Application of CALMET model to the the Veneto region, with particular attention to the shoreline, using offshore data for initialization

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Abstract

CALMET model has been implemented on the Veneto Region, by the Meteorological Center of Teolo, as meteorological pre-processors for pollution dispersion models, with particular attention to the land-sea boundary, for Porto Marghera (the big industrial zone close to Venice). Considering the availability of only one station off-shore of Venice, we have been testing various settings in order to model as best as possible the wind field on the sea. In particular we compared the use of the CALMET "Sea breeze option" with our idea to simply replicate the sea-data on different location "ghost water stations". The graphic comparison show that this is a reasonable solution over sea as the wind field is more uniform both horizontally and vertically. The output wind-field was then tested versus land surface data and the results show that our "ghost water stations" is performing better than the "Sea breeze option" over 6 month data.

Introduction

Within the SIMAGE project (Integrated System for Air quality control and Emergency management in the industrial pole of Porto Marghera, close to Venice) the CMT (Meteorological Centre of Teolo) made the implementation of CALMET model on the Veneto region. CALMET is a meteorological diagnostic model, normally used as a pre-processor for CAPUFF, pollution dispersion model.
It became soon very clear that is extremely important to have at least one station off-shore, as the wind and temperature on the sea are very different from the land. Furthermore, CALMET proposes a "Sea-breeze option" to solve the problem of the impossibility to have a complete stations-network on the sea, but this applies only in the first level of the model. In this work we try to find a solution that can give more reasonable results also in the upper levels.

Short description of the model on Veneto

The CALMET model use the Similarity Theory to calculate mixing heights, see the model manual [1] and related bibliography for details.
Temperature field at surface is calculated by interpolating the data, with the option of considering just the sea stations on the water. On the land an adiabatic extrapolation up to the mixing height is used and interpolation of the upper data above, whereas on the sea a constant lapse rate up to the top is used (respectively -0.98 and -0.45 K/100m under and above mixing height) instead of upper stations data.
Wind field at surface (10m) is calculated by interpolating the data, plus taking into account some features due to orography like slope flows. For the upper levels a blend is made with the extrapolation of the surface wind field with Similarity Theory up to the mixing height and the interpolation of the upper data, whilst above only interpolation of upper data is used.

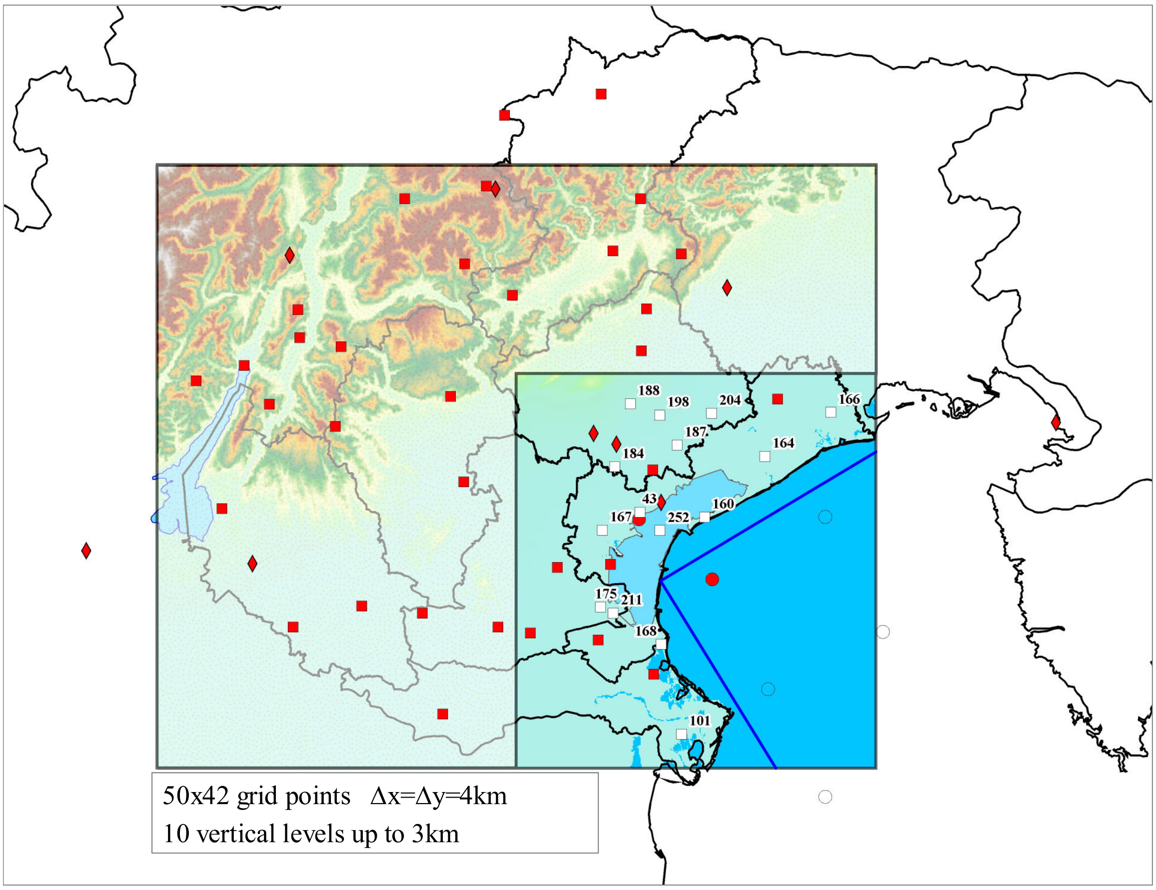

Figure 1: stations data and model domain with the zoom on the area considered on this study. Blue straight lines indicate the artificial shoreline for the CALMET "sea breeze option"

In the Figure 1 the domain of the model is shown, with a zoom on the area of interest.
The input stations are marked in red: 24 CMT, 1 EZI (Industrial site station) and 9 Meteotrentino (red squares), 9 Synop (red diamonds), off-shore Venice Municipality station mounted on CNR platform (red circle).
The Figure 1 also shows the stations used in our "ghost station setting", replication of Venice Municipality data on different location (empty circle, see below for details).
The input upper air station (radiosoundings) are 16080 (Milano) and 16044 (Udine).

CALMET "Sea breeze option"

CALMET comprises the "Sea breeze option" to reduce the problem of not having a stations network on the sea. The result is a different interpolation scheme, that consider the relative distance between the grid point and the station from an artificial user defined shore line (the blue lines in the Figure 1). The new calculation is made just at the surface, and this introduces a strong discontinuity in vertical wind profile between first and levels above (see blue line in the Figure 2, other lines explained below).

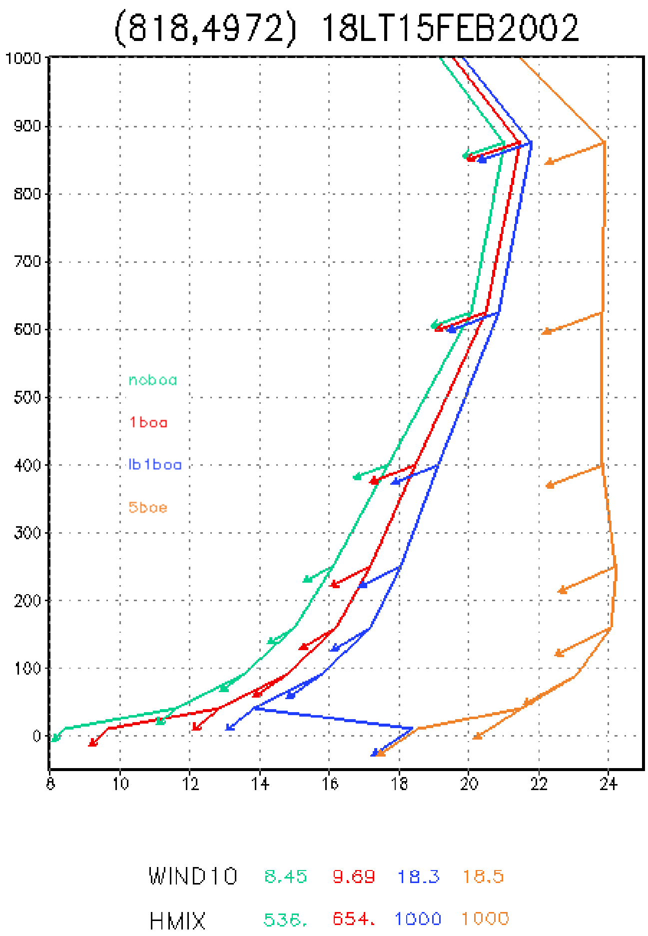

Figure 2: vertical wind profile

Testing different settings

We tested CALMET for the period January-June 2002 with 4 different model settings:

A) without over-water station (called "noboa" in figures);
B) with real over-water station ("1boa");
C) with real over-water station and CALMET Sea breeze option ("lb1boa");
D) with real + 4 ghost over-water stations (5boe").

In the following figures are shown CALMET output under the 4 conditions, for three characteristic winds in the region: sea breeze, south-easterly wind (Scirocco) and north-easterly wind (Bora). The red arrows are input data (over land and over water) and white arrows are verification data.

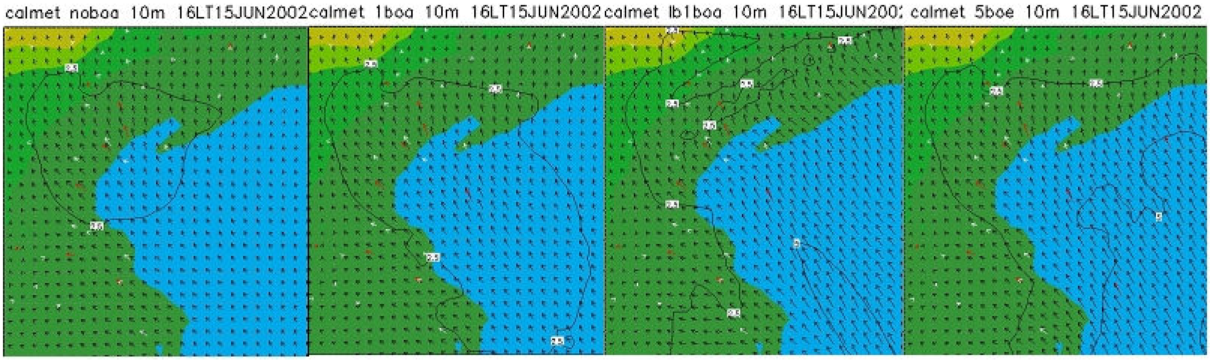

Figure 3: sea breeze wind, June the 15th 2002 at 4PM

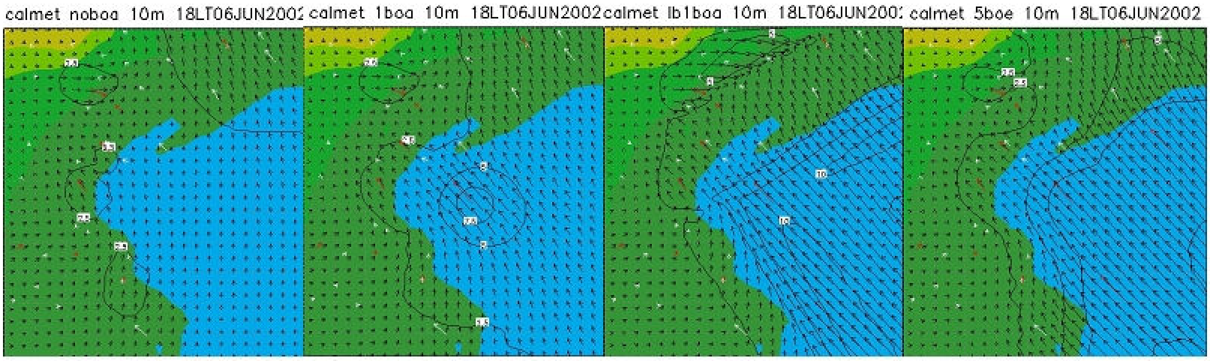

Figure 4: Scirocco wind (SE), June the 6th 2002 at 6PM

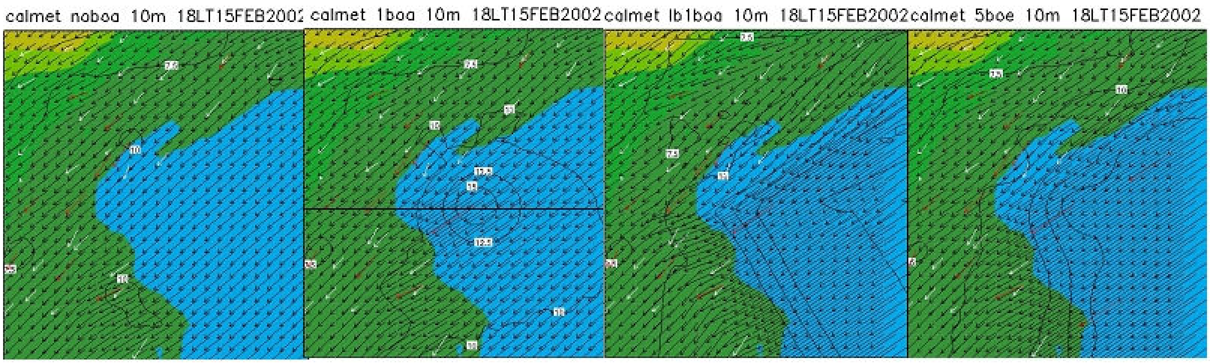

Figure 5: Bora wind (strong NE), February the 15th 2002, at 6PM. Cut for vertical section is shown

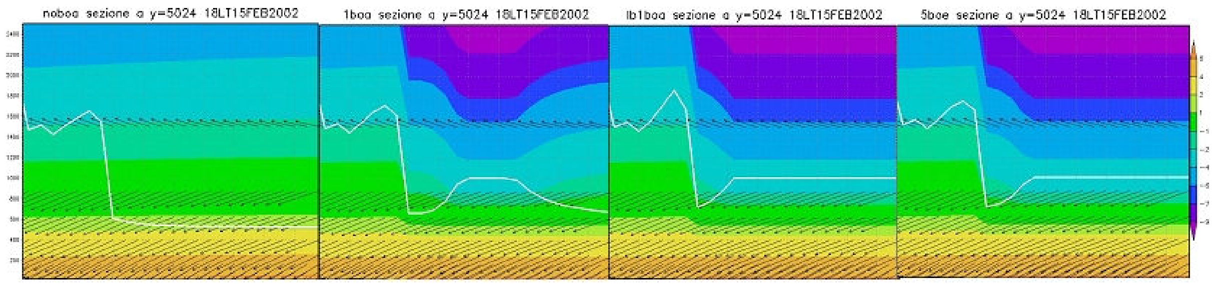

Figure 6: vertical section for cut shown in Figure 5. Wind, T (coloured) and mixing height (white line)

A) No water station

Setting A) shows how misleading can be to neglect the difference of the wind and temperature fields between land and sea.
The vertical section shows the same thermal profile both on land and sea.

B) 1 water station

Setting B) produces "bubbles" of strong winds around and above the water station*,* but still weak winds over water points far from the station.
The vertical section of the temperature over water has changed completely as the model uses a constant lapse rate on the sea, regardless of the upper air station data.

C) 1 water station + CALMET Sea breeze option

Setting C) produces more uniform winds over the sea, but introduces strange behaviour on the horizontal field over land (see Figure 4, above the upper shore line).
Furthermore, strong vertical discontinuities are introduced (see Figure 2). The vertical section of temperature and mixing height are more uniform than case B).

D) The idea! 1 water + 4 ghost water stations

Setting D) replicates Venice Municipality station data on different off-shore locations (in the figures red empty circles and red arrows). It is our idea to make wind over the sea more uniform both in horizontal (as the sea breeze option does) *and* in the vertical (where the sea breeze option fails).
Visual inspection of the results suggests reasonable behaviour both in the horizontal and in the vertical, on the sea. But does this choice worsen the output over the land?

Statistical comparison over land

To compare the four settings over the land we compare statistically the model outputs of the four settings versus a set of verification stations: 2 stations at 10m and 13 stations at 2m (see figures above, white squares and arrows).
The used statistical parameters, calculated on 6 months data, are:
BIAS, RMSE, SKVAR (standard deviation ratio) for wind intensity, %30° and %60° success rates (percent of cases with wind direction in agreement within 30° and 60°, respectively), vector difference (evaluates both intensity and direction).

Both case C) and D) worsen statistical parameters for wind intensity, but case D) almost always is a little better. Success rates are much worse in case C), while case D) performs quite similarly as case B). **Therefore the setting with 4 ghost stations D) outperforms CALMET's sea breeze option C) over land.**

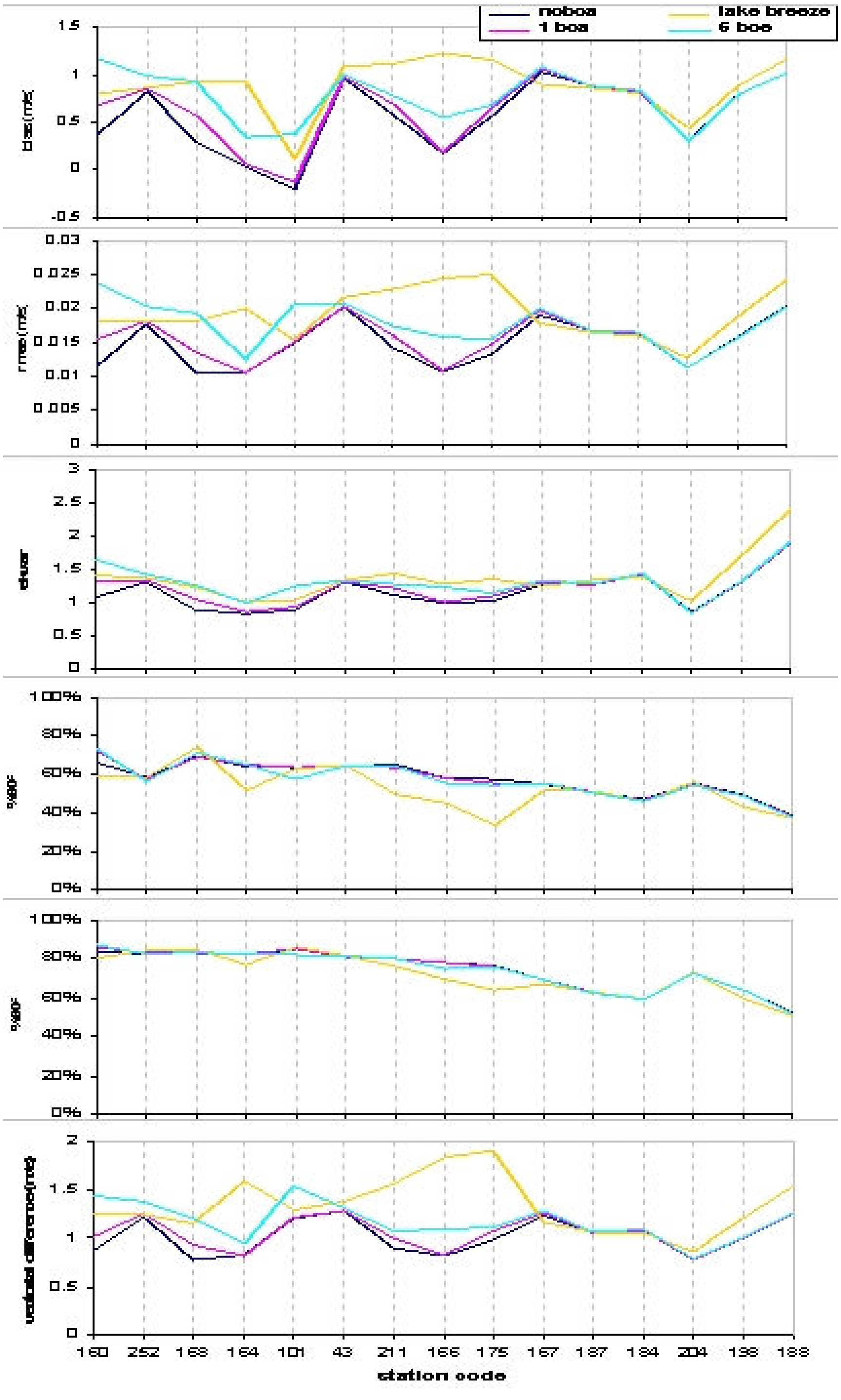

Figure 7: statistical parameters for different settings on wind intensity and direction

Conclusions

The limited number of water station is a big problem both for initialisation and verification of the model, therefore we have to make the assumption of uniform wind field on the sea:

- The use of at least one water station is very important, otherwise underestimate of wind field and mixing height on the sea are likely;

- CALMET's "Sea breeze option" has big problems, especially related to the resulting strong vertical discontinuity on wind field;
- A "ghost water stations" setting to maintain uniform wind over sea is proposed, which works still well on land and reasonably on sea.

Acknowledgments

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Bibliography

1. *J. Scire et al., 2000*: "A user's guide for the CALMET Meteorological Model"