A new approach for multi-category forecast verification method

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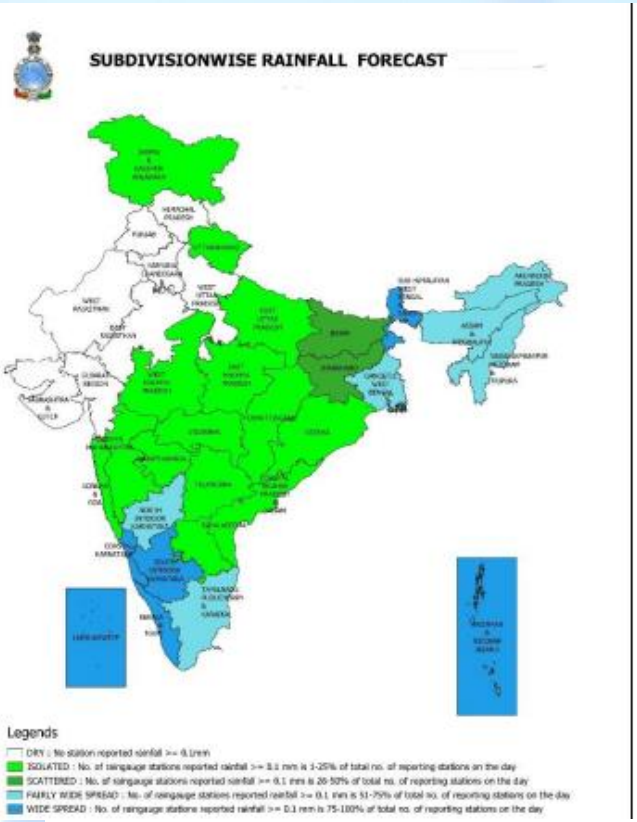
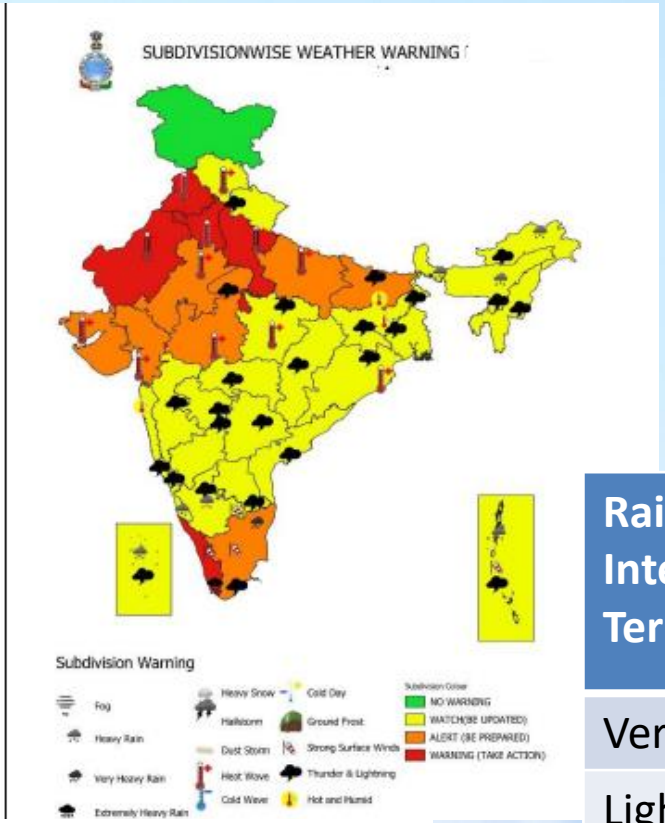
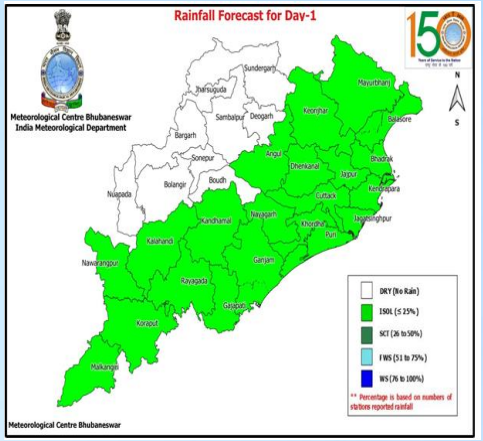
Background

- Forecast verification is an important process to assess its quality and it is also essential to monitor accuracy, understanding of error factors and consequent improvement in forecasting system.
- The outcomes of forecast verification also justify the reliability and greater accountability to users in respect of weather disaster action point of view.
- There are different methods of forecast verification in practice followed by national hydro-meteorological agencies.
- Selection of forecast verification method has become extremely challenging in view of different kind of forecast applications and availability of different source of observational data in different forms & scale.

Different kind of categorical forecast/warning for users



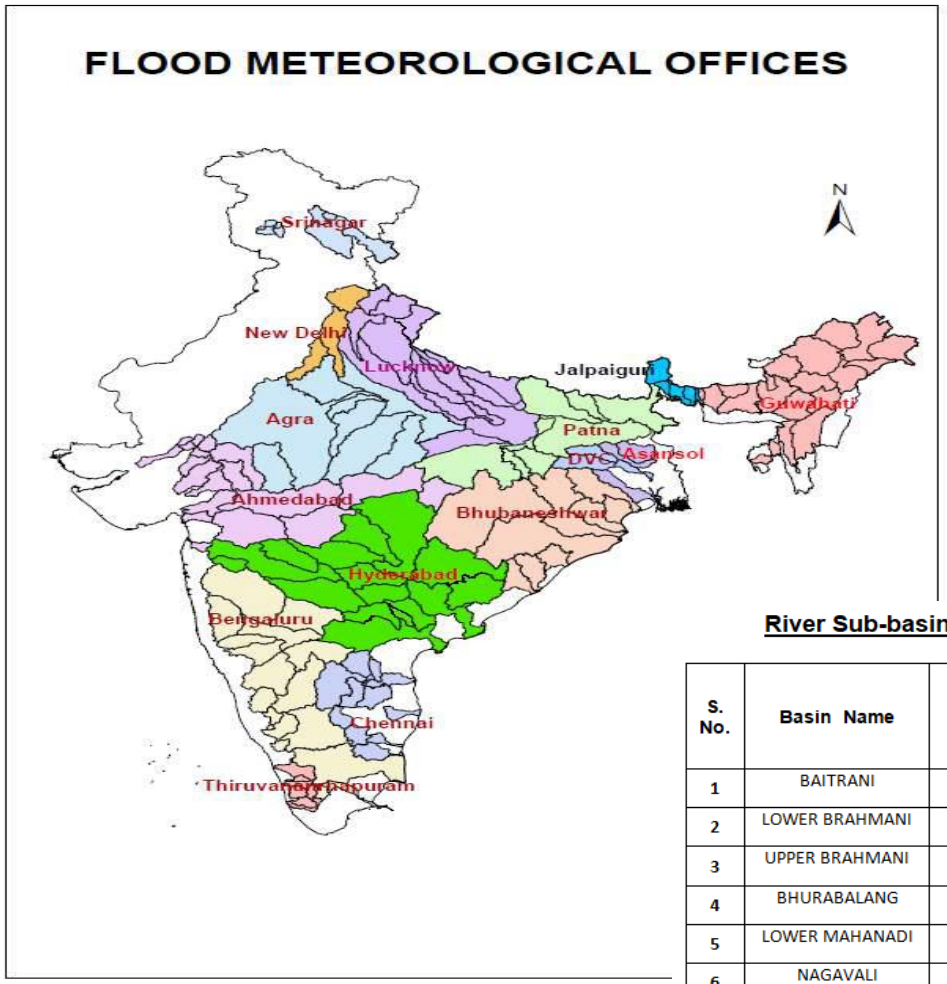




Legend	Category	% Stations
WS	Widespread/Most Places	76-100
FWS	Fairly Widespread/Many Places	51-75
SCT	Scattered/ A Few Places	26-50
ISOL	Isolated Places	1-25
DRY	No Rain	0

Rainfall Intensity Terminology	Rainfall amount (mm)
Very Light	Trace to 2.4
Light	2.5 -15.5
Moderate	15.6 to 64.4
Heavy	64.5 -115.5
Very Heavy	115.6 – 204.4
Extremely Heavy	>= 204.5

QPF forecast for flood monitoring



Quantitative precipitation forecast for river catchments in different ranges 0(No rain), 0.1 - 10 mm , 11-25mm, 26-37 mm, 38-50mm , 51-75mm, 76-100 mm& more than 100 mm used in India for easy understanding and analysis for possible rise of water levels in different river.

River Sub-basin-wise Quantitative Precipitation Forecast (QPF)

S. No.	Basin Name	Sub-basin Name	QPF (mm)						
			Day-1 (01.08.23)	Day-2 (02.08.23)	Day-3 (03.08.23)	Day-4 (04.08.23)	Day-5 (05.08.23)	Day-6 (06.08.23)	Day-7 (07.08.23)
1	BAITRANI	BT	76-100	26-37	11-25	0.1-10	0.1-10	0.1-10	0.1-10
2	LOWER BRAHMANI	LB	51-75	38-50	11-25	0.1-10	0.1-10	0.1-10	0.1-10
3	UPPER BRAHMANI	UB	51-75	51-75	26-37	0.1-10	0.1-10	0.1-10	0.1-10
4	BHURABALANG	BB	51-75	11-25	0.1-10	0.1-10	0.1-10	0.1-10	0.1-10
5	LOWER MAHANADI	LM	38-50	38-50	11-25	0.1-10	0.1-10	0.1-10	0.1-10
6	NAGAVALI	NV	11-25	11-25	0.1-10	0.1-10	0.1-10	0.1-10	0.1-10
7	RUSHIKULIYA	RK	11-25	11-25	0.1-10	0.1-10	0.1-10	0.1-10	0.1-10
8	SUBERNAREKHA	SR	76-100	26-37	11-25	0.1-10	0.1-10	0.1-10	0.1-10
9	UPPER MAHANADI	UM	11-25	38-50	11-25	0.1-10	0.1-10	0.1-10	0.1-10
10	VAMSDHARA	VD	11-25	11-25	0.1-10	0.1-10	0.1-10	0.1-10	0.1-10

FMO: 15 locations
Total No. of Sub basins: 153

Contingency Table for verification of Spatial Rainfall Forecast

Observed Range	Forecast Range					
	Dry	Isolated	Scattered	Fairly Widespread	Widespread	Total
Dry	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_1
Isolated	F_{21}	F_{22}	F_{23}	F_{24}	F_{25}	F_2
Scattered	F_{31}	F_{32}	F_{33}	F_{34}	F_{35}	F_3
Fairly Widespread	F_{41}	F_{42}	F_{43}	F_{44}	F_{45}	F_4
Widespread	F_{51}	F_{52}	F_{53}	F_{54}	F_{55}	F_5
Total	A_1	A_2	A_3	A_4	A_5	T

$PC= \sum F_{II}/T*100$

$CSI = (F_{11}/(F_1+A_1-F_{11}), F_{22}/(F_2+A_2-F_{22}), F_{33}/(F_3+A_3-F_{33}), F_{44}/(F_4+A_4-F_{44}), F_{55}/(F_5+A_5-F_{55}))$

$HSS=(\sum F_{ii} - \sum F_i A_I/T)/(T- \sum F_i A_I/T)$

The POD, FAR, MR,PC, HSS etc for each category can be computed by reducing the contingency table into 2x2 contingency table for Yes/No Forecast

Contingency Table for verification of Rainfall intensity Forecast

Observed Range	Forecast Range						
	Dry	Light	Moderate	Heavy	Very Heavy	Extremely Heavy	Total
Dry	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_1
Light	F_{21}	F_{22}	F_{23}	F_{24}	F_{25}	F_{26}	F_2
Moderate	F_{31}	F_{32}	F_{33}	F_{34}	F_{35}	F_{36}	F_3
Heavy	F_{41}	F_{42}	F_{43}	F_{44}	F_{45}	F_{46}	F_4
Very Heavy	F_{51}	F_{52}	F_{53}	F_{54}	F_{55}	F_{56}	F_5
Extremely Heavy	F_{61}	F_{62}	F_{63}	F_{64}	F_{65}	F_{66}	F_6
Total	A_1	A_2	A_3	A_4	A_5	A_6	T

$PC = \sum F_{II}/T*100$

$CSI = (F_{11}/(F_1+A_1-F_{11}), F_{22}/(F_2+A_2-F_{22}), F_{33}/(F_3+A_3-F_{33}), F_{44}/(F_4+A_4-F_{44}), F_{55}/(F_5+A_5-F_{55}))$

$HSS=(\sum F_{ii} - \sum F_i A_I/T)/(T- \sum F_i A_I/T)$

The POD, FAR, MR,PC, HSS etc for each category can be computed by reducing the contingency table into 2x2 contingency table for Yes/No Forecast

Contingency Table for verification of QPF

Observed Range(mm)	Forecast Range (mm)								
	0	0.1 -10	11-25	26-37	38-50	51-75	76-100	>100	Total
0	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_1
0.1-10	F_{21}	F_{22}	F_{23}	F_{24}	F_{25}	F_{26}	F_{27}	F_{28}	F_2
11-25	F_{31}	F_{32}	F_{33}	F_{34}	F_{35}	F_{36}	F_{37}	F_{38}	F_3
26-37	F_{41}	F_{42}	F_{43}	F_{44}	F_{45}	F_{46}	F_{47}	F_{48}	F_4
38-50	F_{51}	F_{52}	F_{53}	F_{54}	F_{55}	F_{56}	F_{57}	F_{58}	F_5
51-75	F_{61}	F_{62}	F_{63}	F_{64}	F_{65}	F_{66}	F_{67}	F_{68}	F_6
76-100	F_{71}	F_{72}	F_{73}	F_{74}	F_{75}	F_{76}	F_{77}	F_{78}	F_7
>100	F_{81}	F_{82}	F_{83}	F_{84}	F_{85}	F_{86}	F_{87}	F_{88}	F_8
Total	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	T

$$PC = \sum F_{ii}/T*100$$

$$CSI = (F_{11}/(F_1+A_1-F_{11}),\ F_{22}/(F_2+A_2-F_{22}),\ F_{33}/(F_3+A_3-F_{33}),\ F_{44}/(F_4+A_4-F_{44}),\ F_{55}/(F_5+A_5-F_{55}),\ F_{66}/(F_6+A_6-F_{66}),\ F_{77}/(F_7+A_7-F_{77}),\ F_{88}/(F_8+A_8-F_{88}))$$

$$HSS = (\sum F_{ii} - \sum F_i A_i/T)/(T - \sum F_i A_i/T)$$

The POD, FAR, MR,PC, HSS etc for each category can be computed by reducing the contingency table into 2x2 contingency table for Yes/No Forecast

Users/ Disaster managers perspectives:

Users prefers to the prediction which captures the high impact weather events more accurately besides normal weather phenomena.

Frequency of abnormal /high impact rainfall or any other weather parameter is very less than the normal values.

Sometimes forecast verification overall results shows high skill scores though the forecast missed the high impact rare weather events.

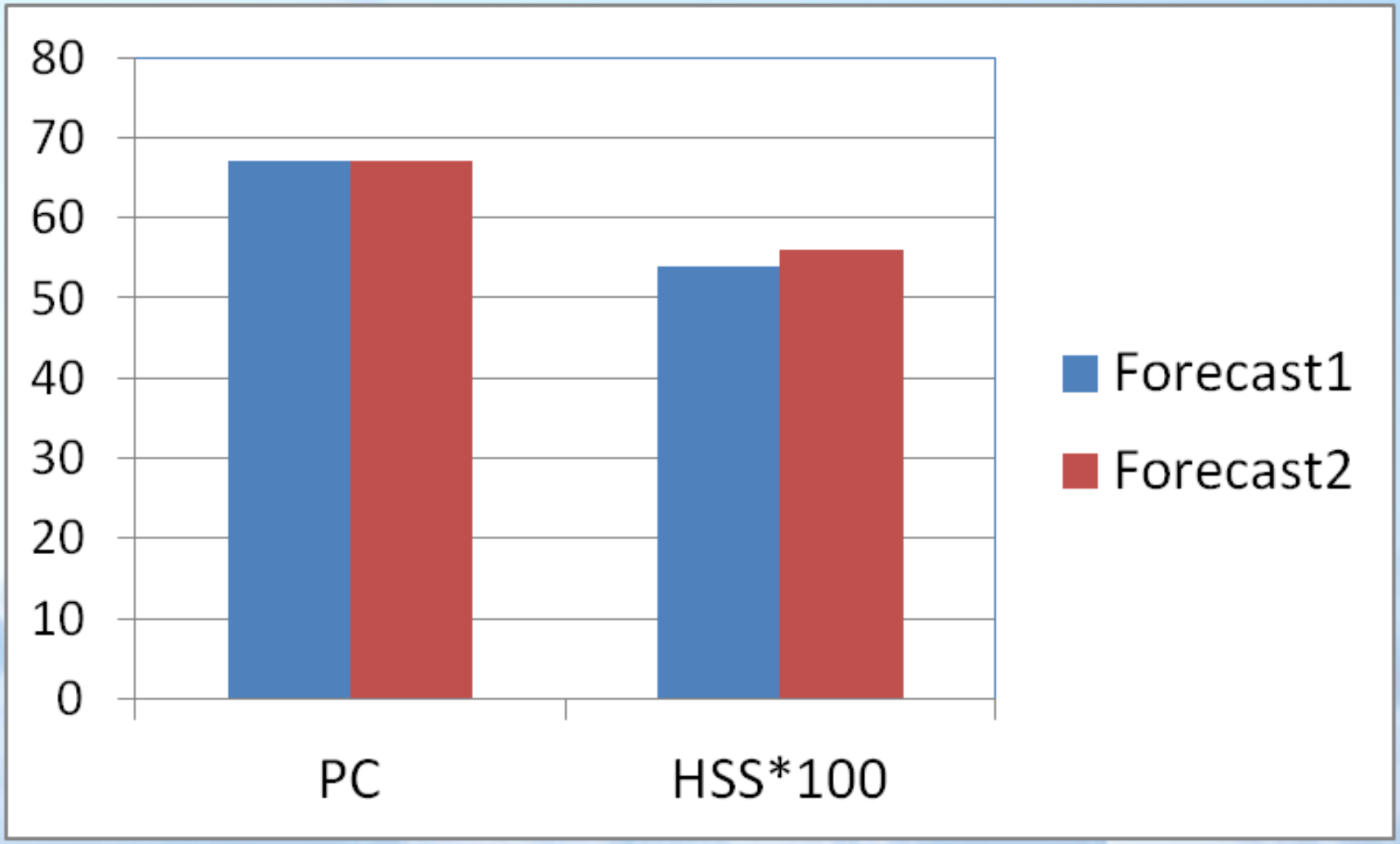
Forecast 1: Poor Skill for less frequency high impact weather

Observed Range(mm)	Forecast Range (mm)								
	0	0.1 - 10	11-25	26-37	38-50	51-75	76-100	>100	Total
0	3	2	0	0	0	0	0	0	5
0.1-10	1	24	4	1	0	0	0	0	30
11-25	0	5	32	3	0	0	0	0	40
26-37	0	0	4	4	1	0	0	0	9
38-50	0	0	1	2	2	1	0	0	6
51-75	0	0	0	1	2	1	0	0	4
76-100	0	0	0	1	1	1	1	0	4
>100	0	0	0	0	1	1	0	0	2
Total	4	31	41	12	7	4	1	0	100

Forecast 2: Better prediction for less frequency high impact weather

Observed Range(mm)	Forecast Range (mm)								
	0	0.1 - 10	11-25	26-37	38-50	51-75	76-100	>100	Total
0	4	1	0	0	0	0	0	0	5
0.1-10	7	18	4	1	0	0	0	0	30
11-25	0	9	28	3	0	0	0	0	40
26-37	0	0	2	6	1	0	0	0	9
38-50	0	0	1	1	4	0	0	0	6
51-75	0	0	0	0	1	3	0	0	4
76-100	0	0	0	0	1	0	3	0	4
>100	0	0	0	0	0	1	0	1	2
Total	11	28	35	11	7	4	3	1	100

Comparison of overall Skill scores of two different sets of forecast



New approach for computation of forecast skill scores

- Overall skill scores (PC, HSS) represents mostly on the performance for predictability of high frequency events.
- To represent the performance for predictability of low frequency events, weighted Overall Skill Scores can be computed with construction of weighted contingency matrix.
- Weights can be taken as percentage of reciprocal of historical/climatological values for each forecast category .

New approach for computation of forecast skill scores

Category of forecast ranges	Climatological percentage of occurrence
0	C_1
0.1-10	C_2
11-25	C_3
26-37	C_4
38-50	C_5
51-75	C_6
76-100	C_7
>100	C_8

Weights for each category is defined as
$W_i = 1/C_i * 100$ where i=1 to 8.

Contingency Table for verification of QPF

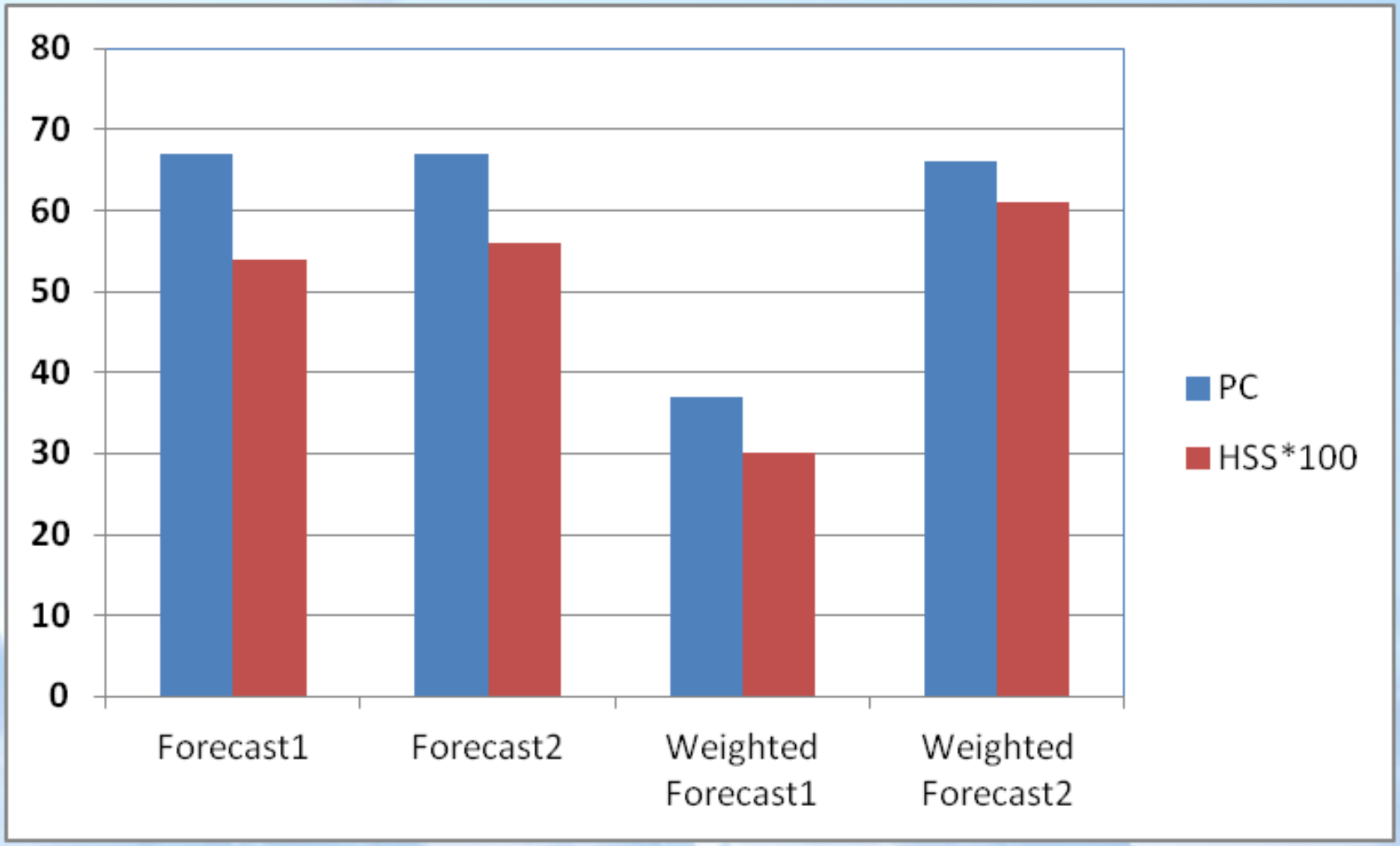
Observed Range(mm)	Forecast Range (mm)								
	0	0.1 -10	11-25	26-37	38-50	51-75	76-100	>100	Total
0	W_1F_{11}	W_1F_{12}	W_1F_{13}	W_1F_{14}	W_1F_{15}	W_1F_{16}	W_1F_{17}	W_1F_{18}	F_1
0.1-10	W_2F_{21}	W_2F_{22}	W_2F_{23}	W_2F_{24}	W_2F_{25}	W_2F_{26}	W_2F_{27}	W_2F_{28}	F_2
11-25	W_3F_{31}	W_3F_{32}	W_3F_{33}	W_3F_{34}	W_3F_{35}	W_3F_{36}	W_3F_{37}	W_3F_{38}	F_3
26-37	W_4F_{41}	W_4F_{42}	W_4F_{43}	W_4F_{44}	W_4F_{45}	W_4F_{46}	W_4F_{47}	W_4F_{48}	F_4
38-50	W_5F_{51}	W_5F_{52}	W_5F_{53}	W_5F_{54}	W_5F_{55}	W_5F_{56}	W_5F_{57}	W_5F_{58}	F_5
51-75	W_6F_{61}	W_6F_{62}	W_6F_{63}	W_6F_{64}	W_6F_{65}	W_6F_{66}	W_6F_{67}	W_6F_{68}	F_6
76-100	W_7F_{71}	W_7F_{72}	W_7F_{73}	W_7F_{74}	W_7F_{75}	W_7F_{76}	W_7F_{77}	W_7F_{78}	F_7
>100	W_8F_{81}	W_8F_{82}	W_8F_{83}	W_8F_{84}	W_8F_{85}	W_8F_{86}	W_8F_{87}	W_8F_{88}	F_8
Total	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	T

$PC = \sum W_i F_{II}/T*100$

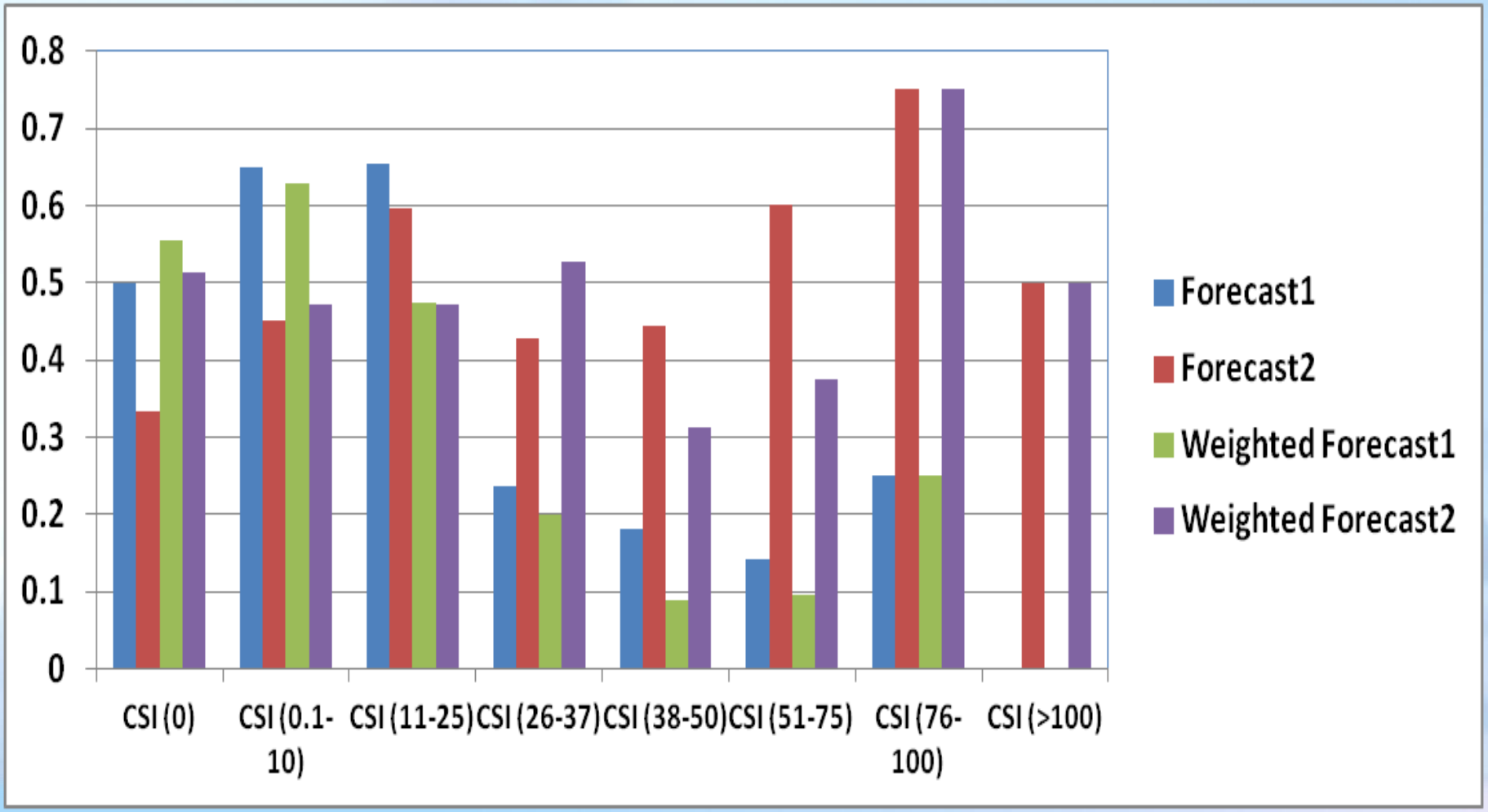
$CSI = (W_1F_{11}/(F_1+A_1- W_1F_{11}), W_2F_{22}/(F_2+A_2- W_2F_{22}), W_3F_{33}/(F_3+A_3- W_3F_{33}), W_4F_{44}/(F_4+A_4- W_4F_{44}), W_5F_{55}/(F_5+A_5- W_5F_{55}), W_6F_{66}/(F_6+A_6- W_6F_{66}), W_7F_{77}/(F_7+A_7- W_7F_{77}), W_8F_{88}/(F_8+A_8- W_8F_{88}))$

$HSS=(\sum W_i F_{ii} - \sum F_iA_I/T)/(T- \sum F_iA_I/T)$

Comparison of overall Skill scores of two different sets of forecast



Comparison of Skill scores for individual cateogories of two different sets of forecast



Conclusions

- Weighted skill scores can be better choice for evaluation of forecast in view of users perspectives.
- It can helps forecasters to choose better performed numerical models as many models usually provide good results for normal range of values while not predicted high impact weather values.
- The method has also scope to utilize in case of some others deterministic verification skill Scores computations.

THANKS