



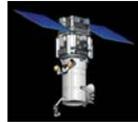
# Generation of very high resolution georeferenced data from GeoEye-1 and WorldView-2 commercial satellite imagery. Applications.

**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](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

**Prodigious Mapping Capabilities, Spatial Resolution and Geolocation Ability**  
**GeoEye's Next-Generation Imaging Satellite**

**Overview**  
 GeoEye's next-generation satellite imagery provides unparalleled resolution and geolocation accuracy. The satellite is designed to provide high-resolution imagery with a resolution of 0.5 meters per pixel. This resolution is achieved through the use of a large aperture telescope and a high-resolution camera. The satellite is also equipped with a high-resolution camera that provides a resolution of 0.5 meters per pixel. This resolution is achieved through the use of a large aperture telescope and a high-resolution camera. The satellite is also equipped with a high-resolution camera that provides a resolution of 0.5 meters per pixel. This resolution is achieved through the use of a large aperture telescope and a high-resolution camera.

**Advantages**  
 GeoEye's next-generation satellite imagery provides unparalleled resolution and geolocation accuracy. The satellite is designed to provide high-resolution imagery with a resolution of 0.5 meters per pixel. This resolution is achieved through the use of a large aperture telescope and a high-resolution camera. The satellite is also equipped with a high-resolution camera that provides a resolution of 0.5 meters per pixel. This resolution is achieved through the use of a large aperture telescope and a high-resolution camera. The satellite is also equipped with a high-resolution camera that provides a resolution of 0.5 meters per pixel. This resolution is achieved through the use of a large aperture telescope and a high-resolution camera.

**Applications**  
 GeoEye's next-generation satellite imagery provides unparalleled resolution and geolocation accuracy. The satellite is designed to provide high-resolution imagery with a resolution of 0.5 meters per pixel. This resolution is achieved through the use of a large aperture telescope and a high-resolution camera. The satellite is also equipped with a high-resolution camera that provides a resolution of 0.5 meters per pixel. This resolution is achieved through the use of a large aperture telescope and a high-resolution camera. The satellite is also equipped with a high-resolution camera that provides a resolution of 0.5 meters per pixel. This resolution is achieved through the use of a large aperture telescope and a high-resolution camera.

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.



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy



# 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

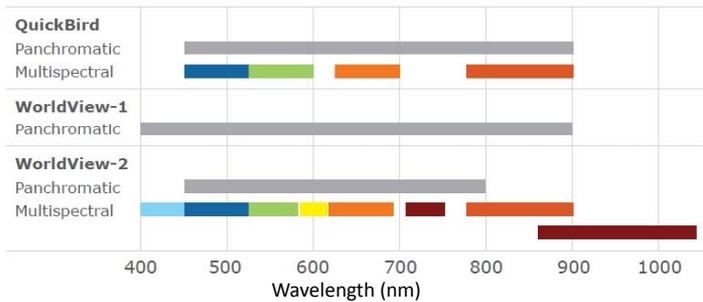


WV2 Pan-sharpened 0.5 m GSD (70 m X 70 m)



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

# 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?



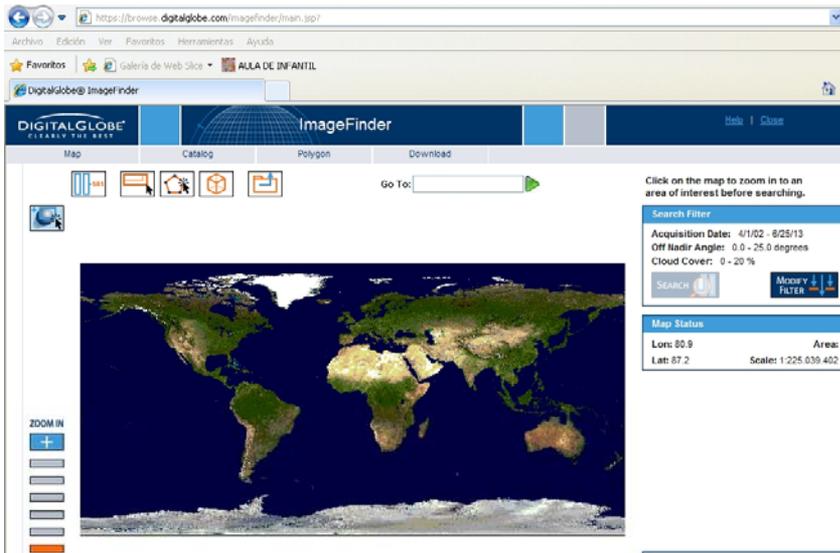
RGB

NirRG

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



## 2.- How to purchase VHR satellite images



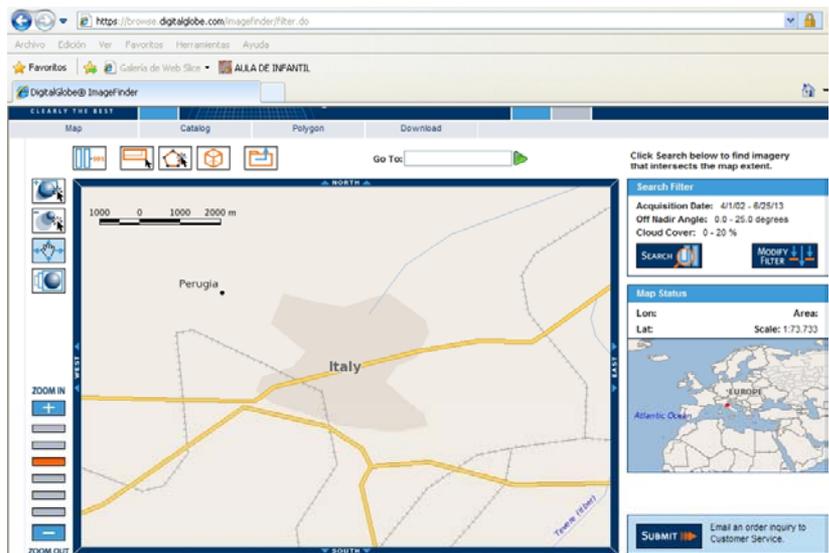
The screenshot shows the DigitalGlobe ImageFinder interface. The browser address bar displays <https://browse.digitalglobe.com/imagefinder/main.jsp?>. The page features a navigation menu with 'Map', 'Catalog', 'Polygon', and 'Download' options. A 'Go To:' search bar is present. The main map area shows a world map with a zoom control on the left. On the right, a 'Search Filter' panel displays the following information: Acquisition Date: 4/1/02 - 6/25/13, Off Nadir Angle: 0.0 - 25.0 degrees, and Cloud Cover: 0 - 20%. Below the filters are 'SEARCH' and 'MODIFY FILTER' buttons. A 'Map Status' panel shows 'Lon: 80.9', 'Lat: 87.2', and 'Scale: 1 225 039 402'.



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

9

## 2.- How to purchase VHR satellite images



The screenshot shows the DigitalGlobe ImageFinder interface with a zoomed-in map of Italy. The browser address bar displays <https://browse.digitalglobe.com/imagefinder/filter.do>. The map shows the outline of Italy with 'Perugia' and 'Italy' labeled. A scale bar indicates 0, 1000, and 2000 meters. The 'Search Filter' panel on the right shows the same acquisition date and cloud cover filters as the previous screenshot. Below the filters are 'SEARCH' and 'MODIFY FILTER' buttons. A 'Map Status' panel shows 'Lon: 12.1' and 'Lat: 43.1' with a scale of 1:73,733. A 'SUBMIT' button is located at the bottom right, with the text 'Email an order inquiry to Customer Service.'



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

10

## 2.- How to purchase VHR satellite images

The screenshot displays the DigitalGlobe ImageFinder web application. On the left, there is a vertical sidebar with logos for the University of Perugia and various funding agencies. The main area shows a satellite image of Perugia, Italy, with a search bar and navigation controls. On the right, a table lists search results for 13 images that meet the 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	To Ck Co P
<input type="checkbox"/>	<a href="#">View</a>	103050007796200	WV02	2010/08/01	19.36°	18.33°	53.43°	0
<input checked="" type="checkbox"/>	<a href="#">View</a>	1020010018057E00	WV01	2012/09/11	20.90°	19.61°	50.09°	2
<input type="checkbox"/>	<a href="#">View</a>	1010010000510400	QB02	2005/07/22	16.62°	17.31°	64.44°	24
<input type="checkbox"/>	<a href="#">View</a>	102005000980200	WV02	2011/04/02	16.17°	7.79°	50.90°	0
<input type="checkbox"/>	<a href="#">View</a>	1020010016E07700	WV01	2011/10/03	16.57°	14.33°	42.22°	0
<input type="checkbox"/>	<a href="#">View</a>	102001000P15A2E00	WV02	2011/11/20	13.70°	13.32°	27.10°	3
<input type="checkbox"/>	<a href="#">View</a>	1010010008C38600	QB02	2008/11/02	18.96°	13.50°	31.48°	11
<input type="checkbox"/>	<a href="#">View</a>	102001004A959900	WV01	2009/11/21	19.65°	18.87°	26.62°	37
<input type="checkbox"/>	<a href="#">View</a>	102005000980100	WV02	2011/04/02	16.69°	14.30°	50.78°	0
<input type="checkbox"/>	<a href="#">View</a>	1010010005AA0000	QB02	2005/12/13	5.33°	4.70°	23.19°	7
<input type="checkbox"/>	<a href="#">View</a>	1010010007D0A700	QB02	2005/02/16	19.70°	13.27°	33.01°	26
<input type="checkbox"/>	<a href="#">View</a>	10100100087D2200	QB02	2005/08/27	18.99°	17.51°	55.21°	4
<input type="checkbox"/>	<a href="#">View</a>	1020010016B21600	WV01	2011/08/00	18.44°	18.32°	54.14°	0

Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

## 2.- How to purchase VHR satellite images

This screenshot is identical to the one above, showing the DigitalGlobe ImageFinder interface with a satellite image of Perugia, Italy, and a table of search results for 13 images.

Select	Browse Image	Catalog Id	Sensor Vehicle	Acquisition Date	Total Max Off Nadir Angle	Area Max Off Nadir Angle	Area Min Sun Elevation	To Ck Co P
<input type="checkbox"/>	<a href="#">View</a>	103050007796200	WV02	2010/08/01	19.36°	18.33°	53.43°	0
<input checked="" type="checkbox"/>	<a href="#">View</a>	1020010018057E00	WV01	2012/09/11	20.90°	19.61°	50.09°	2
<input type="checkbox"/>	<a href="#">View</a>	1010010000510400	QB02	2005/07/22	16.62°	17.31°	64.44°	24
<input type="checkbox"/>	<a href="#">View</a>	102005000980200	WV02	2011/04/02	16.17°	7.79°	50.90°	0
<input type="checkbox"/>	<a href="#">View</a>	1020010016E07700	WV01	2011/10/03	16.57°	14.33°	42.22°	0
<input type="checkbox"/>	<a href="#">View</a>	102001000P15A2E00	WV02	2011/11/20	13.70°	13.32°	27.10°	3
<input type="checkbox"/>	<a href="#">View</a>	1010010008C38600	QB02	2008/11/02	18.96°	13.50°	31.48°	11
<input type="checkbox"/>	<a href="#">View</a>	102001004A959900	WV01	2009/11/21	19.65°	18.87°	26.62°	37
<input type="checkbox"/>	<a href="#">View</a>	102005000980100	WV02	2011/04/02	16.68°	14.30°	50.78°	0
<input checked="" type="checkbox"/>	<a href="#">View</a>	1010010005AA0000	QB02	2005/12/13	5.33°	4.70°	23.19°	7
<input type="checkbox"/>	<a href="#">View</a>	1010010007D0A700	QB02	2005/02/16	19.70°	13.27°	33.01°	26
<input type="checkbox"/>	<a href="#">View</a>	10100100087D2200	QB02	2005/08/27	18.99°	17.51°	55.21°	4
<input type="checkbox"/>	<a href="#">View</a>	1020010016B21600	WV01	2011/08/00	18.44°	18.32°	54.14°	0

Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

## 2.- How to purchase VHR satellite images

http://geofuse.geoeeye.com/maps/Map.aspx#

Archivo Edición Ver Favoritos Herramientas Ayuda

Favoritos galería de Web Slice ALLA DE INFANTIL

Online Maps (GeoEye | GeoFUSE N2 v10.0.7)

GeoFUSE HOME PRODUCTS & SERVICES MARKETS GALLERY HOW TO BUY MEDIA ROOM

1 FIND A PLACE 2 SEARCH IMAGE CATALOG

Show On Map

Image Catalog Search Results MyResults

My Results

There are 0 items in My Results

Image Catalog Search Results

There are 2 image matches on the map. Showing matches 1 through 2.

Hide All Footprints Show All Images

View	#	Src	Cloud	Collected	Details	My Results
	1	IKONOS-2	0%	20-APR-2011	Details	
	2	IKONOS-2	0%	24-MAR-2011	Details	

Copyright © 2013 DigitalGlobeCollected 1-OCT-1999 to 24-JUN-2013 • 20% Max. Cloud Cover • All Sources • Stereo Pairs Only: FALSE • Collection Elev. Angle: 60 to 90 • Sensor Mode: PAN/MSI • Line Rate: ANY: 12.3500

Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

13

## 2.- How to purchase VHR satellite images



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

14

## 2.- How to purchase VHR satellite images



Università degli Studi di Perugia



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

15

## 2.- How to purchase VHR satellite images



Università degli Studi di Perugia



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

16

## 2.- How to purchase VHR satellite images



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

17

## 2.- How to purchase VHR satellite images

Price list: VHR (PAN and MS) in \$ US/km<sup>2</sup>

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

Orthoimage  
50  
1/12000

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

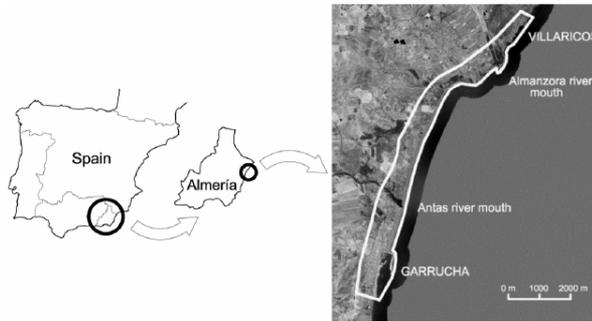


Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

18

## 2.- How to purchase VHR satellite images

Price list: A real example on a 8.5 km<sup>2</sup> area



GE1 Geo {  
 Archive: min 25 km<sup>2</sup> x 16 \$/km<sup>2</sup> = 400 \$  
 Tasking : min 100 km<sup>2</sup> x 25 \$/km<sup>2</sup> = 2500 \$



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

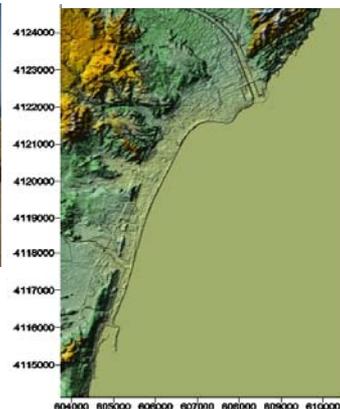
19

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

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

GCPs

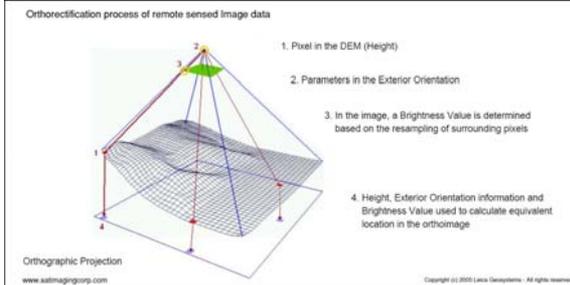
Digital Elevation Model



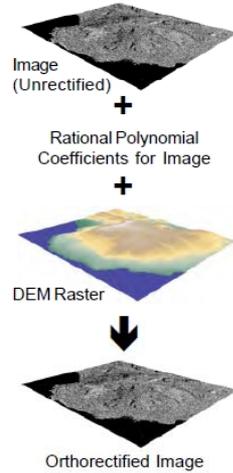
Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

20

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



#### Rational Polynomial Orthorectification



Pushbroom satellite scanners



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



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



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

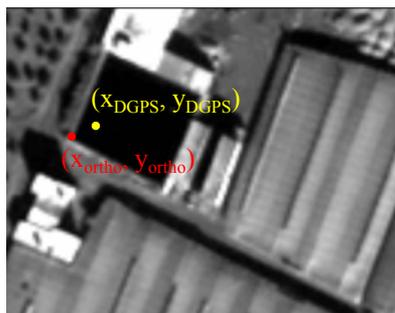
23



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

Geometric accuracy control in orthoimages

RMSE → Root Mean Square Error measured at  $n$  ICPs



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

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

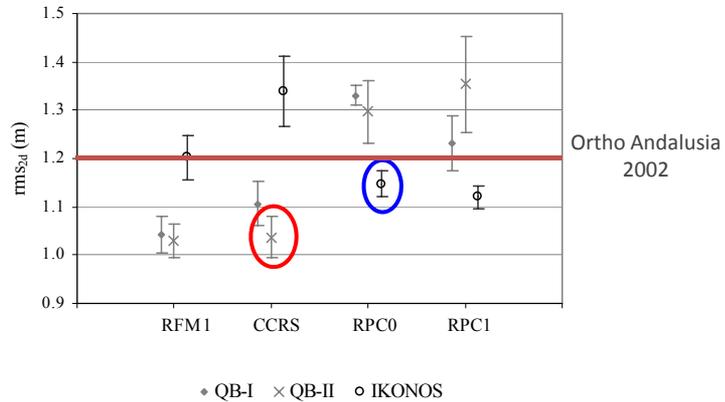
$$RMSE_{2d} = \sqrt{RMSE_x^2 + RMSE_y^2}$$

24



### 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<sub>2D</sub> 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	Orthoimage Andalusia DEM
		ICPs RMSE <sub>2D</sub> (m)	ICPs RMSE <sub>2D</sub> (m)
		Mean	Mean
GeoEye-1 Geo	8.5°	0.404 <sup>a</sup>	0.546 <sup>a</sup>
	20.6°	0.464 <sup>b</sup>	0.622 <sup>b</sup>
	23.1°	0.501 <sup>c</sup>	0.689 <sup>c</sup>
WV-2 ORS2A	5°	0.425 <sup>a</sup>	0.501 <sup>a</sup>
	10°	0.462 <sup>a</sup>	0.584 <sup>b</sup>
	22.4°	0.632 <sup>b</sup>	0.951 <sup>c</sup>

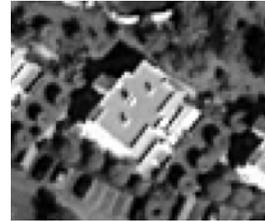
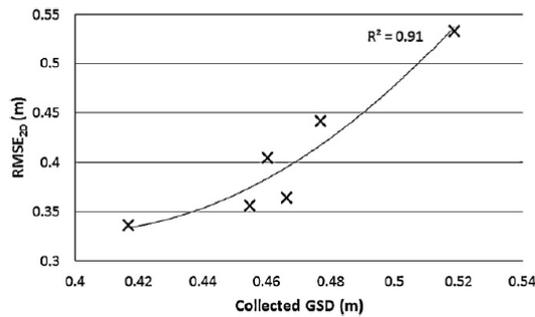
Aguilar et al. (2013). *International Journal of Applied Earth Observation and Geoinformation* 21 (2013) 427–435





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

Geometric accuracy. Off-nadir view angle



GE1 22 degrees



WV21 5 degrees

Fig. 3. Relationship between the collected GSD and the RMSE<sub>2D</sub> attained at the sensor orientation phase by using RPCO 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



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

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

Limiting RMSE <sub>1D</sub> 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
0.50	1:2.000
1.00	1:4.000
1.25	1:5.000
2.50	1:10.000
5.00	1:20.000

GE1 or WV2  
IKONOS or QB

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



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

29



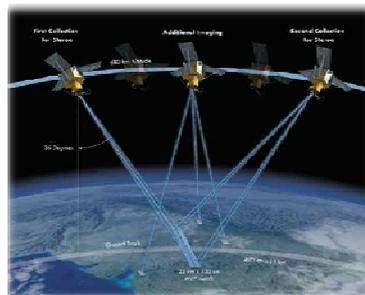
### 4.- DSM and DEM generation from VHR stereo pairs

Digital Elevation Model (**DEM**)

Digital Surface Model (**DSM**)



**DEM**      **DSM**



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

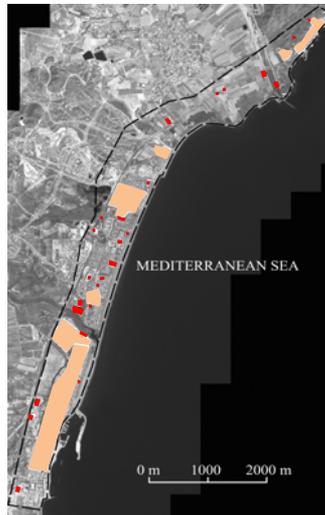
30

## 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



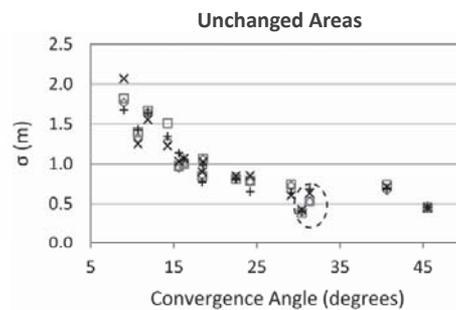
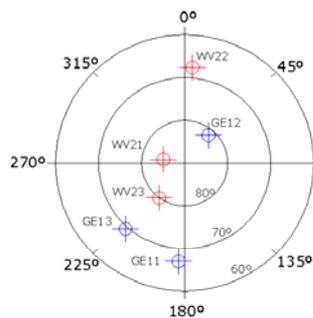
Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

31

## 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)



◇ RPC0 7   □ RPC0 12   + CCRS 12   × CCRS 45

Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

32

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

Aguilar et al., In Press. IEEE TGRS

Stereo Pair	Study Area	LiDAR - VHR	
		Mean	$\sigma$
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

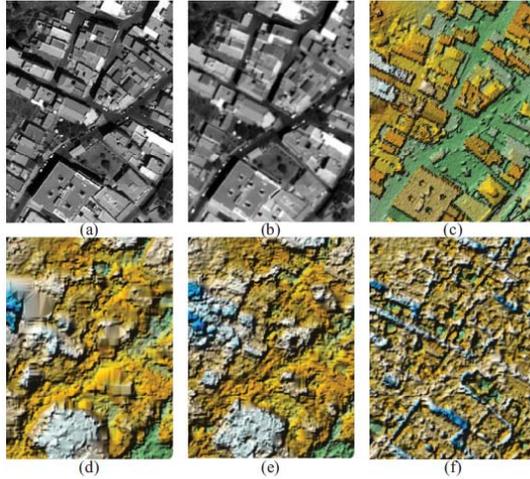


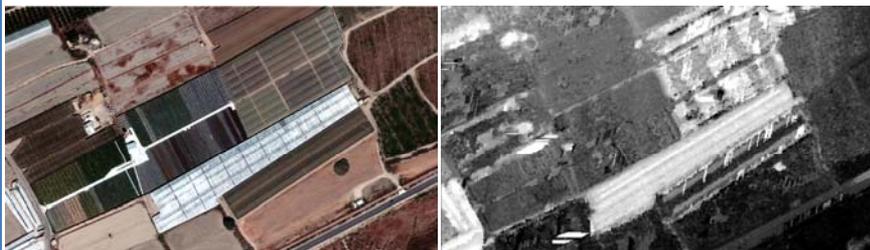
Fig. 3. Visual analysis over a limited urban area ( $112 \times 150$  m). (a) GE12 original PAN image. (b) WV23 original PAN image. (c) LiDAR-derived DSM. (d) DSM from GE12-GE13 (ID 1) stereo pair. (e) DSM from WV22-WV23 (ID 2) stereo pair. (f) vertical residuals from the comparison between LiDAR-derived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



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

33

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



GE1 pure stereopair



WV2 pure stereopair

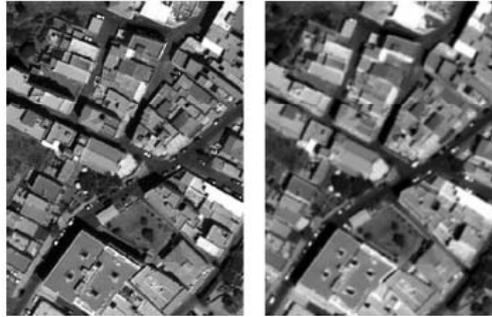


Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

34

## 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%).



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

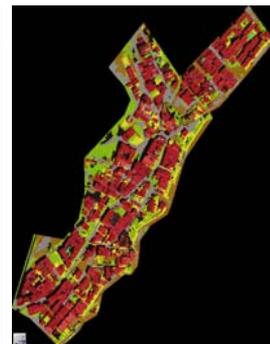
35



## 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



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

36



## 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



Satell

37

## 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.

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



## 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 dynamic coastal areas



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

39

## 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

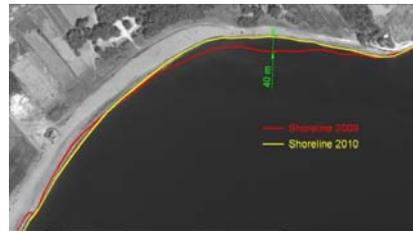


Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

40

## 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



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

41

## 6.- Applications. Monitoring coastal areas.

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

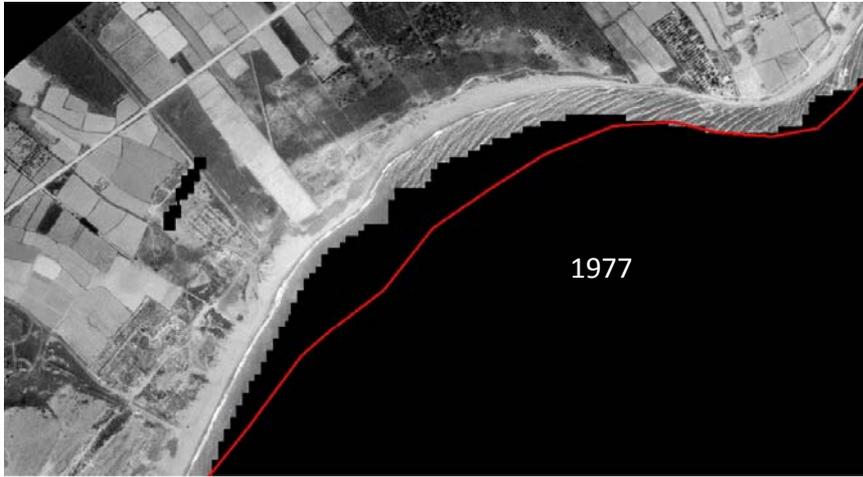


Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

42

## 6.- Applications. Monitoring coastal areas.

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



UNIVERSITÀ DEGLI STUDI DI PERUGIA  
DIPARTIMENTO DI SCIENZE E TECNICHE APPLICATE  
INGEGNERIA E TECNOLOGIA  
UNIVERSITÀ DEGLI STUDI DI PERUGIA  
DIPARTIMENTO DI SCIENZE E TECNICHE APPLICATE  
INGEGNERIA E TECNOLOGIA  
UNIVERSITÀ DEGLI STUDI DI PERUGIA  
DIPARTIMENTO DI SCIENZE E TECNICHE APPLICATE  
INGEGNERIA E TECNOLOGIA  
UNIVERSITÀ DEGLI STUDI DI PERUGIA  
DIPARTIMENTO DI SCIENZE E TECNICHE APPLICATE  
INGEGNERIA E TECNOLOGIA

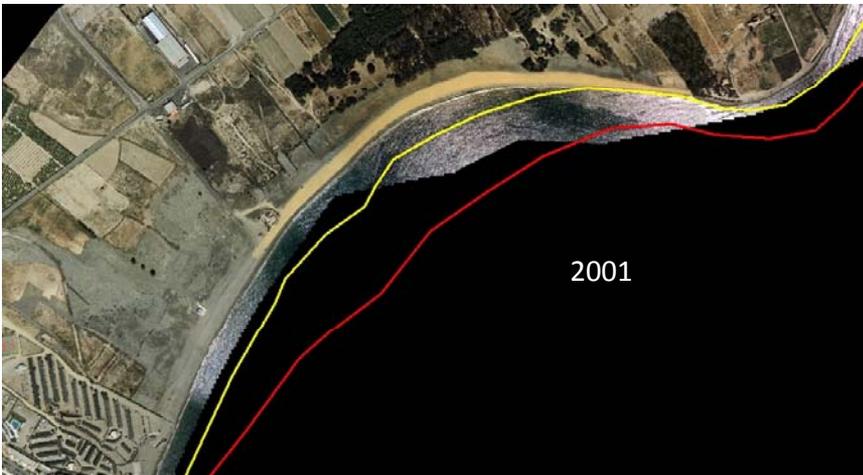


Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

43

## 6.- Applications. Monitoring coastal areas.

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



UNIVERSITÀ DEGLI STUDI DI PERUGIA  
DIPARTIMENTO DI SCIENZE E TECNICHE APPLICATE  
INGEGNERIA E TECNOLOGIA  
UNIVERSITÀ DEGLI STUDI DI PERUGIA  
DIPARTIMENTO DI SCIENZE E TECNICHE APPLICATE  
INGEGNERIA E TECNOLOGIA  
UNIVERSITÀ DEGLI STUDI DI PERUGIA  
DIPARTIMENTO DI SCIENZE E TECNICHE APPLICATE  
INGEGNERIA E TECNOLOGIA  
UNIVERSITÀ DEGLI STUDI DI PERUGIA  
DIPARTIMENTO DI SCIENZE E TECNICHE APPLICATE  
INGEGNERIA E TECNOLOGIA



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

44

## 6.- Applications. Monitoring coastal areas.

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



A vertical sidebar on the left side of the slide. It contains several logos: a building, the 'ARTEMIS' logo, the European Union flag, the 'UNIVERSITÀ DEGLI STUDI DI PERUGIA' logo, and the 'UNIVERSITÀ DEGLI STUDI DI PERUGIA' logo. Text in the sidebar includes 'ARTEMIS', 'UNIVERSITÀ DEGLI STUDI DI PERUGIA', 'UNIVERSITÀ DEGLI STUDI DI PERUGIA', and 'UNIVERSITÀ DEGLI STUDI DI PERUGIA'.



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

45

## 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?

A vertical sidebar on the left side of the slide. It contains several logos: a building, the 'ARTEMIS' logo, the European Union flag, the 'UNIVERSITÀ DEGLI STUDI DI PERUGIA' logo, and the 'UNIVERSITÀ DEGLI STUDI DI PERUGIA' logo. Text in the sidebar includes 'ARTEMIS', 'UNIVERSITÀ DEGLI STUDI DI PERUGIA', 'UNIVERSITÀ DEGLI STUDI DI PERUGIA', and 'UNIVERSITÀ DEGLI STUDI DI PERUGIA'.



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

46



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

- Impervious surface areas (ISAs) are defined as anthropogenic features through which 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



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

47

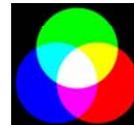


## 7.- Applications. Impervious surface areas (ISAs).

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 ).



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

48

## 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



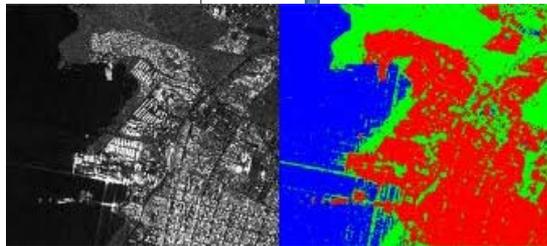
Multiresolution segmentation using eCognition 8.0. 4 pan-sharpened bands plus PAN band. Scale = 50, Shape = 0.3 and Compactness = 0.7

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



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

49

## 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

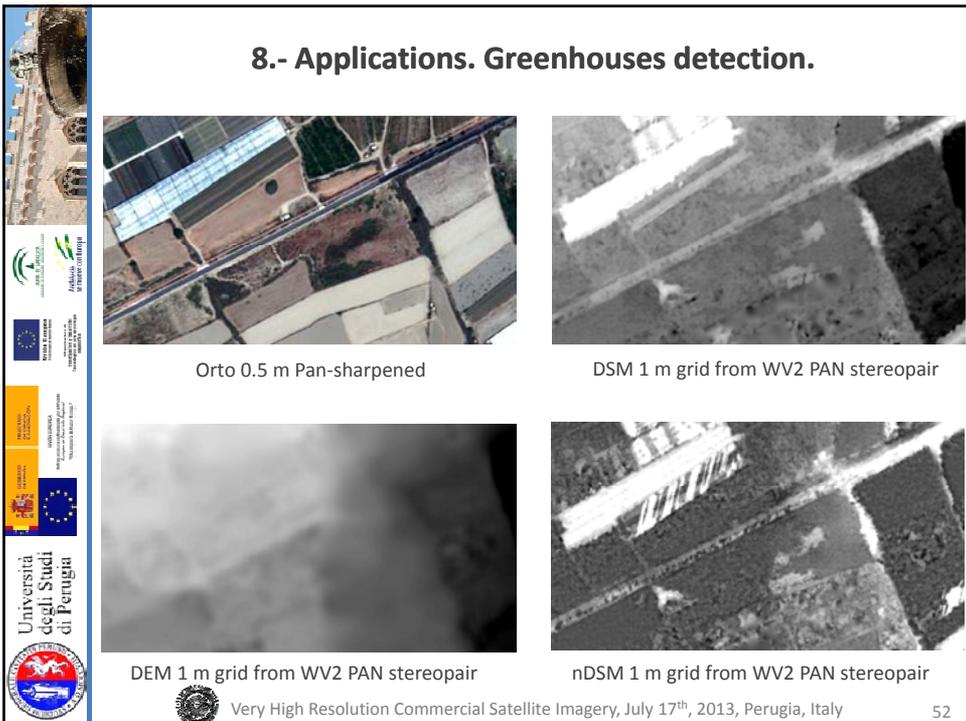
Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

50

## 8.- Applications. Greenhouses detection.



## 8.- Applications. Greenhouses detection.



## 8.- Applications. Greenhouses detection.

### RGB

GE1: 29-9-2010

WV2: 19-7-2011

WV2: 18-8-2011

GE1: 27-8-2011



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

53



## 8.- Applications. Greenhouses detection.

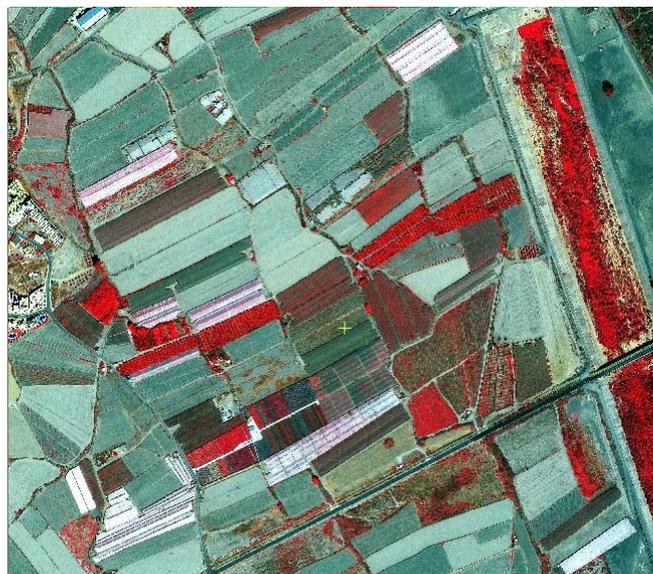
### Nir, R, G

GE1: 29-9-2010

WV2: 19-7-2011

WV2: 18-8-2011

GE1: 27-8-2011



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

54



## 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.



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

55



## 9.- Conclusions

The orthoimages are the main product derived from VHR satellite imagery. 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.



Very High Resolution Commercial Satellite Imagery, July 17<sup>th</sup>, 2013, Perugia, Italy

56





# 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](http://www.ual.es/personal/maguilar)

