WRF PBL schemes for turbulence parameterizations: representing dispersion processes in sub-kilometer horizontally non-homogeneous flows

Elena Tomasi, Lorenzo Giovannini, Pedro Jimenez, Branko Kosovic, Stefano Alessandrini, Enrico Ferrero, Marco Falocchi, Dino Zardi and Luca Delle Monache

UNIVERSITAS ATHESINA STUDIORUM

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

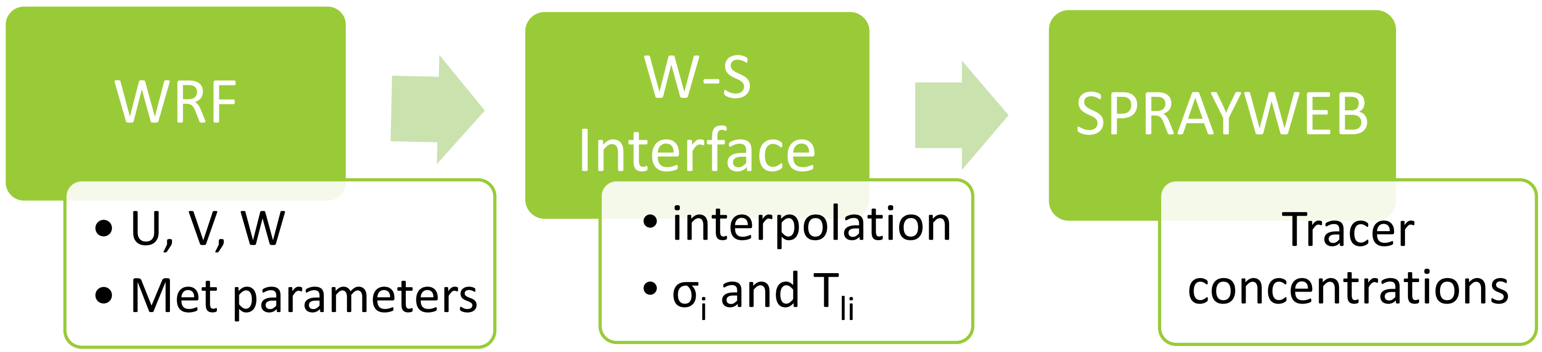
UPO UNIVERSITÀ DEL PIEMONTE ORIENTALE

Outline

1. Aims and Methodology
2. BTEX: the Bolzano Tracer experiment
3. The meteorological simulations with WRF
4. The dispersion simulations with SPRAYWEB
   - Turbulence parameterizations in the WRF-SPRAYWEB Interface
5. Results against measured tracer concentrations
6. Conclusions

Aims and Methodology

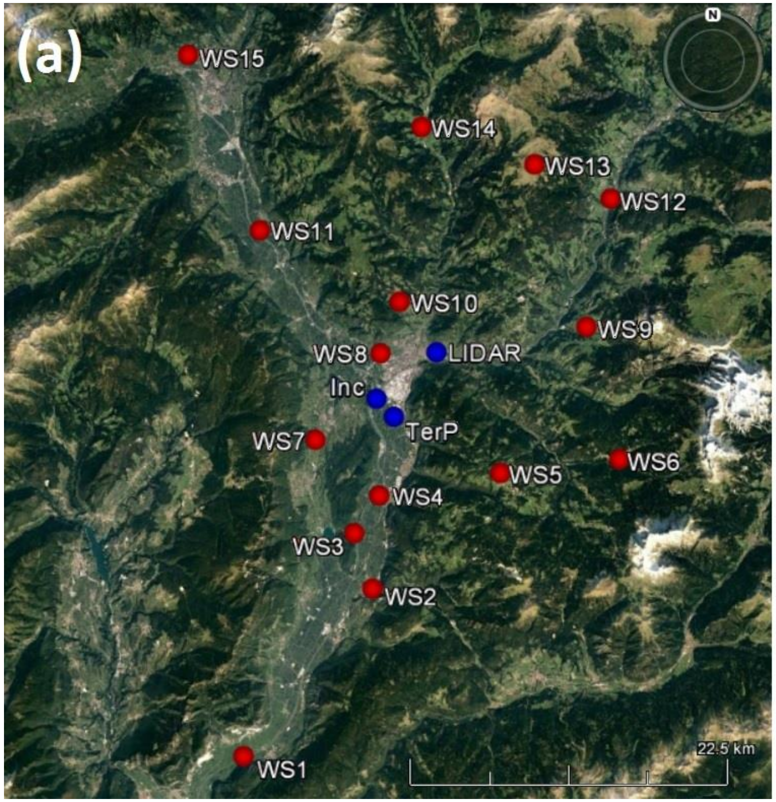
Compare the performance of **different turbulence parameterizations** over complex terrain with a WRF-SPRAYWEB modeling chain

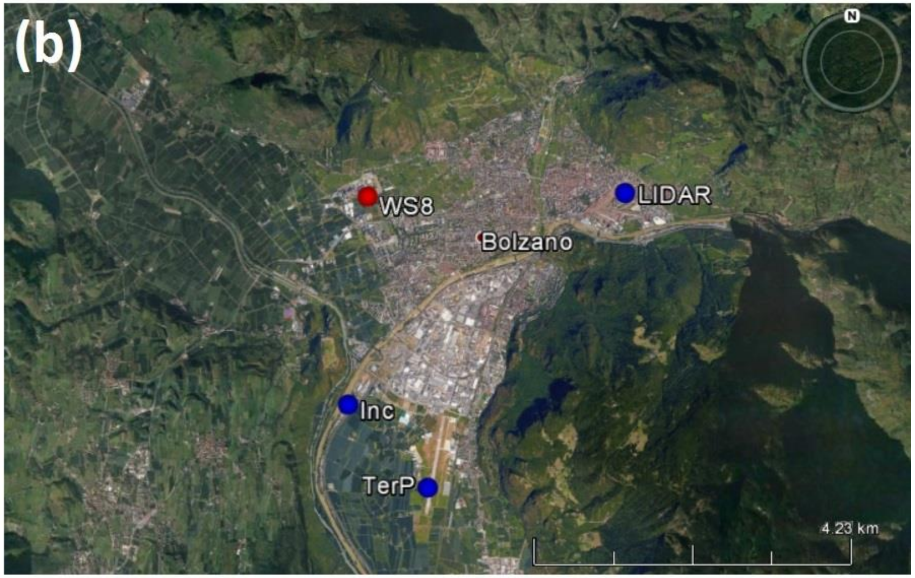


BTEX: the Bolzano Tracer EXperiment

- 14^{th} February 2017
- 2 releases of tracer gas
  7 am and 12:45 am
- 80 samples of ground concentration collected

BTEX: the Bolzano Tracer EXperiment

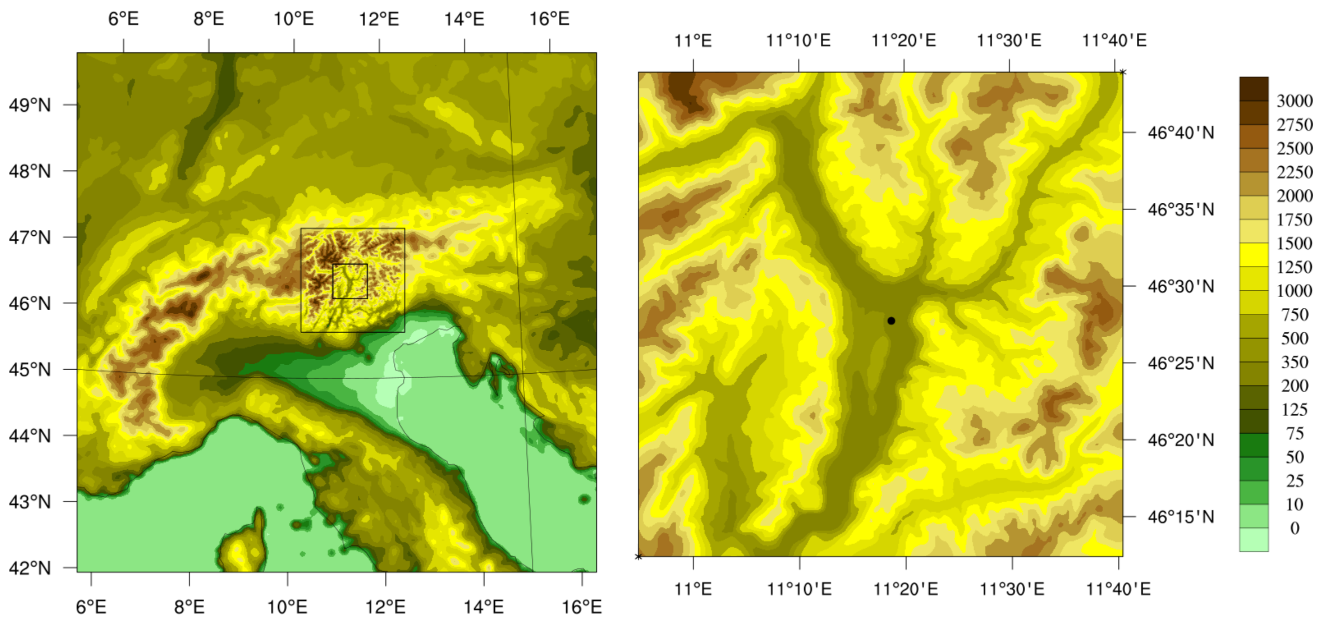




More details on BTEX: Poster H18-184

Meteorological simulations with WRF

- WRF v3.8.1, 3 nested domains, 30m vertical resolution up to 1km
- Innermost domain: 300 m horizontal resolution, obs nudging
- 6-hourly ECMWF HRES Operational Data, 9-km resolution



Meteorological simulations with WRF

- Mellor-Yamada Nakanishi Niino **Planetary Boundary Layer scheme** (MYNN, *Nakanishi and Niino, 2004*)
  - 1D scheme → HP: horizontal homogeneity
  - 1.5-order scheme
  - prognostic equation for turbulent kinetic energy (TKE)
  - Closure constants

(A1, A2, B1, B2, C1) = (1.18, 0.665, 24.0, 15.0, 0.137)

From LES over flat terrain

MODIFICATION

(A1, A2, B1, B2, C1) = (2.135, 0.64, 35.94, 61, 0.167)

From Wind Tunnel data over an idealized valley

Trini Castelli et al. (2001) and *Trini Castelli et al. (1999)*

Meteorological simulations with WRF

OUTPUT FROM THE WRF SIMULATONS

Mean wind

U, V, W

Surface layer scales:

u_*, w_*, L, h_{mix}

Turbulent kinetic energy (prognostic):

TKE

Vertical dispersion coefficient:

K_m

Turbulence parameterizations in the WS-Interface

Development and test of **WRF-SPRAYWEB interface**

From meteorological data to wind standard deviations and lagrangian time scales

1. Hanna (1982) parameterization

$$\sigma_i = f(L, u_*, w_*, H_{mix}, z, C_i)$$

$$T_{li} = f(\sigma_i, L, H_{mix}, z, C_i)$$

2. M-Y parameterization from TKE
3. M-Y parameterization from TKE with MODIFIED closure constants

$$\sigma_U = \sigma_V = \sqrt{(1-\gamma)q^2}$$

$$\gamma = \frac{1}{3} - 2\frac{A_1}{B_1}$$

$$\sigma_W = \sqrt{\gamma\, q^2}$$

$$q^2 = 2\,TKE$$

$$T_{li} = \frac{K_m}{\sigma_i^2}$$

Dispersion simulations with SPRAYWEB

Development and test of **WRF-SPRAYWEB interface**

From meteorological data to wind standard deviations and lagrangian time scales

Dispersion Simulation	WRF PBL scheme	Dispersion model	Turbulence Parameterization
1. SPW_H	Stnd MYNN	SPRAYWEB	Sim. Theory Hanna
2. SPW_{TKE}	Stnd MYNN	SPRAYWEB	TKE scomposition
3. $SPW_{TKE_{mod}}$	Mod MYNN	SPRAYWEB	TKE scomposition

Dispersion simulations with SPRAYWEB

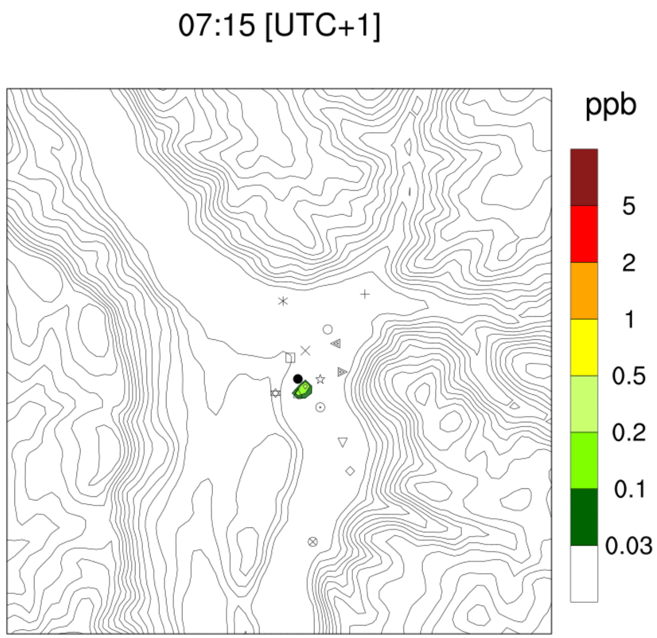
SPRAYWEB setup

- from 7 LST (1st release) to 18 LST (5 h after the 2nd release)
- Incinerator: point source, 60 m a.g.l, constant tracer releases

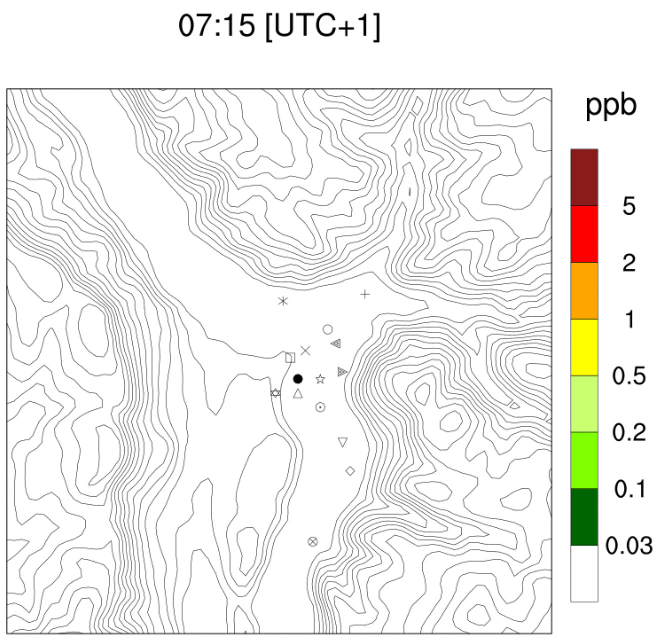
Release	Hour [LST]	Duration [h]	Temperature [°C]	Exit Velocity [m s^{-1}]
1^{st}	7:00	1	140	7.9
2^{nd}	12:45	1.5	140	7.8

- ground concentration grid: 300-m horizontal and 20-m vertical res
- varying time step internally calculated, min time step 2 s, 100 particles are released at every time step

Results



SPW_HANNA



SPW_TKE

Results

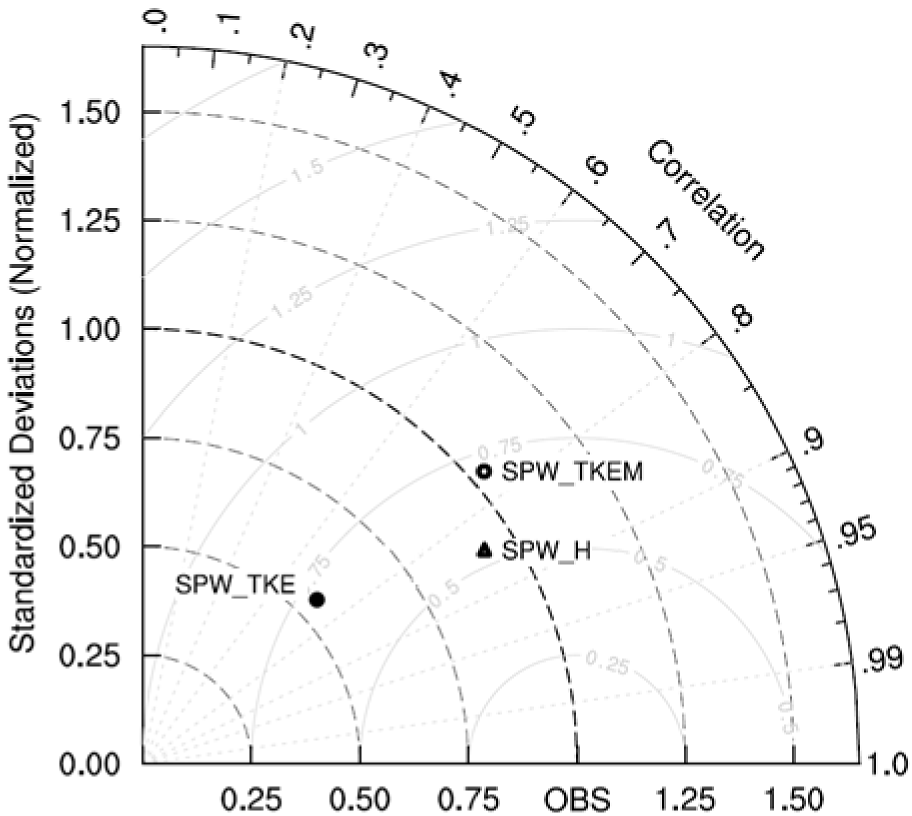
STATISTICAL INDEXES

Modeled mean, Correlation, Fractional BIAS, Norm. mean square error

	meanOBS	meanMOD	Corr	FB	NMSE	f2	Acceptance criteria *Hanna and Chang (2012)*
SPW_H	899.57	**892.9**	**0.85**	**-0.01**	**1.28**	0.41	yes
SPW_{TKE}	899.57	440.86	0.73	-0.68	5.04	0.32	no
SPW_{TKEmod}	899.57	887.7	0.76	**-0.01**	2.23	0.36	yes

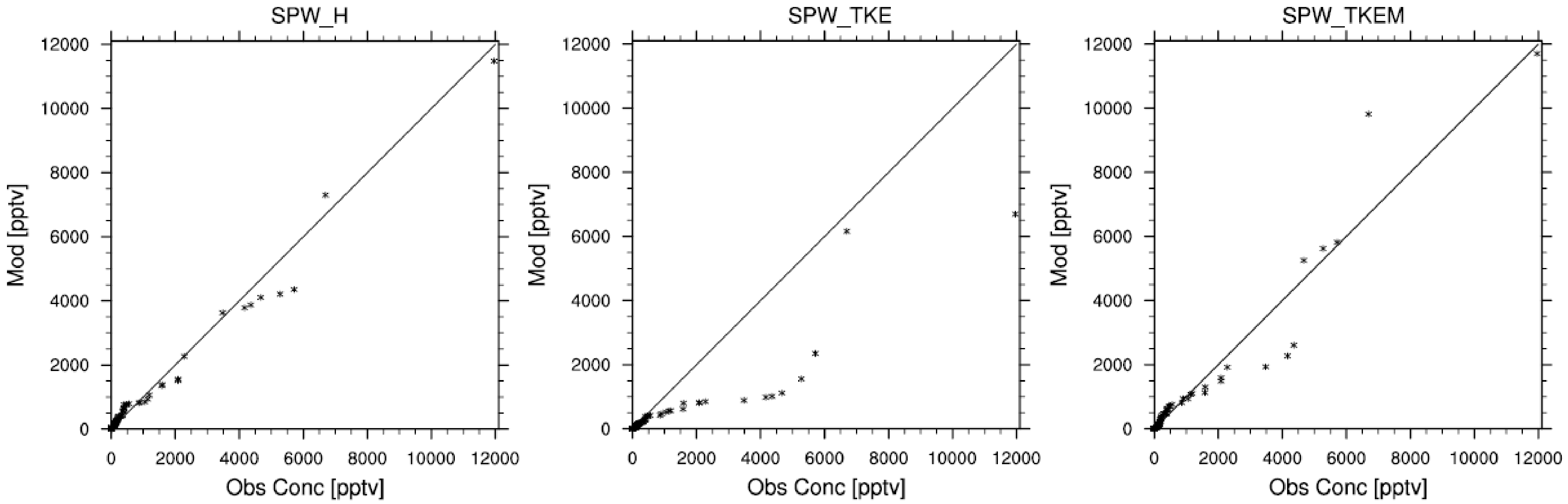
Results

TAYLOR DIAGRAM



Results

Q-QPLOTS



Conclusions

1. Overall results of modeled concentrations against measurements are satisfactory
2. The Hanna parameterization shows best performance
   → Surface layer scales from WRF are reliable in this case study
3. The TKE parameterization is effective only if closure constants for complex terrain are used
4. Improvements of SPW_{TKEmod} can derive from both meteorological changes and dispersion parameterizations
   → Both the wind mean field and the dispersion parameterization are affected by the closure constants

Future work

- Run SPW_{Hanna} with the updated meteorological field
- Compare modeled σ_i with observations from a SODAR over the incinerator roof
- A 3D PBL scheme is under development at NCAR
  - → non-homogeneity also on the horizontal plane
  - → provides dispersion coefficients on the 3 directions

THANK YOU!

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