

Supported Materials

Surface ozone impacts on major crop production in China from 2010 to 2017

Dianyi Li, Drew Shindell, Dian Ding, Xiao Lu, Lin Zhang, Yuqiang Zhang

Table S1. Evaluation results of simulated AOT40 and observational Data during growth season (April to September) from 2013 to 2017.

Year	modeled mean (ppm h)	observation mean (ppm h)	Mean Bias (ppm h)	Normalized Mean Bias	Mean Error	Normalized Mean Error
2013	21200.08	23362.38	-2162.30	-9%	9979.04	43%
2014	22591.57	24196.98	-1605.42	-7%	11178.88	46%
2015	22398.99	23459.15	-1060.16	-5%	10609.44	45%
2016	20851.19	23579.00	-2727.81	-12%	9998.78	42%
2017	16796.01	23313.05	-6517.04	-28%	10973.21	47%

Table S2. 8-year average annual accumulated AOT40 in China provinces. The provinces are listed following the orders of their magnitudes. Unit of ppm h.

	Provinces	AOT40 (ppm h)		Provinces	AOT40 (ppm h)
1	Xizang	41.47	18	Hubei	27.95
2	Tianjin	34.79	19	Chongqing	26.79
3	Qinghai	34.51	20	Shanghai	26.38
4	Shanxi	33.65	21	Xinjiang Uygur	25.01
5	Hebei	32.64	22	Jiangxi	24.29
6	Shaanxi	32.30	23	Nei Mongol	24.03
7	Henan	32.25	24	Fujian	23.96
8	Liaoning	31.72	25	Yunnan	23.35
9	Beijing	31.68	26	Hunan	22.72
10	Sichuan	30.93	27	Taiwan	22.49
11	Anhui	30.81	28	Heilongjiang	22.48
12	Shandong	30.61	29	Guizhou	21.34
13	Ningxia Hui	29.76	30	Guangdong	19.85
14	Jiangsu	29.58	31	Hainan	18.08
15	Gansu	29.10	32	Guangxi	17.81
16	Jilin	28.93	33	HongKong	NA
17	Zhejiang	28.31	34	Macao	NA

Table S3. 8-year average of accumulated AOT40 and RYL for wheat during growing season (March, April, and May).

	Provinces	Growing season AOT40 (ppm h)	RYL		Provinces	Growing season AOT40 (ppm h)	RYL
1	Xizang	14.99	25.14%	18	Jilin	9.33	16.02%
2	Yunnan	12.60	21.29%	19	Liaoning	8.89	15.31%
3	Qinghai	11.77	19.95%	20	Hebei	8.68	14.97%
4	Sichuan	11.64	19.74%	21	Nei Mongol	8.54	14.76%
5	Anhui	10.89	18.53%	22	Fujian	8.49	14.67%
6	Zhejiang	10.60	18.06%	23	Heilongjiang	8.44	14.59%
7	Henan	10.52	17.95%	24	Jiangxi	8.37	14.47%
8	Shaanxi	10.47	17.85%	25	Beijing	8.29	14.34%
9	Jiangsu	10.34	17.64%	26	Tianjin	8.12	14.08%
10	Hubei	10.02	17.13%	27	Taiwan	7.99	13.86%
11	Shanxi	9.74	16.69%	28	Xinjiang Uygur	7.98	13.85%
12	Shandong	9.66	16.56%	29	Hunan	7.92	13.74%
13	Gansu	9.64	16.52%	30	Guangxi	6.83	11.99%
14	Ningxia Hui	9.63	16.51%	31	Guangdong	5.91	10.52%
15	Shanghai	9.63	16.50%	32	Hainan	4.43	8.13%
16	Chongqing	9.62	16.49%	33	HongKong	NA	NA
17	Guizhou	9.47	16.24%	34	Macao	NA	NA

Table S4. As for Table S3 but for double rice (growing season May, June, July for early rice, and September, October and November for late rice).

	Provinces	Growing Season AOT40 (ppm h)	Double Early Rice		Provinces	Growing Season AOT40 (ppm h)	Double Late Rice
1	Anhui	12.09	10.71%	1	Fujian	6.47	8.53%
2	Hubei	10.23	9.99%	2	Jiangxi	6.39	8.49%
3	Zhejiang	8.72	9.40%	3	Guangdong	6.35	8.48%
4	Hunan	6.57	8.56%	4	Anhui	6.17	8.41%
5	Jiangxi	6.41	8.50%	5	Hubei	5.99	8.34%
6	Fujian	4.46	7.74%	6	Zhejiang	5.97	8.33%
7	Yunnan	3.52	7.37%	7	Hunan	5.85	8.28%
8	Guangxi	3.41	7.33%	8	Taiwan	5.62	8.19%
9	Guangdong	2.78	7.08%	9	Hainan	5.27	8.06%
10	Taiwan	2.43	6.95%	10	Guangxi	4.66	7.82%
11	Hainan	1.84	6.72%	11	Yunnan	2.86	7.11%
12	HongKong	NA	NA	12	HongKong	NA	NA
13	Macao	NA	NA	13	Macao	NA	NA

Table S5. As for Table S3 but for single rice (growing season August, September, and October).

	Provinces	Growing Season AOT40 (ppm h)	RYL		Provinces	Growing Season AOT40 (ppm h)	RYL
1	Tianjin	10.81	10.22%	18	Chongqing	7.24	8.82%
2	Shanxi	9.76	9.81%	19	Jilin	6.92	8.70%
3	Henan	9.41	9.67%	20	Shanghai	6.81	8.66%
4	Shaanxi	9.08	9.54%	21	Hunan	6.67	8.60%
5	Hebei	9.06	9.53%	22	Gansu	6.45	8.52%
6	Shandong	8.84	9.45%	23	Fujian	6.30	8.46%
7	Anhui	8.83	9.44%	24	Sichuan	5.46	8.13%
8	Liaoning	8.82	9.44%	25	Xinjiang Uygur	5.04	7.97%
9	Beijing	8.47	9.30%	26	Nei Mongol	4.46	7.74%
10	Jiangsu	8.18	9.19%	27	Heilongjiang	4.18	7.63%
11	Ningxia Hui	8.00	9.12%	28	Guizhou	4.18	7.63%
12	Hubei	7.99	9.12%	29	Guangxi	4.14	7.62%
13	Zhejiang	7.30	8.85%	30	Yunnan	2.02	6.79%
14	Jiangxi	7.28	8.84%				

Table S6. As for Table S3 but for Maize (growing season June, July and August for north maize, and August, September and October for south maize).

	Provinces	Growing Season AOT40 (ppm h)	North Maize		Provinces	Growing Season AOT40 (ppm h)	South Maize
1	Tianjin	20.24	5.29%	1	Jiangsu	8.18	0.94%
2	Beijing	17.92	4.45%	2	Hubei	7.99	0.89%
3	Hebei	17.80	4.41%	3	Zhejiang	7.30	0.64%
4	Shanxi	16.49	3.94%	4	Jiangxi	7.28	0.64%
5	Liaoning	15.57	3.61%	5	Chongqing	7.24	0.65%
6	Shandong	13.93	3.01%	6	Shanghai	6.81	0.50%
7	Henan	13.71	2.93%	7	Xizang	6.81	0.50%
8	Jilin	12.88	2.64%	8	Hunan	6.67	0.47%
9	Shaanxi	12.70	2.57%	9	Fujian	6.30	0.37%
10	Ningxia Hui	11.02	1.97%	10	Guangdong	5.48	0.20%
11	Anhui	10.77	1.88%	11	Sichuan	5.46	0.18%
12	Heilongjiang	9.08	1.27%	12	Taiwan	5.02	0.11%
13	Gansu	8.95	1.22%	13	Guizhou	4.18	0.00%
14	Nei Mongol	8.69	1.13%	14	Guangxi	4.14	0.00%
15	Xinjiang Uygur	7.57	0.74%	15	Hainan	3.85	0.00%
16	Qinghai	6.58	0.48%	16	Yunnan	2.02	0.00%

Table S7. As for Table S3 but for soybean (growing season June, July and August).

	Provinces	Growing Season AOT40 (ppm h)	RYL		Provinces	Growing Season AOT40 (ppm h)	RYL
1	Tianjin	20.24	11.48%	18	Chongqing	8.40	0.00%
2	Beijing	17.92	8.79%	19	Xinjiang Uygur	7.57	0.00%
3	Hebei	17.80	8.65%	20	Zhejiang	7.55	0.00%
4	Shanxi	16.49	7.13%	21	Qinghai	6.58	0.00%
5	Liaoning	15.57	6.07%	22	Sichuan	6.15	0.00%
6	Shandong	13.93	4.15%	23	Xizang	6.02	0.00%
7	Henan	13.71	3.90%	24	Jiangxi	5.59	0.00%
8	Jilin	12.9	3.02%	25	Hunan	5.49	0.00%
9	Shaanxi	12.88	2.73%	26	Fujian	3.62	0.00%
10	Jiangsu	12.70	1.49%	27	Guizhou	3.57	0.00%
11	Ningxia Hui	11.02	1.24%	28	Guangdong	2.42	0.00%
12	Anhui	10.77	0.70%	29	Guangxi	2.36	0.00%
13	Shanghai	9.28	0.47%	30	Taiwan	2.17	0.00%
14	Heilongjiang	9.08	0.00%	31	Hainan	1.54	0.00%
15	Gansu	8.95	0.31%	32	Yunnan	1.39	0.00%
16	Hubei	8.78	0.01%	33	HongKong	NA	NA
17	Nei Mongol	8.69	0.00%	34	Macao	NA	NA

Table S8. Province level of ozone induced production loss for wheat from 2010 to 2017 (1000 metric tons).

Province	2010	2011	2012	2013	2014	2015	2016	2017	2010-2017 Average
Henan	2636	3015	3882	5514	7046	7273	7270	5240	5234
Shandong	2228	2469	3757	4918	6404	6829	6690	4831	4766
Hebei	1237	1052	2097	2784	3865	4424	4044	2805	2788
Jiangsu	1389	2067	2114	2995	3532	3547	3060	2564	2658
Anhui	1457	1978	2120	2816	3444	3325	3055	2468	2583
Shaanxi	820	863	1090	1718	2037	2100	2127	1444	1525
Sichuan	785	925	1011	1243	1218	1260	1218	874	1067
Hubei	556	794	749	1107	1254	1226	1147	922	970
Shanxi	427	405	659	996	1318	1423	1427	966	953
Gansu	466	525	678	1064	1195	1101	1086	748	858
Xinjiang Uygur	415	541	663	839	1087	938	780	653	740
Yunnan	412	354	528	566	602	546	596	452	507
Nei Mongol	187	181	241	554	614	641	554	374	418
Tianjin	105	80	171	240	303	407	373	266	243
Chongqing	153	193	184	263	261	272	257	182	221
Beijing	67	51	101	165	221	277	246	164	161
Guizhou	134	131	162	220	218	206	200	140	176
Ningxia Hui	82	89	114	205	231	212	206	140	160
Heilongjiang	58	50	53	130	146	151	132	103	103
Hunan	31	44	37	56	60	59	55	44	48
Qinghai	26	31	39	60	69	63	62	41	49
Xizang	65	70	90	75	73	79	84	58	74
Zhejiang	31	44	41	53	60	60	46	43	47
Liaoning	10	10	14	24	28	33	28	21	21
Jiangxi	14	21	17	23	26	25	21	19	21
Shanghai	8	13	12	17	19	19	15	14	15
Fujian	5	7	5	7	7	7	7	6	6
Guangxi	5	4	6	7	7	7	8	5	6
Jilin	2	2	3	5	6	7	6	4	4
Guangdong	0	0	0	0	0	0	0	0	0
Hainan	0	0	0	0	0	0	0	0	0
HongKong	0	0	0	0	0	0	0	0	0
Macao	0	0	0	0	0	0	0	0	0
Taiwan	0	0	0	0	0	0	0	0	0
China	13811	16009	20638	28664	35351	36517	34800	25591	26422

Table S9. As Table S8 but for double early rice (1000 Mt)

Province	2010	2011	2012	2013	2014	2015	2016	2017	2010-2017 Average
Hunan	799	880	856	875	1002	937	917	841	888
Jiangxi	883	946	884	835	942	849	821	775	867
Guangdong	443	486	451	462	496	469	469	464	467
Guangxi	420	459	429	453	479	472	449	432	449
Fujian	214	228	218	214	234	217	221	211	220
Anhui	288	303	318	287	296	245	228	208	272
Hubei	242	203	210	191	220	202	145	121	192
Zhejiang	141	146	135	136	146	146	155	142	143
Taiwan	52	52	53	52	55	54	56	54	53
Hainan	34	39	36	38	39	40	39	37	38
Yunnan	9	9	10	9	10	11	10	10	10
HongKong	0	0	0	0	0	0	0	0	0
Macao	0	0	0	0	0	0	0	0	0
Total	3525	3751	3600	3552	3919	3642	3510	3295	3599

Table S10. As Table S8 but for double late rice (1000 Mt)

Province	2010	2011	2012	2013	2014	2015	2016	2017	2010 -2017 Average
Jiangxi	820	865	919	910	915	872	747	750	850
Hunan	745	807	858	928	923	918	812	775	846
Guangdong	515	557	609	607	615	584	534	523	568
Guangxi	451	492	516	531	508	490	480	444	489
Fujian	220	233	264	264	280	260	225	226	247
Anhui	217	219	230	241	233	201	171	158	209
Hubei	194	156	169	175	181	175	118	100	158
Zhejiang	109	117	120	126	138	130	120	122	123
Taiwan	53	58	62	70	79	68	62	62	64
Hainan	41	44	47	49	48	46	44	42	45
Yunnan	9	9	9	9	10	10	10	10	9
HongKong	0	0	0	0	0	0	0	0	0
Macao	0	0	0	0	0	0	0	0	0
Total	3374	3557	3803	3910	3930	3754	3323	3212	3608

Table S 11. As for Table S8 but for single rice (1000 Mt).

Province	2010	2011	2012	2013	2014	2015	2016	2017	2010-2017 Average
Anhui	1692	1746	1840	1936	2043	2142	1932	1918	1906
Jiangsu	1551	1631	1700	1825	1899	1907	1739	1716	1746
Hubei	1128	1294	1323	1419	1452	1518	1437	1411	1373
Sichuan	1048	1071	1080	1245	1209	1258	1219	1091	1152
Hunan	767	815	830	799	830	829	763	800	804
Zhejiang	656	723	769	790	836	799	694	730	750
Henan	420	433	458	492	501	526	482	456	471
Jiangxi	303	357	418	450	506	516	519	542	451
Chongqing	382	391	388	451	442	456	439	399	418
Fujian	269	288	327	331	359	335	299	321	316
Guizhou	257	265	276	308	301	309	289	272	285
Liaoning	250	252	264	282	299	296	294	285	278
Heilongjiang	256	252	259	279	283	294	283	269	272
Yunnan	248	261	268	285	286	287	275	264	272
Jilin	182	186	190	205	213	218	208	197	200
Shandong	145	150	159	171	178	180	176	169	166
Shanghai	87	95	99	105	111	110	98	99	101
Shaanxi	86	87	91	110	105	110	105	95	99
Hebei	84	86	86	95	99	104	106	102	95
Guangxi	70	80	85	93	93	90	89	93	87
Xinjiang Uygur	35	37	38	40	41	39	41	39	39
Tianjin	25	26	26	28	29	32	32	31	29
Nei Mongol	23	24	24	27	28	28	27	26	26
Ningxia Hui	16	17	17	20	20	20	20	19	19
Beijing	4	5	5	5	5	5	5	5	5
Shanxi	4	4	5	5	5	6	6	5	5
Gansu	4	4	5	6	5	5	5	5	5
Total	9992	10580	11030	11802	12178	12419	11582	11359	11370

Table S12. As for Table S8 but for north and south maize (1000 Mt)

North maize									
Province	2010	2011	2012	2013	2014	2015	2016	2017	2010-2017 Average
Hebei	1243	1200	1019	1186	1609	1806	1580	1202	1356
Shandong	898	992	968	1068	1091	1305	1134	808	1033
Henan	550	767	739	607	851	850	789	526	710
Jilin	515	509	500	613	821	865	858	420	638
Liaoning	438	455	427	517	681	729	702	427	547
Heilongjiang	383	392	420	420	469	570	563	243	432
Shanxi	207	261	216	238	307	330	279	216	257
Shaanxi	113	214	157	210	359	359	278	189	235
Nei Mongol	167	175	149	164	206	217	212	113	175
Tianjin	130	114	106	136	193	229	193	149	156
Anhui	110	126	152	130	130	153	159	105	133
Beijing	106	99	75	82	121	139	125	97	106
Xinjiang Uygur	12	44	51	89	98	92	57	25	58
Gansu	9	23	11	27	47	48	31	21	27
Ningxia Hui	7	10	7	12	14	14	11	8	10
Qinghai	0	0	0	0	0	0	0	0	0
South Maize									
Sichuan	48	98	81	203	146	210	168	9.16	121
Jiangsu	33	26	32	85	53	82	44	27	48
Chongqing	9	22	27	73	58	86	57	2	42
Hubei	6	12	26	39	36	56	31	1	26
Hunan	0	1	6	7	7	11	4	0	4
Xizang	0	0	1	5	6	7	6	5	4
Guizhou	0	0	0	4	1	6	1	0	1
Yunnan	0	0	0	1	0	0	0	0	0
Guangxi	0	0	1	0	0	0	0	0	0
Taiwan	0	0	0	1	1	1	0	0	0
Guangdong	0	0	0	0	0	0	0	0	0
Zhejiang	0	0	0	1	1	1	0	0	0
Jiangxi	0	0	0	0	0	0	0	0	0
Fujian	0	0	0	0	0	0	0	0	0
Shanghai	0	0	0	0	0	0	0	0	0
Hainan	0	0	0	0	0	0	0	0	0
HongKong	0	0	0	0	0	0	0	0	0
Macao	0	0	0	0	0	0	0	0	0
China	4984	5540	5171	5918	7306	8166	7282	4593	6119

Table S13. As for Table S8 but for soybean (1000 Mt).

Province	2010	2011	2012	2013	2014	2015	2016	2017	2010-2017 Average
Heilongjiang	103	84	84	76	96	83	93	0	77
Hebei	71	52	31	36	70	62	53	36	51
Henan	39	72	58	22	61	38	35	4	41
Anhui	29	31	44	23	19	17	24	0	23
Tianjin	19	12	9	12	22	20	17	12	15
Jilin	15	9	6	15	21	17	19	3	13
Jiangsu	25	16	3	22	0	4	9	5	11
Shandong	15	14	11	12	13	12	10	4	11
Liaoning	10	9	7	8	13	10	10	5	9
Shanxi	4	7	4	4	8	6	5	3	5
Shaanxi	2	4	2	2	4	3	2	1	3
Nei Mongol	1	1	1	1	1	1	1	0	1
Shanghai	3	1	0	2	0	0	1	0	1
Beijing	1	1	0	0	1	1	1	1	1
Hubei	0	3	2	0	2	1	0	0	1
Chongqing	0	0	0	0	0	0	0	0	0
Hunan	0	0	0	0	0	0	0	0	0
Sichuan	0	1	0	0	1	1	0	0	0
Yunnan	0	0	0	0	0	0	0	0	0
Zhejiang	1	1	0	1	0	0	0	0	0
Guizhou	0	0	0	0	0	0	0	0	0
Xinjiang Uygur	0	0	1	0	1	0	0	0	0
Ningxia Hui	0	1	0	1	1	1	0	0	0
Jiangxi	0	0	0	0	0	0	0	0	0
Guangxi	0	0	0	0	0	0	0	0	0
Fujian	0	0	0	0	0	0	0	0	0
Gansu	0	0	0	0	0	0	0	0	0
Guangdong	0	0	0	0	0	0	0	0	0
Hainan	0	0	0	0	0	0	0	0	0
Qinghai	0	0	0	0	0	0	0	0	0
Xizang	0	0	0	0	0	0	0	0	0
HongKong	0	0	0	0	0	0	0	0	0
Macao	0	0	0	0	0	0	0	0	0
Taiwan	0	0	0	0	0	0	0	0	0
China	338	319	263	237	334	277	280	374	263

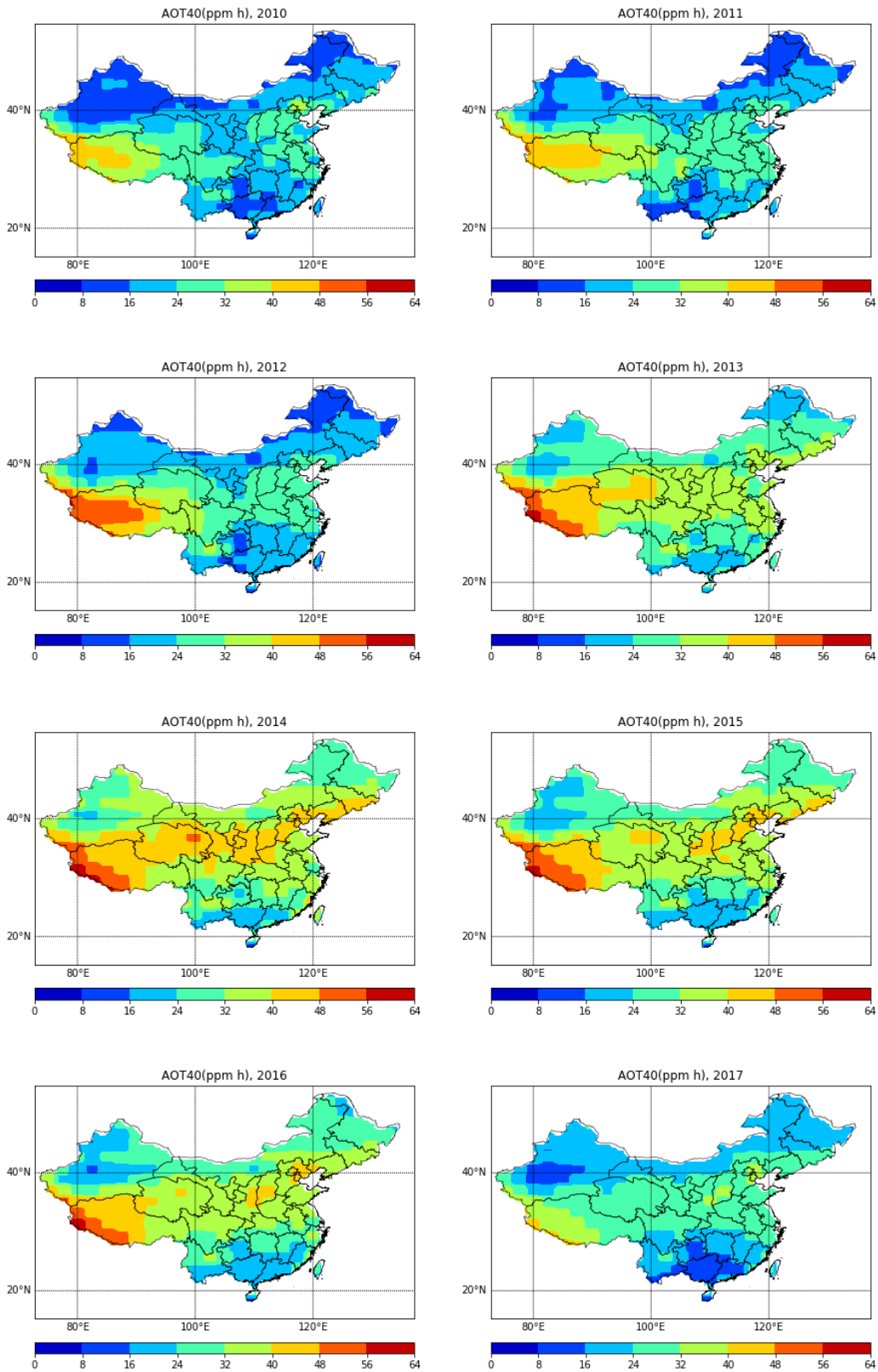


Fig. S1. The spatial distribution of the annual average accumulated AOT40 from 2010 to 2017 (unit of ppm h).

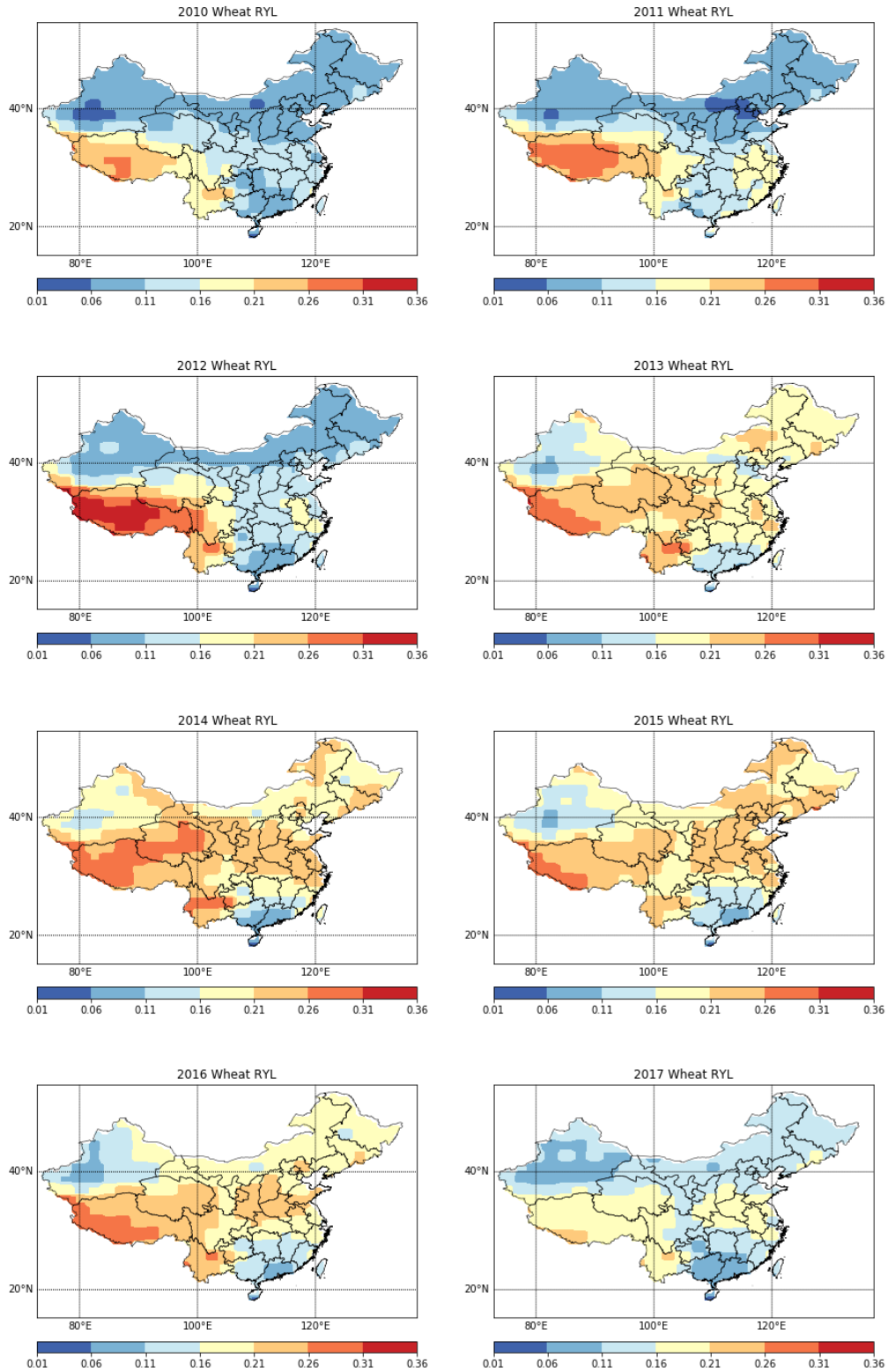


Fig. S2. Spatial distribution of relative yields loss (RYL) for wheat during growing season (March, April, May) from 2010 to 2017.

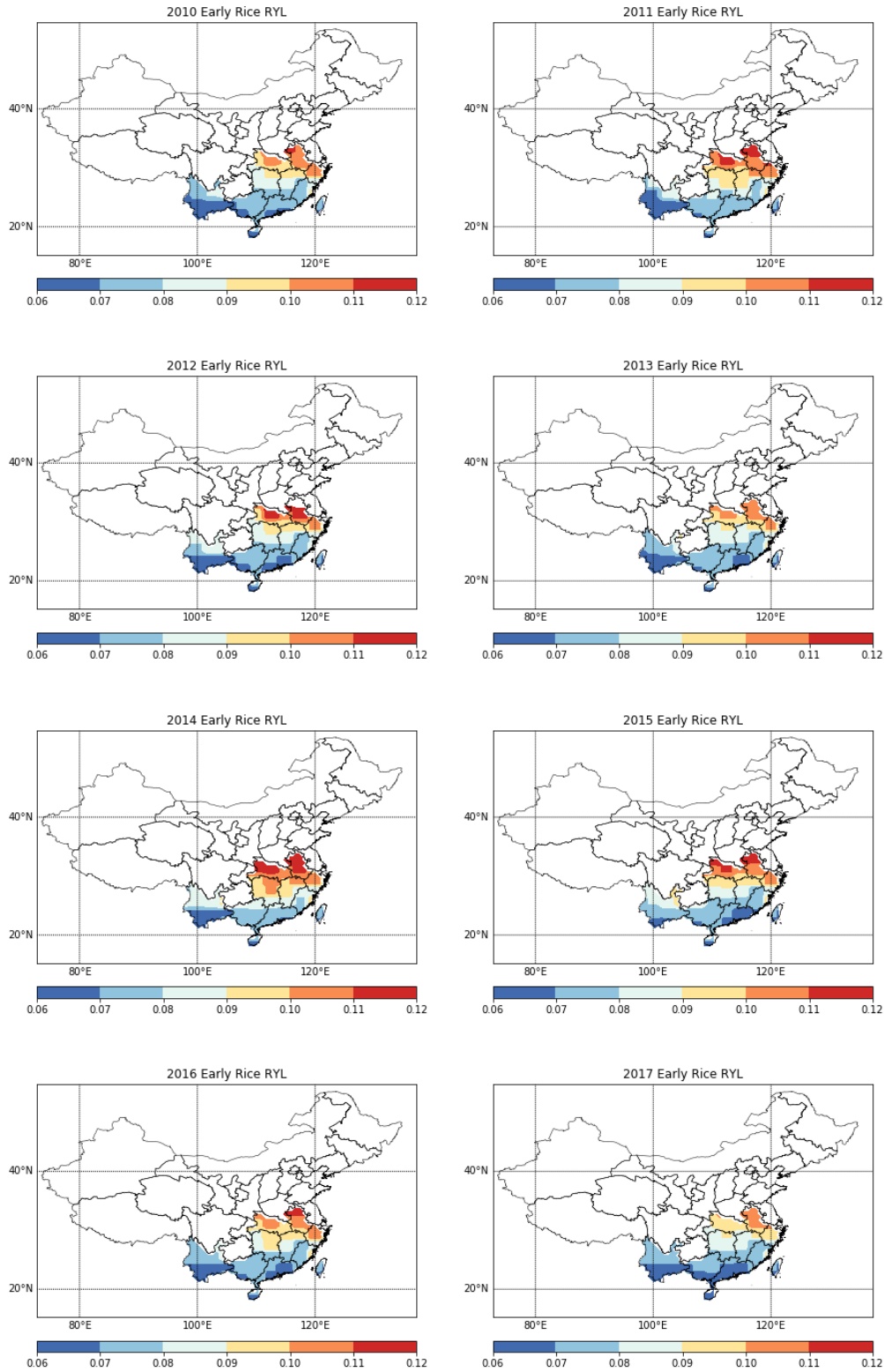


Fig. S3. As Fig. S2 but for double early rice (growing season May, June, July).

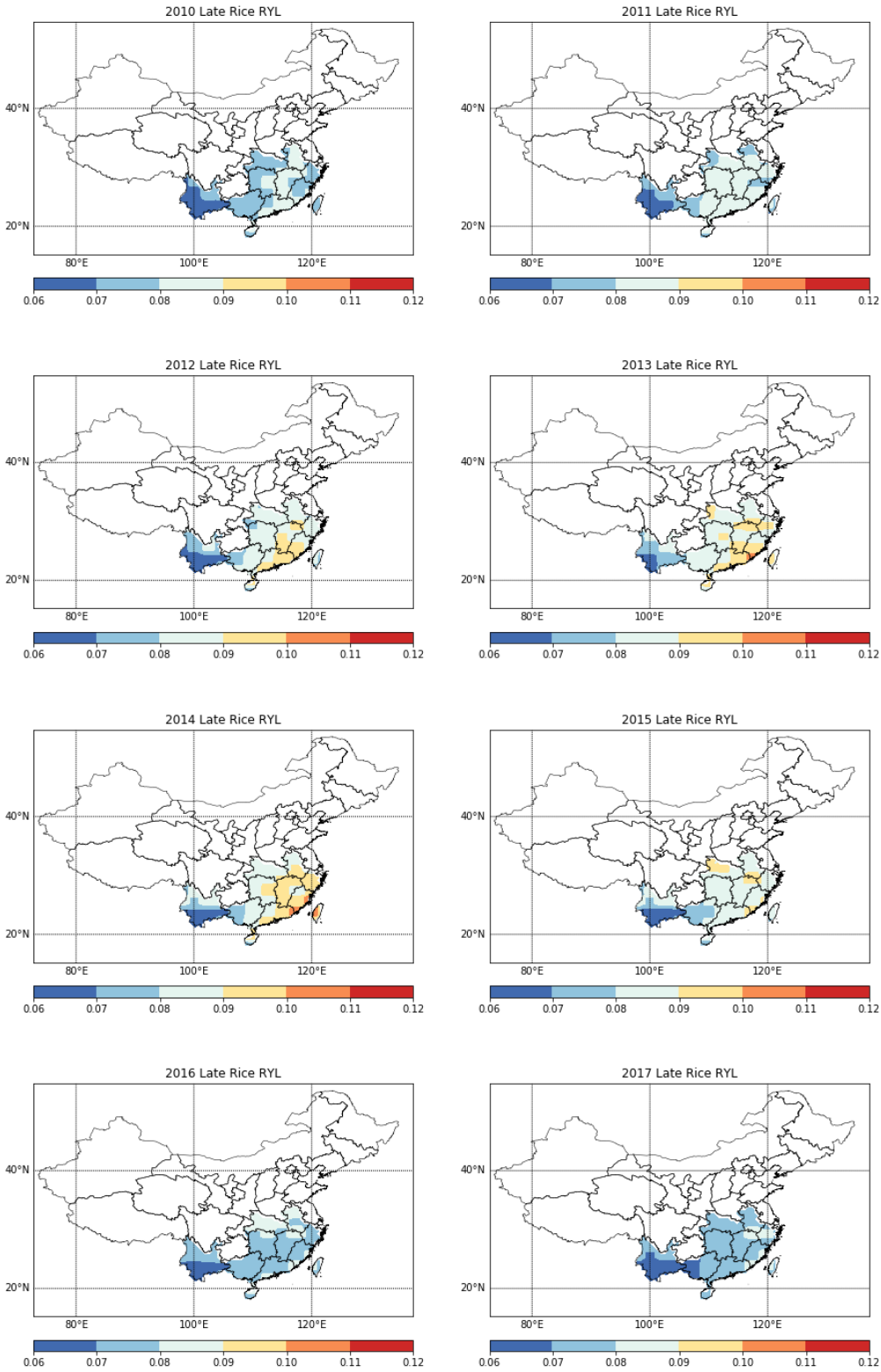


Fig. S4. As Fig. S2 but for double late rice (growing season September, October, November)

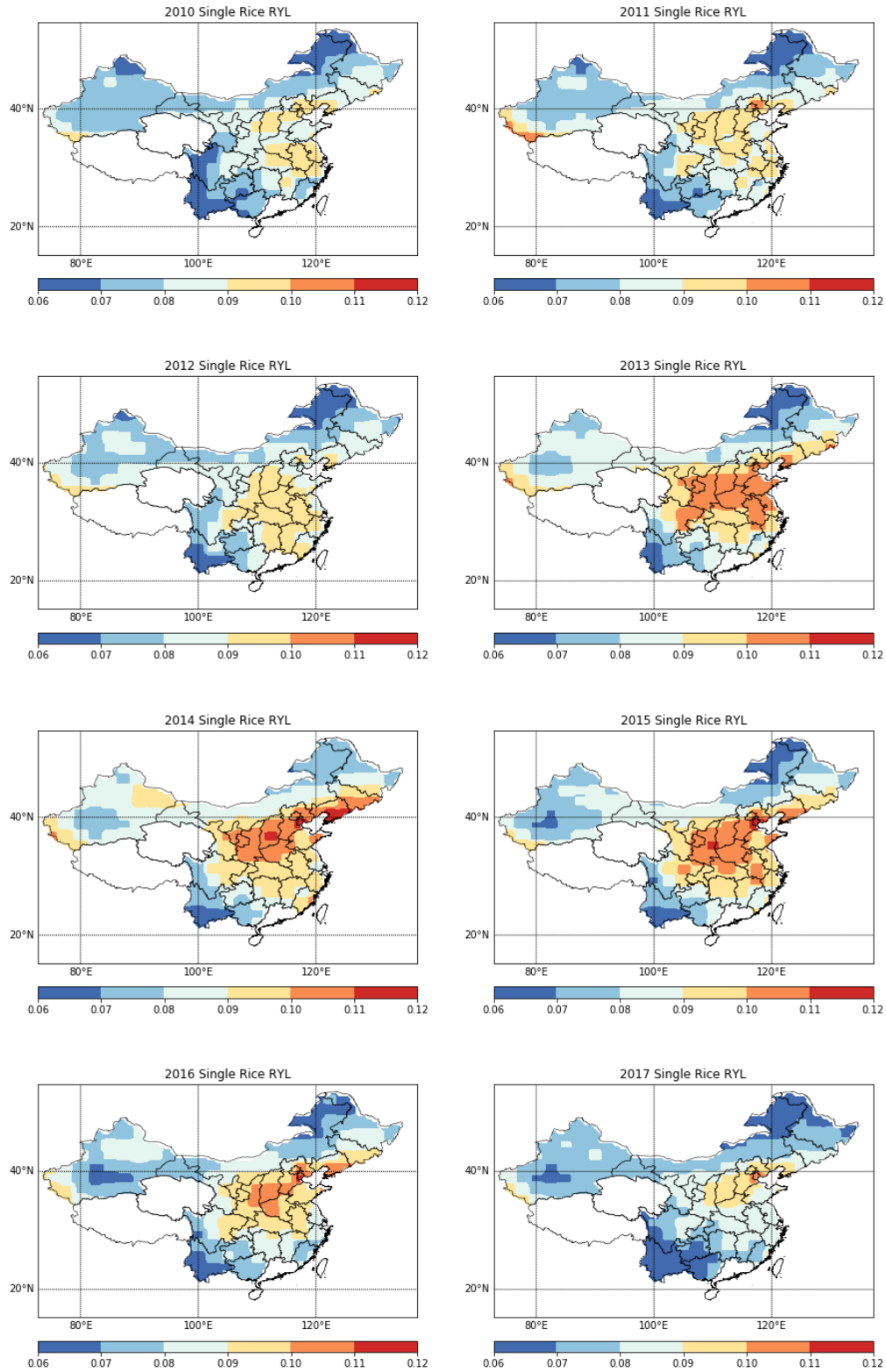


Fig. S5. As Fig. S2 but for single rice (growing season August, September, October).

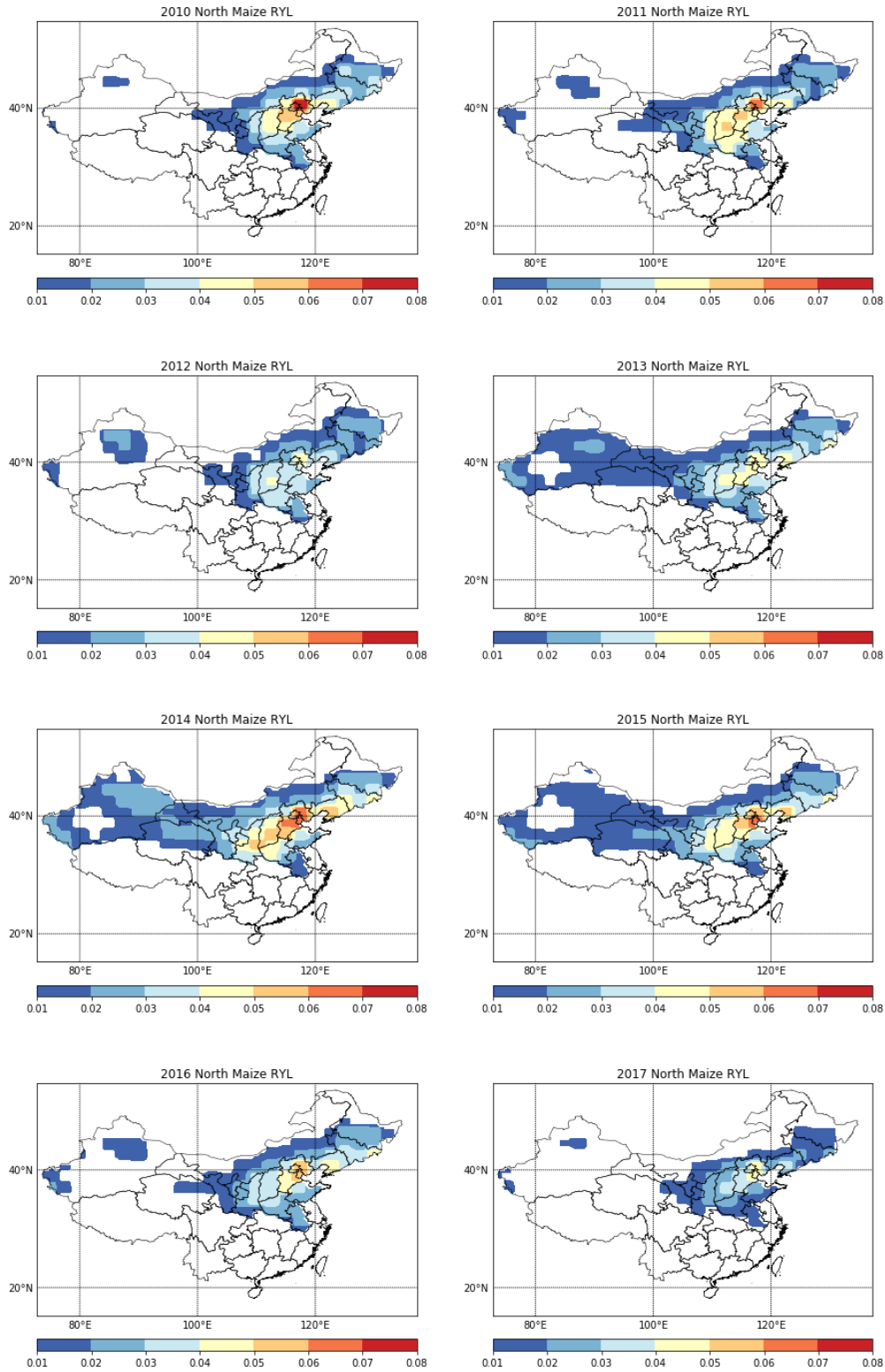


Fig. S6. As Fig. S2 but for north maize (growing season June, July, August).

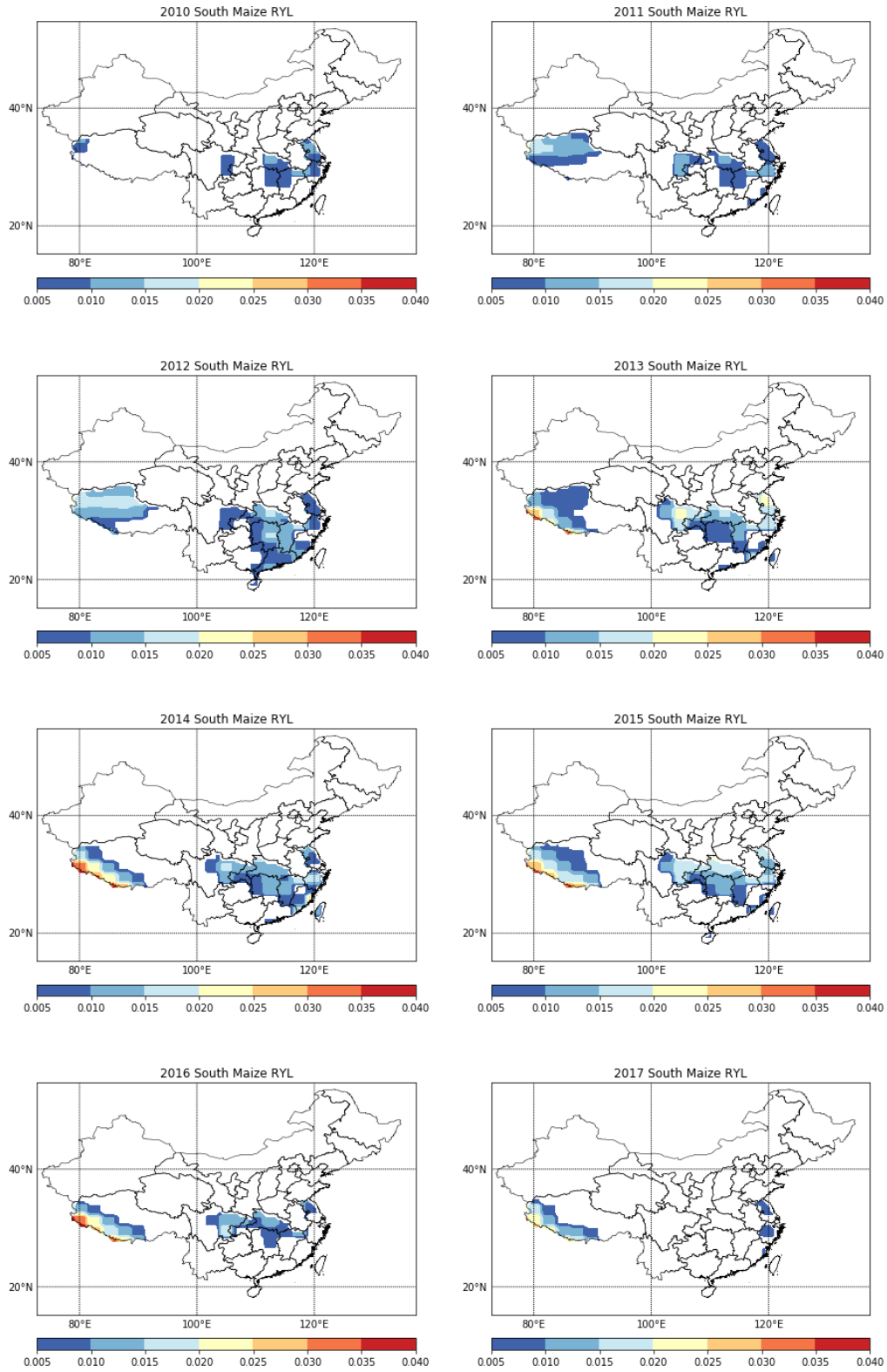


Fig. S7. As Fig. S2 but for south maize (growing season August, September, October).

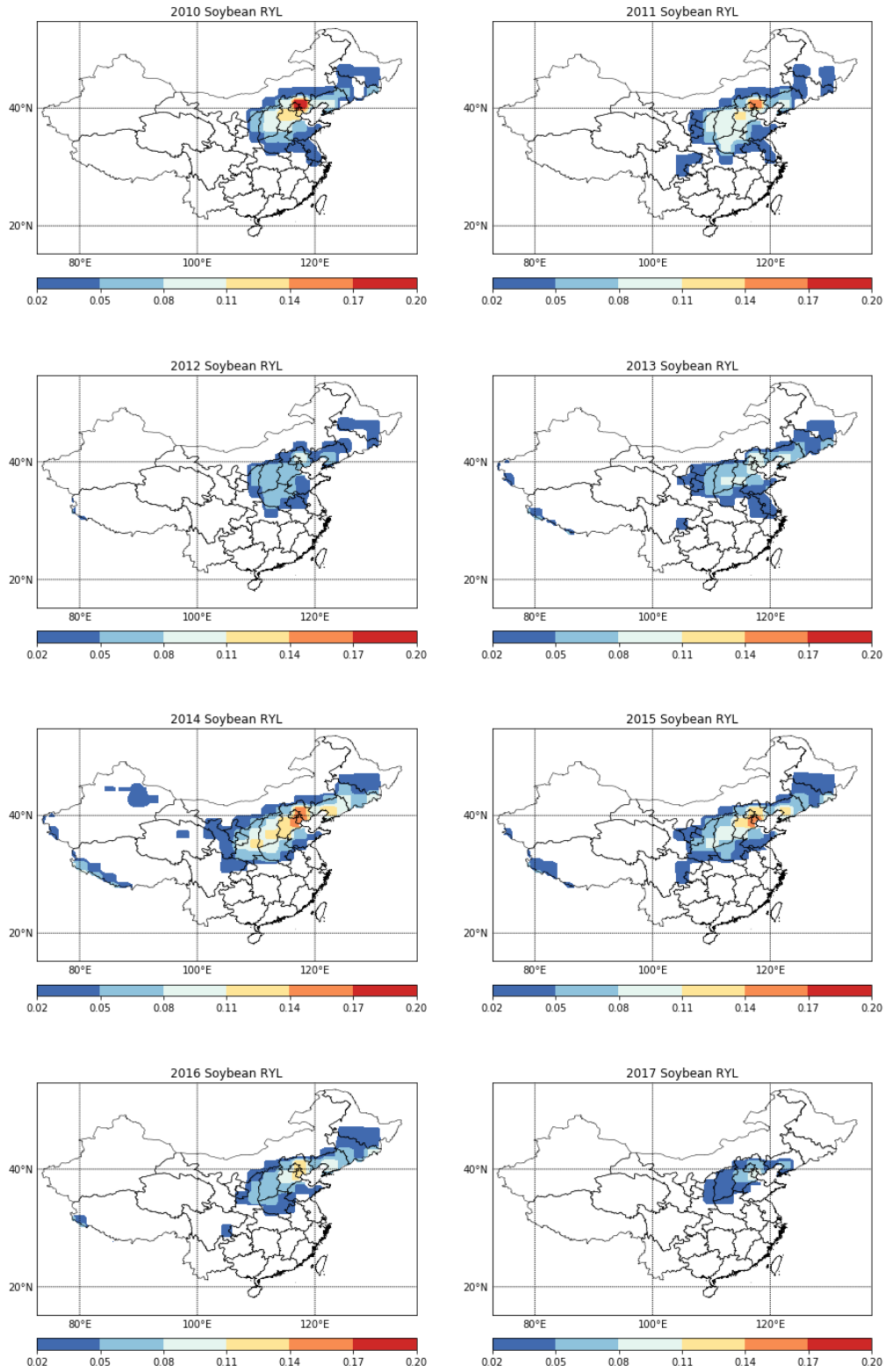


Fig. S8. As Fig. S2 but for soybean (growing season June, July, August).

Fig. S9. Annual Maize Production loss by province from 2010 to 2017 (1000 Mt)

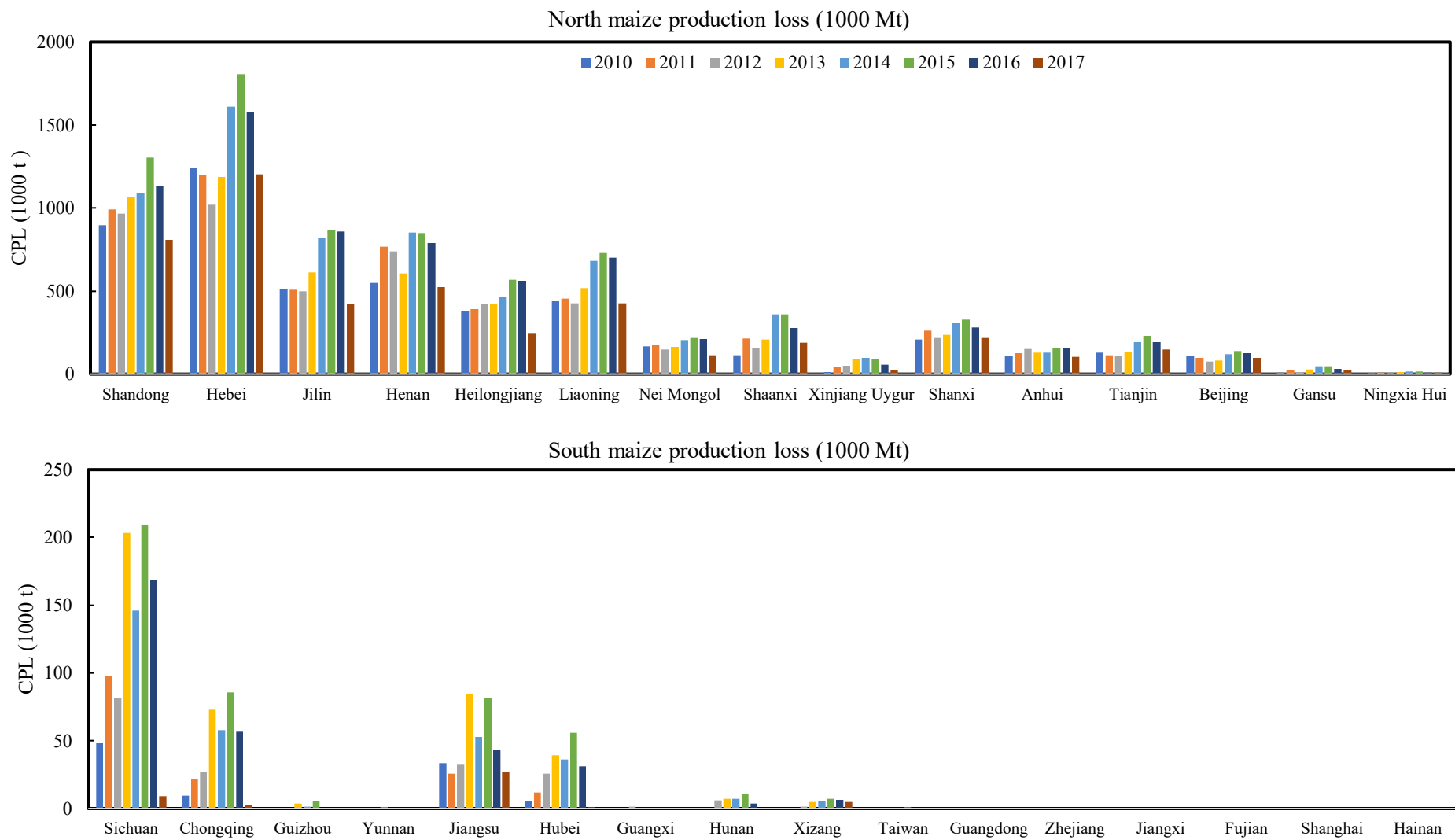


Fig. S10. Annual Soybean Production loss by province from 2010 to 2017 (1000 Mt)

