Comparison of Retrieval Algorithms for the Wet Tropospheric Path Delay

OSTST Meeting, Boulder, October 2013

Introduction

Objective :

- Theorical evaluation of current regression algorithms for the retrieval of the wet tropospheric path delay (dh) :
  - How different are the operational algorithms ?
  - Can we improve those algorithms ?

Outline :

- The wet tropospheric correction
- Algorithms currently used in altimetry missions
- Comparison of two algorithms: log-linear vs neural network
- Correlation analysis of inputs
- Conclusion

The wet tropospheric path delay

- Corresponds to path delay in the radar return signal due to water vapor in the troposphere
- Ranges from 0 to 50 cm.
- Any error in the wet-tropospheric correction directly impacts the sea level determination
- Calculated from radiometer measurements with uncertainty of around 1-cm rms (Ruf et al. 1994)

The wet troposheric path delay retrieval

- Microwave radiometers measure brightness temperature (natural emission of sea surface and atmosphere)

- tb measured at a given frequency depends on the atmospheric profile and on sea surface conditions

- 3 tbs usually used around :
  - tb24GHz : highly sensitive to water vapor (wv)
  - tb37GHz : sensitive to clouds (wc)
  - tb18GHz : sensitive to the surface : temperature (ts) and roughness.

- Relationship between dh and tb is established through statistical regression

Two families of retrieval algorithms

NASA/CNES/NOAA/Eumetsat:

TOPEX/JASON1/JASON2

- RTM
- Radiosondes and Radiometers
- tb18.7,tb23.8,tb34
- Two-step log-linear regression

Keihm et al. 1995

ESA (+CNES/ISRO ALTIKA):

ERS1/ERS2/ENVISAT/SENTINEL3

- RTM
- ECMWF Fields
- wspd/sigKu,tb23.8,tb36.5
- Neural Network

Eymard et al. 1996/Obligis et al. 2006

Comparison of 2 Algorithms

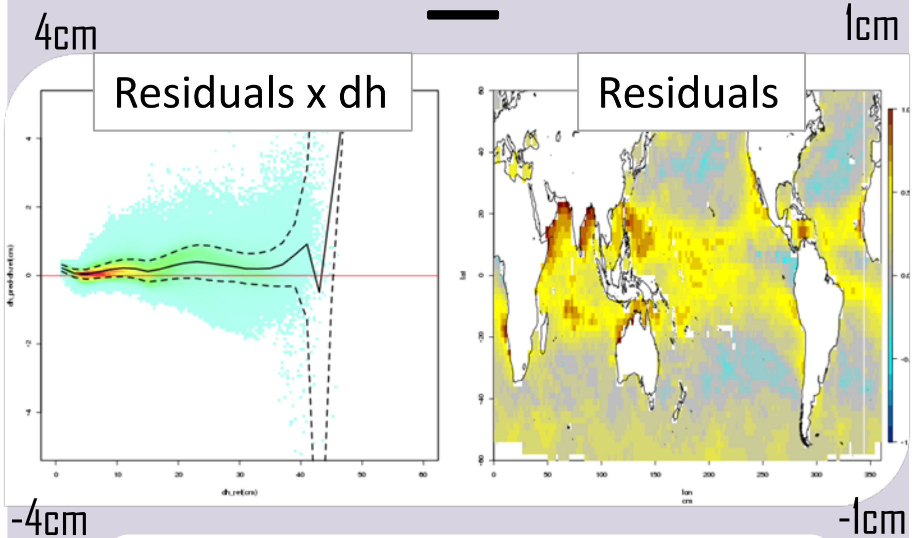
2012 ECMWF fields + UCL RTM :

20% for learning and 80% for testing

JMR_Reg	MWR_NN
Two-step log-linear regression	Neural Network
tb18.7 +tb23.8 +tb34	sigKu + tb23.8 + tb34

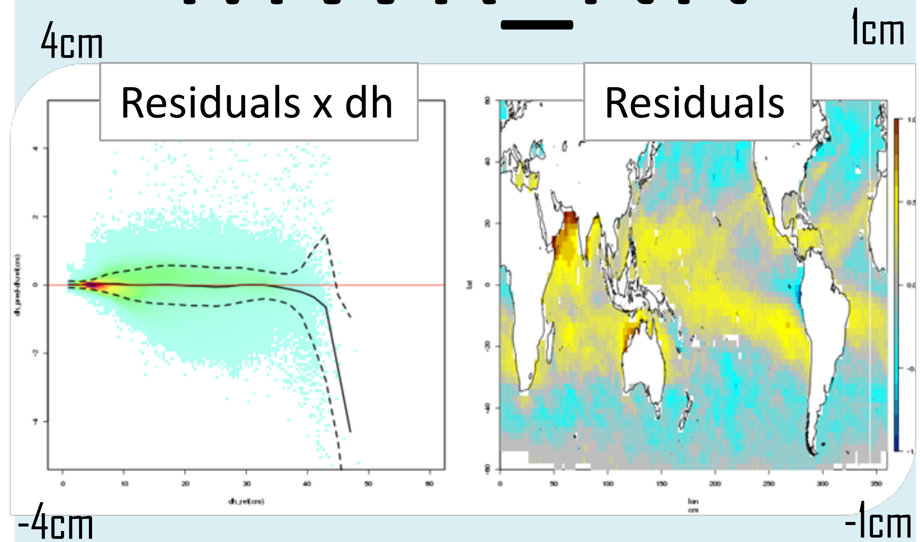
Results on the test database

JMR_REG



RMS = 4.34 mm

MWR_NN



RMS = 4.45 mm

A third Algorithm

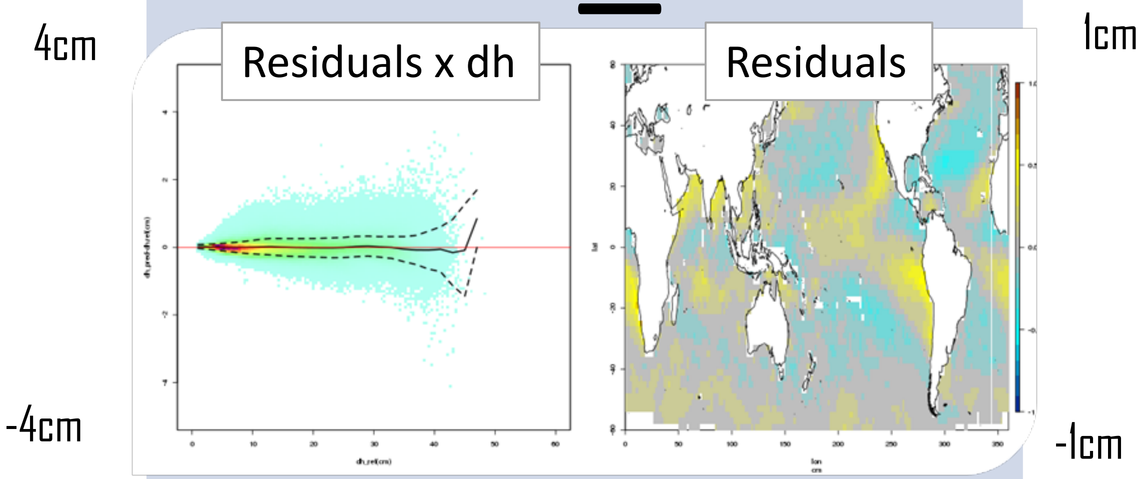
2012 ECMWF fields + UCL RTM :

20% for learning and 80% for testing

JMR_Reg	JMR_NN	MWR_NN
Two-step log-linear regression	Neural Network	Neural Network
tb18.7 +tb23.8 +tb34	tb18.7 + tb23.8 + tb34	sigKu + tb23.8 + tb34

Results on the test database

JMR_NN

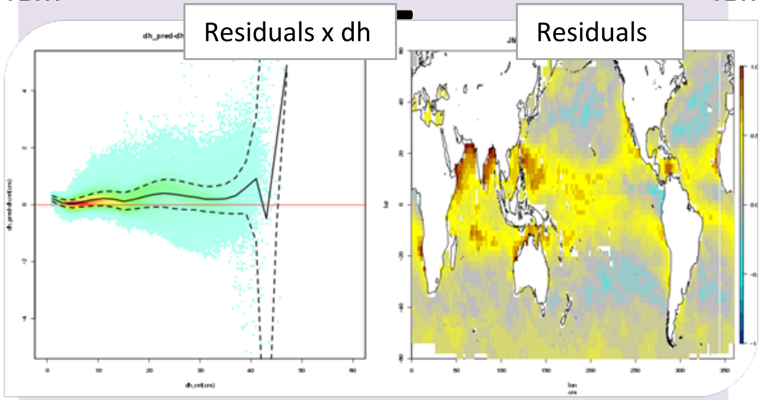


RMS = 2.46 mm

Results on the test database

JMR_REG

4cm 1cm



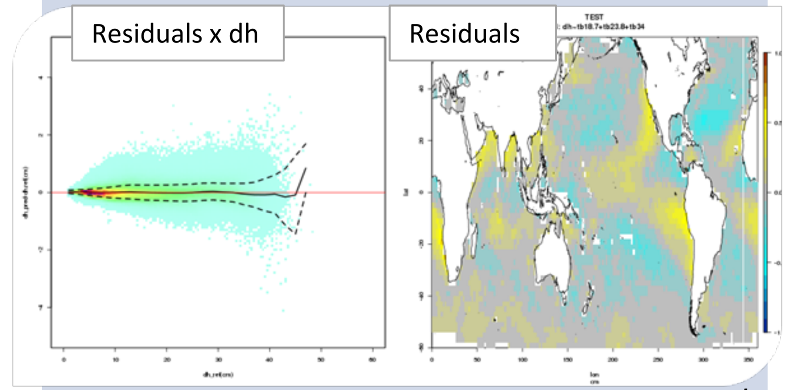
-4cm -1cm

RMS = 4.34 mm

VS

JMR_NN

4cm 1cm



-4cm -1cm

RMS = 2.46 mm

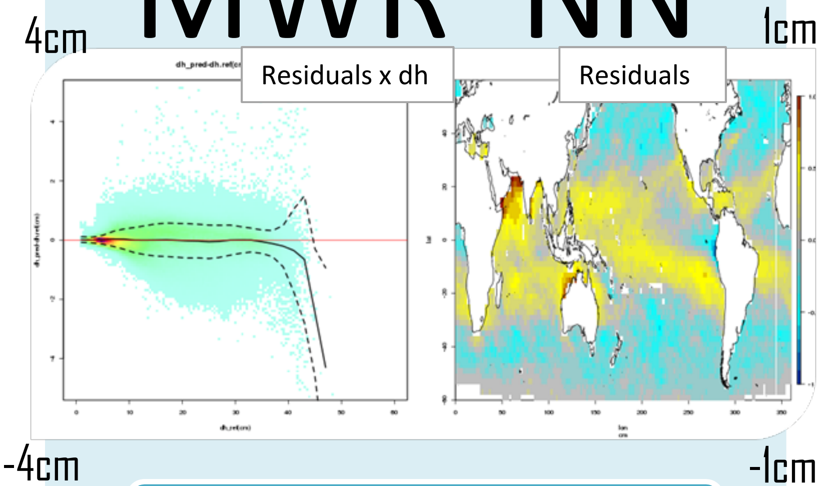
TWO STEP LOG-LINEAR REGRESSION VS NEURAL NETWORK :

- dh-dependent bias for JMR_REG

➢ The two step log-linear regression lacks flexibility to correctly adjust the data compared to neural networks

Results on the test database

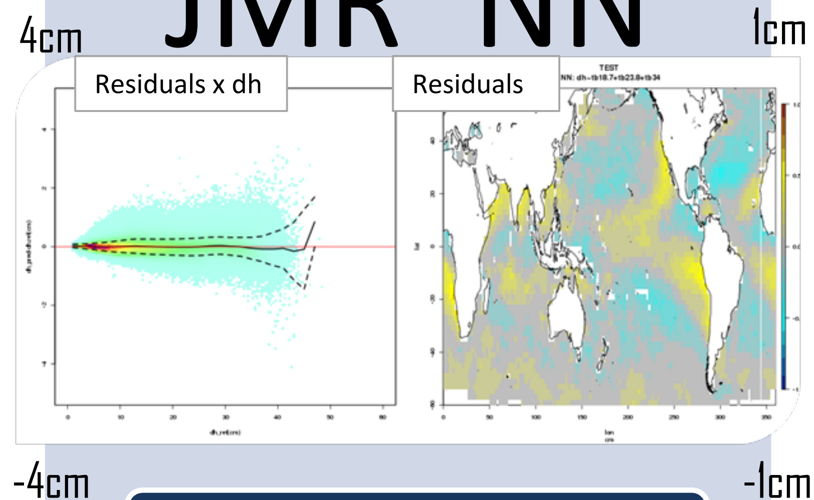
MWR NN



RMS = 4.45 mm

VS

JMR NN



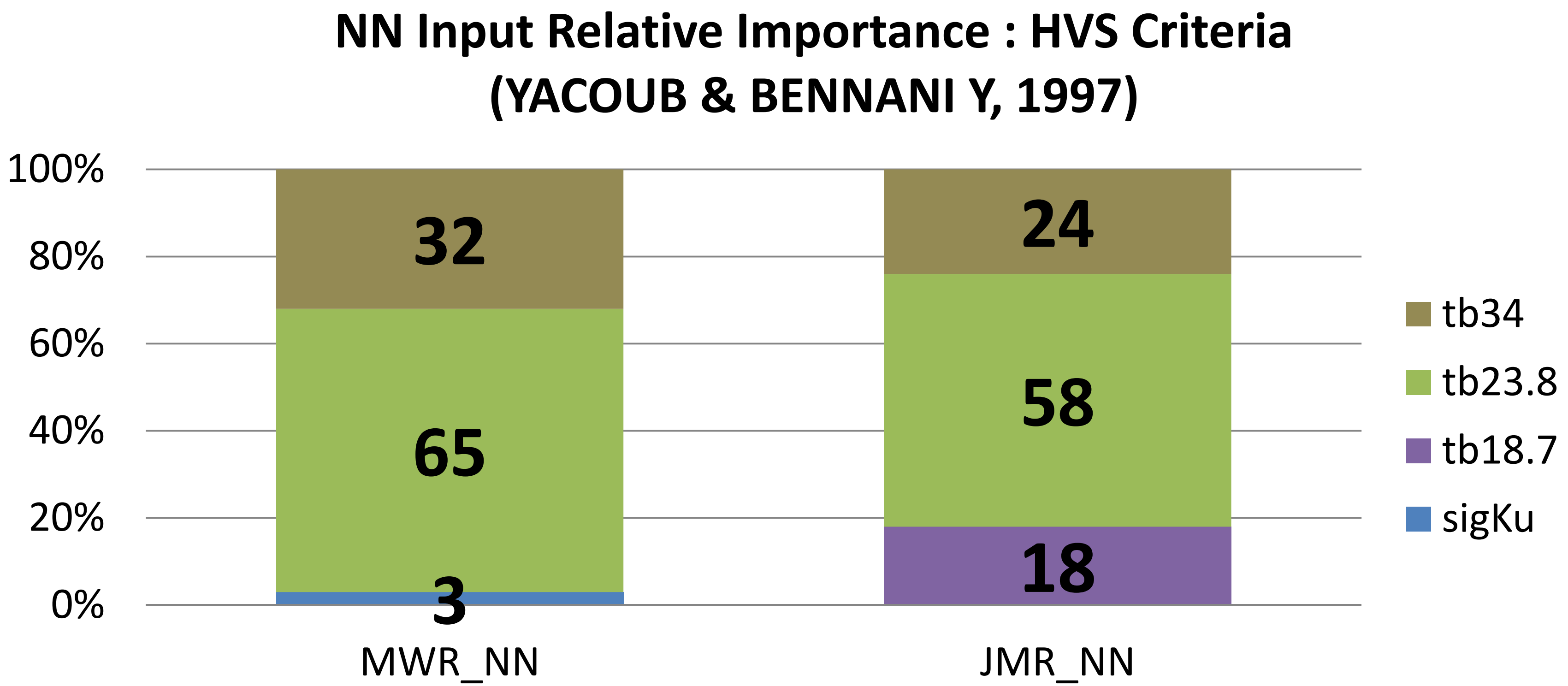
RMS = 2.46 mm

SIGKU VS TB18.7:

- sigKu and tb18.7 do not bring equivalent information on the surface

➢ Use of tb18.7 gives much better performances

Importance of inputs

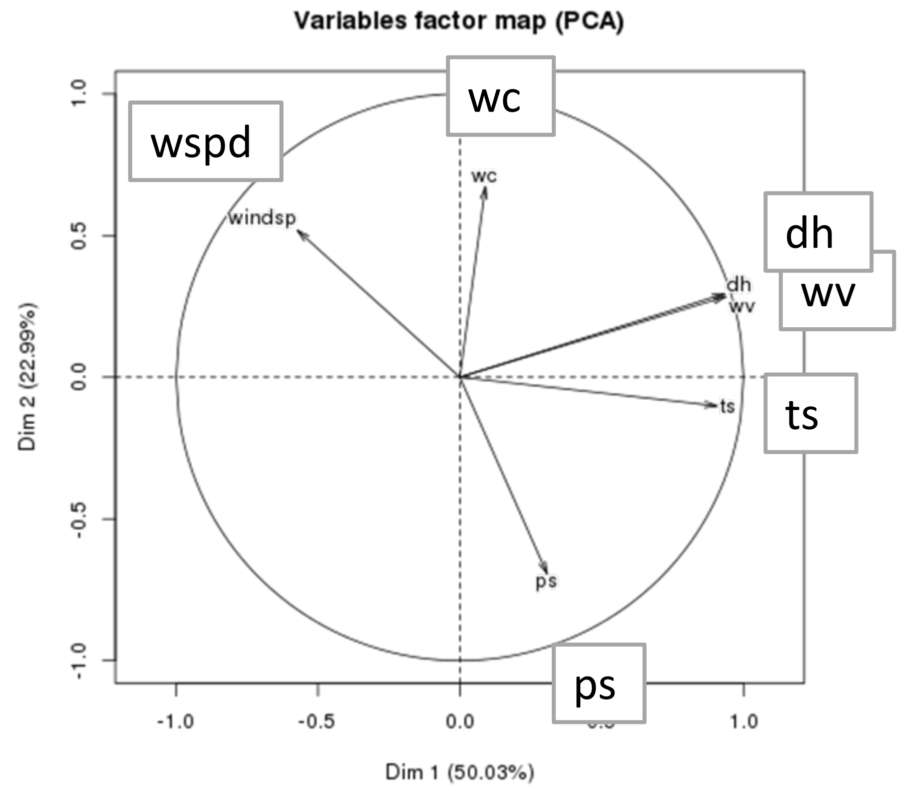


- sigKu is of little importance, compared to tb23.8 and tb34 for the retrieval of dh

- tb18.7 relative importance is much higher than sigKu relative importance

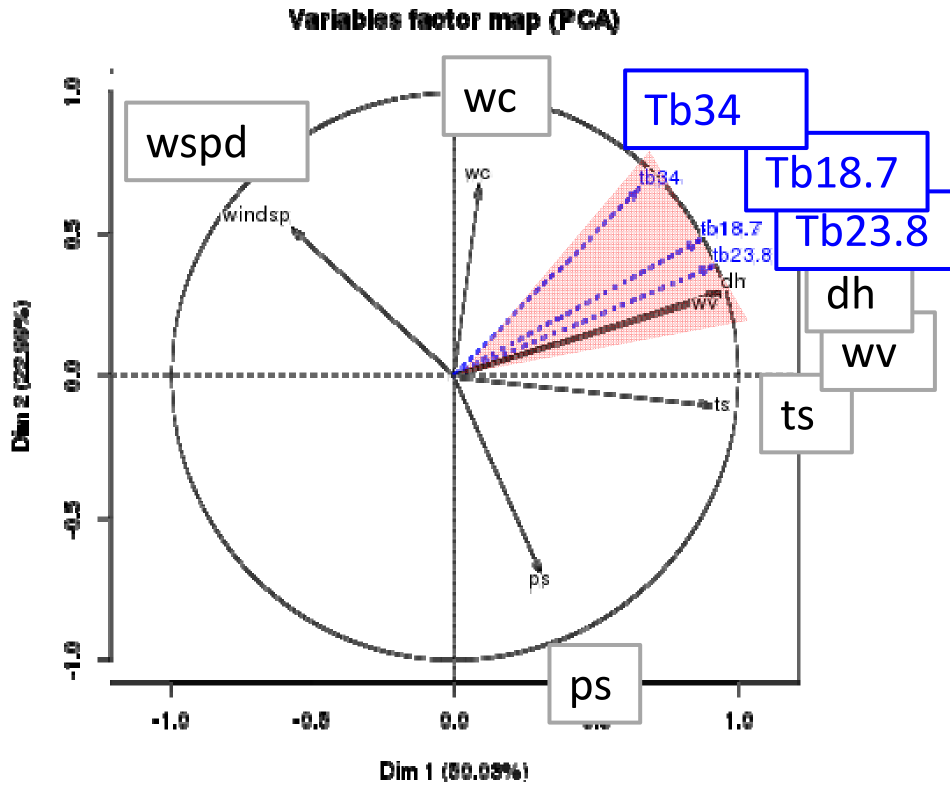
Principal component analysis

- Applied to ts, windsp, wc, wv and dh.
- Best summary of correlation between variables
- Each variable is represented by a vector
- Correlation between two variables is given by cosines of the angle between the two vectors



PCA : Brightness Temperatures

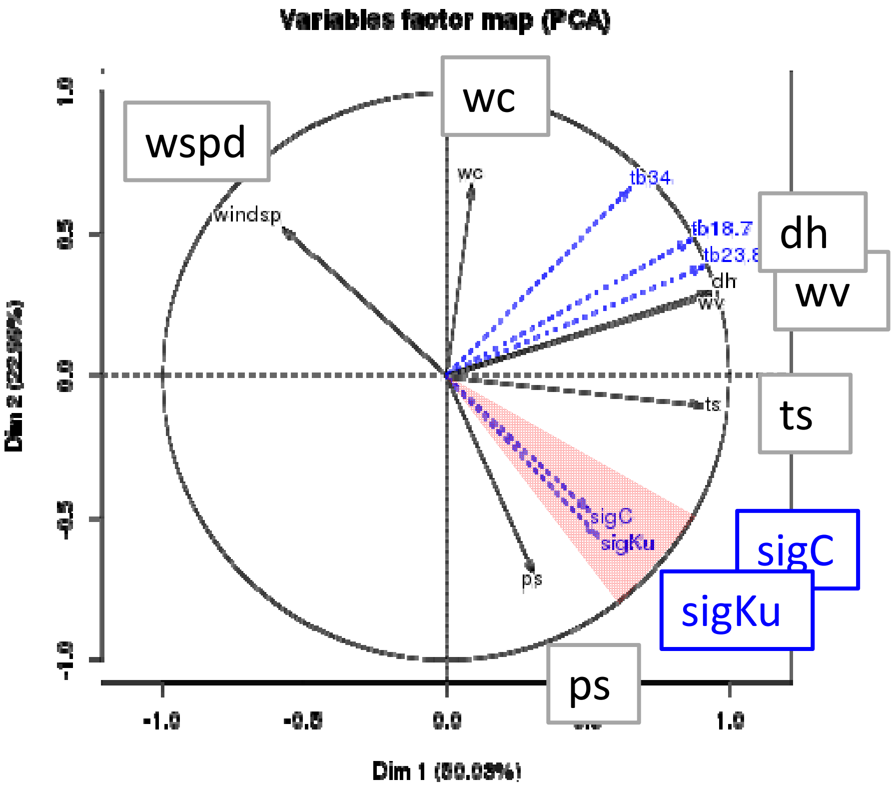
- tb18.7, tb23.8 are highly correlated to dh and wv (*cor >0.90*)
- tb23.8 is the most correlated to dh, wv and ts
- tb34 is the most affected by wc



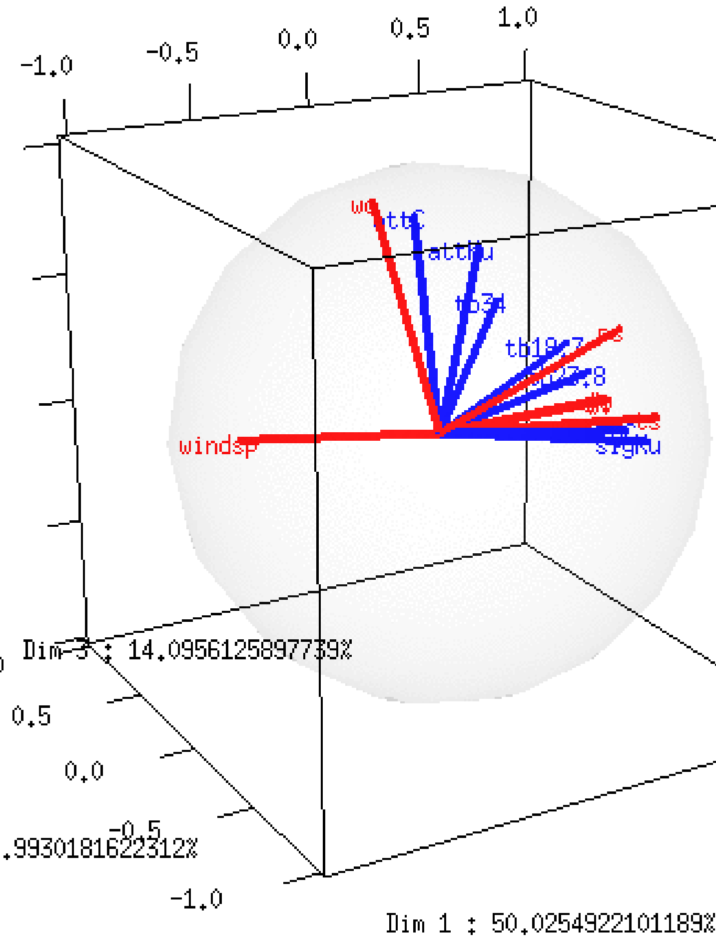
PCA : Backscattering coefficients

- sigC and SiKu are highly correlated with windsp : *cor(sigKu,windsp)= -0.99, cor(sigC,windsp)= -0.93*

- Little correlations are found with dh,wv and tbs (*cor < 0.30*)



PCA : Conclusions



- sigKu is closer to windsp and lacks information about ts and dh
- tb18.7 is closer to ts and dh

➢ MWR_NN lacks information about ts ?

Last Comparisons

MWR_NN

- sigKu+tb23.8+tb37
- **RMS = 4.45 mm**

JMR_NN

- tb18.7+tb23.8+tb37
- **RMS = 2.46 mm**

MWR_NN+**ts**

- **ts**+sigKu+tb23.8+tb37
- **RMS = 2.21 mm**

Conclusions

- Only an assessment of the regression quality on a given simulated database and not of the entire radiometric error budget (regression quality, database representativeness, RTM quality, instrumental noise, pixel heterogeneity, antenna pattern…)

BUT SUCH ANALYSIS HELPS :

- Finding an appropriate method of regression :
  - **NN are more flexible than log-linear regressions**. NN are black-boxes but tools are being developed to make them more transparent.
- Identifying useful sources of information to improve the retrieval :
  - **sigKu** lacks correlation with dh and ts but **provide useful information on windsp** with respect to tb18.7
  - tb18.7 is more important than sigKu in the retrieval of dh : tb18.7 provides additional information on dh and ts **=> 3-channel radiometers should be preferred**
  - **Lack of 18.7 GHz channel can be compensated by ts for equivalent results**. Reynolds SST could probably be used for near real time dh products
- All these results should be assessed on real measurements using usual metrics (SSH variance at crossovers ,radiosonde comparisons…)