On the Balancing of the SMOS Ocean Salinity Retrieval Cost Function

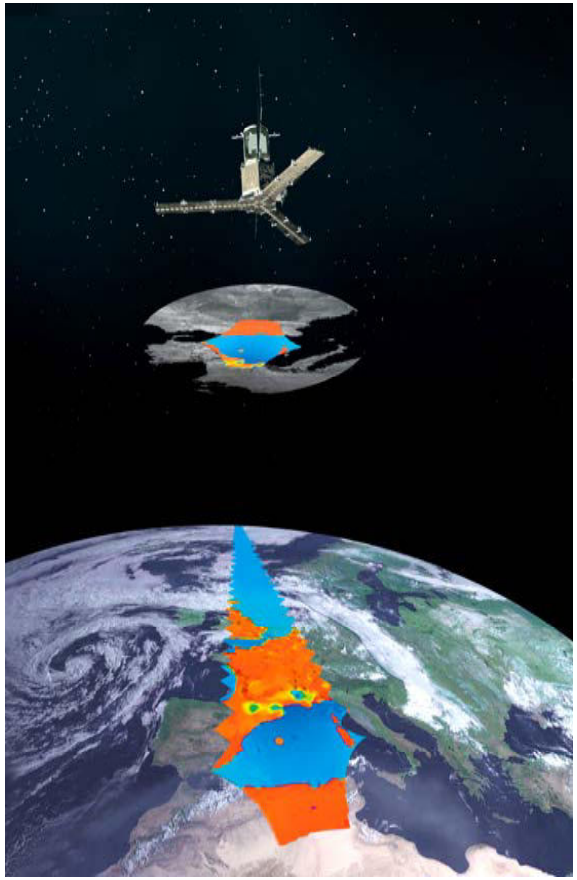
R. Sabia, A. Camps, M. Portabella, M. Talone, J. Ballabrera, J. Gourrion, C. Gabarró, A.L. Aretxabaleta, J. Font

SMOS-BEC, Barcelona Expert Centre on Radiometric Calibration and Ocean Salinity, Barcelona, Spain.

EGU General Assembly 2009, Wien, Austria, 21 April 2009

Contents

- **Sea Surface Salinity (SSS) retrieval**: general features and issues
- **Simulation/processing** tools
- **Retrieved sensitivity** to SSS auxiliary field uncertainty
- **Cost function balancing:** approach and methodology
- **Conclusions** and Open issues



SSS retrieval scheme
General Issues

Lev. **0** Raw data

Lev. **1A** Calibrated Visibilities

Lev. **1B** T_B Fourier components

Lev. **1C** T_B geocoded (ISEA4H9)

Lev. **2** Salinity Maps

Lev. **3** Spatio-temporal averaging

Inversion scheme

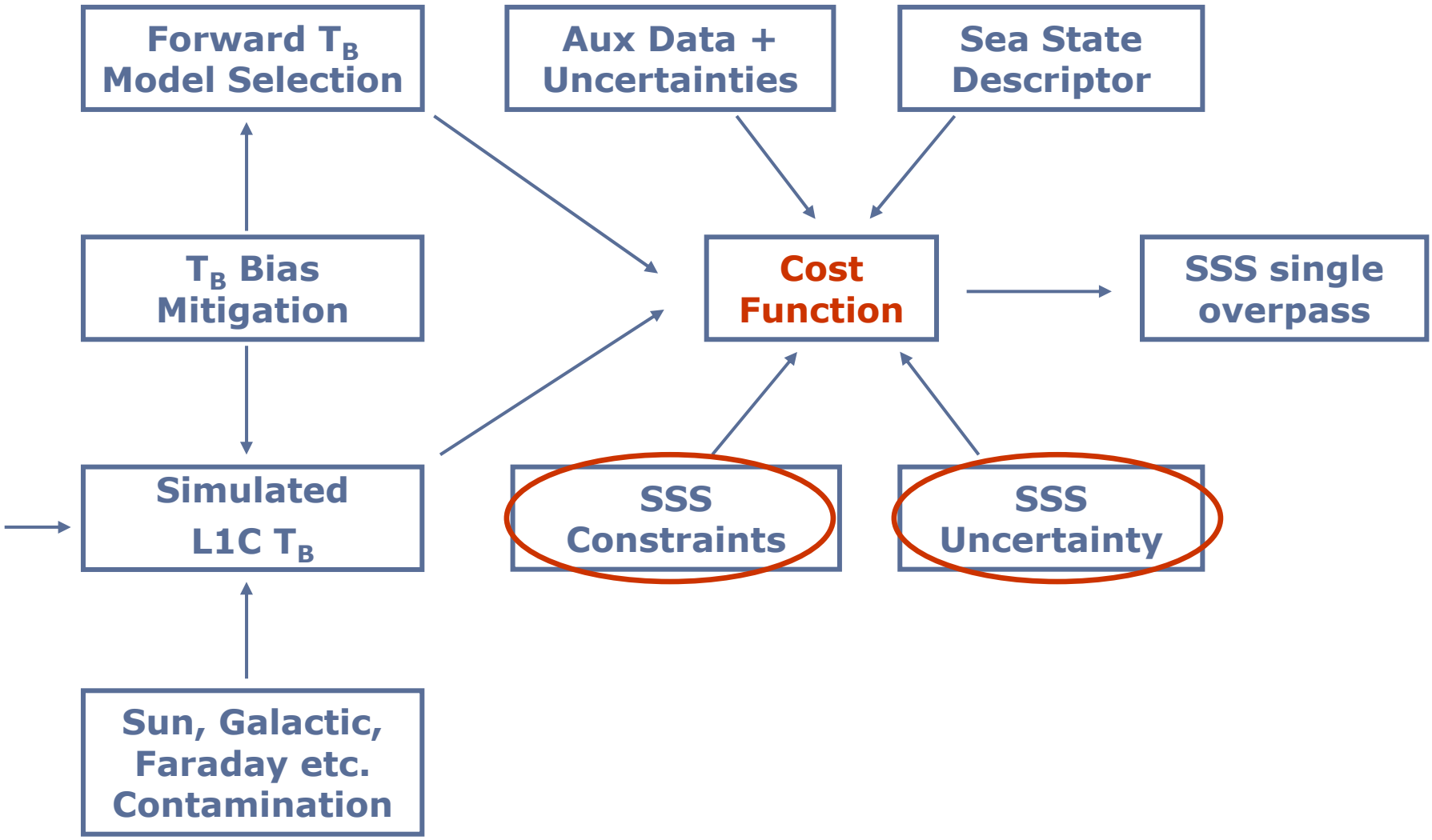
T_B → SSS single overpass (L2)

Iterative algorithm:
minimization **Cost function**

Salinity Retrieval Issues

- **Scene-dependent bias in the simulated T_B measurements**
- **Radiometric errors (associated to thermal noise and imperfect instrument and calibration)**
- **L-band forward modeling definition (Geophysical Model Function)**
- **Auxiliary data, namely sea surface temperature (SST) and wind speed (U_{10}), sources and uncertainties**
- **SSS Constraint and SSS uncertainty**
- **Adequate spatio-temporal averaging (L3)**

SSS retrieval scheme
Flowchart



SSS retrieval scheme
Cost Function

$$\chi^2 = \frac{1}{N_{obs}} \left(\sum_{n=1}^{N_{obs}} \frac{\left\| F_n^{meas} - F_n^{model} \right\|^2}{\sigma_{F_n}^2} \right) + \frac{\left(SSS - SSS_{aux}\right)^2}{\sigma_{SSS}^2} + \frac{\left(SST - SST_{aux}\right)^2}{\sigma_{SST}^2} + \frac{\left(U_{10} - U_{10aux}\right)^2}{\sigma_{U_{10}}^2}$$

$$F = \left[\overline{T}_h, \overline{T}_v\right]$$

$$F = \left[\overline{T}_x, \overline{T}_y\right]$$

$$F = \left[\overline{I}\right] = \left[\overline{T}_h + \overline{T}_v\right] = \left[\overline{T}_x + \overline{T}_y\right]$$

- Levenberg-Marquardt method
- Multi-parameter (SSS, SST, U_{10}) retrieval
- Fixed upper and lower boundaries
- Semi-empirical forward model

N_{Obs} **Number of pixel observations**

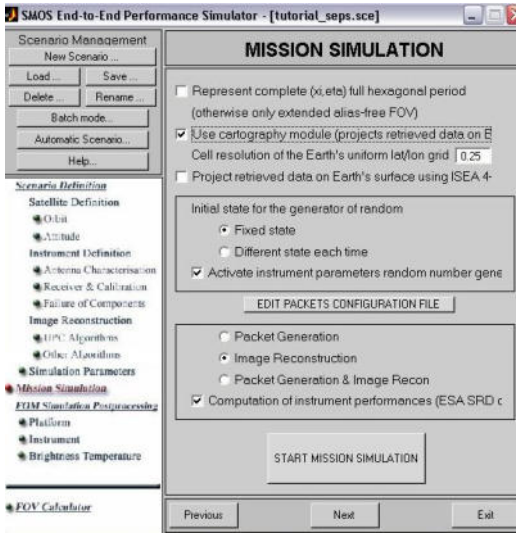
F^{meas} **Future-SMOS or simulated data**

F^{model} **Forward model data**

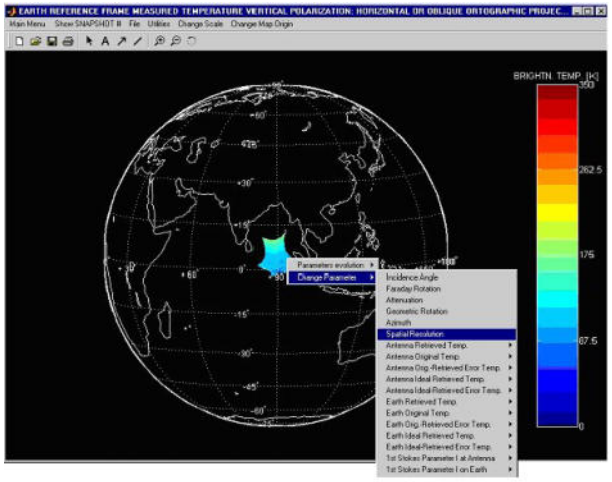
$SSS_{aux}, SST_{aux}, U_{10aux}$ **Reference auxiliary data**

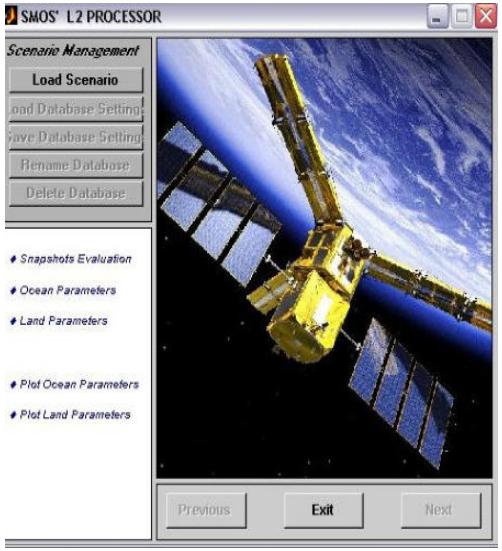
$\sigma_{SSS}, \sigma_{SST}, \sigma_{U_{10}}$ ***A priori* prescribed auxiliary data errors**

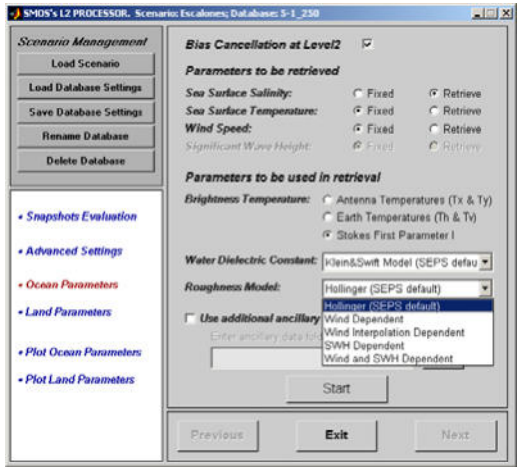
Simulation/Processing Tools
SEPS Simulator and L2 OS Processor

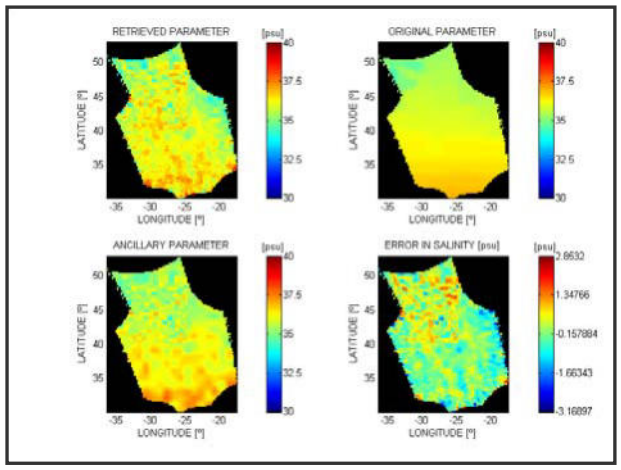


SMOS End-to-end Performance Simulator









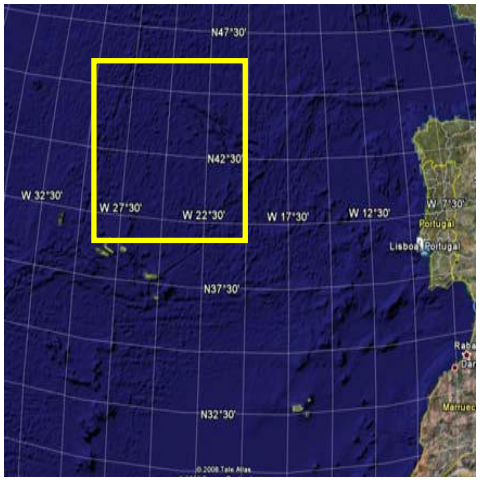
UPC L2 OS Processor

SSS Error Budget
Setting vs Performances

$$\chi^2 = \frac{1}{N_{obs}} \left(\sum_{n=1}^{N_{obs}} \frac{\left\| F_n^{meas} - F_n^{model} \right\|^2}{\sigma_{F_n}^2} \right) + \frac{\left(SSS - SSS_{aux} \right)^2}{\sigma_{SSS}^2} + \frac{\left(SST - SST_{aux} \right)^2}{\sigma_{SST}^2} + \frac{\left(U_{10aux} - U_{10aux} \right)^2}{\sigma_{U10}^2}$$

SSS error budget

- **Non-constrained** configuration: bias/accuracy EB
- **Constrained** configuration: bias/accuracy EB
- Link through tuning σ_{SSS}

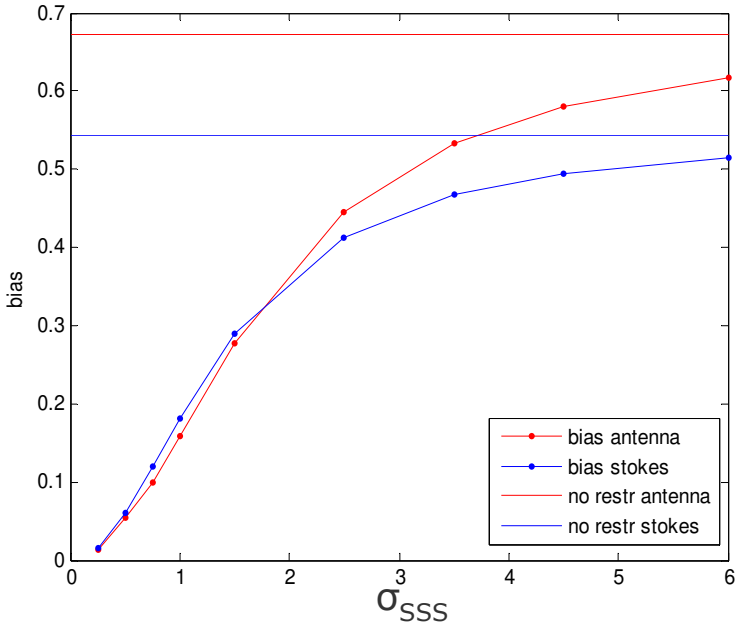


- Non-constrained configuration → **rather poor retrieval performances**
- Constrained configuration with realistically estimated SSS uncertainty → **over constraining**

fully-exploit the information content of real TBs, as well as ensure good retrieval

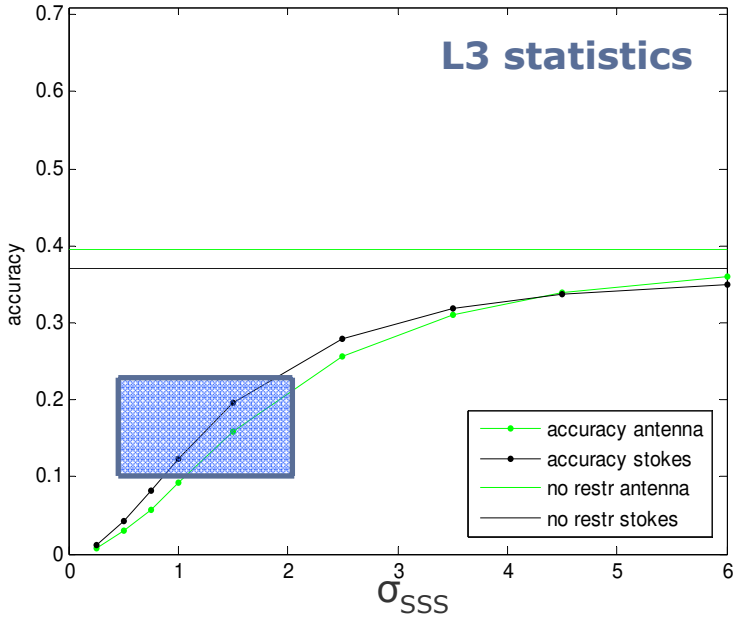
SSS Error Budget

σ_{SSS} Sensitivity



0.673

0.543



0.396

0.370

Bias	***Tx/Ty*** *(psu)*	***I*** *(psu)*
σ_{SSS}=0.25 psu	**0.013**	**0.016**
…	…	…
σ_{SSS}=∞	**0.673**	**0.543**

Accuracy	***Tx/Ty*** *(psu)*	***I*** *(psu)*
σ_{SSS}=0.25 psu	**0.007**	**0.011**
…	…	…
σ_{SSS}=∞	**0.396**	**0.370**

SSS auxiliary uncertainty sensitivity

- Overall trend from fully-constrained to "saturated" zone
- Identification of "optimum" σ_{SSS} (between 0.5 and 2 psu)
- Towards the concept of SSS term balancing

Cost Function Balancing

Methodology and Approach (i)

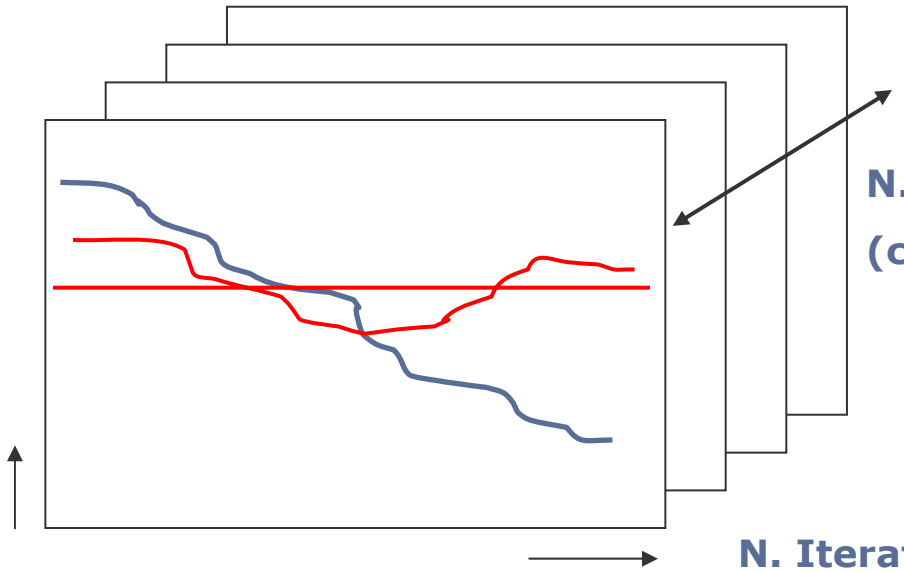
$$\chi^2 = N_{eff}\left(\sum_{n=1}^{N_{obs}} \frac{\left\| F_n^{meas} - F_n^{model} \right\|^2}{\sigma_{F_n}^2}\right) + A\frac{\left(SSS - SSS_{aux}\right)^2}{\sigma_{SSS}^2} + B\frac{\left(SST - SST_{aux}\right)^2}{\sigma_{SST}^2} + C\frac{\left(U_{10aux} - U_{10aux}\right)^2}{\sigma_{U10}^2}$$

Methodology

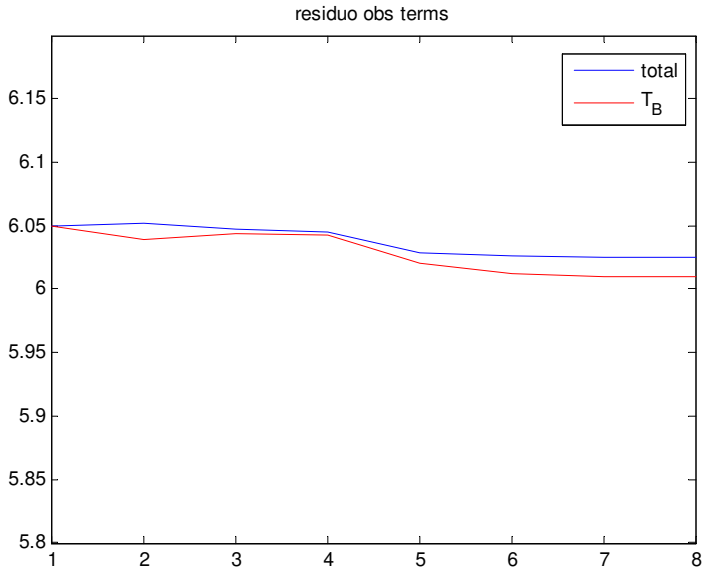
- **Retrieval scenarios: NEMO-OPA and flat**
- ***Tx/Ty* and *I* stokes**
- **SSS-term (constrained) vs (not-constrained)**
- **SEPS brightness temperatures generated in full-mode (realistic instrument characterization)**

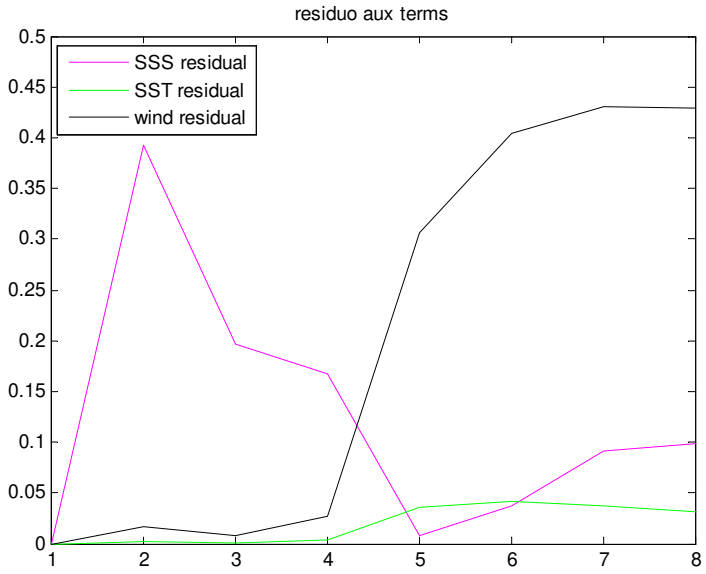
Approach

Evolution with the number of iterations in a single pixel and with the number of observations (cross-track distance) for different pixels



Cost Function Balancing
Methodology and Approach (ii)





Cost function analysis

- **Angular distribution of the SEPS full-mode brightness temperatures**
- **Relationships between N. Iterations and N. pixel observations (cross-track distance)**
- **Absolute residual terms comparisons**
- **Relative residual terms changes**

- **Gradient analysis**

$$\partial\chi \Big/ \partial p \Big|_{p=T_B, SSS, SST, U_{10}}$$

(partial derivatives of the total residual with respect to the different parameters)

- **First-guess values sensitivity**
- **Cost function auxiliary part "plateau" behaviour**

Conclusions and Remarks

- **SSS constraint trade-off**

  physical regularization

  vs

  mathematical minimization

- **Need of a comprehensive study of the cost function behavior (residuals/gradients)**
- **Balancing by introduction of weights, that will change the shape of the different terms of the function**
- **SMOS real data will call for new algorithm refinement and improved assessment of the cost function**
- **L3 adequate spatio-temporal averaging so as to meet the SMOS prescribed requirements**

roberto.sabia@tsc.upc.edu

www.smos-bec.icm.csic.es
www.tsc.upc.edu/prs

UPC

Simulation-Retrieval Cascade

Orbit calculator

Input SSS, SST, U_{10}

T_B generator

Instrument Modelling/Calibration
Visibilities (L1A)
Image reconstruction algorithm

SEPS

T_B (L1c)

T_B bias mitigation

Minimization algorithm

UPC L2 OS Processor

SSS maps over Earth (L2)

SSS averaged maps (L3)

SSS external calibration

...

Lev. 1C T_B geocoded (ISEA4H9 grid)

Lev. 2 Salinity Maps (single overpass)

Lev. 3 Spatio-temporal averaging

...

Error Budget
Simulation Overview

Simulations Strategy

- **Master simulation** without radiometric noise (T_xT_y and I stokes)
- Comparative effects considering **single-parameter** contribution
- **SEPS light** version
- **SSS constrained**
- **Constant auxiliary** fields
- Mid-Atlantic open ocean test zone
- 10 overpasses, 730 snapshots, monthly statistic, summertime
- Ascending passes, Dual-pol
- L3 statistics