Study on land surface emissivity at microwave and sub-mm-wave frequencies

Objective of the project

To provide the community with realistic parameterization / modeling of the surface emissivities from 10 to 700 GHz

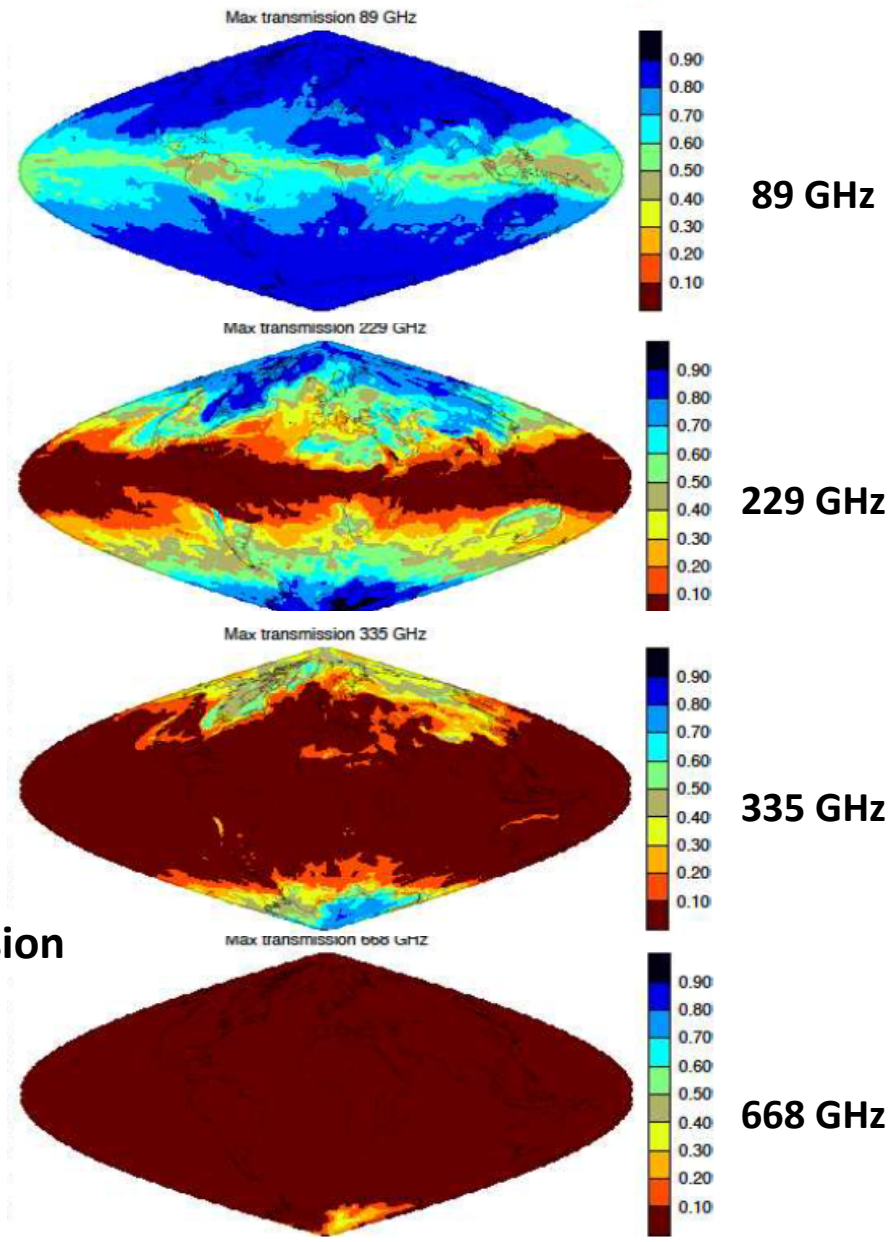
The tools:

- **Existing emissivity models**
- **Satellite-derived emissivities from existing sensors**
- **Aircraft observations with MARSS and ISMAR, the MWI / ICI demonstrator, from 89 to 664 GHz. MWI and ICI to be operated on board the next generation of European meteorological satellites (MetOp-SG).**

Analysis of the surface types to study in priority

Atmospheric transmission can be large at high frequencies, under very dry atmospheres, mostly in cold regions that are snow or ice covered.

Maximum transmission



Proposed methodology

- No surface emissivity modeling efforts above 200 GHz.
- No observations above 200 GHz (except ISMAR).
- Most emissivity works concentrated below 100 GHz.
- Some work up to 183 GHz for AMSU-B / MHS / SSMI / ATMS, but not consolidated at global scale.

Over continents and over sea ice:

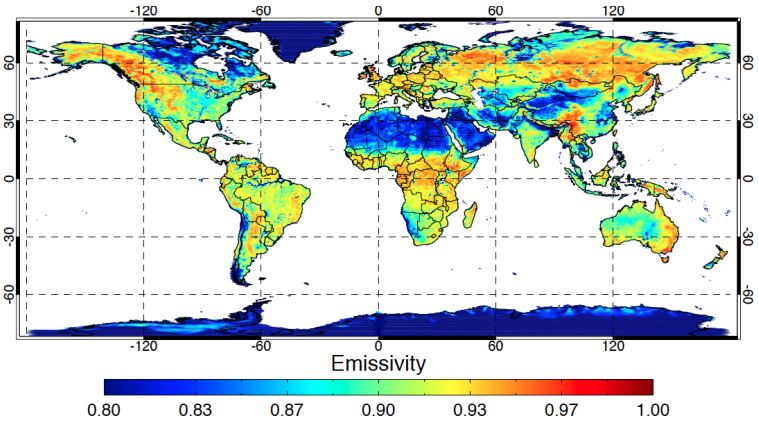
- At global scale, models have difficulties to reproduce the large spatial and time variability of the emissivities, especially over frozen surfaces.
- Lack of reliable inputs for the models at global scale

  => A parameterization anchored to a monthly climatology of satellite-derived emissivities

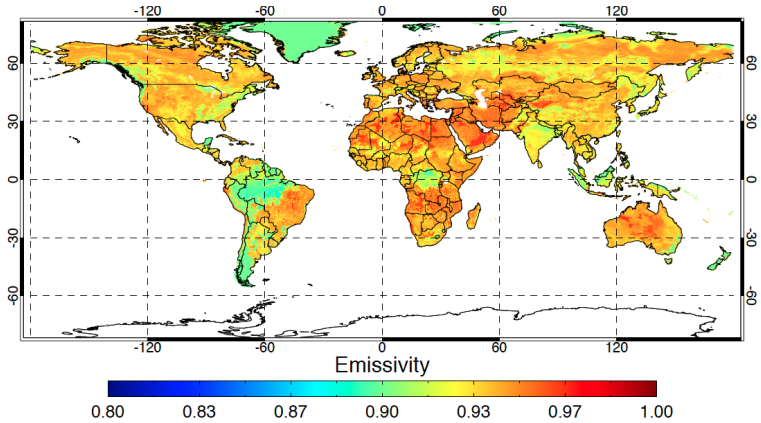
Land and sea ice emissivities

- At global scale, land surface models suffer from the complexity of the radiation interaction with the surface and from the lack of realistic input parameters (soil texture, vegetation properties, snow grain size…)

Satellite-derived emissivity 89 GHz H Pol 53° July



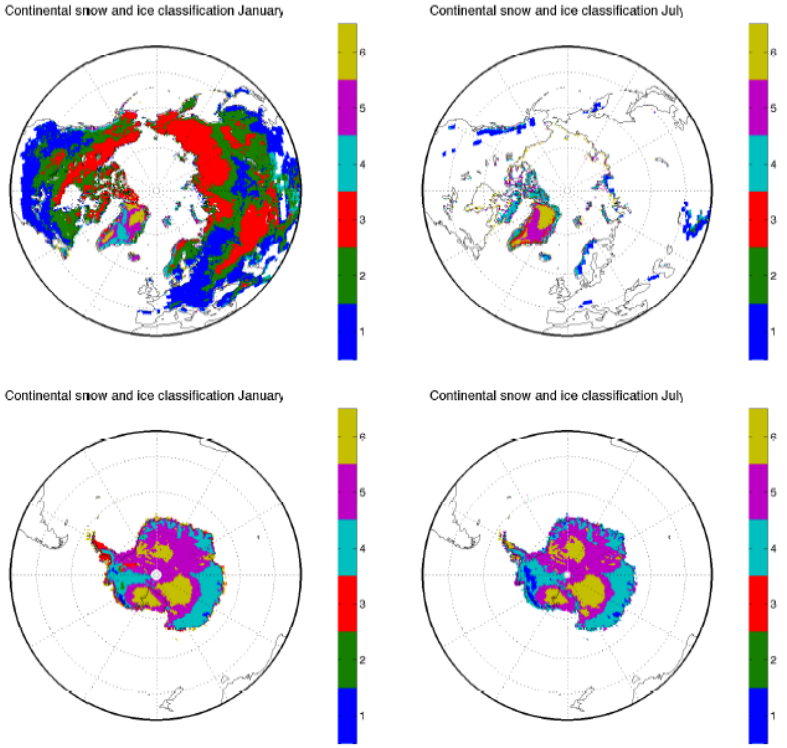
Modeled emissivity 89 GHz H Pol 53° July



- The SSM/I derived emissivity data base (TELSEM) is the basis for the development
  - For the frequency extrapolation above 100 GHz:
    - Météo-France estimates up to 190 GHz (AMSU-B and SSMI/S)
    - NOAA MIRS emissivity estimates up to 190 GHz (here SSMI/S)
  - For the angular and polarization dependences, very limited information available

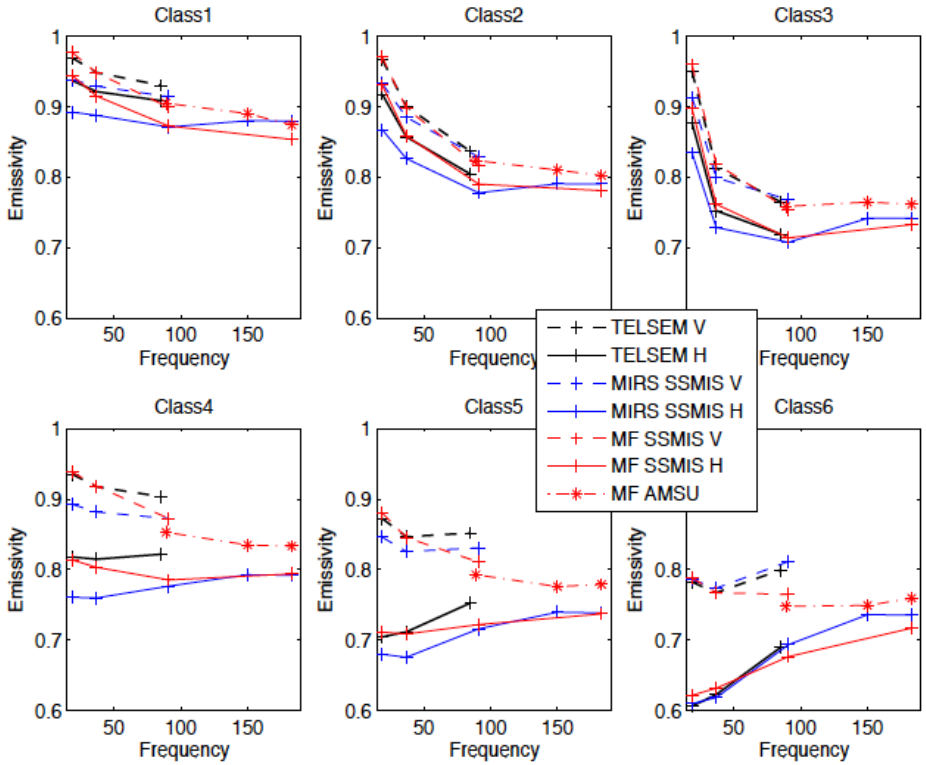
Land and sea ice emissivities

- Classification of the surfaces following the SSM/I TELSEM database
- For each class, look for the correspondant pixels in the other databases and examine the frequency dependence



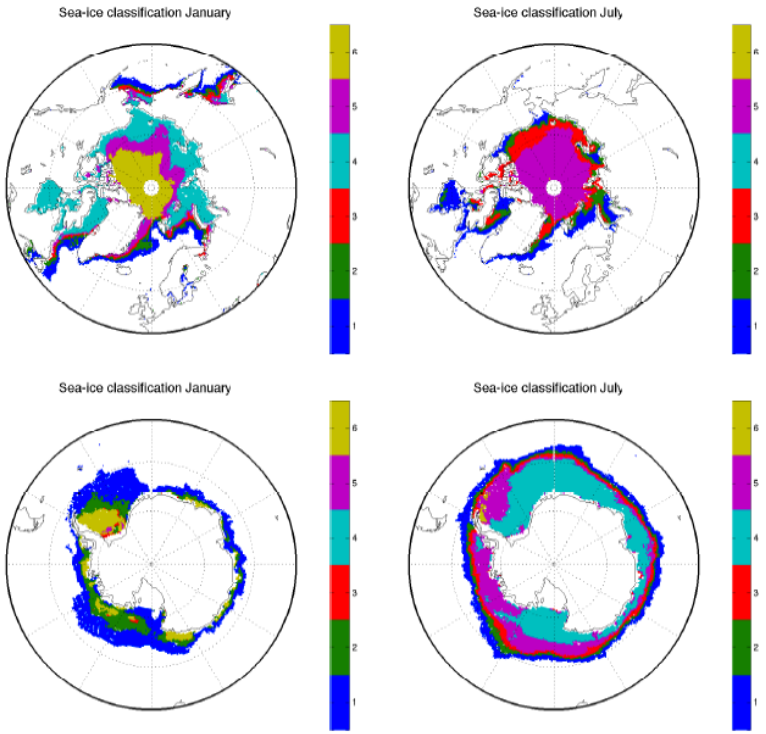
January July

Example: Continental snow and ice



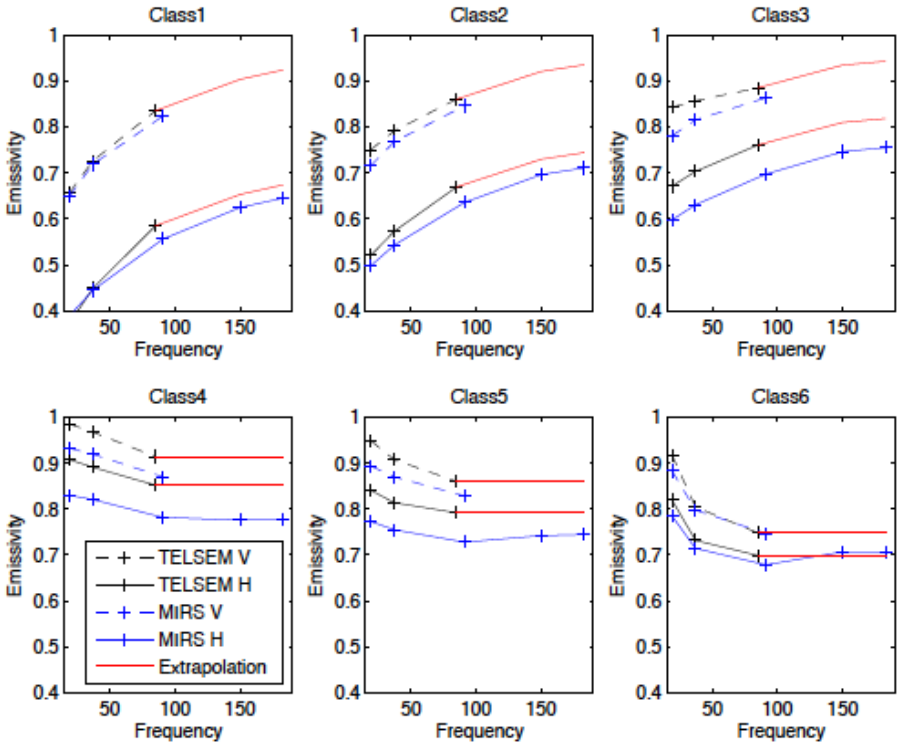
Land and sea ice emissivities

- Classification of the surfaces following the SSM/I TELSEM database
- For each class, look for the correspondant pixels in the other databases and examine the frequency dependence



January July

Example: Sea ice



Land and sea ice emissivities

- A parameterization of the emissivities based on the SSM/I TELSEM dataset, with the addition of the sea ice surfaces
- For most surface types, limited frequency dependence after 100 GHz
- Lack of information on the angular and polarization dependences. A conservative approach adopted.

A fortran code that can easily be switched with TELSEM

TELSEM^2 (Tool to Estimate Land Surface Emissivity from Microwave to sub-Millemeter waves)

Inputs

- Frequency (GHz)
- Incidence angle (deg)
- Latitude and longitude
- Month

Outputs

- Emissivities for the two orthogonal polarizations

Evaluation of TELSEM^2 with aircraft observations

On board the UK Met Office BAe146 aircraft:

ISMAR (International Sub-Millimetre Airborne Radiometer)

MARSS (Microwave Airborne Radiometer Scanning System)

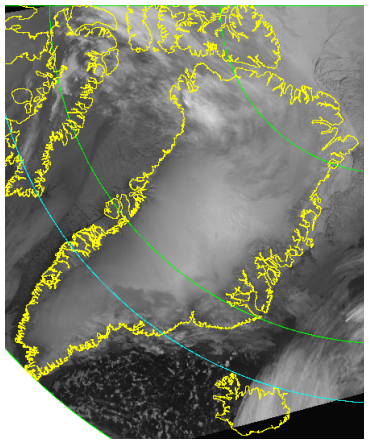
Instrument (GHz)	Channels (GHz)	Freq. Off. (GHz)	BW (K)	NetΔ T	Polar.	FOV	Spectral feature
MARSS (MWI)	89	±1.0	0.65	0.42	Mixed	11.8	Window
ISMAR (MWI)	118.75	±1.1 ±1.5 ±2.1 ±3.0 ±5.0	0.4 0.4 0.8 1.0 2.0	0.5 0.5 0.5 0.5 0.5	V	<3.8	O_2
MARSS (MWI)	157.0	±2.6	2.6	0.69	H	11.0	Window
MARSS (ICI)	183.31	±1.0 ±3.0 ±7.0	0.45 1.0 2.0	0.64 0.44 0.35	H	6.2	H_2O
ISMAR (ICI)	243.2	±2.5	3.0	0.5	V + H	<3.6	Window
ISMAR (ICI)	325.15	±1.5 ±3.5 ±9.5	1.6 2.4 3.0	1.0 1.0 1.0	V	<3.6	H_2O
ISMAR (ICI)	448.0	±1.4 ±3.0 ±7.2	1.2 2.0 3.0	1.2 1.2 1.9	V	<3.6	H_2O
ISMAR (ICI)	664.0	±4.2	3.0	1.5	V + H	<3.8	Window

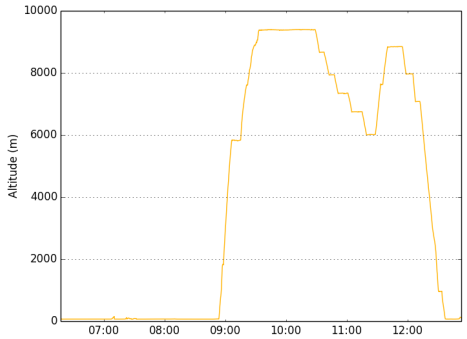
The MARSS / ISMAR campaigns

COSMICS (Cold-air Outbreak and Sub-Millimetre Ice Cloud Study)

- March 2015
- Based in Prestwick with mini-detachment to Keflavik, Iceland
- Further case-studies for ISMAR science, improvements to instrument from STICCS
- Problems with instrument led to a number of aborted flights
- Aircraft power issues cut short some flights
- 5 good science flights

An example: B896 over cold surfaces



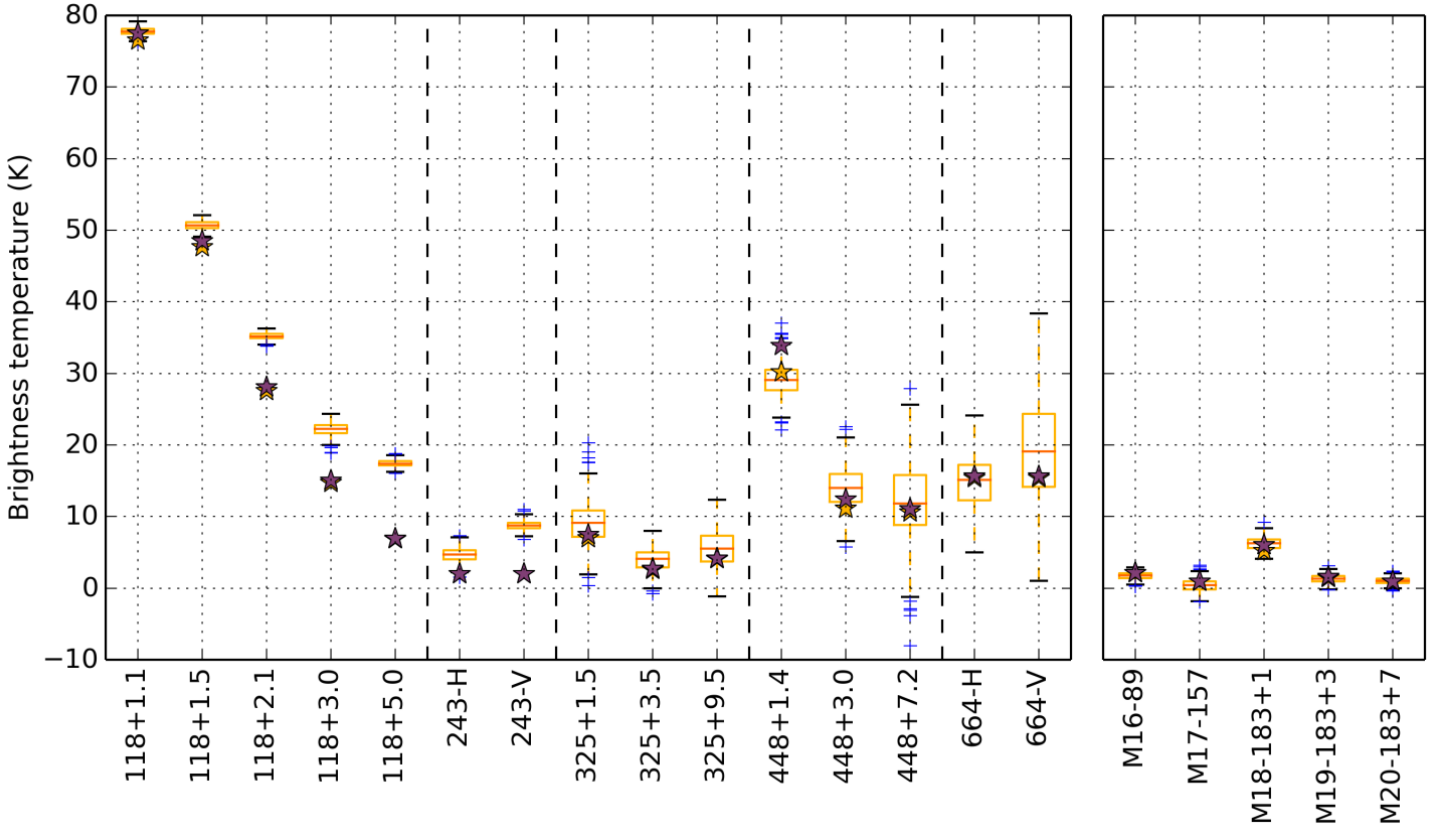


S. Fox, UK Met Office

The ISMAR performances

Comparison between observations and radiative transfer simulations

- Aircraft flying just above tropopause
- Comparison with ARTS simulations using NWP model atmosphere. H_2O, O_2, N_2 and O_3 (climatology). H_2O and O_2 use Rosenkranz 98 complete absorption models



B893 high altitude zenith views

Overall rather good agreement!

S. Fox, UK Met Office

Evaluation with the MARSS / ISMAR observations

Retrieval of surface emissivity

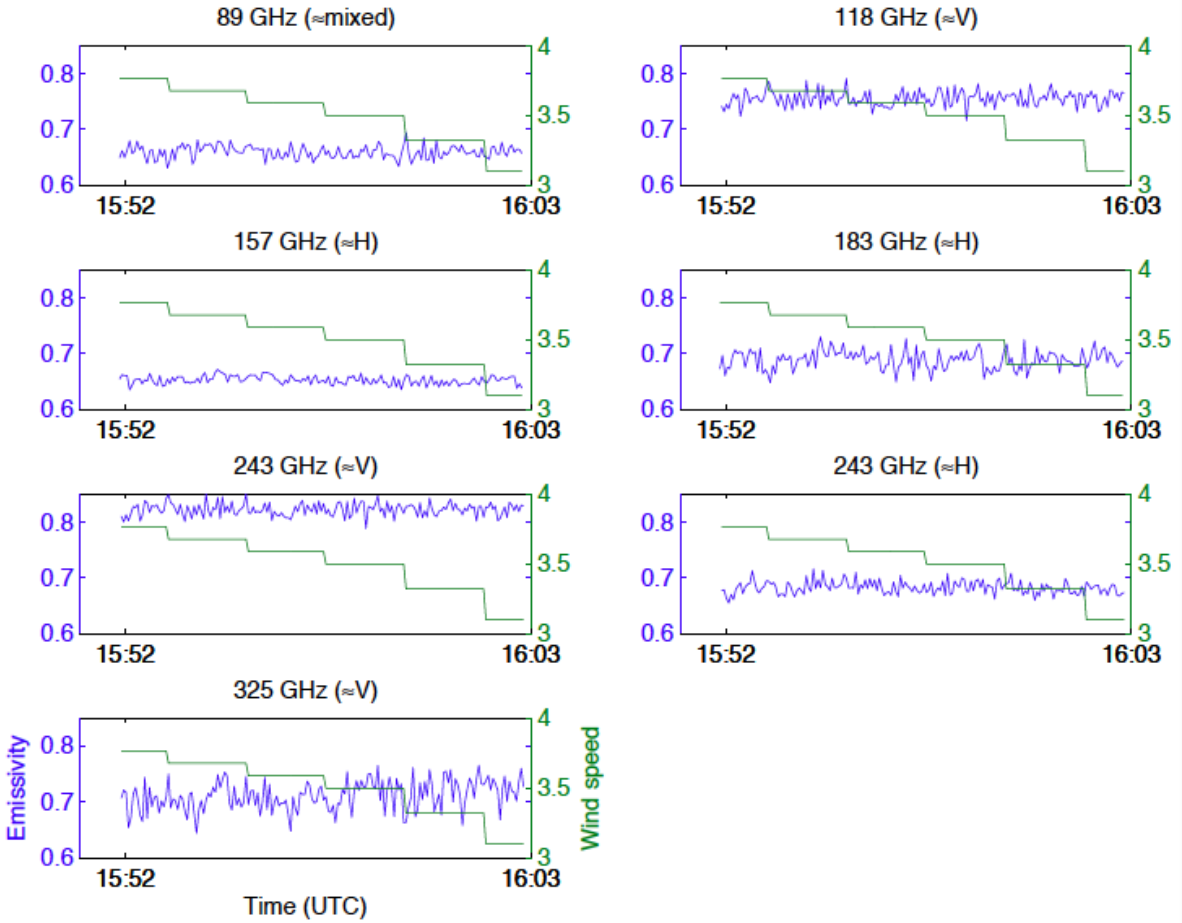
Emissivity calculation:

$$\varepsilon_p = \frac{T_{bp} - T_u - T_d \times e^{-\tau(0,H)/\mu}}{e^{-\tau(0,H)/\mu} \times (T_{surf} - T_d)}$$

For low flying altitude:

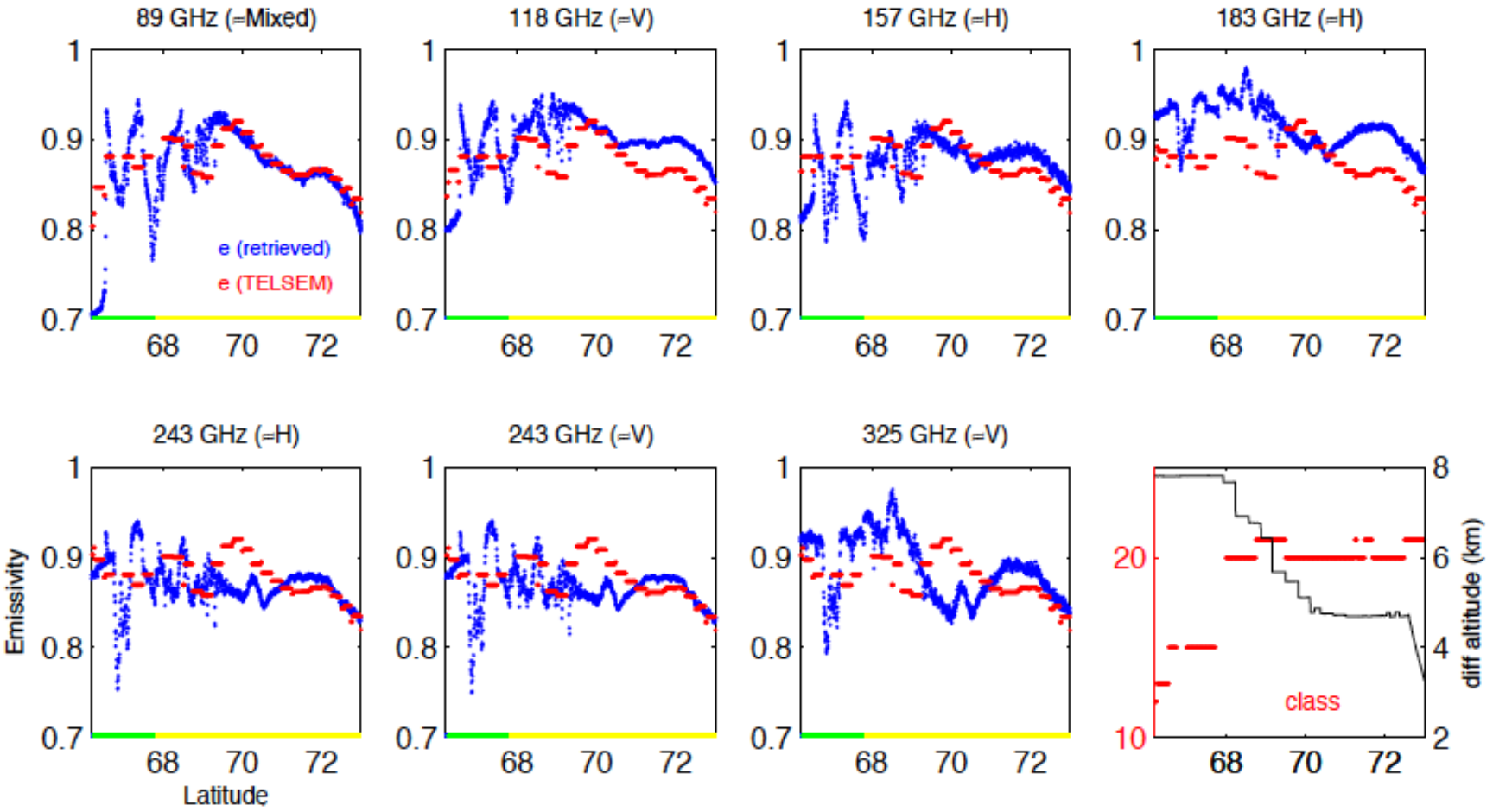
$$\varepsilon_p = \frac{T_{bp} - T_d}{(T_{surf} - T_d)}$$

Example of calculation over ocean (B893)



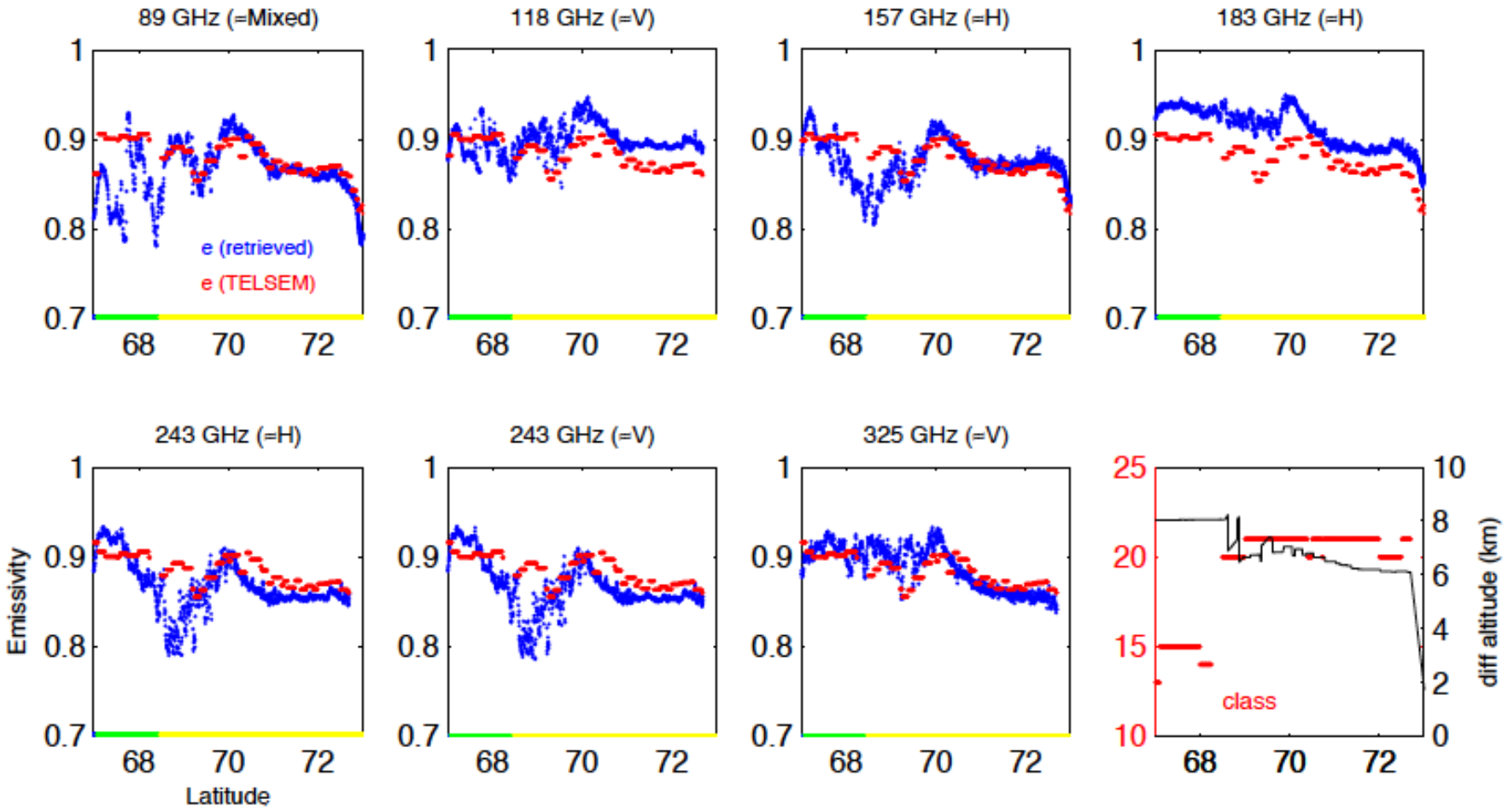
Evaluation with the MARSS / ISMAR observations

Retrieval of surface emissivities: ice emissivities 0° (B896)



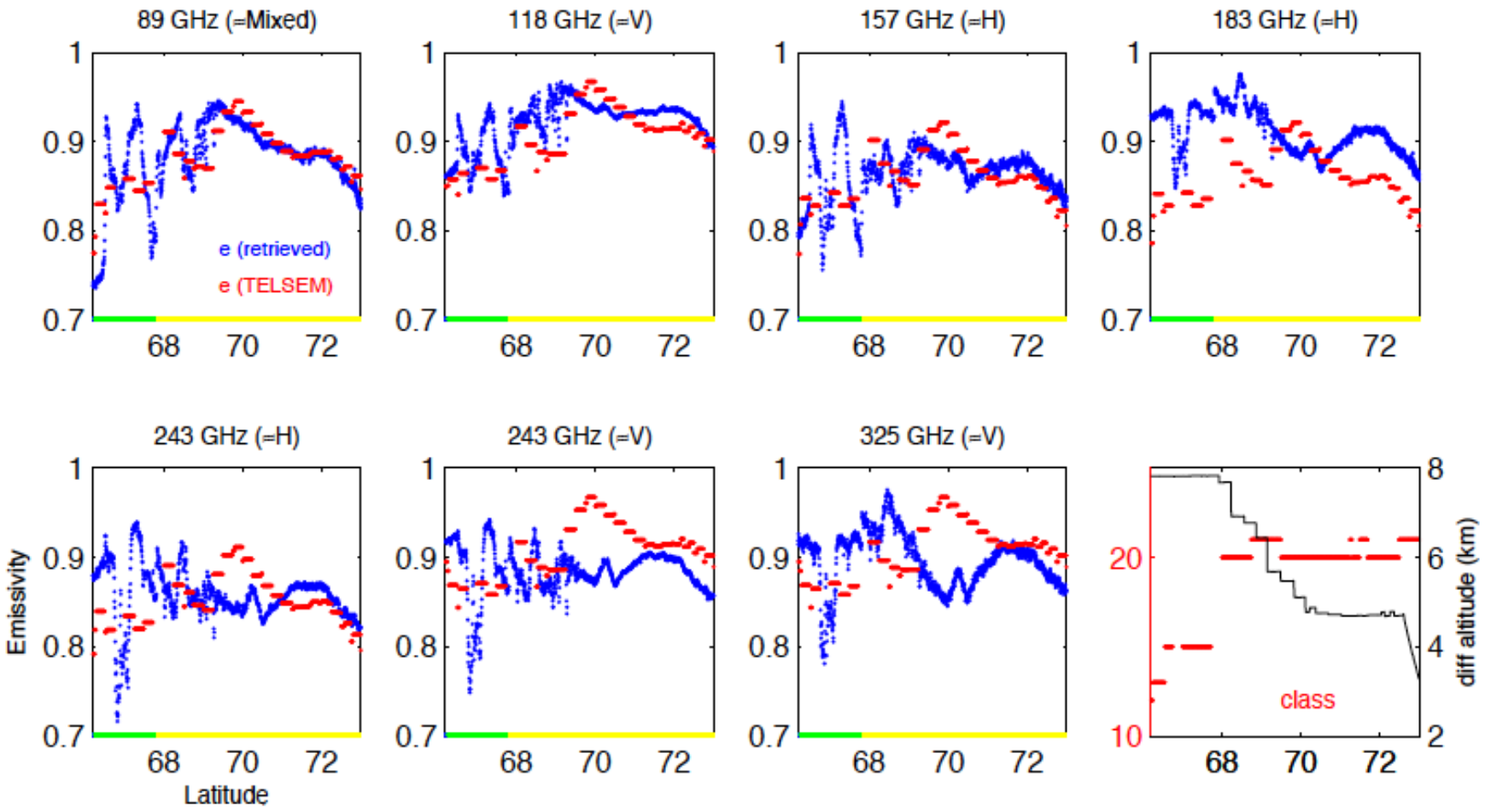
Evaluation with the MARSS / ISMAR observations

Retrieval of surface emissivities: ice emissivities 0° (B898)



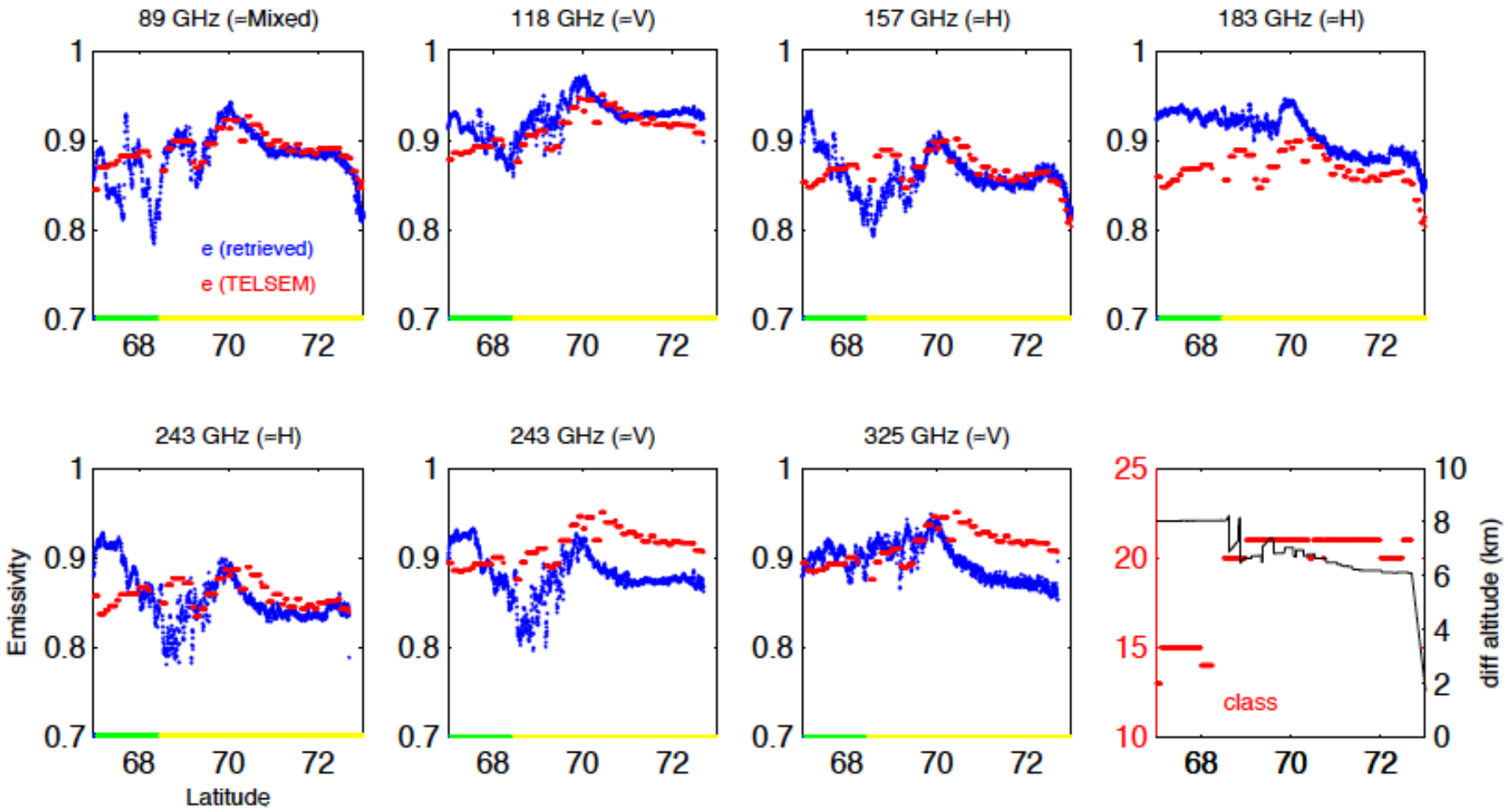
Evaluation with the MARSS / ISMAR observations

Retrieval of surface emissivities: ice emissivities 40° (B896)



Evaluation with the MARSS / ISMAR observations

Retrieval of surface emissivities: ice emissivities 40° (B898)



Conclusions

- Fortran code to estimate emissivity for all continental surfaces and sea-ice from 10 to 700 GHz

  TELSEM^2

- Another code developed for the ice-free ocean from 10 to 700 GHz

  TESSEM^2

- Fast codes and easy to use. Similar in nature to their ancestors (FASTEM and TELSEM)

- Partly evaluated with ISMAR observations