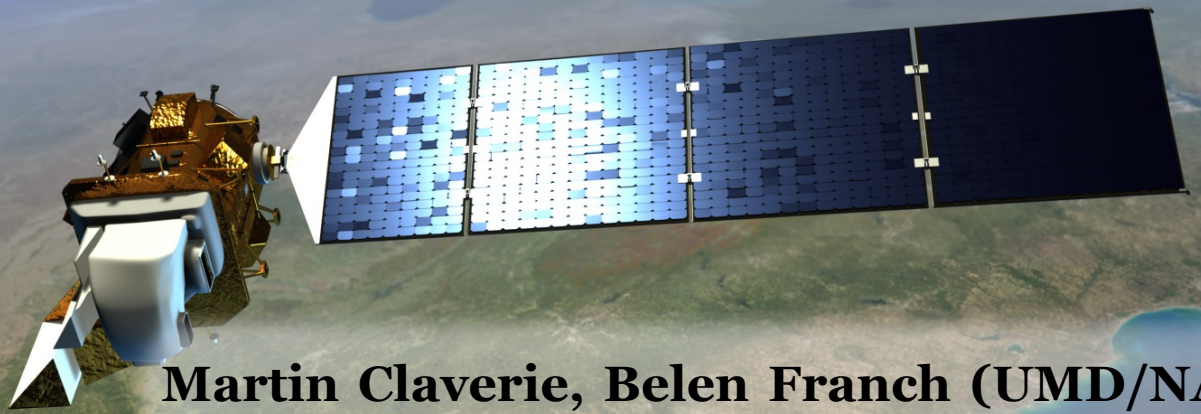
Evaluation of medium spatial resolution BRDF-adjustment techniques using multi-angular SPOT4 (Take5) acquisitions



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Presented by Olivier Hagolle (CESBIO)

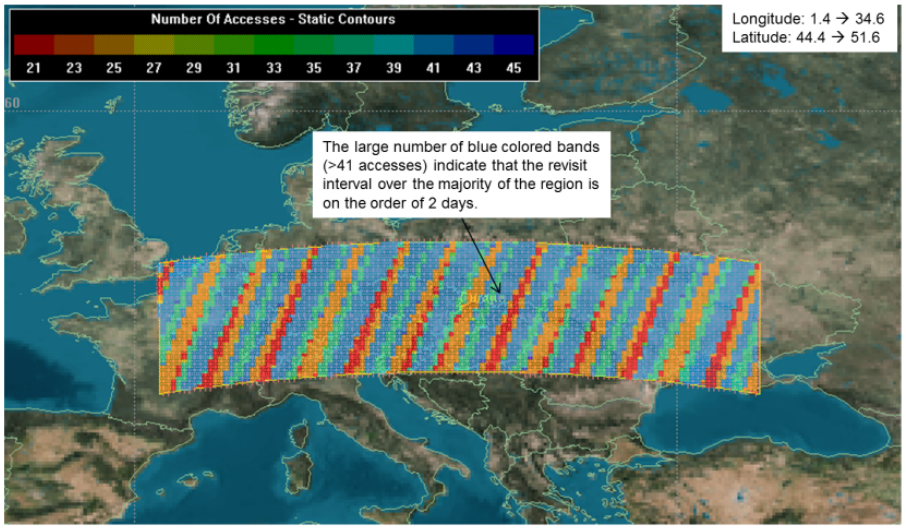
8th International Workshop on the Analysis of Multitemporal Remote Sensing Images July 22-24, 2015 – Annecy, France

Context: the Harmonized Landsat/Sentinel2 product (HLS)

- ❑ Merging Sentinel-2 and Landsat data streams could provide < 5-day coverage
- ❑ Goal is "seamless" near-daily 30m surface reflectance record
- ❑ Cross-calibration, atmospheric corrections, spectral and **BRDF adjustments**, regridding
- ❑ Prototype over 20-30 sites during first MSI year.

- ❑ Some Specifications:
  - ➢ Nadir-corrected – constant SZA
  - ➢ Landsat-like bands + Red-edge + thermal
  - ➢ 30m spatial res., Sinusoidal proj., WELD tiling system (equivalent MODIS @30m)
  - ➢ 6-day temporal composite product (best pixel, no averaging)
  - ➢ Intermediate products distributed (without temporal compositing)

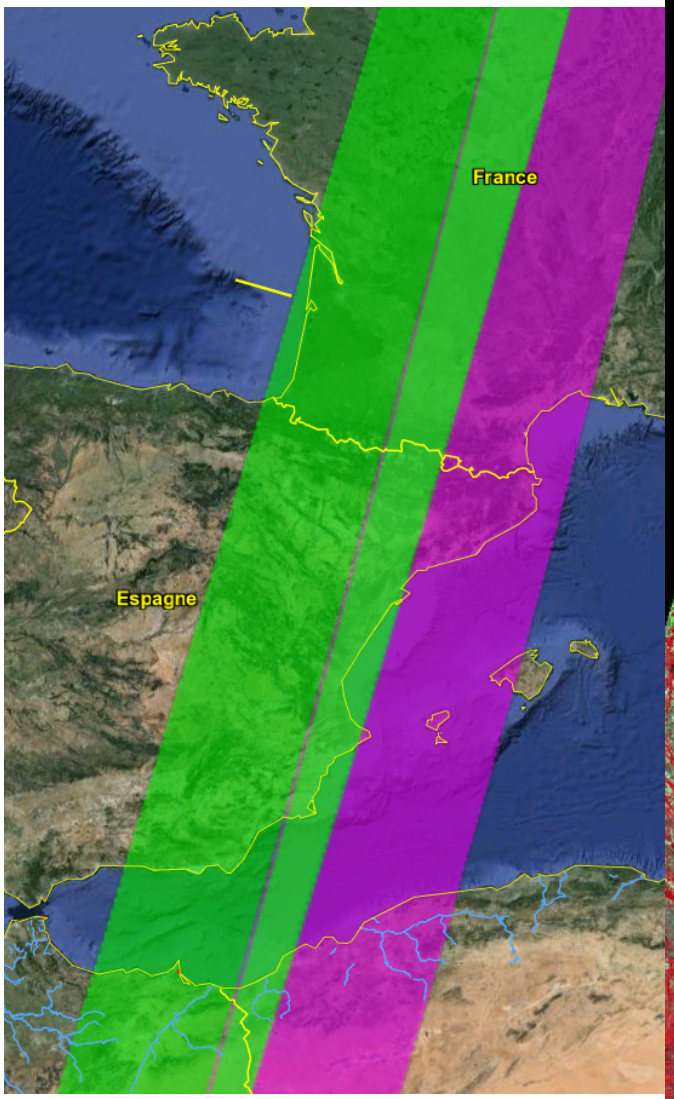
Sentinel 2A and B - LDCM Europe

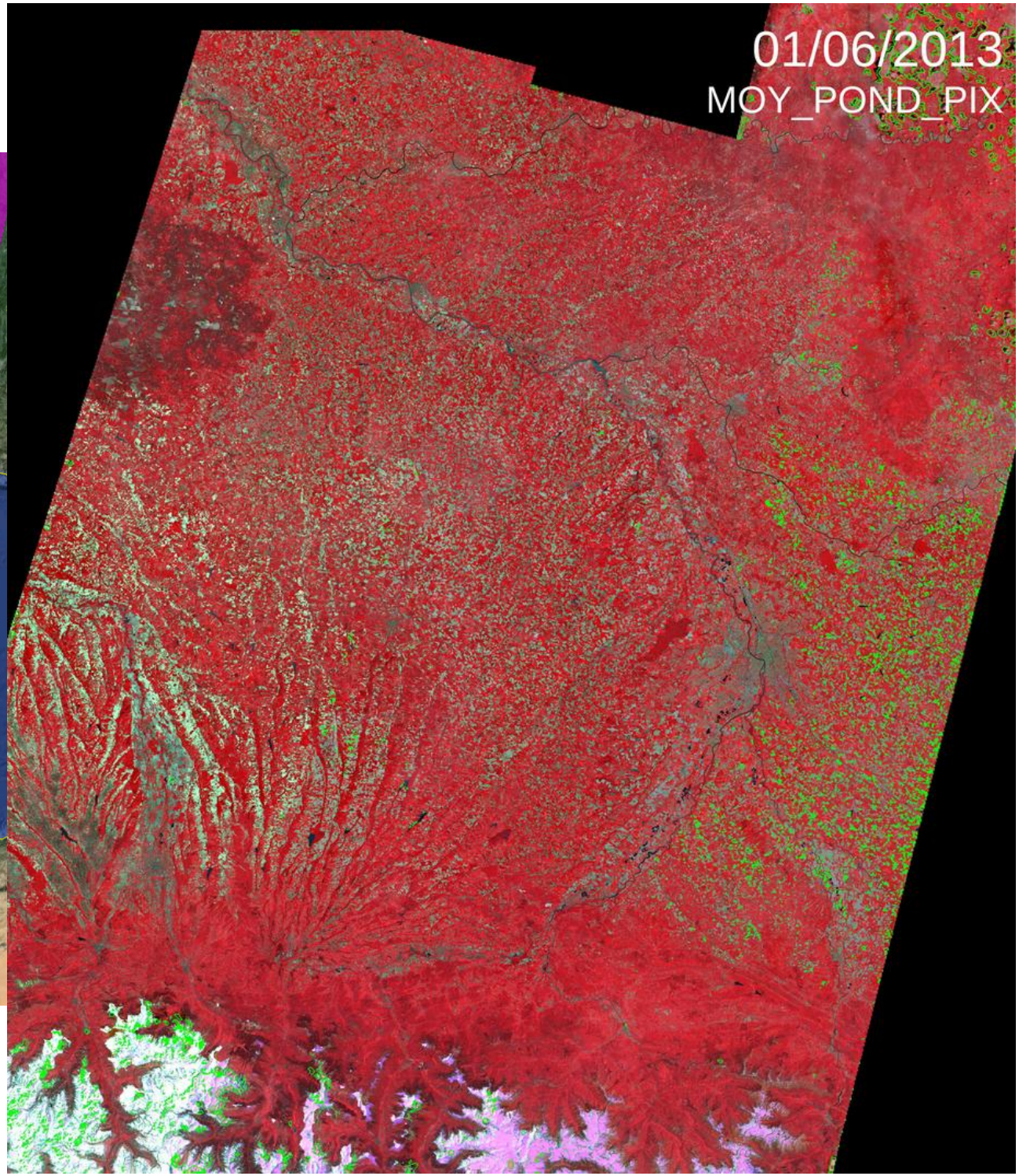


- The picture shows the number of times LDCM and the Sentinel 2 satellites accessed areas on the ground over an 80 day period of time.
  - 21 accesses indicates a maximum revisit interval of ~3 days 19 hours
  - 46 accesses indicates a minimum revisit interval of ~1 day 18 hours

7

Courtesy Brian Killough, NASA LARC

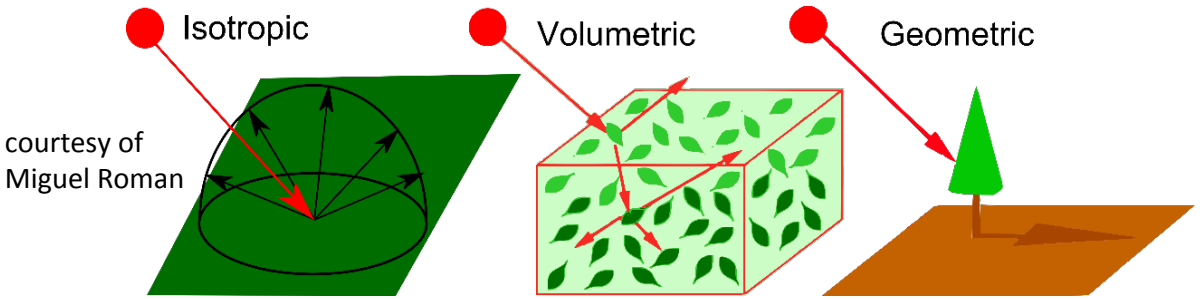

France
Espagne


01/06/2013
MOY_POND_PIX

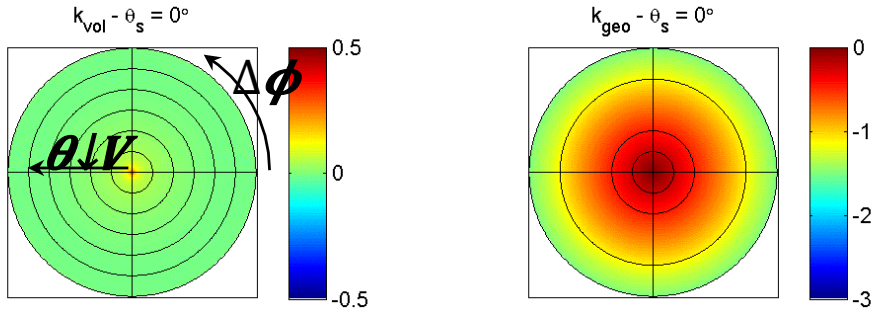
Bidirectional Reflectance Distribution Function

- The BRDF describes the directional way solar radiation reflects from the surface.

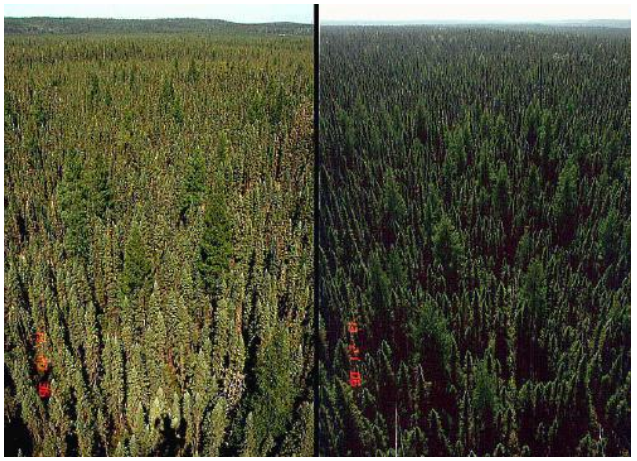
$$\rho(\theta_S, \theta_V, \Delta\phi, \lambda) = f_{iso}(\lambda) + k_{vol}(\theta_S, \theta_V, \Delta\phi) \times f_{vol}(\lambda) + k_{geo}(\theta_S, \theta_V, \Delta\phi) \times f_{geo}(\lambda)$$



courtesy of Miguel Roman



backscattering forwardscattering



Photographs by Don Deering.

Moderate resolution BRDF retrieval

- MODIS BRDF products (MCD43) include albedo, BRDF parameters and NBAR
- NBAR = Nadir BRDF-Adjusted Reflectances (and mean sun zenith angle)
- Inversion approaches were developed using the high temporal and angular sampling (e.g. MODIS = daily, +/- 60°)
- MCD43 products
  - relies on 16-day SR stability to invert $f_{iso}/f_{vol}/f_{geo}$
  - $f_{iso}/f_{vol}/f_{geo}$ are temporally and spatially explicit

$$\rho(\theta) = f_{iso}(\lambda) + k_{vol}(\theta) \times f_{vol}(\lambda) + k_{geo}(\theta) \times f_{geo}(\lambda)$$

- VJB (Vermote et al. 2009):
  - Simplification of the BRDF eq.
  - *V*&*R* = Related to NDVI variation and spatially explicit

$$V(\lambda) = f_{\mathrm{vol}}(\lambda)/f_{\mathrm{iso}}(\lambda) \qquad R(\lambda) = f_{\mathrm{geo}}(\lambda)/f_{\mathrm{iso}}(\lambda)$$

$$\rho(\Theta, \lambda) = f_{iso}(\lambda)\left(1 + V(\lambda)k_{vol}(\theta) + R(\lambda)k_{geo}(\theta)\right)$$

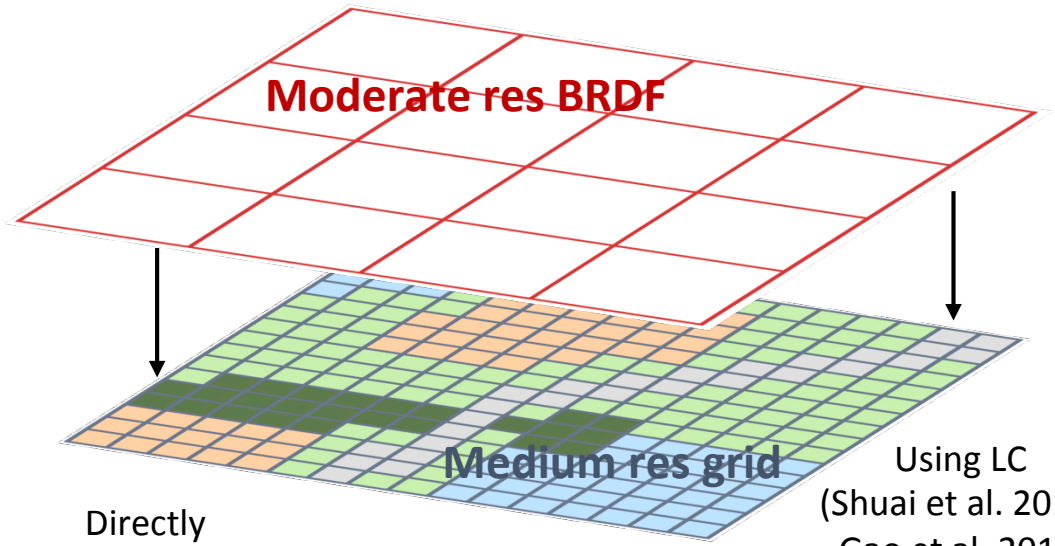
$$V(\lambda) = V_0(\lambda) \times NDVI + V_1(\lambda)$$

$$R(\lambda) = R_0(\lambda) \times NDVI + R_1(\lambda)$$

$\Theta \rightarrow$ sun/view geometry $(\theta_S, \theta_V, \Delta\phi)$

Medium resolution BRDF retrieval

- Not enough temporal and angular sampling to retrieve the BRDF
- BRDF retrieval needs to rely on a-priori of the BRDF shape
  - From Archetypes (fix BRDF shape)
  - From moderate resolution BRDF



Directly
(Roy et al. 2008)

Using LC
(Shuai et al. 2011,
Gao et al. 2014,
Franch et al. 2014)

How to apply MODIS BRDF a-priori?

- MCD43

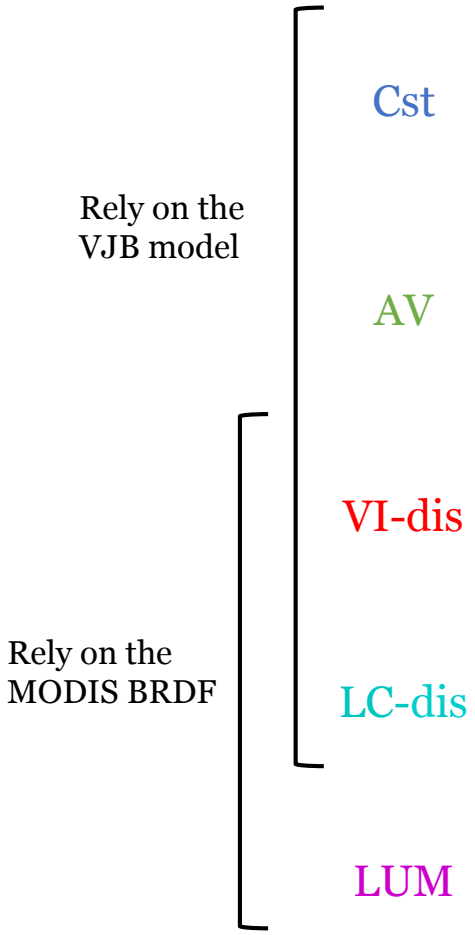
$$c = \frac{f_{iso} + k_{vol}(\theta_0) \times f_{vol} + k_{geo}(\theta_0) \times f_{geo}}{\rho_{MODIS}(\theta_{obs})}$$

- VJB

$$c = \frac{1 + Vk_{vol}(\Theta_0) + Rk_{geo}(\Theta_0)}{1 + Vk_{vol}(\Theta_{obs}) + Rk_{geo}(\Theta_{obs})}$$

Related to NDVI

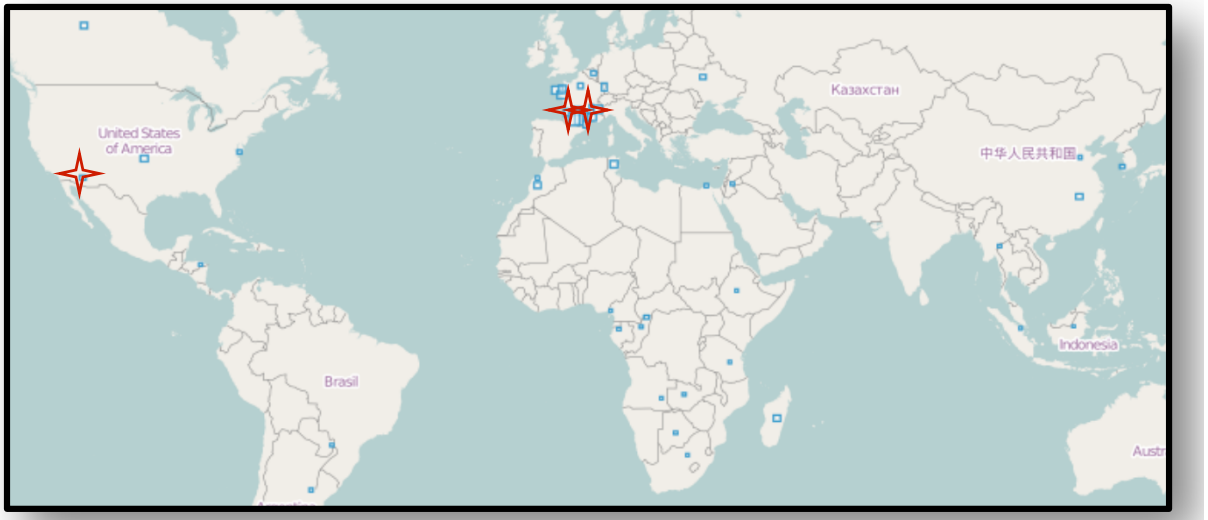
Five BRDF-adjustment techniques



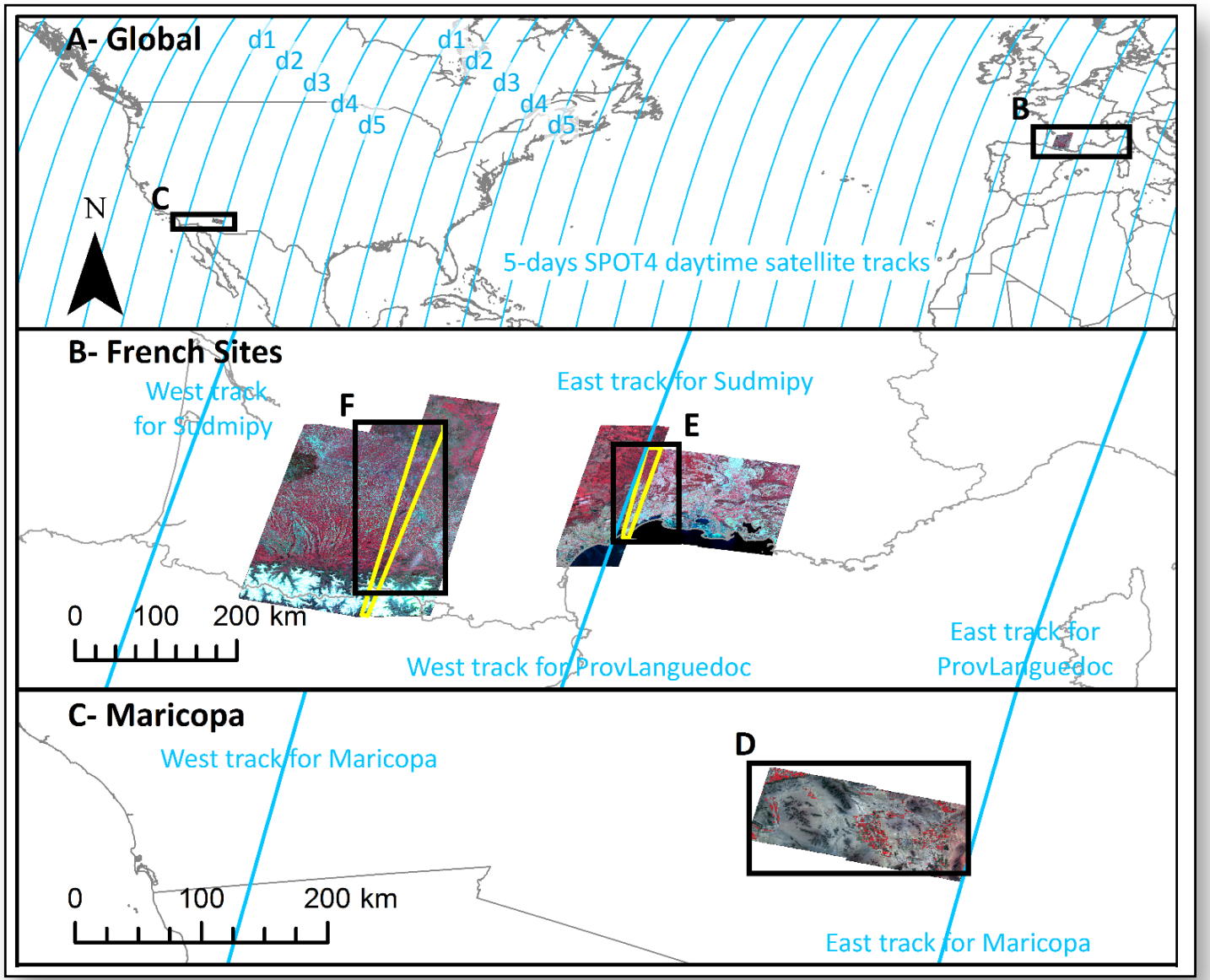
- Constant technique (from CESBIO analysis)
  - Constant BRDF shape for all surfaces
  - Rely on VJB model
- Average technique (Breon et al. 2012)
  - Use of 20m NDVI
  - Not based on MODIS BRDF retrieval
  - Rely on VJB method
- NDVI-disaggregation technique (claverie, 2015)
  - Use of 20m NDVI to disaggregate BRDF shape
  - Based on VJB MODIS BRDF retrieval (@1250m)
- Land Cover disaggregation technique (Franch et al. 2014)
  - Use of per-scene-Land-Cover to disaggregate BRDF shape
  - Based on VJB MODIS BRDF retrieval (@1250m)
- Look-up maps (LUM) technique (Gao et al., 2014)
  - Use of the Crop Data Layer (USDA) to disaggregate BRDF shape
  - Based on MCD43 MODIS BRDF products (@500m)

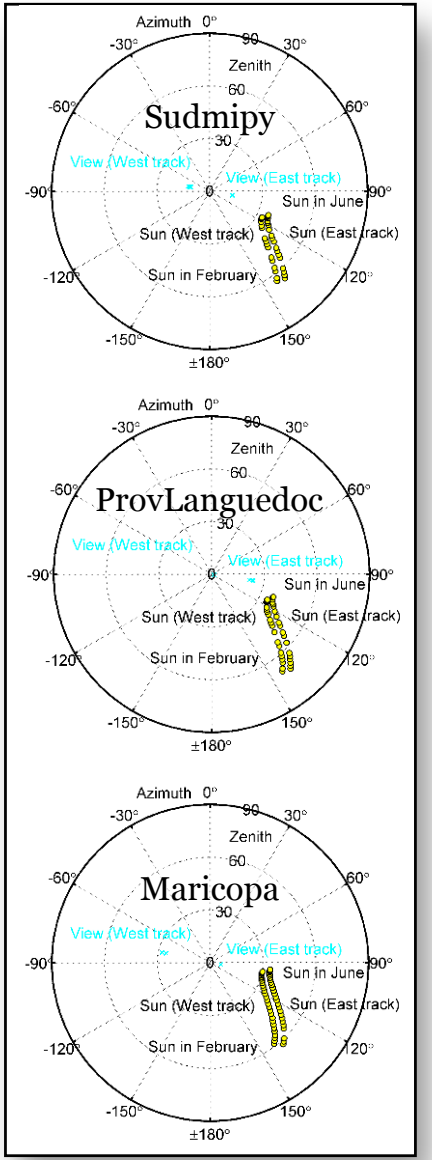
The SPOT4 (Take5) experiment

- From 01/29/2013 to 06/19/2013, SPOT4's orbit was lowered by 3km
- 5 day repeat cycle orbit.
- 45 sites have been observed every 5 days
- SPOT4 HRV1-2 specs:
  - Spatial: 20m
  - Spectral (550nm, 650nm, 850nm, 1600nm)
  - Swath: 60km (but can be extend to 120km using HRV1&2)
  - Pointing capability: +/-30°
- Three Multi-angular sites
  - Sudmipy (France)
  - ProvLanguedoc (France)
  - Maricopa (Arizona, USA)

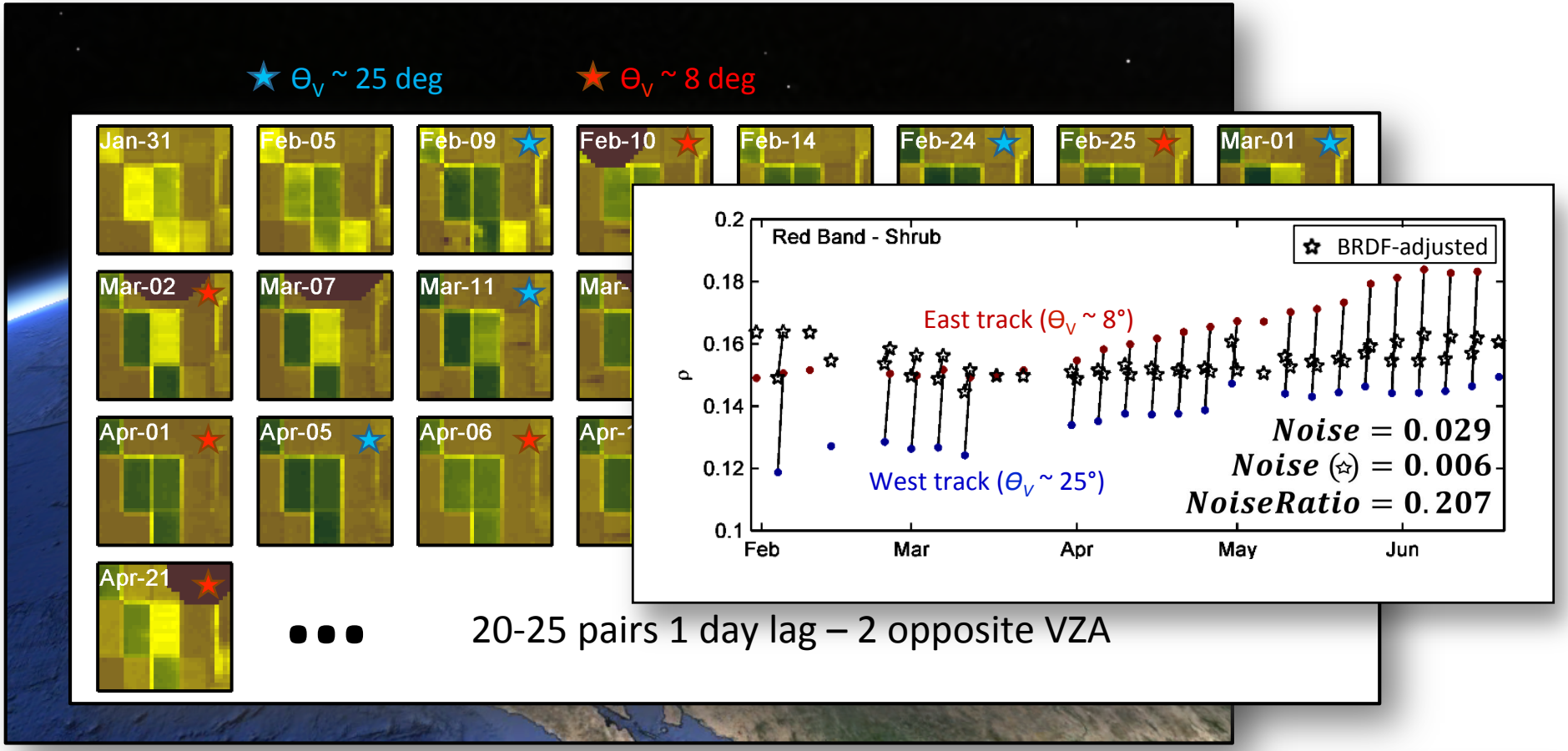


Take5 Multi-angular sites





Evaluation procedure: Time series Noise

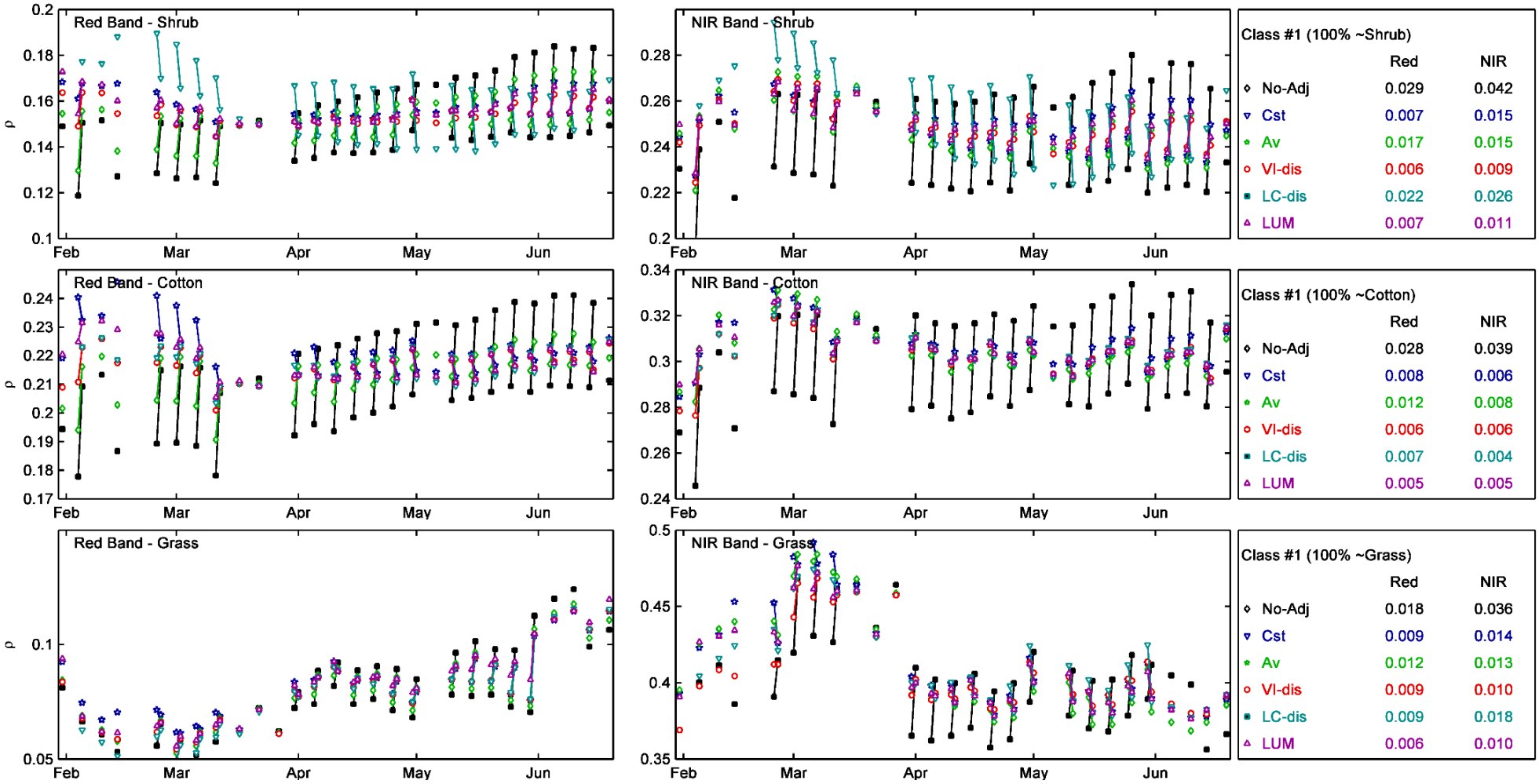


Evaluation metrics

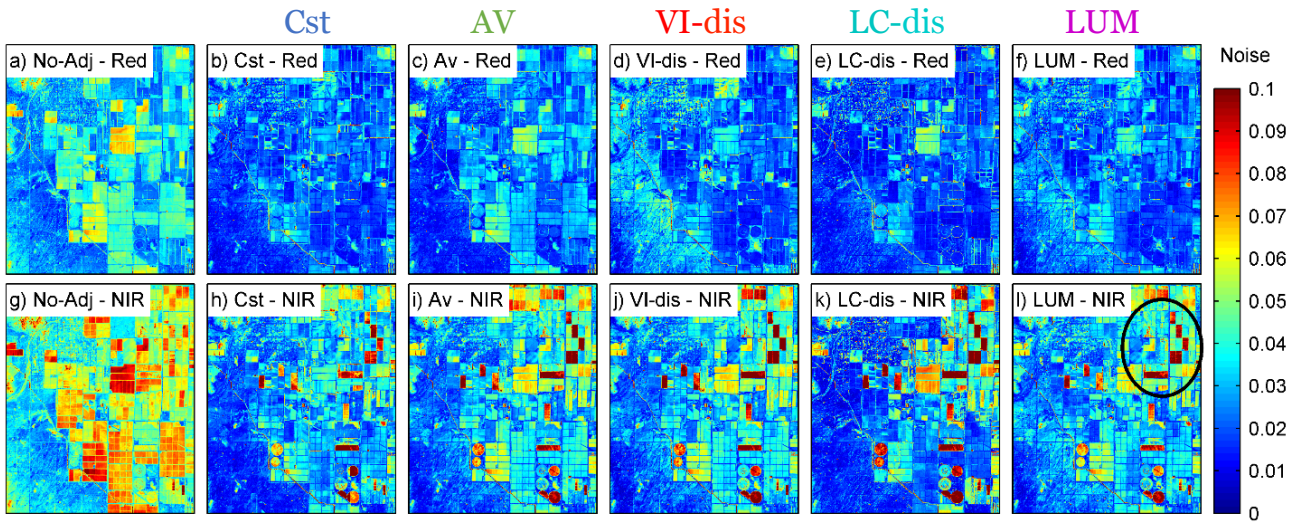
$$Noise = \sqrt{\sum_{i=1}^{n} \frac{(\rho(day_i) - \rho(day_i + 1))^2}{n}}$$

$$NoiseRatio(techniques_j) = \frac{Noise(techniques_j)}{Noise(No\ Adj.)}$$

Time series examples



Noise Analysis – Maricopa site



Red band

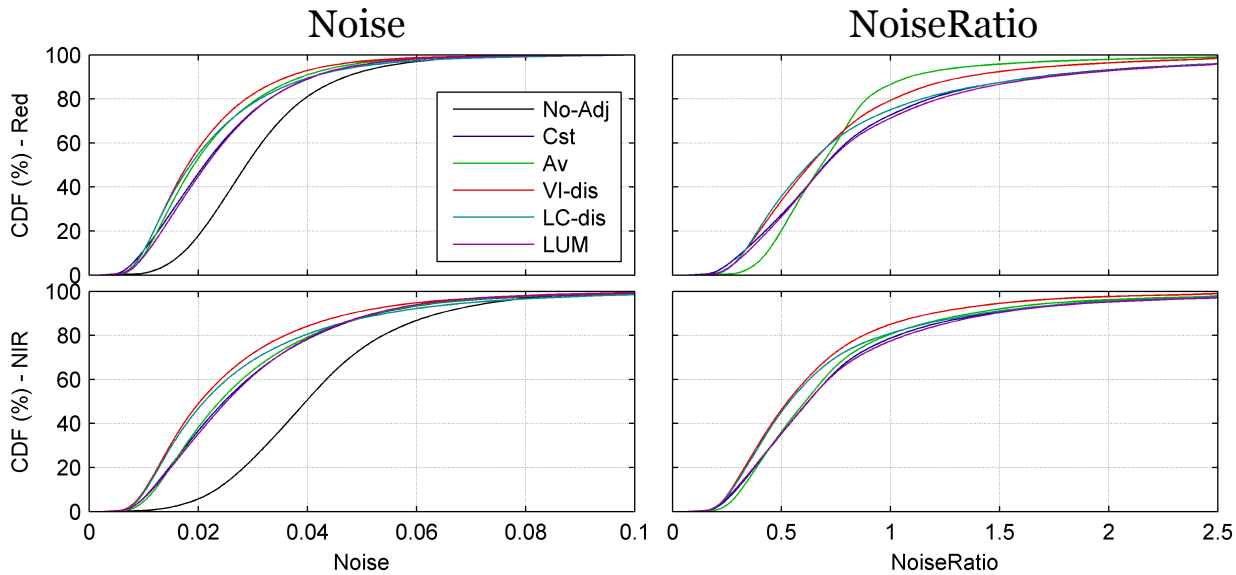
NIR band

Map of the Noise

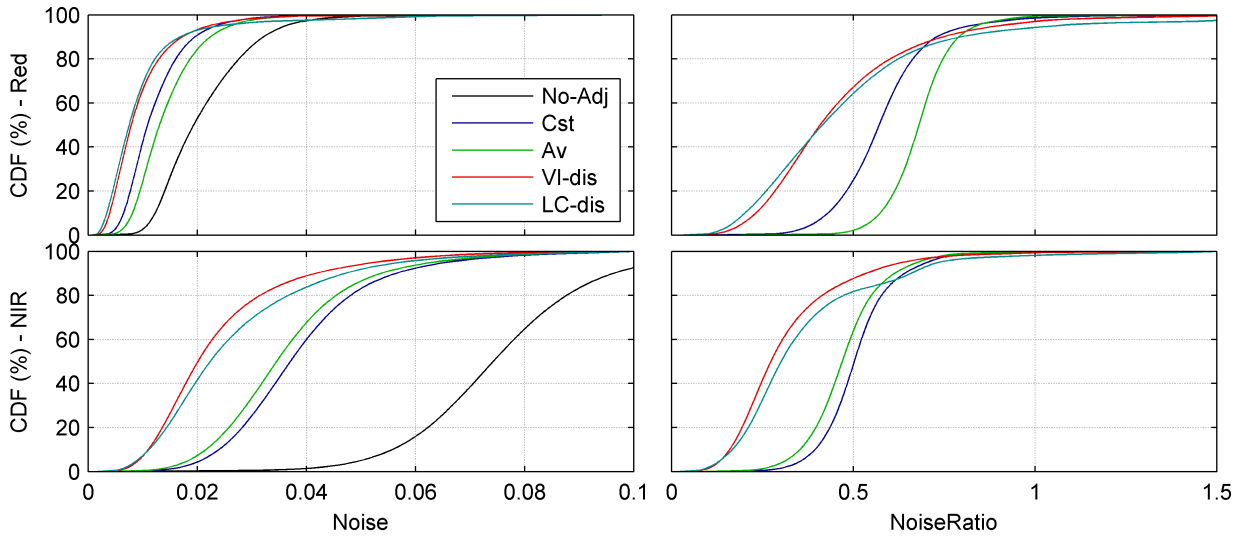
Distribution of The Noise and NoiseRatio

Red band

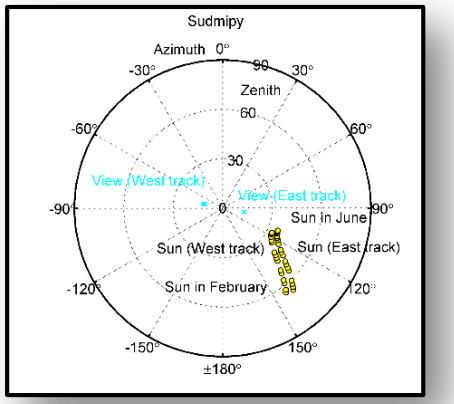
NIR band



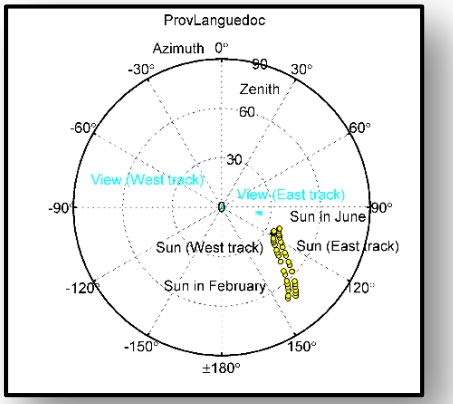
Noise Analysis – French sites

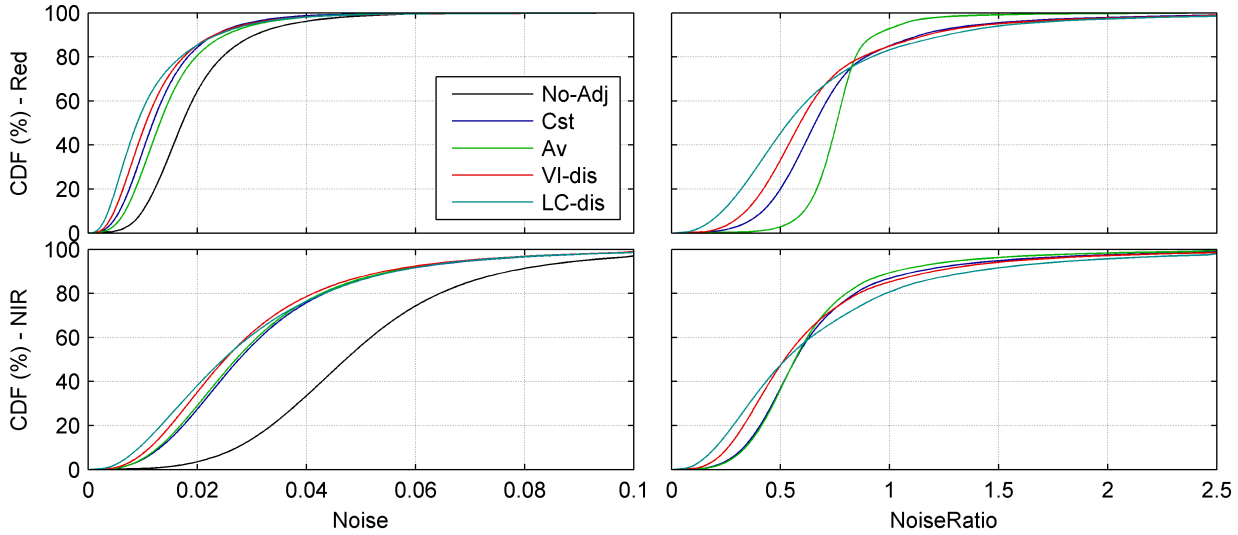


Sudmipy



ProvLanguedoc





Conclusion

- The Multi-angular SPOT4 (Take5) sites provided a unique dataset for medium spatial resolution BRDF retrieval techniques.
- Study can be repeated with SENTINEL-2A

- Results highlights
  - Significant decrease of the Noise using any of the 5 techniques (average reduction: Red=40%; NIR=50%);
  - Spatially uniform techniques (Cst and Av) produce very decent results, knowing the simplicity of the approaches;
  - LUM: very good result over grassland and agriculture land cover, less over shrubland;
  - VI-dis produced the best overall result; consistent over the studied LC; easy to implement in an operational chain.
  - A forward-scattering issue that needs to be studied

- Limitations
  - Need to evaluate additional MOD43-based techniques (eg, Roy et al. 2008);
  - We evaluate BRDF performances over a limited range of sun-view geometry (VZA<28);
  - Forest LC poorly represented (SPOT/ TAKE5)

Claverie, M., et al. Evaluation of medium spatial resolution BRDF retrieval techniques using multi-angular SPOT4 (Take5) acquisitions. Remote Sensing MDPI, Special Issue "Lessons Learned from the SPOT4 (Take5): Experiment in Preparation for Sentinel-2“, In revision.

“Sorry for not being present at the 2015 MultiTemp, feel free to contact me for any questions regarding this presentation or the Landsat/Sentinel2 Harmonized product. *Merci beaucoup Olivier !*”

Martin (martin.claverie@nasa.gov)

Combined NoiseRatio scores (per LC / Site / band)

- Better overall Noise reduction for NIR (43-50%) than Red (28-42%)
- VI-dis = best performances
- LC-dis displays contrasted performances
- Cst and Av show decent performances for such simple approaches

low Noise Ratio high level		Red					NIR					N (in millions)
		Cst	Av	VI-dis	LC-dis	LUM	Cst	Av	VI-dis	LC-dis	LUM	
Agri-culture	Mar	0.755	0.828	0.749	**0.731***	0.748	0.816	0.812	0.781	0.907	**0.779***	1.27
	SMP	0.652	0.769	0.582	**0.502***		0.556	0.562	0.502	**0.438***		4.35
	PL	0.571	0.681	**0.407***	0.413		0.503	0.469	**0.272***	0.301		1.84
	3 Sites	0.638	0.754	0.570	**0.527***	0.748	0.556	0.549	0.473	**0.464***	0.779	7.46
Grass-land	Mar	0.839	0.872	0.829	0.828	**0.817***	0.738	0.701	0.695	**0.648***	0.674	0.50
	SMP	0.785	0.778	**0.689***	0.722		0.604	**0.574***	0.604	0.889		0.63
	PL	**0.724***	0.755	0.771	1.067		0.687	0.676	**0.652***	0.863		0.02
	3 Sites	0.814	0.823	**0.775***	0.806	0.817	0.668	**0.632***	0.652	0.753	0.674	1.14
shrub-land	Mar	0.672	0.642	0.594	**0.587***	0.680	0.590	0.577	**0.492***	0.505	0.596	11.04
	SMP	0.666	0.737	0.587	**0.528***		0.596	0.570	**0.545***	0.563		1.73
	PL											
	3 Sites	0.671	0.665	0.593	**0.581***	0.680	0.591	0.576	**0.499***	0.512	0.596	12.76
Forest	Mar											
	SMP	0.615	0.716	0.553	**0.509***		0.550	0.548	0.482	**0.466***		0.76
	PL											
	3 Sites	0.615	0.716	0.553	**0.509***		0.550	0.548	0.482	**0.466***		0.76
Bare soil / Urban	Mar											
	SMP	0.636	0.735	**0.620***	0.800		0.590	0.604	**0.536***	0.886		0.53
	PL											
	3 Sites	0.636	0.735	**0.620***	0.800		0.590	0.604	**0.536***	0.886		0.53
All classes	Mar	0.698	0.683	0.631	**0.622***	0.702	0.624	0.609	**0.528***	0.537	0.622	12.81
	SMP	0.658	0.757	0.589	**0.535***		0.568	0.566	**0.518***	0.524		7.99
	PL	0.571	0.681	**0.409***	0.415		0.503	0.470	**0.273***	0.302		1.85
	3 Sites	0.660	0.721	0.592	**0.575***	0.702	0.577	0.567	**0.499***	0.516	0.622	22.65

Table: **Median NoiseRatio values** for the 5 BRDF-adjustment techniques, the 2 spectral bands, the 3 sites (Mar=Maricopa, SMP= Sudmipy, PL= ProvLanguedoc) and 5 majors Land-Cover (LC, Agriculture, Grassland, Shrubland, Forest, Bare soil / Urban).

Cells are colored using the colorbar located in the upper left and Median Noise values of each band-site-LC configuration, corresponding to half-a-row.

Lower value of each configuration is written in bold with a star.

Forward scattering on Barley fields