REGTHERM 2001 Convection Model with Local Winds

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ABSTRACT

Differential heating creates horizontal pressure gradients which drive secondary circulations in the form of sea breezes and valley winds. Introducing a horizontal coupling between neighboring regions into the numerical convection model ALPTHERM allows one to model the effects of these secondary circulations on the primary convective circulations in the coupled regions. The weakened thermals in regions affected by sea breeze and in basins surrounded by elevated terrain appear in REGTHERM. Additionally, the effects of valley winds on thermals in mountains can be observed.

INTRODUCTION

Planning of soaring flights can be based on forecasts for regions with homogeneous flight conditions. Such a concept is in operational use at several national weather services based on the regional convection model ALPTHERM [1] nested to global or mesoscale numerical models for the synoptic evolution.

The spatial resolution of synoptic models is continually improved with increasing computational power. In the near future individual mountain valleys will appear in the model orography. Convective processes are not yet calculated explicitely in synoptic models. Parametrization of convection requires less computations and is sufficient for the forecast of the synoptic evolution. Lift rates in thermals, however, are not available from parametrization.

ALPTHERM treats complex topography within a region by considering its area-elevation distribution: the grid points within the region are sorted according to elevation and grouped into layers of constant depth. Atmospheric volume and surface areas thus depend on elevation. With ALPTHERM parametrization of convection can be replaced by explicit calculations of convective mixing of the model layers. This provides the vertical profiles of lift rates required for the forecast of the potential flight distance (PFD) [2].

DIFFERENTIAL HEATING AND EFFECTS OF LOCAL WINDS

Neighboring regions are heated differentially if their surface characteristics (albedo, evaporation) and/or their area-elevation distributions differ. The resulting horizontal temperature gradients will lead to local winds like sea breeze and valley wind (Figure 1). These local winds occur in a typical diurnal pattern and may be seen as a secondary circulation with a longer time scale when compared with the primary convective circulation in each region.

Thermally driven local winds carry heat and moisture. Warmer regions will aspire cooler air from neighboring regions close to the surface (cold air advection). The aspired air often contains more water vapor (moisture advection). Horizontal mass fluxes near the surface will be accompanied by inverted fluxes aloft if there are no gradient winds. In the presence of gradient winds the wind field aloft will be modified by the occurrence of local winds.

The horizontal fluxes of heat and moisture associated with local winds between differentially heated regions affects convection in both regions. The warmer region aspires cooler air in low levels and its convective primary circulation is not closed anymore: air rising in thermals must not be replaced entirely by compensating subsidence any more. The lapse rate in the aspiring region becomes slightly stable at the top of the advected cooler air. At these levels lift rates will decrease. The cooler region, on the other hand, looses air in the lower part of its convection layer. This loss of air is compensated by additional subsidence in and above the convection layer. Convection in the cooler region will not reach to the same height as it would without local winds.

Local winds tend to reduce the temperature gradients created by differential heating and to affect the lift rates of thermals in both regions. Thus, the potential flight distance is also affected by local winds.

MODELING EFFECTS OF LOCAL WINDS

With model orography of synoptic models starting to resolve individual valleys local winds appear. Their regional transport of heat and/or moisture from cooler to warmer regions was thought to be fed into ALPTHERM as advective changes and to affect the lift rates by changing the lapse rate. Above the convective boundary layer (CBL) advective changes are just time-derivatives of temperature and moisture and can directly be fed into the regional convection model. Within the CBL, however, convective fluxes add to the advective changes and simple time-derivatives cannot be used for ALPTHERM.

A different approach to local wind effects on convection may be taken along the concept of the area-elevation distribution: valley winds are related to the area-elevation distribution of a valley [3]. The changing volume effect [1] along a valley creates the differential heating that drives the valley wind. In coastal and flat regions differences of surface characteristics (sea, land, soil moisture, and evapotranspiration) will lead to differential heating and the corresponding local winds. Differential heating of neighboring regions produces time- and altitude-dependent horizontal pressure gradients. These pressure gradients drive horizontal mass fluxes.

Expanding ALPTHERM into REGTHERM

Horizontal mass fluxes driven by pressure gradients were implemented into ALPTHERM applied to neighboring regions in order to find their influence on convection in both regions. The introduction of this horizontal coupling between regions expanded the one-dimensional convection model ALPTHERM into the two-dimensional model

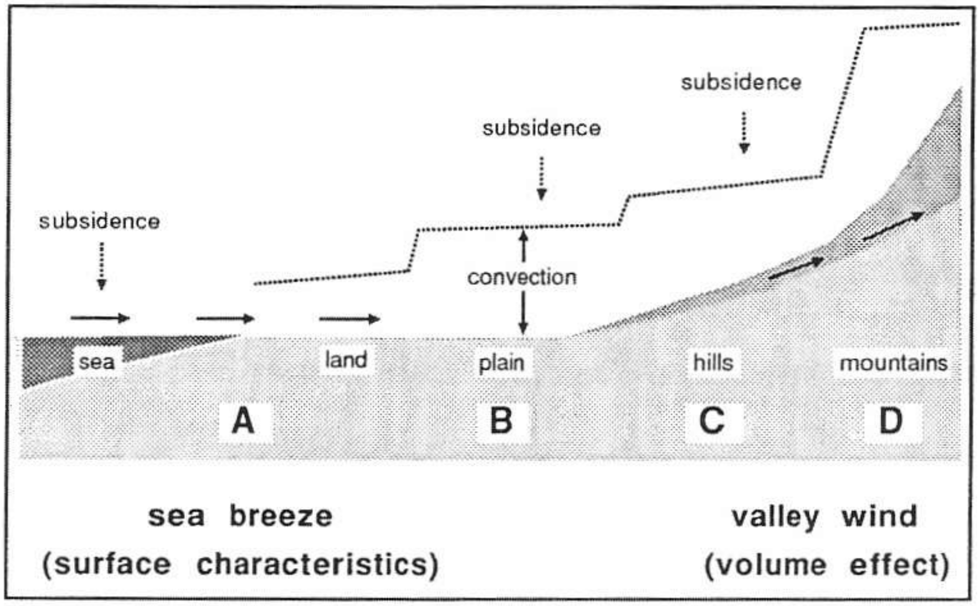

FIG. 1

REGTHERM. ALPTHERM models the primary convective circulation with typical circulation times on the order of 10 minutes, REGTHERM additionally treats the secondary circulation of local winds between differentially heated regions on the time scale of several hours.

REGTHERM (Figure 1)

- couples convection of coastal regions to unheated regions over sea (A)
- couples convection in basins to convection above surrounding elevated terrain (B-C)
- couples convection in chains of regions (A-B-C-D)

Typical Examples of Coupled Regions

Coastal regions (Figure 2):
A: Vorpornmern 2'900 km2 / 5700 km2(sea/land)
B: Osti. Mecklenburg ische Seenplatte 12'600 km2
Intermediate mountains (Figure 2):
C: Rhine basin 7'050 km2
D: Black Forest region 6750 km2

High mountains (Figure 3)
A: Milano (plain)
3'840 km2 median elevation 150 m MSL
B: Bergamo (pre-Alps)
4'315 km2 median elevation 1'000 m MSL
C: Valtellina (Alps)
4190 km2 median elevation 2'000 m MSL
D: Engadin (inner alpine valley)
2'050 km2 median elevation 2'500 m MSL

From a hydrological point of view the Engadin region belongs to the basin of the river Inn draining north-east into Austria. As there is no pass at the upper end of the river Inn near Maloja the "valley wind" in the Engadin region regularly blows from the south-west and is called the Maloja wind. From the aerological point of view the Engadin region D must be coupled to the regions A, B, and C along the Adda river. Similar patterns of unusual, valley winds" near the upper end of a valley occur in other places [4].

EFFECTS ON FORECASTS

Heating of coastal regions is reduced if areas above sea level also have to be heated by areas over land (Figure 2, region A). Maximum temperature, the height of convection and lift rates are clearly reduced in region A. Fully heated regions further inland (B) aspire this less heated coastal air. Inregion B the maximum temperature, the height of cloud base and lift rates are only slightly reduced.

Intermediate mountains coupled to basins tend to show higher cloud cover. In the basins, cloudiness is reduced (Figure 2, regions C and D). In comparatively dry air masses good thermal conditions tend to be shifted from the basins towards the elevated areas. In moist air, soaring is only possible in the lower lying regions with their limited cloudiness.

For a good soaring day with relatively dry air typical of the effects of horizontal coupling between regions C and D (Figure 2) are as follows:

region	Tmax (°C)	Td (°C)	Base/Top (m MSL)	Cu (octa)	PFD (km)	coupling
C	25	11	2100/2600	1-2	614	no
C	25	11	2100/2500	1	604	yes
D	25	10	2400/2800	1-2	713	no
D	25	11	2300/2800	2-3	685	yes

Convective cloud cover cu is reduced in the basin C and increased in the elevated region D. Under high pressure conditions dry convection is often found in basins and cumulus clouds only form over elevated regions.

Coupling regions along major valley wind systems in the Alps has similar effects. When sufficiently moist air from

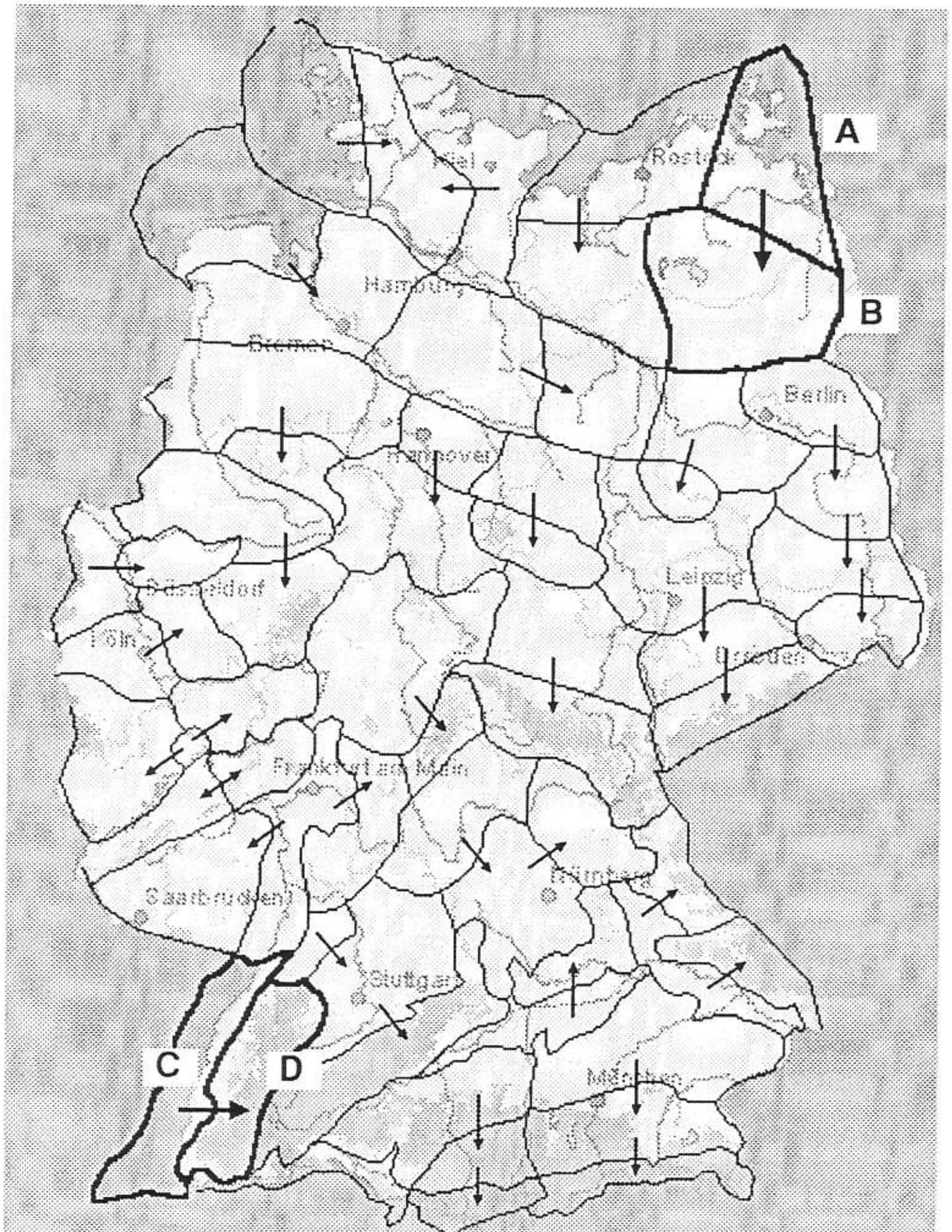
A
Rostock
Kiel
Hamburg
B
Bremen
Berlin
Hannover
Düsseldorf
Leipzig
Köln
Dresden
Frankfurt am Main
Nürnberg
Saarbrücken
Stuttgart
C
D
München

Fig 2.

the plains is aspired into the higher regions their cloud base is seen to become lower during the afternoon.

OPERATIONAL ASPECTS OF REGTHERM

Regions are defined by polygons. The area-elevation distribution of the polygon is generated from global digital elevation data. Surface characteristics like albedo and evaporation are specified individually for each layer if necessary. Model initialization requires radiosonde and ground station data. Representative stations are assigned to each polygon based on distance, direction, and altitude criteria. The larger scale atmospheric evolution calculated by a synoptic weather model can be fed to each region individually. Advection rates are only considered above the CBL.

CONCLUSIONS

Forecasts from a regional convection model like REGTHERM offer an efficient way of overcoming the shortcomings of synoptic weather models in forecasting climb rates for thermal flight. The introduction of a horizontal coupling between differentially heated neighboring regions is reflected in the forecasts of the coupled regions and improves planning of soaring flights based on regional forecasts.

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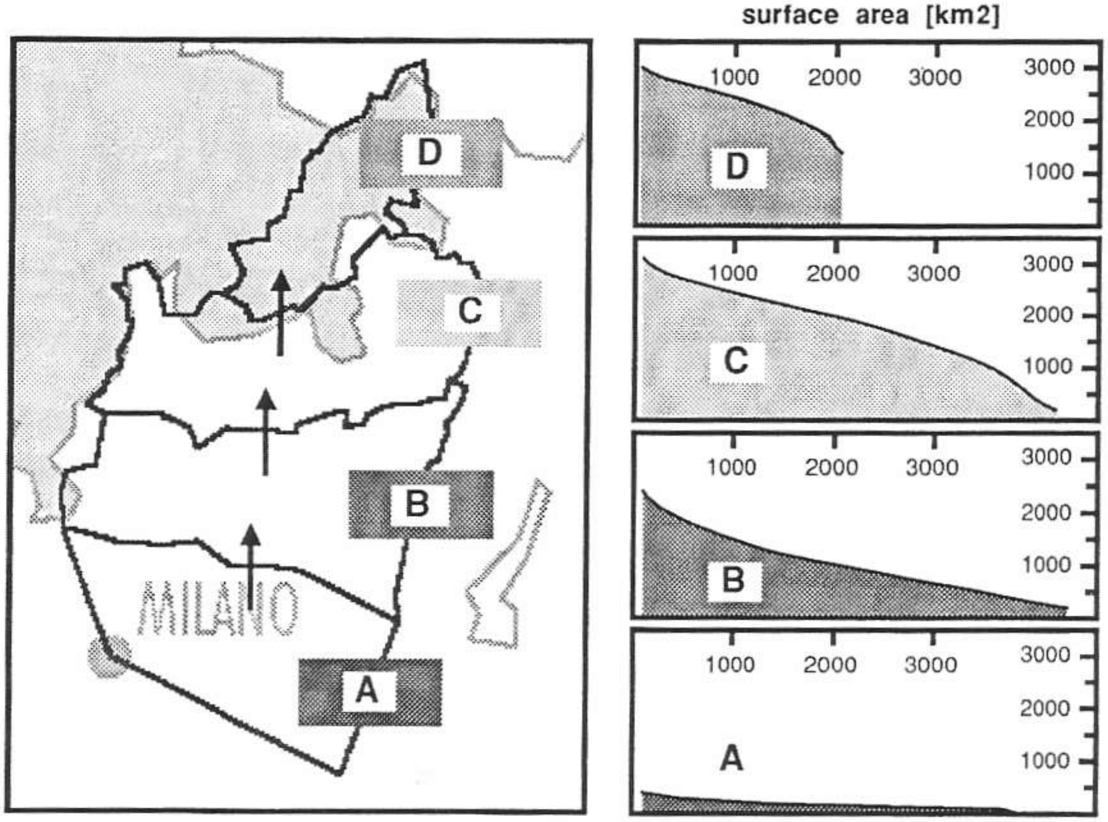

Fig. 3