LAND-ATMOSPHERE INTERACTIONS IN MOUNTAINOUS REGIONS

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Heat and mass fluxes associated with mesoscale circulations generated by relatively large topographical features and other landscape discontinuities are typically stronger than turbulent fluxes. As a result, they contribute significantly to subgrid-scale fluxes in large-scale atmospheric models (e.g., GCMs), but are omitted in these models. Avissar and Chen (1993) developed a set of prognostic equations for large-scale atmospheric models, which accounts for both turbulent and mesoscale subgrid-scale fluxes. They also developed prognostic equations for these mesoscale fluxes, which present a closure problem, thus implying the need to develop appropriate parameterisations.

For the purpose of developing such a parameterisation, several experiments were conducted.

1. Using the Fourier Amplitude Sensitivity Test (FAST) with a state-of-the-art land-surface scheme for atmospheric models, Collins and Avissar (1994) found that mostly five land-surface characteristics affect the energy fluxes near the ground surface: stomatal conductance, soil surface wetness, surface roughness, leaf area index, and albedo. Li and Avissar (1994) found that under unstable atmospheric conditions the spatial variability (at the canopy scale) of stomatal conductance and leaf area index have the most significant effect on the spatially-integrated energy fluxes from vegetated land. Correspondingly, in bare land, the spatial variability of soil-surface wetness is most important. Under stable atmospheric conditions, the spatial variability of surface roughness seems to have the predominant effect on spatially-integrated fluxes from the ground surface. The spatial variability of albedo has only a small impact

on the energy fluxes from the ground surface, indicating that a mean value can be used confidently in atmospheric models.

2. A Large-Eddy Simulation (LES) model was used to evaluate the impact of landscape heterogeneieties created by small topographical features (Avissar and Zeng 1995) and by mosaics of land patches (Avissar and Smith 1995) with different sensible heat fluxes, on the structure of the Atmospheric Planetary Boundary Layer (APBL) and, in particular, on the domain-averaged turbulent heat fluxes. These LESs indicate that as long as the characteristic horizontal length scale of the heterogeneiety (i.e., the patch size) is smaller than about 2km, and as long as the topographical feature is smaller than about 200m, the APBL that develops above a heterogeneous domain as well as a homogeneous domain are very similar. Therefore, under such conditions, these results support the approach of the "mosaic of land patches" suggested by Avissar and Pielke (1989) to represent heterogeneous domain in atmospheric models.

3. A state-of-the-art mesoscale atmospheric model (namely the Regional Atmospheric Modeling System [RAMS] developed at Colorado State University) is currently used to study the impact of various topographical features (i.e., different inclinations and orientations, with different vegetation coverage) on mesoscale and turbulent heat fluxes, as well as on clouds and precipitation. Preliminary results indicate that very strong mesoscale circulations can develop as a result of relatively large topographical features, but that unstressed vegetation can significantly reduce these circulations. Clouds and precipitation are affected by the presence of vegetation and vice versa. This investigation complements preliminary experiments summarised by Pielke and Avissar (1990).

Lynn et al. (1995) used the similarity theory to develop a preliminary parameterisation of mesoscale fluxes induced by landscape patchiness. For this purpose, they used the Buckingham Pi Theory, a systematic method for performing dimensional analysis, to derive a set of dimensionless groups, which describes the large-scale atmospheric background conditions, the spatial variability of surface sensible heat flux, and the characteristic structure of the landscape. These dimensionless groups were used to calculate the coefficients of a fourth-order Chebyshev polynomial, which represents the self-similar vertical profiles of dimensionless mesoscale heat fluxes obtained for a broad range of large-scale atmospheric conditions and different landscapes. This parameterisation will be extended to include the impacts of topography, clouds, and precipitation. As a first step towards that objective, Liu and Avissar (1995) studied the relative importance of the various clouds and precipitation parameters included in the RAMS microphysical scheme, as well as the impact of atmospheric dynamics on this scheme. As expected, this study revealed that the vertical component of the wind, which is very sensitive to the model grid resolution, is the most important dynamical parameter. This implies that only high-resolution models can be used for this type of study, until an appropriate parameterisation is developed.

The various issues related to modelling land-atmosphere interactions in complex terrain (including landscape heterogeneities) and their parameterisation in large-scale atmospheric models have been discussed by Avissar (1995a and 1995b). They will be presented and discussed at the conference, together with recent research progress.

REFERENCES

Avissar, R., 1995a. 'Recent Advances in the Representation of Land-Atmosphere Interactions in Global Climate Models'. In *Rev. Geophys.* Supplement of the U.S. National Report to International Union of Geodesy and Geophysics, (pp1,005-1,010).

Avissar, R., 1995b. 'Scaling of Land-atmosphere Interactions: An Atmospheric Modelling Perspective'. In *Hydrological Processes*, 9 (pp679-695).

Avissar, R. and Chen, F.,1993. 'Development and Analysis of Prognostic Equations for Mesoscale Kinetic Energy and Mesoscale (subgrid-scale) Fluxes for Large-scale Atmospheric Models'. In *Journal of Atmopheric Science*, 50, (pp3,751-3,774).

Avissar, R. and Pielke, R.A.,1989. 'A Parameterisation of Heterogeneous Land-surface for Atmospheric Numerical Models and Its Impact on Regional Meteorology'. In *Mon. Weather Review*, 117, (pp2,113-2,136).

Avissar, R. and Schmidt, T.,1995. 'Large-Eddy Simulations (LES) of the Impact of Land Patchiness on the Convective Boundary Layer'. In *Journal of Atmospheric Science*, (in preparation).

Avissar, R. and Zeng, F.,1995. 'Large-eddy Simulations of the Atmospheric Boundary Layer in Complex Terrain: Implication for Subgrid-scale

Avissar, R. and Zeng, F.,1995. 'Large-eddy Simulations of the Atmospheric Boundary Layer in Complex Terrain: Implication for Subgrid-scale Parameterisations in Atmospheric Models'. In *Journal of Atmospheric Science*, (in preparation).

Collins, D. and Avissar, R.,1994. 'An Evaluation with the Fourier Amplitude Sensitivity Test (FAST) of which Land-surface Parameters are of Greatest Importance for Atmospheric Modelling'. In *Journal of Climate*, 7 (pp681-703).

Li, B. and Avissar, R.,1994. 'The Impact of Variability of Landscape Characteristics on the Variability of Land-surface Heat Fluxes. In *Journal of Climate*, 7 (pp527-537)

Liu, Y. and Avissar, R.,1995. 'Sensitivity of Shallow Convective Clouds and Precipitation Induced by Land-surface Forcings to Dynamical and Cloud Microphysics Parameters'. In *Journal of Geophys. Res.* (accepted for publication).

Lynn, B.H.; Abramopolous, F.; and Avissar, R.,1995. 'Using Similarity Theory to Parameterise Mesoscale Heat Fluxes Generated by Subgrid-scale Landscape Discontinuities in GCMs'. In *Journal of Climate*, 8 (pp932-951).

Pielke, R.A. and Avissar, R.,1990. 'Influence of Landscape Structure on Local and Regional Climate'. In *Landscape Ecology*, 4 (pp133-155)