CENTRE NATIONAL D'ÉTUDES SPATIALES

Physical Model to Describe the PARASOL Radiometric Trending

Definition, Adjustment, and Validation

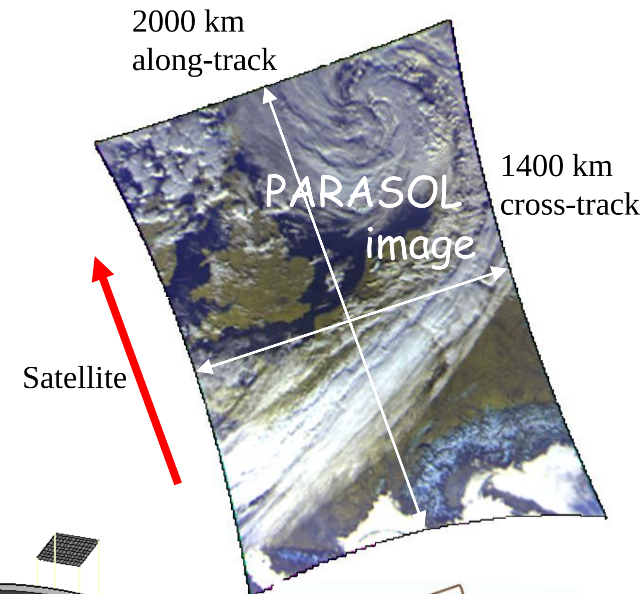
Bertrand Fougnie

CNES

Summary

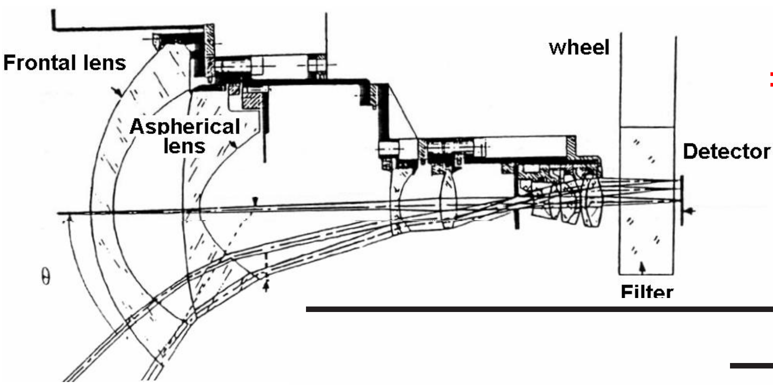
- The PARASOL instrument & mission
- Evidences a of radiometric drift : mean + within fov
- Remider : calibration approaches
- Mean behavior
- Drift physical model
- Extrapolation to drift within fov
- Adjustment using DCC/RAY/DES
- Validation
- Conclusion

The PARASOL Instrument

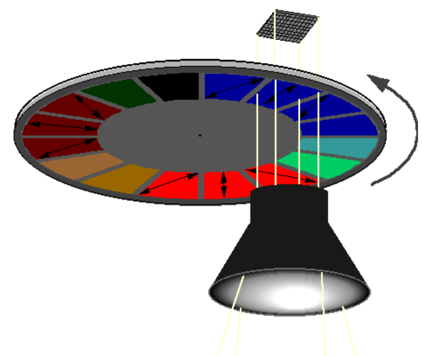


POLDER instrument onboard PARASOL : Dec 04 to now…

- **Camera = wide fov optic + CCD matrix**
  - 2D detector array 274x242 pixels
  - fov : ±50° incident angle (i.e. ±60° viewing angle)
  - Large swath: 2200 km for POLDER, 1400 km for Parasol
  - Moderate resolution : about 6 km
- **Multidirectionality : bidirectional + wide fov**
- **Multispectral and multi-polarisation**



⇒ No on-board calibration device



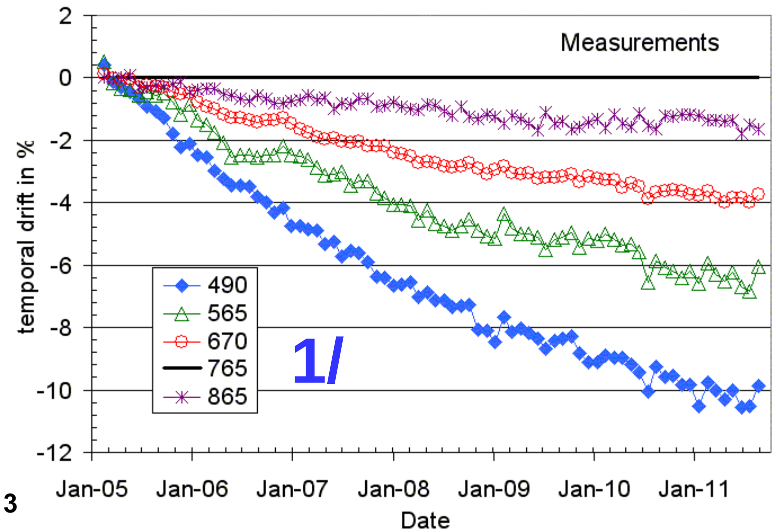
	Spectral Band								
	443	490	565	670	763	765	865	910	1020
Central wavelength (nm)	443.5	490.9	563.8	669.9	762.9	762.7	863.7	907.1	1019.6
Bandwidth (nm)	13.4	16.3	15.4	15.1	10.9	38.1	33.7	21.1	17.1
Polarization	—	yes	—	yes	—	—	yes	—	—
Saturation level (reflectance)	1.28	0.99	1.06	1.01	1.04	0.96	1.00	0.98	1.70

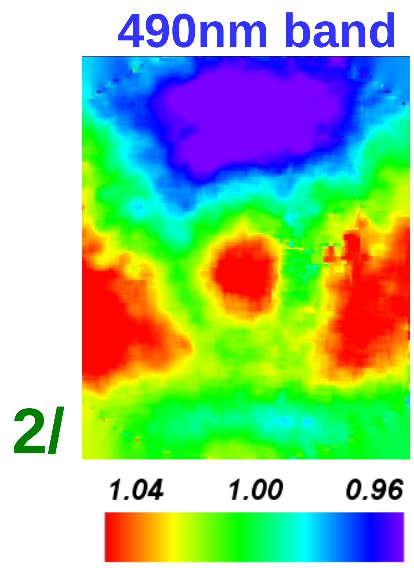
The PARASOL Instrument

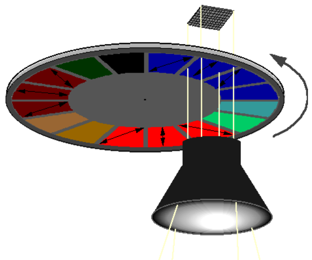
No onboard calibration device = in-flight characterization relies on vicarious technics

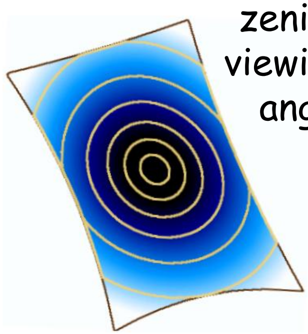
- based on natural targets
- characterization during the commissioning phase
- monitoring

- **1/ Ageing → decrease of the radiometric sensitivity detected**
  Development of an operational correction based on DCC (Fougnie et al., 2009)
  corrected but some limitations
- **2/ Ageing → differential variation inside the field-of-view**
  up to now not corrected









The PARASOL Instrument

No onboard calibration device = in-flight characterization relies on vicarious technics

- based on natural targets
- characterization during the commissioning phase
- monitoring

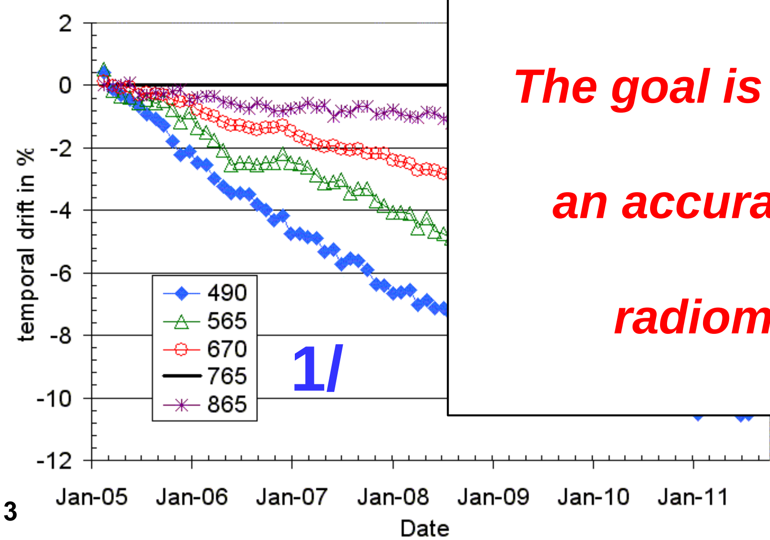
- **1/ Ageing → decrease of the radiometric sensitivity detected**

  Development of an operational correction based on DCC (Fougnie et al., 2009)

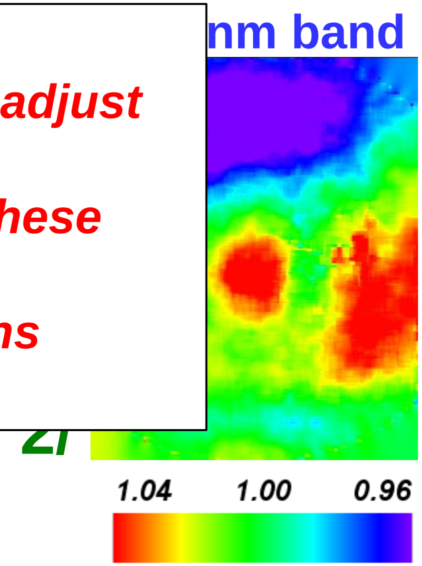
  corrected but some limitations

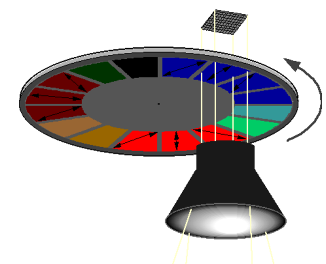
- **2/ Ageing → differential variation inside the field-of-view**

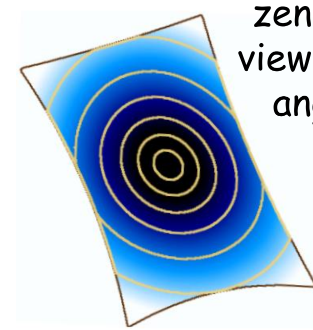
  up to now not corrected



The goal is to define and adjust an accurate model for these radiometric evolutions



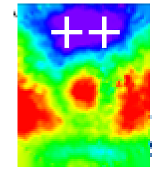


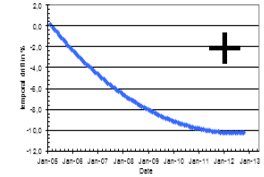


Calibration methods reminder

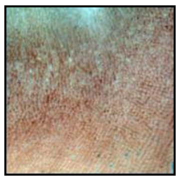
■ **Absolute over Rayleigh scattering** (Hagolle et al., 1999)

- Reference = Rayleigh scattering
- VIS bands + field-of-view coverage

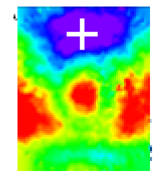


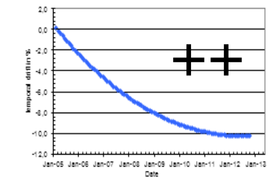


■ **Intercalibration over desert** (Lachérade et al., 2013)



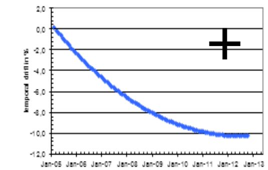
- Reference = one sensor (i.e. POLDER-1 or MODIS) or one date
- Pseudo-invariant site, geometrical matching + spectral interpolation





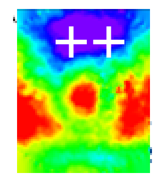
■ **Interband over sunglint** (Hagolle et al., 2004)

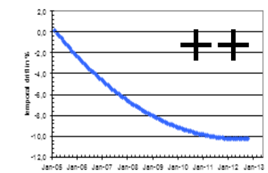
- Reference = one band (i.e. 765)



■ **Interband over DCC (clouds)** (Fougnie et al., 2009)

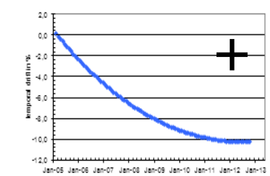
- Reference = one band (i.e. 765)





■ **Intercalibration over Antarctica** (Six et al., 2004)

- Reference = one sensor (i.e. POLDER-1 or MODIS) or one date



→ All applied to PARASOL in Fougnie et al., 2007

Trending Physical Model

…to improve the trending model and describe what happens

▪ Simple Physical Model - band k

- 1 time constant Dk (= 1 ageing process)
- 1 amplitude Bk

$$\frac{Ak(t)}{Ak(to)} = \left[1 - Bk \times (1 - exp(-Dk \times t))\right]$$

▪ Very realistic up to 2011

- Dk initially estimated for each band
- Unique time constant D
  - Estimated for shortest wavelengths
  - Valid for other bands

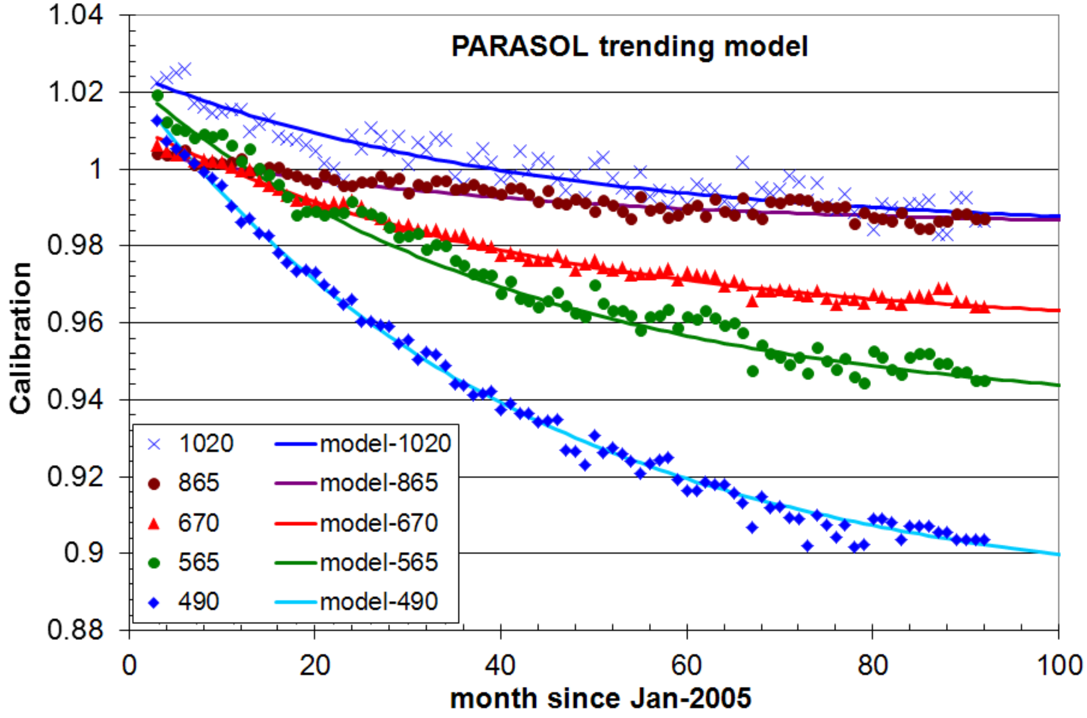
$$\frac{Ak(t)}{Ak(to)} = \left[1 - Bk \times (1 - exp(-D \times t))\right]$$

- « Instrumental » time constant

  D = 0.0006 day^{-1} = 0.018 $month^{-1}$

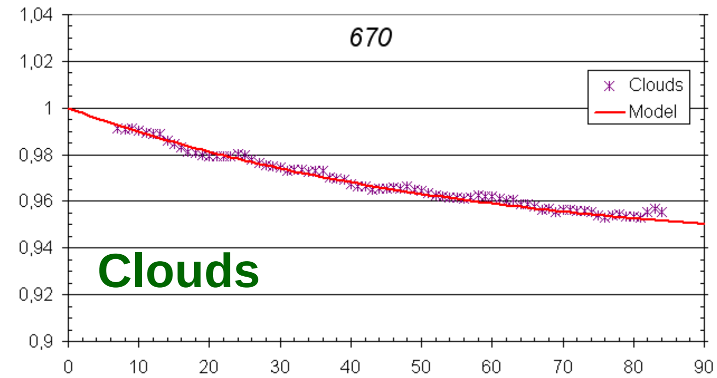
→ estimate the amplitude Bk for all bands

DCC measurements



Trending Physical Model

Calibration versus month



- **Adjustment – Validation combining all methods**
  - **1 amplitude Bk**

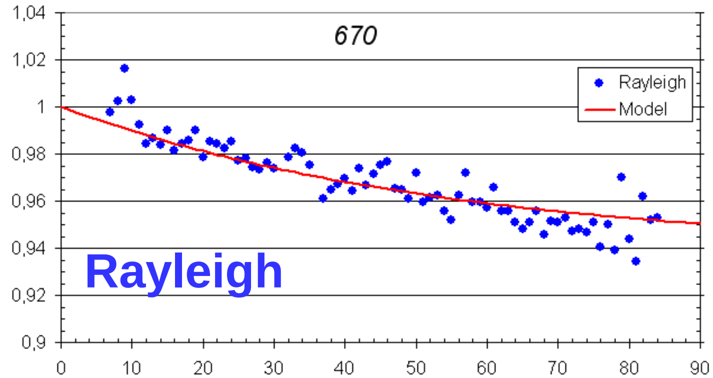
$$\frac{Ak(t)}{Ak(to)} = \left[1 - Bk \times (1 - exp(-D \times t))\right]$$

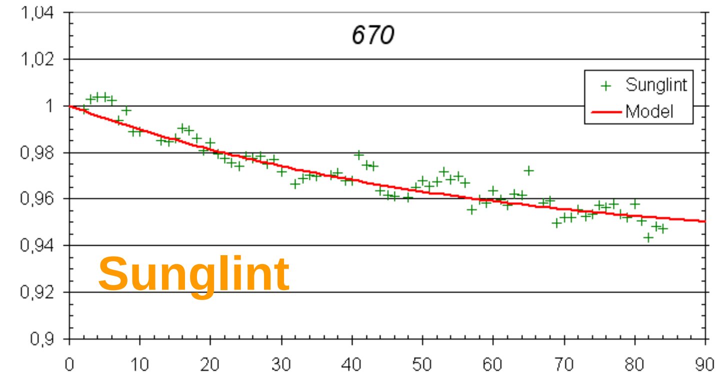
  - **Consistency in the « red »**

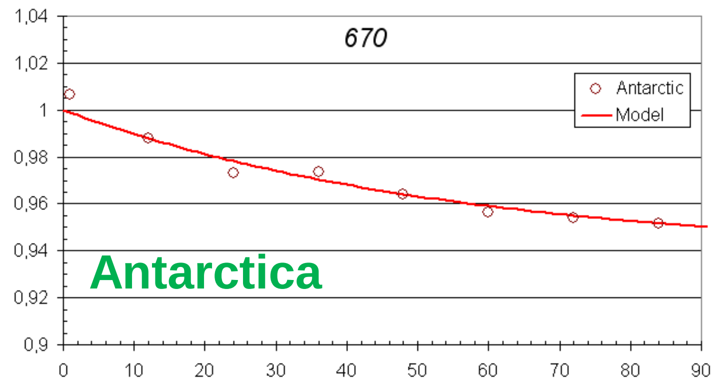
Band 670nm

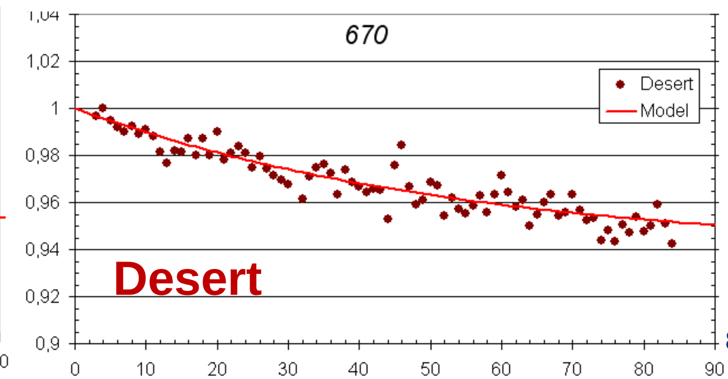
$D = 0.018$ month^{-1}

$B_{670} = 0.062$









Trending Physical Model

■ Adjustment – Validation combining all methods

- 1 amplitude Bk

$$\frac{Ak(t)}{Ak(to)} = \left[1 - Bk \times (1 - \exp(-D \times t))\right]$$

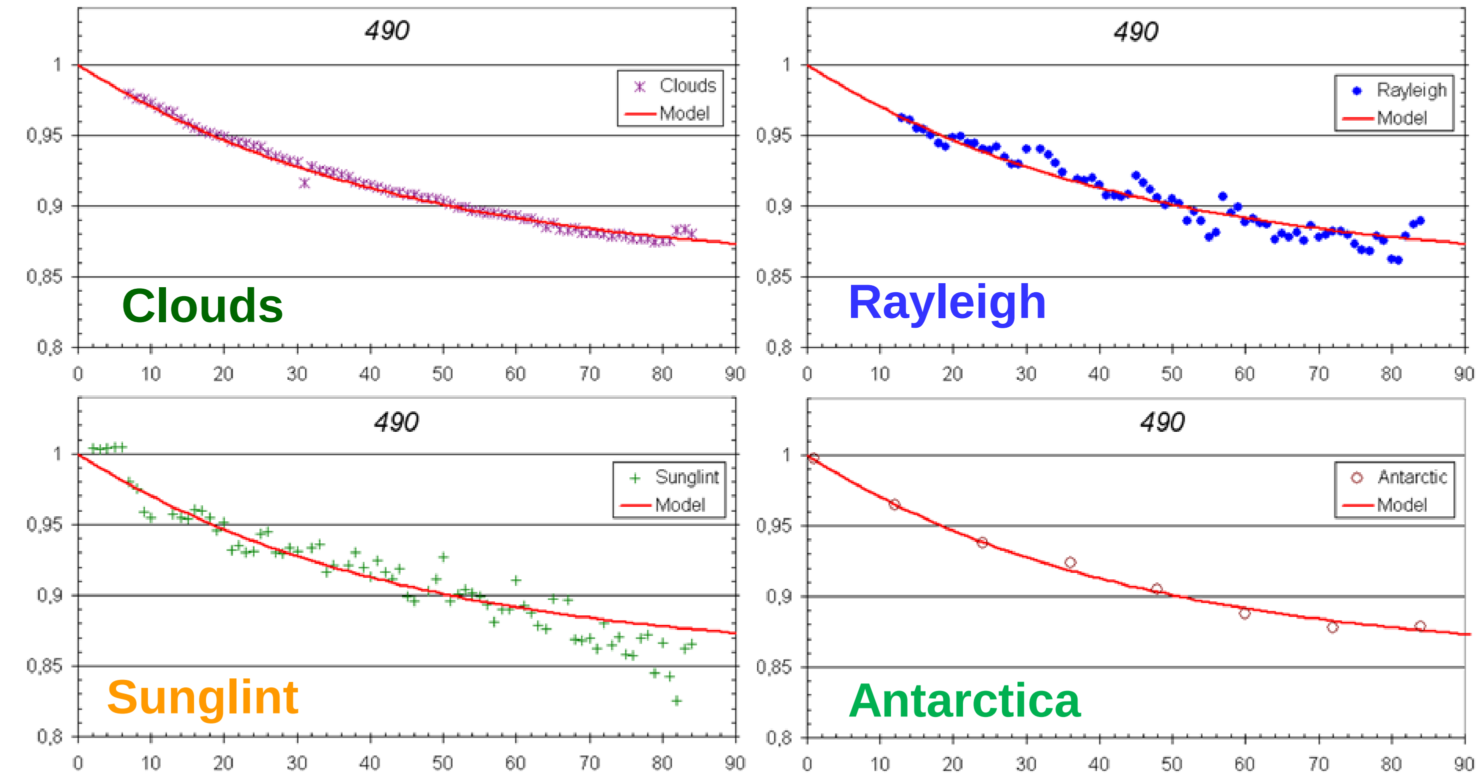
- Consistency in the « blue »

Band 490nm

D=0.018 month^{-1}

B_{490} = 0.16

Calibration versus month



Trending Physical Model

- **Adjustment – Validation combining all methods**
  - **1 amplitude Bk**

$$\frac{Ak(t)}{Ak(to)} = \left[1 - Bk \times (1 - \exp(-D \times t))\right]$$

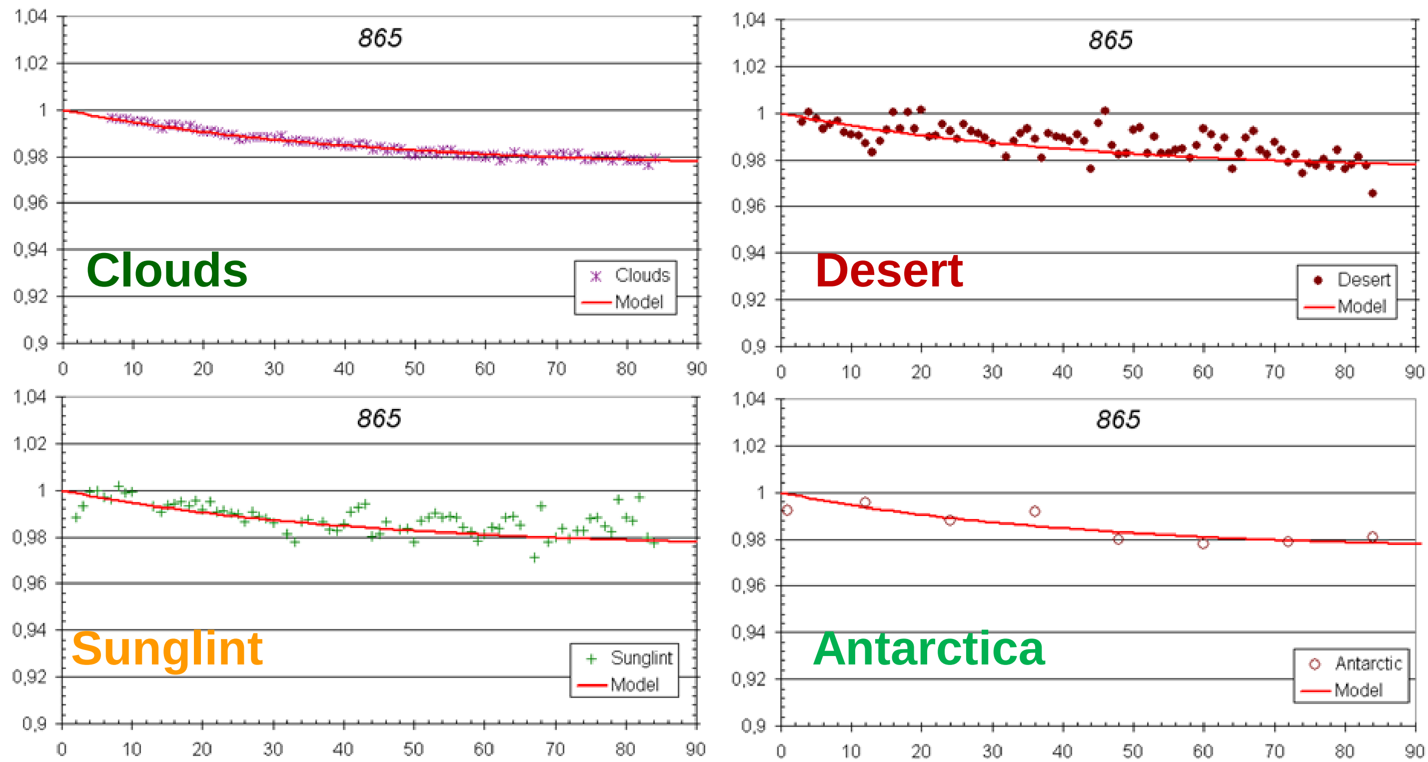
  - **Consistency in the « NIR »**

Band 865nm

D=0.018 month^{-1}

$B_{490} = 0.024$

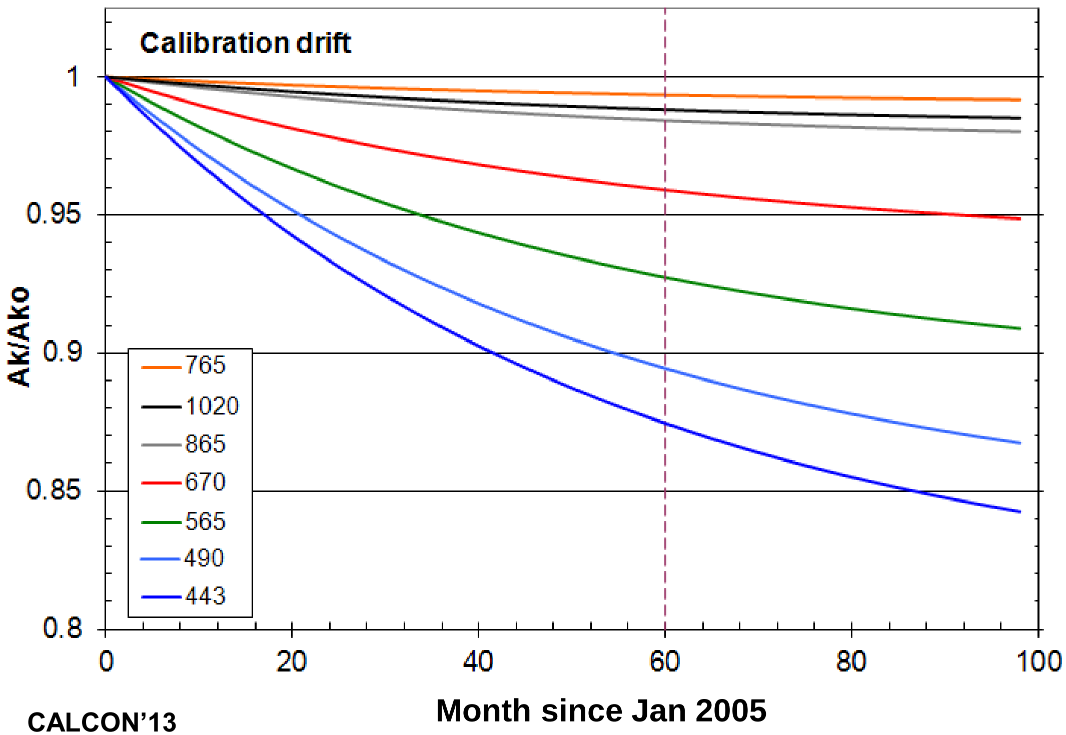
Calibration versus month

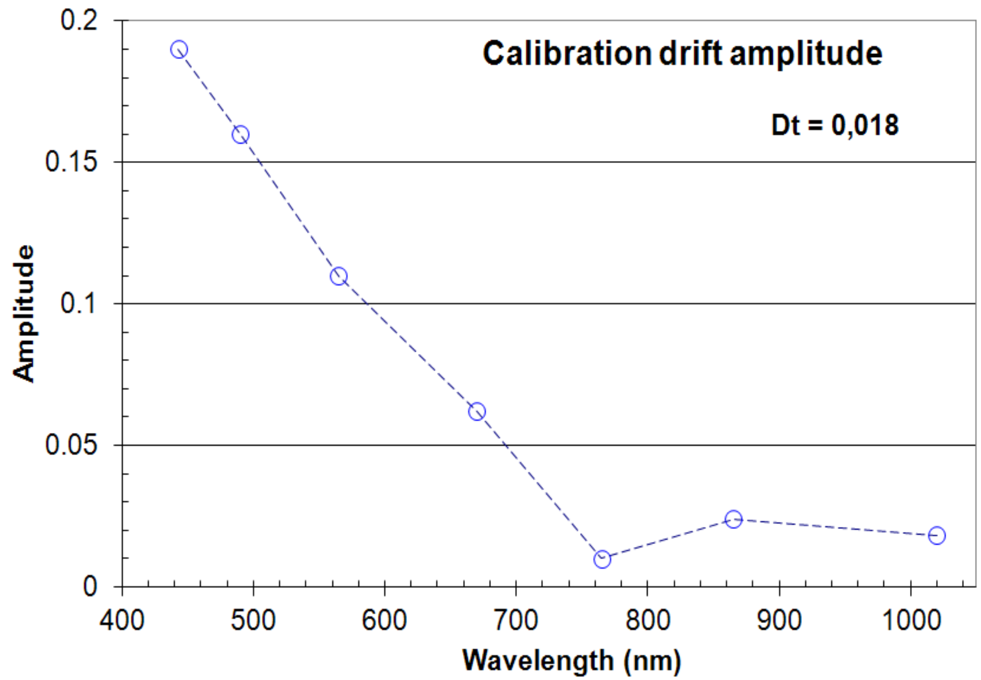


Trending Physical Model

- **Adjustment – Validation combining all methods**

$$\frac{Ak(t)}{Ak(to)}=\left[1-Bk\times(1-exp(-D\times t))\right]$$





Trending Physical Model within FOV

Differential trending within the field-of-view

- **Adopted model for the mean behavior :**

$$\frac{Ak(t)}{Ak(to)} = \left[1 - Bk \times (1 - exp(-D \times t))\right]$$

- **Same assumption for all viewing direction (l,p)**
  - same instrumental time constant D
  - amplitude for every pixel (l,p)
  - by definition : glpk(t0) = 1

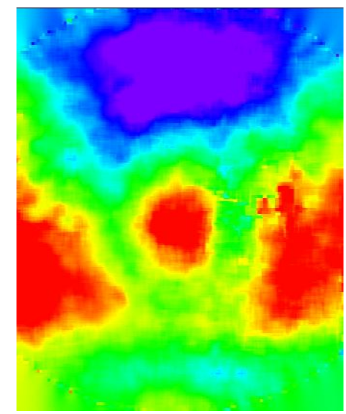
$$glpk(t) = \left[1 - \beta lpk \times (1 - exp(-D \times t))\right]$$

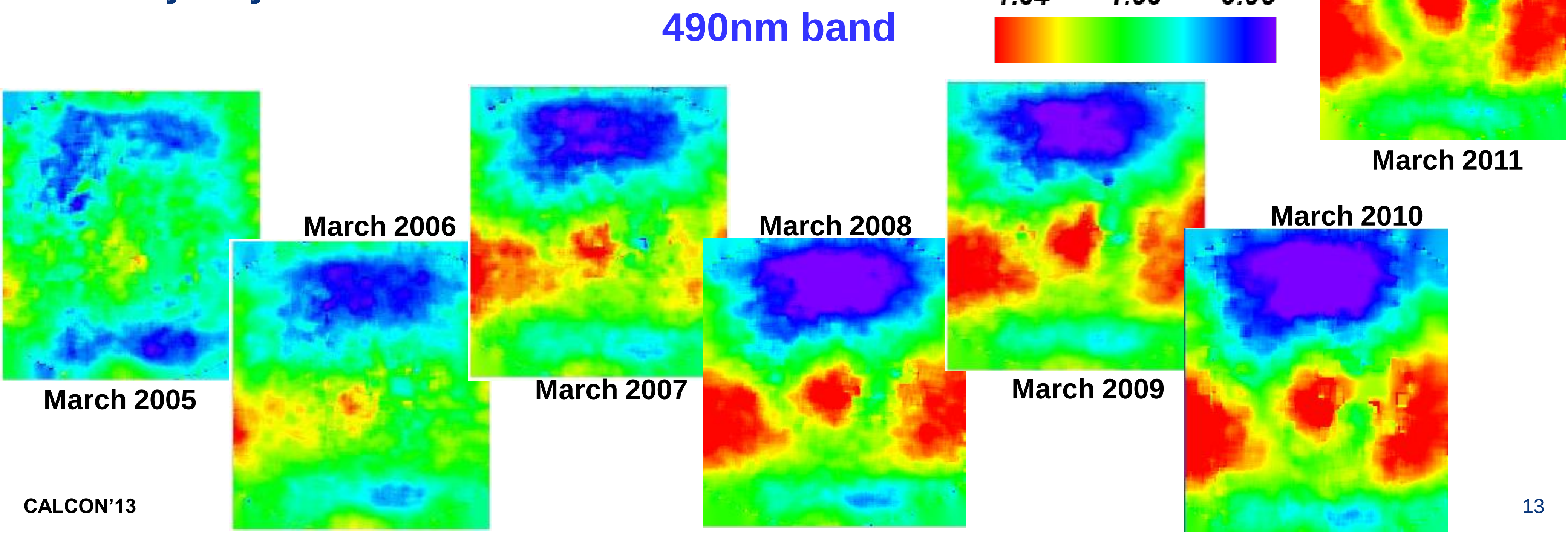
- **Very convenient to merge easily multiple methods and multiple dates (archive)**
  - reference date = end of A-train period (end-2009)

$$glpk(tref) = \left[1 - \frac{(1 - exp(-D \times tref))}{(1 - exp(-D \times t))} \times (1 - glpk(t))\right]$$

Drift within the FOV

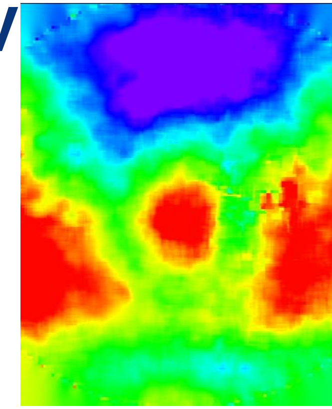
- Most appropriate dataset = clouds (DCC)
- Enlarging the viewing geometries (to all possible viewing angles)
  - the DCC have still good spectral properties
  - shown by computation (except the heterogeneity aspect)
- Band 490nm over DCC - still assuming a stable band (765)
  - yearly evolution



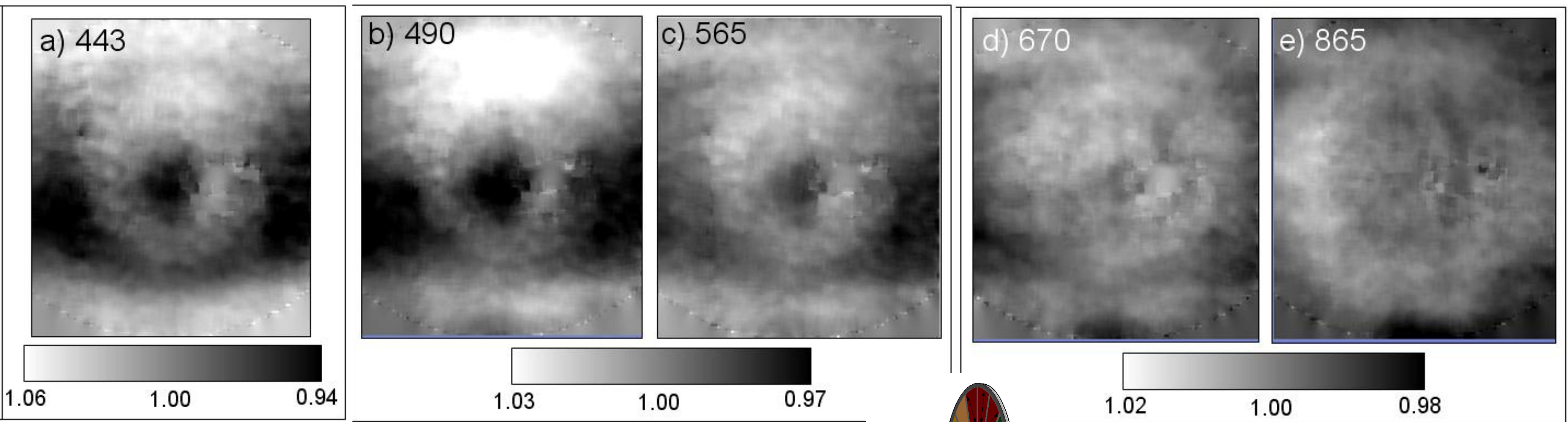


Drift within the FOV

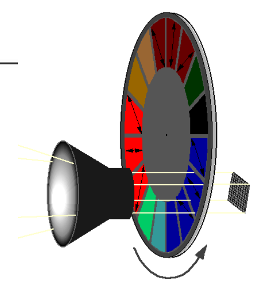
- **Interband evolution over DCC for the entire FOV**
  - assuming 765 is stable → to be verified
  - spectral behavior



March 2011



B&W cartography of the evolution



PARASOL instrumental concept

Drift within the FOV

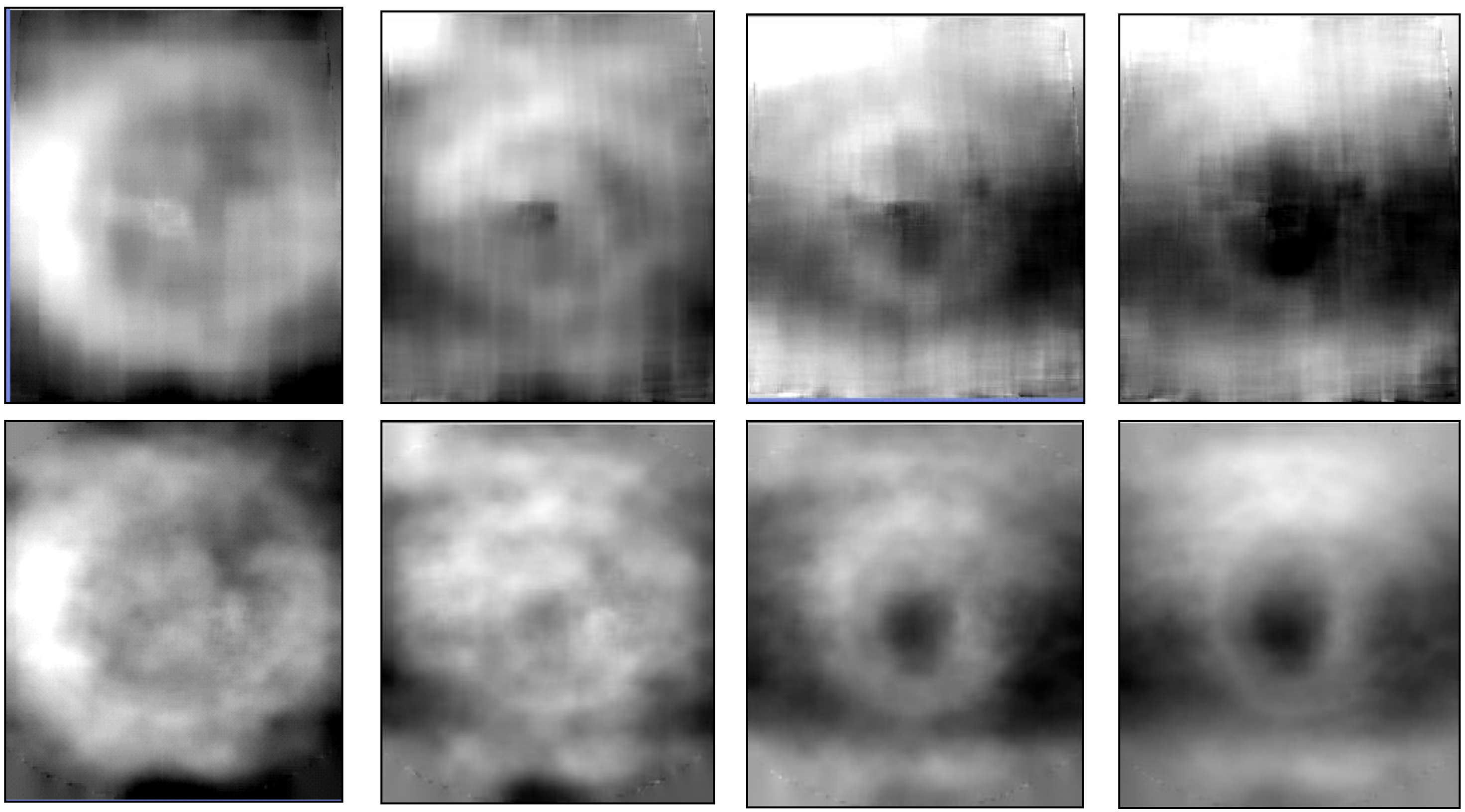
- Cross-calibration vs POLDER-1 → very good coverage of the entire field-of-view
  - the interband behavior from DCC is very nicely confirmed = validation
  - Desert are used to derivate NIR bands

865/765 670/765 565/670 490/765

Desert POLDER-1

Clouds

Same dynamic



Drift within the FOV

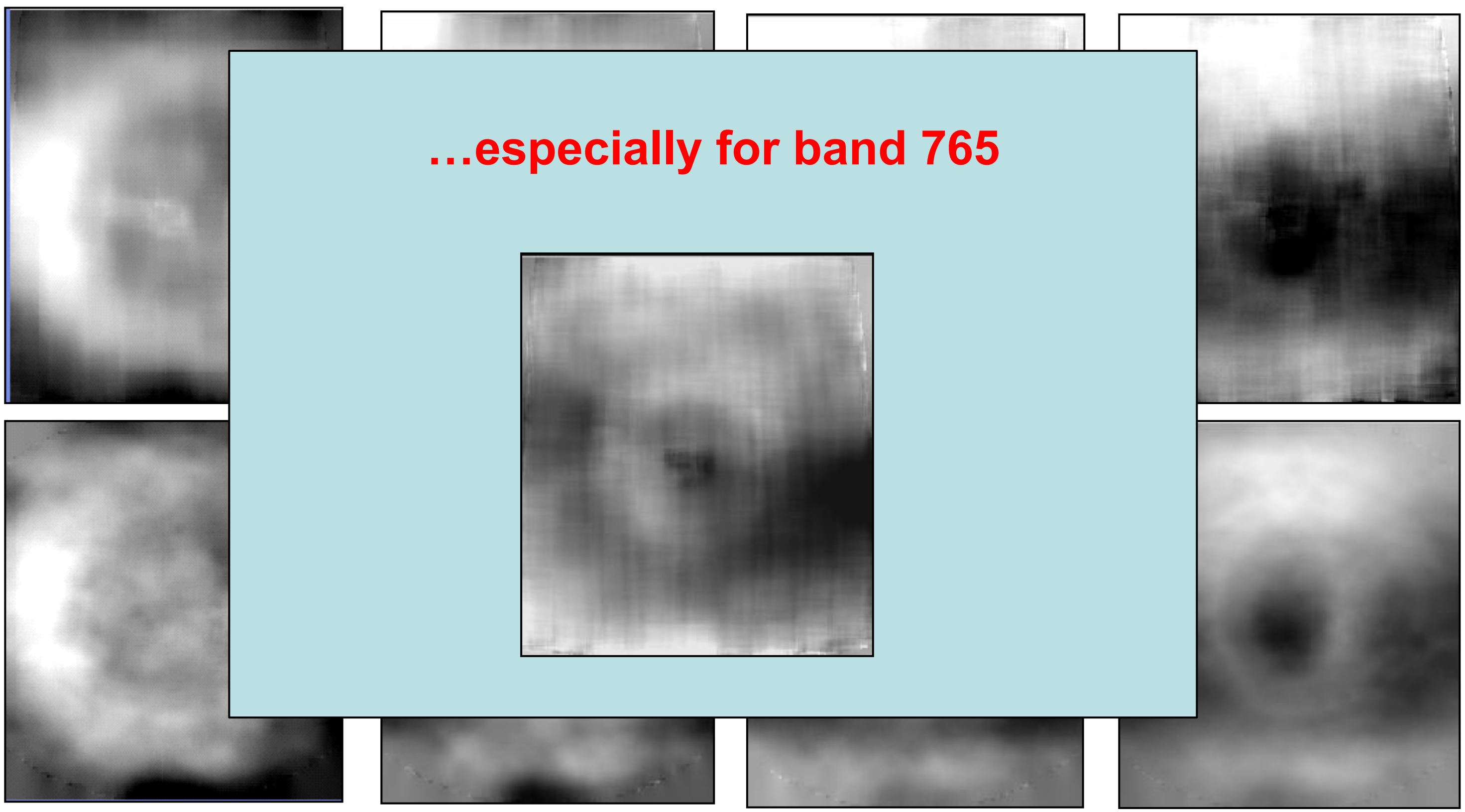
- Cross-calibration vs POLDER-1 → very good coverage of the entire field-of-view
  - the interband behavior from DCC is very nicely confirmed = validation
  - Desert are used to derivate NIR bands

865/765 670/765 565/670 490/765

Desert POLDER-1

Clouds

Same dynamic

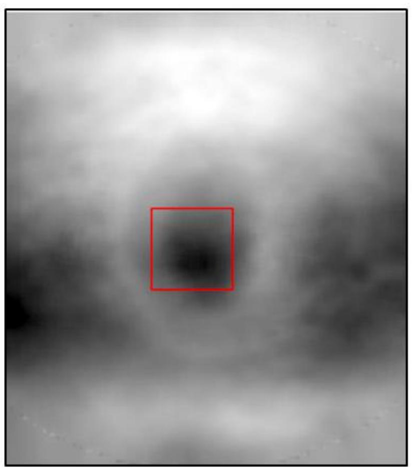


Drift within the FOV

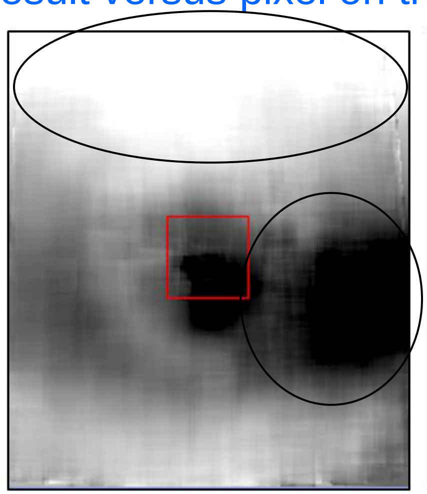
- **Synergic calibration for the in field-of-view evolution**
  - **Clouds suppose the reference band is stable (765nm)**
  - **Desert (reference = POLDER1) suggest it is not the case**
  - **Rayleigh (absolute reference) confirm that for 80% of the coverage – sufficient to generalize**
  - **Confirmed also for most of other bands**

Calibration result versus pixel on the CCD matrix

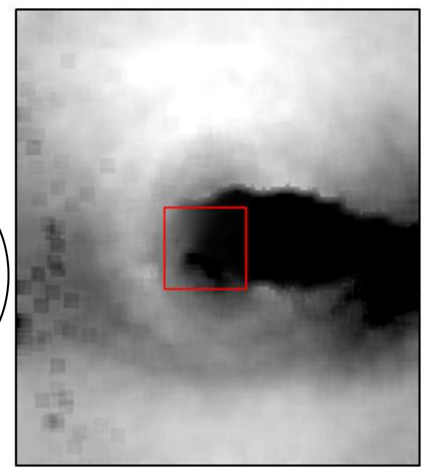
Band 490nm



Interband over DCC (ref=765)

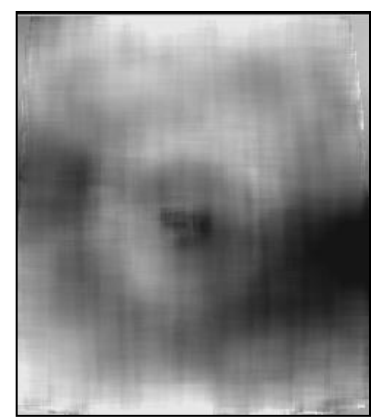


Intercalibration over desert (ref=POL1)



Absolute calibration over Rayleigh

The black hole from band 765nm

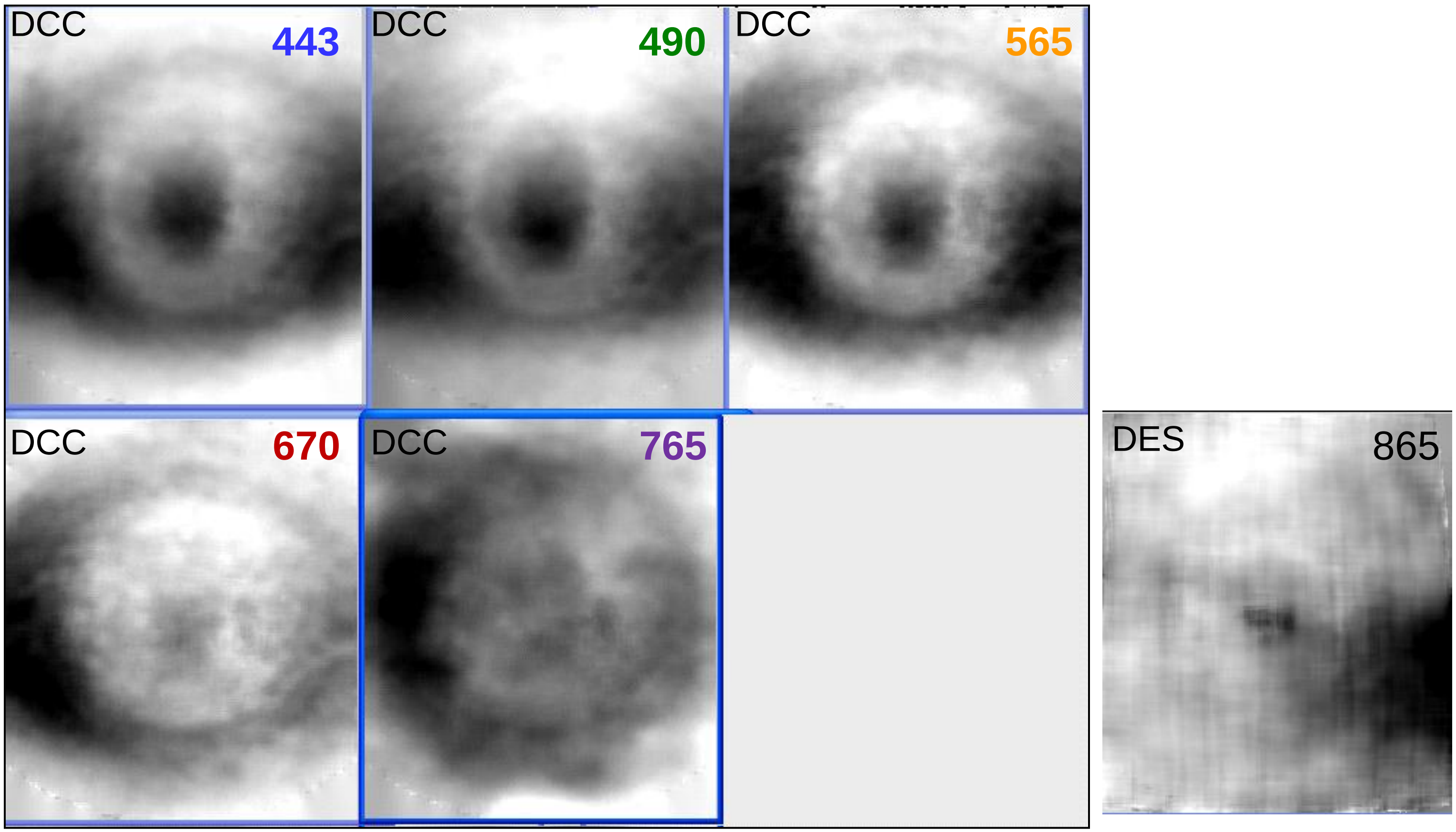


Black hole – confirmed by Rayleigh → Instrument-765

Bright banner – not confirmed → method artefact

Drift within the FOV

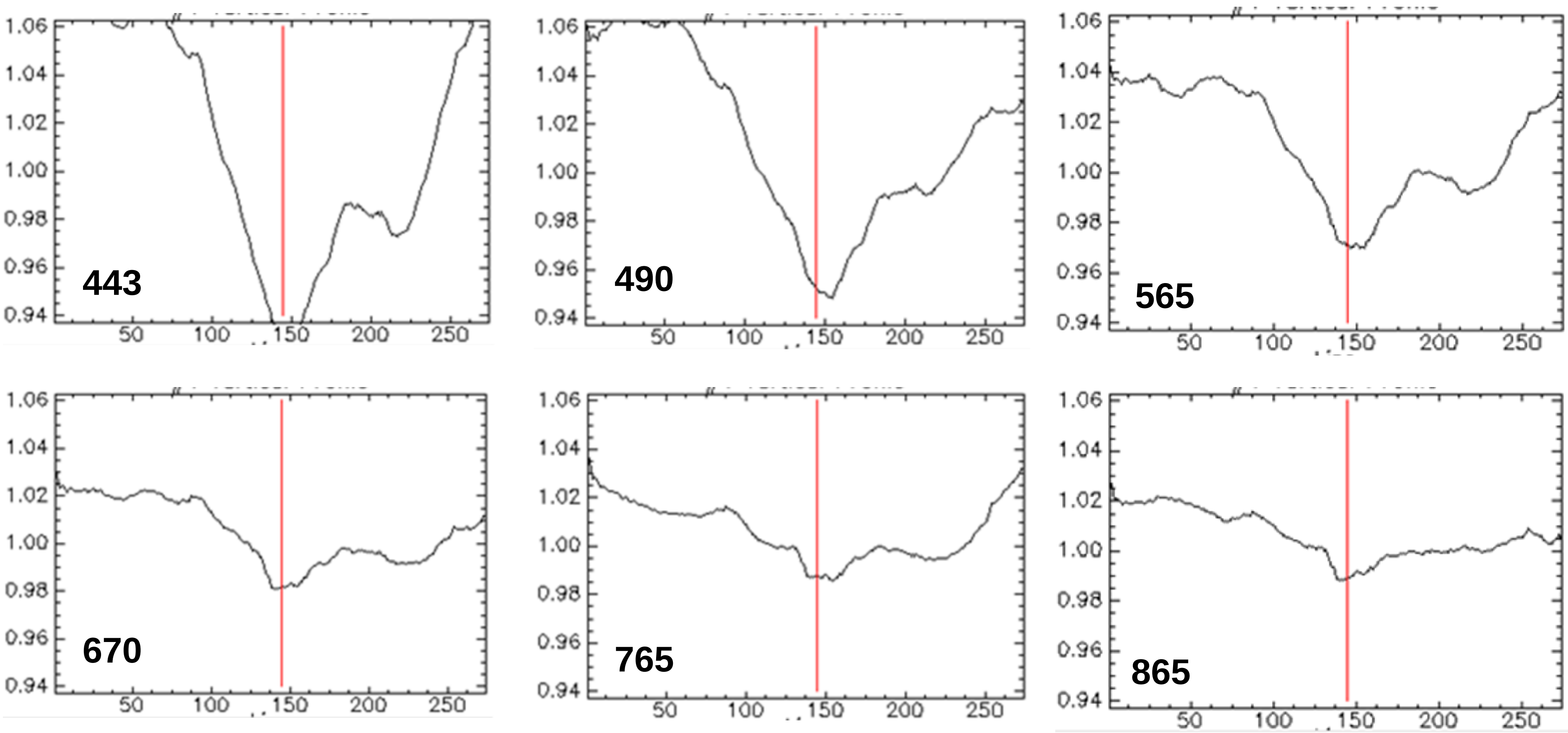
- **Final calibration of the field-of-view equivalent to December 2009 (glp)**
  - Interband contribution from DCC using NIR as reference
  - Evolution of NIR band from Desert (vs POLDER-1)



under finalization

Drift within the FOV

- **Final calibration of the field-of-view equivalent to Dec. 2009 – Vertical profile**



Conclusion

- A decrease of the PARASOL radiometric sensitivity has been detected
  - mean decrease : roughly corrected on the operational processing
- This decrease is not homogeneous within the field-of-view
  - Variation within FOV : previously identified but uncorrected

- A physical model has been considered
- This very simple model describes the instrumental behavior
  - one single “instrument” time constant is sufficient
  - amplitudes have been adjusted considering a multiple methods approach

- Mean drift and calibration within FOV have been elaborated for all bands
- On-going end-of-life reprocessing for level-1
  - reprocessed 9-years archive will be available in 2014

Thank you for your attention !

If you want more : Back up slides →

Calibration method reminder

- **Indicative classification**

Method	Reference need	Spectral validity	Range of data	Temporal coverage	Field-of-view Coverage
Cross-calibration over Desert	one sensor	**VIS/NIR/SWIR**	good (20 sites)	**permanent**	subsampled (orbit track)
Absolute Calibration over Rayleigh	**no**	VIS	very good (6 large sites)	**permanent**	**full except sunglint geo.**
Interband Calibration over Sunglint	one band	**VIS/NIR/SWIR**	very good (6 large sites)	frequent	only sunglint geo
Interband Calibration over DCC	one band	VIS/NIR	very good (2 large sites)	**permanent**	**full**
Cross-calibration over Antarctica	one sensor	VIS/NIR	limited (4 sites)	limited (3 months)	subsampled (orbit track)

Trending Physical Model

■ **Adjustment – Validation combining all methods**

- **1 amplitude Bk**

$$\frac{Ak(t)}{Ak(to)} = \left[1 - Bk \times (1 - \exp(-D \times t))\right]$$

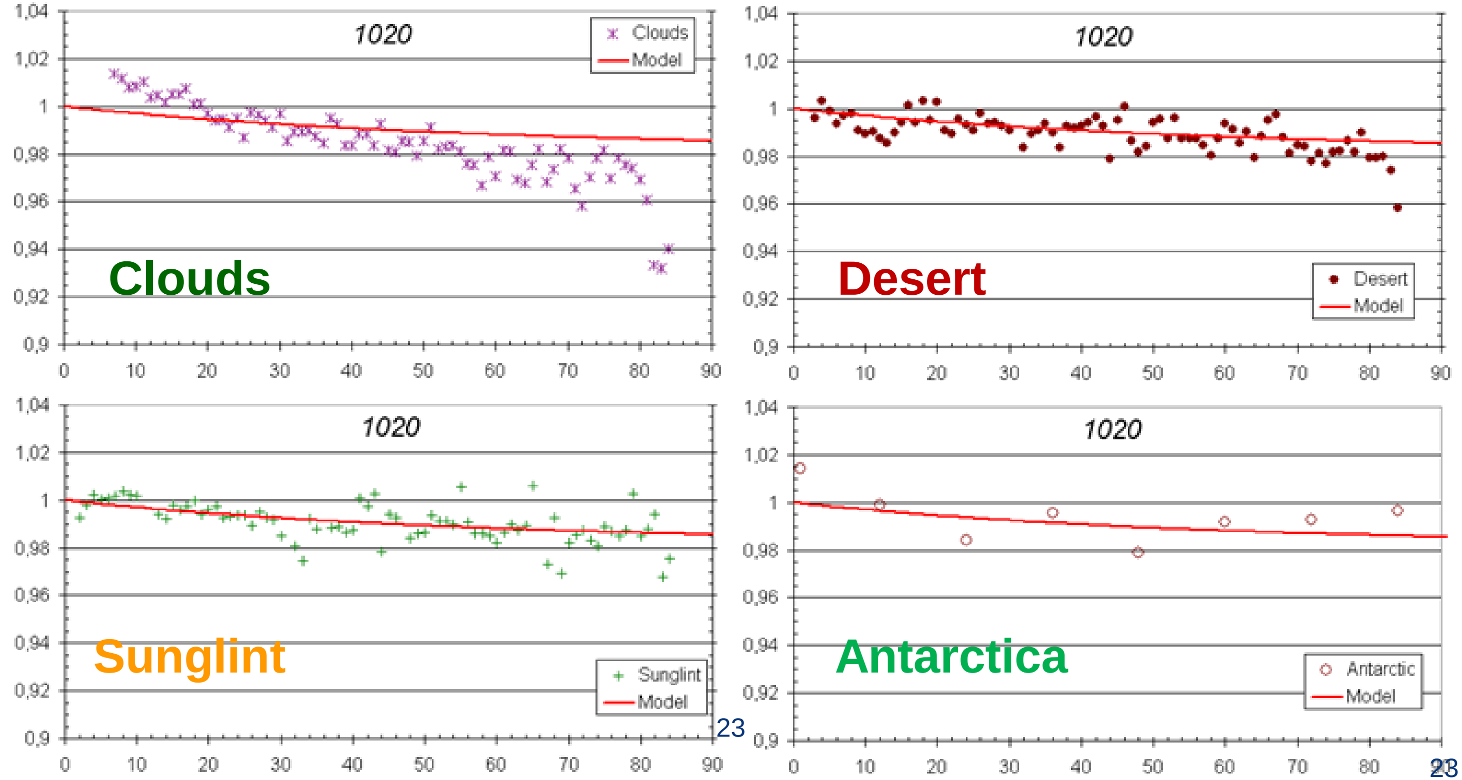
- **Consistency in the « NIR »**

Band 1020nm

D=0,018

B_{490} = 0,018

Calibration versus month



Trending Physical Model

■ Adjustment – Validation combining all methods

- 1 amplitude Bk

$$\frac{Ak(t)}{Ak(to)}=\left[1-Bk\times(1-\exp(-D\times t))\right]$$

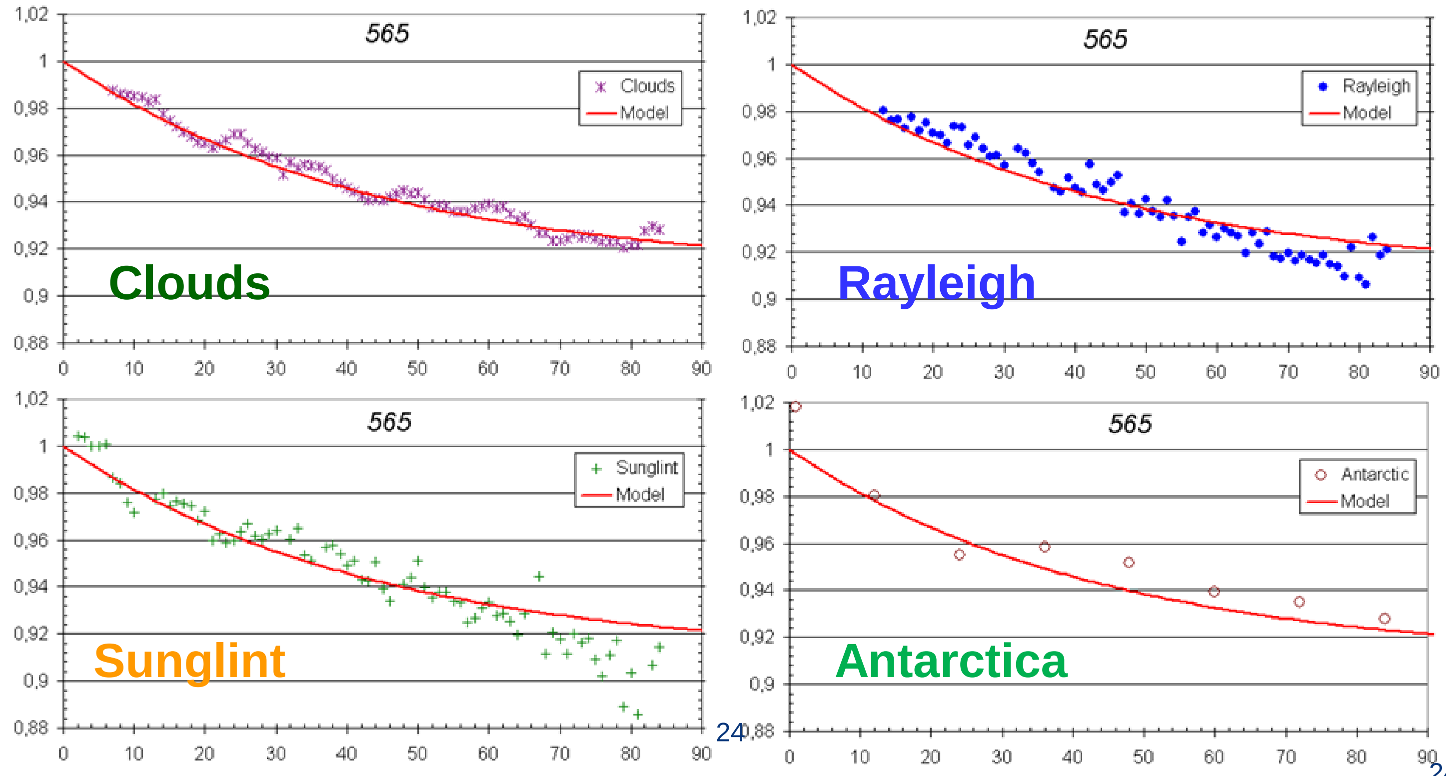
- Consistency in the « Yellow »

Band 565nm

D=0,018

B_{490} = 0,11

Calibration versus month



Trending Physical Model

- **Adjustment – Validation combining all methods**
  - **1 amplitude Bk**

$$\frac{Ak(t)}{Ak(to)} = \left[1 - Bk \times (1 - exp(-D \times t))\right]$$

  - **Consistency in the « NIR »**

Calibration versus month

Band 765nm

D=0,018

B_{490} = 0,01