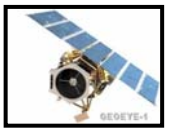
Generation of very high resolution georeferenced data from GeoEye-1 and WorldView-2 commercial satellite imagery. Applications.

Manuel Ángel Aguilar

Senior Lecturer , Department of Engineering, University of Almeria, Spain

Research Group: Integrated Land Management and Spatial Information Technologies

http:// www.ual.es/personal/maguilar



Thanks to the Research Projects:

"Generation of very high resolution georeferenced data from GeoEye-1 and WorldView-2 satellite imagery"
(CTM2010-16573, 2010-13)
http://www.ual.es/Proyectos/GEOEYE1WV2/

"Integration and analysis of multi-date and multi-source geospatial data for the monitoring and modeling of coastal areas"
(RNM-3575, 2009-12)
http://www.ual.es/GruposInv/ProyectoCostas/index.htm

Università degli Studi di Perugia

Introduction

1.- What are VHR commercial satellites?. Present and future.

2.- How to purchase VHR satellite images and prices list.

Basic products

3.- Orthoimages, the star product from VHR satellites.

4.- DSM and DEM generation from VHR stereo pairs.

Applications based on our research group experiences

5.- Applications. Classification in urban environments.

6.- Applications. Monitoring coastal areas.

7.- Applications. Impervious surface areas (ISAs).

8.- Applications. Greenhouses detection.

Final conclusions

9.- Conclusions.

1.- Commercial Very High Resolution (VHR) satellites

In 1900, the magazine Ladies Home Journal published an article making predictions for the next century saying:

"Flying machines will carry powerful telescopes that beam back to Earth photographs as distinct and large as if taken from across the street".

1.- Commercial Very High Resolution (VHR) satellites

Satellite	Country	Launched	Res. PAN (m)	Res. MS (m)	Swath (km)
IKONOS	US	09/24/99	1.0	4	11
QuickBird-2	US	10/18/01	0.61	2.44	16
EROS B1	Israel	04/25/06	0.7		7
Resurs DK-1	Russia	06/15/06	1.0	3	28
KOMPSAT-2	Korea	07/28/06	1.0	4	15
IRS Cartosat 2	India	01/10/07	0.8		10
WorldView -1	US	09/18/07	0.5		16
GeoEye-1	US	06/09/08	0.41*	1.64*	15
WorldView -2	US	08/10/09	0.46*	1.84*	16
Pleiades-1	France	16/12/2011	0.7	2.8	20
Pleiades-2	France	2/12/2012	0.7	2.8	20
KOMPSAT-3	Korea	17/5/2012	0.7	3.8	15
WorldView -3	US	¿2014?	0.31*	1.24*	16

* Down-sampled to 0.5 m and 2 m in PAN and MS respectively as a requirement of U.S.

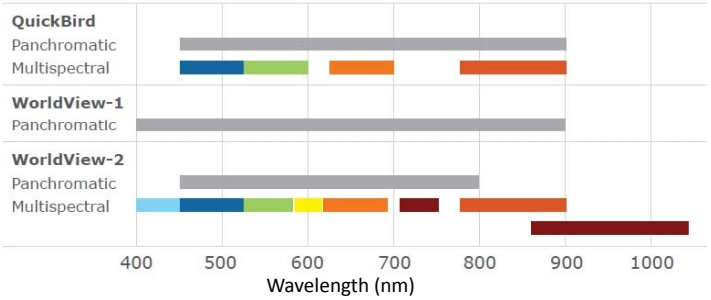
1.- Commercial Very High Resolution (VHR) satellites

Geometric Resolution

GE1 PAN 0.5 m GSD MS 2 m GSD Pan-sharpened 0.5 m GSD

WV2 Pan-sharpened 0.5 m GSD (70 m X 70 m)

1.- Commercial Very High Resolution (VHR) satellites

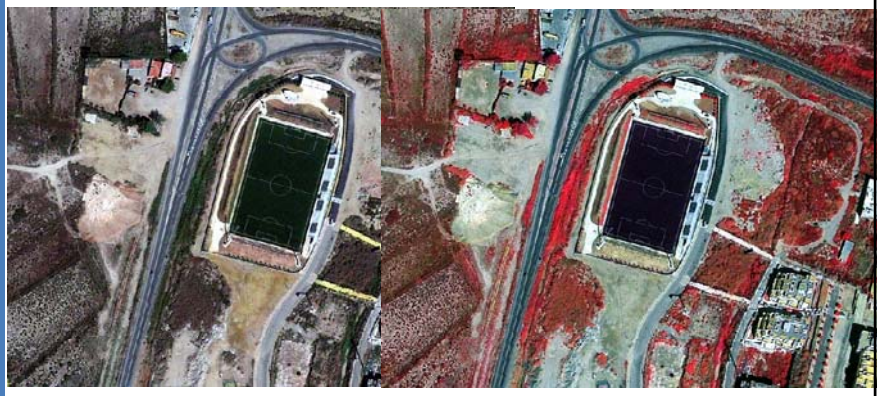


WorldView-2 is the first commercial VHR satellite to provide eight spectral bands in the visible to near-infrared range.

1.- Coastal Blue (400-450 nm)
2.- Blue (450-510 nm)
3.- Green (510-580 nm)
4.- Yellow (585-625 nm)
5.- Red (630-690 nm)
6.- Red-Edge (705-745 nm)
7.- NIR1 (770-895 nm)
8.- NIR2 (860-1040 nm)

1.- Commercial Very High Resolution (VHR) satellites

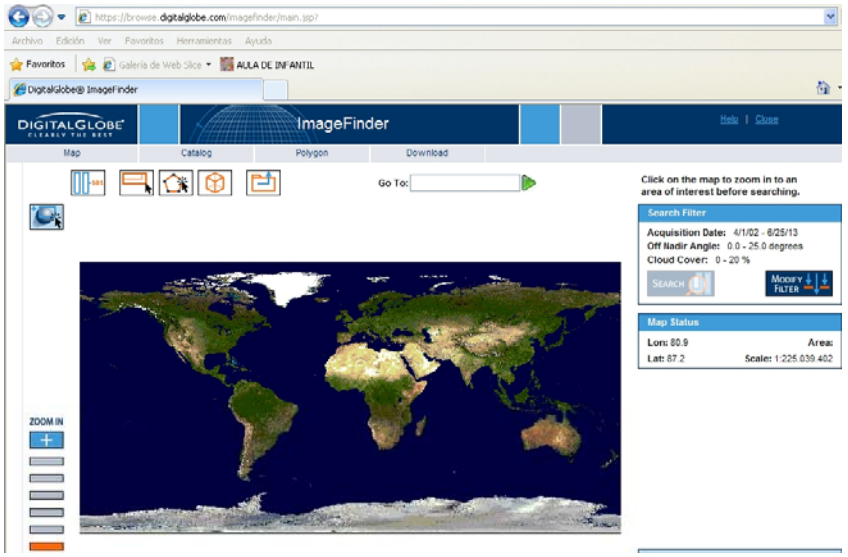
Why is so important the extra spectral information?



RGB NirRG

Pan-sharpened image GE1, Garrucha's football pitch.
Artificial or natural grass?

2.- How to purchase VHR satellite images



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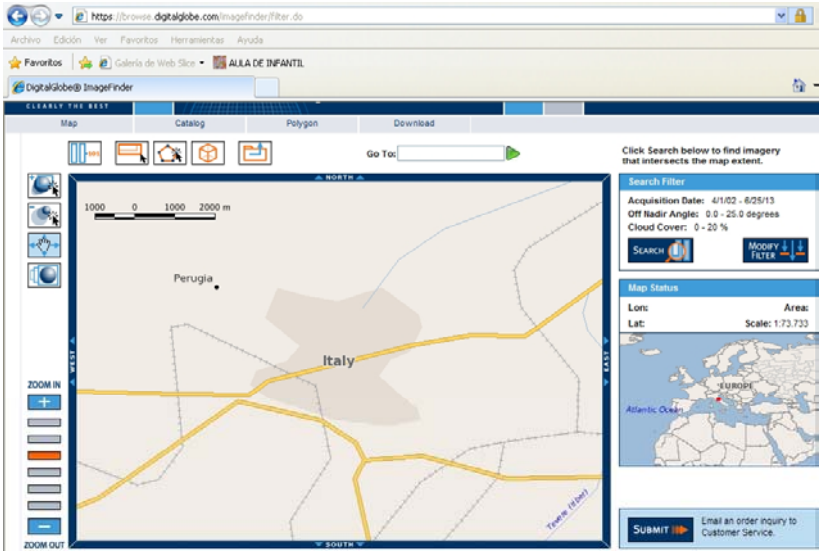

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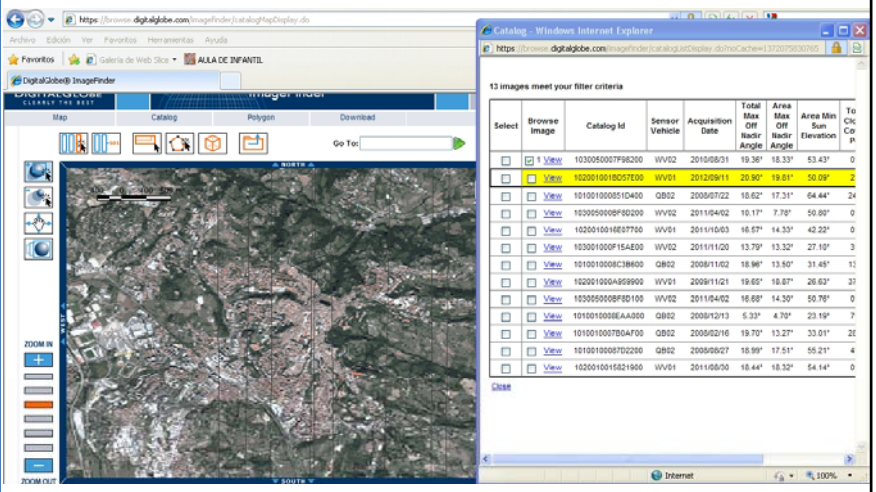

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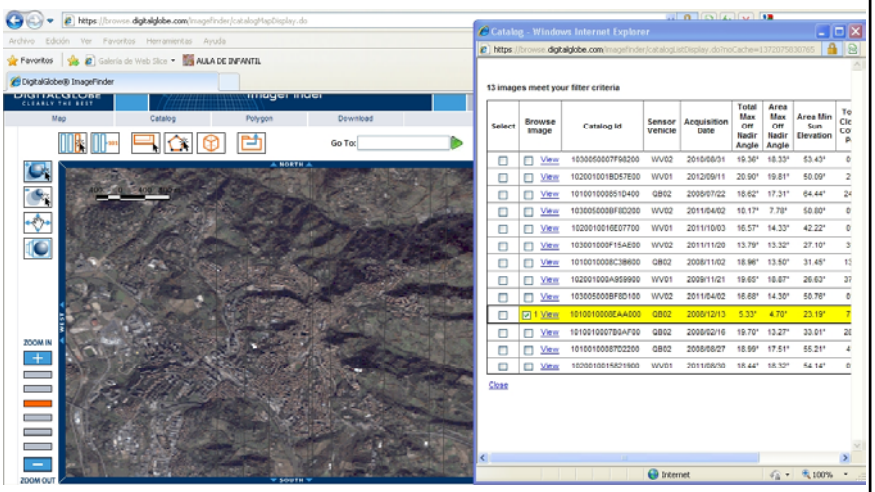

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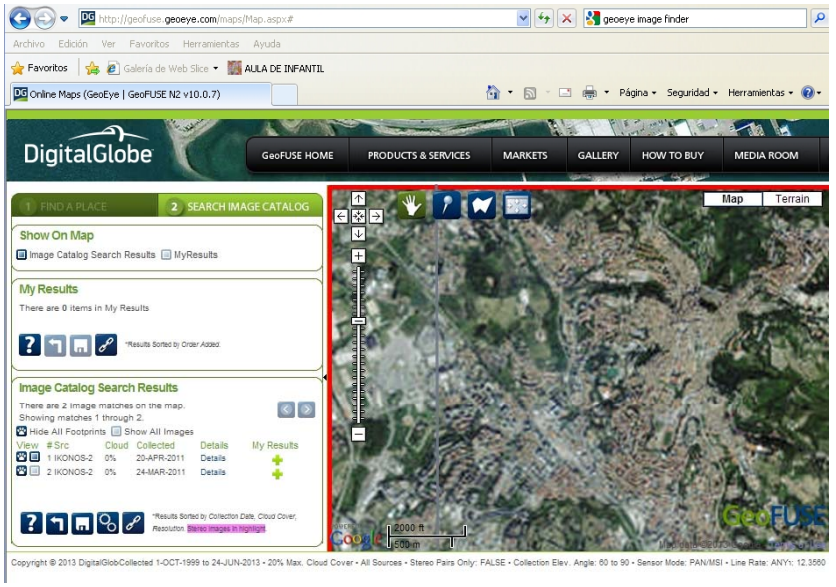

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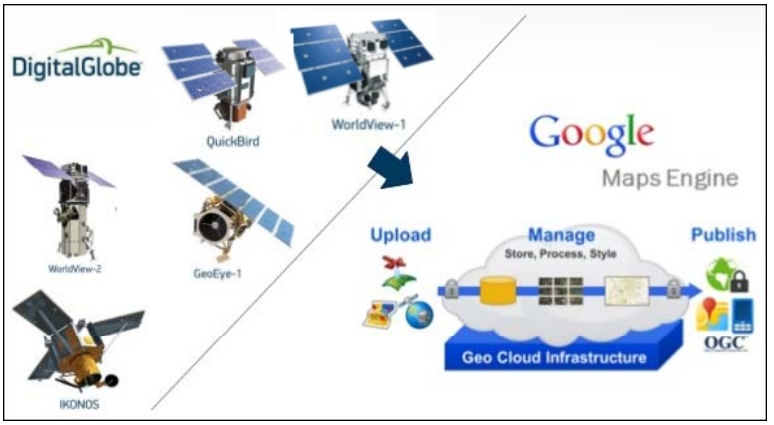

2.- How to purchase VHR satellite images

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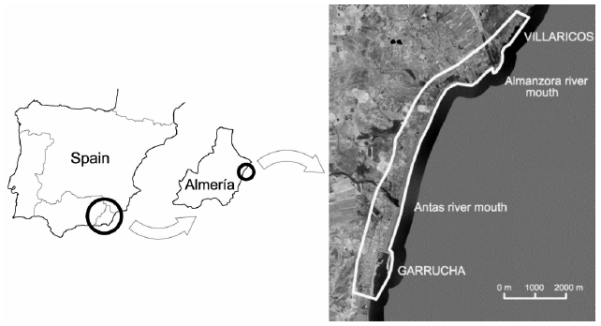
Price list: VHR (PAN and MS) in $ US/km^2

		PAN		PAN & MS		
		Archive	Tasking	Archive	Tasking	
DigitalGlobe (Basic ORS2A)	QuickBird	14	20	17	25	
	WordView-1	14	20	x	x	
	WordView-2	13	22	29	38	Orthoimage 50 1/12000
GeoEye (Geo)	IKONOS	10	20	10	20	
	GeoEye-1	13	22	16	25	

http://www.e-geos.it/products/pdf/prices.pdf

2.- How to purchase VHR satellite images

Price list: A real example on a 8.5 km^2 area



GE1 Geo

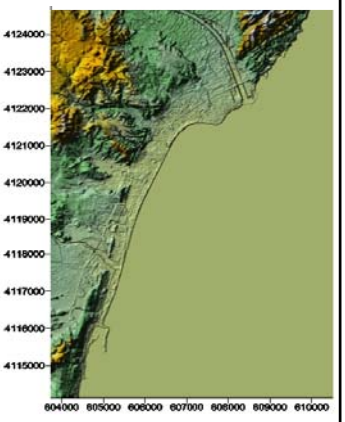
- Archive: min 25 km^2 x 16 $/km^2 = **400 $**
- Tasking : min 100 km^2 x 25 $/km^2 = **2500 $**

3.- Orthoimages, the star product from VHR satellites

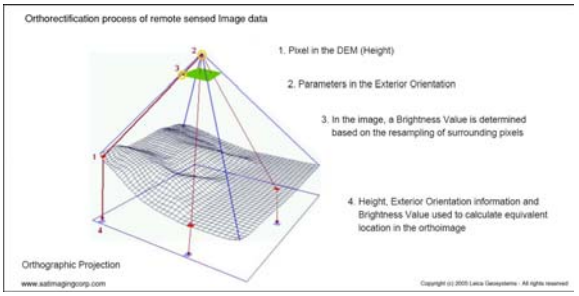
Direct geopositioning of GeoEye-1 and WorldView-2 products without GCPs is around 5 m CE90. QB or IKONOS 16 CE90.

GCPs

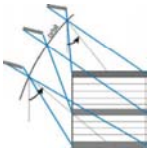
Digital Elevation Model

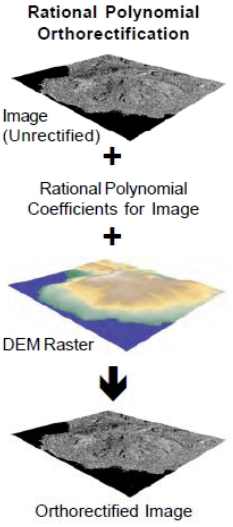


3.- Orthoimages, the star product from VHR satellites



Pushbroom satellite scanners





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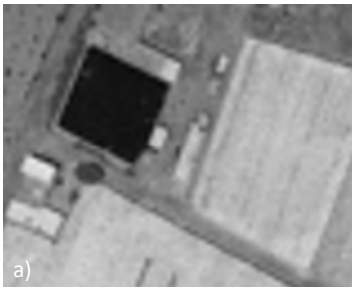
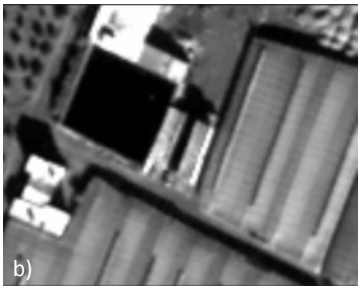




Orthoimages of 72 m per 68 m

a) Photogrammetric flight 1:20,000
Junta de Andalucía 0.5 m GSD

b) QuickBird 0.6 m GSD

c) IKONOS 1 m GSD

Aguilar *et al.* (2008). *International Journal of Remote Sensing*

3.- Orthoimages, the star product from VHR satellites

QUICKBIRD (0.6 m), 2004

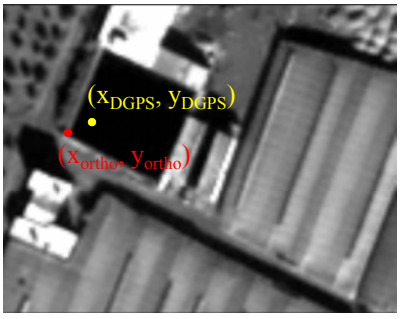
Orthoimage (0.5 m), 2008-09

Orthoimage (0.5 m), 2002

3.- Orthoimages, the star product from VHR satellites

Geometric accuracy control in orthoimages

RMSE ➔ Root Mean Square Error measured at *n* ICPs



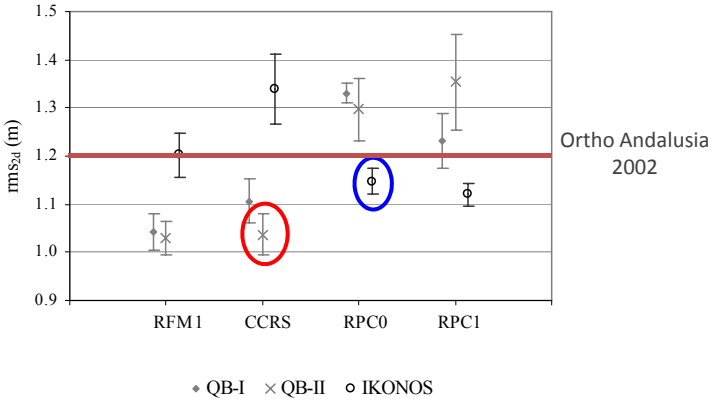
$$RMSE_x = \sqrt{\frac{\sum_{i=1}^{n}(x_{ortho_i} - x_{DGPS_i})^2}{n}}$$

$$RMSE_y = \sqrt{\frac{\sum_{i=1}^{n}(y_{ortho_i} - y_{DGPS_i})^2}{n}}$$

$$RMSE_{2d} = \sqrt{RMSE_x^2 + RMSE_y^2}$$

3.- Orthoimages, the star product from VHR satellites

Geometric accuracy QB and IKONOS orthoimages



Aguilar *et al.* (2008). *International Journal of Remote Sensing*

3.- Orthoimages, the star product from VHR satellites

$RMSE_{2D}$ Mean values computed on the orthorectified GeoEye-1 Geo and WV-2 ORS2A imagery by using RPC0 model and seven GCPs.

Image Product	Off-Nadir	Orthoimage LiDAR DEM ICPs $RMSE_{2D}$ (m)	Orthoimage Andalusia DEM ICPs $RMSE_{2D}$ (m)
		Mean	Mean
GeoEye-1 Geo	8.5°	0.404 [a]	0.546 [a]
	20.6°	0.464 [b]	0.622 [b]
	23.1°	0.501 [c]	0.689 [c]
WV-2 ORS2A	5°	0.425 [a]	0.501 [a]
	10°	0.462 [a]	0.584 [b]
	22.4°	0.632 [b]	0.951 [c]

Aguilar *et al.* (2013). *International Journal of Applied Earth Observation and Geoinformation 21 (2013) 427–435*

3.- Orthoimages, the star product from VHR satellites

Geometric accuracy. Off-nadir view angle

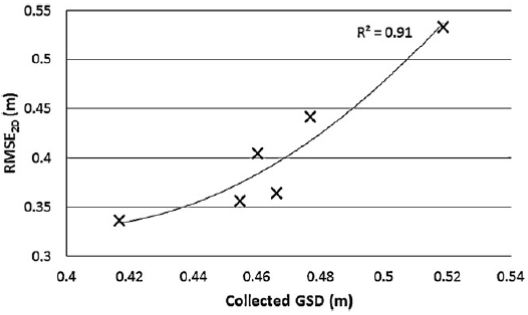
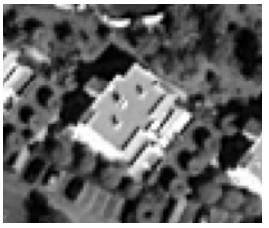


Fig. 3. Relationship between the collected GSD and the $RMSE_{2D}$ attained at the sensor orientation phase by using RPC0 for GeoEye-1 Geo and WV-2 ORS2A images.

Aguilar *et al.* (2013). *International Journal of Applied Earth Observation and Geoinformation 21 (2013) 427–435*



GE1 22 degrees

WV21 5 degrees

3.- Orthoimages, the star product from VHR satellites

American Society for Photogrammetry and Remote Sensing (ASPRS) Accuracy Standard, RMSE (X or Y)

Limiting $RMSE_{1D}$ error, meters	Typical map scale	
0.0125	1:50	
0.025	1:100	
0.050	1:200	
0.125	1:500	
0.25	1:1.000	GE1 or WV2
0.50	1:2.000	
1.00	1:4.000	IKONOS or QB
1.25	1:5.000	
2.50	1:10.000	
5.00	1:20.000	

ASPRS (1989). *PE&RS*

3.- Orthoimages, the star product from VHR satellites

The new **VHR commercial satellites** provide a tool to generate large scale orthophotos (1:1000 - 1:4000).

ADVANTAGES:

⇨ Global Coverage

⇨ High temporal resolution

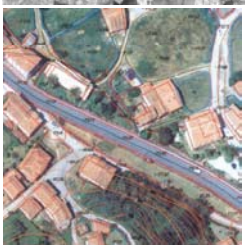
⇨ Simultaneous Data Acquisition PAN and MS

⇨ Ability to cover large areas in a single shot

⇨ Geometric and radiometric homogeneity

⇨ Speed of data processing

⇨ High accuracy orthophotos and DEM

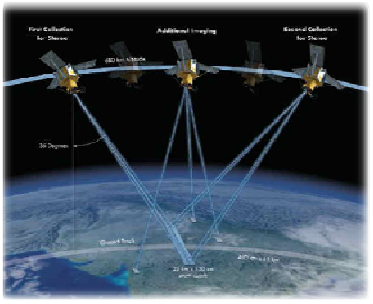


4.- DSM and DEM generation from VHR stereo pairs

Digital Elevation Model **(DEM)**

Digital Surface Model **(DSM)**

DEM ***DSM***



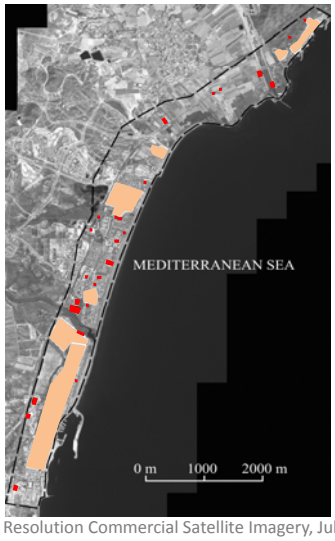
4.- DSM and DEM generation from VHR stereo pairs

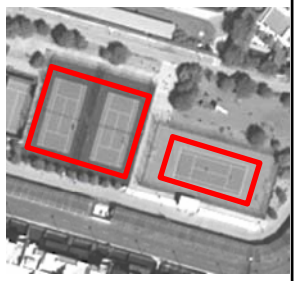
Aguilar et al., In Press. **Generation and Quality Assessment of Stereo-Extracted DSM from GeoEye-1 and WorldView-2 Imagery.**
IEEE Transactions on Geoscience and Remote Sensing. (Ranked 2 of 27: REMOTE SENSING)

Whole Area

Urban Areas

Unchanged Areas





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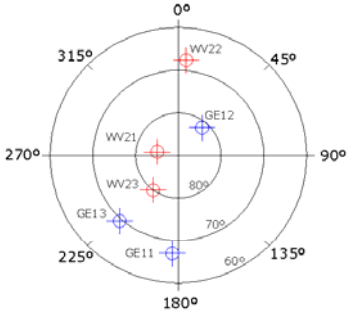
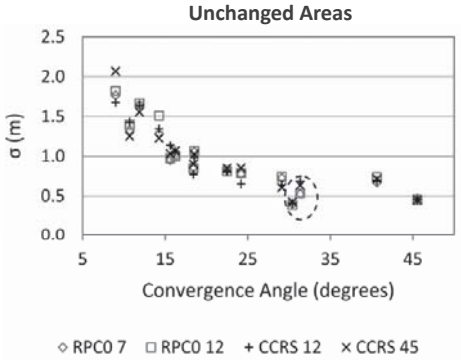




4.- DSM and DEM generation from VHR stereo pairs

Aguilar et al., In Press. IEEE TGRS

Stereo Pair	Study Area	LiDAR – VHR	
		Mean	σ
ID 1 GE1	Urban area	0.87	2.67
	Whole area	0.22	1.32
ID 2 WV2	Urban area	1.03	2.74
	Whole area	0.12	1.75

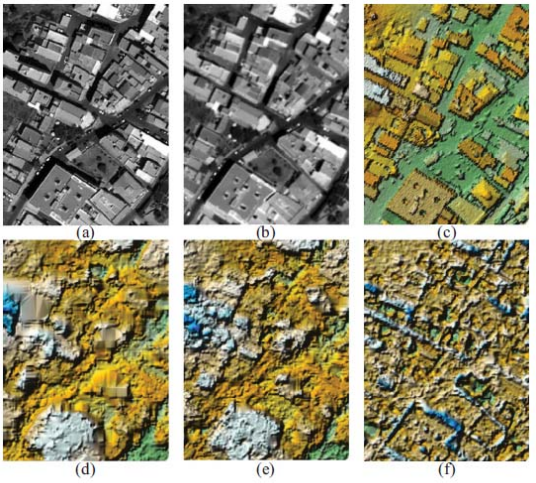
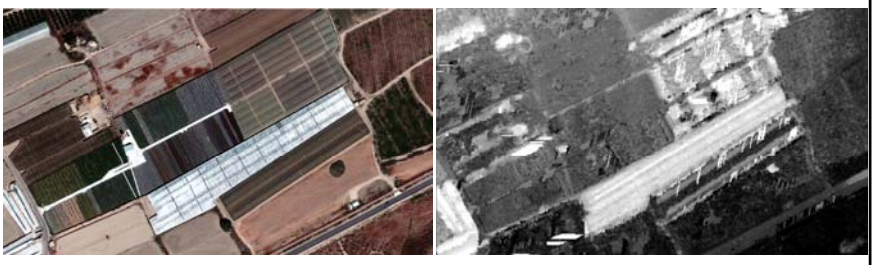


Fig. 3. Visual analysis over a limited urban area (112 × 150 m). (a) GE12 original PAN image. (b) WV23 original PAN image. (c) LiDAR-derived DSM. (d) DSM from GE12-GE13 (ID 1) stereo pair. (e) DSM from WV22-WV23 (ID 2) stereo pair. (f) vertical residuals from the comparison between LiDAR-derived DSM with WV2's DSM.

4.- DSM and DEM generation from VHR stereo pairs

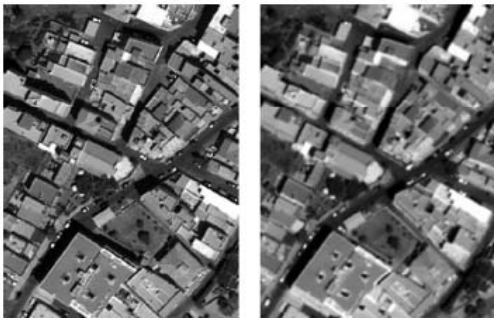


GE1 pure stereopair

WV2 pure stereopair

4.- DSM and DEM generation from VHR stereo pairs

Aguilar et al., In Press. IEEE TGRS

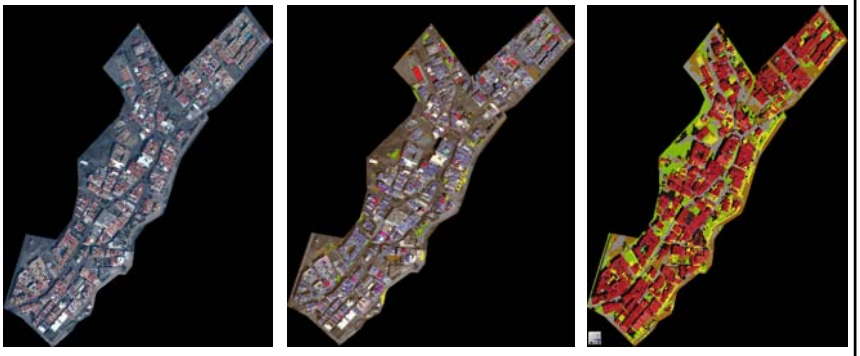


1.- Over unchanged areas, better DSM vertical accuracy (measured as standard deviation) was achieved in GE1 pure stereo pair (0.39 m) than in WV2 (0.53 m).

2.- DSMs higher matching success rate (completeness) values were achieved from WV2 (83.35%) as compared with GE1 (74.50%).

5.- Applications. Classification in urban environments.

M.A. Aguilar , M.M. Saldaña & F.J. Aguilar, 2013.
GeoEye-1 and WorldView-2 pan-sharpened imagery for object-based classification in urban environments.
International Journal of Remote Sensing, 34:7, 2583-2606



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International Journal of Remote Sensing, 34:7, 2583-2606

Classification GE1

Classification WV2

5.- Applications. Classification in urban environments.



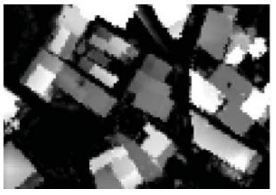


Table 7. Comparison of mean values of overall accuracy (OA) and kappa (KIA) for the sets of features or strategies and sensor tested.

	GeoEye-1		WV2	
Strategies	OA (%)	KIA	OA (%)	KIA
Basic 2	–	–	71.3[d]	0.598[d]
Geometry	78.3[d]	0.665[d]	71.7[d]	0.601[d]
Basic 1	81.5[c]	0.717[c]	72.1[d]	0.609[d]
Texture	81.0[c]	0.707[c]	74.9[c]	0.652[c]
NDIs	84.9[b]	0.769[b]	74.1[c]	0.638[c]
Elevation	84.3[b]	0.761[b]	77.4[b]	0.683[b]
Elevation + NDIs	87.2[a]	0.806[a]	78.6[b]	0.701[b]
All	86.4[a]	0.791[a]	80.7[a]	0.729[a]

6.- Applications. Monitoring coastal areas.

Why are the VHR satellite images being used more and more in coastal applications?

"Integration and analysis of multi-date and multi-source geospatial data for the monitoring and modeling of coastal areas"
(RNM-3575, 2009-12)
http://www.ual.es/GruposInv/ProyectoCostas/index.htm

1.- Very dinamic coastal areas

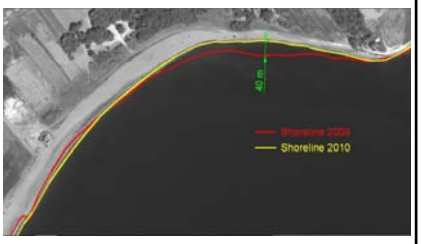
6.- Applications. Monitoring coastal areas.

Why are the VHR satellite images being used more and more in coastal applications?

2.- Shoreline very changeable in long period of time

6.- Applications. Monitoring coastal areas.

Why are the VHR satellite images being used more and more in coastal applications?



3.- Shoreline very changeable in short period of time

6.- Applications. Monitoring coastal areas.

Time sequence at Quitapellejos beach (Palomares): 1956-2009.

6.- Applications. Monitoring coastal areas.

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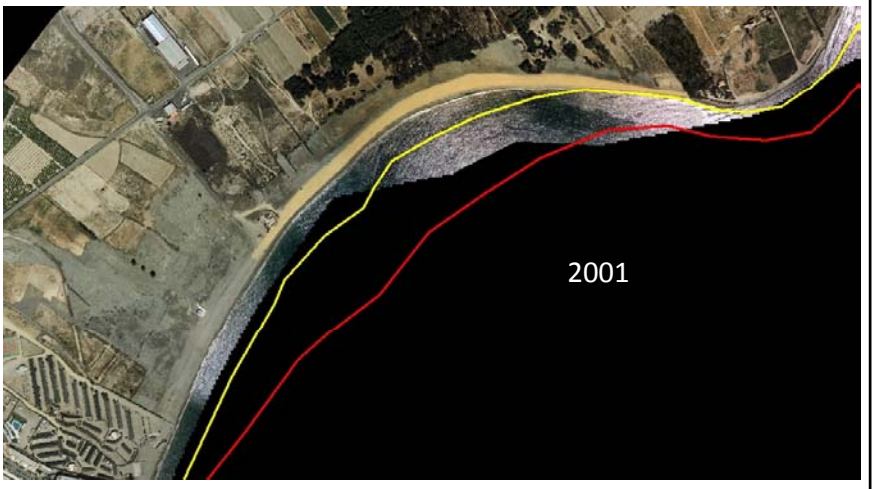
6.- Applications. Monitoring coastal areas.

Time sequence at Quitapellejos beach (Palomares): 1956-2009.



6.- Applications. Monitoring coastal areas.

Time sequence at Quitapellejos beach (Palomares): 1956-2009.

6.- Applications. Monitoring coastal areas.

Why are the VHR satellite images being used more and more in coastal applications?

Shoreline ground truth by DGPS, summer 2011

Are we using the correct tool?

7.- Applications. Impervious surface areas (ISAs).

- Impervious surface areas (ISAs) are defined as anthropogenic features thorough water cannot infiltrate into the soil (pavements, roads, sidewalks, driveways, parking lots…).

- ISAs influence the hydrology of the watershed, impacting on the runoff features and increasing the stormflow.

Why were we interested in ISAs detection?

1956 Puerto Rey 2009

7.- Applications. Impervious surface areas (ISAs).

I. Fernández, F.J. Aguilar, F. Álvarez, M.A. Aguilar, In Press. **Non-Parametric Object-Based Approaches to Carry Out ISA Classification From Archival Aerial Orthoimages**. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing.

Colour

Indexes

Texture descriptors

OBIA techniques for ISAs detections from 2001 archival aerial orthoimages (0.20 m GSD and RGB) in coastal areas:

- Optimizing the Feature Space for OBIA classification.

- Comparison of classifiers (**SVM**, NN and Classification And Regression Trees).

7.- Applications. Impervious surface areas (ISAs).

Basic spectral information, indexes between bands and basic texture information are tested to find the most suitable feature set for ISAs detection with GeoEye-1 imagery.

Segmentation

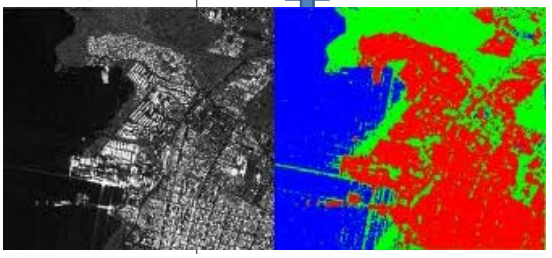
Multiresolution segmentation using eCognition 8.0. 4 pan-sharpened bands plus PAN band. Scale = 50, Shape = 0.3 and Compactness =0.7

Ground Truth based on visual inspection

Subclass	Target class
Dark sea	Pervious
Bright sea	
Individual trees	
Bare soil	
Scrubland	
Beach	
Cultivated agricultural field	

Supervised classification, SVM

Well-distributed samples were collected :
215 training set
728 validation set



7.- Applications. Impervious surface areas (ISAs).

TextureAll:

R, G, B, PAN, Nir means values **(5)**

+ ratios to scene for R, G, B and Nir **(4)**

+ the normalized differences for B, G and R (NDBI, NDGI and NDVI) **(3)**

+ local variance estimated through a 3x3 window size on PAN orthoimage, 5x5 and 7x7 **(3)**

= (15 total features)

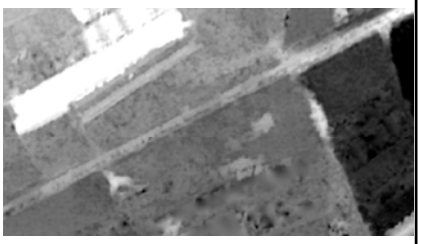
Accuracy results for the entire area using TextureAll strategy.

	GE1	ArO
OA	90.4	88.1
PA p	90.5	88.6
PA i	90.1	87.5
UA p	91.5	89.2
UA i	89.0	86.8
KHAT	0.806	0.760

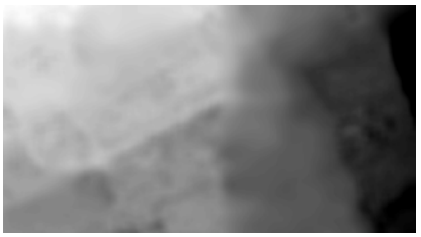
8.- Applications. Greenhouses detection.

8.- Applications. Greenhouses detection.

Orto 0.5 m Pan-sharpened



DSM 1 m grid from WV2 PAN stereopair



DEM 1 m grid from WV2 PAN stereopair

nDSM 1 m grid from WV2 PAN stereopair

8.- Applications. Greenhouses detection.

RGB

GE1: 29-9-2010

WV2: 19-7-2011

WV2: 18-8-2011

GE1: 27-8-2011

8.- Applications. Greenhouses detection.

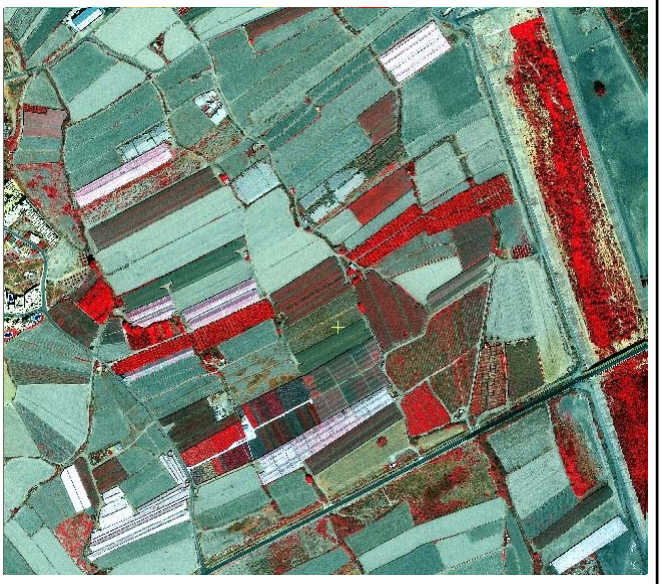
Nir, R, G

GE1: 29-9-2010

WV2: 19-7-2011

WV2: 18-8-2011

GE1: 27-8-2011



8.- Applications. Greenhouses detection.

✓ The main object would be **remotely** monitor and detect greenhouses (including nets and plastic), using multi-angle and multi-data VHR satellite imagery using OBIA techniques.

✓ Texture is an important characteristic to improve the accuracy in the classification of greenhouses.

9.- Conclusions

The orthoimages are the main product derived from VHR satellite imagey. We can achieve geometric accuracies from GE1 or WV2 compatible with large scales map (1/2000) using only few GCPs and a DEM.

DSMs or DEM can be extracted from VHR satellite stereo pair. Vertical accuracies around GSD of the original images could be attained.

The accuracies obtained in PAN and MS orthoimages together with the possibility of using Vertical Information (DSM or DEM), provide high capabilities for land-use classification, change detection and automatic update of large-scale mapping.

The constant improvement of the geometric and radiometric resolution that offer VHR satellite images (e.g. WorldView-2) makes this research line especially interesting, moreover, a certain challenge.

Thanks for your attention

Manuel Ángel Aguilar

Senior Lecturer , Department of Engineering, University of Almeria, Spain

Research Group: Integrated Land Management and Spatial Information Technologies

http:// www.ual.es/personal/maguilar