Temperature, humidity and surface emissivity retrieval experiments with IASI simulated data

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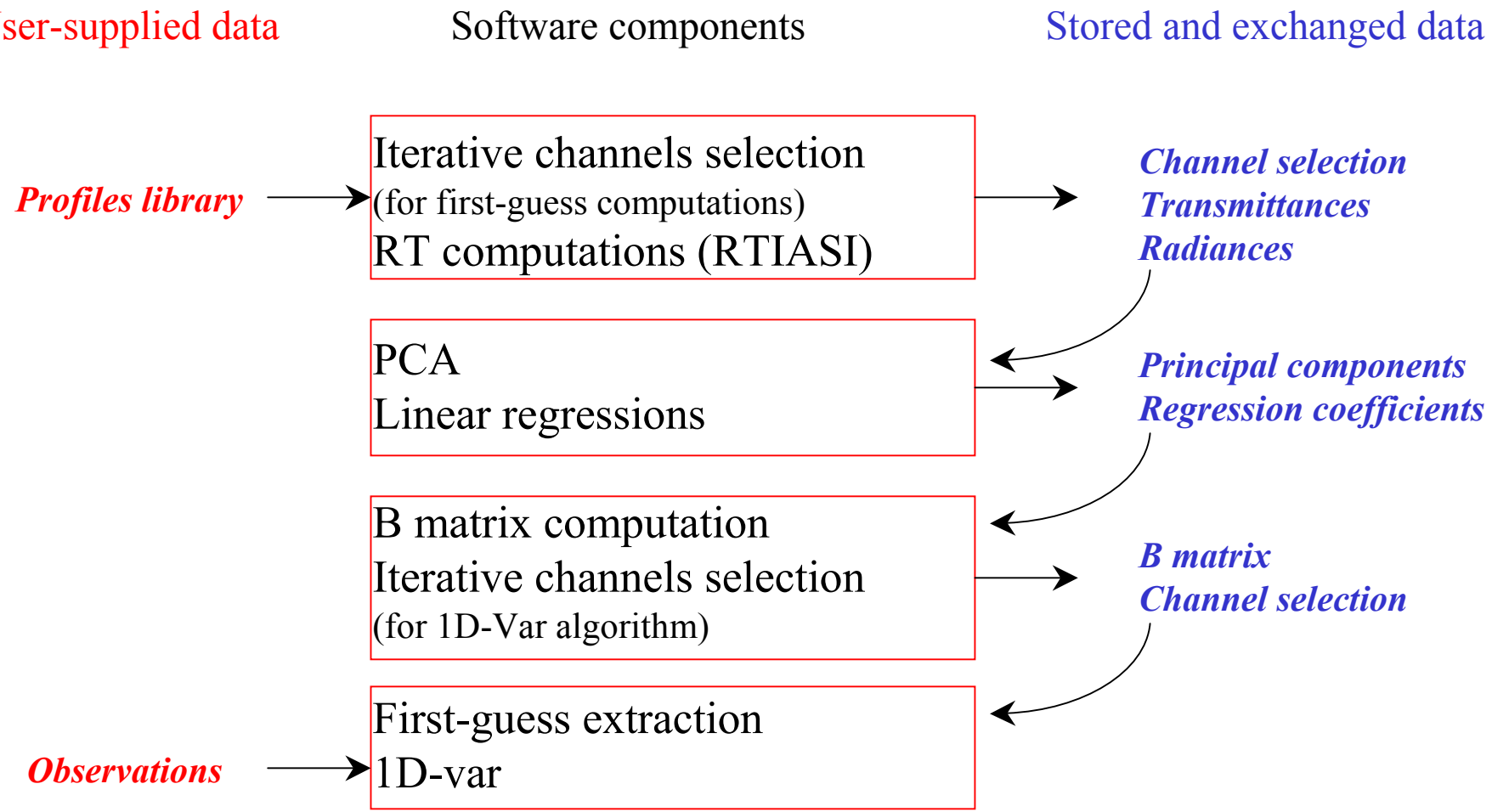
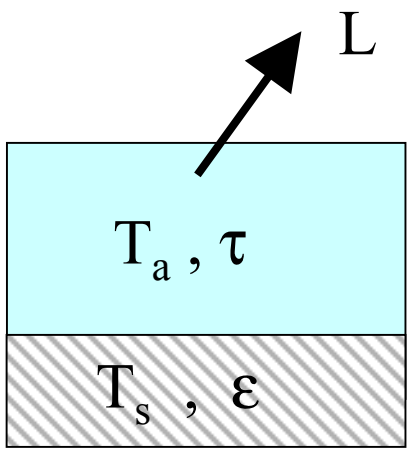
METEO FRANCE


User-supplied data
Software components
Stored and exchanged data
Profiles library
Iterative channels selection
(for first-guess computations)
RT computations (RTIASI)
Channel selection
Transmittances
Radiances
PCA
Linear regressions
Principal components
Regression coefficients
B matrix computation
Iterative channels selection
(for 1D-Var algorithm)
B matrix
Channel selection
Observations
First-guess extraction
1D-var

$$Water\text{-}vapor\ jacobian \propto \frac{\partial L}{\partial \tau} \approx \varepsilon B(T_s) - B(T_a)$$

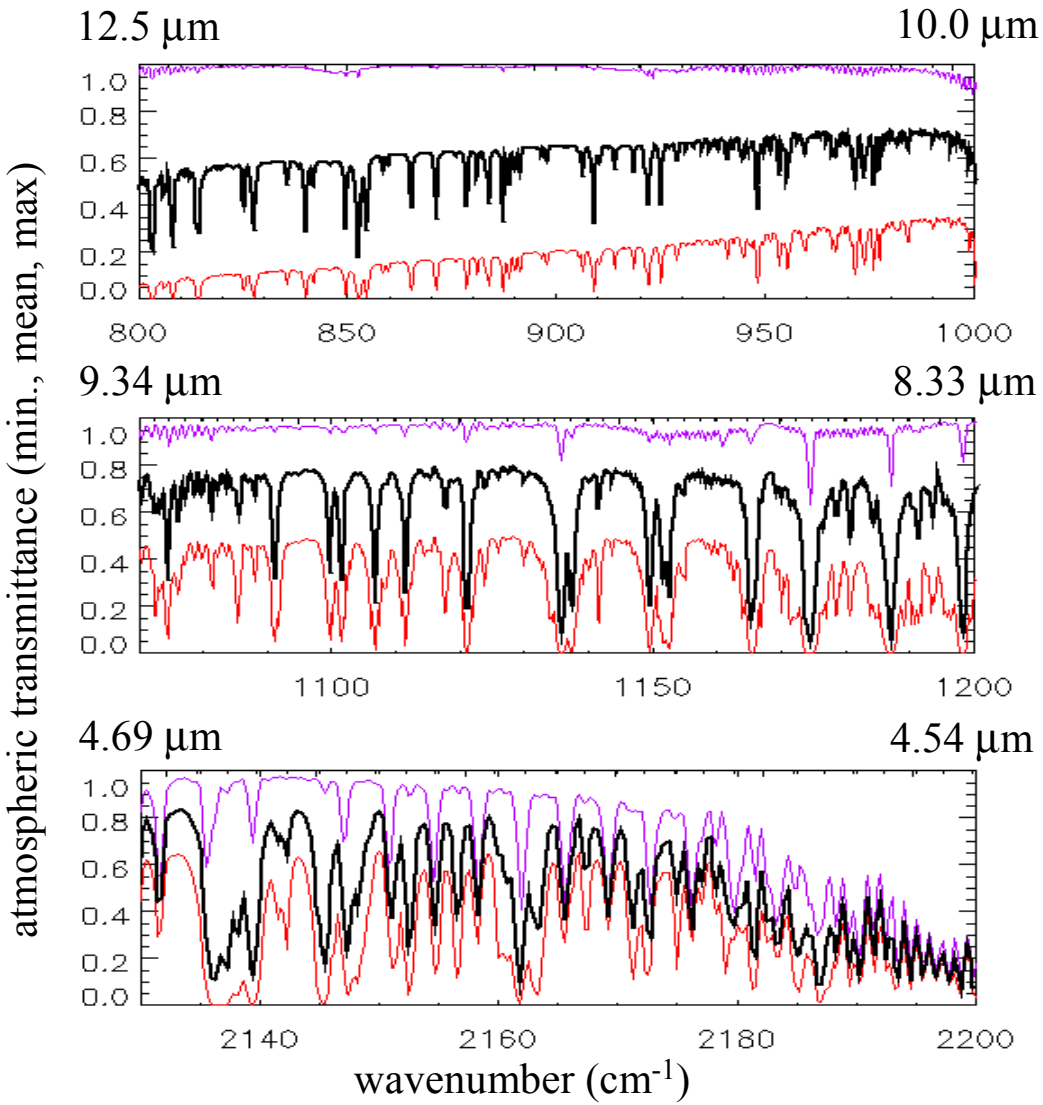


Nearly unit emissivity (>0.95) and $T_s \approx T_a$ ➡ No sensitivity to surface moisture

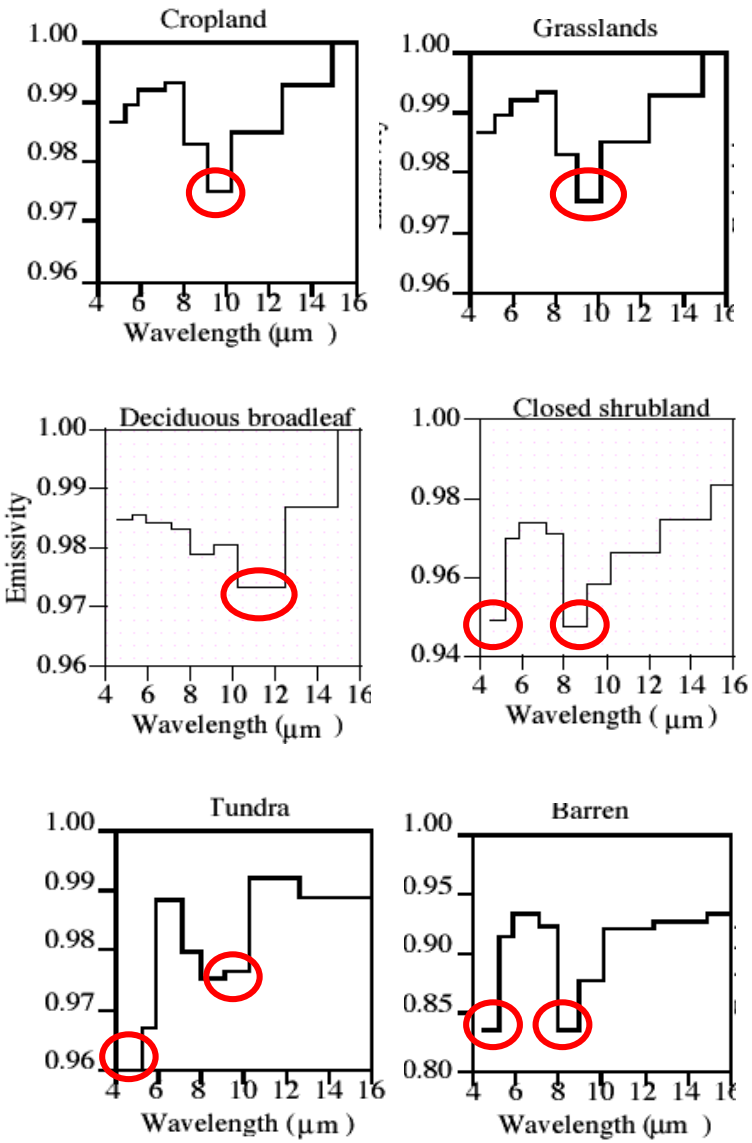
Lower, but poorly estimated emissivity ➡ Error on water-vapor jacobian

- Making use of realistic emissivity in forward calculations (surface emissivity model)
- Selecting channels sensitive to low-level water vapor and located in « low » emissivity spectral range
- Introducing emissivity parameters as control variables of the 1D-Var.

- weak water-vapor absorption
- no other significantly absorbing gas
- possibly low surface emissivity



Land emissivity models (Wilber et al., NASA technical report, 1999)



Iterative channels selection (C. Rodgers, 1996)

Profile+surface variables

Background error covariance

Analysis error covariance

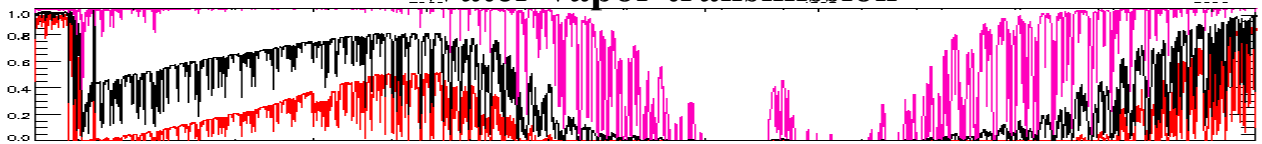
Current channel selection

Loop over selectable channels

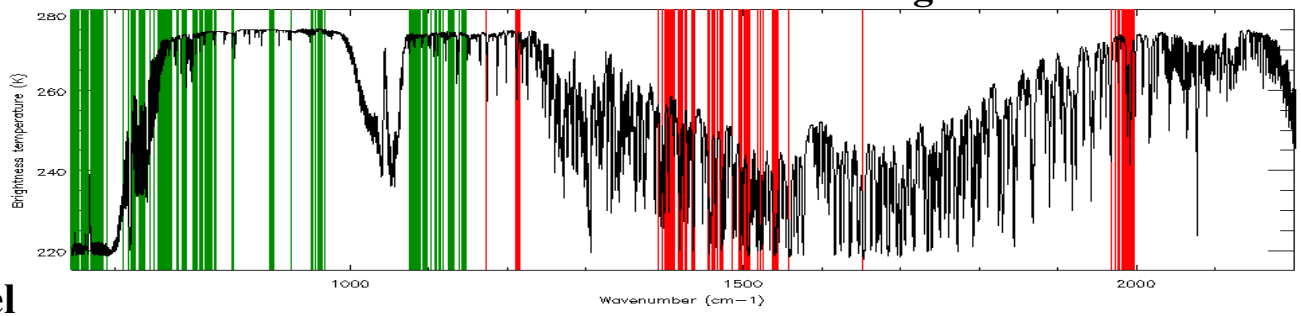
1D-Var

New selected channel
best information supply

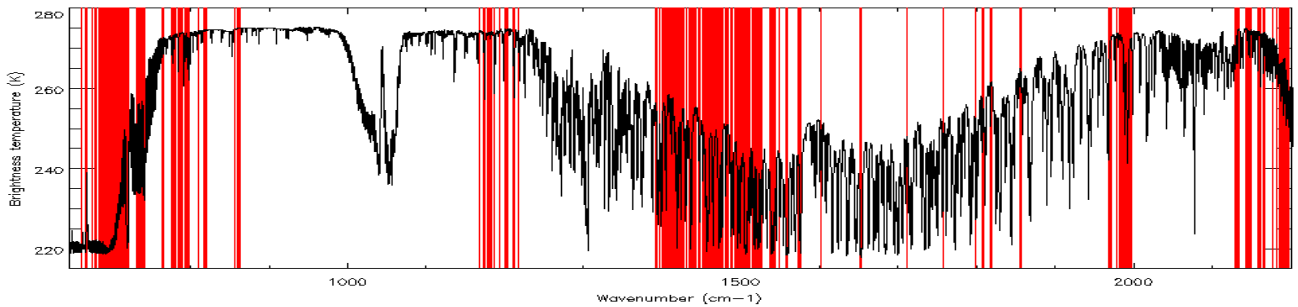
Water-vapor transmission



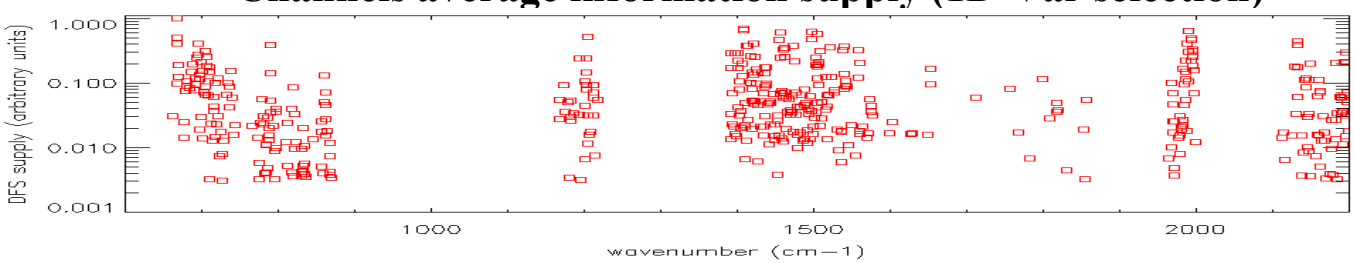
300 channels selected for linear regressions



300 channels selected for 1D-Var retrievals



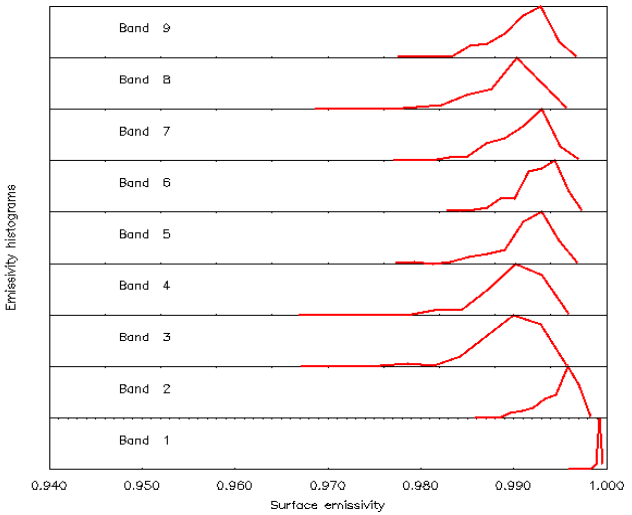
Channels average information supply (1D-Var selection)



Retrieval experiments with low spectral resolution emissivity models

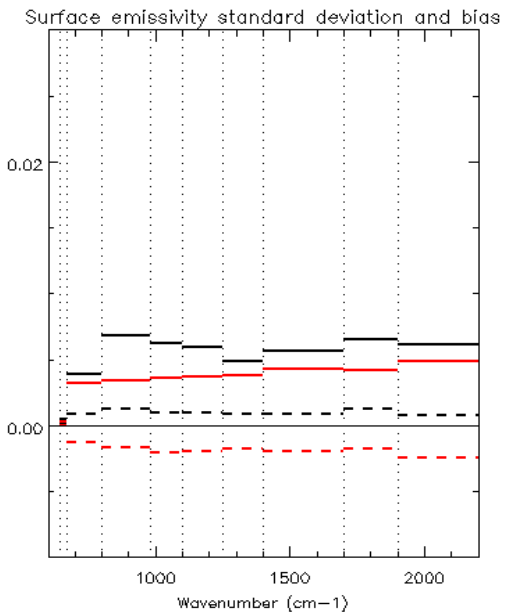
- 9 spectral bands, 18 surface types (following Wilber et al.)
- Emissivity standard deviation in band i proportional to $(1-\varepsilon_i)$
- Constant 0.8 correlations between bands
- Emissivity control variables: $-\ln(1-\varepsilon_i)$, with normal distributions

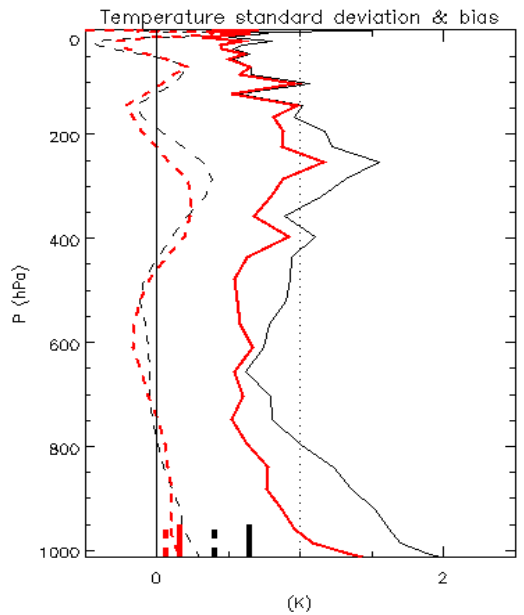
emissivity distributions

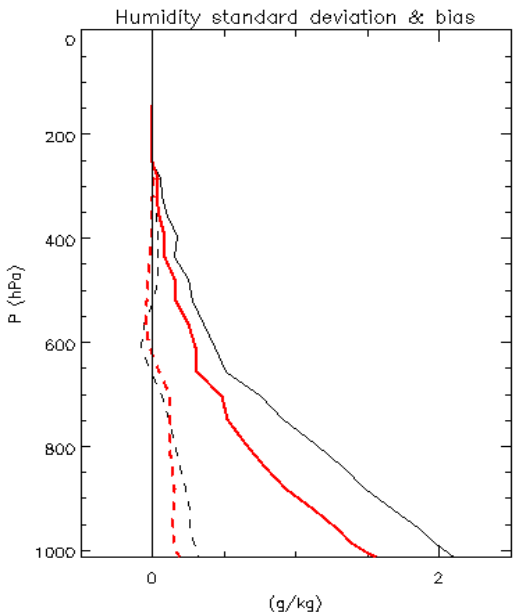


True profiles: 153 situations from a 10X10 sampling of 18/08/2001 00H Arpege analysis (100°W-65°E, 0°-80°N).
Profiles library: sampled 00H analyses from the 10 previous days

Type 2: « evergreen broadleaf forest »

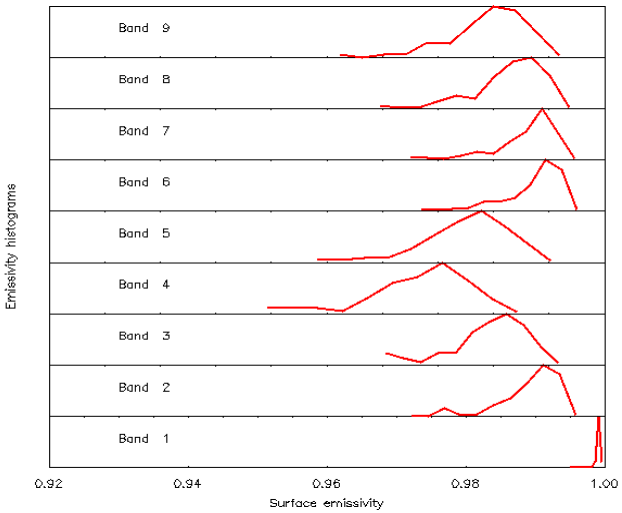


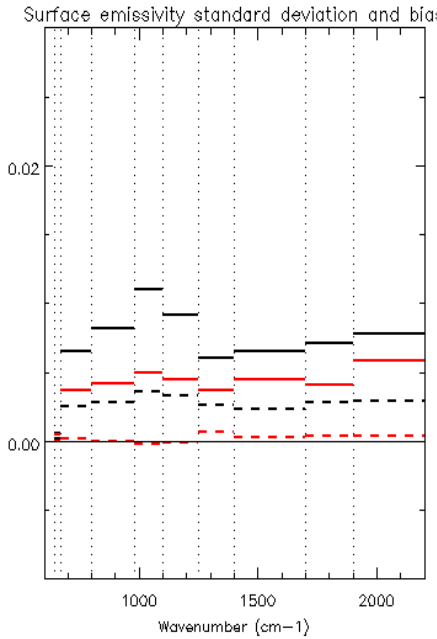


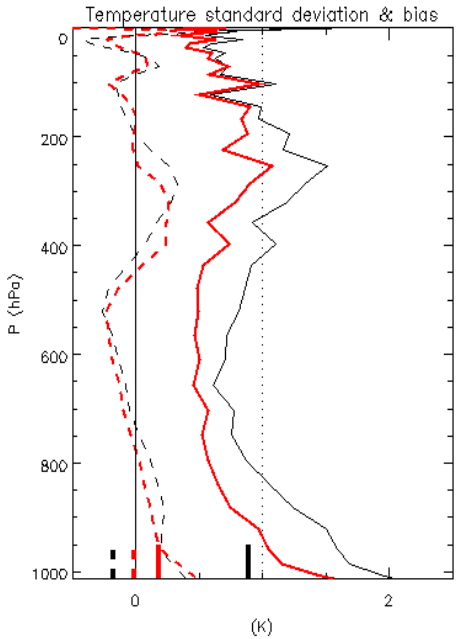


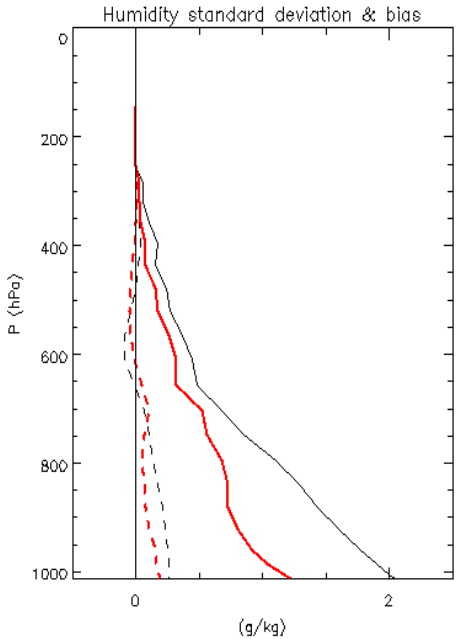
Standard deviation
first guess
retrieval
Bias
first guess
retrieval

Type 10: « grasslands »

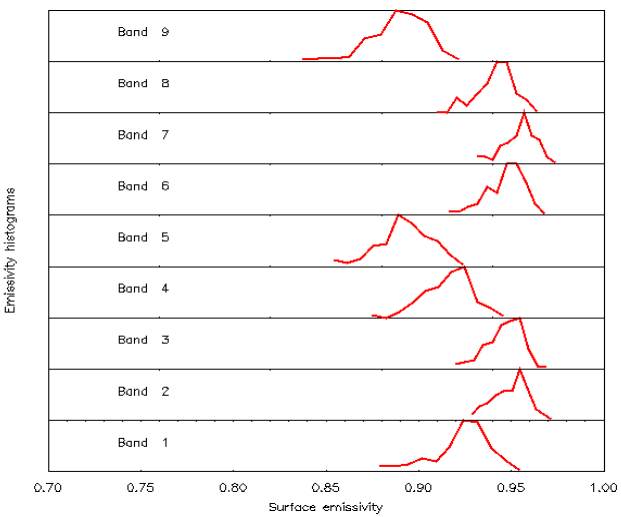


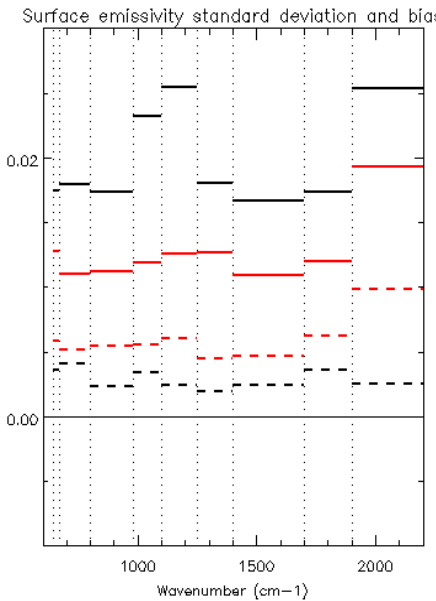


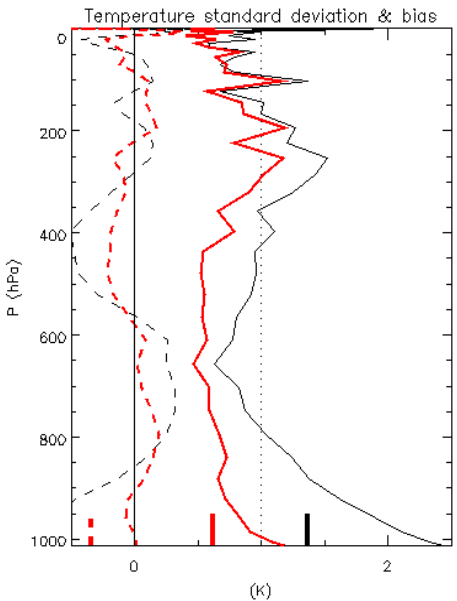


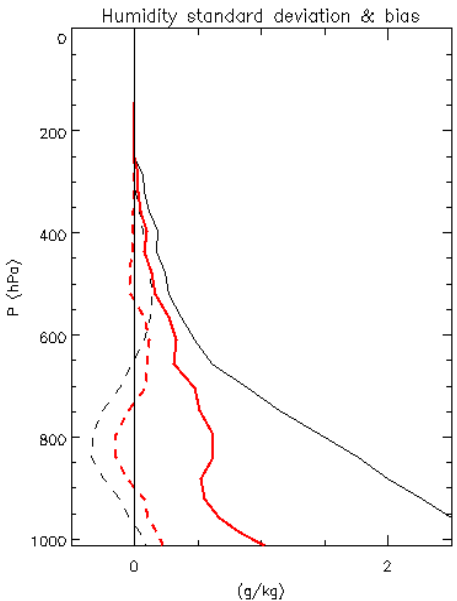


Type 16: « bare soil »





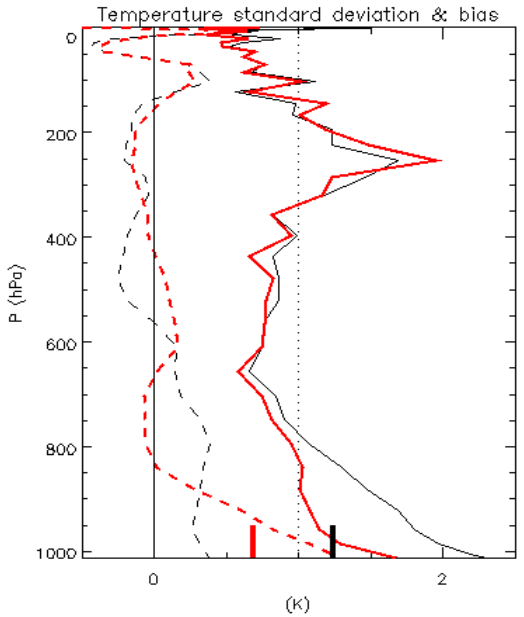


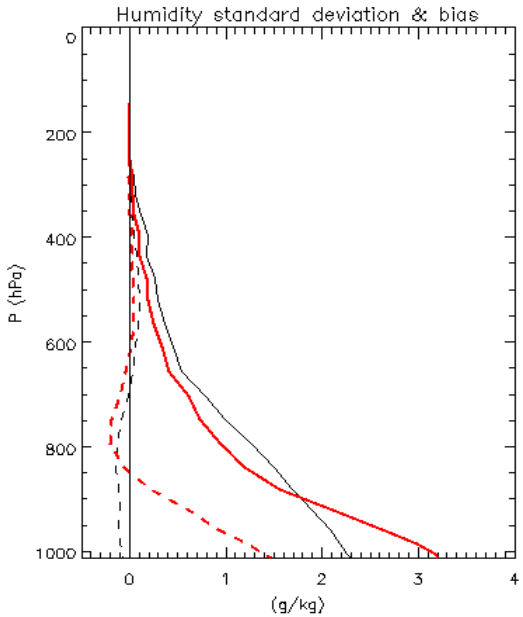


Illustrating emissivity retrieval benefit: a surface misclassifiaction case

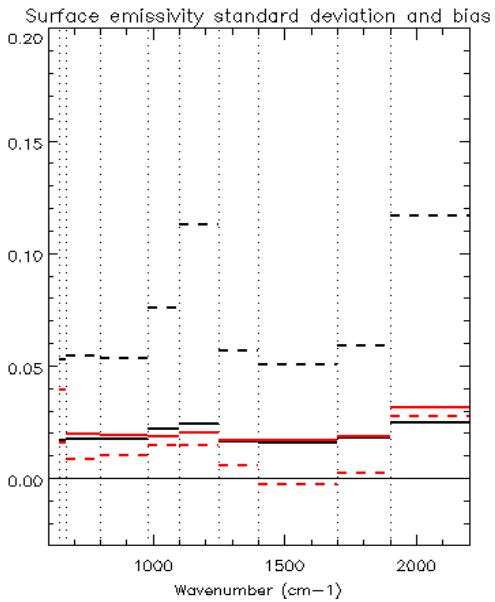
Real surface type : 7, « open shrublands »
First-guess surface type : 10, « grasslands »

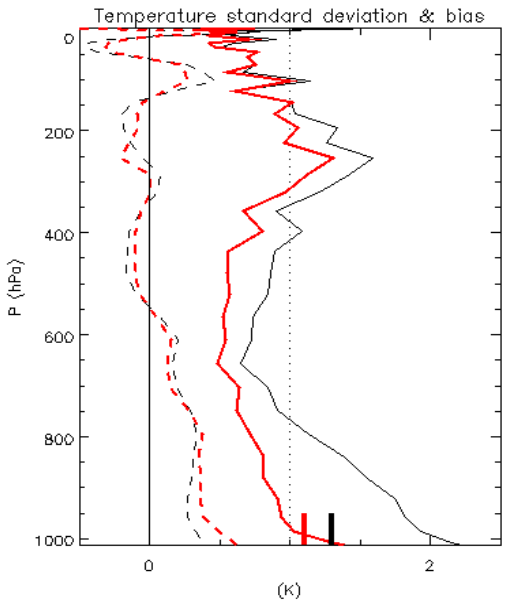
Without emissivity retrieval

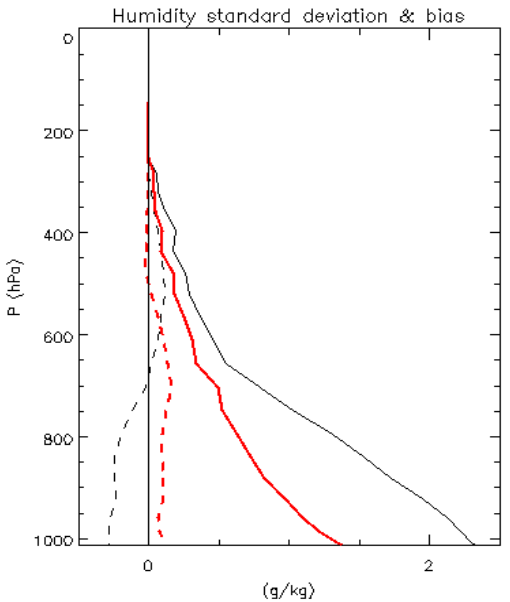




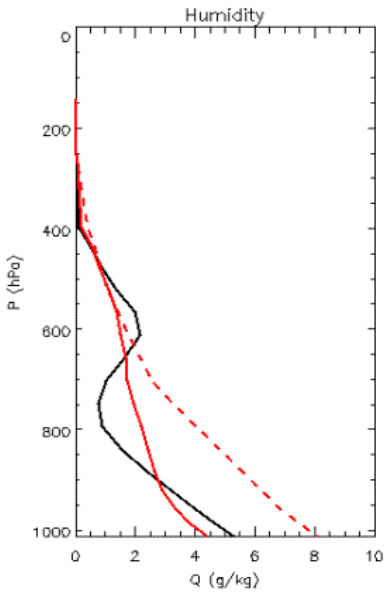
With emissivity retrieval



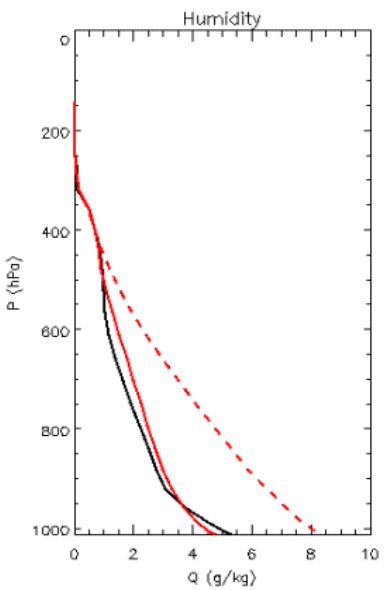




Real profile retrieval

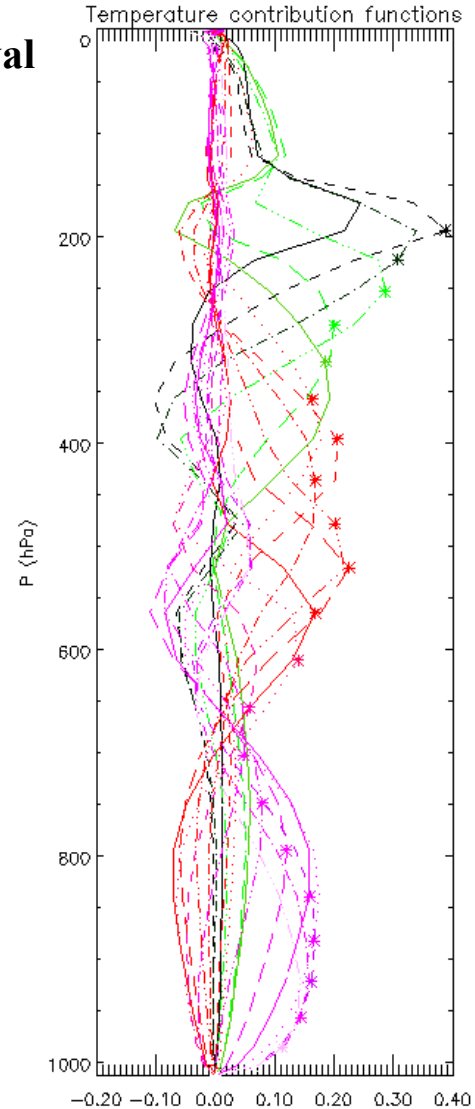


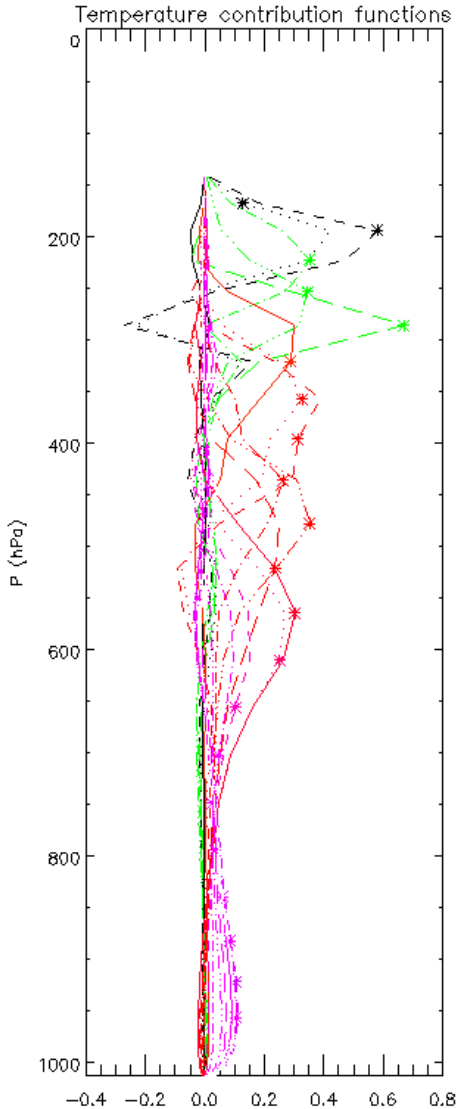
Smoothed profile retrieval



Temperature and water vapor contribution functions

$$\hat{X}^i - X_g^i = \sum_j C_{i,j}\left(X^j - X_g^j\right)$$



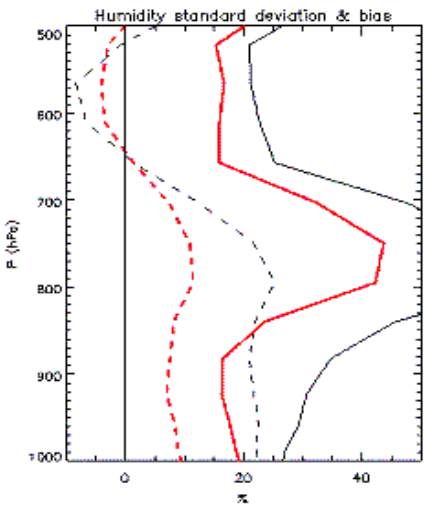


Real profiles

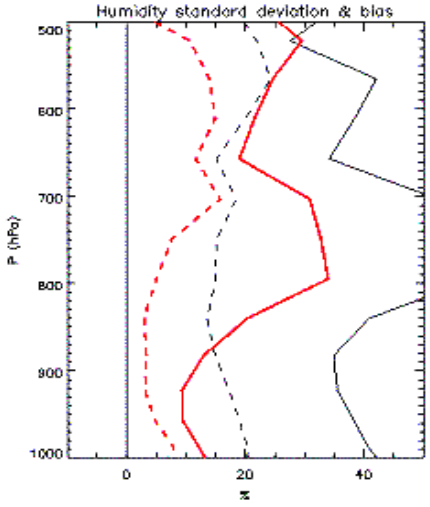
Smoothed profiles

IWC<2. g/cm²

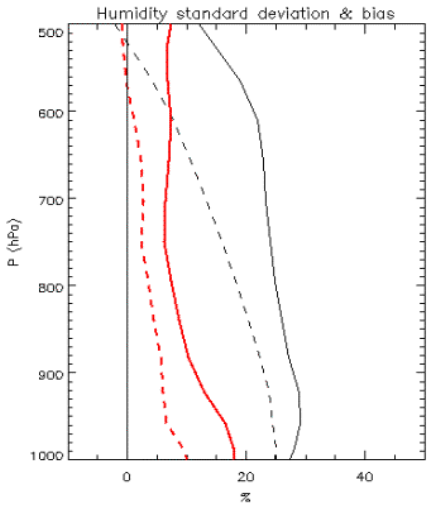
Type 2



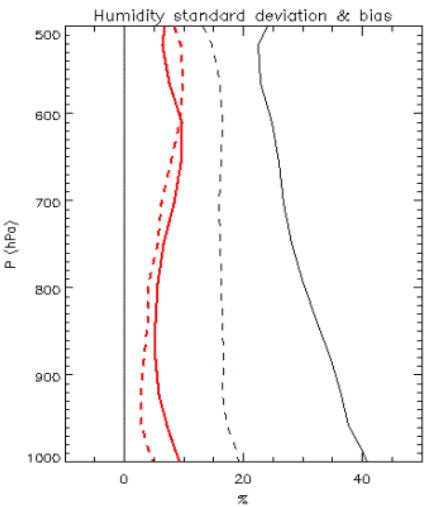
Type 16



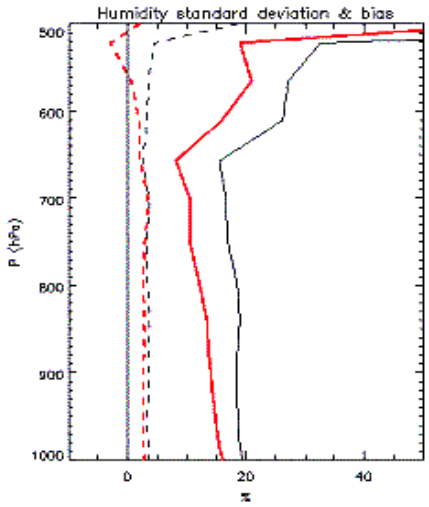
Type 2

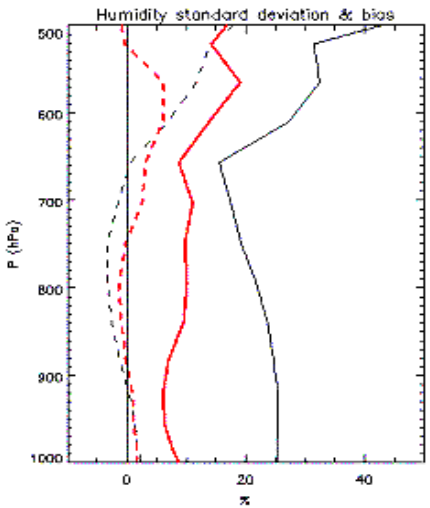


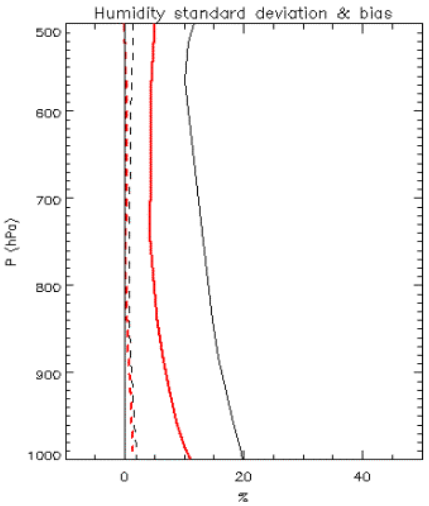
Type 16

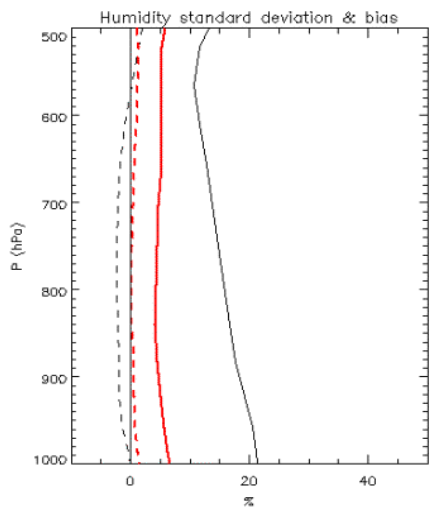


IWC>2. g/cm²

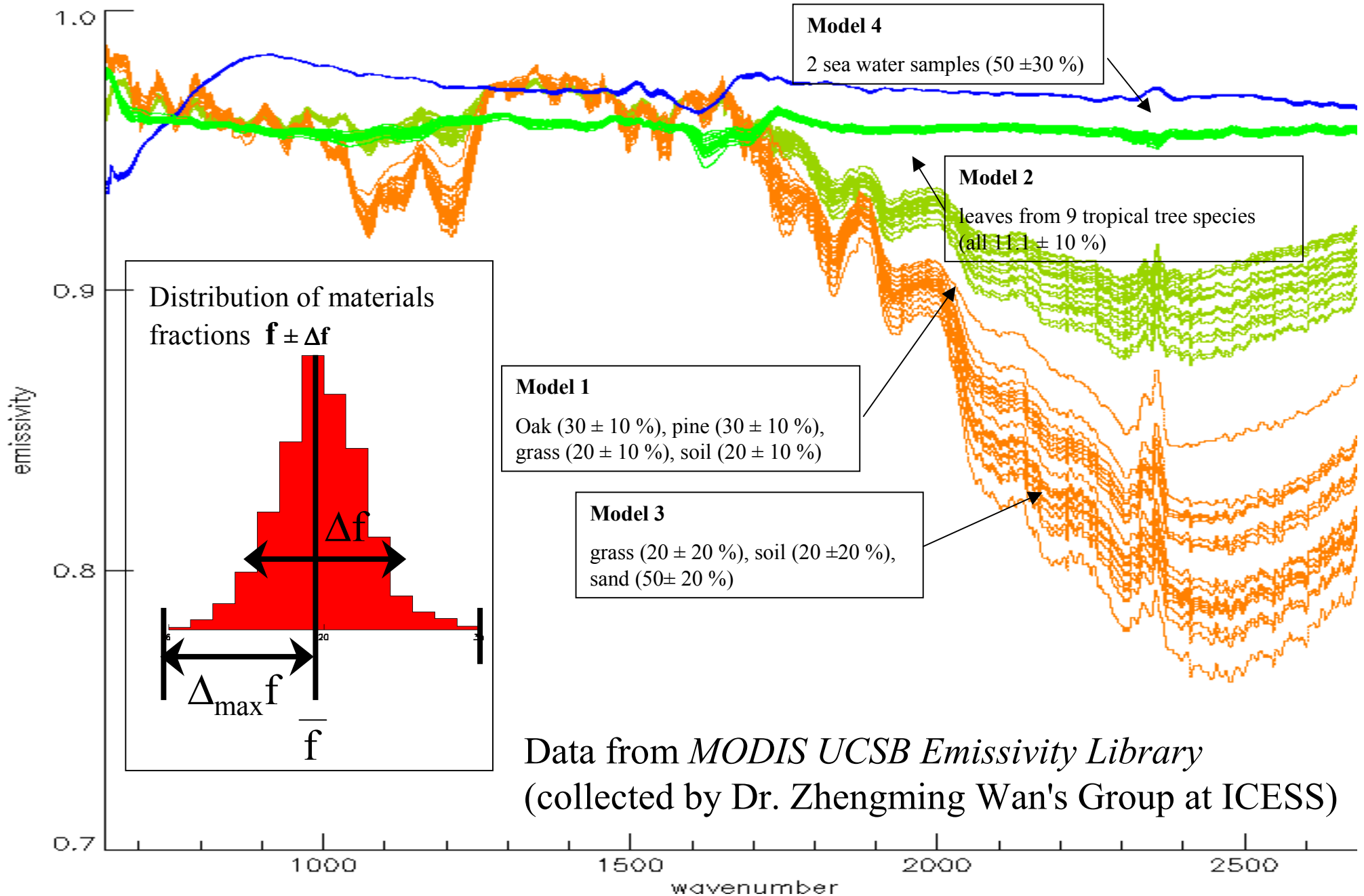


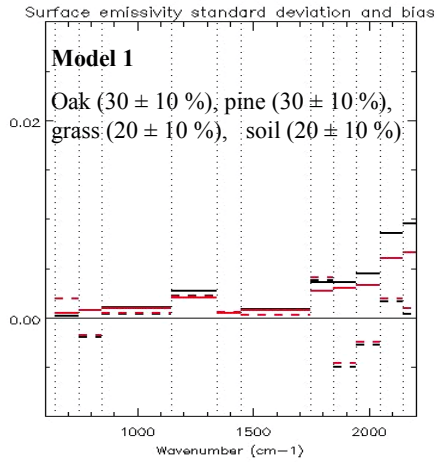


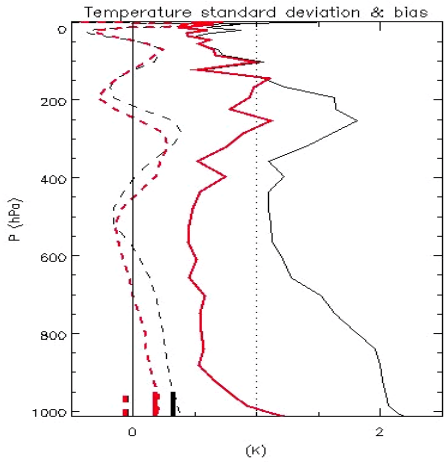


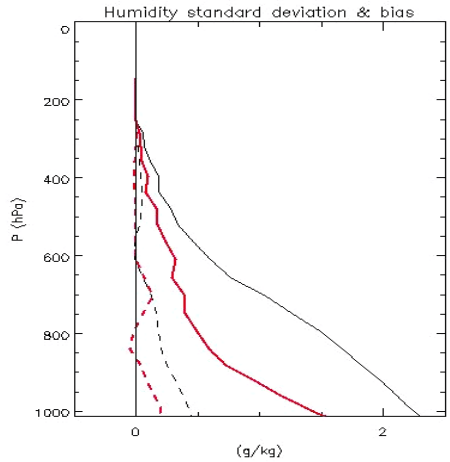


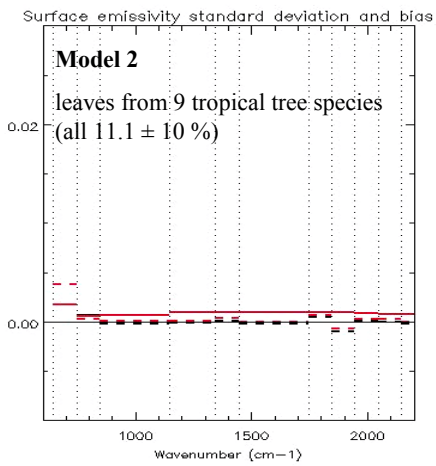
Experiments with high-resolution emissivity spectra

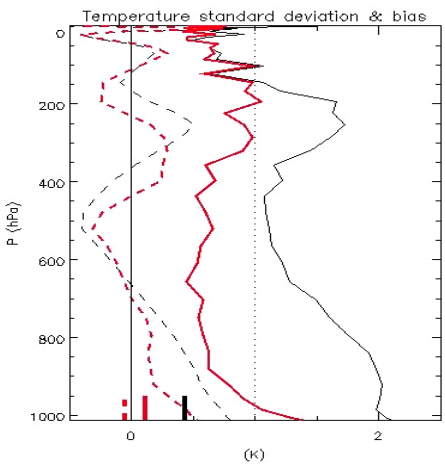


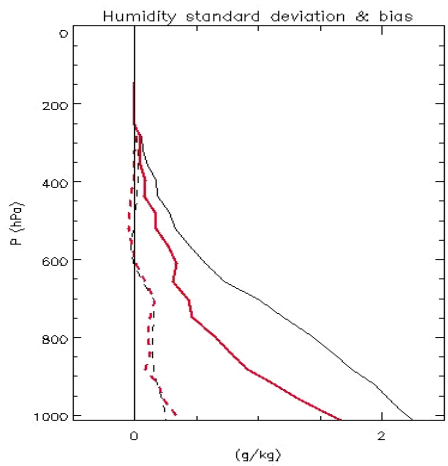

Surface emissivity standard deviation and bias
Model 1
Oak (30 ± 10 %), pine (30 ± 10 %),
grass (20 ± 10 %), soil (20 ± 10 %)
0.02
0.00
1000
1500
2000
Wavenumber (cm−1)

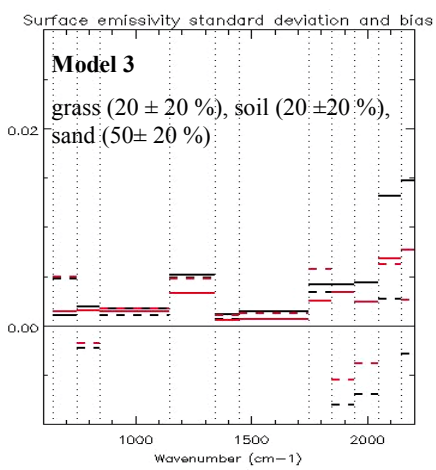

Temperature standard deviation & bias
P (hPa)
0
200
400
600
800
1000
0
2
(K)

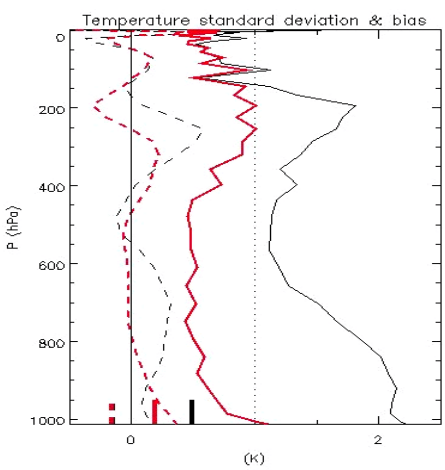

Humidity standard deviation & bias
P (hPa)
0
200
400
600
800
1000
0
2
(g/kg)

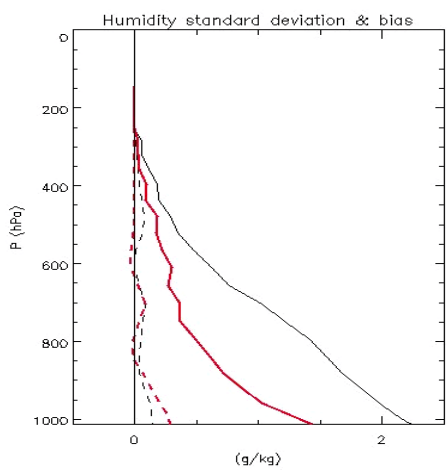

Surface emissivity standard deviation and bias
Model 2
leaves from 9 tropical tree species
(all 11.1 ± 10 %)
0.02
0.00
1000
1500
2000
Wavenumber (cm−1)

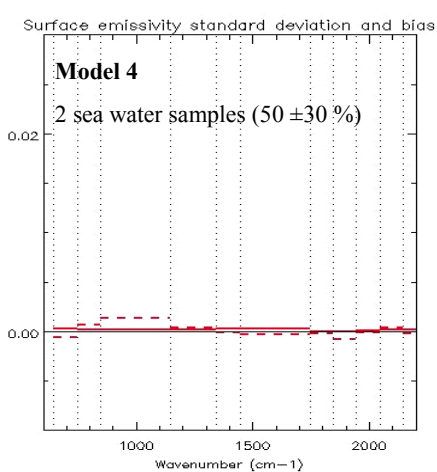

Temperature standard deviation & bias
P (hPa)
0
200
400
600
800
1000
0
2
(K)

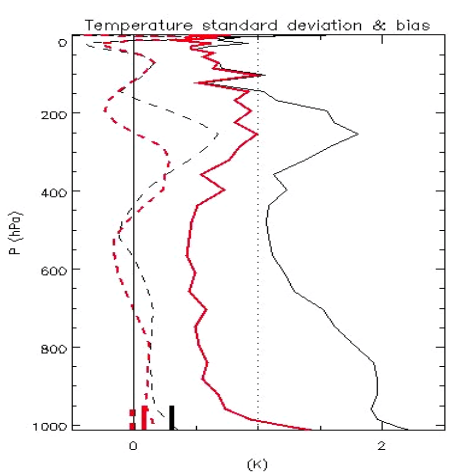

Humidity standard deviation & bias
P (hPa)
0
200
400
600
800
1000
0
2
(g/kg)

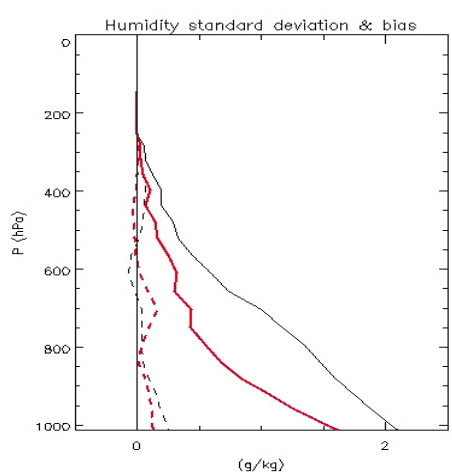

Surface emissivity standard deviation and bias
Model 3
grass (20 ± 20 %), soil (20 ±20 %),
sand (50± 20 %)
0.02
0.00
1000
1500
2000
Wavenumber (cm−1)


Temperature standard deviation & bias
P (hPa)
0
200
400
600
800
1000
0
2
(K)


Humidity standard deviation & bias
P (hPa)
0
200
400
600
800
1000
0
2
(g/kg)

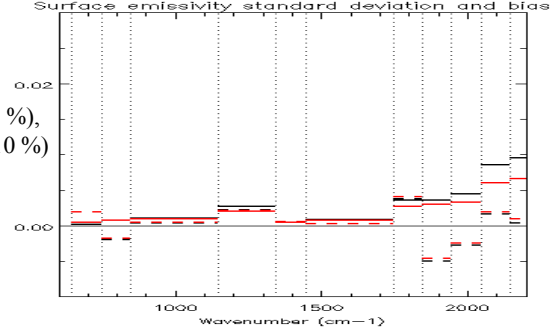

Surface emissivity standard deviation and bias
Model 4
2 sea water samples (50 ±30 %)
0.02
0.00
1000
1500
2000
Wavenumber (cm−1)

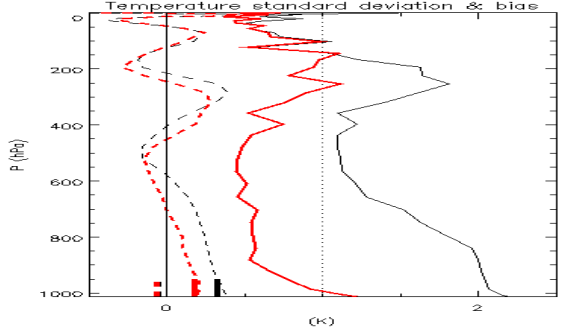

Temperature standard deviation & bias
P (hPa)
0
200
400
600
800
1000
0
2
(K)

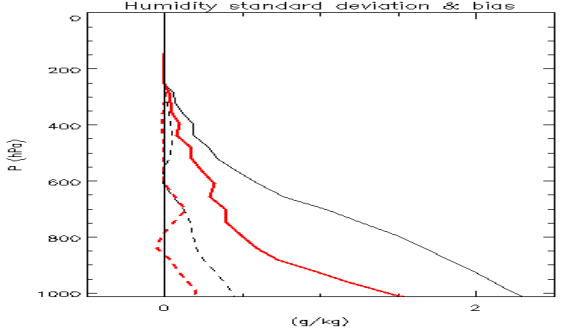

Humidity standard deviation & bias
P (hPa)
0
200
400
600
800
1000
0
2
(g/kg)

Model 1

Oak (30 ± 10 %), pine (30 ± 10 %), grass (20 ± 10 %), soil (20 ± 10 %)

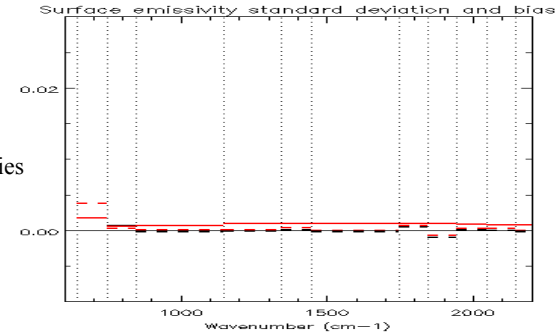


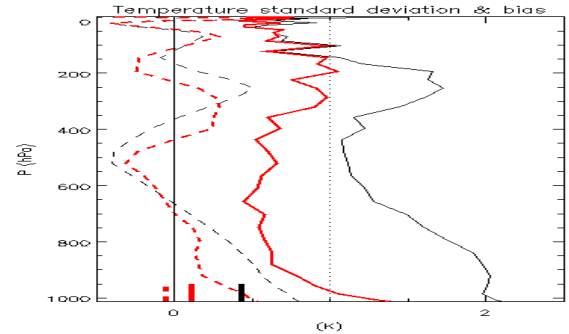


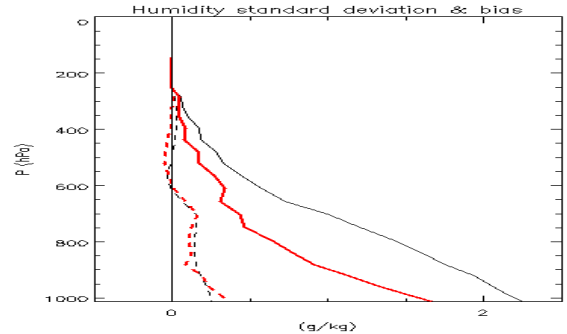


Model 2

leaves from 9 tropical tree species (all 11.1 ± 10 %)

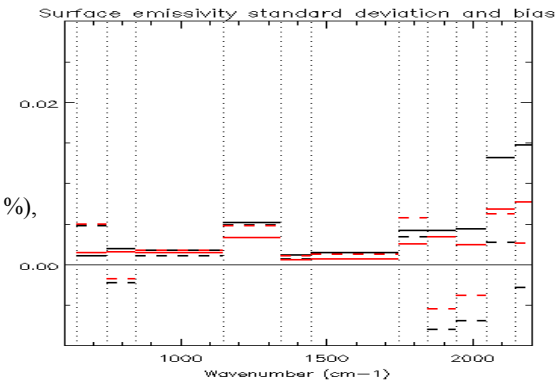


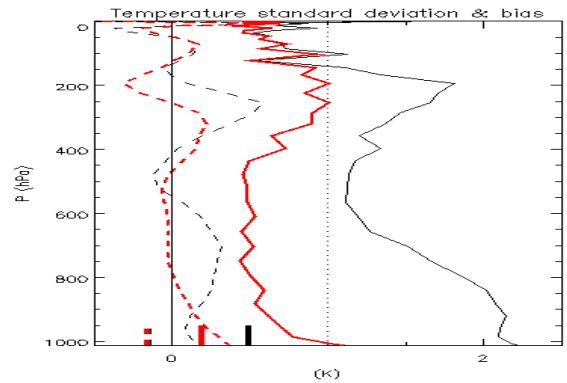


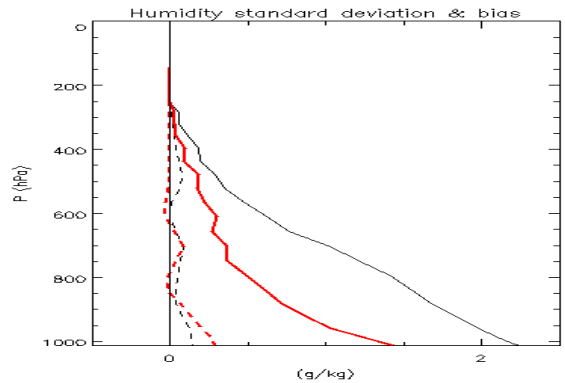


Model 3

grass (20 ± 20 %), soil (20 ±20 %), sand (50± 20 %)

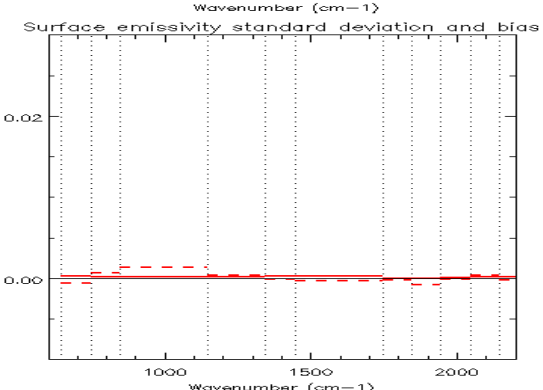


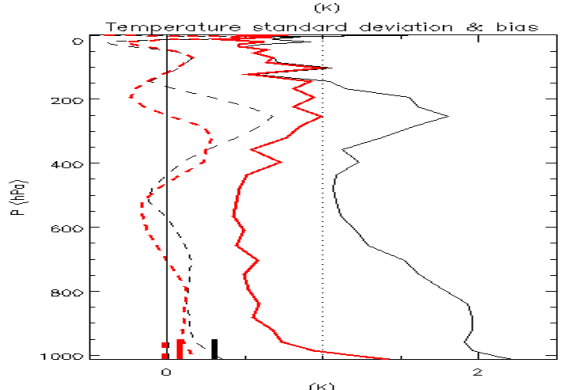


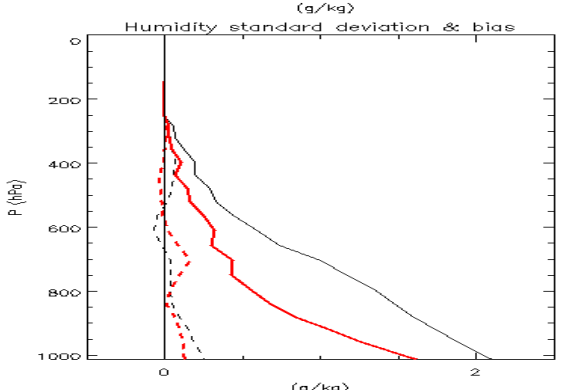


Model 4

2 sea water samples (50 ±30 %)







- Clear situations allow to fully benefit from infrared sounders capabilities
- Even then, the underlying surface can have a strong impact on retrievals quality:
  - large systematic error on the emissivity spectra can compromise the retrieval efficiency over land.
  - in the particular framework of a « stand-alone » retrieval scheme, only low-emissivity can provide a reasonable sensitivity to water-vapor.
- Handling properly emissivity variables requires:
  - An unbiased emissivity first-guess, with a 100 cm^{-1} or less spectral resolution
  - A model of spatial an temporal emissivity variability
- Those required data will probably be made available and reliable by the advanced sounders themselves (AIRS, IASI).