

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

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**SMHI**



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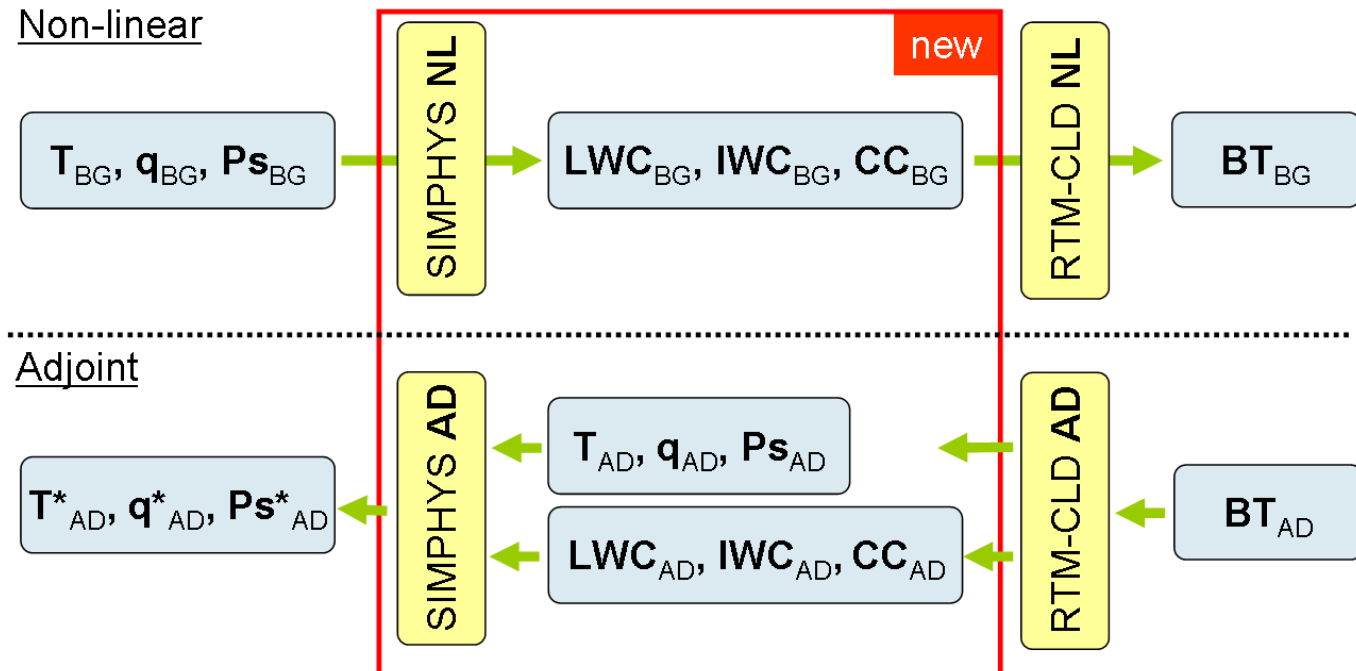
# Outline

- **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**

# 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



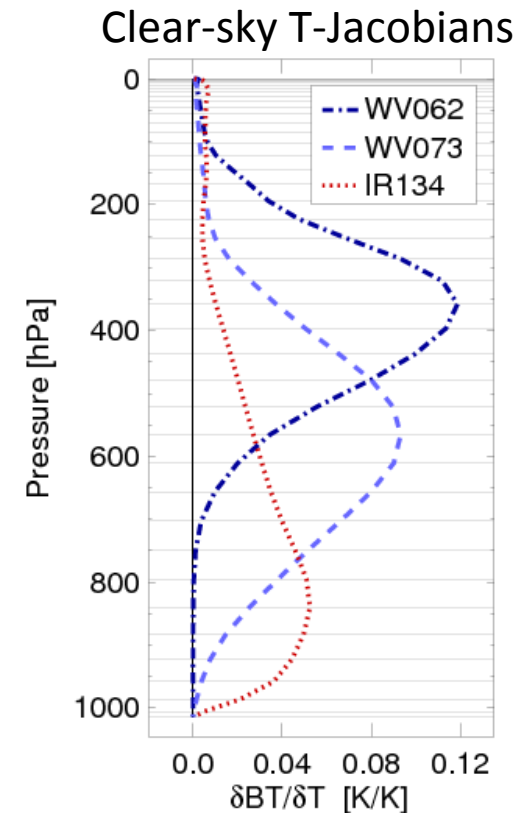
# Methodology

- **SEVIRI data:**

- WV062, WV073, IR134 radiances
- Super-observations (5x5 pixel box)
- NWCSAF cloud mask “fraction” (CF)
- NWCSAF cloud-top pressure

- **Observation selection**

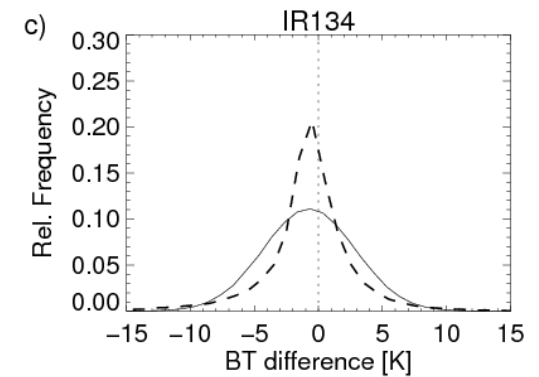
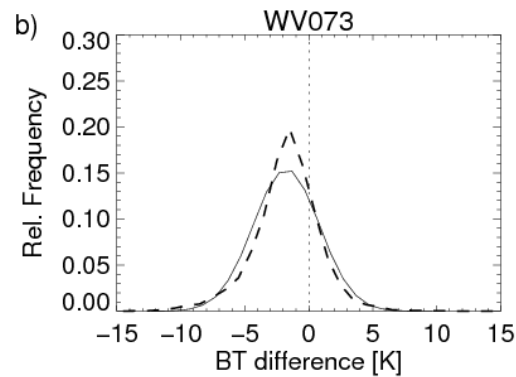
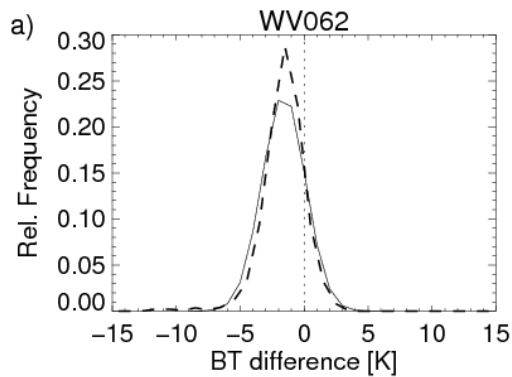
- Cloudiness in observations and in SIMPHYS
- Defining ‘broken clouds’:  $0.1 < CF < 0.9$
- Defining ‘overcast’:  $CF = 1.0$
- Reject scenes with  $0.9 < CF < 1.0$  to avoid strong non-linearities



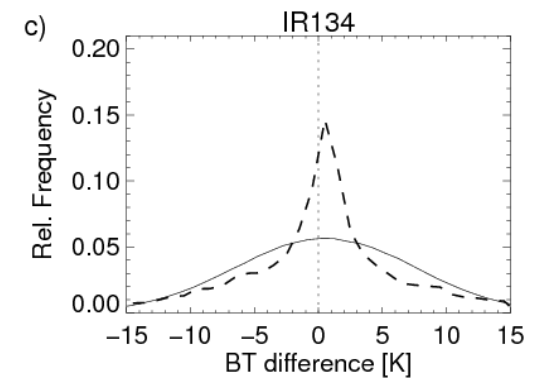
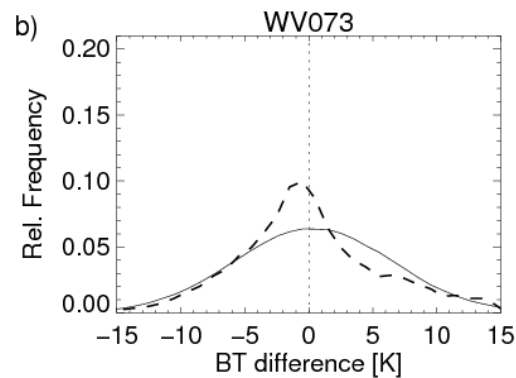
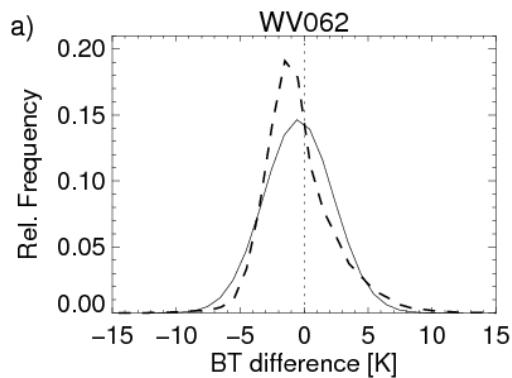
# Evaluation of the observation operator

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

## Broken clouds ( $0.1 < CF < 0.9$ ):

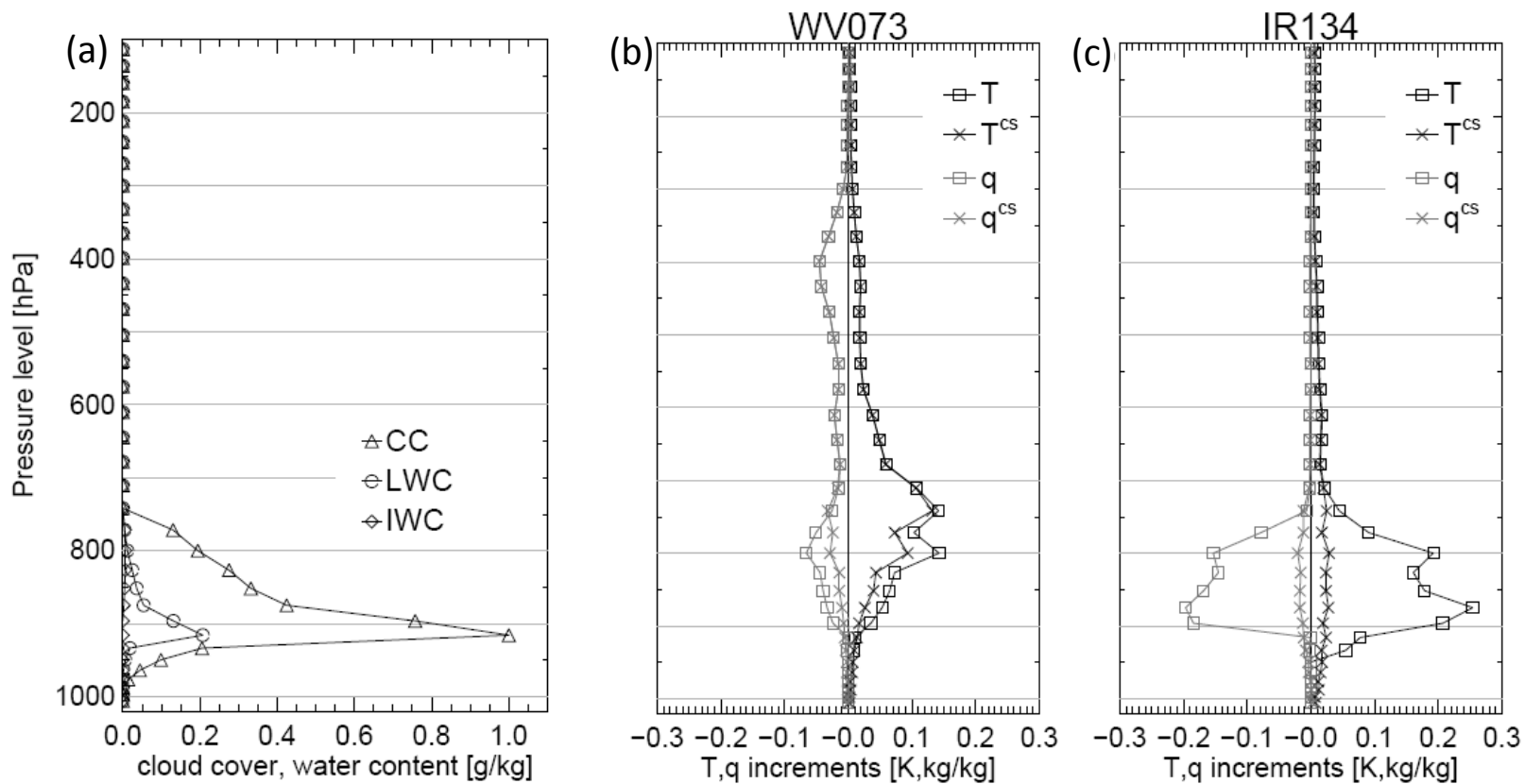


## Overcast ( $CF=1.0$ ):



# Evaluation of the observation operator

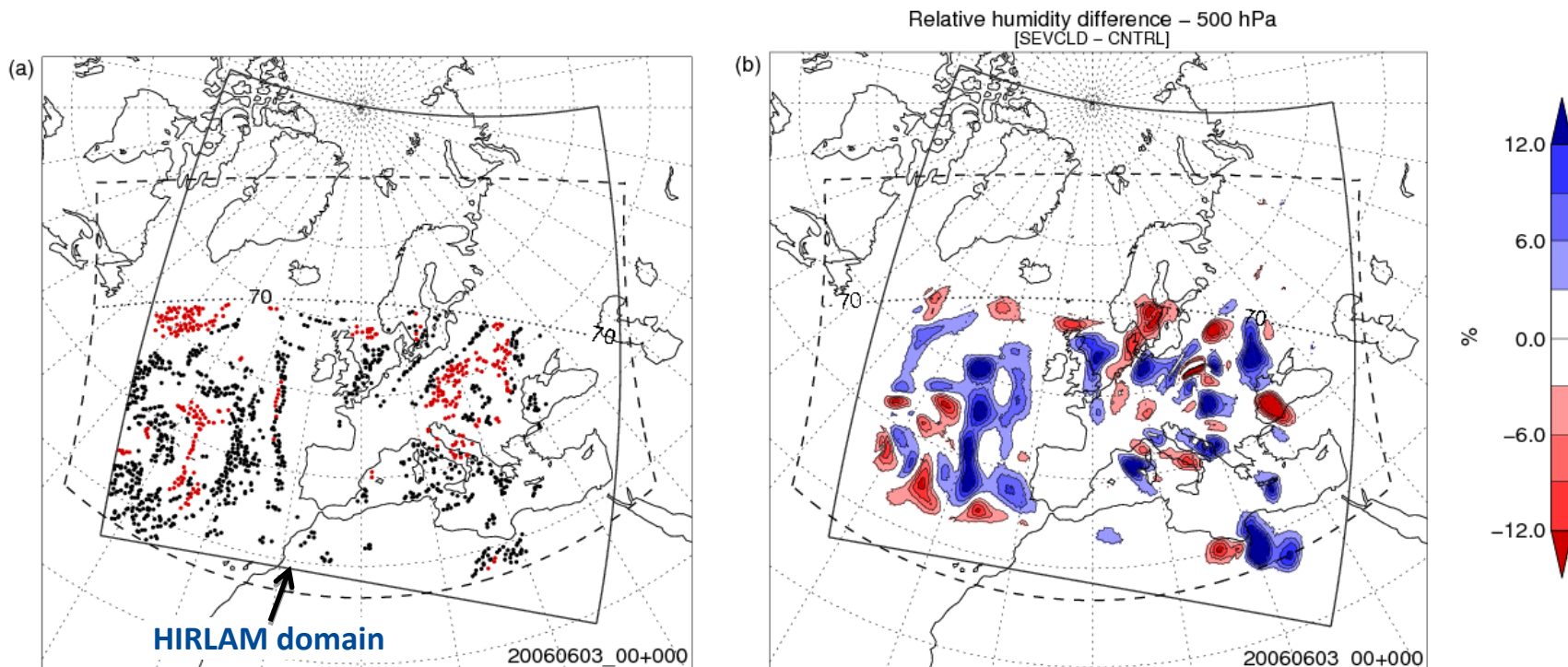
- **Jacobians in the presence of clouds**  
(Derived using the Adjoint of the observation operator)



# 4D-Var case study

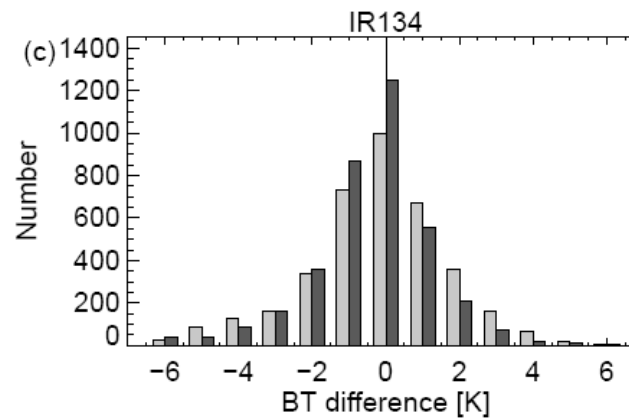
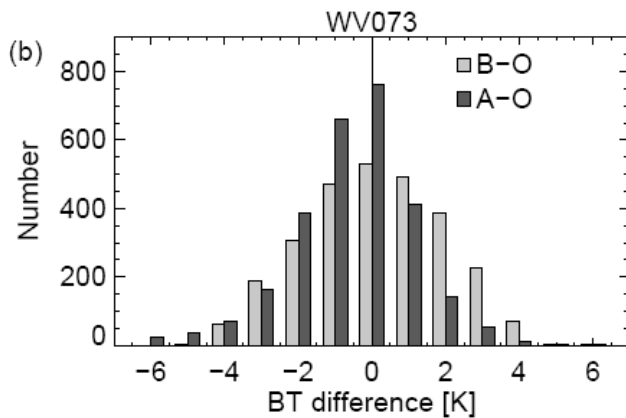
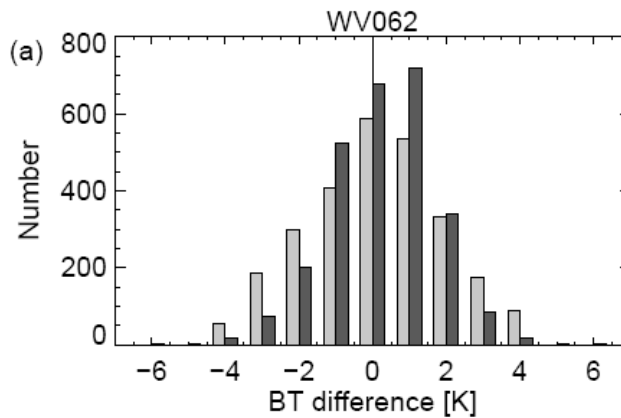
- **Assimilated observations & Analysis increments**

Plots shown are for the centre of the 4<sup>th</sup> obs. window (12 UTC)  
(Similar increments are found for wind)



# 4D-Var case study

- Observation departures of analysis and background





# Forecast experiments

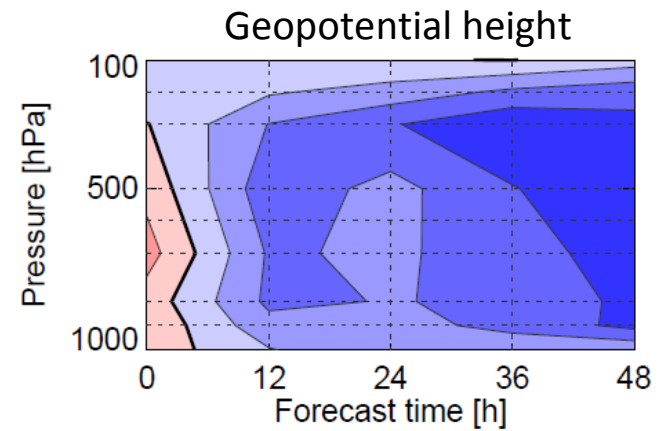
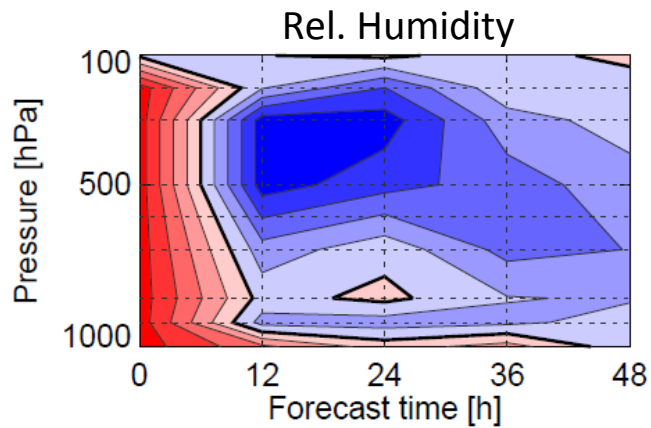
- **Experimental framework**

- 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

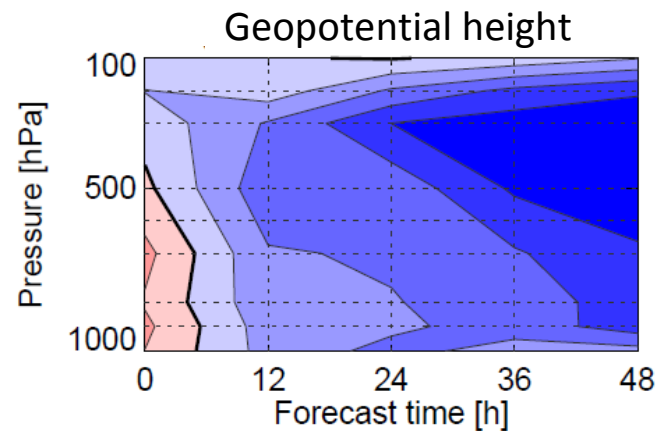
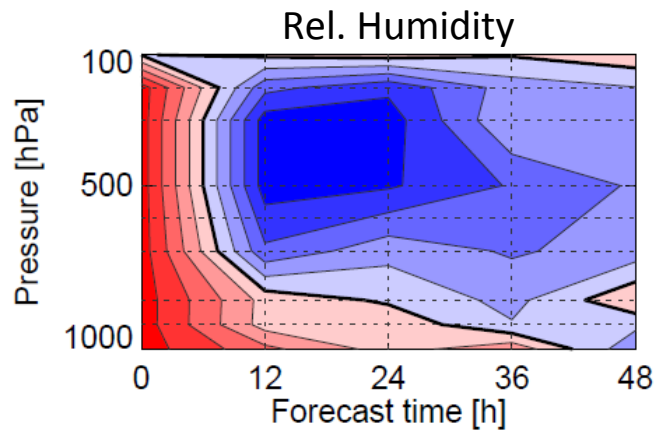
# Forecast experiments

- **Relative change in forecast error**

## SEV CLEAR vs. CNTRL

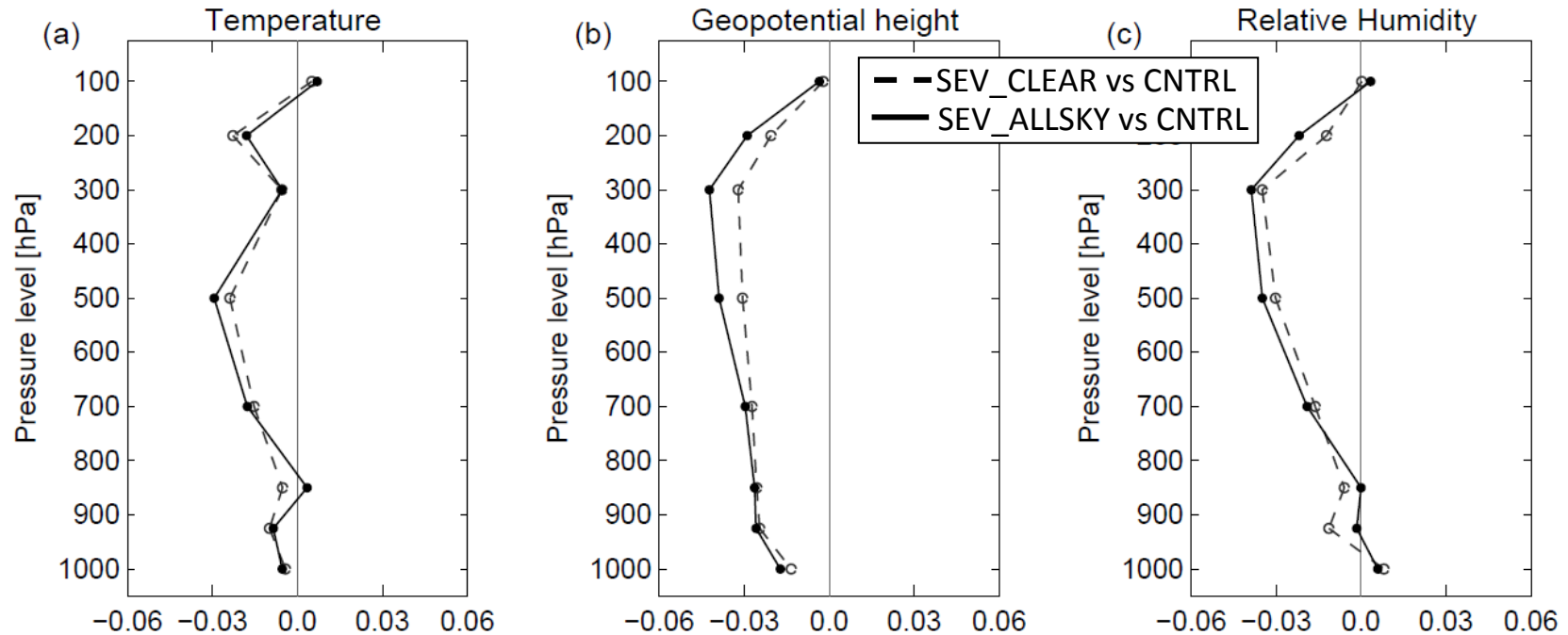


## SEV ALLSKY vs. CNTRL



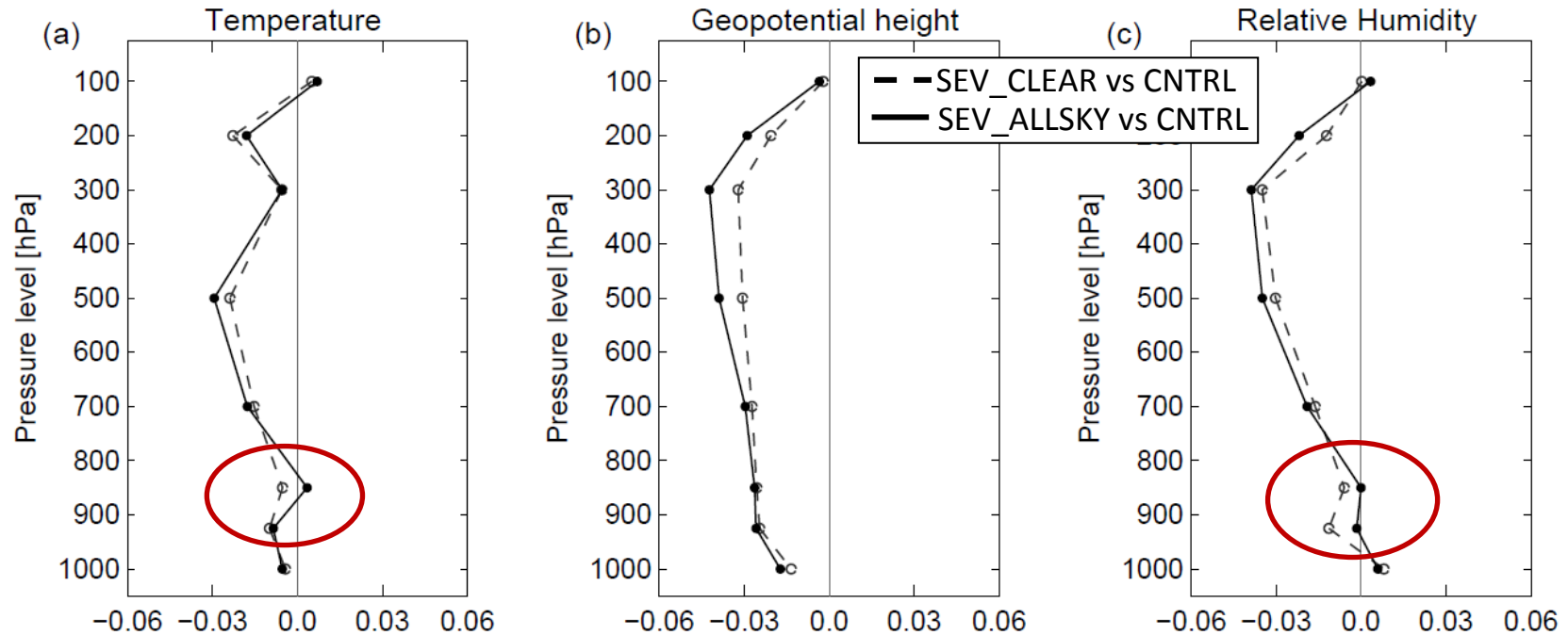
# Forecast experiments

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



# Forecast experiments

- **Relative change in forecast error**  
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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.

**Stengel M., Undén P., Lindskog M., Dahlgren P., Gustafsson N., Bennartz R.(2009).** Assimilation of SEVIRI infrared radiances with HIRLAM 4D-Var. *Q. J. R. Meteorol. Soc.* 135: 2100–2109.

**Stengel M., Lindskog M., Undén P., Gustafsson N., Bennartz R. (2010).** An extended observation operator in HIRLAM 4D-VAR for the assimilation of cloud-affected satellite radiances. *Q. J. R. Meteorol. Soc.* (accepted) .

**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 Norrköping, Sweden*

***Thank you!***



# Evaluation of the observation operator

- **Linearity test**

- Correlation coefficients of TL vs. NL increments

↓                      ↘

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

	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