Schweizerische Eidgenossenschaft
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Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

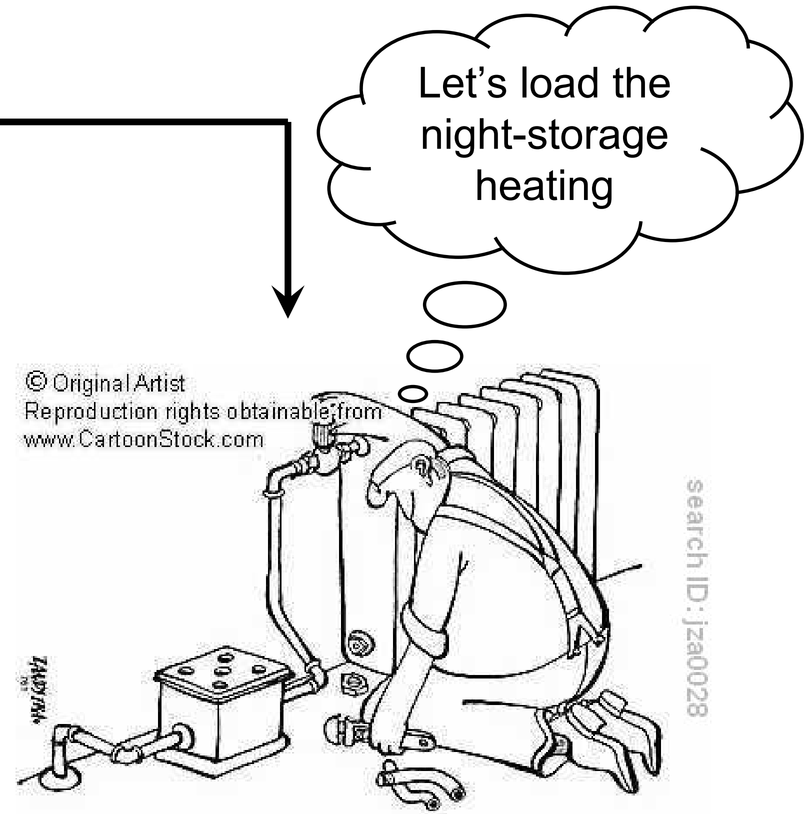
Tailored high-resolution numerical weather forecasts for energy efficient predictive building control

ECAC & EMS, September, 14th 2010

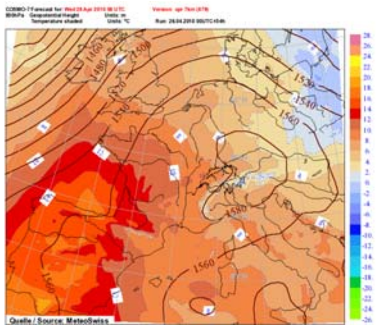
Vanessa Stauch (MeteoSwiss)

DIY predictive indoor climate control

Cold weather forecast

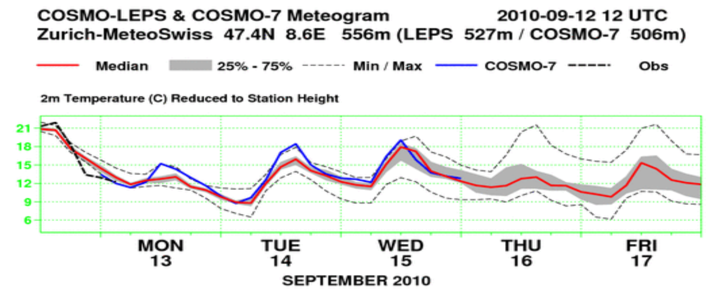


... automatic and optimised

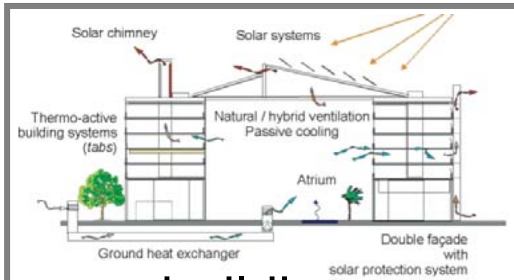


NWP system

statistical adaptation



local forecast



building

measurements

?

control inputs

controller, optimisation

energy costs
comfort requirements

Applied research project OptiControl

Objective

The investigation of the potential benefit of using weather and occupancy forecasts for optimal building climate control

www.opticontrol.ethz.ch

Coordinator, BACLab Software

stochastic model predictive control (SMPC)

Participants

Terrestrial Ecosystems, ETH Zurich: D. Gyalistras, A. Fischlin

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MeteoSwiss, Zurich: P. Steiner, F. Schubiger, V. Stauch

Siemens Switzerland, Zug: D. Habermacher, C. Gähler, M. Gwerder, B. Illi, J. Tödtli

Gruner AG, Basel: A. Seerig, C. Sagerschnig

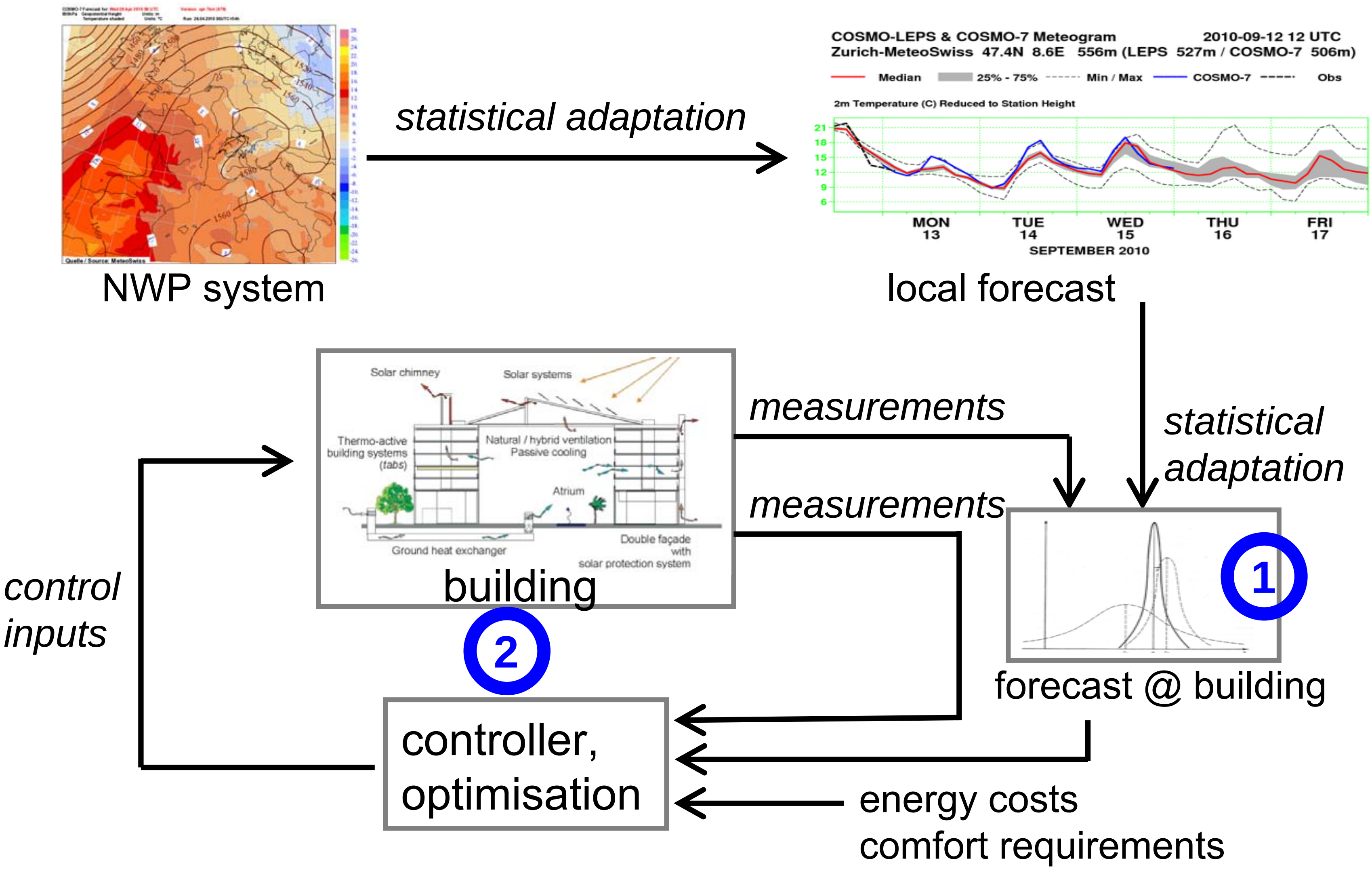
(predictive) rule based control (RBC)

Sponsors

Swiss Electric Research, Switzerland

Competence Centre energy and Mobility, Switzerland

Presentation‘s content



NWP models @ MeteoSwiss

ECMWF IFS (global)

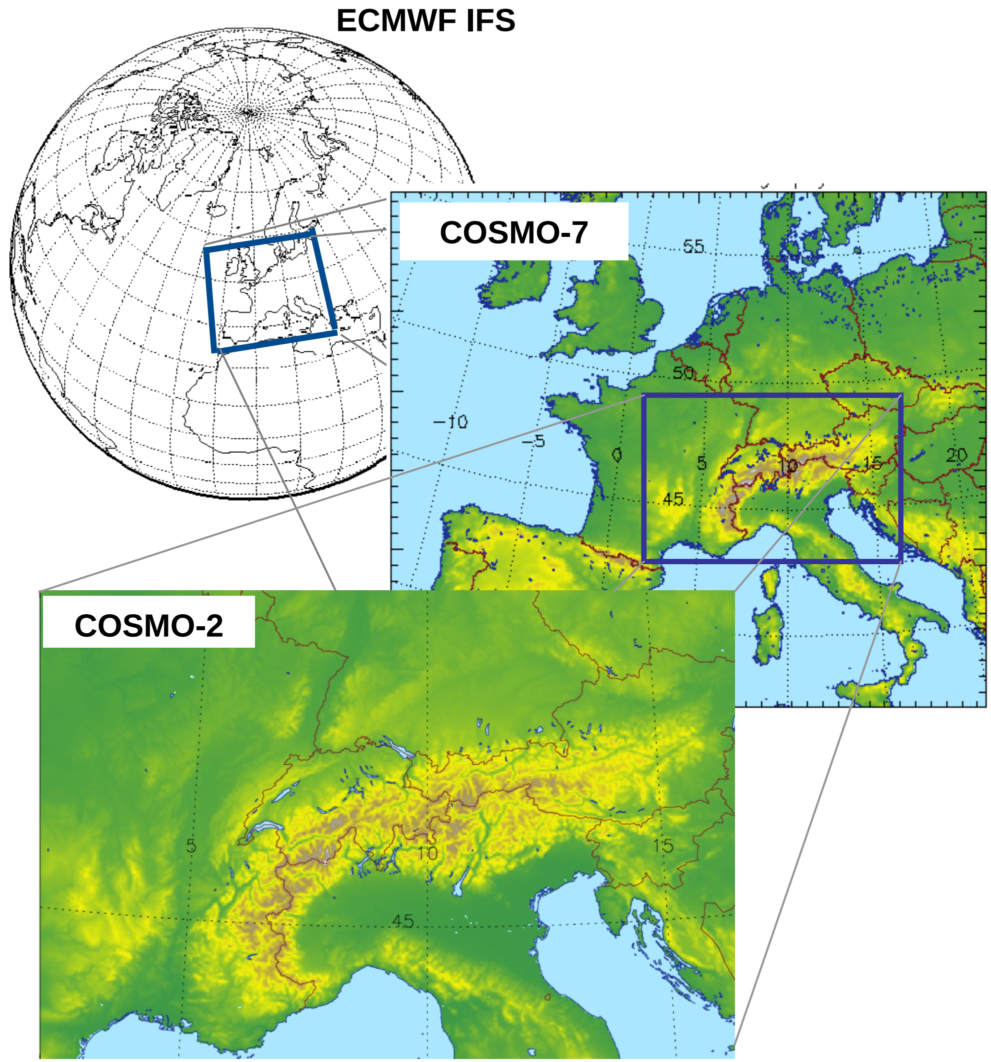
- 16km, 91 layers
- 2 x 240h per day

COSMO-7 (regional)

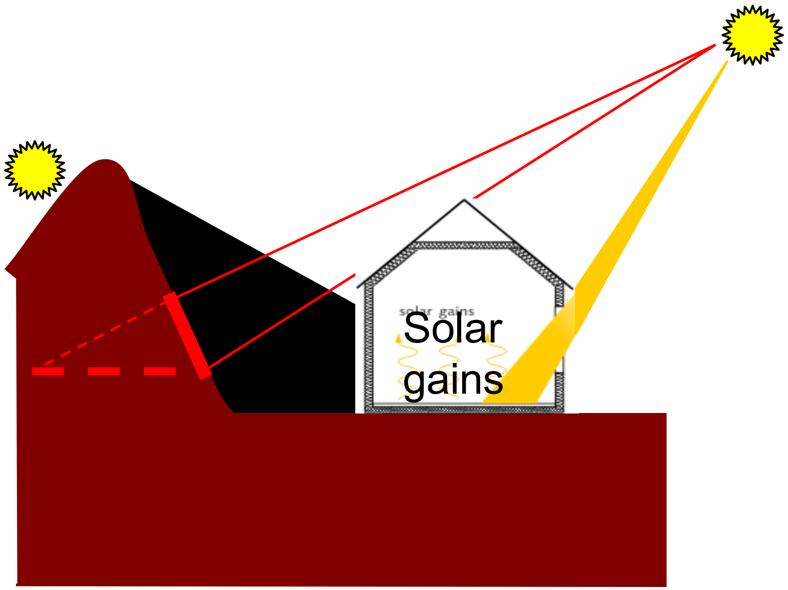
- 6.6km, 60 layers
- 3 x 72h per day

COSMO-2 (local)

- 2.2km, 60 layers
- 8 x 24h per day



Particular local conditions at a building



Radiation
Solar heat gains through windows are most important for buildings thermal dynamics & comfort

Temperature

Humidity

» Slope and horizon dependent radiation in COSMO (Buzzi 2008)

» Measured horizon accounted for in postprocessing (in radiation disaggragation, Perez et al. 1987, 1992)

Notes on radiation data properties

Zurich, MeteoSwiss

Cloud cover as the controlling factor of radiation components

spatial heterogeneity:

COSMO predictions are averaged values over 6.6x6.6km grid cells, observations are point measurements

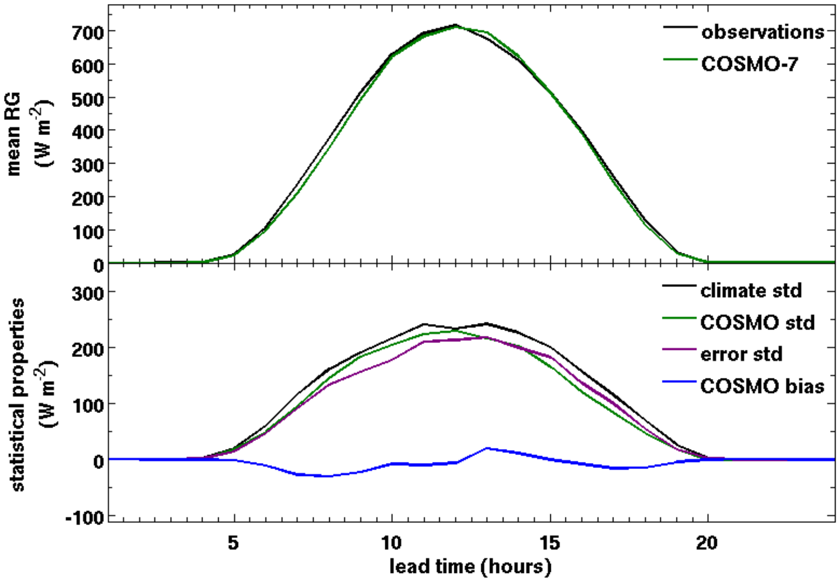
temporal dynamic:

cloud cover changes quickly in reality, in the model world this is held constant over the radiation update cycle (COSMO-7 60 min)

→ **large uncertainties in point predictions, double penalty effect when comparing with point obs**

Variability of local radiation forecasts

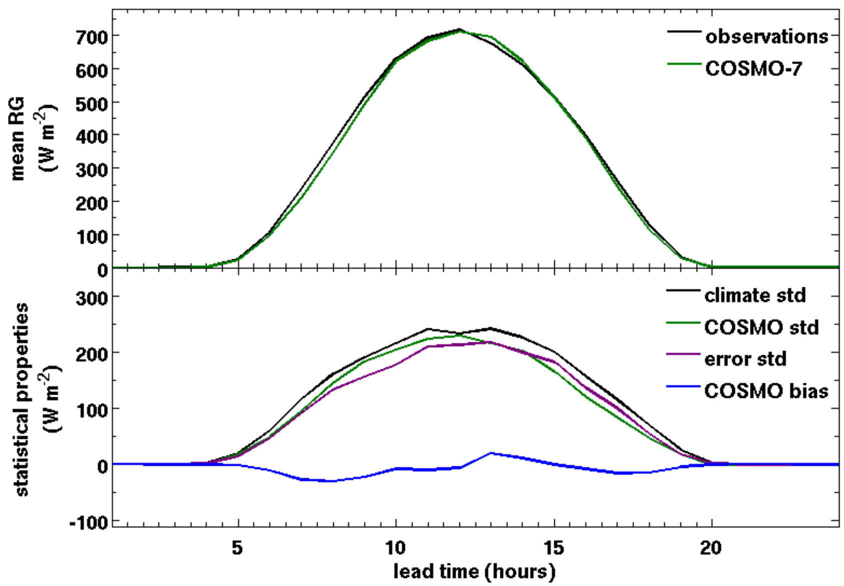
June-August 2009
Basel, Zurich, Geneva, Lugano



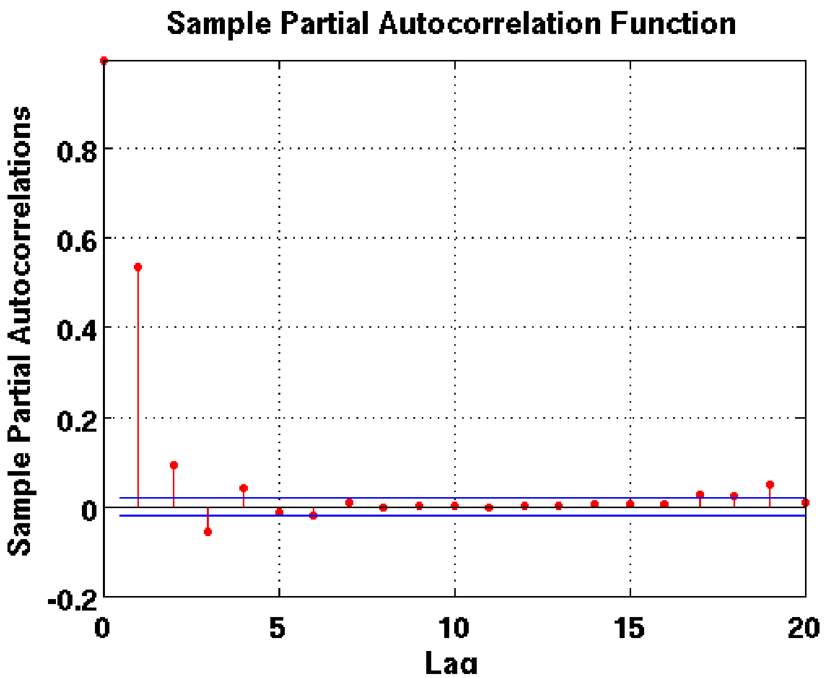
Very small systematic error but high variability

Variability of local radiation forecasts

June-August 2009
Basel, Zurich, Geneva, Lugano



Zurich, 2009



Very small systematic error but high variability
Forecast errors are temporally autocorrelated

» model for statistical postprocessing with Kalman filter (kf)

Rapid forecast update & correction

» controller ready to take **very frequent forecast updates** ("the more often the better")

» **short term correction** modelling first order autocorrelation: adapt forecast with every new obs (e.g. hourly)

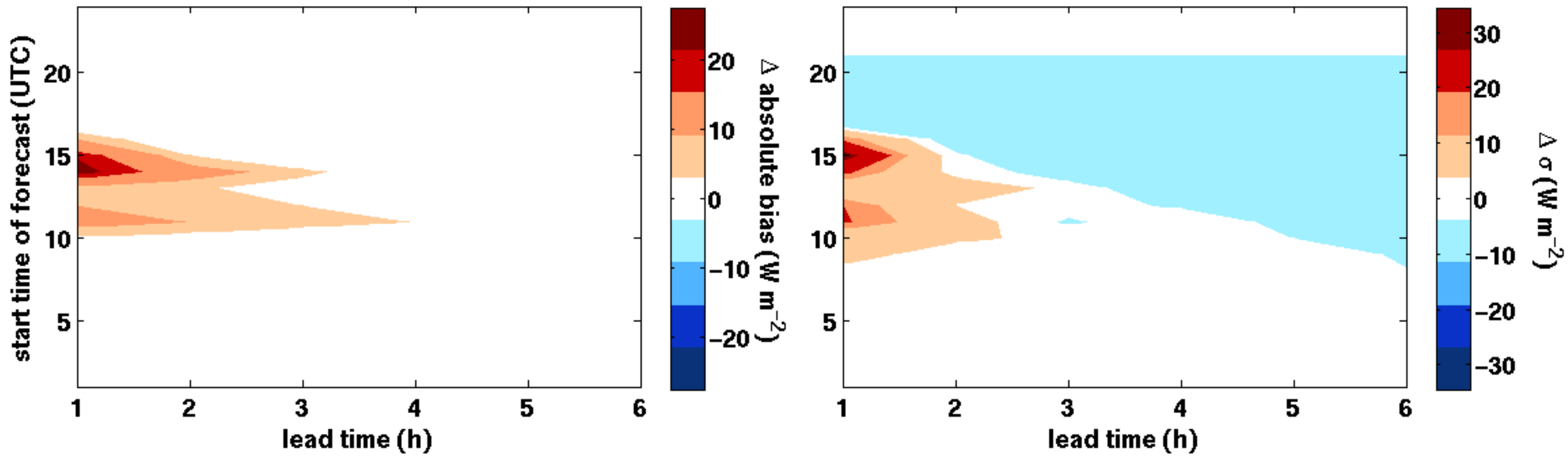
model for: $$y_t = obs_t - pred_t$$

system equation: $$x_t = x_{t-1} + w_{t-1}, \quad p(w_t) \sim N(0, Q_t)$$

observation equation: $$y_t = x_t y_{t-1} + v_t, \quad p(v_t) \sim N(0, R_t)$$

KF for Shortterm Forecast Correction

ΔBias   Δσ

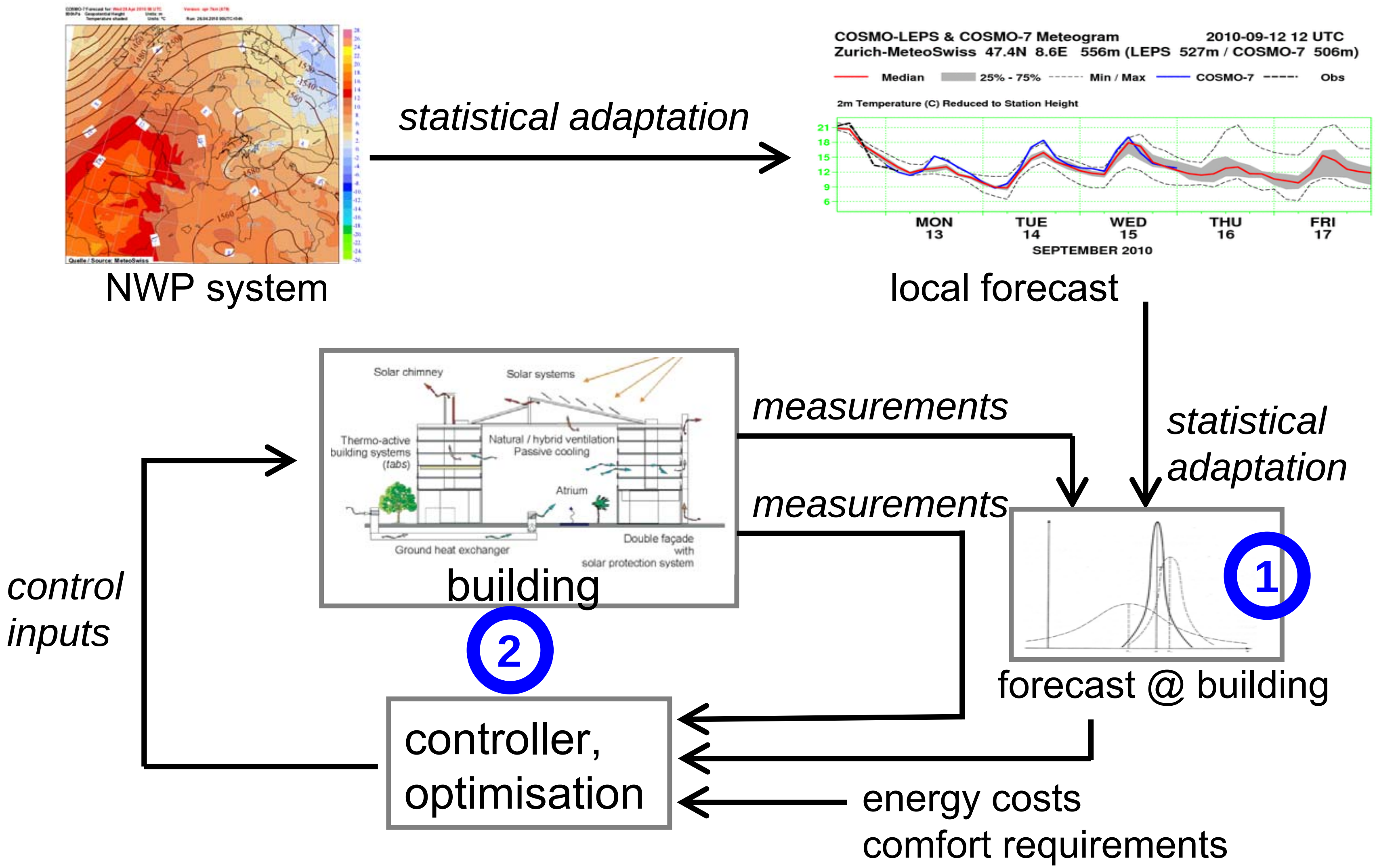


Solar heat gain
Zurich 2007, south orientation

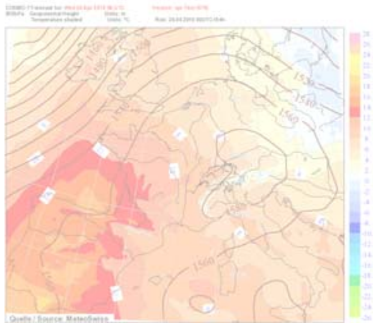
» affects the first few hours only

» corrects for ~ 50-70% of the forecast bias and ~ 10-30% of the forecast error standard deviation in the first 3 forecast hours

Effect on building energy consumption

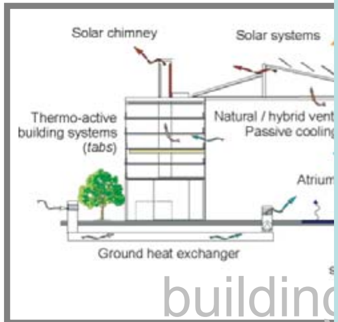


Effect on building energy consumption



NWP system

statistical a



building

control inputs

2

controller optimisat

Simulation experiments:

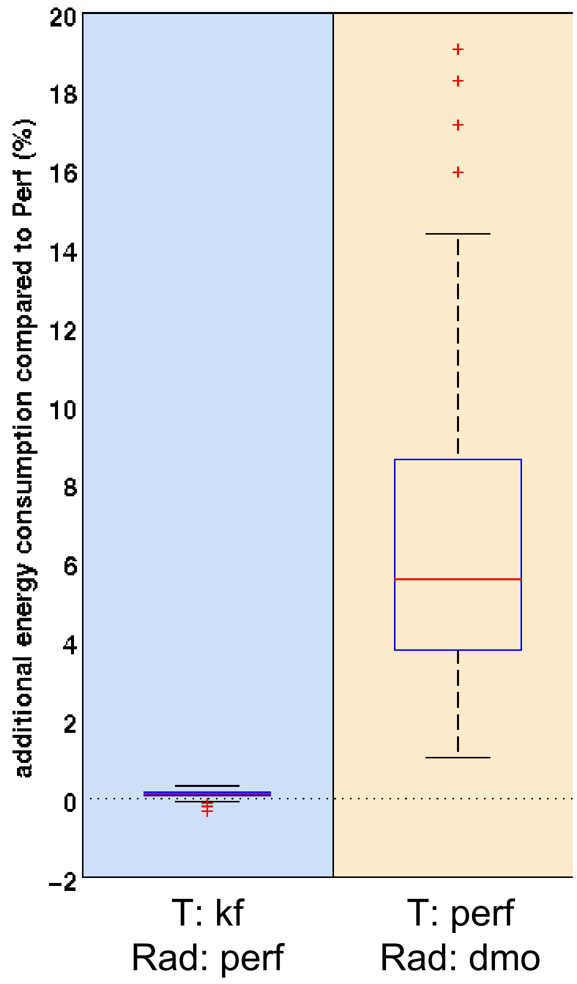
» 2 controllers
(predictive rule based (pRBC), stochastic model predictive control (SMPC))

» TABS building system
» 4 locations
» 2 thermal insulation levels
» 2 construction types
» 2 window area fraction levels
» 2 window orientation variants

»» 64 cases for pRBC

»» 6 cases for SMPC

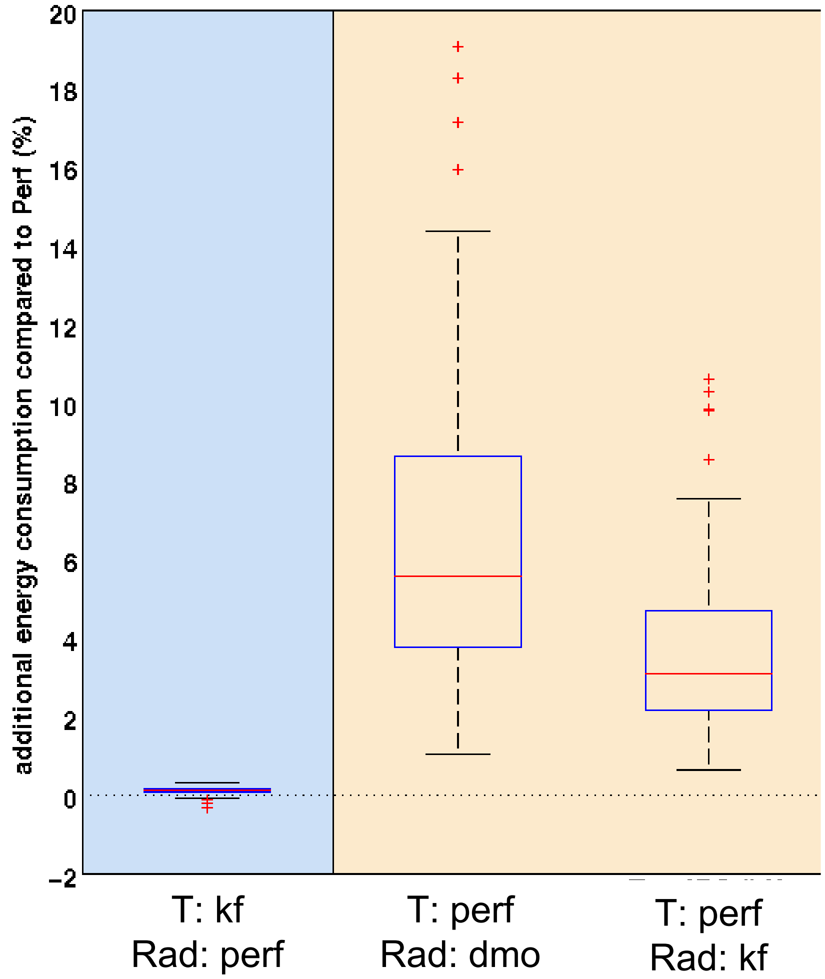
Effect on building energy consumption



high relative importance of radiation forecasts

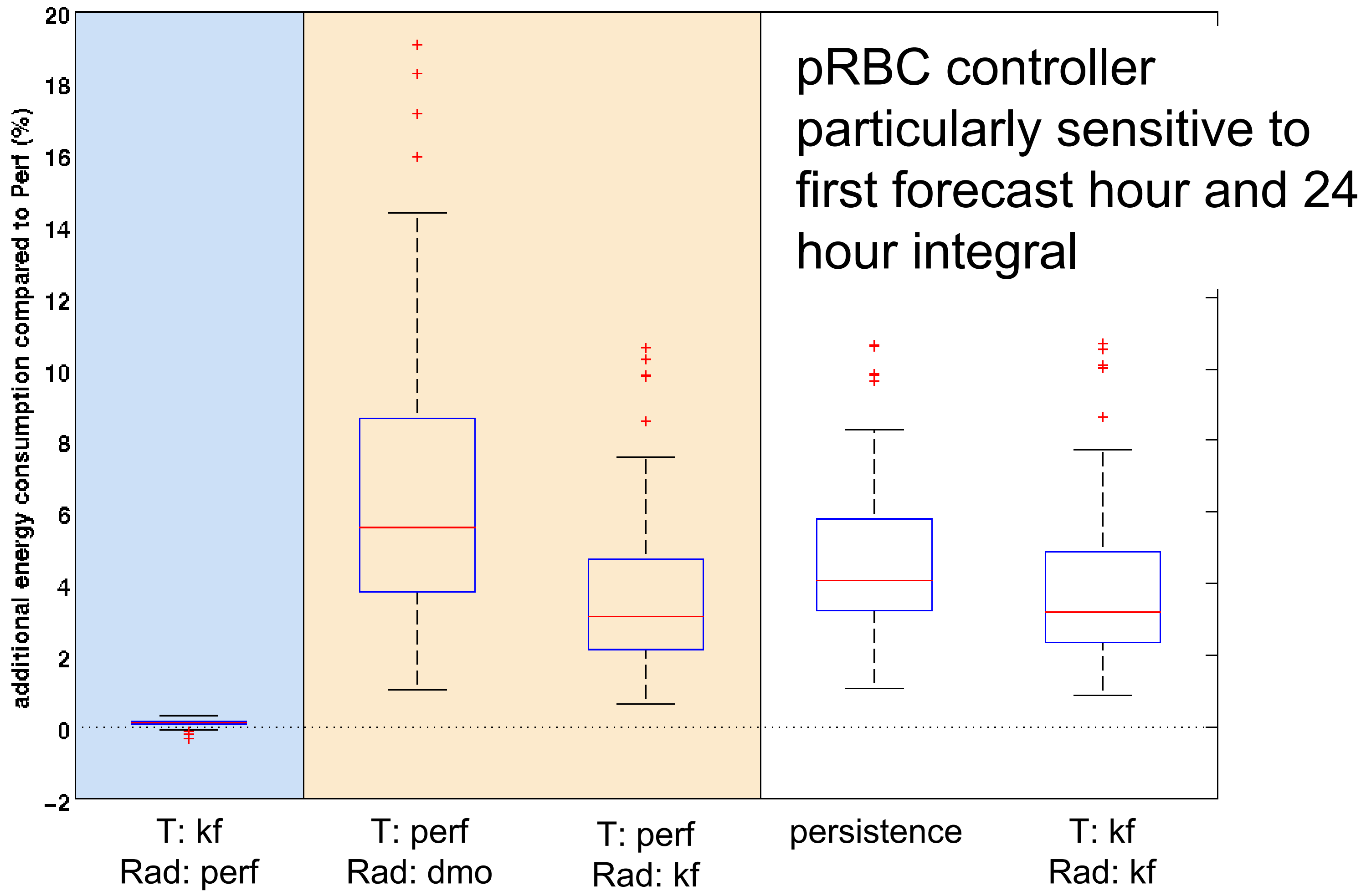
(blind control, variable energy input)

Effect on building energy consumption



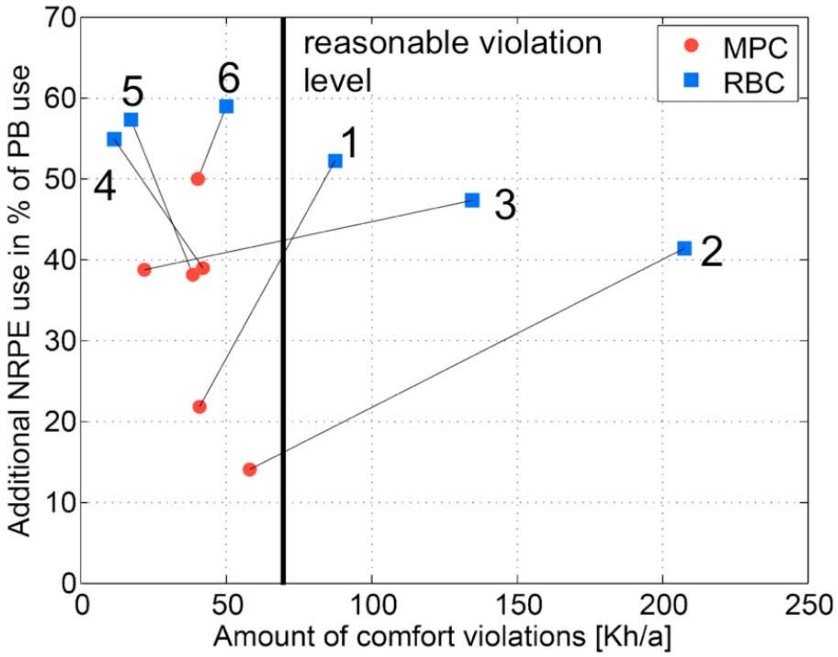
Statistical postprocessing significantly helps reducing energy consumption

Effect on building energy consumption



Stochastic Model Predictive Control

Comparison of:
- model predictive control (MPC)
- rule-based control (RBC)

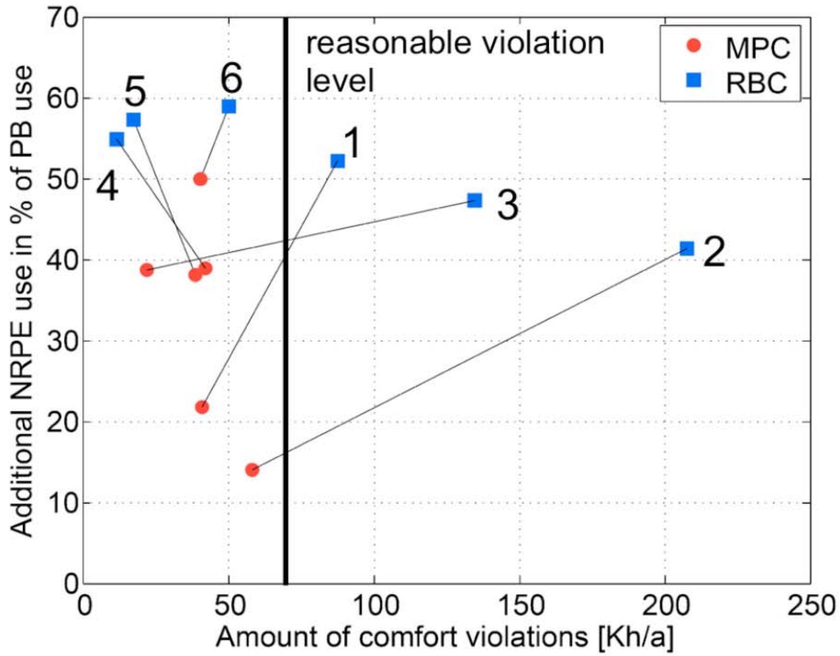


Simulations of primary energy consumption (NRPE) and comfort for integrated room automation

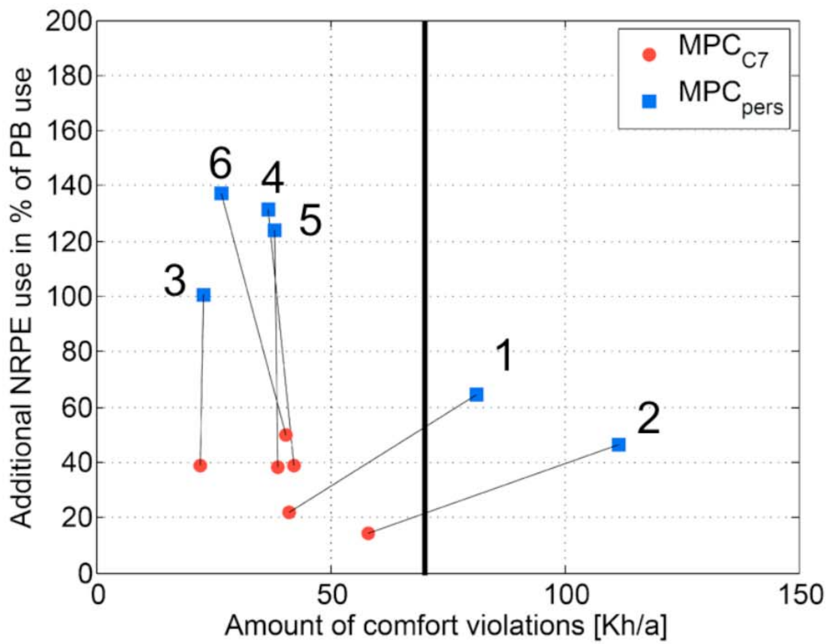
Vanessa Stauch, Vanessa.Stauch@meteoswiss.ch

Stochastic Model Predictive Control

Comparison of:
- model predictive control (MPC)
- rule-based control (RBC)



Comparison of:
- MPC with COSMO-7 forecast (MPC_{C7})
- MPC with persistence forecast (MPC_{pers})



Simulations of primary energy consumption (NRPE) and comfort for integrated room automation

Conclusions

Predictive building control challenges numerical weather prediction models (needs point predictions from a grid) but simulations show promising results

Physical and statistical postprocessing with local observations is indispensible to meet the particular requirements of this application

Effect of errors in the weather forecasts on building control performance varies widely with building properties and controllers

Interdisciplinary discussion and collaboration give valuable impulses to develop links between numerical weather prediction and specific applications

Effect on room temperature violations