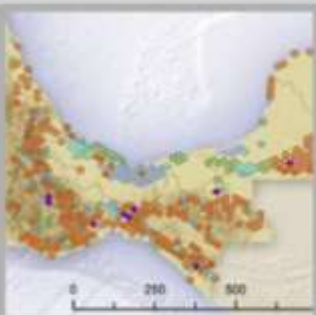




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MAD-MEX: Landsat classification - Methodology



Dr. Steffen Gebhardt





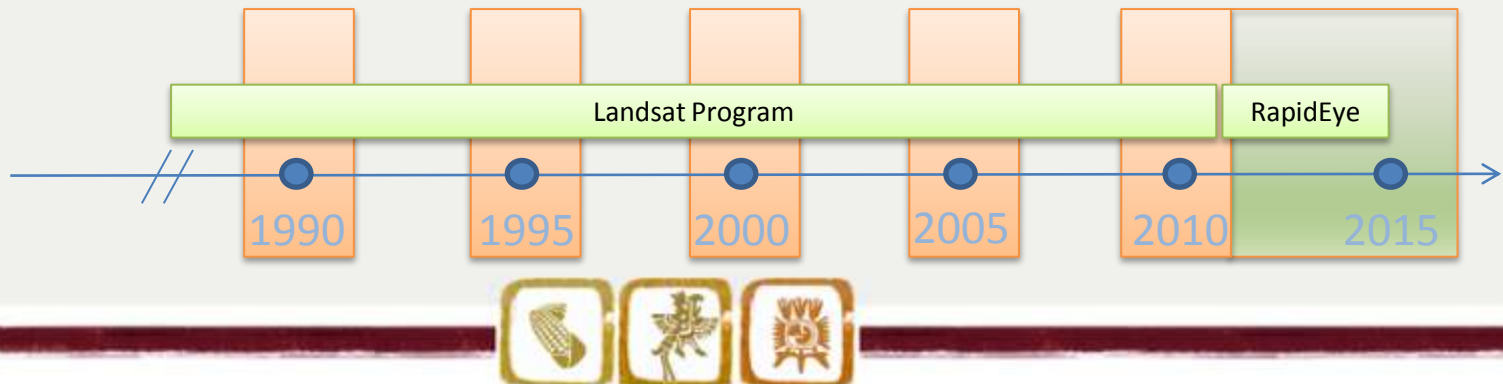
MRV Satellite Monitoring System

- MAD-MEX: “The Measuring, Reporting and Verification - Activity Data (MRV-AD) Monitoring System within the Mexican REDD+ program”
- Products at 1:100,000 and 1:20,000
 - Land Cover (LC)
 - Land Cover Change (LCC)
 - Forest / Non-Forest
 - Forest Change (FC)
 - Cover density
- Methods
 - Automated wall-to-wall baseline land cover mapping
 - “Map-to-Image” using (historical) land use cartography
 - Validation and calibration using field sampling data and imagery



MRV Baseline

- Historical baseline utilizing the Landsat archive
 - 40 years data archive freely available since 2008
 - Multi-temporal coverage per year
- Today's and future monitoring based on RapidEye
 - High spatial resolution
 - Pre-processed data of high accuracy in geo-location
 - Constellation of satellites, continuity, likelihood of multi-temporal coverage

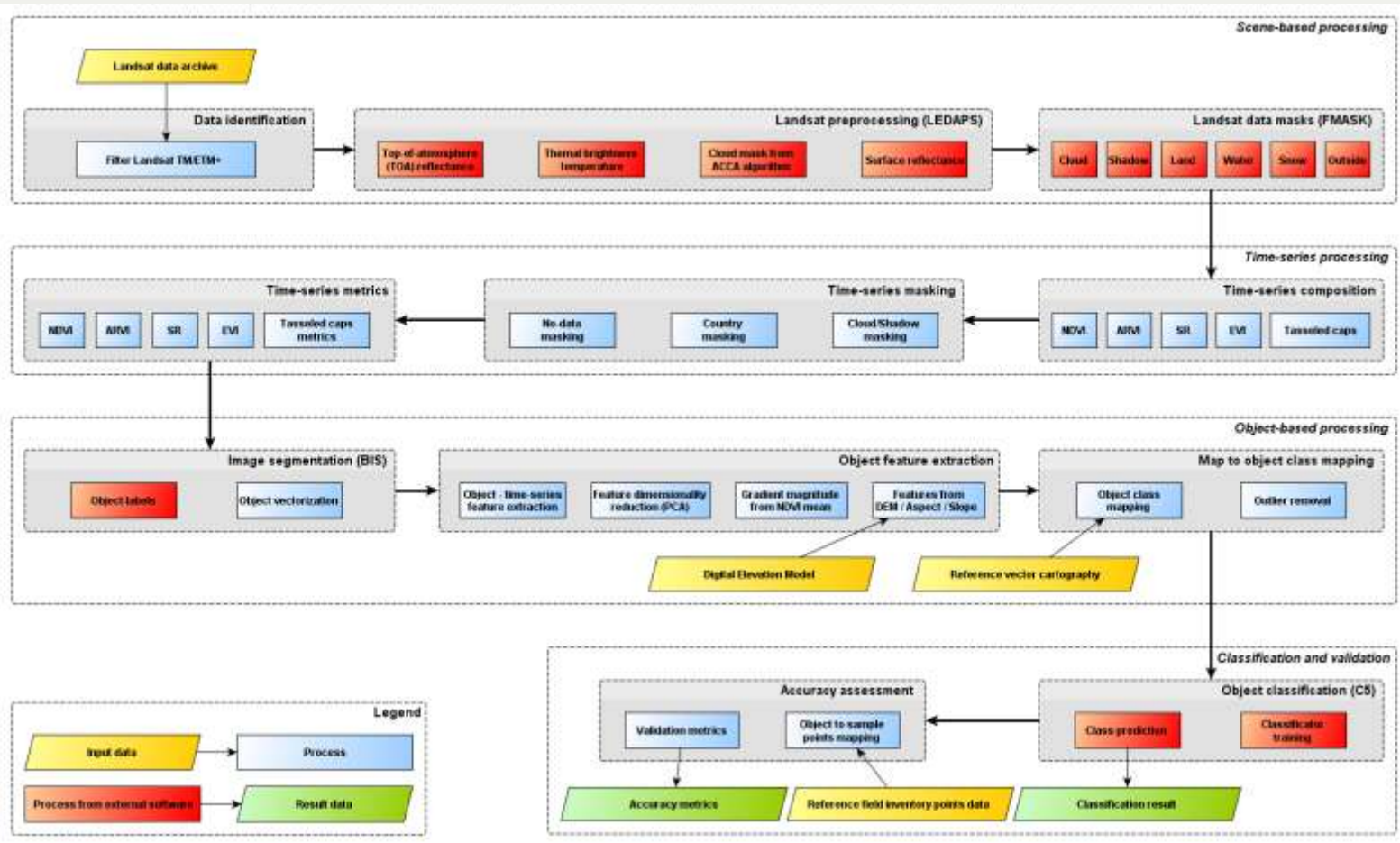




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MAD-MEX Landsat processing



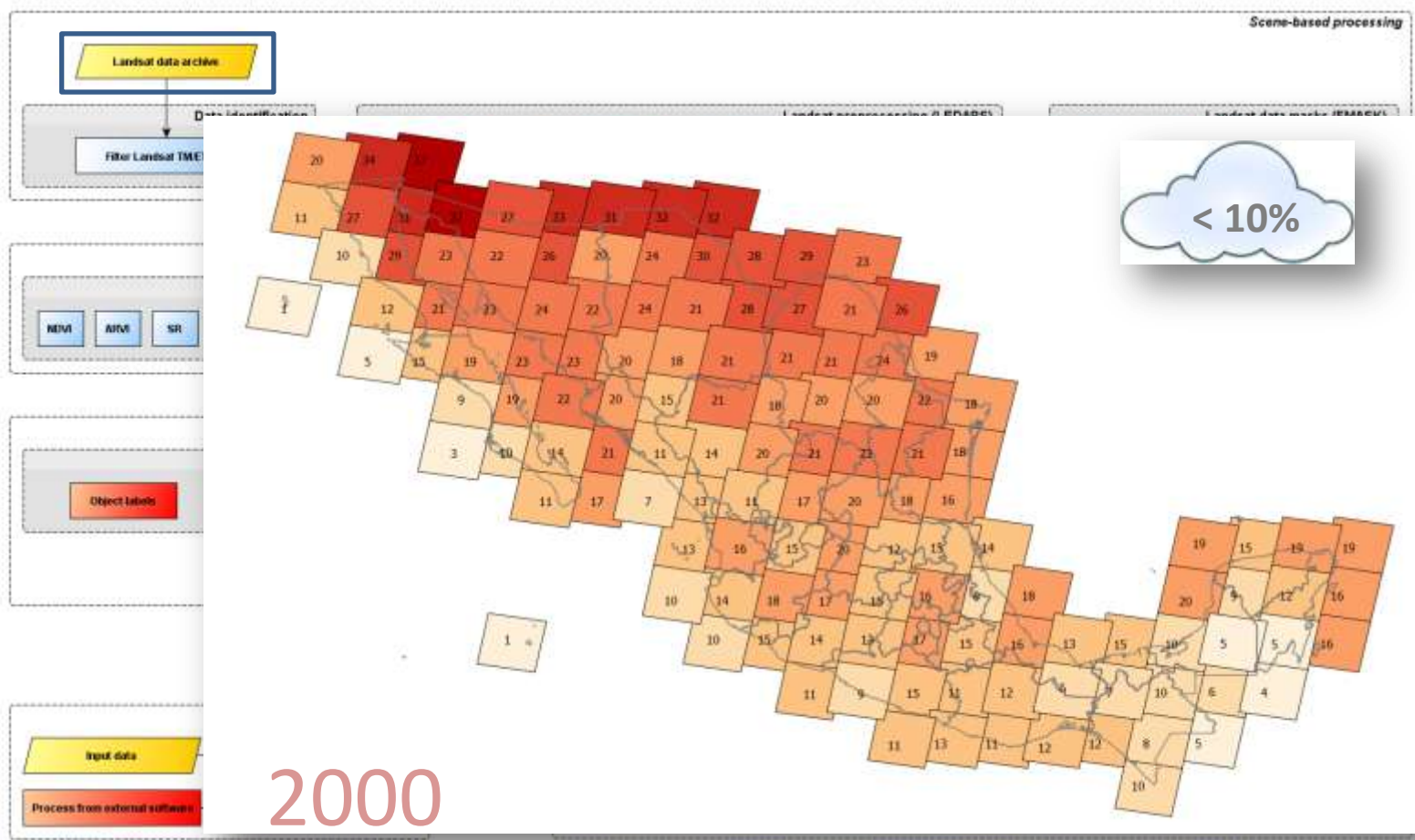


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MAD-MEX Landsat processing

Scene-based processing



2000

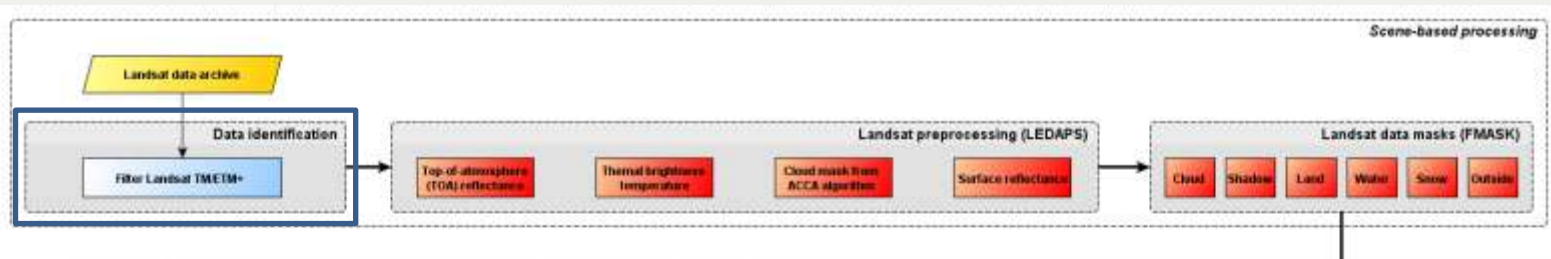




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MAD-MEX Landsat processing



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60516	4	963577	28/03/2000 17:28	0	1T	/bigdata/landsat/LT50350432000088XXX02/L5035043_04320000328_MTL.txt
60148	5	963577	05/04/2000 17:46	9.65	1T	/bigdata/landsat/LE70350432000096EDC01/L71035043_04320000405_MTL.txt
63159	4	963577	13/04/2000 17:28	10	1T	/bigdata/landsat/LT50350432000104AAA01/L5035043_04320000413_MTL.txt
60149	5	963577	07/05/2000 17:45	0.32	1T	/bigdata/landsat/LE70350432000128EDC01/L71035043_04320000507_MTL.txt
69064	4	963577	15/05/2000 17:29	0	1T	/bigdata/landsat/LT50350432000136XXX00/L5035043_04320000515_MTL.txt
63351	4	963577	18/07/2000 17:30	0	1T	/bigdata/landsat/LT50350432000200XXX02/L5035043_04320000718_MTL.txt
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MAD-MEX Landsat processing



LEDAPS Landsat Calibration, Reflectance, Atmospheric Correction Preprocessing Code. Model Product. Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A., 2012.

Landsat 1T calibration, TOA reflectance, cloud masking, and atmospheric correction; LEDAPS Preprocessing software

Feng, Min, Chengquan Huang, Saurabh Channan, Eric F. Vermote, Jeffrey G. Masek, and John R. Townshend. "Quality Assessment of Landsat Surface Reflectance Products Using MODIS Data." *Computers & Geosciences* 38, no. 1 (January 2012): 9–22.

Masek, J.G., Vermote, E.F., Saleous, N., Wolfe, R., Hall, F.G., Huemmrich, F., Gao, F., Kutler, J., and Lim, T.K. "A Landsat Surface Reflectance Dataset for North America, 1990–2000." *IEEE Geoscience and Remote Sensing Letters* 3, no. 1 (2006): 68–72.

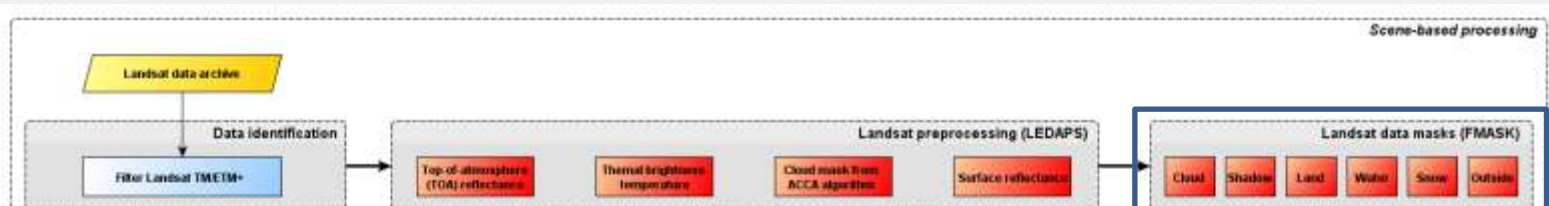




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MAD-MEX Landsat processing



Fmask: Automated clouds, cloud shadows, land, water, nodata and snow masking for Landsat TM/ETM+ image

Zhu, Zhe, and Curtis E. Woodcock. "Object-based Cloud and Cloud Shadow Detection in Landsat Imagery." *Remote Sensing of Environment* 118 (March 15, 2012): 83–94.
Zhu, Zhe, Curtis E. Woodcock, and Pontus Olofsson. "Continuous Monitoring of Forest Disturbance Using All Available Landsat Imagery." *Remote Sensing of Environment* (n.d.).

<http://www.sciencedirect.com/science/article/pii/S0034425712000387>.

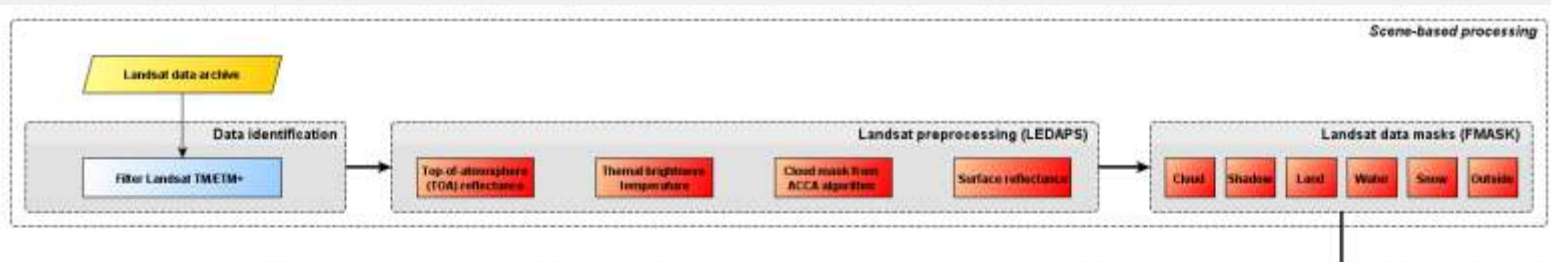




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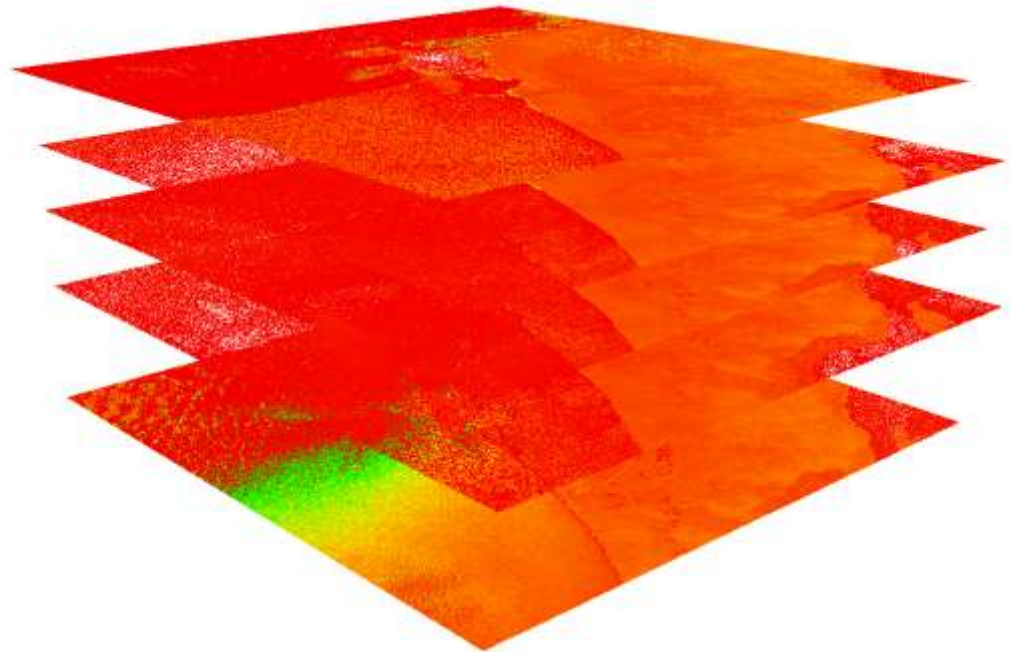
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MAD-MEX Landsat processing



Time-series generation:

Creation of multi-temporal image stacks over vegetation indices, tasseled caps and masks

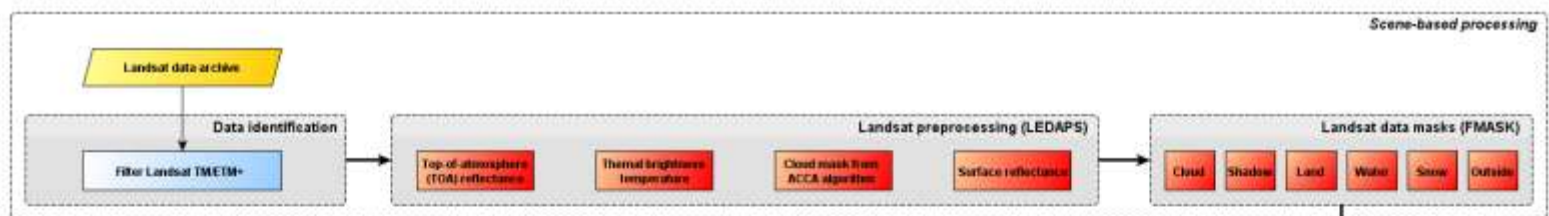




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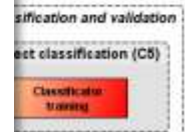
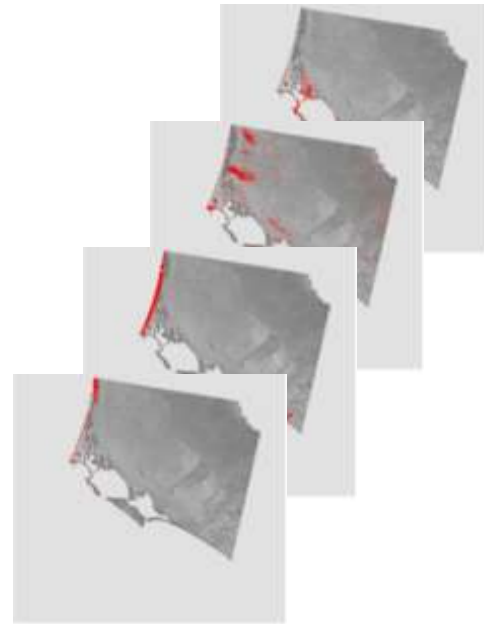
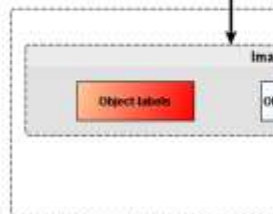
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MAD-MEX Landsat processing



Time-series masking:

Apply masks for cloud/shadow, water and outside to each band in the multi-temporal stacks of vegetation indices and tasseled caps and set the masked values to "nodata"

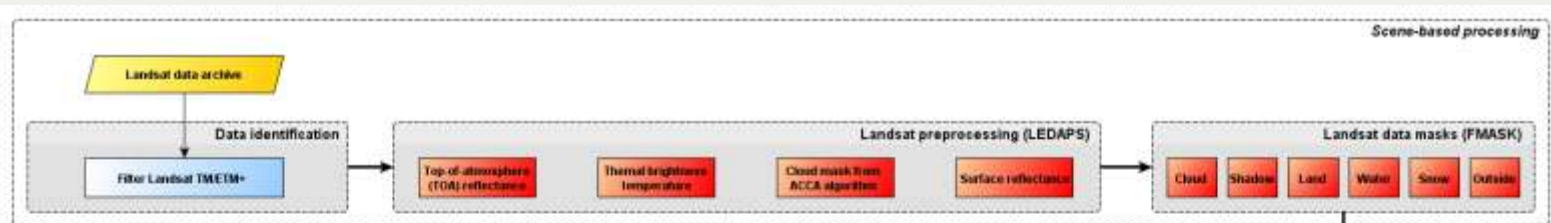




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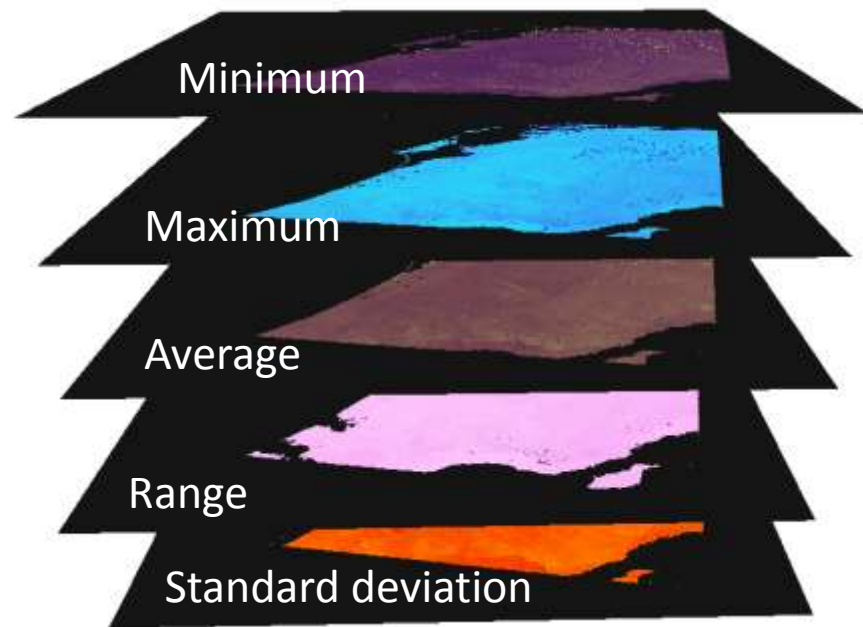
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MAD-MEX Landsat processing



Time-series metrics:

Calculate descriptive statistics for each pixel over the masked time-series and store back to 5 band image stacks. Thereby, ignore all pixels masked as "nodata" for statistics.



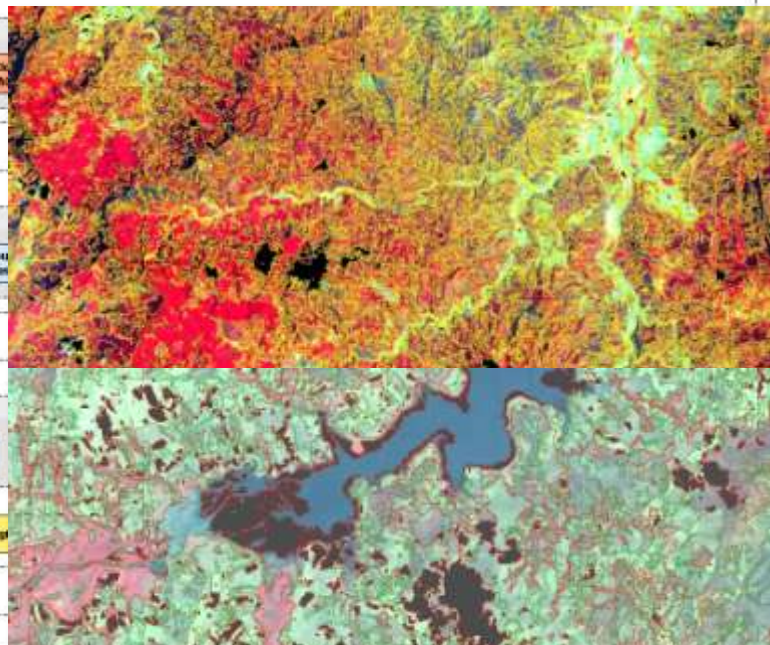
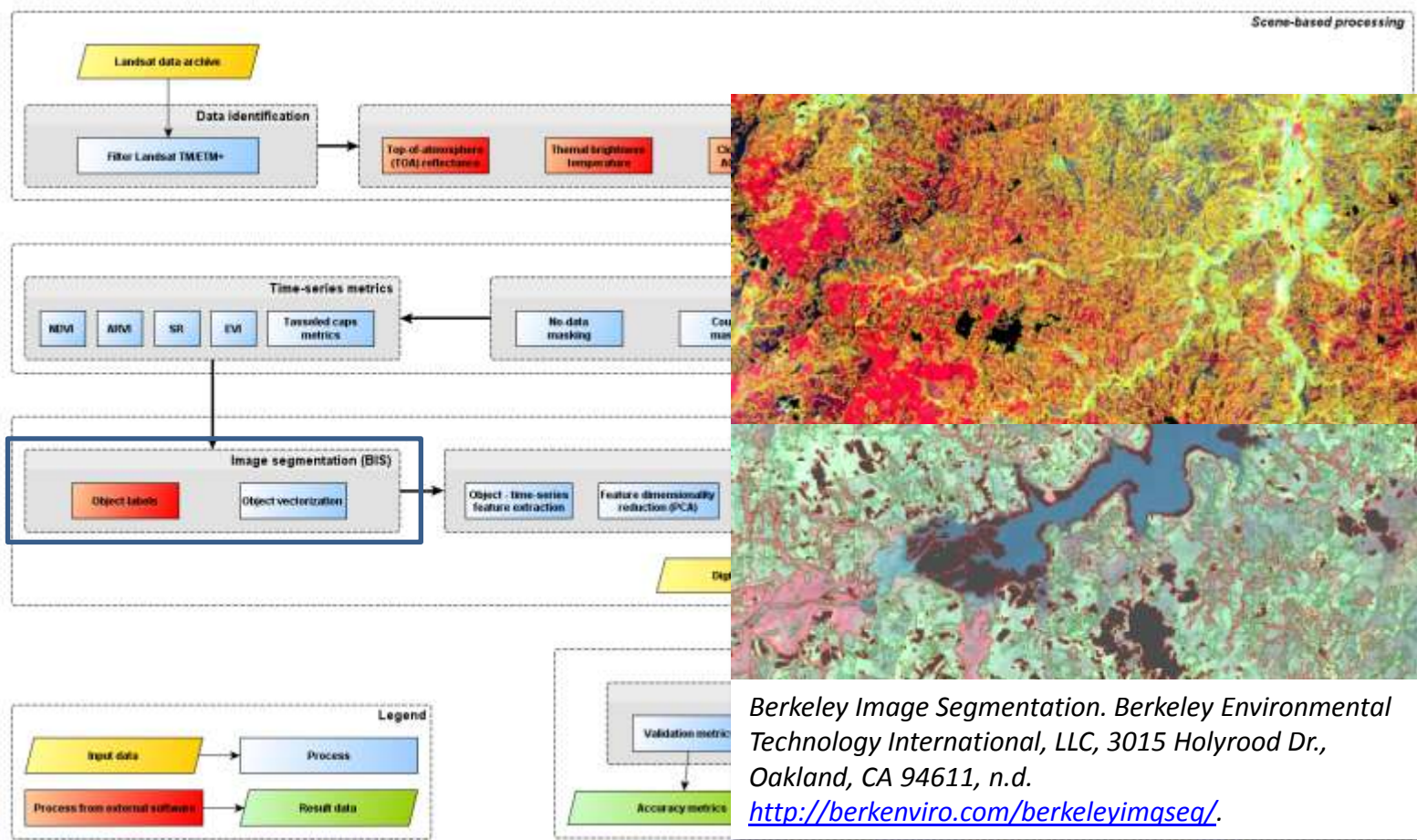


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MAD-MEX Landsat processing

Scene-based processing



Berkeley Image Segmentation. Berkeley Environmental Technology International, LLC, 3015 Holyrood Dr., Oakland, CA 94611, n.d.

<http://berkenviro.com/berkeleyimgseg/>

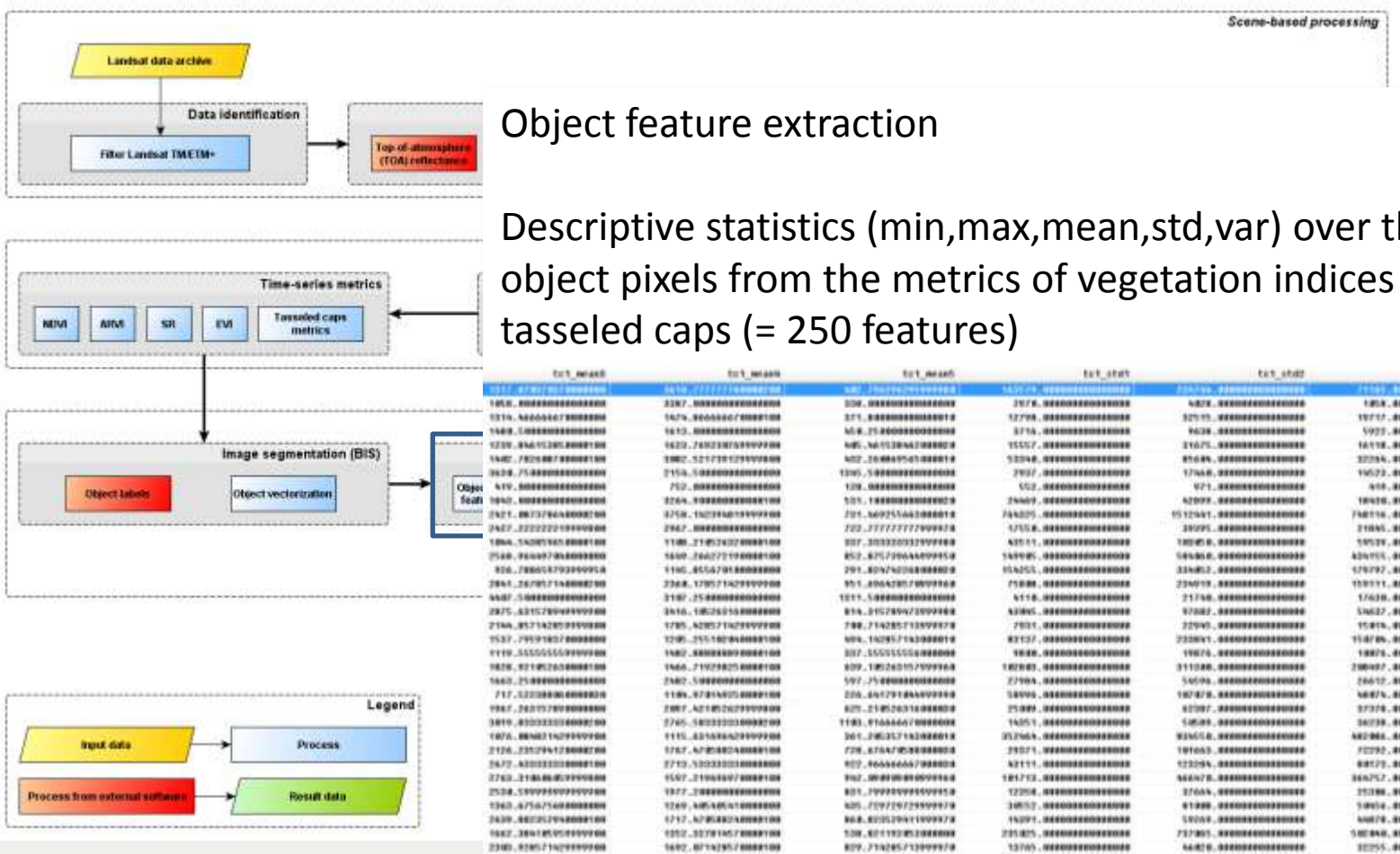




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MAD-MEX Landsat processing



Scene-based processing

Object feature extraction

Descriptive statistics (min,max,mean,std,var) over the object pixels from the metrics of vegetation indices and tasseled caps (= 250 features)

tot_mean	tot_mean	tot_mean	tot_std	tot_std	tot_std
1017.8780700000000	1676.7177771400000	167.7000000000000	15379.00000000000	75676.00000000000	71000.00000000000
165.0000000000000	3387.0000000000000	208.0000000000000	2078.0000000000000	4628.0000000000000	1828.0000000000000
1076.0000000000000	1676.0000000000000	371.0000000000000	12798.00000000000	52703.00000000000	19717.00000000000
1488.0000000000000	1673.0000000000000	16.875000000000000	9718.0000000000000	9638.0000000000000	5927.0000000000000
1239.0000000000000	1623.7492387000000	160.0000000000000	15557.00000000000	31675.00000000000	16118.00000000000
1402.7825887000000	3982.5277381200000	102.3688476100000	53248.00000000000	87648.00000000000	32204.00000000000
1628.7500000000000	2158.5000000000000	1395.5000000000000	2927.0000000000000	17648.00000000000	14523.00000000000
119.0000000000000	752.0000000000000	128.0000000000000	522.0000000000000	971.0000000000000	418.0000000000000
1640.0000000000000	3264.0000000000000	159.1000000000000	2469.0000000000000	4299.0000000000000	18418.00000000000
1627.8873784000000	3758.1423148199999	701.1692516410000	74829.00000000000	151241.00000000000	78216.00000000000
2427.2222221999999	2467.0000000000000	722.7777777999999	755.8000000000000	39291.00000000000	21861.00000000000
1884.5426160000000	1188.2187242700000	337.3033333399999	43511.00000000000	18088.00000000000	51979.00000000000
1548.9669776000000	1649.2462771900000	852.8757264499999	54886.00000000000	54886.00000000000	42675.00000000000
926.2885479999999	1146.8554791000000	291.8974803800000	91251.00000000000	33482.00000000000	17972.00000000000
2861.2478714000000	2268.1785714299999	951.8964287100000	91888.00000000000	234078.00000000000	191711.00000000000
1482.5000000000000	2187.2500000000000	1518.5000000000000	21748.00000000000	21748.00000000000	17478.00000000000
2875.8235278991999	3416.1882631800000	814.2107892710000	82861.00000000000	87382.00000000000	54227.00000000000
2164.8571428571999	1785.4285714299999	788.2142857142999	7931.0000000000000	22945.00000000000	15814.00000000000
1537.7951827000000	1295.2551828400000	984.1628571428000	82137.00000000000	232801.00000000000	158786.00000000000
1119.5555555999999	1482.8888889000000	337.5555555400000	1848.0000000000000	1878.0000000000000	14878.00000000000
1828.8718526300000	1466.7197982500000	409.1852631570000	180802.00000000000	311248.00000000000	28837.00000000000
1643.2500000000000	2482.5000000000000	597.2500000000000	27884.00000000000	56584.00000000000	26612.00000000000
717.3233333000000	1188.8791487500000	228.4477918499999	28884.00000000000	187478.00000000000	48878.00000000000
1947.2487578900000	2887.4218526318000	425.2185263180000	25889.00000000000	82387.00000000000	37378.00000000000
1819.8303333000000	2745.8303333000000	1183.0166667000000	14851.00000000000	58589.00000000000	30728.00000000000
1676.8888216299999	1115.8316832999999	361.2883271830000	352684.00000000000	83664.00000000000	48286.00000000000
2126.2377947800000	1673.6783824000000	728.8784780380000	25071.00000000000	187668.00000000000	72292.00000000000
1673.8303333000000	3713.5303333000000	107.8666666700000	42114.00000000000	122284.00000000000	68778.00000000000
2763.2186868699999	1697.2196868699999	942.8888888000000	181732.00000000000	44678.00000000000	34778.00000000000
2538.5099999999999	1977.5000000000000	807.7099999999999	12288.00000000000	32684.00000000000	25108.00000000000
1368.6756756800000	1249.4854854100000	405.7097297299999	38557.00000000000	81888.00000000000	58978.00000000000
2439.4823274000000	1717.4782327400000	648.8232740100000	14097.00000000000	57088.00000000000	44878.00000000000
1682.3841851999999	1552.3278185700000	538.8219285180000	23582.00000000000	72782.00000000000	58288.00000000000
2382.8785714299999	1692.871428571399999	809.7142857139999	15781.00000000000	44828.00000000000	32755.00000000000





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MAD-MEX Landsat processing

Object feature reduction

Dimensionality reduction based on principal component analysis by keeping those transformed components explaining 95% of total variance

tc1_min1	tc2_min1	tc4_min1	tc3_min1	tc5_min1	tc6_min1	ndvi_min1
tc1_min2	tc2_min2	tc4_min2	tc3_min2	tc5_min2	tc6_min2	ndvi_min2
tc1_min3	tc2_min3	tc4_min3	tc3_min3	tc5_min3	tc6_min3	ndvi_min3
tc1_min4	tc2_min4	tc4_min4	tc3_min4	tc5_min4	tc6_min4	ndvi_min4
tc1_min5	tc2_min5	tc4_min5	tc3_min5	tc5_min5	tc6_min5	ndvi_min5
tc1_max1	tc2_max1	tc4_max1	tc3_max1	tc5_max1	tc6_max1	ndvi_max1
tc1_max2	tc2_max2	tc4_max2	tc3_max2	tc5_max2	tc6_max2	ndvi_max2
tc1_max3	tc2_max3	tc4_max3	tc3_max3	tc5_max3	tc6_max3	ndvi_max3
tc1_max4	tc2_max4	tc4_max4	tc3_max4	tc5_max4	tc6_max4	ndvi_max4
tc1_max5	tc2_max5	tc4_max5	tc3_max5	tc5_max5	tc6_max5	ndvi_max5
tc1_mean1	tc2_mean1	tc4_mean1	tc3_mean1	tc5_mean1	tc6_mean1	ndvi_mean1
tc1_mean2	tc2_mean2	tc4_mean2	tc3_mean2	tc5_mean2	tc6_mean2	ndvi_mean2
tc1_mean3	tc2_mean3	tc4_mean3	tc3_mean3	tc5_mean3	tc6_mean3	ndvi_mean3
tc1_mean4	tc2_mean4	tc4_mean4	tc3_mean4	tc5_mean4	tc6_mean4	ndvi_mean4
tc1_mean5	tc2_mean5	tc4_mean5	tc3_mean5	tc5_mean5	tc6_mean5	ndvi_mean5
tc1_std1	tc2_std1	tc4_std1	tc3_std1	tc5_std1	tc6_std1	ndvi_std1
tc1_std2	tc2_std2	tc4_std2	tc3_std2	tc5_std2	tc6_std2	ndvi_std2
tc1_std3	tc2_std3	tc4_std3	tc3_std3	tc5_std3	tc6_std3	ndvi_std3
tc1_std4	tc2_std4	tc4_std4	tc3_std4	tc5_std4	tc6_std4	ndvi_std4
tc1_std5	tc2_std5	tc4_std5	tc3_std5	tc5_std5	tc6_std5	ndvi_std5
tc1_var1	tc2_var1	tc4_var1	tc3_var1	tc5_var1	tc6_var1	ndvi_var1
tc1_var2	tc2_var2	tc4_var2	tc3_var2	tc5_var2	tc6_var2	ndvi_var2
tc1_var3	tc2_var3	tc4_var3	tc3_var3	tc5_var3	tc6_var3	ndvi_var3
tc1_var4	tc2_var4	tc4_var4	tc3_var4	tc5_var4	tc6_var4	ndvi_var4
tc1_var5	tc2_var5	tc4_var5	tc3_var5	tc5_var5	tc6_var5	ndvi_var5

feat_1

feat_2

feat_3

feat_4

feat_5

feat_6

feat_7

feat_8

feat_9

feat_10

feat_11

feat_12

feat_13

feat_14

feat_15

feat_16

feat_17

feat_18

feat_19





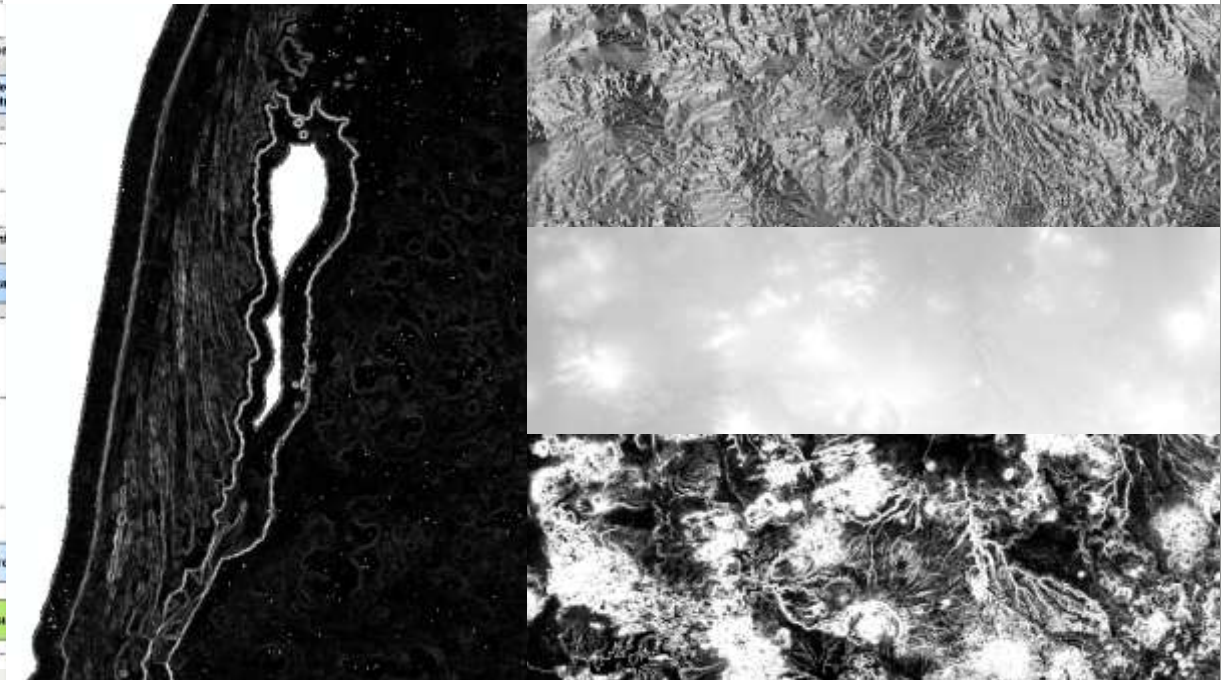
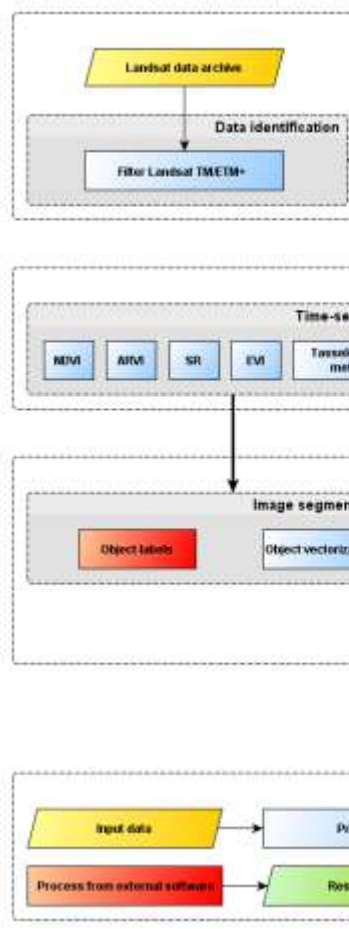
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MAD-MEX Landsat processing

Object texture and elevation feature extraction

Descriptive statistics (min,max,mean,std,var) over the object pixels from the DEM, Aspect and Slope as also from the magnitude of the sobel gradient over NDVI mean image





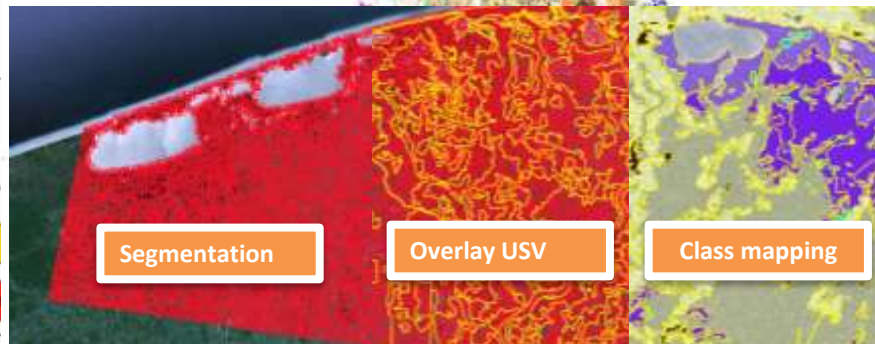
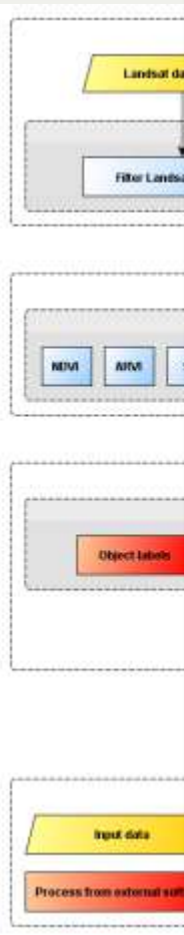
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MAD-MEX Landsat processing

Object class mapping

Utilizing persistent polygons from INEGI USV series mapped to classification scheme



- AGRICULTURA
- BOSQUE DE CONIFERAS
- BOSQUE DE CONIFERAS ARBOREA
- BOSQUE DE CONIFERAS ARBUSTIVA
- BOSQUE DE CONIFERAS HERBACEA
- BOSQUE DE ENCINO
- BOSQUE DE ENCINO ARBOREA
- BOSQUE DE ENCINO ARBUSTIVA
- BOSQUE DE ENCINO HERBACEA
- BOSQUE DE ENCINO-PINO Y PINO-ENCINO
- BOSQUE DE ENCINO-PINO Y PINO-ENCINO ARBOREA
- BOSQUE DE ENCINO-PINO Y PINO-ENCINO ARBUSTIVA
- BOSQUE DE ENCINO-PINO Y PINO-ENCINO HERBACEA
- CUERPO DE AGUA
- MATORRAL XEROFILO
- MATORRAL XEROFILO ARBOREA
- MATORRAL XEROFILO ARBUSTIVA
- MATORRAL XEROFILO HERBACEA
- PASTIZALES
- PASTIZALES ARBUSTIVA
- SELVAS HUMEDAS Y SUBHUMEDAS Y BOSQUE MESOFILO
- SELVAS HUMEDAS Y SUBHUMEDAS Y BOSQUE MESOFILO ARBOREA
- SELVAS HUMEDAS Y SUBHUMEDAS Y BOSQUE MESOFILO ARBUSTIVA
- SELVAS HUMEDAS Y SUBHUMEDAS Y BOSQUE MESOFILO HERBACEA
- SELVAS SECAS
- SELVAS SECAS ARBOREA
- SELVAS SECAS ARBUSTIVA
- SELVAS SECAS HERBACEA
- SUELO DESNUDO
- URBANO Y CONSTRUIDO
- VEGETACION HIDROFILO
- VEGETACION HIDROFILO ARBUSTIVA





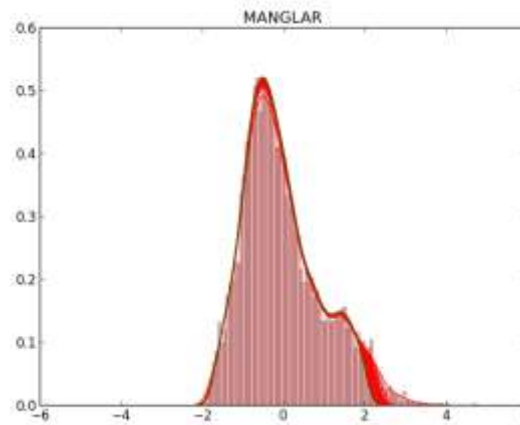
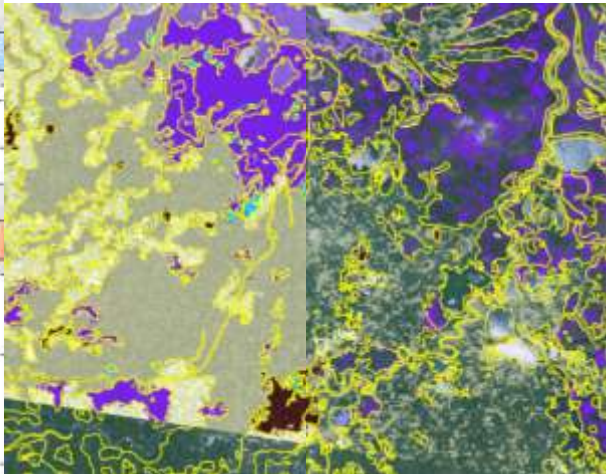
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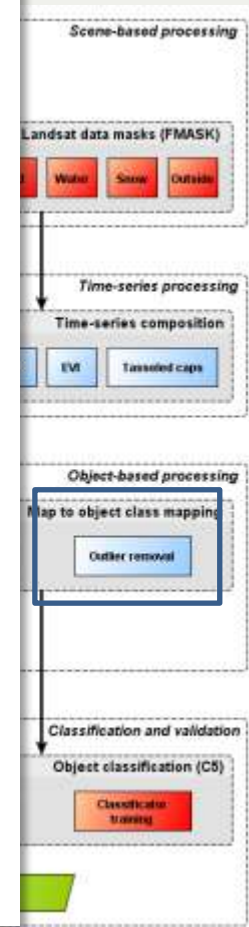
MAD-MEX Landsat processing

Outlier removal

To account for discrepancies between reference map and image objects – to create “clean” training dataset
Outlier removal utilizing classwise iterative histogram trimming on the first 3 principal component features



Radoux, Julien, and Pierre Defourny. “Automated Image-to-Map Discrepancy Detection Using Iterative Trimming.” *Photogrammetric Engineering & Remote Sensing* 76, no. 2 (2010): 173–181.





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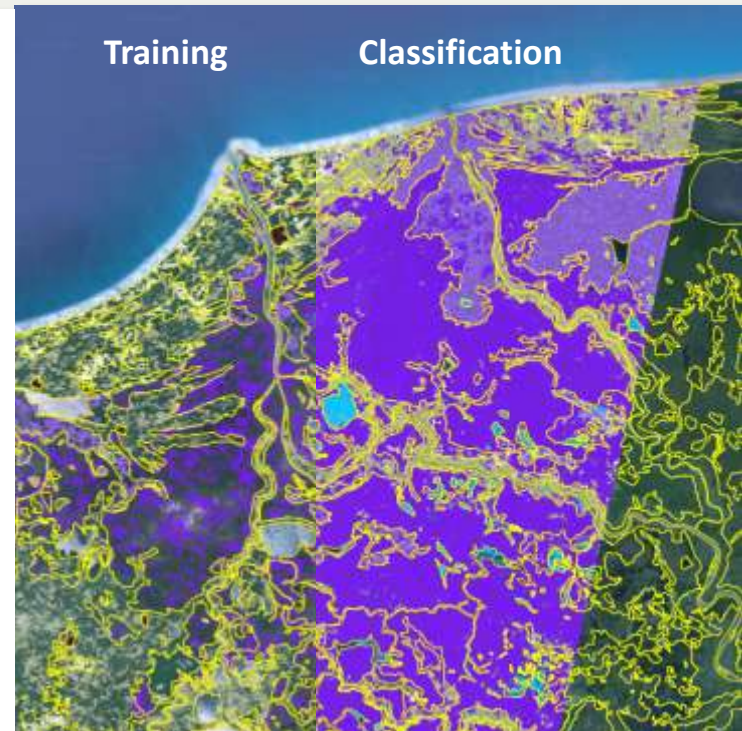
MAD-MEX Landsat processing

Object classification based on C5 decision tree

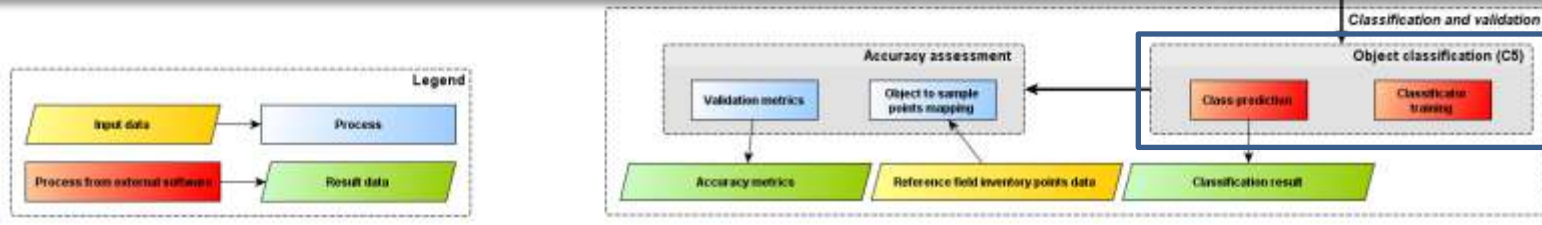
Training of the classifier based on the outlier cleaned training data.

Training of 10-folded boosted decision tree.

Classification of all objects and export to Shapefile.



Hodge, Victoria, and Jim Austin. "A Survey of Outlier Detection Methodologies." *Artificial Intelligence Review* 22, no. 2 (2004): 85–126.
Quinlan, J. Ross. *C4.5: Programs for Machine Learning* (Morgan Kaufmann Series in Machine Learning). 1st ed. Morgan Kaufmann, 1992.



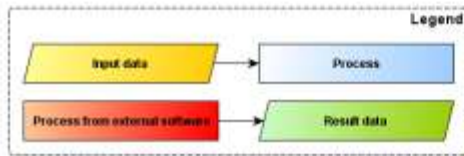
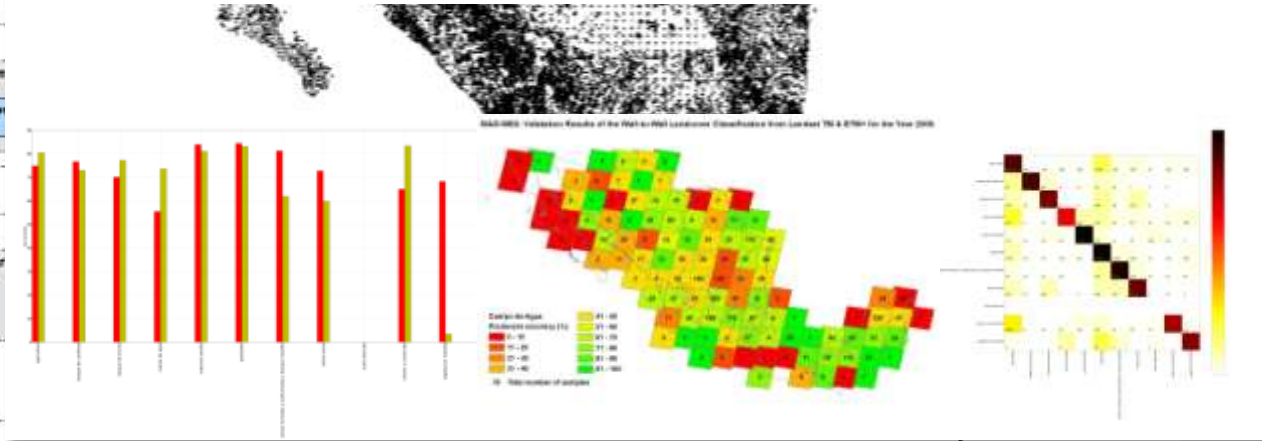
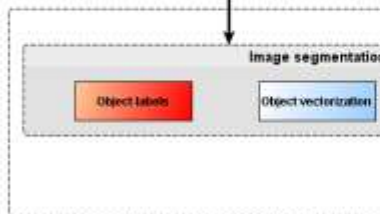
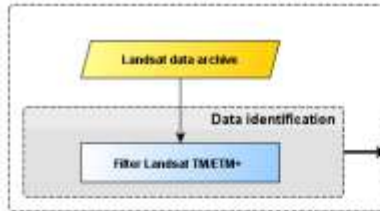


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MAD-MEX Landsat processing

Validation based on reference points available from:
 Colpos, Procede (Agriculture, Pastures)
 INFyS (Forest areas, homogeneous conglomerates)
 NALCMS (Matorrales)
 INEGI/CONABIO (Urban areas, Water bodies)

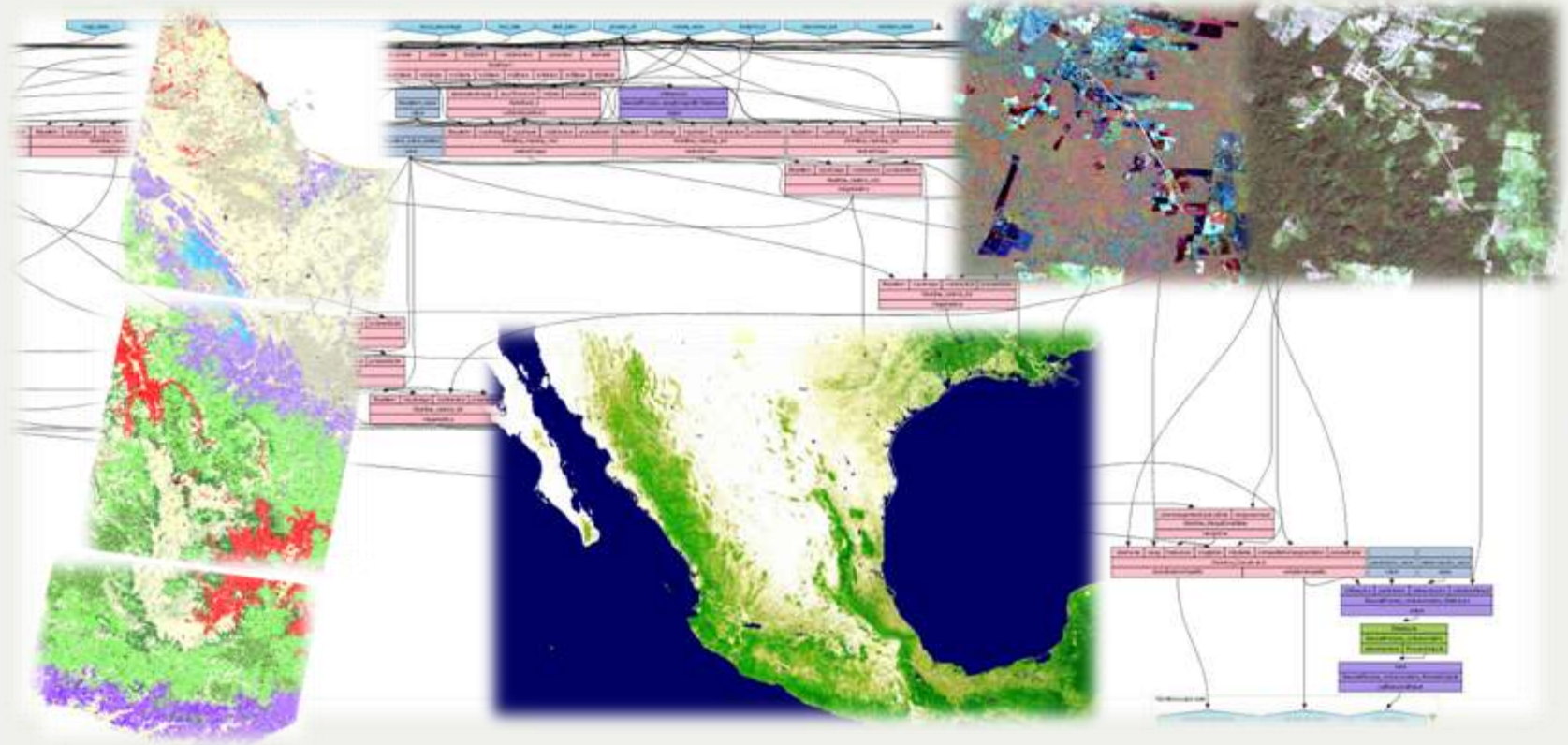




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Thank you



Dr. Steffen Gebhardt, steffen.gebhardt@cimonline.de

