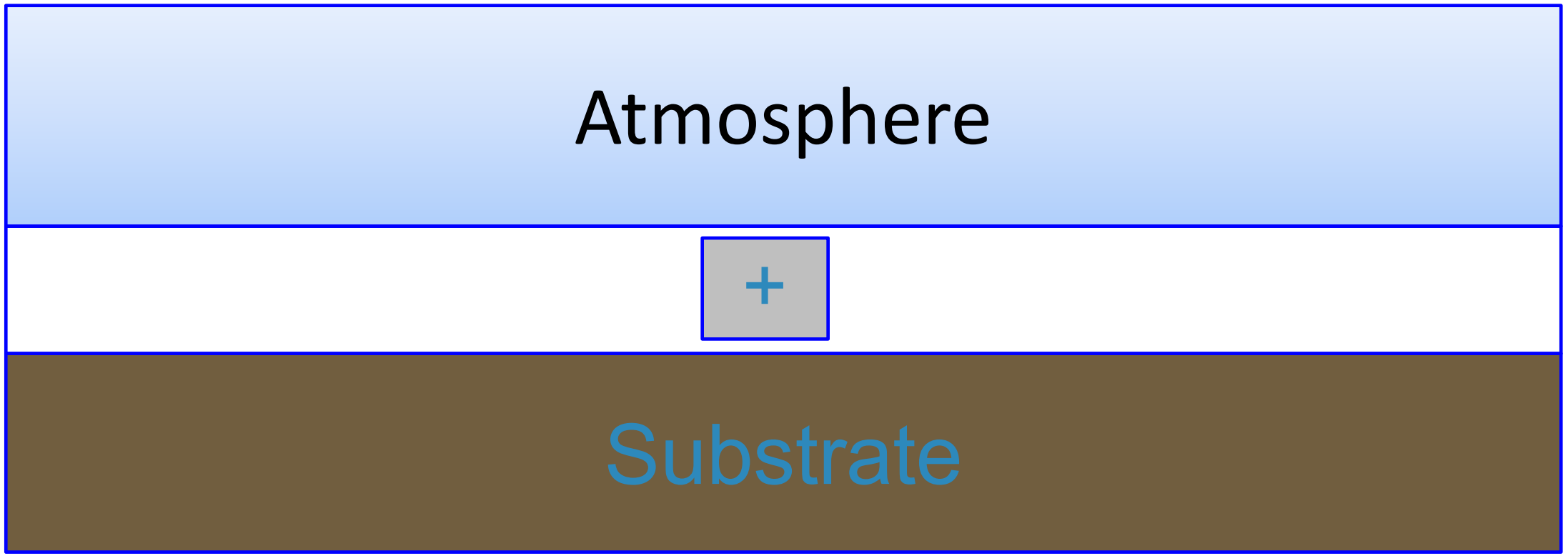
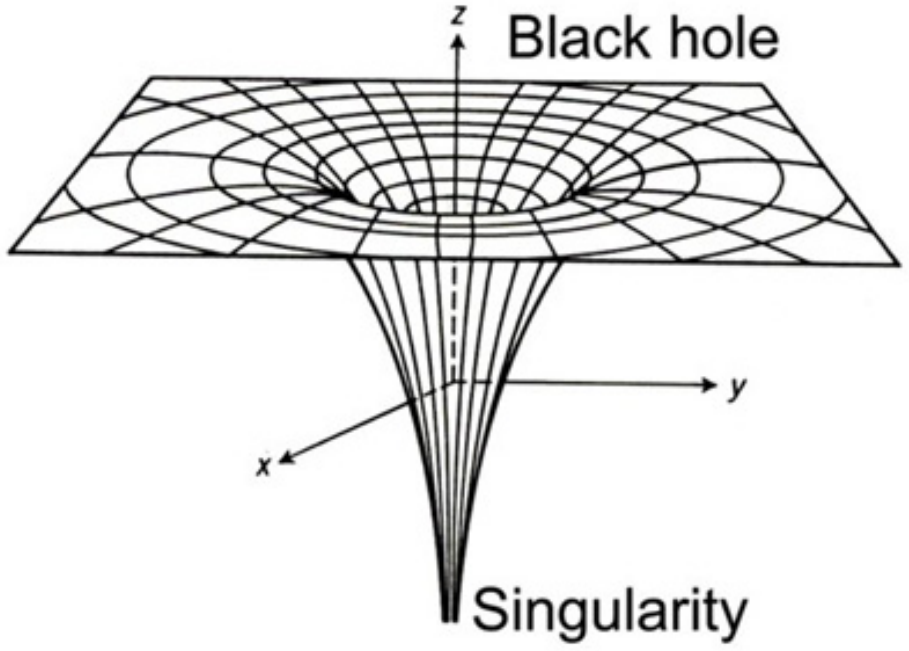
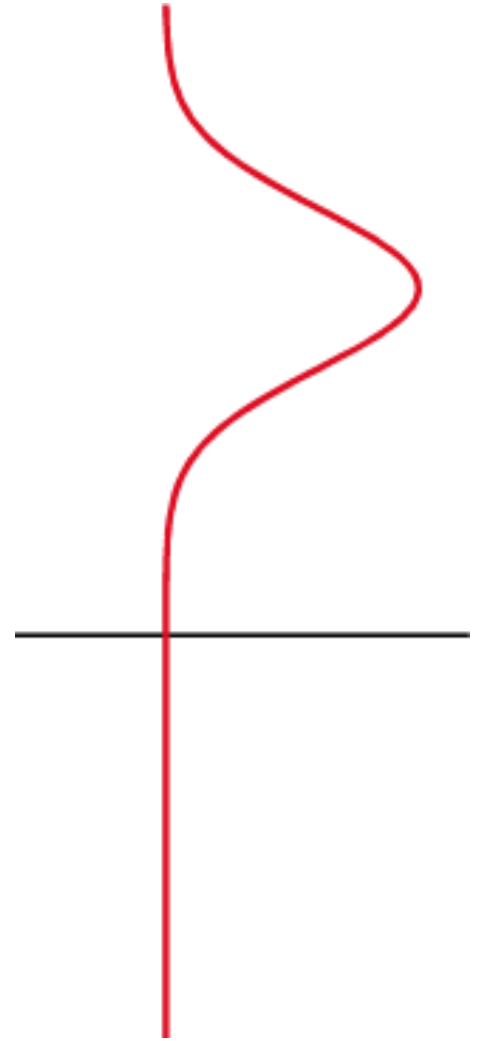

Atmosphere
+
Substrate

Need a lower boundary!





```
/mnt/c/Users/melod/OneDrive/Projects/smrt/smrt/rtsolver/dort.py:506: SMRTWarning: DORT has detected that the snowpack is optically shallow (tau=0.00397591) and no substrate has been set, meaning that the space under the snowpack is vaccum and that the snowpack is shallow enough to affect the signal measured at the surface.This is usually not wanted. Either increase the thickness of the snowpack or set a substrate. If wanted, add a transparent substrate to supress this warning
  smrt_warn("DORT has detected that the snowpack is optically shallow (tau=%g) and no substrate has been set, meaning that the space "
```

Types of substrate

A way to specify the lower boundary: what is underneath the lowest layer





Specialist materials: reflector plate, absorber….

It's a choice!

$\frac{\partial T}{\partial z}$? λ? structure?

1827

Simplest case: flat boundary

- Specular reflection

MÉMOIRE

SUR LA DOUBLE RÉFRACTION,

PAR M. A. FRESNEL (1).

INTRODUCTION.

HUYGENS, guidé par une hypothèse puisée dans la théorie des ondes, a reconnu le premier les véritables lois de la double réfraction des cristaux à un axe. Cette découverte était peut-être plus difficile à faire que toutes celles de Newton sur la lumière; et ce qui semble le prouver, c'est qu'ici Newton, après

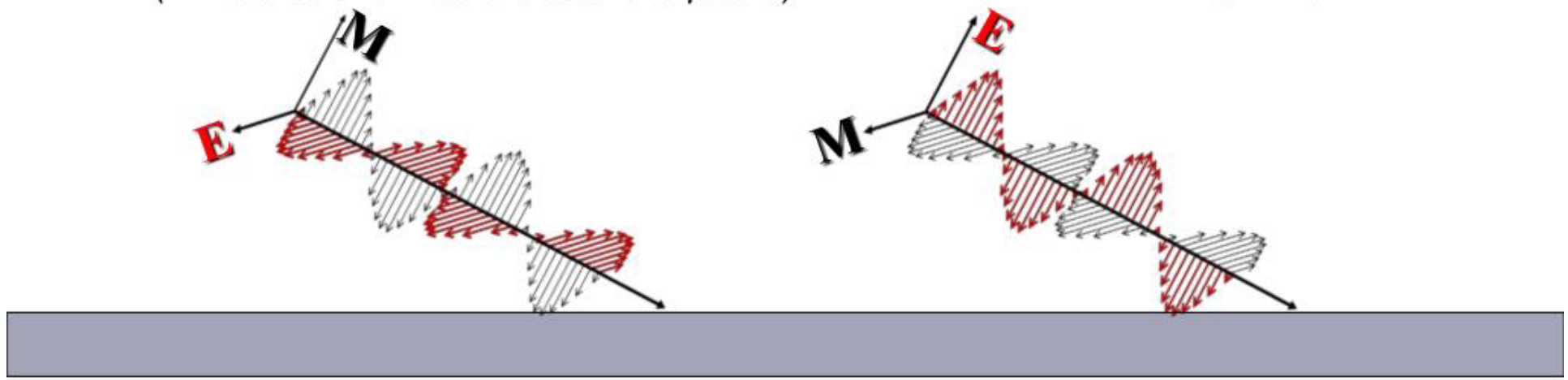
(1) Les trois Mémoires dont celui-ci offre la réunion ont été successivement présentés à l'Institut le 26 novembre 1821, le 22 janvier 1822, et le 22 avril de la même année. En les réunissant, on a changé l'ordre des

Polarization modes (= confusing nomenclature!)

always relative to plane of incidence

TE: Transverse electric
s: senkrecht polarized
*(E-field **s**ticks in and out of the plane)*

TM: Transverse magnetic
p: plane polarized
*(E-field in the **p**lane)*

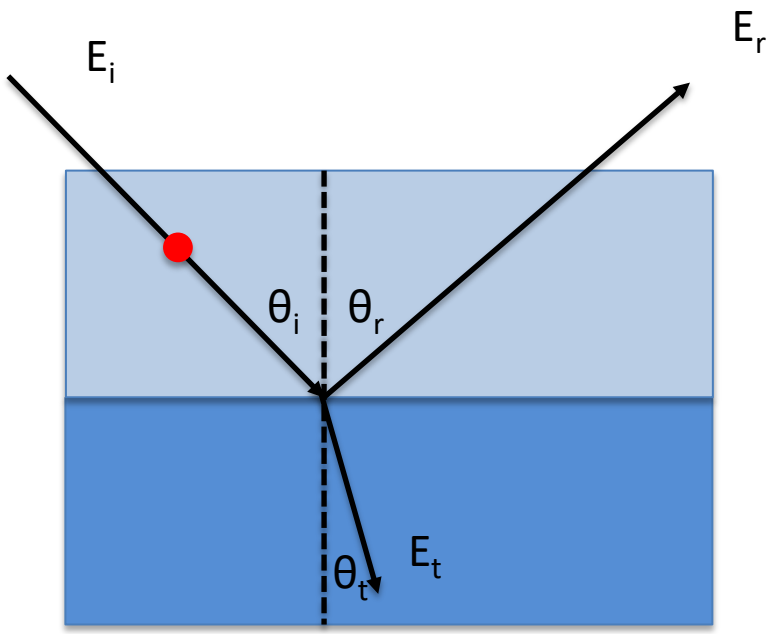


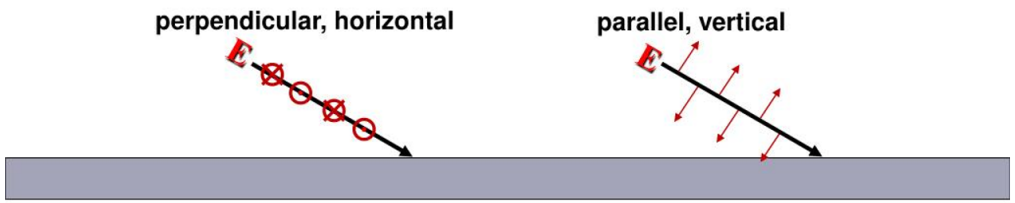
perpendicular, horizontal

parallel, vertical

https://image3.slideserve.com/5503639/slide8-l.jpg

Fresnel





Use

- continuity equations across boundary
- Relationship between electric and magnetic field
- law of reflection: $\theta_i = \theta_r$
- Snell's law of refraction: $n_1 \sin\theta_i = n_2 \sin\theta_t$
- $n^2 = \varepsilon$

$$R_H = \left| \frac{\cos\theta_i - \sqrt{\frac{\varepsilon_2}{\varepsilon_1} - \sin^2\theta_i}}{\cos\theta_i + \sqrt{\frac{\varepsilon_2}{\varepsilon_1} - \sin^2\theta_i}} \right|^2$$

$$R_V = \left| \frac{\frac{\varepsilon_2}{\varepsilon_1}\cos\theta_i - \sqrt{\frac{\varepsilon_2}{\varepsilon_1} - \sin^2\theta_i}}{\frac{\varepsilon_2}{\varepsilon_1}\cos\theta_i + \sqrt{\frac{\varepsilon_2}{\varepsilon_1} - \sin^2\theta_i}} \right|^2$$

Soil permittivity

$$R_H = \left| \frac{\cos\theta_i - \sqrt{\frac{\varepsilon_2}{\varepsilon_1} - \sin^2\theta_i}}{\cos\theta_i + \sqrt{\frac{\varepsilon_2}{\varepsilon_1} - \sin^2\theta_i}} \right|^2$$

$$R_V = \left| \frac{\frac{\varepsilon_2}{\varepsilon_1}\cos\theta_i - \sqrt{\frac{\varepsilon_2}{\varepsilon_1} - \sin^2\theta_i}}{\frac{\varepsilon_2}{\varepsilon_1}\cos\theta_i + \sqrt{\frac{\varepsilon_2}{\varepsilon_1} - \sin^2\theta_i}} \right|^2$$

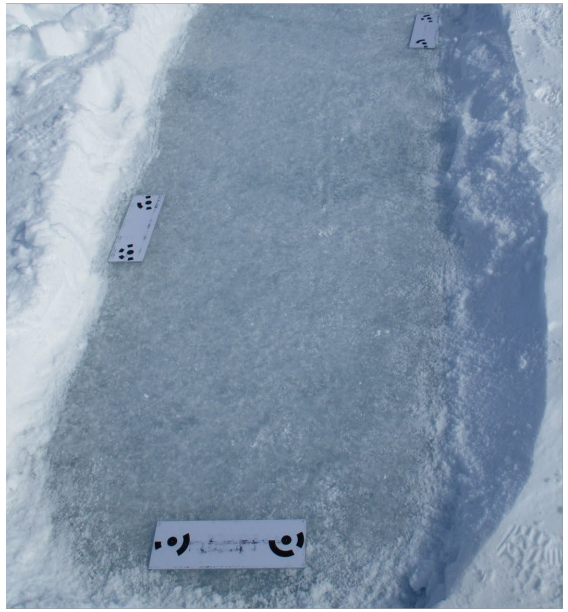
Need to define soil permittivity. Depends on:

- Soil moisture
- Soil type
- Bulk soil density

Photo courtesy: Ian Davenport

A rough surface?

a) Snow surface (AK2)



b) Flat ice (AK2)

c) Rough ice (AK3)

Courtesy: Julien Meloche

Modelling roughness

Geometric roughness vs Dielectric roughness

Variation in surface height
- analytical models of surface scattering
  (e.g. IEM, Geometrical Optics)
- semi-empirical
  (e.g. Wegmüller and Mätzler, 1999 - passive)

Dielectric discontinuities
- numerical solution of Maxwell's equations

Including substrate in SMRT

```
substrate = make_soil("iem_fung92", "dobson85", temperature=260,
                                                roughness_rms=1e-3,
                                                corr_length=5e-2,
                                                autocorrelation_function="exponential",
                                                moisture=0.25, sand=0.01, clay=0.7, drymatter=1300)
```

```
# Make simple snowpack, including substrate
snow = make_snowpack([1], "exponential", temperature=[265],
                     density=[280], corr_length=[5e-5], substrate=substrate)
```

or

```
snow = make_snowpack([1], "exponential", temperature=[265],
                     density=[280], corr_length=[5e-5])
medium = snow + substrate
```

Atmosphere

Lawrence et al., 2019

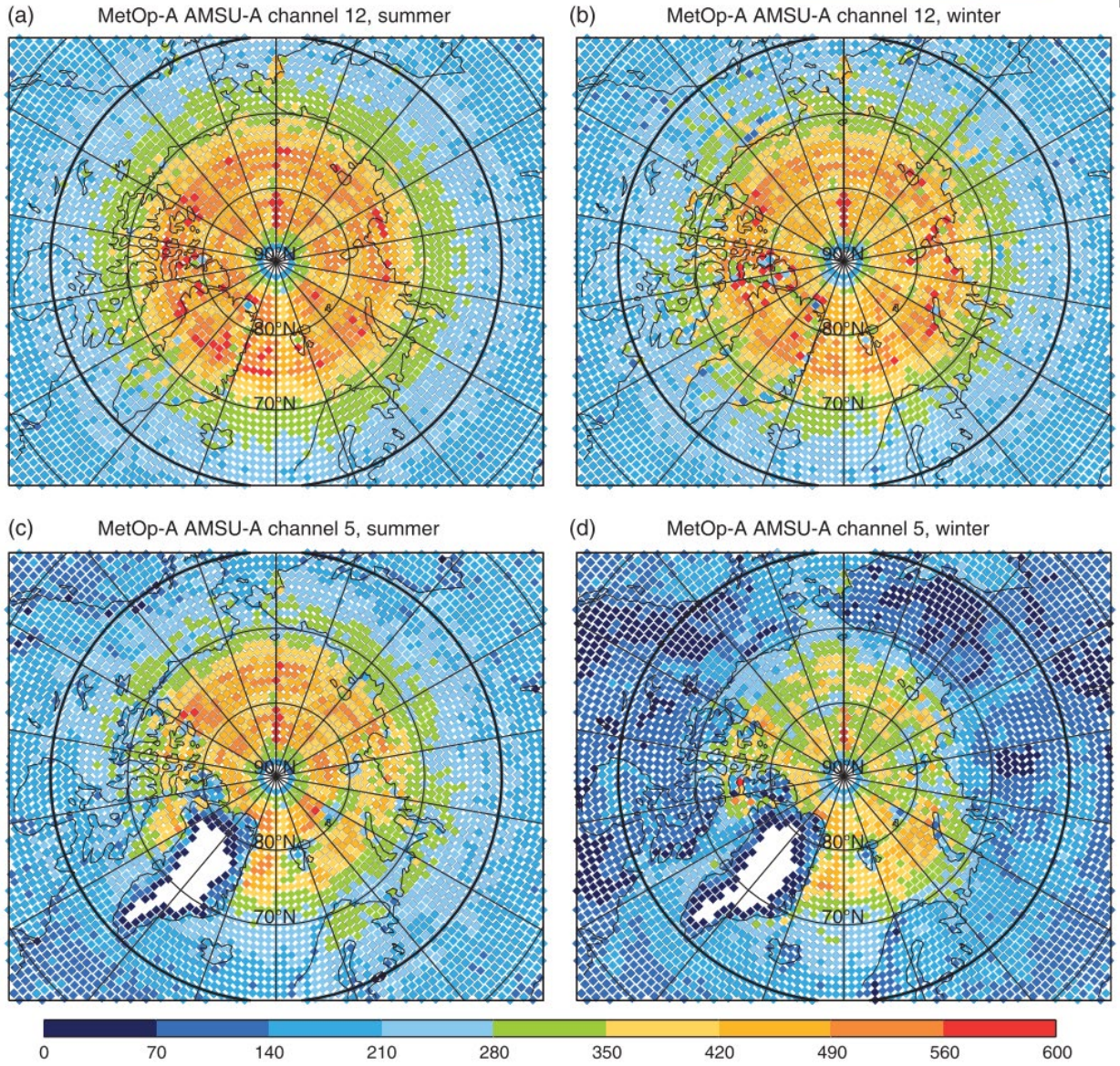
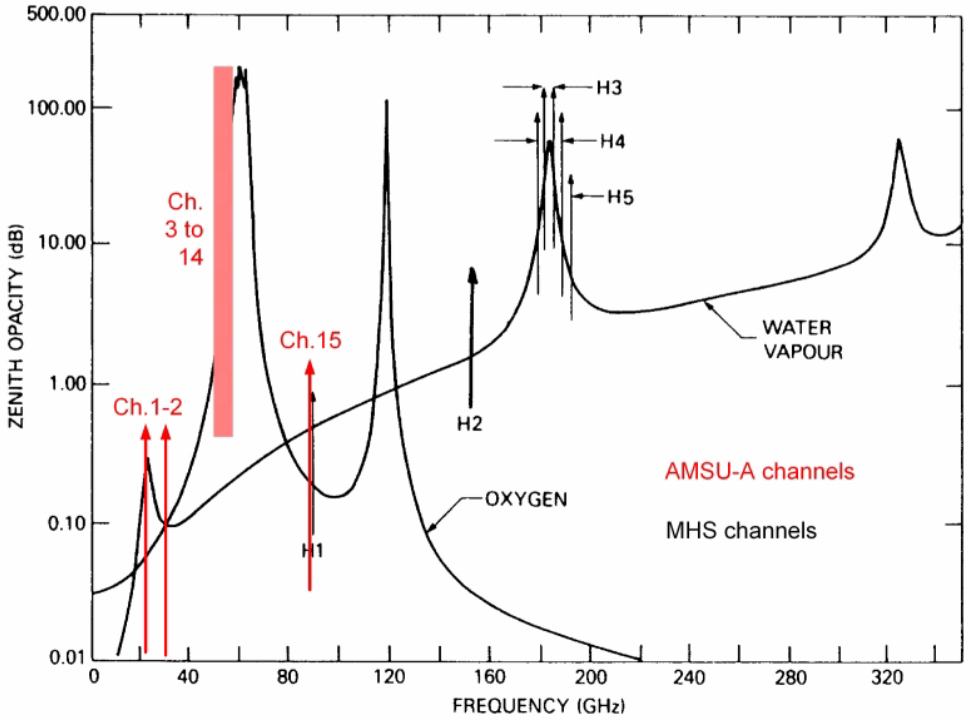
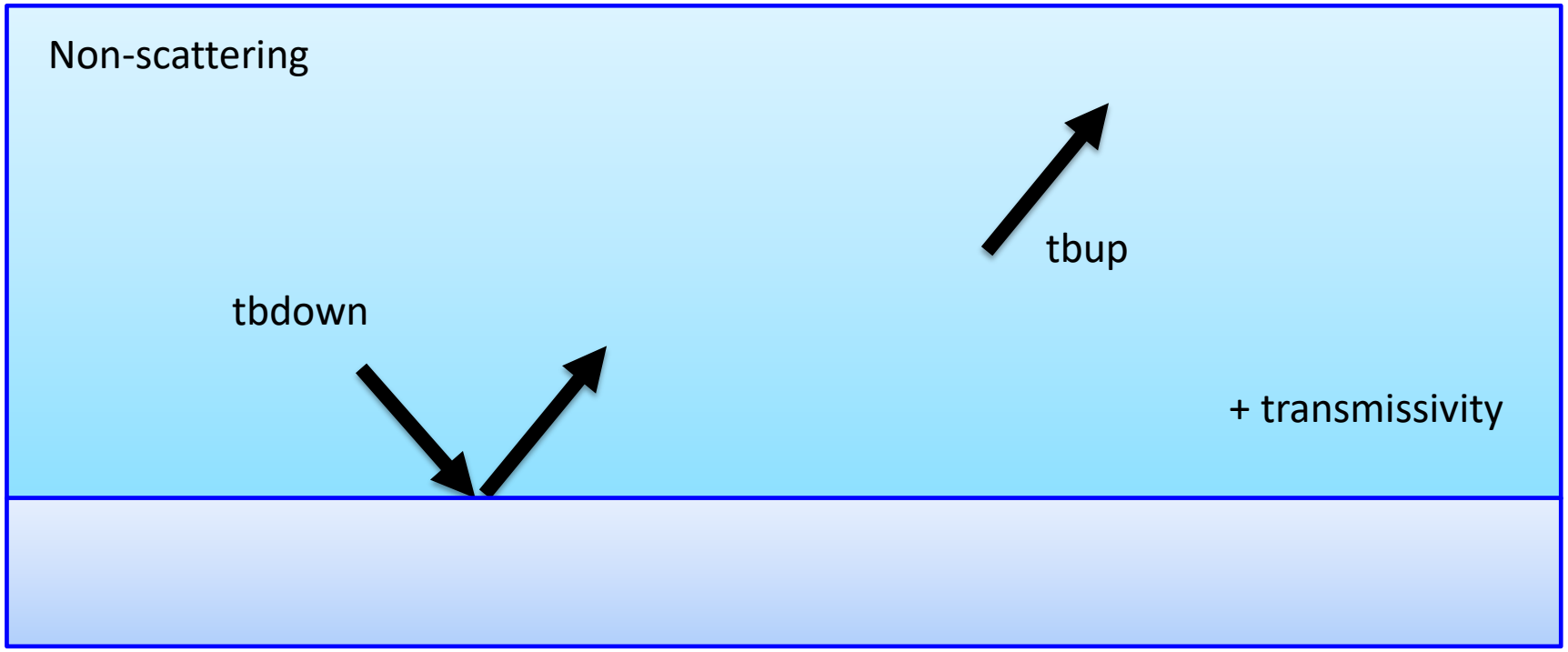


FIGURE 2 Number of observations assimilated in the ECMWF operational system from MetOp-A AMSU-A channel 12 (peaking around 10 hPa) in (a) June–September 2016 and (b) December 2017 to March 2018, and from MetOp-A AMSU-A channel 5 (peaking around 850 hPa) in (c) June–September 2016 and (d) December 2017 to March 2018. Note that 60°N is indicated as a solid black line



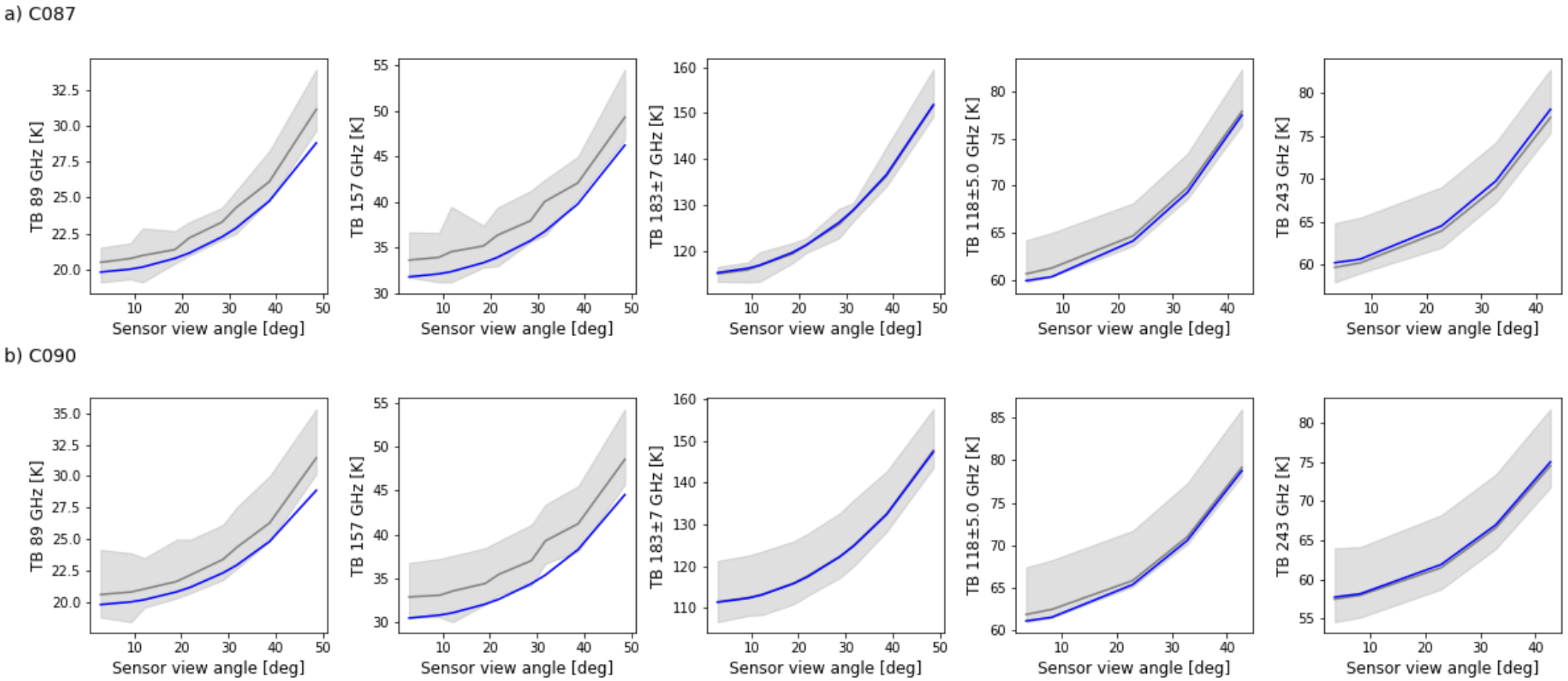
https://www.eumetsat.int/amsu-a

SMRT Basic Atmosphere



medium = atmosphere + snow

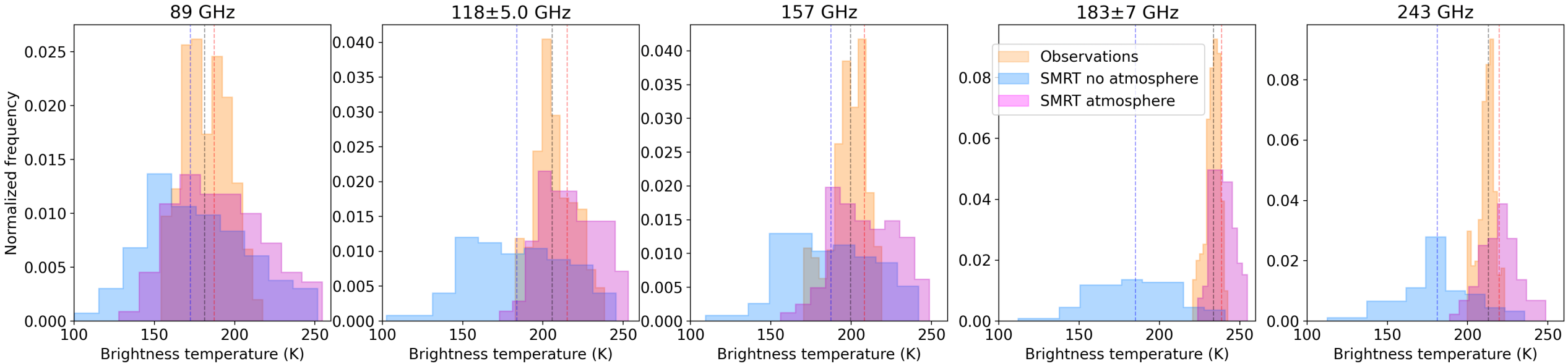
Sandells et al., 2023 (pre-print)



Blue: ARTS simulation (Atmospheric Radiative Transfer Simulator)
Grey: Observed (airborne)

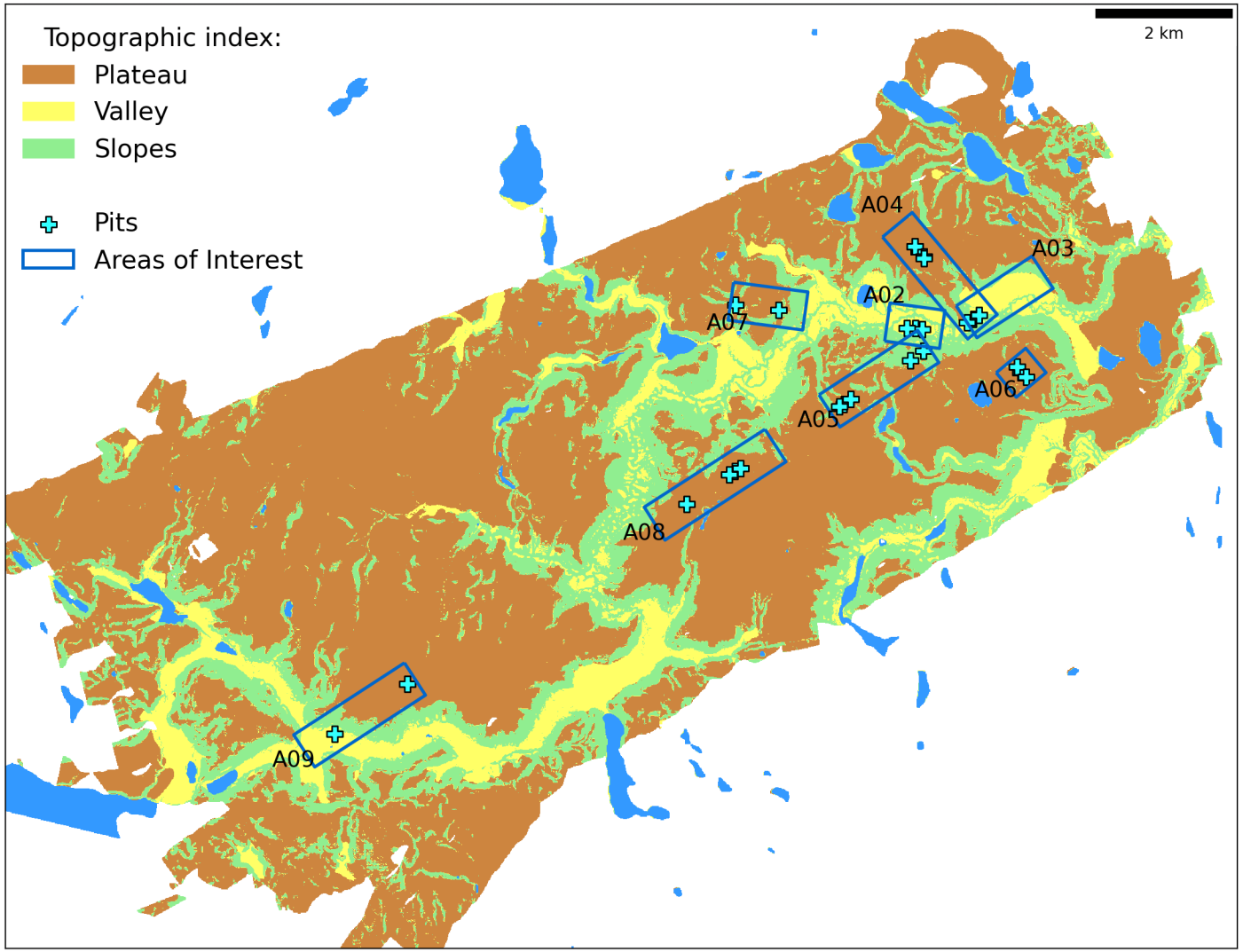
Sandells et al., 2023 (pre-print)

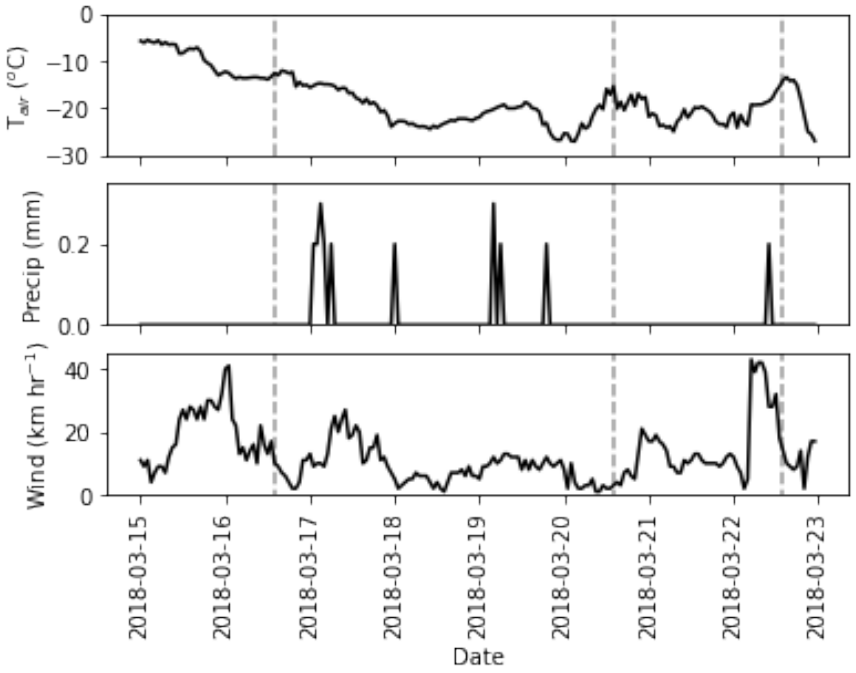
ARTS+SMRT



Sandells et al., 2023 (pre-print)

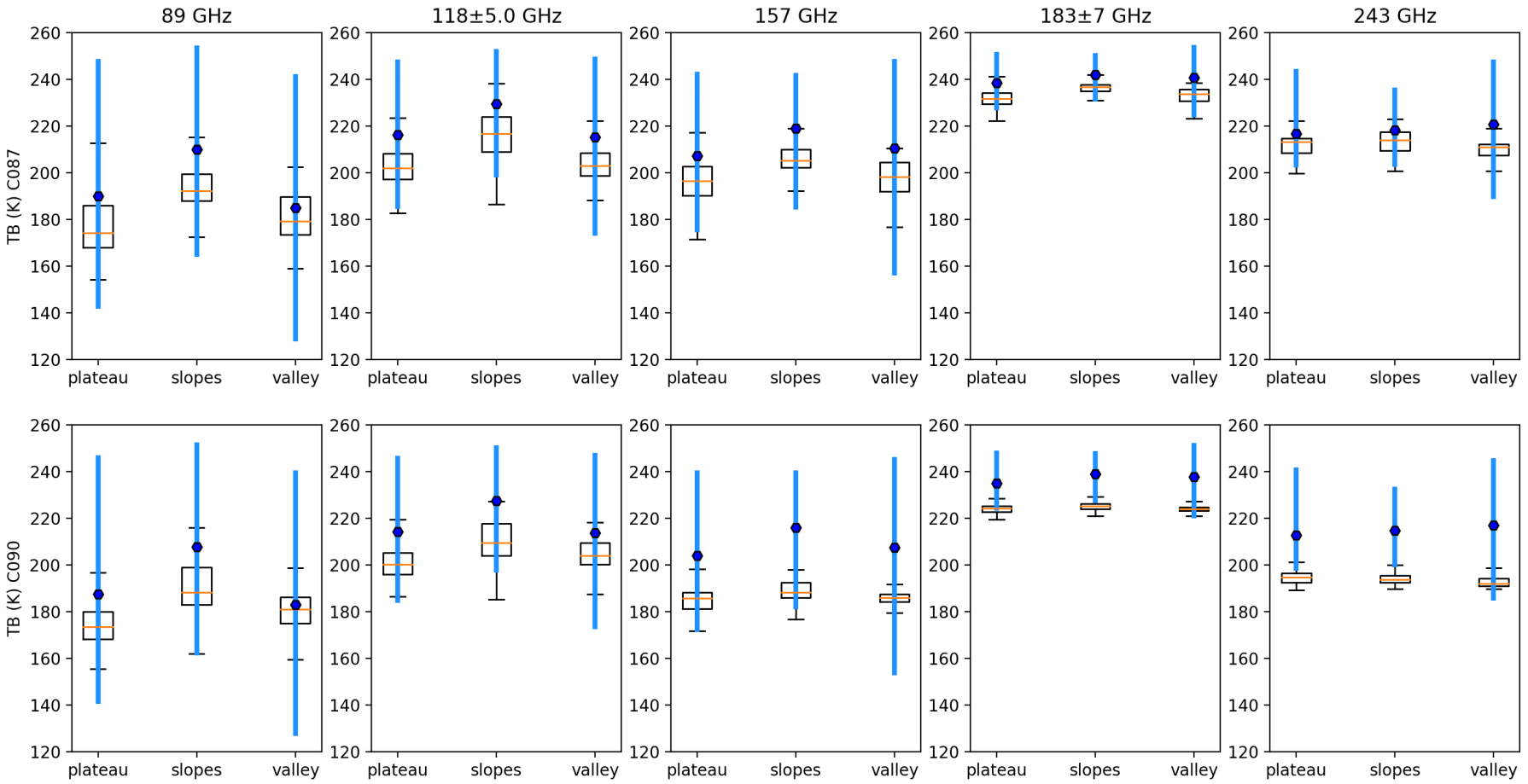
SMRT+ARTS

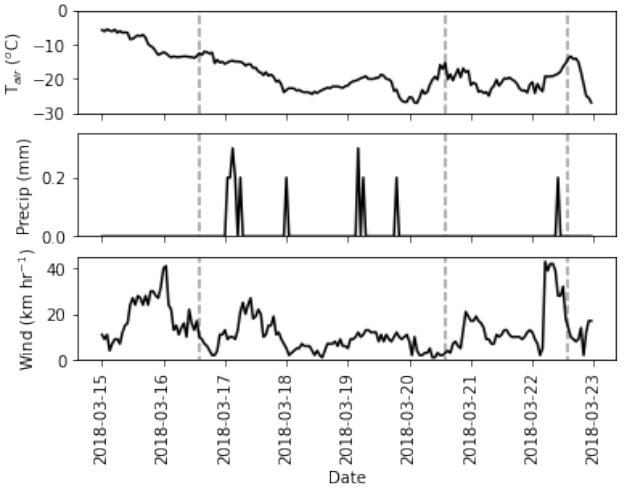




- Field campaign 14-22nd March 2018
- Pits classified as plateau / valley / slopes
- 3 airborne flights @ ~500m

SMRT+ARTS





- Underlying topography
- Difference between flights

Sandells et al., 2023 (pre-print)

Summary

- Need substrate unless semi-infinite
- Can specify soil / reflectivity / rough interface model
- Argument when creating snowpack or additive

- Needed at higher frequencies
- SMRT has basic atmosphere (TB does not depend on θ)
- For more complicated – couple with ARTS

Schaufenster Fischereihafen