1D variational retrievals of boundary layer temperature profiles from ground-based microwave radiometers in an Alpine valley

Pauline Martinet

D. Cimini, F. De Angelis, G. Canut, A. Paci, V. Unger

1 : Météo France, CNRM-UMR3589
2 : IMAA-CNR
3 : CETEMPS, University of L'Aquila
Content

- Motivation
- Overview of the Passy-2015 field experiment
- AROME forecast errors in stable conditions
- 1D assimilation of MWR data into AROME
Motivation of the study

Remote sensing:
- radar
- lidar
- sodar

Satellite

Aircraft

Balloon

Weather station
Motivation of the study

- Remote sensing: radar, lidar, sodar
- Satellite
- Aircraft
- Balloon
- Weather station
- Pollution
- Fog
- Storms

PBL: very few data of temperature and humidity

Remote sensing:
- radar
- lidar
- sodar
Motivation of the study: benefit from ground-based microwave radiometer

- Continuous measurements
- Clear-sky and cloudy-sky
- Information content mainly residing in the boundary layer

Remote sensing:
- radar
- lidar
- sodar
The Passy-2015 field experiment

- **Mountainous regions** are known for complex atmospheric situations: anabatic and katabatic winds, strong temperature inversions.
- The Arve river valley near Chamonix suffers from high **pollution** events during wintertime anticyclonic conditions.
- **NWP models** suffer from large **forecast errors** during very **stable** boundary layer.

View of the Arve River Valley on 11 February 2015 from Paci et al 2016

Conceptual scheme of wind circulation in moutainous region Courtesy T. Sabatier
A HATPRO ground-based microwave radiometers has been deployed down the valley.

Collocated with radiosondes launched every 3 hours during 13 days of IOP in February 2015.

Many instruments: ceilometers, wind profilers, aerosol lidars, tower measurements ...

http://passy.sedoo.fr/
Overview of the Passy 2015 experiment

- Persistent temperature inversions
- Destruction of the stability only between noon and 3 to 5 pm
- Temperature cooling up to -10°C at the surface well described by the MWR
AROME forecast errors during the Passy-2015 experiment

- Small errors (within 2 K) at 1500m stable during the IOP: **synoptic circulation** decoupled from the valley circulation

- High correlation between **surface temperature** error and atmospheric stability
From brightness temperatures (BT) to atmospheric profiles: 1D-Var retrievals

Model Space: T, Q, LWC

\( x_b = \text{Background} \)

1h AROME forecast

Radiative Transfer (F)

ARTS

BT simulation (F(x))

Observation: y

Minimization of the cost function J:

\[
J(x) = (x - x_b)^T B^{-1} (x - x_b) + (y - F(x))^T R^{-1} (y - F(x))
\]

Iterative minimization
Adjustment of the background profile

Can be run everywhere, evaluation of NWP analysis improvement

Convergence, slow (with ARTS), specification B matrix, R matrix

1D assimilation in the AROME model

Temperature RS/Radiometer 07 Feb 2015 06:04

Temperature RS/Radiometer 13 Feb 2015 02:56

RS
AROME

altitude [m]
temperature [K]
1D assimilation in the AROME model

Temperature RS/Radiometer 07 Feb 2015 06:04

Temperature RS/Radiometer 13 Feb 2015 02:56
1D assimilation in the AROME model: RMSE with respect to radiosondes

Clear-sky (56 cases)

Cloudy-sky (25 cases)
1D assimilation in the AROME model: RMSE with respect to radiosondes

**Clear-sky (56 cases)**

- RMSE < 1K
- Main improvement for \( z < 2000 \) m
- 8K to 0.5 K

**Cloudy-sky (25 cases)**

- Stratus: from 4.5 K to 2.4 K
- 4.5 K to 0.3 K

---

1DVAR Arome
AROME 1h forecast
What benefit from MWR can we expect in NWP models?

Radiosonde

1h AROME forecasts
Before assimilation
What benefit from MWR can we expect in NWP models?

Radiosonde

1h AROME forecasts
Before assimilation

1D AROME analysis
After assimilation
The 1DVAR can also be adapted for BL processes studies.
The 1DVAR can also be adapted for BL processes studies.
Conclusions

Main Results

- Temperature retrievals with an **accuracy of 0.5 to 1 K** with highest information content in the boundary layer **below 2 km**
- Large **improvement** of AROME forecasts through 1D assimilation of MWR data: from **8 K to 0.5 K** RMSE
- Significant benefit can be expected in NWP models by the assimilation of MWR brightness temperatures
- **High temporal resolution** for a fine description of atmospheric processes in the boundary layer and future 4DVAR assimilation
Conclusions

Main Results

- Temperature retrievals with an **accuracy of 0.5 to 1 K** with highest information content in the boundary layer **below 2 km**
- Large **improvement** of AROME forecasts through 1D assimilation of MWR data: from **8 K to 0.5 K** RMSE
- Significant benefit can be expected in NWP models by the assimilation of MWR brightness temperatures
- **High temporal resolution** for a fine description of atmospheric processes in the boundary layer and future 4DVAR assimilation

Future Prospects

- Use of the fast radiative transfer model **RTTOV-gb** on an extensive dataset (1 year of data, six instrumented sites)
- **Data assimilation** (1D-Var + 3D-Var or direct 3D-Var) and **reanalysis of experimental campaigns** to evaluate the improvement in NWP forecasts especially during fog conditions.
THANKS FOR YOUR ATTENTION

References:

Passy campaign website: http://passy.sedoo.fr/

Martinet et al, 2017, AMT, submitted: 1D variational retrievals of boundary layer temperature profiles from ground-based microwave radiometers in an Alpine Valley

Martinet et al, 2015, Tellus: 1D-Var temperature retrievals from microwave radiometer and convective scale model