**JP5.9** AGGREGATION OF REMOTELY SENSED VEGETATION AND DERIVED LATENT HEAT FLUX

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## 1. Introduction

An understanding of the interaction between surface spatial variability in vegetation and the resultant turbulent fluxes is important for the ability to compute large-scale estimates of the surface energy balance using remote sensing. A problem in land atmosphere interactions research is that the processes which govern the transfer of mass, energy, and momentum across the land atmosphere interface are non-linear, due to the interdependence of the dominant variables and parameters. Specifically, this means that the average value of a flux is not predicted from the average value of the controlling variables and parameters. It is not enough to know the spatial distribution of the controlling variables; it is necessary to understand how these distributions are altered with a change in scale. In this context two aspects of the scaling issue are presented – (a) the aggregation of Normalized Difference Vegetation Index (NDVI) and fractional vegetation cover (Fr), and (b) the aggregation of local scale input parameters (i.e., Fr and surface temperature) in order to calculate larger scale fluxes (e.g., latent heat flux, $L_eE$). These analyses are performed using relatively low spatial resolution satellite (AVHRR) data (1 km pixel size) and high spatial resolution (12 m pixel size) airborne data – namely the TMS and TIMS sensors.

## 2. Methods

NDVI and Fr – the NDVI was calculated for images over the Southern Great Plains (SGP) 1997 experimental area in Oklahoma. NDVI was calculated in terms of surface reflectance as

$$NDVI = \frac{\rho_{ir} - \rho_{red}}{\rho_{ir} + \rho_{red}} \quad (1)$$

where $\rho_{red}$ is the surface reflectance in the red band of the sensor and $\rho_{ir}$ is the near-infrared surface reflectance.

Fr was calculated according to Gillies et al., (1997)

$$Fr = \left[\frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}}\right]^2 \quad (2)$$

where $NDVI_{soil}$ and $NDVI_{veg}$ are the bare soil and vegetated NDVI values.

(a) The AVHRR at-sensor radiance data at 1 km$^2$ was first aggregated, via linear averaging, to 16 km$^2$ pixels. Atmospheric corrections were applied to the 16 km$^2$ radiance data and resulted in 16 km$^2$ surface reflectance values; these values were subsequently used to calculate the NDVI and Fr. Since this aggregation of the radiance field is equivalent to what would be measured by a sensor at this resolution, this is regarded as the true value of these fields to which the aggregated fields are compared.

(b) $L_eE$ – $L_eE$ was derived for the same region using the AVHRR data, and high-resolution (12 m) airborne (TMS/TIMS) data. A Soil-Vegetation-Atmosphere-Transfer (SVAT) model was used to derive $L_eE$ as a function of the remotely sensed Fr and radiometric temperature (T). A regression equation was derived for $L_eE$ as a function of T and Fr using the 'triangle method' of Gillies et al., (1997):

$$L_eE = \sum_{i=0}^{3}\sum_{j=0}^{3} a_{i,j} T^i Fr^j \quad (3)$$

where $a_{i,j}$ are the polynomial regression coefficients.

## 3. Results

(a) The original 1 km NDVI and Fr values (defined with respect to surface reflectance) were linearly averaged to a resolution of 16 km$^2$ compared to values calculated directly at 16 km$^2$. The results of these comparisons are presented in Figure 1(a) and (b). The RMS error for aggregating NDVI was found to be 0.01, while for Fr an RMS error of 0.22 was observed and the figure shows nonlinearity in the relationship. However, an aggregation of NDVI to 16 km$^2$ for which Fr was subsequently computed resulted in an RMS error of 0.02 (Figure 1c).

(b) Direct comparison of derived $L_eE$ with in-situ eddy covariance measurements, taken at four flux stations in the SGP regions, was performed using 2 schemes: (i) pixel-wise comparisons, and (ii) through the estimation of the flux footprint of a station via the algorithm of Scheupp et al. 1990.

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Table 1 presents the RMS errors of various comparison schemes. In general, there was good agreement between the surface and the TMS/TIMS derived fluxes regardless of scheme. The AVHRR data was compared with the surface stations solely by pixelwise comparison, where poorer agreement was observed. Pixelwise comparison of the 12m estimates of $L_eE$ resulted in small errors ( | | 15%) while, interestingly, errors were higher for the Schuepp footprint (Schuepp et al., 1990) estimate ( | | 27%) as compared to the simple pixelwise method ( | | 15%).

| Source | Comp | Method | $L_eE$ | RMS/$L_eE$ |
|---|---|---|---|---|
| TMS/TIMS | Surf | pixelwise | 45 | 0.15 |
| TMS/TIMS | Surf | Schuepp | 80 | 0.27 |
| AVHRR | Surf | pixelwise | 145 | 0.5 |
| TMS/TIMSa | Surf | pixelwise | 21 | 0.07 |
| TMS/TIMSb | Surf | pixelwise | 87 | 0.3 |
| TMS/TIMSc | Surf | pixelwise | 55 | 0.19 |
| TMS/TIMSd | Surf | pixelwise | 43 | 0.12 |
| TMS/TIMSe | Surf | pixelwise | 50 | 0.14 |

Table 1. RMS errors ($Wm^{-2}$) for comparison (Comp) of remotely derived $L_eE$ compared to surface measurements (Surf) for different methods of comparison. TMS/TIMS refers to $L_eE$ derived from 12m data. TMS/TIMS (a-e) refers to an aggregation of $L_eE$ to 1080 metres for comparison with AVHRR via (a) linear averaging of 12m flux values, (b) T and NDVI linearly averaged, (c) T and Fr linearly averaged, (d) T aggregated in a similar manner to Norman et al., (1995) and Fr linearly averaged, and (e) T aggregated as in (d) and NDVI linearly averaged.

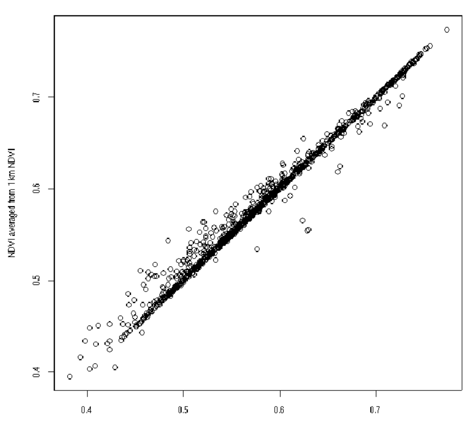


Figure 1a Effect of calculating NDVI from aggregated radiance data versus aggregating NDVI from 1 km data. (b) Same as (a) for Fractional Vegetation. (c) Effect of calculating Fractional Vegetation at 16 km versus calculating it from NDVI values averaged from 1 km data.

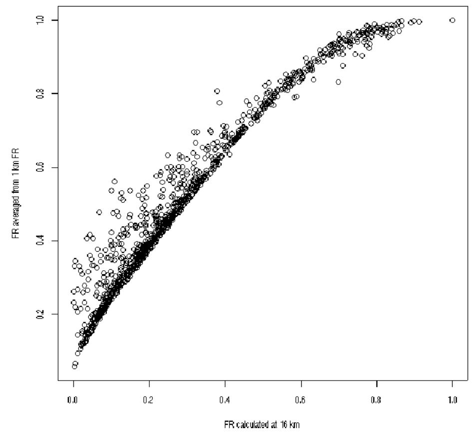


Figure 1b. Same as Figure 1a but showing fractional vegetation cover (Fr).

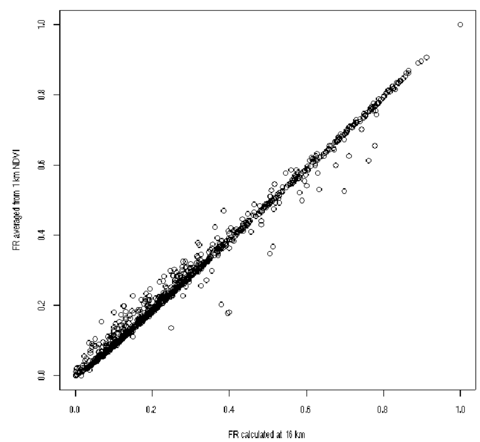


Figure 1c. Fr at 16 km vs. averaged 1 km NDVI.

**4. Conclusions and Discussion**

The results presented in section 3(a) suggest that NDVI is a conserved quantity while fractional vegetation is not. As a result, it is recommended that, for any desired resolution, the fractional vegetation be calculated from an aggregation of NDVI.

In section 3(b), the comparative results between derived $L_eE$ and flux tower measurements showed good agreement for the high resolution airborne data while not so for the satellite AVHRR data. The comparison between surface measurements and remotely sensed estimates highlights one of the primary problems with large-scale application data for calculating surface energy fluxes like $L_eE$: i.e., how to validate the resultant fluxes. It is likely that the direct comparison of satellite estimates with surface measurements is unrealistic due to differences in spatial heterogeneity captured within the two different measurements.

The possible cause for the agreement between the high-resolution data and the surface is the length scale of the surface variability. In the case of SGP97 site, the average field size was on the order of 800 metres as compared to the high-resolution data with pixel size being a great deal smaller. Thus, the dominant scale of variability is easily captured by the high-resolution data. However, this scale is completely missed by the AVHRR sensor.

The results demonstrated here emphasize the complexities of remotely sensed data when considering assimilation into meteorological models. The pertinent point is that if such fields are to be used to define boundary conditions, it is necessary to assess the effect of aggregation of the underlying fields. Such considerations, from the validation perspective, are also necessary if one is comparing remotely sensed parameters with model output.

## 5. References

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