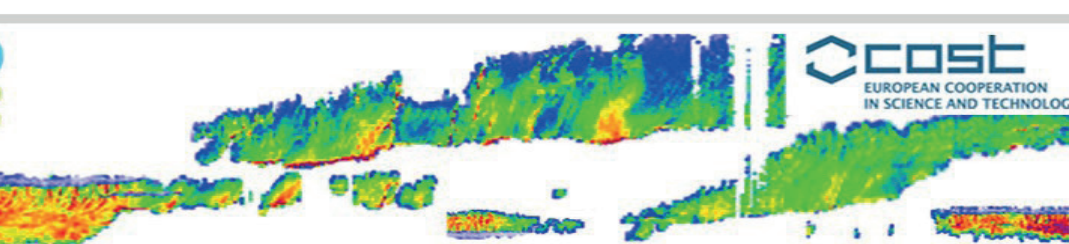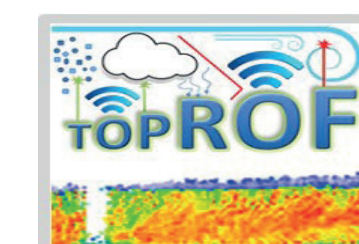# Bodengebundene Mikrowellenradiometer zur Atmosphärensondierung in der Vorhersage:
Fehlermodell, Kalibration, Rauschanalyse, Qualitätskontrolle, Datenformate

Harald Czekala, Gerrit Maschwitz, Emilano Orlandi, Thomas Rose [1]
Ulrich Löhnert, Susanne Crewell [2],
Nico Cimini [3] [4], Francesco De Angelis [4]

RPG Radiometer Physics — A Rohde & Schwarz Company

Introduction: RPG-HATPRO-G5 - Humidity And Temperature PROfiler („Sounder")

Direct Detection Filter-Bank Design
7 channel water vapour band (22 to 31 GHz)
7 channel oxygen band (51 to 58 GHz)
All channels parallel @1s res. (100% duty cycle)

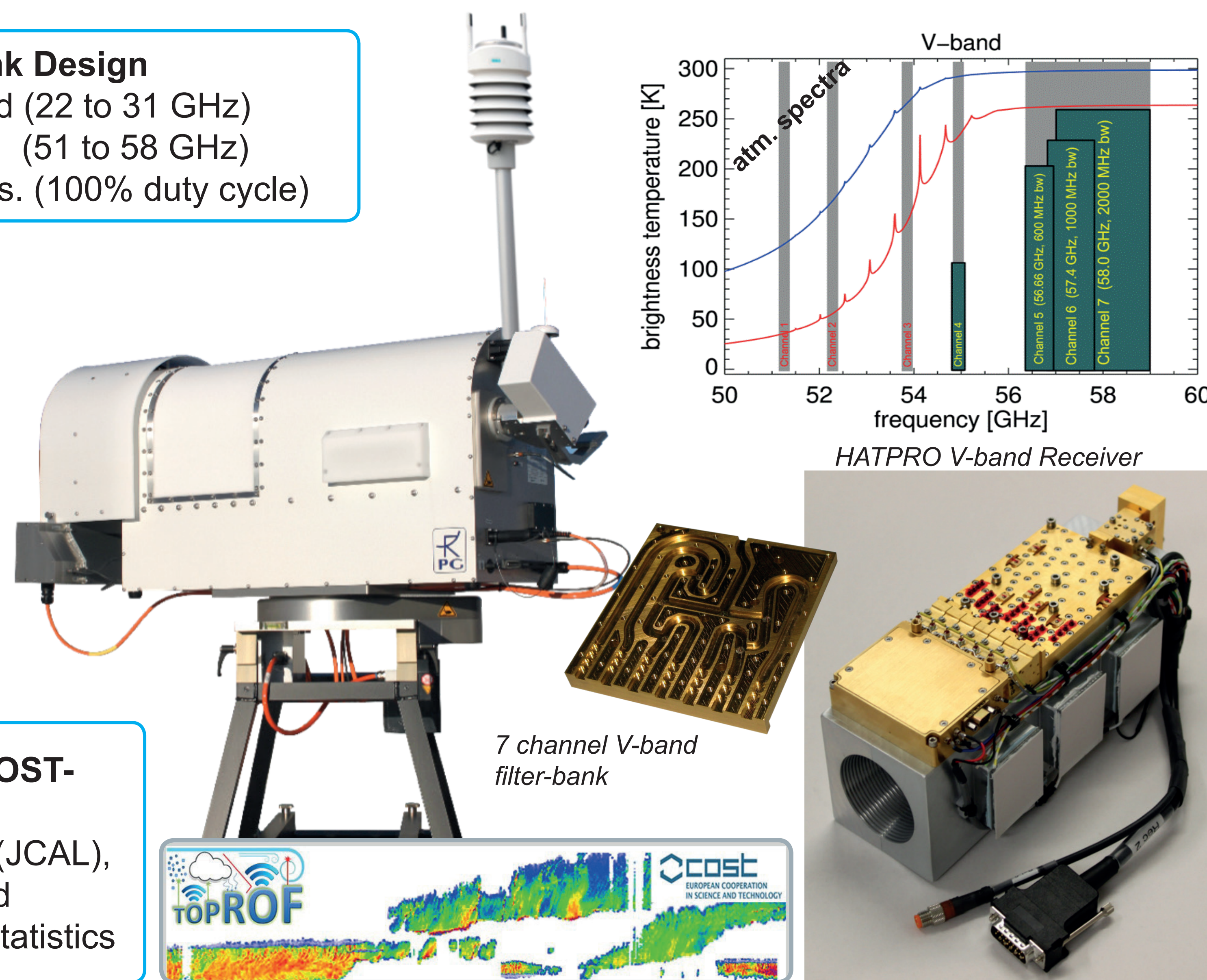**Individual Band-Passes**
200 MHz – 2000 MHz
→ optimized TB sensitivity

Network Suitable
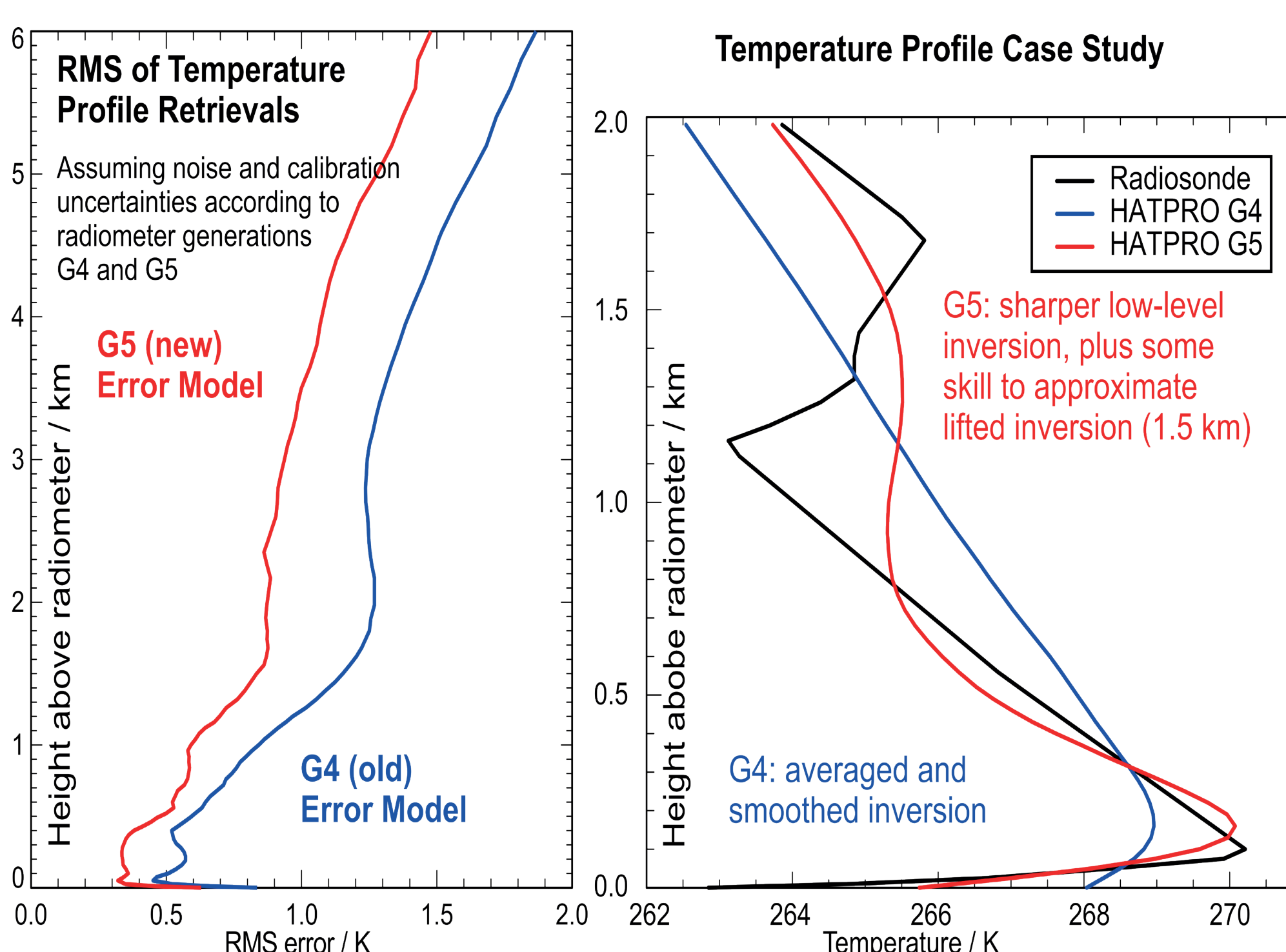TCP/IP interface, internal monitoring, house-keeping data, sanity checks, automatic alerts

Standardization Efforts (COST-TOPROF)
Joint calibration campaigns (JCAL), format requirements, forward operator (RTTOV-gb), O-B statistics

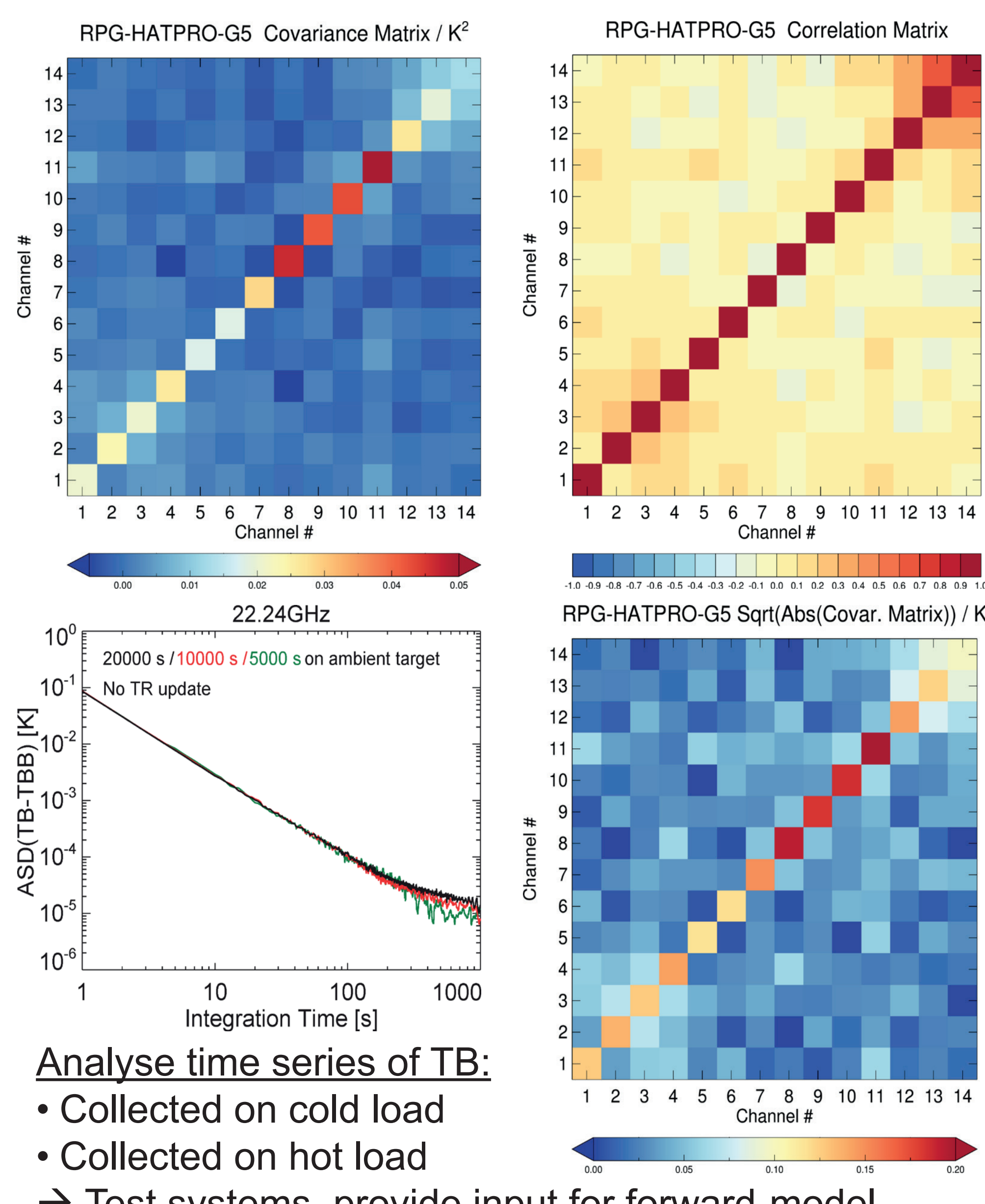*7 channel V-band filter-bank*

HATPRO V-band Receiver

Generation 5 (G5) Improvements

- Rapid noise switching (64 Hz) at all channels
- Novel precision calibration approach
  → Improved noise performance ($\leq$0.05 K RMS @10s integration time)
  → Improved radiometric stability
- → retrievals profit in RMS
- → more degrees of freedom / added features

RMS of Temperature Profile Retrievals — Assuming noise and calibration uncertainties according to radiometer generations G4 and G5. G5 (new) Error Model. G4 (old) Error Model.

Temperature Profile Case Study — Radiosonde, HATPRO G4, HATPRO G5. G5: sharper low-level inversion, plus some skill to approximate lifted inversion (1.5 km). G4: averaged and smoothed inversion.

Receiver Covariance, RMS, Allan Std.-Dev.

RPG-HATPRO-G5 Covariance Matrix / K²
RPG-HATPRO-G5 Correlation Matrix
22.24GHz
RPG-HATPRO-G5 Sqrt(Abs(Covar. Matrix)) / K

20000 s / 10000 s / 5000 s on ambient target. No TR update.

Analyse time series of TB:
- Collected on cold load
- Collected on hot load
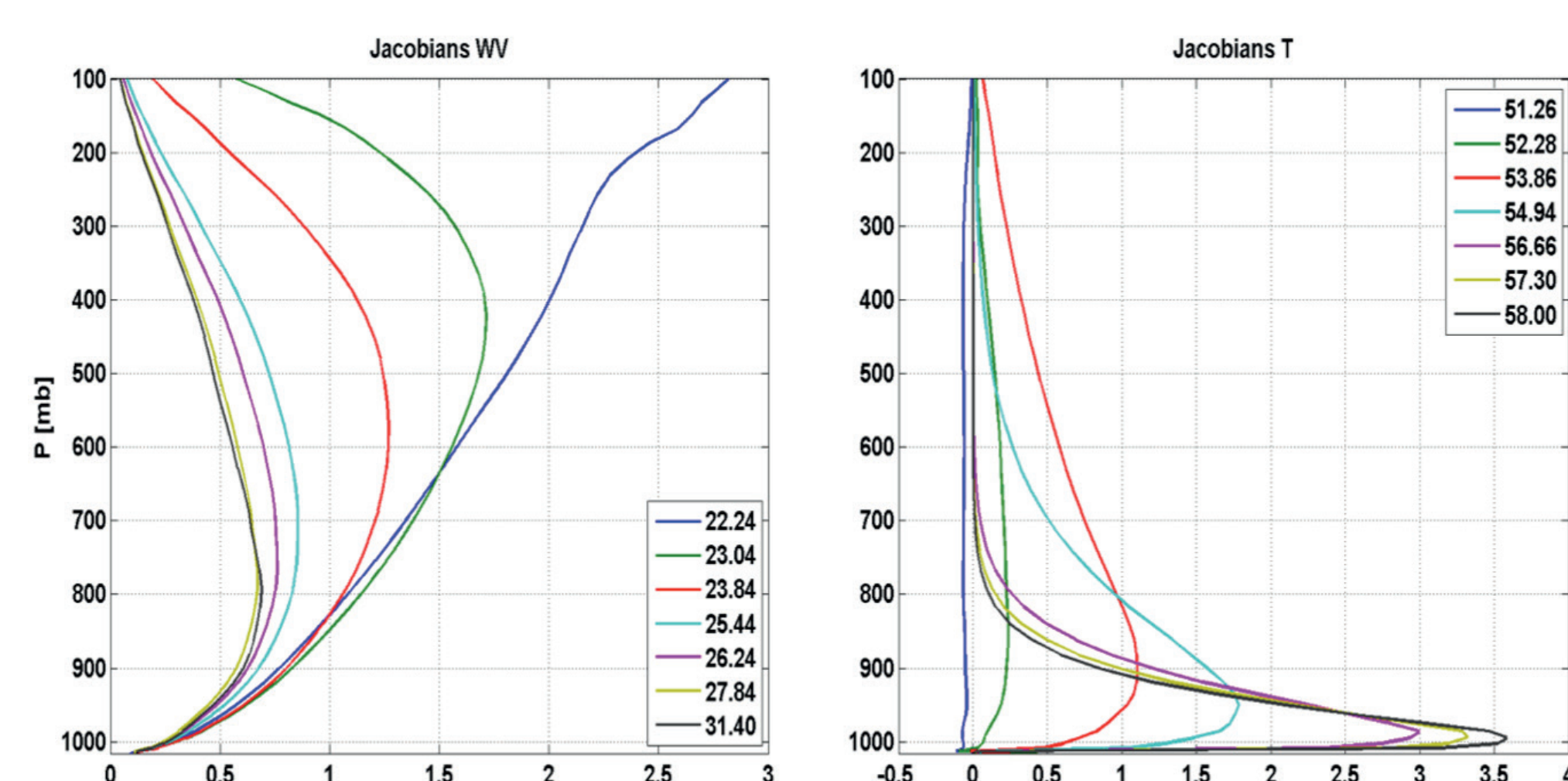→ Test systems, provide input for forward-model

Forward Operator: RTTOV-gb

Triggered by COST-TOPROF, adaption of RTTOV:
(De Angelis et al., Geoscientific Model Development, 2016)

- From satellite perspective to ground-based
- Multiple elevation angles, RMS < 0.2 K
- Provides TB / Jacobians → Radiance Assimilation

Future distribution: usual RTTOV release channels

- Example of Jacobians for water vapour and temperature profiles (vertical pointing only).

Jacobians WV — 22.24, 23.04, 23.84, 25.44, 26.24, 27.84, 31.40
Jacobians T — 51.26, 52.28, 53.86, 54.94, 56.66, 57.30, 58.00

Automatic Quality Checks → Blacklisting

Using spectral retrieval $\mathrm{TB_{INS}} = f(\mathrm{TB_{measured}})$
- Calculate instrument's $\mathrm{TB_{INS}}$ spectrum using
  - Finite band-passes (integrate TB within filter)
  - Finite beam effects
  - Covariance and calibration errors
- Deviations (measured TB versus INS-spectrum):
  → **problem with hardware or model statistics**
- **Automatic checks in server software**

Diffs (TB-Ref),(SPC-Ref) (K,V) — *Side-by-Side comparison at 1 s sampling*
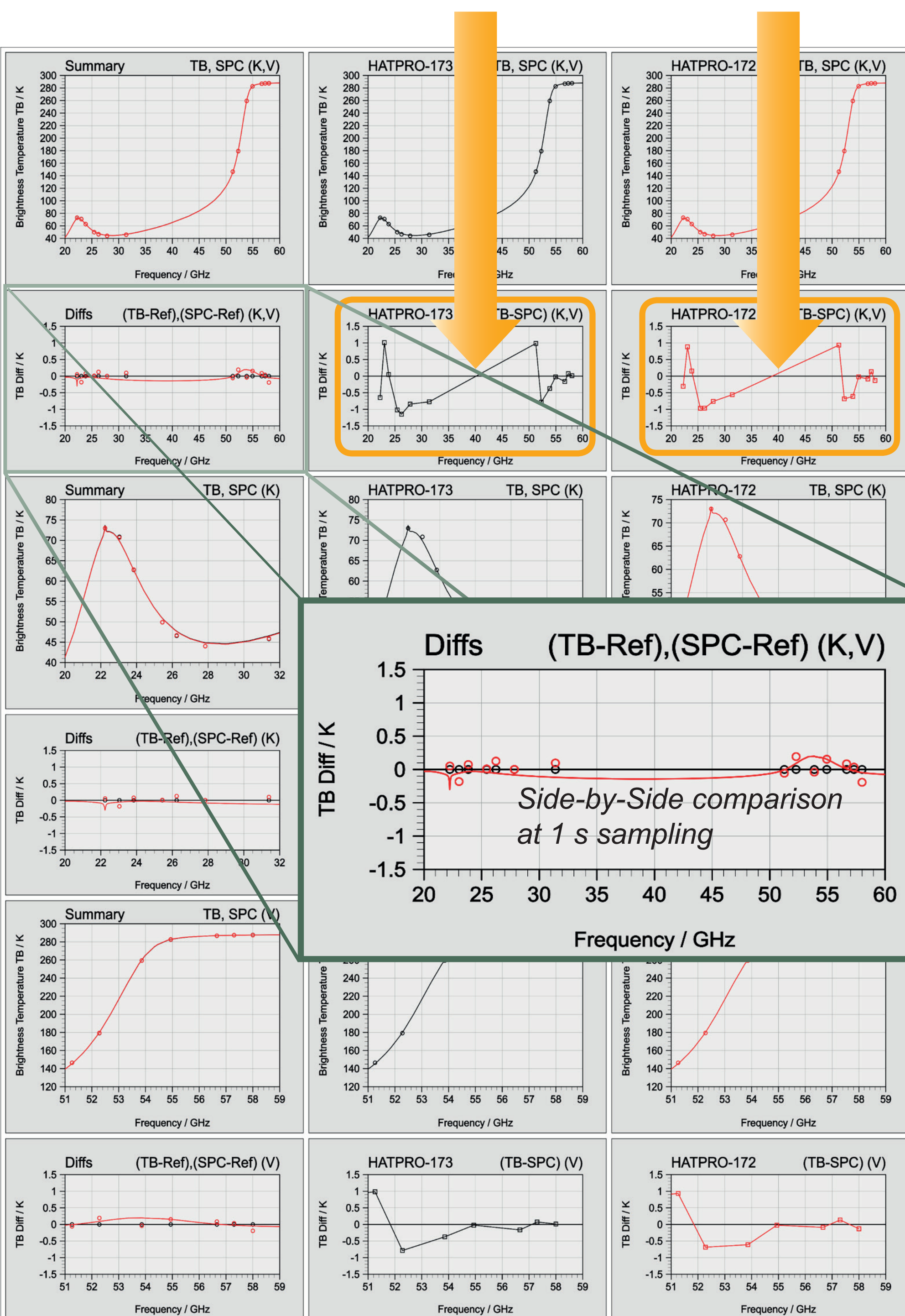
G5 Calibration Procedures

G5 receivers require more precise calibration

- New design for cold calibration (liquid nitrogen) target
- → No reflections at target
- → No standing waves
- → Minimized evaporation of LN2
- → Minimized entrainment of oxygen
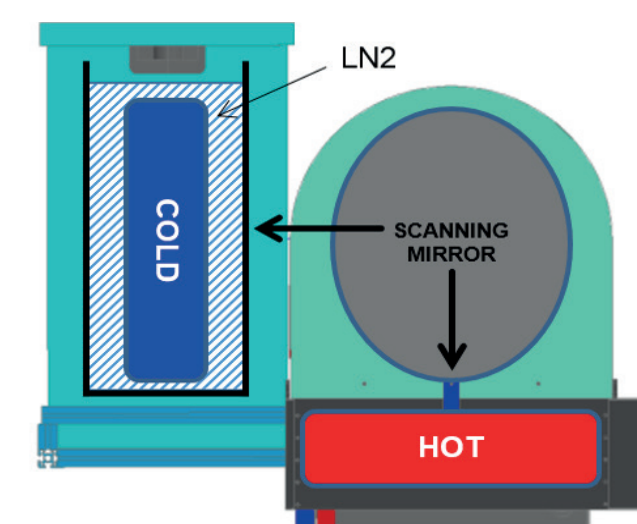
Absoulte TB Accuracy / Repeatability ±0.15 K

Data Files, Formats: NetCDF-CF 1.6

Client/server Software for data-streaming
Automatic checks + meta-data updates

L1B: per sensor, Microwave-TB, IRR-TB, ...
L1C: co-located on time-grid
L1D: derived L1 like *cloud-removal* from TB
L2B: retrieved products (T,Q,IWV, LWP,...)

Meta-Data-L1: Covar-Matrix, calibrations, filters, ...
Meta-Data-L2: Retrieval type, data source, RTM, ...

Conclusion & Recommendations

By joint efforts with the user community (COST-TOPROF), the latest Generation-5 MWR have reached maturity in precision, stability, robustness, and software tools.
MRW data assimilation can now start and close the observation gap in the boundary layer.

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RPG Radiometer Physics — A Rohde & Schwarz Company

www.radiometer-physics.de/download/PDF/Radiometers/HATPRO/RPG-DA.pdf

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