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Radiation use different estimation models influence on the effect of the APSIM model

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Background

- Daily solar radiation value is a very important parameter in earth science, agriculture science, and other research fields. However, compared with the conventional meteorological observation station, the global radiation observatories are less. Therefore, accurately estimating solar radiation is a key question.
- Five representative models, such as Angstrom-Prescott model, Ogelman model, Bahel model, the comprehensive model of sunshine duration and diurnal temperature range, and Liu's model (named model I to V), were used to estimate solar radiation in this paper, under the analysis and comparison previous solar radiation estimation models.

Background

- Different daily solar radiation estimation models has different error, it is unknow that radiation use different estimation models influence on the effect of the APSIM model .
- Six kinds of simulation scheme(scheme 0: daily solar radiation values are observed, scheme 1to 5: daily solar radiation values are model I to V simulated.) scheme1to 5 simulation results compared with the measured values and scheme 0 simulation results .

Technical route

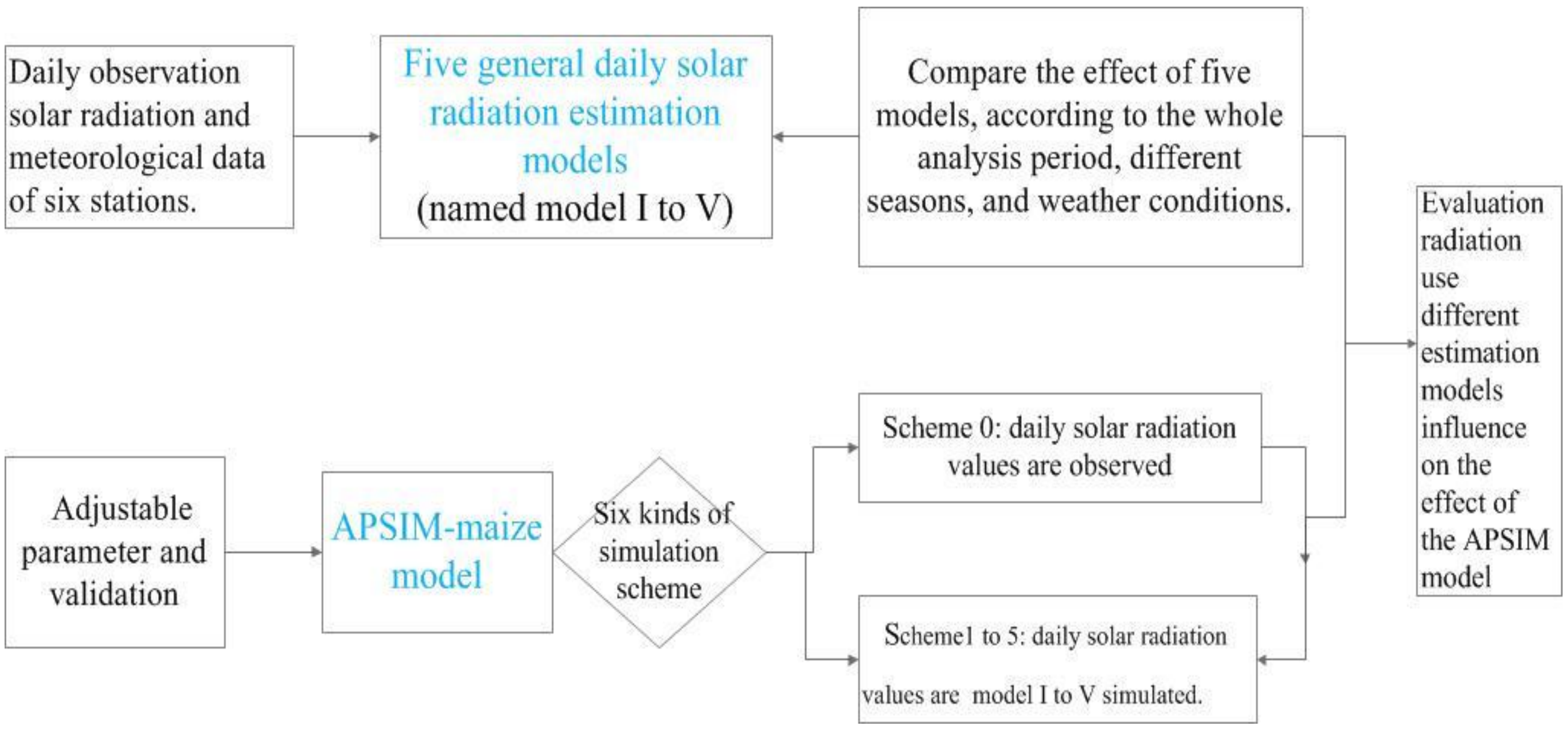


Fig.1 The diagram of analytical procedures in this study

Part one

- Validation and analysis of five general daily solar radiation estimation models used in Northern China

Data

- Daily observation solar radiation and meteorological data (from 2001 to 2010) of six representative stations in Northern China Plain.

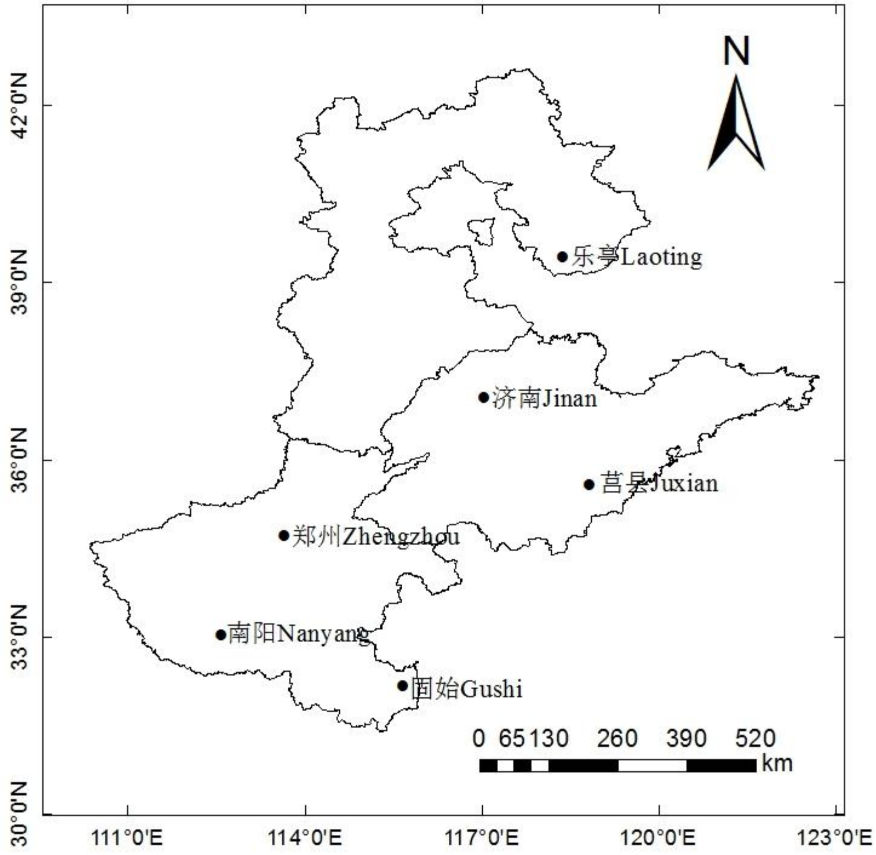


Fig.2 The geographical distribution of the selected meteorological stations

Five general daily solar radiation estimation models

Model I: A-P model $\frac{Q}{Q_0} = a + b\frac{n}{N}$ (1)

a =0.161, b=0.614

Model II: Ogelman model $\frac{Q}{Q_0} = a + b\frac{n}{N} + C(\frac{n}{N})^2$ (2)

a =0.1404,b =0.6126,
c =0.0351

Model III: Bahel model $\frac{Q}{Q_0} = a + b(\frac{n}{N}) + c(\frac{n}{N})^2 + d(\frac{n}{N})^3$ (3)

a =0.17,b =0.93,
c =-1.08,d =0.73

Model IV: The comprehensive model of sunshine duration and diurnal temperature range

$$\frac{Q}{Q_0} = a\ln(T_M - T_m) + b(\frac{n}{N})^c + d \quad (4)$$

a =0.04,b =0.48,
c = 0.83,d =0.11

Model V： Liu's model

With sunshine duration $\frac{Q}{Q_0}=a_0+a_1(\frac{n}{N})+a_2\lg(W+P)$ (5)

Without sunshine duration $\frac{Q}{Q_0}=b_0+b_1(T_M-T_m)\times(1-Abs)$ (6)

$a_0=0.221, a_1=0.464,$
$a_2=-0.003$
$b_0=0.071, b_1=0.015$

Note

Q: daliy total solar radiation ($MJ\cdot m^{-2}\cdot d^{-1}$);

Q_0 : sextraterrestrial radiation for initial value ($MJ\cdot m^{-2}\cdot d^{-1}$);

N : maximum sunshine hours(h);

n : sunshine hours (h);

W: atmospheric precipitable water (mm);

P: daily precipitation(mm);

Abs: atmospheric precipitation levels influence factor;

T_M :Daily maximum temperatures(℃);

T_m ： Daily minimum temperatures(℃);

$$Q_0 = \frac{24 \times 60}{\pi} 0.082 d_r (w_s \sin\varphi \sin\delta + \cos\varphi \cos\delta \sin w_s) (7)$$

$$d_r = 1 + 0.33 \cos(\frac{2\pi}{365} J) (8)$$

$$\delta = 0.409 \sin(\frac{2\pi}{365} J - 1.39) (9)$$

$$w_s = ar\cos(-\tan\varphi \tan\delta) (10)$$

$$N = \frac{24}{\pi} w_s (11)$$

$$T_d = \frac{g \times \lg\frac{e}{E_0}}{K - \lg\frac{e}{E_0}} (12)$$

$$W = 10^{0.0337 T_d + 0.849} (13)$$

$$Abs = \frac{0.29(W + 10P)}{0.5925(W + 10P) + [1 + 14.15(W + 10P)]^{0.635}} (14)$$

φ: latitude(°);

δ: declination of the sun (°);

dr : the inverse relative distance Earth-Sun;

ω_s : sunset hour angle;

J: the order number of solar calendar;

T_d: the dew point temperature(℃);

e: vapor pressure（hPa）;

E_0: the saturated vapor pressure of zero degrees celsius(=6.1078 hPa)

◆Methods of model evaluation

R, MAPE, RMSE, NRMSE

$$MAPE = \frac{\frac{100}{n}\sum_{i=1}^{n}\left|O_i - S_i\right|}{\frac{1}{n}\sum_{i=1}^{n}O_i} \quad (15)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(O_i - S_i)^2}{n}} \quad (16)$$

$$NRMSE = \frac{RMSE}{\frac{1}{n}\sum_{i=1}^{n}O_i} \times 100 \quad (17)$$

S_i : the simulated values of solar radiation ,

O_i : the observed values of solar radiation,

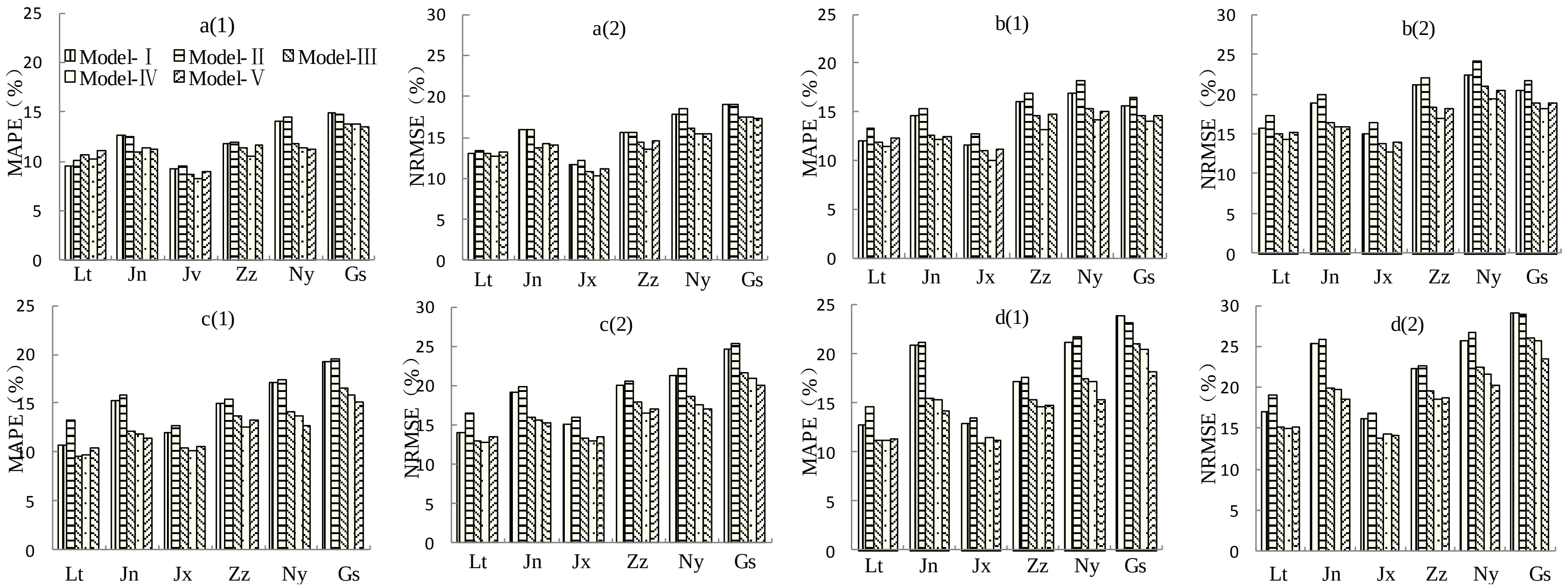
n: as the sample.

Results

Table 1 Statistical characteristics of five models in each station(from 2001 to 2010)

Site	Model	R	MAPE(%)	RMSE(MJ m^{-2} d^{-1})	NRMSE
Laoting	I	0.95	11.01	2.10	15.17
	II	0.95	12.37	2.29	16.55
	III	0.96	10.86	2.01	14.52
	IV	0.96	10.60	1.94	14.06
	V	0.96	11.34	2.04	14.84
Jinan	I	0.94	14.99	2.46	19.19
	II	0.94	15.39	2.55	19.82
	III	0.94	12.33	2.10	`16.35
	IV	0.94	12.22	2.09	16.21
	V	0.95	14.44	2.42	18.79
Juxian	I	0.96	11.09	1.94	14.36
	II	0.95	11.79	2.08	15.43
	III	0.96	10.12	1.77	13.10
	IV	0.96	9.68	1.68	12.47
	V	0.97	10.35	1.79	13.29
Zhengzhou	I	0.94	14.59	2.55	19.80
	II	0.94	15.06	2.62	20.33
	III	0.95	13.41	2.27	17.58
	IV	0.95	12.32	2.11	16.34
	V	0.96	13.47	2.25	17.45
Nanyang	I	0.93	16.67	2.62	21.81
	II	0.93	17.38	2.78	23.12
	III	0.93	14.28	2.39	19.89
	IV	0.94	13.61	2.24	18.65
	V	0.95	13.54	2.32	19.26
Gushi	I	0.93	17.35	2.74	22.43
	II	0.93	17.56	2.81	23.00
	III	0.93	15.68	2.49	20.34
	IV	0.93	15.20	2.44	19.91
	V	0.94	14.91	2.42	19.80

Daily observation solar radiation data (from 2001 to 2010) of six representative stations in Northern China Plain were used to compare the effect of five models, according to different seasons



a：Spring；b：Summer；c：Autumn；d：Winter

a1、b1、c1、d1 ：MAPE　a2、b2、c2、d2：NRMSE

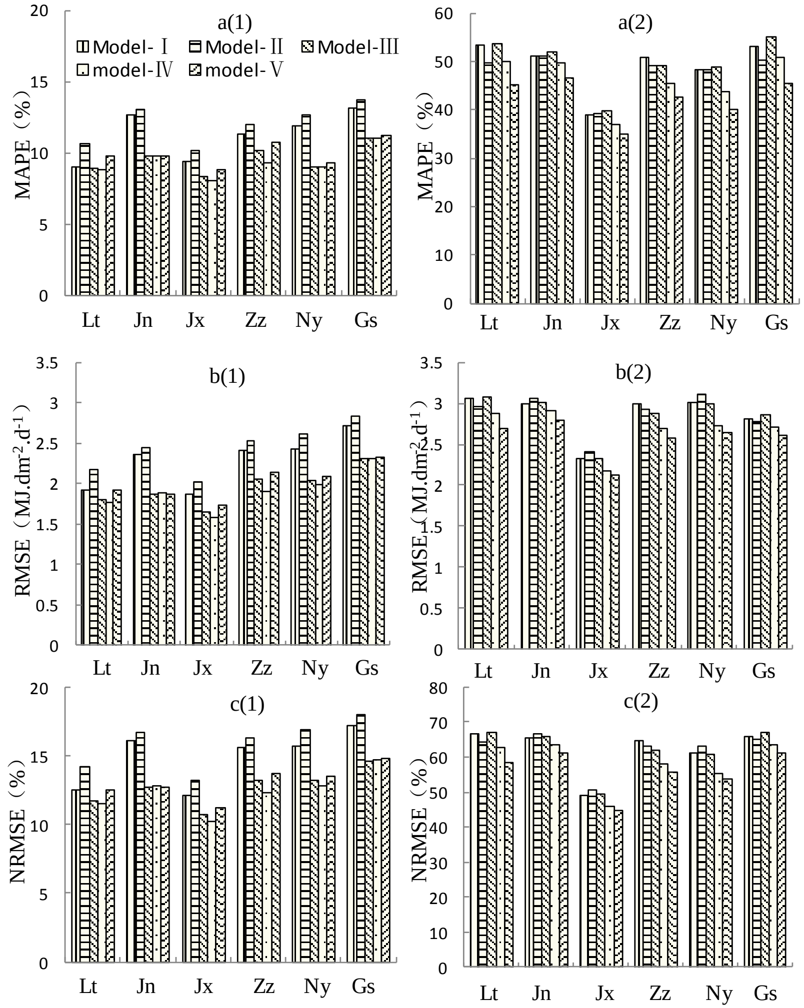
Fig. 3 Simulated error of five models during different seasons in each station

Note：Lt、Jn、Jx、Zz、Ny、Gs is Laoting, Jinan, Juxian, Zhengzhou, Nanyang, Gushi, respectively. The same as below

Table 2 Statistical characteristics of five models in every season

Season	Model	Average MAPE(%)	Average NRMSE (%)
Spring(Mar.,Apr., May)	I	11.97	15.46
	II	12.19	15.75
	III	11.17	14.27
	IV	10.86	13.95
	V	11.24	14.27
Summer(Jun.,Jul.,Aug.)	I	14.46	18.89
	II	15.47	20.21
	III	13.32	17.21
	IV	12.45	16.22
	V	13.36	17.05
Autumn(Sep.,Oct.,Nov.)	I	14.81	18.94
	II	15.65	20.00
	III	12.67	16.66
	IV	12.19	15.94
	V	12.20	15.95
Winter(Dec.,Jan.,Feb.)	I	18.08	22.52
	II	18.56	23.28
	III	15.19	19.42
	IV	14.99	19.06
	V	14.11	18.31

Daily observation solar radiation data (from 2001 to 2010) of six representative stations were used to compare the effect of five models, according to weather conditions.



a：MAPE；b：RMSE；c：NRMSE

a1、b1、c1：sunshine duration

a2、b2、c2、d2：without sunshine duration

Fig. 4 Simulated error of five models under sunshine duration and without conditions

Conclusion

- During the whole analysis period, Model IV was the best, following by model III and V.
- Model IV showed best in spring, summer, and autumn, while model V showed best in winter, following by model IV.
- Under the condition that sunshine duration existed, All of the simulation results were "good", model IV showed best. In contrast, without sunshine duration, All of the simulation results were "bad“.
- five models could be used to estimate the daily solar radiation in Northern China Plain, and model IV (the comprehensive model of sunshine duration and diurnal temperature range) showed the highest accuracy.

Part two

Radiation use five general daily solar radiation estimation models (model I to V)influence on the effect of the APSIM model

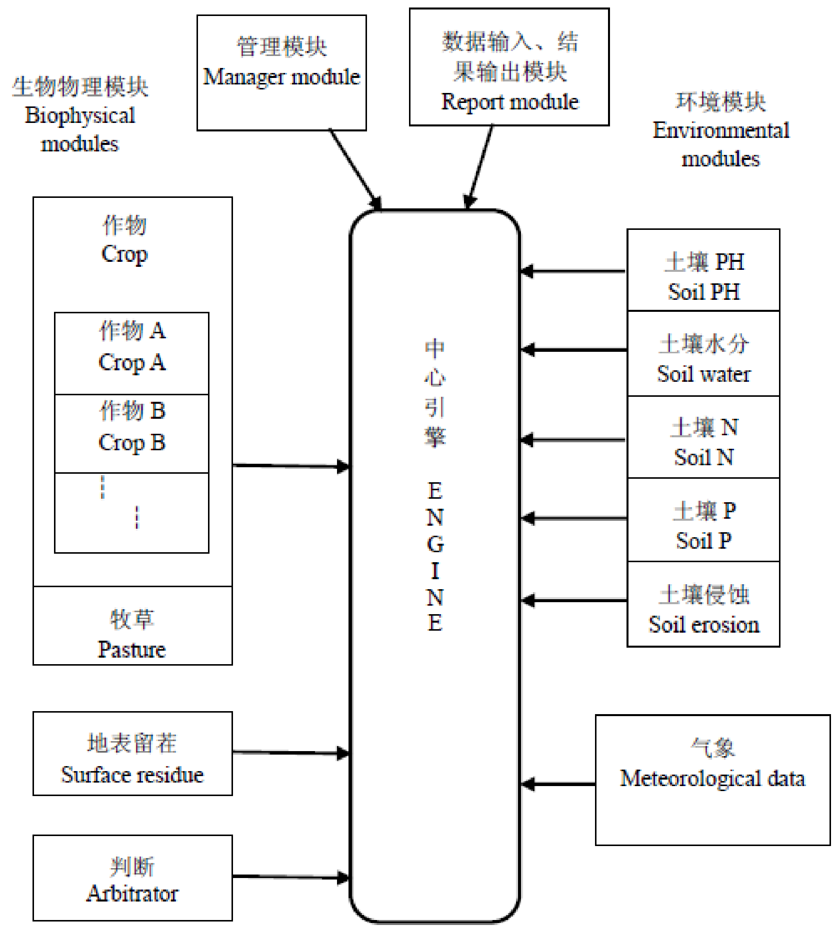


Fig.5 Diagram of the APSIM simulation framework with separate modules interfaces and simulation engine(Chenchao 2009)

Calibration and validation

- data

Juxian(2001-2010), yongnian(2008-2009), baofeng(2008-2009), zhengzhou(2008-2011), shijiazhuang(2008-2009), dezhou(2008-2009), zaozhuang(2008-2009),meteorological and maize data.

- **Method**

Data of Juxian site from 2001to 2005 as a group to calibrate, from 2006 to 2010 as a group to validate.

Data of yongnian, baofeng, zhengzhou,shijiazhuang,dezhou, zanzhuang site in 2008 as a group to calibrate,, 2009 as a group to validate.

- **Methods of APSIM evaluation**

R, RMSE, NRMSE

Results

Table 3 Parameters of APISM-Maize for varieties of maize

Parameter	Code	Xundan29	Juxian
Thermal time required from emergence to end of juvenile (℃ d)	tt_emerg_to endjuv	130	120
Thermal time required from flowering to maturity (℃ d)	tt_flower_to_maturi-ty	850	650
Maximum grain number per head	head_grain_no_max	600	610
Grain filling rate ($mg·grain^{-1}·d^{-1}$)	grain_gth_rate	11	10
Photoperiod slope (℃ h^{-1})	photoperiod_slope	18	20

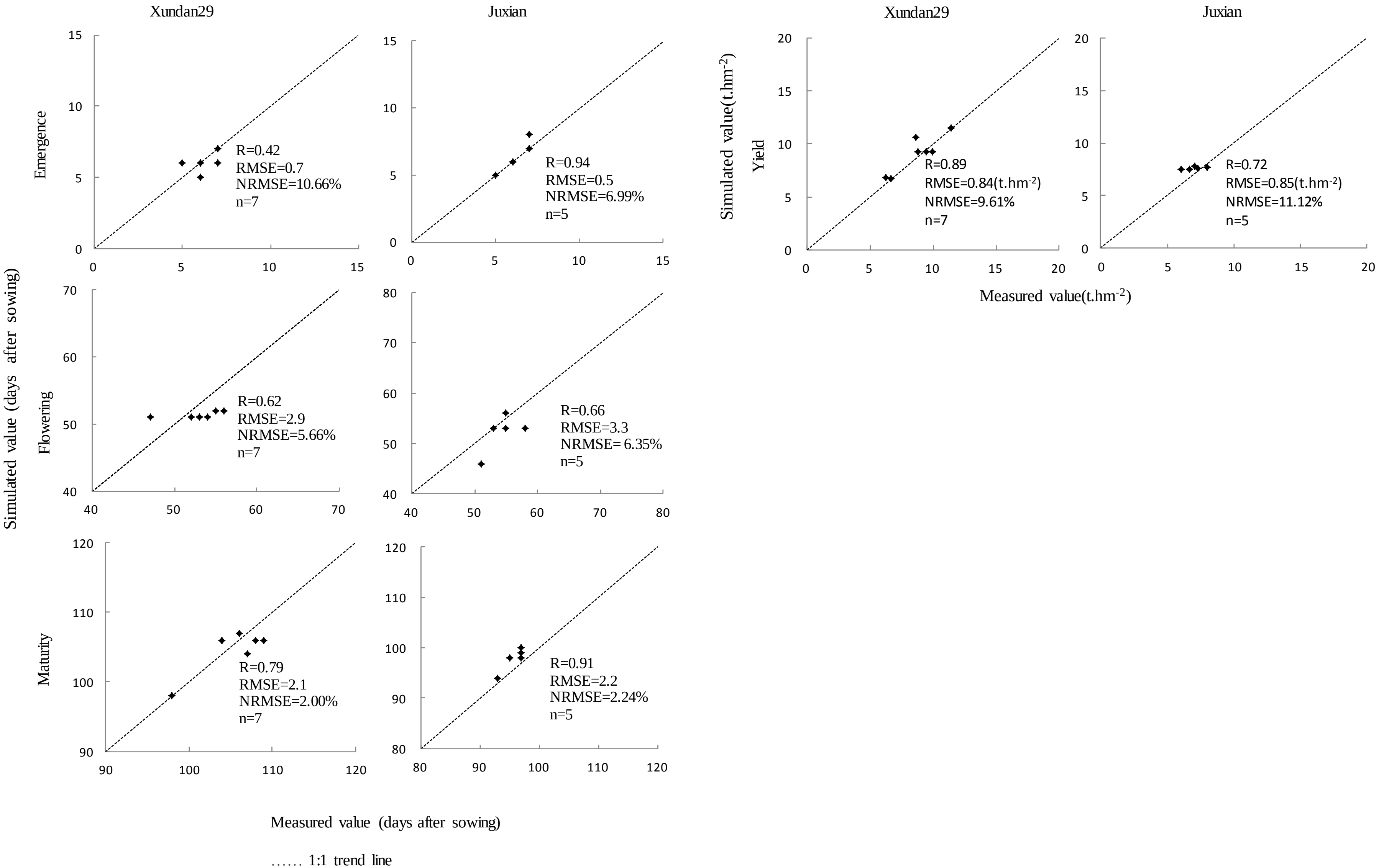


Fig.6 Validation results between simulated and observed

Materials and Methods

- **Study site**

Juxian(2013-2014),zhengzhou(2012 and 2014), Nanyang(2008-2009)site.

- **Six kinds of simulation scheme**

scheme 0: daily solar radiation values are observed

scheme1 to 5: daily solar radiation values are Angstrom -Prescott model, Ogelman model, Bahel model, the comprehensive model of sunshine duration and diurnal temperature range, and Liu's model (named model I to V) simulated.

- Methods of evaluation radiation use different estimation models influence on the effect of the APSIM model

MAPE

Table 4 Six kinds of simulation scheme simulation results compared with the measured values in zhengzhou site

year	Simulation scheme	Emergene	Flowering	Matunity	Yield t/hm^2	Yield error	Daily solar radiation error	Magnification times
2012		166	215	258	7.5			
	0	166	210	259	8.39			
	1	166	210	259	8.44	0.60%	11.90%	0.05
	2	166	210	259	7.86	6.32%	12.64%	0.50
	3	166	210	259	8.21	2.15%	11.13%	0.19
	4	166	210	259	8.37	0.24%	10.38%	0.02
	5	166	210	259	7.54	10.13%	11.15%	0.91
2014		161	207	260	7.5			
	0	161	206	256	8.56			
	1	161	206	256	8.49	0.82%	13.31%	0.06
	2	161	206	256	8.31	2.92%	14.73%	0.20
	3	161	206	256	8.58	0.23%	13.44%	0.02
	4	161	206	256	8.60	0.47%	11.66%	0.04
	5	161	206	256	8.44	1.40%	13.08%	0.11

**red is measured values

Table 5 Six kinds of simulation scheme simulated results compared with the measured values in Juxian site

year	Simulation scheme	Emergence	Flowering	Matunity	Yield t/hm^2	Yield error	Daily solar radiation error	Magnification times
		181	221	268	9.49			
	0	180	225	266	7.85			
	1	180	225	266	7.47	4.84%	10.39%	0.46
2013	2	180	225	266	6.99	10.96%	12.07%	0.91
	3	180	225	266	7.43	5.35%	10.11%	0.53
	4	180	225	266	7.52	4.20%	9.40%	0.45
	5	180	225	266	7.16	8.79%	11.16%	0.78
		175	218	270	11.25			
	0	174	222	267	8.65			
	1	174	222	267	8.34	3.58%	10.70%	0.33
2014	2	174	222	267	7.98	7.75%	11.81%	0.66
	3	174	222	267	8.08	6.59%	10.47%	0.63
	4	174	222	267	8.37	3.24%	8.74%	0.37
	5	174	222	267	7.80	9.83%	11.55%	0.85

Table 6 Six kinds of simulation scheme simulated results compared with the measured values in Nanyang site

year	Simulation scheme	Emergence	Flowering	Matunity	Yield t/hm^2	Yield error	Daily solar radiation error	Magnification times
		168	215	255	9.76			
	0	164	210	259	8.23			
	1	164	210	259	6.25	24.06%	16.42%	1.47
2008	2	164	210	259	5.55	32.56%	18.17%	1.79
	3	164	210	259	6.29	23.57%	13.78%	1.71
	4	164	210	259	6.67	18.96%	13.78%	1.38
	5	164	210	259	5.71	30.62%	14.46%	2.12
		162	205	256	8.87			
	0	161	206	255	7.75			
	1	161	206	255	6.5	16.13%	20.71%	0.78
2009	2	161	206	255	5.98	22.84%	22.32%	1.02
	3	161	206	255	6.62	14.58%	21.04%	0.69
	4	161	206	255	6.72	13.29%	19.92%	0.67
	5	161	206	255	6.09	21.42%	22.29%	0.96

Table 7 Six kinds of simulation scheme simulated results compared with the measured values in 2008

site	Simulation scheme	Emergence	Flowering	Maturity	Yield t/hm^2	Yield error	Daily solar radiation error	Magnification times
Zheng zhou		172	220	274	11.89			
	0	173	220	271	8.36			
	1	173	220	271	6.95	16.87%	16.84%	1.00
	2	173	220	271	6.25	25.24%	18.78%	1.34
	3	173	220	271	6.99	16.39%	15.93%	1.03
	4	173	220	271	7.35	12.08%	14.45%	0.84
	5	173	220	271	6.87	17.82%	14.63%	1.22
Nan yang		168	215	255	9.76			
	0	164	210	259	8.23			
	1	164	210	259	6.25	24.06%	16.42%	1.47
	2	164	210	259	5.55	32.56%	18.17%	1.79
	3	164	210	259	6.29	23.57%	13.78%	1.71
	4	164	210	259	6.67	18.96%	13.78%	1.38
	5	164	210	259	5.71	30.62%	14.46%	2.12
Ju xian		176	221	266	7.65			
	0	175	223	265	7.33			
	1	175	223	265	6.69	8.73%	11.40%	0.77
	2	175	223	265	6.04	17.59%	13.03%	1.35
	3	175	223	265	6.62	9.68%	13.58%	0.71
	4	175	223	265	6.75	7.91%	11.67%	0.68
	5	175	223	265	5.75	21.56%	14.05%	1.53

Table 8 Six kinds of simulation scheme simulated results compared with the measured values in 2009

site	Simulation scheme	Emergence	Flowering	Maturity	Yield t/hm^2	Yield error	Daily solar radiation error	Magnification times
Zheng zhou		174	224	283	9.89			
	0	175	221	277	8.23			
	1	175	221	277	7.19	12.64%	15.09%	0.84
	2	175	221	277	6.55	20.41%	16.56%	1.23
	3	175	221	277	7.31	11.18%	15.14%	0.74
	4	175	221	277	7.44	9.60%	14.15%	0.68
	5	175	221	277	6.95	15.55%	14.64%	1.06
Nan yang		162	205	256	8.87			
	0	161	206	255	7.75			
	1	161	206	255	6.5	16.13%	20.71%	0.78
	2	161	206	255	5.98	22.84%	22.32%	1.02
	3	161	206	255	6.62	14.58%	21.04%	0.69
	4	161	206	255	6.72	13.29%	19.92%	0.67
	5	161	206	255	6.09	21.42%	22.29%	0.96
Ju xian		175	224	269	7.72			
	0	175	223	266	7.98			
	1	175	224	266	7.02	12.03%	11.24%	1.07
	2	175	224	266	6.57	17.67%	12.28%	1.44
	3	175	224	266	6.94	13.03%	12.31%	1.06
	4	175	224	266	7.13	10.65%	10.89%	0.98
	5	175	223	266	6.50	18.55%	13.19%	1.40

Nest work

- Calibration and validation again

Thank you