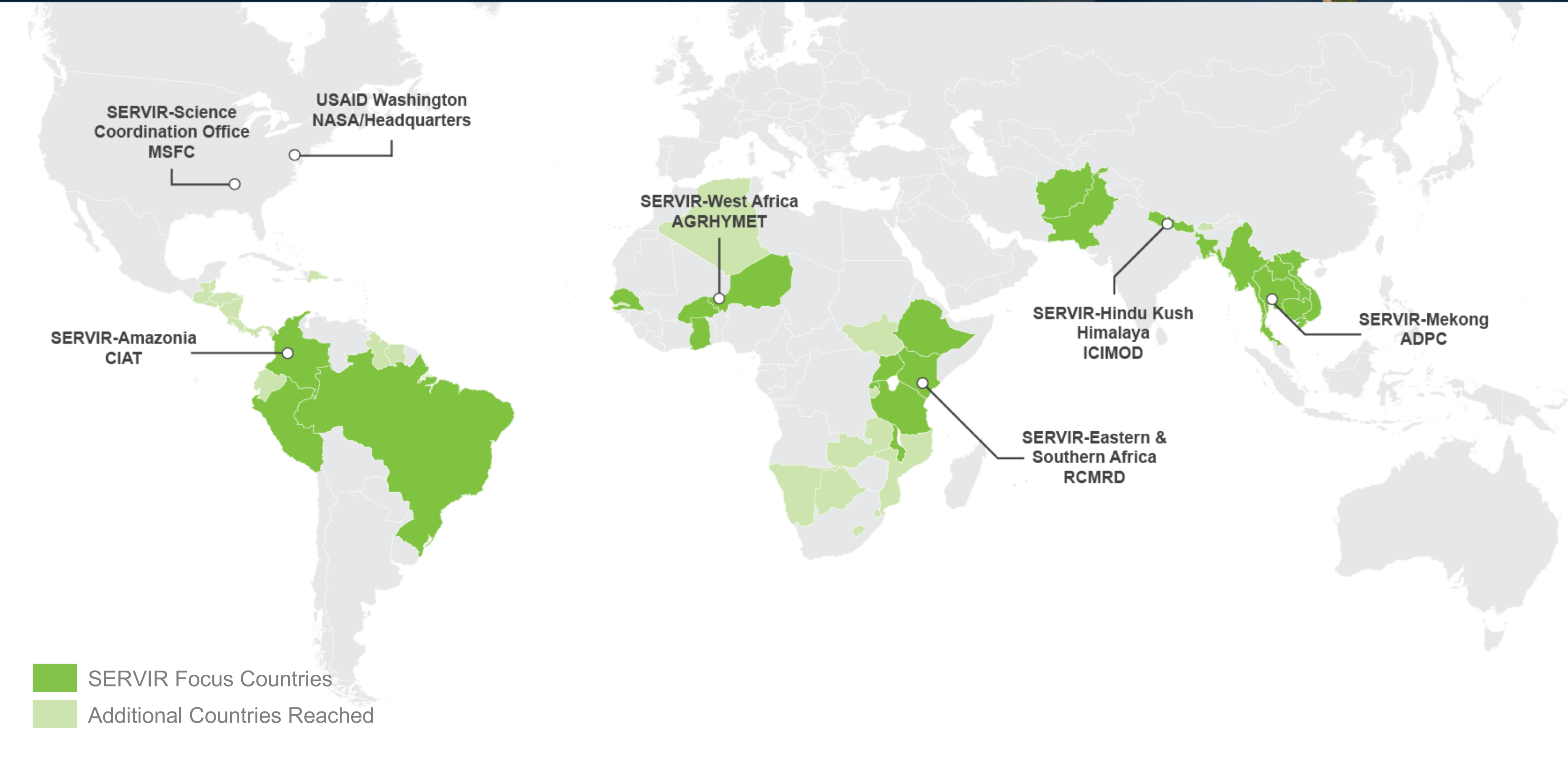
12E.5 Forecasting Frost: Using high resolution WRF runs to predict frost occurrence in the tea growing regions of Kenya

Emily C Adams, NASA SERVIR / UAH
James W Nyaga, RCMRD
W. Lee Ellenburg, NASA SERVIR / UAH
Ashutosh Limaye, NASA SERVIR
Robinson Mugo, RCMRD
Africa Flores, NASA SERVIR / UAH
Dan Irwin, NASA SERVIR
Jon Case, NASA SPoRT / ENSCO Inc
Susan Malaso
Absea Sedah

SERVIR is a partnership of **NASA, USAID, and leading technical organizations.** SERVIR develops innovative solutions to improve livelihoods and foster self-reliance in Asia, Africa, and the Americas.

SERVIR Focuses on Countries in Asia, Africa, and the Americas



Countries Around the World Need Satellite Data

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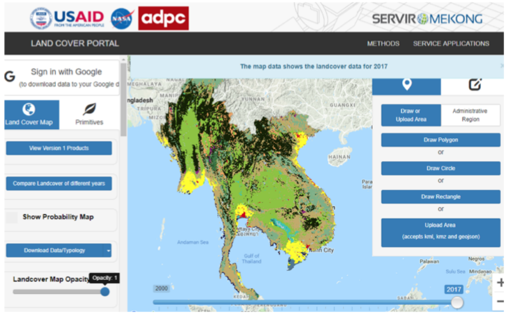
Problem

- Complex challenges occur in data-scarce environments
- Most countries lack the capacity to use satellite data and geospatial technologies to manage risk

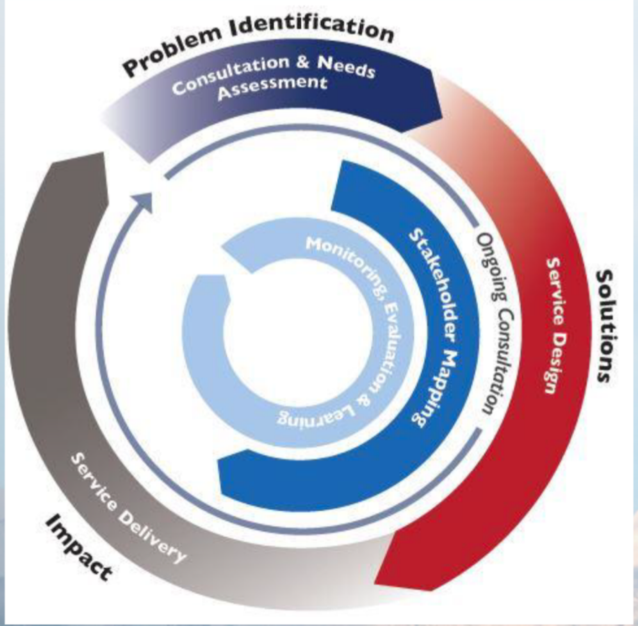
Approach

- Build lasting capacity through regional partners in the spirit of self-reliance
- Ensure needs-driven and collaborative solutions for accurate problem identification, buy-in, and sustainability
- Leverage US leadership in applied technology



SERVIR's Service Planning Approach

Kenya Tea Development Agency (KTDA)- the agency responsible for production and marketing of the produce from **more than 500,000 small scale tea farmers**, **recorded losses of about 9.6 million** USD within a week following a **frost event in January 2012**

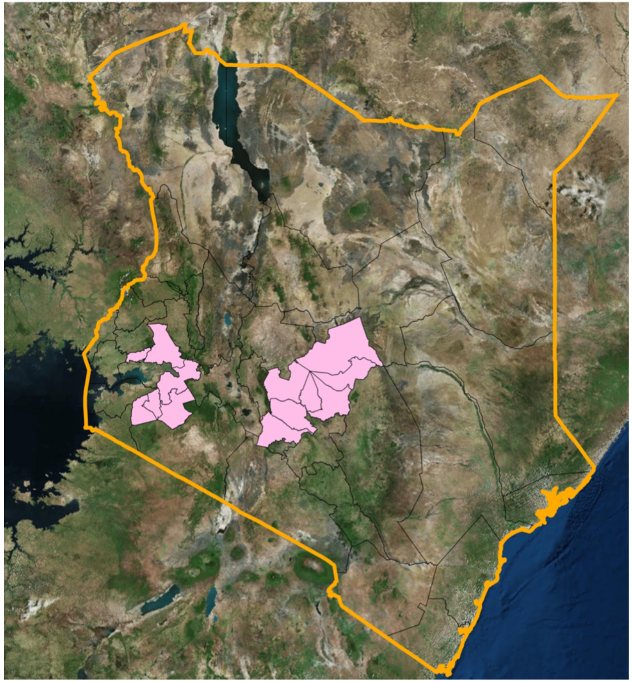


Stakeholder engagement workshop

Image sources: SERVIR Global

Study Area

•Frost season: December - March (dry season) characterized by cloudless nights.
•Characterized by highly undulating to rolling topography
•Altitude varying between 1500 m asl and 2400 m asl.
•Complex microclimates often override mesoscale systems hence the challenge in predicting LST and weather variables especially given the paucity of meteorological data.



Tea growing counties highlighted in pink

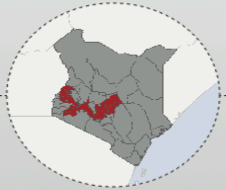
Image sources: SERVIR Global

FROST MAPPING, MONITORING, AND FORECASTING SYSTEM IN KENYA

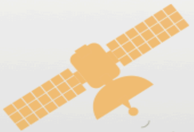
The Kenya **tea industry** supports **10 percent** of Kenya's population, around **3 million families**. This industry is prone to **damage by frost** due to the altitudes in which it is grown. SERVIR, in partnership with its regional partner the Regional Center for Mapping of Resources for Development, developed **a tool to map the frost potential with up to three days' warning**.

1 Kenya is the third largest tea exporter in the world, producing 10% of the world's black tea.

60% of Kenya's tea comes from more than 600,000 smallholder farmers across the country.

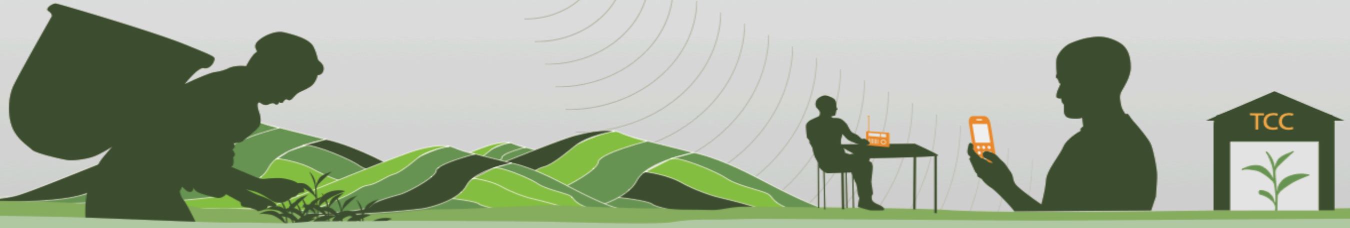


2 On average, smallholder tea farmers lose around USD200 worth of their crop to frost.



4 Warnings are sent to farmers via mobile messaging and/or radio. More than 90% of tea farmers have access to radio and/or mobile phones; 99.4% share or receive messages from neighbors. Mass warnings are also shared using tea collection centers (TCC) as proxies for nearby farms.

Using a SERVIR developed app, farmers can report incidences of frost to help make the system better.



3 The SERVIR frost forecasting tool provides daily maps of frost potential with a capability for 72 hours pre-frost warning.

5 With a 40% accuracy rate, a 3-day warning enables preventative actions that reduce average annual losses by USD83. Equivalent to:

25 days of household food spending

60 days of household health spending

A full year of school tuition for one child

Frost Forecasting

Assessment of Hindcast runs to predict frost

1. Evaluation of sample WRF outputs using the Model Evaluation Tool

Image source: SERVIR Global

Evaluation of sample WRF outputs using the MET tool

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- 4 km outputs from 3/01/16 – 7/01/16 18 z start time (Study area is GMT+3)
  - Control run - standard UEMS config

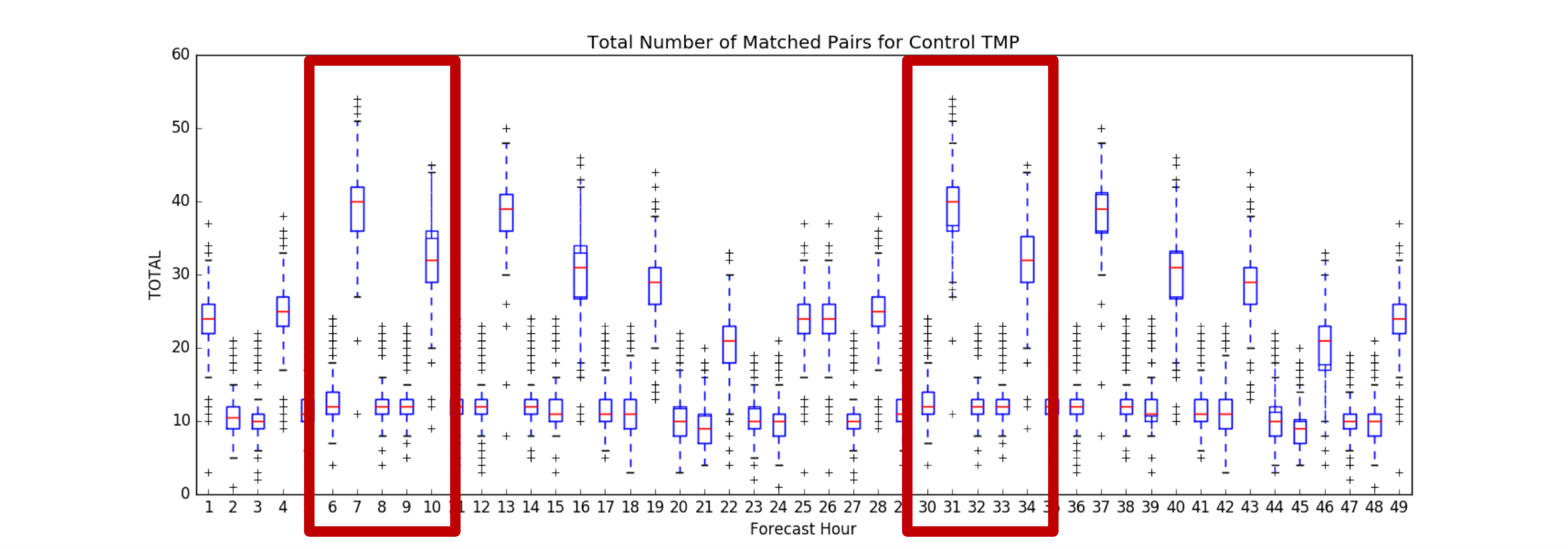
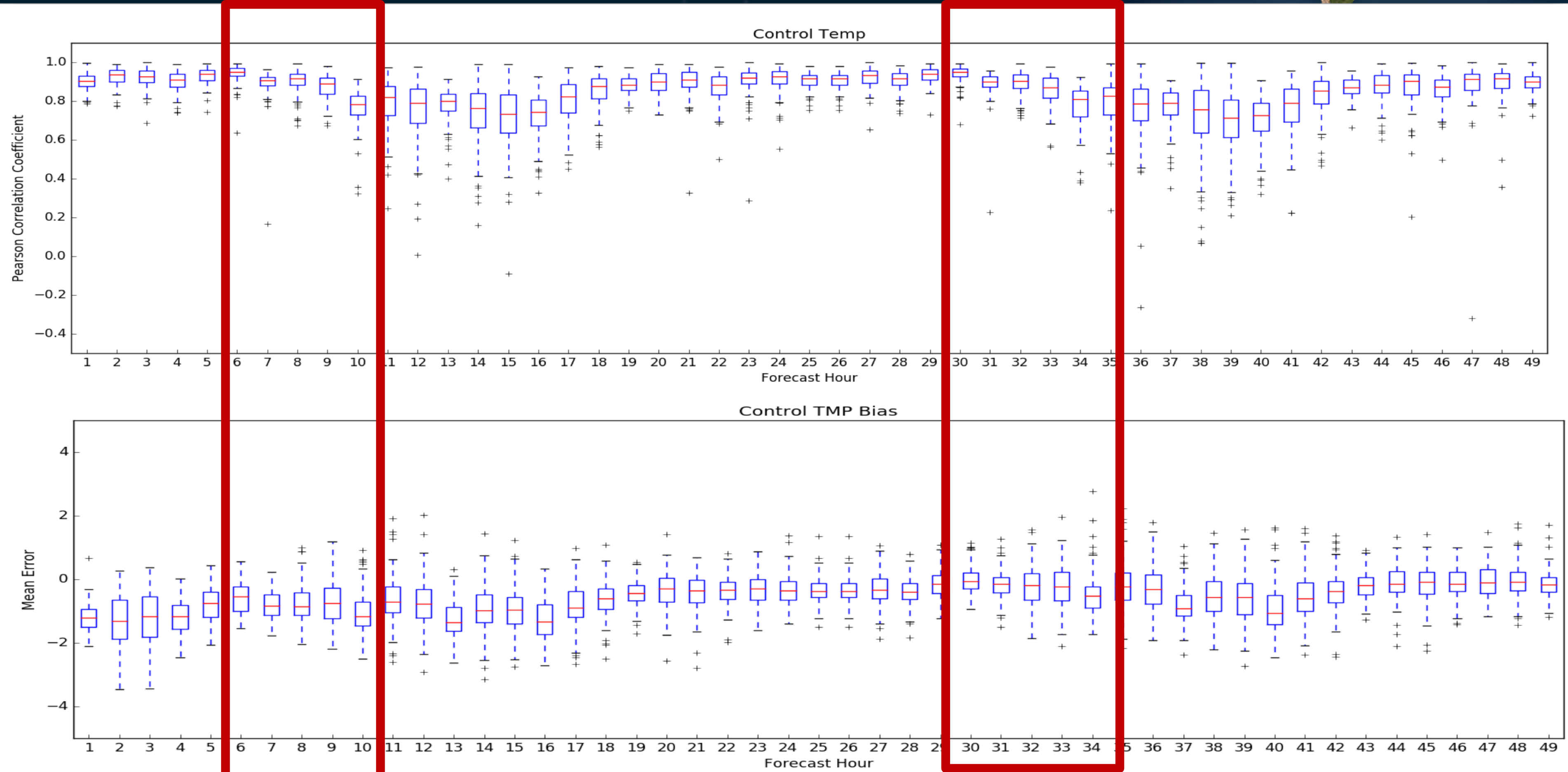


Image source: SERVIR Global

Evaluation of sample WRF outputs using the MET tool



Assessment of Hindcast runs to predict frost

1. Evaluation of sample WRF outputs using the MET tool
    1. Confidence in WRF as a system
2. Systematic UEMSv18.3 (WRF v3) 9:3:1 runs for all recorded frost points

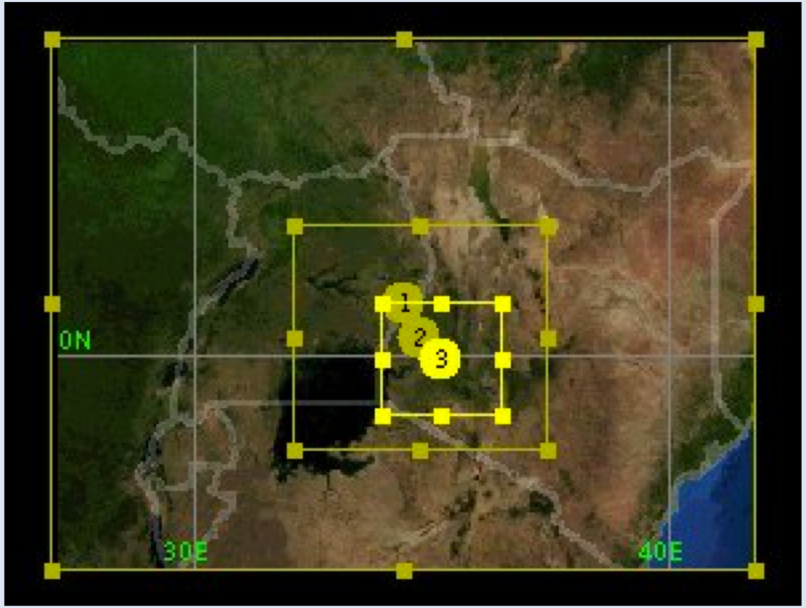


Image source: SERVIR Global

Systematic WRF 9:3:1 runs for all recorded frost points

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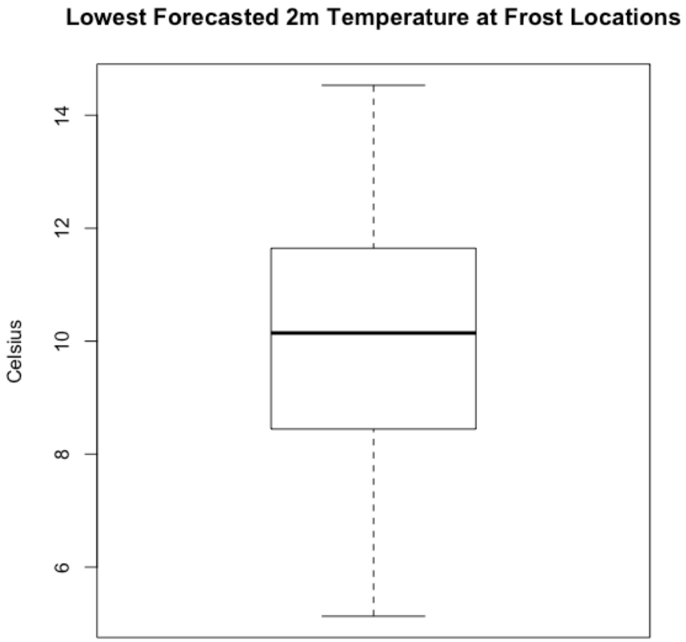
- Case studies using base UEMS physics parametrizations for all 100 frost observations from January 1994 – February 2017



Assessment of Hindcast runs to predict frost

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1. Evaluation of sample WRF outputs using the MET tool
   1. Confidence in WRF as a system
2. Systematic UEMSv18.3 (WRF v3) 9:3:1 runs for all recorded frost points
   1. Base UEMS physics do not represent field conditions conducive to frost at known frost locations
3. Case study example on 12/16/16 with various physics combinations

Image source: SERVIR Global

Case study examples with various physics combinations

Selected based on reviewed literature on high resolution WRF and minimal literature from runs using WRF in East Africa

Land Surface Models –

- NOAH
- NOAH Multi-Physics (MP)
- Pleim Xiu Land Surface Model (PXLSM)
- RUC

Planetary Boundary Schemes

- Asymmetrical Convective Model v2 (ACM2)
- Mellor-Yamada-Janjic (MYJ)
- Yonsei University Scheme (YSU)

Microphysics

- ETA
- Lin
- WSM Single Moment 6 class
- Goddard

Additional parameterizations

- Lakes on / off
- Cumulus Schemes
  - On (BMJ / Grell 3D) / Off
- Topo Wind Correction
- SST off and on
- Snow/ Ice / Grapuel off / on

Longwave Radiation Schemes

- RRTM
- CAM

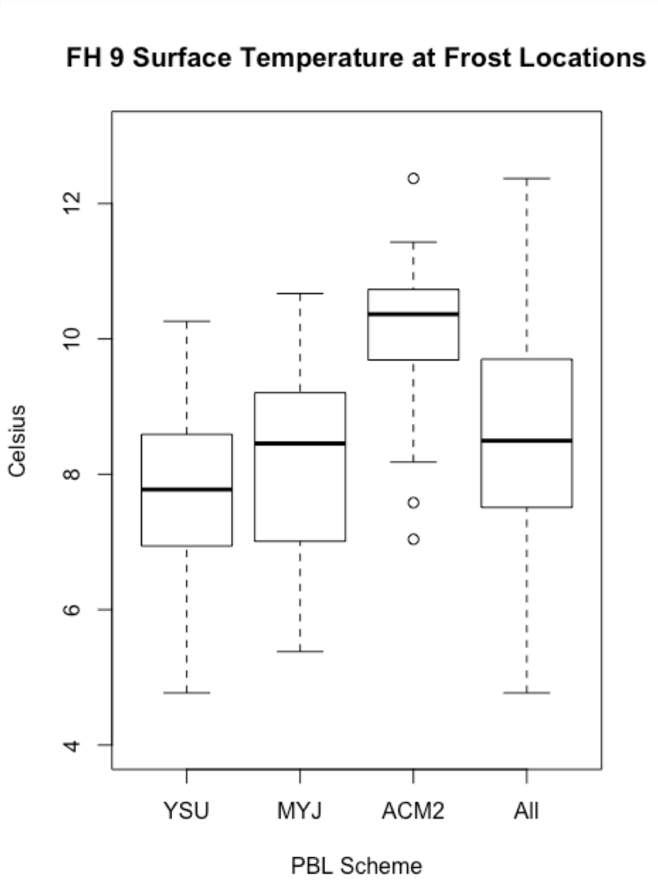
Shortwave Radiation Schemes

- Dudhia

Cumulus Schemes

- BMJ
- Grell 3D

Case study examples with various physics combinations



Coolest Scheme:

- YSU PBL
- Unified Noah LSM
- Goddard Microphysics

Assessment of Hindcast runs to predict frost

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1. Evaluation of sample WRF outputs using the MET tool
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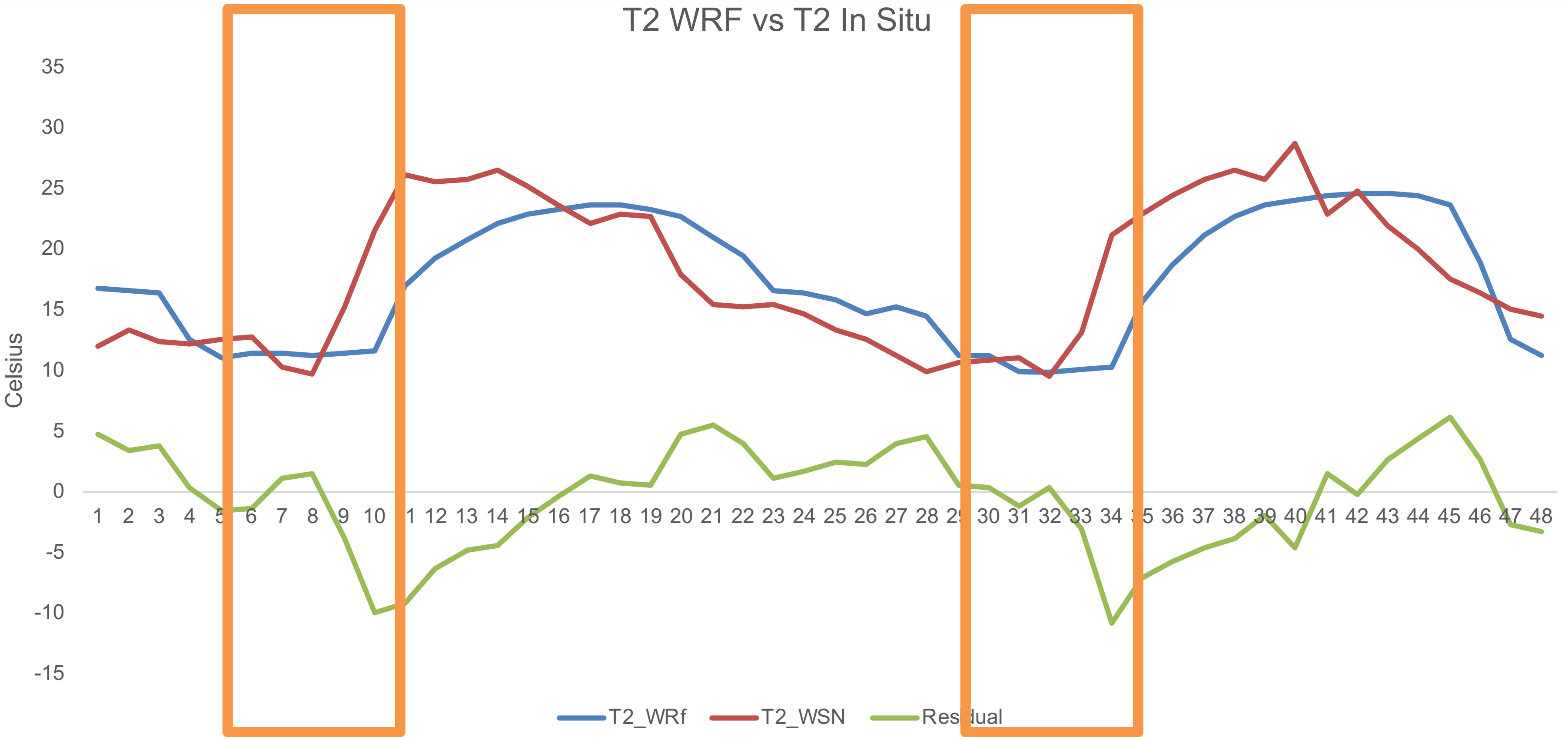
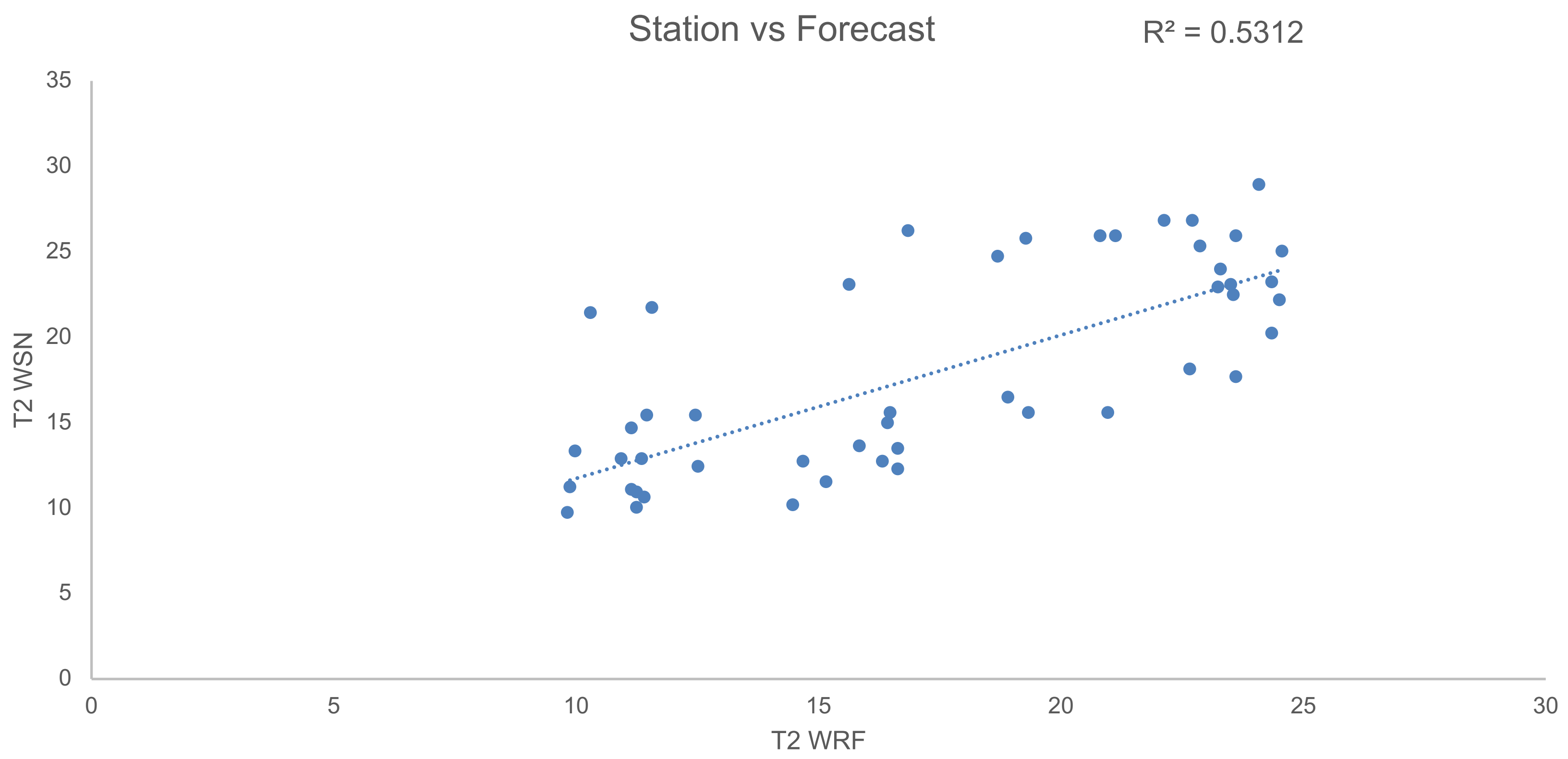
    1. Base UEMS physics do not represent field conditions conducive to frost at known frost locations
3. Case study example on 12/16/16 with various physics combinations
    1. Still not representative of field conditions
4. Comparison of forecasted temperatures with 1 station

Comparison with Station Data



Comparison with Station Data



Assessment of Hindcast runs to predict frost

SERVIR

1. Evaluation of sample WRF outputs using the MET tool
    1. Confidence in WRF as a system
2. Systematic UEMSv18.3 (WRF v3) 9:3:1 runs for all recorded frost points
    1. Base UEMS physics do not represent field conditions conducive to frost at known frost locations
3. Case study example on 12/16/16 with various physics combinations
    1. Still not representative of field conditions
4. Comparison of forecasted temperatures with 1 station
    1. Not a strong relationship with limited *in situ* station data

Conclusions

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Conclusions:

1. High resolution WRF runs in the highlands of Kenya alone do not capture the variability in temperature accurately
    1. Variable topography
    2. Effects from Lake Victoria

Limitations :

1. Limited availability of in situ data stations particularly during frost events
2. Limited availability of frost and non-frost events
3. Compute power limitations

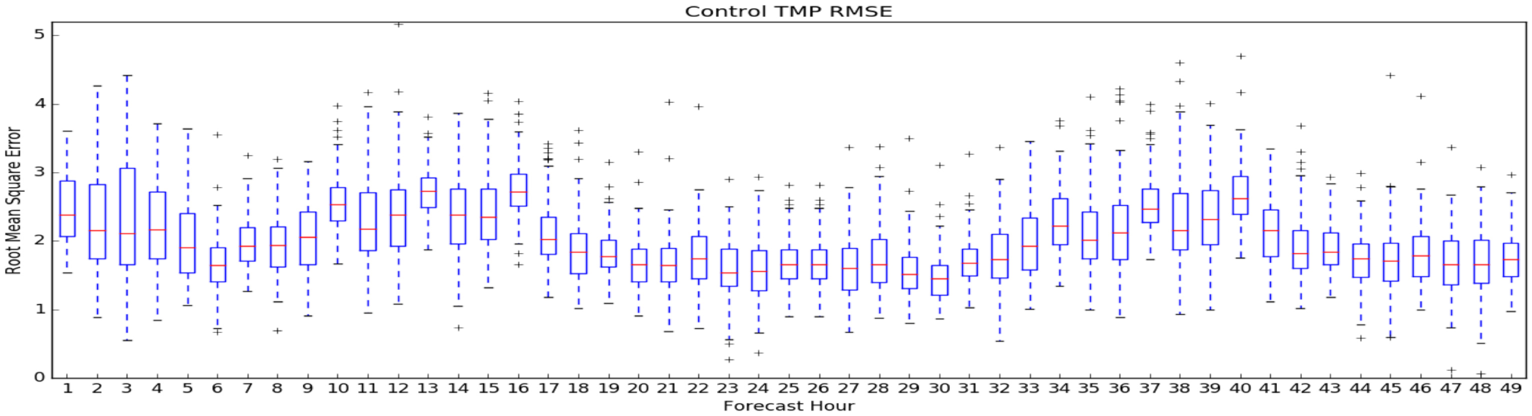
The Potential Ways Forward

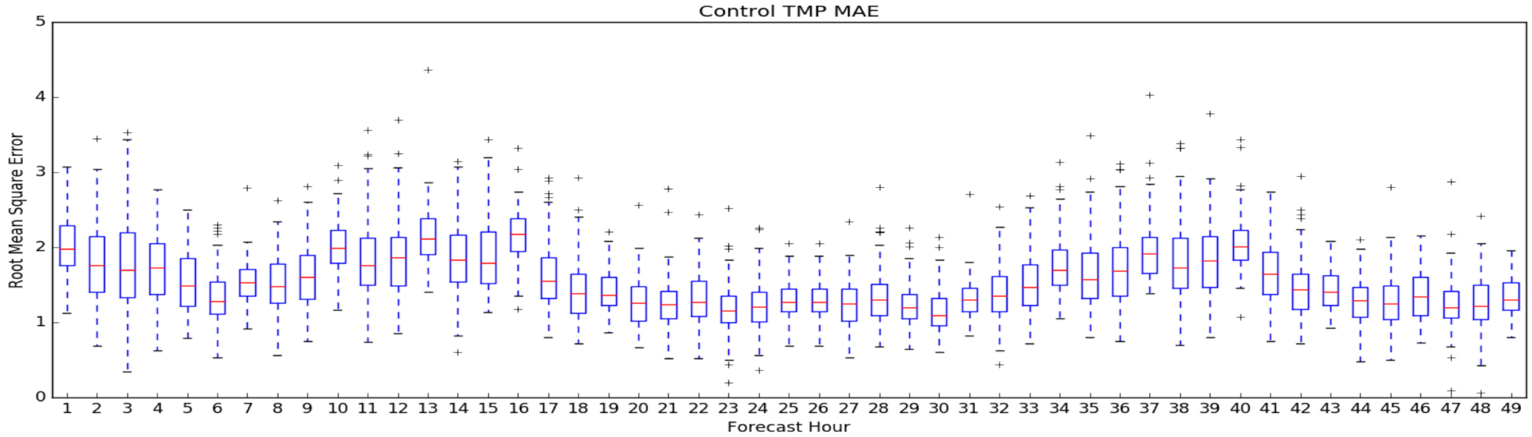
1. Exploration of initialization of high resolution (3 km LIS LST outputs OR 1 km FLDAS LST outputs) and 4 km VIIRS Green Vegetation Fraction for improved forecasts
2. Update to WRF v4
3. Exploration of Bias Correction of WRF temperature using LST trends

Questions?

Backup Slides

Evaluation of sample WRF outputs using the MET tool





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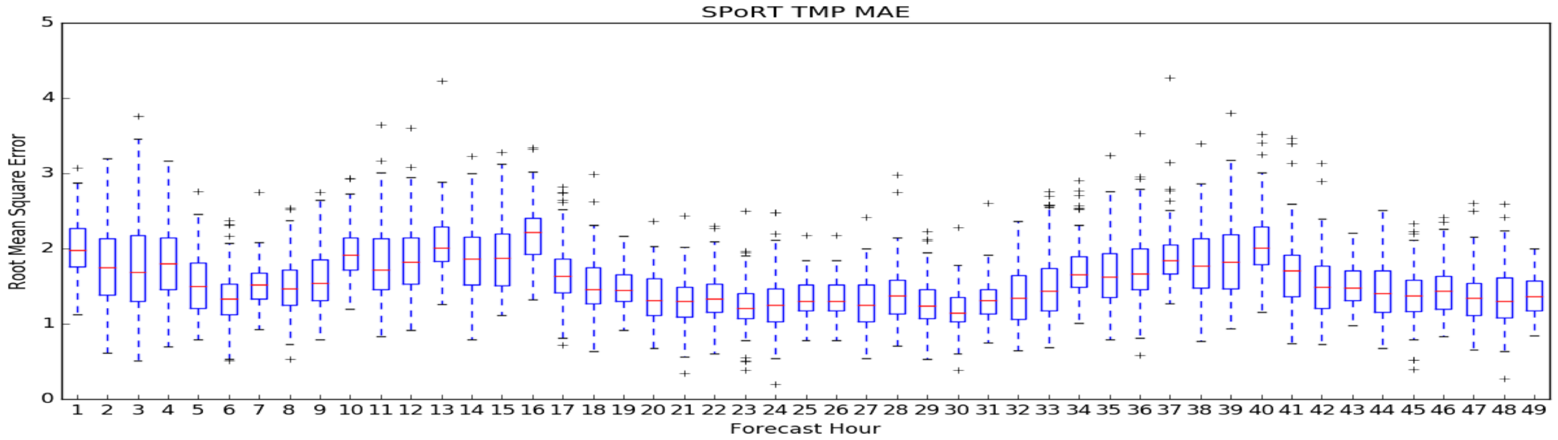

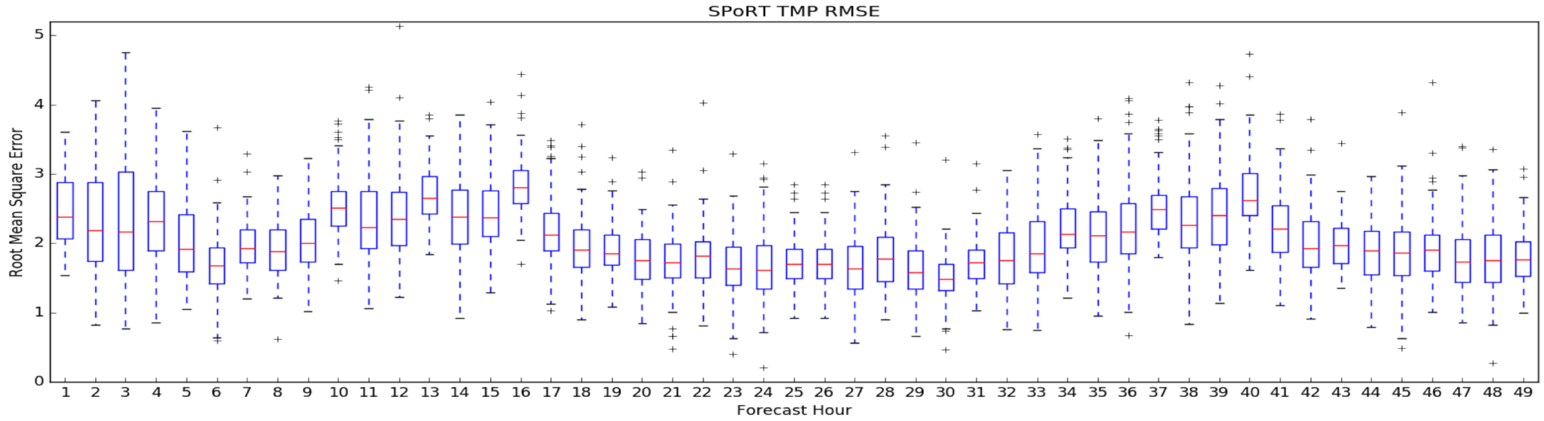

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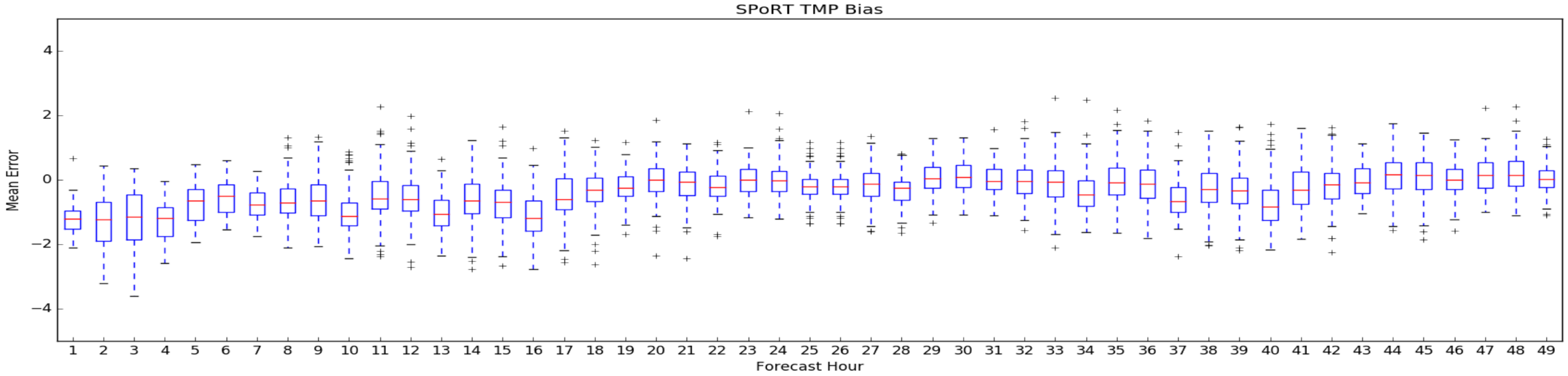

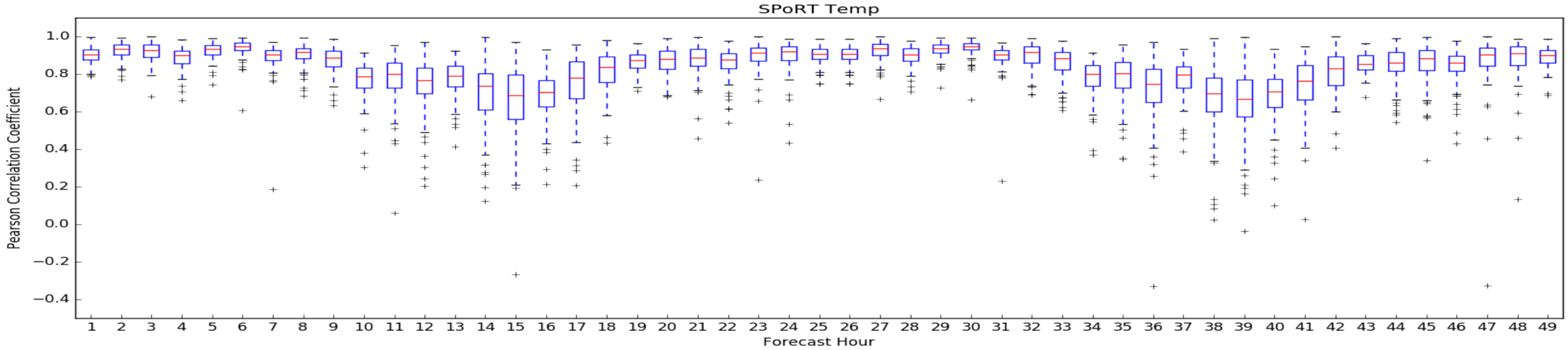

MYJ Test

Lat	Long	PBL	LSM	Lakes	Mphys	Cu	LW	SW	ST @ FH 9	W @ FH 9	RH @ FH 9	Frost	Notes
-0.3399217	35.3192017	MYJ	RUC	def	Goddard	off	def	def	9.04	5.9	75.34	0	
-0.405817	35.3240383	MYJ	RUC	def	Goddard	off	def	def	8.42	7.5	69.65	0	
-0.3399217	35.3192017	MYJ	RUC	def	Goddard	off	def	def	8.4	7.5	69.6		
-0.405817	35.3240383	MYJ	RUC	def	Goddard	off	def	def	8.9	5.9	78.24		
-0.3399217	35.3192017	MYJ	UnifiedNoah LSM	def	Goddard	off	def	def	5.38	2.31	68.03		
-0.405817	35.3240383	MYJ	UnifiedNoah LSM	def	Goddard	off	def	def	9.42	4.93	66.48		
-0.3399217	35.3192017	MYJ	MPNoah	def	Goddard	off	def	def	6.97	0.95	74	0	
-0.405817	35.3240383	MYJ	MPNoah	def	Goddard	off	def	def	6.79	1.79	89.4	0	
-0.3399217	35.3192017	MYJ	MPNoah	def	Goddard	off	def	def	7.02	1.36	72.69		engage show ice graupel in microphysics
-0.405817	35.3240383	MYJ	MPNoah	def	Goddard	off	def	def	8.34	2.89	80.04		
-0.3399217	35.3192017	MYJ	MPNoah	on	Goddard	off	def	def	7	1.35	72.74		SST on and snow ice graupal
-0.405817	35.3240383	MYJ	MPNoah	on	Goddard	off	def	def	8.34	2.85	80.06		SST on
-0.3399217	35.3192017	MYJ	UnifiedNoah LSM	def	WSM Single moment 6 class	off	def	def	5.38	2.3	68.12		
-0.405817	35.3240383	MYJ	UnifiedNoah LSM	def	WSM Single moment 6 class	off	def	def	9.6	4.97	66.69		
-0.3399217	35.3192017	MYJ	MPNoah	def		off	def	def	9.37	2.26	77.55		
-0.405817	35.3240383	MYJ	MPNoah	def		off	def	def	10.67	2.77	74.7		
-0.3399217	35.3192017	MYJ	RUC	def	WSM Single moment 6 class		RRTM	Dudhia	8.49	7.64	69.76		
-0.405817	35.3240383	MYJ	RUC	def	WSM Single moment 6 class		RRTM	Dudhia	8.51	5.97	83.14		
-0.3399217	35.3192017	MYJ	RUC	def	WSM Single moment 6 class		RRTM	Dudhia	8.5	7.65	70.1		engage snow ice graupel in microphysics
-0.405817	35.3240383	MYJ	RUC	def	WSM Single moment 6 class		RRTM	Dudhia	9.4	5.87	72.67		

ACM2 Test

Lat	Long	PBL	LSM	Lakes	Mphys	Cu	LW	SW	ST @ FH 9	W @ FH 9	RH @ FH 9	Frost	Notes
-0.3399217	35.3192017	ACM2	Noah	on	Eta	BMJ	RRTM	Dudhia	7.58	2.93	81.38	0	Model busted @FH 10
-0.405817	35.3240383	ACM2	Noah	on	Eta	BMJ	RRTM	Dudhia	10.6	3.67	67.2	0	Model busted @FH 10
-0.3399217	35.3192017	ACM2	Noah	on	Eta	Grell 3D	CAM	Dudhia	7.04	3.36	81.77	0	Model busted @FH 9
-0.405817	35.3240383	ACM2	Noah	on	Eta	Grell 3D	CAM	Dudhia	10.13	3.87	69.01	0	Model busted @FH 9
-0.3399217	35.3192017	ACM2	NOAH MP	def	def		def	def	9.69	6.69	77.73	0	
-0.405817	35.3240383	ACM2	NOAH MP	def	def		def	def	10.71	8.96	73.11	0	
-0.3399217	35.3192017	ACM2	NOAHMP	def	Lin	off	def	def	10.96	3.74	66.99	0	
-0.405817	35.3240383	ACM2	NOAHMP	def	Lin	off	def	def	8.18	3.07	81.07		Model busted @FH 10
-0.3399217	35.3192017	ACM2	PXLSM	off	WSM Single6	off	def	def	11.43	0	2.35	0	
-0.405817	35.3240383	ACM2	PXLSM	off	WSM Single6	off	def	def	12.37	0	2.84		
-0.3399217	35.3192017	ACM2	RUC	def	Eta	Grell 3D	RRTM	Dudhia	9.689	6.58	77.67	0	
-0.405817	35.3240383	ACM2	RUC	def	Eta	Grell 3D	RRTM	Dudhia	10.71	8.94	72.98	0	
-0.3399217	35.3192017	ACM2	RUC	on	Eta	Grell 3D	RRTM	Dudhia	9.689	6.69	77.73	0	
-0.405817	35.3240383	ACM2	RUC	on	Eta	Grell 3D	RRTM	Dudhia	10.71	8.96	73.11	0	
-0.3399217	35.3192017	ACM2	RUC	def	Goddard	off	def	def	10.75	9.17	73.25		
-0.405817	35.3240383	ACM2	RUC	def	Goddard	off	def	def	9.7	6.2	77.68		

YSU Test

Lat	Long	PBL	LSM	Lakes	Mphys	Cu	LW	SW	ST @ FH 9	W @ FH 9	RH @ FH 9	Frost	Notes			
-0.3399217	35.3192017	YSU	CM	on	def		def	def	7.81	1.35	92.86	0				
-0.405817	35.3240383	YSU	CM	on	def		def	def	6.07	7.29	94.12	0				
-0.3399217	35.3192017	YSU	CM	on	Goddard	off	RRTM	Dudhia	6.8	0.61	93.2		SST and snow ice graupal on			
-0.405817	35.3240383	YSU	CM	on	Goddard	off	RRTM	Dudhia	6.97	1.2	93.8					
-0.3399217	35.3192017	YSU	RUC	def	WSM Single moment 6 class	off	def	def	8.43	8.2	81.33	0	Topo wind correction = 1		Only for YSU	
-0.405817	35.3240383	YSU	RUC	def	WSM Single moment 6 class	off	def	def	8.59	0.83	80.63	0	Topo wind correction = 1			
-0.3399217	35.3192017	YSU	RUC	def	WSM Single moment 6 class	off	def	def	8.86	7.87	80.1	0	Topo wind correction = 0			
-0.405817	35.3240383	YSU	RUC	def	WSM Single moment 6 class	off	def	def	9.98	7.59	79.87	0	Topo wind correction = 0			
-0.3399217	35.3192017	YSU	RUC	def	Goddard	off	def	def	9.89	0.589	95.2	0				
-0.405817	35.3240383	YSU	RUC	def	Goddard	off	def	def	10.26	1.65	92.3	0				
-0.3399217	35.3192017	YSU	UnifiedNoahLSM	def	Goddard	off	def	def	4.77	1.86	69.83	0				
-0.405817	35.3240383	YSU	UnifiedNoahLSM	def	Goddard	off	def	def	6.94	3.15	76.4	0				
-0.3399217	35.3192017	YSU	MPNoah	def	Goddard	off	def	def	7.87	1.47	74.5	0				
-0.405817	35.3240383	YSU	MPNoah	def	Goddard	off	def	def	7.7	1.8	88.8	0				
-0.3399217	35.3192017	YSU	MPNoah	on	Goddard	off	def	def	7.9	1.47	74.4		SST on			
-0.405817	35.3240383	YSU	MPNoah	on	Goddard	off	def	def	7.74	1.82	88.9		SST on			
-0.3399217	35.3192017	YSU	UnifiedNoahLSM	def	WSM Single moment 6 class	off	def	def	5.22	2.35	71.3					
-0.405817	35.3240383	YSU	UnifiedNoahLSM	def	WSM Single moment 6 class	off	def	def	7.51	3.97	74.8					