Bringing IPCC forecasts into probabilistic form for monitoring of climatic indexes of drought

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Spring-to-summer drought

- Light 0,61 < $HTC_{v\text{-}vi}$ < 0,75
- Mild 0,40 < $HTC_{v\text{-}vi}$ < 0,60
- Heavy $HTC_{v\text{-}vi}$ < 0,39
- 0,39 < $HTC_{v\text{-}vi}$ < 0,75 defines the **territories** that are **susceptible to drought**

HTC contains values of **temperature and precipitation** that in general **can be forecasted and estimated by climate models**. The objects of the research were forecast given by IPCC climate models.

When forming informational base out of IPCC data **two problems** arise:

1. Finding the model with the highest degree of forecast adequacy to the observed meteorological situations

2. While forecasts fall into probabilistic category, IPCC forecasts are given as a set of determined data

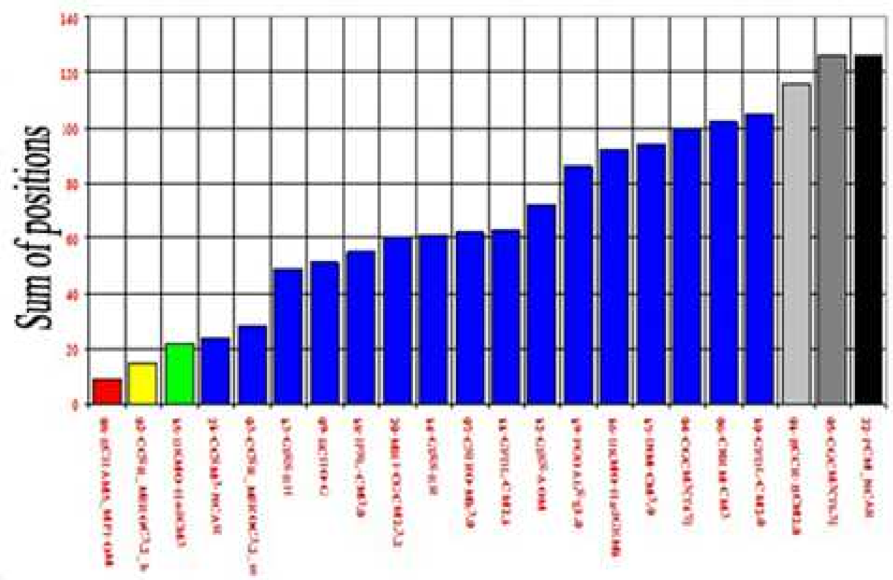
Retrospective calculations were done on all available mathematical models of global atmosphere and ocean circulation, and these calculations were compared to actually observed and recorded values. Deviations from the observed data were also compared.

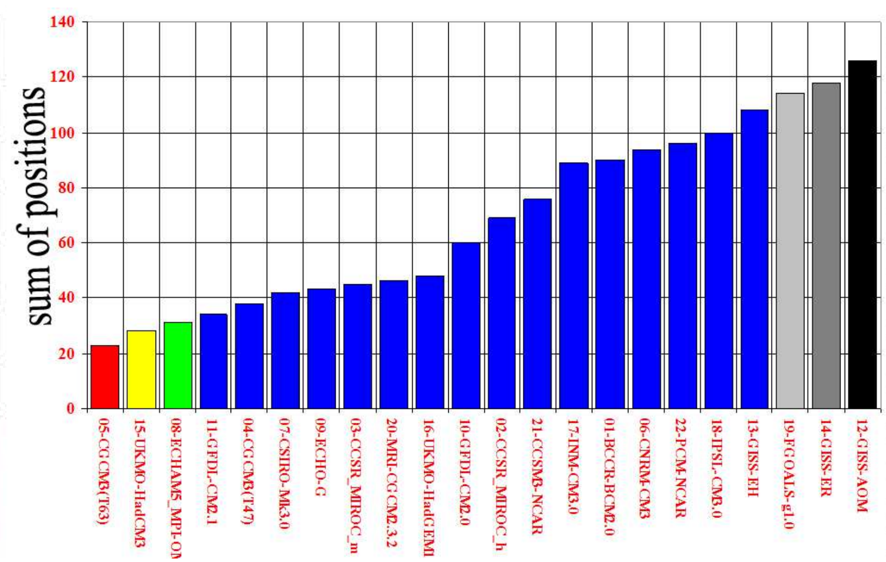
Climate models were ranged by sum of positions they get in the 7 degrees of temperature forecast accuracy and precipitation forecast accuracy in all climatic zones on all continents.

5 sequantial 30-year periods were analysed

1) 1916–1945
2) 1931–1960
3) 1946–1975
4) 1961–1990
5) 1976–2005

Sum of positions in the 7 degrees of temperature and precipitation forecast accuracy (all climatic zones,all continents)





Temperature forecast accuracy

Precipitation forecast accuracy

Conclusions and findings of the undertaken analysis:

- All mathematical models show **only positive signal** when reproducing fields of temporal temperature trends

- Indexes characterising extremums of precipitation show **no significant similarities between calculated and actual data**

- When representing multi-year global average trends and historical trends in extreme characteristics **not a single model can be considered the best**

- There is **not a single model that can properly depict** temporal change in temperature regime during the warm period of the year

- Such modelling is **impossible to use** for direct assesment of climate and ecological characteristics’ changeability.

Climatology, 2011 to 2030AD

Time and location selection

Use the boxes below to alter the region viewed. After selecting values, click on "Submit" below.		
Time period	Jan	
Upper Latitude	73.18	
Lower Latitude	37.58	
Upper Longitude	177.50	
Lower Longitude	17.50	

Submit

Select display mode:

Latitude-Longitude grid

Time series at a point

Data table

Download as csv spreadsheet

Precipitation rate [mm/day], Jan

latitude	*longitude*																								
	17.50	*22.50*	*27.50*	*32.50*	*37.50*	*42.50*	*47.50*	*52.50*	*57.50*	*62.50*	*67.50*	*72.50*	*77.50*	*82.50*	*87.50*	*92.50*	*97.50*	*102.50*	*107.50*	*112.50*	*117.50*	*122.50*	*127.50*	*132.50*	*137.50*	*142.*
73.18	1.12	0.76	0.58	0.61	0.74	0.63	0.73	0.66	1.76	0.30	0.57	0.41	0.52	0.42	0.76	0.63	0.48	0.35	0.58	0.42	0.46	0.34	0.32	0.31	0.34	0.43
69.22	2.25	3.50	0.91	0.60	0.73	0.79	0.71	0.72	0.86	0.45	0.93	0.58	0.80	0.69	0.65	1.27	0.44	0.21	0.52	0.20	0.33	0.25	0.84	0.15	0.44	0.29
65.27	4.04	0.76	1.09	1.18	0.69	1.17	0.70	0.93	0.91	0.99	0.70	0.63	0.68	0.55	0.77	0.97	0.36	0.26	0.44	0.34	0.37	0.20	0.85	0.37	0.54	0.24
61.31	1.52	1.36	1.58	1.13	1.33	1.11	1.20	0.99	1.54	0.63	0.99	0.82	0.82	0.80	0.75	1.08	0.44	0.70	0.31	0.43	0.18	0.35	0.21	0.13	0.66	1.86
57.36	1.64	2.05	1.64	1.53	1.42	1.21	1.20	1.22	1.07	0.51	0.78	0.77	0.84	0.85	0.73	1.01	0.57	0.74	0.68	0.73	0.74	0.47	0.99	0.39	2.53	0.88
53.40	1.55	1.32	1.54	1.73	1.70	1.30	1.40	1.18	1.47	0.52	0.83	0.42	0.45	0.58	0.98	0.78	1.88	0.16	0.70	0.99	0.18	0.29	0.19	0.77	1.92	1.97
49.44	1.23	1.56	1.34	1.51	1.57	0.85	1.23	0.90	1.18	0.55	1.07	0.67	0.83	1.02	3.49	0.49	0.86	0.16	0.22	0.23	0.07	0.33	0.17	0.50	1.64	3.92
45.49	1.10	2.04	0.95	2.11	2.54	0.81	0.39	0.91	0.83	0.66	0.52	0.43	0.28	0.71	0.13	0.72	0.74	0.13	0.16	0.10	0.26	0.09	0.27	0.24	1.68	4.32
41.53	1.61	4.71	0.64	1.44	1.99	4.27	0.58	0.48	0.59	0.47	0.94	2.41	0.60	0.43	0.26	0.17	0.56	0.35	0.40	0.12	0.17	0.06	0.52	1.52	2.92	1.97
37.58	2.61	2.90	2.42	4.28	2.05	1.09	1.79	0.26	1.16	0.06	0.77	2.79	1.42	0.21	1.87	0.18	1.36	0.16	0.22	0.19	0.17	0.42	0.61	1.64	5.86	3.75

Example of IPCC data

Hence arises the problem - how to turn IPCC data into probabilistic form

We proposed the **new modification of ensemble method** that allows us to turn determined data, given by IPCC climatic models, into probabilistic form with the use of **fuzzy logic**.

Methodically this is achieved by sequentialy performing the procedures which lead us to finding out **characteristic membership function** of ensemble’s data.

Criteria of fuzzy logic applicability:

❖ data should be structured

❖ mathematical model of relationship between expert data can’t be built

❖ exact conditions of the forecasted situations are unknown

We postulate the hypothesis that if we deem data from multitude of models as opinions of independent experts, that do not correlate with each other, we substitute eventuality (randomness) with expectancy.

In such case we can use methodic and corresponding mathematics of fuzzy logic to bring an ensemble into probabilistic form and to calculate statistical characteristics of probability density function.

We assume that calculated statistical characteristics will be identical to statistical characteristics of the probability density function of the forecasted metheorological parameters (temperature and precipitation).

- 2011-2030 period was chosen
- 20 models have data on chosen time period
- Out of **20** models, presented in IPCC's 4th assesment report we took 10 for our research. Criteria for inclusion was data availabilty for all 4 emission scenarios (Commit, SRA1B, SRA2, SRB1).

The chosen models:

- UKMO-HanCM3
- NPIM – Echam
- GFDL-CM-2.1
- CSIRO-MK3
- CCSM3-NCAR
- NIES-miroc3.2-med
- MRI-CGCM-2.3.2
- GFDL-CM2
- INM-CM3
- BCCR-BCM20
- IPSL-CM4
- GISS-ER

Non-SRES Scenario: **COMMIT**

- An idealised scenario in which the atmospheric burdens of long-lived greenhouse gasses are held fixed at AD2000 levels.

The SRES **A1B** Emissions Scenarios

- Very rapid economic growth
- Low population growth
- Rapid introduction of new and more efficient technology
- Economic and cultural convergence and capacity building
- Substantial reduction in regional differences in per capita income
- People pursue personal wealth rather than environmental quality

The SRES **A2** Emissions Scenarios

- Very heterogeneous world
- Strengthening regional cultural identities, with an
- Emphasis on family values and local traditions,
- High population growth,
- Less concern for rapid economic development
- Continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines

SRB1

- Convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.

For the SRES scenarios, SRA1B, SRA2, SRB1, anomalies are calculated relative to the 1961-1990 mean of the 20th century simulation, ***20C3M***

Non-SRES Scenario: **20C3M**

- Experiments run with greenhouse gasses increasing as observed through the 20th century.

Availability of scenarios by the temperature factor

Model	Stepping		Sceniario			
	Lat.	*Lon.*	Commit	SRA1B	SRA2	SRB1
UKMO-HanCM3	2.5	3.75				
NPIM - Echam	1,86-1,87	1,87-1,88				
GFDL_CM_2_1	2.01	2.05				
CSIRO_MK3	1,86-1,87	1,87-1,88				
ECHO-G	3,7-3,71	3.75				
CCSM3_NCAR	1,4-1,41	1,4-1,41				
NIES_miroc_3_2_med	2,78-2,79	2,81-2,82				
CGCM3(T47)	3,7-3,71	3.75				
NIES_MIROC_3_2_h	1,12-1,13	1,12-1,13				
MRI_CGCM_2_3_2	2,78-2,79	2,81-2,82				
UKMO_HADGEM1	1.25	1,87-1,88				
GFDL_CM2	2	2.5				
INM_CM3	4	5				
BCCR-BCM20	2,78-2,79	2,81-2,82				
PCM_NCAR	2,78-2,79	2,81-2,82				
IPSL_CM4	2,53-2,54	3.75				
GISS_EH	3,95-3,96	5				
FGOALS_g1	3.05	2,81-2,82				
GISS_ER	3,95-3,96	5				
GISS_AOM	3	4				

- Different models have different coordinate grid stepping
- Common coordinate points in the boundaries of coordinate stepping can't be found

Stations chosen for research

Station number	Station name	Longtitude	Latitude
20946	Bolvanskiy Nos	59.08	70.45
21982	Vrangel Island	178.48	70.98
22551	Mud'yug	40.28	64.85
23058	Antipayuta	76.9	68.08
24143	Jarjan	124	68.73
25173	Shmidt Cape	179.5	68.9
26063	Saint Petersburg	30.3	59.97
27995	Bezenchuk	49.4	53
28275	Tobol'sk	68.25	58.15
29128	Parabel'	81.5	58.7
30089	Jikimda	121.77	59.02
31866	Sosunovo	138.33	46.53
32069	Pil'vo	142.2	50.1
33976	Feodosiya	35.38	45.03
34824	Promorsko-Amursk	38.15	46.03
35001	Bol'shaya Glushica	50.5	52.4
36021	Klyuchi	79.13	52.25
37163	Kizlyar	46.7	43.8

17 metheorological stations in 17 climatic zones

Full set of probabilty density function characteristics for forecasted daily mean temperatures (July of 2011-2030)

Station	Mean	Geometric mean	Harmonic mean	Median	Mode	Frequency of mode	Lower quartile	Upper Quartile	Range	Quartile range	Variance	St. Deviation	Coeff. of variation	Skewness	Kurtosis
20982	0.987767	0.987698	0.987627	0.989384	Multiple	3	0.985033	0.995997	0.046641	0.010964	0.000137	0.011721	1.186633	-2.02921	4.11394
21921	0.987716	0.987686	0.987656	0.989924	,9958304	5	0.981063	0.994962	0.026407	0.013899	0.000060	0.007756	0.785224	-0.26695	-1.38651
22551	0.980490	0.980450	0.980411	0.979918	,9639547	3	0.974940	0.986440	0.039478	0.011500	0.000079	0.008870	0.904688	-0.09873	0.00433
23058	0.988456	0.988378	0.988298	0.991646	Multiple	3	0.988688	0.994953	0.050122	0.006265	0.000154	0.012413	1.255768	-2.43850	5.37079
24143	0.988192	0.988171	0.988151	0.988809	,9783058	3	0.983127	0.993285	0.027204	0.010158	0.000041	0.006380	0.645669	-0.22874	-0.60227
25503	0.981172	0.981142	0.981112	0.979623	,9780822	3	0.974829	0.986473	0.032877	0.011644	0.000060	0.007748	0.789667	0.46883	-0.34043
26063	0.988189	0.988175	0.988160	0.986381	,9863807	4	0.984848	0.992850	0.020429	0.008001	0.000029	0.005427	0.549180	0.60625	-0.61424
27995	0.982632	0.982589	0.982546	0.981574	Multiple	3	0.973606	0.989542	0.029216	0.015936	0.000086	0.009299	0.946307	0.40846	-1.15585
28275	0.986109	0.986081	0.986053	0.985284	,9918809	4	0.981563	0.991881	0.031461	0.010318	0.000056	0.007470	0.757495	-0.24474	0.03491
29128	0.989149	0.989125	0.989101	0.988979	,9874534	3	0.985927	0.993388	0.029162	0.007460	0.000049	0.006968	0.704416	-0.70747	0.79220
30089	0.986671	0.986648	0.986626	0.987415	,9891156	4	0.982993	0.989966	0.028912	0.006973	0.000045	0.006724	0.681482	-0.14794	-0.18908
31866	0.980691	0.980648	0.980605	0.981036	,9810362	4	0.973417	0.983237	0.035896	0.009821	0.000086	0.009278	0.946049	0.43330	-0.15713
32069	0.979309	0.979232	0.979154	0.980855	Multiple	2	0.970256	0.987863	0.048547	0.017607	0.000154	0.012421	1.268356	-0.41356	-0.37420
33976	0.988728	0.988703	0.988677	0.988701	Multiple	4	0.985876	0.994516	0.027584	0.008641	0.000051	0.007152	0.723366	-0.74814	-0.03677
34824	0.981509	0.981475	0.981441	0.980769	,9746877	4	0.974030	0.988823	0.029586	0.014793	0.000069	0.008280	0.843643	0.42454	-0.91658
35001	0.983164	0.983120	0.983077	0.982107	Multiple	3	0.974155	0.990060	0.029821	0.015905	0.000087	0.009318	0.947760	0.37144	-1.16103
36021	0.984564	0.984537	0.984511	0.983062	Multiple	2	0.979907	0.989040	0.029226	0.009133	0.000053	0.007246	0.735984	0.47552	-0.30695
37163	0.979852	0.979823	0.979794	0.978611	Multiple	3	0.975650	0.982725	0.032906	0.007075	0.000059	0.007656	0.781339	0.93158	1.13069

Effective set of probabilty density function characteristics for forecasted daily average precipitation

(July of 2011-2030)

Station	Mean	Median	Mode	Frequency of mode	Range	St. Deviation	Skewness	Kurtosis	Sum
20946	0,69	0,65	0,65	8	0,59	0,17	0,34	-0,74	27,65
21982	0,74	0,77	0,80	9	0,60	0,16	-0,16	-0,74	29,73
22551	0,75	0,75	0,75	10	0,50	0,12	0,25	0,01	30,17
23058	0,73	0,73	Multiple	6	0,55	0,13	-0,23	-0,41	29,32
24143	0,66	0,65	0,63	6	0,57	0,13	0,33	0,32	26,30
25173	0,70	0,71	0,71	8	0,67	0,15	-0,35	-0,10	28,19
26063	0,74	0,77	0,77	6	0,63	0,16	-0,64	-0,52	29,50
27995	0,54	0,54	Multiple	4	0,84	0,24	0,26	-0,95	21,76
28275	0,72	0,72	Multiple	5	0,59	0,17	-0,22	-1,03	28,69
29128	0,65	0,63	0,75	6	0,63	0,16	0,36	-0,61	25,81
30089	0,71	0,72	0,76	8	0,53	0,11	-0,01	0,20	28,29
31866	0,55	0,53	0,51	7	0,68	0,14	1,52	3,33	21,85
32069	0,57	0,53	Multiple	5	0,68	0,15	0,93	0,53	22,87
33976	0,40	0,36	0,27	8	0,91	0,26	0,81	0,05	16,18
34824	0,41	0,32	0,29	8	0,86	0,24	0,96	0,17	16,36
35001	0,52	0,50	Multiple	4	0,87	0,24	0,33	-0,79	20,65
36021	0,56	0,52	Multiple	4	0,76	0,22	0,39	-0,84	22,29
37163	0,37	0,26	0,21	7	1,00	0,27	1,05	0,39	14,68

Sets of data on forecasted temperature and precipitation, that had their expected values calculated can be the basis for calculation of expected HTC, which can help define:

- expected new boundries of desertification zones;
- comparing calculated and observed values of index in the monitoring system
- foreseeing the probabilty of a drought of certain expected intensity

Thanks for your attention!