New generation of wet tropospheric correction algorithms for altimetry missions

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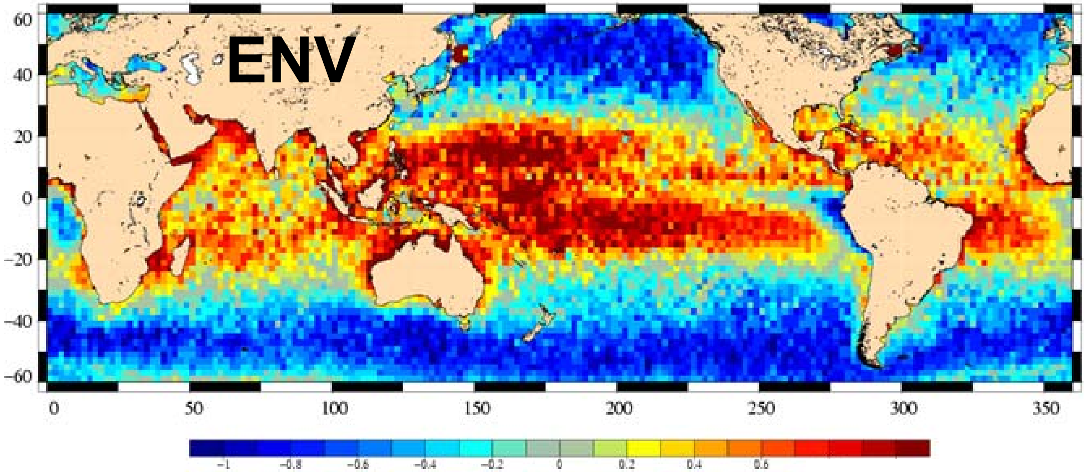
The wet tropospheric correction

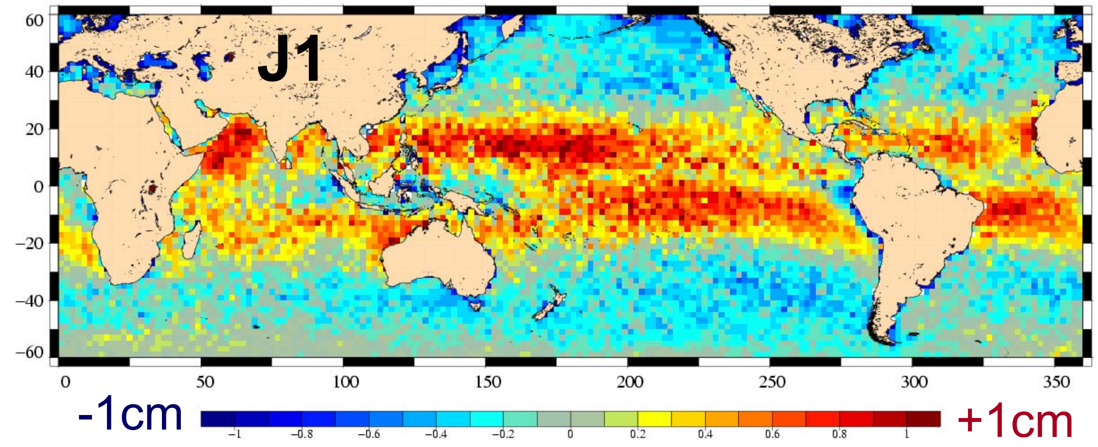
- Extra path delay due tu water vapor in the troposphere (between 0 and 50 cm)
- Proportionnal to the integrated water vapor content
- Highly variable in space and time (30’, 50 km)
- Microwave radiometers added to altimetry missions
  - ✓ ESA missions ERS1&2, Envisat (23.8, 36.5 GHz)
  - ✓ NASA/CNES/EUMETSAT/NOAA : Topex / TMR (18, 21, 37 GHz), Jason1&2 / JMR & AMR (18.7, 23.8, 34 GHz)
  - ✓Future missions : AltiKa (23.8, 37 GHz), Sentinel3 (23.8, 36.5 GHz)…

Objective of the radiometers : to provide the wet pah delay dh

- with a good accuracy (≈ 1 cm rms)
- with a good stability (≈ 1 mm/year)
- with no geographically correlated errors

Difference between radiometer and ECMWF estimation
Year 2005 - 1°x1° boxes





Very similar structures

ECMWF model or radiometer errors ?

SUMMARY

1) Development of standard retrieval algorithms
2) Error characterization
3) Proposition of improvement
4) Validation
5) Conclusions/perspectives

DATABASE

- 12 global ECMWF analyses at noon, one per month in 2005 (annual cycle)

- 0.5° resolution, 91 pressure levels

- For each mesh of these global grid
  - ✓ surface parameters (temperature and wind)
  - ✓ atmospheric profiles (temperature, specific humidity, cloud liquid water)

- Simulations with a radiative transfer model in Envisat/MWR configuration: brightness temperatures TBs (23.8 and 36.5 GHz) and altimeter backscattering coefficient in Ku band (σ_0)

≈ 1 500 000 triplets (dh,TB23.8,TB36.5,σ0)

- 100000 data randomly selected for learning

- the rest for validation to check the generalization power of the algorithm

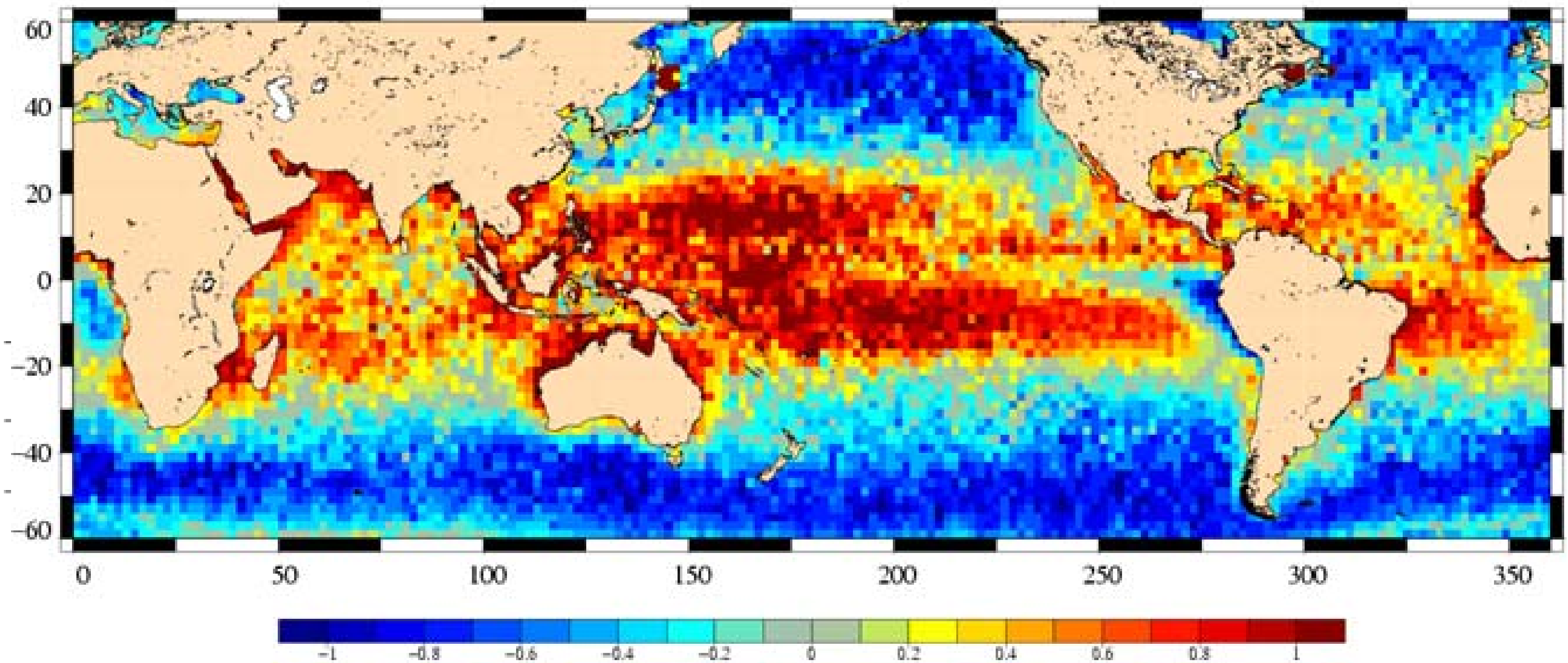
First algorithm : linear dh=f(TB23.8,TB36.5,σ_0)

$dh = c0 + c1 \ln(280\text{-}TB23.8) + c2 \ln(280\text{-}TB23.8) + c3 / \sigma_0^2$

≈ERS1/2 operational algorithms *(Eymard et al)*

~TMR/JMR/AMR operational algorithms *(Kheim et al, Brown et al)*

Retrieved – Reference dh (cm)



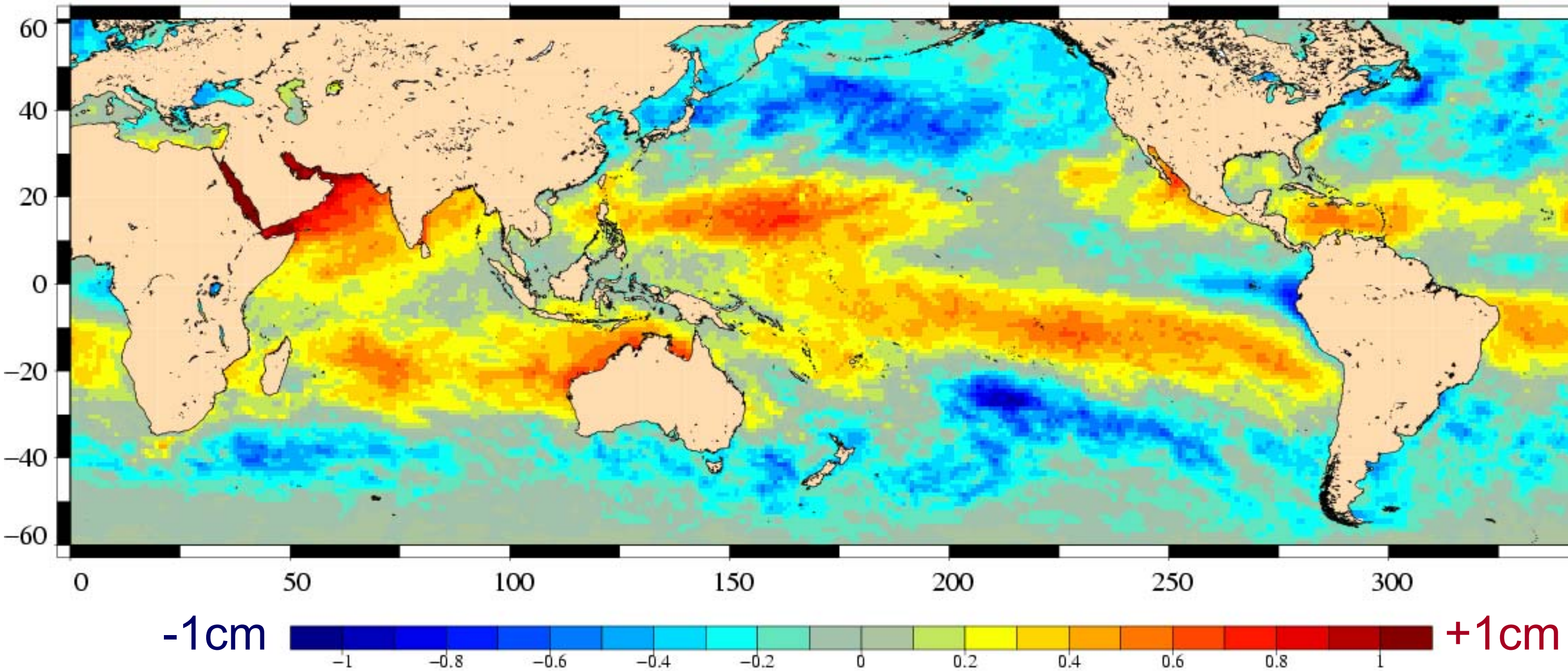
- Same structures than over (Radiometer-ECMWF) map

➢ confirmation that errors come from the statistical retrieval algorithm

➢ translate to a similar distorsion in the altimeter sea level map

Second algorithm : dh=NN(TB23.8,TB36.5,σ0)
≈ Envisat operationnal algorithm *(Obligis et al)*

Retrieved – Reference dh (cm)

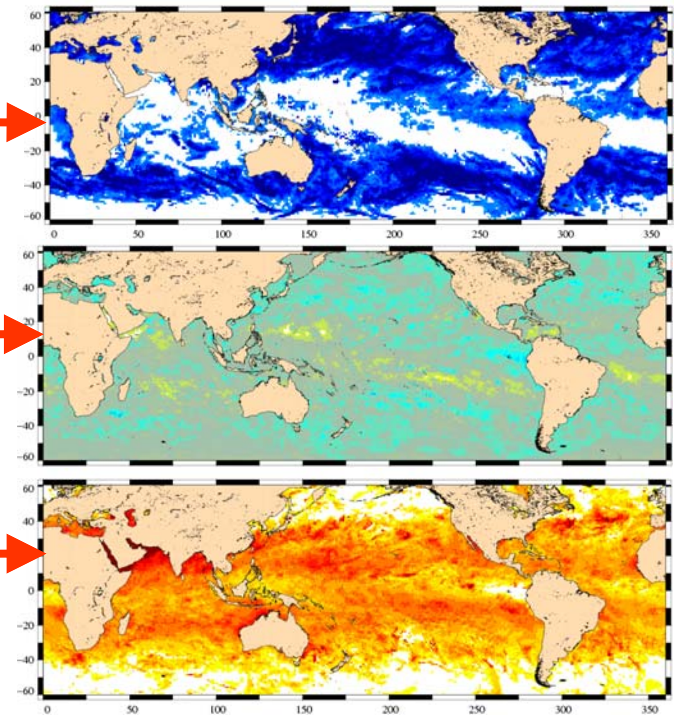


mean bias: 0.001cm – standard deviation: 0.48cm

- Much better but same over and underestimation structures remain

Error map analysis: What are the correlations between these error structures and the different pertinent physical parameters?

1. Classification (K_means) of the differences in 3 classes:
   - Underestimation
   - Good estimation
   - Overestimation

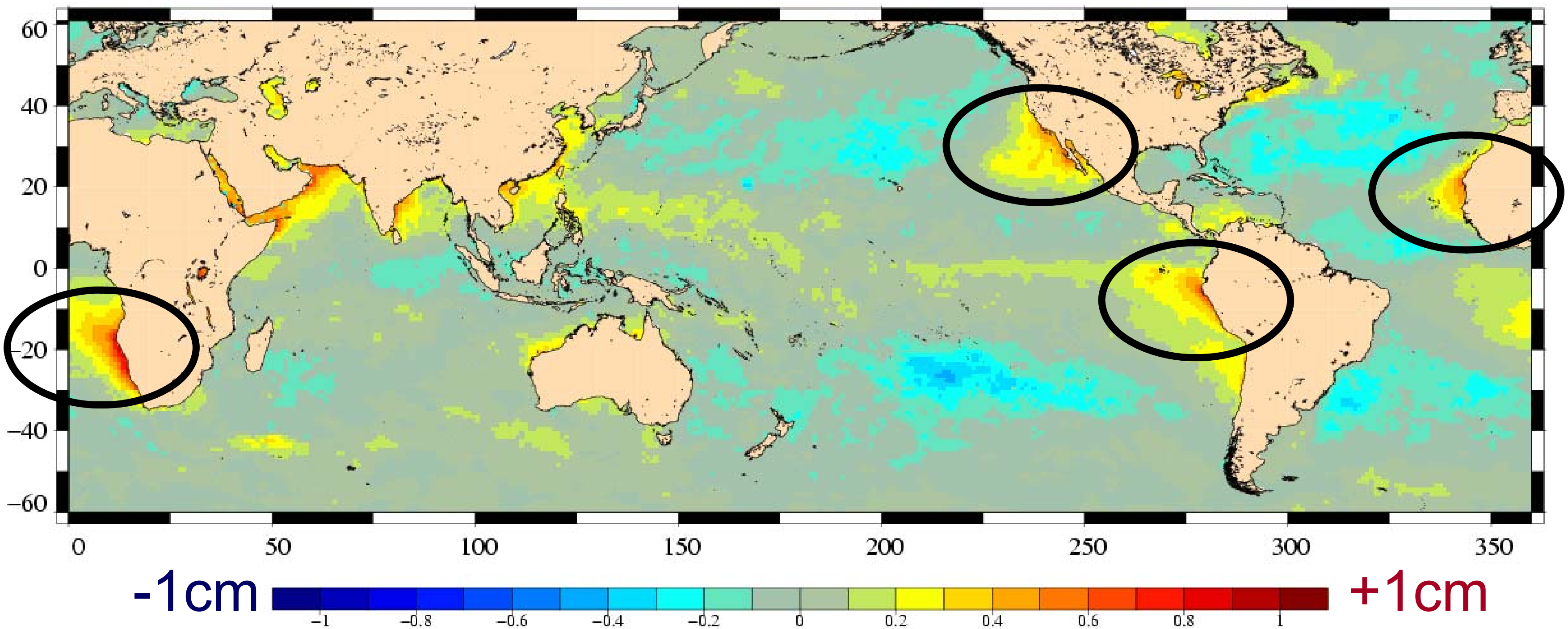


2. Binary tree method to determine the most pertinent variable (predictor) to separate the 3 classes

Sea surface temperature SST

Third algorithm : dh=NN(TB23.8,TB36.5,σ0,SST)

Retrieved – Reference dh (cm)



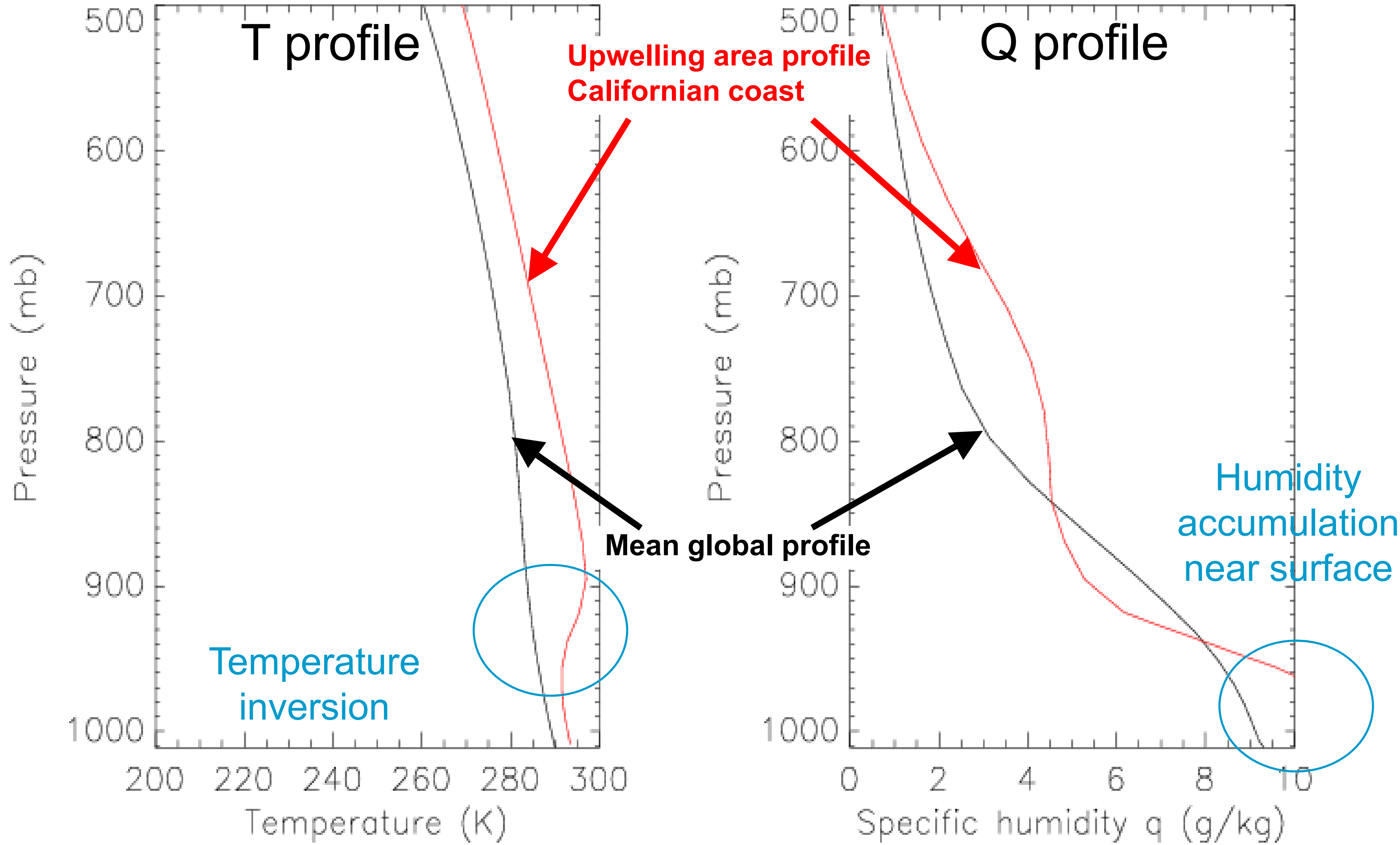
mean bias: 0.001cm - standard deviation: 0.20cm

- Much better

BUT

- Error structures remain in the eastern part of the subtropical basins
- Located in oceanic upwelling areas associated to strong atmospheric subsidence (temperature inversion, humidity accumulation near the surface)
- Specific atmospheric profiles -> Global statistical method fails

Example of atmospheric profiles near the Californian coast



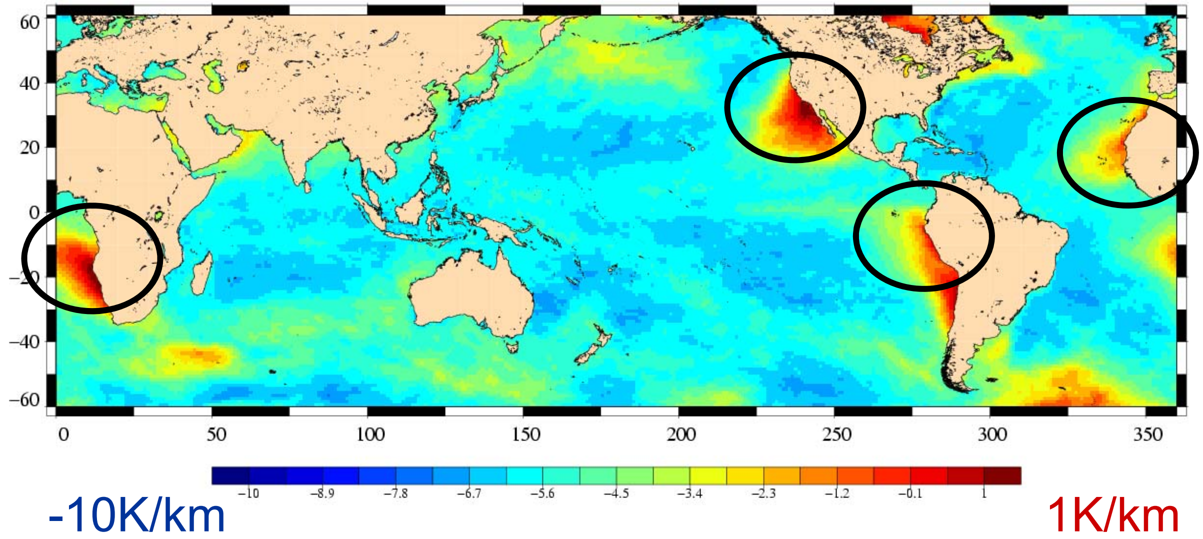
Introduction of Γ : decrease rate of the temperature with altitude (K/km) estimated between the surface and 800 mb

A new parameter to characterize the atmospheric stratification : Γ800

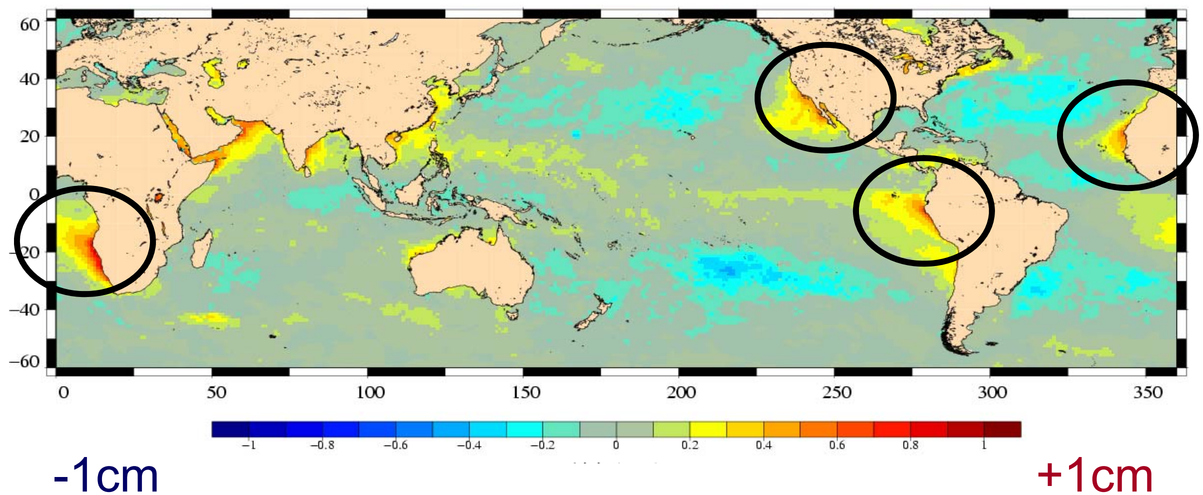
Γ: lapse rate (up to 800mb)

Climatological value

Around -5K/km

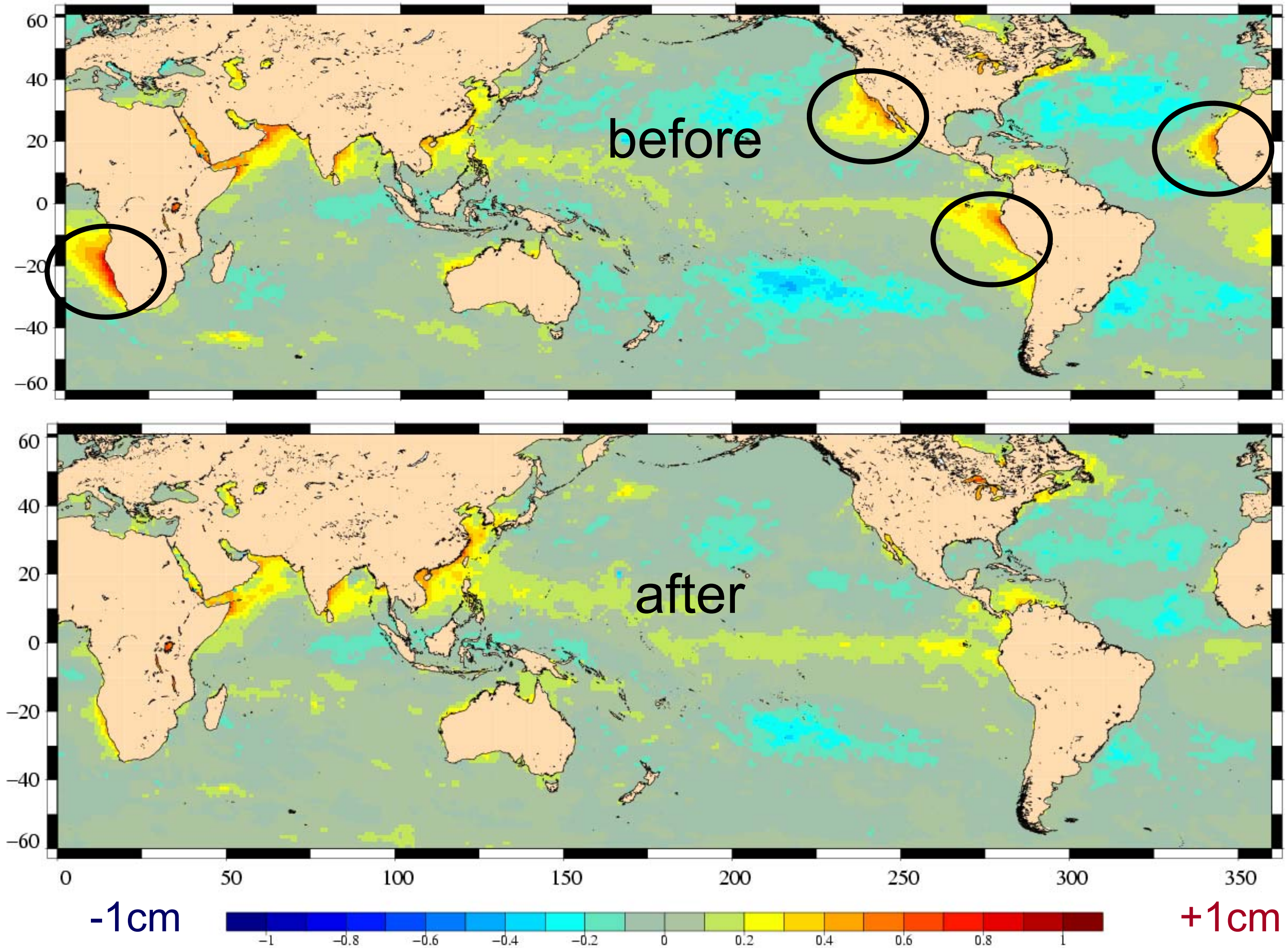


Error structures



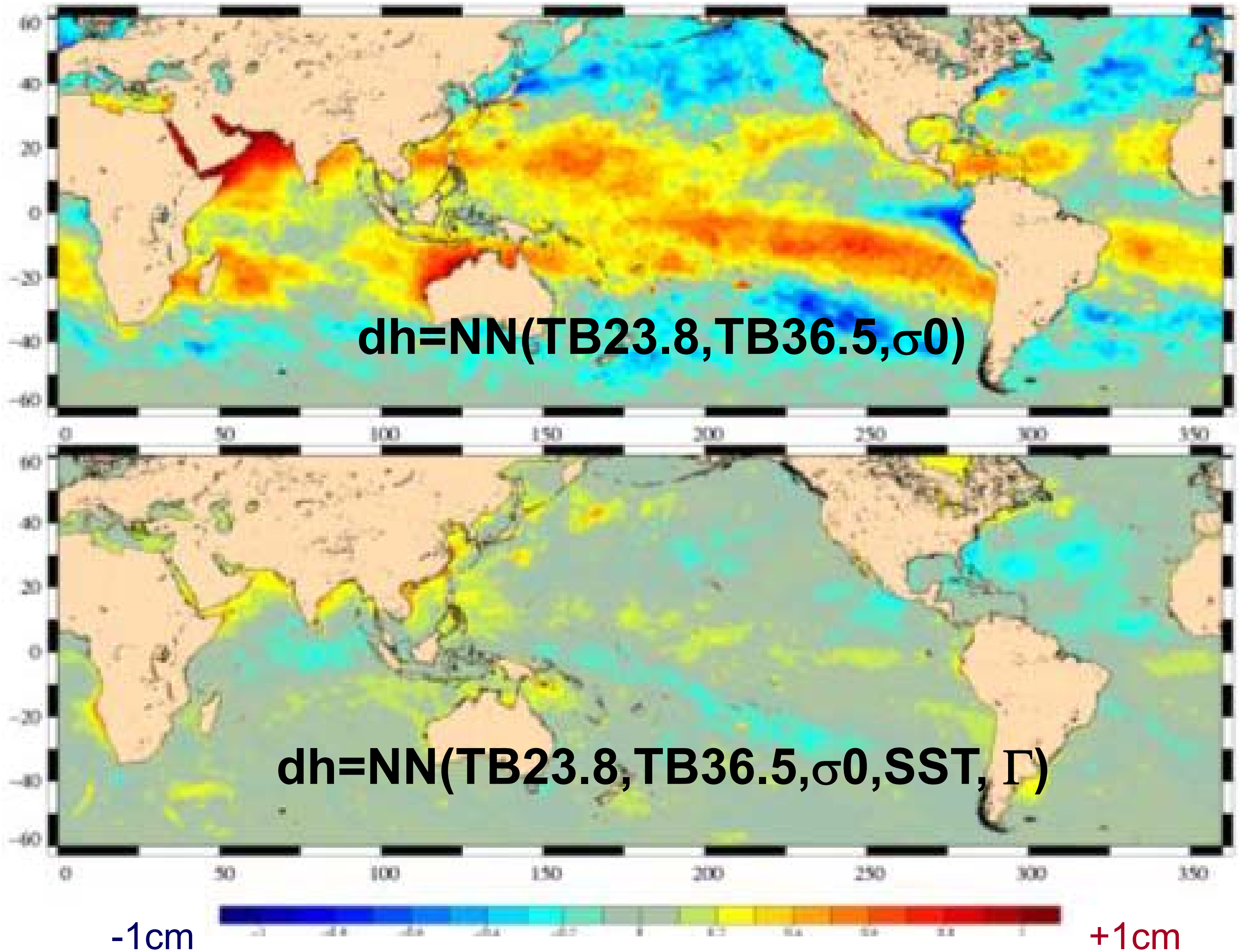
Remaining errors drastically correlated with specific atmospheric stratification conditions due to upwelling phenomenon

Fourth algorithm : dh=NN(TB23.8,TB36.5,σ0,SST, Γ)



mean bias: 0.01cm - standard deviation: 0.12cm

Validation on an independent dataset
2005 algorithm applied over 2003 simulations…



Performances of different 2005 algorithms over 2003 simulations

2003	Biais cm	Standard deviation cm
Parametric model	-0.02	0.72
NN(TB23.8,TB36.5, σ0Ku)	0.04	0.58
NN(TB23.8,TB36.5, σ0Ku, SST, Γ)	0.01	0.25

CONCLUSIONS

- Global statistical approaches from TBs only create systematic correlated errors on global humidity fields

- Actual products suffer for error structures related to:
  - SST variations (especially for bi-frequencies radiometer) not well taken into account
  - Atmospheric stratification characteristics (neglected with a global statistical approach)

- Taking SST and lapse rate as new parameters in the Envisat algorithm improves significantly the error maps

- Error variance decreased more when adding two new parameters than when changing the regression formalism

- Similar behavior (lower amplitude) for other altimetry missions (Topex, Jason1, and probably 2)

PERSPECTIVES

- To develop this type of algorithm in Jason1/Jason2 configurations (SLOOP CNES project)
- To perform a more extended validation on real radiometer measurements, and comparison with radiosonde in-situ measurements
- To propose this type of algorithm for future altimetry missions (AltiKa, Sentinel3), or reprocessing of past/current missions

YES radiometer wet path delay products are not perfect

- such **large time/space scale** errors
- stability problems (drift due components aging, thermal effects…)

BUT radiometer remains an essential altimeter companion for high resolution altimetry !