Assimilation of Cloud-Affected Infrared Radiances in HIRLAM 4D-Var

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Outline

- **Methodology**
  - Observation operator / Satellite data used
- **Evaluation of the observation operator**
  - B-O / Cloudy Jacobians
- **4D-Var case study**
  - Analysis increments / Observation departures of B and A
- **Forecast experiments**
  - Experimental framework / Forecast skills
- **Summary**

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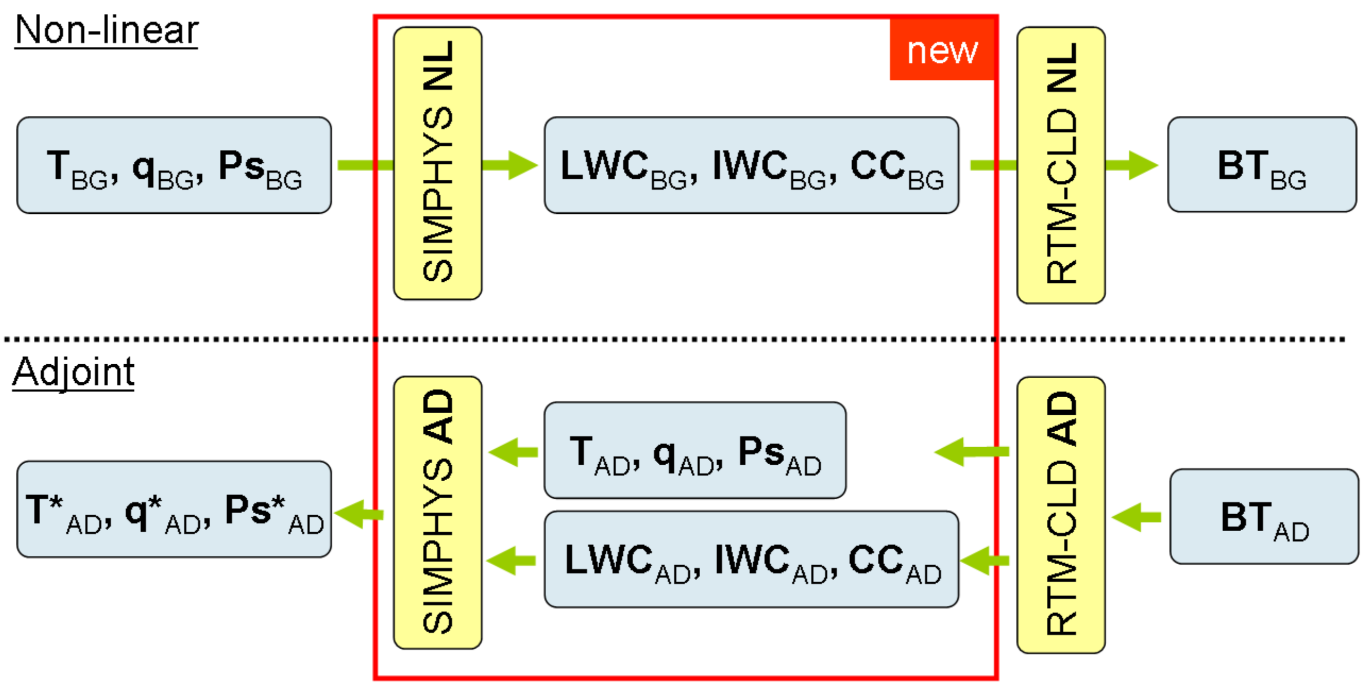
Methodology

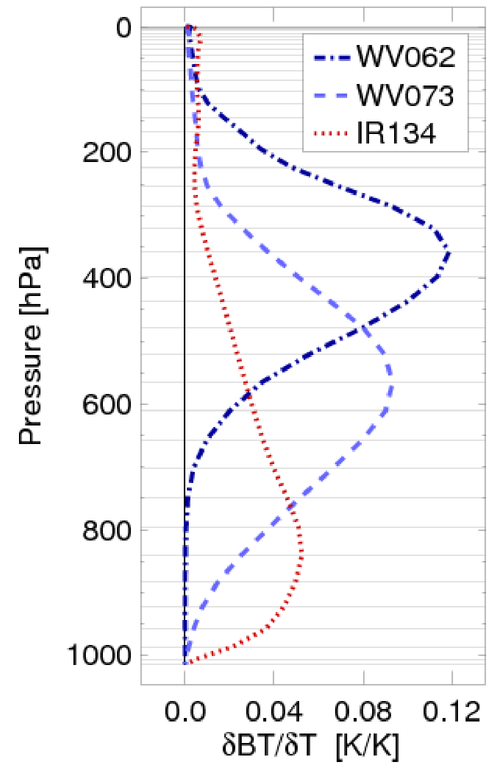
- **Modified observation operator in HIRLAM**
  - Extended observation operator as in Chevallier et al. (2004)
  - **SIMPHYS**: Simplified moist physics; convection (Lopez & Moreau, 2005), large-scale cloud scheme (Tompkins & Janisková, 2004)
  - **RTM**: RTTOV-8.7 using advanced RTTOVCLD interface
  - Modelled cloudiness exists within the obs. operator only



Methodology

- **SEVIRI data:**
  - WV062, WV073, IR134 radiances
  - Super-observations (5x5 pixel box)
  - NWCSAF cloud mask “fraction” (CF)
  - NWCSAF cloud-top pressure
- **Observation selection**
  - Cloudiness in observations and in SIMPHYS
  - Defining ‘broken clouds’: 0.1 < CF < 0.9
  - Defining ‘overcast’: CF = 1.0
  - Reject scenes with 0.9 < CF <1.0 to avoid strong non-linearities

Clear-sky T-Jacobians



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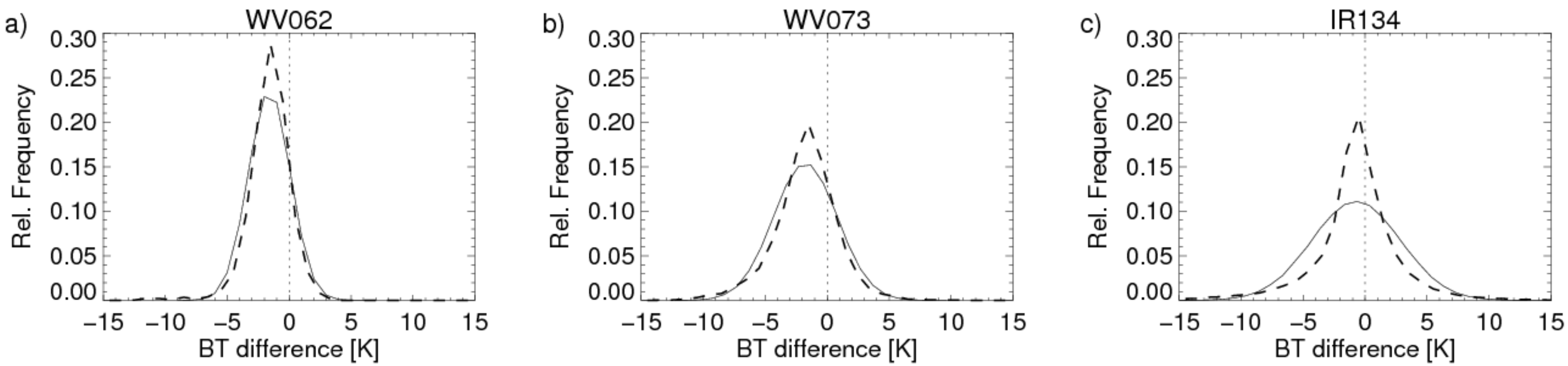
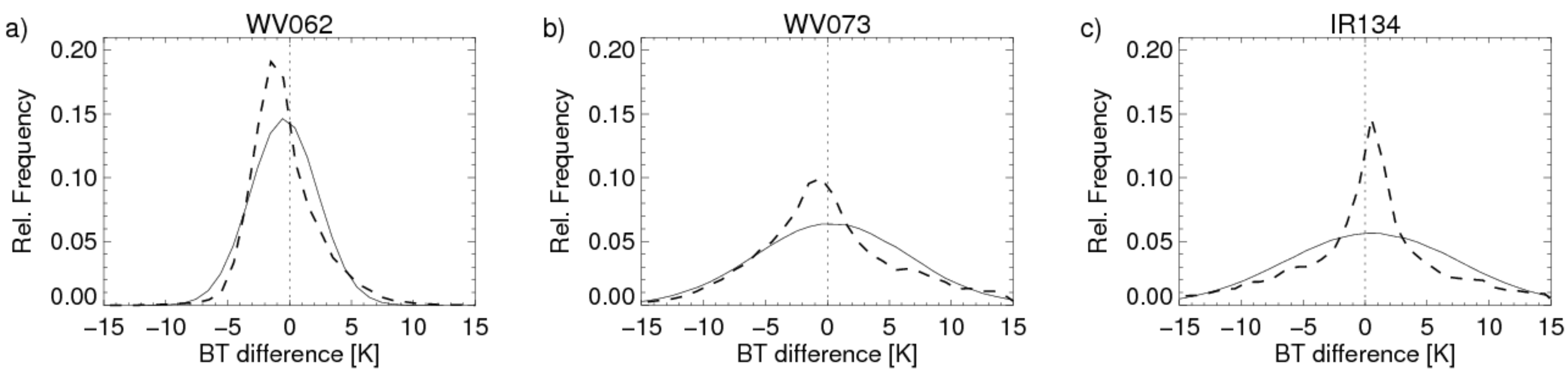
Evaluation of the observation operator

- **Background - observations departures**
  (observations passively monitored)

Broken clouds (0.1<CF<0.9):

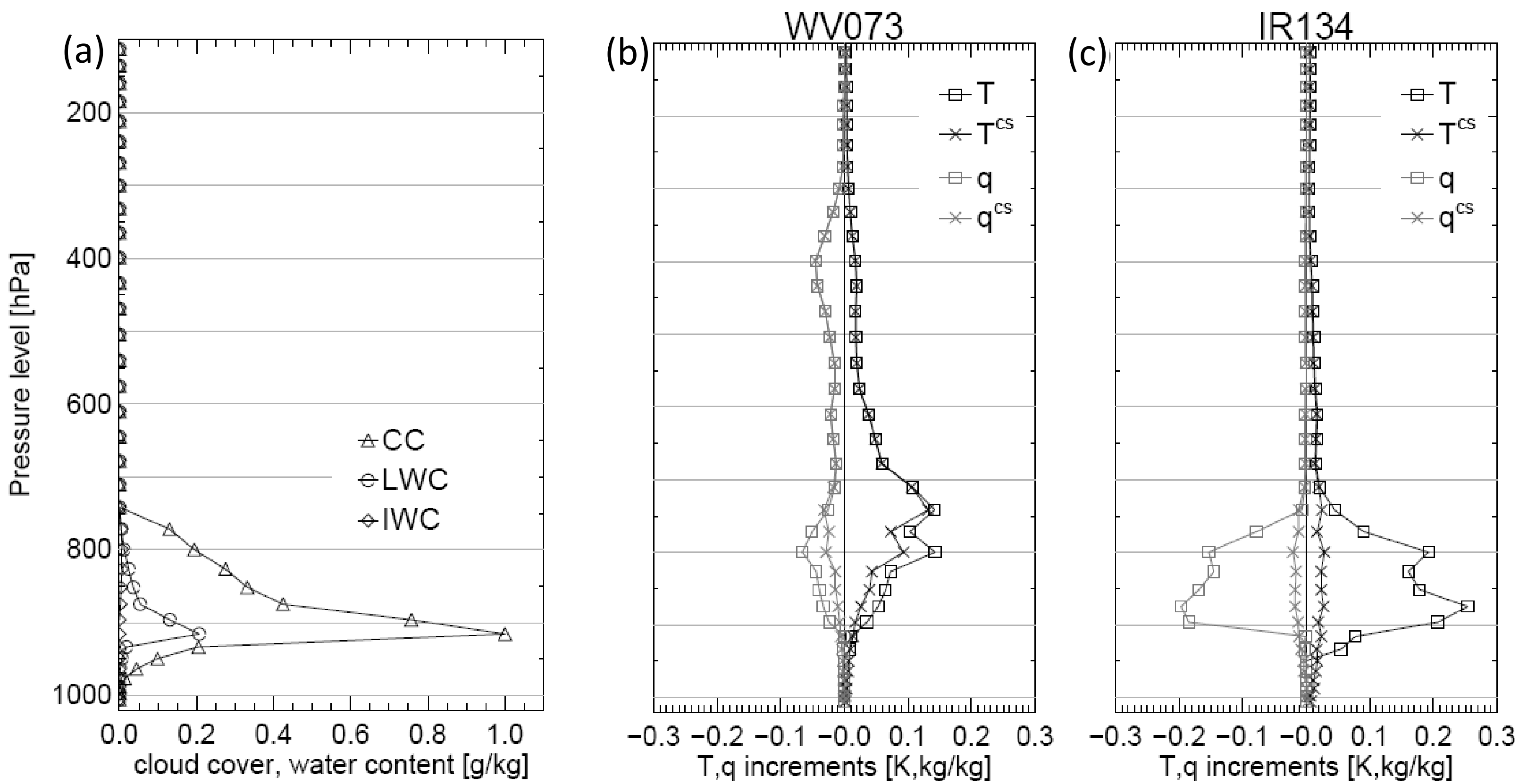


Overcast (CF=1.0):



Evaluation of the observation operator

- **Jacobians in the presence of clouds**
  (Derived using the Adjoint of the observation operator)



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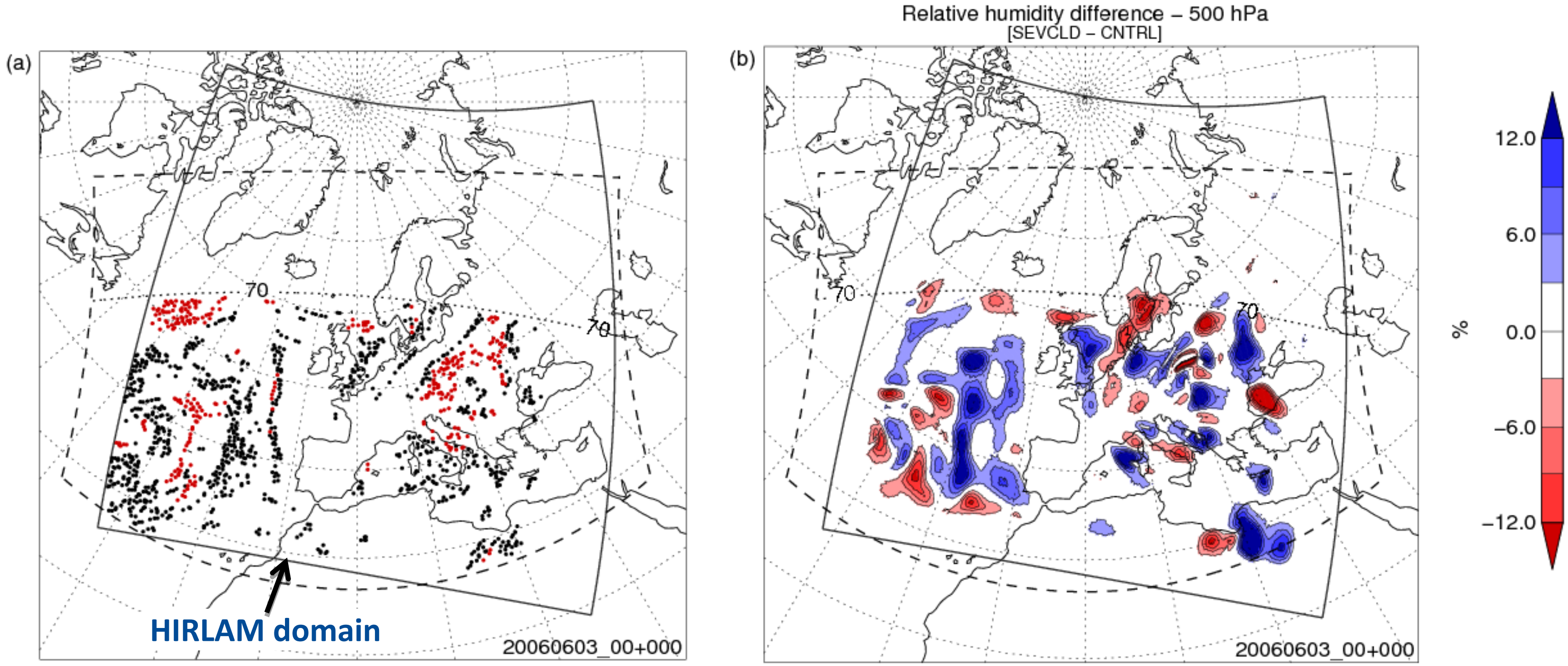
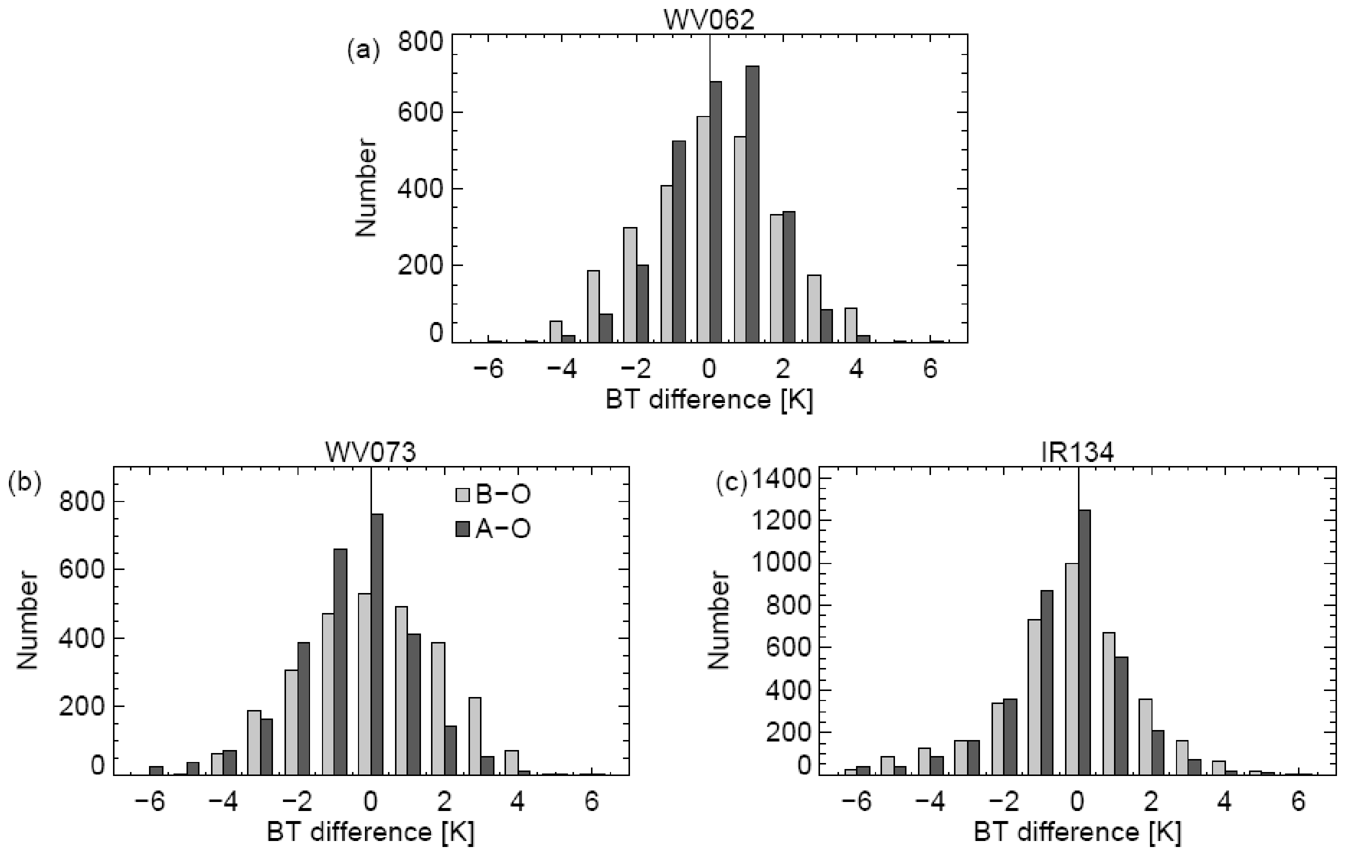
4D-Var case study

- **Assimilated observations & Analysis increments**
  Plots shown are for the centre of the 4th obs. window (12 UTC)
  (Similar increments are found for wind)



4D-Var case study

- **Observation departures of analysis and background**



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Forecast experiments

- **Experimental framework**
  - 3 experiments, 2 months (July, August 2006)
  - 4D-Var 6-hourly, 2 outer-loops, 6h assimilation window

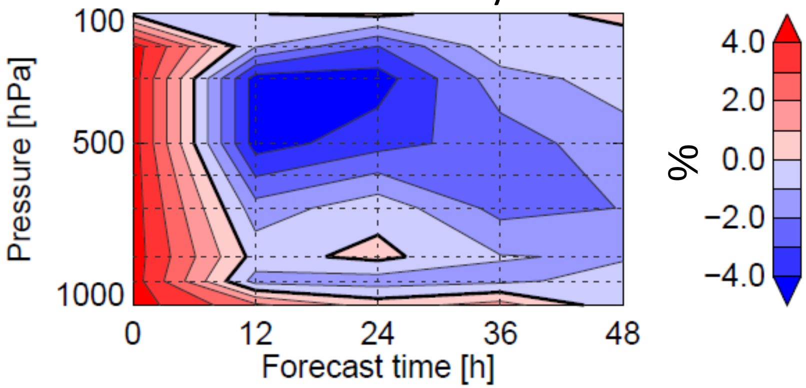
  - **CNTRL**
    → Conventional observations
  - **SEV_CLEAR**
    → Conventional observations
    → SEVIRI radiances in clear-sky and low-level cloud conditions
  - **SEV_ALLSKY**:
    → Conventional observations
    → SEVIRI radiances in clear-sky and low-level cloud conditions
    → SEVIRI radiances affected by clouds

Forecast experiments

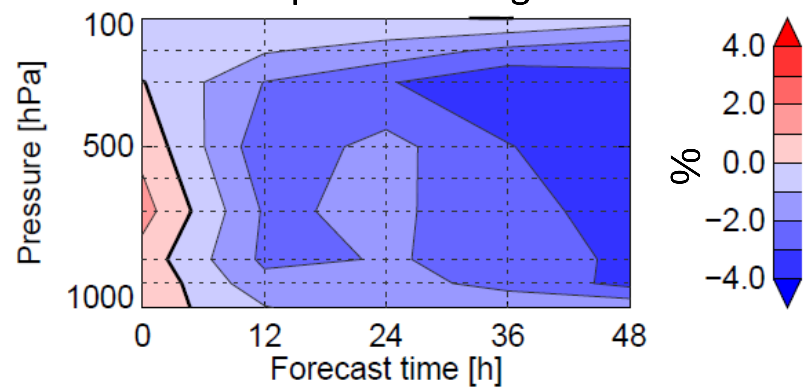
- **Relative change in forecast error**

SEV_CLEAR vs. CNTRL

Rel. Humidity

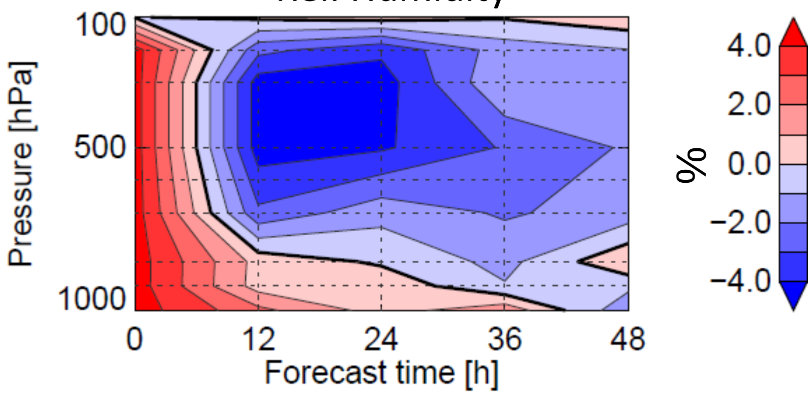


Geopotential height

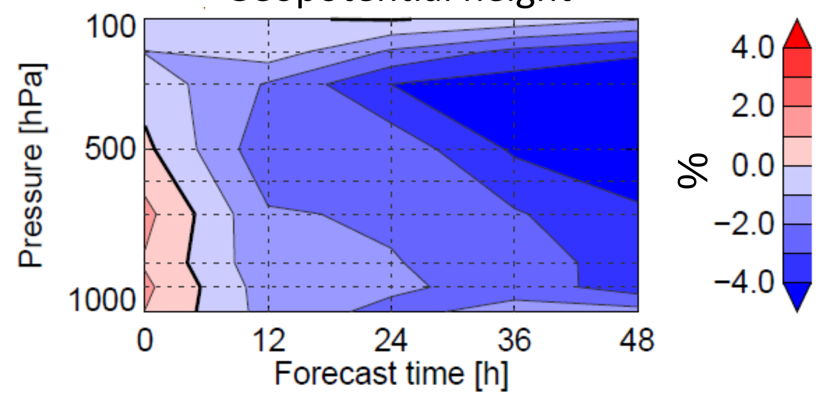


SEV_ALLSKY vs. CNTRL

Rel. Humidity

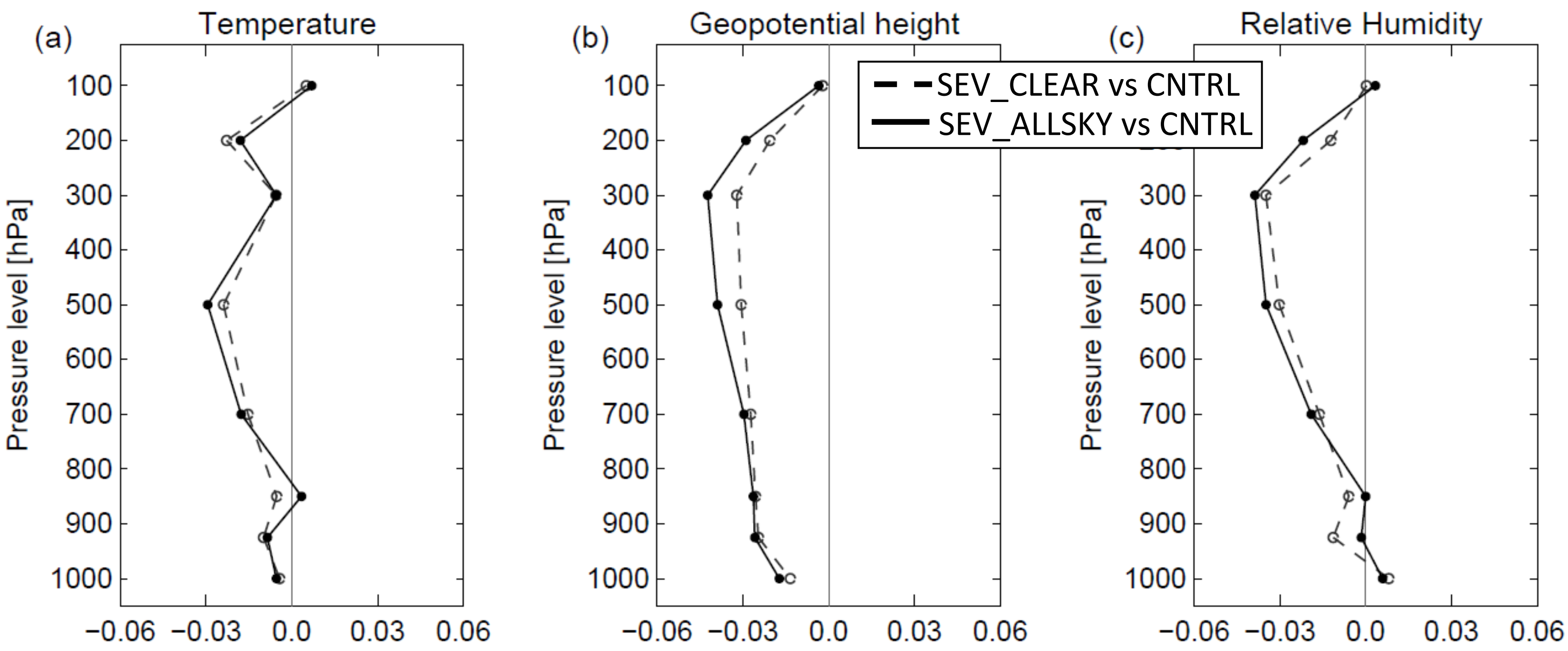


Geopotential height



Forecast experiments

- **Relative change in forecast error**
  (Averaged over 12h, 24h, 36h, and 48h forecast lengths)



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Forecast experiments

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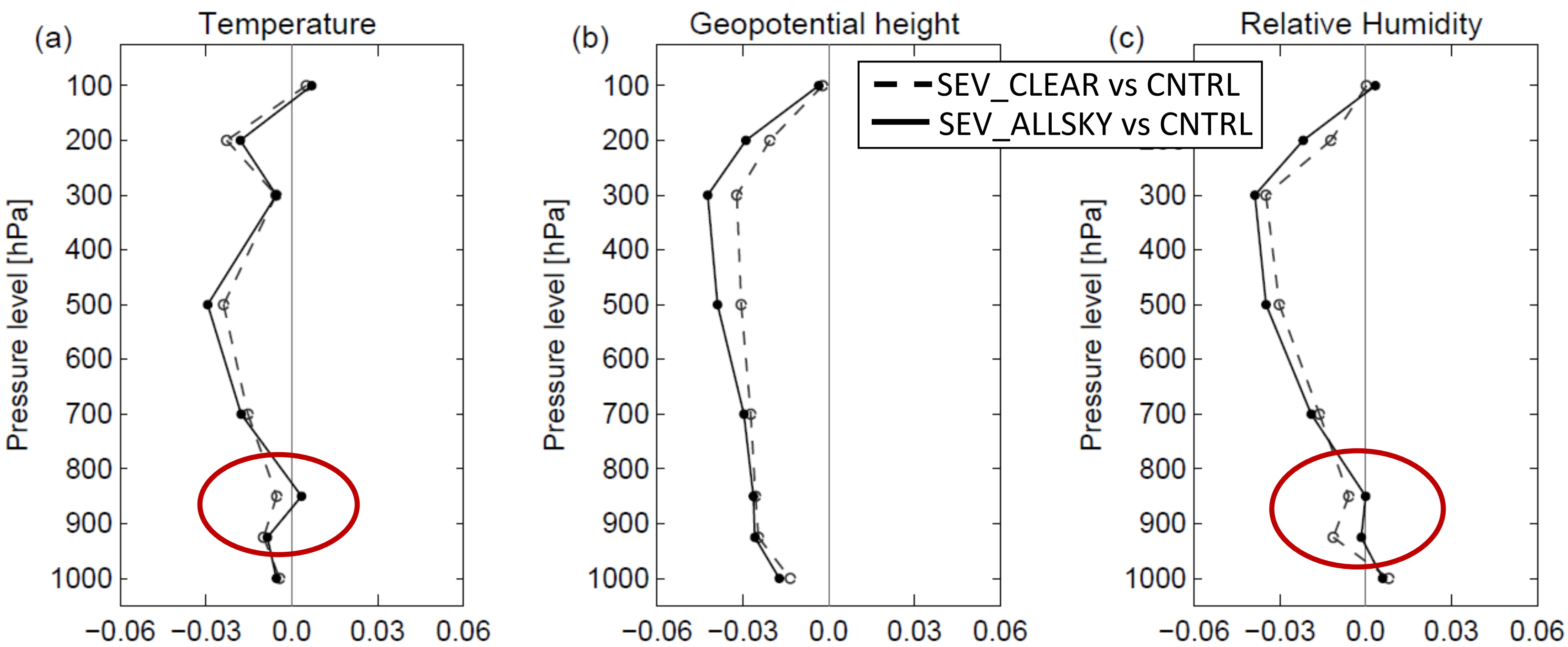

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Summary & Outlook

- **Remaining tasks**
  - Problems in the lower troposphere
  - Strong non-linearities occur near cloud fraction of 1
    1. Check if strong non-linearities can be expected
    2. More ‘outer-loops’ in 4D-Var to update Jacobians
  - Other data selection issues
  - Observation errors and Bias correction to be revised (currently taken from Std and mean of B-O in preceding monitoring period)
  - Redo experiments with AMSU-A included
  - ....

Summary & Outlook

- An extended observation operator has been introduced into the limited area NWP model HIRLAM and the capabilities of this operator have been tested using cloud-affected SEVIRI IR radiances (Stengel et al., 2010)
- Evaluation of the OO and preliminary forecast experiments show promising results
- Some remaining challenges have been identified and will be addressed and investigated in the near future
- In general, the approach used is also applicable to other instruments

References

Chevallier F, Lopez P, Tompkins A, Janiskova M, Moreau E. **(2004)**. The capability of 4D-Var systems to assimilate cloud-affected satellite infrared radiances. *Q. J. R. Meteorol. Soc.* 130(598).

Lopez, P. & Moreau, E. **(2005**). `A convection scheme for data assimilation: Description and initial tests', *Q. J. R. Meteorol. Soc.* 131, 409-436.

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Tompkins, A. M. & Janisková , M. (**2004**). A cloud scheme for data assimilation: Description and initial tests, *Q. J. R. Meteorol. Soc.* 130, 2495-2518.

Undén, P., Laura Rontu, Heikki Järvinen, Peter Lynch, et al. (**2002**). “HIRLAM-5 Scientific Documentation” *available SMHI*, S-601 76 Norrkoping, Sweden

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Thank you!

Evaluation of the observation operator

- **Linearity test**
  - Correlation coefficients of TL vs. NL increments

$(\mathbf{H}(\delta\mathbf{x}))$ $\qquad$ $(H(\mathbf{x}^b + \delta\mathbf{x}) - H(\mathbf{x}^b))$

	Broken clouds - high	Overcast - high
WV062	0.95 (0.96) ✓	0.88 (0.87) ✓
WV073	0.89 (0.92) ✓	0.70 (0.72) ✗
IR134	0.82 (0.87) ✓	0.66 (0.74) ✗

	Broken clouds - low	Overcast - low
WV062	* (*)	* (*)
WV073	0.95 (0.96) ✓	0.88 (0.94) ✓
IR134	0.83 (0.88) ✓	0.62 (0.85) ✗

✓- selected
✗- rejected

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