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EFFECT OF LAND USE/ LAND COVERS CHANGE ON RADAR REFLECTIVITY BASED CONVECTIVE PRECIPITATION IN SOUTH FLORIDA

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Abstract

Development of urban heat island and increase of sensible heat flux above the urban center are known to spatially shift and diurnally accelerate sea breeze convergence thereby altering convective precipitation in south Florida. This study investigates the effect of land use /land covers change on warm season convective rainfall using radar reflectivity in south Florida for the first time. Weather Surveillance Radar (WSR-88D) expresses its backscattered energy in terms of decibels of reflectivity (dBZ), which estimates the size of the hydrometeor target and can be used to separate convective rainfall from stratiform type.

Frequency and magnitudes of eighteen years (1995-2012) of radar reflectivity data from Miami station (KAMX) for three afternoon hours of summer months: June, July, and August are analyzed. Since 40 dBZ has been considered as the most commonly used reflectivity threshold for convective rain, selective reflectivity values ≥ 40 dBZ are chosen for this analysis. Synoptically active weather days are removed from the analysis so that any change in thunderstorms pattern through time and space reflects only the effects of surface induced convection. Land use/ land cover change of south Florida during the same temporal range as of radar data and a comparative analysis thereafter indicates that medium and high intensity developed urban covers tend to enhance the convective activity, hence increasing the frequency and intensity of thunderstorms.

Thermodynamics of Land Cover

Change in surface cover brings about the changes in radio-thermal characteristics of the surface such as albedo, emissivity, heat conductivity, and heat capacity, which in turn alters the radiation and moisture balance. Wet and vegetated surfaces with the range of albedo ≈ 10% for moist soil to 15 to 25% for forest and grasses, when transformed to agricultural and urban covers, acquire relatively higher albedo: 20 to 25% for crops and lower: 5 to 20% for urban built up surfaces (streets, highways, roofs). The emissivity also, decreases from wet and vegetated surfaces (0.9 to 0.99) to urban surfaces 0.71 to 0.88 for most of the constructed areas and 0.88 to 0.95 for black topped areas (Arya, 2001). Low albedo and low emissivity surfaces coupling with their low specific heat store more radiation, warm quickly and begin to release sensible heat increasing the temperature of surface layer atmosphere. As a result of these changes in land use of the underlying surface, variations in the depth and structure of planetary boundary layer (thickness: tens of meters to several kilometers) occur. Negative $\partial\Theta/\partial Z$ implying instability of surface layer produces net upward mass transport i.e. air parcel ascends, which later cools, condenses in the upper level atmosphere to form the rain drop if it was moist and coalesce with other drops sustained by the strong updraft ultimately to fall as thunderstorm. Instability in lower level boundary layer, therefore, is essential to initiate the entire process of thunderstorm formation.

Variation of air temperature and associated instantaneous flux of heat are also the function of roughness length. Roughest element such as buildings and trees force for greatest vertical turbulence. Unstable boundary layer with strong updraft sets convergent and divergent motions in lower and upper levels respectively. The moisture laden sea breeze, hence, converges towards the heating maxima of the surface, rises upwards and distribute it towards downwind direction. Summer time rainfall maxima in eastern coast of south Florida is one example of this process as dominant wind direction is southeastward .

Radar Reflectivity: Basics, Data Source and Method

Radar emits microwave energy as pulses and measures backscattered energy from any object on atmosphere it strikes with. The reflected energy is measured in decibels (dB) of reflectivity Z (dBZ) and is equivalent to *10*log Z, where Z is the reflectivity factor equal to ΣD^6, D being the size of the drop. Z proportional to the 6th power of drop sizes means larger drops make much more reflectivity than smaller drops. Studies have indicated below 40 dBZ as stratiform, 40 to 60 dBZ as thunderstorm, and 60 to 80 dBZ as hail mixed precipitation. This study uses NEXRAD level II radar reflectivity from Miami station (KAMX) with the recording history since October 1993. The radar is S band (10 cm wavelength), 5 min. temporal, 1 km x 1 degree spatial resolution called legacy resolution prior to 2008 and 0.25 km x 0.5 degree called super resolution after that. Base reflectivity for all but vertical structure is used. The generic data were imported in NOAA weather and climate toolkit, exported into point shape file and analyzed finally in excel.

Study Area: Land Use/ Land Cover

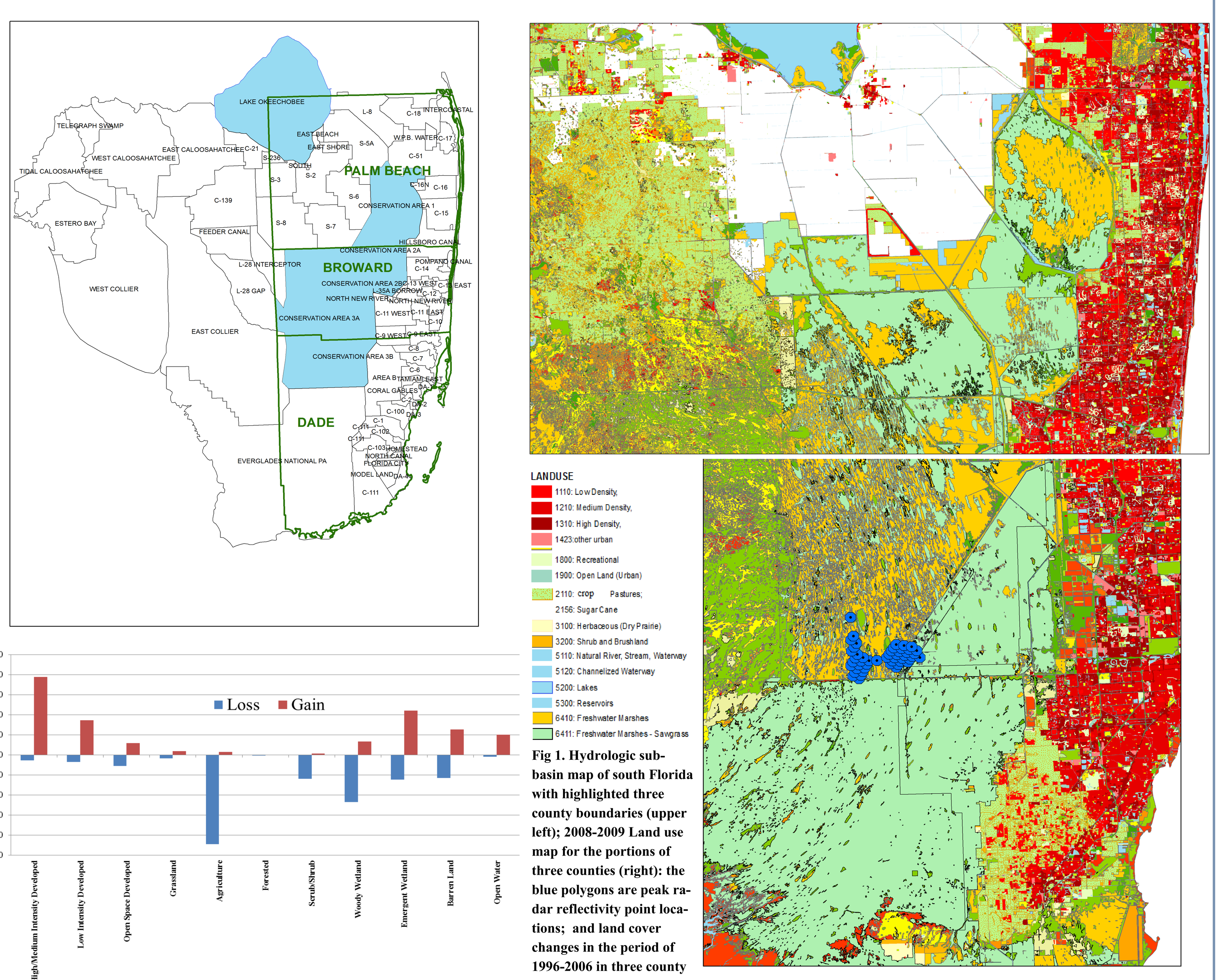


Fig 1. Hydrologic sub-basin map of south Florida with highlighted three county boundaries (upper left); 2008-2009 Land use map for the portions of three counties (right): the blue polygons are peak radar reflectivity point locations; and land cover changes in the period of 1996-2006 in three county

Boundary Layer Observation

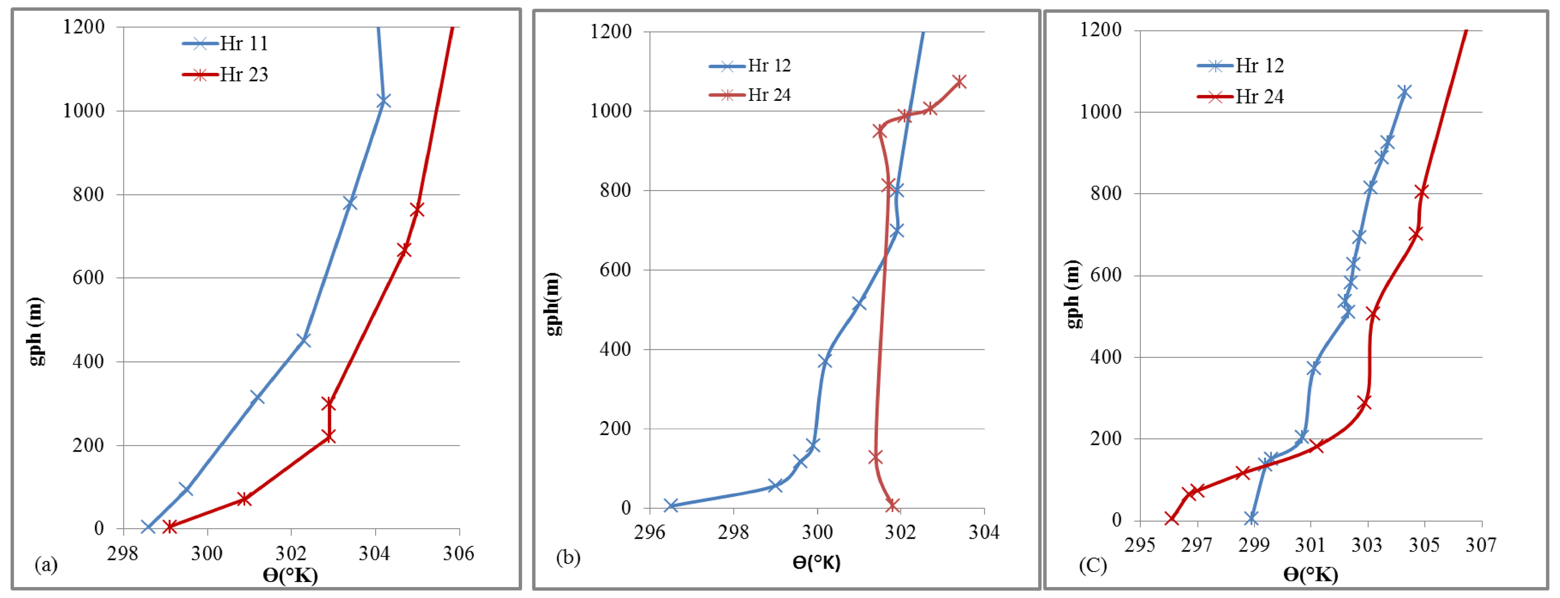


Fig 2 Potential temperature profiles from Miami Radiosonde station (72202) a) August 15 1995, b) August 15 2007, c) August 15 2010 (time :UTC)

The profiles are for morning and evening (UTC - 4hr) local time. Morning soundings in 2007 and 2010 show $\partial\Theta/\partial Z$ higher compared to evenings which still show the remnants of day time instability in various heights near the surface. Since all the days studied are selected as clear sky days, the diurnal variation observed account surface conditions. Higher diurnal range for Aug 15, 2007 could be indicating the dry bare surface characteristics. In 2010, even though, it is not as higher as 2007, is still higher than 1995. Profiles are generally inversion types showing stable boundary layer i.e. temperature increasing with height. These types of stratification just moderate the vertical exchange and no convection occurs. Exception is evening of 2007 showing slightly unstable surface layer and a very deep mixed layer. Since radiosonde records are available only twice a day in UTC time, diurnal comparison of boundary layer structure for local mid-day and mid-night is impossible.

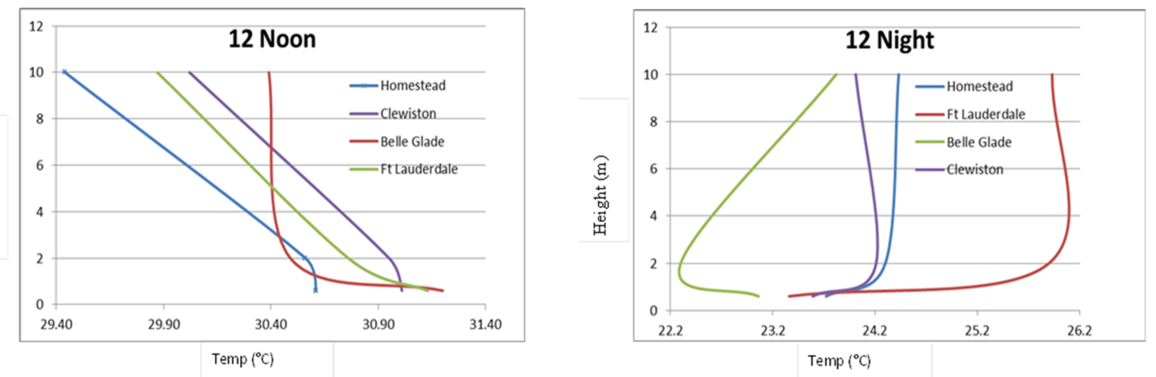


Fig 3 Temperature profiles of laminar boundary layers from south Florida stations showing lapse rate and inversion at mid-day and mid-night respectively

Therefore, very low level (within 10 m) from the surface for different stations are carried out which clearly show the spatial as well as diurnal variation of $\partial T/\partial Z$ (Fig. 3).

Radar Reflectivity and Convective Precipitation

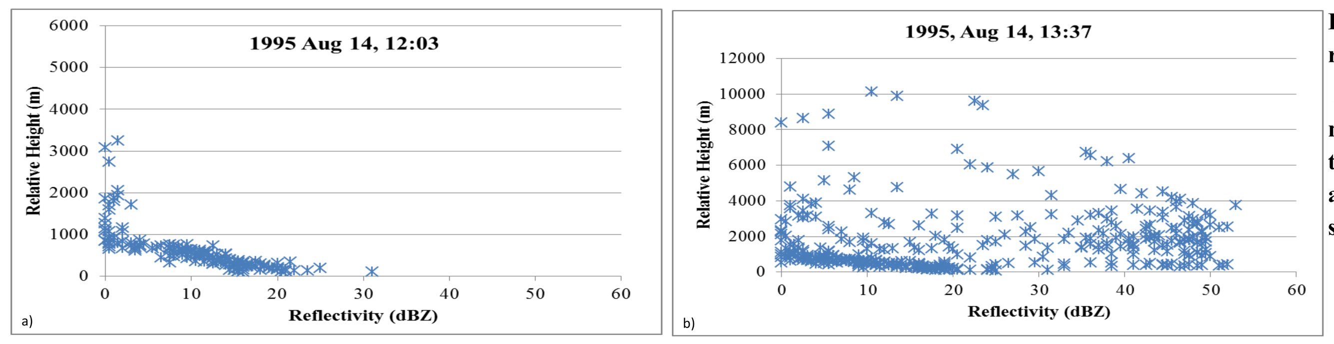
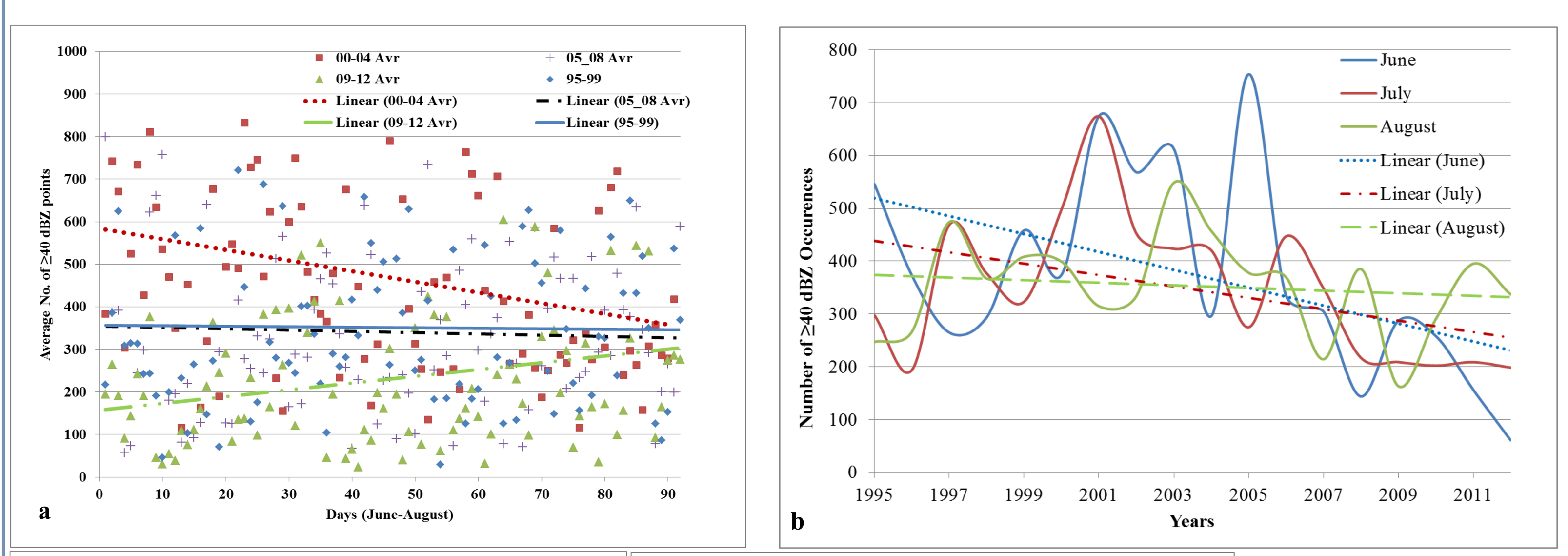


Fig.4.Vertical structure of reflectivity: a) without convective element and b) with convective element from selected area coverage of Miami station

Atmospheric convection occurs when the fluid heated from below becomes buoyantly unstable and overturns to stabilize the density stratification. Vertically circulating elements with ideal geometric symmetry, thus characterize the convective rainfall . Represented by a bulk of the precipitation mass fallen out within a few kilometers of updraft centers, radar reflectivity pattern associated with convective air motions show a concentrated peaks of reflectivity (Houze, 1997) which matches our case shown in Fig. 1 and 4 b.

Radar Results: Point Counts



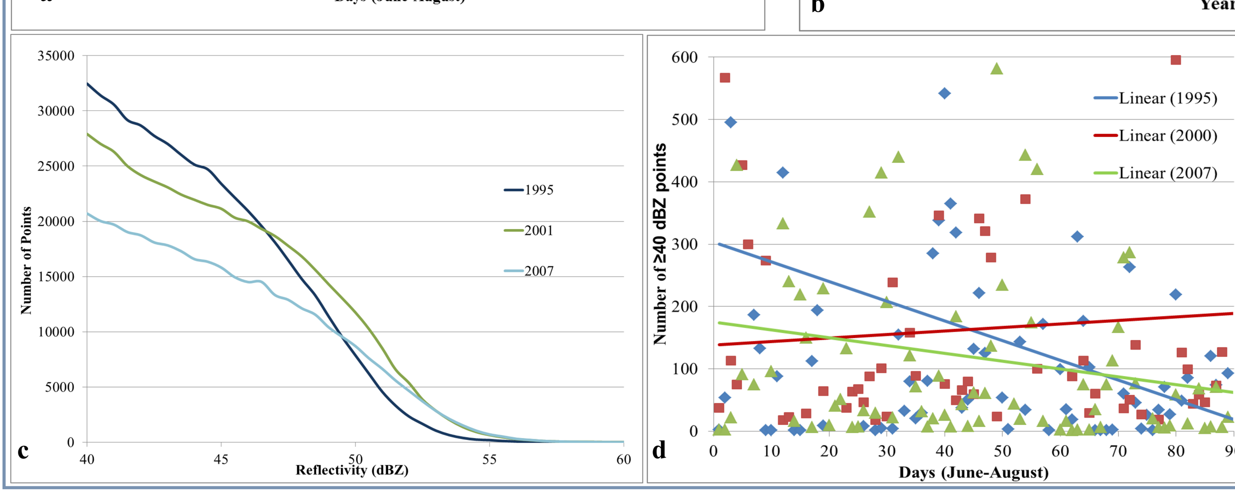


Fig. 5. Average Number of ≥40 dBZ points recorded: 5 min. occurrences averaged for each 4 years a); 5 min. occurrences averaged for each months b); average 5 min. occurrences for each reflectivity values c); 5 min. occurrences averaged for each year from selected days of benign weather. a and b are entire south Florida ,c and d are only eastern urbanized area

- Fig 5 a reveals that there are less thunderstorm type precipitation drops recorded in latest 4 year average (09-12) compared to previous averages in the entire south Florida which is also confirmed by 5 b showing descending trend of monthly averages going from 1995 to 2011.

- Both daily average and dBZ average counts in urbanized part (5 c and 5 d) suggest that July and August days and above 50 dBZ have higher occurrences for later years as compared to June and below 50 dBZ that contrasts with entire SF scenario

Maximum Reflectivity Comparison

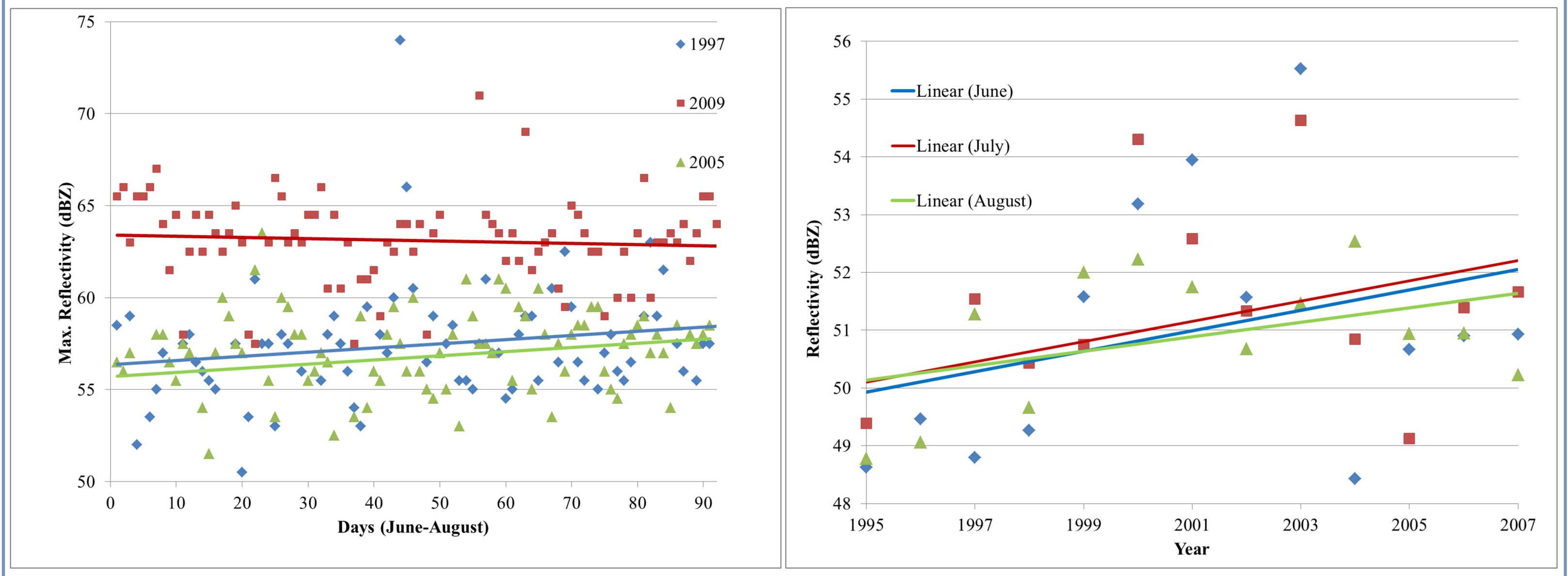


Fig. 6. Temporal comparison of 5 min. maximum reflectivity - daily average of three summer months for south Florida a); monthly average for eastern urbanized portion of south Florida

- Maximum reflectivity significantly higher in 2009 compared to two closer years 1997 and 2005, implies the increase of rainfall rate

- Consistent rise of maximum reflectivity for all three months throughout the study period of 1995-2007 for only urbanized portion shows that increase in rainfall rate is more prominent in urbanized area compared to the whole south Florida.

Variance Comparison

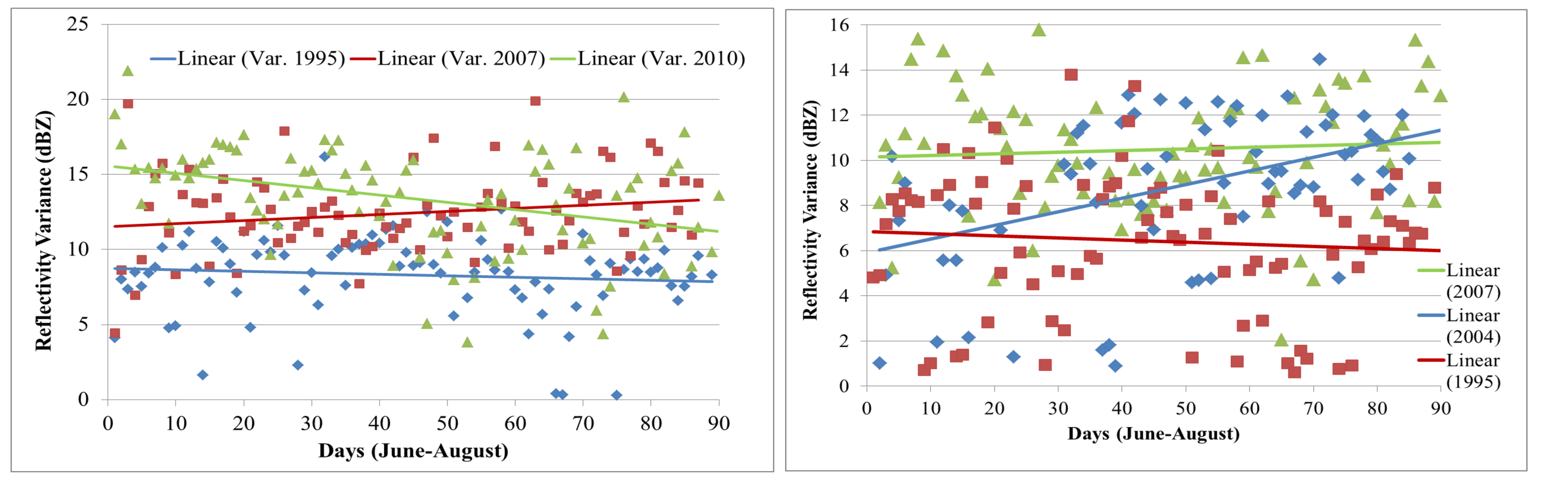


Fig. 7. Temporal comparison of 5 min. reflectivity variance - daily average of three summer months for south Florida a); monthly average for eastern urbanized portion of south Florida

- Variance of reflectivity values for each 5 minute sweep indicates the extent of spatial variability of thunderstorm occurrence. Larger spatial coverage of SF exhibits expectedly wider variance, and relatively higher variance values in both cases for later years could be the direct reflection of greater variability in current land cover mosaics.

Conclusion and Recommendation

South Florida is continuously being urbanized and gone through vast agricultural development with replacement of saw-grass marsh and forested land by dominantly high, and medium density residential covers and expanding sugarcane farm. The highly negative vertical gradient of temperature profiles particularly for Homestead which is a growing city and also negative in Fort Lauderdale, an intensely urbanized station, implies that cities are more favorable locations for convection. Even though the number of point count shows lesser thunderstorm type rainfall overall, more number of points for higher reflectivity values, increasing trend of maximum reflectivity for later years with conspicuous consistency in eastern urbanized areas, and larger spatial variability of reflectivity for later years are some signatures of anthropogenic modification of south Florida land cover observed in radar reflectivity data. Also, the vertical structure and horizontal extent of chosen reflectivity clearly shows the usefulness of above threshold radar reflectivity for convective rainfall studies.

Further studies showing radar reflectivity relation with rainfall intensity, and land cover wise comparison of reflectivity would strengthen this conclusion.

References

Arya, S.P. (2001) *Introduction to Micrometeorology,* 2nd ed., 420 pp, International Geophysics Series, Vol. 79, Academic Press , Newyork

Houze, R. A. (1997) Stratiform precipitation in regions of convection: A meteorological Paradox?, *Bulletin of the American Meteorological Society, Vol. 78, No. 10*, 2179-2196

NOAA Satellite and Information Service, National Climatic Data Center, http://has.ncdc.noaa.gov/pls/plhas/HAS.FileAppSelect?datasetname=6500, Accessed in April-June 2013

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