A Statistical Analysis of the GOES-12 Sounder Derived Lifted Index

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ABSTRACT

In 1994, Derived Product Imagery was implemented on the GOES-8 sounder to provide a representation of the atmosphere in areas where radiosonde data is limited. While numerous research has been done to test its validity, no recent research has been performed on the lifted index. This research tests the correlation between lifted index values on the GOES-12 Sounder with radiosonde measurements over January, March, June, and September of 2007 for four Florida stations. McIDAS was used to extract lifted index values from the GOES-12 Sounder using a 15 X 15 pixel grid and performing a Barnes analysis to calculate the average lifted index for each station. Linear regression, bias and RMSE are calculated to look at the correlation and averaged differences between the two LI values. While Miami had the best correlation, the convective months of June and September had poor results. This is possibly due to the assumptions, biases, and problems with the derived product imagery as discussed in this paper.

1) Introduction and Objectives

When it comes to convective initiation, forecasters rely on severe weather indices to determine where a storm will form, and whether it will strengthen or dissipate. Two indices that are most often used in operational meteorology are the lifted index (LI) and convective available potential energy (CAPE). These values are taken from radiosonde sounding data twice daily (00 Z and 12 Z) across the country.

Unfortunately, there are only sixty to seventy soundings launched across the United States (Storm Prediction Center 2008). The values at one point do not necessarily reflect the values 25 or 50 km away. This, along with the relative infrequency of observations, creates a poor spatial and temporal resolution of these stability parameters.

To help solve for this, NOAA’s next generation of geostationary satellites, the GOES-I (now known as GOES-8), was launched and put into operation in 1994. The new sounder instrument, which consisted of 18 thermal infrared bands and 1 visible band, could produce wavelengths that are sensitive to temperature, moisture and ozone (Menzel and Purdom 1994). From these values, a vertical profile can be constructed, and other values such as LI and precipitable water, could be generated through the Derived Product Imagery (DPI).

Many tests have been made since GOES-8 was put into operation, however as of 2008, the sounders on GOES-8 and GOES-9 have been decommissioned and replaced by GOES-11 (known as GOES West) and GOES-12 (GOES East). Recent statistical analysis has been performed testing the correlation between radiosonde and GOES-12 sounder values of CAPE (Belge 2007), total precipitable water in the latitude (Fusco 2006), and total precipitable water in the longitude (Balschmiter 2007). However no recent research has been performed on the lifted index. Since lifted index is often used in severe weather forecasting, new research should be done on that variable as well. This paper will attempt to test the validity of GOES-12 Sounder derived lifted index.

2) Background

a) Derived Product Imagery

The Derived Product Imagery, which was first introduced on the GOES-8 sounder, is able to generate images of precipitable water, lifted index, and surface skin temperature. In the year 2000, CAPE was added to provide a better view of atmospheric stability than just the lifted index (Belge 2007). The DPI is able to create these images hourly with a horizontal resolution of 10km. This provides a better spatial and temporal resolution than radiosonde soundings. (Menzel and Purdom 1994).

The sounder uses a non-linear physical retrieval algorithm to calculate the temperature and moisture profile needed to compute the lifted index. First, it provides a first-guess estimate, which is provided by either surface radiosondes or numerical weather models. The first guess values are then linearly interpolated to the nearest hour of the satellite data. Using Plank's blackbody term, radiances are calculated from the first guess and compared to the observed radiances. If the generalized error is small and acceptable, the temperature profile is constructed and finished. If the error is large, then the first guess profile is modified until the error is deemed acceptable. To determine the moisture profile, it assumes the temperature profile has already been created and the value of the temperature error is the result of the water vapor mixing ratio. (Kidder and Vonder Haar 1995).

It is important to note the following: the wavelengths that produce infrared radiation are absorbed by clouds, therefore the DPI can only display adequate images when skies are clear (Hayden et al. 1996). The derived product imagery consists of 19 channels, 18 infrared and 1 visible. The visible channel is used for cloud detection, and if clouds are present, the data is considered contaminated and disregarded. The other 18 bands are used to detect rotational transitions of carbon dioxide, water vapor, and ozone, as well as detecting surface skin temperature. These bands are used to construct the radiances in the vertical sounding.

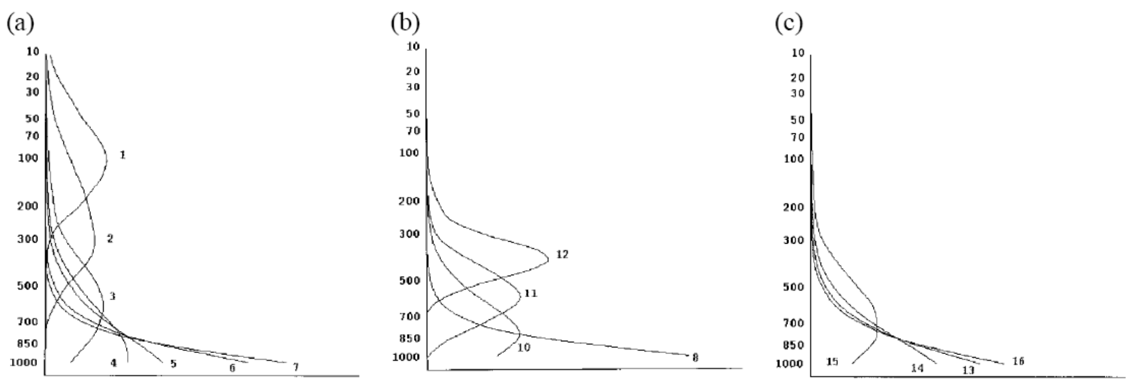


Fig. 1: GOES Sounder weighting functions for a) long-wave, b) mid-wave and c) shor-twave radiation (Menzel et al 1998)

Figure 1 shows the weighting functions for the GOES 8 sounder derived product imagery. The first graph represents long-wave absorption, the second represents mid-wave absorption, and the third shortwave. It is important to note that the weighting functions tend to overlap near the surface, which causes the data to be smoothed out. For the derived product imagery on the current sounder, the 18 weighting functions will create a higher resolution of the temperature profile. On the other hand, the vertical profile will be smoothed near the surface, due to this overlapping. Therefore the vertical temperature and moisture profile will not be as accurate, especially in the planet boundary layer, and could create a bad misrepresentation of the final values outputted from the derived product imagery.

Since the DPI was first introduced, statistical analysis has been performed to compare the DPI values against radiosonde values. This poses another problem with the overall results. Radiosonde measurements are not considered the true state of the atmosphere, and have their own errors on the order of 1 degree Kelvin (Kidder and Vonder Haar 1995). Also, the radiosonde measurements, which are advected by the mean flow, are different than the retrieved volumetric measurements of the GOES sounder. Additionally, because most radiosondes are land based, it will be hard to provide a good statistical representation over the ocean (Dostalek and Schmit 2001).

Dostalek and Schmit (2001) tested the total precipitable water using data from a twelve month period. Their data were split into four groups: spring (March – May 1998), summer (June – August 1998), fall (September – November 1998) and winter (December 1998 – February 1999). The data were plotted in scatter plots and statistics were calculated on the data, including the mean difference, bias, standard deviation, and r value. Results showed that the data were well correlated each season. No r value was less than 0.91. They also showed that the data were better correlated in the fall and winter months, along with better correlation at 12 Z than at 00 Z. (Dostalek and Schmit 2001).

The Cooperative Institute for Meteorological Satellite Studies also tested the GOES derived lifted index. They did statistical analysis between the GOES-8 DPI retrievals and both RAOB calculations and the NGM first guess. Using 00Z data between April 1996 and February 1997, they determined that the GOES derived LI were found to be less stable than radiosonde values by 0.6°C, with a RMS difference of 2.2°C. The

GOES derived LI only showed to be 0.4°C less stable than the NGM first guess field with a RMS difference of 2.4°C. Figure 2 shows the GOES-8 DPI image of lifted index along with 00Z RAOB measurements of LI. (COMET 2006).

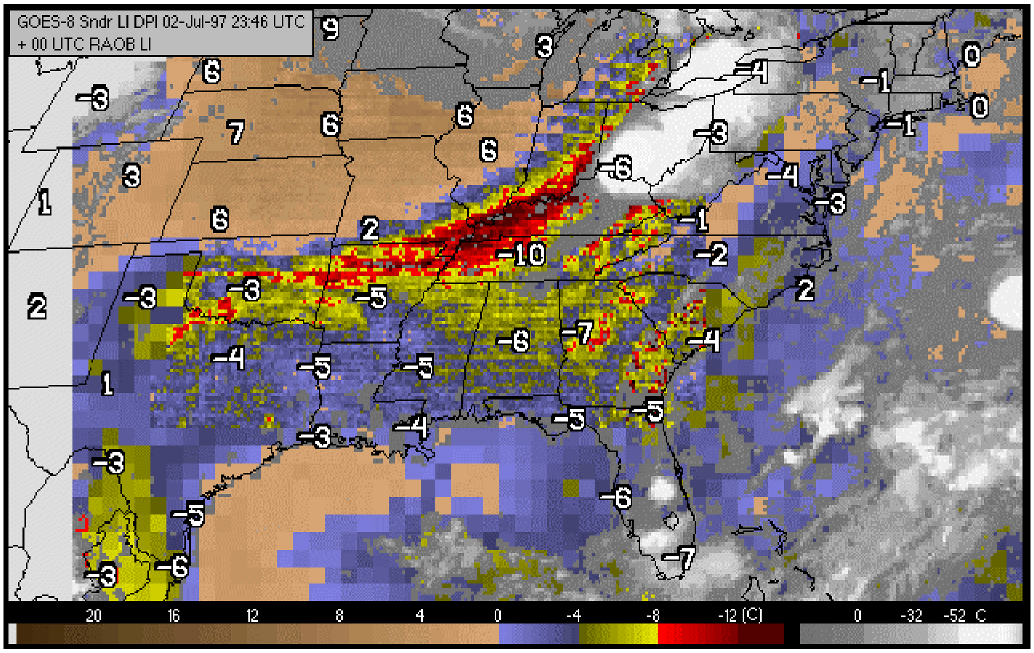


Fig. 2: GOES-8 Sounder Lifted Index DPI for 23:46 UTC 2 July 1997 with 00 UTC RAOB Lifted Indices (COMET 2006).

b) Lifted Index

The lifted index is calculated by lifting a parcel in the boundary layer to 500 hPa and comparing the parcel temperature with the temperature of the environment at 500 hPa. It is similar to the Showalter index, except the temperature and dew point are averaged over the first 100 hPa above the surface and then lifted from 50 hPa above the surface to 500 hPa. A positive value indicates the parcel is colder than the environment, causing the parcel to sink, thus indicating stable conditions. On the other hand, a negative value shows the parcel warmer than its surroundings, meaning the parcel is in an unstable environment and will continue to rise (Galway 1956). Figure three shows the simple equation to calculate the lifted index:

$$\textbf{Lifted Index} = T_{E\ 500\ hPa} - T_{P\ 500\ hPa}$$

Fig. 3: Equation for the lifted index, where $T_{E\ 500\ hPa}$ *is the environment temperature at 500hPa, and* $T_{P\ 500\ hPa}$ *is the parcel temperature at 500hPa. (Galway 1956).*

Using the physical retrieval algorithm, the DPI estimates the incremental temperature for the boundary layer and is added to the forecasted temperature profile over the first 100 hPa of the atmosphere. Along with this, the average mixing ratio for the boundary layer is also estimated and added over the first 100 hPa. These values are then lifted from 50 hPa to 500 hPa to estimate a parcel temperature at 500 hPa. The environmental 500 hPa temperature is taken directly from the forecast. These two numbers are then subtracted from each other to obtain the value of the lifted index. (Hayden et al 1996).

Recall the DPI has 18 infrared channels used to construct the vertical temperature and moisture profile. Since the weighting functions overlap near the surface, the temperature and moisture profiles below 500 hPa are not accurately represented. Since the lifted index depends on both temperature and moisture values from the surface to 500 hPa, there could be a large error with the final lifted index result.

c) GOES-12 Sounder

The current GOES sounder is similar to the sounder used on both GOES-8 and GOES-9. Figure four shows the schematic of the current GOES sounder in operation (OSO 2008). Like the original sounder on GOES-8, it still consists of 19 channels, one visible and 18 infrared. The infrared detector has a rotating color wheel to filter through the eighteen channels. Each channel is equipped with four detectors, 10km apart, which will generate a scan line consisting of scan spots every 10km. It takes approximately 100 microseconds to generate one scan spot.

It is important to note that the scan spot is circular, so not everything is picked up within a 10km box. The actual diameter the sounder receives within the 10km box is only approximately 8.7 km. Additionally, because of the field of view of the camera, the 10km by 10km box is only valid at the sub-satellite point. The farther away the scan spot is from nadir, the larger the scan spot. This is an indicator of a much coarser resolution than just 10 km. Once again this could cause issues when determining an actual value of the lifted index (Miller 2008).

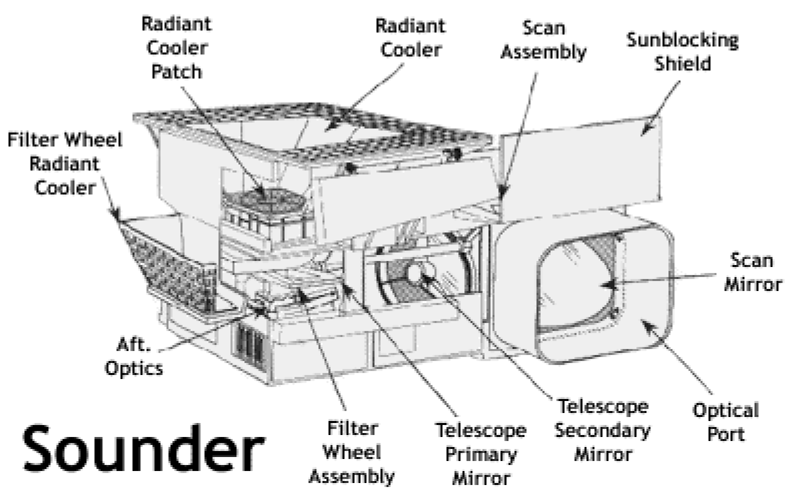


Fig. 4: Schematic of the Sounder used on GOES-12 (OSO 2008).

Belge (2007) did her research on the CAPE values. She chose three stations across the country (Albany NY, Norman OK, and Miami FL) and data were taken during the months of January and June of 2006. Her results showed that Miami had the best correlation. The R^2 value was 0.661 but the RMSE was over 415 JKg^{-1}. (Belge 2007).

It is important to note the following: geostationary satellites orbit over the equator. The slant range from the satellite to a spot located in higher latitudes will be larger than a slant range near the equator. While more data can be obtained, the resolution will be coarse because of the field of view of the camera. Belge (2007) suggested Miami had a better correlation due to the city being closer to the sub satellite point than the other two cities. She also concluded that a larger sample size might improve the results. Because of the better results in Florida, this research will compare GOES derived and radiosonde calculated lifted index for the Florida area only.

3) Data and Methodology

For this paper we would like to know the following: What is the correlation between the GOES sounder and RAOB-based calculations of lifted index in Florida, and how does this correlation vary by season? Because we are limiting this research to Florida, GOES-12 derived product imagery and radiosonde values of lifted index were taken from four stations in the Florida area: Jacksonville (KJAX), Tallahassee (KTLH), Tampa Bay (KTBW), and Miami (KMFL). Data from the months of January, March, June, and September 2007 were extracted and tested to compare these values by season, and by time (00Z and 12Z). We would expect lower values of lifted index in the spring and summer months and higher values in the fall and winter months. Because the DPI can only display images when the skies are clear (Hayden et al 1996), it is important to find days when the area is not obscured by clouds.

Radiosonde data will be considered the “true” value for this research. Soundings from both 00Z and 12Z were taken from the University Of Wyoming’s Department Of Atmospheric Sciences. The dates where there are valid DPI estimates of lifted index were chosen for consistency. A script was run to extract the lifted index value from the raw text file and placed into a more formal text file. These values are considered the “true” estimates of lifted index when the statistical comparisons are performed.

The DPI values of the lifted index were taken from the sounder instrument on the GOES-12 Satellite. This data was obtained from the Cooperative Institution for Meteorological Satellite Studies at the University of Wisconsin-Madison Space Science and Engineering Center, courtesy of Mr. Jim Nelson. The dataset included 00Z and 12Z area files every day for the months of January, March, June and September 2007. The files obtained were then added into a dataset that could be interpreted and viewed by the McIDAS software package.

McIDAS was able to produce images of lifted index from the dataset, and could be probed for the Florida stations. However there were some issues when interpreting the data. First, the values probed from the image were in values of brightness and not the lifted index. To correct for this, a linear interpolation equation was constructed using current LI images from the CIMMS server and invoked on this dataset. The range of the lifted index was between -15°C and 25°C. If there were values over 25°C, this indicated the pixel was cloud contaminated.

Additionally, the probing of lifted index in a single 10km by 10km pixel is not a good representation, due to the errors discussed in the background section. To create a better representation of the lifted index, a 15 X 15 pixel grid was probed through the

McIDAS program, with the center of the grid indicating the location of the Florida station. To average these values to a specific point, a Barnes analysis was implemented. A Barnes analysis determines the value at a grid point based on observations falling within a specific radius of influence. The closer the observation value is to the grid point, the higher weight it will have on the final result (Barnes 1964). A smoothing parameter of 50km was used so that point values within this area would have the greatest weight when calculating the average mean.

Once the Barnes analysis was completed, another script was run to perform quality control on the results. The 15 by 15 pixel grid contained 225 pixels. If more than 200 pixels were cloud contaminated, or if the center station was cloud contaminated, then they were disregarded and values of -9999 were given in the final data table. These resulting values were matched with their respective radiosonde values and considered the derived estimates of the lifted index.

Once the data was collected and quality controlled, the lifted index values from the DPI were to be regressed against the values of the radiosonde data using statistical tests. Scatter plots were generated in Microsoft Excel, with the true value of the lifted index (radiosonde) on the x-axis, and the derived estimate (GOES-12 sounder) on the y-axis. Plots were made for each season, 00Z and 12Z times, and all data for each individual station, as well as all four stations combined.

To perform a correlation test between the derived and true values of lifted index, a linear regression was calculated where an R^2 value was given. The R^2 value is a number between 0 and 1. A value of 0 provides no correlation between the two variables, while a value of 1 represents a perfect correlation. The higher the value, the better the data are correlated with each other. For our purposes, we would like to see high R^2 values.

The average bias is calculated to determine the overall difference between the satellite and radiosonde values of the lifted index. Additionally, because we are comparing satellite data to the real or “true” estimate, the root mean square error (RMSE) were also calculated. The RMSE will show an averaged difference between the derived and true values of lifted index. A small value indicates the derived values of LI are close to the true (radiosonde) values. For our purposes, we would like to see small values of both RMSE and averaged bias.

4) Results

Table 1 lists the amount of observations, root mean square error, and bias for each station. Scatter plots were also plotted for each station by month (Jan, Mar, Jun, and Sep), time (00Z and 12Z) and the entire year of 2007. Results from all four stations were also plotted and tested for correlation. Similar to the other graphs, plots were again composed by month, time, and entire year. All tables and graphs generated in this research are placed in the appendix for reference.

Figures 5-11 show the scatter plots, linear regression, average bias and RMSE for Tallahassee, Florida. Overall the data is well correlated, as Figure 11 shows an R^2 value of 0.9132 with a RMSE of 2.82 and bias of 0.9. There does not seem to be a difference between 00Z and 12Z values, as they both appear to be correlated very well. However, when comparing by month, there are noticeable differences. January and March have very good correlations, (0.8932 and 0.9152, respectively). However they have large

RMSE values (3.73 and 2.91, respectively), and large biases (1.51 and 1.91, respectively). June had the worst correlation as Figure 7 indicates an R^2 value of 0.3741. September had a decent correlation of 0.773, and had the lowest RMSE of 1.69.

Figures 12-18 show the scatter plots, linear regression, average bias and RMSE for Jacksonville, Florida. Overall Figure 18 shows the R^2 value and RMSE were better than the Tallahassee values. However when comparing by month, each R^2 value turns out to be worse than those of Tallahassee. While January and March still have a decent correlation (R^2 values of 0.8614 and 0.8764, respectively), June and September values are not as correlated (R^2 values of 0.4996 and 0.4664, respectively.) As reflected from the Tallahassee results, the RMSE values of January and March 2007 are high (3.29 and 2995, respectively), while the RMSE for June and September are low (1.92 and 2.16, respectively).

Figures 19-25 show the scatter plots, linear regression, average bias and RMSE for Tampa Bay, Florida. Overall this station had the highest correlation out of the four, as Figure 25 shows an R^2 value of 0.9488. The RMSE and bias are also small (1.92 and 0.8, respectively). However the same results are reflected when comparing them by month. January and March have good correlations (0.9449 and 0.9069, respectively), but high RMSE values (1.87 and 2.42, respectively), and June and September have low correlations (0.3329 and 0.5185, respectively), but the lowest RMSE values (1.84 and 1.59, respectively).

Figures 26-32 show the scatter plots, linear regression, and RMSE for Miami, Florida. This station appears to have the best overall data, as Figure 32 shows a very high correlation (0.9221) and the lowest RMSE (1.59) and bias (0.51) out of the four stations.

The RMSE for all four months are low, ranging between 1.38 – 1.78. However the correlations show the same results as those from the other stations. January and March have high correlations (0.9083 and 0.907, respectively) while the months of June and September still have poor correlations (R^2 value of 0.5192 and 0.4191, respectively).

Figures 33-39 show the scatter plots, linear regression, and RMSE for all four stations in Florida. Figure 39 indicates there was a total of 715 observations, with an R^2 value of 0.9281, an RMSE of 2.26, and a bias of 0.76. The 00Z and 12Z values also have high correlations (R^2 values of 0.9344 and 0.9286, respectively. January had the best correlation (R^2 value of 0.9176), with March also having a good correlation (R^2 value of 0.9004). However their RMSE values (2.64 and 2.5, respectively), were the highest out of the four. The same can be said for their biases (0.78 and 1.19, respectively) January and September had the best RMSE values (2.1 and 1.74, respectively) and biases (0.74 and 0.34, respectively), but both months had poor correlations (R^2 values of 0.4228 and 0.6806, respectively).

Figure 39 also includes the linear regression equation for all of the data obtained in this research. This equation, given by y = 0.9524x * 0.8978, could be used as an adjustment for the GOES derived values of lifted index within the Florida area. The sounder value (y), once known, can be adjusted and linearly interpolated to a grid that could be used in numerical models. However, this equation is not considered accurate, as radiosonde values would need to be known in order to make this adjustment. Additionally, because the radiosonde values were assumed to be the “true” value, they still may not provide an accurate representation of the atmosphere, as well as all of the assumptions and problems with the instrumentation of the sounder.

5) Conclusions

As expected from Belge (2007), Miami saw the best results. They had the lowest root mean square error (1.59) and lowest bias (0.51), while conserving a high correlation (0.9221). This is once again probably due to Miami being located at lower latitudes than the other four stations, making it closer to the equator and therefore the sub-satellite point at nadir. The shorter slant range between the sounder instrument and the station can help preserve the resolution of the sounder, as the field of view of the camera could create a much coarser view with a larger slant range.

Comparing by time, it appears that both 00Z and 12Z correlations were high and similar to each other. However, the 00Z values have lower RMSE and biases throughout all four stations. This may imply that the sounder's value of lifted index is closer to the radiosonde value at 00Z than 12Z. These results may be helpful when forecasting for nighttime convection, however most of Florida's convection occur in the afternoon before 00Z, where daytime heating is at its maximum

January and March saw the best correlations but higher values of RMSE and bias. June and September, on the other hand saw the worst correlations, but lower RMSE and bias values. This is problematic due to June and September having a climatologically higher convective activity than January and March in Florida. The reason for this large error could be due to large moisture and temperature fluxes near the surface. As said before, the 18 infrared bands are smoothed out near the surface, due to the overlapping of the different weighting functions. During June and September, sharp lapse rates and moisture fluxes may not be accurately represented on a GOES sounder vertical profile, thus contaminating the value of the lifted index.

It is also important to note the following: the process of a sounding retrieval has many assumptions and biases. This, along with instrumentation and cloud contamination could drastically affect the results. Also, the assumption was made that the radiosonde measurement of lifted index was the true value. This again is not always the case, since the vertical profile isn't directly over the station, along with their own problems with instrument contamination that could affect the overall results.

Additionally, this research only dealt with one area of the United States, perhaps if different stations were collected from different parts of the United States, one could determine how well the GOES Sounder DPI performs in different regions. Even though the sample size was larger than Belge (2007), it can still be increased. One could increase the seasons from one month to three months (for example, Dec-Jan-Feb for winter, Mar-Apr-May for spring, Jun-Jul-Aug for summer, and Sep-Oct-Nov for fall).

6) Summary

Since the implementation of the derived product imagery in 1994, research has been performed to test the validity of the GOES sounder derived product imagery. This research attempted to compare GOES-12 derived values of lifted index to radiosonde values for the state of Florida. Data was taken over four months and tested for regression, correlation, bias and the root mean square error. Results were promising for the non convective months of January and March however did not provide good results for the convective months of June and September.

Even though a lot of assumptions were made, the DPI can still provide some sort of representation of the atmosphere in places where radiosondes cannot (for example, over the oceans). Because of this, the derived product imagery can still be considered a decent tool for forecasting, but should be taken with a grain of salt, as it may not be an accurate and complete representation of the atmosphere.

7) References and Acknowledgments

Balschmiter, B., 2007 Seasonal and Longitudinal Effects on Precipitable Water from GOES 12 Sounder. *Satellite Meteorology*

Barnes, S. L., 1964: A Technique for Maximizing Details in Numerical Weather Map Analysis. *Journal of Applied Meteorology*., **3,** 396–409.

Belge, J. Q., 2007 A Statistical Analysis of the GOES Sounder Derived CAPE. *Satellite Meteorology*.

COMET, MetEd, cited 2008: Satellite Meteorology: Introduction to Using the GOES Sounder. [Available online at http://www.meted.ucar.edu]

Dostalek, J.F. , and T.J.Schmit, 2001: Total Precipitable Water Measurements from GOES Sounder Derived Product Imagery, *Weather and Forecasting,* **16**, 573-587

Fusco, T, 2006: Seasonal and Latitudinal Differences in RAOB and Satellite-Derived Precipitable Water. *Satellite Meteorology.*

Galway, J.G., 1956: The Lifted Index as a Predictor of Latent Instability. *Bulletin of the American Meteorological Society*., **37**, 528-529.

Hayden, C.M., G.S. Wade and T.J. Schmit, 1996: Derived Product Imagery from GOES-8, *Journal of Applied Meteorology*., **35**, 153-162

Kidder, S.Q., and Vonder Haar, T.H., 1995: *Satellite Meteorology: An Introduction*. Academic Press, 466 pp.

Menzel P.W. and J.F.W. Purdom, 1994: Introducing GOES-I: The First of a New Generation of Geostationary Operational Environmental Satellites, *Bulletin of the American Meteorological Society*., **75**, 757-781

---, F.C. Holt, T.J. Schmit, R.M. Aune, A.J. Schreiner, G.S. Wade and D.G. Gray, 1998: Application of GOES-8/9 Soundings to Weather Forecasting and Nowcasting, *Bulletin of the American Meteorological Society*., **79**, 2059-2077.

Miller, S. T. K., *Class Lecture* (27 Oct 2008).

Nelson, J: Email Correspondence, October 2008.

OSO, cited 2008: Geostationary Operational Environmental Satellites: Sounder [Available online at http://www.oso.noaa.gov/goes/sounder/sounder.htm]

Storm Prediction Center, cited 2008: Observed Sounding Archive. [Available online at http://www.spc.noaa.gov/exper/soundings/.]

8) Appendix

		January	March	June	September	00Z	12Z	All
KTLH	n	40	52	45	47	84	100	184
	RMSE	3.73	2.91	2.72	1.69	2.37	3.15	2.82
	Bias	1.51	1.91	-0.1	0.22	0.67	1.09	0.9
KJAX	n	23	48	49	47	78	89	167
	RMSE	3.29	2.95	1.92	2.16	2.03	2.89	2.53
	Bias	-0.42	1.62	0.22	1.3	0.09	1.48	0.84
KTBW	n	46	36	44	46	78	94	172
	RMSE	1.87	2.42	1.84	1.59	1.65	2.12	1.92
	Bias	0.87	0.88	0.49	0.97	0.3	1.21	0.8
KMFL	n	54	50	42	46	91	101	192
	RMSE	1.76	1.38	1.78	1.4	1.37	1.77	1.59
	Bias	0.68	0.25	0.67	0.46	0.29	0.72	0.51
ALL	n	163	186	180	186	331	384	715
	RMSE	2.64	2.5	2.1	1.74	1.88	2.54	2.26
	Bias	0.78	1.19	0.31	0.74	0.34	1.11	0.76

Table 1: Number of observations (n), root mean square error (RMSE), and average bias for KTLH, KJAX, KTBW, KMFL, and all four Florida Stations. Results are organized by month (Jan, Mar, Jun, Sep), time (00Z and 12Z) and All data points for 2007.

1) Tallahassee, Florida

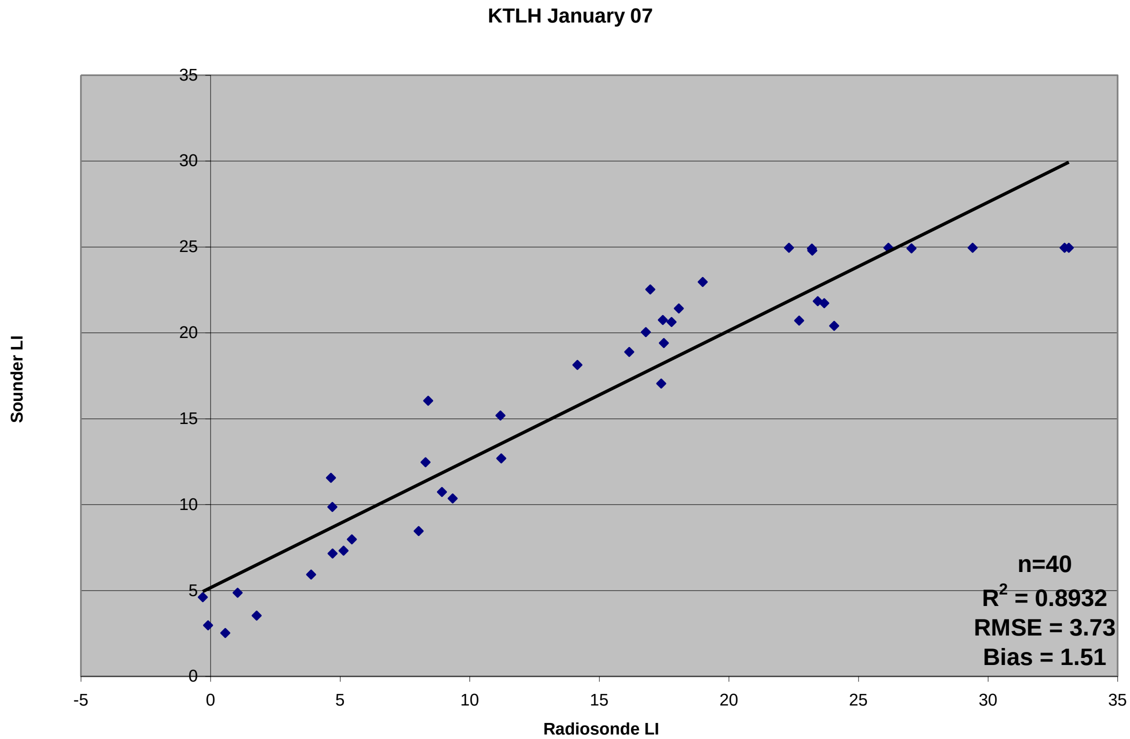


Fig 5: Scatter plot of January 2007 data for Tallahassee, FL with linear regression, R^2 value, average bias and Root Mean Square Error. Number of data points is given by n.

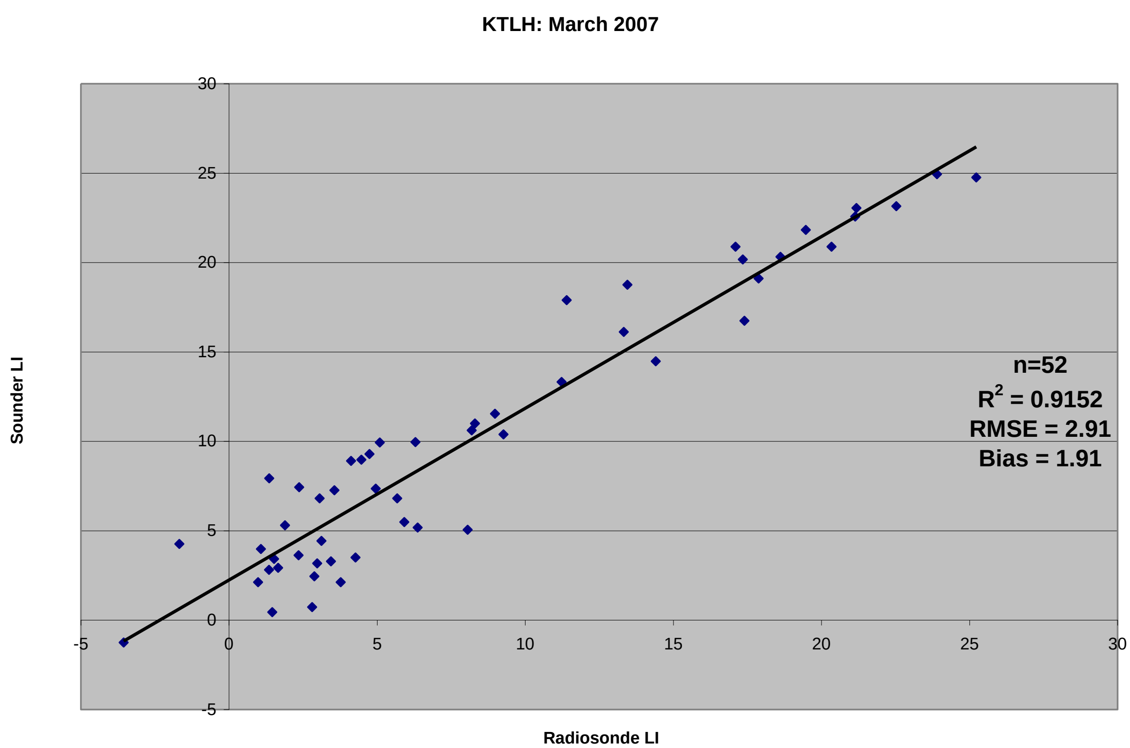


Fig 6: Same as Fig 5, but for March 2007

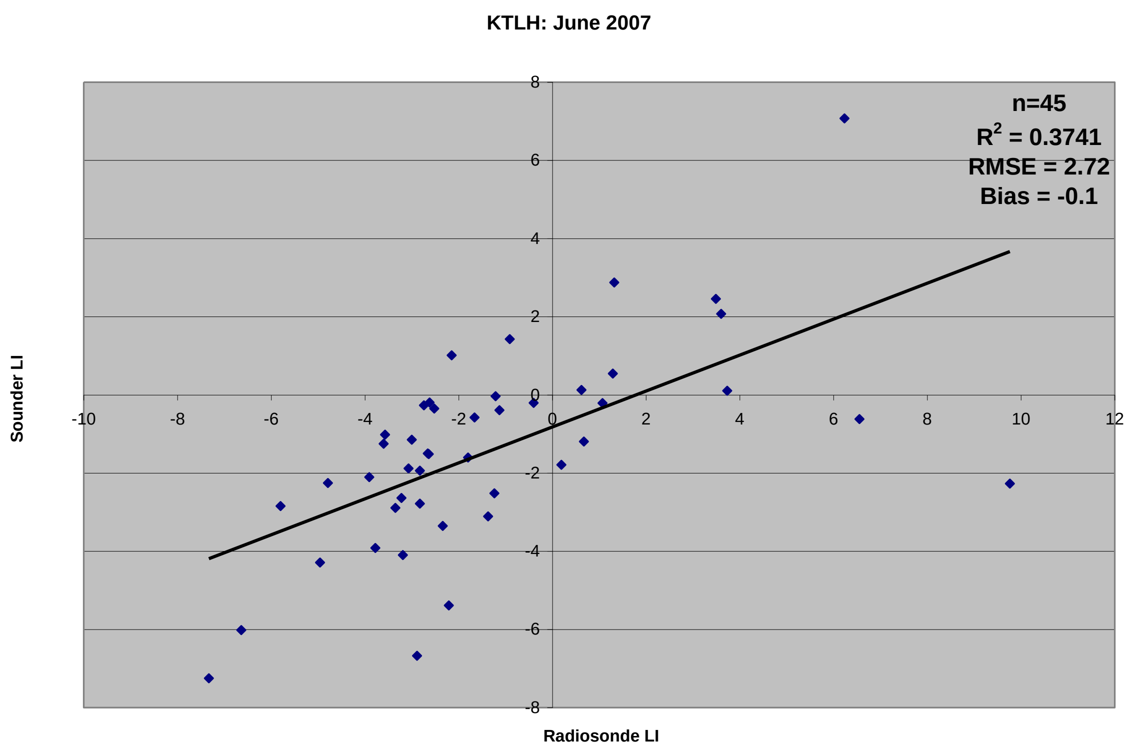


Fig 7: Same as Fig 5, but for June 2007

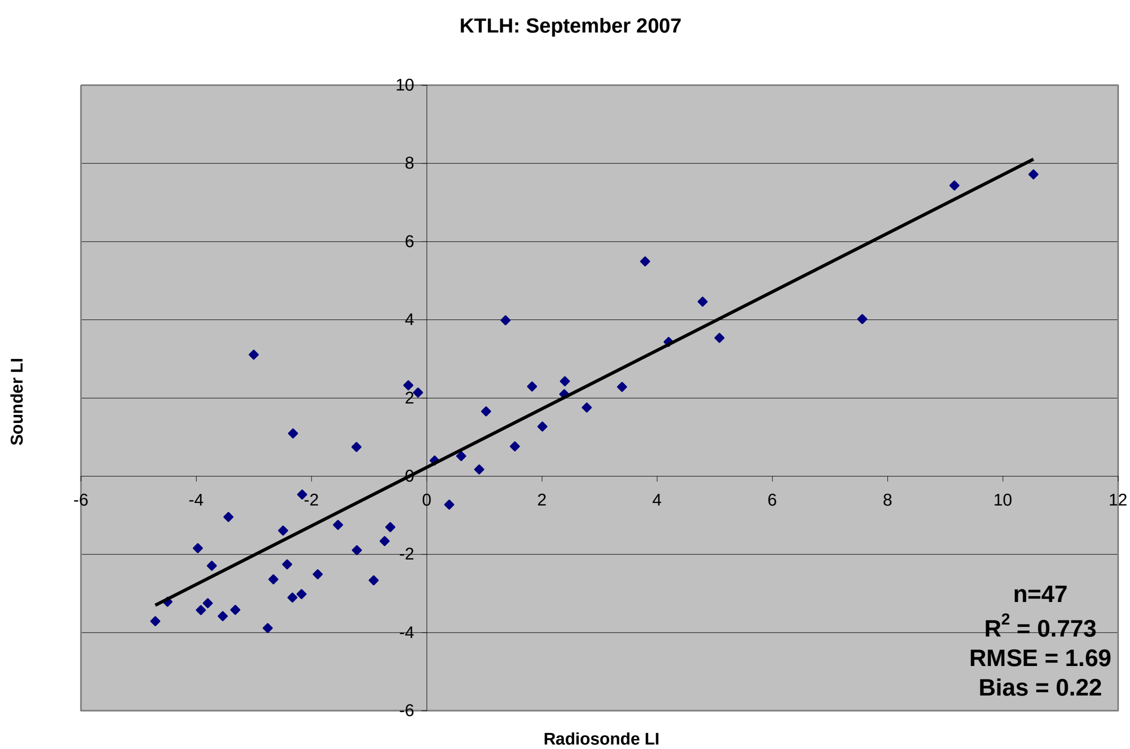


Fig 8: Same as Fig 5, but for September 2007

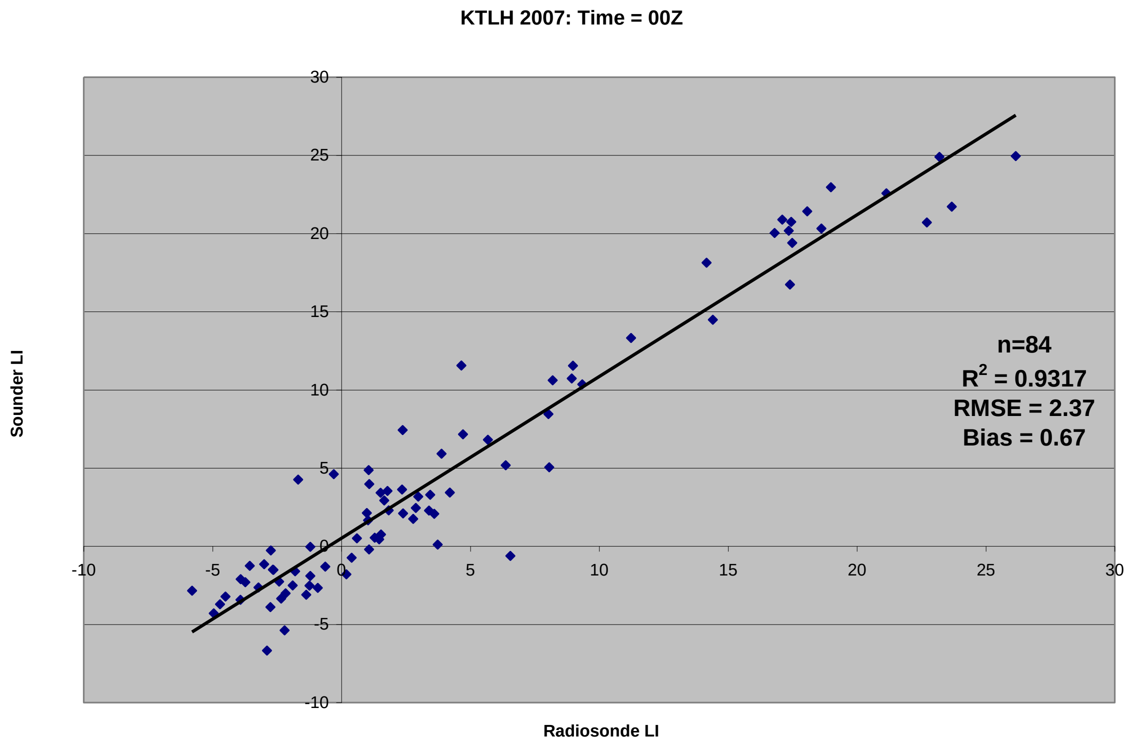


Fig 9: Scatter plot of 00Z data for Tallahassee, FL with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n.

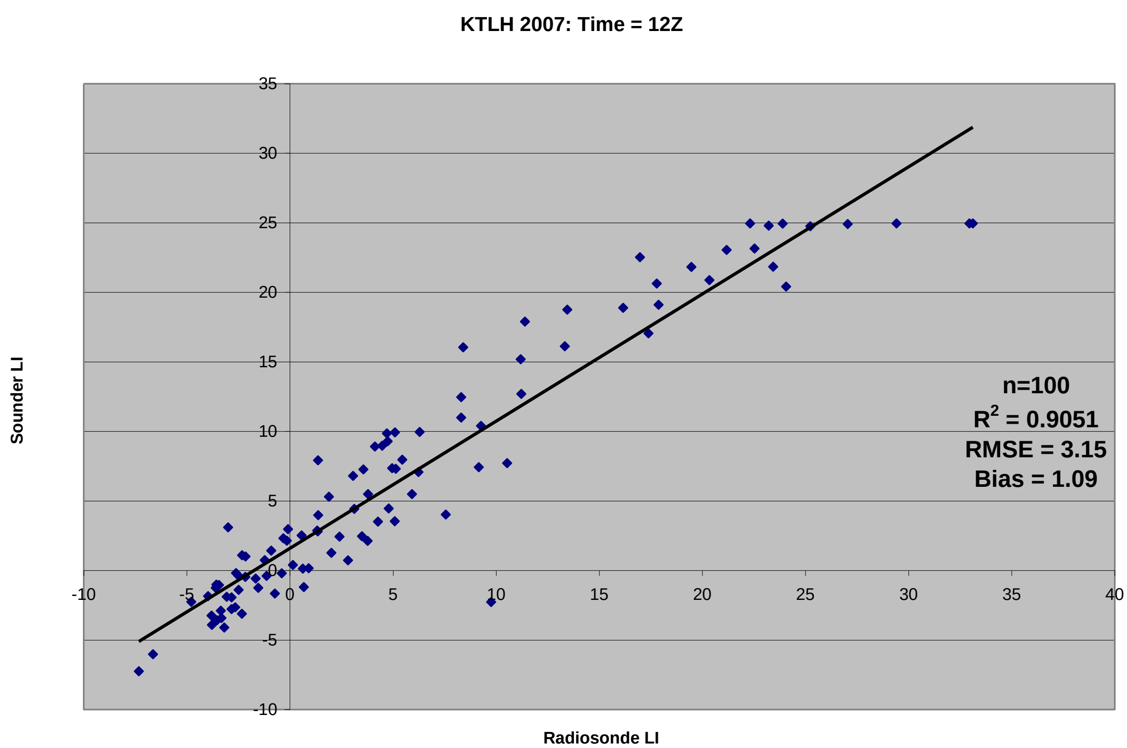


Fig. 10: Same as Fig. 9, but for 12Z

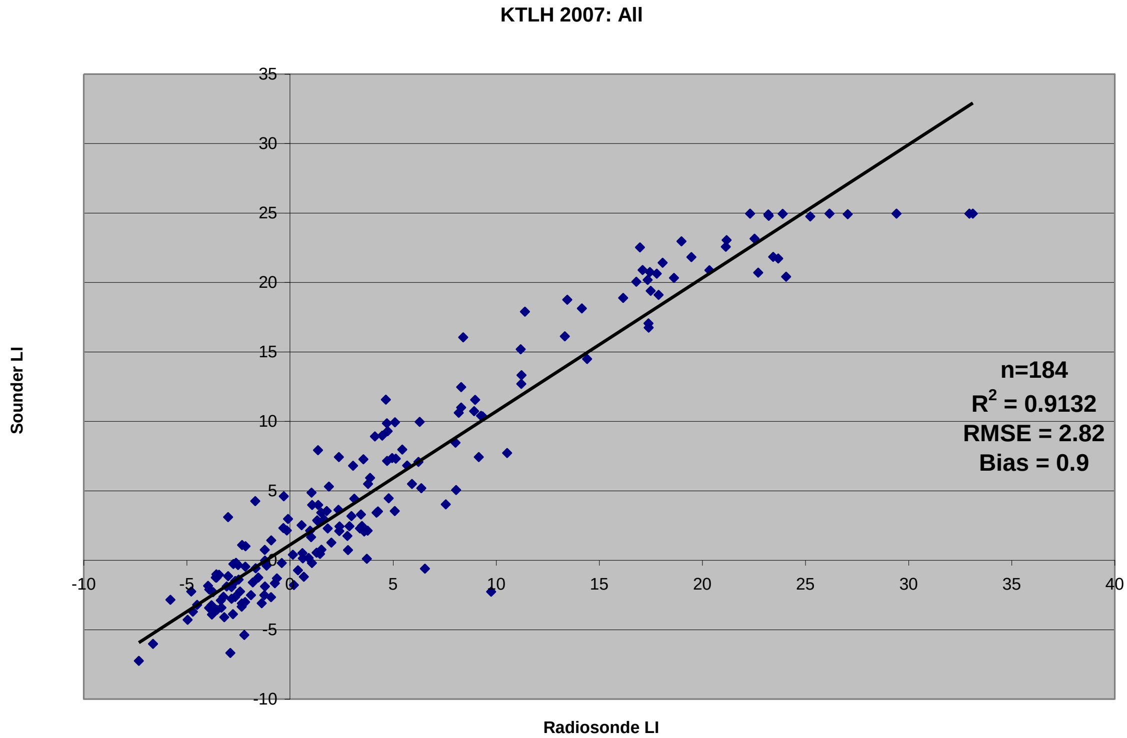


Fig 11: Scatter plot of all data for Tallahassee, FL with linear regression, R^2 value, average bias and Root Mean Square Error. Number of data points is given by n

2) Jacksonville, Florida

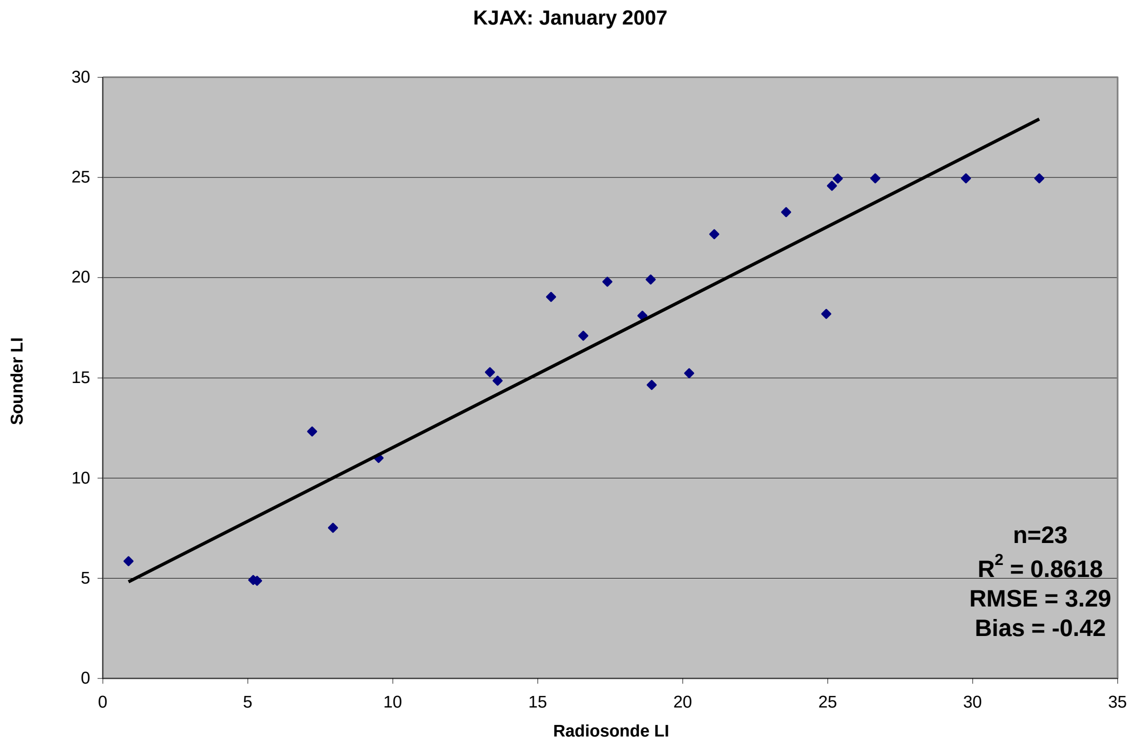


Fig 12: Scatter plot of January 2007 data for Jacksonville, FL with linear regression, R^2 value average bias,, and Root Mean Square Error. Number of data points is given by n.

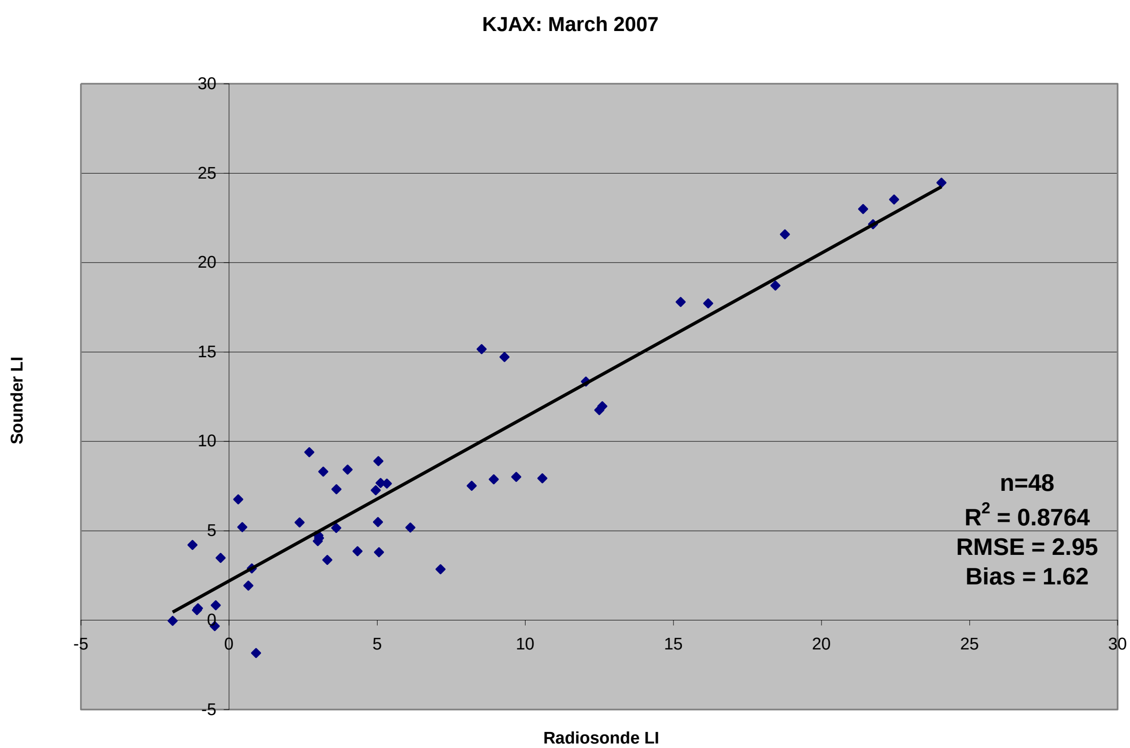
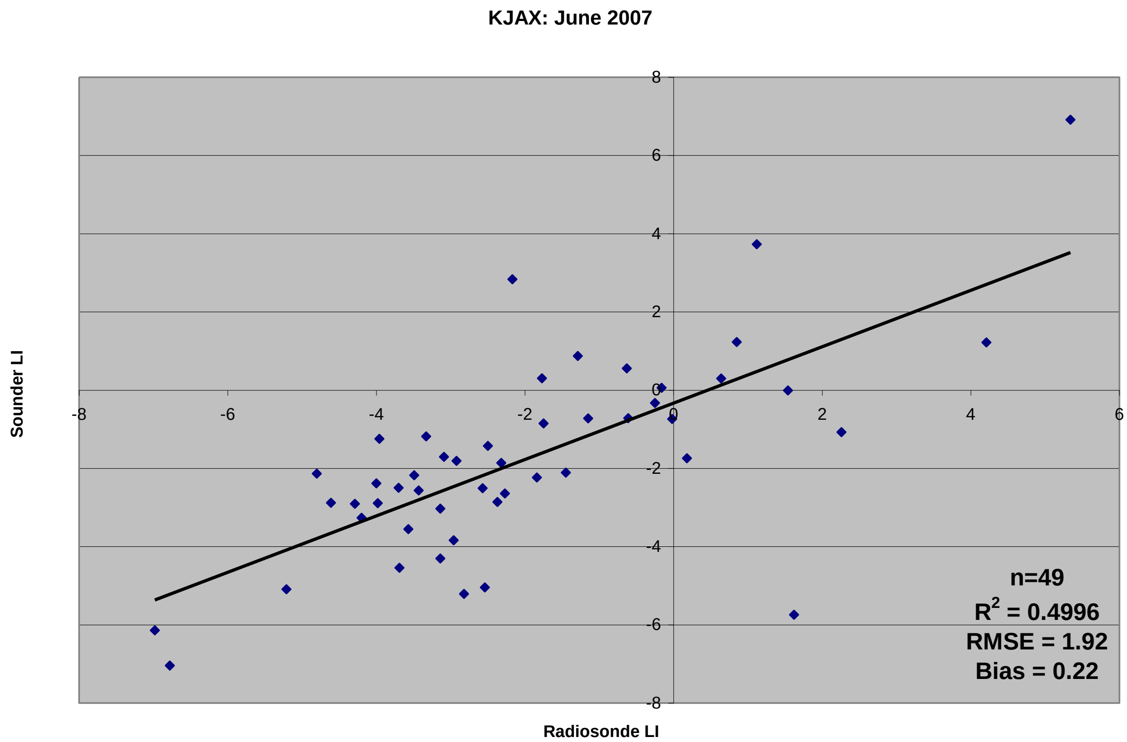


Fig 13: Same as Fig 12, but for March 2007



. *Fig 14: Same as Fig 12, but for June 2007*

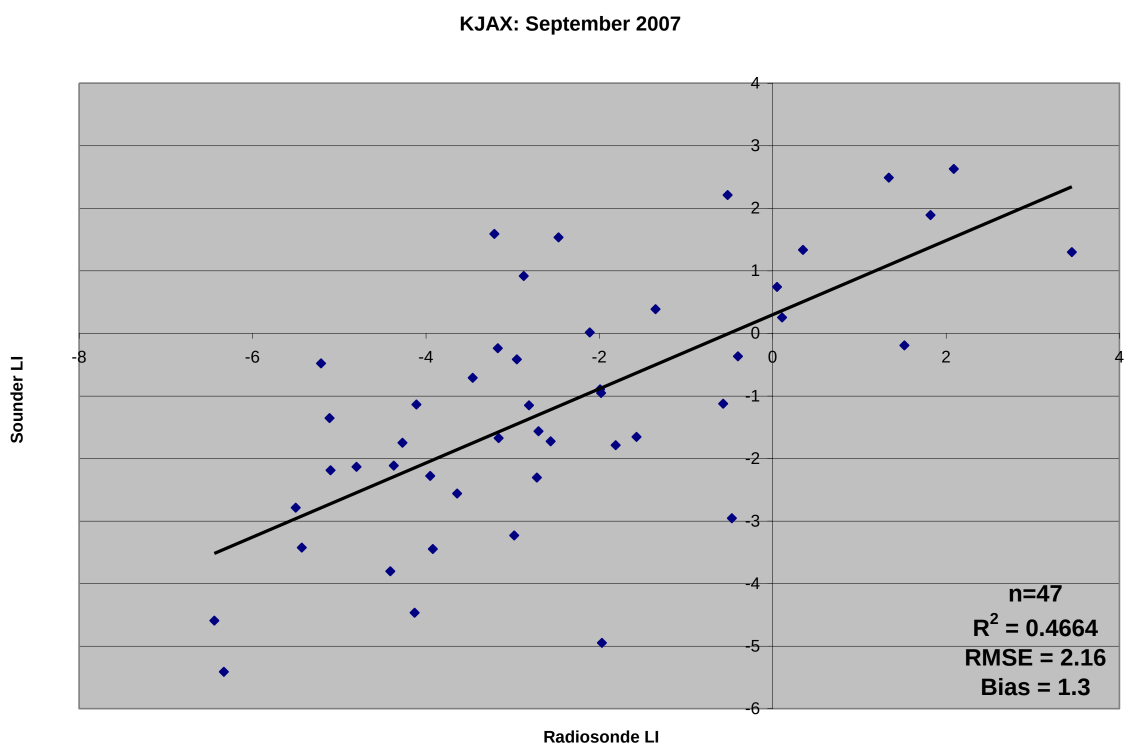


Fig 15: Same as Fig 12, but for September 2007

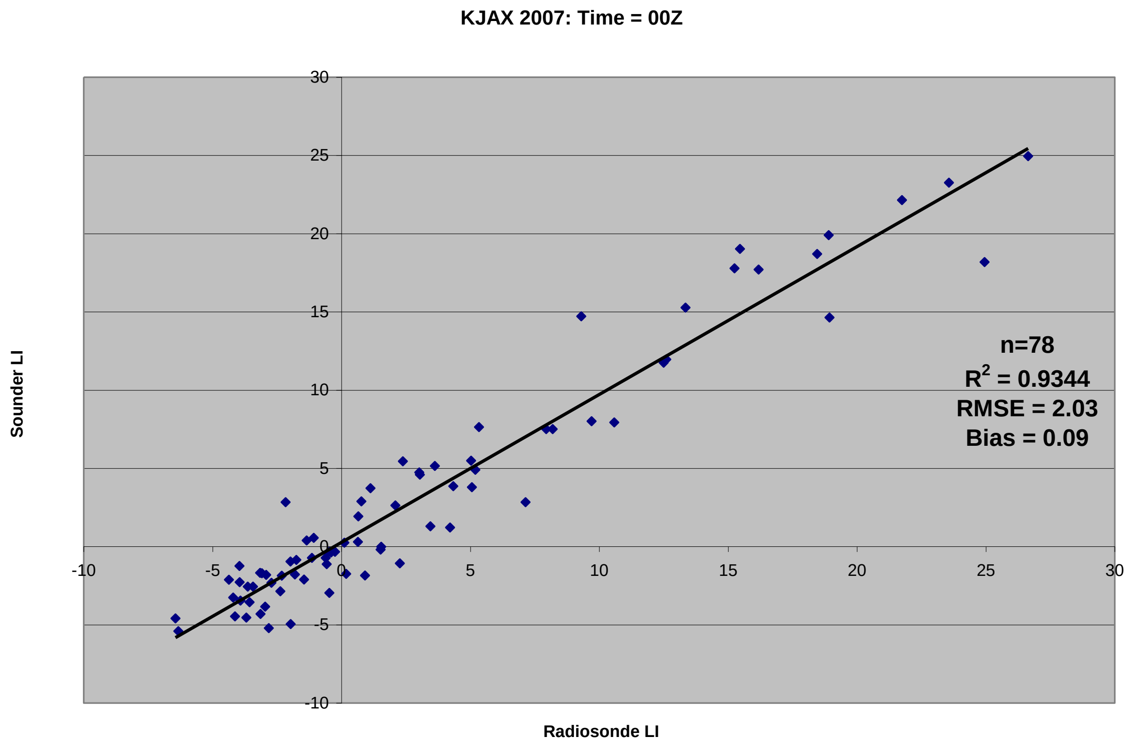


Fig 16: Scatter plot of 00Z data for Jacksonville, FL with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n.

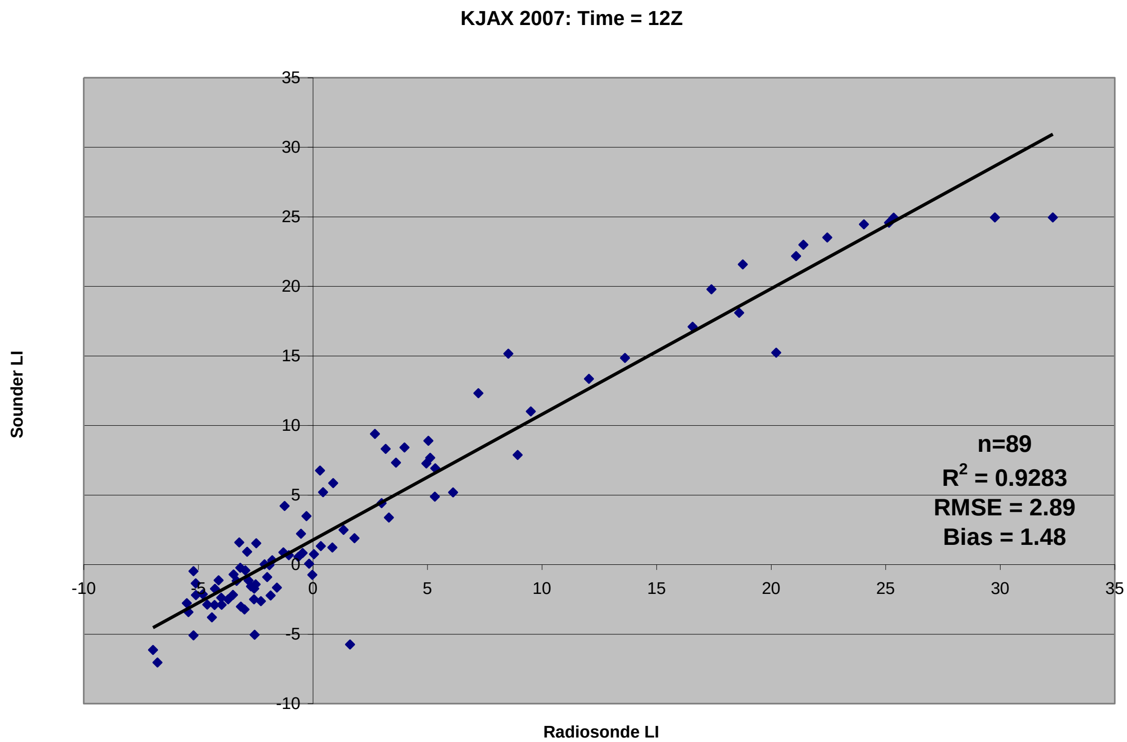


Fig 17: Same as Fig 16, but for 12Z

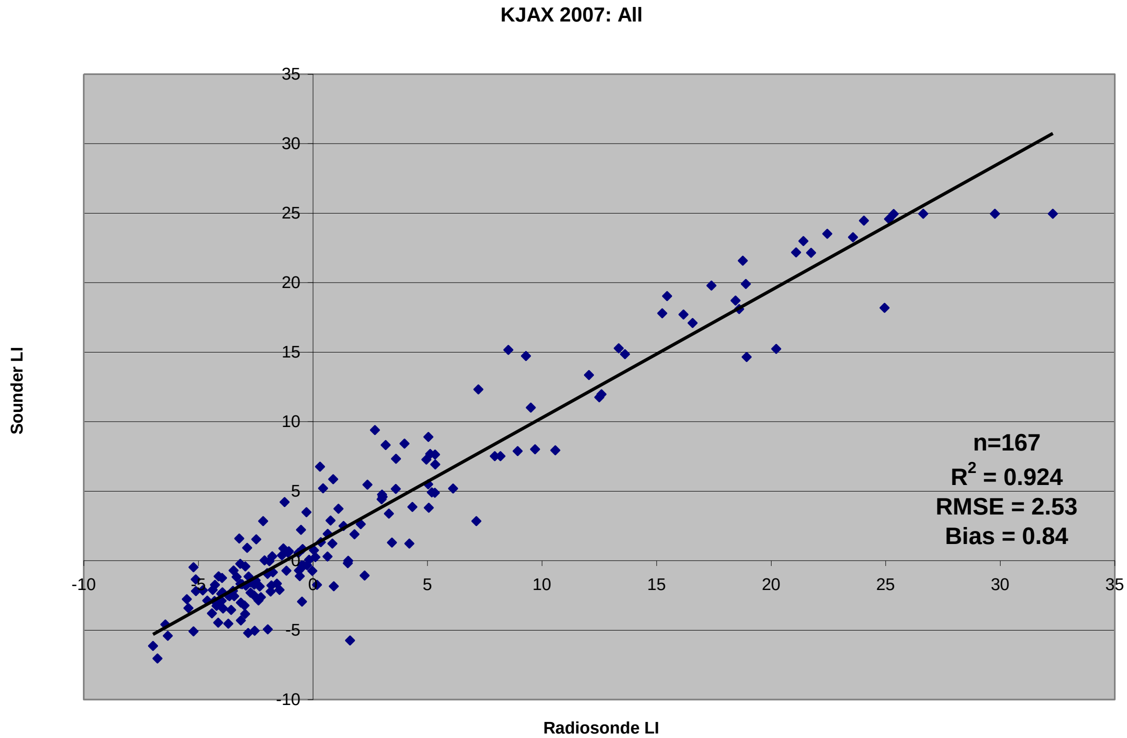


Fig 18: Scatter plot of all data for Jacksonville, FL with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n

3) Tampa Bay, Florida

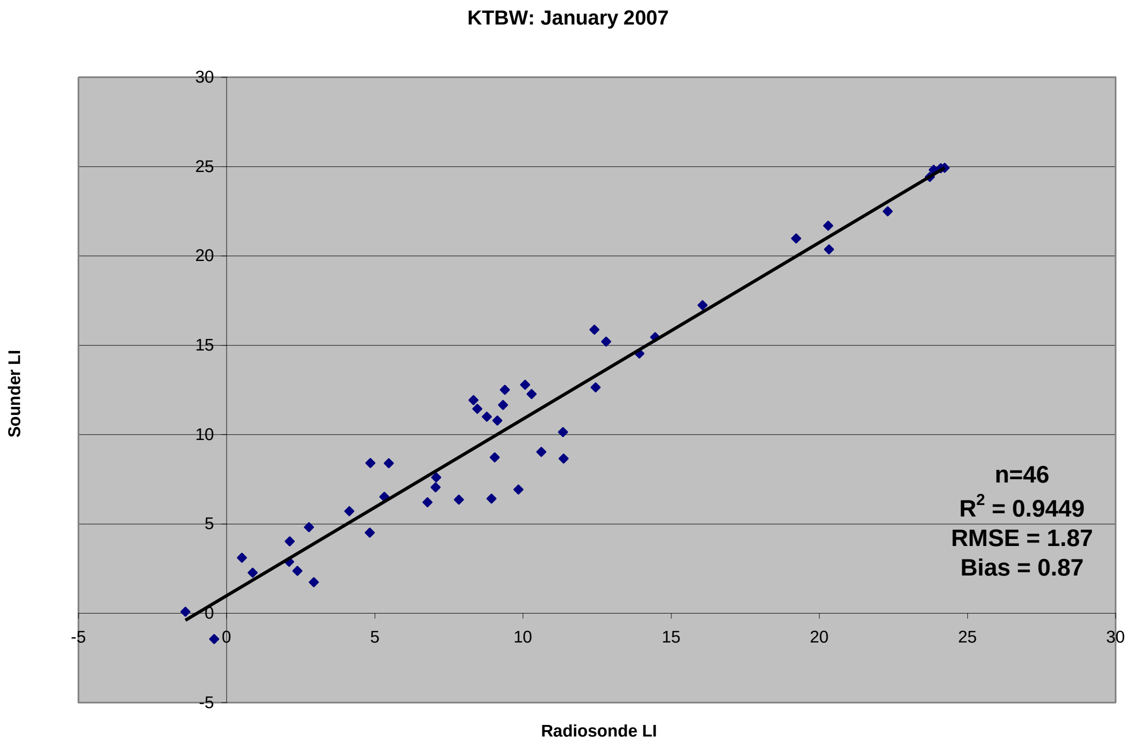


Fig 19: Scatter plot of January 2007 data for Tampa Bay, FL with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n.

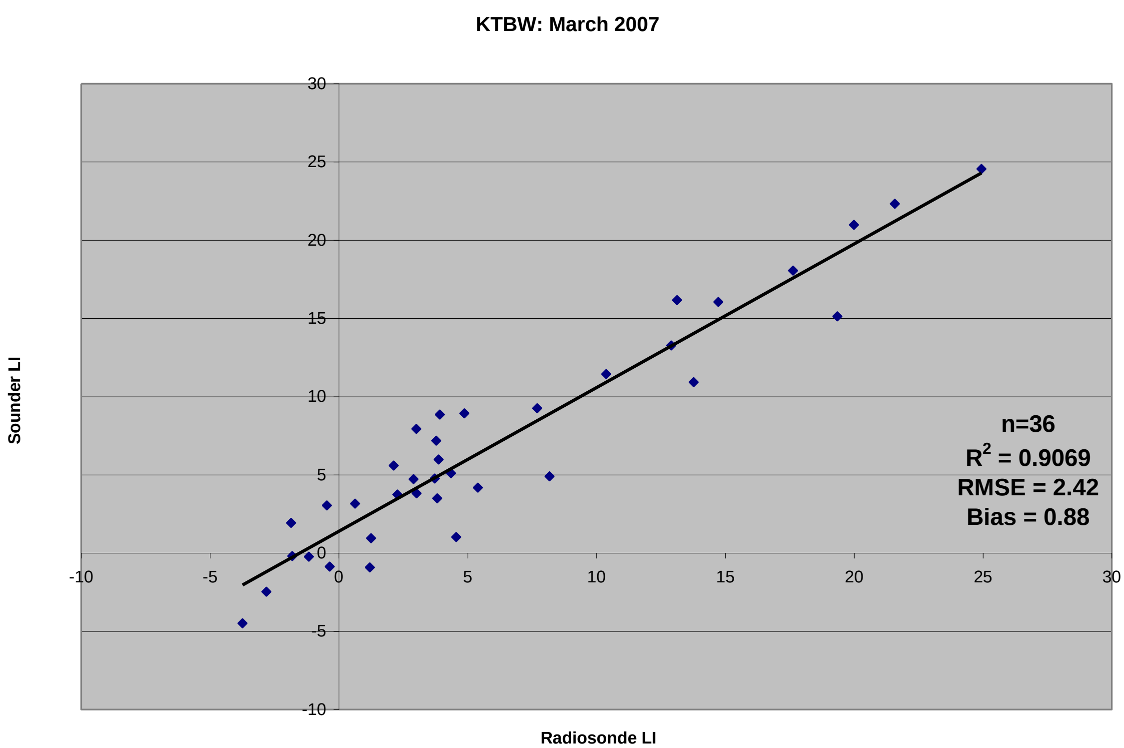


Fig 20: Same as Fig 19, but for March 2007

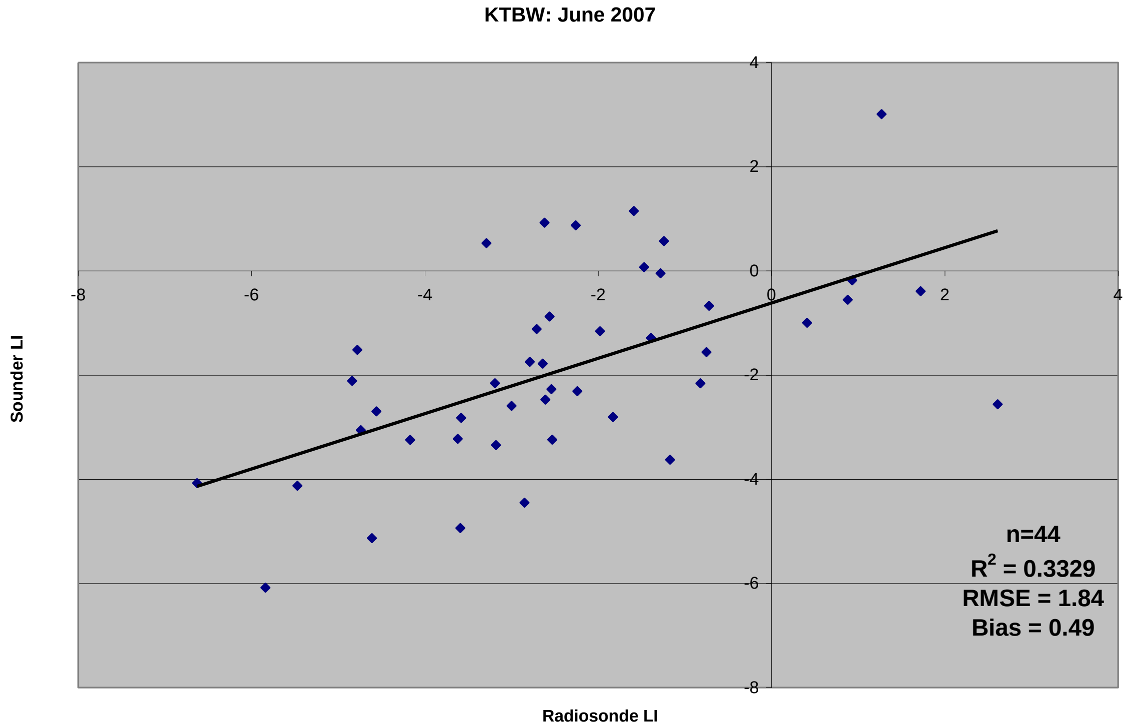


Fig 21: Same as Fig 19, but for June 2007

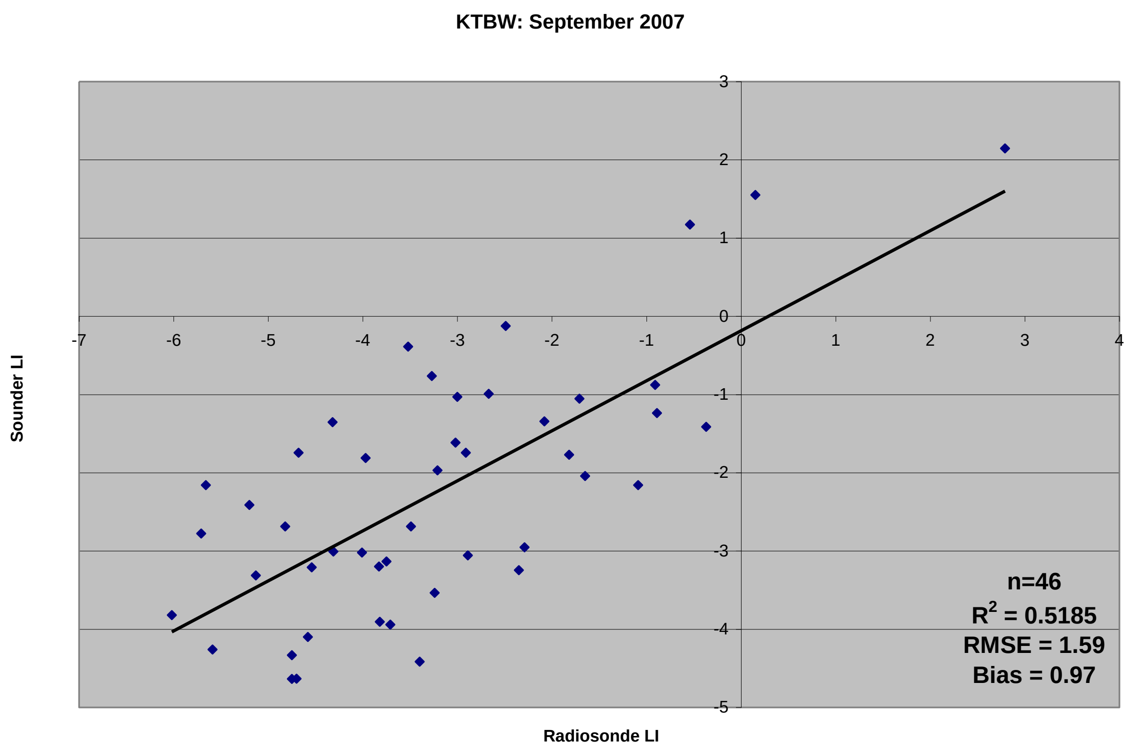


Fig 22: Same as Fig 19, but for June 2007

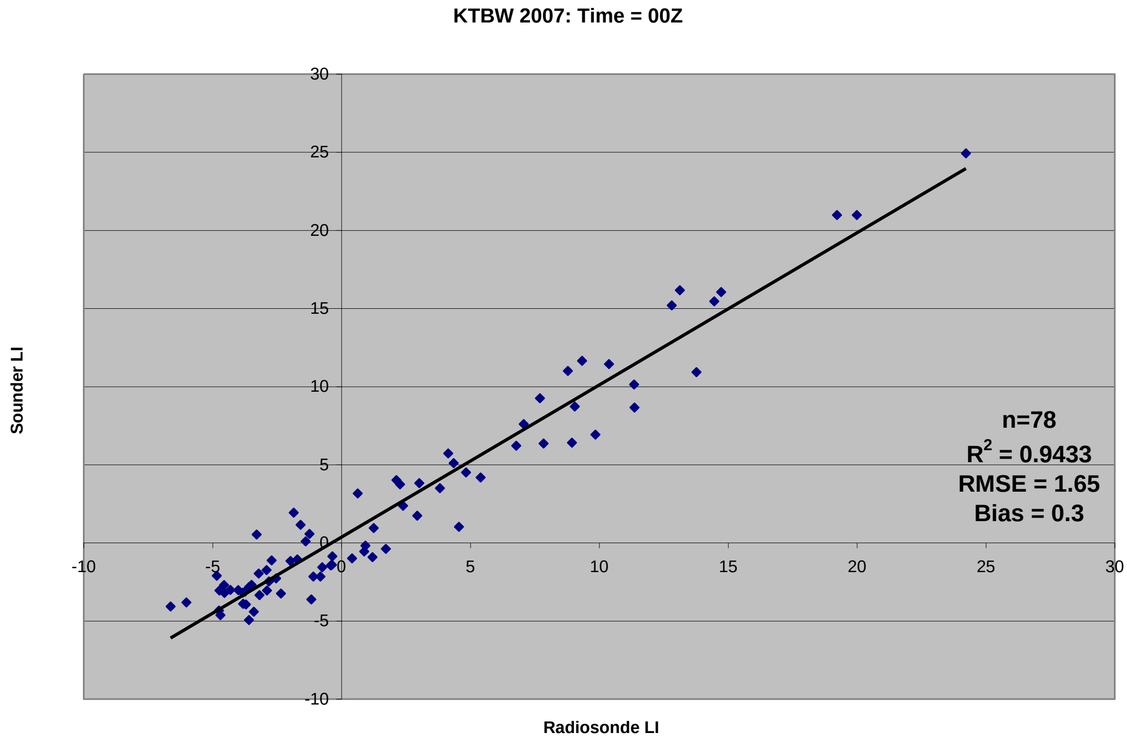


Fig 23: Scatter plot of 00Z data for Tampa Bay, FL with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n.

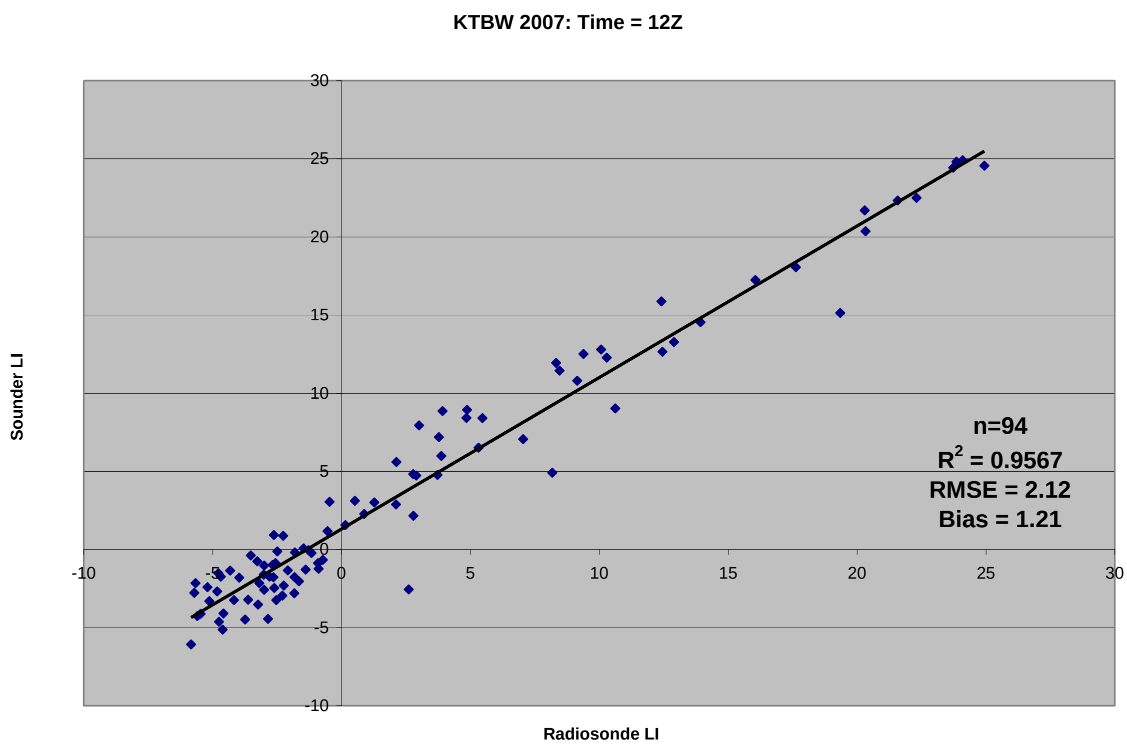


Fig 24: Same as Fig. 23, but for 12Z

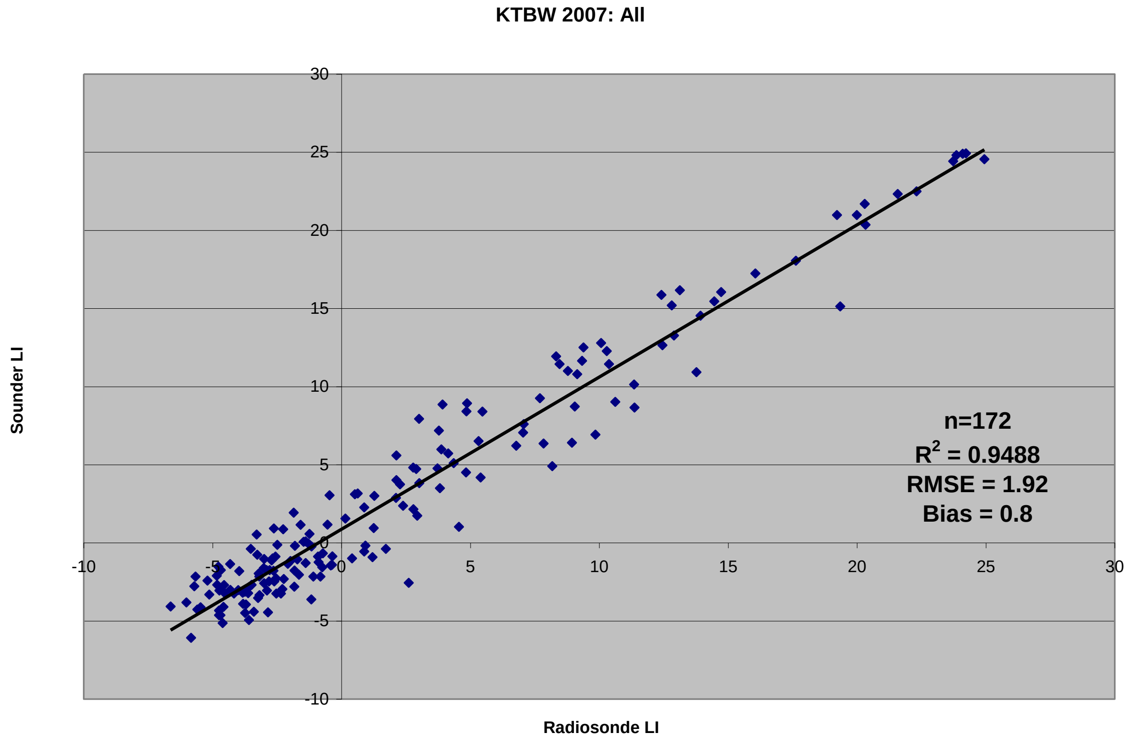


Fig 25: Scatter plot of all data for Tampa Bay, FL with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n

4) Miami, Florida

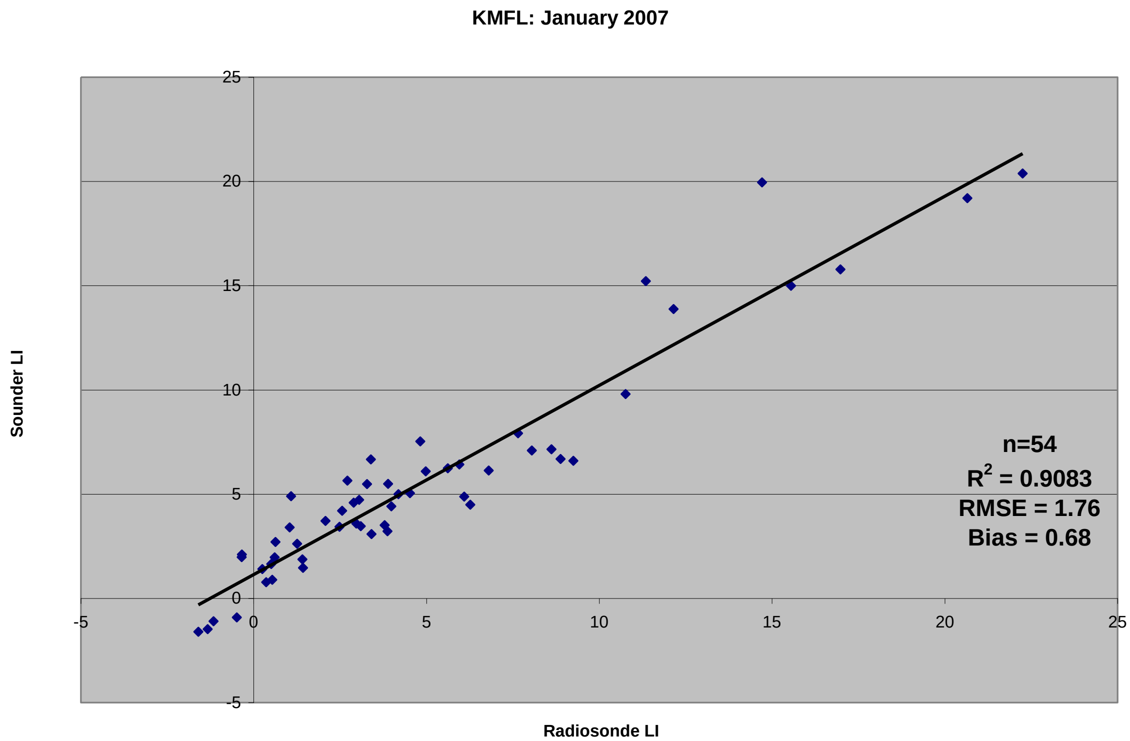


Fig 26: Scatter plot of January 2007 data for Miami, FL with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n.

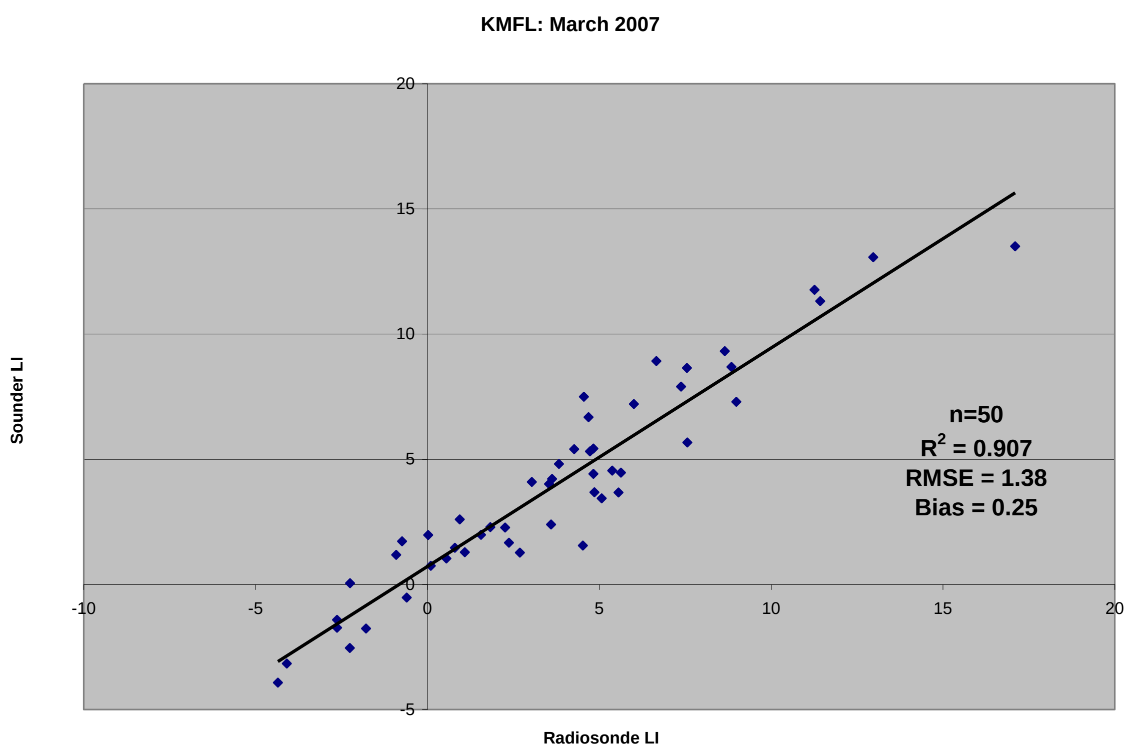


Fig 27: Same as Fig 26, but for March 2007

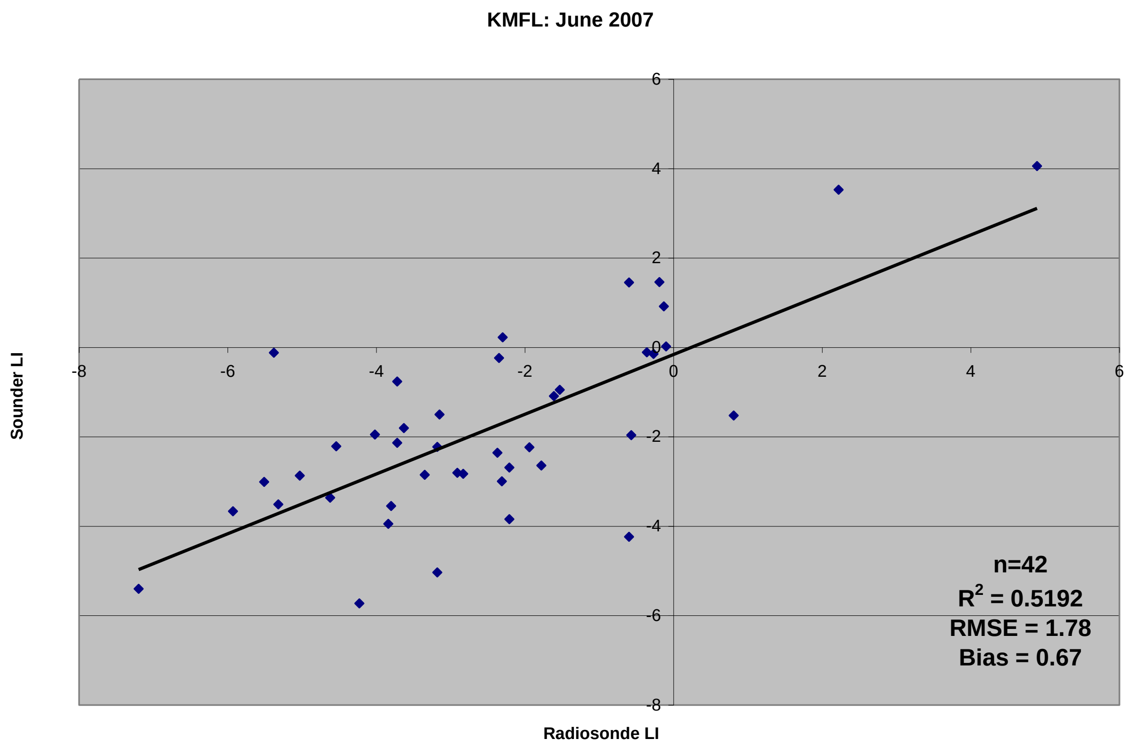


Fig 28: Same as Fig 26, but for June 2007

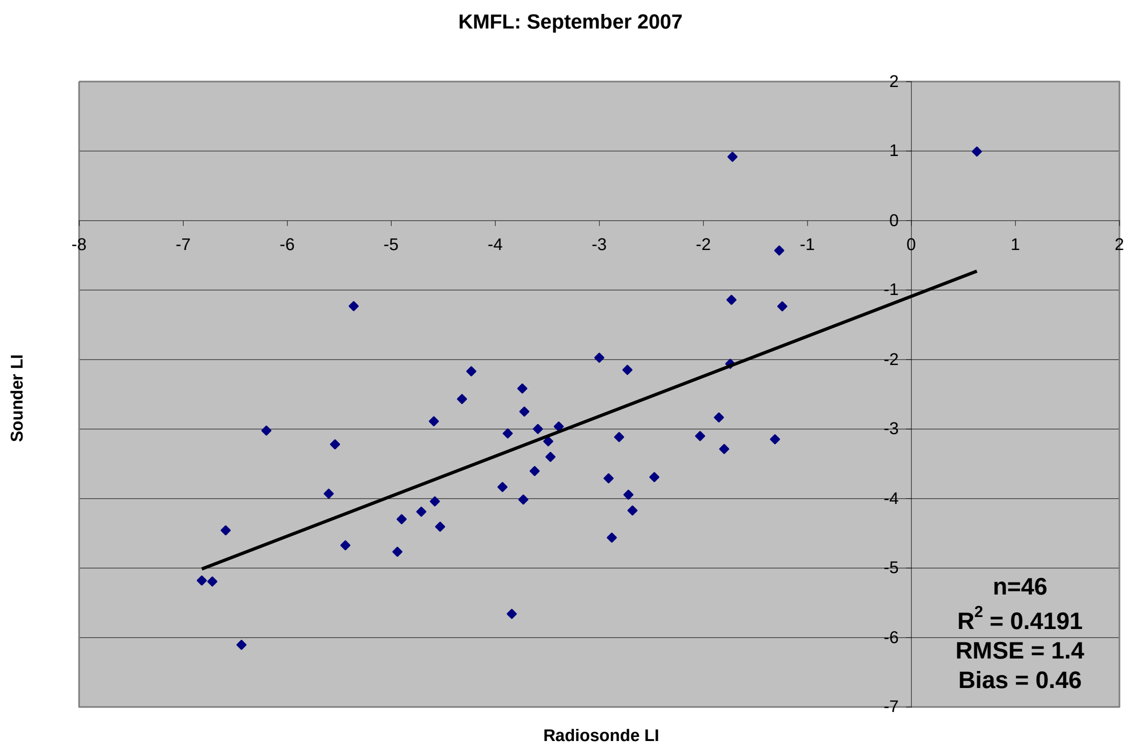


Fig 29: Same as Fig 26, but for Septembter 2007

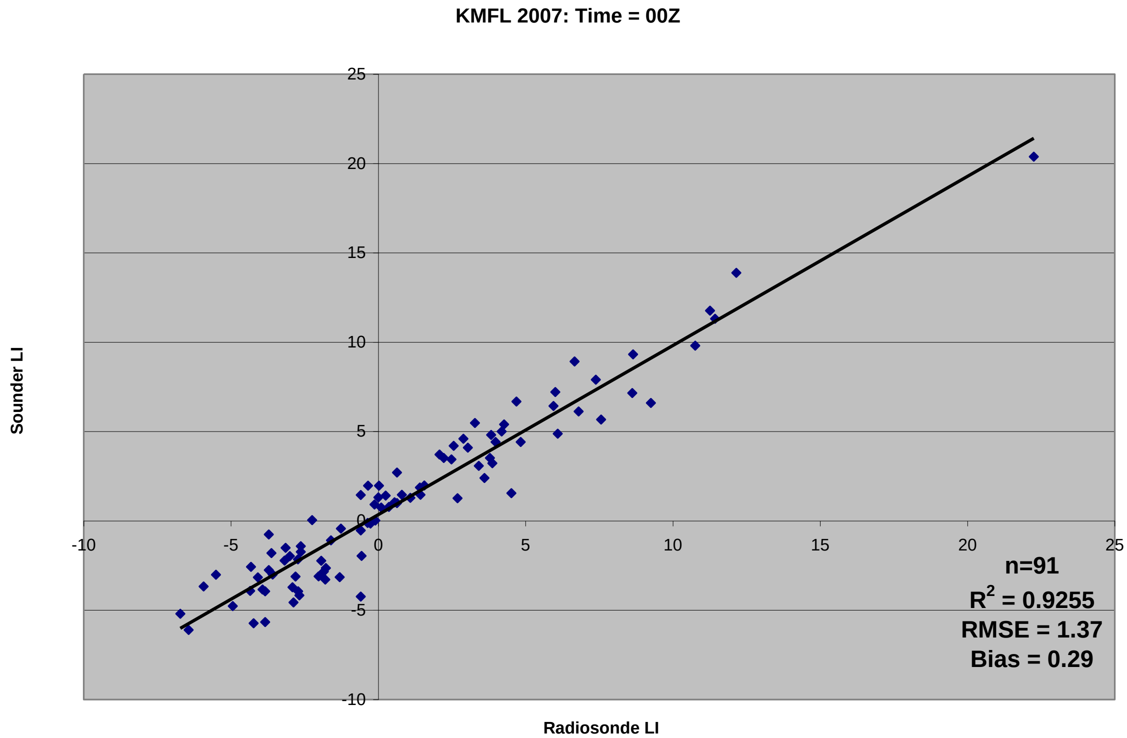


Fig 30: Scatter plot of 00Z data for Tampa Bay, FL with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n.

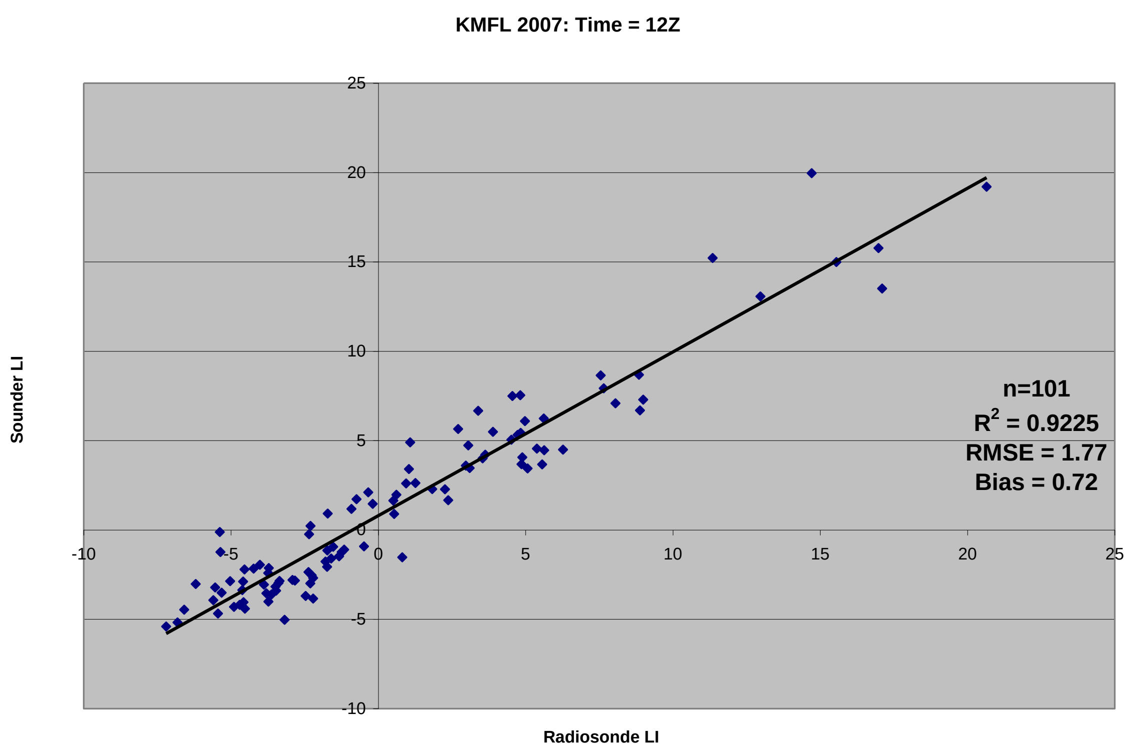


Fig 31: Same as Fig. 30, but for 12Z

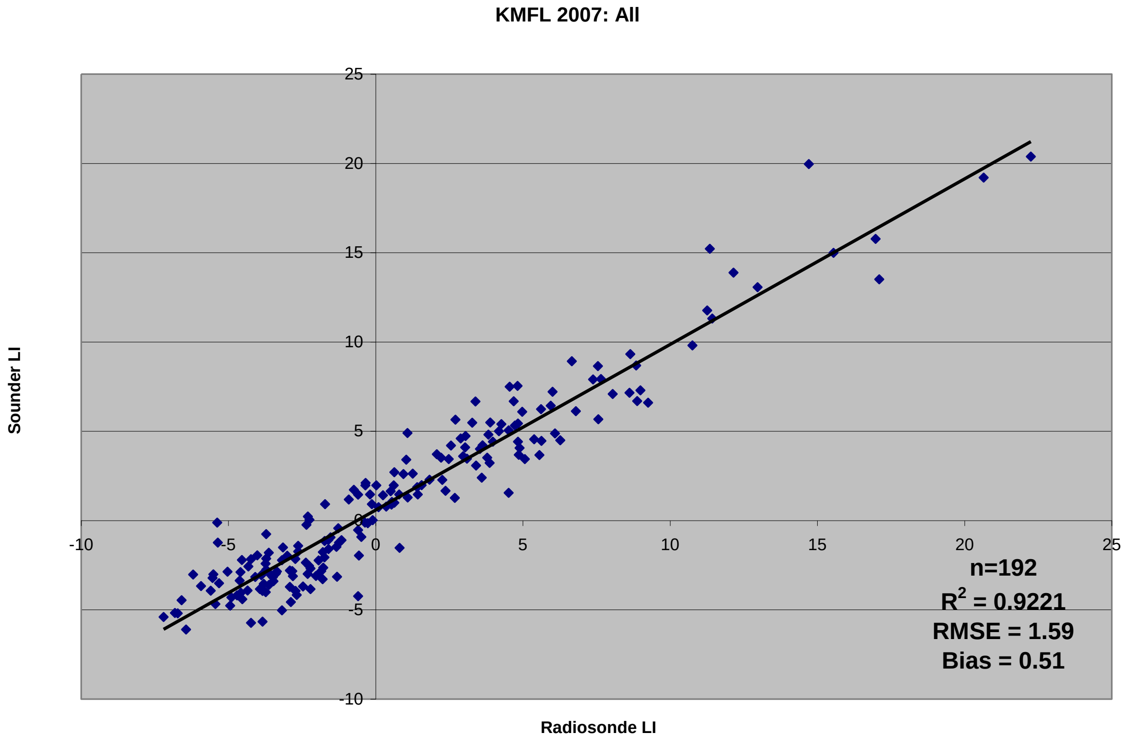


Fig 32: Scatter plot of all data for Miami, FL with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n

5) All Four Stations (KTLH, KJAX, KTBW, KMFL)

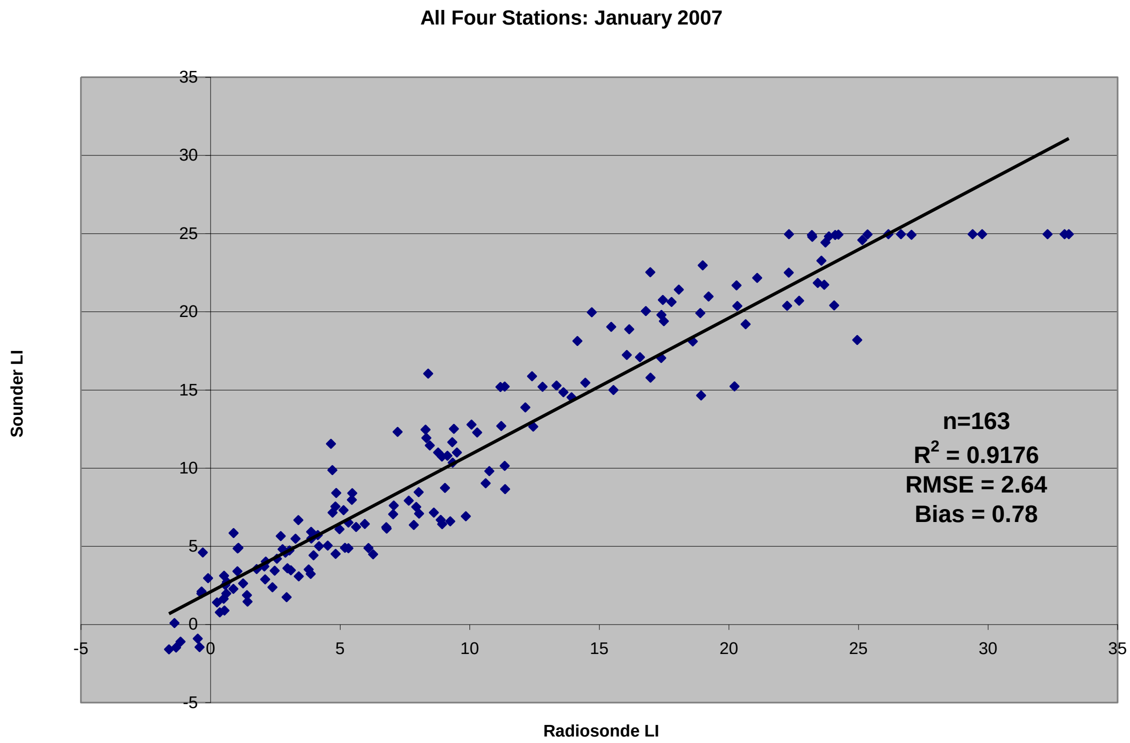


Fig 33: Scatter plot of January 2007 data for All Florida Stations with linear regression, R^2 value, bias, and Root Mean Square Error. Number of data points is given by n.

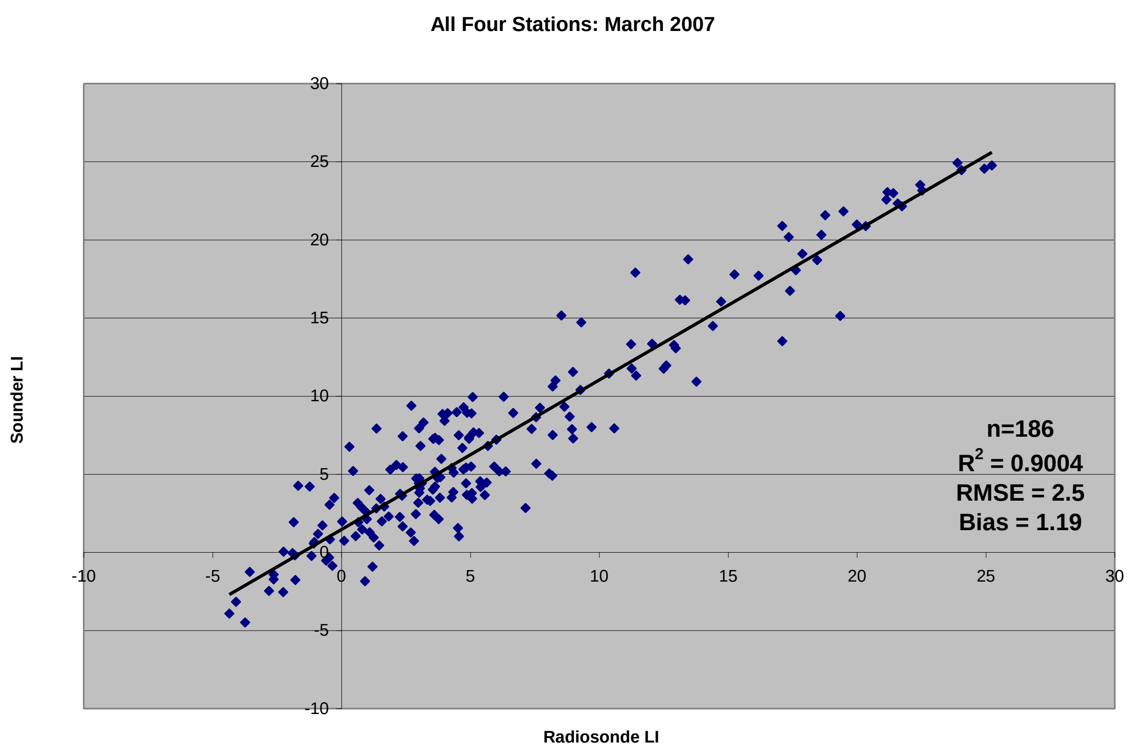


Fig 34: Same as Fig. 33, but for March 2007

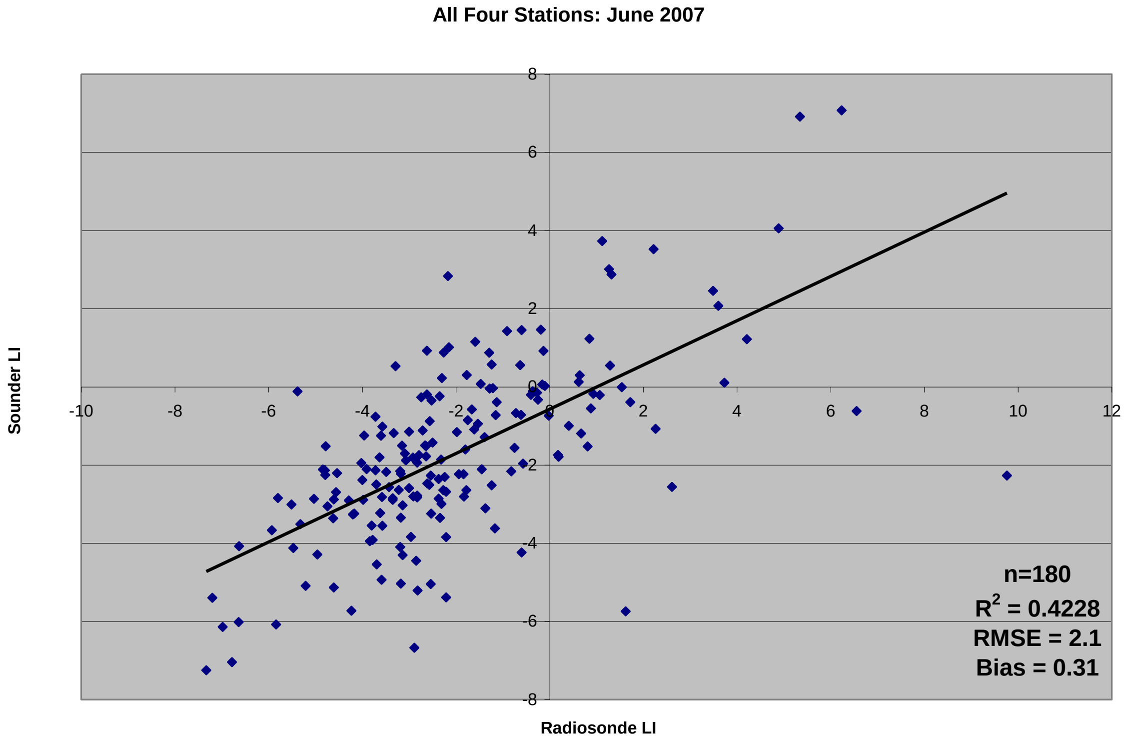


Fig 35: Same as Fig. 33, but for June 2007

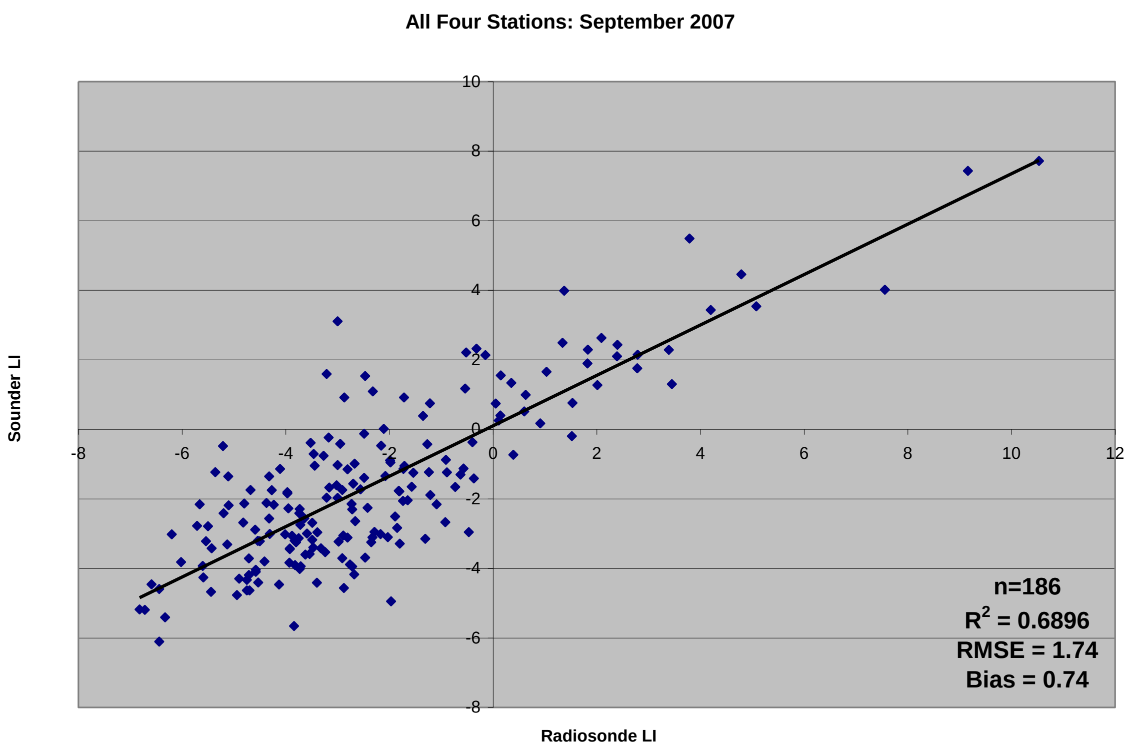


Fig 36: Same as Fig. 33, but for June 2007

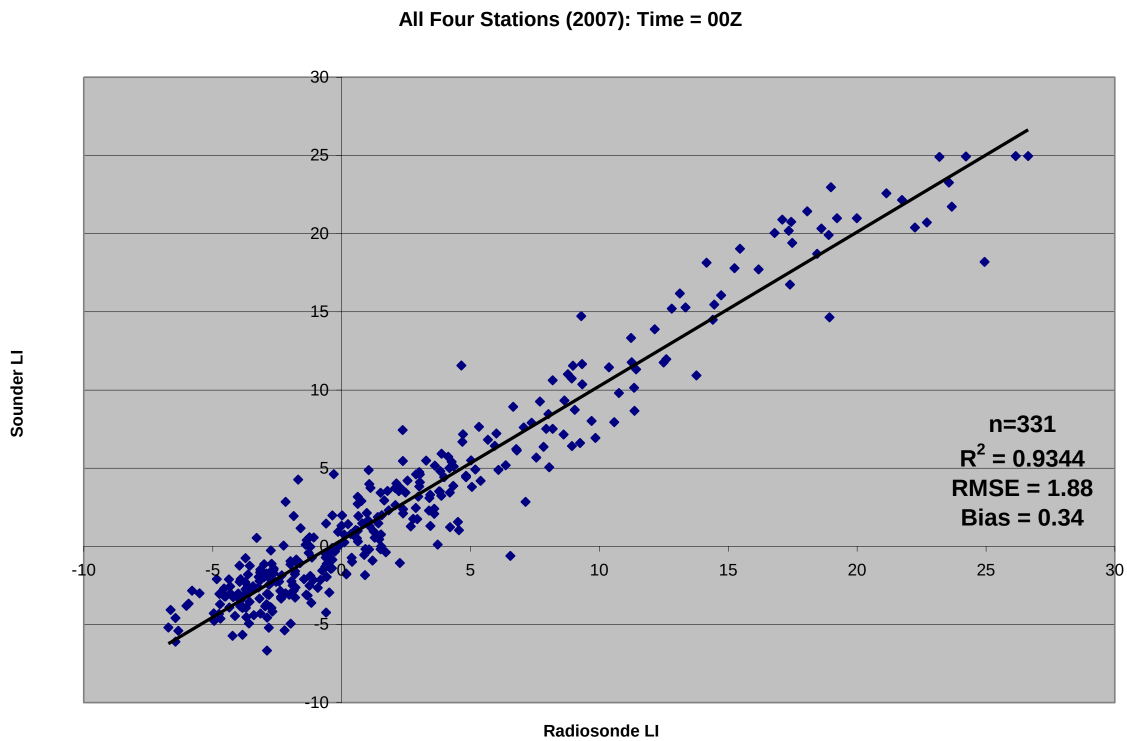


Fig 37: Scatter plot of 00Z data for All Florida Stations with linear regression, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n.

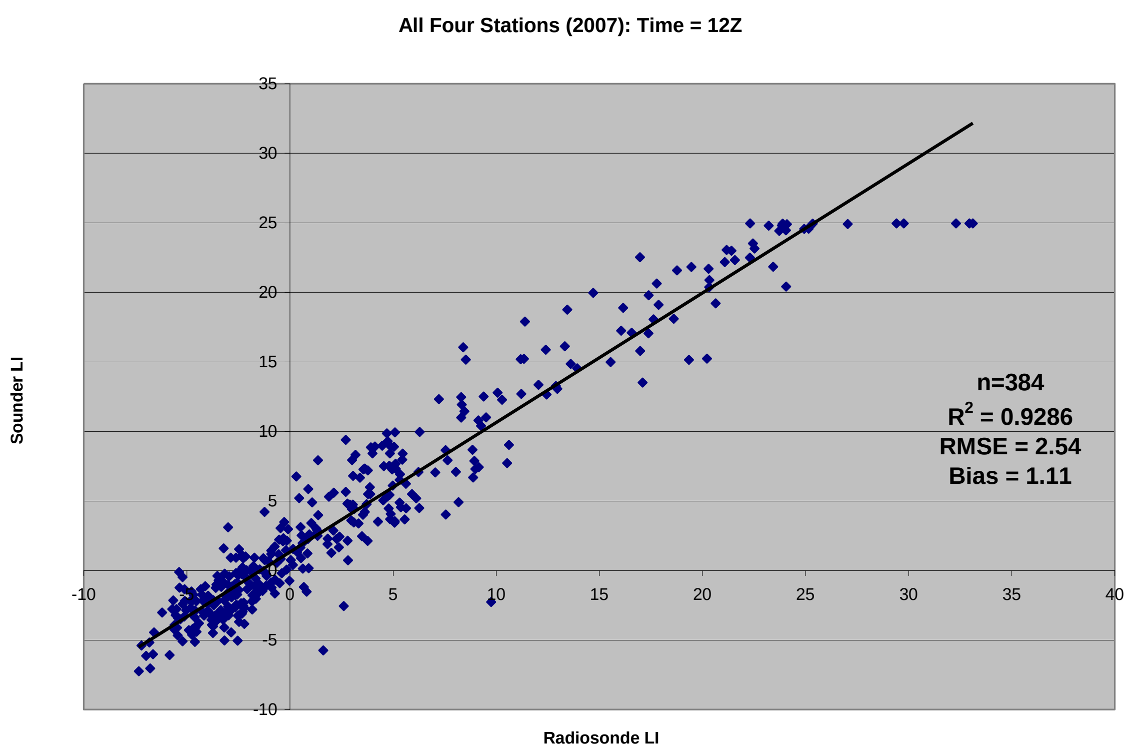


Fig 38: Same as Fig. 37, but for 12Z

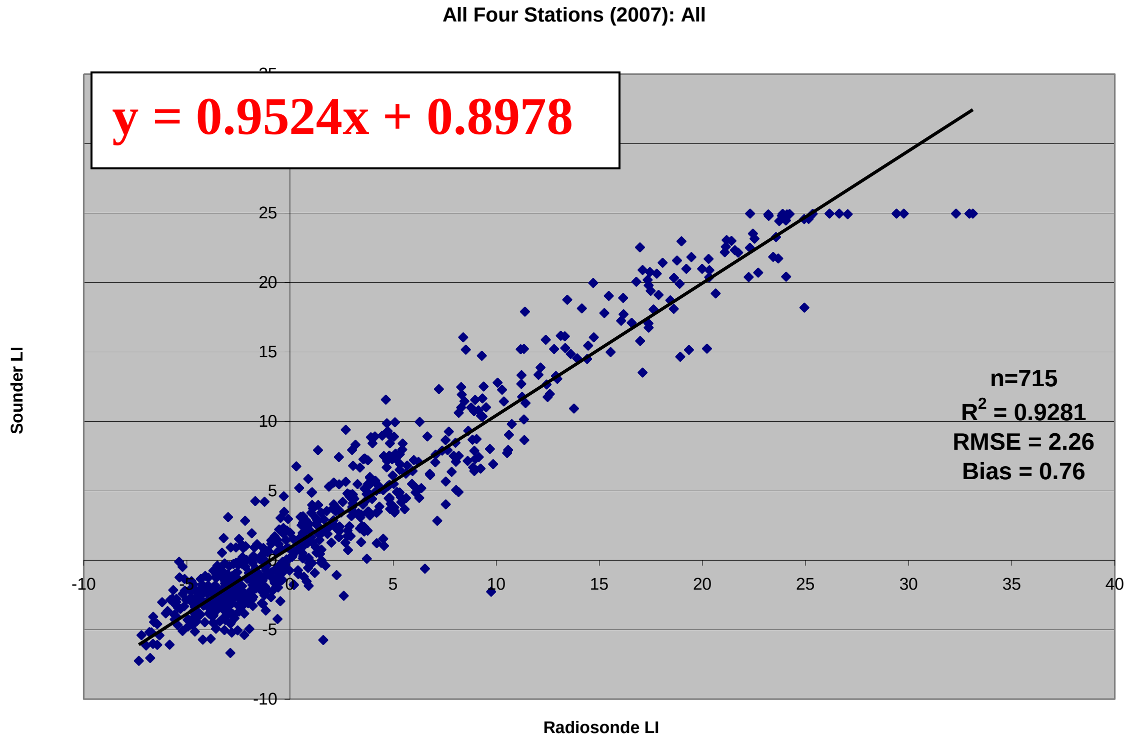


Fig 39: Scatter plot of all data for All Florida Stations with linear regression equation, R^2 value, average bias, and Root Mean Square Error. Number of data points is given by n