Uncertainty in Agricultural Responses using Climate Forecast

Climate variability associated with ENSO is now predictable.

This suggests a potential to tailor agricultural management to benefit from climate variability.

Deterministic/stochastic crop model is recognized method to address climate sensitivities and are used routinely in decision/management formulation.

Why Uncertainty in a crop model matters?

1. Most times, the only uncertainty considered is climate uncertainty
2. Quantification of uncertainty is required as input to any decision analysis
3. Uncertainty analysis should play a diagnostic role in an assessment to highlight factors whose uncertainty is pivotal in determining actions
4. We have not put enough efforts to document impacts of uncertainty on decisions

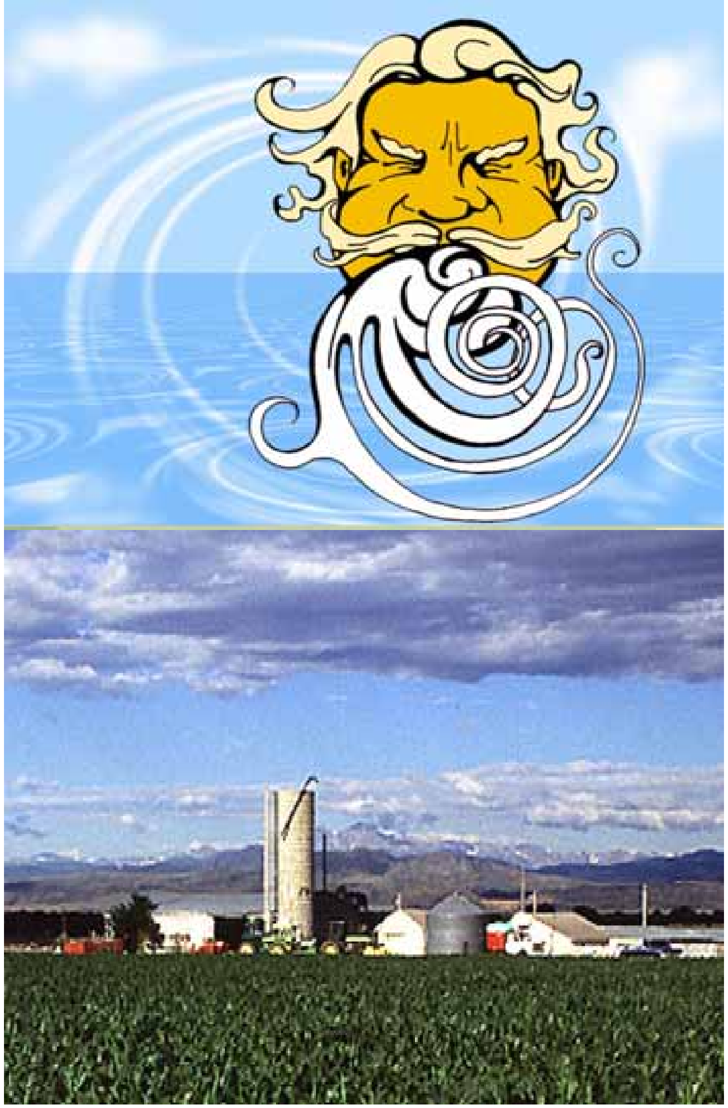
Ho: Uncertainties add another level of complexity in decision making.

When uncertainty is likely to trigger change in a decision?

An evolving research theme in the SECC

Shrikant Jagtap (SECC Team)

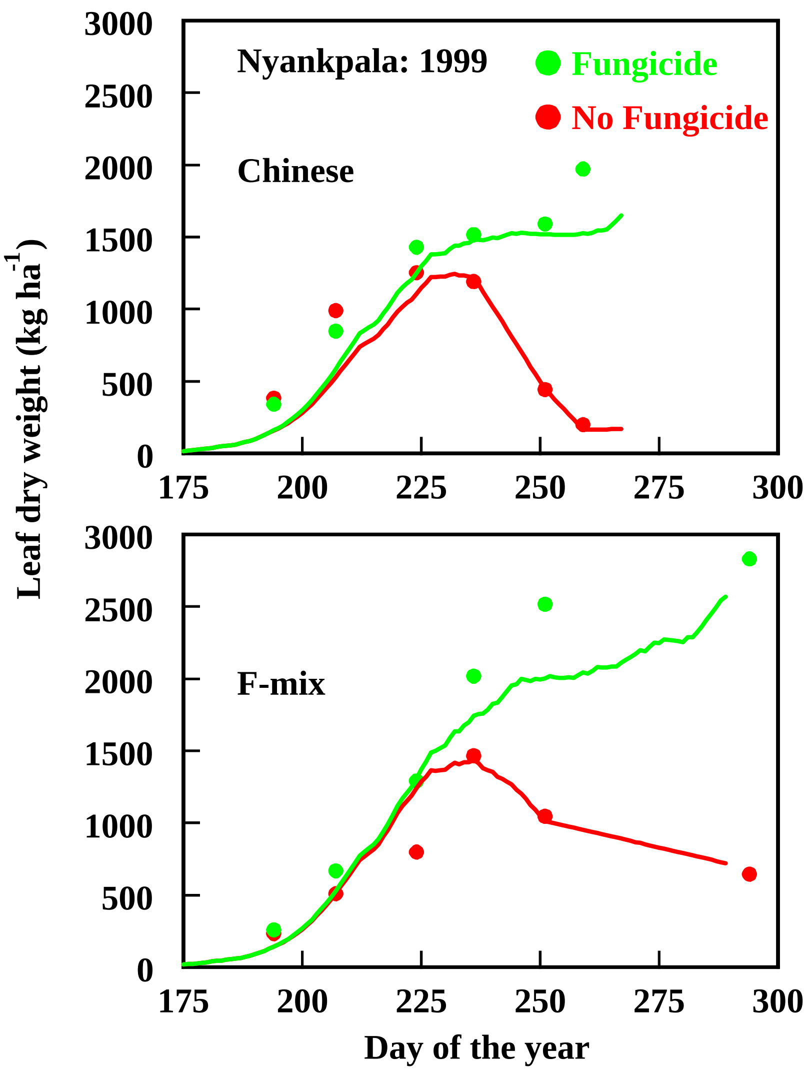
How uncertainty is currently handled in Ag Models?



Uncertainty in Agricultural Responses using Climate Forecast

How uncertainty is currently handled in Ag Models?

- Field calibration/validation
- Spatial / temporal probability inputs



Uncertainty in Agricultural Responses using Climate Forecast

How uncertainty is currently handled in Ag Models?

- Field calibration/validation

- Spatial / temporal probability inputs

Examples within the SECC:

✓ Drought mitigation

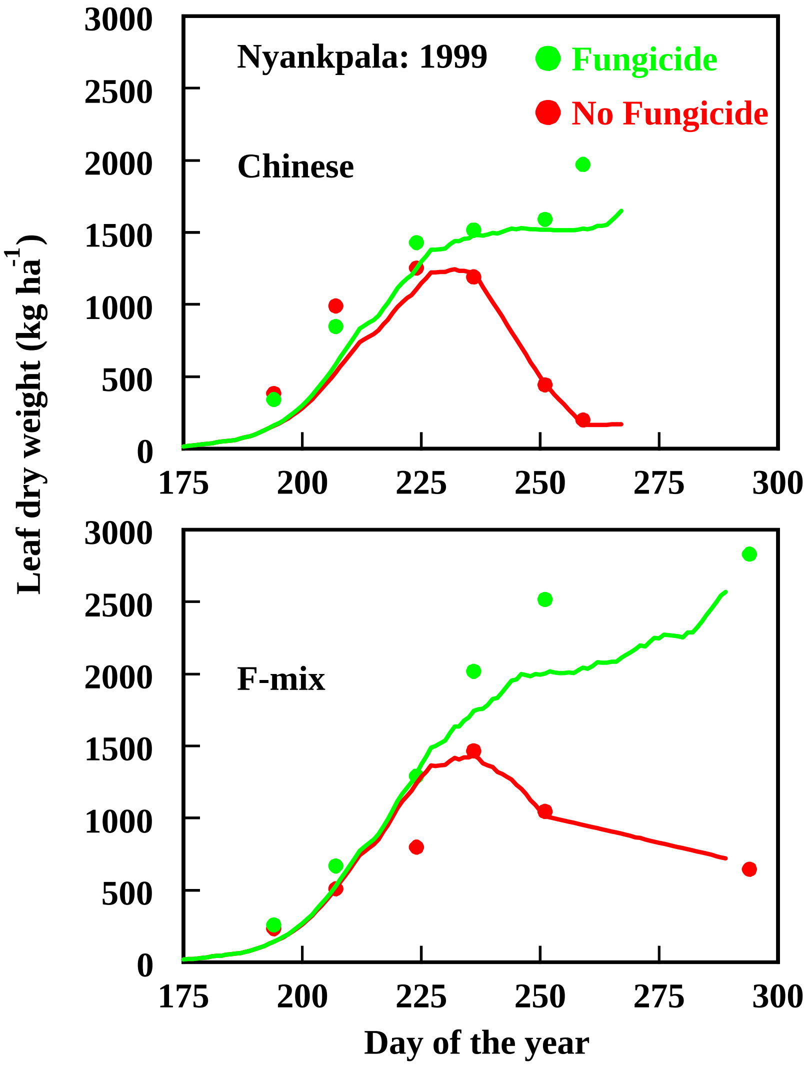
✓ Crop mix

✓ Risk management/Insurance Products

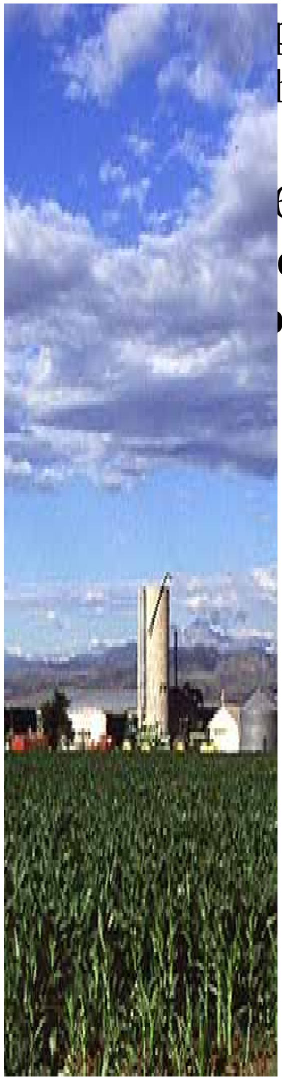
✓ Environmental protection

4-sources of uncertainties

1. Model
2. Downscaling climate forecast
3. Validity of assumptions
4. Scaling-up/ aggregation



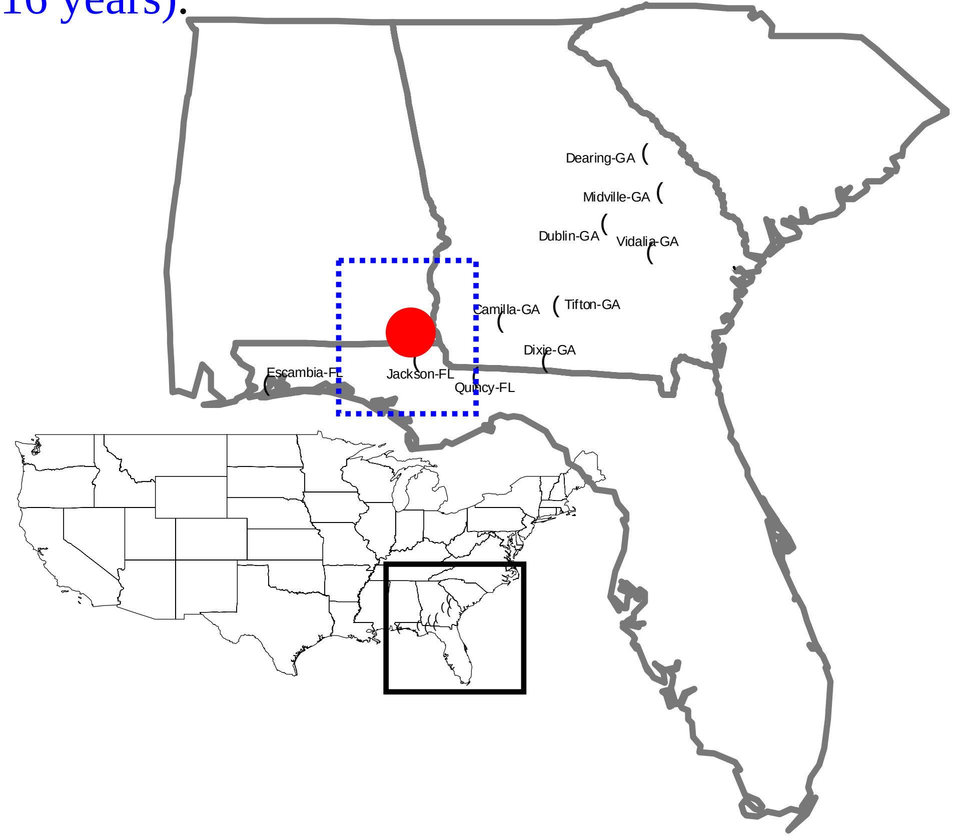
Uncertainty in Agricultural Responses using Climate Forecast



Case Study: Sensitivity of peanut yields, a major cash crop, on a North Florida peanut farm in **Jackson County**. Jackson county has been the highest peanut growing county in the state.

65-years climate data suggests that **higher rainfall** and **cooler emperatures** are observed during El Nino (14 years), with the **pposite being true** in La Nina (16 years).

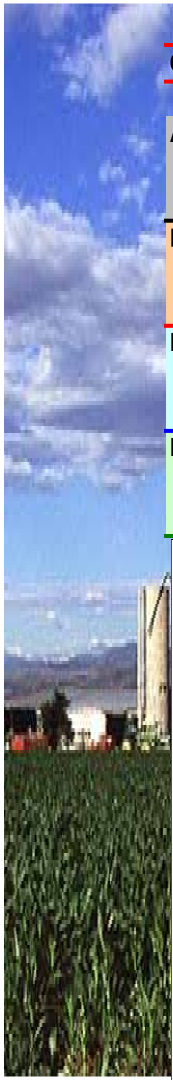
Virtual simulations used the PNUT-GRO, a well calibrated and tested simulator, using current management practices in the region for varieties, fertilization and sowing dates (16 April to 12 June at weekly interval).



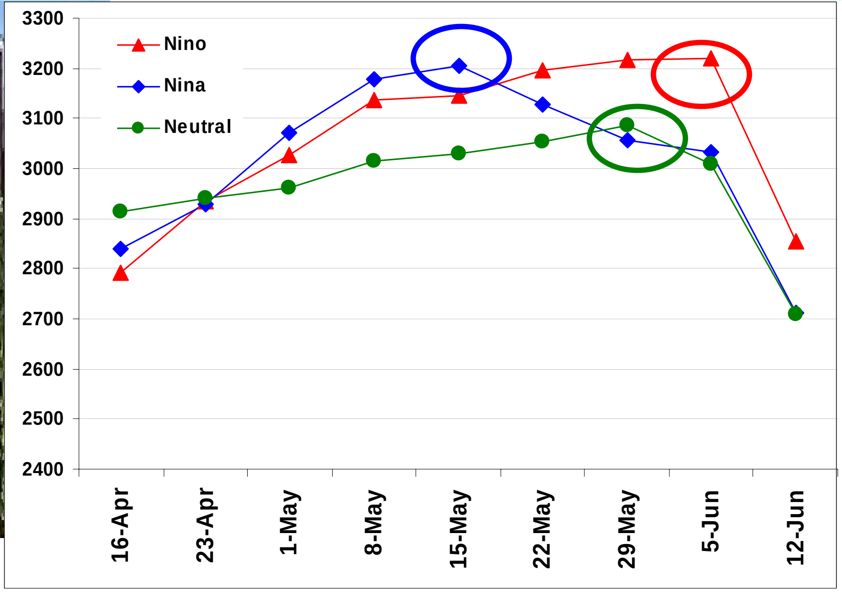
Source : www.AgClimate.org

Uncertainty in Agricultural Responses using Climate Forecast

Virtual simulations used the PNUT-GRO model



Georgia-Green Simulated yield			16-Apr	23-Apr	1-May	8-May	15-May Recommended Dates	22-May Recommended Dates	29-May	5-Jun	12-Jun
	Years	Uncorrected simulated yields									
All yrs	**65**	**Avg (kg/ha)**	2870	2937	3003	3082	3097	3103	**3107**	3060	2742
		SD (kg/ha)	1379	1393	1376	1337	1258	1193	1159	1142	1301
		CV(%)	48	47	46	43	41	38	37	37	47
Nino	14	**Avg (kg/ha)**	2792	2935	3027	3138	3146	3197	3216	**3219**	2856
		SD (kg/ha)	1672	1719	1689	1668	1554	1436	1360	1313	1495
		CV(%)	60	59	56	53	49	45	42	41	52
Nina	16	**Avg (kg/ha)**	2839	2928	3072	3179	**3204**	3128	3055	3033	2712
		SD (kg/ha)	1242	1235	1210	1193	1163	1150	1115	1104	1274
		CV(%)	44	42	39	38	36	37	36	36	47
Neutral	35	**Avg (kg/ha)**	2915	2942	2962	3015	3029	3054	**3086**	3009	2709
		SD (kg/ha)	1350	1360	1350	1289	1203	1140	1125	1116	1269
		CV(%)	46	46	46	43	40	37	36	37	47



1. The case study shows potential for enhancing peanut yields on average about 4% by tailoring planting dates to expected ENSO conditions.
2. Tailored management calls for **later** planting during an El Nino, and **earlier** planting in La Nina.

Sources of Uncertainty: 1. Model errors

Sources of uncertainty: The assumed form of model is likley to have substantial effect on the results of analysis.

							Recommended Dates				
Georgia-Green Simulated yield			**16-Apr**	**23-Apr**	**1-May**	**8-May**	**15-May**	**22-May**	**29-May**	**5-Jun**	**12-Jun**
	Years	**Uncorrected simulated yields**									
All yrs	**65**	**Avg (kg/ha)**	2870	2937	3003	3082	3097	3103	**3107**	3060	2742
		SD (kg/ha)	1379	1393	1376	1337	1258	1193	1159	1142	1301
		CV(%)	48	47	46	43	41	38	37	37	47
Nino	14	**Avg (kg/ha)**	2792	2935	3027	3138	3146	3197	3216	**3219**	2856
		SD (kg/ha)	1672	1719	1689	1668	1554	1436	1360	1313	1495
		CV(%)	60	59	56	53	49	45	42	41	52
Nina	16	**Avg (kg/ha)**	2839	2928	3072	3179	**3204**	3128	3055	3033	2712
		SD (kg/ha)	1242	1235	1210	1193	1163	1150	1115	1104	1274
		CV(%)	44	42	39	38	36	37	36	36	47
Neutral	35	**Avg (kg/ha)**	2915	2942	2962	3015	3029	3054	**3086**	3009	2709
		SD (kg/ha)	1350	1360	1350	1289	1203	1140	1125	1116	1269
		CV(%)	46	46	46	43	40	37	36	37	47

Simulated yields corrected for spotted wilt virus of peanuts (Ref. Bulletin 1165, UGA, 2003)											
All yrs	**65**	**Avg (kg/ha)**	2152	2203	2703	2774	3097	**3103**	2951	2907	2330
		SD (kg/ha)	1034	1045	1238	1203	1258	1193	1101	1085	1106
		CV(%)	48	47	46	43	41	38	37	37	47
Nino	14	**Avg (kg/ha)**	2094	2201	2725	2824	3146	**3197**	3056	3058	2427
		SD (kg/ha)	1254	1290	1520	1502	1554	1436	1292	1247	1270
		CV(%)	60	59	56	53	49	45	42	41	52
Nina	16	**Avg (kg/ha)**	2130	2196	2765	2861	**3204**	3128	2903	2881	2306
		SD (kg/ha)	932	926	1089	1074	1163	1150	1059	1048	1083
		CV(%)	44	42	39	38	36	37	36	36	47
Neutral	35	**Avg (kg/ha)**	2186	2206	2665	2714	3029	**3054**	2932	2858	2303
		SD (kg/ha)	1013	1020	1215	1160	1203	1140	1069	1060	1078
		CV(%)	46	46	46	43	40	37	36	37	47

Sources of Uncertainty: 1. Model errors

Methods for dealing with uncertainty on decision making

a. Hybrid model (s)

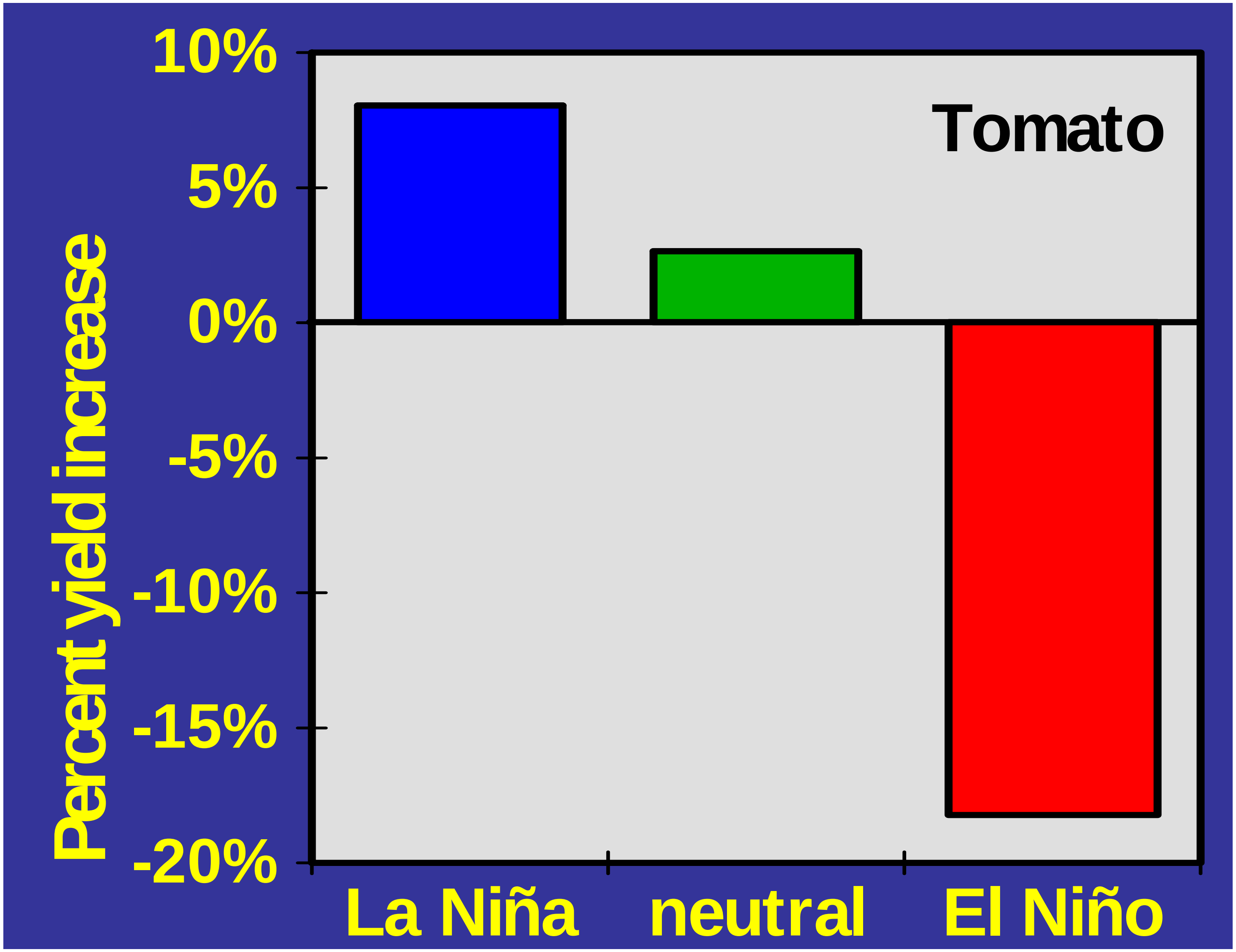
Calculate your risk	Risk Index
Peanut variety	10-50
Planting date	5-30
Plant population	5-25
Row pattern	5-15
Tillage	5-15
Insecticide used	5-15
Total Index Value	

b. Agricultural Response Team - an inter-disciplinary or agency, effort to effectively communicating forecast driven decisions and planning for agriculturally-related activities

c. Participatory development and evaluation of forecast product (i.e. Australian example)

Source of Uncertainty: Variability in ENSO signal

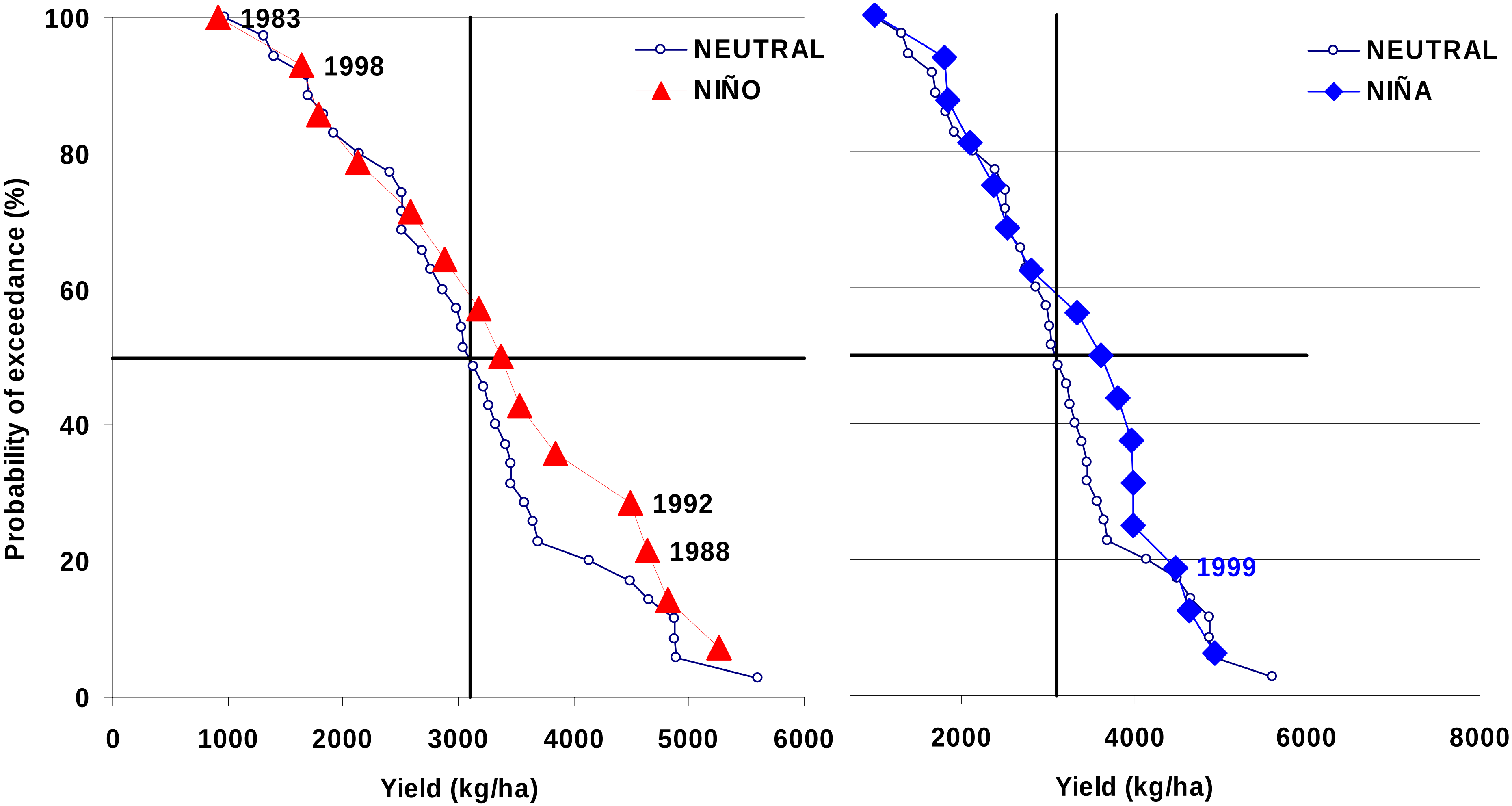
Sources of Uncertainty: 2. Downscaling forecast



Source of Uncertainty: Variability in ENSO signal

Sources of Uncertainty: 2. Strength of ENSO

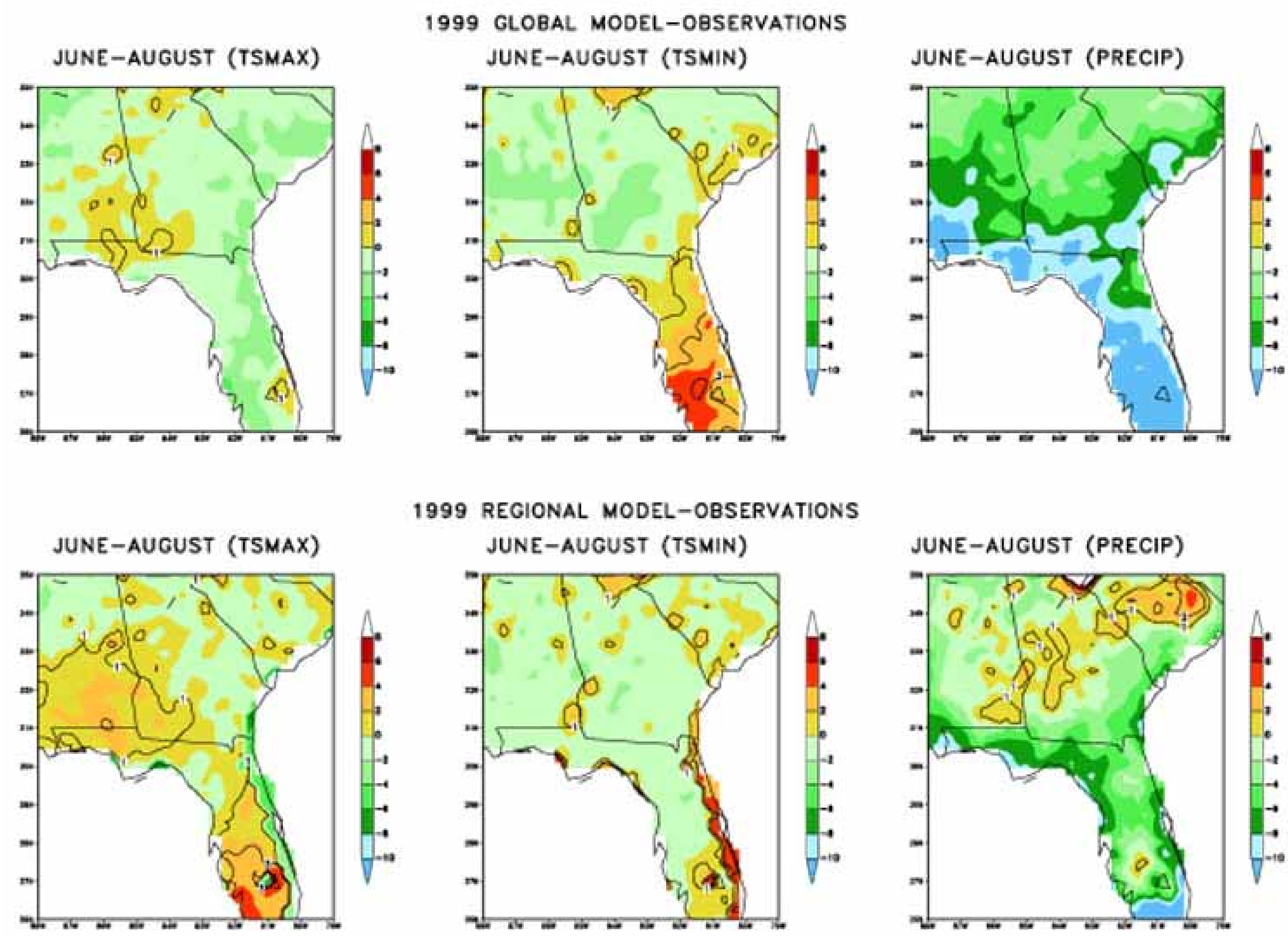
Success in long-lead seasonal forecasts has led to, often unrealistic expectations. The fact remains that climate predictions have modest skill, **and in many instances no or marginal skill, even with strong ENSO signal**.



Sources of Uncertainty: 2. Downscaling forecast

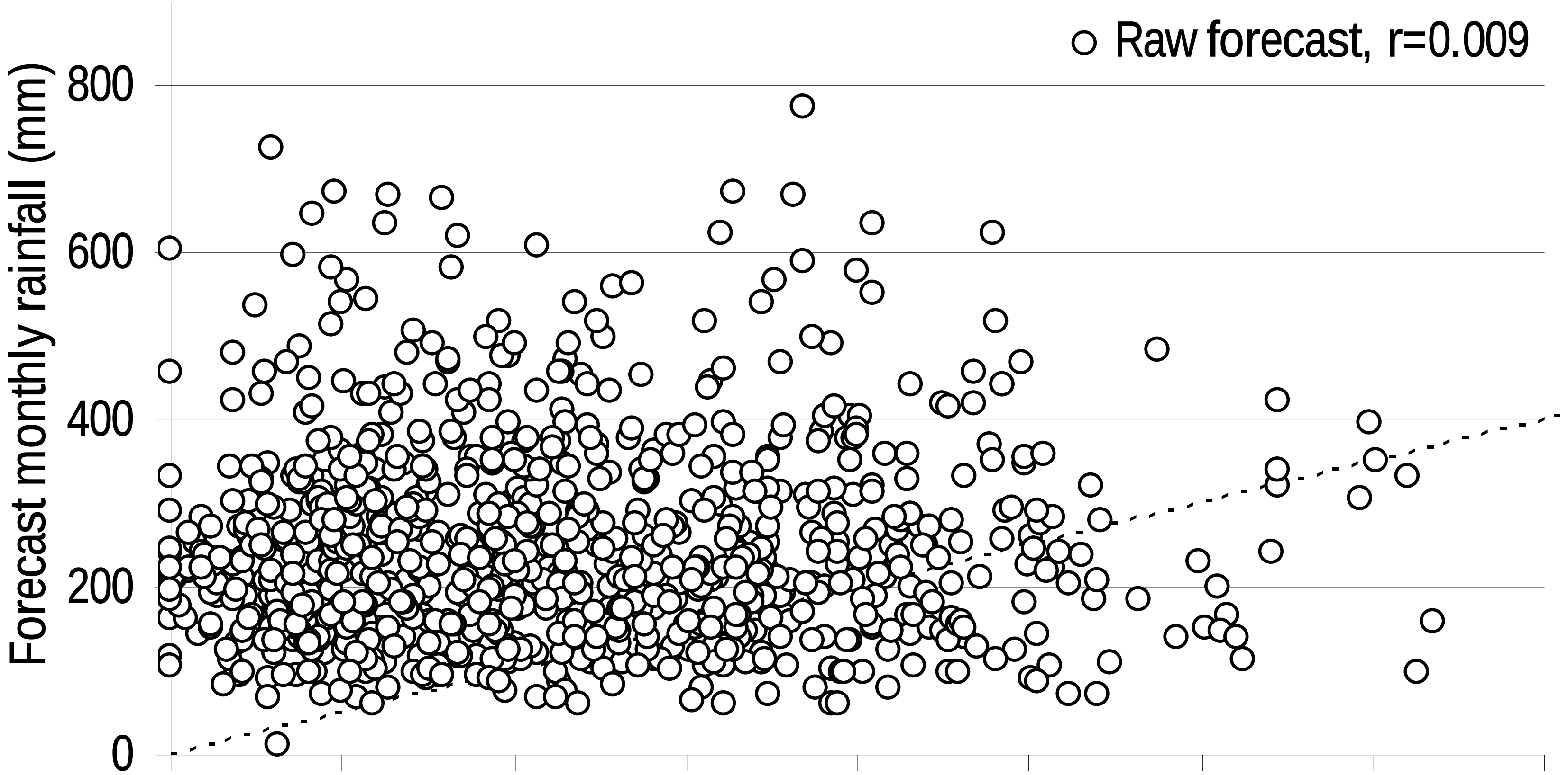
Methods for dealing with uncertainty on decision making

a. Enhance reliability of coupled ocean-atmospheric models



Raw forecast (95% CI r>0.065,n=906)

RMSE=195 mm
MBE =132 mm
d =0.31

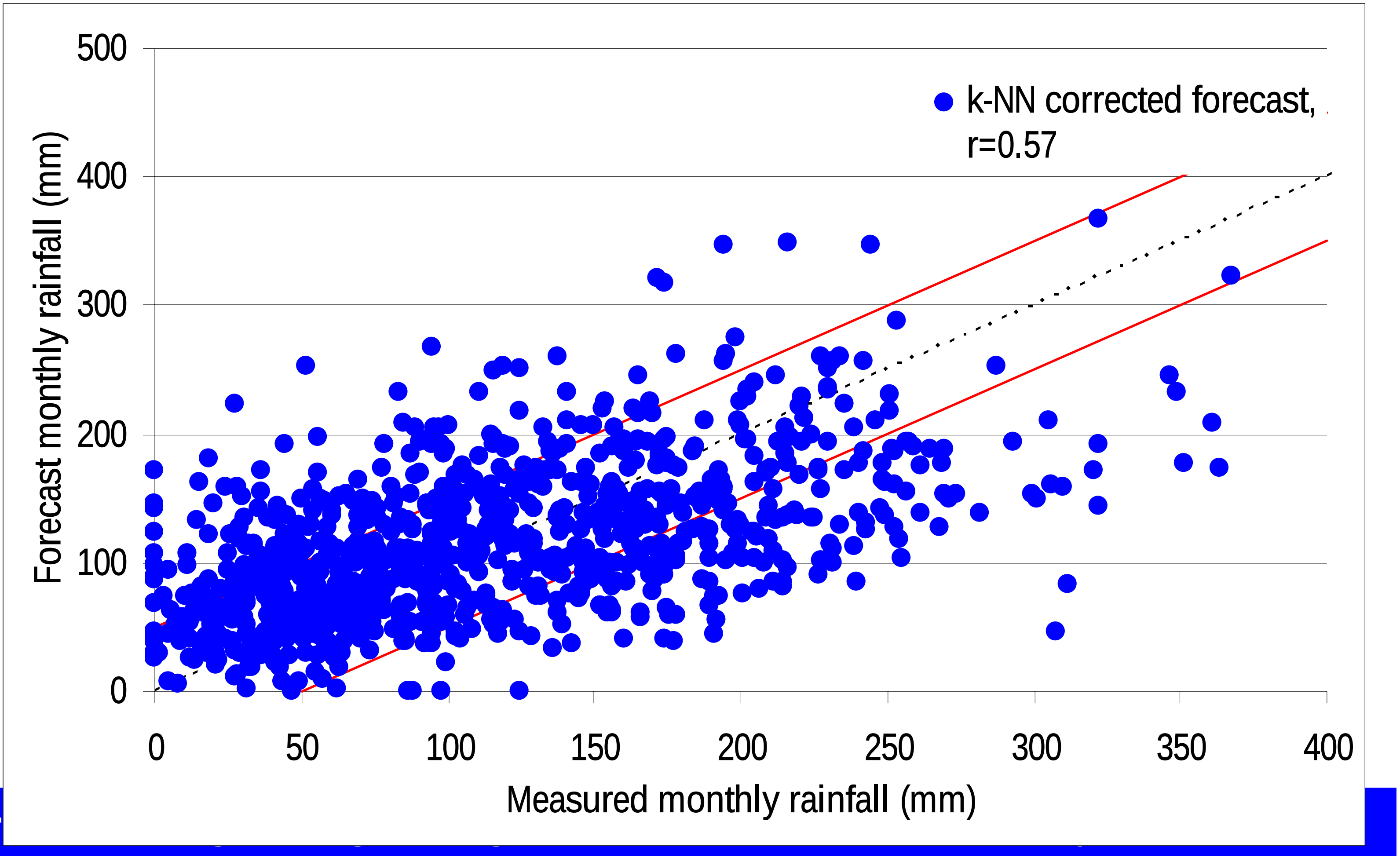


K-NN method corrected forecast (95% CI r>0.065,n=906)

RMSE= 66 mm (Raw=195 mm and MBC=87 mm)

MBE = -0.5 mm

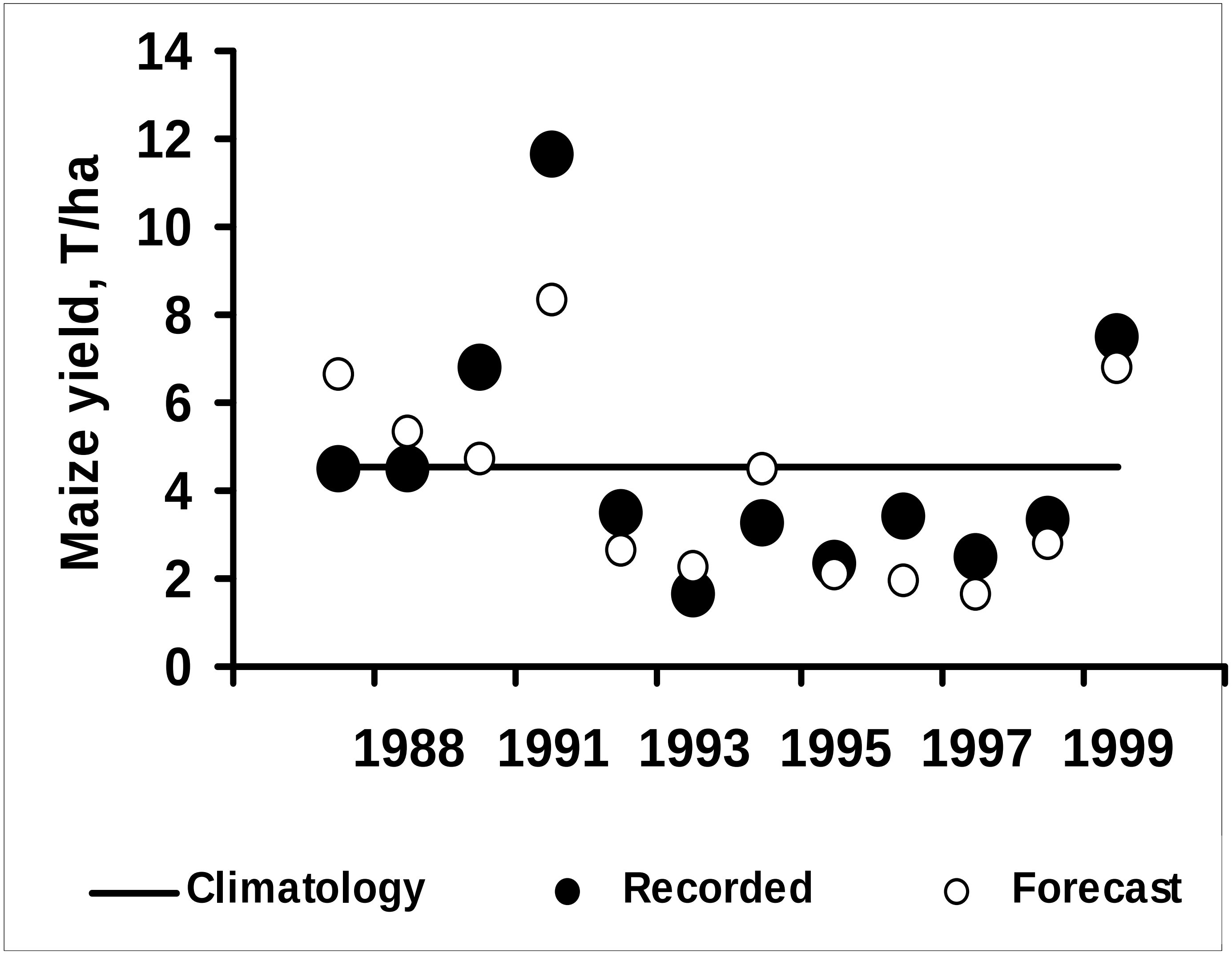
d = 0.74 (Raw=0.31 and MBC=0.52)



Sources of Uncertainty: 2. Variability in ENSO strength

Methods for dealing with uncertainty on decision making

b. Integrated assessment with coupled ocean-atmospheric & crop models



Sources of Uncertainty: 3. Error of judgment (assumptions)

Value of climate forecast to users

Within in the SECC and elsewhere, it has been shown that climate forecasts have tangible economic value for users.

Assumptions/hypothesis

1. the user must exercise the prescribed process over many years in a disciplined and consistent manner.

2. The user's decision-making environment remains static for entire period,

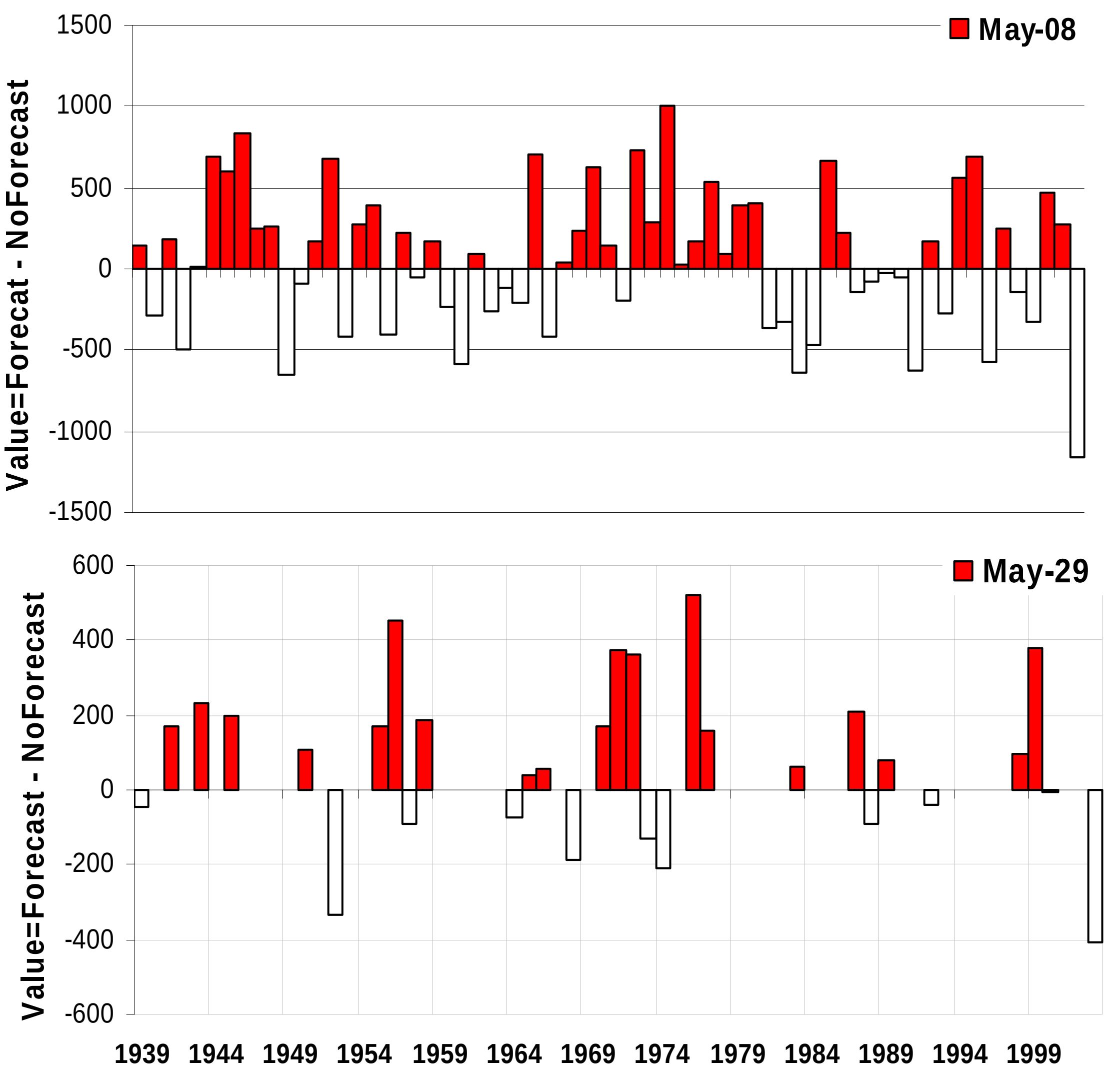
3. The user does not abandon use of the forecast, even it the forecast was wrong in several successive years.

Let's see what happens when a grower in Jackson county modifies planting date according to ENSO phase forecast we developed earlier……

Sources of Uncertainty: 3. Validity of assumptions

Year	Forecast	May-08	May-29
1939	3335	146	-46
1940	2406	-288	0
1941	3837	188	168
1942	2761	-490	0
1943	3817	11	232
1944	3047	685	0
1945	3626	596	199
1946	4880	831	0
1947	2519	251	0
1948	3268	256	0
1949	5607	-647	0
1950	3993	-93	108
1951	2508	174	0
1952	1789	680	-333
1953	2683	-419	0
1954	1309	279	0
1955	3970	390	167
1956	4632	-408	451
1957	1846	218	-89
1958	3373	-54	187
1959	2148	173	0
1960	3328	-238	0
1961	3465	-584	0
1962	1828	89	0
1963	4498	-257	0
1964	5258	-114	-74
1965	2373	-214	37
1966	2588	698	57
1967	3407	-411	0
1968	2529	35	-186
1969	3570	232	0
1970	2887	627	172
1971	4938	145	375
1972	1006	-197	362
1973	2132	725	-130
1974	2097	282	-209

Recommendation: Ideal planting window: Mid-May



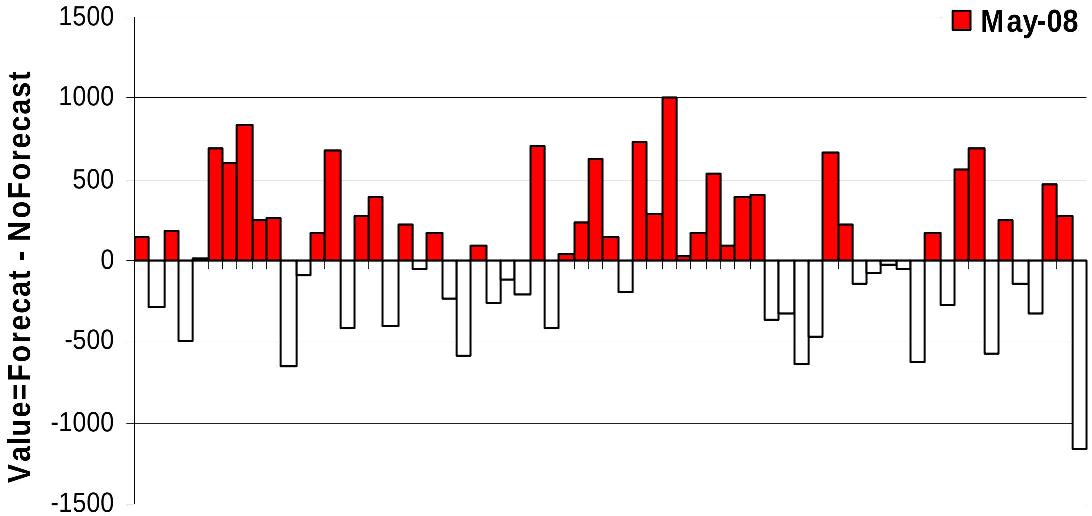
Sources of Uncertainty: 3. Error of judgment (measurement)

Methods for dealing with the psychology of users

a. How resilient is the user? – risk aversion/utility theory?

b. How many times, before the user abandons use of forecast?

c. Take into account these uncertainties to provide a sense of what skill levels are necessary to increase chance that even relatively short sequence of decisions will be of value.



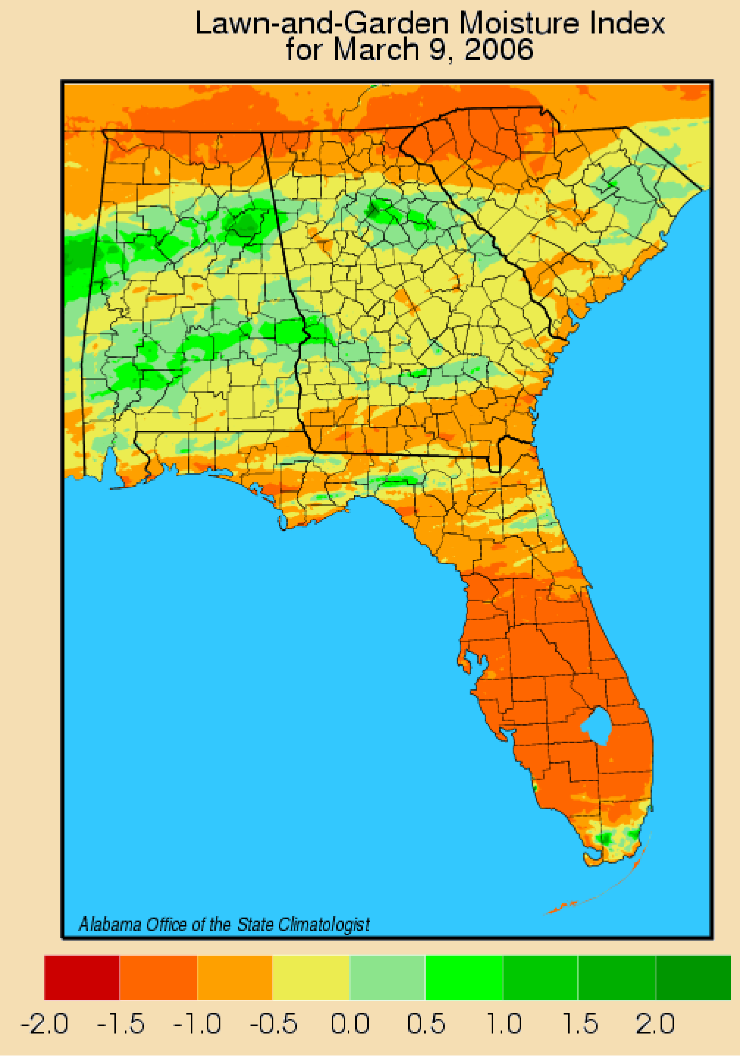
Sources of Uncertainty: 4. Scaling-up / Aggregation with plot-scale models

There are clear advantages to adopting plot-scale models to regional scale, as recommendations and policies are generally implemented at this scale.

SECC – wants to produce forecasts of agricultural responses at watershed and state scales using climate forecasts, and need to know the forecast uncertainty

In applying a field scale model over space may require perfect aggregation of effects of all possible input combinations over geographic space and probability space.

What sort of uncertainties are introduced by this mismatch of scales?

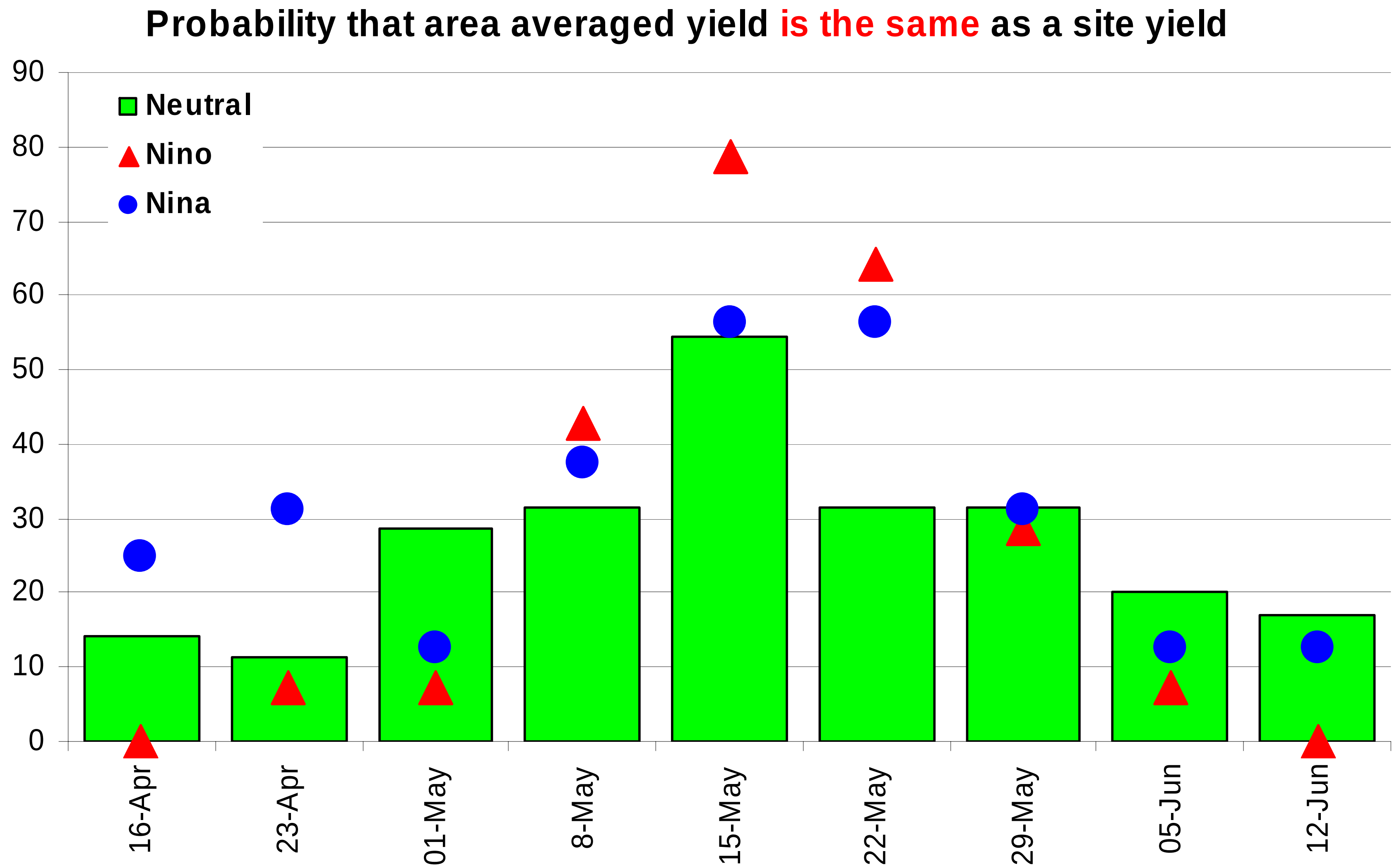


Sources of Uncertainty: 4. Scaling up plot-scale models

Ho: The use of probabilistic inputs will underestimate risks that producers face!

		April-16	April-23	May -1	May-8	15-May	May 22	May 29	June-05	June-12	Mean	SE	16-Apr p-value
1939	**NIÑA**	3755	3457	3235	3189	3335	3186	3585	4125	3979	3539	116	**0.050**
1940	**NEUTRAL**	3066	3152	2931	2694	2091	1921	1828	1488	1057	2247	249	**0.006**
1941	**NIÑO**	2431	3018	3373	3649	3744	3697	3372	3373	3174	3314	136	**0.000**
1942	**NEUTRAL**	4615	4448	3814	3252	2749	2219	1922	1788	1446	2917	392	**0.001**
1943	**NIÑA**	3150	3333	3508	3806	3817	3740	3382	3268	3074	3453	94	**0.006**
1944	**NEUTRAL**	1440	1720	2093	2362	2944	3754	4662	4821	4595	3154	445	**0.002**
1945	**NIÑA**	2008	2312	2601	3030	3626	3968	4111	4173	3704	3281	272	**0.001**
1946	**NEUTRAL**	3420	3427	3697	4049	4178	4702	4880	4812	4477	4183	192	**0.002**
1947	**NEUTRAL**	2694	2537	2347	2269	2591	2905	3133	3673	3816	2885	185	**0.166**
1948	**NEUTRAL**	1200	1694	2451	3012	3482	3891	4144	4029	3852	3084	359	**0.000**
1949	**NEUTRAL**	5429	5989	6230	6254	6080	5876	5607	5407	5292	5796	123	**0.009**
1950	**NIÑA**	2436	2709	3445	4086	3993	4006	3923	3522	3136	3473	201	**0.000**
1951	**NEUTRAL**	2115	1928	2110	2335	2484	2604	2761	2779	2586	2411	102	**0.010**
1952	**NIÑO**	475	553	770	1110	1526	2282	2968	3179	0	1429	381	**0.018**
1953	**NEUTRAL**	2717	2833	3137	3102	2688	2521	2508	2220	1788	2613	141	**0.240**
1954	**NEUTRAL**	644	693	839	1029	1103	1090	969	884	657	879	61	**0.002**
1955	**NIÑA**	1801	2230	2832	3580	3970	4244	4181	3955	3561	3373	295	**0.000**
1956	**NIÑA**	4443	4589	4963	5040	4632	4205	3885	3574	3824	4351	171	**0.302**
1957	**NIÑA**	1965	1811	1683	1629	1846	1687	1280	1154	1179	1581	101	**0.003**
1958	**NIÑO**	4052	3808	3508	3427	3069	2800	2530	2132	1787	3013	255	**0.002**
1959	**NEUTRAL**	2713	2477	2270	1975	1982	2230	2508	2757	3037	2439	120	**0.026**
1960	**NEUTRAL**	3324	3534	3566	3565	3518	3369	3268	3352	3482	3442	38	**0.007**
1961	**NEUTRAL**	4102	4151	4019	4049	3845	3509	3328	2919	2280	3578	213	**0.020**
1962	**NEUTRAL**	2471	2368	2010	1739	1496	1681	1679	1619	1592	1851	118	**0.000**
1963	**NEUTRAL**	4973	5007	5107	4755	4060	3144	3220	3282	3046	4066	300	**0.008**
1964	**NIÑO**	4166	4746	5069	5372	5614	5546	5331	5258	5073	5130	149	**0.000**
1965	**NIÑA**	2878	2934	2863	2588	2373	2323	2715	3140	3098	2768	98	**0.146**
1966	**NIÑO**	1341	1480	1684	1889	2114	2461	2715	2887	2630	2133	189	**0.002**
1967	**NEUTRAL**	3806	3862	3937	3818	3570	3368	3407	3455	0	3247	412	**0.106**
1968	**NIÑA**	3104	2897	2674	2494	2529	2419	2336	2529	2685	2630	81	**0.000**

Sources of Uncertainty: 4. Scaling up plot-scale models



Deterministic models with probabilistic inputs will underestimate risks and should be a reason for caution in using such deterministic analysis.

Summary

4-types of uncertainties have been identified

1. Model errors
2. Variability in ENSO
3. Measurement errors
4. Scaling-up/ aggregation

Likely Activities: Methodology development for routine applications to identify high impact areas for uncertainty

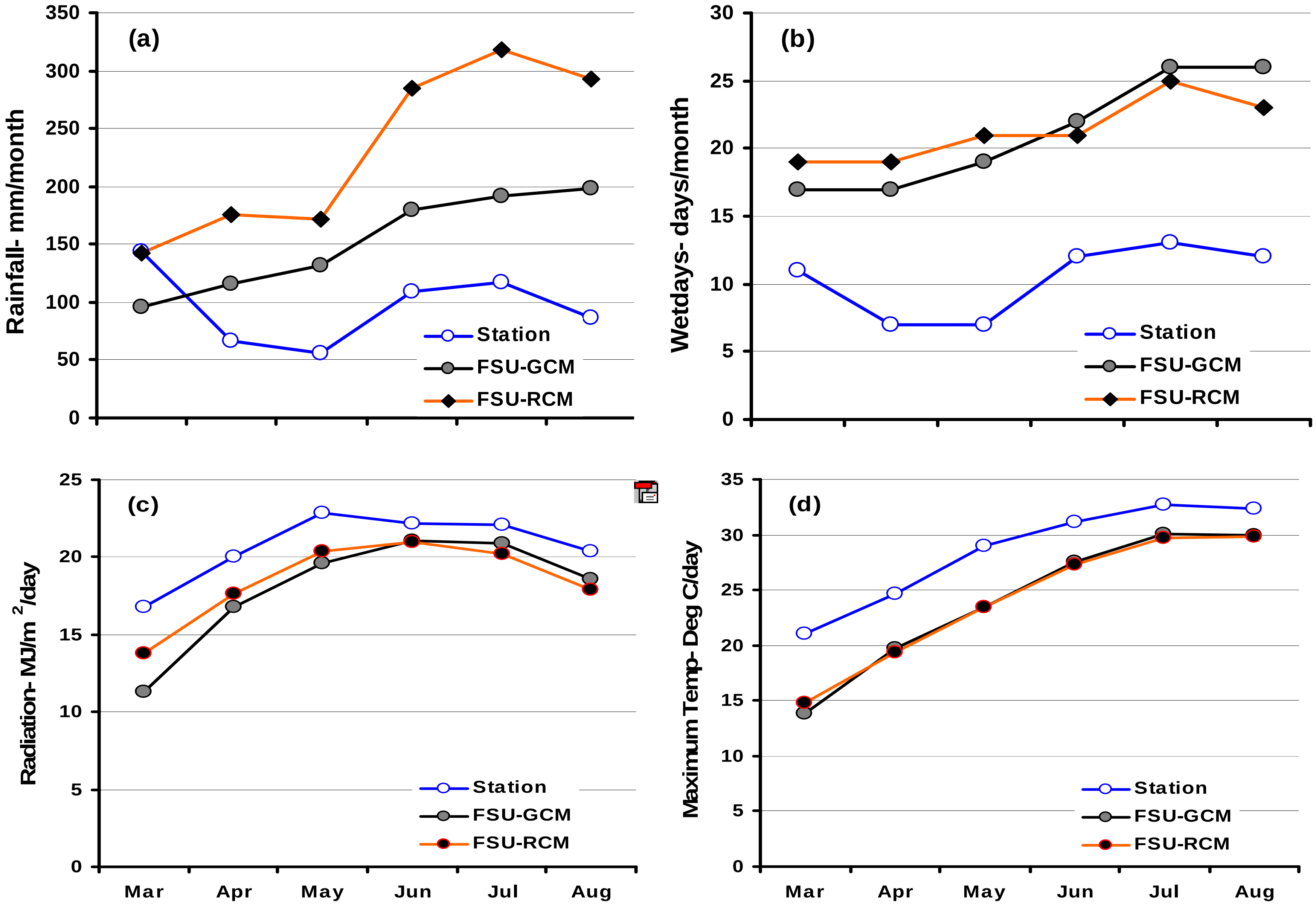
1.Uncertainty can affect decisions.

2. Recognizing impacts require that uncertainty analysis should be an integral part of forecast recommendation development process

3. It should be probabilistic, as actions may differ from those taken when only the best estimates are provided to decision makers

4. Past SECC studies will be used to prioritize studies

Thanks!


(a)
Rainfall- mm/month
0
50
100
150
200
250
300
350
Station
FSU-GCM
FSU-RCM
(b)
Wetdays- days/month
0
5
10
15
20
25
30
Station
FSU-GCM
FSU-RCM
(c)
Radiation- MJ/m 2/day
0
5
10
15
20
25
Station
FSU-GCM
FSU-RCM
Mar
Apr
May
Jun
Jul
Aug
(d)
Maximum Temp- Deg C/day
0
5
10
15
20
25
30
35
Station
FSU-GCM
FSU-RCM
Mar
Apr
May
Jun
Jul
Aug

Sources of Uncertainty: 4. Scaling up plot-scale models

Methods for dealing with uncertainty

1. Use factorial analysis to simultaneously evaluate the contribution of each factor to the total uncertainty.
2. Propagation of uncertainty using either addition or multiplication rule for n independent events

Addition of the N *independent variances*: $Var(f_1+f_2+\ldots f_n) = Var(f_1)+\ldots Var(f_n)$

Multiplication rule: $p(f1+f2+\ldots fn) = p(f1)+\ldots p(fn)$

Key References

1. SECC case studies
2. Morgan MG, and Henrion M, 1990. Uncertainty: a guide to dealing with uncertainty in quantitative risk and policy analysis. Cambridge University Press, Cambridge.
3. Katz RW, 2002.Techniques for estimating uncertainty in climate change scenarios and impact assessment studies, Climate Research, 20:167-185
4. Hammitt JK, Shlyakhter AI, 1999. The expected value of information and the probability of surprise. Risk Analysis, 19:135-152.
5. Mearns LO, Rosenzweig C, Goldberg R, 1997. Mean and variance change in climate scenarios: methods, agricultural applications, and measures of uncertainty. Clim Change 32:257-292
6. Webster MD, Sokolov AP, 2000. A methodology for quantifying uncertaionty in climate projections. Clim Change 46:417-446.
7. Wilks DS, 1995. Statistical methods in the atmospheric sciences. Academic Press, San Diego.

Sources of Uncertainty: 1. Model errors

Sources of uncertainty: The assumed form of model is likley to have substantial effect on the results of analysis.

							Recommended Dates				
Georgia-Green Simulated yield			**16-Apr**	**23-Apr**	**1-May**	**8-May**	**15-May**	**22-May**	**29-May**	**5-Jun**	**12-Jun**
	Years	**Uncorrected simulated yields**									
All yrs	**65**	**Avg (kg/ha)**	2870	2937	3003	3082	3097	3103	**3107**	3060	2742
		SD (kg/ha)	1379	1393	1376	1337	1258	1193	1159	1142	1301
		CV(%)	48	47	46	43	41	38	37	37	47
Nino	14	**Avg (kg/ha)**	2792	2935	3027	3138	3146	3197	3216	**3219**	2856
		SD (kg/ha)	1672	1719	1689	1668	1554	1436	1360	1313	1495
		CV(%)	60	59	56	53	49	45	42	41	52
Nina	16	**Avg (kg/ha)**	2839	2928	3072	3179	**3204**	3128	3055	3033	2712
		SD (kg/ha)	1242	1235	1210	1193	1163	1150	1115	1104	1274
		CV(%)	44	42	39	38	36	37	36	36	47
Neutral	35	**Avg (kg/ha)**	2915	2942	2962	3015	3029	3054	**3086**	3009	2709
		SD (kg/ha)	1350	1360	1350	1289	1203	1140	1125	1116	1269
		CV(%)	46	46	46	43	40	37	36	37	47

Tomato wilt virus has a profound effect on when growers plant peanuts. In past years, growers typically planed peanuts in mid-April. Now, the ideal planting date for peanuts is between May 11-May 25. The risk increases at other times. The planting date producing highest yield in each forecast category is marked

Ref: The Spotted Wilt Risk Index, Extension Bulletin No. 1165, 2003
The University of Georgia, Athens, Georgia