Towards a unique method for a global and multi-surface Wet Tropospheric Correction retrieval : a 1-D Variational approach

Laura Hermozo [1], Bruno Picard [1], Laurence Eymard [2], Fatima Karbou [3], Estelle Obligis [1]

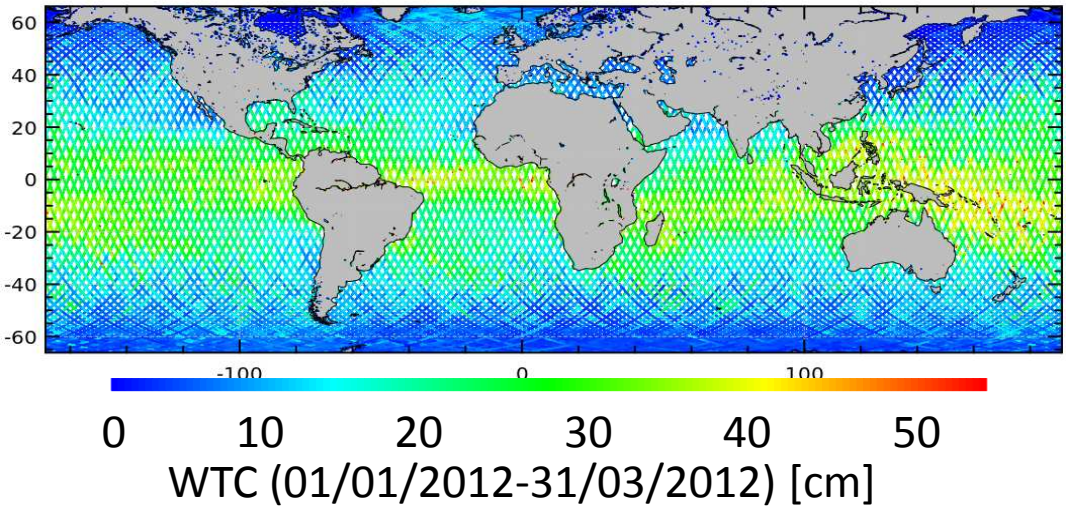
[1] CLS, [2] LOCEAN, [3] CNRM-GAME

On the need of an improved wet tropospheric correction for future altimetry missions

Wet Tropospheric Correction (WTC)

WTC [0 cm; 50 cm]

correct altimeter range from delay caused by water vapor and cloud liquid water in the troposphere



✓ WTC Provided by :

Radiometer coupled to altimeter

TOA TBs at frequencies near water vapor absorption band

CURRENT WTC ALGORITHMS

Empirical approach:

Measured (radiosondes) or Modeled (NWP analysis) atmospheric profiles

+

Radiative transfer model

(Relates integrated WTC to TOA BTs)

Retrieval of

integrated value of WTC

WTC = f(BTs)

- **Relation valid for mean conditions (open ocean)**
- **Regional corrections needed over heterogeneous surfaces (coastal regions, land waters, sea ice), upwelling regions**

On the need of an improved wet tropospheric correction for future altimetry missions

❑ Objectives of my PhD thesis ?

Propose a new solution inline with the new objectives of altimetry

WTC retrieved over ocean, coastal areas, sea ice, inland waters

« Towards a **unique method** for a **global** and **multi-surface** Wet Tropospheric Correction retrieval »

A single method for all types of water-covered surfaces

Valid over open ocean and under specific atmospheric conditions (upwelling regions)

➔ **Reach performances of reference WTC retrieval algorithm over ocean surfaces**

➔ **Improve WTC retrieval algorithm performances over specific regions : upwelling regions, coastal regions, sea ice, inland waters**

On the need of an improved wet tropospheric correction for future altimetry missions

CURRENT WTC ALGORITHMS
Empirical approach:

Measured (radiosondes) or Modeled (NWP analysis) atmospheric profiles
+
Radiative transfer model
(Relates integrated WTC to TOA BTs)

Retrieval of
integrated value of WTC
WTC = f(BTs)

- **Relation valid for mean conditions (open ocean)**
- **Regional corrections needed over heterogeneous surfaces (coastal regions, land waters, sea ice) or upwelling regions**

1D-VAR APPROACH FOR WTC ESTIMATION
Geophysical approach:

Measured BTs and Modeled atmospheric profiles (NWP analysis)

Retrieval of most probable
atmospheric profiles
$WTC = \int$ **(atmospheric profiles)**

Description of the 1D-Var approach

Observation errors

Background errors

$$J(x) = (Y - H(x))^T R^{-1} (Y - H(x)) + (x - x^b)^T B^{-1} (x - x^b)$$

OBSERVATION SPACE

Measured BTs at TOA

Y

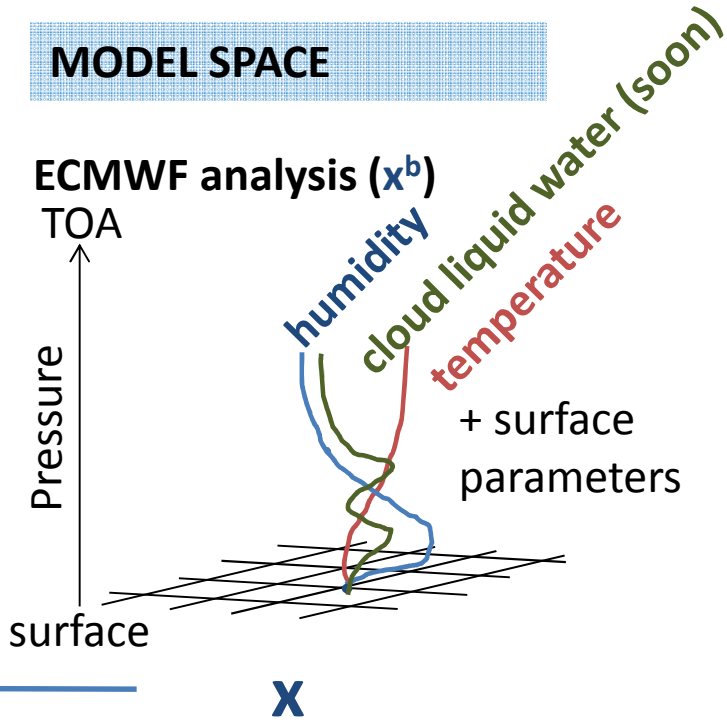
Simulated BTs at TOA

H(x)

Radiative transfer model (RTTOV)

MODEL SPACE

ECMWF analysis (x^b)



X

WTC estimated from the most probable atmospheric profile :

$$WTC = \int_p K . \frac{humidity\ (p)}{temperatur\ e(p)} dp$$

Setting the background errors : Background error covariance matrix

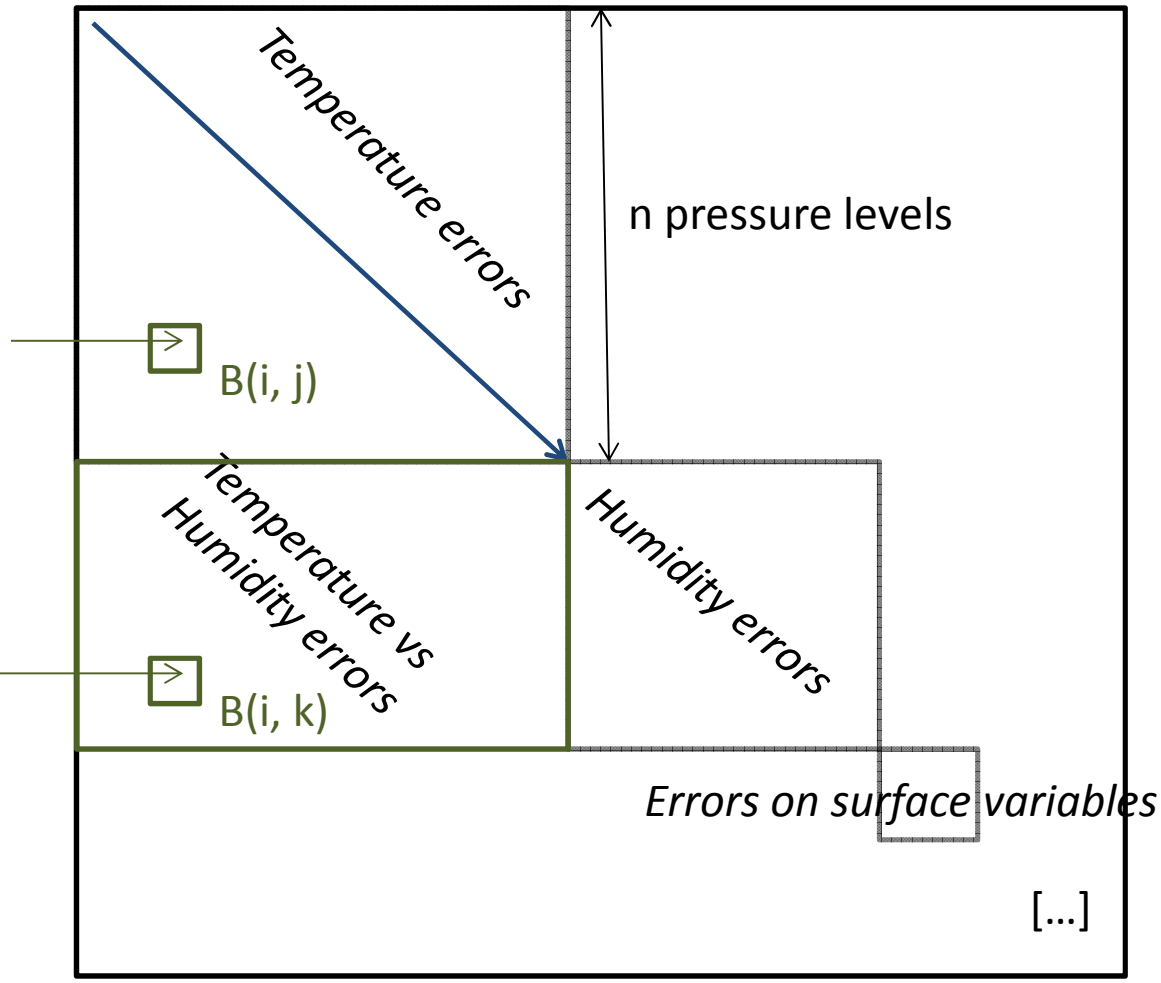
• Need to **adapt the background error covariance matrix (matrix B) to ECMWF input** atmospheric profiles and surface variables

✓ **Diagonal coefficients: Error variance on temperature (humidity/etc)**

✓ **Non-diagonal coefficients : Error covariance on temperature (humidity/etc) between pressure levels i and j**

✓ **Non-diagonal coefficients : Error covariance between temperature at level i and humidity at level k**

Scheme of matrix B in the 1D-Var minimization



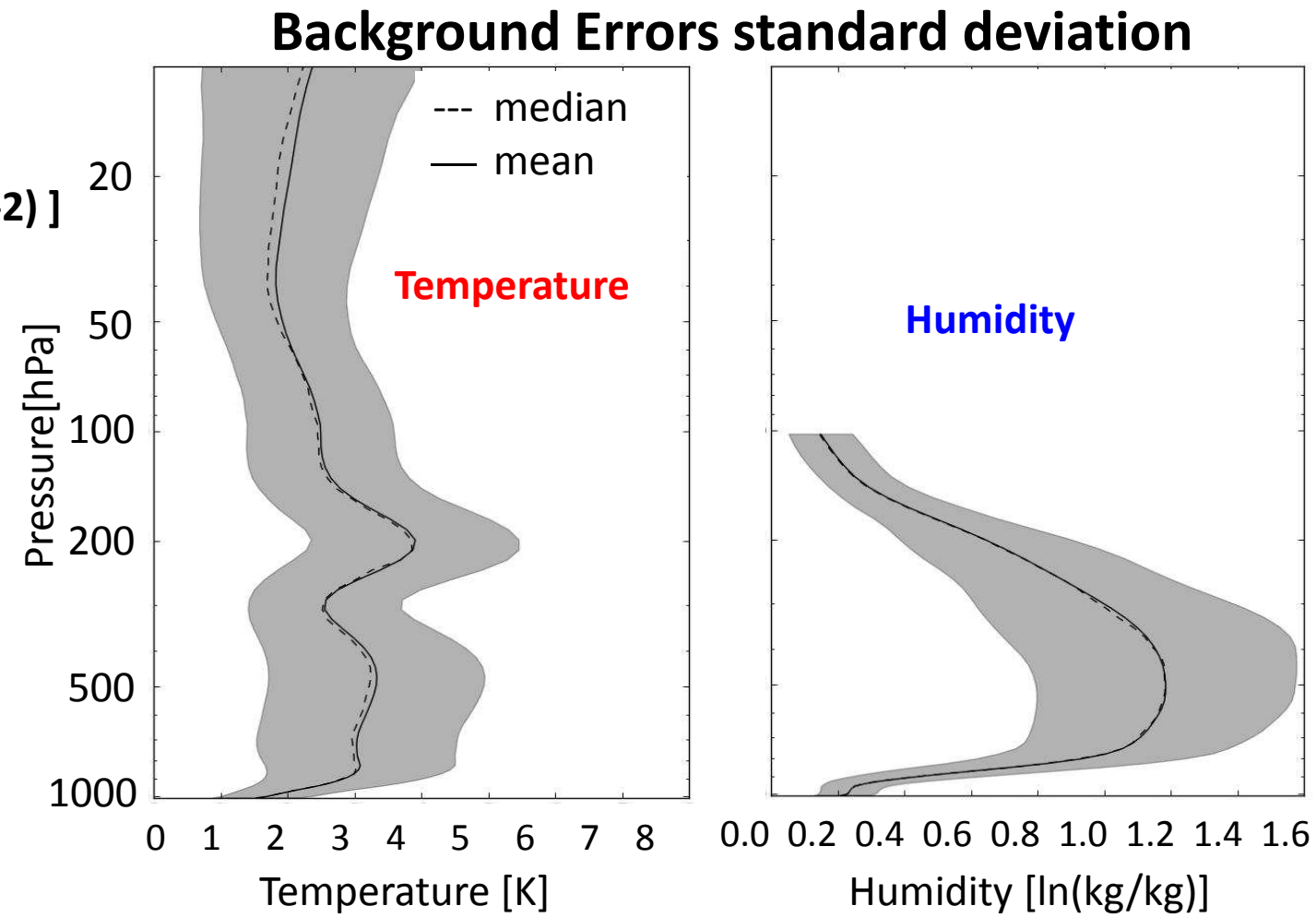
Setting the background errors : Background error covariance matrix

• Calculation of an adapted background error covariance matrix :

NMC method (Rabier et. al., 1998)

statistics
[forecasts(d-1) - forecats(d-2)]
valid at d

Forecast error statistics



• **Observation inputs used for the 1D-Var approach…**

✓Radiometer : **Advanced Microwave Radiometer (AMR)**

✓ Coupled to altimeter onboard **Jason-2**

✓ **3-band** nadir-viewing radiometer :

18.7 GHz → surface roughness, wind

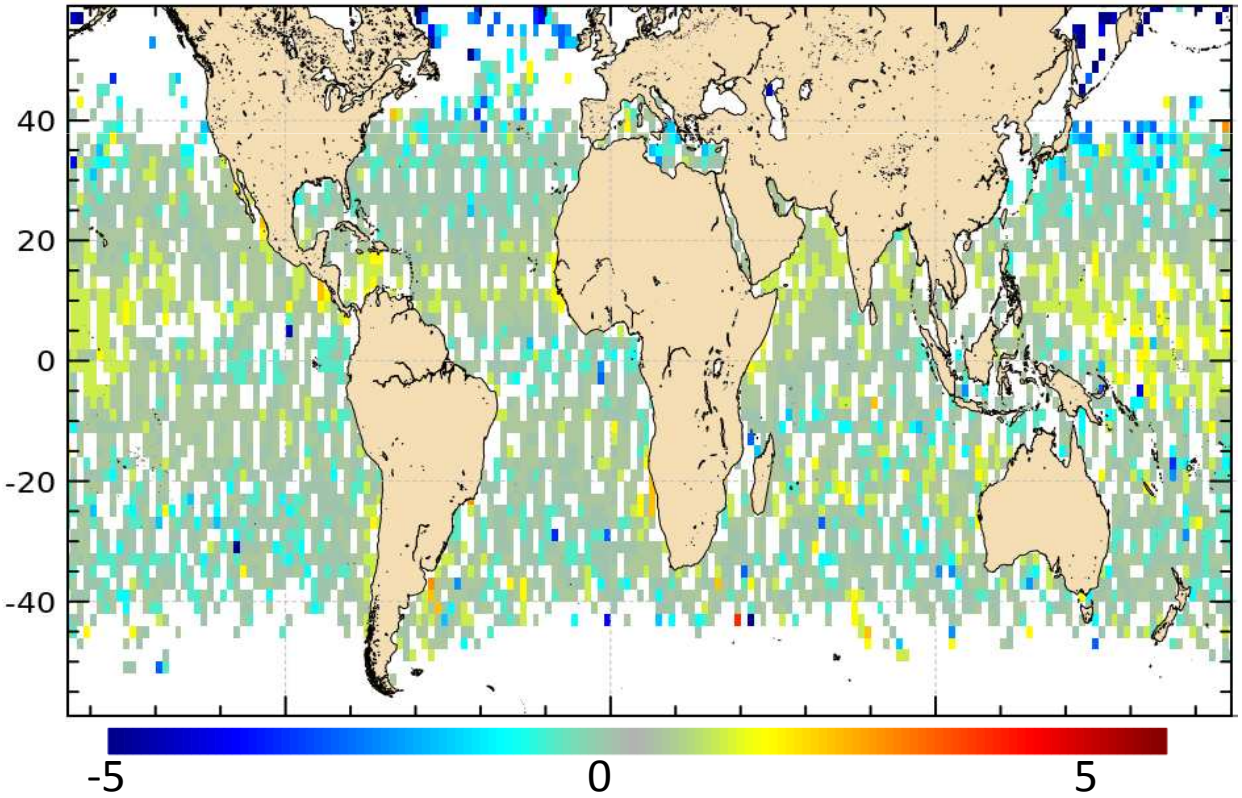
23.8 GHz; 34 GHz → water vapor, clouds

✓ **REFERENCE : AMR WTC**

→ provided by JPL and available in operationnal products (GDR, see aviso website)

- ✓ **Period: 01/2012 – 03/2012**
- ✓ **Statistics for clear sky conditions** (AMR CLWC = 0)
  - ➔ 30% of total nb of estimations
  - ➔ nb of points/bin: ≈25-40 (mid-latitudes) // ≈10-15 (low latitudes)

AMR_WTC - 1DVAR_WTC [cm]



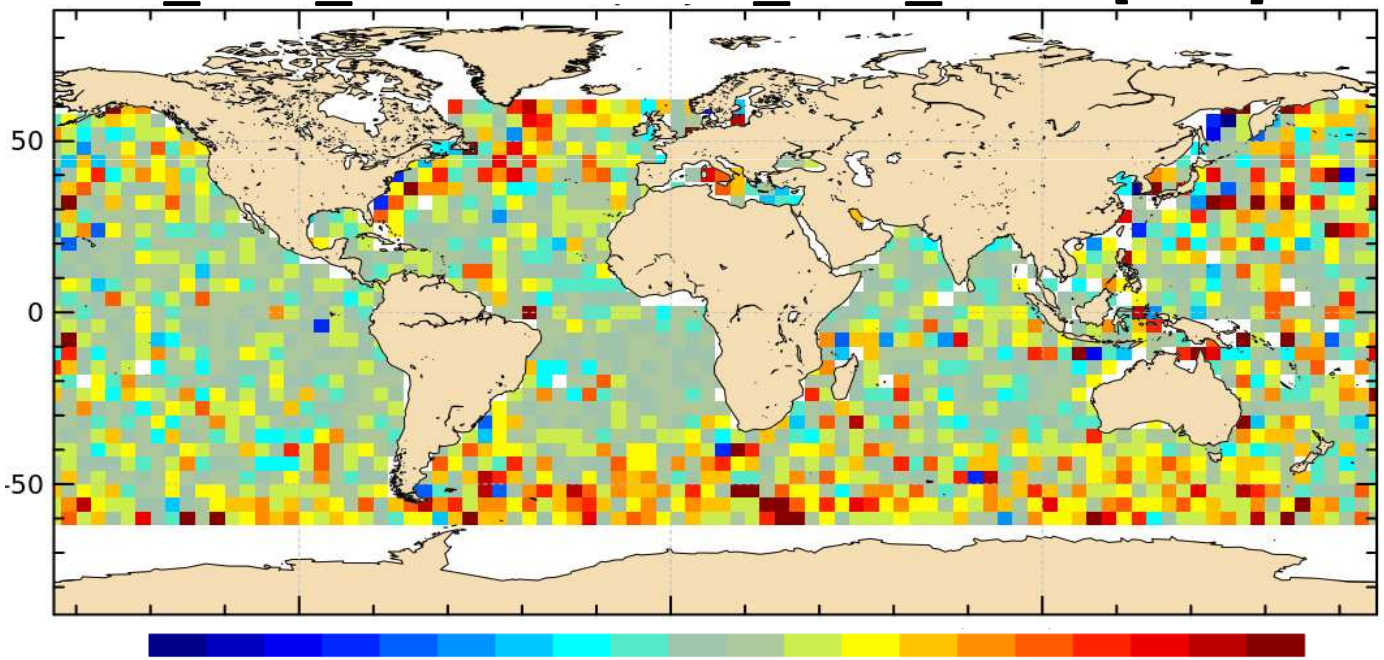
nb of samples	= 194557
mean	**= 0.05 cm**
std	**= 0.6 cm**

A validation tool to evaluate the performance of WTC retrievals

- **Impact of the retrievals on Sea Surface Height (SSH)**
  → assumption : stability of the sea state below 10 days (→ low variance of SSH)

✓**Period: 01/2012 – 03/2012**
✓ **Statistics for clear sky & cloudy conditions**

VAR_SSH_1DVAR – VAR_SSH_AMR [cm²]

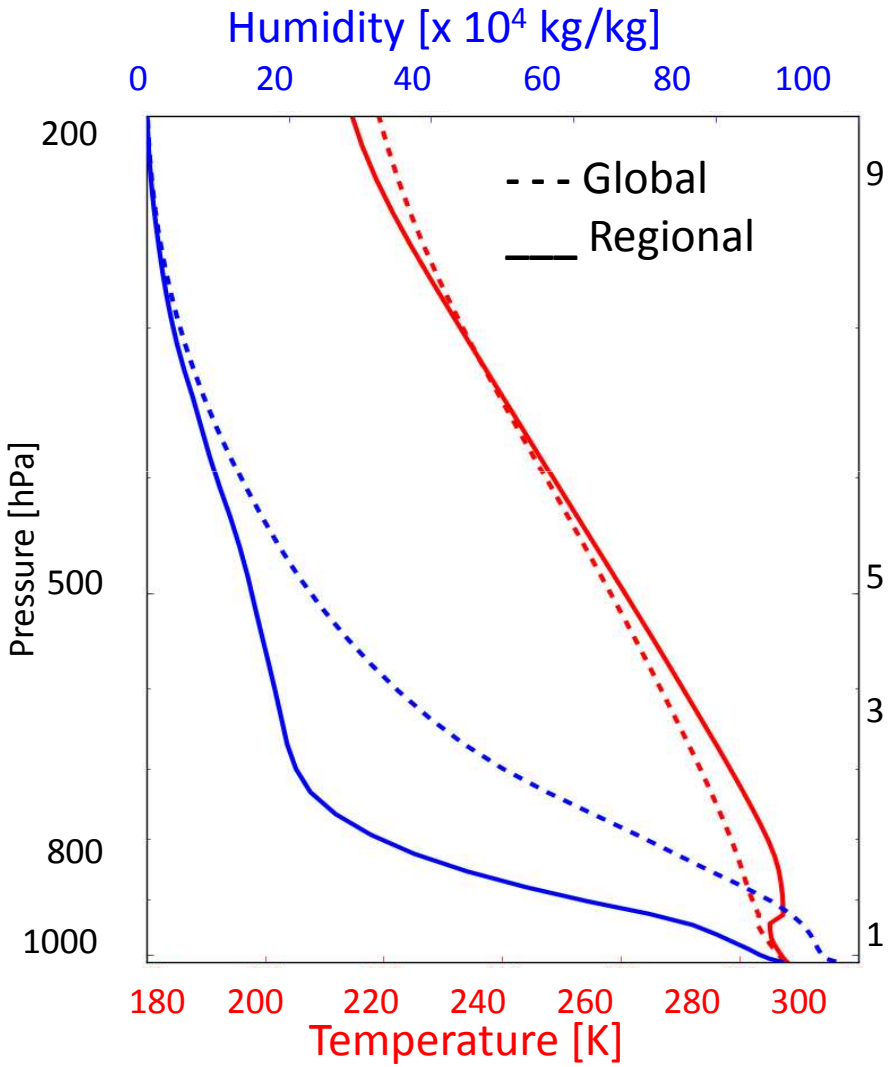


mean = 3.91 cm²

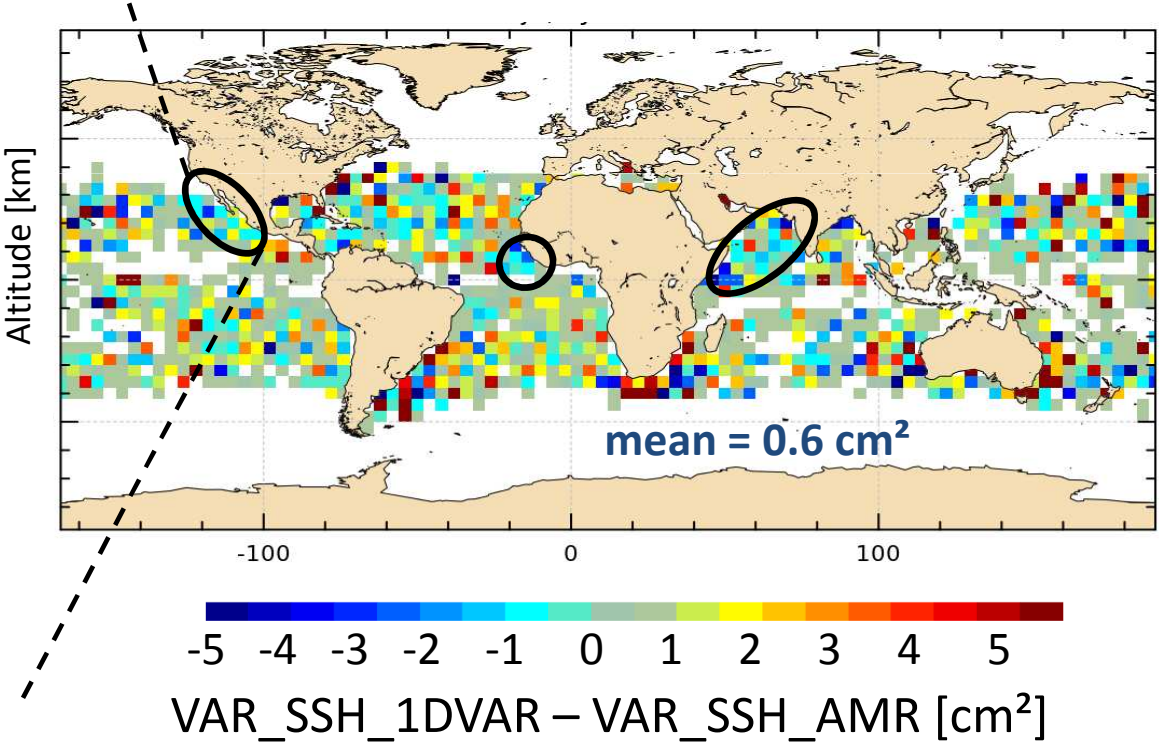
std = 0.83 cm²

IMPROVEMENT **DEGRADATION**

A validation tool to evaluate the performance of WTC retrievals



- ✓ **Period: 01/2012 – 03/2012**
- ✓ **Statistics for clear sky conditions (AMR CLWC=0)**



Conclusions : Benefits of the 1D-Var approach for global WTC retrievals

- **Benefits of this new approach:**

✓ Valid over **different types of surfaces** and **different atmospheric conditions using model atmospheric profile and surface characteristics**

(≠ current WTC retrieval algorithms : valid for mean conditions only)

✓ **As good as reference WTC algorithm over mean ocean conditions**

✓ **Better than reference WTC algorithm over heterogeneous surfaces**

(upwelling regions over ocean, near coast, sea ice, inland waters)

Conclusions : Further improvements of the method

- **Further improvements**

✓ WTC estimations over **cloudy conditions**

→ use of profiles of cloud liquid water content in 1D-Var process

✓ Integration of **zonal/seasonal background errors**

→ background error covariance matrix adapted to climate scales

✓ Evaluation of **impact of colocations** on 1D-Var WTC retrievals : time gap between background (model) and observations (measurements) < 3h

→ solution to avoid time gaps (*interpolation of model in time?)*

✓ Application of non oceanic / heteregenous surface

✓ Use of **additional surface information** for WTC retrieval over heterogeneous surfaces (coastal regions, sea ice, inland waters)

→ integration of **surface emissivities** in the 1D-Var process

→ integration of **surface emissivities *from other frequencies*** in the 1D-Var process

✓ **Validation of WTC retrievals** over coastal areas, sea ice, inland waters : comparison with in-situ measurements (radiosondes)