



Master SIG

Fusion des Données Hétérogènes Techniques et Applications

processed by GAEL Consultant

Envisat Meris - Acquisition March April 2003 - Plate-carrée projection





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- ✦ Synthèse de produits image
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- ✦ Références



✦ Images – Distributions et statistiques

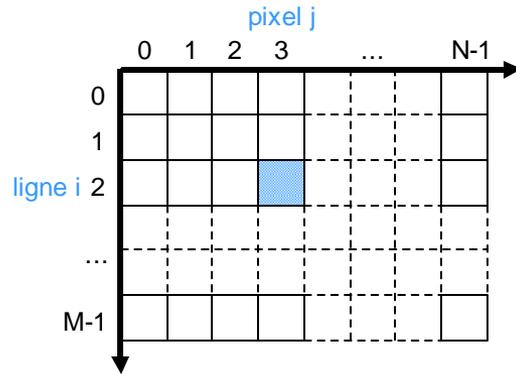
- ❖ Statistiques élémentaires
- ❖ Histogrammes bi-dimensionnels
- ❖ Corrélations
- ❖ Variogrammes



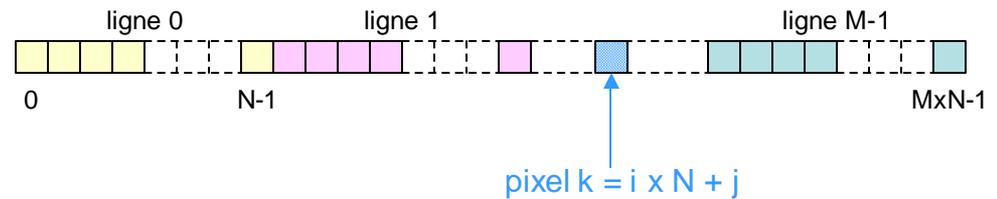


Notion de « distribution radiométrique »

Représentation à 2 dimensions



Représentation à 1 dimension



« Fonction image » ou « distribution radiométrique »

$$R(i,j), i=0..(M-1), j=0..(N-1)$$

$$\forall i=0..(M-1), \forall j=0..(N-1),$$

$$R(i,j) \in [0, 2^d - 1]$$

avec d: nombre de bits par pixels

d = 8 bits
dans le cours
⇒ [0,255]

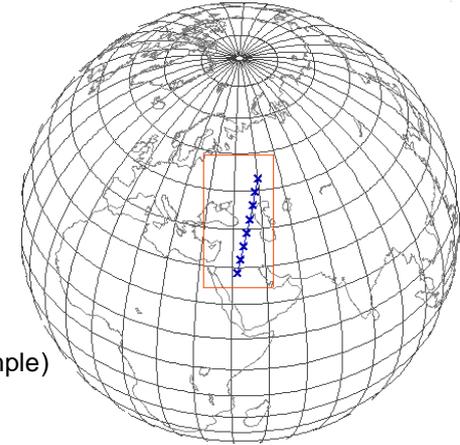
$$R(k), k=0..(M \times N - 1)$$

représentation adoptée
dans le cours

D'un point de vue statistique, $R(i,j)$ est un échantillon d'une variable aléatoire réalisée sur l'intervalle $[0, 2^d - 1]$



✦ Background et image



- pas de background
- pixel image $R(i,j) \in [0,255]$

- background de valeur 0 (par exemple)
- pixel image $R(i,j) \in [1,255]$

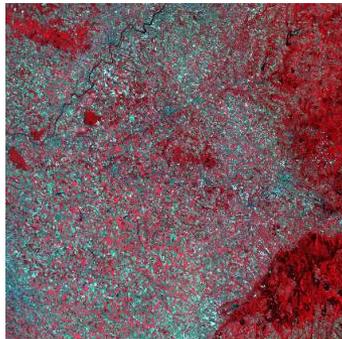
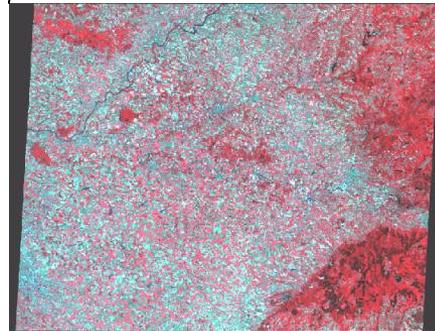
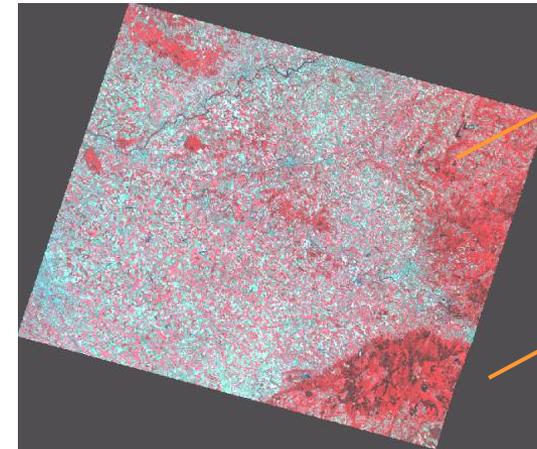


image acquise par le satellite SPOT



correction des effets :
- panoramique,
- de sphéricité et
- de rotation de la Terre



pixels image

pixels de background (ou padding)

mise en projection cartographique

Ne pas comptabiliser les pixels de background dans les statistiques !!!

Information relative à une image:

-format, -taille, -nombre bits par pixel, **-présence background, -valeur background**

Histogramme

$$\forall r = 0 \dots 2^d - 1, H(r) = \text{Card} \left(\{ R(i,j)=r, i=0..(M-1), j=0..(N-1) \} \right) \text{ avec } d: \text{ nombre de bits par pixels}$$

$H(r)$
Occurrences de la
radiométrie r dans
l'image entière

girl.r



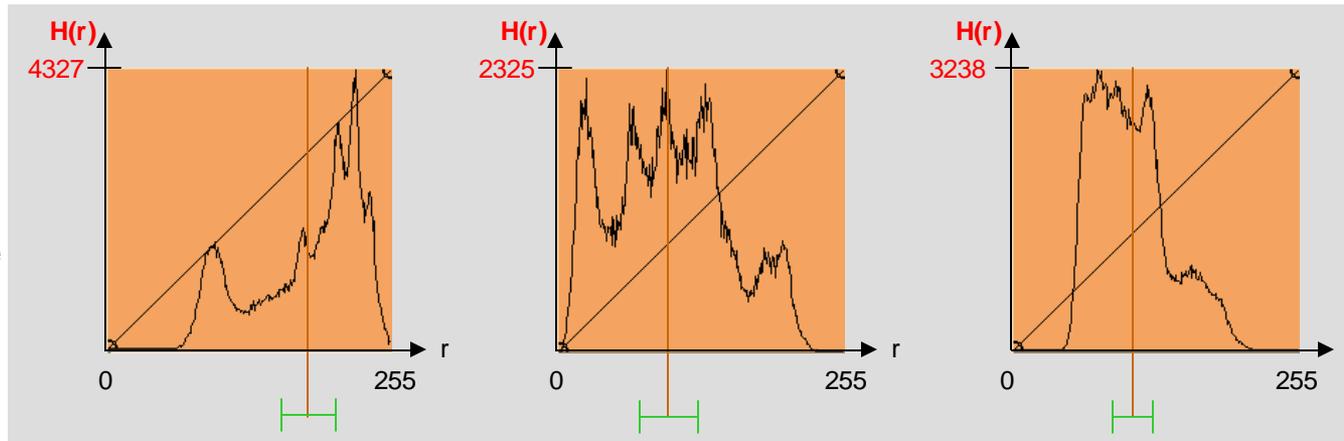
girl.g



girl.b



affichage calibré
sur le maximum
de l'histogramme
($\max(H(k))$)



$m = 180,22$
 $\sigma = 49,05$

$m = 99,05$
 $\sigma = 52,88$

$m = 105,41$
 $\sigma = 34,06$

Exemple 2 – Roissy (SPOT XS)

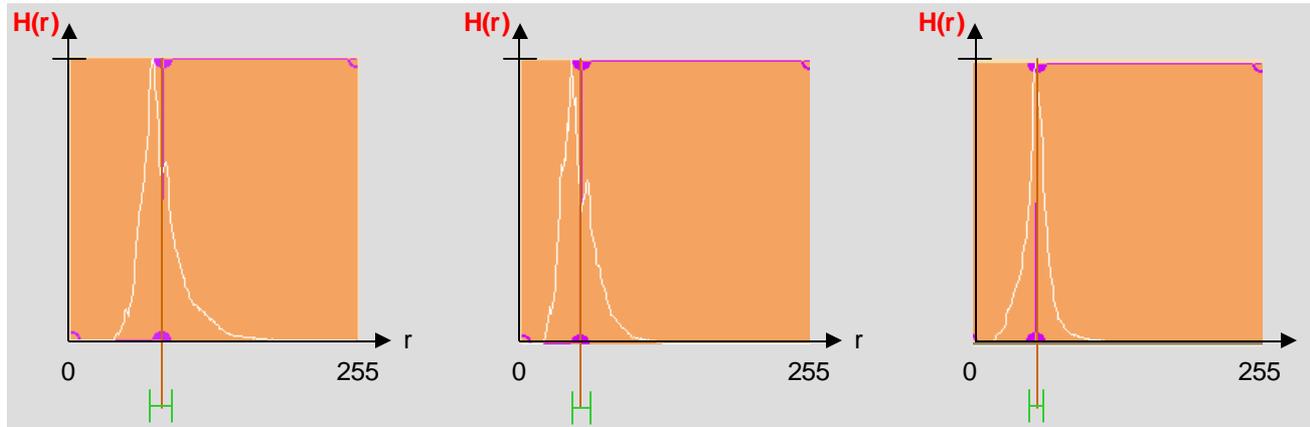
roissy.1



roissy.2



roissy.3



$m = 81.243$
 $\sigma = 19.546$
skewness = +1.255
kurtosis = +2.423

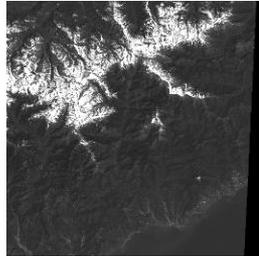
$m = 50.899$
 $\sigma = 15.791$
skewness = +1.077
kurtosis = +1.755

$m = 59.202$
 $\sigma = 11.888$
skewness = +0.413
kurtosis = +2.249

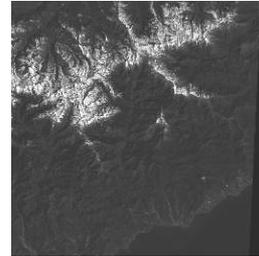


Exemple 3 – San-Remo (Landsat TM)

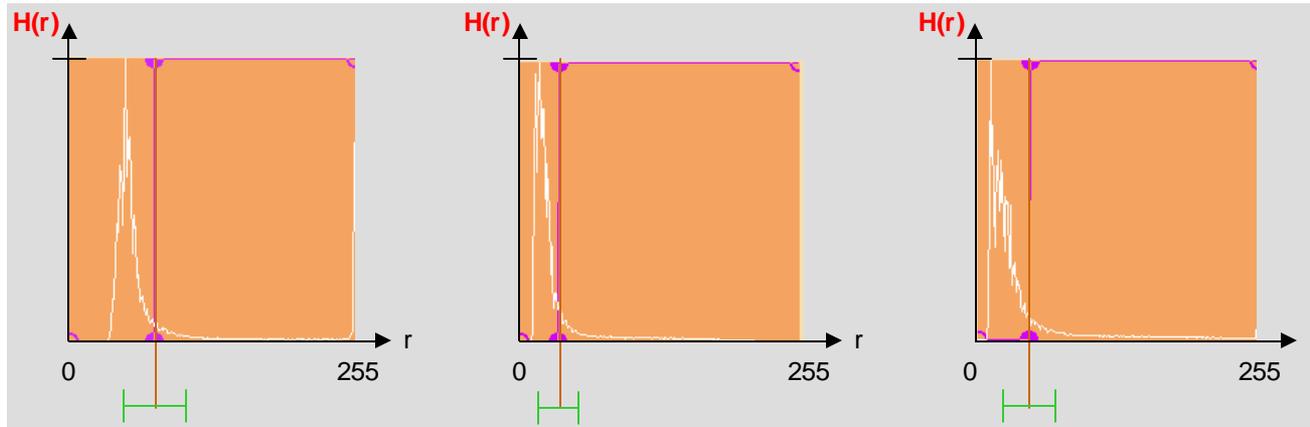
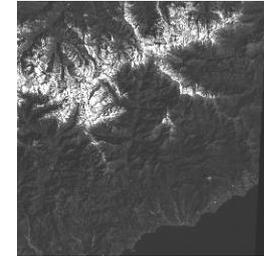
san-remo.1



san-remo.2



san-remo.3



$m = 75.445$
 $\sigma = 55.984$
skewness = +2.359
kurtosis = +4.339

$m = 34.901$
 $\sigma = 36.624$
skewness = +2.891
kurtosis = +8.276

$m = 39.810$
 $\sigma = 45.782$
skewness = +2.735
kurtosis = +7.344



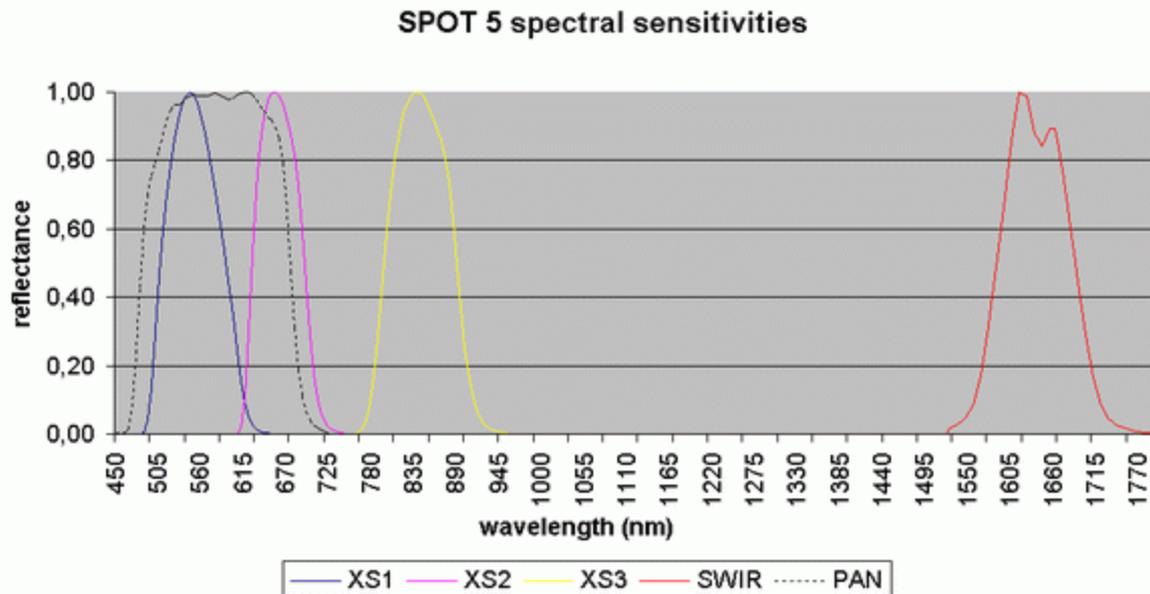
❖ Instruments et plate-formes – Géométrie de prise de vue

- ❖ Résolution spatiale – Résolution fréquentielle
- ❖ Référentiel image - Référentiels terrestres
- ❖ Géométries d'acquisition
- ❖ Niveaux de produit
- ❖ Format des images
- ❖ Données auxiliaires - Éphémérides et attitudes
- ❖ Calibration (avant-vol, à-bord, inter-instruments)
- ❖ Temps de revisite
- ❖ Satellites en formation



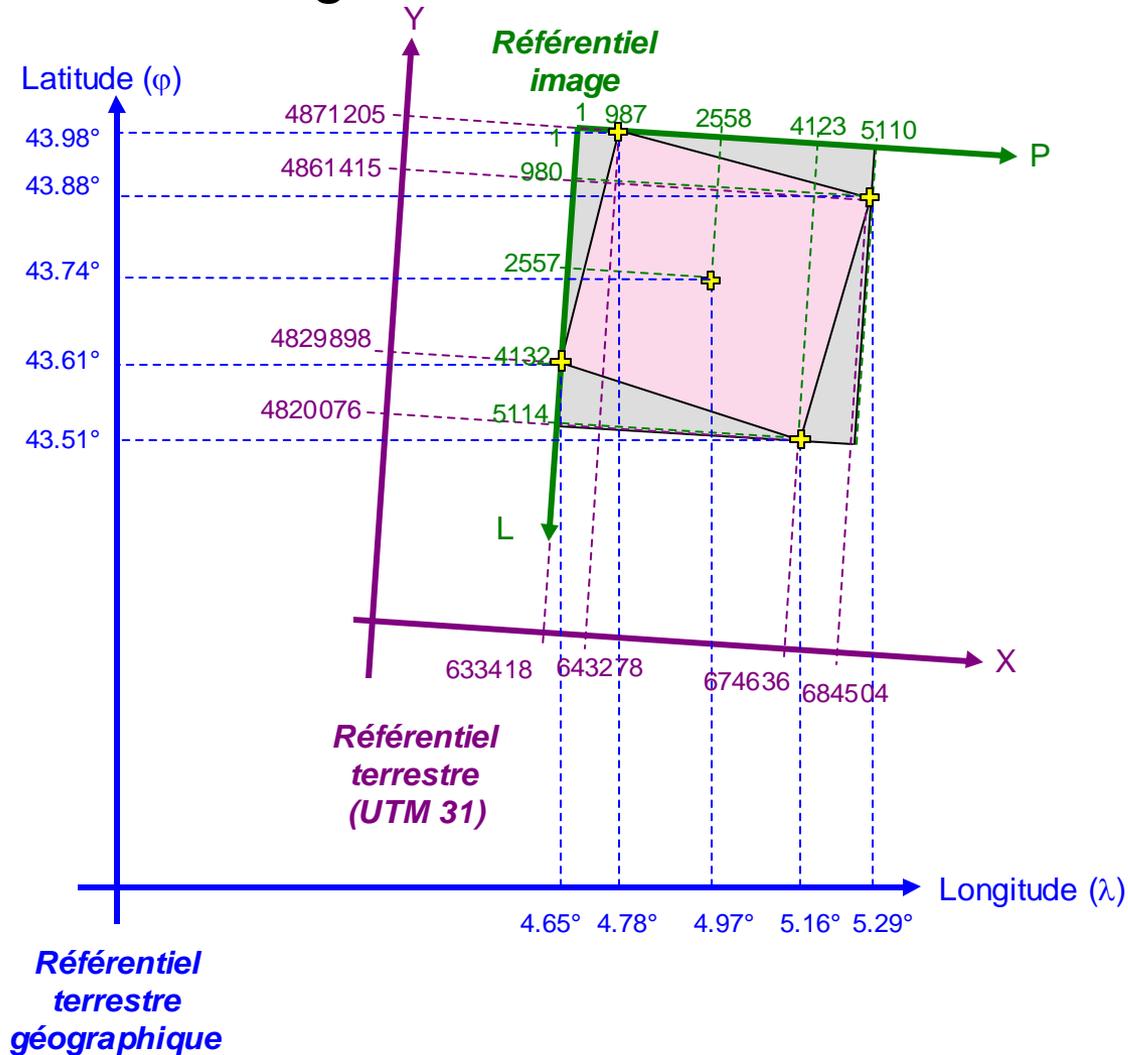
INSTRUMENTS ET PLATE-FORMES GEOMETRIE DE PRISE DE VUE

✦ Résolution spatiale – Résolution fréquentielle



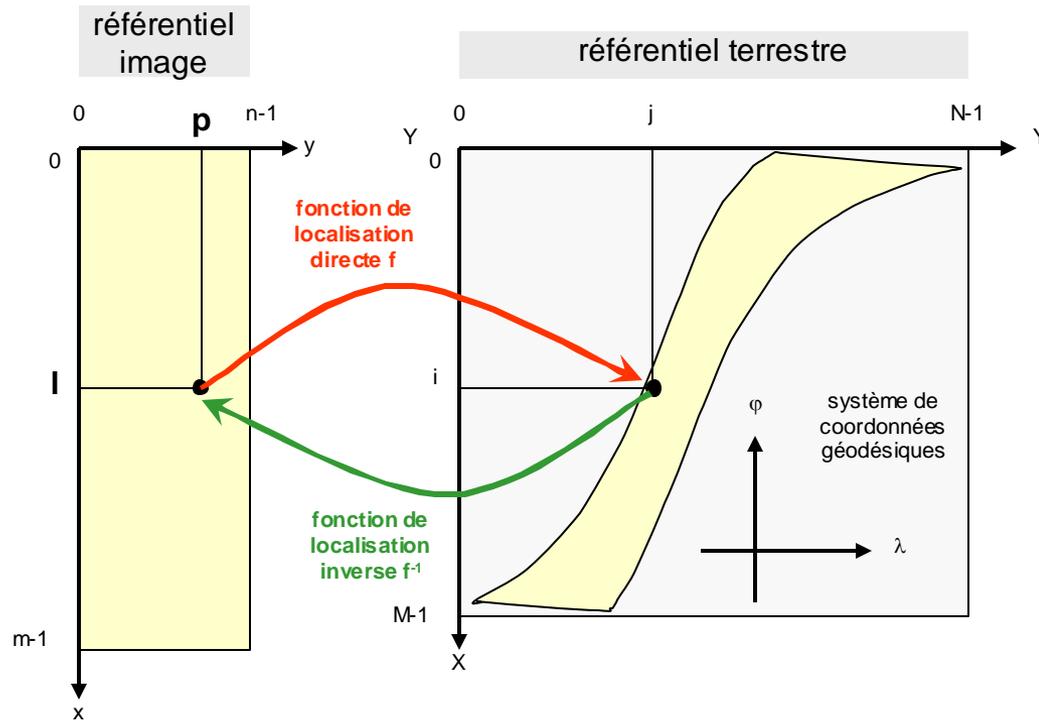


✦ Référentiel image – Référentiels terrestres



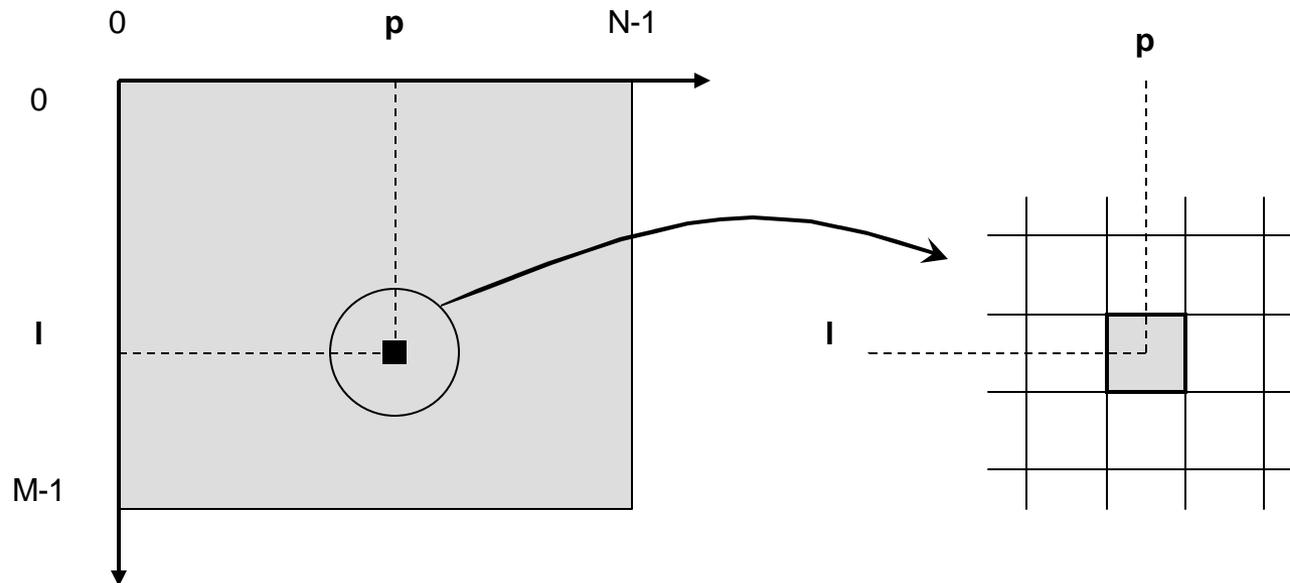
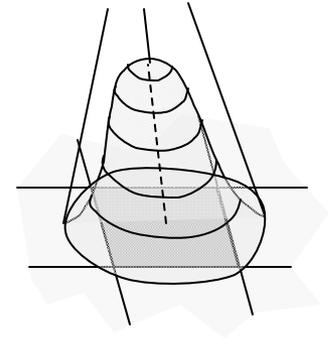


✦ Géocodage d'une image



❖ Référentiel image

- Origine de l'image
- Sens de parcours de l'image
- Centre du pixel





❖ Référentiels terrestres

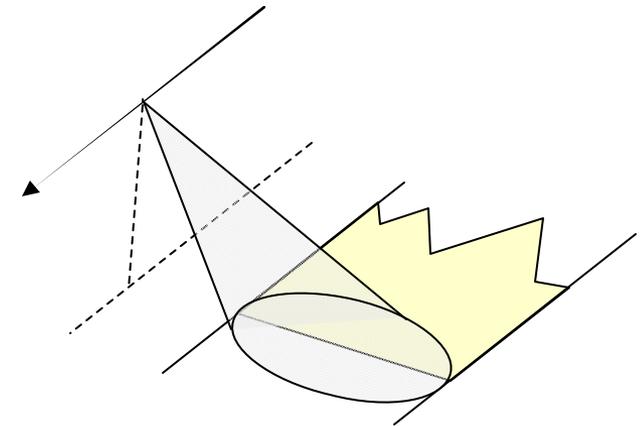
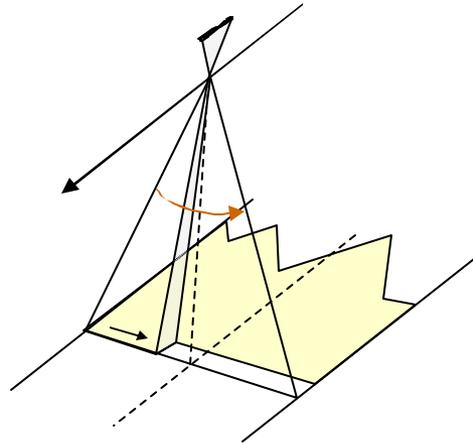
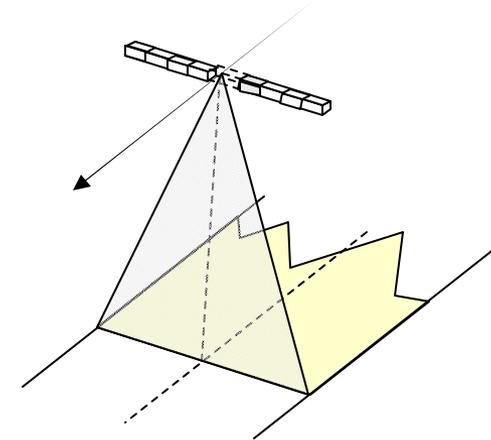
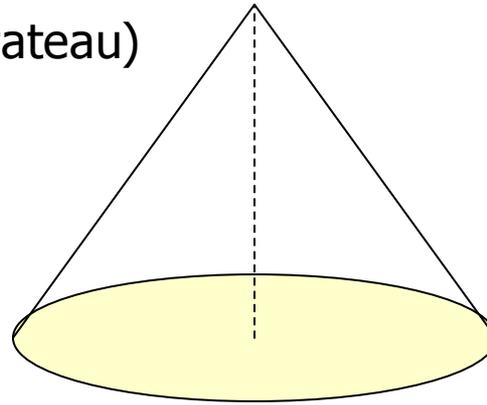
✦ Géométrie d'acquisition

- ❖ Géométrie conique

- ❖ Push-broom (rateau)

- ❖ Scanner

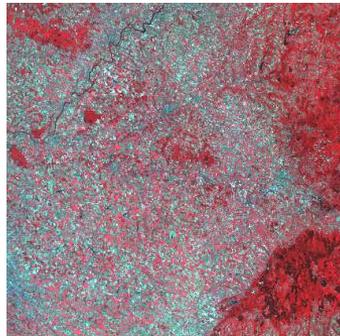
- ❖ Radar





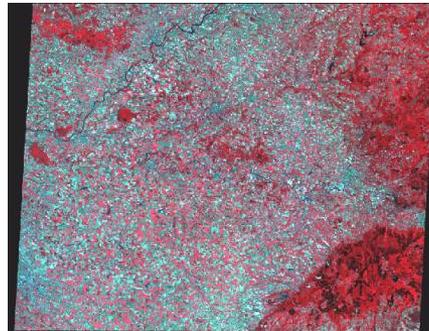
✦ Niveaux de produit

Niveau 1A

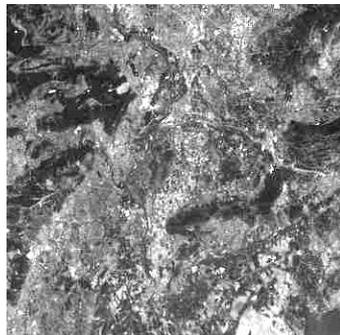
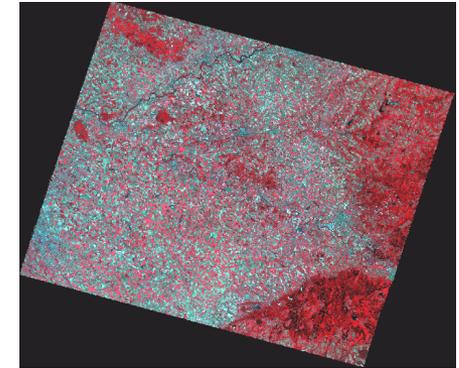


SPOT123-4
XS

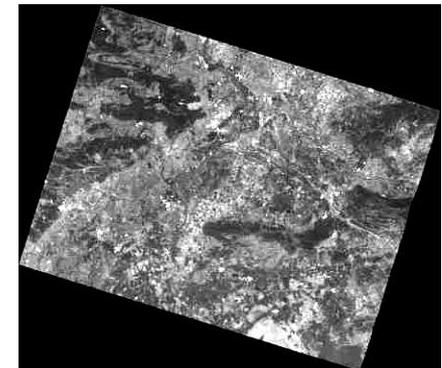
Niveau 1B



Niveau 2



SPOT5
PAN





✦ Format des images



✦ Données auxiliaires – Éphémérides et attitudes



✦ Calibration (avant-vol, à-bord, inter-instruments)



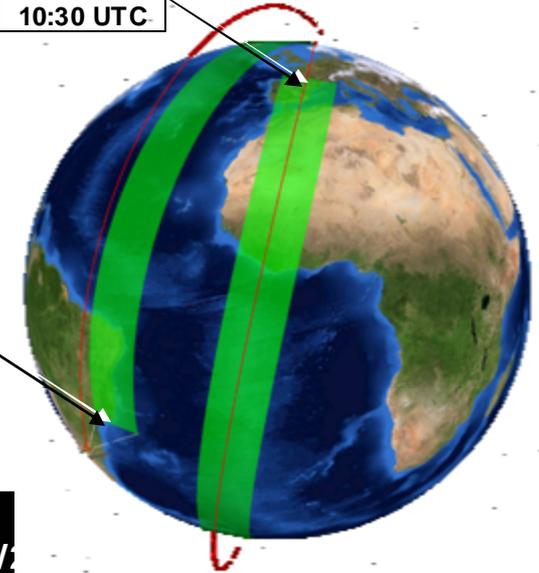
14/01/2009
10:30 UTC



⊕ Temps de revisite

- ❖ Cycle du satellite
- ❖ Largeur de fauchée
- ❖ Dépointage de l'instrument
- ❖ Agilité du satellite

14/01/2009
12:30 UTC



© 2009 BROCKMANN CONSULT
Couverture des 14 révolutions de l'instrument Envisat / MERIS le 14/01/2009

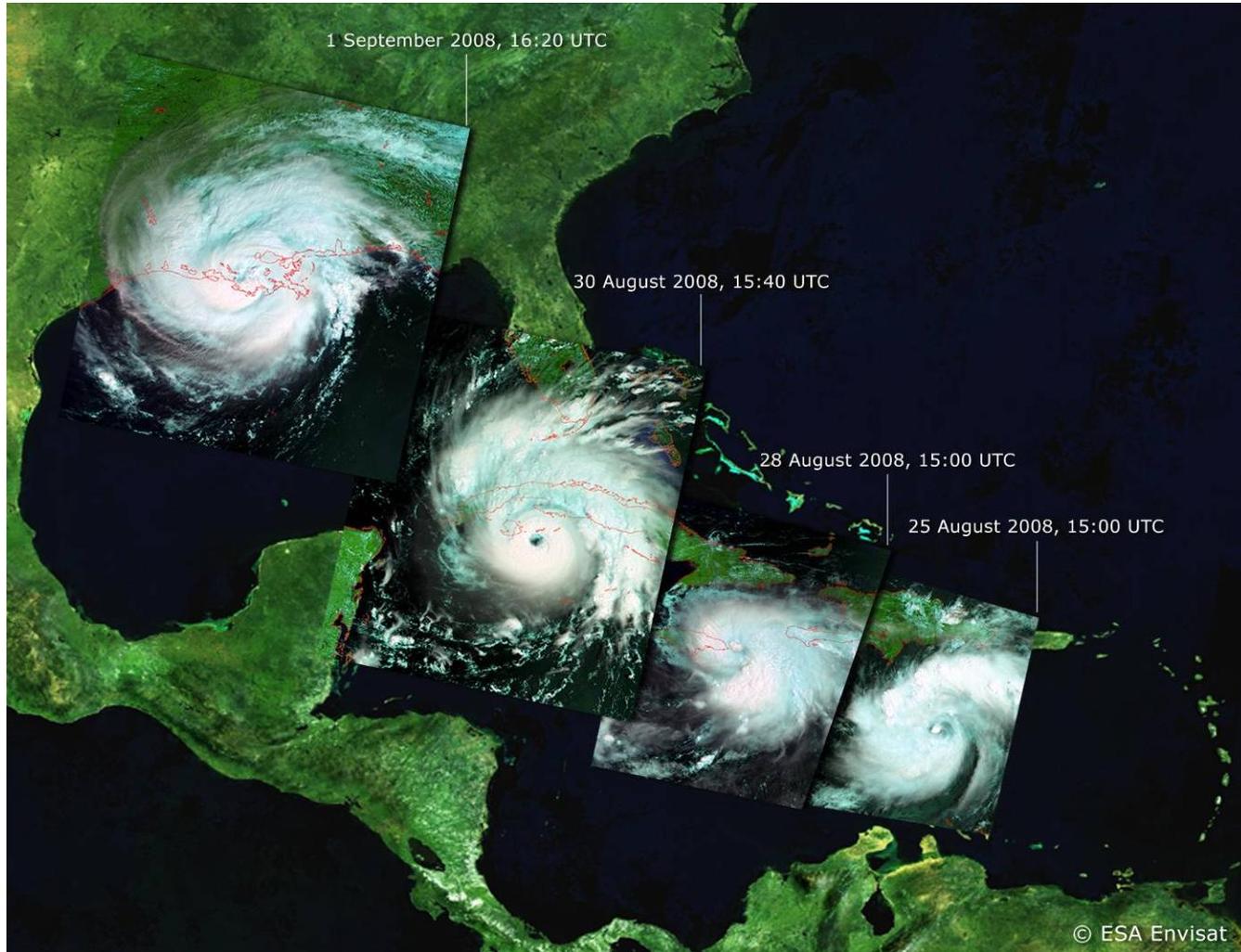
<http://www.brockmann-consult.de/waqss/mosaic.html>



Acquisition DATE: 20090114, Orbits 35942 - 35956

BROCKMANN CONSULT

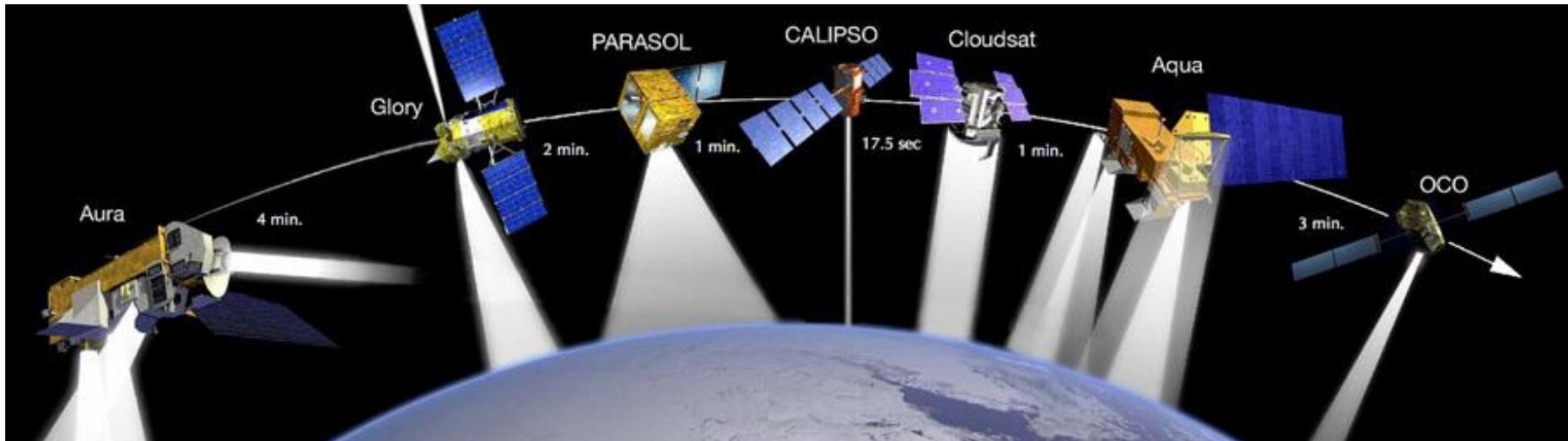
❖ Temps de revisite – Exemple Envisat / MERIS – Suivi du cyclone Gustav



http://www.esa.int/esaEO/SEM_V0RO4KKF_index_0.html

✦ Satellites en formation

- ❖ cross-calibration
- ❖ observations complémentaires
- ❖ caractérisation des aérosols
- ❖ modélisation de l'atmosphère
- ❖ évaluer le bilan radiatif



<http://glory.gsfc.nasa.gov/a-train.html>
<http://smsc.cnes.fr/PARASOL/Fr/a-train.htm>
http://aqua.nasa.gov/doc/pubs/A-Train_Fact_sheet.pdf



✦ Echelles et résolution

- ❖ Données vectorielles
- ❖ Données matricielles (raster)
- ❖ Modèles Numériques de Terrain



ECHELLES ET RESOLUTIONS

Données raster

Calcul empirique à partir des données écran en « pleine résolution »
1 pixel écran ↔ 1 pixel image en résolution spatiale native (GSD)

$$\begin{array}{l} 0,33 \text{ m} \rightarrow 1920 \text{ pixels} \times \text{GSD} \\ 1 \text{ m} \rightarrow s \text{ (dénominateur de l'échelle)} \end{array} \Rightarrow s = \frac{1920 \times \text{GSD}}{0,33} \approx 5818 \times \text{GSD}$$



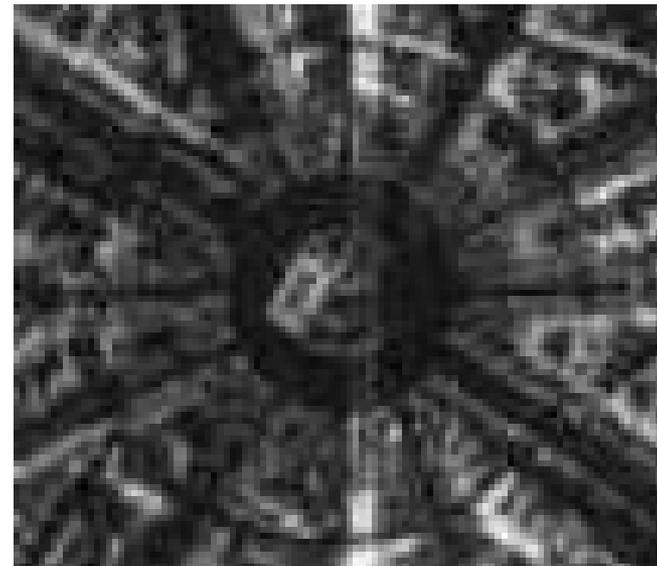
Résolution spatiale	Échelle cartographique
30 m	1:400 000 ^{ème} à 1:250 000 ^{ème}
20 m	1:80 000 ^{ème} à 1:200 000 ^{ème}
10 m	1:50 000 ^{ème} à 1:100 000 ^{ème}
5 m	1:25 000 ^{ème} à 1:50 000 ^{ème}
1 m	1:5 000 ^{ème} à 1:25 000 ^{ème}

Table de correspondance fournie par I-SPACE [2005], page 46

ECHELLES ET RESOLUTIONS - Exemples



Extrait de la scène GeoEye acquise le 12/10/2008 à 0,40 m de résolution sur l'aéroport Moffet en Californie



Extrait de la scène COSMO-Skymed acquise le 25/11/2008 à 1 m de résolution sur Paris Arc-de-Triomphe



✦ Données satellitaires disponibles

❖ Imagerie optique

- Basse résolution (pas d'échantillonnage au sol: $pes > 100$ m)
- Moyenne résolution ($5 \text{ m} < pes \leq 100$ m)
- Haute résolution ($pes \leq 5$ m)

❖ Imagerie Radar

- Basse résolution
- Moyenne résolution
- Haute résolution

❖ Modèles Numériques de Terrain

❖ Les futures missions

- Géostationnaire à haute résolution



DONNEES SATELLITAIRES DISPONIBLES

☩ Sensor Categories (CEOS[2005])

- ☩ Atmospheric chemistry instruments
- ☩ Atmospheric temperature and humidity sounders
- ☩ Cloud profile and rain radars
- ☩ Earth radiation budget radiometers
- ☩ **High resolution optical imagers**
- ☩ **Imaging multi-spectral radiometers (vis/IR)**
- ☩ Imaging multi-spectral radiometers (passive microwave)
- ☩ **Imaging microwave radars**
- ☩ Lidars
- ☩ Multiple direction/polarisation instruments
- ☩ **Ocean color instruments**
- ☩ Radar altimeters
- ☩ Scatterometers
- ☩ Gravity, magnetic field, and geodynamic instruments





✦ Catalogues des missions / instruments

- ✦ CNES - *Earth Observation Satellites & Sensors*
http://www.space-risks.com/SpaceData/index.php?id_page=5
- ✦ NASA - *Satellite Missions*
http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/
- ✦ ESA - *Resources of Earth observation*
http://directory.eoportal.org/res_p1_Earthobservation.html
- ✦ SEDAC (socioeconomic data and resource center) - *Annex A. Satellites and Sensors*
http://sedac.ciesin.org/tg/guide_glue.jsp?rd=rs&ds=6



Optique – Récapitulatif

mission / instrument agence (pays)	lancement / fin mission cycle	technologie fauchée dép/ agilité	bande(s) spectrale(s) id: DES – bande passante (DES: Distance d Echantillonnage au Sol)	- produits image - format(s) - bits/pixel	- portail de commande des données - description de la mission - description de l'instrument
EROS-A ImageSat Int. (Israël)					- www.kos.mosnimki.ru/
GeoEye-1 GeoEye (USA) Space Imaging détail	06/09/2008 / - ?? jours	pushbroom 11,3 km agile +/-30°	P: 0,41 m - 0,450-0,800 μm B: 1,65 m – 0,450-0,510 μm G: 1,65 m – 0,510-0,580 μm R: 1,65 m – 0,655-0,690 μm NIR: 1,65 m – 0,780-0,920 μm	- Geo (avec RPC) GeoProfessional (orthorectifié) GeoStereo - TIFF / GeoTIFF / NITF + RPC - 11 bits/pixel	- http://www.euspaceimaging.com/ - http://launch.geoeye.com/LaunchSite/Default.aspx http://www.geoeye.com/CorpSite/products/imagery-sources/
IKONOS GeoEye (USA) Space Imaging détail	24/09/1999 / - ?? jours	pushbroom 11,3 km agile +/-30°	P: 0,82 m - 0,526-0,929 μm B: 3,2 m – 0,445-0,516 μm G: 3,2 m – 0,506-0,595 μm R: 3,2 m – 0,632-0,698 μm NIR: 3,2 m – 0,757-0,853 μm	<i>idem</i>	- http://www.eurimage.com/products/quickbird.html - http://www.geoeye.com/CorpSite/products/imagery-sources/Default.aspx#ikonos
QuickBird DigitalGlobe (USA) détail	18/10/2001 / - ?? jours	pushbroom 16,5 km agile +/-30°	P: 0,61 m - 0,445-0,900 μm B: 2,4 m – 0,45-0,52 μm G: 2,4 m – 0,52-0,60 μm R: 2,4 m – 0,63-0,69 μm NIR: 2,4 m – 0,76-0,90 μm	- Basic Imagery Standard & Ortho-ready Imagery Orthorectified Imagery - PAN / MS / PAN+MS / PAN sharp., Dynamic Range Adjustment (DRA) - 11 bits/pixel	- http://www.eurimage.com/products/quickbird.html - http://www.digitalglobe.com/index.php/85/QuickBird - http://spot5.cnes.fr/gb/satellite/satellite.htm
SPOT-5 / HRG CNES (France) détail	04/05/2002 / - 35 jours	pushbroom 60 km dép! +/-27°	P: 5 m ou 2,5 m - 0,49-0,69 μm B1: 10 m – 0,50-0,59 μm B2: 10 m – 0,61-0,68 μm B3: 10 m – 0,78-0,89 μm MIR: 20 m – 1,58-1,75 μm	- niveaux 1A,1B,2A, SPOTView 2B, SPOT DEM - DIMA P GeoTIFF, CEOS - 8bits/pixel	- http://sirius.spotimage.fr/ - http://spot5.cnes.fr/index2.htm - http://spot5.cnes.fr/satellite/camerasHRG.htm

voir <http://gmesdata.esa.int/web/gsc/home>



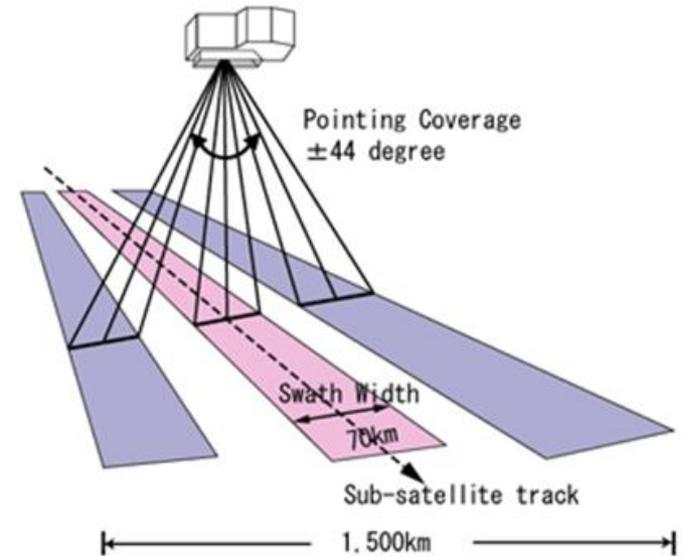
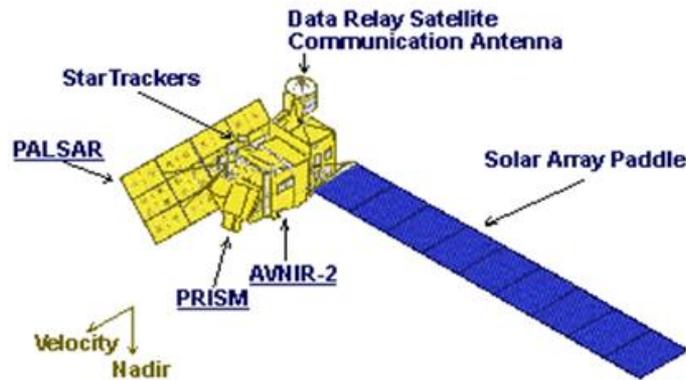
✚ Radar – Récapitulatif

mission / instrument agency (country)	launch / mission end cycle	technology frequency polarisation	modes ID: GSD – sw ath x length (km) (GSD: Ground Sampling Distance)	- image product - format(s)	- data ordering portal - mission reference site - instrument reference site
COSMO-SkyMed 1234 - ASI detail	07.06.2007 09.12.2007 25.10.2008 ?? ?? 2010 16 days	SAR 9.6 GHz (band X) HH, HV, VH, VV	SCANSAR 100 m 200 x 200 km STRIPMAP 3-15 m 40 x 40 km PINGPONG 15 m 30 x 30 km SPOTLIGHT 1 m 10 x 10 km	- Level 0 RAW Level 1A SLC Level 1B MDG (Multi-lookDetected Ground) Level 1C GEC / ellipsoid Level 1D GEC / DEM - HDF5	- http://www.e-geos.it/ - http://www.e-geos.it/cosmoMission.htm http://space.skyrocket.de/index_frame.htm?http://space.skyrocket.de/doc_sdat/cosmo-skymed-1.htm - http://www.e-geos.it/documents.htm
Envisat / ASAR ESA detail					
ERS-1 / SAR ESA detail	17.07.1991 / 10.03.2000 35 days	SAR 5.3 GHz (band C) VV	AMI IM 30 m 100 x 100 km	- PRI: Precision image SLC: Single Look Complex GEC: Ellipsoid Geocoded image - CEOS format Envisat format	- dd - http://earth.esa.int/ers/ http://earth.esa.int/ers/satconc/ - http://earth.esa.int/object/index_cf_m?fobjectid=4001&contentid=4018
ERS-2 / SAR ESA detail	21.04.1995 / - 35 days	SAR 5.3 GHz (band C) VV	AMI IM 30 m 100 x 100 km	- PRI: Precision image SLC: Single Look Complex GEC: Ellipsoid Geocoded image - CEOS format Envisat format	- dd - http://earth.esa.int/ers/ http://www.esa.int/SPECIALS/Operations/SEMM1Z8L6VE_0.html - http://earth.esa.int/object/index_cf_m?fobjectid=4001&contentid=4018
Sentinel-1 ESA detail					
TerraSAR-X DLR (Allemagne) detail	15.06.2007 / - 11 days	SAR 9.65 GHz (band X) Dual (HH, VH, HV, VV)	SM Stripmap: 3-6 m 30 x 50 km SL SpotLight 1-2 m 10 x 10 km SC ScanSAR 18 m 100 x 150 km	- SSC: Single Look MGD: MultiLook GEC: Geocoded EEC: Enhanced - ???	

Mission	Name	Agency	Frequency Band	Dates
SEASAT	SEASAT	NASA (USA)	L-band	1978
ERS-1	European Remote Sensing Satellite-1	ESA (Europe)	C-band	1991-2000
J-ERS-1	Japanese Remote Sensing Satellite	NASDA (J)	L-band	1992-1998
SIR-C/X-SAR	Spaceborne Imaging Radar-C/ X-Band Synthetic Imaging Radar	NASA/DLR/ASI	L-, C-, X-bands	1994
RADARSAT-1	RADARSAT-1	CSA (CAN)	C-band	1995-present
ERS-2	European Remote Sensing Satellite-2	ESA	C-band	1995-present
SRTM	Shuttle Radar Topography Mission	NASA/DLR	C-, X-bands	2000
ENVISAT/ASAR	ENVISAT	ESA	C-band	2002-present
ALOS/PALSAR	Advanced Land Observing Satellite	JAXA (J)	L-band	2005
SAR-Lupe	SAR-Lupe	BMVg (D)	X-band	2006
TerraSAR-X	TerraSAR-X	DLR/Astrium (D)	X-band	2007
CosmoSkymed	CosmoSkymed	ASI (I)	X-band	2007
RADARSAT-2	RADARSAT-2	CSA	C-band	2007



ALOS / AVNIR



ALOS Characteristics

Launch Date	Jan. 24, 2006
Launch Vehicle	H-IIA
Launch Site	Tanegashima Space Center
Spacecraft Mass	Approx. 4 tons
Generated Power	Approx. 7 kW (at End of Life)
Design Life	3-5 years
Orbit	Sun-Synchronous Sub-Recurrent
	Repeat Cycle: 46 days Sub Cycle: 2 days
	Altitude: 691.65 km (at Equator) Inclination: 98.16 deg.
Attitude Determination Accuracy	2.0×10^{-4} degree (with GCP)
Position Determination Accuracy	1m (off-line)
Data Rate	240Mbps (via Data Relay Technology Satellite) 120Mbps (Direct Transmission)
Onboard Data Recorder	Solid-state data recorder (90Gbytes)

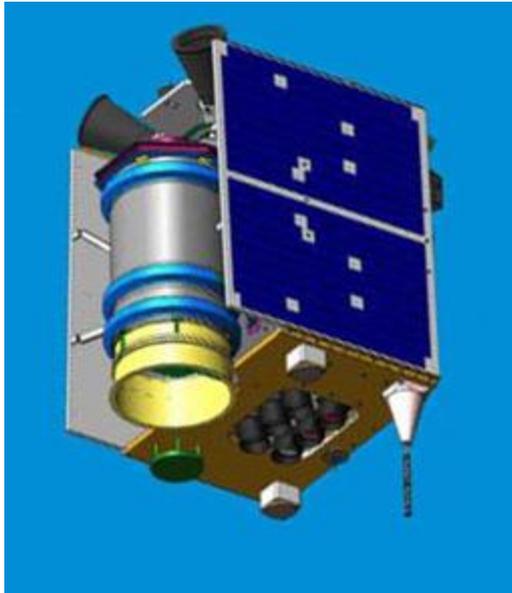
AVNIR-2 Characteristics

Number of Bands	4
Wavelength	Band 1 : 0.42 to 0.50 micrometers Band 2 : 0.52 to 0.60 micrometers Band 3 : 0.61 to 0.69 micrometers Band 4 : 0.76 to 0.89 micrometers
Spatial Resolution	10m (at Nadir)
Swath Width	70km (at Nadir)
S/N	>200
MTF	Band 1 through 3 : >0.25 Band 4 : >0.20
Number of Detectors	7000/band
Pointing Angle	- 44 to + 44 degree
Bit Length	8 bits





✚ Beijing-1



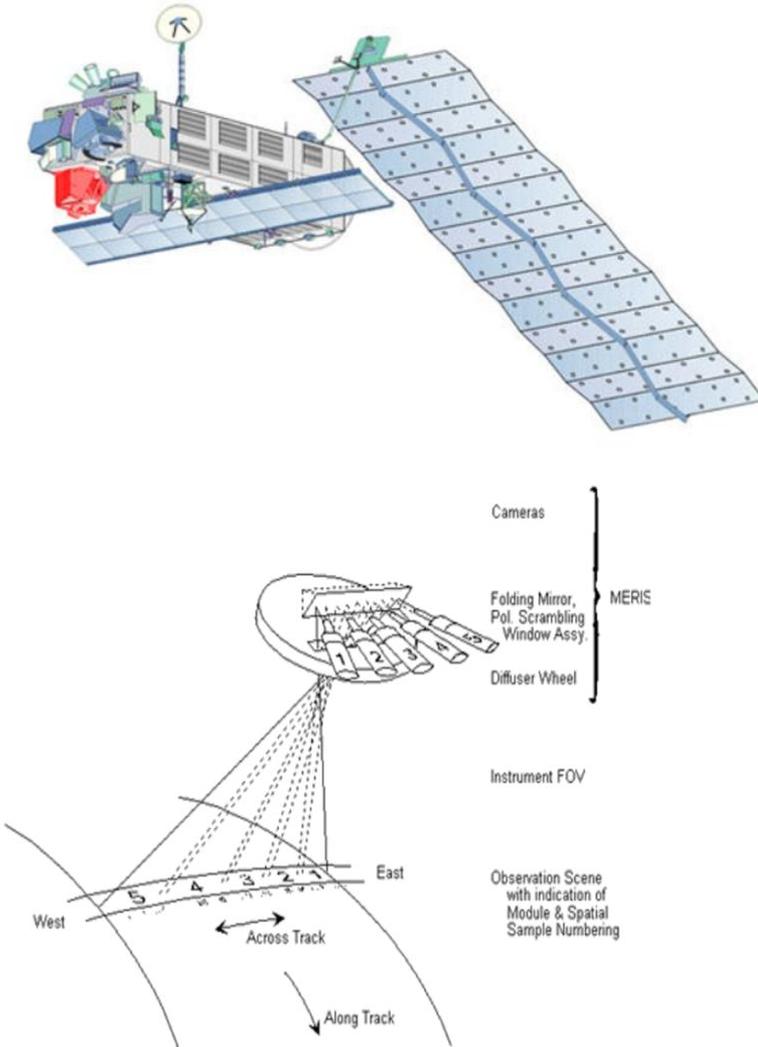
Nation:	China
Type / Application:	Earth observation
Operator:	Beijing Landview Mapping Information Technology Ltd (BLMIT)
Contractors:	SSTL
Equipment:	4 meter, image, 32-meter resolution imager in 3 spectral bands
Configuration:	SSTL-150
Propulsion:	Resistojets
Lifetime:	
Mass:	166 kg
Orbit:	

Satellite	Date	LS	Launcher	Remarks:
China-DMC+4 (Beijing 1)	27.10.2005	PI LC-132/1	Kosmos-3M	with TopSat 1 , Mozhayets 5 , Sinah 1 , SSETI-Express , UWE 1 , XI 5 , Ncube 2 , Rubin 5-ASOLANT





Envisat / MERIS



	Band	Band centre (nm) ¹	Bandwidth (nm)	Primary Use
VISIBLE	1	412.5	10	Yellow substance and detrital pigments
	2	442.5	10	Chlorophyll absorption maximum
	3	490	10	Chlorophyll and other pigments
	4	510	10	Suspended sediment, red tides
	5	560	10	Chlorophyll absorption minimum
	6	620	10	Suspended sediment
	7	665	10	Chlorophyll absorption and fluo. reference
	8	681.25	7.5	Chlorophyll fluorescence peak
	9	708.75	10	Fluo. Reference, atmospheric corrections
INFRARED	10	753.75	7.5	Vegetation, cloud
	11	760.625	3.75	Oxygen absorption R-branch
	12	778.75	15	Atmosphere corrections
	13	865	20	Vegetation, water vapour reference
	14	885	10	Atmosphere corrections
	15	900	10	Water vapour, land

¹ Bands width 1 to 15 are given in nm





COSMO-SkyMed –

COnstellation of small Satellites for Mediterranean basin Observation

Wide Field

SCANSAR
HUGEREGION
200 x 200 km
100m pixel

WIDEREGION
100 x 100 km
30m pixel

STRIPMAP
HIMAGE
40 X 40 km
3–15m pixel

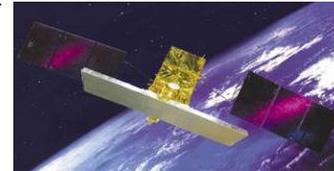
PINGPONG
30 x 30 km
15m pixel



Narrow Field

SPOTLIGHT
SPOTLIGHT1
(Classified)

SPOTLIGHT2
10 x 10 km
1m pixel



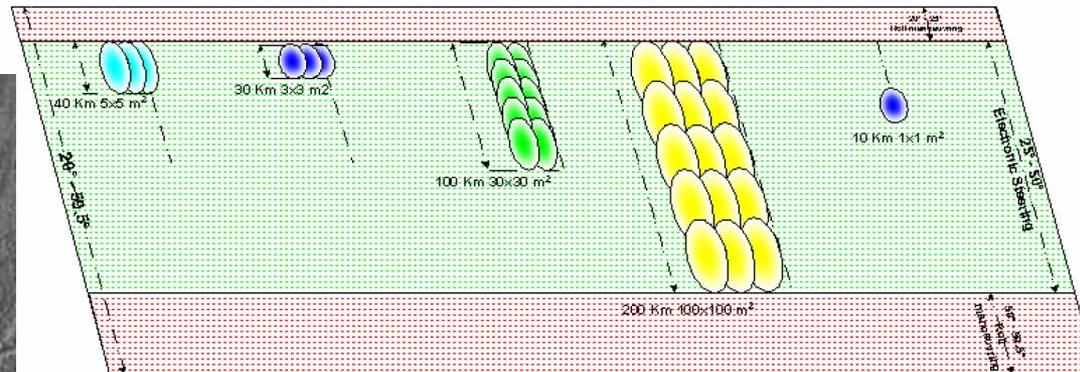
STRIPMAP

SCANSAR

SPOTLIGHT-2



619 Km



	Spotlight	Stripmap		ScanSAR	
		HIMAGE	Ping Pong	Wide Region	Huge Region
Polarization	Single	Single	Dual	Single	Single
Swath width [kmxkm]	10X10	40X40	30X30	100X100	200X200
Accessible swath		~620 km			
Geometric Resolution [m]	1	3	15	30	100



Envisat / ASAR

Spécifications du mode **ASAR IM** (pour une altitude du satellite de 786 km).

image swath	swath width (km)	ground position from nadir (km)	incidence angle range
IS1	105	187 – 292	15.0 – 22.9
IS2	105	242 – 347	19.2 – 26.7
IS3	82	337 – 419	26.0 – 31.4
IS4	88	412 – 500	31.0 – 36.3
IS5	64	490 – 555	35.8 – 39.4
IS6	70	550 – 620	39.1 – 42.8
IS7	56	615 – 671	42.5 – 45.2

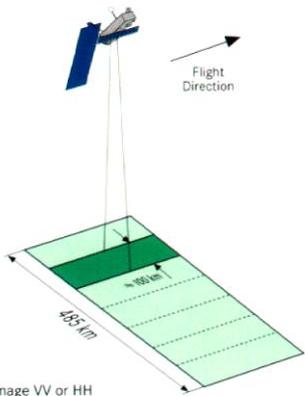
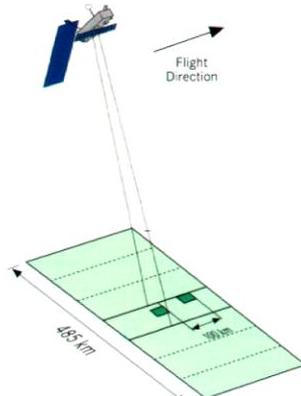


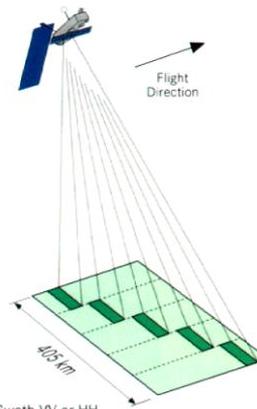
Image VV or HH
30 m Resolution
<100 km Swath Width
(Selectable)

Figure 1.10 Image Mode



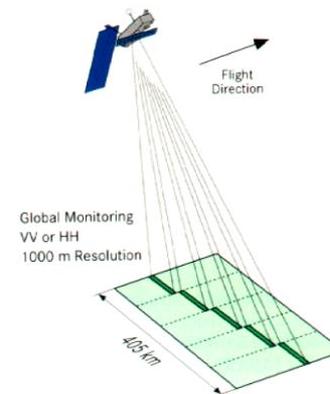
Wave VV or HH
30 m Resolution
5 km x 5 km Vignettes

Figure 1.11 Wave Mode



Wide Swath VV or HH
150 m Resolution
(using ScanSAR
technique)

Figure 1.12 Wide Swath Mode



Global Monitoring
VV or HH
1000 m Resolution

Figure 1.13 Global Monitoring Mode

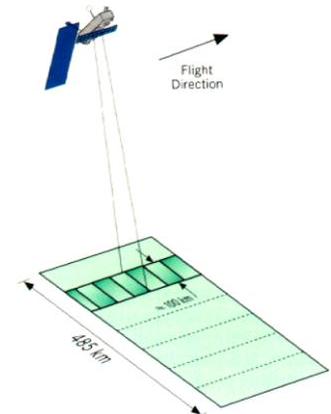
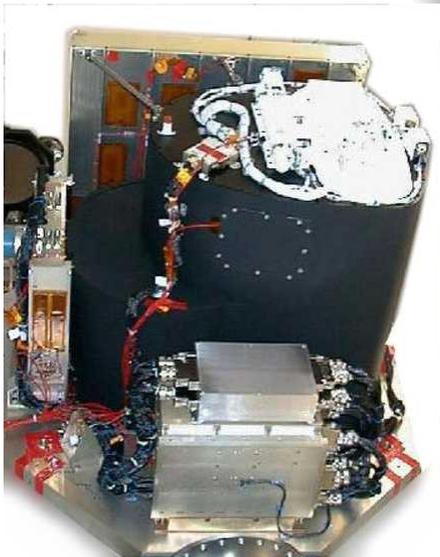
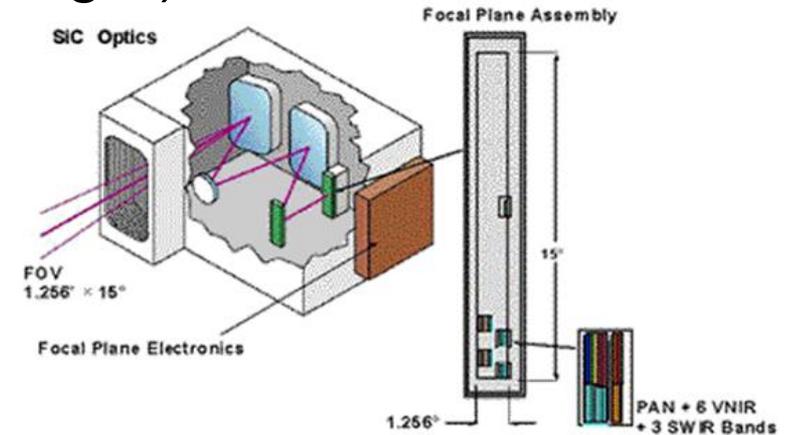


Figure 1.14 Alternating Polarisation Mode

EO-1 / ALI (Advanced Land Imager)



EO-1 ALI Spectral Coverage

Band	Wavelength (μm)	Ground Sample Distance (m)
Pan	0.48 - 0.69	10
MS-1'	0.433 - 0.453	30
MS-1	0.45 - 0.515	30
MS-2	0.525 - 0.605	30
MS-3	0.63 - 0.69	30
MS-4	0.775 - 0.805	30
MS-4'	0.845 - 0.89	30
MS-5'	1.2 - 1.3	30
MS-5	1.55 - 1.75	30
MS-7	2.08 - 2.35	30



EROS-A



Imaging Technique - EROS A

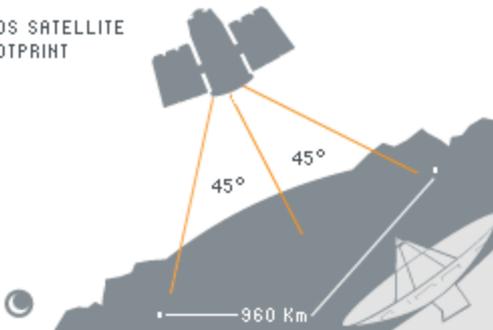
Panchromatic Images	Dimensions	Remarks
Basic Image	14 km x 14 km	1.9 meter ground sampling distance (GSD) at nadir for an orbit of 510km. It is possible to acquire longer "vector" scene, up to ~200 km, depends on resolution and destination (On Board Recorded image or directly acquired).
Stereo Pair	14 km x 14 km	Two overlapped images of the same scene, acquired at symmetric or non-symmetric different viewing angles (fore and aft) during the same pass.

Imaging Parameters – EROS A

The imaging performances of the EROS A panchromatic camera will be as follows:

Scanning	Push-broom
Imaging sunlight conditions	Sun-over-horizon angle more than 10°
Sensor type	CCD
Spectral band	0.5 to 0.9
Sampling Depth transmitted	10 bits
Ground Sampling Distance	1.9 m at Nadir from 510 km
Swath Width	14 km at Nadir from 510 km
Inclination	97.2°
Local time of descending node	09:45

EROS SATELLITE
FOOTPRINT





EROS-B



Imaging Technique - EROS B

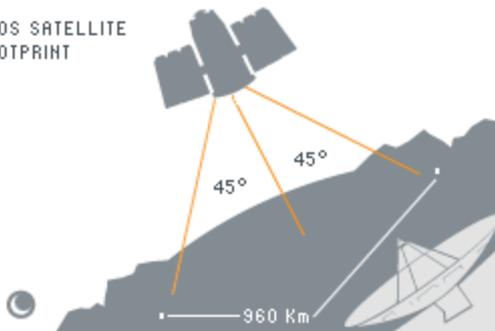
Panchromatic Images	Dimensions	Remarks
Basic Image	7 km x 7 km	0.7 meter ground sampling distance (GSD) at nadir using TDI level 8 for an orbit of 510km. It is possible to acquire longer "vector" scene, up to ~480 km, depends on resolution, scanning direction, and destination (On Board Recorded image or directly acquired)
Stereo pair	7km x up to 21 km	Two overlapped images of the same scene, acquired at symmetric or non-symmetric different viewing angles (fore and aft) during the same pass.
Triplet	7 km x 14 km	Two Stereo images + one overhead Standard image of the same scene, acquired during the same pass. It is possible to acquire multiple images of the same scene in basic mode (for example two stereo pairs) in the same pass.
Mosaic	28 km x 26 km	Four adjoined images acquired during the same pass with small (500 m) overlapping.

Imaging Parameters – EROS B

The imaging performances of the EROS B panchromatic camera will be as follows:

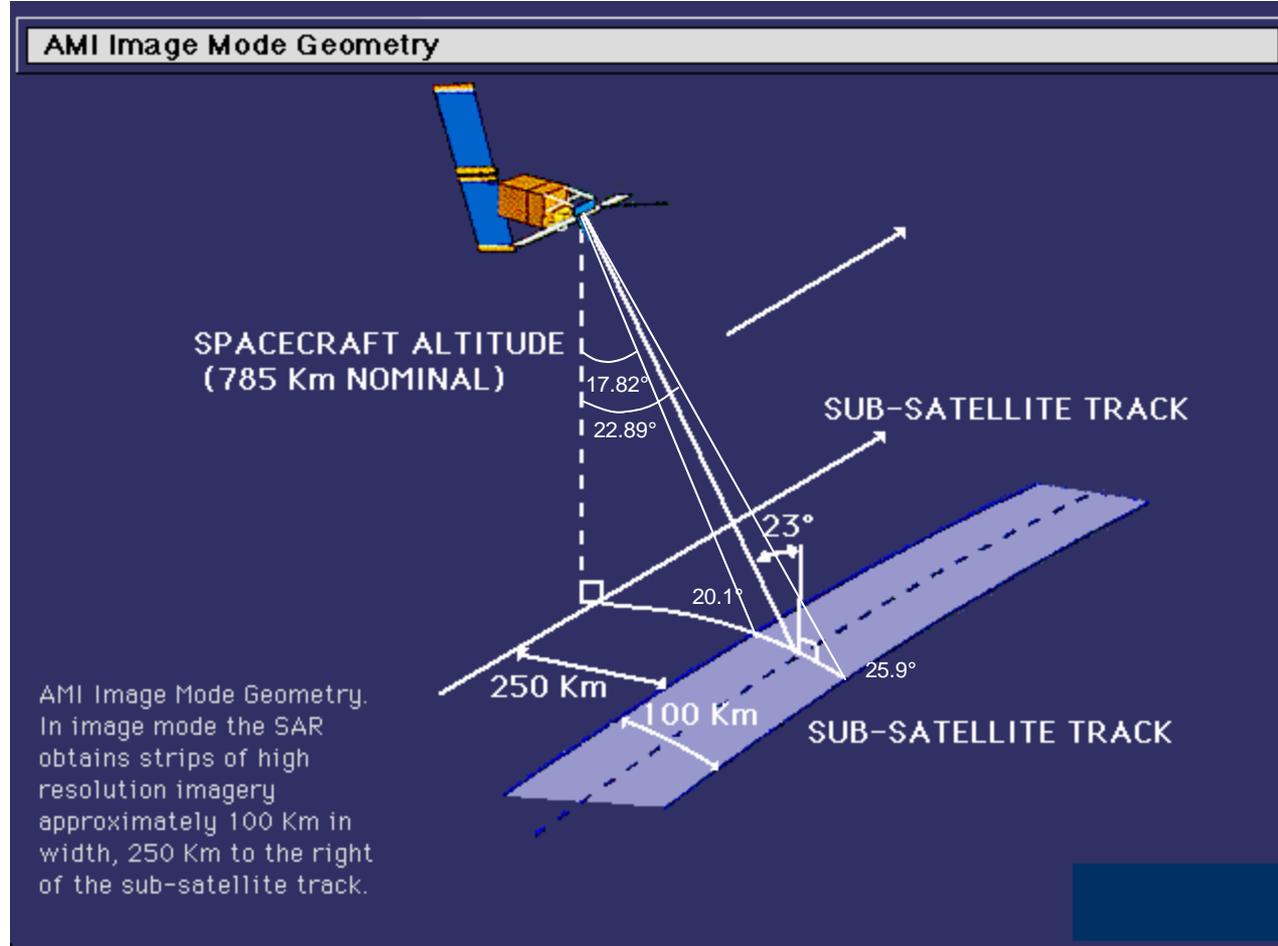
Scanning	Push-broom, maximum scanning rate of 2400 lines/sec
Imaging sunlight conditions	Sun-over-horizon angle more than 10°
Sensor type	CCD-TDI, Selectable 1,4,8,16,32,48,64,96
Spectral band	0.5 to 0.9
Sampling Depth transmitted	10 bits
Ground Sampling Distance	0.7 m at Nadir from 510 km for TDI stages 1,4,8 0.8 m at Nadir from 510 km for all other TDI stages
Swath Width	7 km at Nadir from 510 km
Inclination	97.2°
Local time of descending node	13:45
System corrected geolocation accuracy (w/o external information)	< 50 Meter

EROS SATELLITE
FOOTPRINT



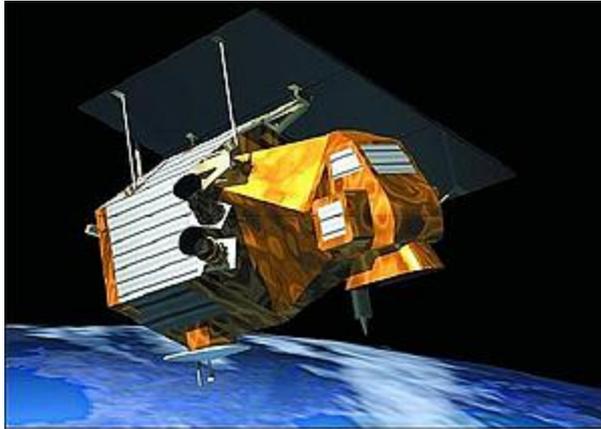


ERS-2 / SAR





✦ Formosat-2



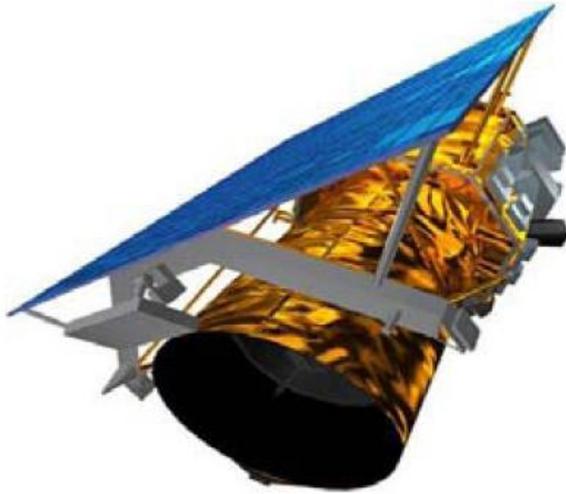
FORMOSAT-2 SATELLITE SENSOR SPECIFICATIONS

Imaging Data Products	<ul style="list-style-type: none">• B&W: 2-m• Color: 2-m (merge)• Multispectral (R, G, B, NIR): 8-m• Bundle (separate Pan and MS images)
Spectral Bands	<ul style="list-style-type: none">• P: 0.45 - 0.90 μm (Panchromatic)• B1: 0.45 - 0.52 μm (Blue)• B2: 0.52 - 0.60 μm (Green)• B3: 0.63 - 0.69 μm (Red)• B4: 0.76 - 0.90 μm (Near-infrared)
Sensor Footprint	24 km x 24 km
Revisit Interval	Daily
Viewing Angles	Cross-track and along-track (forward/aft): +/- 45°
Satellite Tasking	Yes - Panchromatic and multispectral images can be acquired at the same time
Image Dynamics	8 bits/pixel
Image File Size (level 1A without metadata)	<ul style="list-style-type: none">• MS: 35 Mb• Pan: 137 Mb





GeoEye-1

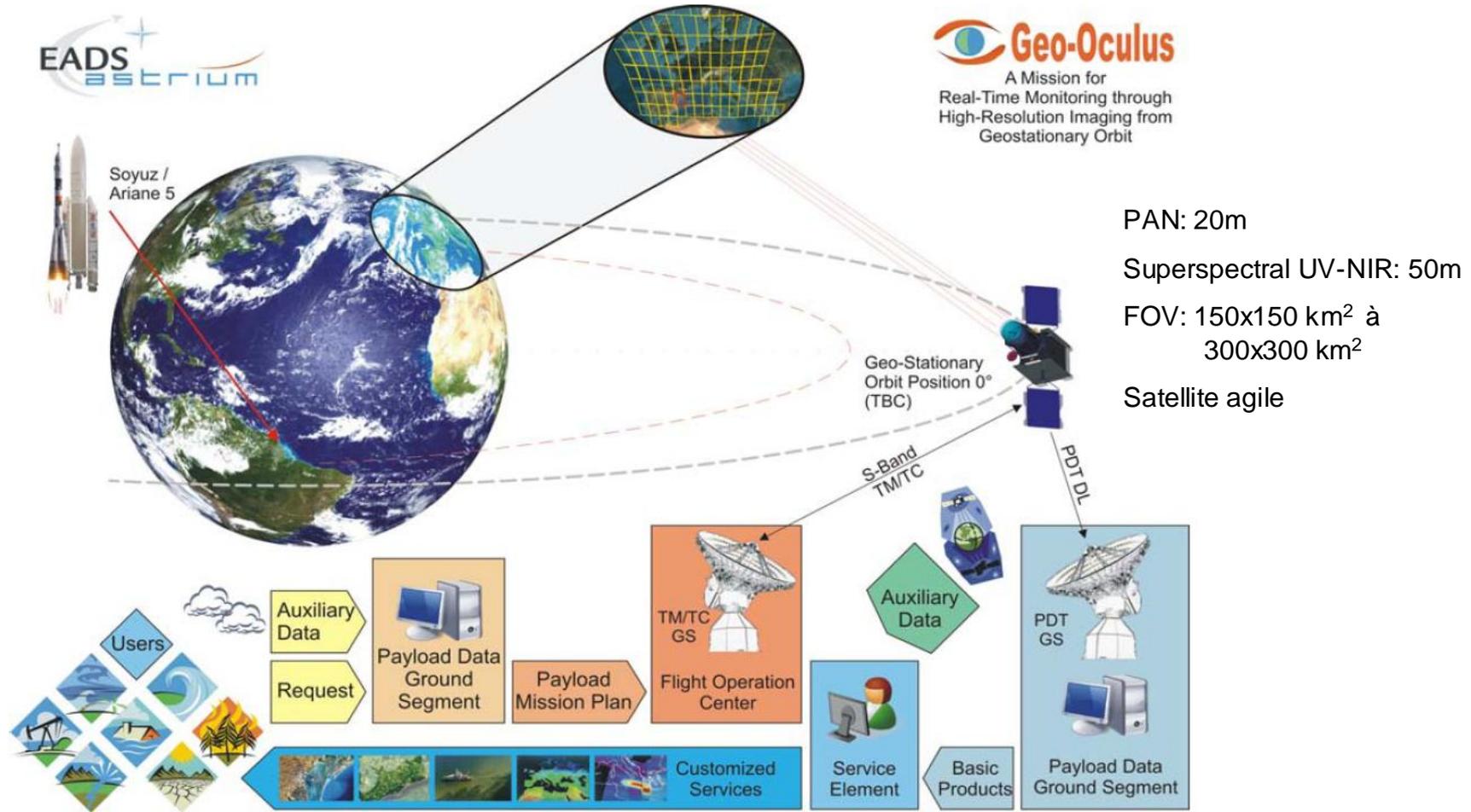


GEOEYE-1 SPECIFICATIONS	
Spatial Resolution	
Panchromatic Sensor	0.41 meters x 0.41 meters
Multispectral Sensor	1.65 meters x 1.65 meters
Spectral Range	450–800 nm 450–510 nm (blue) 510–580 nm (green) 655–690 nm (red) 780–920 nm (near IR)
Swath Width	15.2 km
Off-Nadir Imaging	Up to 60 degrees
Dynamic Range	11 bits per pixel
Mission Life Expected	> 10 years
Revisit Time	Less than 3 days
Orbital Altitude	681 km
Nodal Crossing	10:30 a.m.

- Brochure « *GeoEye Product Guide* » - http://www.geoeye.com/CorpSite/assets/docs/brochures/GeoEye_Product_Guide.pdf ou [SR-FUSION-COURS\GeoEye_Product_Guide.pdf](SR-FUSION-COURS/GeoEye_Product_Guide.pdf)
- Navigateur Web <http://geofuse.geoeye.com/landing/Default.aspx>



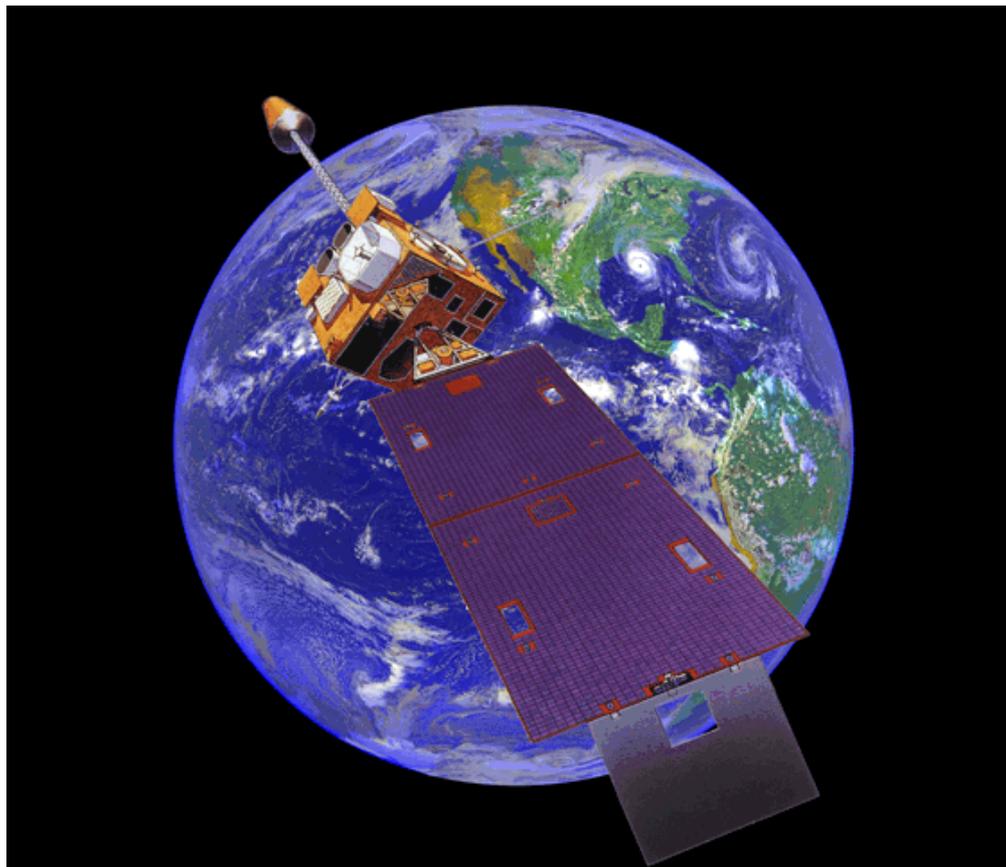
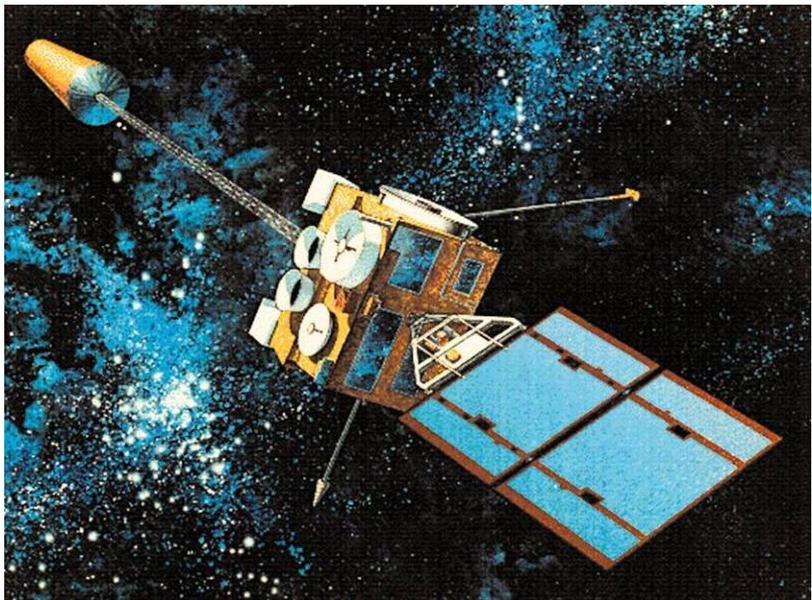
Geo-Oculus - Géostationnaire optique à haute résolution



Extrait de « **Geo-Oculus, A mission for real-time monitoring through high-resolution imaging from geostationary orbit – Executive summary** » - http://www.esa.int/SPECIALS/GSP/SEMD7232BZF_0.html et <SR-FUSION-COURS\C21096ExS.pdf>

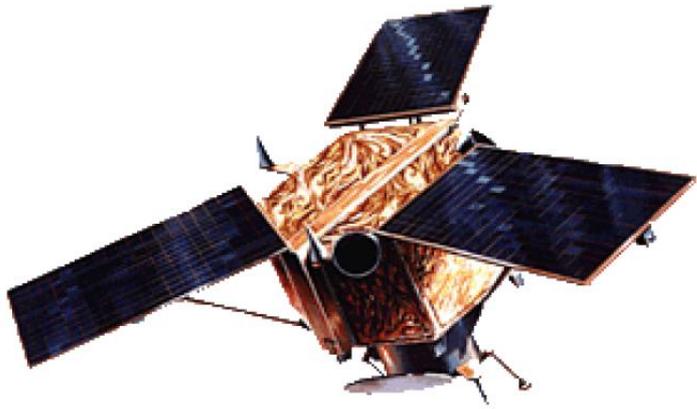


GOES

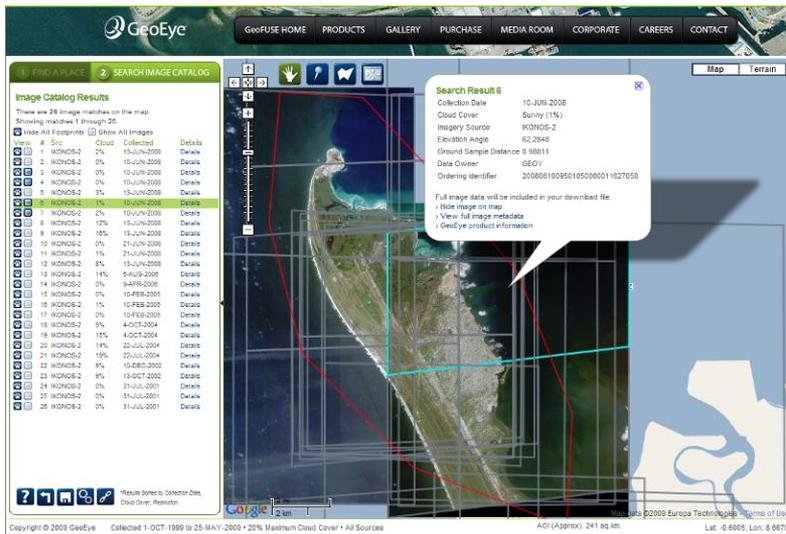




IKONOS



IKONOS SPECIFICATIONS	
Spatial Resolution	0,82 meter x 3.2 meters
Spectral Range	526–929 nm 445–516 nm (blue) 506–595 nm (green) 632–698 nm (red) 757–853 nm (near IR)
Swath Width	11.3 km
Off-Nadir Imaging	Up to 60 degrees
Dynamic Range	11 bits per pixel
Mission Life Expected	> 8.3 years
Revisit Time	Approximately 3 days
Orbital Altitude	681 km
Nodal Crossing	10:30 a.m.

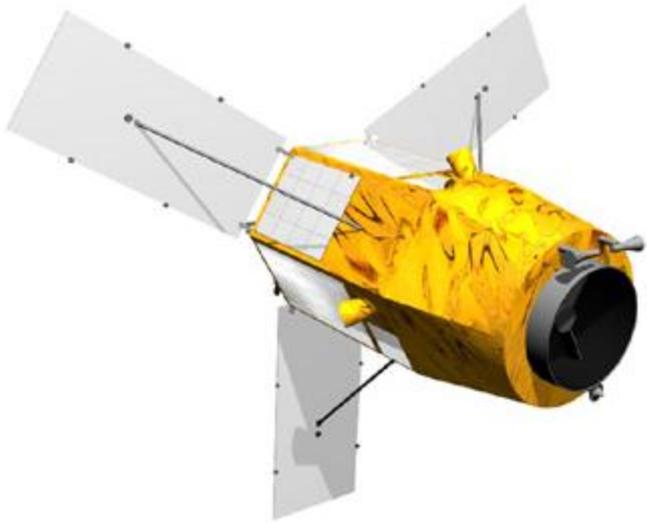


- Brochure « *GeoEye Product Guide* » - http://www.geoeeye.com/CorpSite/assets/docs/brochures/GeoEye_Product_Guide.pdf ou [SR-FUSION-COURS\GeoEye Product Guide.pdf](http://SR-FUSION-COURS/GeoEye_Product_Guide.pdf)
- Navigateur Web <http://geofuse.geoeeye.com/maps/Map.aspx>





KOMPSAT



Produits	N&B : 1 m Couleurs (4 bandes) : 1 m Multispectral (R, V, B, PIR) : 4 m Bundle (images Pan et MS séparées)	
Bandes spectrales	Pan : 0,50 - 0,90 μm	Localiser, identifier et mesurer les caractéristiques et objets essentiellement par leur aspect physique
	MS1 (bleu) : 0,45 - 0,52 μm	Cartographie des hauts fonds, différenciation entre terres et végétation
	MS2 (vert) : 0,52 - 0,60 μm	Différenciation de la végétation par son état de santé
	MS3 (rouge) : 0,63 - 0,69 μm	Différenciation de la végétation par espèces/essences
	MS4 (proche infrarouge) : 0,76 - 0,90 μm	Cartographie de la végétation, de l'état de vigueur ou de santé de la végétation
Emprise	15 km x 15 km	
Revisite/angles de visée	Période de 28 jours Délai de revisite de 3 jours avec un angle roulis de 30°	
Programmation	oui L'acquisition simultanée des images panchromatiques et multispectrales est possible	
Dynamique de l'image	Acquisition 10 bits/pixel, livraison 16 bits/pixel	
Niveaux de prétraitement	1A, 2A et ortho	



✦ Landsat-5 and Landsat-7



Landsat-5



Landsat-7

Table 8.1.1 TM and ETM+ Spectral Bandwidths

Bandwidth (μ) Full Width - Half Maximum

Sensor	Band 1	Band 2	Band 3	Band 4	Band 5	Band 6	Band 7	Band 8
TM	0.45 - 0.52	0.52 - 0.60	0.63 - 0.69	0.76 - 0.90	1.55 - 1.75	10.4 - 12.5	2.08 - 2.35	N/A
ETM+	0.45 - 0.52	0.53 - 0.61	0.63 - 0.69	0.78 - 0.90	1.55 - 1.75	10.4 - 12.5	2.09 - 2.35	.52 - .90



✦ Photos d'astronautes

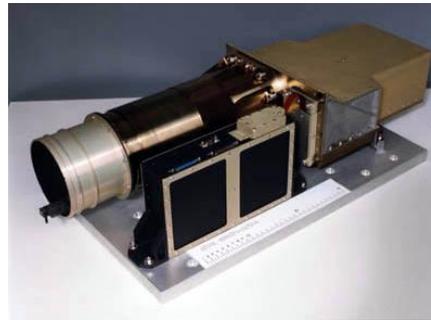
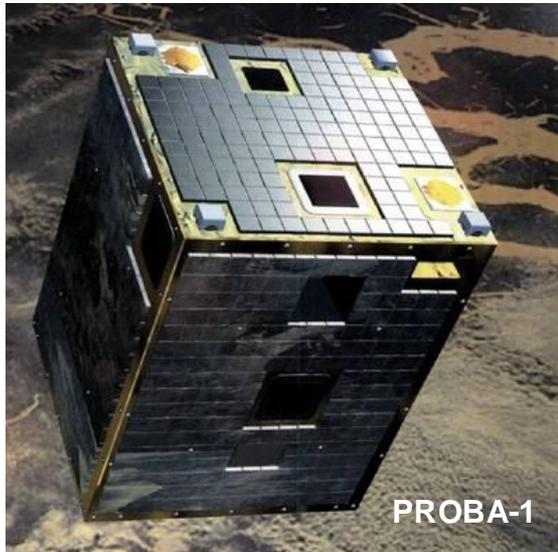


http://www.capcomespace.net/dossiers/photographier_le_spatial/ISS/index.htm

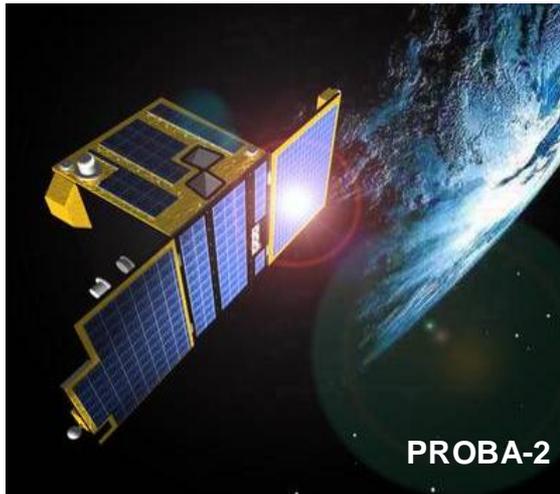




✚ Proba



multiple imaging of same target area under different viewing and illumination geometries	
spectral range	415-1050 nm
spectral resolution	5-12 nm
spatial resolution	20 m at nadir
swath width	14 km
up to 19 spectral bands simultaneously at full resolution	





QuickBird



ImageFinder

Map Catalog Polygon Download

Go To:

Search Filter

Acquisition Date: 4/1/02 - 5/25/09
Off Nadir Angle: 0.0 - 25.0 degrees
Cloud Cover: 0 - 20 %

SEARCH

Map Status

Lon: 12.097 Area: 1551 km²
Lat: 3.773 Scale: 1:1 022 531

Map Status

AFRICA

Atlantic Ocean

SUBMIT

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- Brochure EURIMAGE « QuickBird – The world’s highest resolution commercial satellite » - <http://www.eurimage.com/products/docs/quickbird.pdf> ou [SR-FUSION-COURS\quickbird.pdf](http://SR-FUSION-COURS/quickbird.pdf)
- Navigateur Web <http://browse.digitalglobe.com/imagefinder/main.jsp>

8 images meet your filter criteria

Select	Browse Image	Catalog Id	Sensor Vehicle	Acquisition Date	Total Max Off Nadir Angle	Area Max Off Nadir Angle	Area Min Sun Elevation	Total Cloud Cover Pct	Area Cloud Cover Pct	Imaging Bands
<input type="checkbox"/>	View	1010010000A50100	QB02	2002/06/22	14.94°	14.68°	59.79°	43%	0%	Pan-MS1
<input type="checkbox"/>	View	10100100037AED00	QB02	2004/12/29	14.88°	14.18°	55.19°	77%	18%	Pan-MS1
<input type="checkbox"/>	View	10100100055B8E00	QB02	2006/12/04	11.15°	10.98°	59.89°	33%	0%	Pan-MS1
<input type="checkbox"/>	View	10100100058D1000	QB02	2007/01/14	14.07°	12.12°	58.93°	11%	1%	Pan-MS1
<input type="checkbox"/>	View	101001000581E900	QB02	2007/03/04	13.43°	11.88°	67.41°	24%	8%	Pan-MS1
<input checked="" type="checkbox"/>	View	1010010007911900	QB02	2008/01/12	19.24°	18.60°	57.50°	7%	3%	Pan-MS1
<input type="checkbox"/>	View	10100100056A9600	QB02	2007/01/09	8.48°	8.20°	57.89°	22%	4%	Pan-MS1
<input type="checkbox"/>	View	10100100059A8A00	QB02	2007/05/02	19.59°	18.64°	71.43°	37%	17%	Pan-MS1



Catalog ID: 1010010007911900 Acq Date: Jan 12, 2008 Center Lat,Long: 11.493°/3.862°
Avg Off Nadir Angle: 19.24° Avg Target Azimuth: 230° Sensor: QB02 Band Info:

Image Resize: 512x512

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Sentinel-1

Extrait de « GMES Space Component Sentinel-1 – Payload Data Ground Segment (PDGS) – Operations Concept Document (OCD) » (GMES-GSEG-EOPG-TN-08-0012-1.3.pdf).

Mode	Access range (incidence angle)	Swath range resolution (1 look) (Swath Range x Azimuth)	Swath Width	Resolution
Stripmap	20-47 deg	1800 m x 5 m	80 km	100 m x 10 m or 100 m x 5 m
Interferometric Wide Swath	31-40 deg	27-35 m x 20 m	200 km	100 m x 10 m or 100 m x 5 m
Wide Swath Swath	20-47 deg	8-145 m x 40 m	400 km	100 m x 10 m or 100 m x 5 m
Wave	20 deg ± 30 deg	12-115 m x 5 m	20 x 20 km with step of 100 km intervals	100 m x 10 m

For All Modes

Radiometric accuracy (σ _c)	< 1 dB
Radiometric stability (σ _s)	< 0.5 dB
Range Resolution (σ _{range})	< 4 m
Point Target Azimuth Ratio	< 2 dB
Distributed Target Azimuth Ratio	< 20 dB

Table 3-1-1 Characteristics of the Sentinel-1 ground maintenance modes

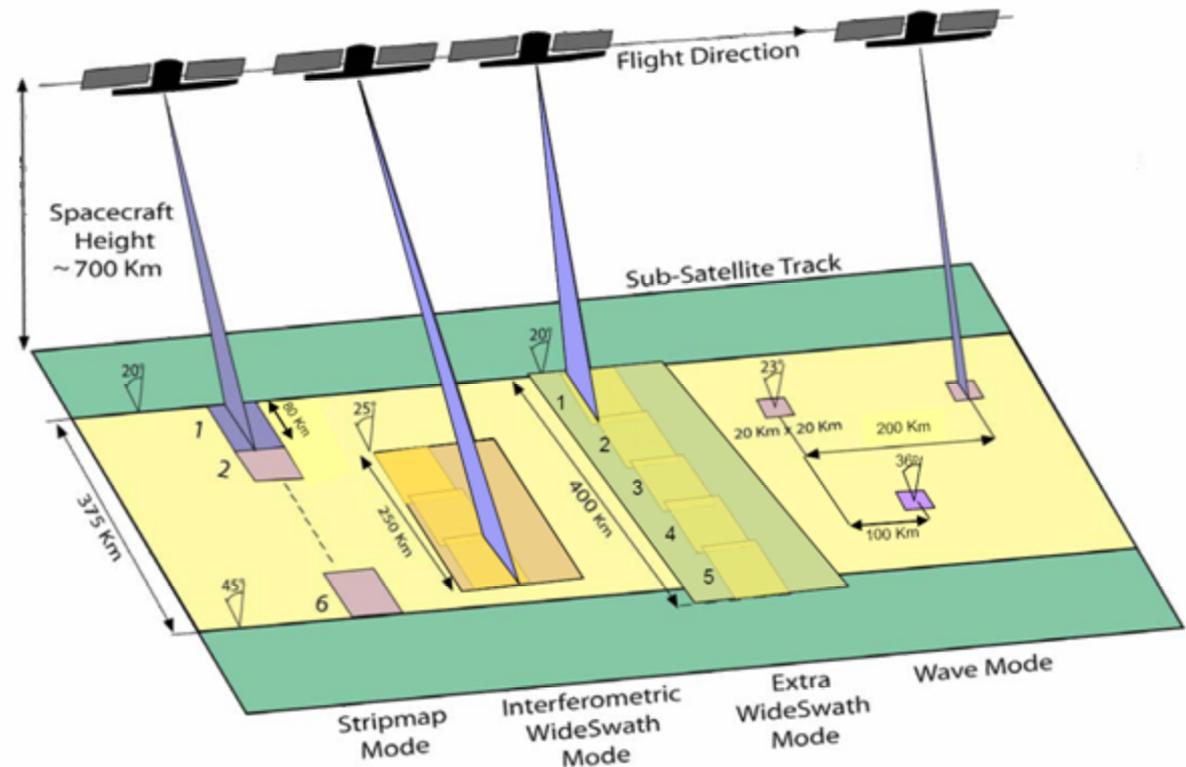
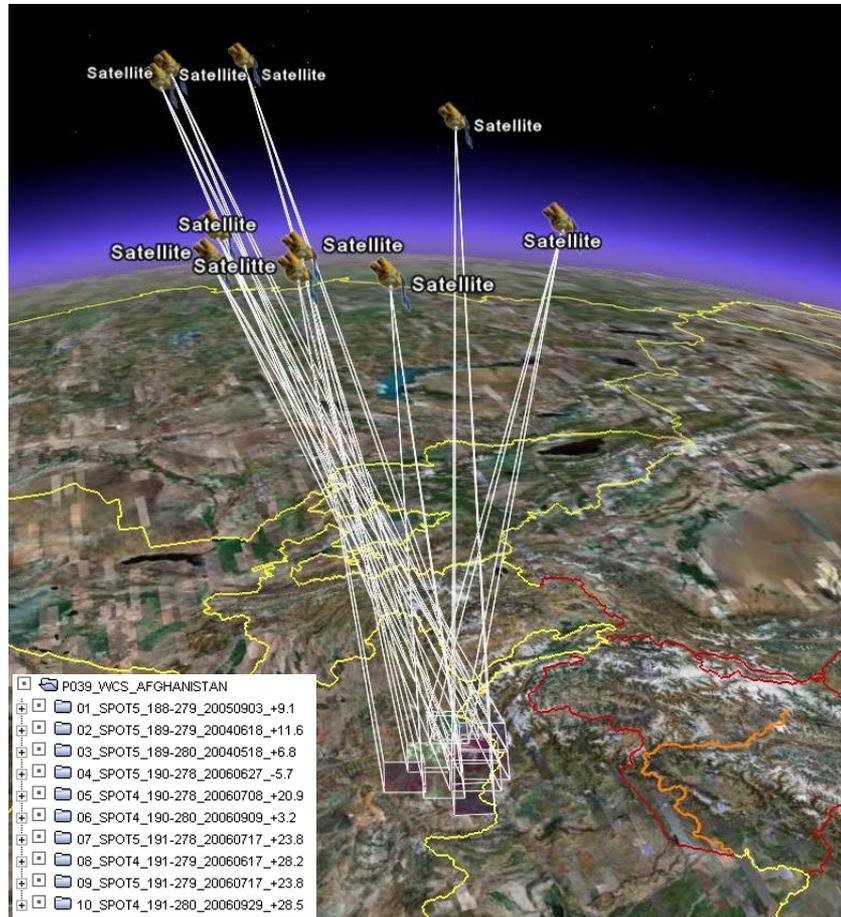


Figure 3-1 Sentinel-1 modes observation geometry

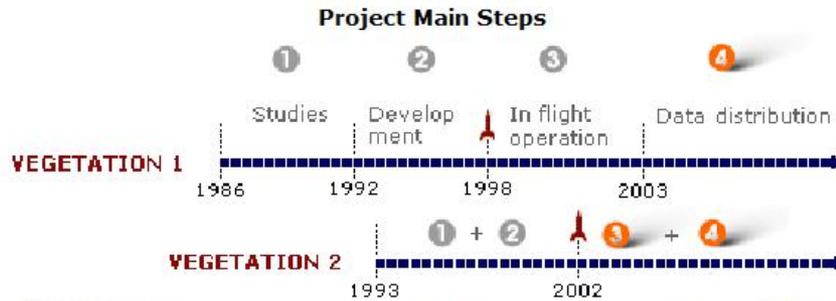


SPOT





SPOT 4,5 / VEGETATION



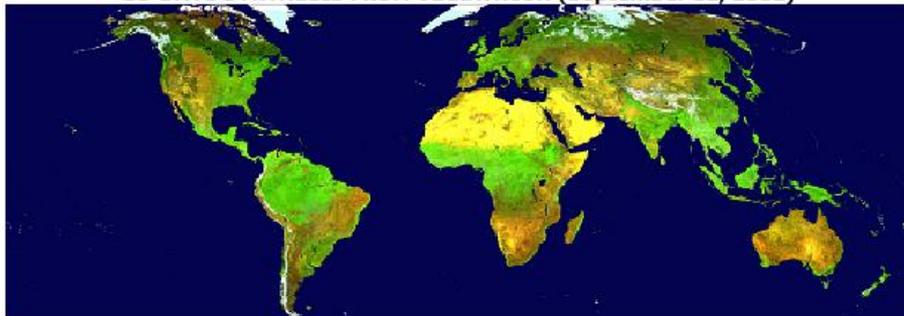
<http://www.spot-vegetation.com/>

The **VEGETATION** instrument is an **imaging** system in 4 spectral bands : **blue** (0.43-0.47 microns), **red** (0.61-0.68 microns), **near infrared** (0.78-0.89 microns), and **SW infrared** (1.58-1.75 microns).

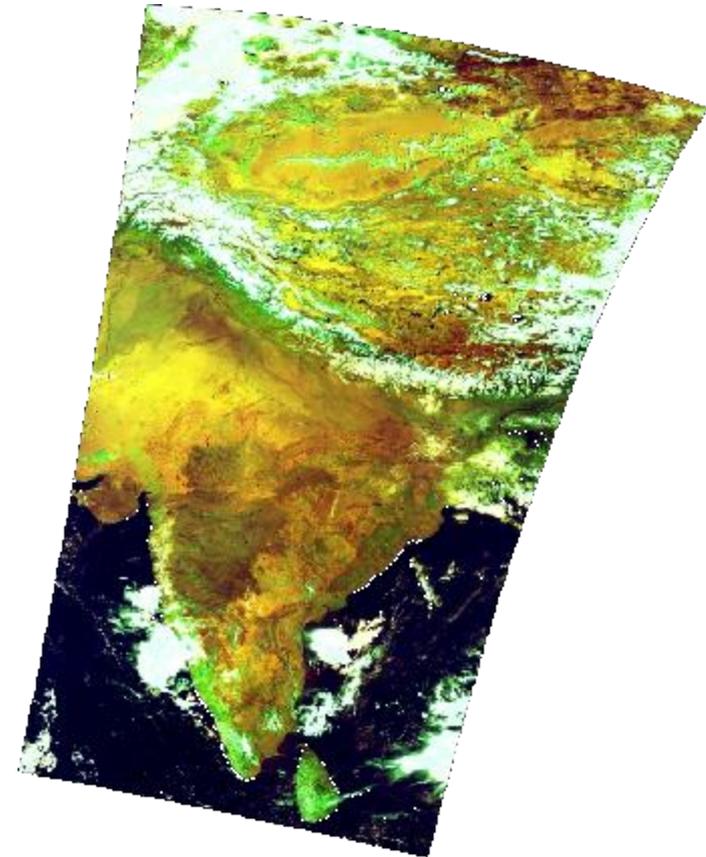
The **red and near infrared** are particularly well adapted to describe the **vegetation photosynthesis activity**, while the **SW infrared** is a good detector for the ground and vegetation **humidity**. The **blue**, is designed in this case to make **atmospheric corrections**.

VEGETATION uses **telecentric optics** giving a quasi constant spatial resolution through the field of view, particularly wide (**2 200 km on the ground**) : this **resolution is 1.15 km at nadir**, and still 1.7 km on the sides of the field of view (101°).

10-DAYS SYNTHESIS FROM VEGETATION (September 11, 2002)



<http://smsc.cnes.fr/VEGETATION/index.htm>





✦ Terra / ASTER ou EO-1 / ASTER

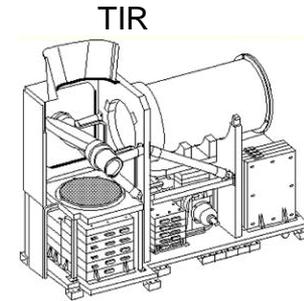
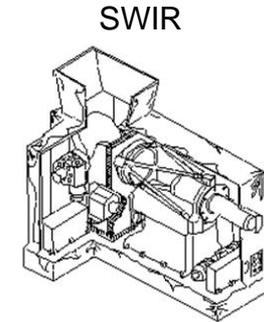
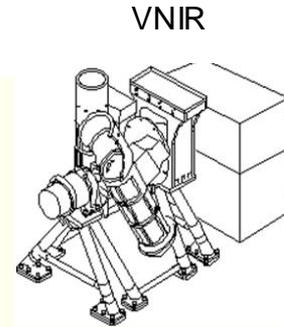
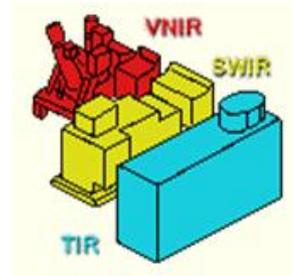


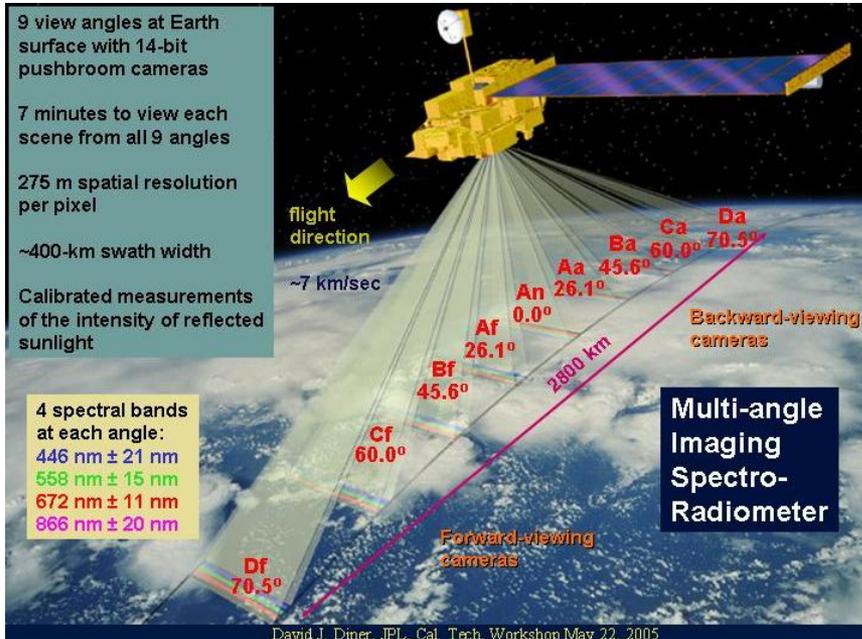
Table 1: 14 Spectral bands of ASTER

Spectral channel	Spectral range	Spatial resolution	Dynamic range	Comment
1 (Visible Green)	0.520 to 0.600um	15m	8 bit integer	Near Infrared has 2 bands (3B and 3N) which are stereo pair images from which DEM can be generated. Orbit: 705km, 10:30am descending node, Sun-synchronous Swath=60x 60 km
2 (Visible Red)	0.630 to 0.690um	15m	8 bit integer	
3 (Near Infrared)	0.760 to 0.860um	15m	8 bit integer	
4 (SWIR)	1.60 to 1.70um	30m	8 bit integer	
5 (SWIR)	2.145 to 2.185um	30m	8 bit integer	
6 (SWIR)	2.185 to 2.225um	30m	8 bit integer	
7 (SWIR)	2.235 to 2.285um	30m	8 bit integer	
8 (SWIR)	2.295 to 2.365um	30m	8 bit integer	
9 (SWIR)	2.36 to 2.43um	30m	8 bit integer	
10 (TIR)	8.125 to 8.475um	90m	12 bit integer	
11 (TIR)	8.475 to 8.825um	90m	12 bit integer	
12 (TIR)	8.925 to 9.275um	90m	12 bit integer	
13 (TIR)	10.25 to 10.95um	90m	12 bit integer	
14 (TIR)	10.95 to 11.65um	90m	12 bit integer	

Launch date:	December 1999	
Orbit:	705 km altitude, sun-synchronous, so that at any given latitude it crosses directly overhead at the same time each day.	
Orbit inclination:	98.3 degrees from the Equator	
Orbit period:	98.88 minutes	
Equator crossing:	10.30 a.m. (north to south)	
Ground track repeat cycle:	16 days, i.e. every 16 days (or 233 orbits) the pattern of orbits repeats itself	
Builder:	Lockheed Martin	

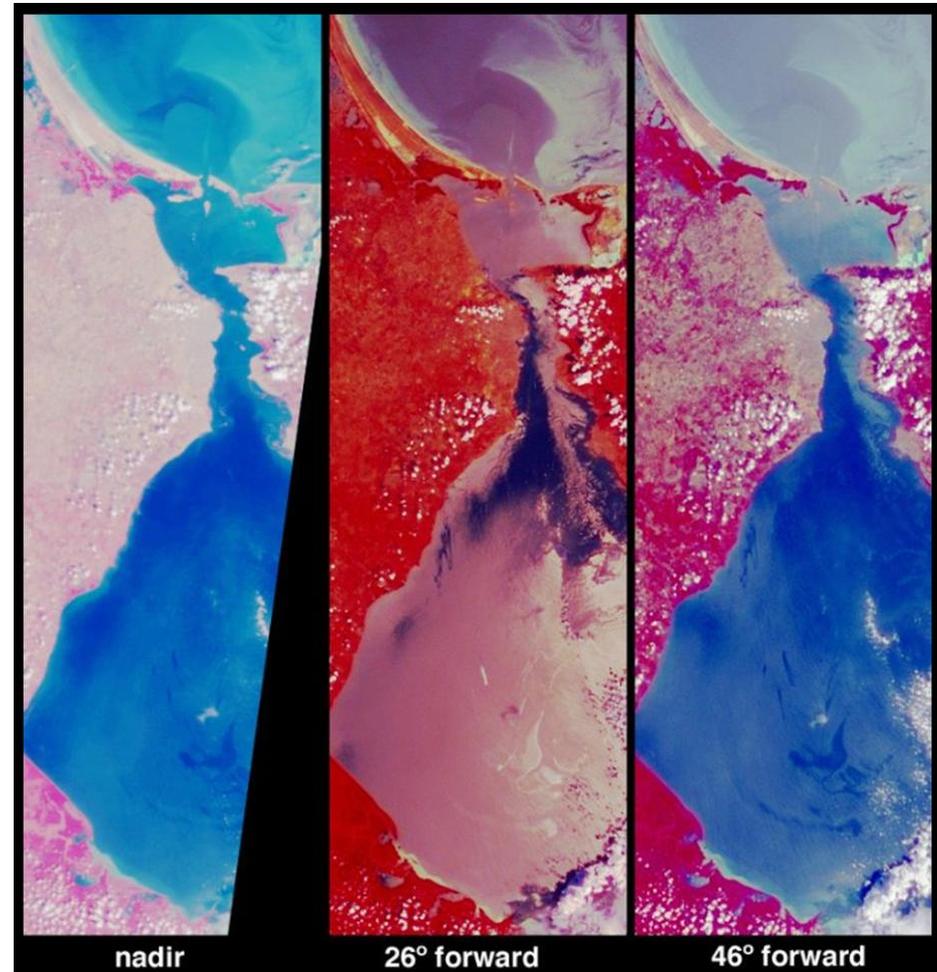


Terra / MISR (Multi-angle Imaging SpectroRadiometer)



MISR project handbook

http://eosweb.larc.nasa.gov/GUIDE/campaign_documents/misr_ov2.html

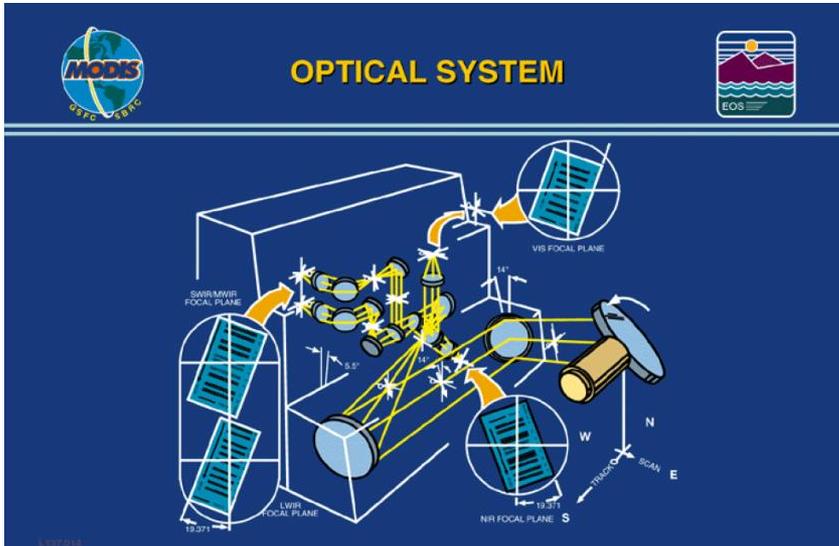


Nappes d'huile dans le lac de Maracaibo – 26/12/2002

[http://www.nasaimages.org/luna/servlet/view/all/w/hat/Multi-angle+Imaging+SpectroRadiometer+\(MISR\)/](http://www.nasaimages.org/luna/servlet/view/all/w/hat/Multi-angle+Imaging+SpectroRadiometer+(MISR)/)



Terra / MODIS et Aqua / MODIS



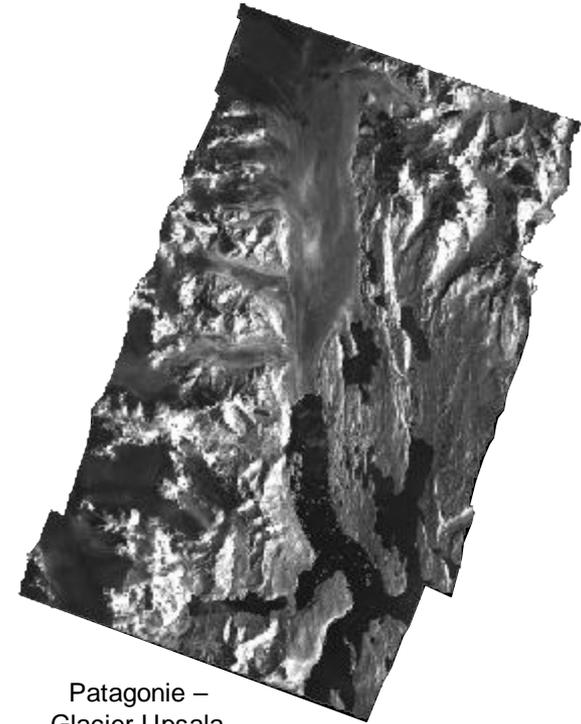
Primary Use	Band	Spatial resolution	Bandwidth ¹	Spectral Radiance ²	Required SNR
Land/Cloud/Aerosols Boundaries	1	250	620 - 670	21.8	128
	2	250	841 - 876	24.7	201
Land/Cloud/Aerosols Properties	3	500	459 - 479	35.3	243
	4	500	545 - 565	29.0	228
	5	500	1230 - 1250	5.4	74
	6	500	1628 - 1652	7.3	275
	7	500	2105 - 2155	1.0	110
Ocean Color/Phytoplankton/Biogeochemistry	8	1000	405 - 420	44.9	880
	9	1000	438 - 448	41.9	838
	10	1000	483 - 493	32.1	802
	11	1000	526 - 536	27.9	754
	12	1000	546 - 556	21.0	750
	13	1000	662 - 672	9.5	910
	14	1000	673 - 683	8.7	1087
	15	1000	743 - 753	10.2	586
	16	1000	862 - 877	6.2	516
Atmospheric Water Vapor	17	1000	890 - 920	10.0	167
	18	1000	931 - 941	3.6	57
	19	1000	915 - 965	15.0	250
Primary Use	Band		Bandwidth ¹	Spectral Radiance ²	Required NE Δ T (K)
Surface/Cloud Temperature	20	1000	3.660 - 3.840	0.45(300K)	0.05
	21	1000	3.929 - 3.989	2.38(335K)	2.00
	22	1000	3.929 - 3.989	0.67(300K)	0.07
	23	1000	4.020 - 4.080	0.79(300K)	0.07
Atmospheric Temperature	24	1000	4.433 - 4.498	0.17(250K)	0.25
	25	1000	4.482 - 4.549	0.59(275K)	0.25
Cirrus Clouds Water Vapor	26	1000	1.360 - 1.390	6.00	150(SNR)
	27	1000	6.535 - 6.895	1.16(240K)	0.25
	28	1000	7.175 - 7.475	2.18(250K)	0.25
Cloud Properties	29	1000	8.400 - 8.700	9.58(300K)	0.05
Ozone	30	1000	9.580 - 9.880	3.69(250K)	0.25
Surface/Cloud Temperature	31	1000	10.780 - 11.280	9.55(300K)	0.05
	32	1000	11.770 - 12.270	8.94(300K)	0.05
Cloud Top Altitude	33	1000	13.185 - 13.485	4.52(260K)	0.25
	34	1000	13.485 - 13.785	3.76(250K)	0.25
	35	1000	13.785 - 14.085	3.11(240K)	0.25
	36	1000	14.085 - 14.385	2.08(220K)	0.35

http://modis.gsfc.nasa.gov/MODIS/CAL/DOCS/L137_014.pdf

<http://modis.gsfc.nasa.gov/about/specifications.php>



✚ TerraSAR-X - Documentation

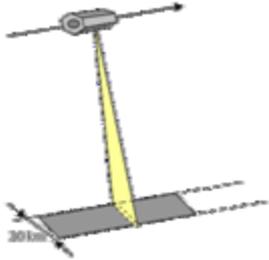


Patagonie –
Glacier Upsala

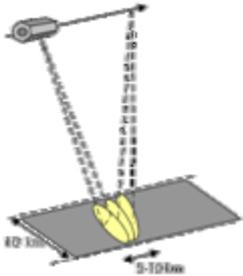
- Brochure DLR « *The German Radar Eye in Space* » - [SR-FUSION-COURS\TSX_brosch.pdf](#)
- SPOT IMAGE - TerraSAR-X description technique - <http://www.spotimage.fr/web/683-terrasar-x.php>
- SPOT IMAGE – Liste des prix et bon de commande - <http://www.spotimage.fr/web/335-listes-de-prix.php>
- DLR - TX-GS-DD-3302 - « TerraSAR-X Ground Segment Basic Product Specification Document » - [SR-FUSION-COURS\TX-GS-DD-3302_SAR_Basic_Products.pdf](#)
- DLR - TX-GS-DD-3307 - « TerraSAR-X Ground Segment Level 1b Product Format Specification » - [SR-FUSION-COURS\TX-GS-DD-3307_Level-1b-Product-Format-Specification_1.3.pdf](#)

TerraSAR-X – Géométrie d'acquisition

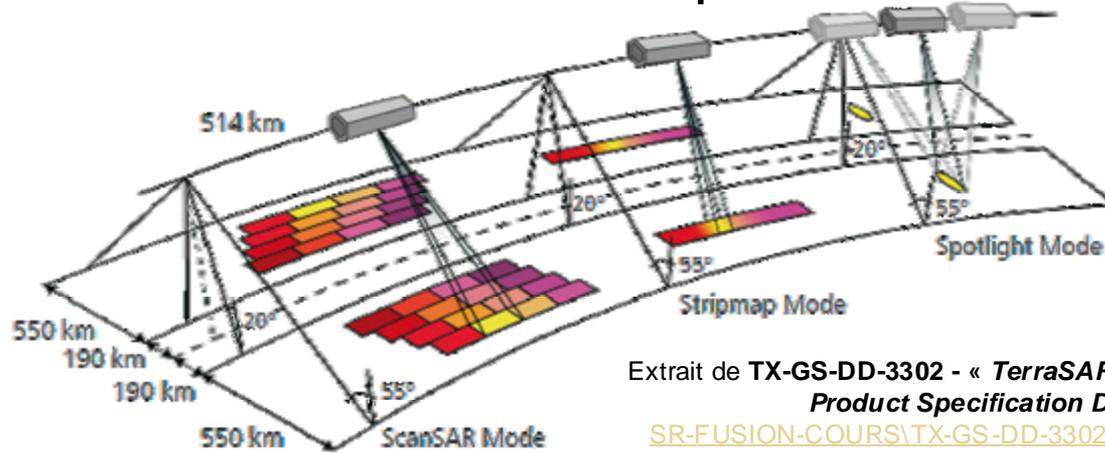
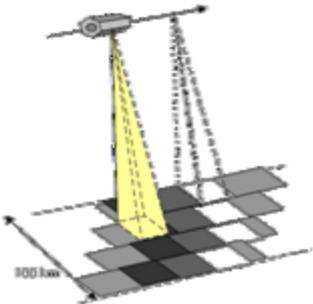
Stripmap Mode (SM)



Spotlight Mode (SL)



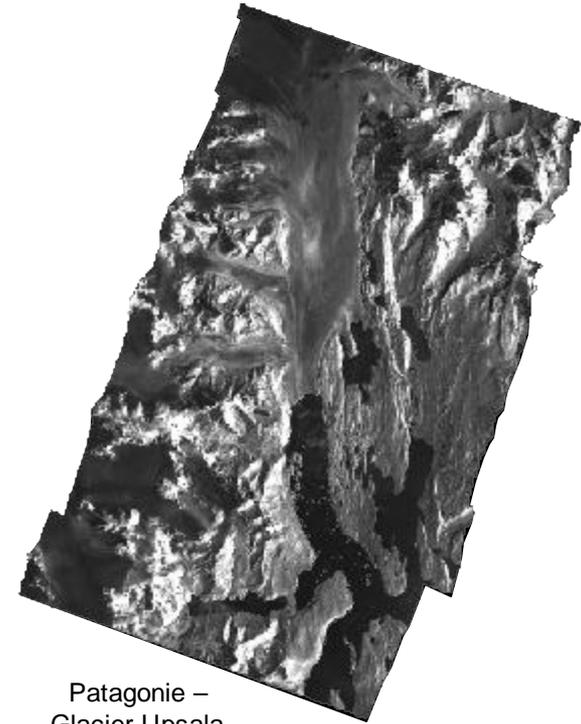
ScanSAR Mode (SC)



Extrait de TX-GS-DD-3302 - « TerraSAR-X Ground Segment Basic Product Specification Document » -
[SR-FUSION-COURS\TX-GS-DD-3302_SAR_Basic_Products.pdf](https://www.igmp.fr/IMG/pdf/SR-FUSION-COURS/TX-GS-DD-3302_SAR_Basic_Products.pdf)

Parameter	Stripmap Mode (SM)	Spotlight Mode (SL)	High Resolution Spotlight Mode (HS)	ScanSAR (SC)
Number of sub-swaths	-	-	-	4
Swath width (ground range)	30 km (single pol.) 15 km (dual pol.)	10 km	10 km	100 km
Nominal L1B product length	50 km	5 km	10 km	150 km
Full performance incidence angle range	20° - 45°	20° - 55°	20° - 55°	20° - 45°
Data access incidence angle range	15° - 60°	15° - 60°	15° - 60°	15° - 60°
Number of elevation beams	27	91 (full performance) 122 (data access)	91 (full performance) 122 (data access)	27
Azimuth resolution	1,70 m (single pol.) 3,49 m (dual pol.)	1,1 m (single pol.) 2,2 m (dual pol.)	1,7 m (single pol.) 3,4 m (dual pol.)	18,5 m
Ground range resolution	1,70 m – 3,49 m (at 45°...20° incidence)	1,48 m – 3,49 m (at 55°...20° incidence)	1,48 m – 3,49 m (at 55°...20° incidence)	1,70 m – 3,49 m (at 45°...20° incidence)
Polarizations	HH or VV (single) HH/VV, HH/HV, VV/VH (dual)	HH or VV (single) HH/VV (dual)	HH or VV (single) HH/VV (dual)	-

✚ TerraSAR-X - Documentation

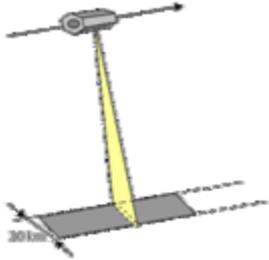


Patagonie –
Glacier Upsala

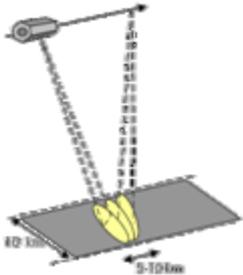
- Brochure DLR « *The German Radar Eye in Space* » - [SR-FUSION-COURS\TSX_brosch.pdf](#)
- SPOT IMAGE - TerraSAR-X description technique - <http://www.spotimage.fr/web/683-terrasar-x.php>
- SPOT IMAGE – Liste des prix et bon de commande - <http://www.spotimage.fr/web/335-listes-de-prix.php>
- DLR - TX-GS-DD-3302 - « TerraSAR-X Ground Segment Basic Product Specification Document » - [SR-FUSION-COURS\TX-GS-DD-3302_SAR_Basic_Products.pdf](#)
- DLR - TX-GS-DD-3307 - « TerraSAR-X Ground Segment Level 1b Product Format Specification » - [SR-FUSION-COURS\TX-GS-DD-3307_Level-1b-Product-Format-Specification_1.3.pdf](#)

TerraSAR-X – Géométrie d'acquisition

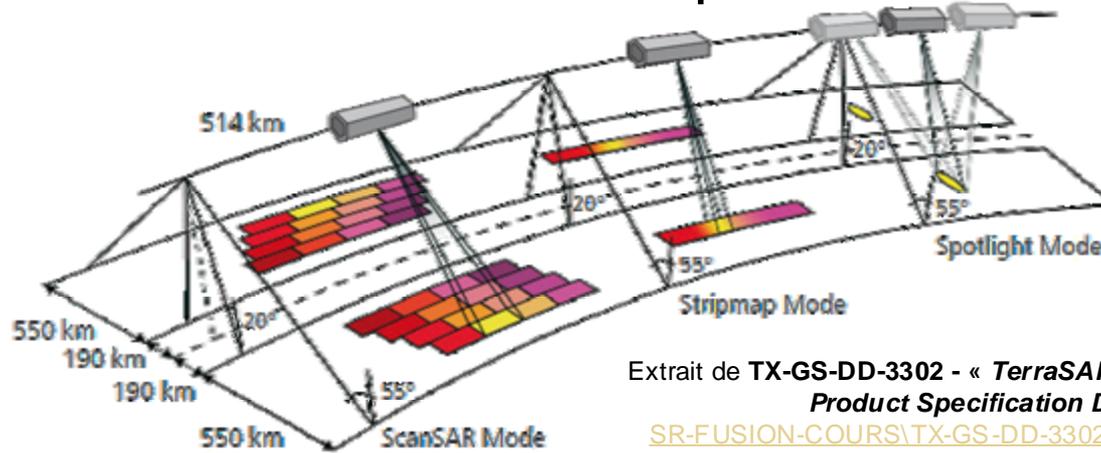
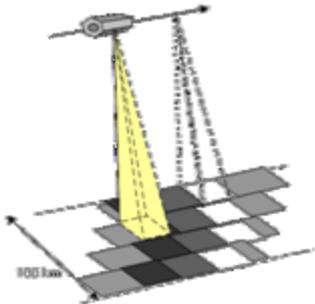
Stripmap Mode (SM)



Spotlight Mode (SL)



ScanSAR Mode (SC)

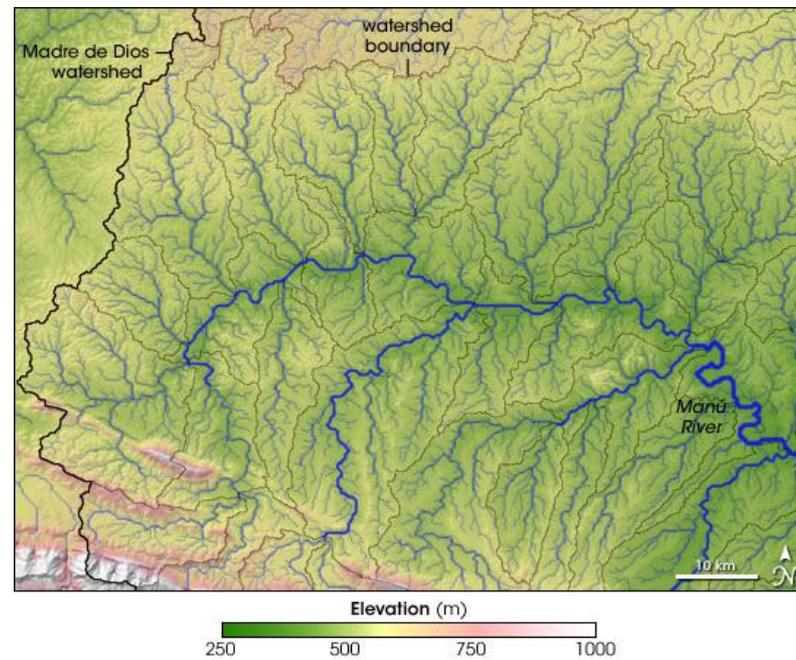


Extrait de TX-GS-DD-3302 - « TerraSAR-X Ground Segment Basic Product Specification Document » -

[SR-FUSION-COURS\TX-GS-DD-3302_SAR_Basic_Products.pdf](#)

Parameter	Stripmap Mode (SM)	Spotlight Mode (SL)	High Resolution Spotlight Mode (HS)	ScanSAR (SC)
Number of sub-swaths	-	-	-	4
Swath width (ground range)	30 km (single pol.) 15 km (dual pol.)	10 km	10 km	100 km
Nominal L1B product length	50 km	5 km	10 km	150 km
Full performance incidence angle range	20° - 45°	20° - 55°	20° - 55°	20° - 45°
Data access incidence angle range	15° - 60°	15° - 60°	15° - 60°	15° - 60°
Number of elevation beams	27	91 (full performance) 122 (data access)	91 (full performance) 122 (data access)	27
Azimuth resolution	1,70 m (single pol.) 3,49 m (dual pol.)	1,1 m (single pol.) 2,2 m (dual pol.)	1,7 m (single pol.) 3,4 m (dual pol.)	18,5 m
Ground range resolution	1,70 m – 3,49 m (at 45°...20° incidence)	1,48 m – 3,49 m (at 55°...20° incidence)	1,48 m – 3,49 m (at 55°...20° incidence)	1,70 m – 3,49 m (at 45°...20° incidence)
Polarizations	HH or VV (single) HH/VV, HH/HV, VV/VH (dual)	HH or VV (single) HH/VV (dual)	HH or VV (single) HH/VV (dual)	-

**Bassins versants extraits du MNT SRTM
Zone « Madre de Dios » (SO Amazonie)**



http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17549



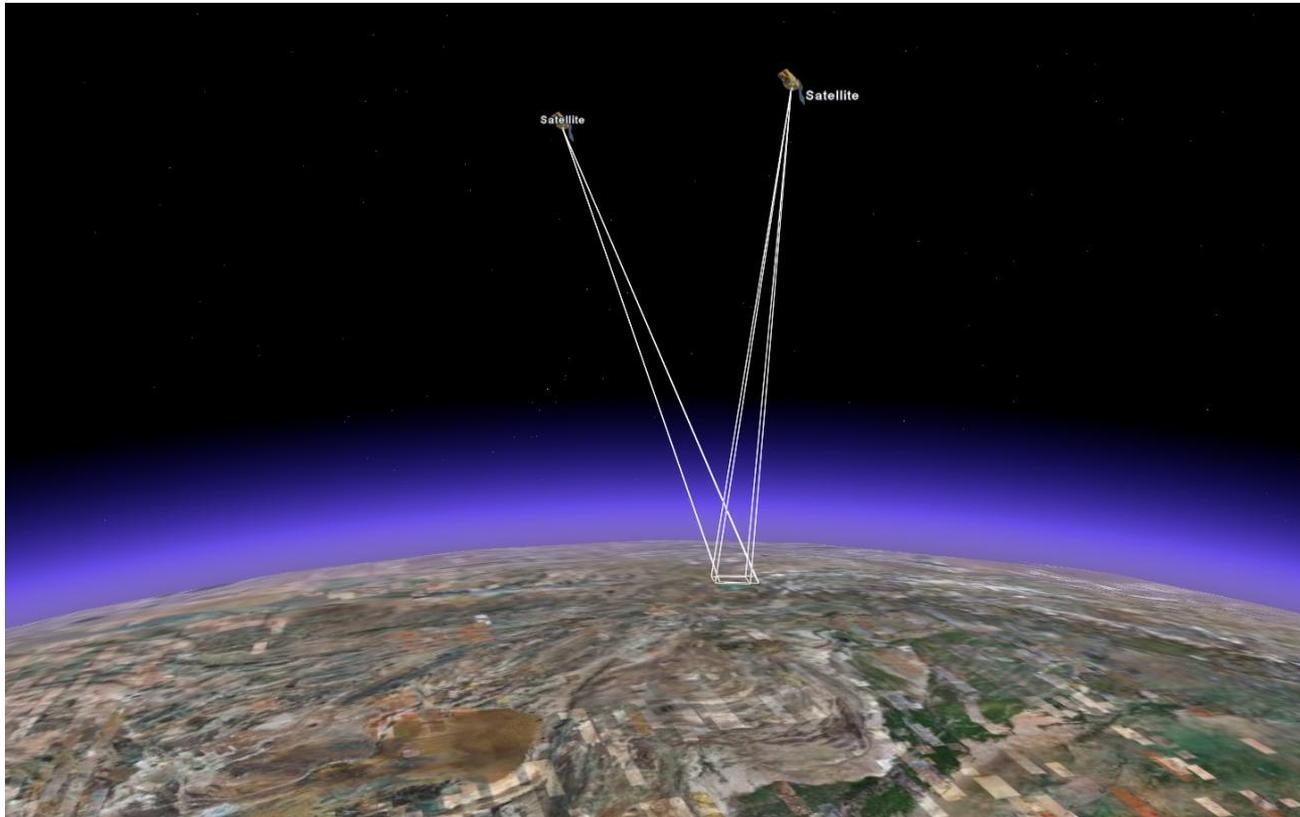
❖ Appariement d'images – Cas d'utilisation

- ❖ Stéréoscopie
- ❖ Mosaïques et synthèses
- ❖ Préparation des classifications (reconnaissance de formes)
- ❖ Analyse multi-temporelle des changements
- ❖ Analyse en composantes principales
- ❖ Pan-sharpening





Stéréoscopie



Couple stéréoscopique SPOT sur l'Est de l'Afghanistan

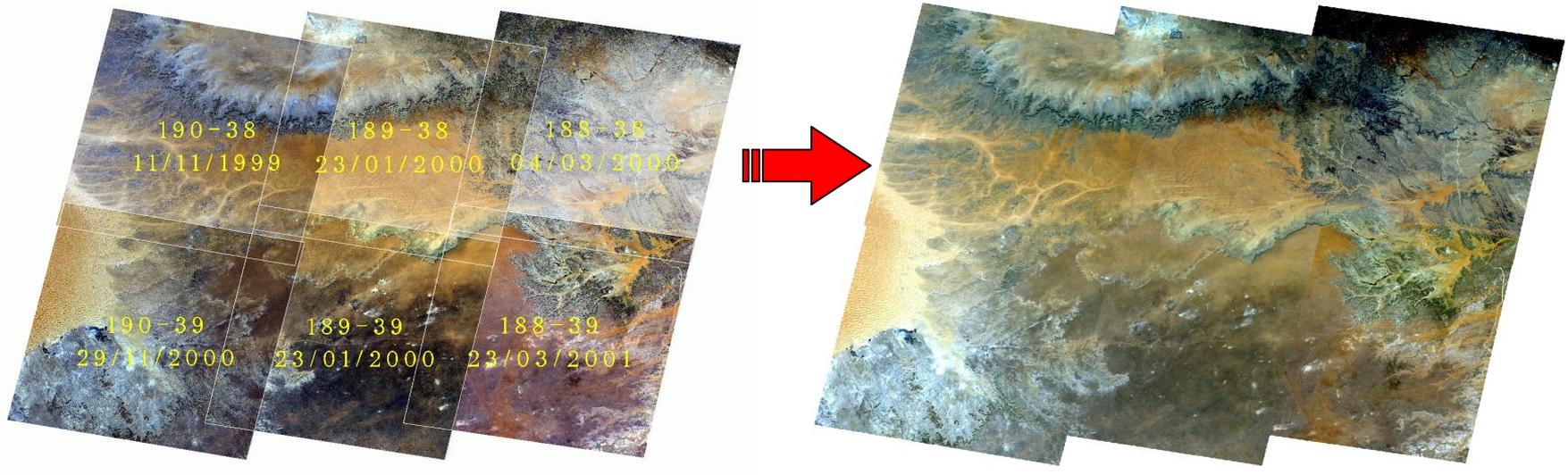
Scène 190-278 acquise le 08/07/2006 $+20.9^\circ$ (vue est)

Scène 190-278 acquise le 27/06/2006 -5.7° (vue ouest)

✦ Histogrammes bi-dimensionnels

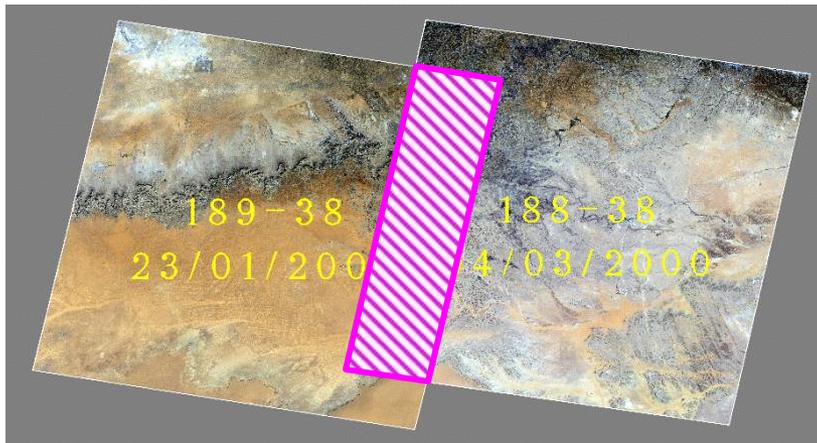
✦ Applications

- Ajuster les radiométries
- Contrôler la qualité radiométrique



✦ Détermination de l'aire de recouvrement

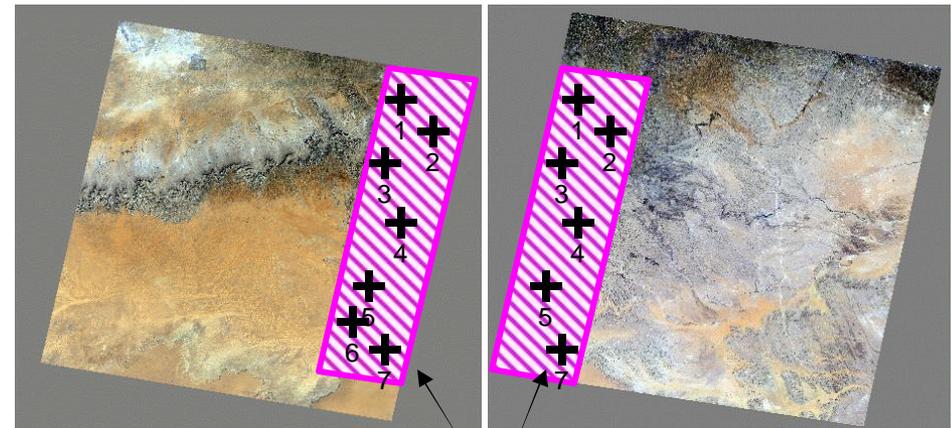
Cas d'images géocodées



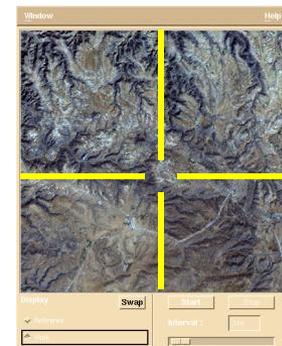
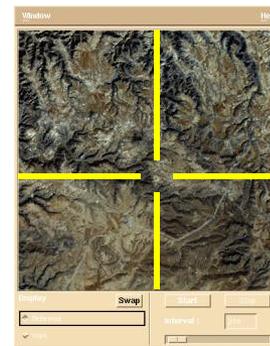
Cas d'images non géocodées

Image de référence

Image de travail



points d'amer
points homologues
(*tie-points*)





✦ Mosaiques et synthèses

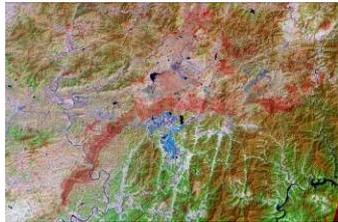
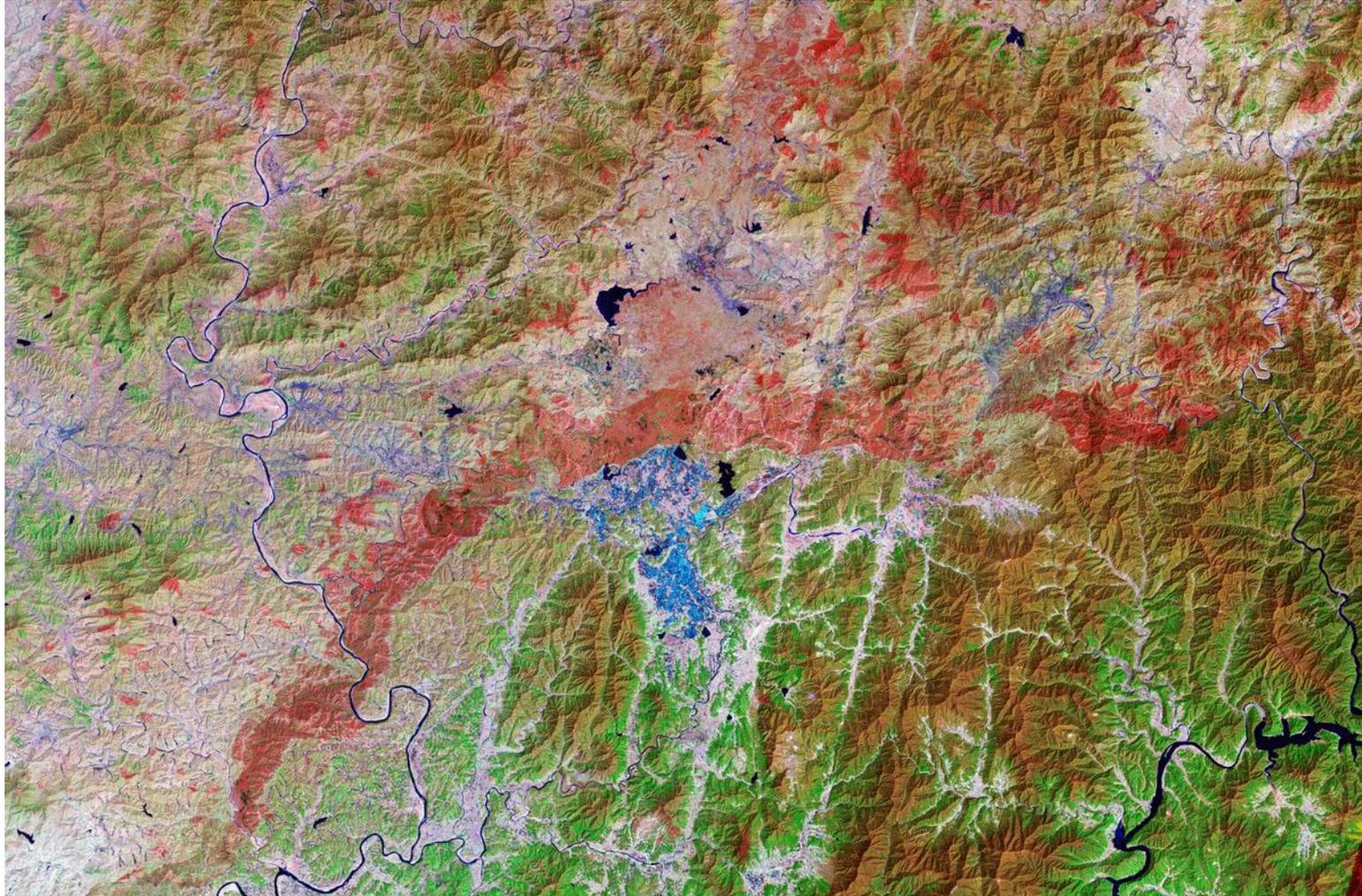


✦ Préparation des classifications (reconnaissance de formes)



✦ Analyse multi-temporelle des changements – Exemple 1

Surveillance par
Landsat ETM+ de la
zone démilitarisée à
la frontière entre
Corée du Nord et
Corée du Sud



29/05/2000



06/05/2003

<http://earthobservatory.nasa.gov/IOTD/view.php?id=36231>



✦ Analyse multi-temporelle des changements – Exemple 2

Impact des pluies
torrentielles dans le
désert Simpson au
centre de l'Australie
observé par
Landsat-5 TM



09/05/2009



24/05/2009

<http://earthobservatory.nasa.gov/IOTD/view.php?id=38717>

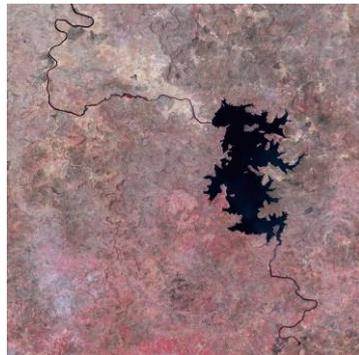
✦ Analyse multi-temporelle des changements – Exemple 3

Guinée et Mali

Impact de la construction du barrage Manantali sur la rivière Bafing (affluent du fleuve Sénégal).



Landsat 2 TM
31/01/1978



Landsat 7 ETM+
24/03/2003



<http://earthobservatory.nasa.gov/IOTD/view.php?id=36241>

✦ Analyse multi-temporelle des changements – Exemple 4

Croissance des zones urbaines

Las Vegas – Landsat 5 TM



22/10/1984



29/05/1989



28/06/1994



09/05/1999



07/06/2004



12/01/2009



<http://earthobservatory.nasa.gov/IOTD/view.php?id=37228>



✦ Analyse multi-temporelle des changements – Exemple 5

Pluies torrentielles et glissements de terrain

Volcan San Vicente (Salvador) – Terra / ASTER



30/11/2002



17/11/2009

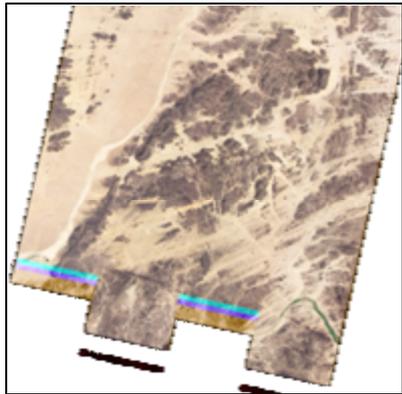


<http://earthobservatory.nasa.gov/IOTD/view.php?id=41365>

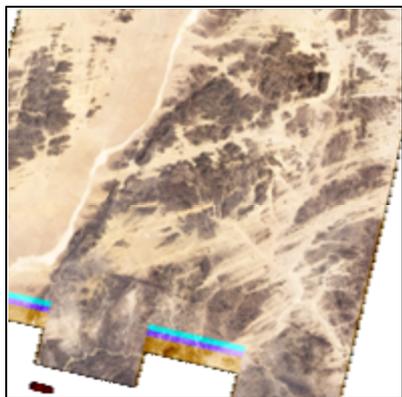
✦ Analyse multi-temporelle des changements – Exemple 6

Variation de la végétation dans les oueds (wadi)

Désert du Sahara (Niger) – EO-1 / ALI



19/09/2007



18/09/2009



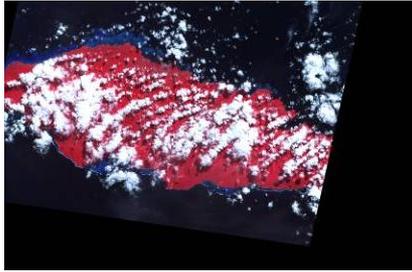
<http://earthobservatory.nasa.gov/IOTD/view.php?id=41016>



✦ Analyse multi-temporelle des changements – Exemple 7

Tsunami sur la côte sud de l'Île d'Upolu suite au tremblement de terre du 29/09/2009 au large des îles Samoa

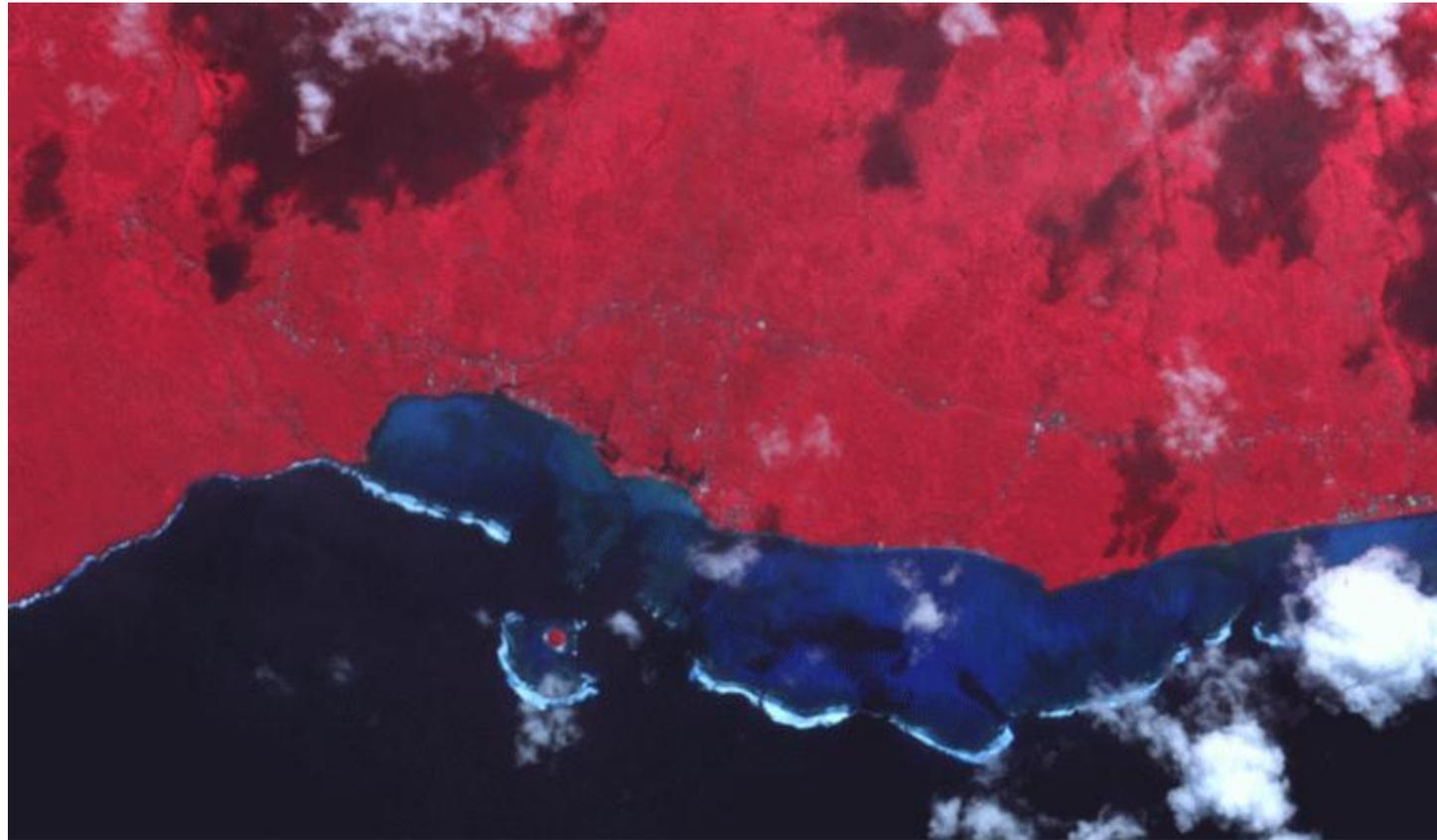
Île Upolu (extrême est des îles Samoa) – Terra / ASTER



10/06/2004



12/10/2009



<http://earthobservatory.nasa.gov/IOTD/view.php?id=40745>

✦ Analyse multi-temporelle des changements – Exemple 8

Sédiments et delta de la « Rivière Jaune » (Chine)



Landsat-5 TM
13/02/1989



Landsat-7 ETM+
20.06.2009



<http://earthobservatory.nasa.gov/IOTD/view.php?id=42439>



✦ Analyse en composantes principales



Pan-sharpening

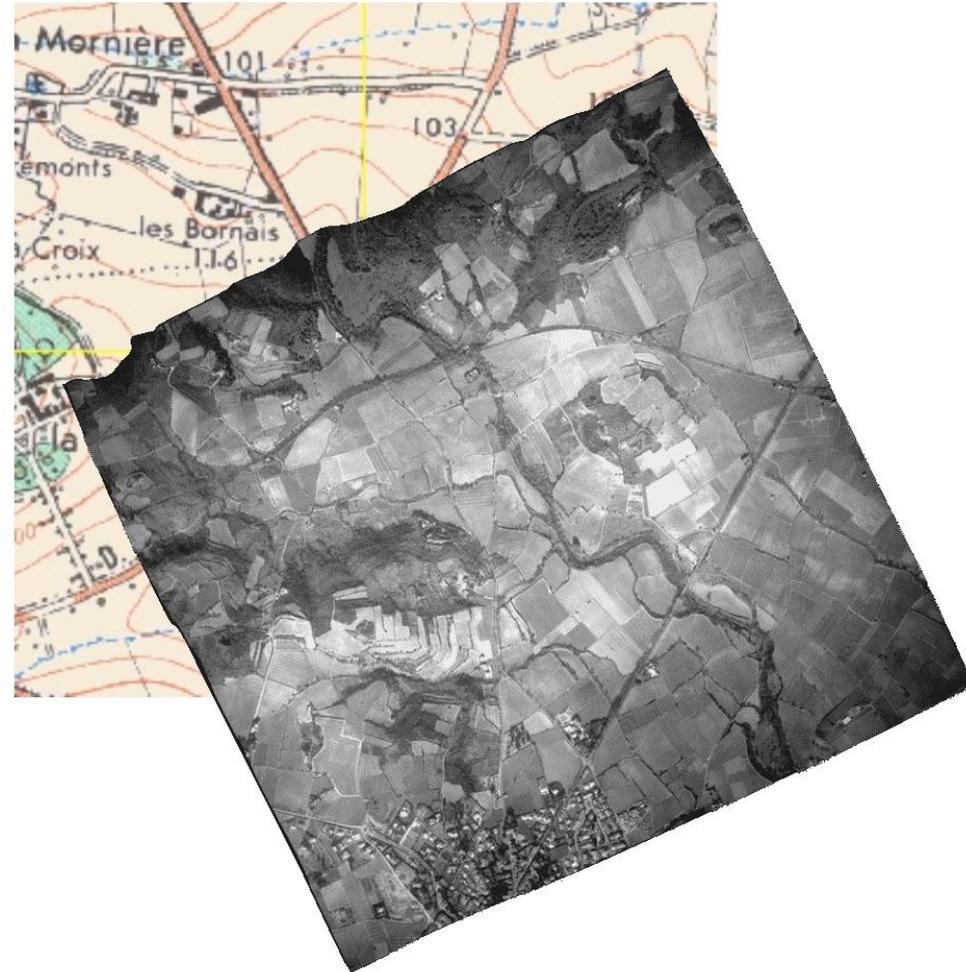


❖ Recalage géométrique

- ❖ Statistiques de mesures de la:
 - Précision de localisation absolue
 - Géométrie interne
- ❖ Références cartographiques, points de contrôle et points d'appui
- ❖ Analyse de disparité
- ❖ Stratégies de déformation
 - Modèles mathématiques d'interpolation globale
 - Modèles locaux (splines, morphing, kriggeage...)
 - Modèles physiques de prise de vue

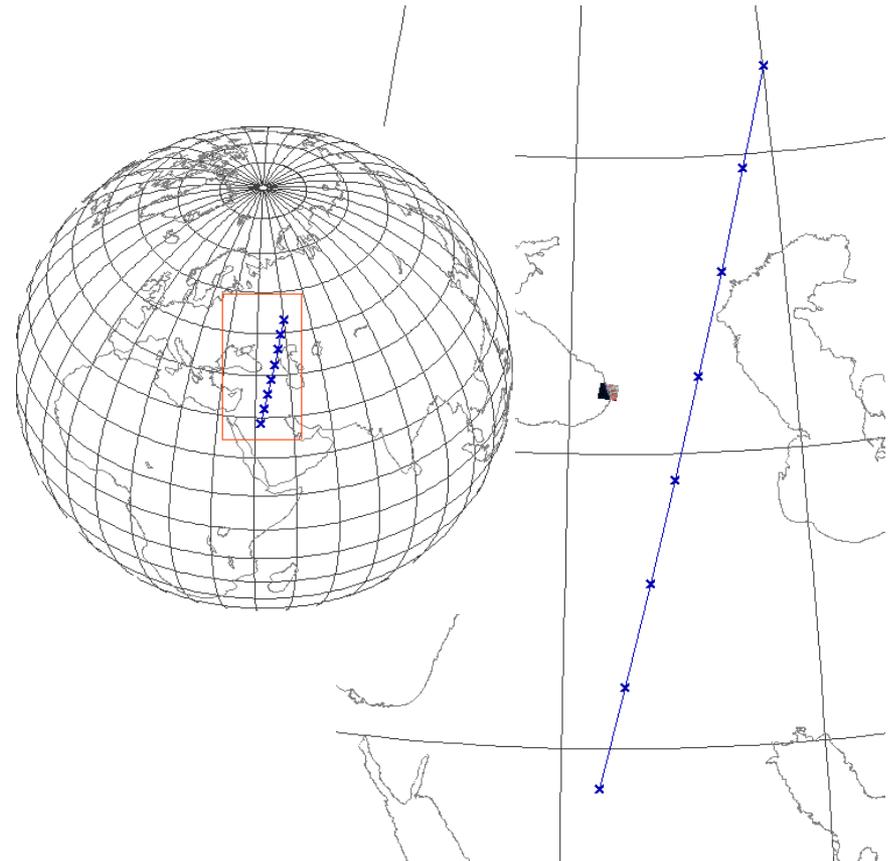
Recalage géométrique

- ✦ Exigence préalable
 - ❖ mosaïques ou synthèses
 - ❖ analyse multi-temporelle
 - ❖ fusion de données



❖ Défauts de géométrie

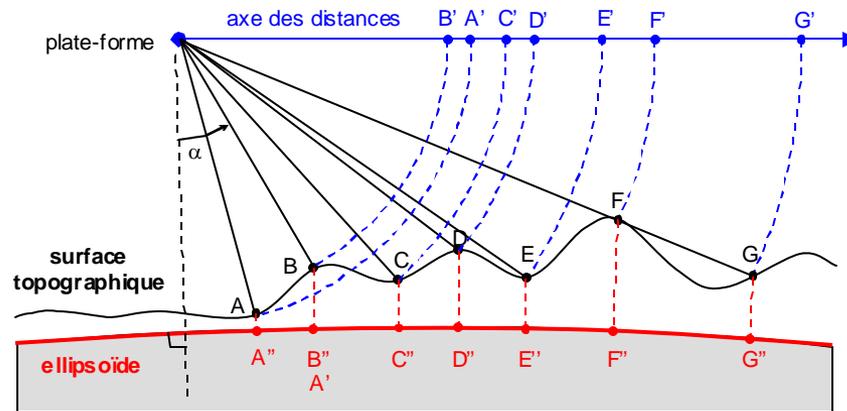
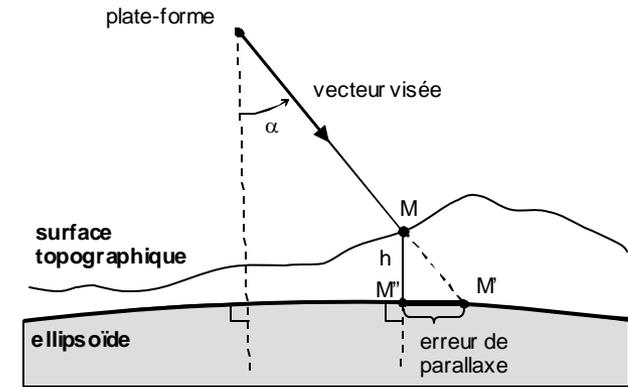
- ❖ Localisation absolue (orientation externe)
 - Erreurs d'éphémérides
 - Erreurs de transmission des coordonnées de l'origine
 - ...



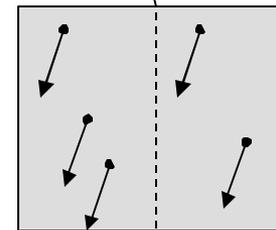


❖ Géométrie interne (orientation interne)

- Défaut de parallaxe
- Erreurs d'attitude
- Extensions, compressions et repliement du radar
- Déformation du document scanné
- ...

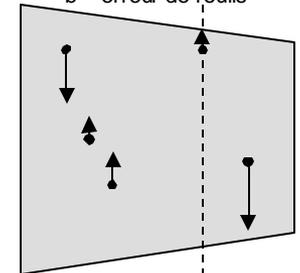


a – erreur de localisation absolue

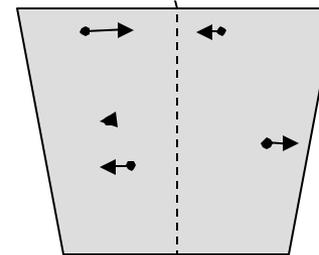


trajectoire de la plate-forme

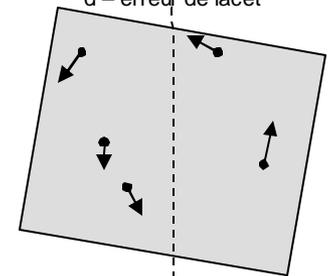
b – erreur de roulis



c – erreur de tangage



d – erreur de lacet



❖ Références cartographiques

❖ Points de contrôle et points d'appui

❖ Types de références

- Cartes topographiques (raster ou vecteur)
- Levées GPS
- Images géocodées de référence
- Constellation des puits
- Points géodésiques
- ...

❖ Outils de géoréférencement

- Logiciels de saisie de points
- Table à numériser
- ...

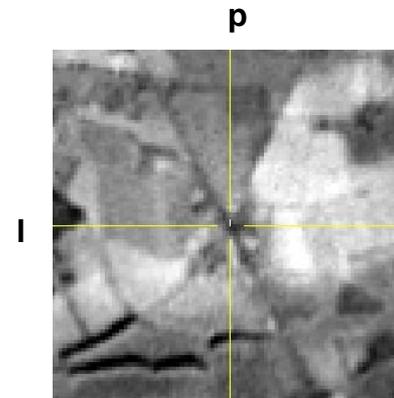
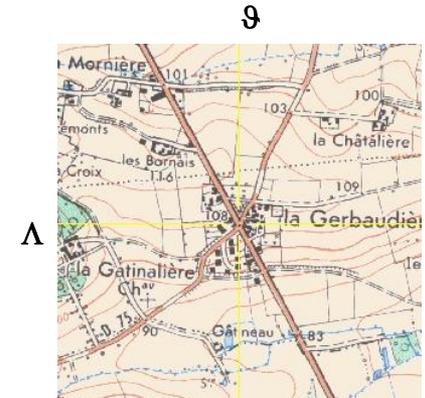


image à contrôler
ou à recaler



carte de référence



✦ Mesures d'erreur

- ❖ Écart du modèle image (λ, φ) à la référence cartographique (Λ, θ)
- ❖ Moyenne quadratique des erreurs de localisation

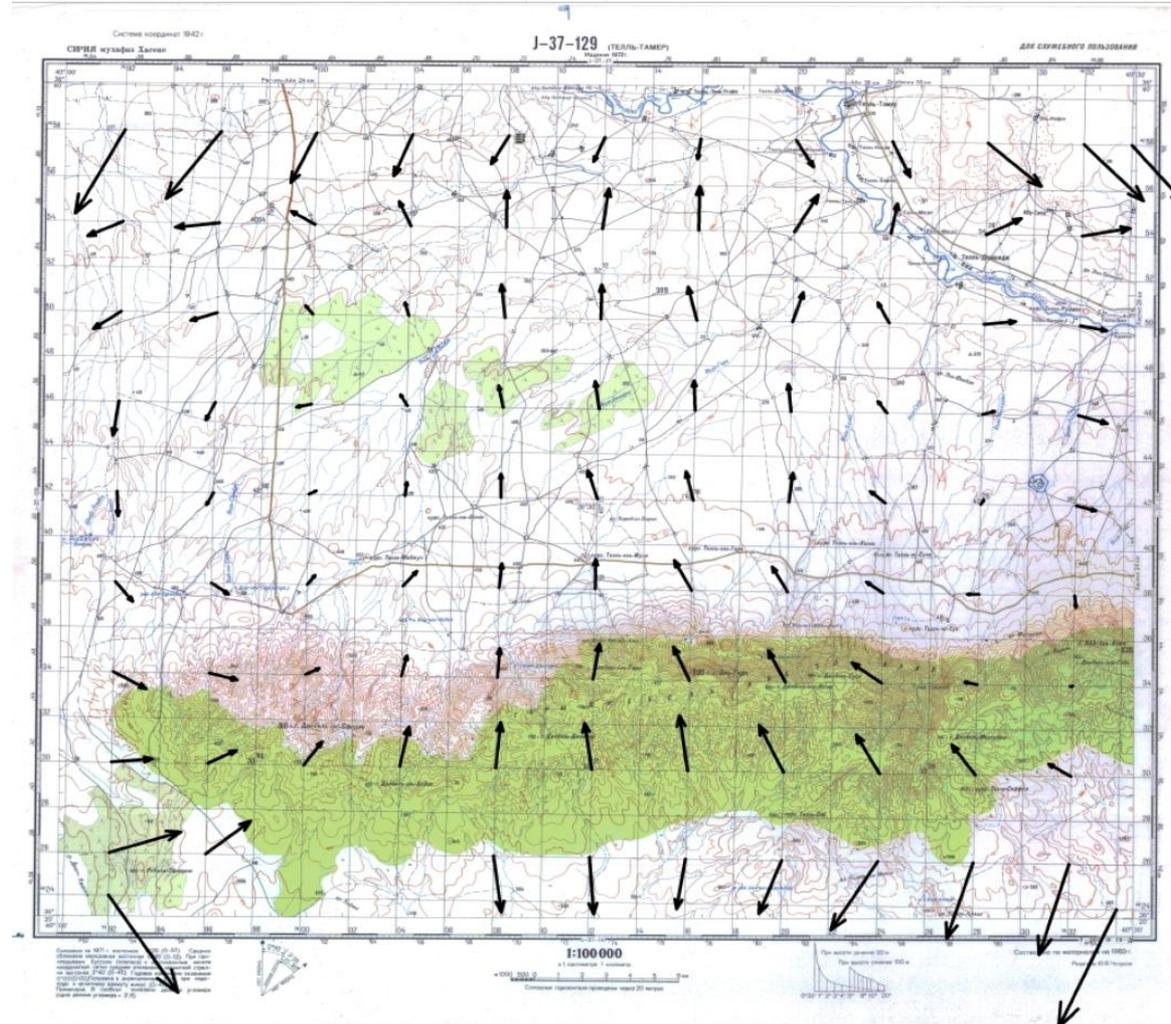
$$e = \text{dist}[(\lambda, \varphi), (\Lambda, \theta)]$$

$$eqm = \sqrt{\frac{1}{n} \sum_{i=1}^n e_i^2}$$

$$eqm = \sqrt{\frac{1}{n} \sum_{i=1}^n \text{dist}[(\lambda_i, \varphi_i), (\Lambda_i, \theta_i)]^2}$$

❖ Champ de vecteurs d'erreur

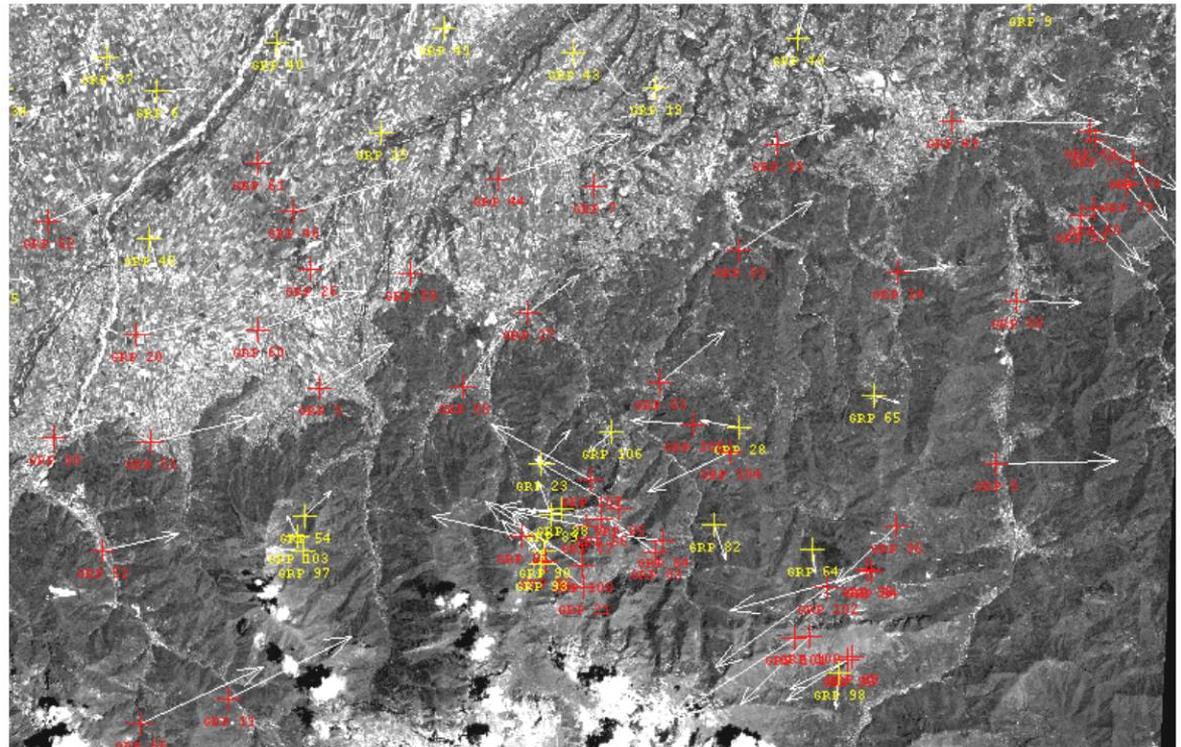
$$\vec{v}_i = \begin{pmatrix} \Lambda_i - \lambda_i \\ \theta_i - \varphi_i \end{pmatrix}$$



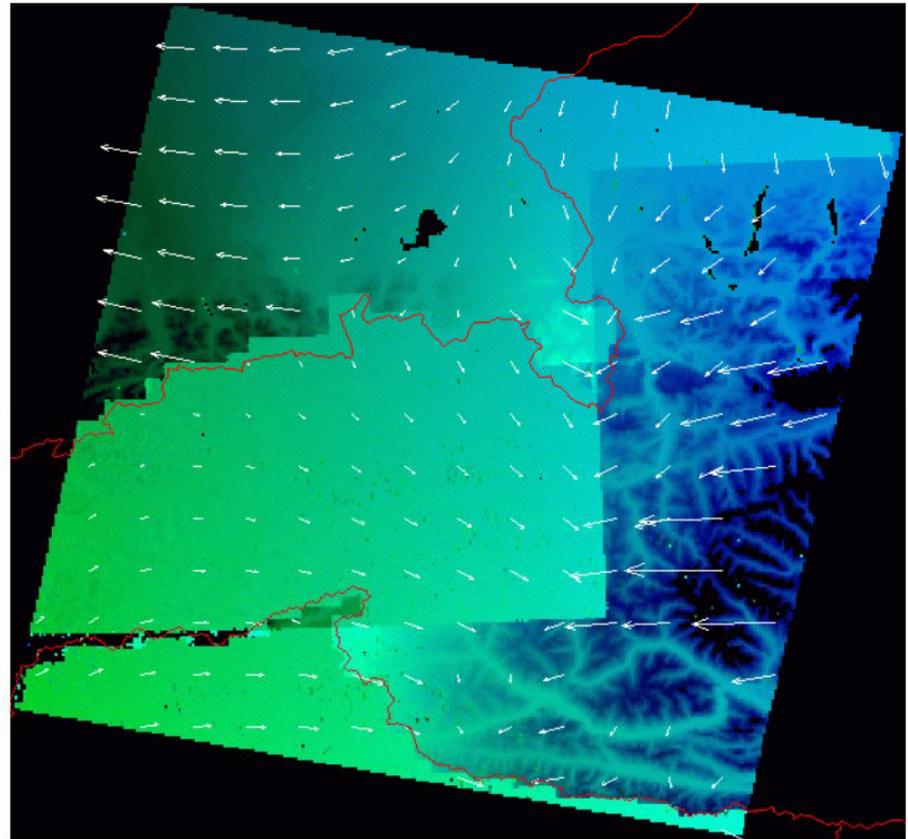
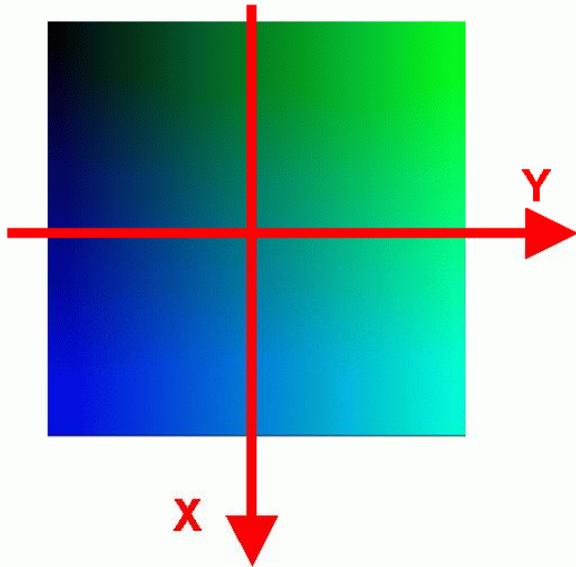
❖ Erreur de localisation absolue

- Calculer la moyenne arithmétique
- Ajouter cette moyenne aux coordonnées origine

$$\begin{cases} \bar{m}_\lambda &= \frac{1}{n} \sum_{i=1}^n (\Lambda_i - \lambda_i) \\ \bar{m}_\varphi &= \frac{1}{n} \sum_{i=1}^n (\theta_i - \varphi_i) \end{cases}$$



✦ Analyse de disparité



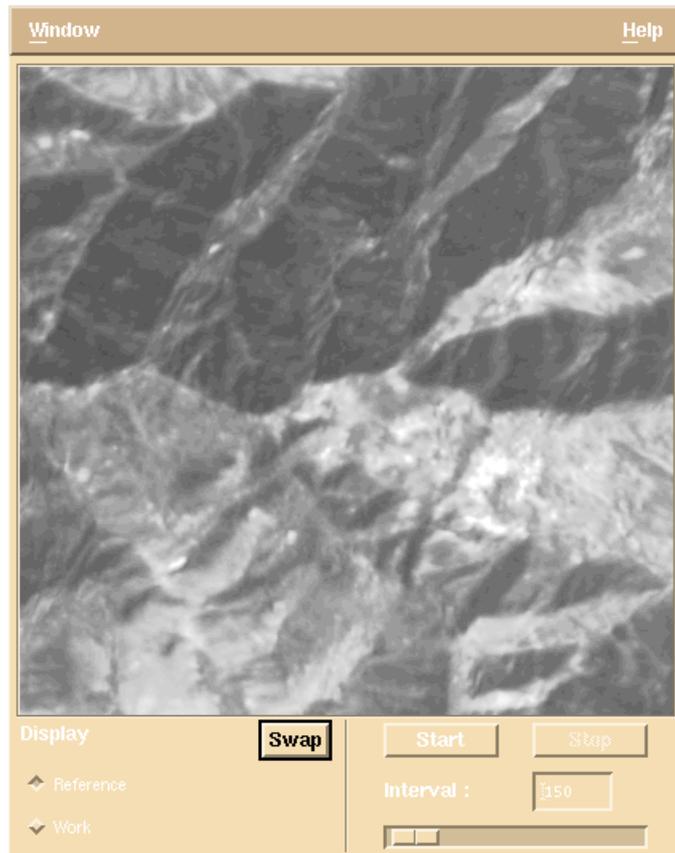


✦ Stratégies de déformation

- ✦ Modèles mathématiques d'interpolation globale

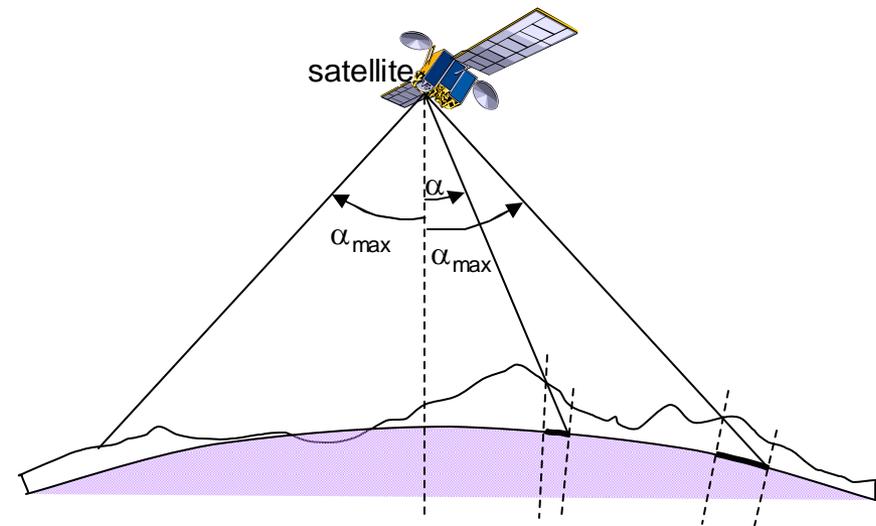
Le recalage géométrique – Un préalable à la fusion

- ✦ Orthorectification avec un MNT de mauvaise qualité



SPOT 4 bande 2 (+27°)
Landsat ETM+ PAN

Afghanistan Est





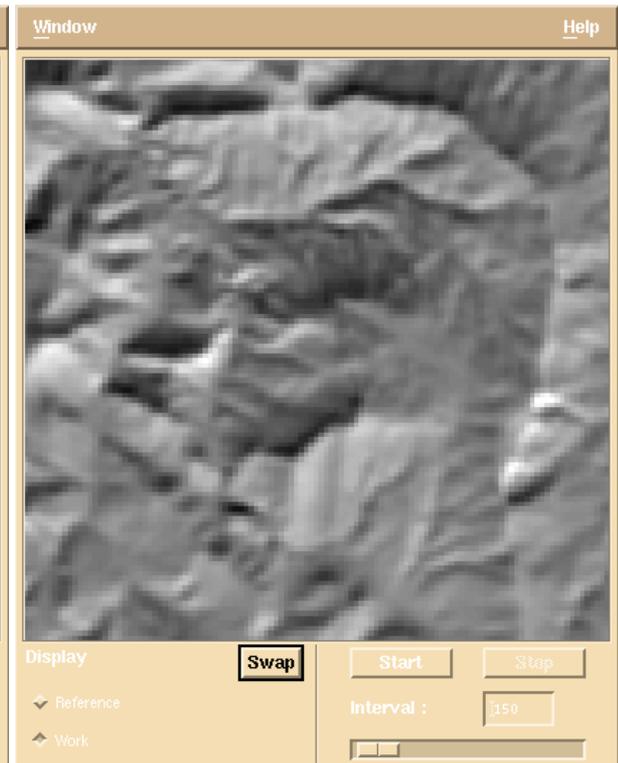
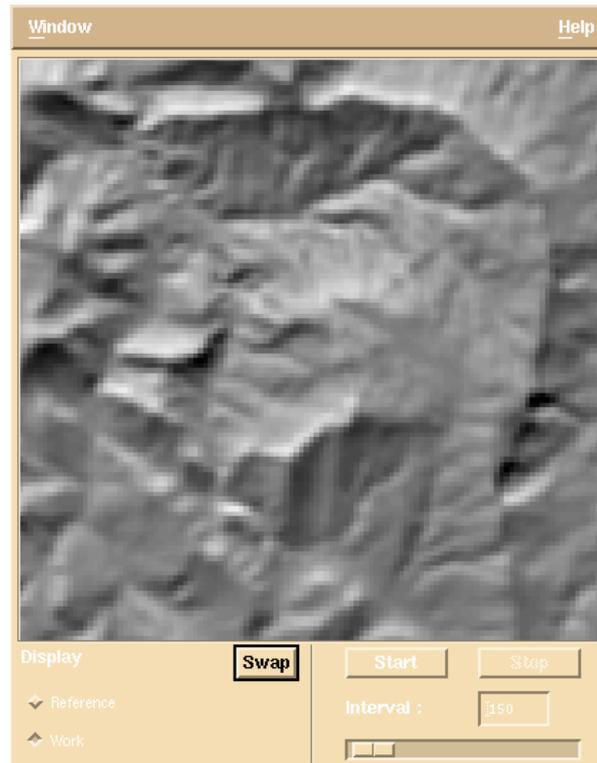
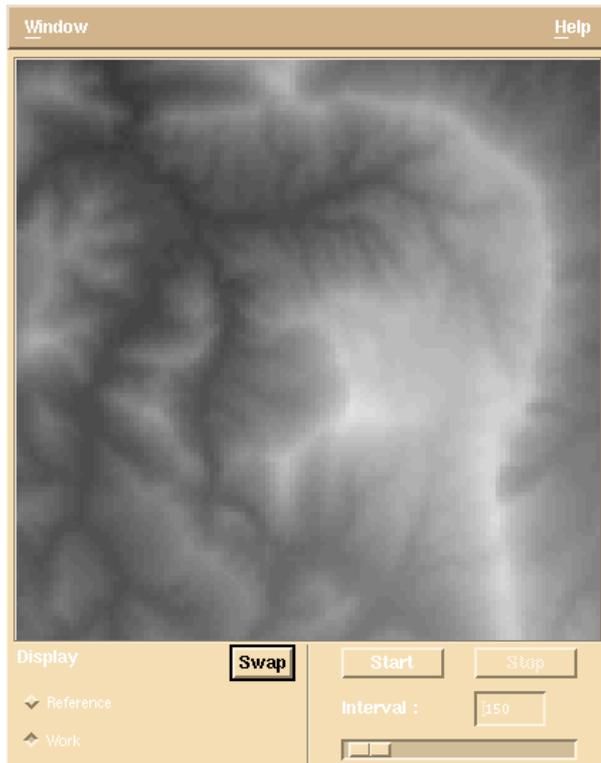
Recalage optique / MNT

✦ Zone 1 – Mont Ventoux

niveaux de gris

éclairage nord-ouest

éclairage sud-est



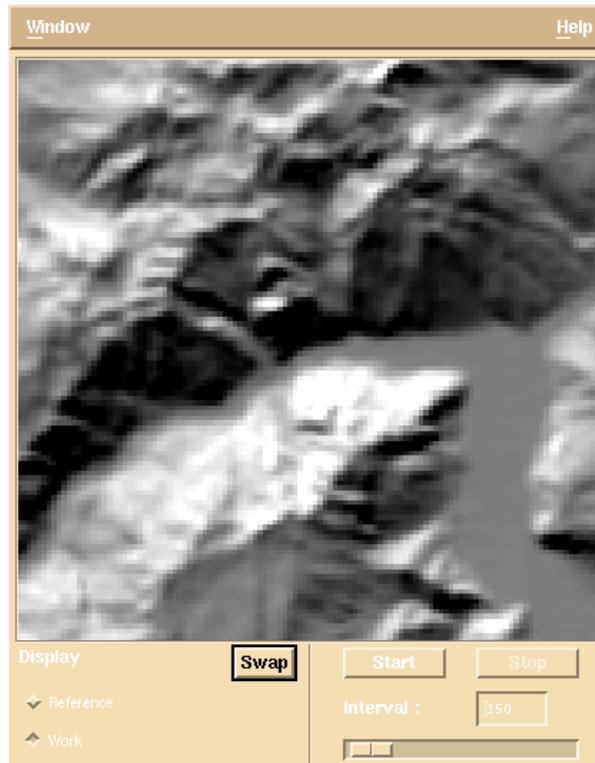
Recalage optique / MNT

✦ Zone 2 – Chamrousse (sud de Grenoble)

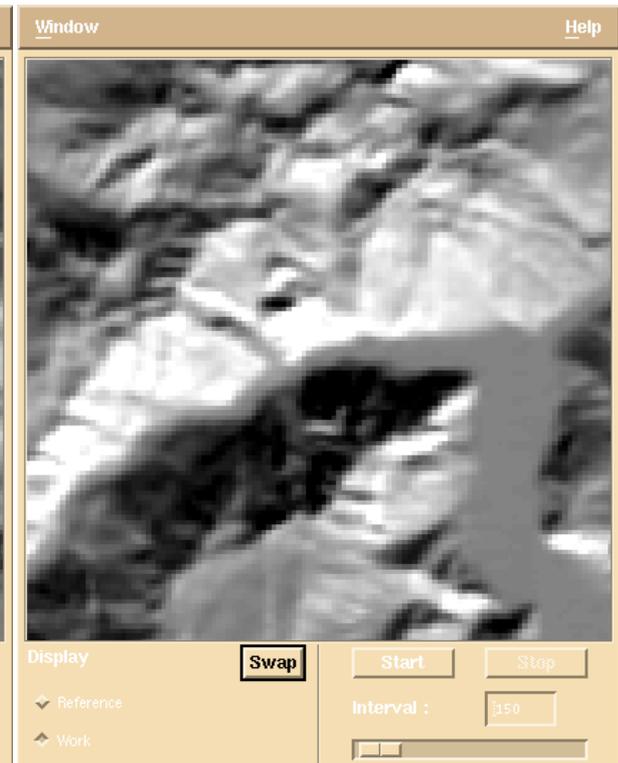
niveaux de gris



éclairage nord-ouest



éclairage sud-est





✦ Recalage radiométrique

- ❖ Analyse de régression selon modèles
- ❖ Adaptation d'histogramme
- ❖ Combinaison linéaires d'adaptation spectrale





Recalage radiométrique

- ✦ Analyse de régression selon modèles



✦ Adaptation d'histogramme



✦ Combinaison linéaires d'adaptation spectrale



❖ Synthèse de produits image

- ❖ Produits périodiques
- ❖ Synthèse itérative
- ❖ Algorithmes de sélection (radiance maximum, NDVI minimum...)
- ❖ Algorithmes de remplacement (substitution, moyenne ou médiane glissante...)
- ❖ Exemple de projet – Synthèse MERIS mars-avril 2003





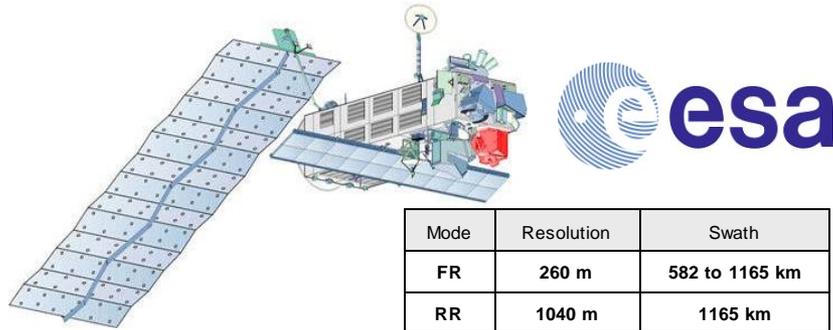
SYNTHESES DE PRODUITS IMAGES

- ✦ Produits périodiques
- ✦ Analyse des changements

- ✦ Géoréférencement assumé
→ pas de mosaïque géométrique
- ✦ Calibration radiométrique assumée
→ pas de mosaïque radiométrique



Synthèse – Envisat / MERIS mars-avril 2003



<http://envisat.esa.int/>

Mode	Resolution	Swath
FR	260 m	582 to 1165 km
RR	1040 m	1165 km

Band	Band centre (nm)	Bandwidth (nm)	Primary Use
1	412.5	10	Yellow substance and detrital pigments
2	442.5	10	Chlorophyll absorption maximum
3	490	10	Chlorophyll and other pigments
4	510	10	Suspended sediment, red tides
5	560	10	Chlorophyll absorption minimum
6	620	10	Suspended sediment
7	665	10	Chlorophyll absorption and fluo. reference
8	681.25	7.5	Chlorophyll fluorescence peak
9	708.75	10	Fluo. Reference, atmospheric corrections
10	753.75	7.5	Vegetation, cloud
11	760.625	3.75	Oxygen absorption R-branch
12	778.75	15	Atmosphere corrections
13	865	20	Vegetation, water vapour reference
14	885	10	Atmosphere corrections
15	900	10	Water vapour, land

VISIBLE

INFRARED

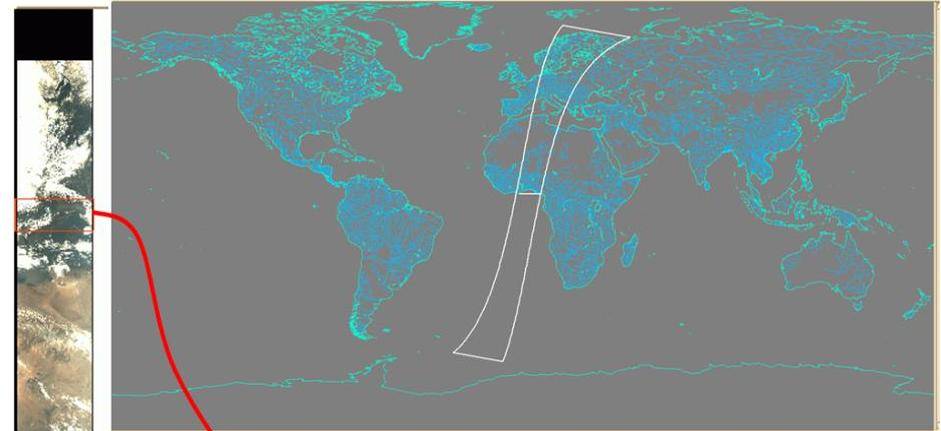


fig. 1 - Footprint of acquisition 20030408_093303

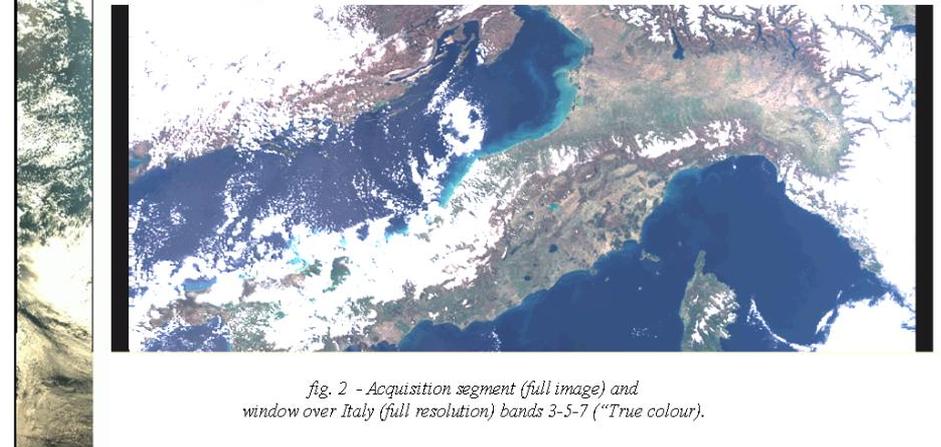
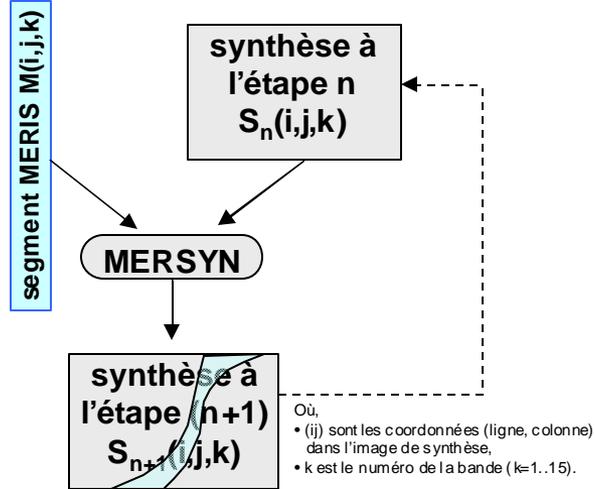


fig. 2 - Acquisition segment (full image) and window over Italy (full resolution) bands 3-5-7 ("True colour").



Synthèse – Algorithme de traitement des segments



3 - 5 - 7

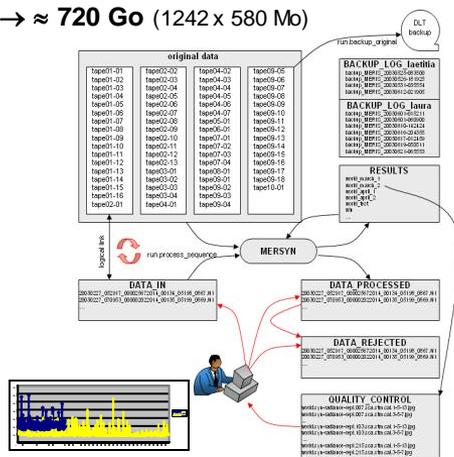


Taille d'une synthèse :

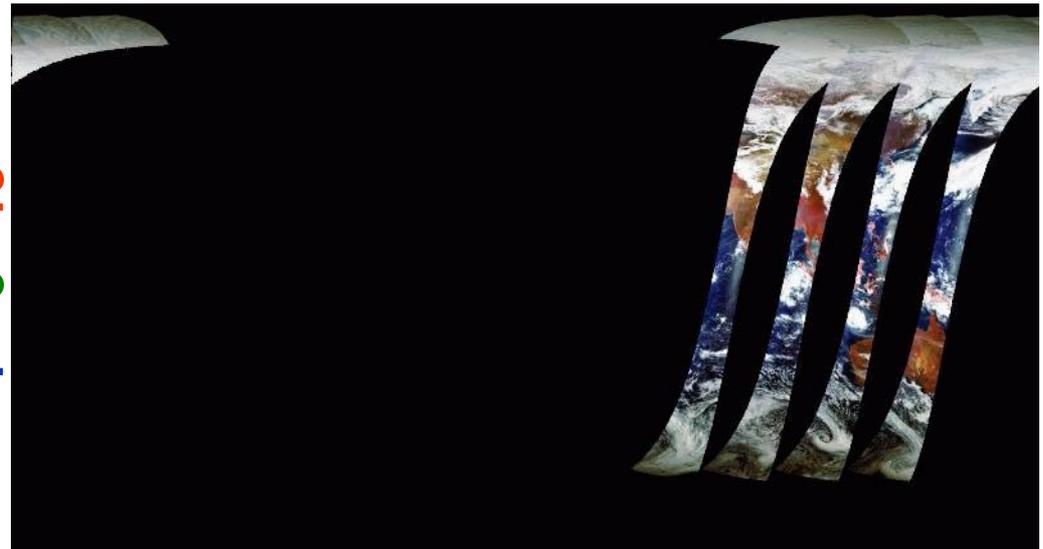
8 Go (5 bandes x 20,000 lignes x 40,000 pixels x 2 octets/pixel)

1242 segments en entrée \approx **10 TB traités** (1242×8 Go)

$\rightarrow \approx$ **720 Go** (1242×580 Mo)



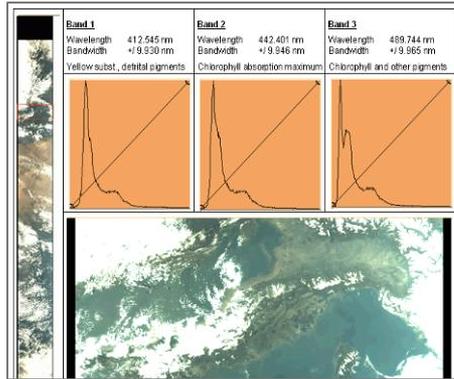
1 - 5 - 13



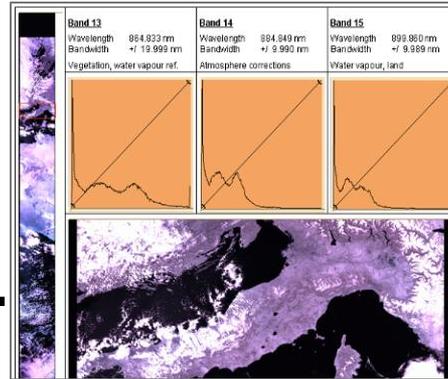


Synthèse – Pré-étude – Ajustement des paramètres

1 – Composition colorée



3-5-7 et 1-13



3 – Algorithme de sélection

Radiance minimum



NDVI maximum

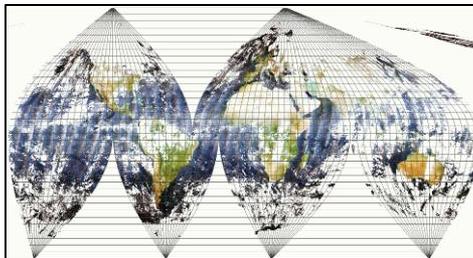


2 – Projection

Goode homolosine



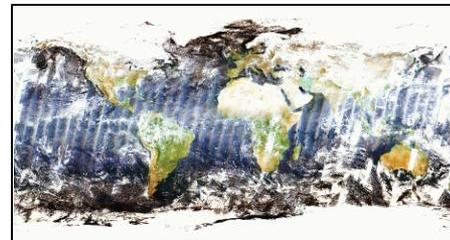
Goode sinusoïdale



Mercator



Plate-Carrée

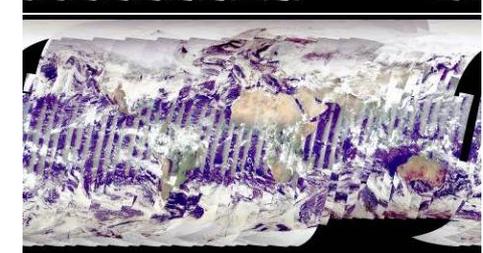


4 – Algorithme de fusion

Remplacement



Moyenne

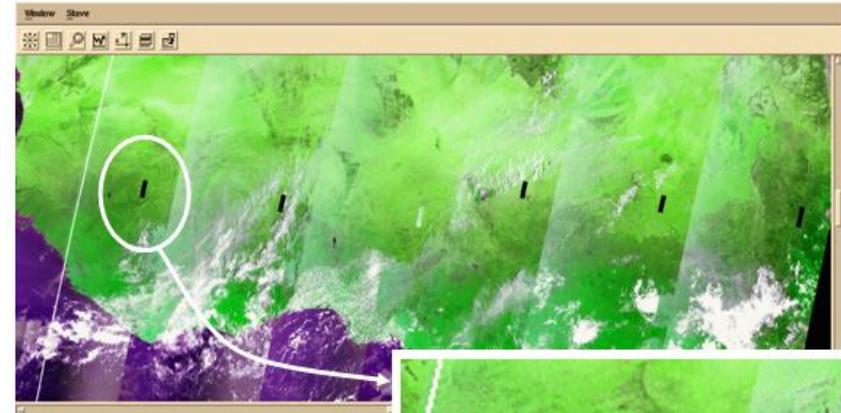


Synthèse – Contrôle qualité



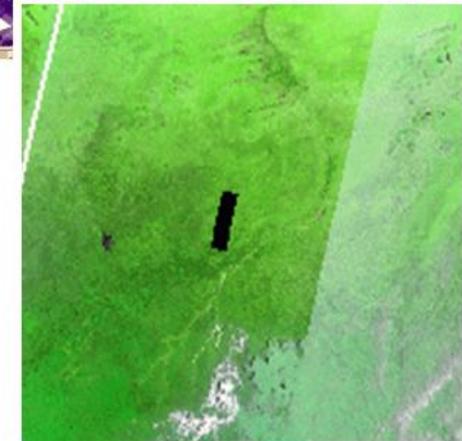
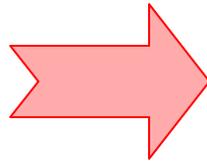
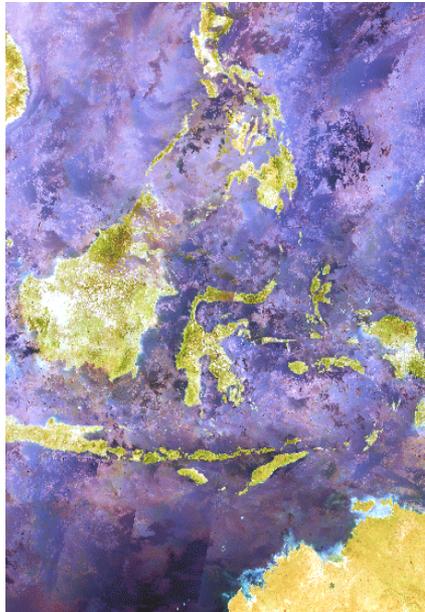
Synthèse avant fusion

1 – Erreur de calibration



2 – Erreur de localisation

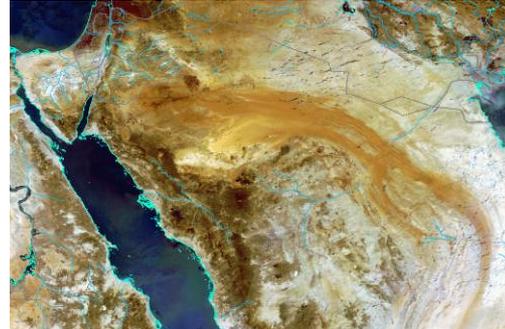
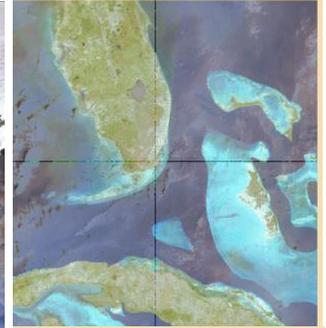
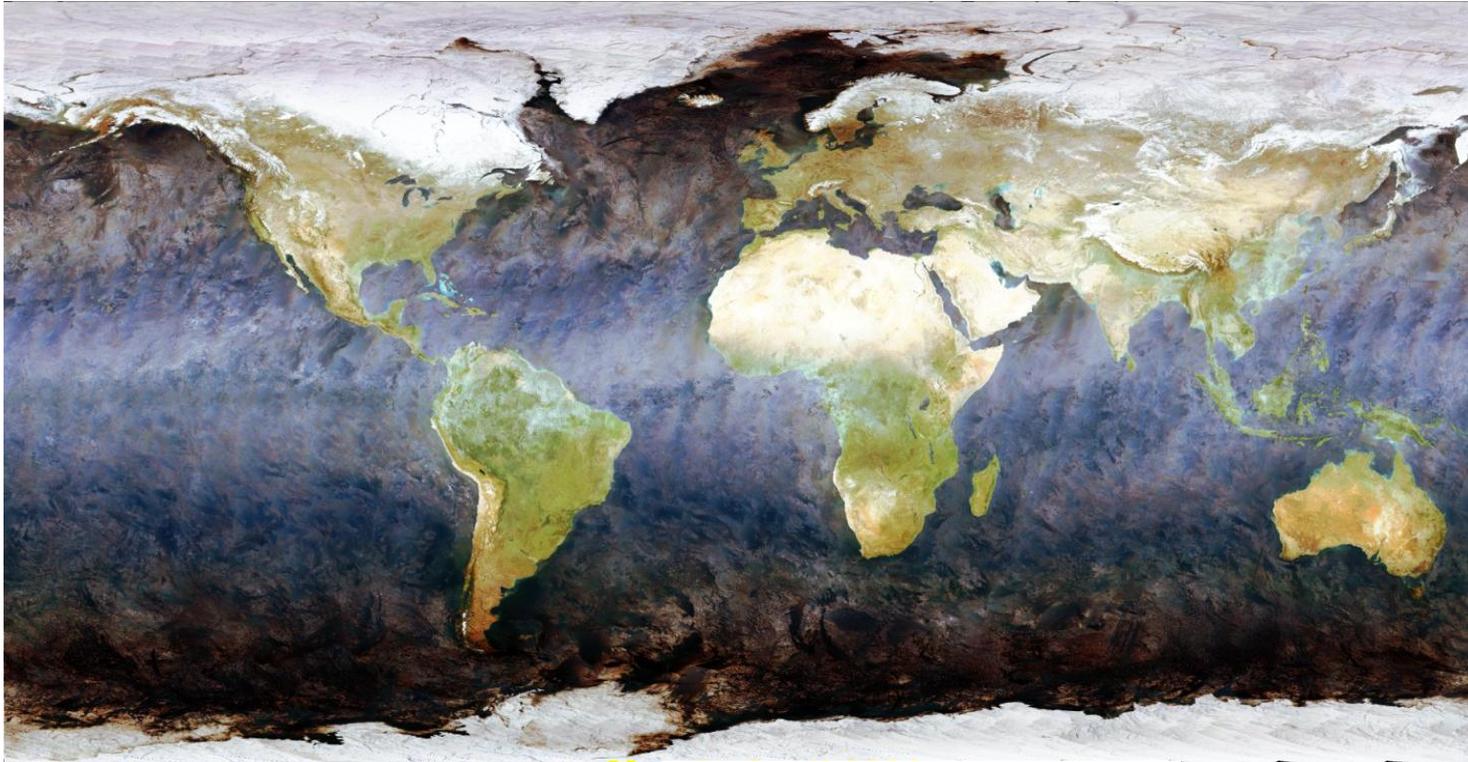
Synthèse après fusion



3 – “Trou” périodique



Synthèse – Résultats





❖ Techniques de fusion

- ❖ Fonction(s) de régression selon modèles(s)
- ❖ Compositions colorées
- ❖ Analyse en composantes principales (ACP)
- ❖ Pan-sharpening (fusion panchromatique / composition colorée)
 - RGB – ICS
 - Brovey
 - HPF – Filtrage passe-haut
 - AWI – Fonctions d'ondelettes additives
 - Méthodes d'adaptation du canal panchromatique
- ❖ Superposition
 - Transparence et background
 - Tamis ou somme pondérée
 - Animations



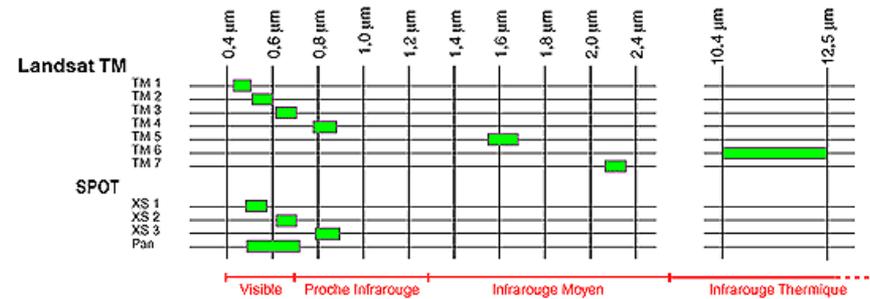
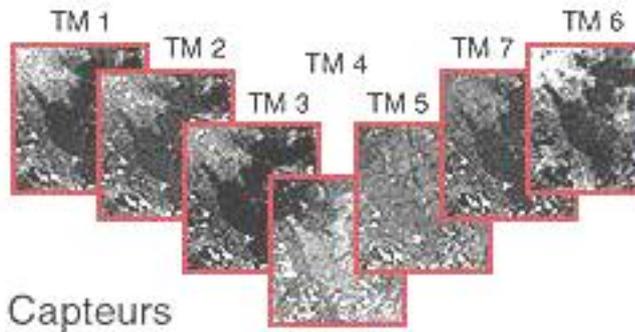
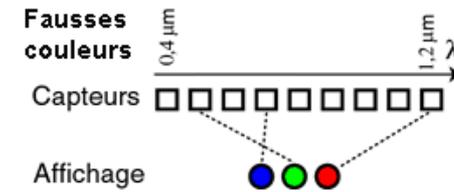


Fonctions de régression selon modèles



Compositions colorées

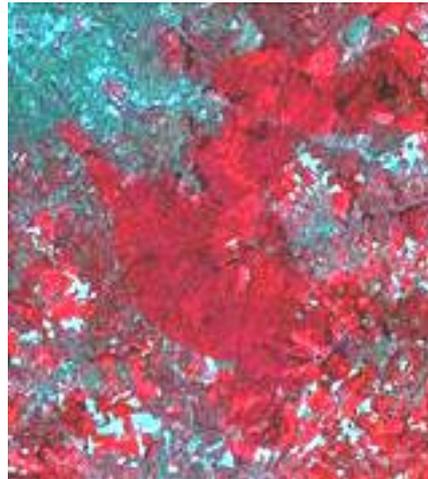
<http://telsat.belspo.be/beo/fr/guide/index.htm>



TM 321 (« Vraies couleurs »)



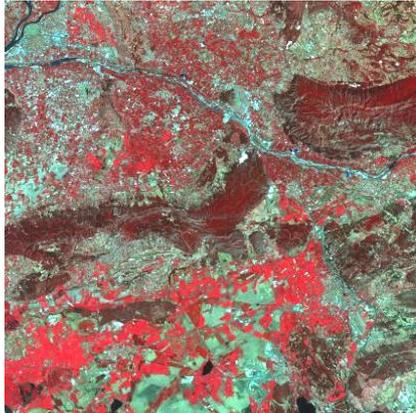
TM 432 (« Proche Infrarouge »)



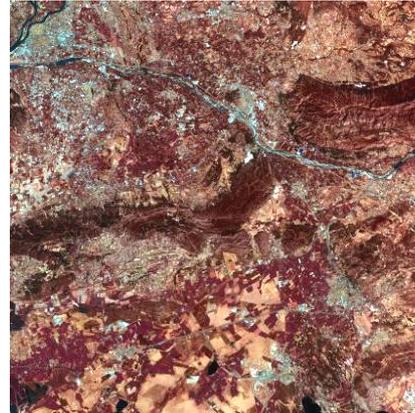
TM 354



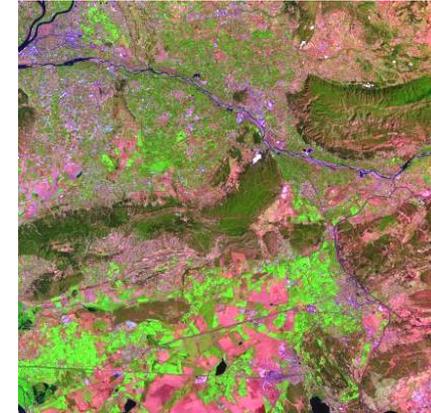
✦ Compositions colorées (exemples SPOT5 HRVIR Avignon)



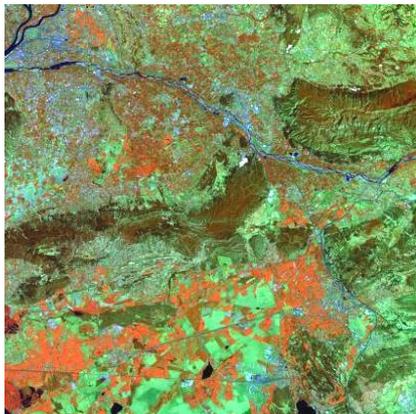
3 (R) 2 (V) 1 (B)



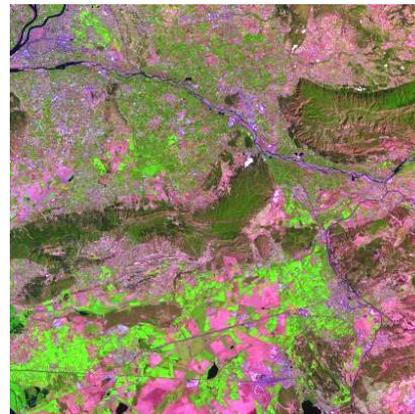
4 (R) 2 (V) 1 (B)



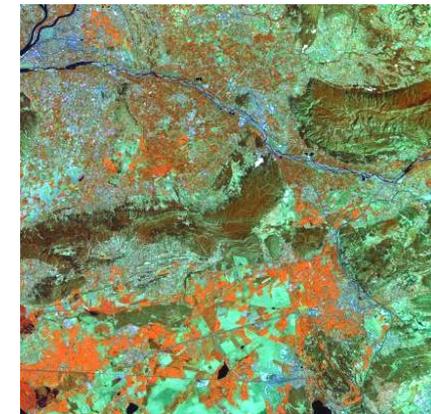
4 (R) 3 (V) 1 (B)



3 (R) 4 (V) 1 (B)



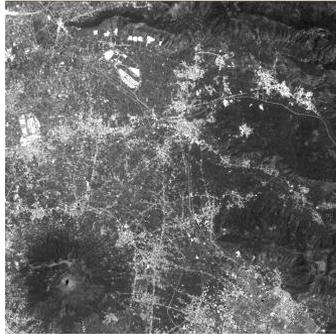
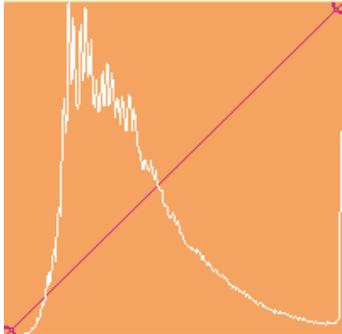
4 (R) 3 (V) 2 (B)



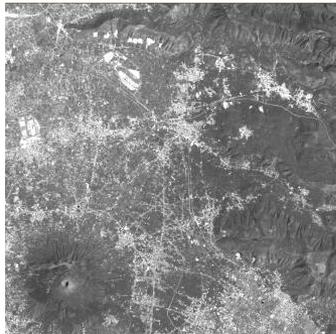
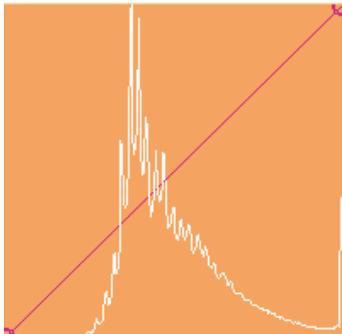
3 (R) 4 (V) 2 (B)

✦ Compositions colorées (exemple Landsat TM de Naples)

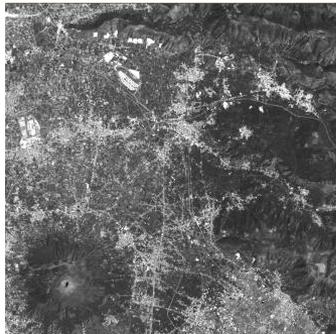
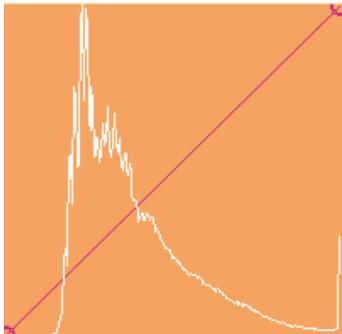
1 (B)



2 (V)



3 (R)





ITS: Intensité Teinte Saturation IHS: Intensity Hue Saturation

$$B' = \frac{B}{255} \quad V' = \frac{V}{255} \quad R' = \frac{R}{255}$$

$$\text{Intensité} = \begin{cases} \max(B', V', R') & \text{ou} \\ \frac{B'+V'+R'}{3} & \text{ou} \\ \frac{\min(B', V', R') + \max(B', V', R')}{2} \end{cases}$$

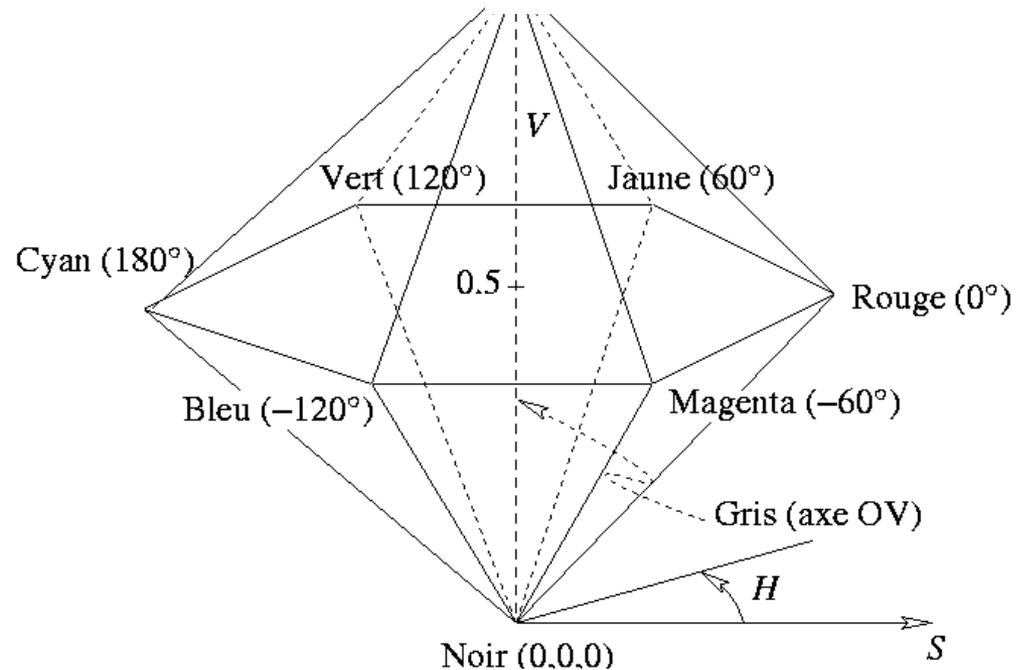
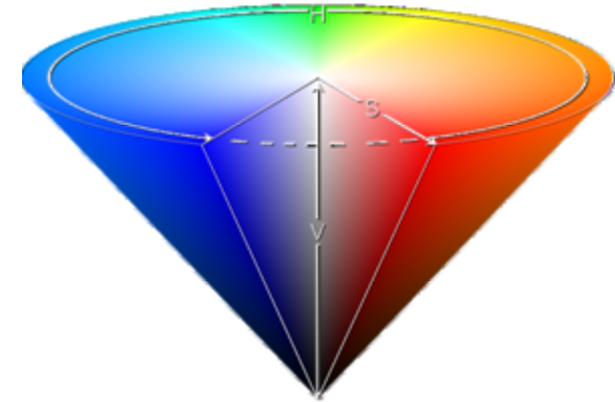
$$\text{Saturation} = \frac{\max(B', V', R') - \min(B', V', R')}{\max(B', V', R')}$$

$$dR = \frac{\max(B', V', R') - R'}{\max(B', V', R') - \min(B', V', R')}$$

$$dV = \frac{\max(B', V', R') - V'}{\max(B', V', R') - \min(B', V', R')}$$

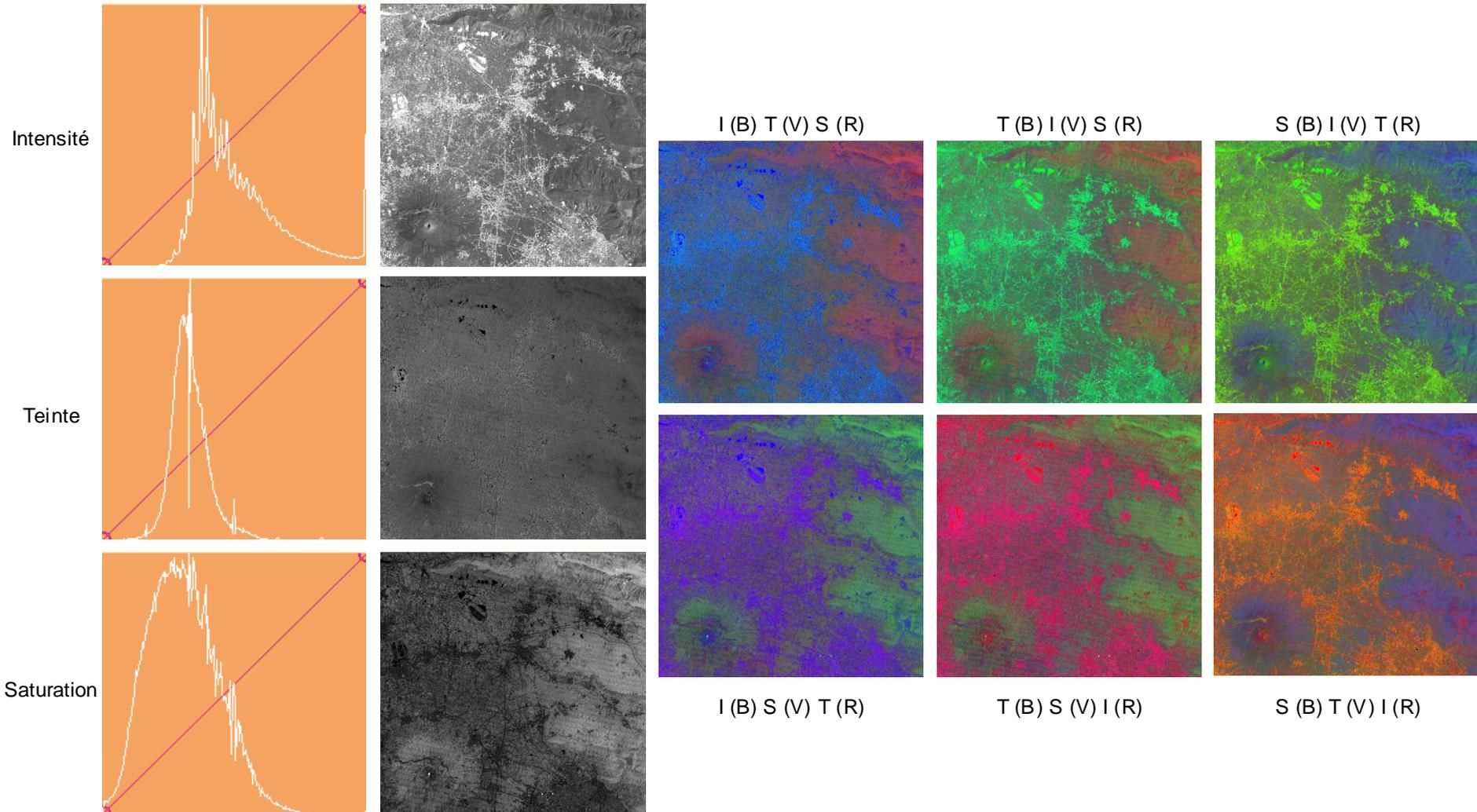
$$dB = \frac{\max(B', V', R') - B'}{\max(B', V', R') - \min(B', V', R')}$$

$$\text{Teinte} = \begin{cases} \frac{dB - dV}{6} & \text{si } R' = \max(B', V', R') \\ \frac{2 + dR - dB}{6} & \text{si } V' = \max(B', V', R') \\ \frac{4 + dV - dR}{6} & \text{si } B' = \max(B', V', R') \end{cases}$$



http://www.tsi.enst.fr/tsi/enseignement/ressources/mti/correl_couleur/
http://fr.wikipedia.org/wiki/Teinte_Saturation_Valeur

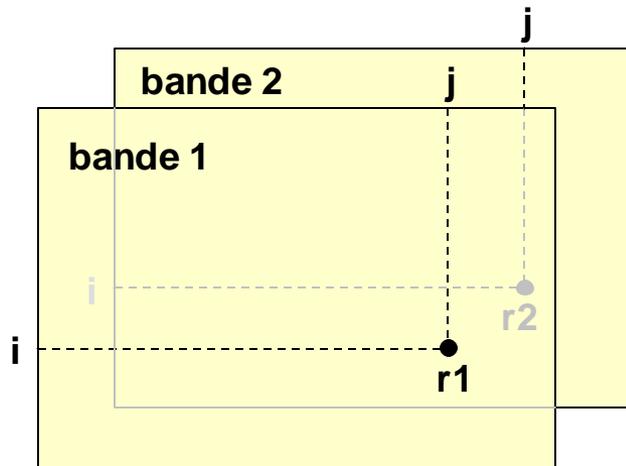
ITS: Intensité Teinte Saturation (exemple Landsat TM de Naples)



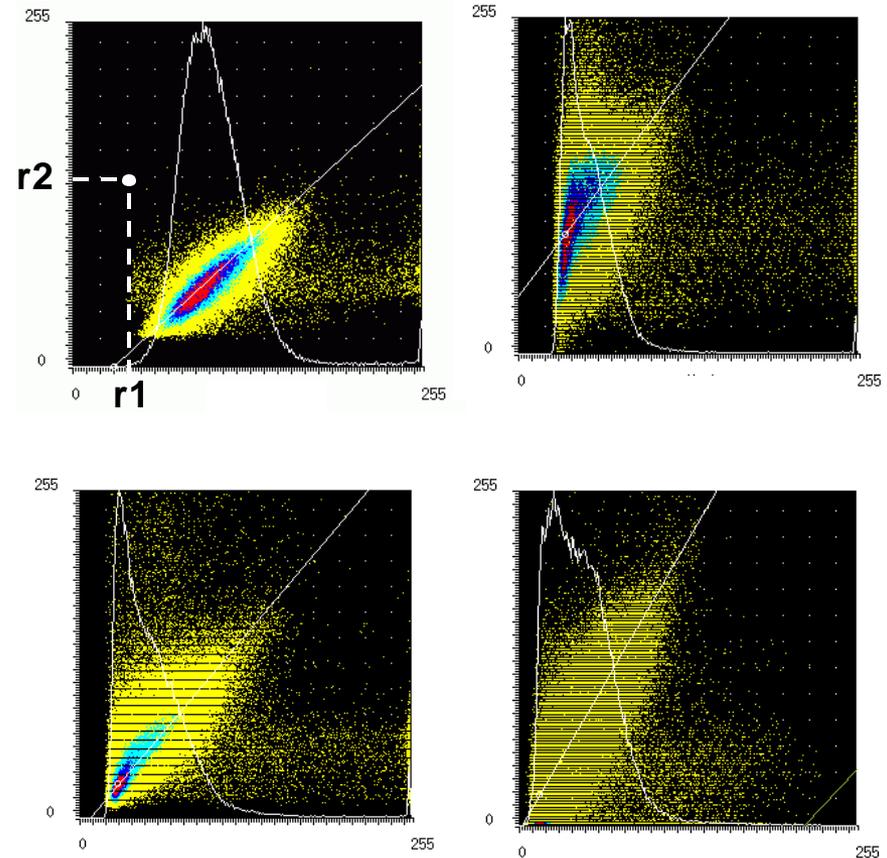


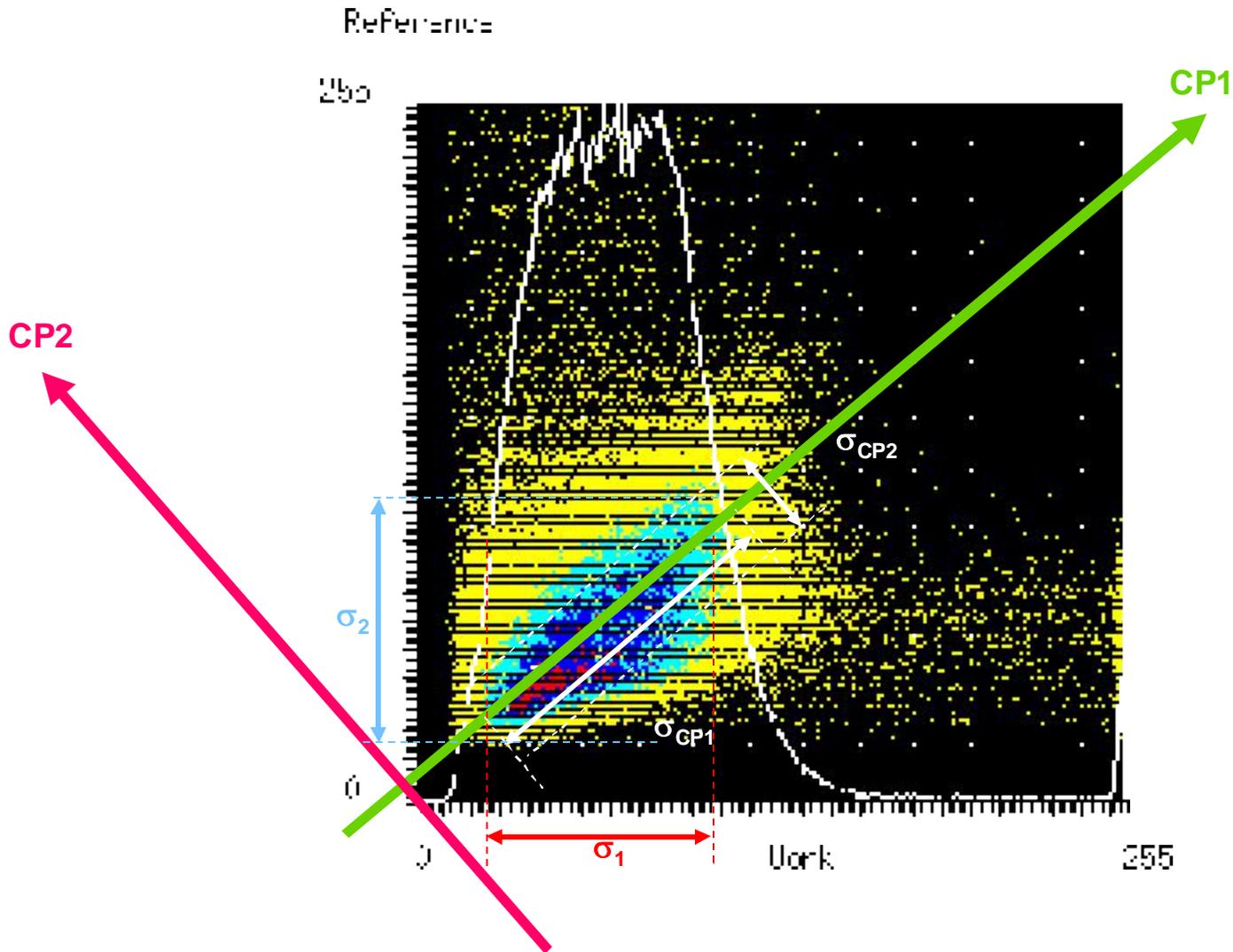
✦ Analyse en composantes principales

histogramme bidimensionnel



$$r2 \approx A \times r1 + B$$

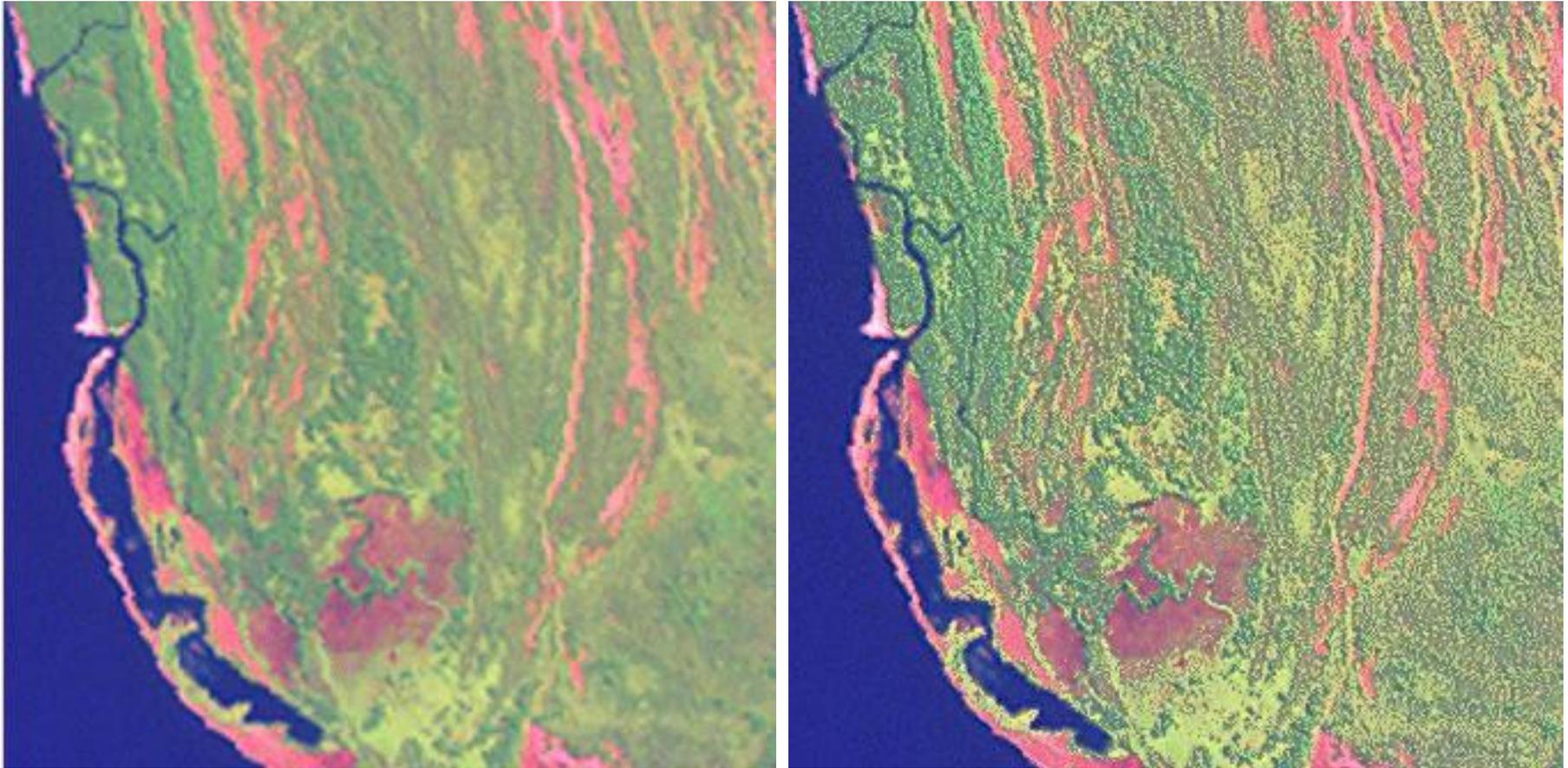






✦ Fusion panchromatique / composition colorée

✦ PAN-sharpening



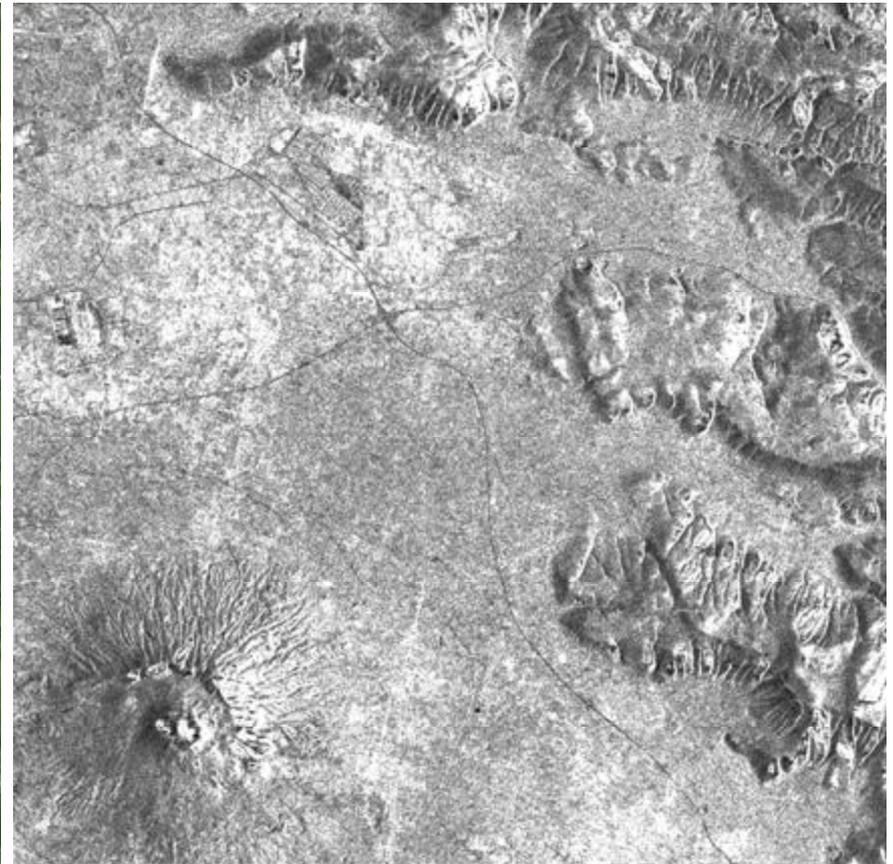
Landsat-7 ETM+ - Scène 31/07/2001 – Presqu'île Mandji (Gabon)

✚ Fusion panchromatique / composition colorée

✚ Radar + Optique

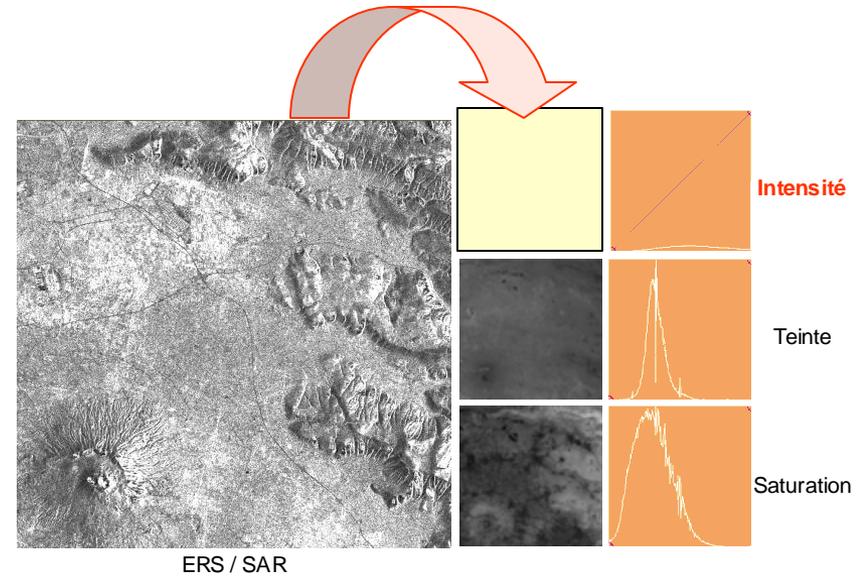
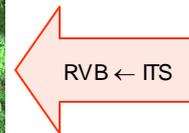
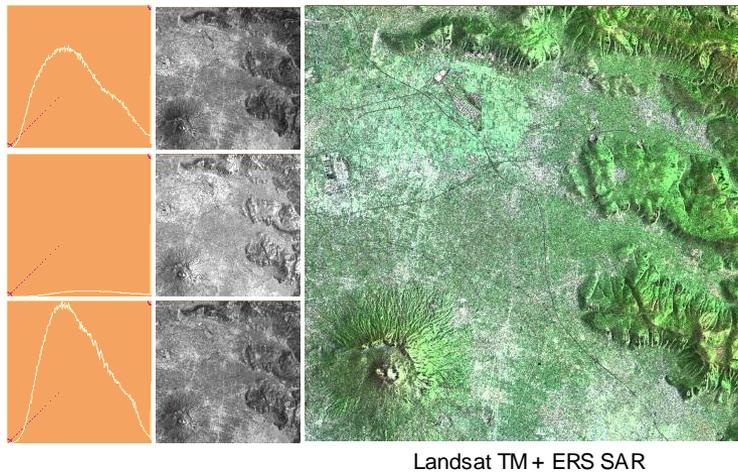
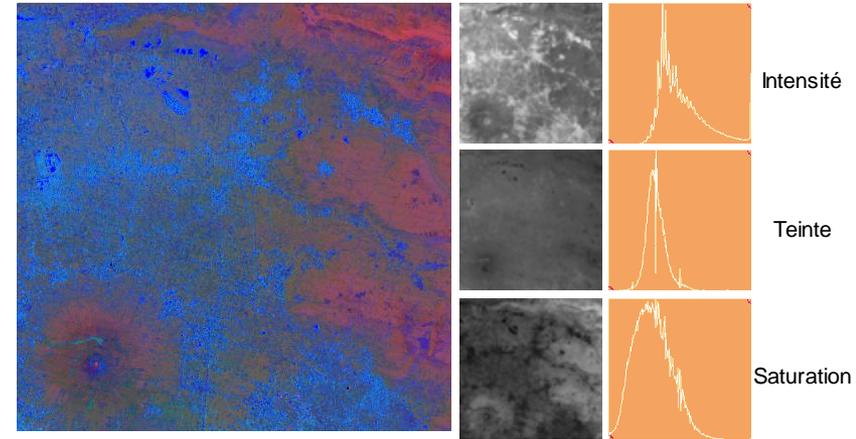
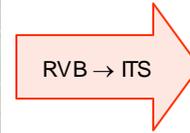
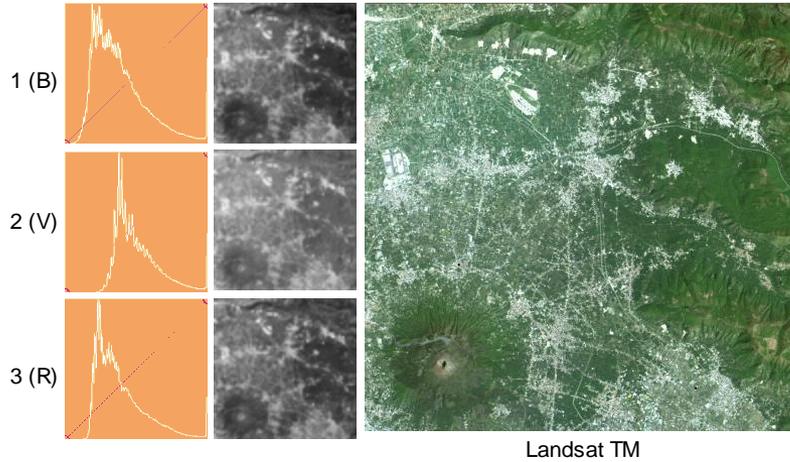


Landsat TM



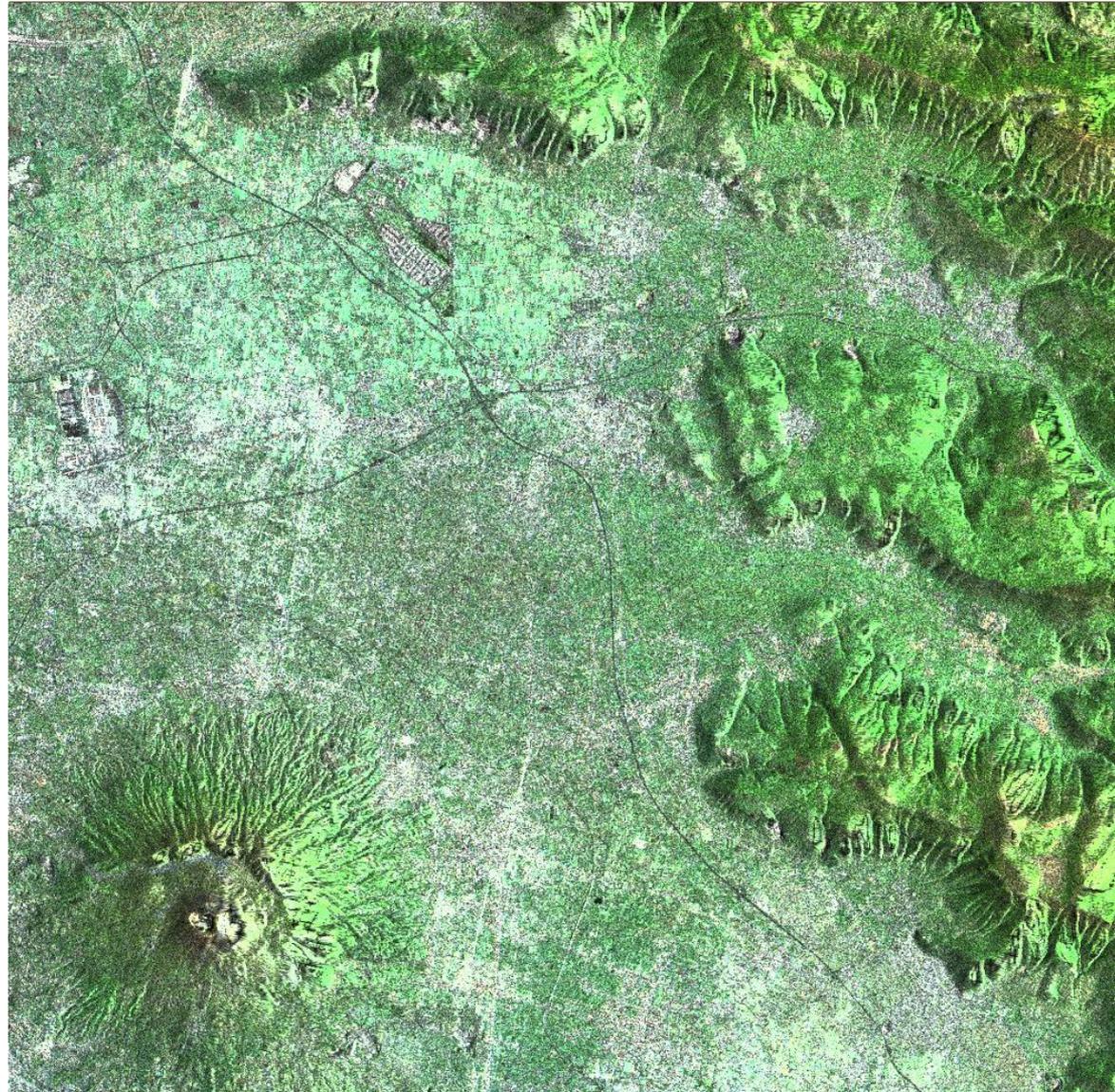
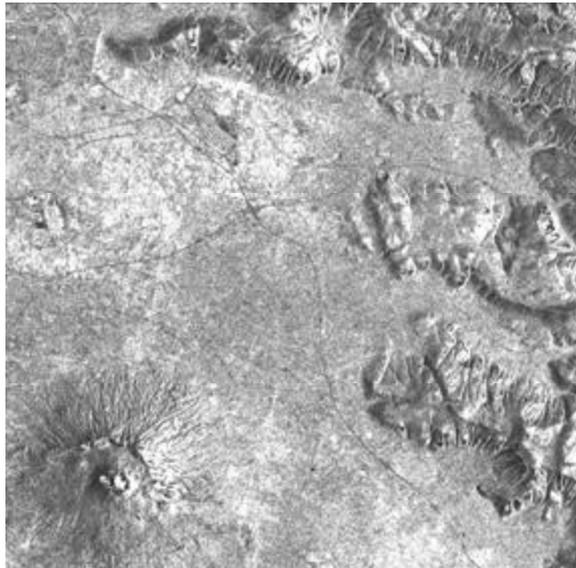
ERS / SAR

❖ RVB ↔ ITS - Principe



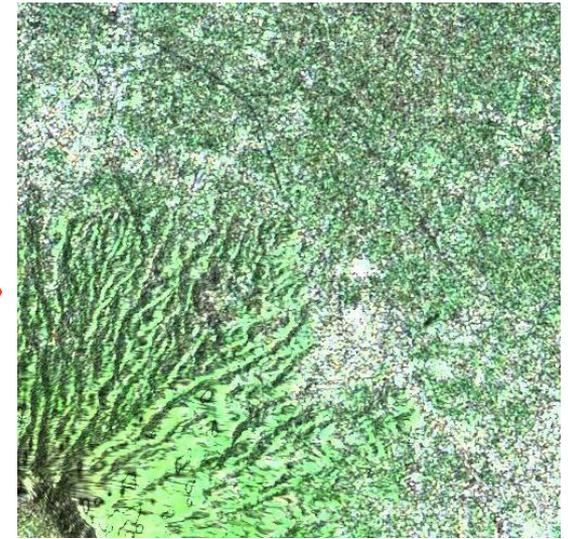
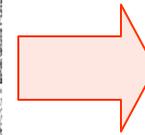
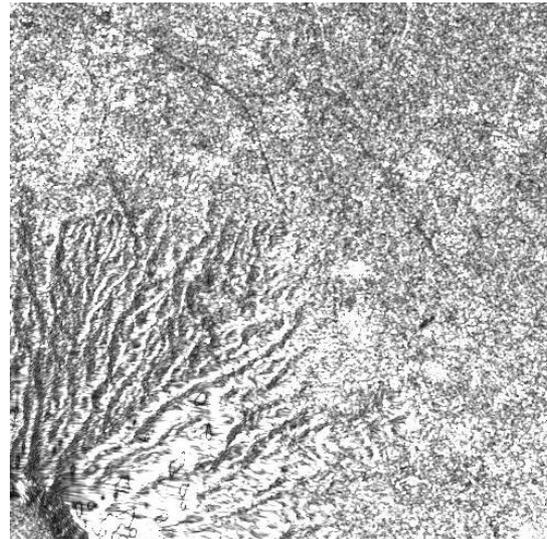
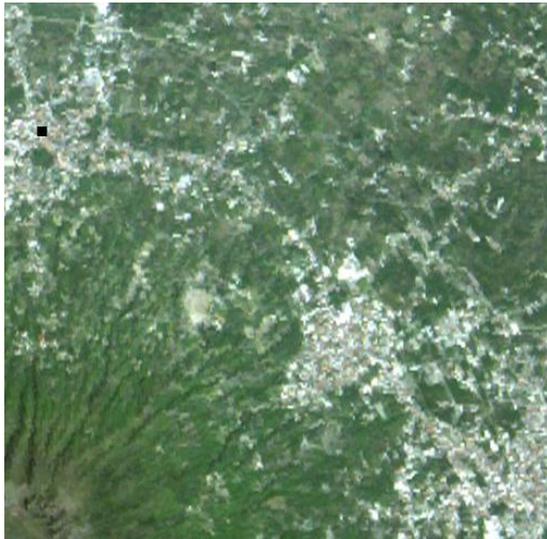
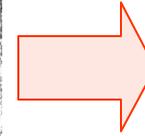
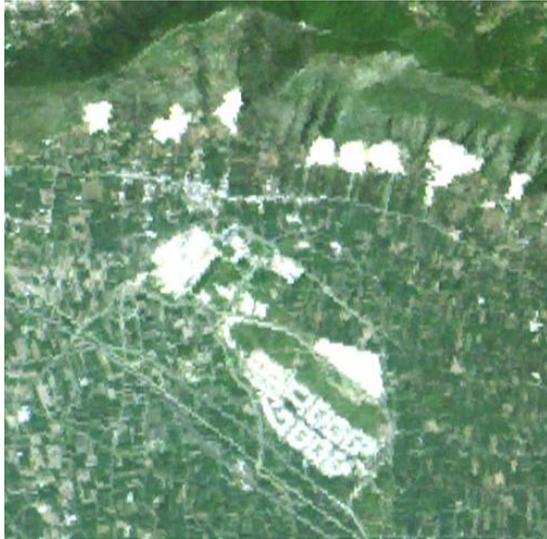


❖ **RVB** ↔ **ITS** – Résultats – Image globale





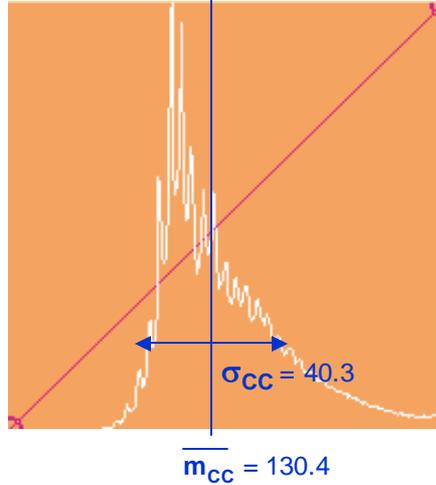
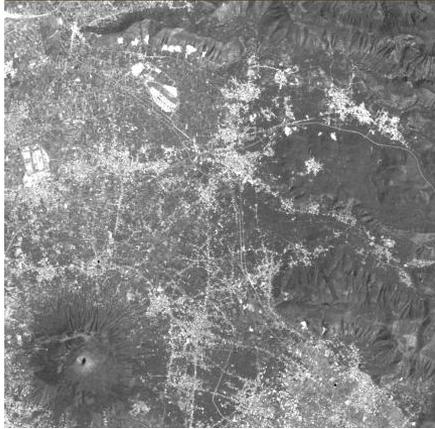
❖ **RVB** ↔ **ITS** – Résultats – Imagettes locales



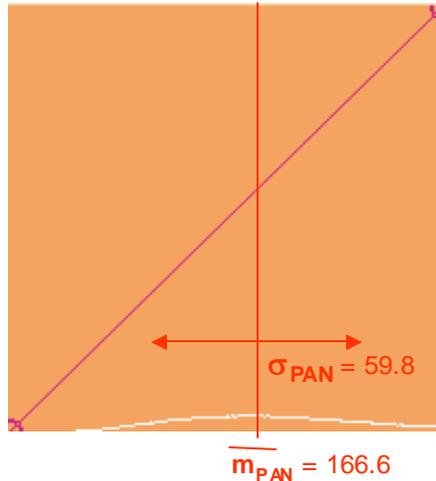
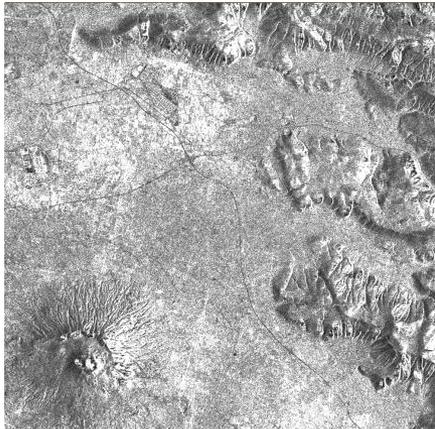


RVB ↔ ITS – Adaptation des distributions

i_{CC} : Intensité de la composition colorée



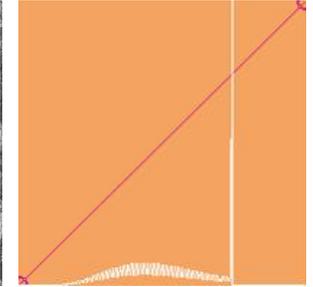
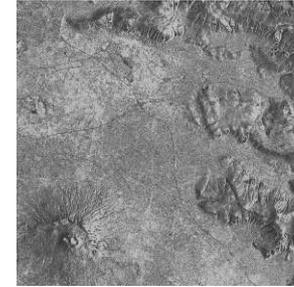
i_{PAN} : Intensité de l'image panchromatique



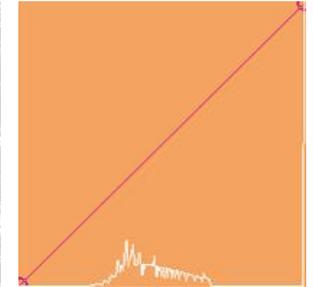
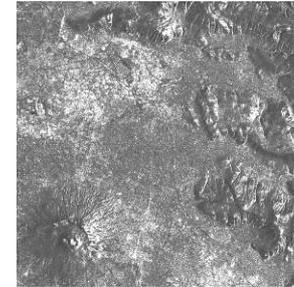
Solutions

1. Adaptation de la moyenne et de l'écart-type (régression linéaire)

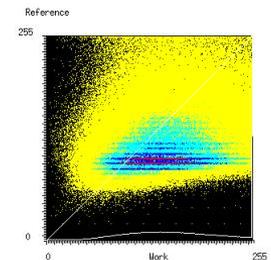
$$i'_{PAN} = \overline{m_{CC}} + \frac{\sigma_{CC}}{\sigma_{PAN}} \times (i_{PAN} - \overline{m_{PAN}}) = \frac{\sigma_{CC}}{\sigma_{PAN}} \times i_{PAN} + \left(\overline{m_{CC}} - \frac{\sigma_{CC}}{\sigma_{PAN}} \times \overline{m_{PAN}} \right)$$



2. Adaptation globale de l'histogramme selon le modèle i_{CC}



3. Adaptation point-par-point dans l'histogramme bi-dimensionnel

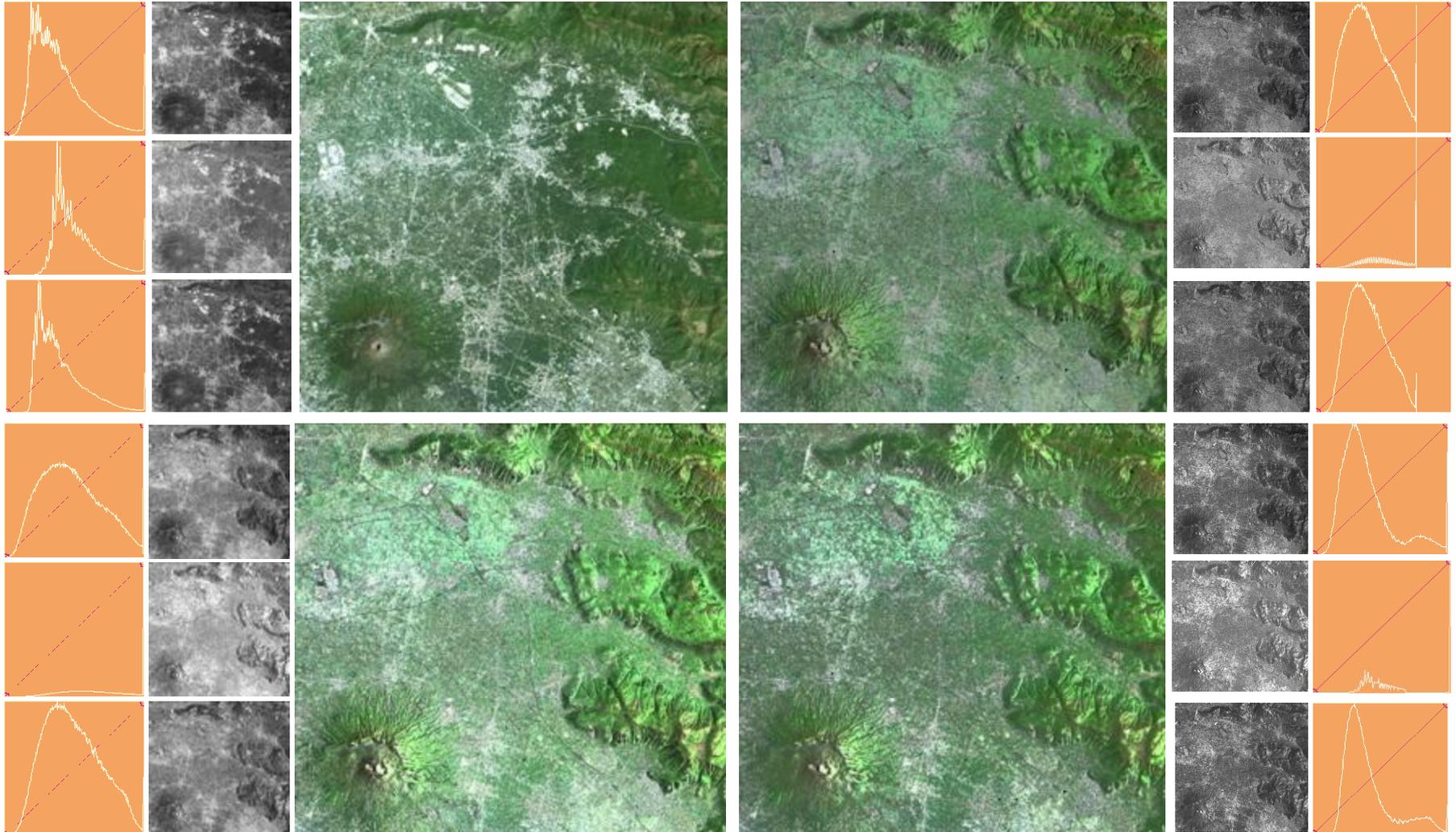




❖ **RVB** ↔ **ITS** - Résultats de l'adaptation du panchromatique sur l'intensité

Landsat TM

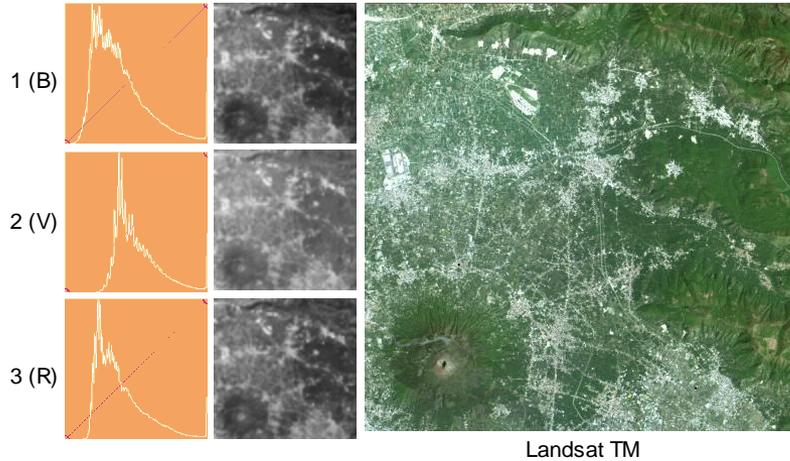
Adaptation de moyenne et écart-type



Sans adaptation

Adaptation d'histogramme

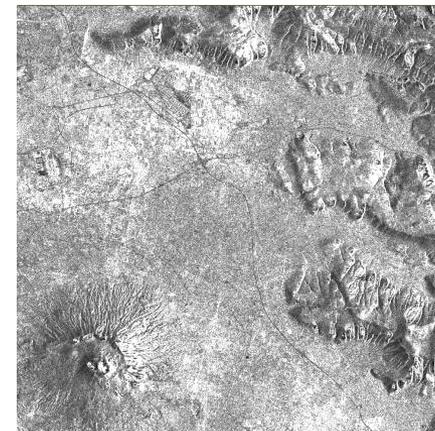
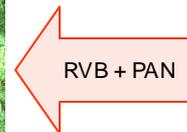
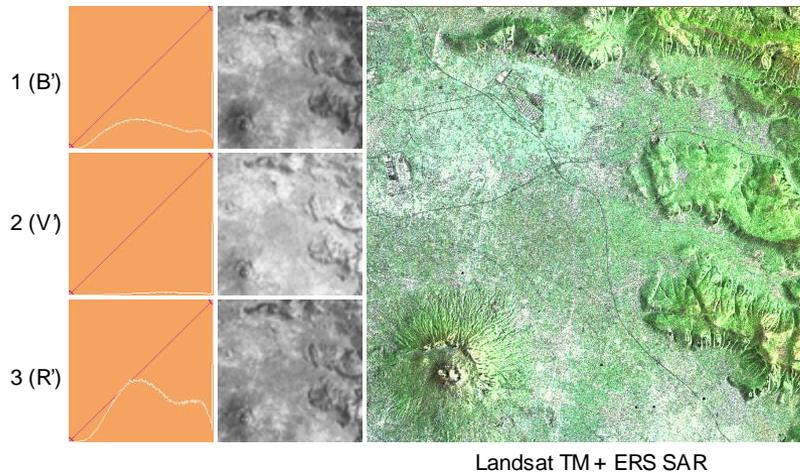
❖ BROVEY - Principe



$$B' = \frac{B}{(B + V + R)} \times PAN$$

$$V' = \frac{V}{(B + V + R)} \times PAN$$

$$R' = \frac{R}{(B + V + R)} \times PAN$$



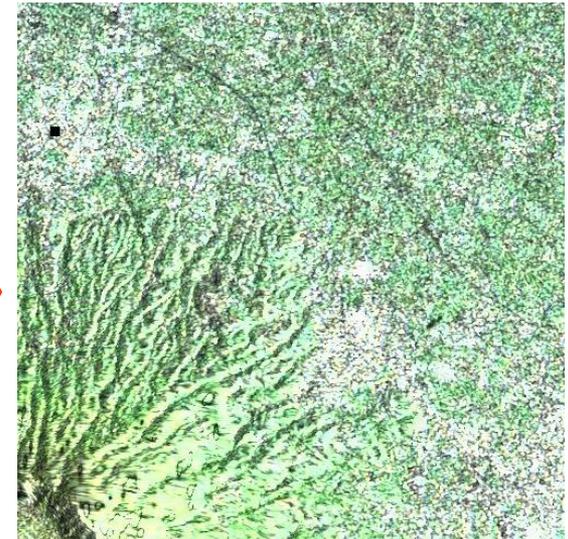
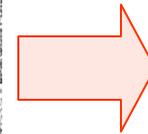
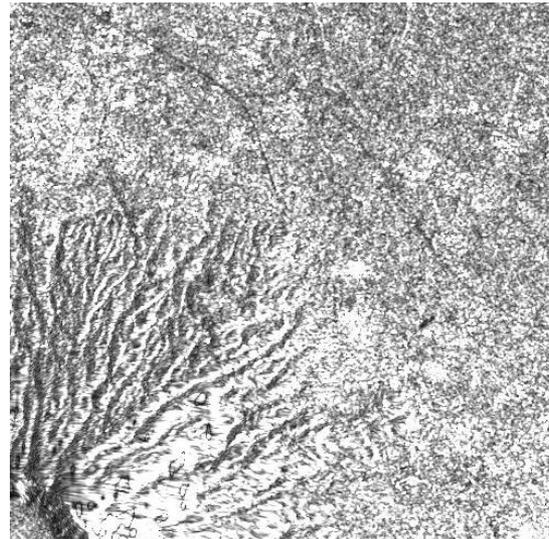
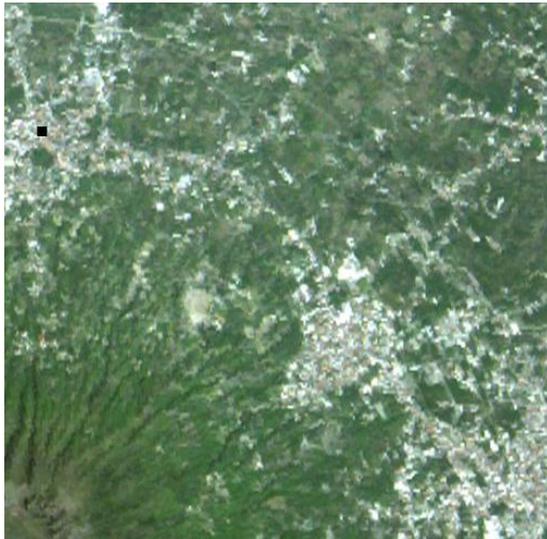
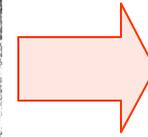
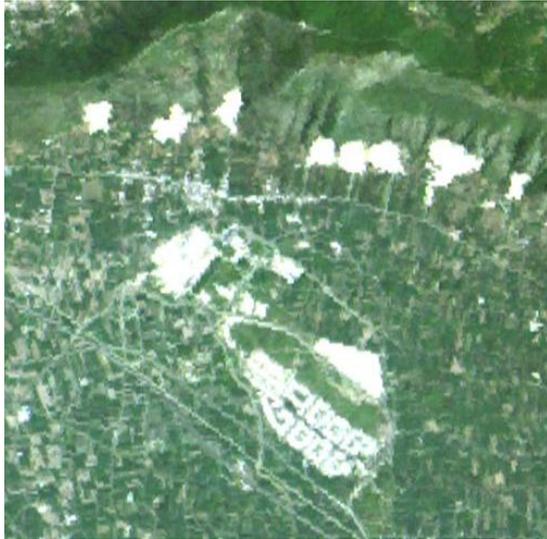


❖ BROVEY– Résultats – Image globale

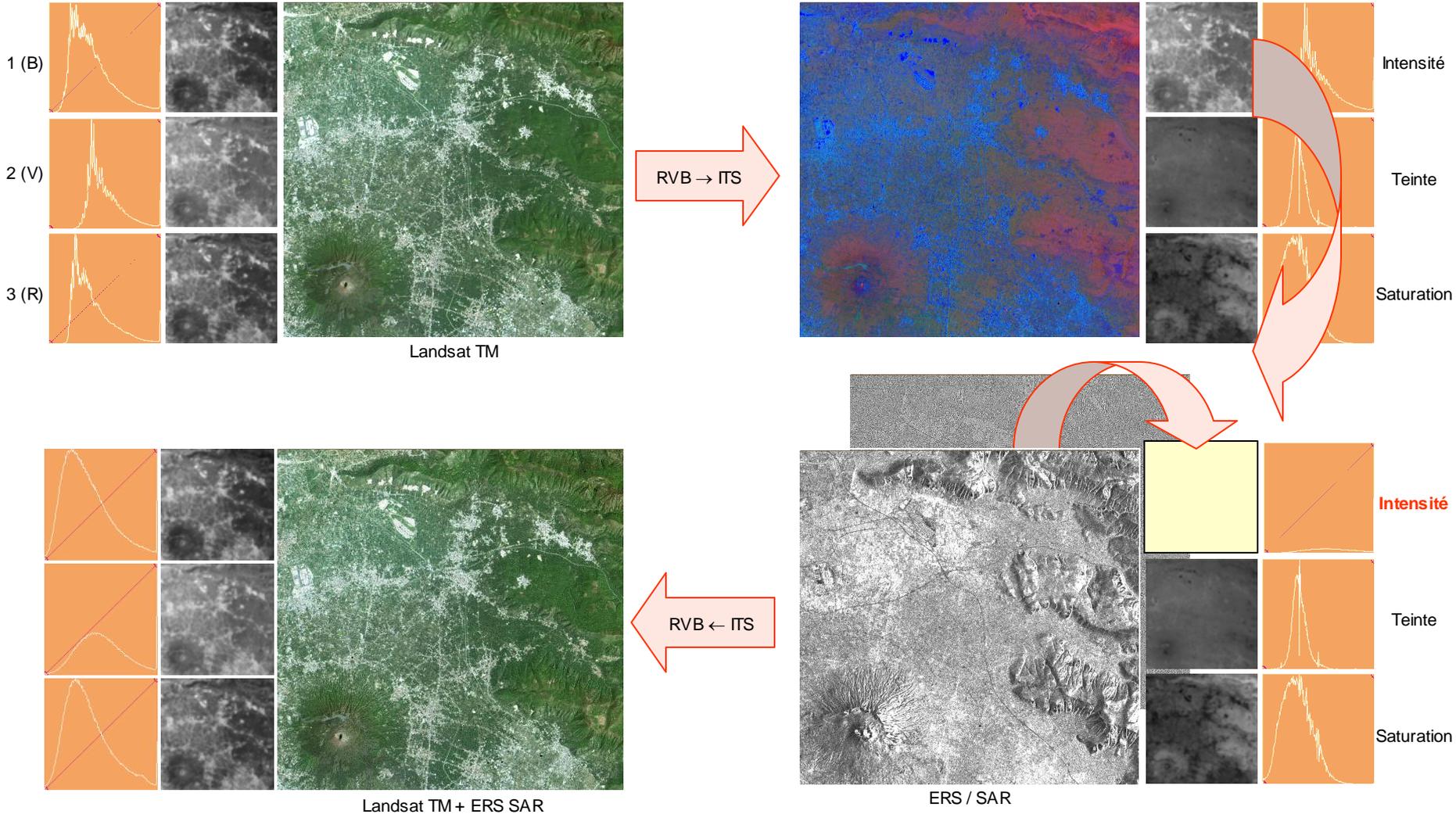




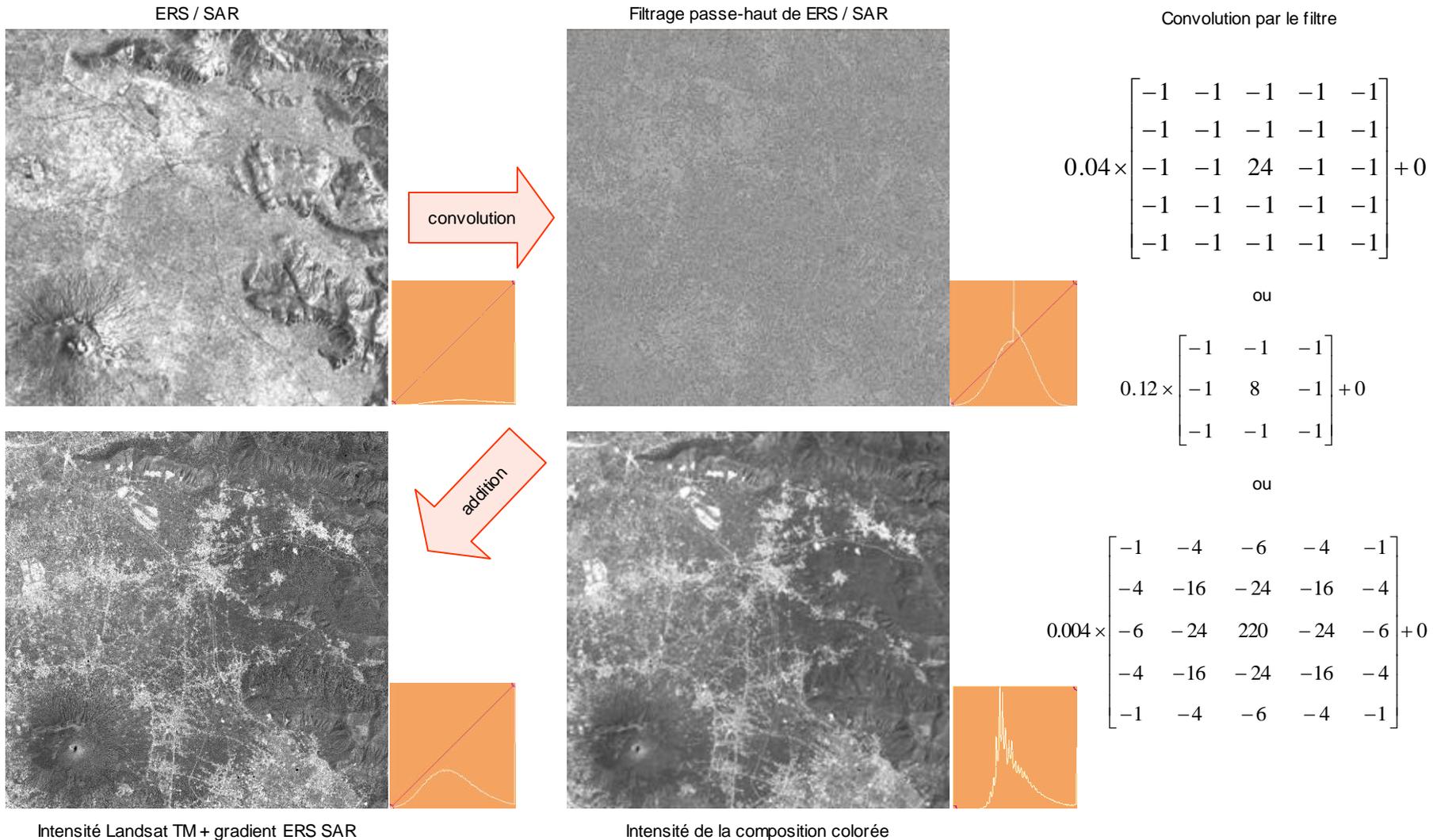
❖ BROVEY – Résultats – Imagettes locales



❖ HPF « High Pass filter » - Principe

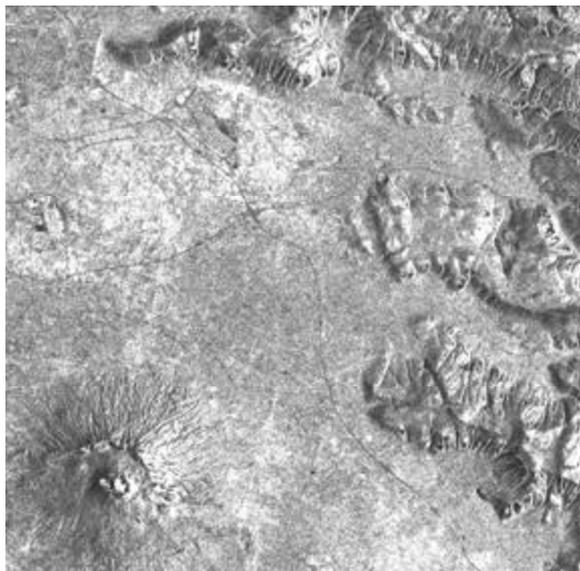


❖ HPF – Convolution par un filtre passe-haut et addition à l'intensité



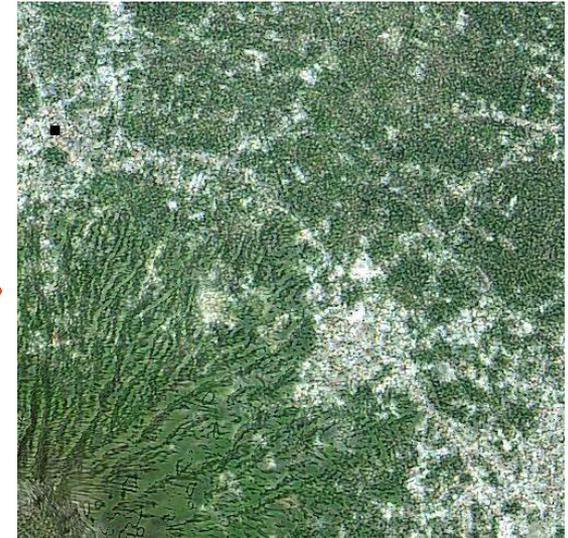
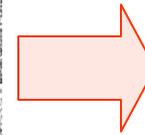
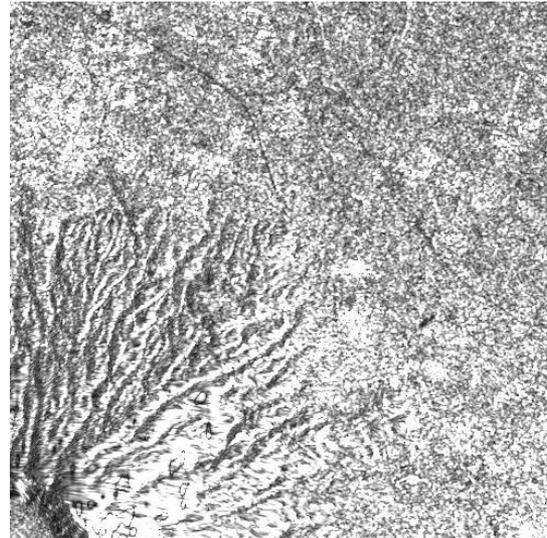
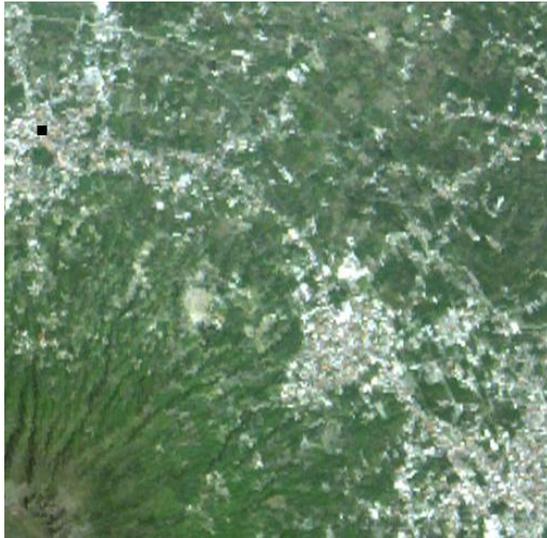
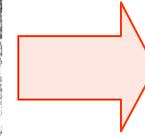
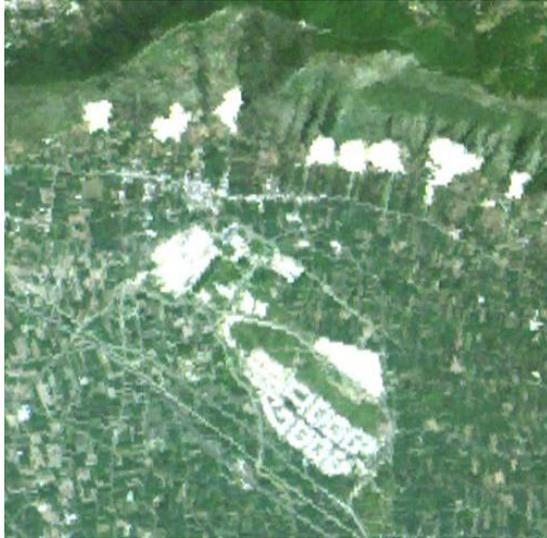


❖ HPF – Résultats – Image globale

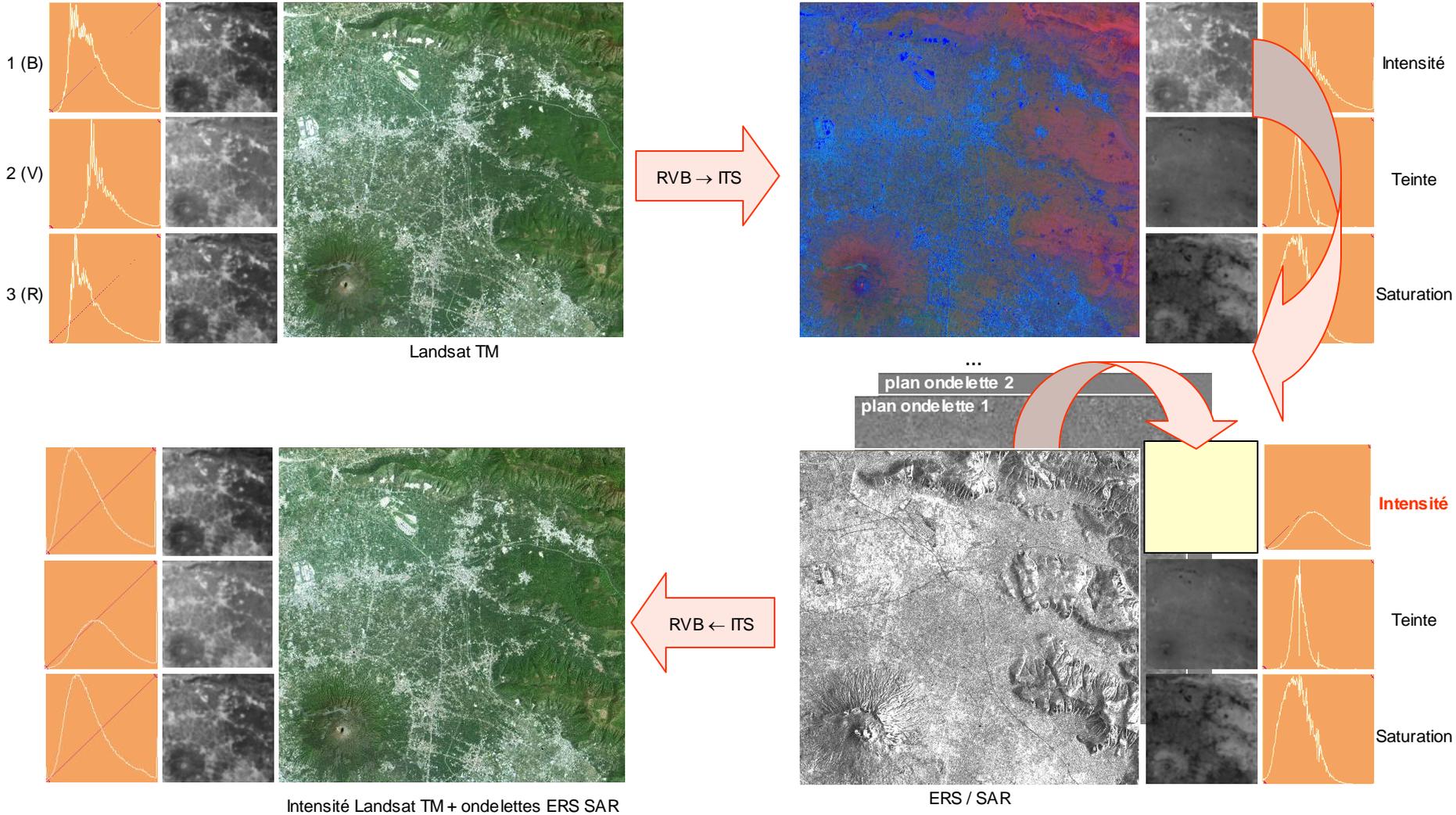




❖ HPF – Résultats – Imagettes locales



❖ **AWI** (*Additive Wavelet on Intensity*) - Principe



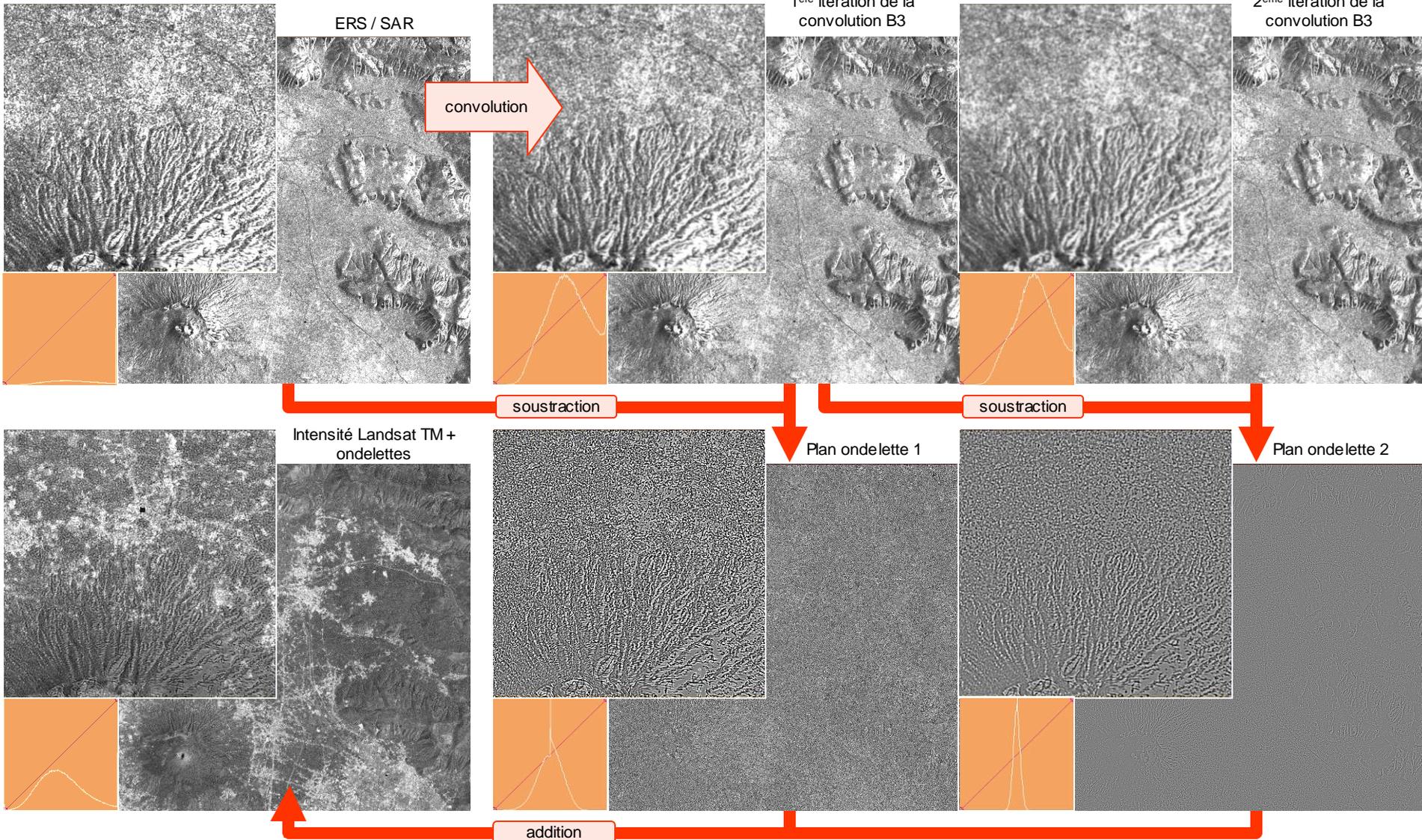


AWI – convolution et addition des ondelettes

« Spline cubique B3 » $\frac{1}{256} \times$

1	4	6	4	1
4	16	24	16	4
6	24	36	24	6
4	16	24	16	4
1	4	6	4	1

+0



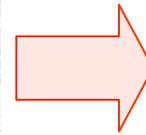
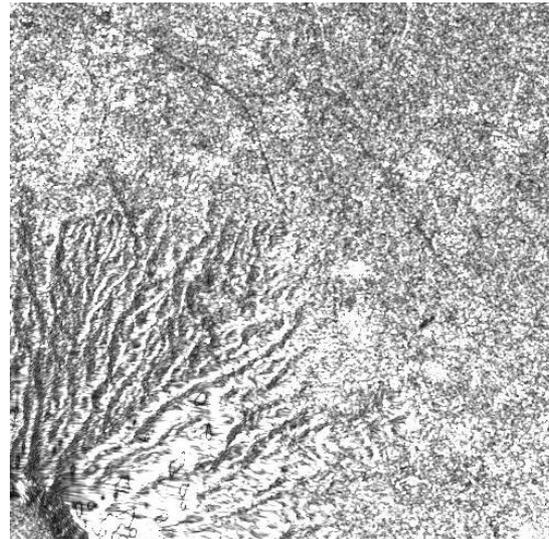
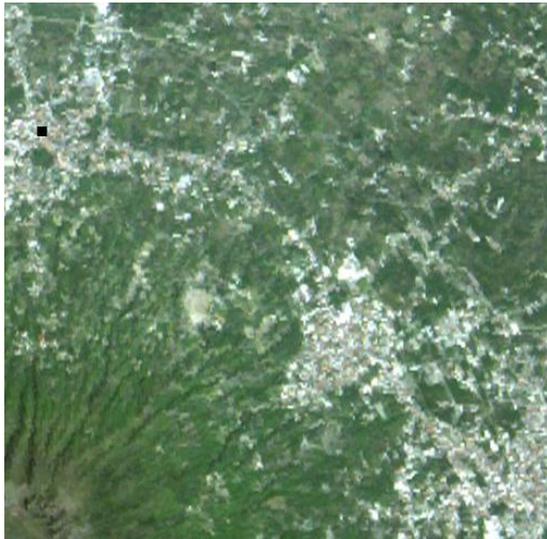
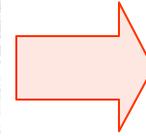


❖ **AWI**– Résultats – Image globale

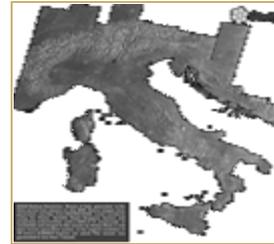
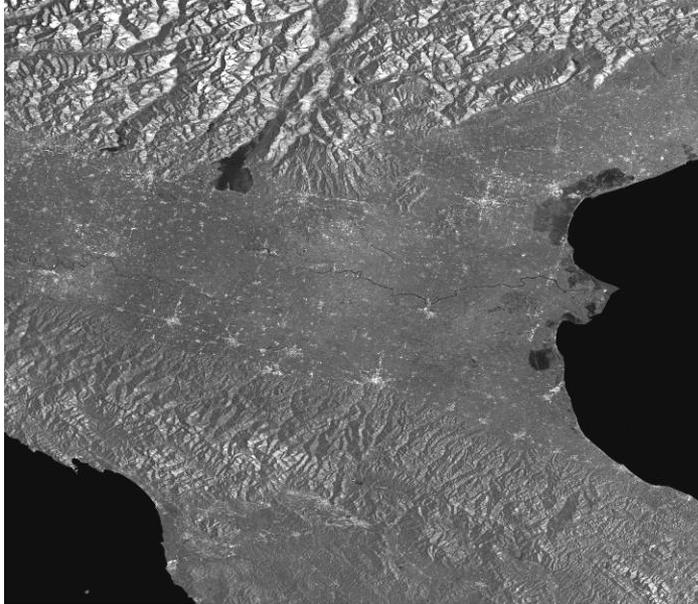




❖ **AWI** – Résultats – Imagettes locales



❖ SAR-sharpening



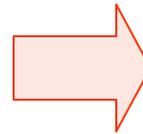
Envisat / ASAR
acquis entre janvier
et juillet 2009



Envisat / MERIS
acquis entre avril et
novembre 2008

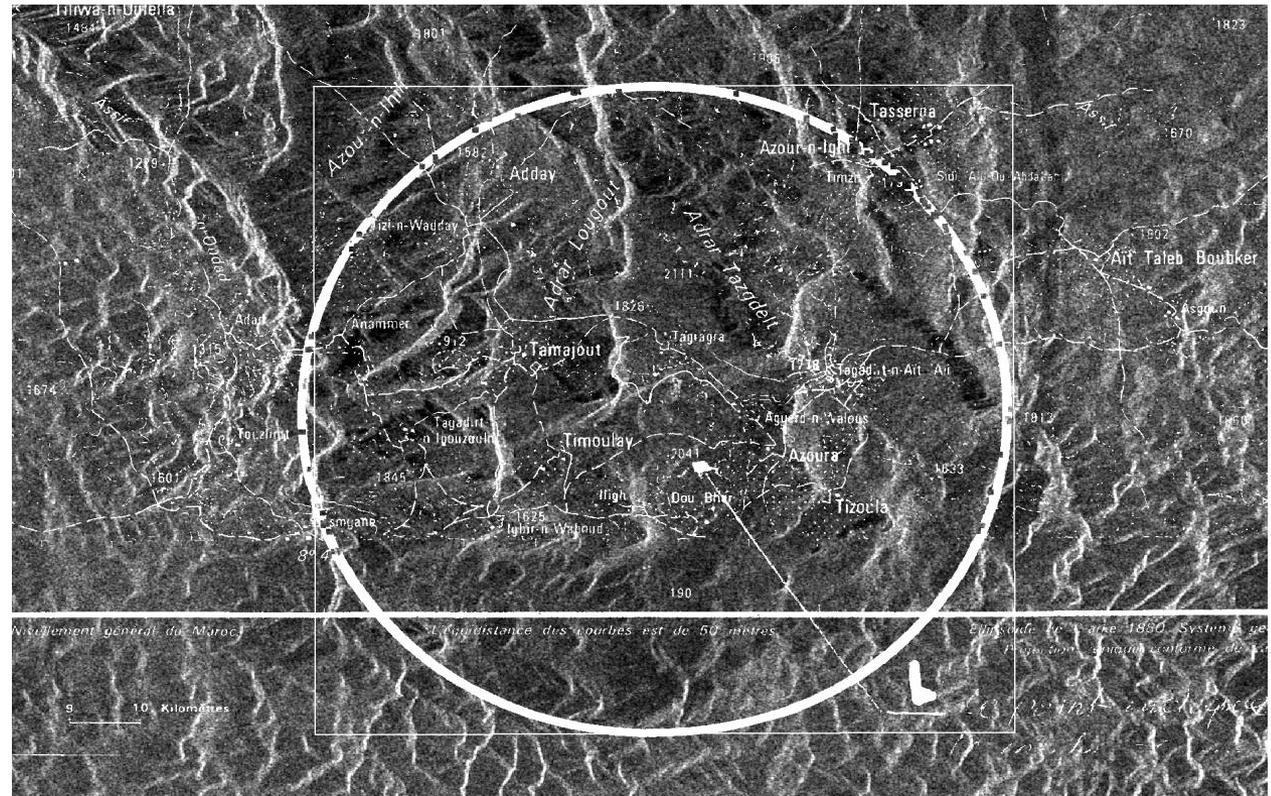
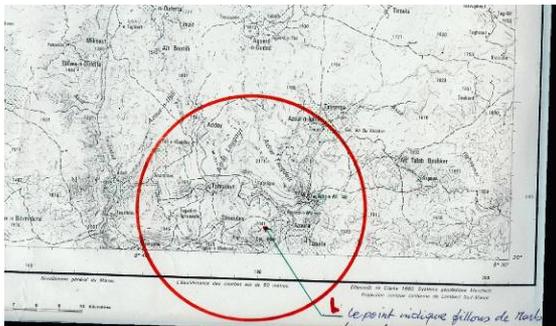
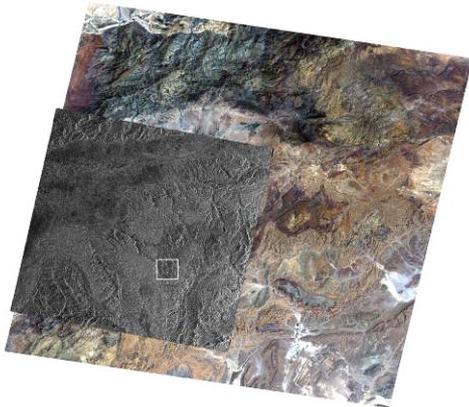
Production CHELYS

http://www.eosnap.com/?page_id=2668



✚ Superposition

- ✚ Transparence ou background





❖ Tamis ou somme pondérée



❖ Animations



Landsat MSS 29/01/1976

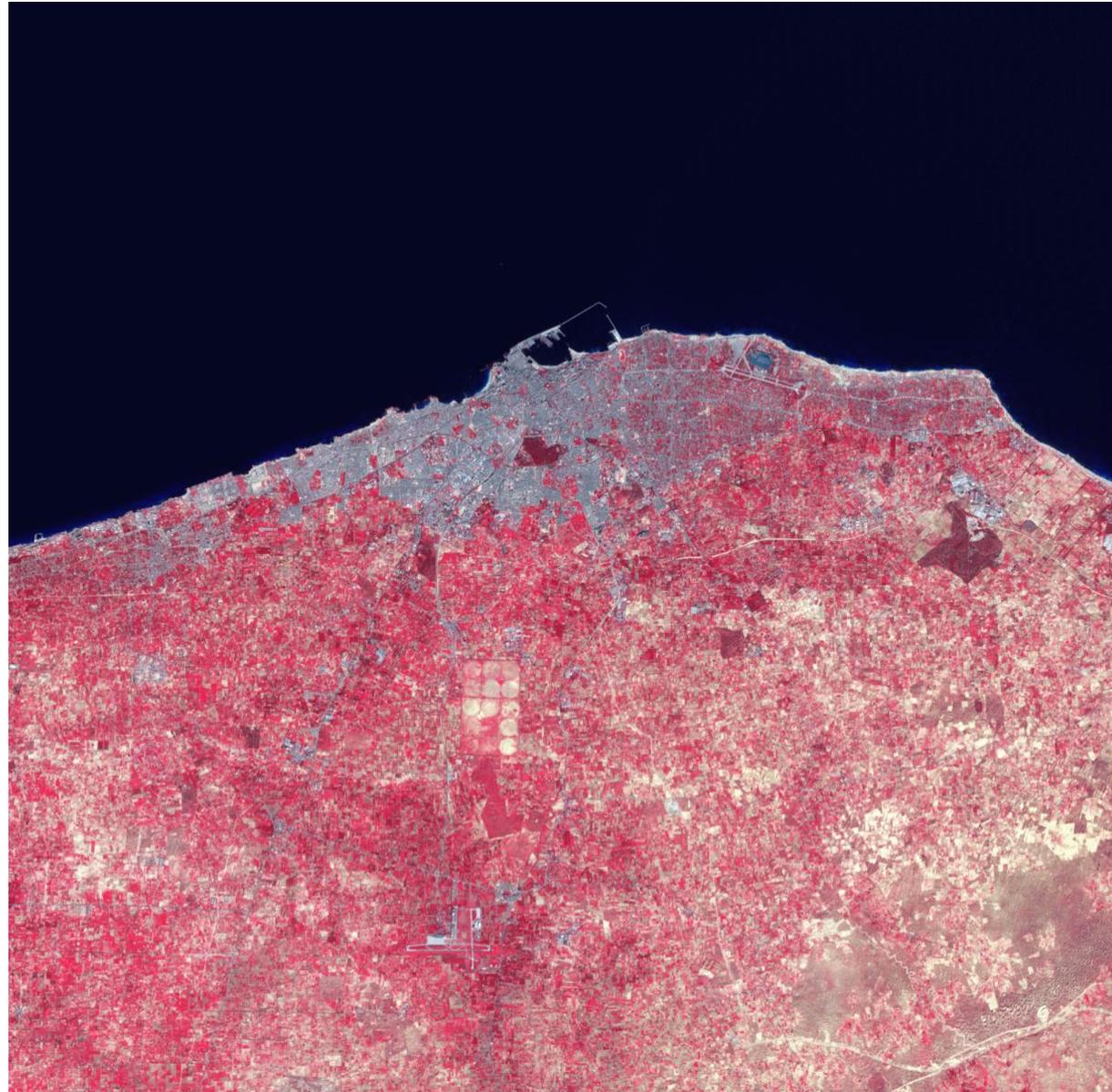


Landsat ETM+ 12/01/2002

Tripoli (Libye)

<http://earthobservatory.nasa.gov/IOTD/view.php?id=35836>

<http://www-igm.univ-mlv.fr/~riazano/>
version 1.9



Serge RIAZANOFF
Fusion des Données Hétérogènes



✚ Références

- ✚ Liens externes
- ✚ Bibliographie





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- ❖ CNES [2007] – « *PREVIEW – Earth observation satellites and sensors for risk management* » - http://www.space-risks.com/SpaceData/index.php?id_page=5.
- ❖ KRAMER [2002] – « *Observation of the Earth and its Environment* » - 4th edition – Springer Verlag
- ❖ I-SPACE [2005] - « *Imagerie satellitaire et Infrastructure de transport* » – Rapport de Groupe de Travail.