Nansen Centers 25 years Colloquium
in honour of Fridtjof Nansens
150 years anniversary

The Planetary Boundary Layer:
Impact on the Earth Climate and Climate Change

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25 years in science 1986 - 2011

Earth Heat Budget

Surface black body radiation balance
-18°C

Cenozoic Era Climate
+12°C – +28°C

Surface – Atmosphere black body balance
+ 30.5°C

Pleistocene Climate
+12°C – +16°C

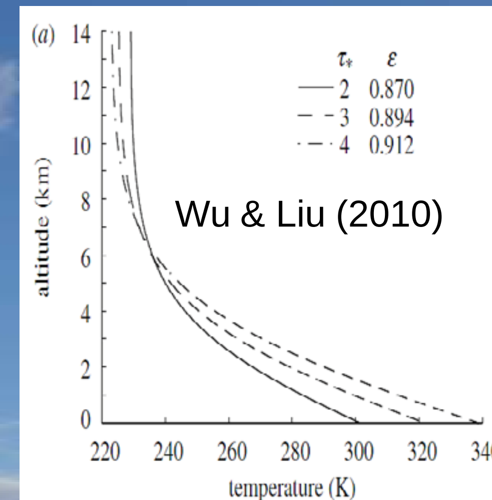
Holocene Climate
+14°C – +15°C

What cools our planet?

Solar system habitable zone

Earth's TOA spectral observations
-53°C to + 12°C

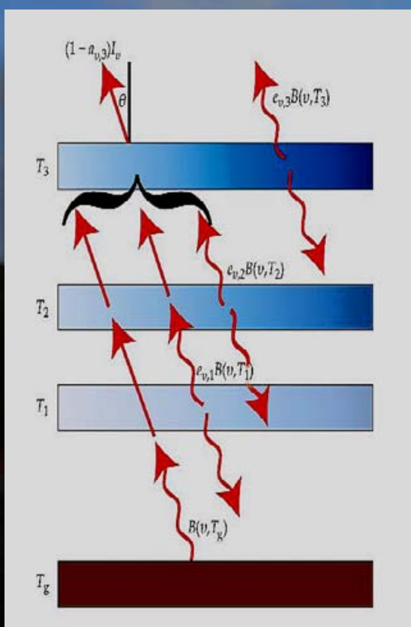
Atmospheric Convection



Wu & Liu (2010)

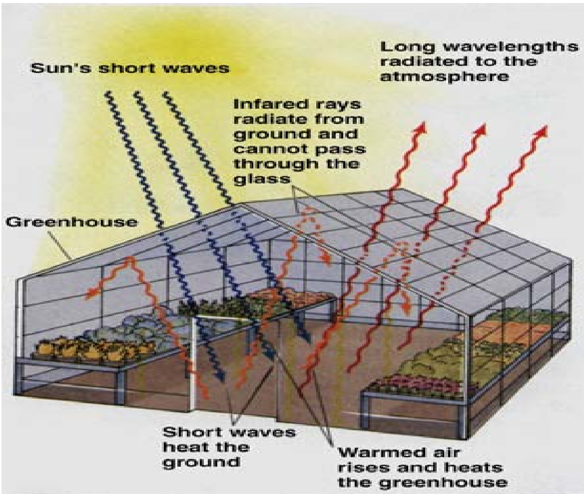
Temperature gradient cannot exceed an adiabatic gradient

Convection elevates warm air helping to radiate heat more efficiently

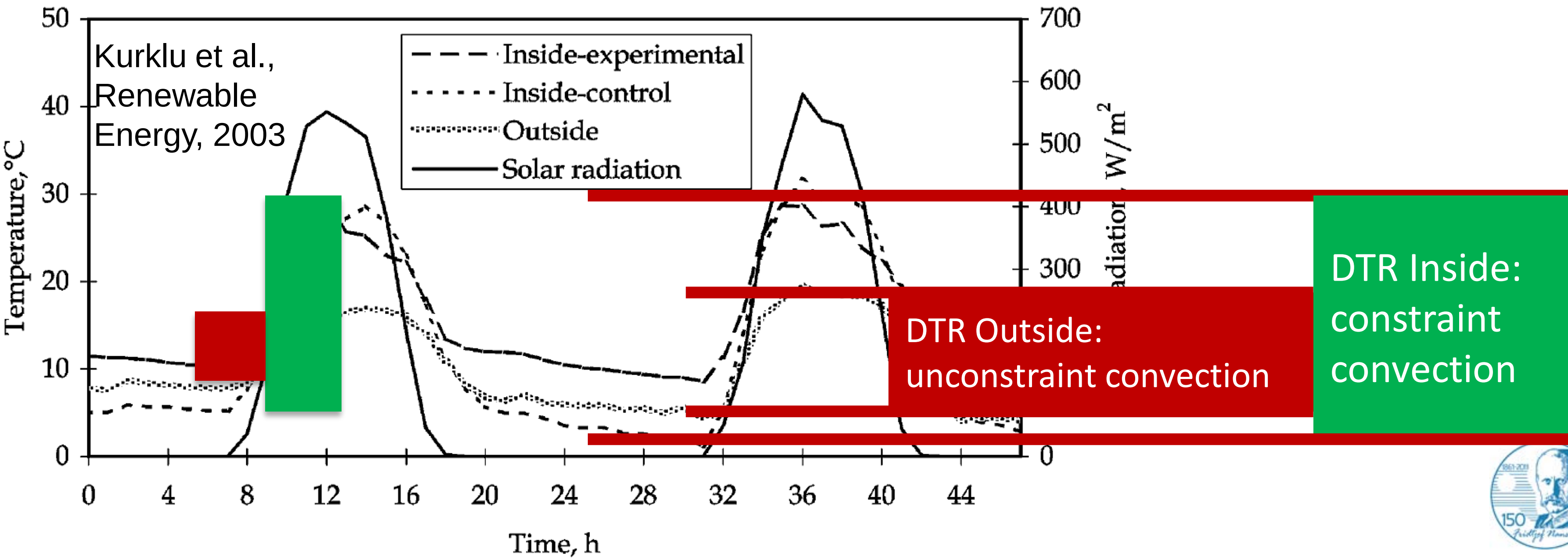


What impact would constraints have on convection?

Impact of Constraints



- Popular but erroneous cartoon draws analogy between the Earth and Greenhouse
- Greenhouse effect caused by severe constraints on turbulent convection (R. Wood, 1909)
- Greenhouses work in both directions - more constraints lead to larger variability



Planetary Boundary Layer Effect

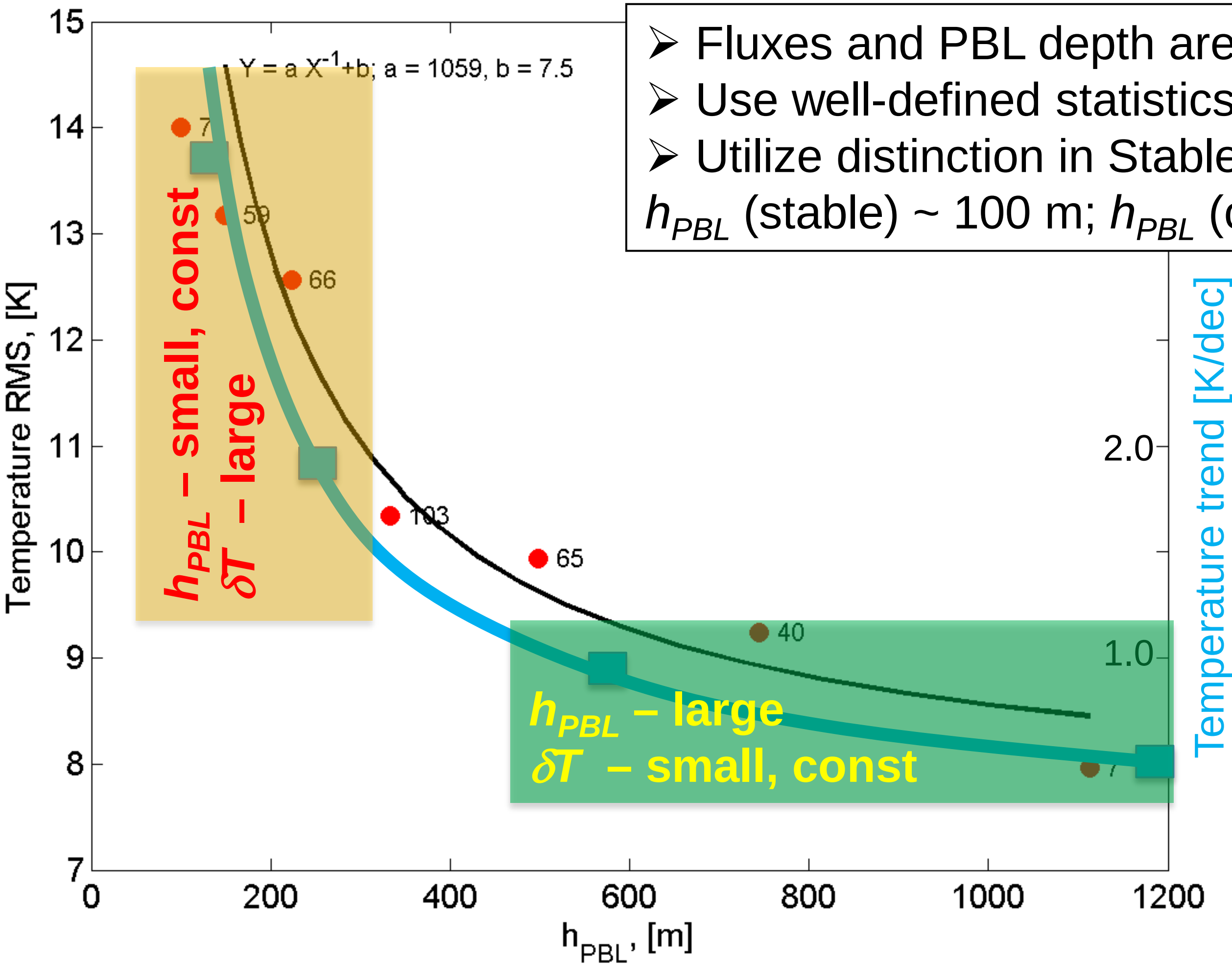
$$\frac{dT}{dt} \propto \frac{Q}{h_{PBL}}$$

Temperature changes (DTR,RMS,TRD) on different time scales are physically related and reciprocally proportional to h_{PBL}

Proxy for PBL Effect

- Fluxes and PBL depth are ill-defined
- Use well-defined statistics for temperature
- Utilize distinction in Stable and Convective PBLs

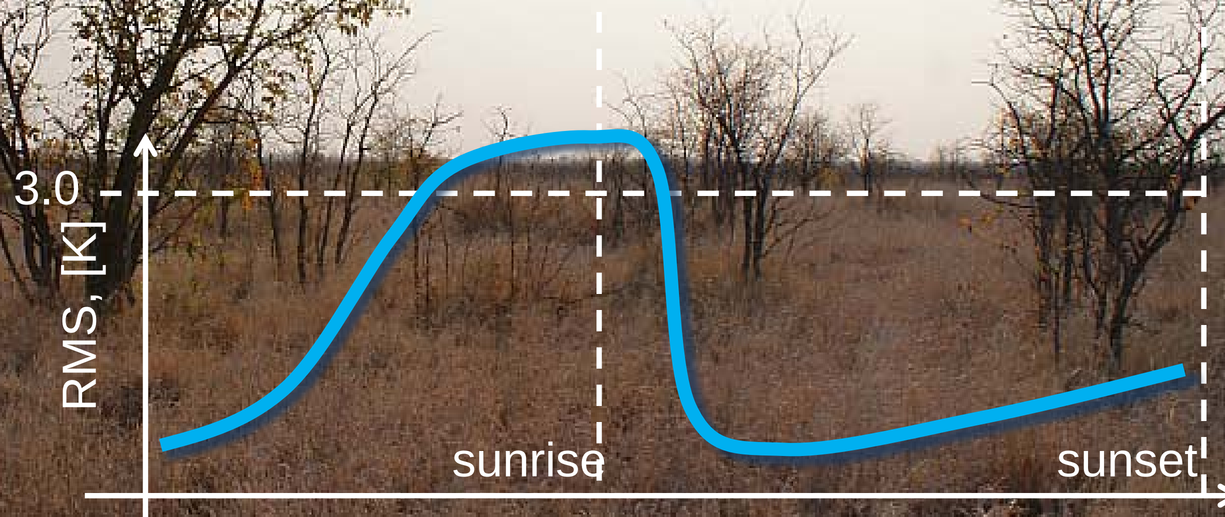
h_{PBL} (stable) ~ 100 m; h_{PBL} (convective) ~ 1000 m



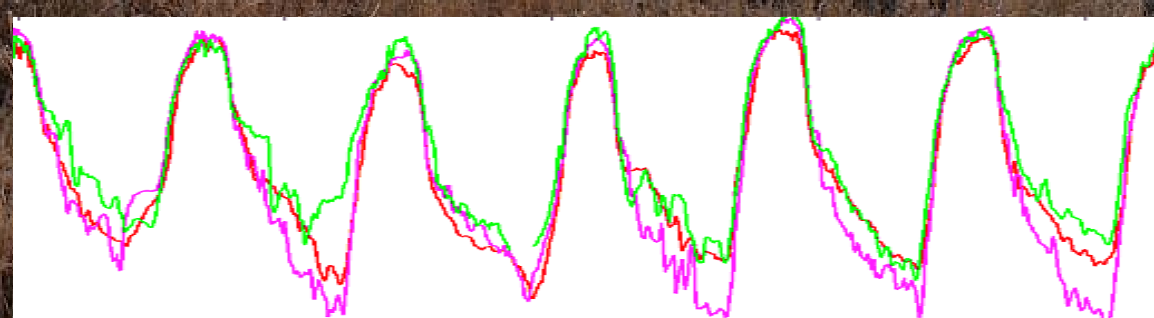
Empirical Evidences: Micro-Meteorology

(South Africa)

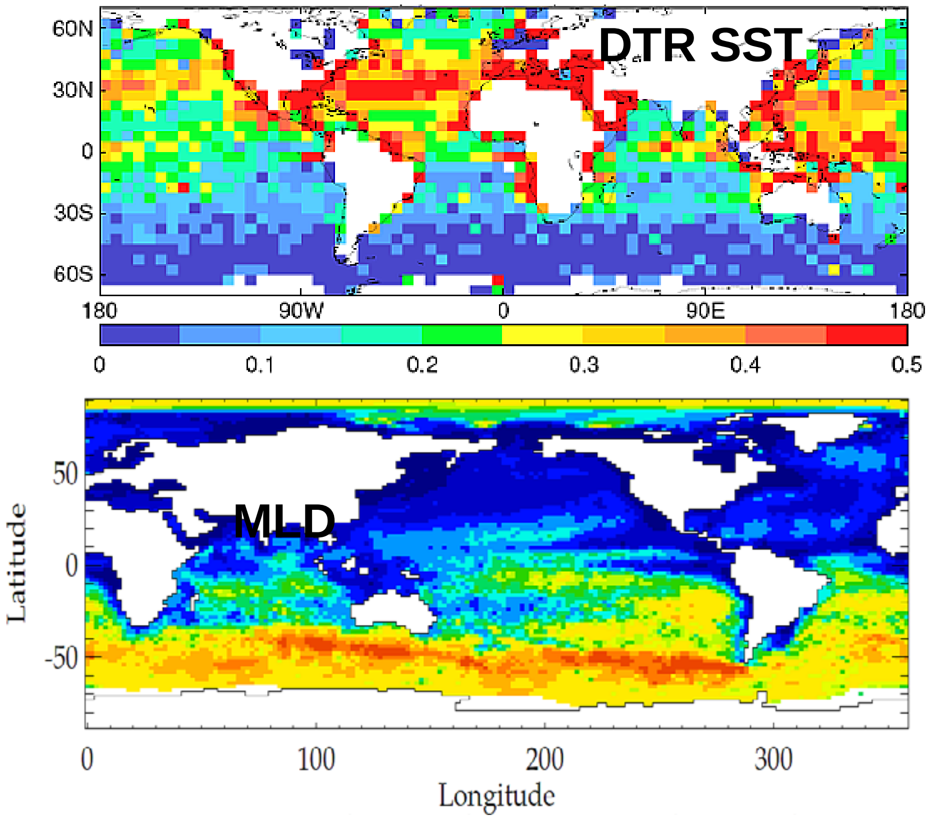
5 automatic stations
8 – 40 km distance
Similar conditions
2008 – 2010 period



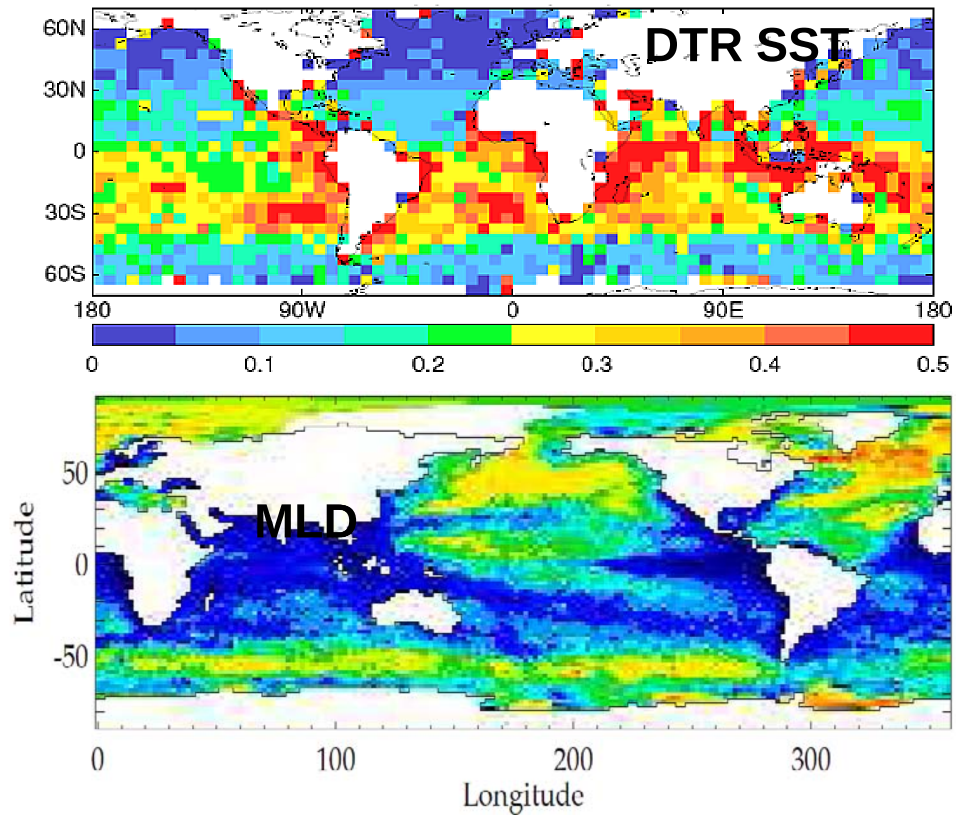
Results:
Very high nocturnal variability in space and time



Empirical Evidences: Oceans



Upper panel: Summer (JJA) DTR in the upper ocean (Kennedy et al., 2007)
Lower panel: September MLD (de Boyer Montegut et al., 2004)

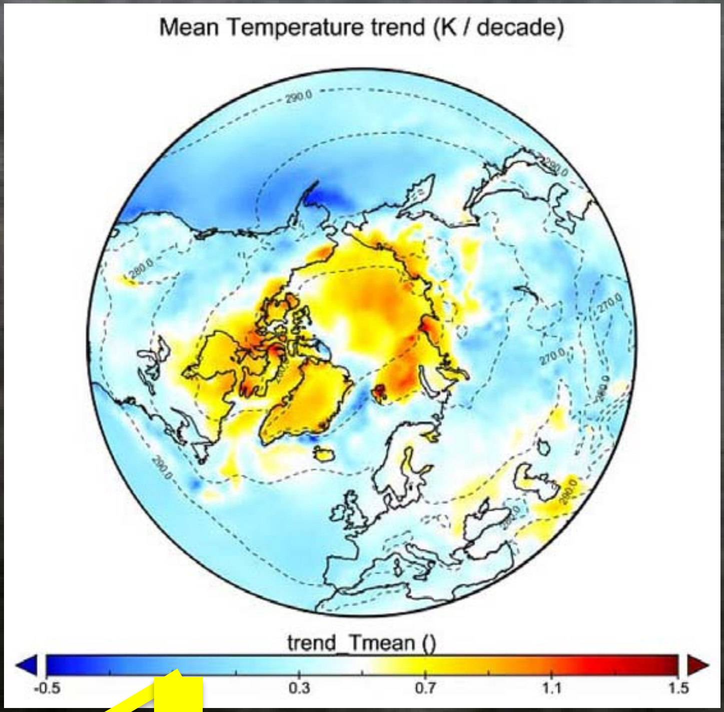


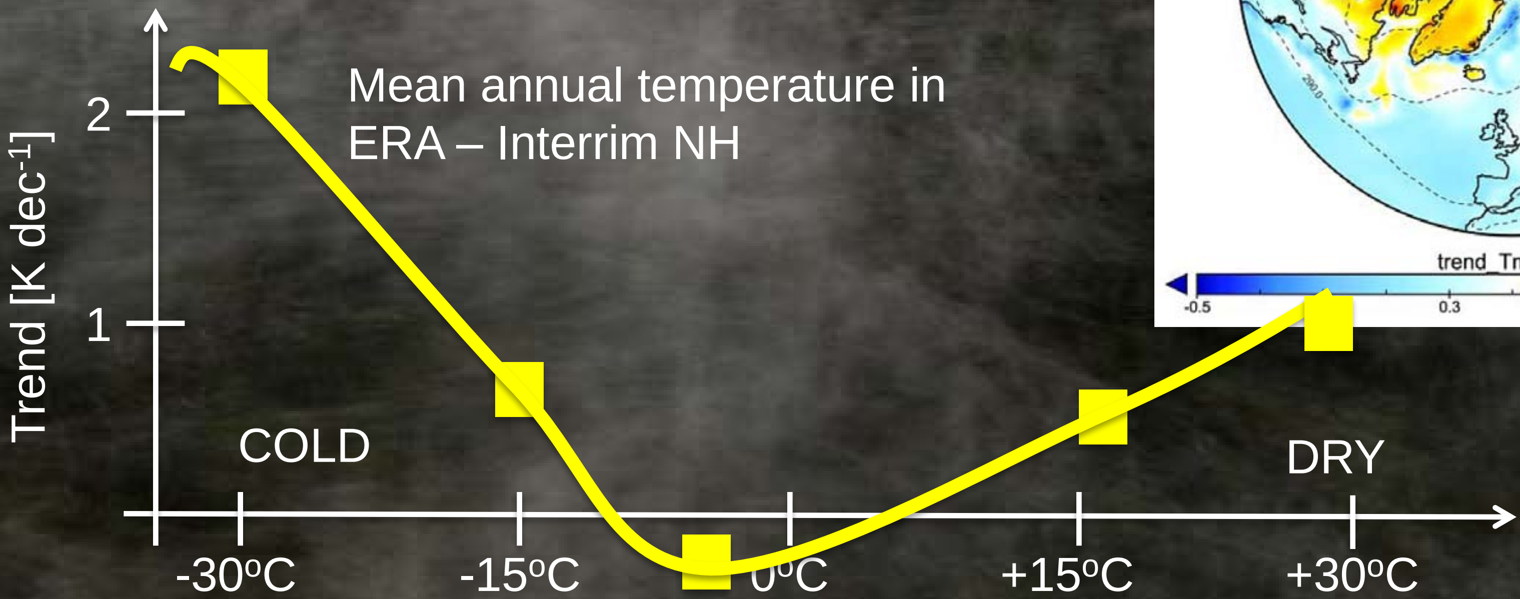
Upper panel: Winter (DJF) DTR in the upper ocean (Kennedy et al., 2007)
Lower panel: March MLD (de Boyer Montegut et al., 2004)

Attribution of Observed Climate Variability to the Direct Effect

<u>Drawbacks of some previous studies:</u>

- Tendency toward geographical explanations
- Attempts to invoke geographical corrections
- Over-reliance on empirics in parameterizations
- Calibration over a narrow range of parameters





Impact of Clouds vs Impact of PBL

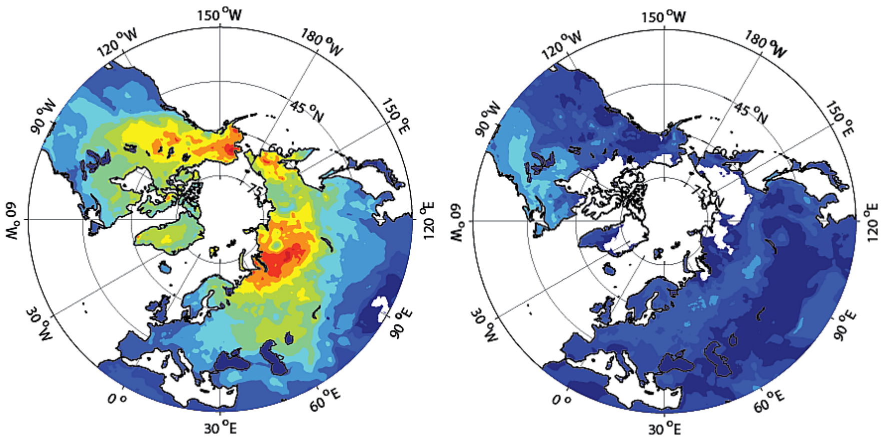
<u>Cloud hypothesis (Dai et al., 1999):</u>
Variations in cloudiness modulate trends
Cloudiness affect **<u>maximum T</u>**

<u>PBL hypothesis (Esau et al.):</u>
Variations in PBL depth modulate trends
PBL depth affect **<u>minimum T</u>**

ERA-Interim unfiltered annual mean data:

	$\dot{T}_{min}$	$\dot{T}_{max}$	$D\dot{T}R$
$\dot{T}_{min}$		0,89	-0,39
$\dot{T}_{max}$	0,89		0,07
$D\dot{T}R$	-0,39	0,07	
Ratio	0,43	0,39	-0,15
$\dot{C}C$	0,00	0,03	0,06

Cloudiness – no significant correlation with T
DTR correlates with minimum T
Temperature RMS – large in shallow PBL

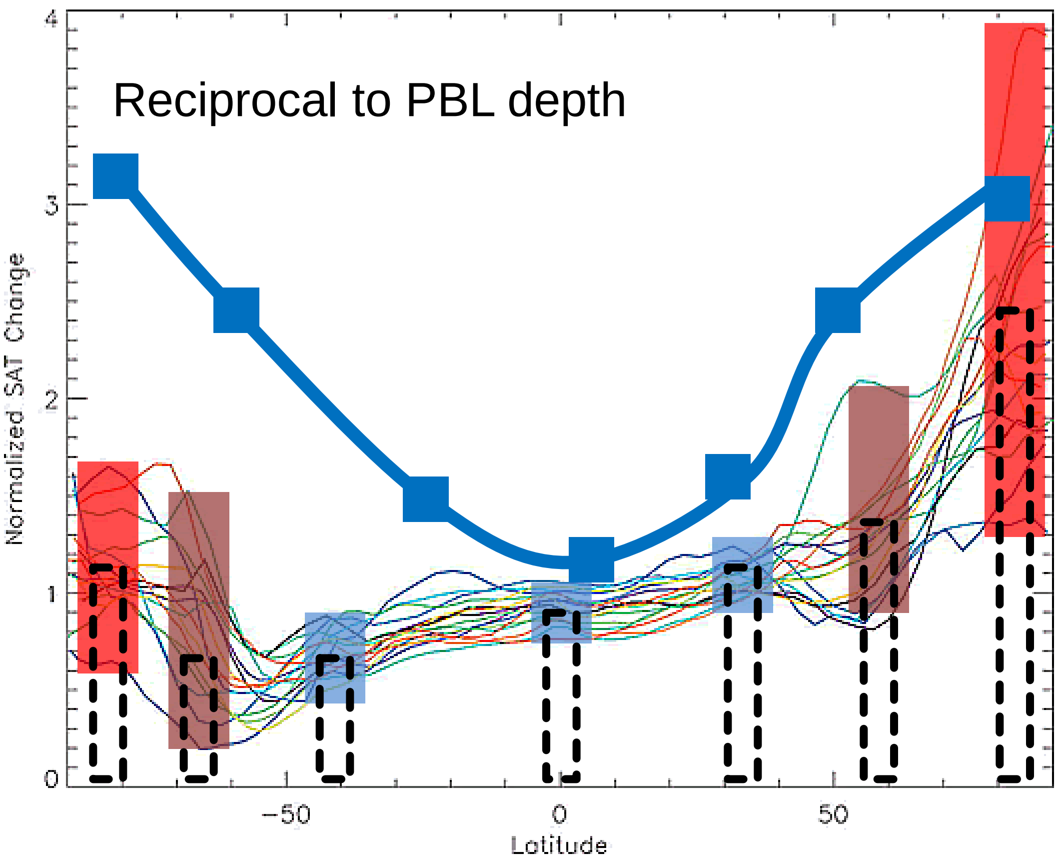


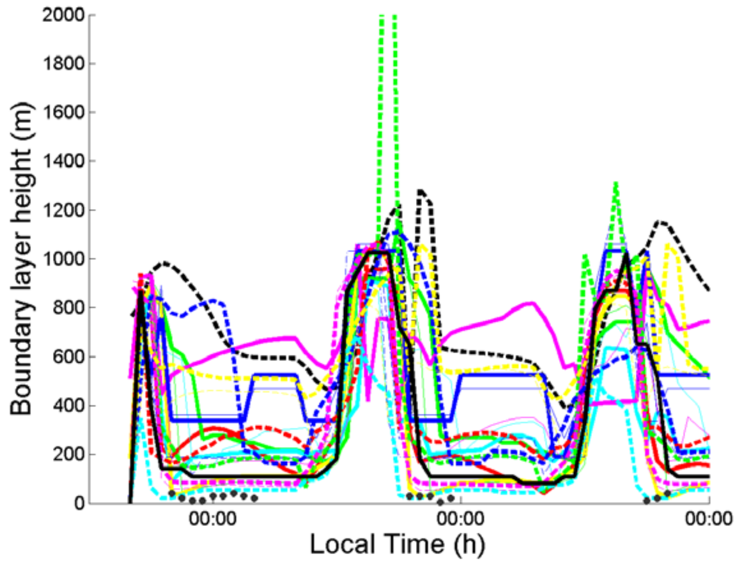
ERA-I (1989-2009) SAT RMS in shallow (0 – 500 m) and deep (>500 m) PBL

PBL Effect on Climate Change

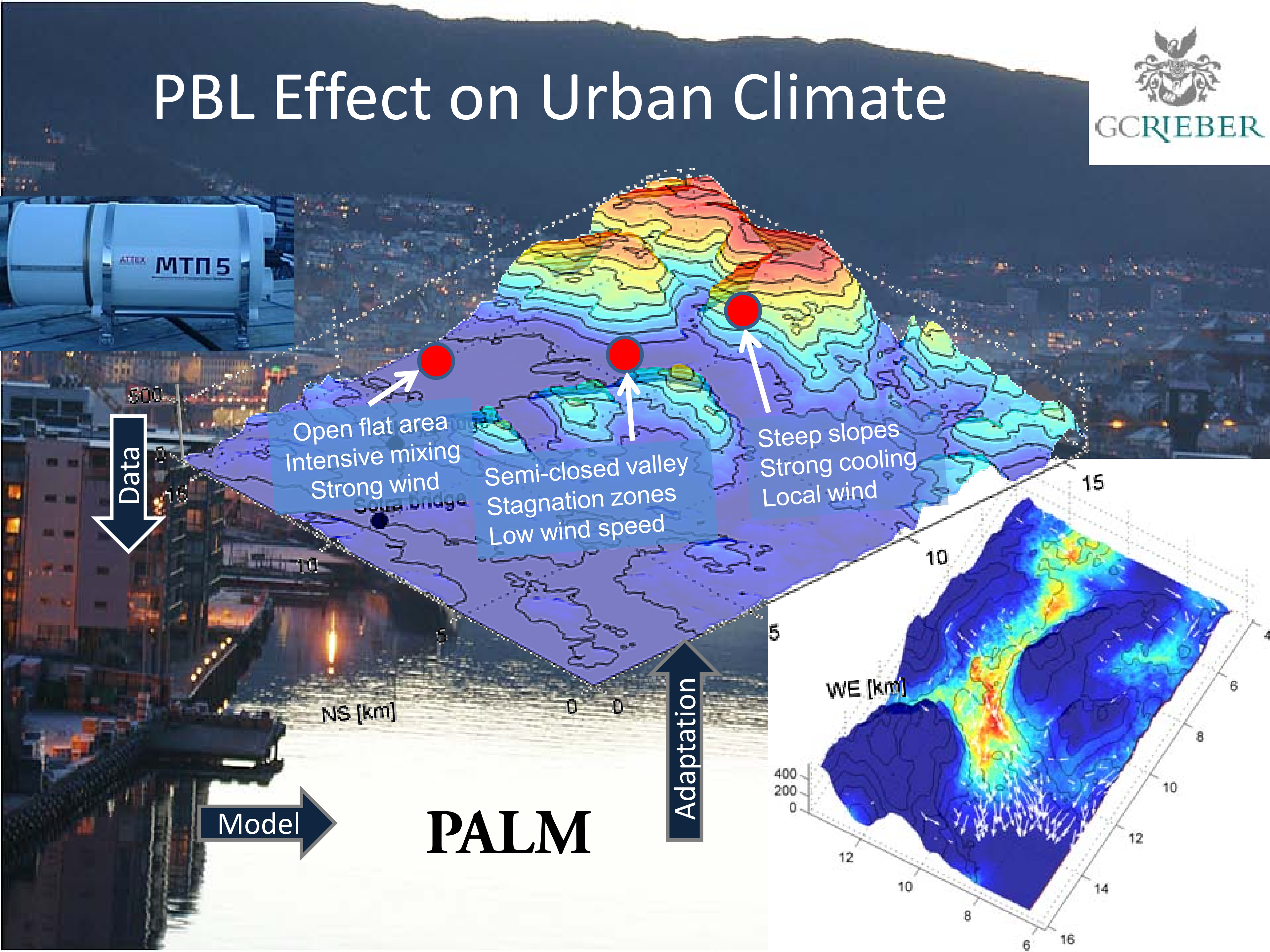
Inter-model variability

Total temperature change

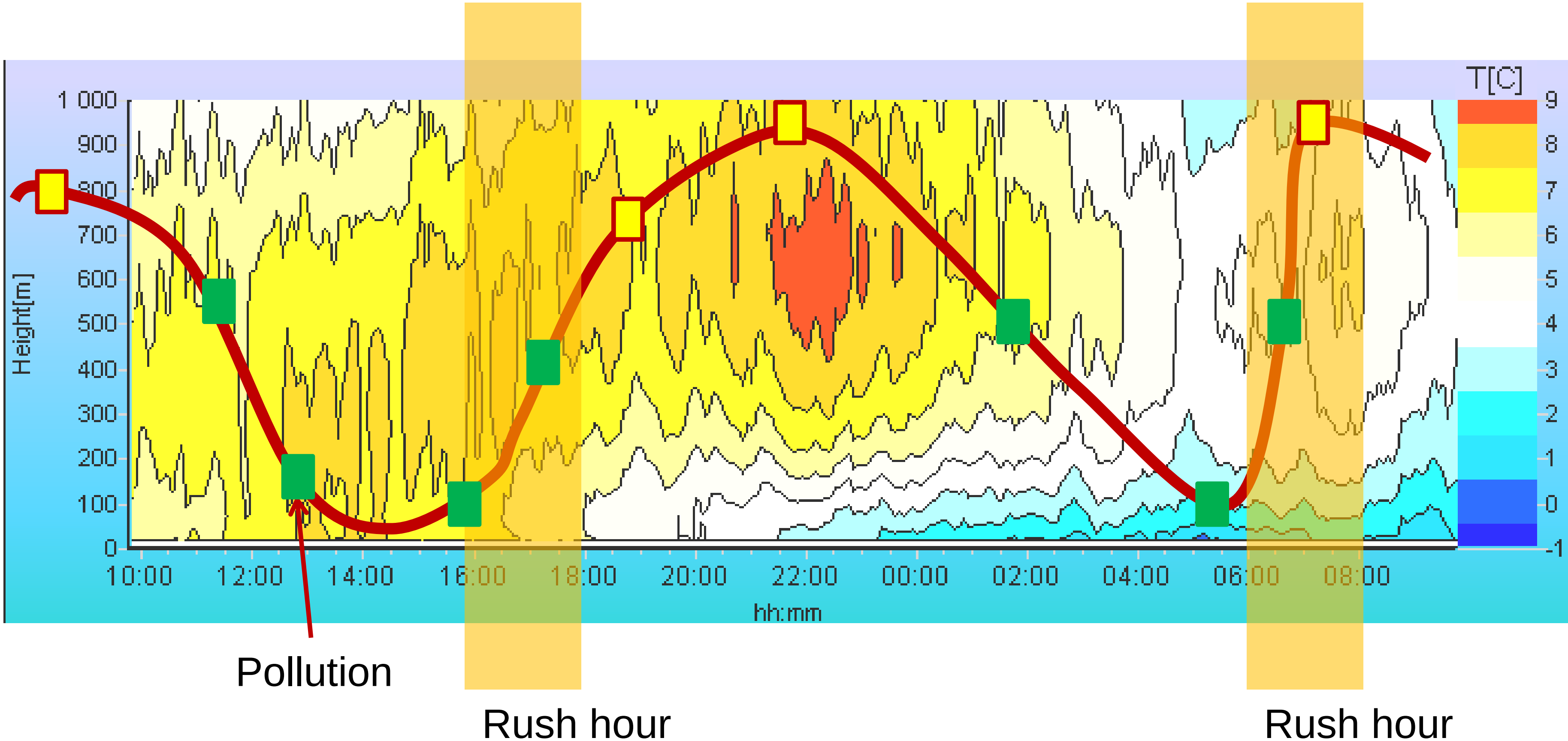




Bony, S., et al. 2006: J. Climate
GABLS, Cuxart et al., 2006: BLM

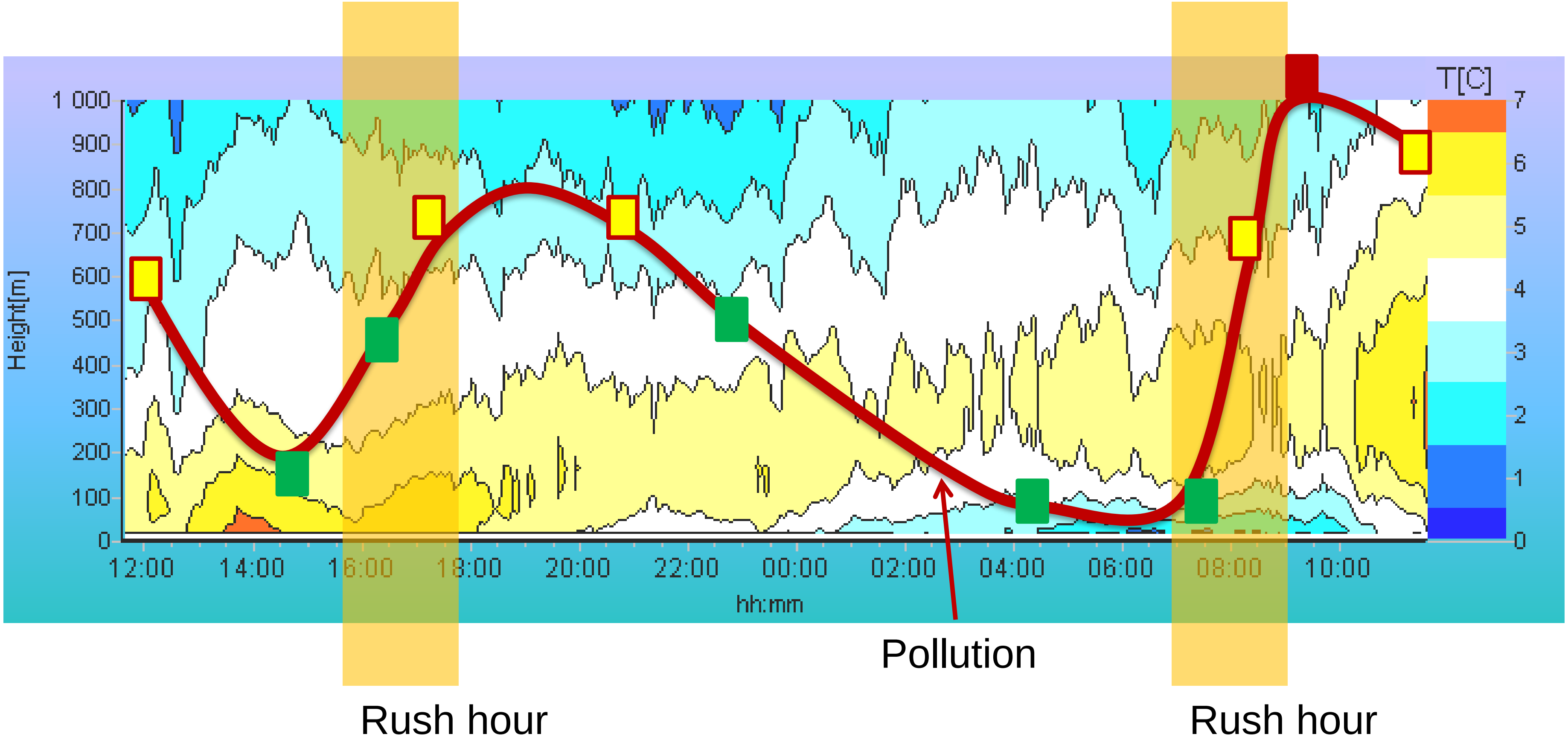

PBL Effect on Urban Climate
GCRIEBER
ATTEX MTΠ 5
Data
Open flat area
Intensive mixing
Strong wind
Semi-closed valley
Stagnation zones
Low wind speed
Steep slopes
Strong cooling
Local wind
NS [km]
WE [km]
Model
PALM
Adaptation

Bergen Air Quality 13 – 14 Nov



Temperature data from MTP-5 (**NERSC**) http://veret.gfi.uib.no/?action=mtp
Air quality data (NOx) from http://www.luftkvalitet.info

Bergen Air Quality 15 – 16 Nov



Temperature data from MTP-5 (**NERSC**) http://veret.gfi.uib.no/?action=mtp
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Research Prospects at G.C. Rieber Climate Institute

Problems	Global Climate Research & Modeling	Regional Climate Research & Scenarios	Local Climate Research & Adaptation
Tools	NorESM: Single-Column Model	WRF: Statistical-Dynamical Downscaling	PALM: Urban & Micro-Climate
Results	Understanding of: PBL Role in Climate	Improvement of: PBL Climate Projections	Contribution to: PBL Theory & Models