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Influence of halophyte plantings in arid regions on local atmospheric structure

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Abstract. The practicality of modifying climate in arid regions through irrigation has up to now been constrained by the availability of fresh water with which to grow crops. The present results suggest a new paradigm: the use of salt water to grow halophyte crops and modify local climate along coastal deserts and other arid regions where saline water supplies are available.

Key words: Halophytes – Effect on weather; arid region climate modification; irrigation – Effect on weather; vegetation – Effect on weather; Deliberate climate modification by vegetation

Introduction

Salt-tolerant vegetation in the form of halophyte plantations have been recommended as a mechanism to sequester carbon from the atmosphere, similar to the case that has been made for reforestation (Glenn et al. 1991 a, 1992 a, b). Halophyte crops have also been suggested as major oilseed (Glenn et al. 1991 b) and fodder (Glenn et al. 1992 c) crops for direct sea water irrigation along subtropical coastal deserts. It has been estimated that 130×10^6 ha of coastal and inland saline desert land may be amenable to these type of plantings (Glenn et al. 1991 a). This paper examines the expected meteorological impact of such plantings over relatively large areas. The particular case of the oilseed halophyte, *Salicornia bigelovii* Torr., growing in the Saudi peninsula (Hicks et al. 1992), was chosen for analysis.

This brief paper examines the expected meteorological impact of such planting over relatively large areas. Since it is proposed to plant this crop in the Saudi peninsula, that area is used to evaluate the impact of this vegetation on local climate.

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Study methodology

The meteorological model used to evaluate the impact is the Colorado State University Regional Atmospheric Modeling System – RAMS (Pielke et al. 1992). This model is based on the physical relations which describe atmospheric flows using basic conservation principles. The representation of vegetation and soil physics in RAMS uses a parameterization model called LEAF (Land Ecosystem-Atmosphere Feedback) as described in Lee et al. (1992).

The input parameters used in the simulation are in Table 1. *Salicornia bigelovii* is a leafless, annual salt marsh succulent plant with photosynthetic stems. It reaches a peak biomass of approxi-

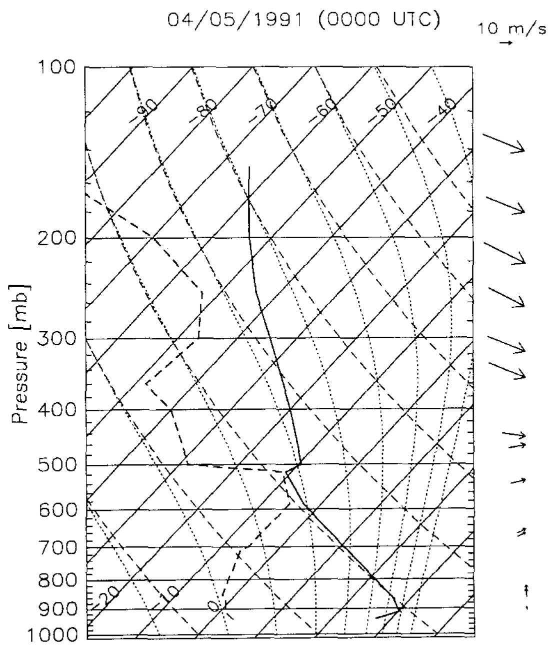

Fig. 1. Atmospheric temperature (*solid line*) and moisture sounding (*dashed line*) of April 5, 1991 for the region in degrees Celsius. Temperature values are given on the diagonal lines. The pressure altitude in millibars is presented in the left-hand axis. The horizontal winds for the pressure heights listed on the figure are shown on the right-hand side of the figure where a length corresponding to 10 m s^{-1} is drawn in the upper right

Table 1. Input parameters for vegetation and soil model used in the simulations

Vegetation	
Photosynthetic stem area index	3
Non-photosynthetic stem area index	0.3
Transmissivity	0.08
Emissivity	0.95
Albedo	0.18
Displacement height	0.375 m
Surface roughness	0.06 m
Soil	
Texture class	sand
Soil moisture (volumetric)	0.158 (under vegetation) 0.004 (bare soil)
Albedo (dry)	0.34

mately 2 kg m^{-2}, 200 days after planting and achieves a canopy height of approximately 50 cm (Glenn et al. 1991 b). At peak density the crop forms a very dense stand of intertwined green stems. For the simulation we assumed a maximum standing crop by April 5, the date for which atmospheric soundings were available (Fig. 1).

Results

Figure 2 presents the fields of potential temperature, horizontal wind, vertical motion and mixing ratio of water vapor for a simulation in which a flat portion of the desert region of the Saudi peninsula (left hand side of the domain) is situated adjacent to the Persian Gulf. The results are shown at 1400 Local Standard Time (LST). The occurrence of a well developed sea breeze is evident as a result of the large sensible heat flux from the desert.

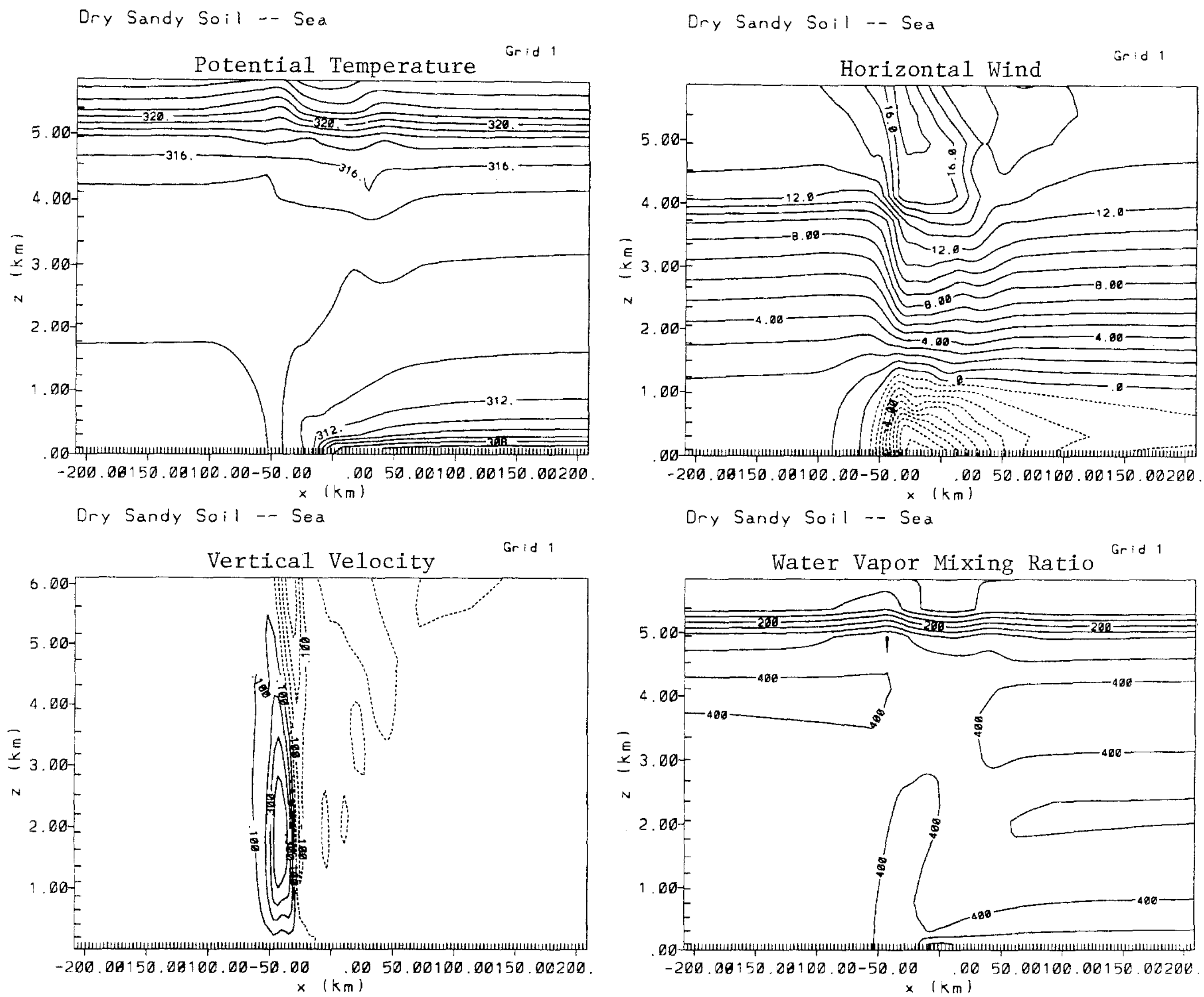

Fig. 2. Simlation of a sea breeze result at 1400 LST for (a) potential temperature (*1 K interval, upper left*); (b) horizontal wind component (*1 m s^{-1} interval, upper right*); (c) vertical wind component (*0.1 m s^{-1} interval, lower left*); and (d) water vapor mixing ratio (*0.5 g kg^{-1} interval, labels have been multiplied by 100, lower right*). The left side of the domain is dry, sandy soil and the right side is sea

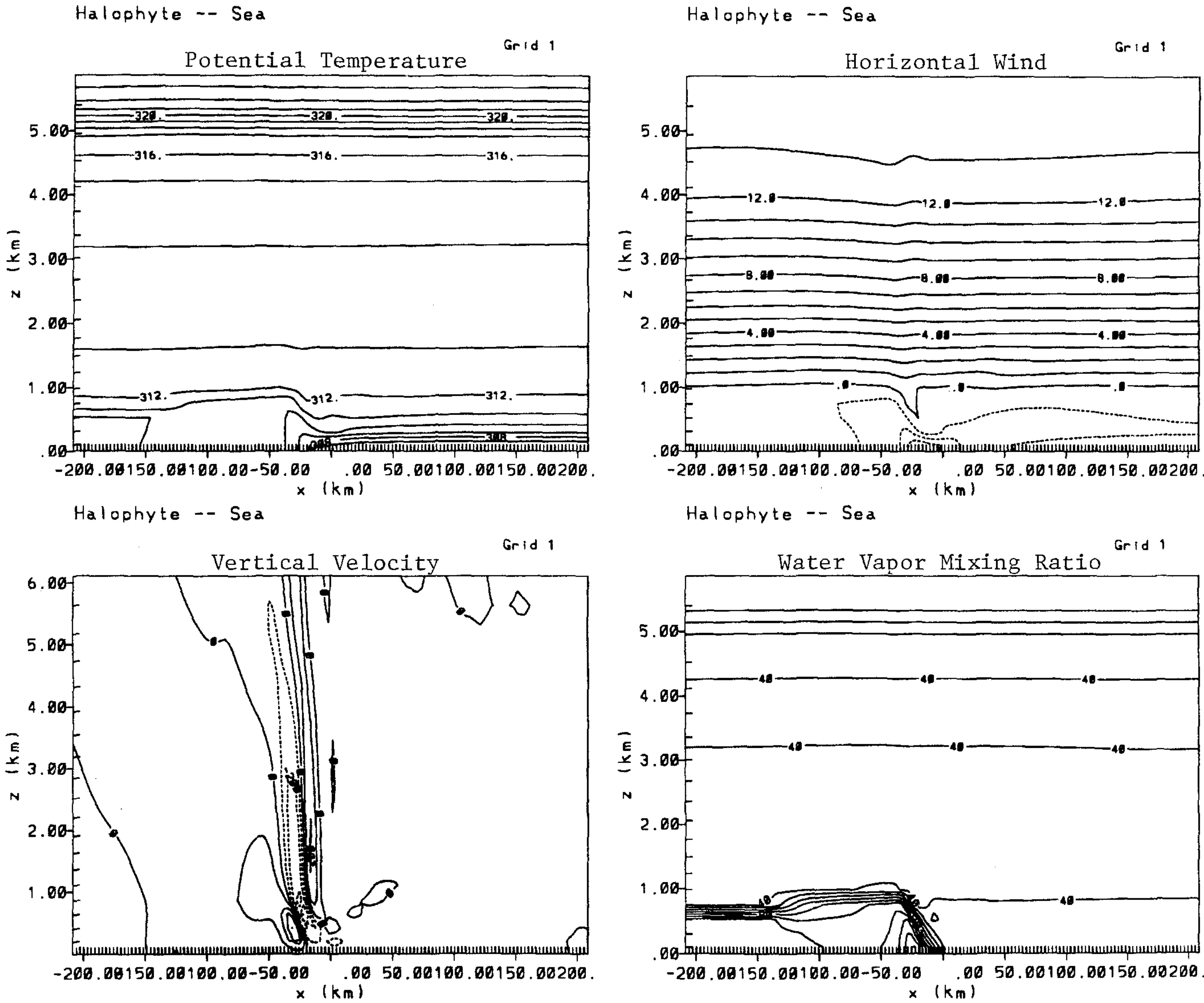

Fig. 3. Same as Fig. 2, except the dry, sandy soil is replaced by halophyte planting

Figure 3 presents results for the same background meteorology except it has been assumed in the model that the land region has been planted with halophytes. The halophytes are assumed to be unstressed due to the irrigation. The differences in the results are significant. The sea breeze circulation is much weaker than in Fig. 2 since the solar radiation is used for transpiration from plants rather than a direct heating of the desert surface as in Fig. 2. The addition of water to the atmosphere over the land shown in Fig. 3 has several implications: (i) the relative humidity is higher which would increase human discomfort in the area as well as make a more hospitable environment on the plants for certain diseases; subsequent irrigated water needs, however, would be reduced since the atmosphere overlying the plants would be more moist; and (ii) if the atmosphere were conducive for cumulus rainfall, as often occurs in this region during the cooler season, the additional moisture in the atmosphere could increase rainfall over and adjacent to the region. The second implication further supports the hypothesis that irrigation in arid and semi-arid areas can be used to increase local rainfall (Anthes 1984; Yan and Anthes 1988; Pielke and Zeng 1989).

Figure 4 presents results when the halophytes are planted at an inland region adjacent to desert. The impact of the halophytes is significant with the added impact that the magnitude of the local moisture convergence can be optimized if the size of the irrigated area is around 100 km across (Yan and Anthes 1988; Xian and Pielke 1991).

Conclusions

These results demonstrate that local climate changes should be expected due to large scale planting of halophytes. As discussed by Pielke (1984), the mesoscale processes described in this paper are affected by synoptic-scale atmospheric conditions. For instance, a strong synoptic wind from the colder to the warmer region weakens

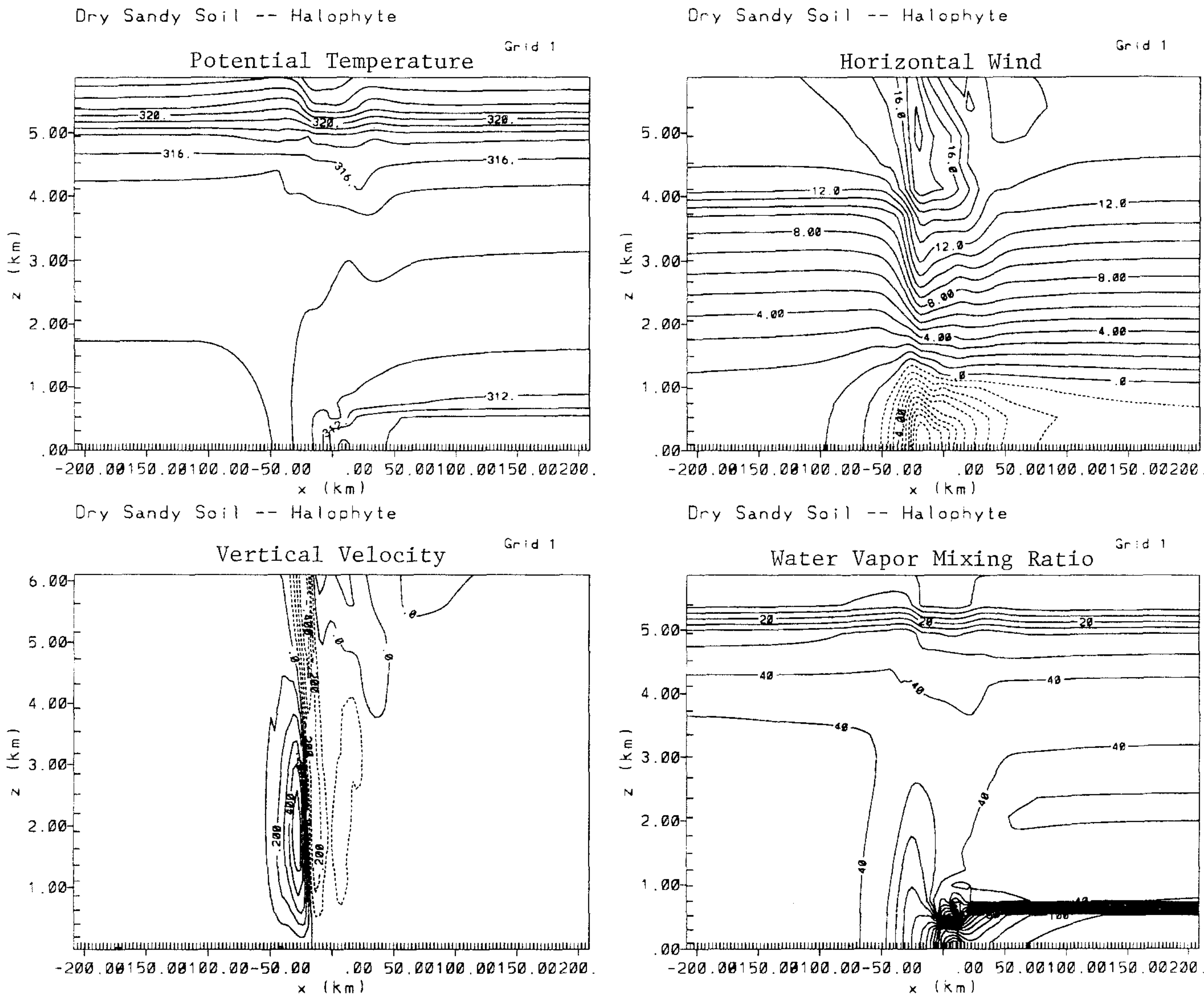

Fig. 4. Same as Figure 2 except the sea is replaced by halophyte planting. Notice that the contour interval for panel (c) vertical wind component has been changed to 0.2 m s^{-1}, and for (d) water vapor mixing ratio has been changed to 2 g/kg

the intensity of the local wind by diminishing the horizontal temperature gradient. By contrast, the same synoptic wind from the warmer to the colder region would strengthen the temperature gradient and, consequently, the local wind. Furthermore, the temperature gradient between the area planted with halophytes and its surrounding region would be reduced by clouds (Segal et al. 1986). Thus, overcast conditions are also expected to reduce the local wind. However, in the Saudi Peninsula, cloudless skies are customary most of the year. Therefore, the impact of planting halophytes in this region, illustrated for April 5, 1991 in this study, is likely to persist most of the year. Such conclusions are consistent with other numerical studies of the influence of irrigation on local atmospheric structure (Avissar and Pielke 1989; Segal et al. 1988, 1989).

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