CARD International Journal of Science and Advanced Innovative Research (IJSAIR)
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 2, Number 1, March 2017
http://www.casirmediapublishing.com

ARIMA Intervention Modelling of Monthly GBP-NGN Exchange Rates

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ABSTRACT

A look at the trend of monthly British Pound (GBP) – Nigerian Naira (NGN) exchange rates since 2008 to 2016 reveals a fairly horizontal trend prior to 2015 and all-time high values currently. This necessitates some intervention. Going by the time-plot, the intervention point is pegged at February 2015 after which the rates are above 280 naira to a pound sterling. Even though economic recession in Nigeria was noticeable in mid 2016, it is being believed that its earlier signals were being ignored leading to its manifestation. It is therefore being assumed that this relative depreciation of the naira is accounted for by the recession. The pre-intervention data is modelled as an ARIMA (18, 1, 18) process, on the basis of which post-intervention forecasts are obtained. The difference between the post-intervention forecasts and the actual post-intervention observations is modelled for the transfer function. There is a close agreement between the intervention forecasts and the observations in the period of study (2008 – 2016). The model may therefore be used as basis for intervention in the exchange rates.

Keywords: Naira, Pound, Exchange Rates, Intervention analysis, ARIMA modelling

INTRODUCTION

Apart from the usual bilateral trade relations between any two countries, relationship between Britain and Nigeria is particularly of interest because the former was the colonialist of the latter. Study of the relative movements of their currencies, the British Pound (GBP) and the Nigerian Naira (NGN), has engaged the attention of scholars. For instance, Etuk and Igbudu (2013) have proposed and fitted a SARIMA (0, 1, 0) x $(2, 1, 1)_{12}$ model to their monthly exchange rates. A comparative analysis of the exchange rates of the NGN against the US Dollars (USD), the GBP and the European Euro (EUR) has been done by a simulation approach by Oyelami and

Edooghogho (2013). They observed, *inter alia,* some similarity between the NGN/GBP and the NGN/EUR exchange rates. Etuk (2014) fitted a SARIMA (0, 1, 1) x $(0, 1, 1)_7$ to daily NGN-GBP exchange rates, to mention a few.

A look at the monthly GBP-NGN exchange rates reveals that currently there is a rise in the rates to an all-time high value in further favour of the pound sterling. This calls for intervention on the part of the Nigerian Government. Intervention analysis is a statistical tool for examining the nature and extent of the change of the trend of a time series as a result of a perturbation of the series by virtue of the occurrence of an event.

Box and Tiao (1975) pioneered the discussion and application of autoregressive integrated moving average (ARIMA) model-based intervention analysis. Since then quite a number of authors have engaged themselves with intervention modelling of time series. For example, Prates *et al.* (2010) used intervention analysis to study the effect of hurricane on the abundance of snails in the Luquillo Mountains. Su and Deng (2014) studied the effect of the chief executive editor of the CCTV security information channel, Wenxin Niu's negative comment on the yield production of Yu Ebao, a series of internet financial products. Intervention analysis of the exchange rates of NGN and the USD has been done by Mosugu and Anieting (2016). Soric (2012) showed that the EUR induced bank customers' inflation perception errors. Min (2008) has shown that the 9-21 earthquakes in 1999 and the Severe Acute Respiratory Syndrome outbreak in 2003 temporarily affected Japanese demand to travel to Taiwan. Etuk and Amadi (2016) have proposed and fitted an ARIMA-based intervention model on exchange rates of the GBP and the USD occasioned by the exit of Britain from the European Union.

MATERIALS AND METHOD

Data

The data for this work are monthly amounts of NGN per GBP from 2004 to 2016 from the website of the Central Bank of Nigeria (CBN) www.cenbank.org . It is published under the **Monthly Averages of Exchange Rates** section of the **Statistics** heading.

Intervention Analysis

Consider a time series $\{X_t\}$. If the trend of the series changes on account of the occurrence of a phenomenon at time T, the phenomenon is called an intervention and the study of the effect on the series of such a phenomenon is referred to as intervention analysis.

Box and Tiao (1975) proposed that the pre-intervention series $\{X_t\}$, $t < T$, be modelled by an autoregressive integrated moving average (ARIMA) model. Suppose this be of order p, d and q. Then, for $t < T$,

$$Y_t = \alpha_1 \; Y_{t-1} + \; \alpha_2 Y_{t-2} + \cdots + \; \alpha_p Y_{t-p} + \; \beta_1 \varepsilon_{t-1} + \; \beta_2 \varepsilon_{t-2} + \cdots + \beta_q \varepsilon_{t-q} \quad (1)$$

where $Y_t = \nabla^p X_t$ is the d^{th} difference of X_t , $\{\varepsilon_t\}$ is a white noise process, the α's and β's constants such that the model is stationary as well as invertible and d is the least positive integer such that $\{Y_t\}$ is stationary. Series stationary status might be ascertained by the use of Augmented Dickey Fuller (ADF) test. The dimension p of the autoregressive (AR) component of model (1) might be determined as the cut-off point of the partial autocorrelation function (PACF) just as that of the moving average (MA) component q might be determined by the cut-off point of the autocorrelation function (ACF) in the correlogram of the series. If (1) is put as

$$(1 - \alpha_1 L - \; \alpha_2 L^2 - \cdots - \alpha_p L^p) Y_t = (1 + \beta_1 L + \; \beta_2 L^2 + \cdots + \beta_q L^q) \varepsilon_t \qquad (2)$$

where L is the backward shift operator such that $L^k X_t = X_{t-k}$ and $\nabla = 1 - L$. Clearly the model (1) may be put as

$$\Phi(L)(1 - L)^p X_t = \; \Theta(L) \varepsilon_t \qquad (3)$$

Or

$$X_t = \frac{\Theta(L)\varepsilon_t}{\Phi(L)(1-L)^p} \qquad (4)$$

where $\Phi(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \ldots - \alpha_p L^p$ and $\Theta(L) = 1 + \beta_1 L + \beta_2 L^2 + \ldots + \beta_q L^q$. On the basis of model (4) forecasts are obtained for the post-intervention period, i.e. for $t \geq T$. Let the difference between these forecast at t and the corresponding (post-intervention) observation, X_t, be Z_t.

Then for $t \geq T$

$$Z(t) = c(1)*(1-c(2)\string^(t-T+1))/(1-c(2)) \qquad (5)$$

Represents the intervention transfer function which may be estimated by the least squares procedure (The Pennsylvania State University, 2016) .

The intervention model is given by

$$X_t = \frac{\Theta(L)\varepsilon_t}{\Phi(L)(1-L)^p} + I_t Z(t) \qquad (6)$$

where $I_t = 1, t \geq T, zero\ otherwise.$

RESULTS AND DISCUSSION

The time plot of the monthly exchange rates in Figure 1 shows a generally horizontal trend below 280 until February 2015 after which there is astronomical rise beyond 280 and even reaching 400 in August and September 2016. This calls for intervention. The intervention point for this work is therefore taken to be March 2015.

The pre-intervention data is plotted in Figure 2 and the trend is fairly horizontal. However the Augmented Dickey Fuller (ADF) Test, with a test statistic value of -2.26 and with the 1%, 5% and 10% critical values of -3.48, -2.88 and -2.58 respectively and a p-value of 0.1870, is not significant meaning that the series is not stationary. This called for differencing.

First differences are plotted in Figure 3 and the trend is generally horizontal. Moreover the ADF Test with a test statistic value of -11.15 and a p-value of 0.0000 is significant showing that the first differences are stationary. That is d=0. The correlogram of Figure 4 has significant spikes at lag 18 on the ACF and the PACF. This suggests an ARIMA(18,1,18) which is estimated in Table 1 as

$$Y_t = 0.7775Y_{t-18} - 0.8685\varepsilon_{t-18} + \varepsilon_t \quad (7)$$

(± 0.0589) (± 0.0243)

Or

$$X_t = \frac{(1-0.8685L^{18})\varepsilon_t}{(1-L)(1-0.7775L^{18})} \quad (8)$$

where $\{X_t\}$ are the pre-intervention exchange rates. Adequacy of the model is not in doubt. Its residuals are uncorrelated (See Figure 5) and are normally distributed (See Figure 6).

On the basis of model (8) forecasts are obtained in the post-intervention period, that is, from March 2015 to December 2016. The difference Z between these forecasts and their corresponding post-intervention data is modelled (as in (5)) in Table 2 to obtain

Z(t) = 1.0492*(1-1.1292^(t-133))/(-0.129319) (9)

And the intervention model, by (8) and (9), is

$$W_t = X_t + I_t Z_t \quad (10)$$

Where $I_t = 1$ after March 2015 and zero before March 2015.

A close agreement is being observed between the actual observations and the intervention forecasts in Figure 7.

CONCLUSION

It may be concluded that model (10) is an adequate intervention model for monthly GBP-NGN exchange rates occasioned by the current economic recession in Nigeria. It may be used as a basis for intervening to salvage the situation on the part of the Nigerian nation.

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FIGURE 1: MONTHLY GBP-NGN EXCHANGE RATES

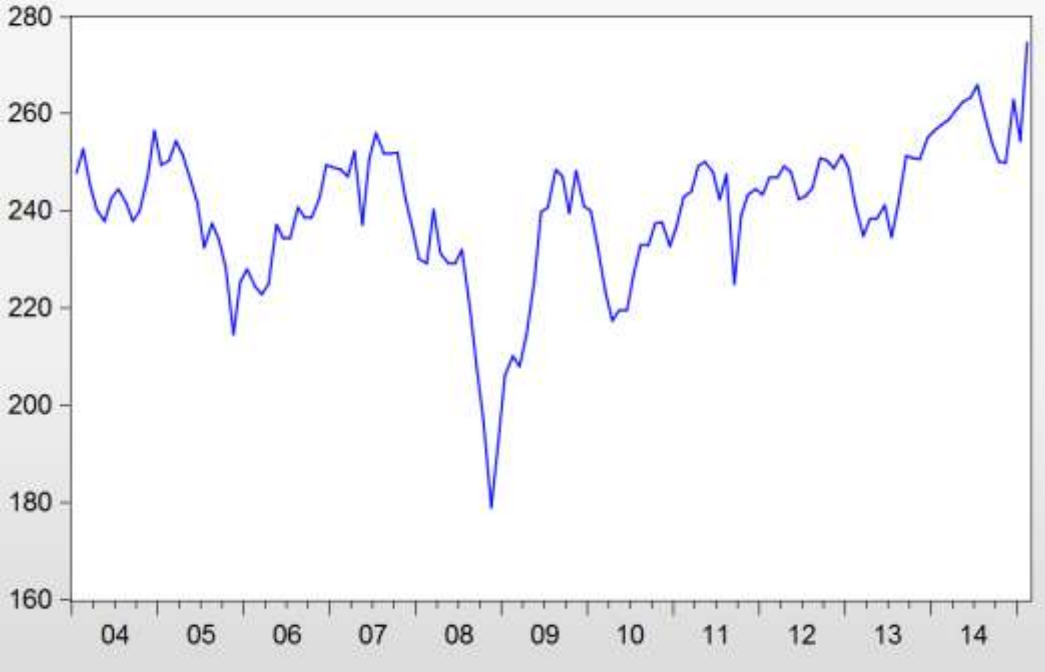

FIGURE 2: PRE-INTERVENTION SERIES

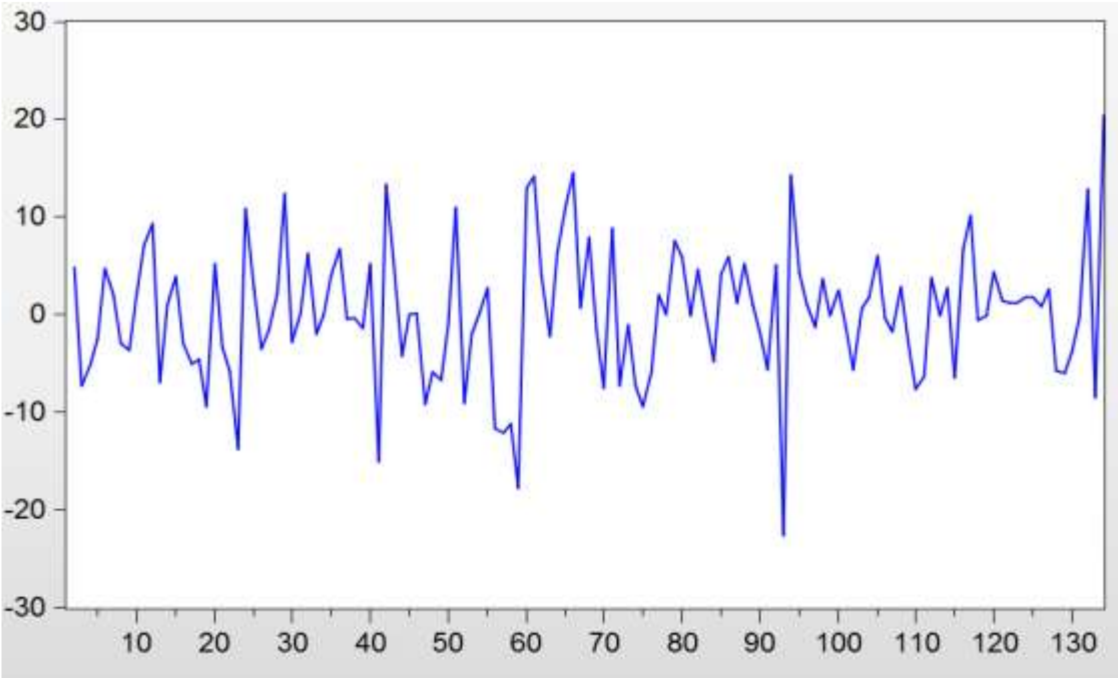

FIGURE 3: DIFFERENCE OF PRE-INTERVENTION SERIES

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.009	-0.009	0.0119	0.913
		2	0.018	0.018	0.0554	0.973
		3	-0.004	-0.004	0.0581	0.996
		4	0.027	0.027	0.1596	0.997
		5	-0.032	-0.032	0.3076	0.997
		6	-0.060	-0.061	0.8137	0.992
		7	-0.135	-0.136	3.4098	0.845
		8	-0.090	-0.095	4.5738	0.802
		9	-0.005	-0.004	4.5779	0.869
		10	-0.073	-0.072	5.3609	0.866
		11	-0.004	-0.005	5.3633	0.912
		12	-0.136	-0.148	8.1072	0.777
		13	-0.056	-0.093	8.5702	0.805
		14	-0.020	-0.058	8.6328	0.854
		15	0.033	-0.008	8.7977	0.888
		16	-0.057	-0.080	9.2891	0.901
		17	0.045	0.004	9.6071	0.919
		18	0.278	0.256	21.683	0.246
		19	-0.021	-0.063	21.754	0.297
		20	-0.019	-0.084	21.811	0.351
		21	-0.102	-0.146	23.464	0.320
		22	0.070	0.028	24.253	0.334
		23	-0.060	-0.065	24.833	0.359
		24	-0.102	-0.128	26.551	0.326
		25	-0.035	0.016	26.751	0.368
		26	0.126	0.150	29.432	0.292
		27	-0.069	-0.099	30.241	0.303
		28	0.010	-0.047	30.259	0.351
		29	0.014	-0.013	30.293	0.400
		30	-0.056	-0.014	30.844	0.423
		31	0.066	0.051	31.613	0.436
		32	-0.059	-0.091	32.228	0.455
		33	-0.047	-0.096	32.620	0.486
		34	0.127	0.193	35.540	0.396
		35	0.054	0.016	36.066	0.419
		36	0.115	0.000	38.532	0.356

FIGURE 4: Correlogram of differences of the pre-intervention data

Table 1: Estimation of the pre-intervention ARIMA(18,1,18) Model

Dependent Variable: DANNGP
Method: Least Squares
Date: 01/25/17 Time: 11:40
Sample (adjusted): 20 134
Included observations: 115 after adjustments
Convergence achieved after 11 iterations
MA Backcast: 2 19

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR(18)	0.777490	0.058879	13.20485	0.0000
MA(18)	-0.868547	0.024348	-35.67273	0.0000

R-squared	0.278955	Mean dependent var	0.368783
Adjusted R-squared	0.272574	S.D. dependent var	7.047412
S.E. of regression	6.010685	Akaike info criterion	6.442193
Sum squared resid	4082.502	Schwarz criterion	6.489931
Log likelihood	-368.4261	Hannan-Quinn criter.	6.461569
Durbin-Watson stat	1.981495		

Inverted AR Roots	.99	.93+.34i	.93-.34i	.76+.63i
	.76-.63i	.49-.85i	.49+.85i	.17-.97i
	.17+.97i	-.17-.97i	-.17+.97i	-.49-.85i
	-.49+.85i	-.76+.63i	-.76-.63i	-.93-.34i
	-.93+.34i	-.99		
Inverted MA Roots	.99	.93+.34i	.93-.34i	.76-.64i
	.76+.64i	.50+.86i	.50-.86i	.17-.98i
	.17+.98i	-.17+.98i	-.17-.98i	-.50+.86i
	-.50-.86i	-.76+.64i	-.76-.64i	-.93+.34i
	-.93-.34i	-.99		

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.041	-0.041	0.2025	
		2	-0.028	-0.029	0.2929	
		3	0.084	0.082	1.1444	0.285
		4	0.020	0.026	1.1936	0.551
		5	-0.067	-0.061	1.7446	0.627
		6	0.013	0.002	1.7656	0.779
		7	-0.113	-0.121	3.3647	0.644
		8	-0.092	-0.094	4.4318	0.618
		9	0.022	0.010	4.4919	0.722
		10	-0.083	-0.074	5.3719	0.717
		11	0.071	0.090	6.0231	0.738
		12	-0.077	-0.090	6.7967	0.744
		13	-0.097	-0.104	8.0327	0.710
		14	-0.028	-0.064	8.1380	0.774
		15	0.114	0.084	9.8940	0.703
		16	-0.141	-0.116	12.581	0.560
		17	0.013	-0.006	12.603	0.633
		18	0.085	0.059	13.598	0.629
		19	-0.044	-0.038	13.866	0.677
		20	-0.097	-0.138	15.207	0.648
		21	0.002	-0.056	15.207	0.709
		22	0.100	0.105	16.660	0.675
		23	-0.024	-0.001	16.741	0.727
		24	-0.058	-0.092	17.243	0.750
		25	-0.011	-0.025	17.262	0.796
		26	0.198	0.169	23.174	0.510
		27	-0.068	-0.054	23.882	0.526
		28	0.060	0.033	24.432	0.551
		29	0.048	0.020	24.792	0.586
		30	-0.012	0.006	24.813	0.638
		31	0.061	0.104	25.405	0.657
		32	-0.024	-0.090	25.500	0.700
		33	-0.035	-0.046	25.704	0.735
		34	0.065	0.133	26.399	0.746
		35	-0.050	-0.014	26.815	0.768
		36	-0.135	-0.157	29.915	0.668

Figure 5: Correlogram of the Pre-Intervention ARIMA(18,1,18) Residuals

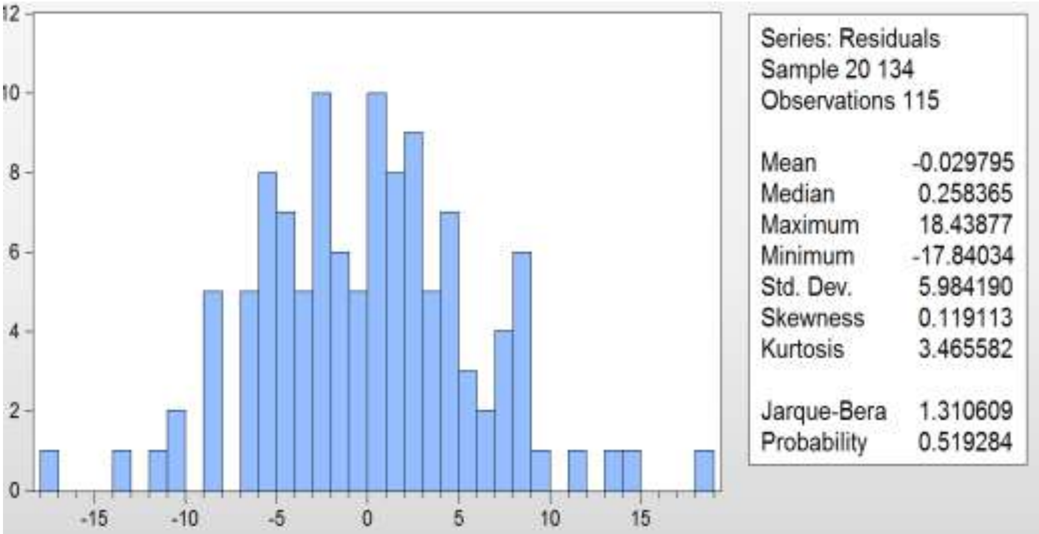

Figure 6: Histogram of the Pre-intervention ARIMA (18, 1, 18) Residuals

Table 2: Intervention Model Estimation

Dependent Variable: Z
Method: Least Squares
Date: 01/25/17 Time: 13:51
Sample: 135 156
Included observations: 22
Convergence achieved after 14 iterations
Z=C(1)*(1-C(2)^(T-133))/(1-C(2))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	1.049159	0.590099	1.777937	0.0906
C(2)	1.129319	0.047007	24.02466	0.0000

R-squared	0.602061	Mean dependent var	44.08727
Adjusted R-squared	0.582164	S.D. dependent var	42.38641
S.E. of regression	27.39868	Akaike info criterion	9.545375
Sum squared resid	15013.75	Schwarz criterion	9.644560
Log likelihood	-102.9991	Hannan-Quinn criter.	9.568740
Durbin-Watson stat	0.422756		

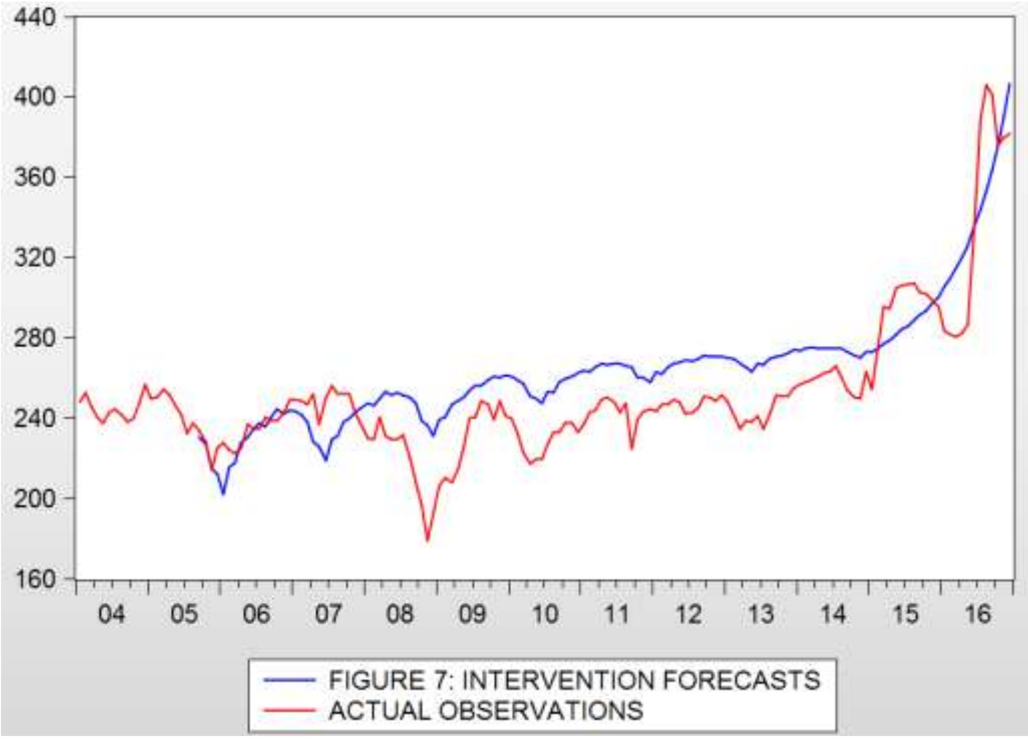
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FIGURE 7: INTERVENTION FORECASTS
ACTUAL OBSERVATIONS