Modeling the DORIS tropospheric corrections with the help of ECMWF models

L. Soudarin[1], H. Capdeville[1], R. Biancale[2],

[1] *CLS, Collecte Localisation Satellites, Ramonville, France*
[2] *CNES, Toulouse, France*

Summary

The model currently used by SSALTO and LEGOS/CLS to correct the tropospheric effect on the DORIS doppler measurement does not allow to take into account the total effect.
One way of improvement is the use of vertical tropospheric correction grids performed for the altimetry by METEO France from ECMFWF models.

The study is led by H. Capdeville at CLS with the support of CNES

Content:

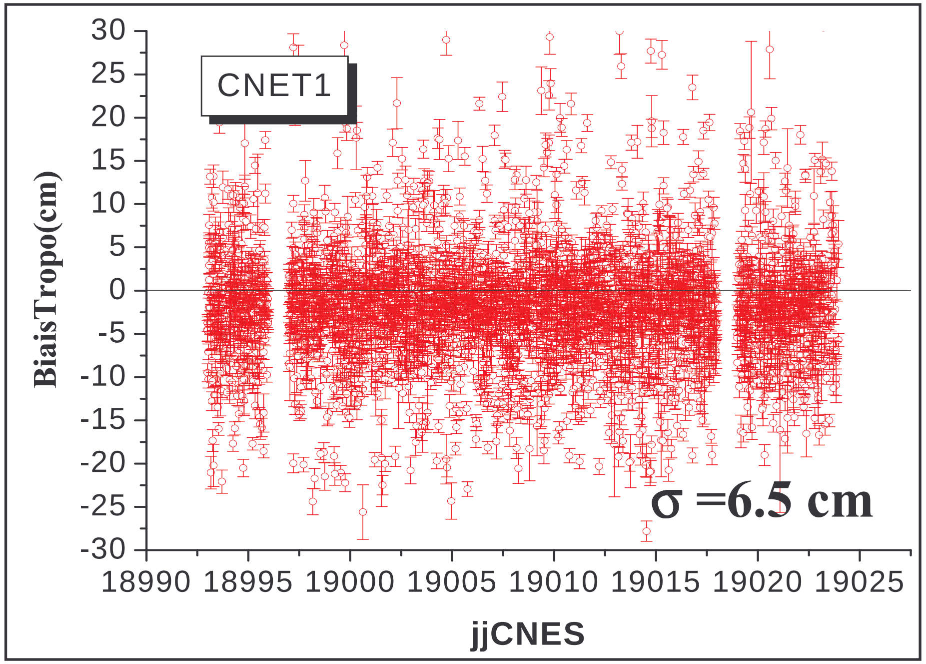
- Vertical tropospheric correction
- Mapping function
- Comparison DORIS, GPS, METEO model

Vertical tropospheric correction : CNET1

Principle

- Total vertical delay $\Delta L_v = \Delta L_{dry} + \Delta L_{wet}$
- Mapping function $f(\phi_0)$
- Use of ground measurements P, T and H

Results



Estimated vertical bias per pass (June 2002, Spot2)

Mismodeling of ΔL_v due to:
- reliability of the ground data P,T,H
- validity of the default values
- bad estimation of ΔL_{wet} from the ground humidity

ΔL_{wet} ~estimated bias

Vertical tropospheric correction : tropospheric maps

Objective

Use of meterological grids to compute the vertical delay

Tropospheric maps

- maps of dry and wet vertical corrections (from ECMWF grids)
- every 6 hours
- Gaussian grid (~ 0.5°)

→

Avantages:

- maps available at CLS
- independant from the ground data

Drawbacks:

- smoothed topographic grid
- mapping function needed (symmetry)

Computation of the tropospheric maps by METEO FRANCE

Computation of the vertical delay based on:

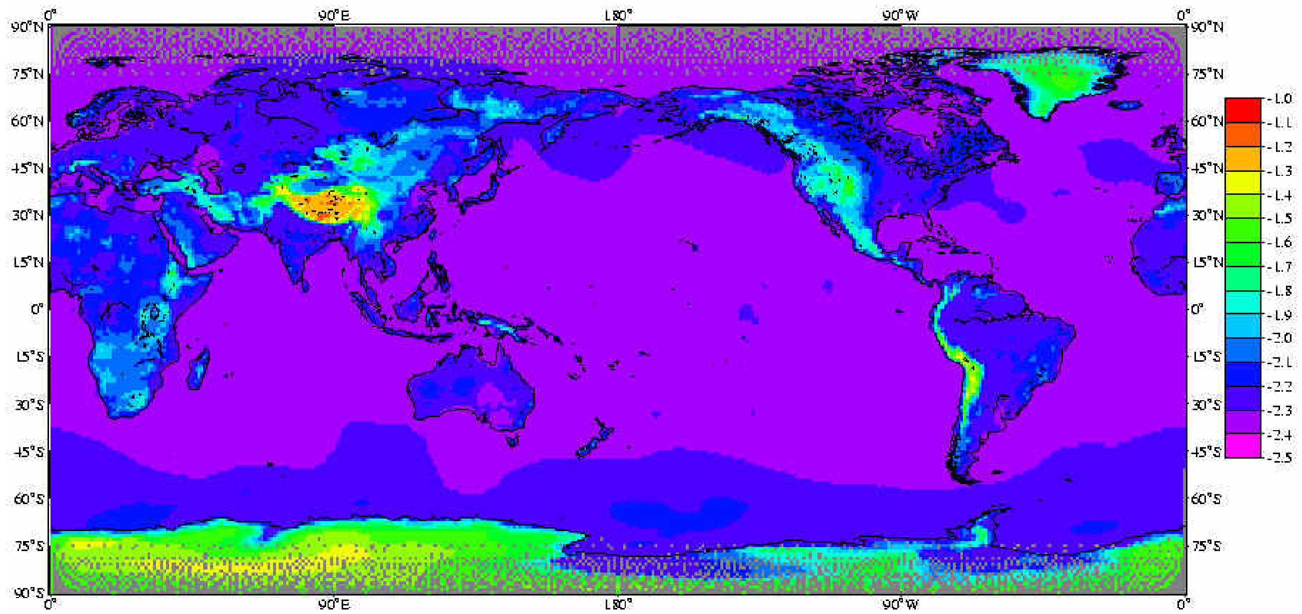
- ECMWF grids (60 levels of P,T,H)
- model of surface pressure
- topographique grid (0.5°) from the numerical model *"Terrain Base Digital Elevation Model "*

$$\Delta L_v = \Delta L_d + \Delta L_w$$

Vertical tropospheric correction : tropospheric maps

Tropospheric map

Dry component
(0H00 01/06/2002)



Interpolation method

DORIS pass → Time (day, seconds), lat, lon → ① Selection of the grids → G_{before}, G_{after}

② Selection of the mesh → lat, lon (x4) for G_{before}, G_{after}

③ → ΔL_v before, ΔL_v after

④ Linear time interpolation → ΔL_v

Vertical tropospheric correction : altitude correction

Altitude discrepancy between the topographic grid and the DORIS network

-contrasts at small scale not represented by the topographic grid

- imply an error of the tropospheric correction

Methods to correct this effect

- from the ground pressure: fiability of the data?
- from the interpolated pressure (ECMWF grids): availability of the grids?
- from an adjustement based on the GINS estimated tropospheric correction: both wet and dry effects taken into account

$$\Delta L_v = \Delta L_{v\,METEO} + b + a\,(\Delta L_{v\,METEO} - Mean(\Delta L_{v\,METEO}))$$

(over one month for a station)

ΔL_v: tropospheric correction *estimated with GINS (CNET1+bias per pass)*

$\Delta L_{v\,METEO}$: tropospheric correction *from the meteorological grids*

$Mean(\Delta L_{vMETEO})$: annual mean of METEO corrections

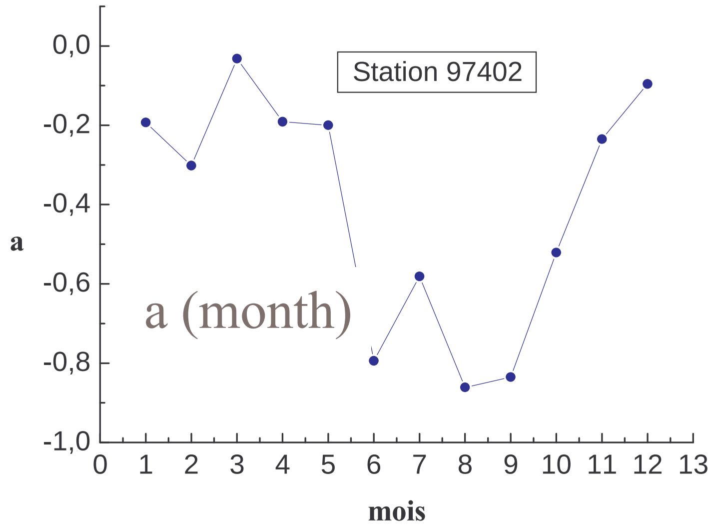
b: *altitude correction*

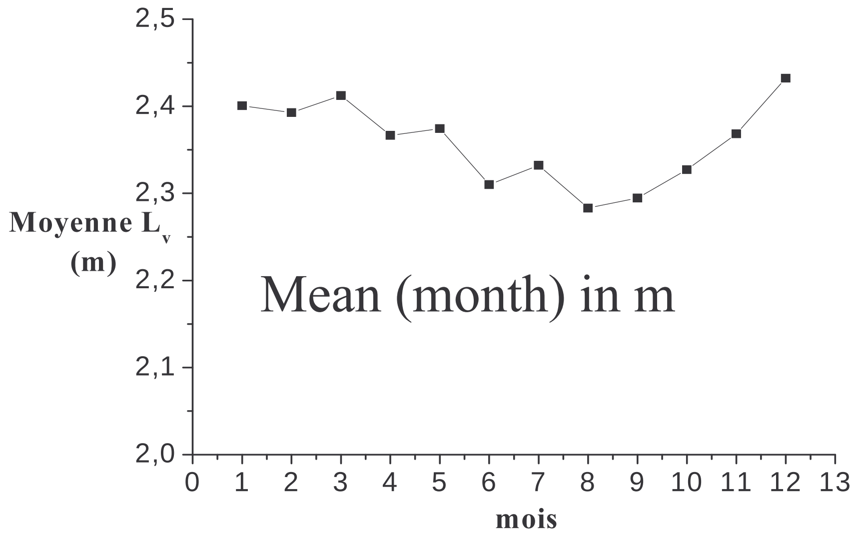
a: *modulation of the amplitude of the variations at the level of the DORIS station (effect of the first atmospheric level)*

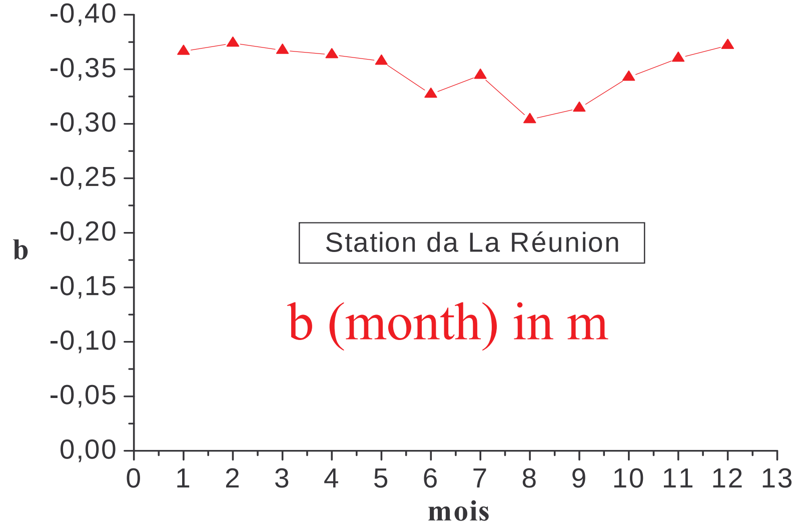
Vertical tropospheric correction : altitude correction

Estimated parameters

- year 2002 (Spot2 + Spot4)
-computed by month
- Ex. La Reunion







Vertical tropospheric correction : altitude correction

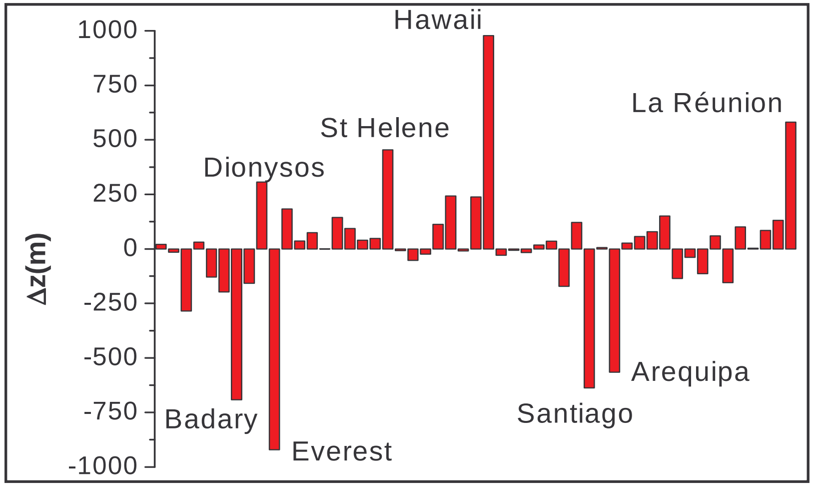
Effect of the altitude difference

$\Delta z = z - z_{int}$

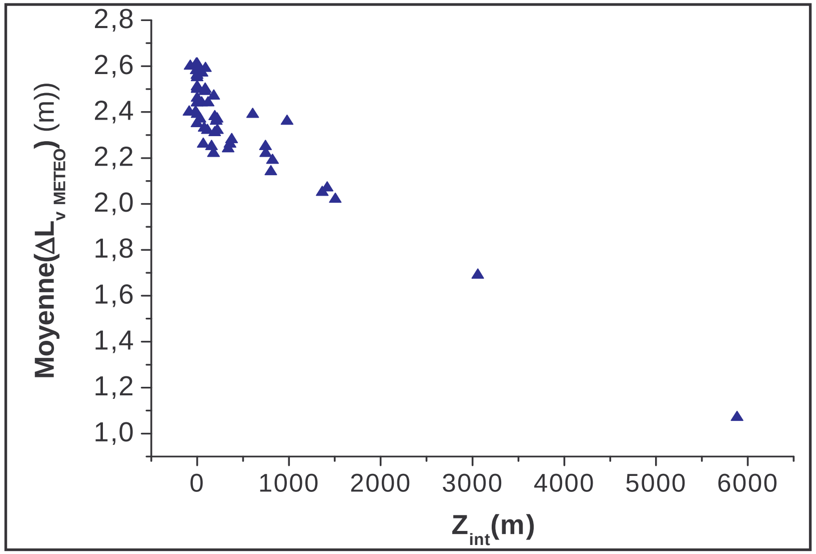
z: altitude of the DORIS station

z_{int}: altitude interpolated (grid)

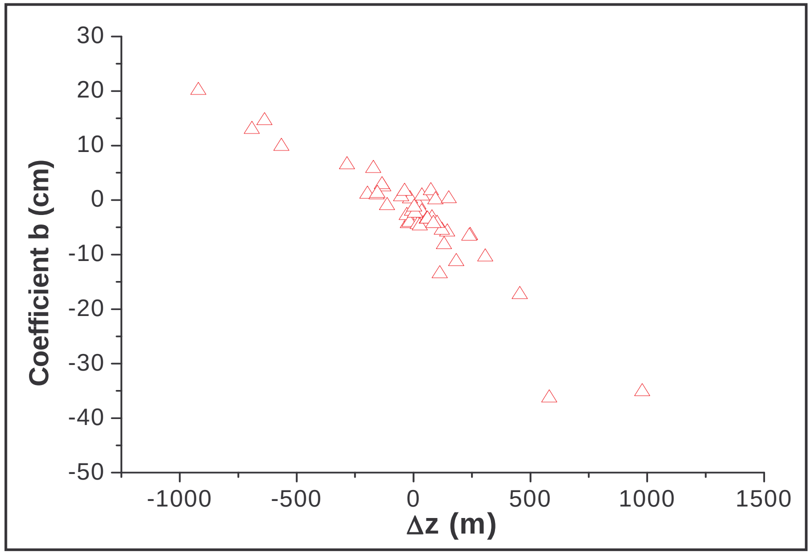
- b < 0 when $\Delta z > 0$
- b decreases when Δz increases
- Djibouti: b high but Δz low
- Mean($\Delta L_{v\ METEO}$) decreases when z_{int} increases



Altitude differences (station –grid)



Mean($\Delta L_{v\ METEO}$) vs interpolated altitude



Coefficient b (annual mean) vs Alttitude differences

Vertical tropospheric correction : altitude correction

Altitude correction:1 or 2 parameters?

Residuals (RMS) $\Delta L_v - \Delta L_{vMETEO\ corrected}$

Station of La Réunion

in cm

Month	01	02	03	04	05	06	07	08	09	10	11	12
(1)	*2.8*	*2.2*	*3.4*	*3.1*	*2.9*	***6.9***	***4.2***	***6.8***	***6.2***	***4***	*3.1*	*2.6*
(2)	*2.5*	*2.1*	*3.3*	*3*	*2.9*	***3.1***	***3***	***3***	***3***	***2.8***	*3*	*2.5*

(1) $\Delta L_v = \Delta L_{vMETEO} + \mathbf{b}$

(2) $\Delta L_v = \Delta L_{vMETEO} + \mathbf{b} + \mathbf{a}\,(\Delta L_{vMETEO} - \mathrm{Mean}(\Delta L_{vMETEO}))$

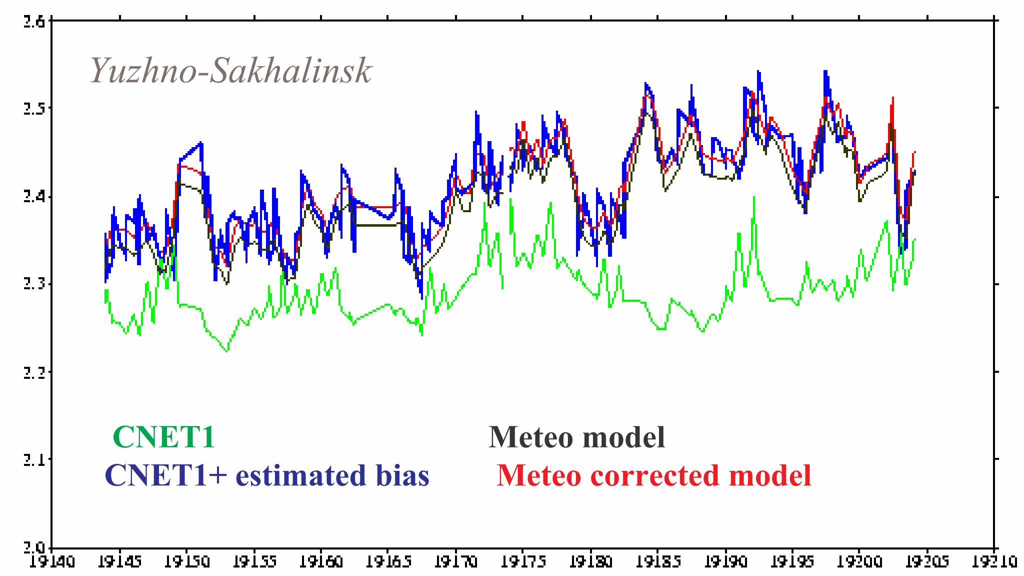
> Gain of several millimeters to some centimeters when two parameters are estimated

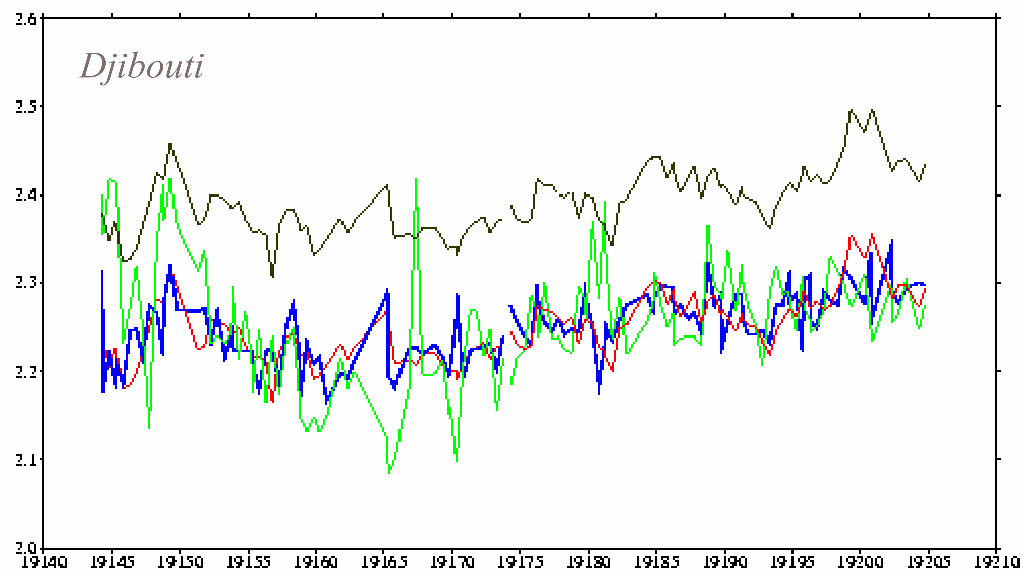
Tropospheric correction model

Zenithal delays (expressed in meter) over June and July 2002 (Spot2) derived from CNET1, METEO and METEO corrected, compared to the one adjusted in the orbit computation (CNET1 + estimated bias).

A good agreement can be seen between METEO corrected and the estimated delay.

Note for Djibouti the bad values of CNET1 due to a failure of the pressure sensor.

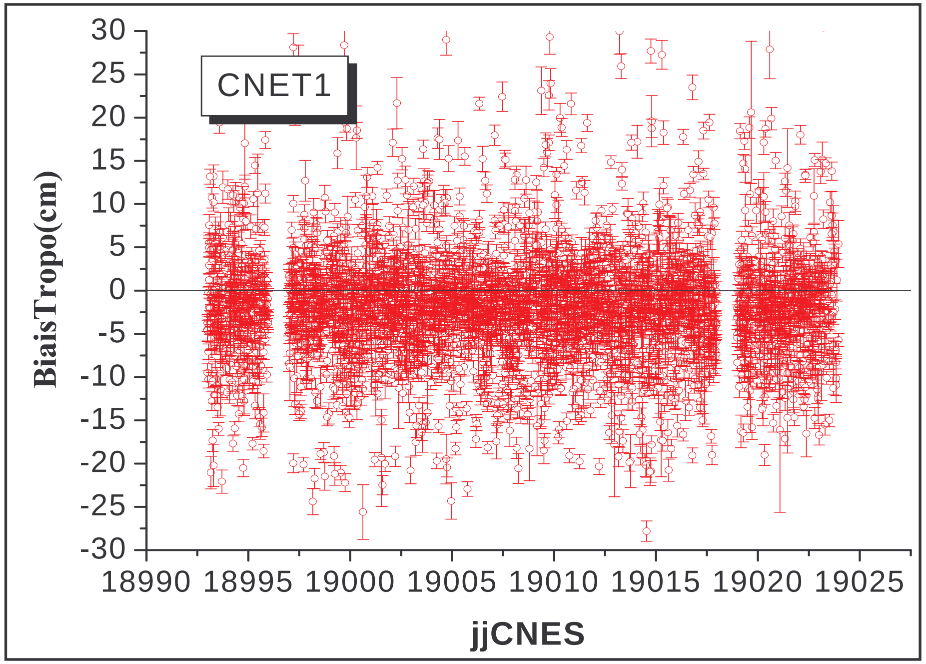


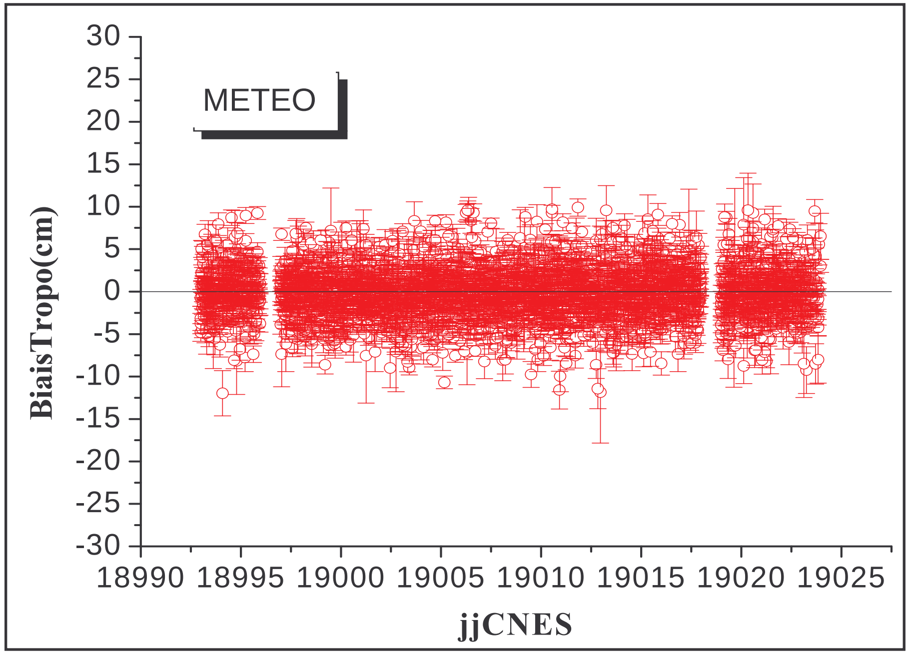


Vertical tropospheric correction : results

Estimation of tropospheric bias (GINS)

(SPOT2 - June 2002 - All the stations)





Input CNET1
σ =6.5 cm, Max = 32 cm, Min = - 28 cm

Input METEO model
σ = 2.9 cm, Max = 12 cm, Min = -13 cm

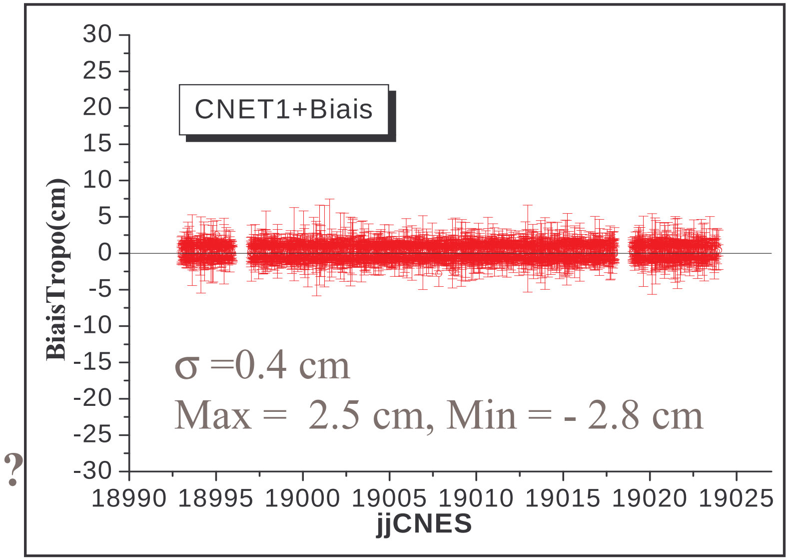
> Improvement of a factor 2 of the estimated bias with our model

Vertical tropospheric correction

Model of vertical tropospheric correction:

- METEO France grids + correction (set per station of 3 values : a, b, $\Delta L_{v\ mean}$ (means of year 2002))

- Residual noise estimated lower than 1 cm →



But estimation of one tropospheric bias per pass still neccesary

> **Improvement of the mapping function ?**

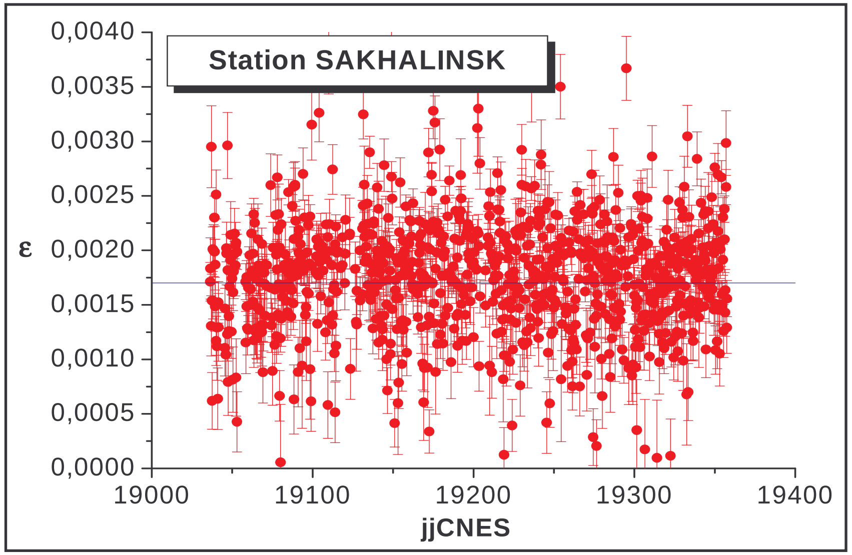
Mapping function 1/3

Tropospheric correction at each elevation angle: $\Delta L(\Phi_0) = f(\Phi_0)\,\Delta L_v$
where

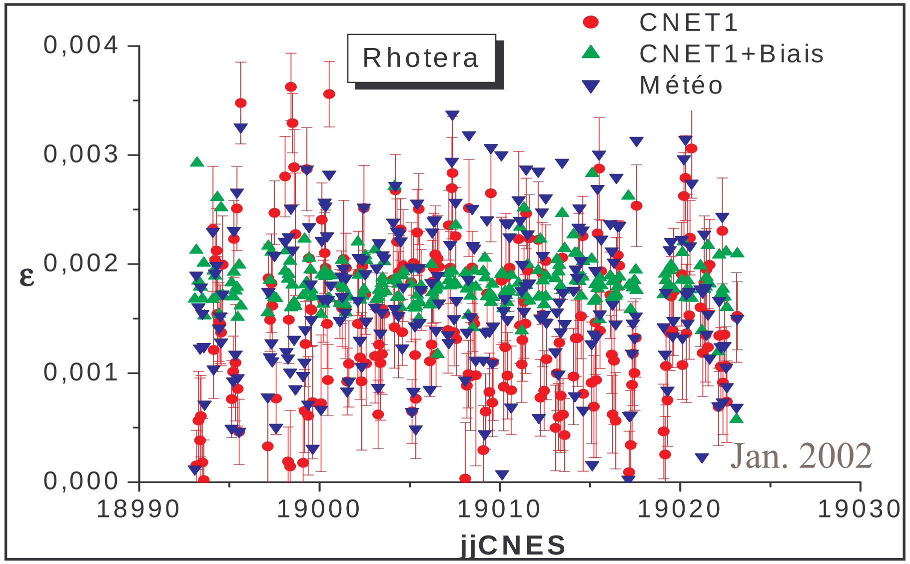
Φ_0:elevation angle

$$f(\Phi_0) = 1/[\sin\Phi_0\,(1+\varepsilon\,\mathrm{cotan}^2\Phi_0)^{1/2}] \quad (\text{CNET1: } \varepsilon = 17\ 10^{-4})$$

ε is adjusted by pass and by station, ΔL_v is fixed to the model values (CNET1, METEO, GINS determination with CNET1 as input)



METEO model **year 2002**
Mean =17.8 10^{-4} **StDev= 6.6 10^{-4}**



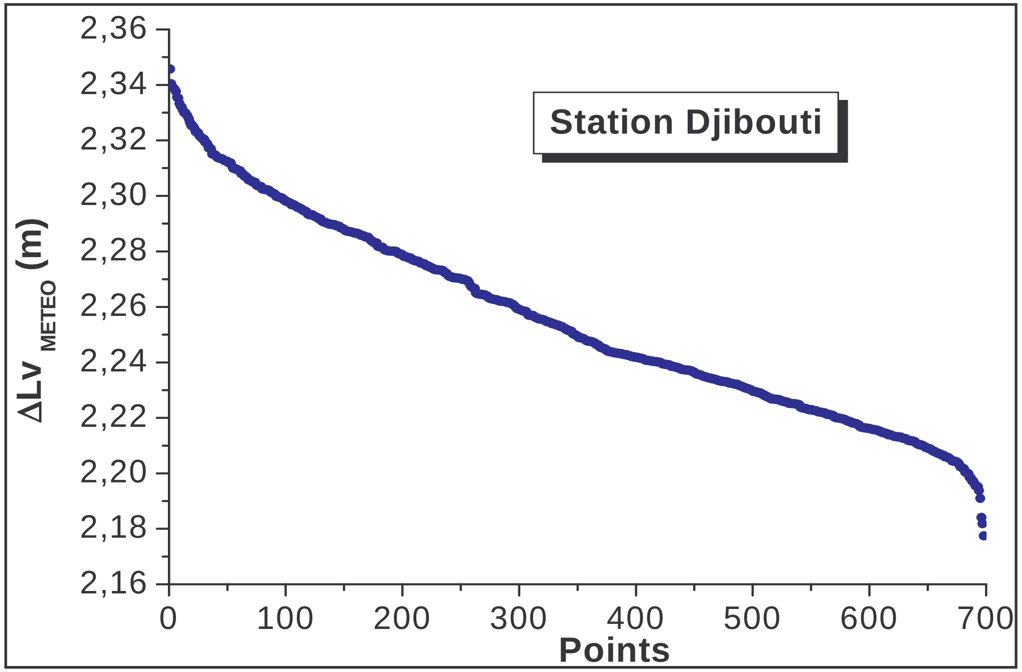
CNET1: Mean =14.0 10^{-4} StDev= 8.7 10^{-4}
GINS (CNET1+Bias): Mean =18.0 10^{-4} StDev= 2.5 10^{-4}
METEO: Mean =17.0 10^{-4} StDev= 7.0 10^{-4}

Mapping function 2/3

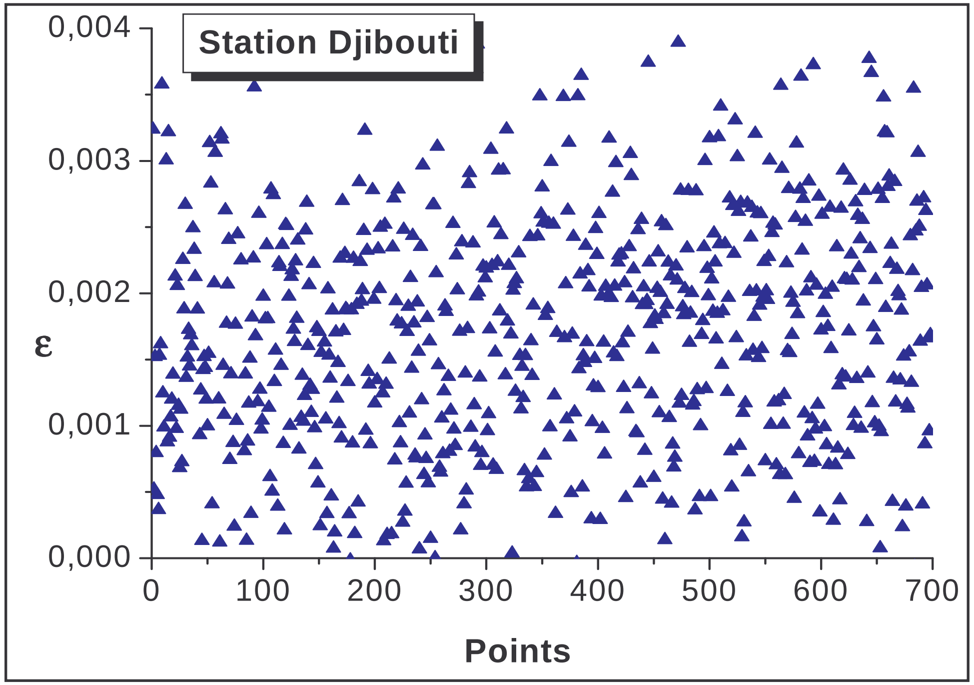
Correlation ε and meteorological conditions ?

Ex. of Djibouti for 2002

1. Representation of P,T,H conditions: sort of the estimated vertical corrections in decreasing order



2. Corresponding estimations of ε : strong dispersion, no particular trend



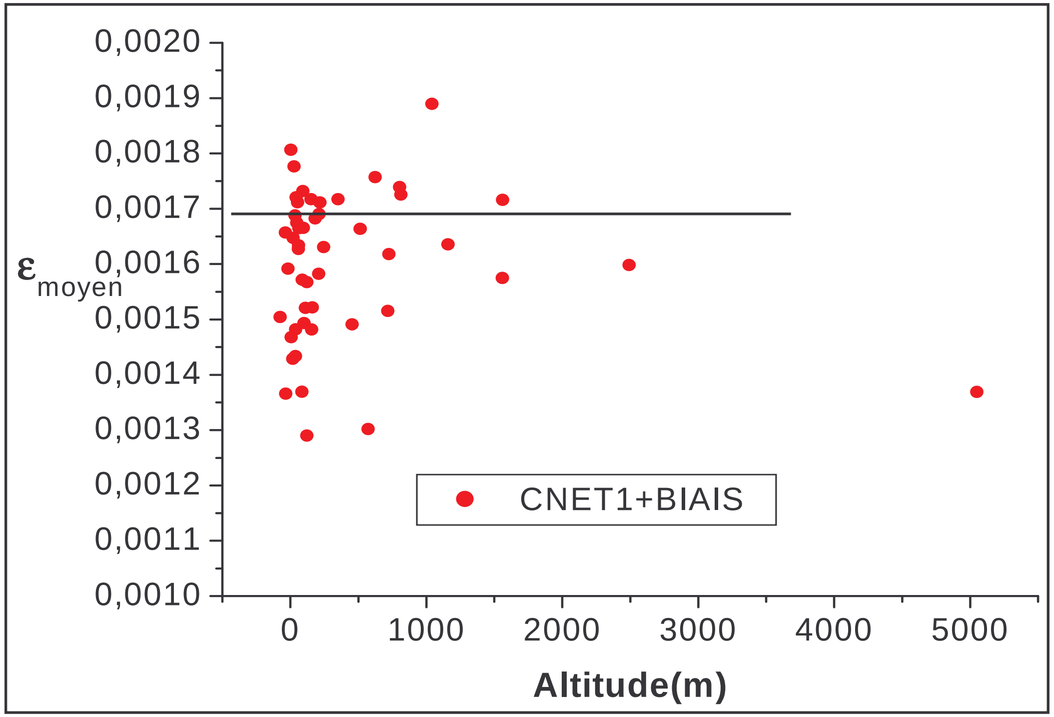
Mapping function 3/3

Correlation ε and station altitude ?

Annual mean of ε for each station:

- **no correlation with altitude**

- **important variation depending of the station: from 13 10^{-4} to 19 10^{-4}**

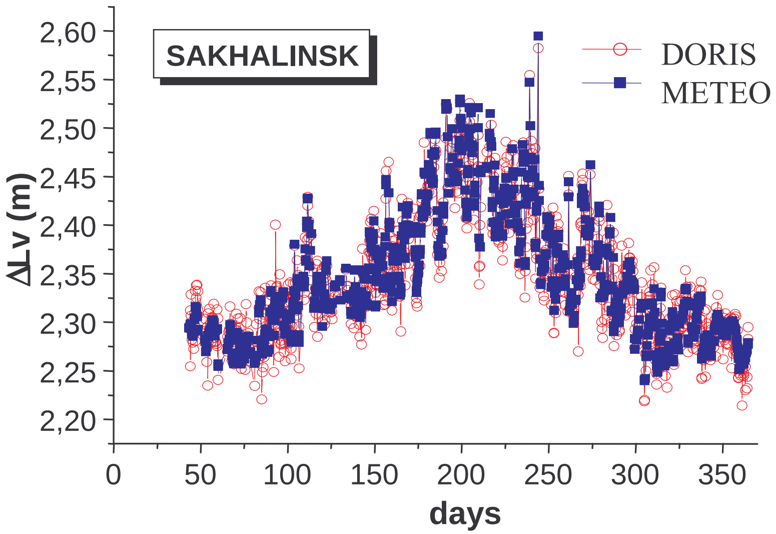


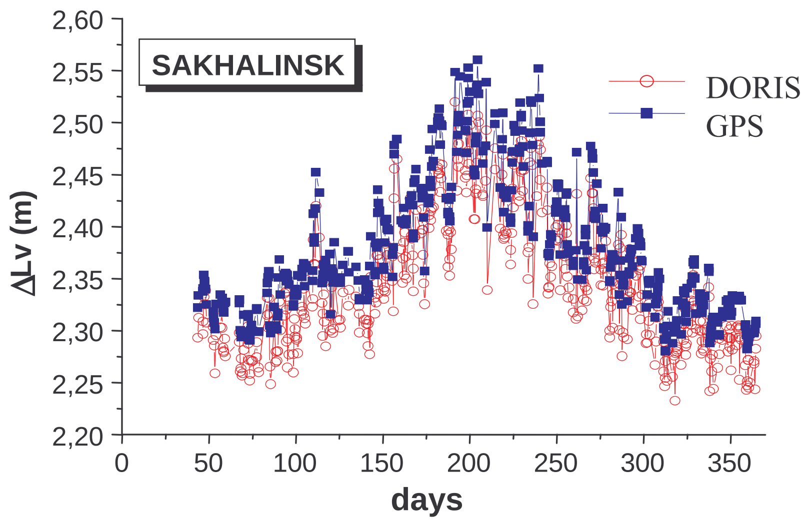
- **No obvious correlation with the meteorological conditions at the station nor with its altitude**

- **One value of ε can be used per station**

Comparison DORIS(GINS), GPS(IGS), METEO 1/2

Station: Sakhalinsk (altitude gaps < 10 m)
Year 2002
Model METEO: no correction applied
GPS values from IGS: http://igscb.jpl.nasa.gov/components/dcnav/ign_tropo.html



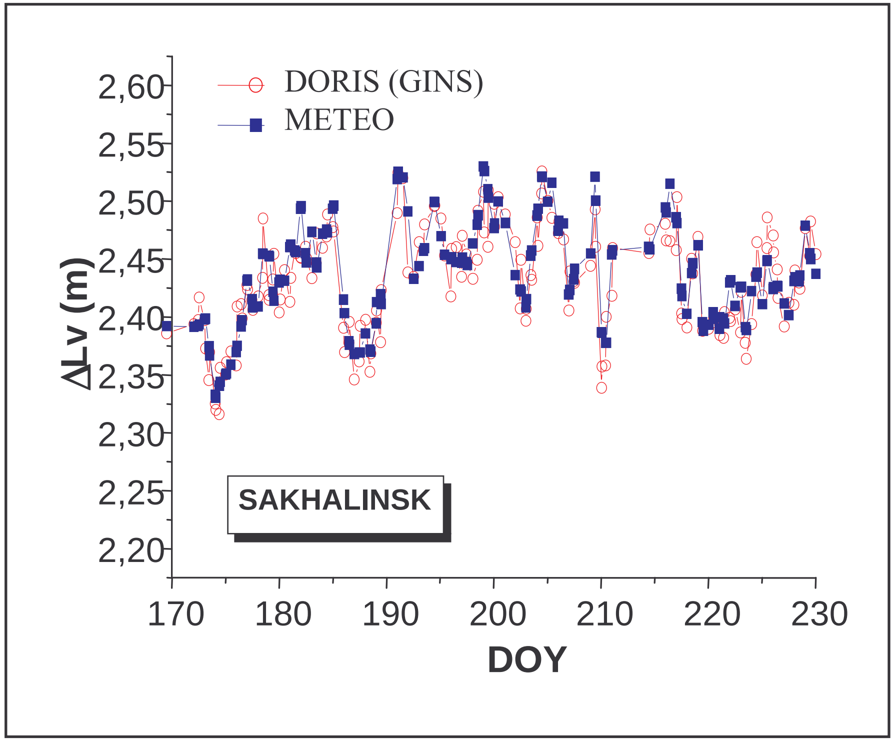


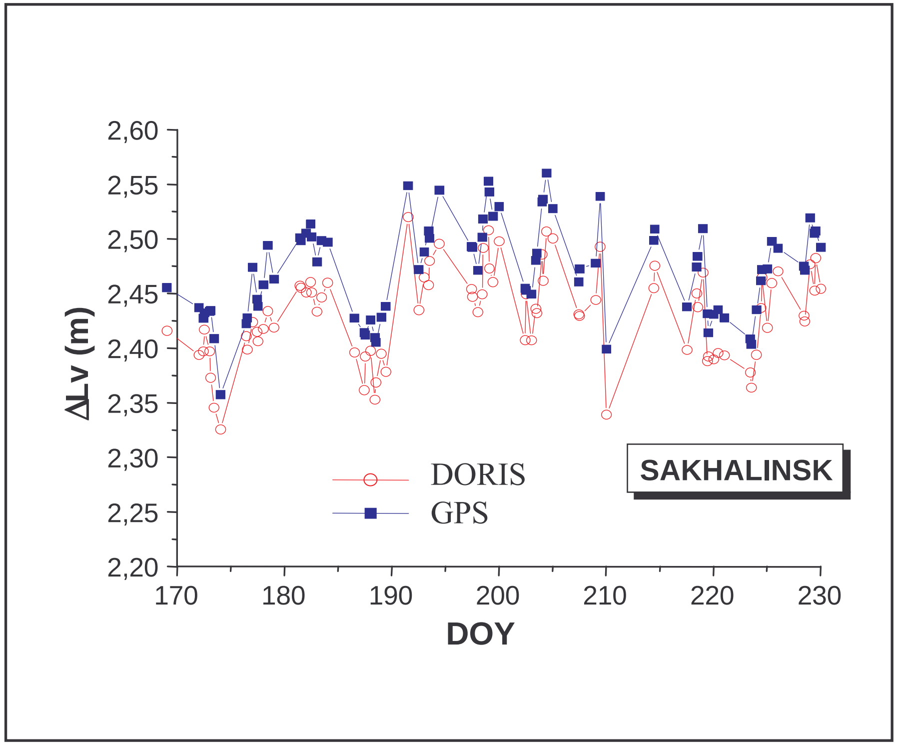
DORIS (GINS):	**offset = 2.34 m**	**stdev = 6.43 cm**
METEO:	**offset = 2.35 m**	**stdev = 6.42 cm**
GPS (IGS):	**offset = 2.37 m**	**stdev = 6.62 cm**

RMS DORIS-METEO: 1.95 cm
RMS DORIS-GPS: 3.87 cm

Comparison DORIS(GINS), GPS(IGS), METEO 2/2

Station: Sakhalinsk (altitude gaps < 10 m)
Year 2002
Model METEO: no correction applied
GPS values from IGS





Conclusions

Conclusion:
Validation of the tropospheric correction performed by METEO France
Validation of the bias estimated by GINS
Mapping function not adapted

Study to be completed by impact on the orbit computation and geodesic products

Comparison study (DORIS, GPS, METEO) to be completed

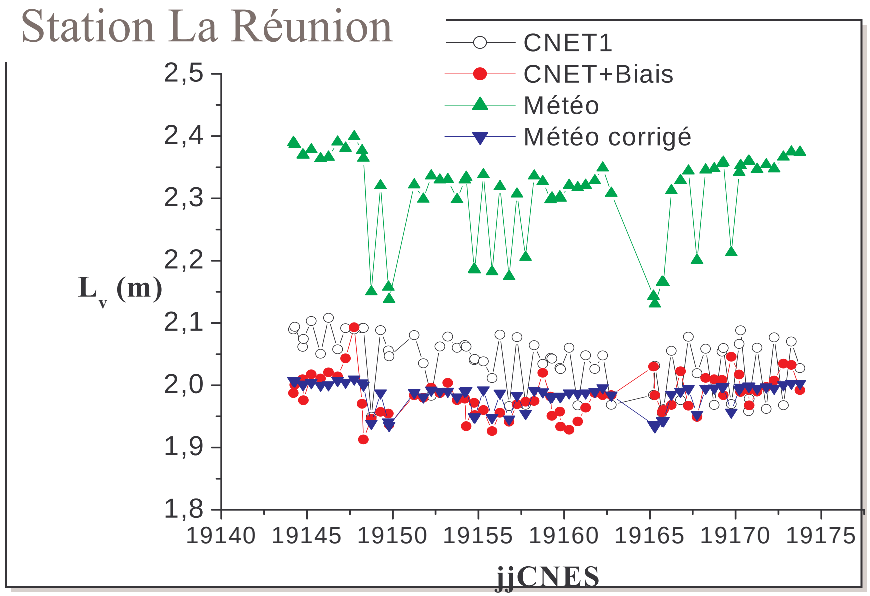
Perspectives:
Integrate the model (grids + coefficients set a,b and ε per station) in SSALTO
Computation of the vertical correction for the network by METEO France
Computation of the correction for each measurement (integration along the path) by METEO France

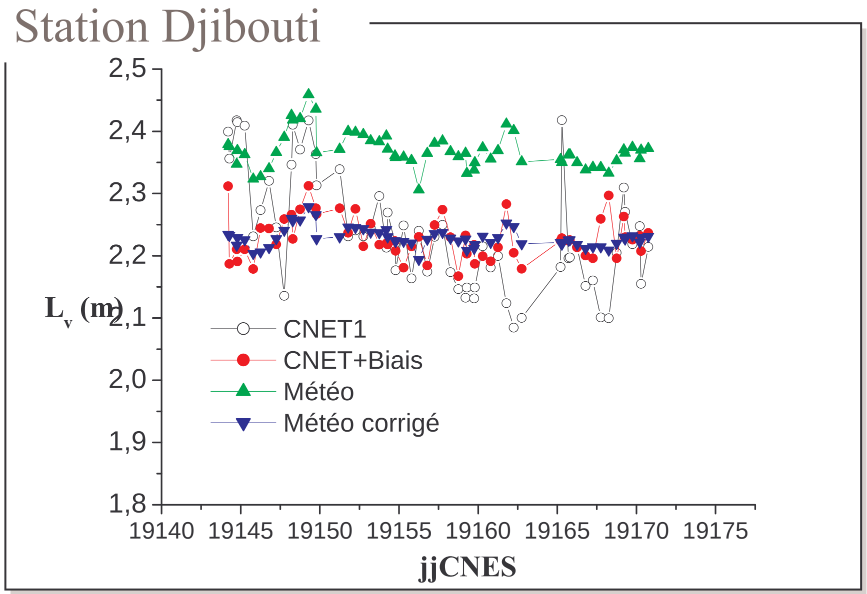
DORIS tropospheric corrections as a new product

Vertical correction : comparison of models

Allongements troposphériques

Mois de 06/2002





Interprétations

valeurs de référence:CNET1+Biais

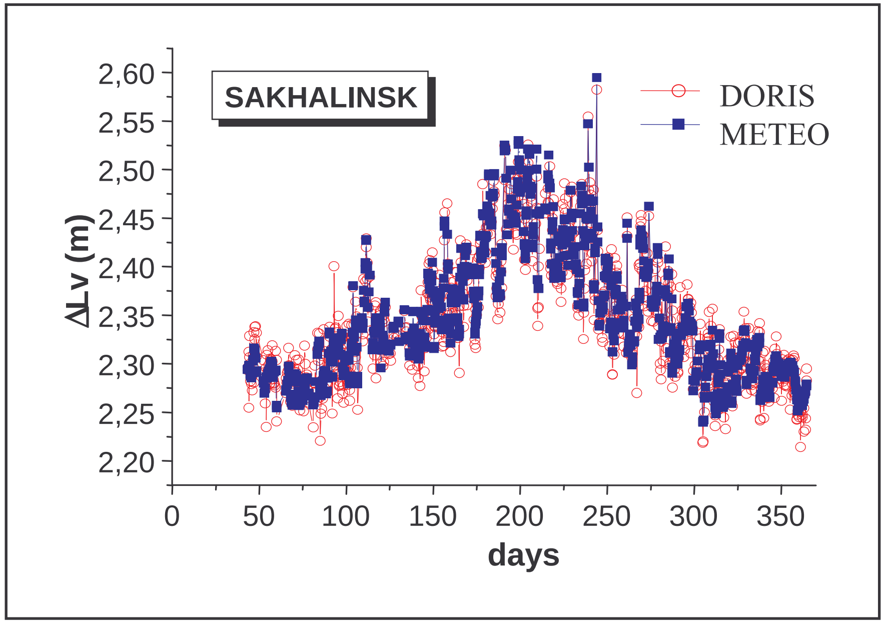
- profil Météo proche du profil de référence
- Météo corrigé rapproche quantitativement

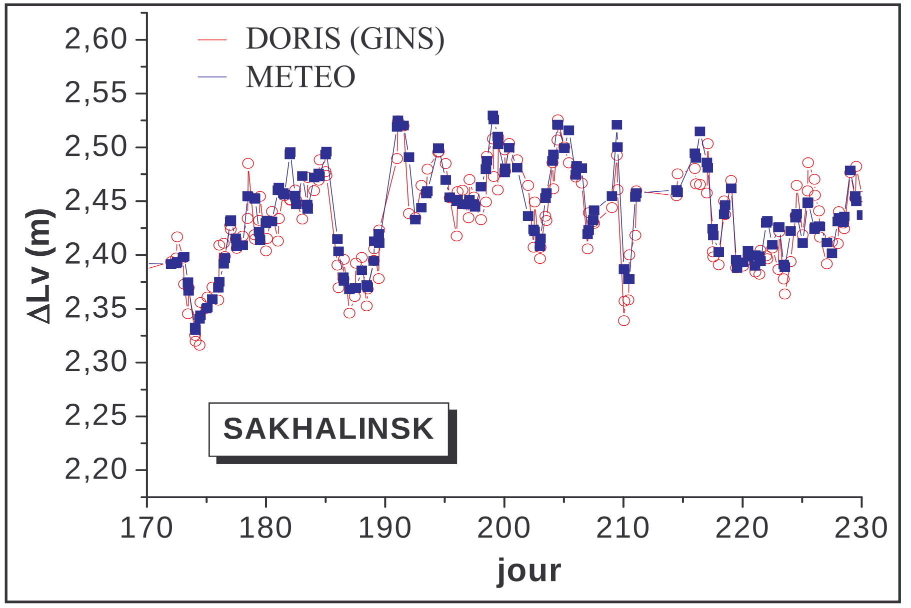
Station Djibouti:

- données au sol douteuses
- correction élevée

Vertical correction: DORIS vs METEO

Station: Sakhalinsk (altitude gaps < 10 m)
Year 2002
Model METEO: no correction applied
DORIS (GINS: CNET1+Estimated Bias)





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