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Potential benefits of urban High-Resolution NWP Predictions to Air quality modelling

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Cloud Physics and severe weather

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Overview

Planetary Boundary-Layer Height (PBLh)

- Air Quality models need the PBLh
- In GEM model PBLh diagnostics from surface layer parameters
- Recent efforts to improve such diagnostics (ongoing at RPN-A)

Urban GEM-LAM, sub-km (downscaling to 250 m here)

- Boundary-layer details achieved with high-resolution NWP
- Evidence of the impact on the urban fabric on
  - turbulence,
  - internal boundary-layers,
  - Convergence fronts (eg, interactions with sea and lake-breezes)
- Diagnostics based on vertical profiles of meteorological variables

Problems and solutions

- Scientists have pulled-out hair about determination of PBL…

here are some PBLh attempts (**1st, 2nd , 3rd**) !

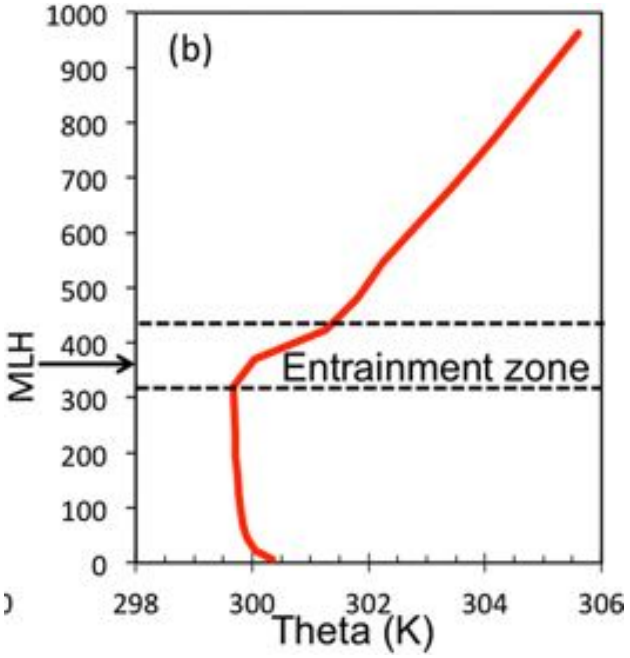
- Other turbulent caracteristics could be more relevant

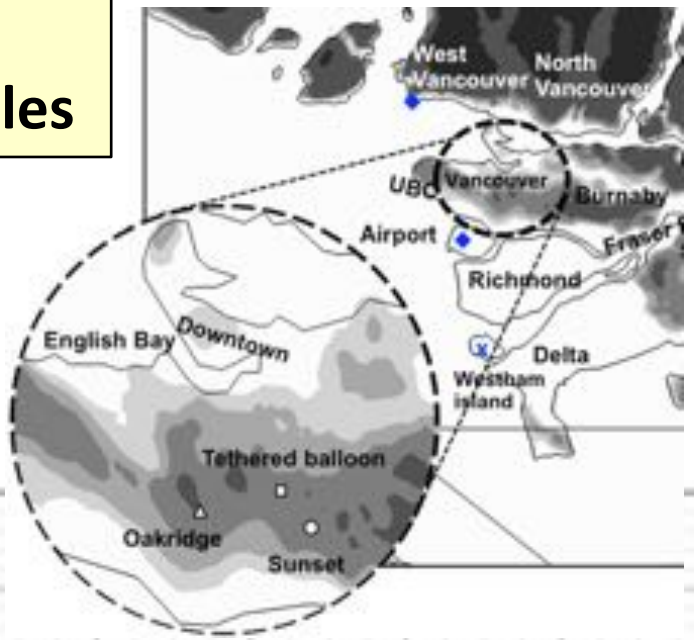
  vertical velocities, TKE, Tau, Heat and moisture fluxes

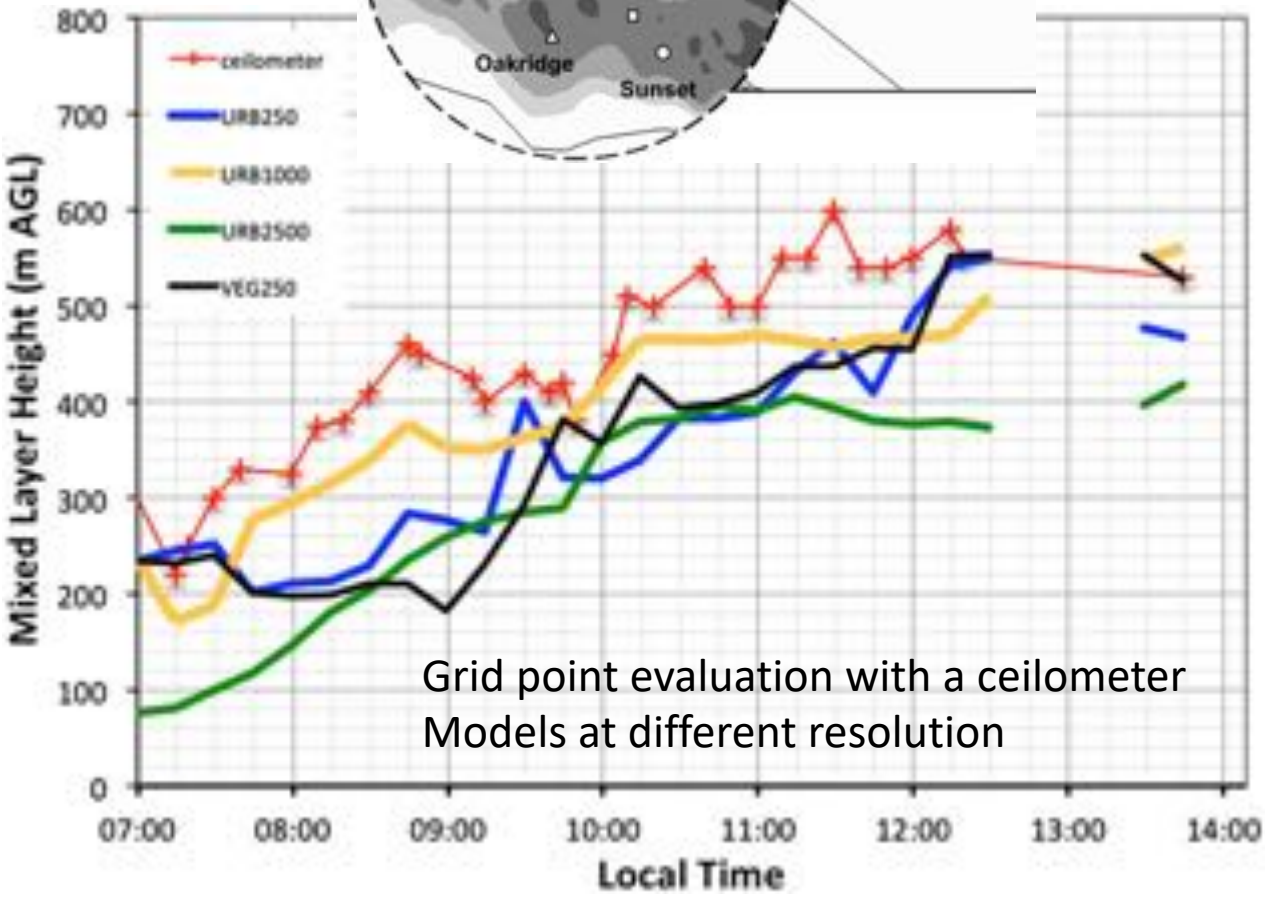
1st attempt for PBLh
Diagnostics based on Θ vertical profiles

In Leroyer et al. (2014), Vancouver

Model vertical profile
26 levels < 1500 m



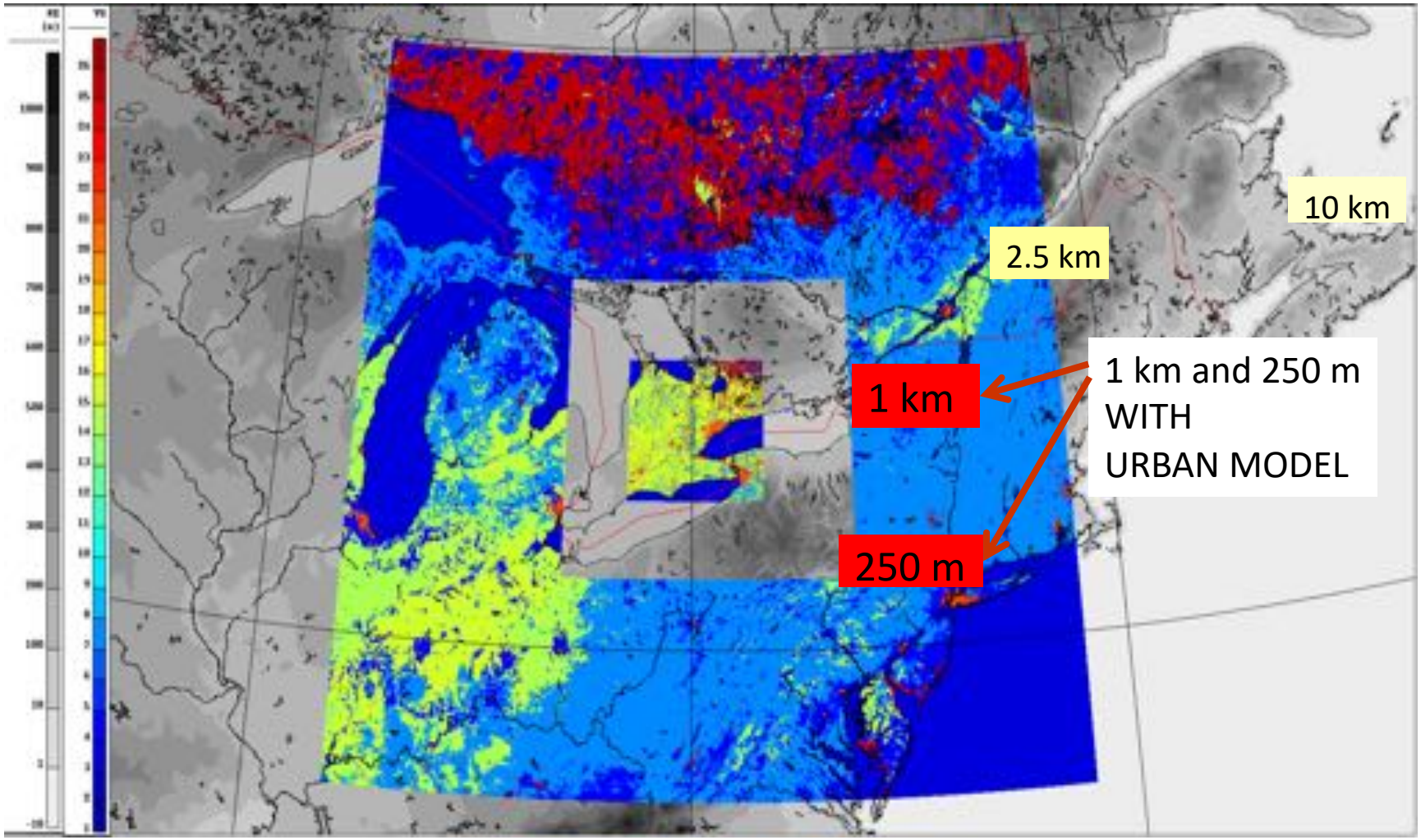




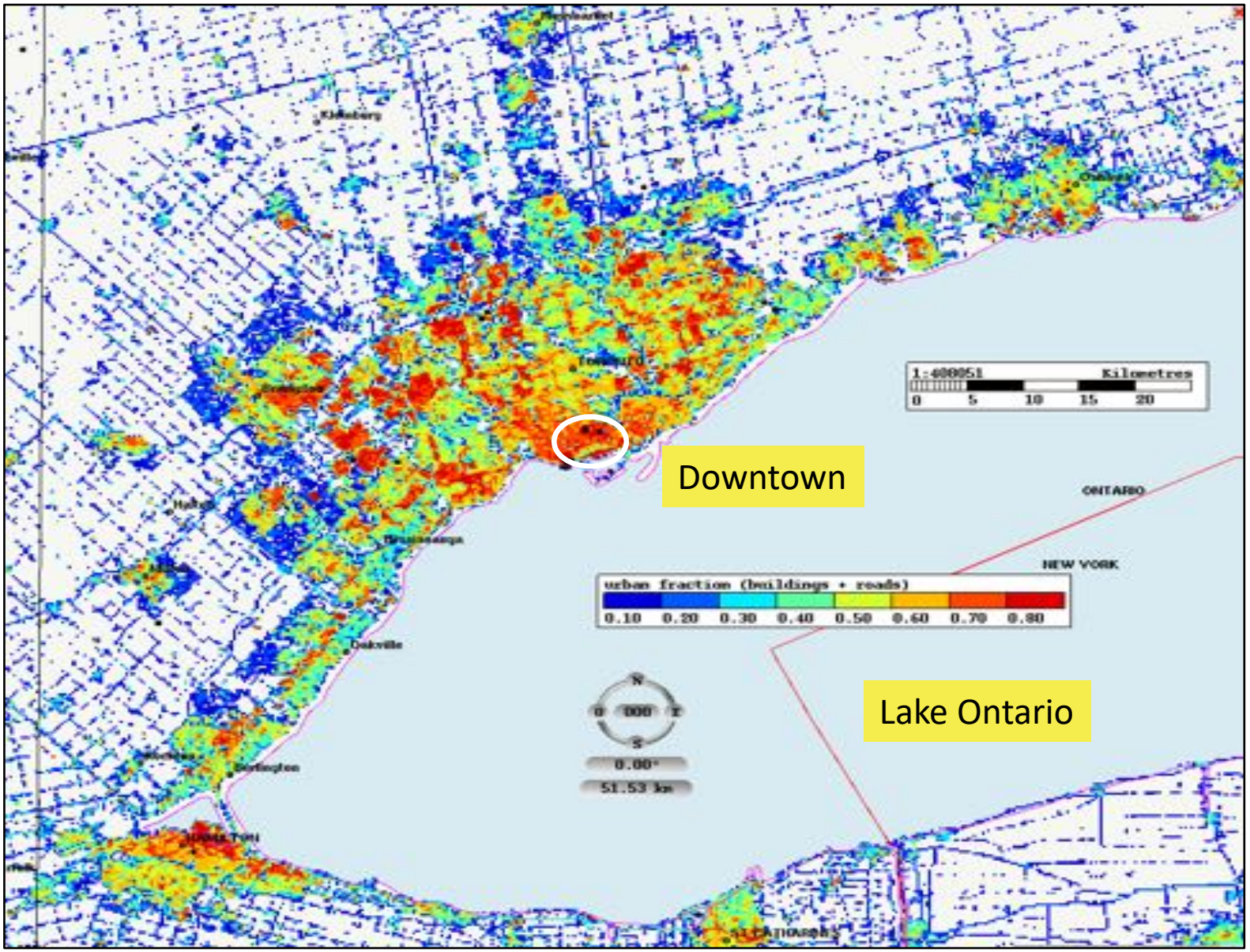
Grid point evaluation with a ceilometer
Models at different resolution

Urban GEM-LAM over GTA

- One-year testbed experiment over the Greater Toronto Area (GTA)
- context of 2015 Pan-American Games project, see tomorrow's talk (Belair et al.)

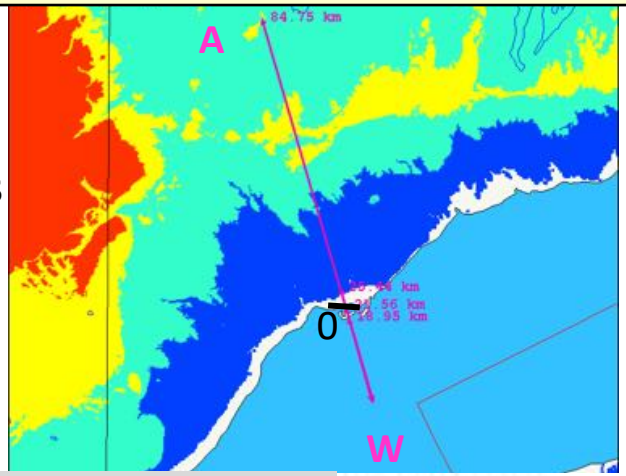


250-m GRID SPACING, *Urban fraction in the grid cell*

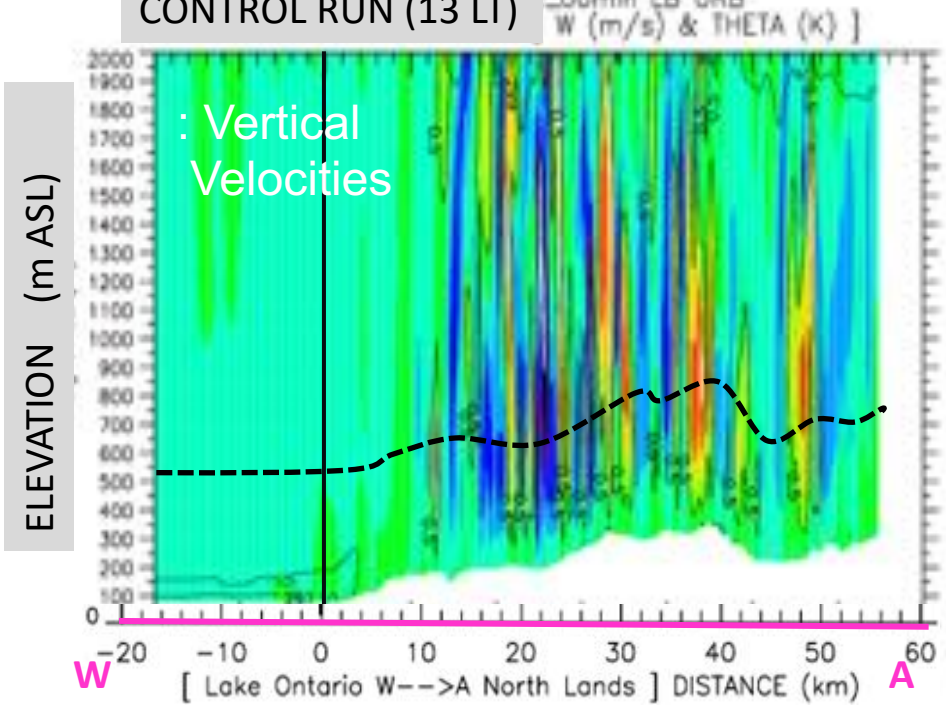


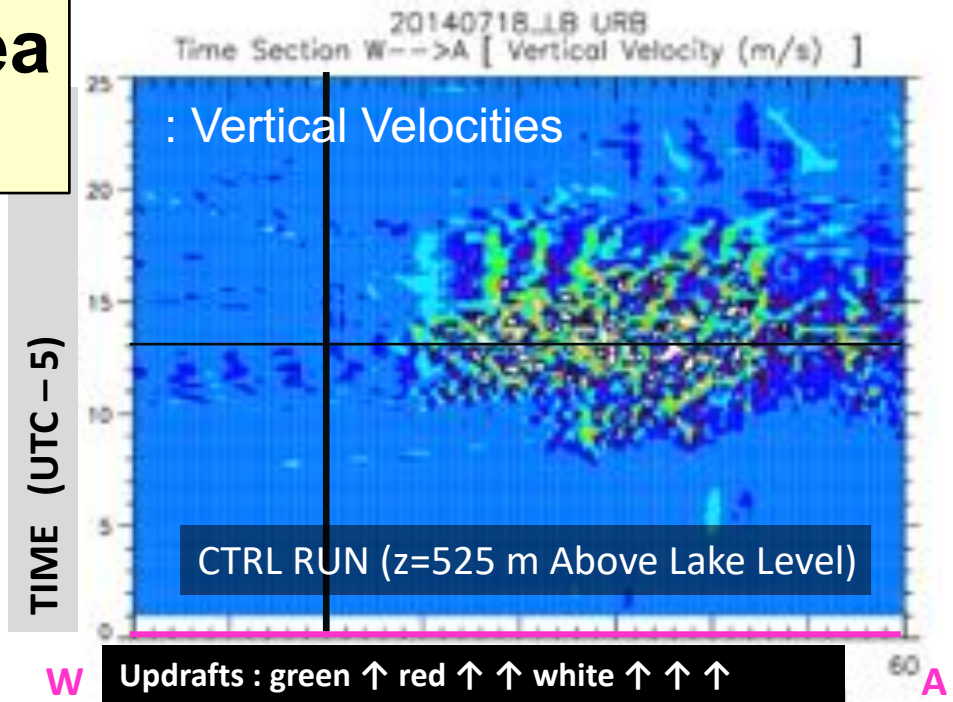
Influence of the urban area on the lake-breeze front

- 18 July 2014
- cumulus inland
- ideal Lake-breeze

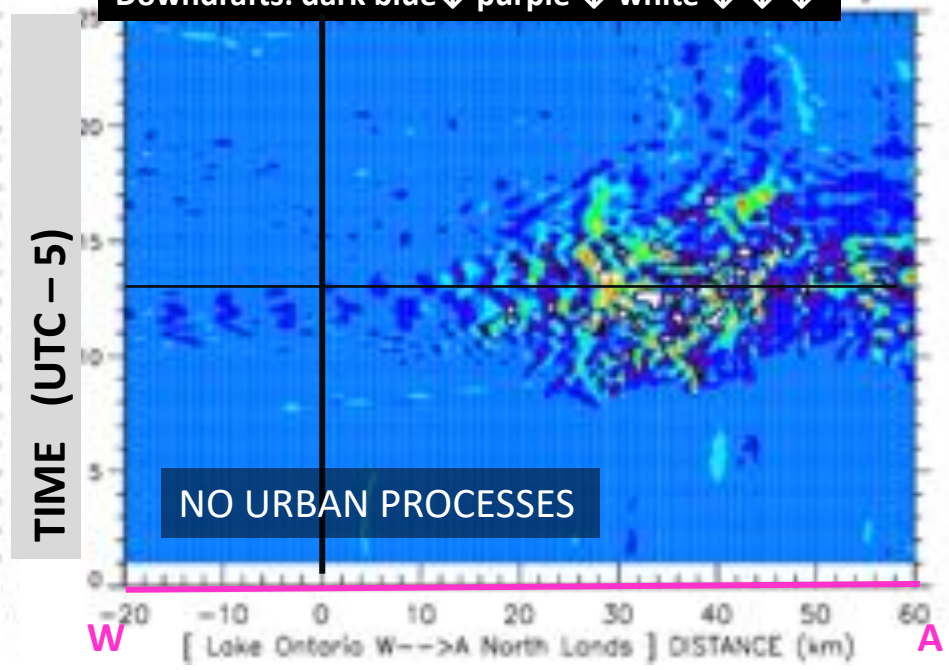


CONTROL RUN (13 LT)



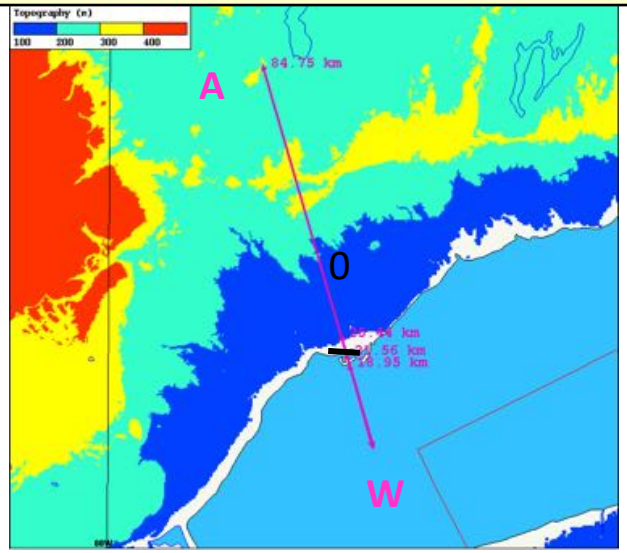


Updrafts : green ↑ red ↑ ↑ white ↑ ↑ ↑
Downdrafts: dark blue↓ purple ↓ white ↓ ↓ ↓

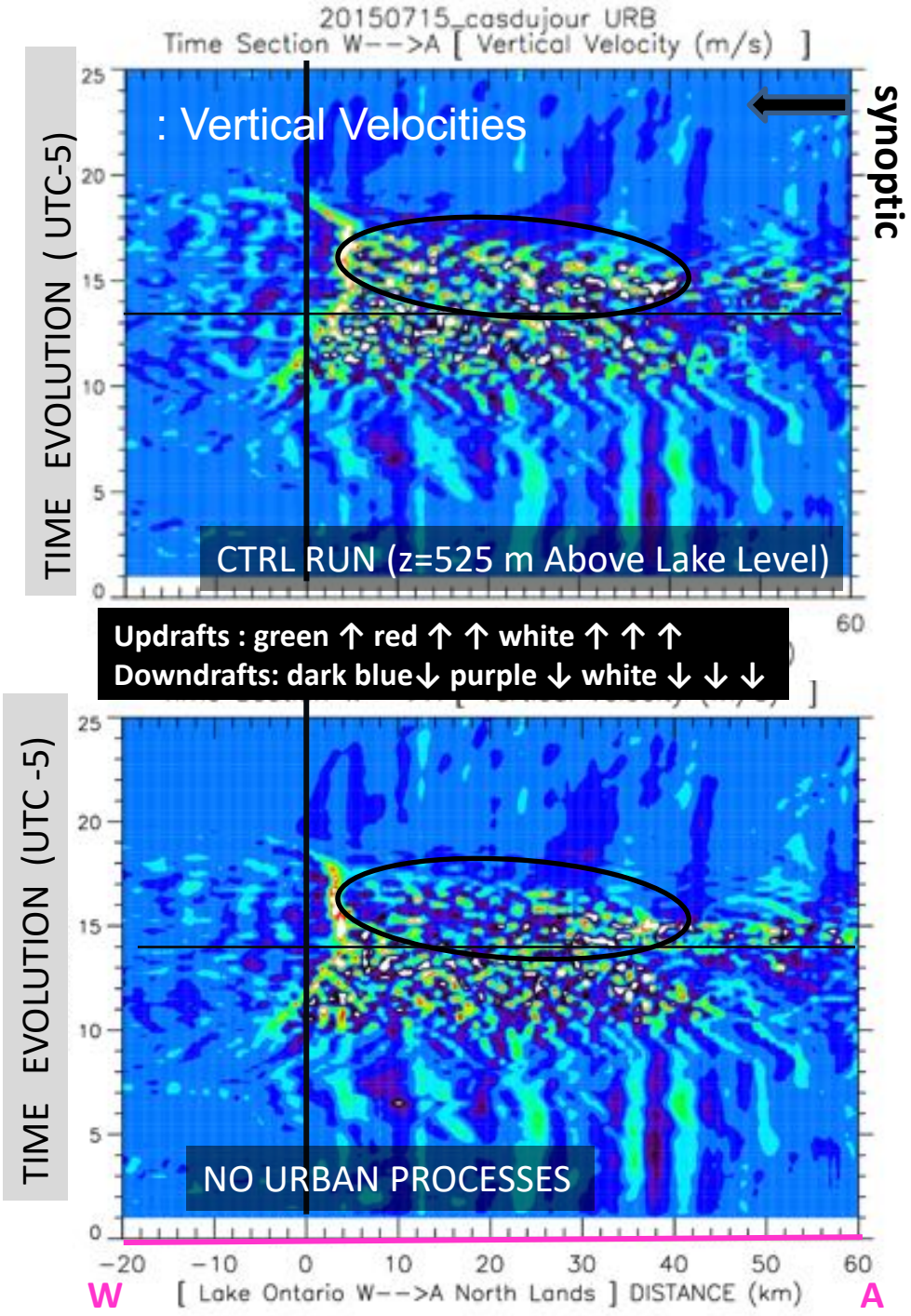


Influence of the urban area on the turbulence

15 July 2015

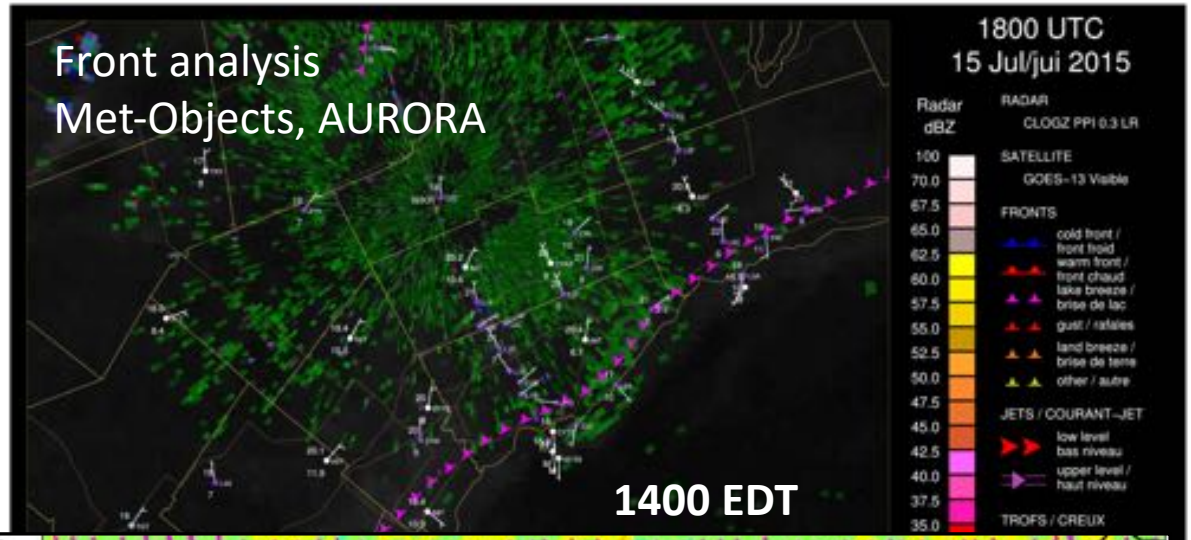


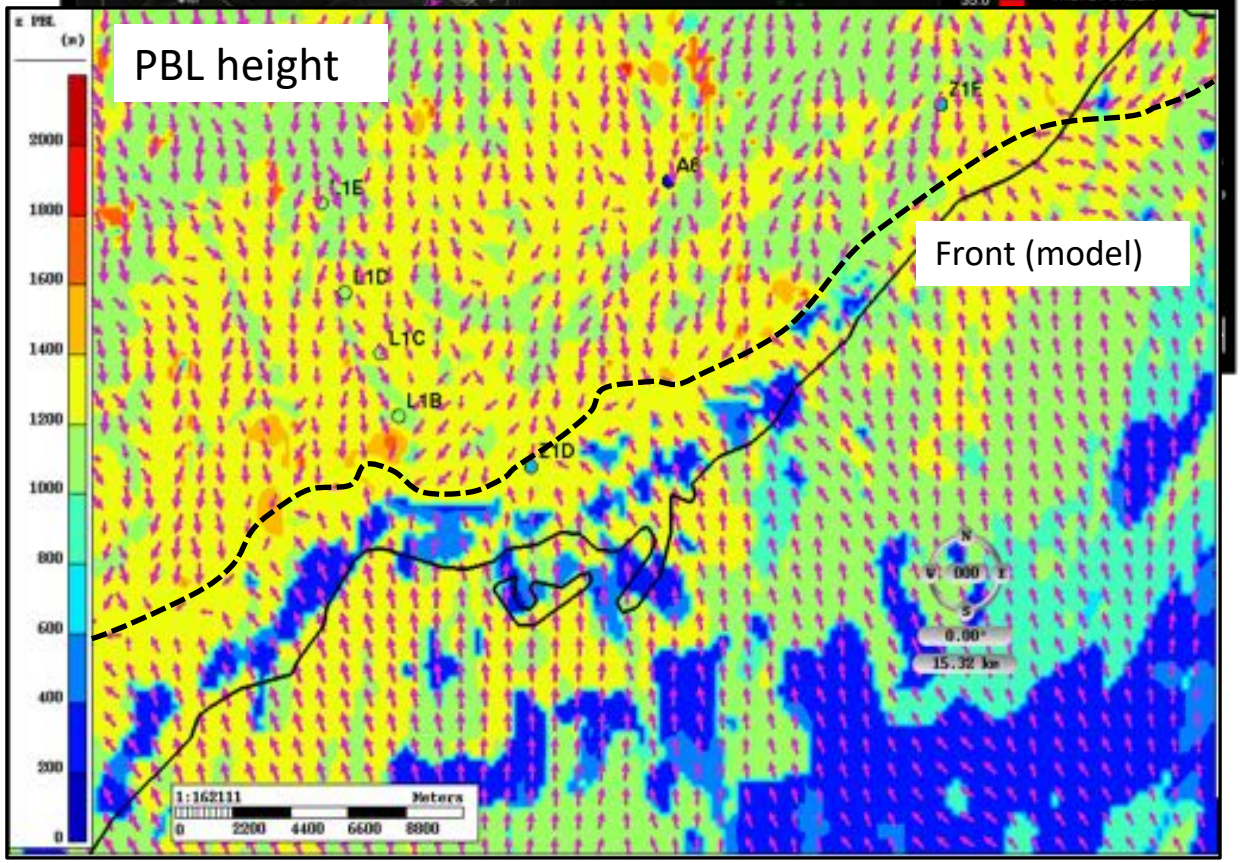
- Strong synoptic flow (NW) prevents Inland penetration of the lake breeze
- **Influence of the urban area is not predominant on the front location for this case**
- However, **increase of turbulence in late afternoon north from the front**



Evaluation of the lake-breeze front

2nd attempt for PBLh

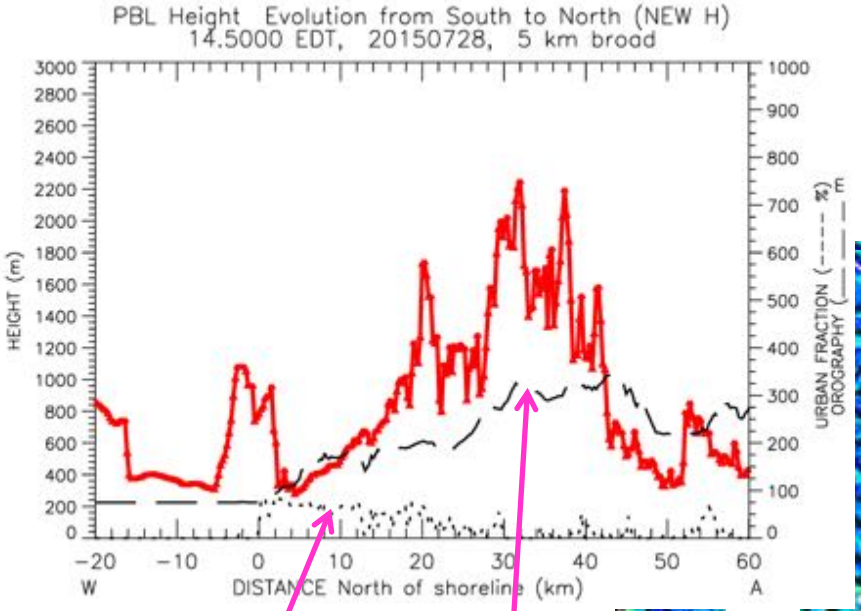




- Automatic grid-point PBLh diagnostics
- Find inflection based on vertical profiles of
  - → Θv (virtual pot. Temp., spec. Humidity (instable),
  - → surface-layer parameters (stable conditions)

2nd attempt for PBLh

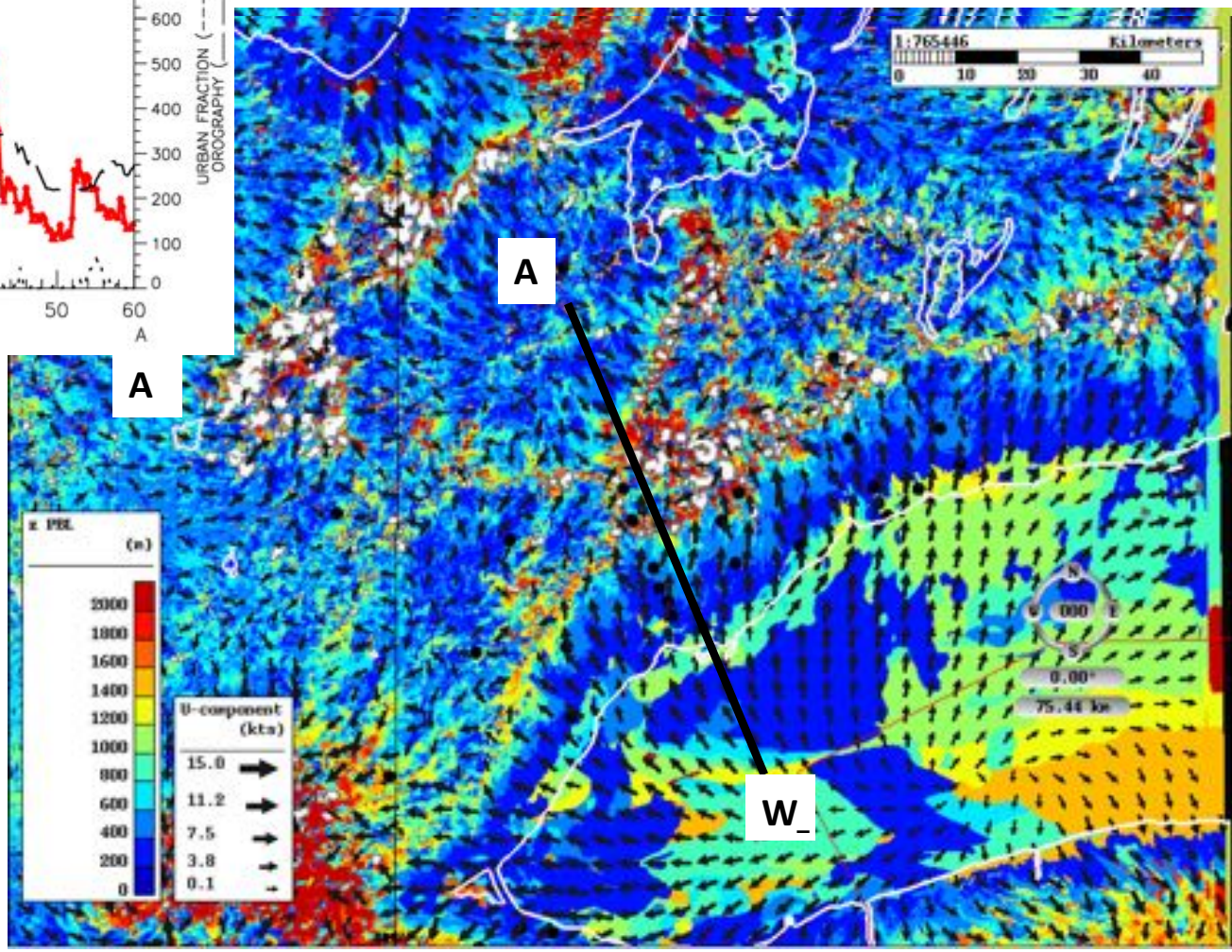
28 July 2015



W_

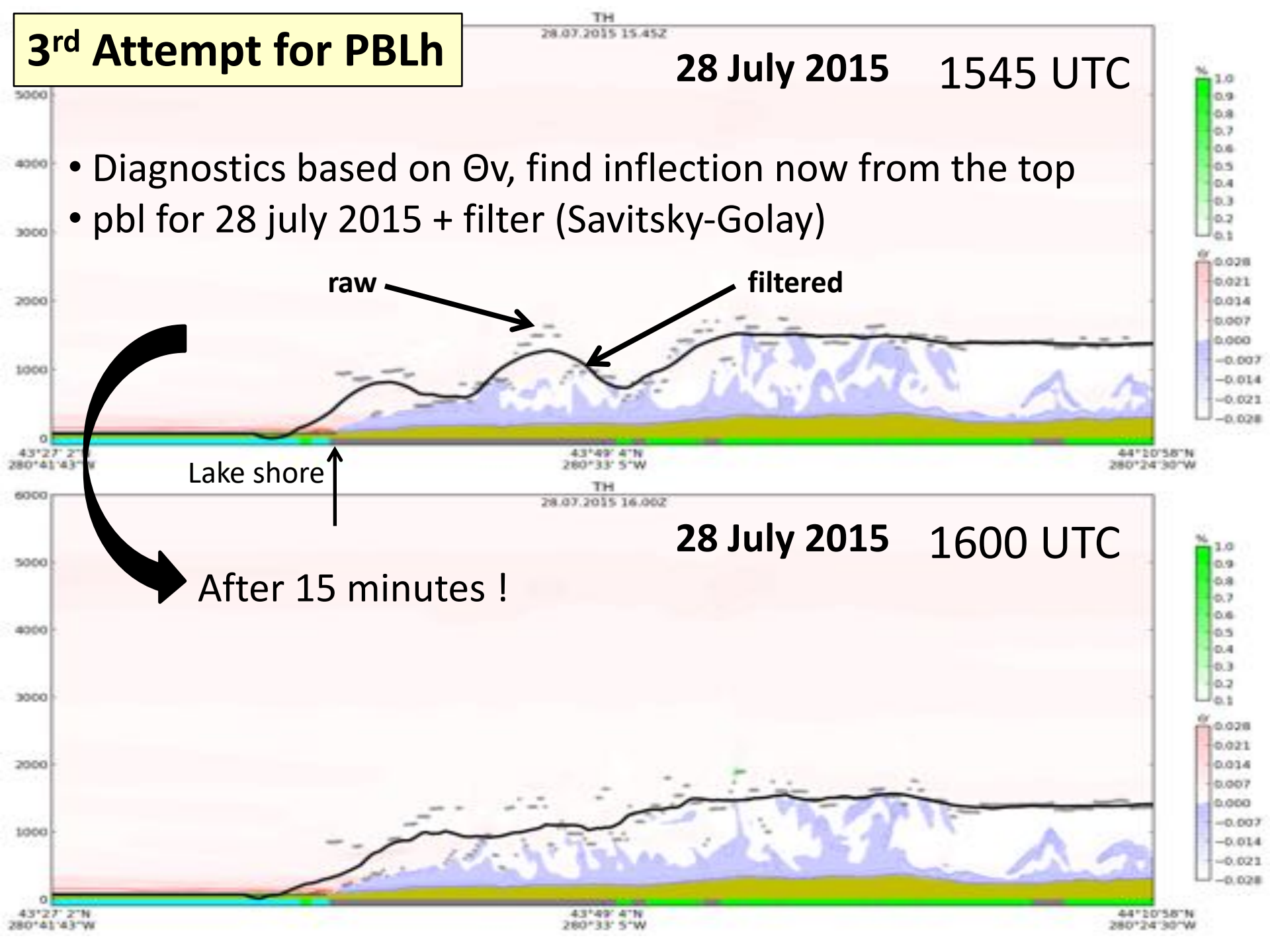
Orographie

Urb %



- Sometimes questionable
- Artefacts ?

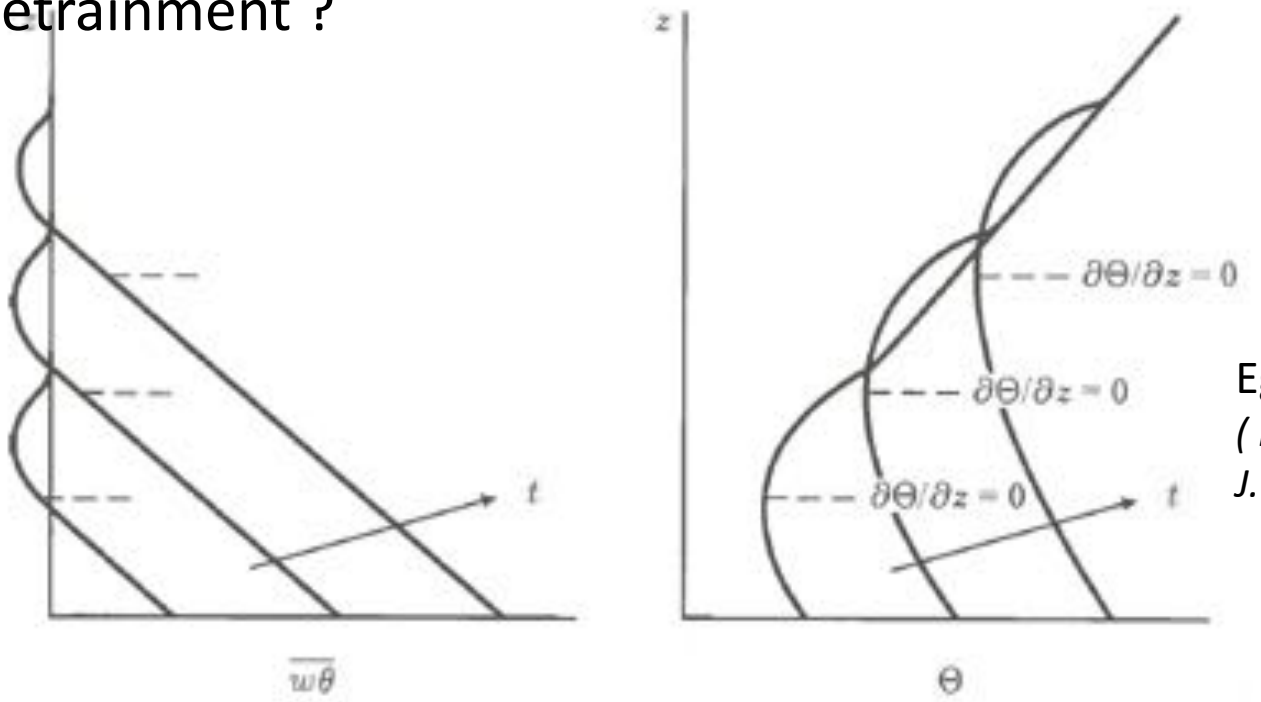
3rd Attempt for PBLh



- Diagnostics based on Θv, find inflection now from the top
- pbl for 28 july 2015 + filter (Savitsky-Golay)

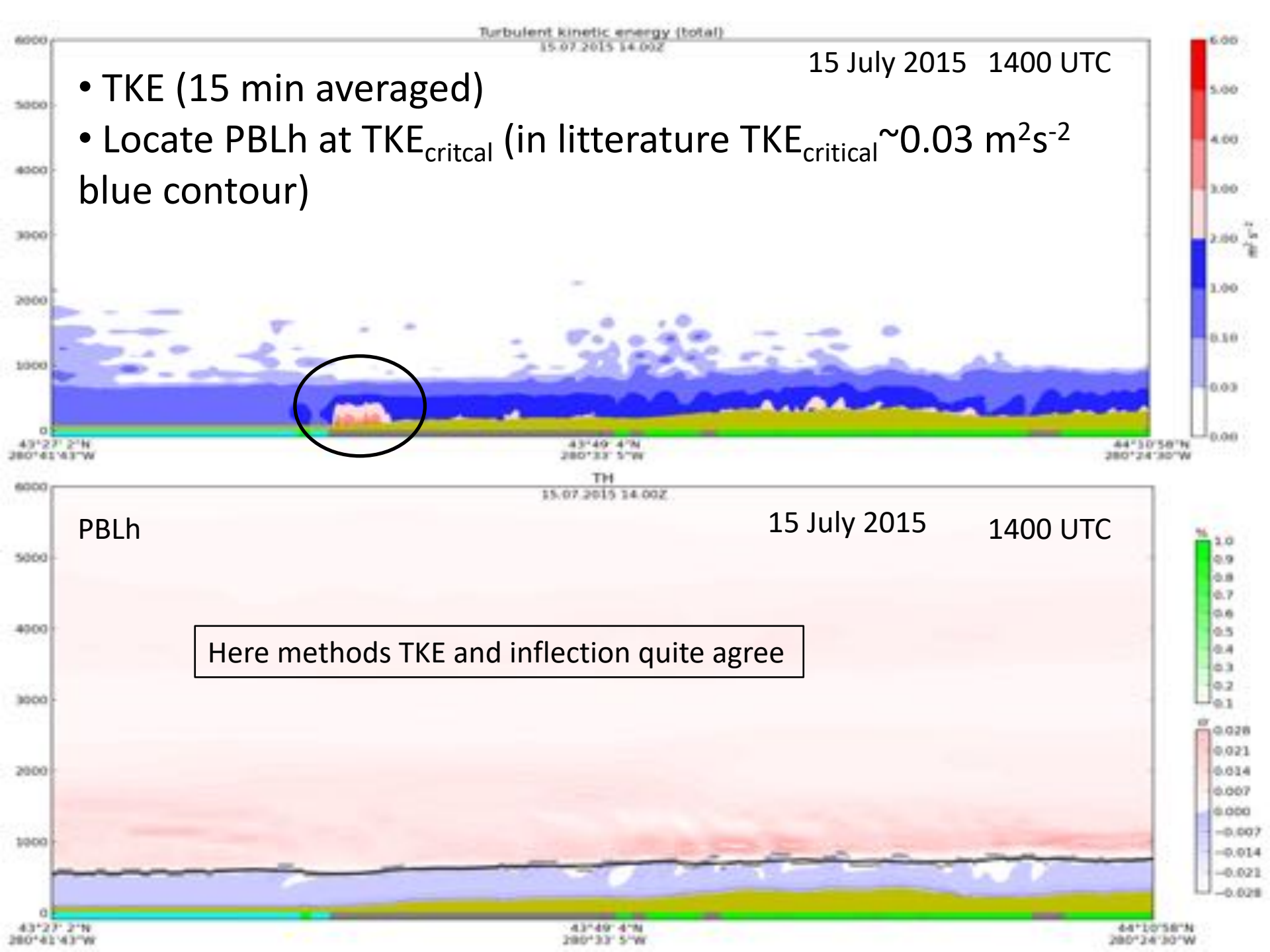
Should we try to determine the PBLh ?
Other turbulent features of interest

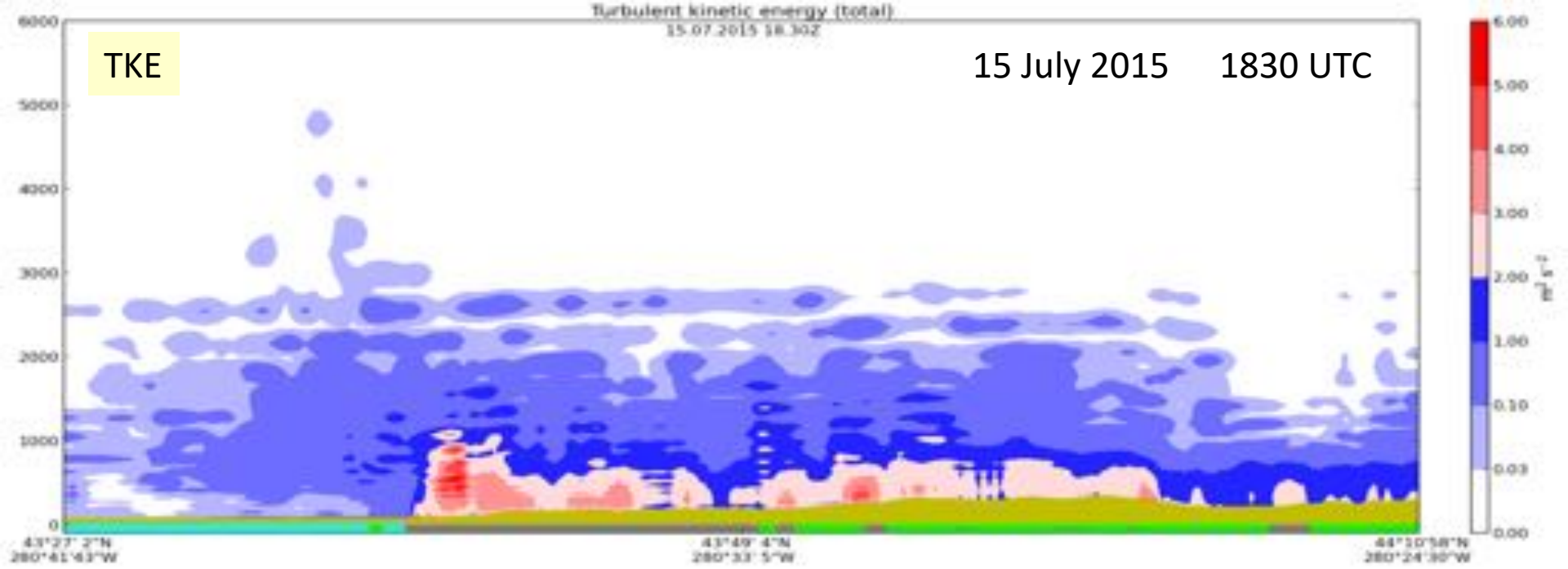
Challenges : residual layer ? Several inflections ? Growing mixed layer ? Detrainment ?

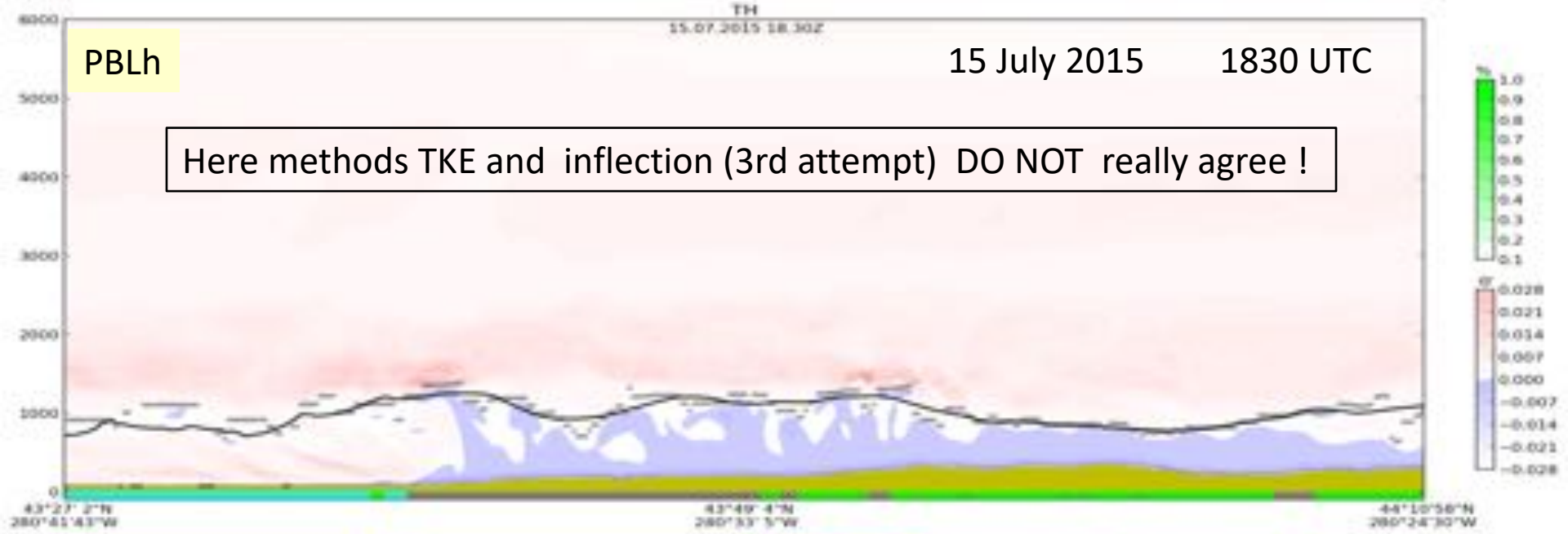


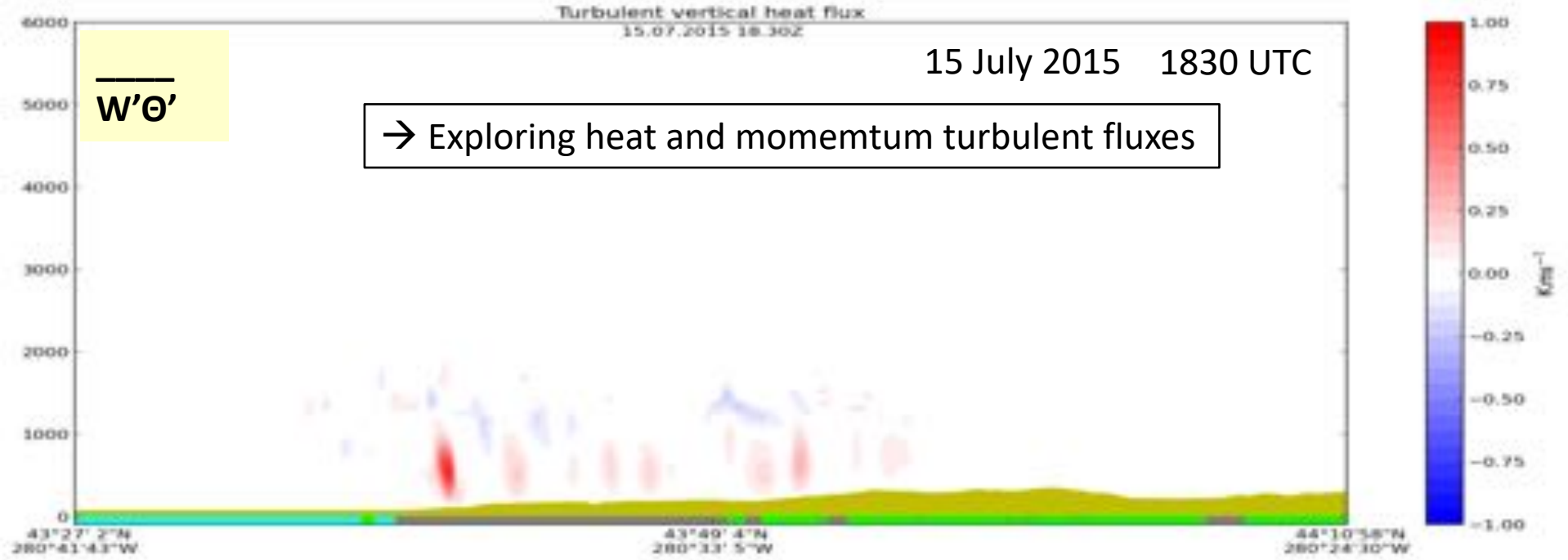
Eg, growing mixed layer
(In Turbulence in the atmosphere J. C. Wyngard)

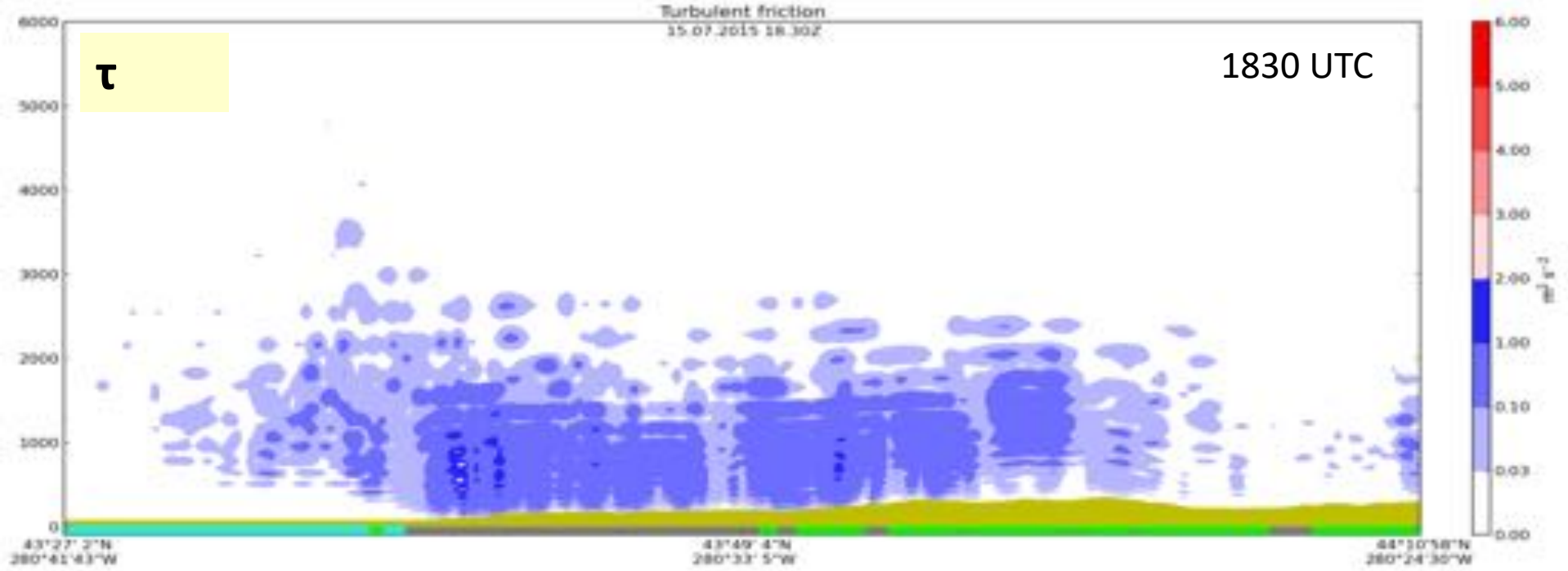
- Turbulence at such resolution : grid-scale (parametrized) + resolved
- Turbulent Kinetic Energy (TKE)
- Heat and Moisture Fluxes (w'Θ' & w'q')
- Momentum fluxes (τ)

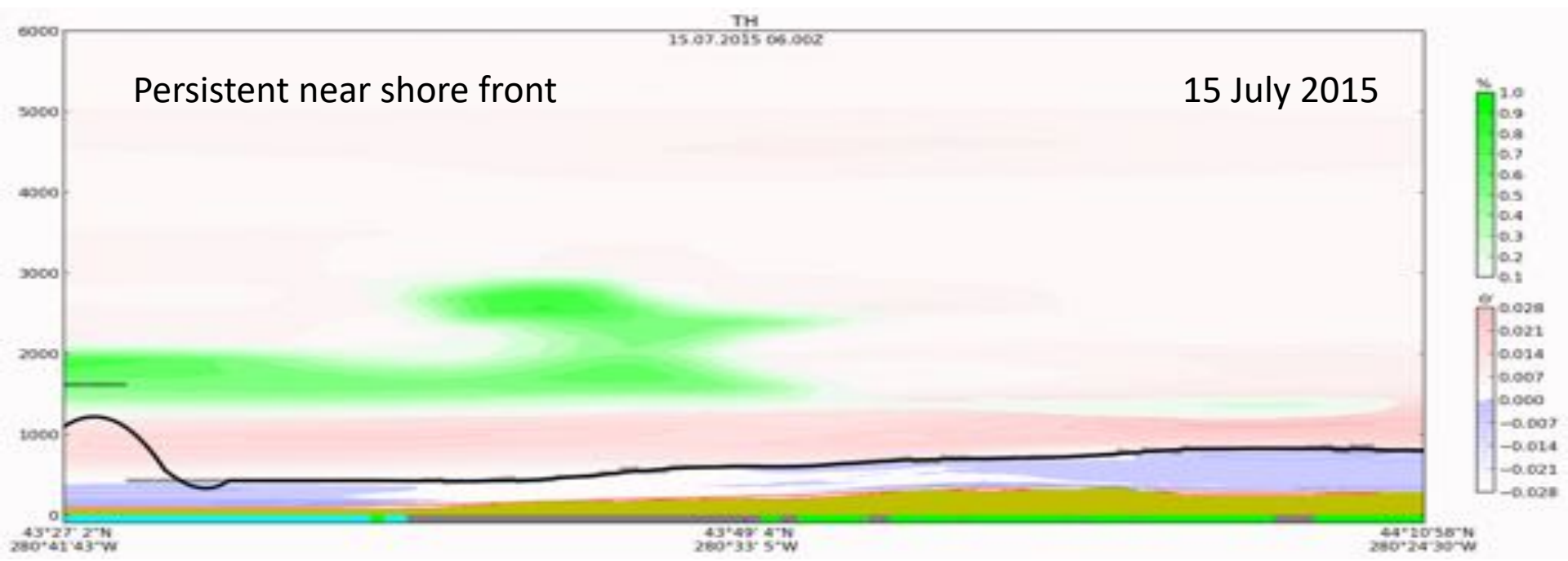

Turbulent kinetic energy (total)
15.07.2015 14:00Z
15 July 2015 1400 UTC
• TKE (15 min averaged)
• Locate PBLh at TKE$_{critcal}$ (in litterature TKE$_{critical}$~0.03 m^{2}s^{-2} blue contour)
TH
15.07.2015 14:00Z
PBLh
15 July 2015
1400 UTC
Here methods TKE and inflection quite agree

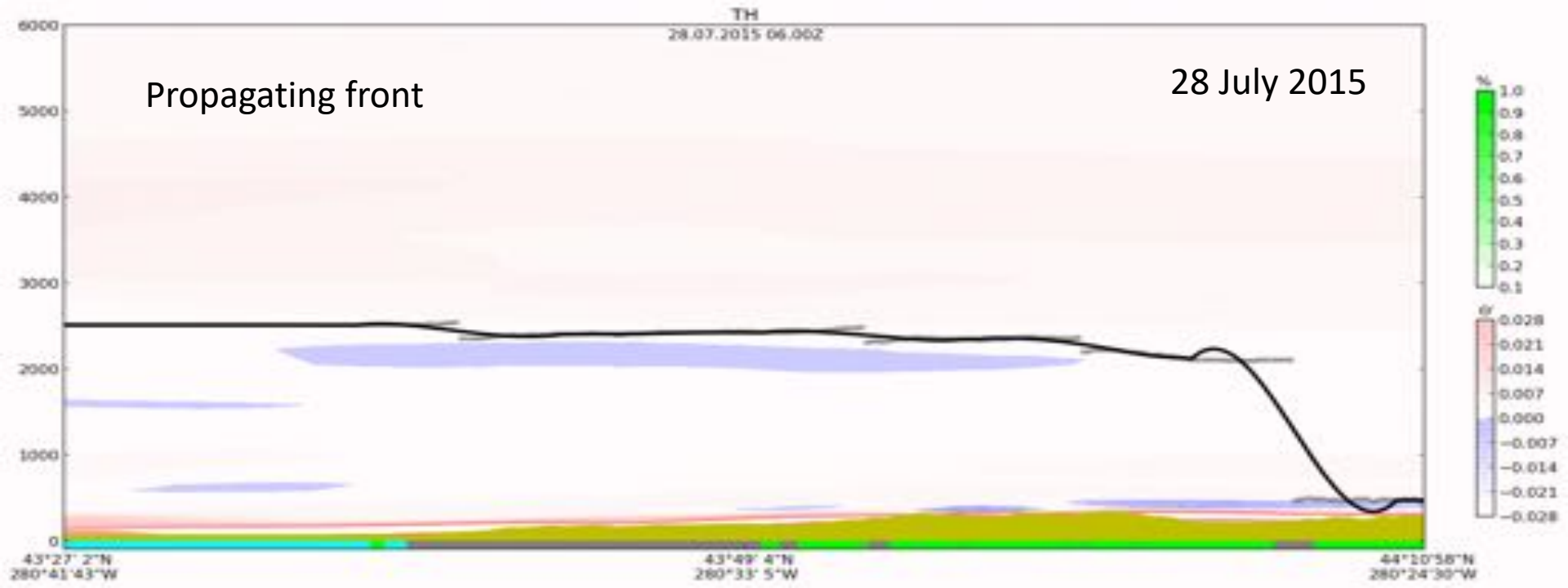

Turbulent kinetic energy (total)
15.07.2015 18:30Z
TKE
15 July 2015 1830 UTC
6000
5000
4000
3000
2000
1000
0
6.00
5.00
4.00
3.00
2.00
1.00
0.10
0.03
0.00
43°27' 2"N
280°41'43"W
43°49' 4"N
280°33' 5"W
44°10'58"N
280°24'30"W


TH
15.07.2015 18:30Z
PBLh
15 July 2015 1830 UTC
Here methods TKE and inflection (3rd attempt) DO NOT really agree !
6000
5000
4000
3000
2000
1000
0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.028
0.021
0.014
0.007
0.000
−0.007
−0.014
−0.021
−0.028
43°27' 2"N
280°41'43"W
43°49' 4"N
280°33' 5"W
44°10'58"N
280°24'30"W


Turbulent vertical heat flux
15.07.2015 18:30Z
$\overline{w'\theta'}$
15 July 2015 1830 UTC
→ Exploring heat and momemtum turbulent fluxes
6000
5000
4000
3000
2000
1000
0
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
Kms⁻¹
43°27' 2"N
280°41'43"W
43°49' 4"N
280°33' 5"W
44°10'58"N
280°24'30"W


Turbulent friction
15.07.2015 18:30Z
τ
1830 UTC
6000
5000
4000
3000
2000
1000
0
6.00
5.00
4.00
3.00
2.00
1.00
0.10
0.03
0.00
m² s⁻²
43°27' 2"N
280°41'43"W
43°49' 4"N
280°33' 5"W
44°10'58"N
280°24'30"W


TH
15.07.2015 06.00Z
Persistent near shore front
15 July 2015
6000
5000
4000
3000
2000
1000
0
43°27' 2"N
280°41'43"W
43°49' 4"N
280°33' 5"W
44°10'58"N
280°24'30"W
%
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
dT
0.028
0.021
0.014
0.007
0.000
−0.007
−0.014
−0.021
−0.028


TH
28.07.2015 06.00Z
Propagating front
28 July 2015
6000
5000
4000
3000
2000
1000
0
43°27' 2"N
280°41'43"W
43°49' 4"N
280°33' 5"W
44°10'58"N
280°24'30"W
%
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
dT
0.028
0.021
0.014
0.007
0.000
−0.007
−0.014
−0.021
−0.028

Conclusions

Planetary Boundary-Layer Height (PBLh)

- No revolution : It is difficult to get automatic PBLh diagnostics in urban GEM-LAM → but It is worth having a guess
- Can be used for lower resolution model
- Planed evaluations with observations
- Could Air Quality models be designed not to use PBLh ?

Benefits of urban and high-resolution modelling system for use to air quality

- Impact of urban and surface heterogeneities on small-scale meteorological processes
- Detailed turbulence representation
- Detailed advection

Limitations

Too low resolution of emissions inventories

THE END

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