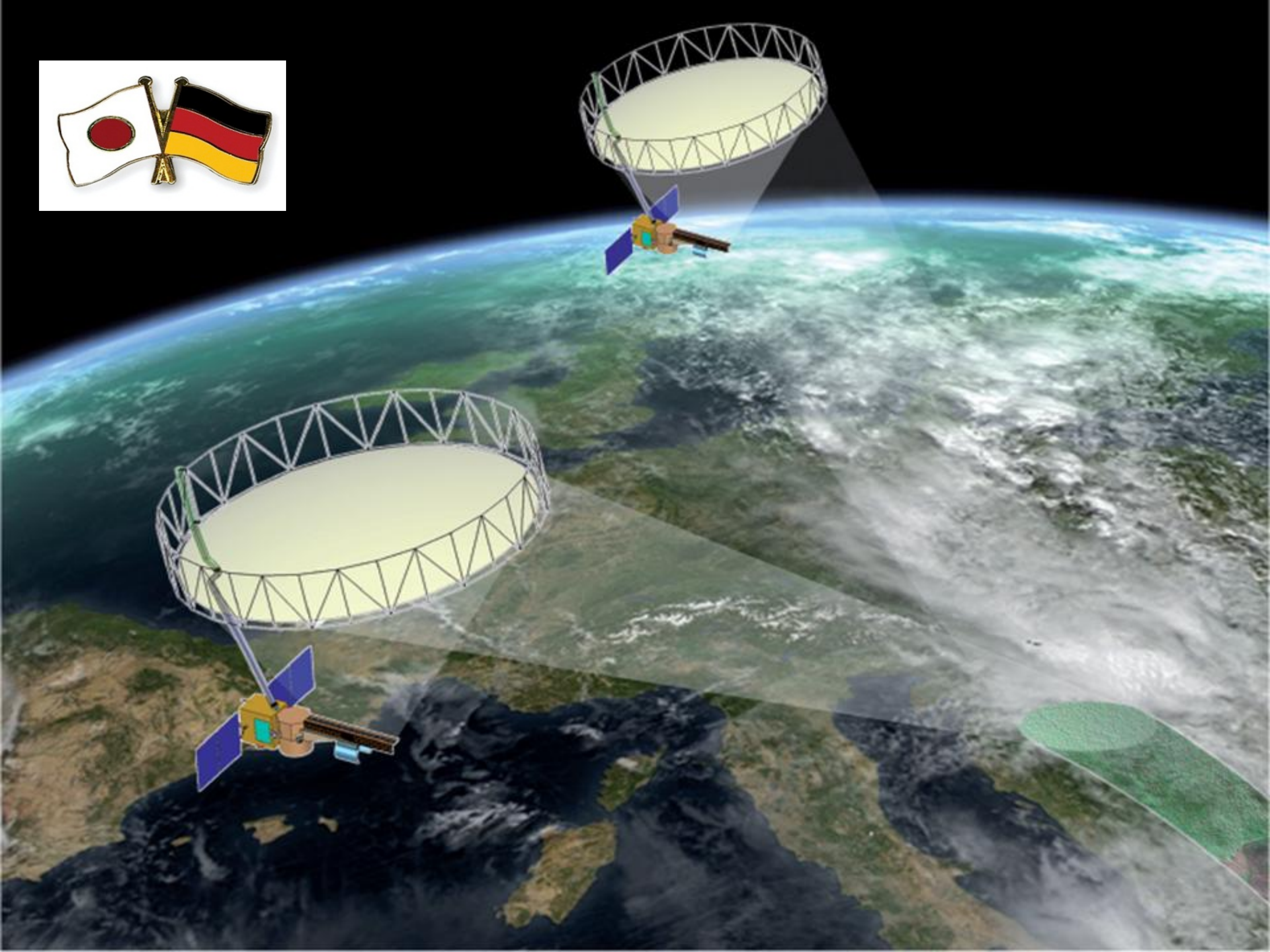
2010/10/28
2009/09/09
2009/03/09
2008/10/22
2008/06/06
2008/04/21
2008/03/06
2008/01/20
2007/12/05
2007/10/20
2007/07/20
2007/03/04
2007/01/17



Comparison of the JERS-1 SARとALOS PALSAR on data amount/no. of scenes(daily)

	Data Amount (GByte)	Number of scenes	Remarks
JERS-1 SAR	17.58	192.80	Based on 1993 ～1997
ALOS PALSAR	355.69 （20.24）	1176.38 （6.10）	Based on 2007-2009
ALOS-2	553 (31.45)	1,344 (6.97)	Simulation
FSAR	TBD	TBD	Simulation

・CAL included
・All the OBS data included.



Japanese user community

- 2 general meetings to discuss requirements (Jan. & Apr.)
- 9 science & application fields
- 129 members registered

@ 1st meeting on Jan. 25

Main Observations for Future SAR

Category	Main Observables
Surface deformation	Global Surface deformation with mm order accuracy
Forestry	Global distribution of forest, height, biomass, 3D structures, clear-cut, and wetland
Disaster	High resolution and wide range detection of disaster info. （Flooding, land slide, volcano, debris, building damage), rescue info.
Snow Ice	Sea Ice distribution, glacier movement, snow amount
Ocean	Wind speed, current distribution, coastal erosion, etc.
Marine Surveillance	Ships and drifting debris
Agriculture	Rice paddy field, crop estimation, soil moisture, river-water amount, crop calendar
Resources	Oil will, deposit finding, subsidence for oil pumping, deposit estimation, pressure of geopressured of geothermal reservoir
Ionosphere	TEC, Bubbles, TID
Urban Study	Subsidence, distortion of the infrastructure, traffic jam
Map Generation	Global – DEM, Land Use Land Cover

日独連携で検討中の地球物理量

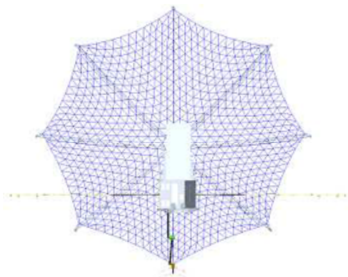
Geosphere	Solid earth	Global deformation monitoring
	Solid earth	GPS network fusion
	Solid earth	Earthquake/risk area tectonic motion
	Solid earth	Earthquake deformation (co-seismic)
	Solid earth	Earthquake deformation (post-seismic)
	Solid earth	Volcanoes surface deformation (shallow source, co-eruptive)
	Solid earth	Volcanoes surface deformation (shallow source, post-
	Solid earth	Volcanoes surface deformation (deep source)
	Solid earth	Volcanoes surface disruptions
	Solid earth	Landslides motion
	Solid earth	Urban subsidence

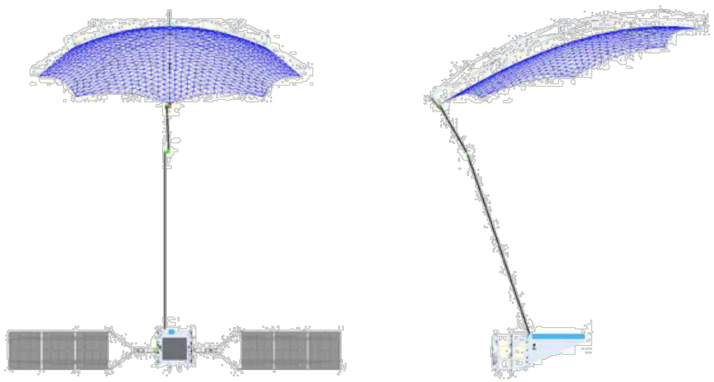
Biosphere	**Forest/wetland**	Forest aboveground biomass (global)
	Forest/wetland	Forest aboveground biomass (regional)
	Forest/wetland	Forest height (global)
	Forest/wetland	Forest height (regional)
	Forest/wetland	Forest height (local)
	Forest/wetland	Forest structure (global)
	Forest/wetland	Forest structure (regional)
	Forest/wetland	Underline topography
	Forest/wetland	Aboveground biomass change (global)
	Forest/wetland	Aboveground biomass change (regional)
	Forest/wetland	Forest height change (global)
	Forest/wetland	Forest height change (regional)
	Forest/wetland	Forest structure change (global)
	Forest/wetland	Forest structure change (regional)
	Forest/wetland	Underline topography change
	Forest/wetland	Forest/non-forest classification
	Forest/wetland	Forest area change (deforestation/afforestation)
	Forest/wetland	Deforestation early detection
	Forest/wetland	Forest fire detection
	Forest/wetland	Degradation monitoring
	Forest/wetland	Forest type classification
	Forest/wetland	Mangrove extent and changes
	Forest/wetland	Peat land subsidence
	Forest/wetland	Wetland inundation
	Forest/wetland	Wetland type and morphology
	Agriculture	Rice paddy mapping
	Agriculture	Crop type classification
	Agriculture	Crop calendar
	Agriculture	Crop hazard (drought, falling, etc.)
	Agriculture	Aboveground biomass of large crops

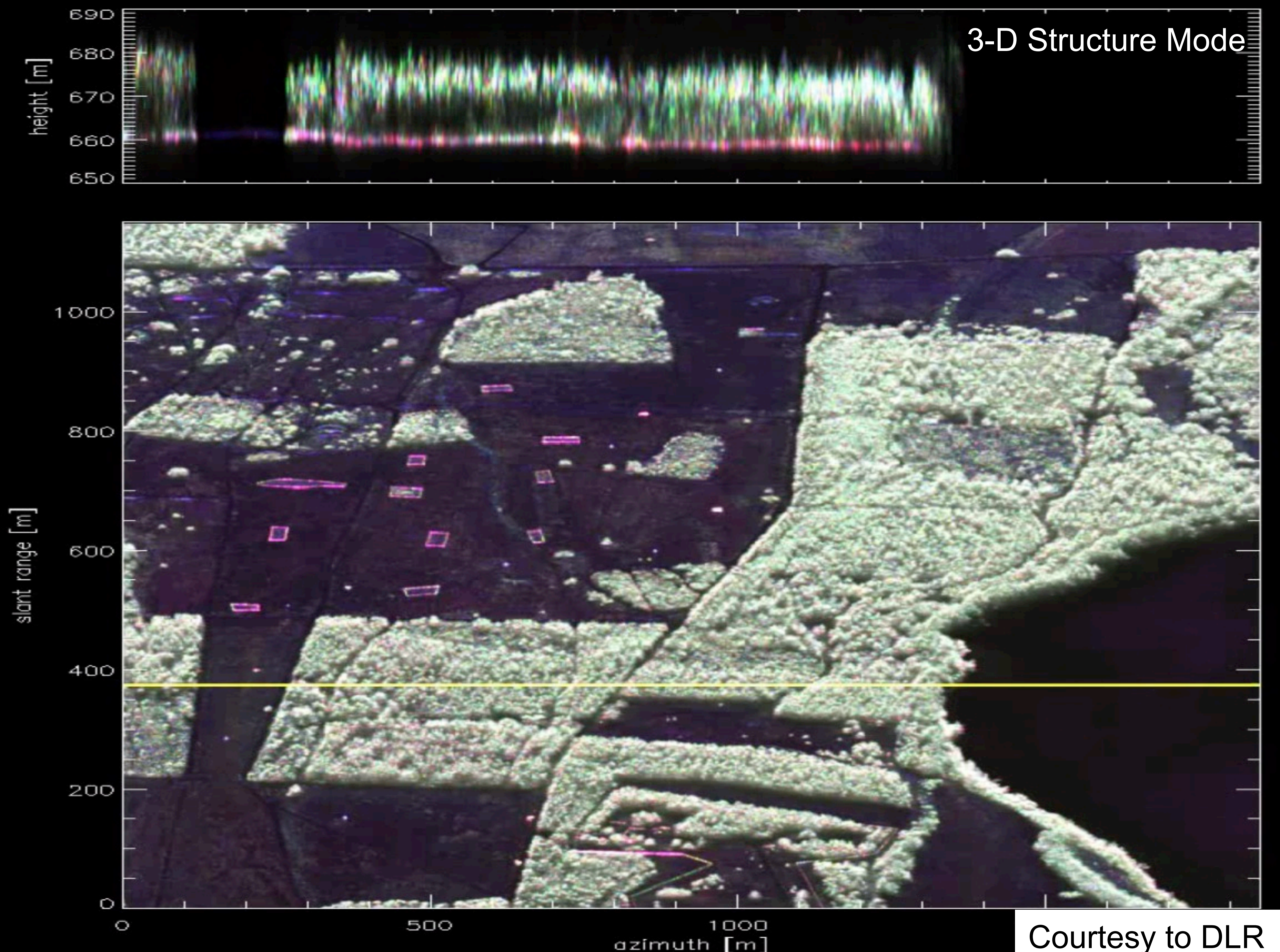
Cryosphere (land ice)	Ice/snow	Surface displacements
	Ice/snow	Surface topography
	Ice/snow	Detection dry snow line
	Ice/snow	Coastal area change
	Ice/snow	Ice stream/gracier velocity
	Ice/snow	Grounding line position
	Ice/snow	Ice structure and change
	Ice/snow	Snow water equivalent
	Ice/snow	Permafrost freeze and thaw change
	Ice/snow	Ice shelf and iceberg distribution
Cryosphere (sea ice)	Ice/snow	Changes in sea ice thickness
	Ice/snow	Sea ice motion and circulation
	Ice/snow	Ice type distribution and ice water seperation (Arctic & Antarctic)
	Ice/snow	Ice type distribution and ice water seperation (Okhotsk sea)
	Ice/snow	Ice distribution and thickness monitoring for Northern sea route
	Ice/snow	Sea ice topography and roughness

Hydrosphere (surface water)	**Agriculture (Hydro)**	Surface roughness
	Agriculture (Hydro)	Surface moisture (regional)
	Agriculture (Hydro)	Surface moisture (local)
	Agriculture (Hydro)	Surface water velocity (river)
	Agriculture (Hydro)	Flooded areas (river and coastal)
	Ocean	Coastal erosion
Hydrosphere (ocean)	**Ocean**	Tidal flat height and waterlines
	Ocean	Coastal bathymetry
	Ocean	Internal wave positions
	Ocean	Ocean currents
	Ocean	Ocean roughness
	Ocean	Ocean wave (wavelength, direction, height)
	Ocean	Ocean surface wind (coastal)
	Ocean	Ocean surface wind (not coastal)
Others	**Ocean**	Sea drifting objects
	Ocean	Ship detection and identification
	Ocean	Ship detection and identification (on demand)
	Urban/mapping	Urban traffic control
	Urban/mapping	Interference from ground radars
	Urban/mapping	Land cover/use mapping
	Urban/mapping	Displacement of large structure
	Disaster	Condition of volcanic mouse
	Disaster	Volcanic ash and deposit distribution
	Disaster	Damage of buildings and infrastracture
	Disaster	Flooding area (disaster)
	Disaster	Landslide and natural dam detection (disaster)
	Disaster	Oil slick
	Natural resources	Deformation due to natural resource production
	Natural resources	Mineral exploration (topography, geology)
	Ionosphere	Ionospheric activities

Spec(TBD)
SW:350km
Strip Map
Full Polarimetry
8 days orbit
Bw:20MHz~80MHz
Az:1m~10m







Courtesy to DLR

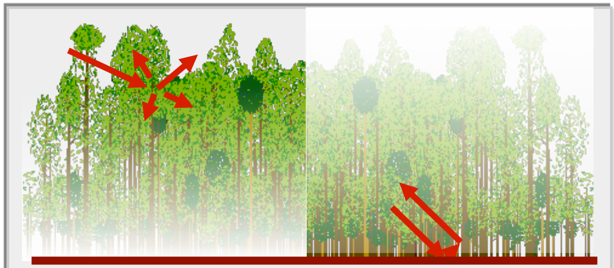
Conclusion

- L-band SAR has a big potential for capturing the land surface features.
- Time series amplitude, interferometric, polarimetric data can contribute to the science and applications.
- JERS-1, ALOS, ALOS-2, and its further continuity will provide the robust observation scheme.
- Germany-Japan-Twin 350km L-band SAR enhances the observation capability.

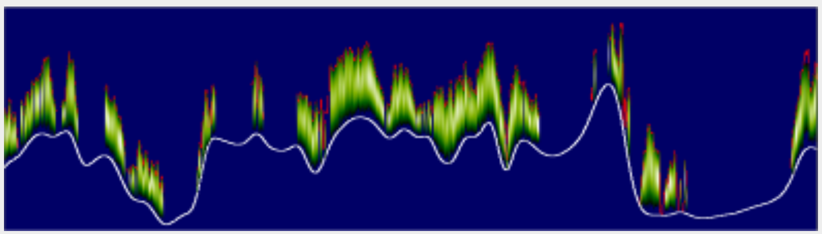
Joint Pre-Phase A Study

3-D Structure Mode

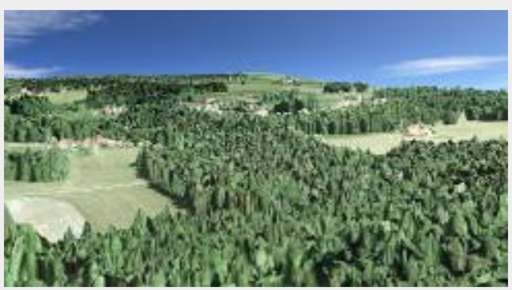
Polarimetric Backscattering



3-D Forest Structure



Forest height and Biomass



Tomography