GEFS 35-day forecast experiments

- Support SubX project

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Summary of progress report
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Main contributors

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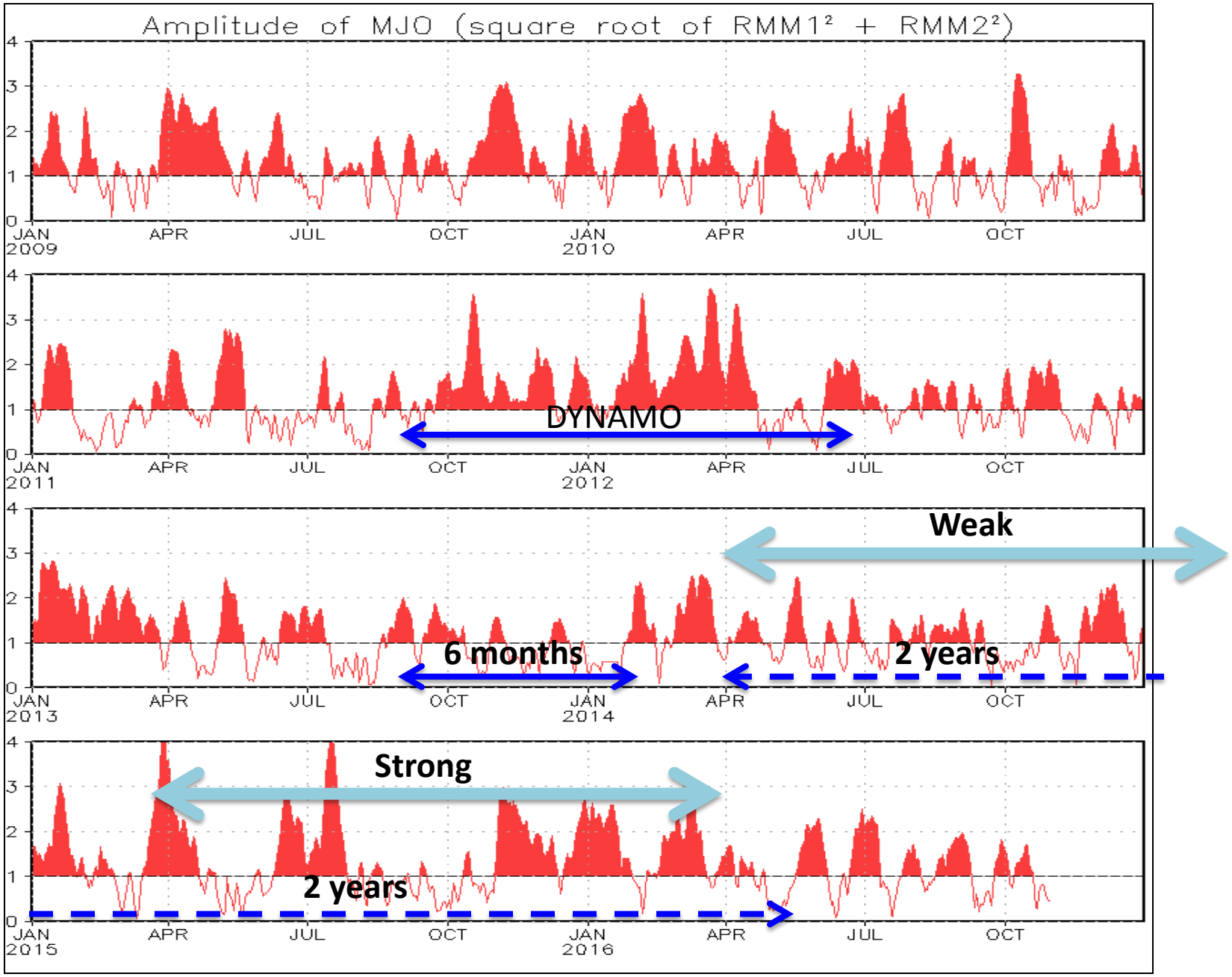
- Eric Sinsky, Hong Guan
- Christopher Melhauser, Dingchen Hou
- All ensemble team members

Acknowledgements

- Malaquias Pena and Wanqiu Wang (CPC)
- Jongil Han
- Xu Li
- Xingren Wu
- Ruiyu Sun
- Kun Liu

Courtesy of CPC web-site



Un-coupled Investigation (1) (GEFS v11)

- New NCEP state-of-art GEFS (version 11.0.0) , based on GFS (version 12.0.0 - 2014), is used for this study. It is semi-Lagrangian model with upgrades of physical and land-surface models, higher resolutions (33km for day 0-8, 55km for day 8-16, **73km for day 16-35**), EnKF assimilated initial perturbations with Stochastic Total Tendency Perturbation (**STTP**) into forecast integration.

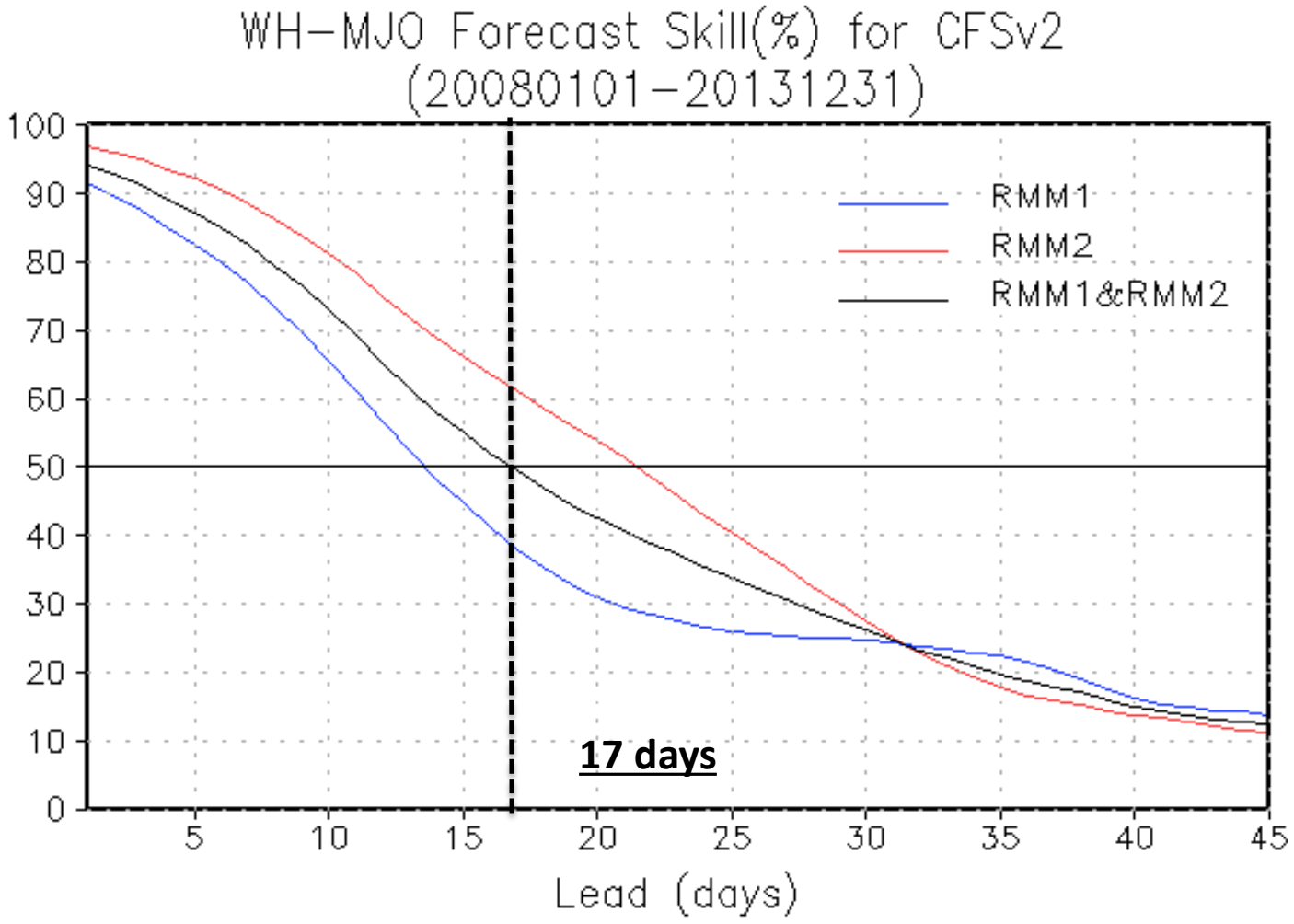
- Period - extended 2013-2014 winter season (September 1 2013 – February 28 2014). *One initial forecast for each day.*

- Four experiments have be studied (finished by end of 2015):
  - Control (CTL): analysis SST relaxes to climatology
  - Optimum (RTG): realistic SST forcing every 24 hours (AMIP like)
  - Forcing (CFS): CFSv2 predicted SST forcing every 24 hours
  - Forcing (CFS): CFSv2 predicted SST anomaly with bias correction

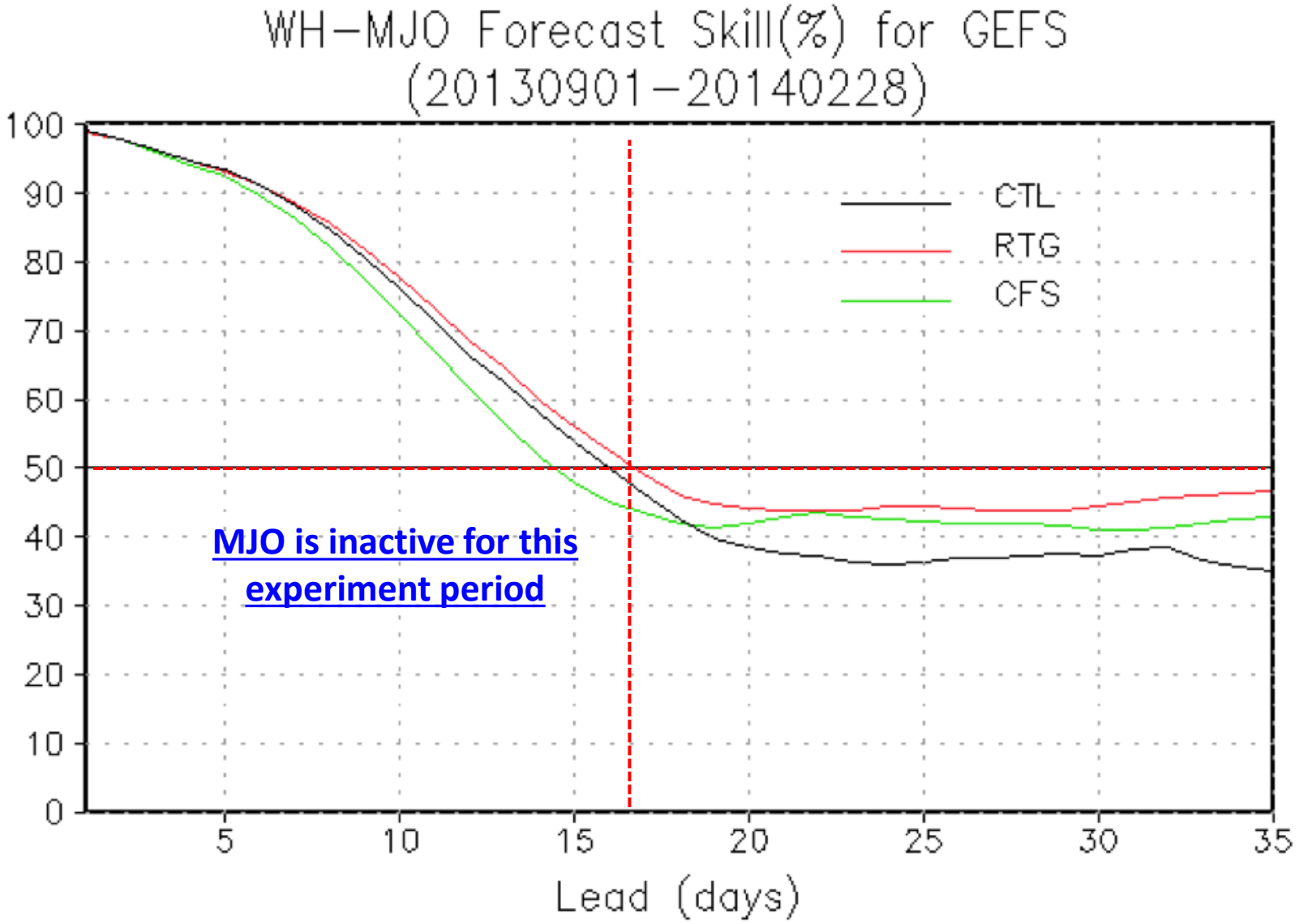
- Targeting:
  - A capability to have skills for extend-range forecast
  - To assimilate maximum impact from observed SST – AMIP run
  - To assimilate the impact of atmosphere-ocean coupling

- GEFS reference: Zhou, X. Y. Zhu, D. Hou, Y. Luo, J. Peng and D. Wobus, 2017: *"The NCEP Global Ensemble Forecast System with the EnKF Initialization" Submit to Weather and Forecasting (in process).*

6-year average WH-MJO forecast skills for CFSv2



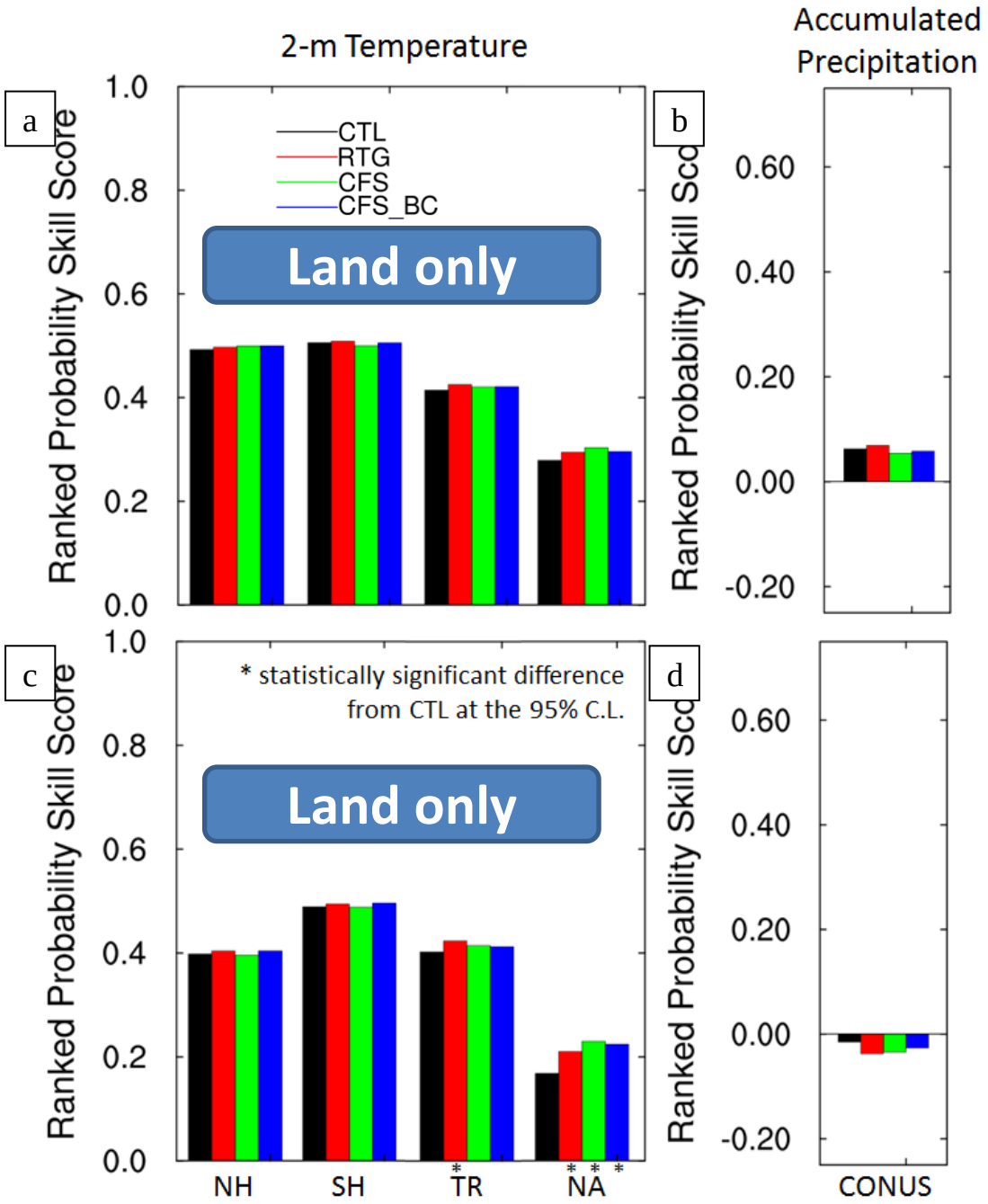
Courtesy of Dr. Qin Zhang



Lower resolution (70km) for week 3&4 with STTP

Week-2

Week 3&4



Un-coupled Investigation (2) (GEFS v11)

- New NCEP state-of-art GEFS (version 11.0.0) , based on GFS (version 12.0.0 - 2014), is used for this study. It is semi-Lagrangian model with upgrades to the physical and land-surface models, higher resolution (33km for days 0-8, 55km for days 8-16, **55km for days 16-35**), initial perturbations from EnKF, different stochastic perturbations (either **STTP or SPs=SKEB+SPPT+SHUM**), and varying SST (CFS with bias correction, with and without **NSST**) in forecast integration. Later, we tested new scale-aware convective scheme instead of operational SAS

- Period: May 2014 – May 2016. *One initial forecast for every 5 days*.

- Four experiments have be studied (finished on April 15 2017):
  - CTL (STTP): analysis SST relaxes to climatology (STTP)
  - SPs: CTL with updated stochastic physics (SKEB+SPPT+SHUM)
  - SPs+CFSBC: SPs with CFSv2 predicted SST anomaly with bias correction (assimilate coupling)
  - SPs+CFSBC+NSST: SPs+CFSBC with NSST (will discuss this later)
  - SPs+CFSBC+SA-CNV: SPs+CFSBC with scare aware convective scheme

- Targeting:
  - Three scientific areas for tropical MJO prediction
    - Ensemble and stochastic physics
    - Atmosphere-ocean interaction through 2-tier SST (assimilate coupling)
    - Tropical convection through improved new scale aware convection scheme

- Support SubX project – real-time forecast for CPC NMME

- GEFS reference: Zhou, X. Y. Zhu, D. Hou, Y. Luo, J. Peng and D. Wobus, 2017: *"The NCEP Global Ensemble Forecast System with the EnKF Initialization" Submit to Weather and Forecasting (in process).*

Evaluation of MJO skills

Based on Wheeler-Hendon Index

An improvement comes from three areas:

1. Ensemble and stochastic physic perturbations
2. 2-tier SST to assimilate coupling
3. New scale-aware convective scheme

Stochastic Schemes for Atmosphere

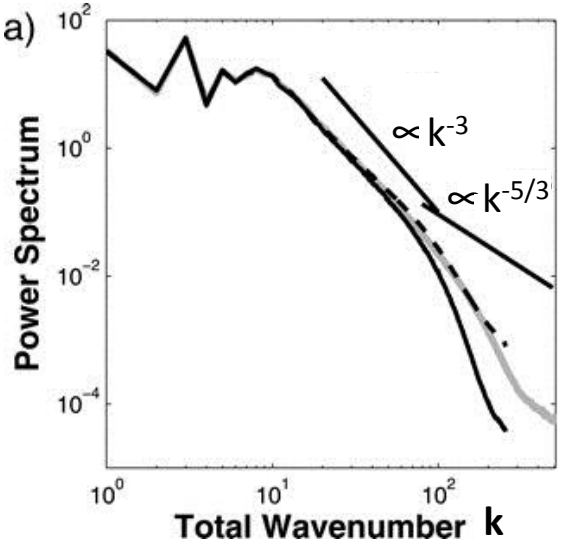
- Applied to GEFS experiments

- **Dynamics**: Due to the model's finite resolution, energy at non-resolved scales cannot cascade to larger scales.
  - Approach: Estimate energy lost each time step, and inject this energy in the resolved scales. a.k.a stochastic energy backscatter (SKEB; Berner et al. 2009)

- **Physics**: Subgrid variability in physical processes, along with errors in the parameterizations result in an under spread and biased model.
  - Approach: perturb the results from the physical parameterizations, and boundary layer humidity (Palmer et al. 2009), and inspired by Tompkins and Berner 2008, we call it SPPT and SHUM

- *Above schemes has been tested for current operational GEFS (spectrum model) with positive response – plan to replace STTP for next implementation*

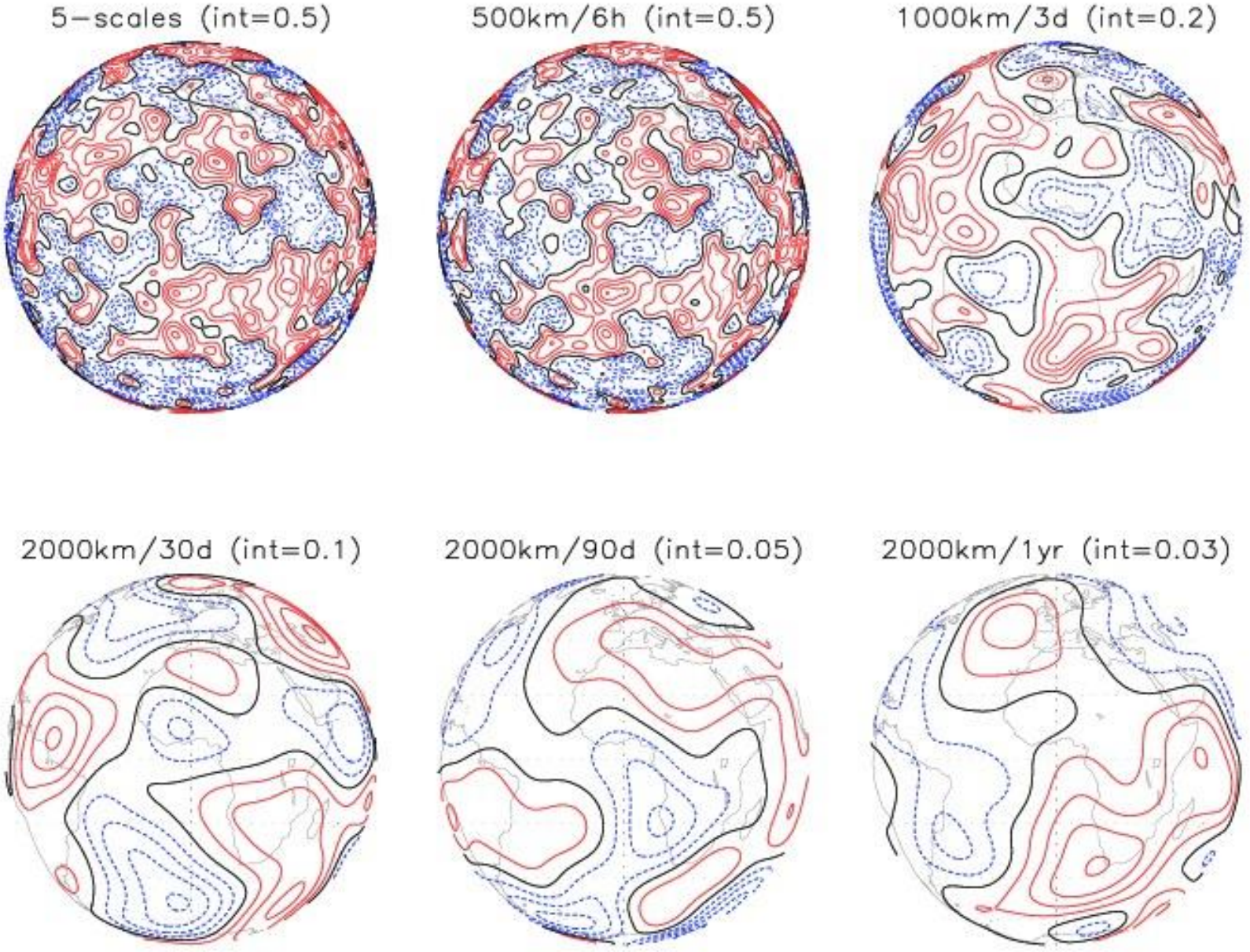
Kinetic Energy Spectrum



Berner et al. (2009)

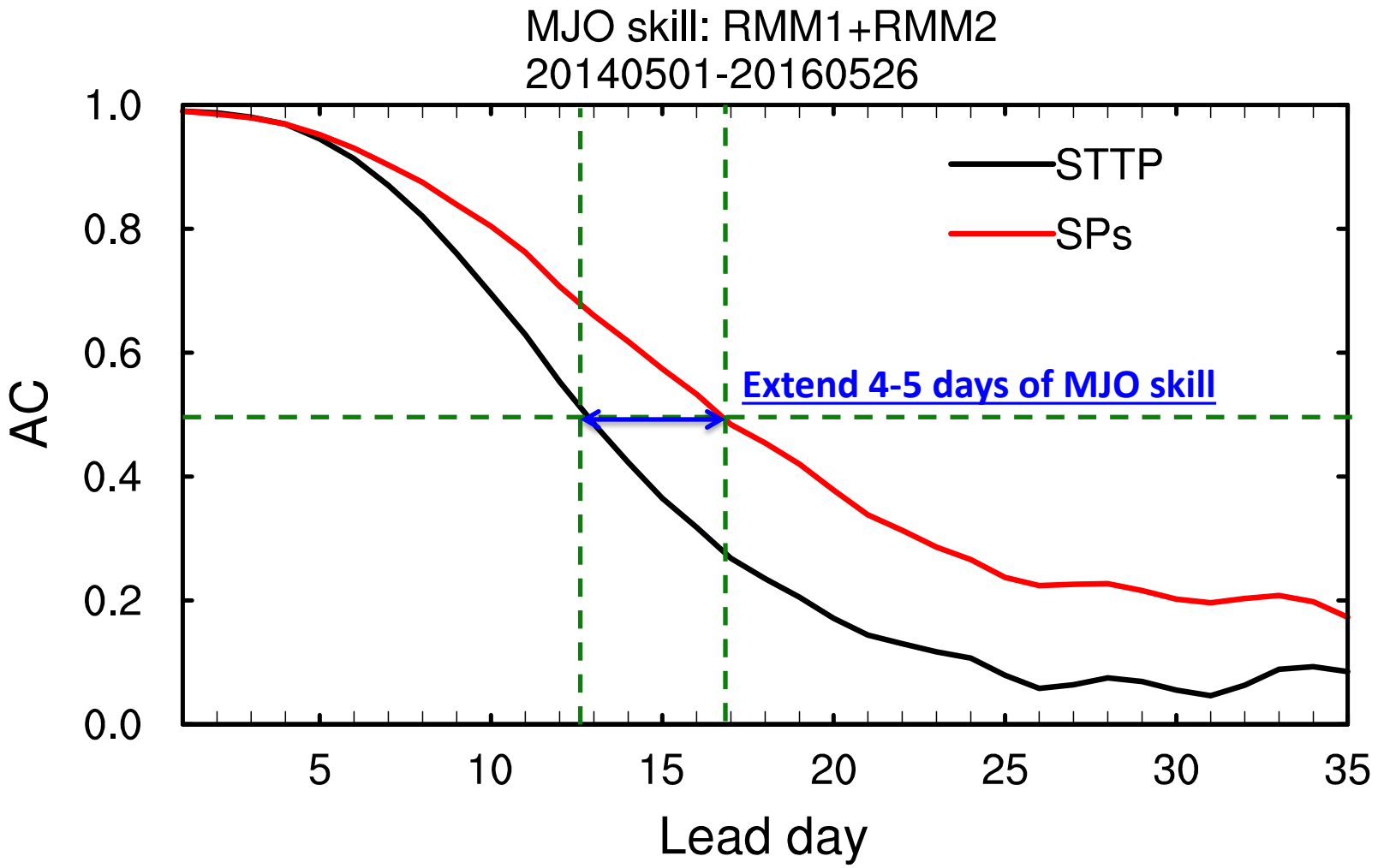
See next slide for the example of random pattern

Examples of stochastic patterns for SPPT



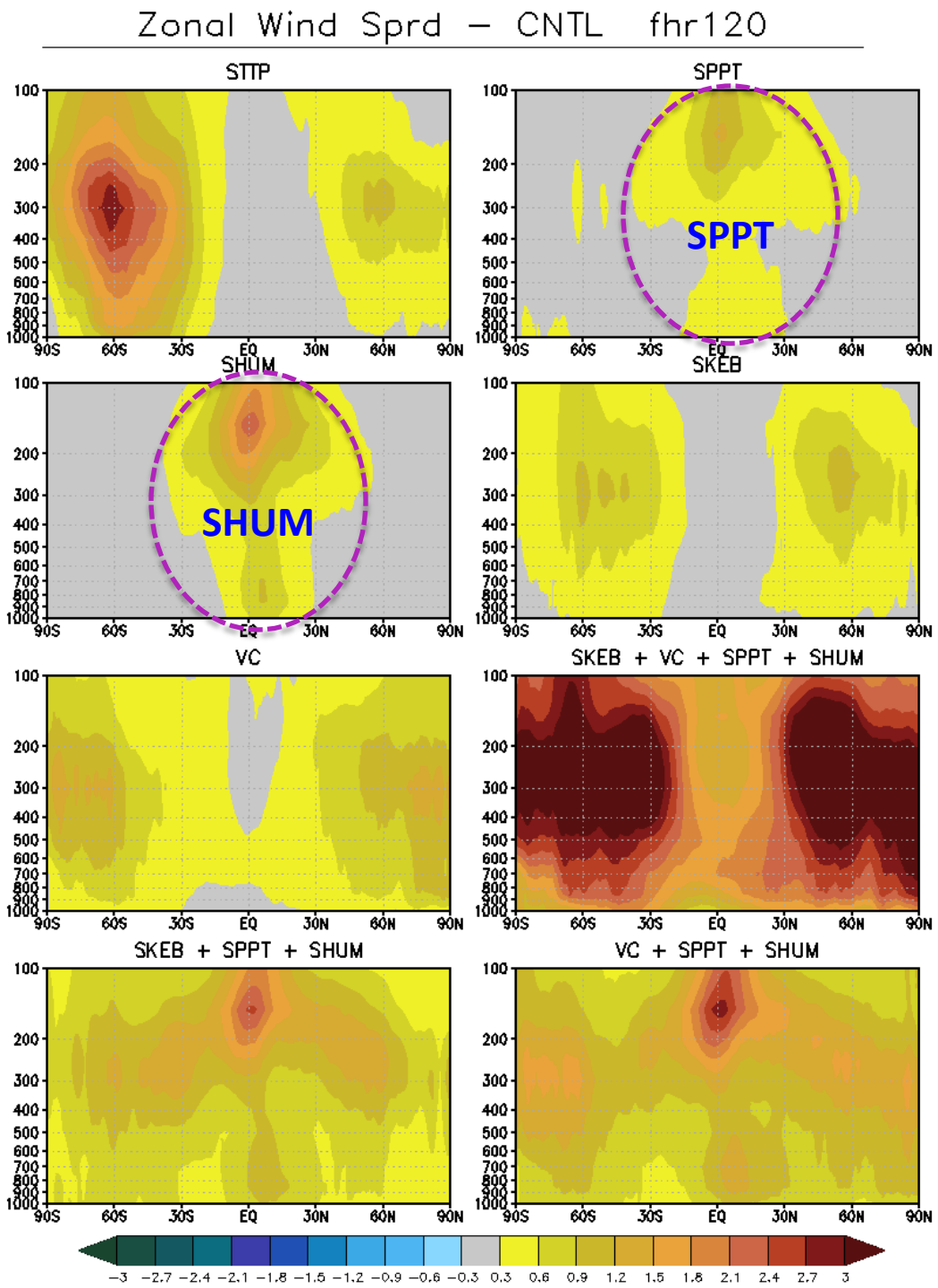
Courtesy of Dr. Bing Fu

GEFS week 3&4 forecasts (May 2014-May 2016)



Apply new stochastic schemes:

Higher resolution (~50km) for week 3&4 with different SPs



Characteristics of one summer month test

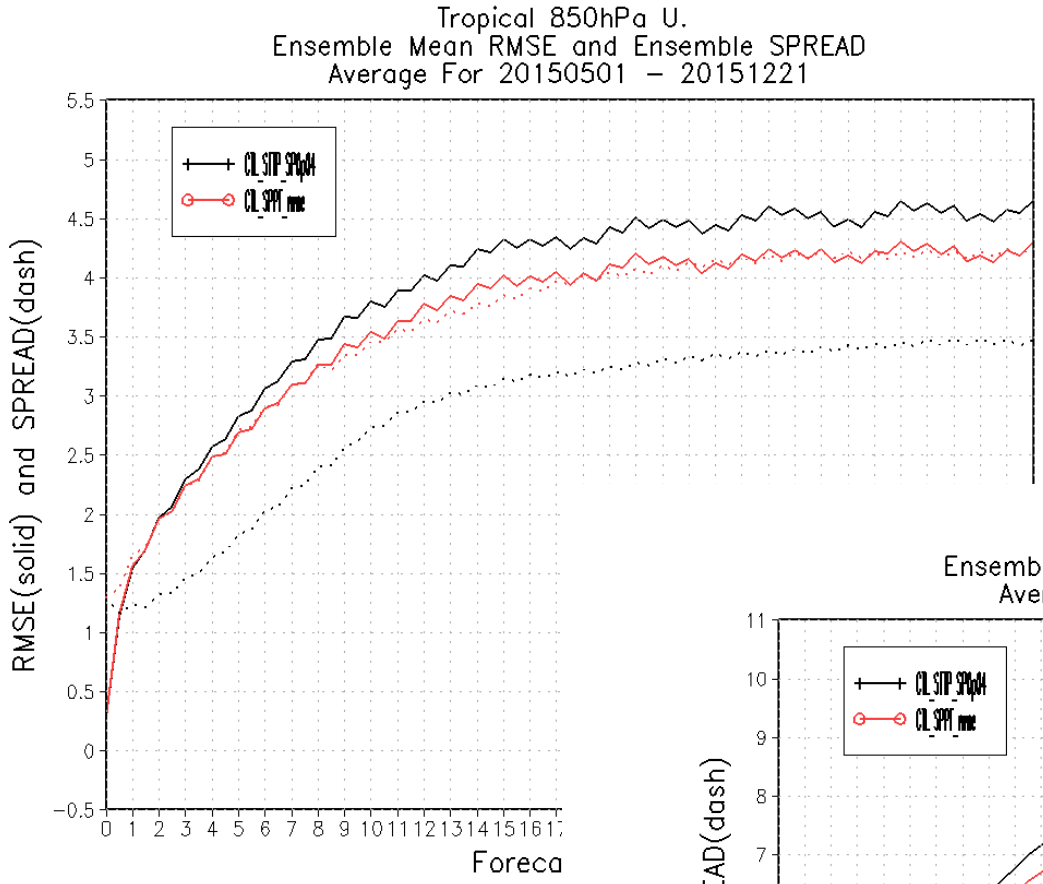
STTP → strong at winter hemisphere

SKEB → similar to STTP, but for large scale

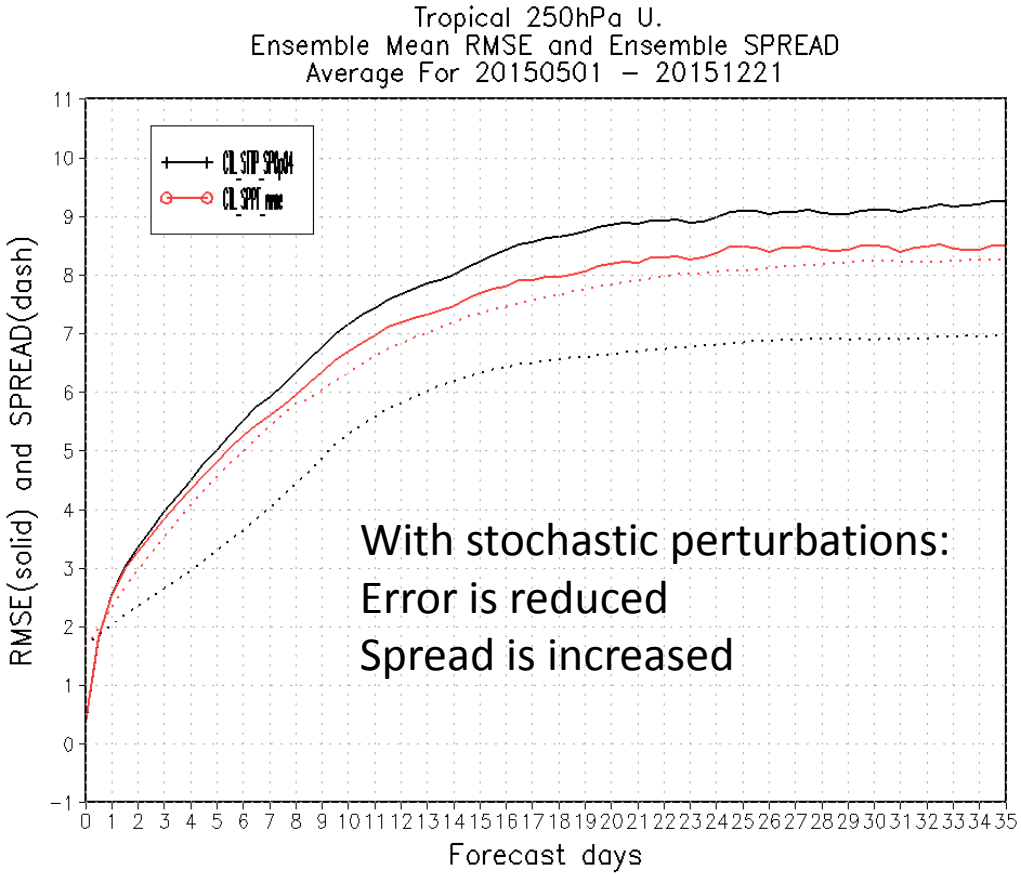
SPPT → big impact is tropical, not mid-latitude

SHUM – big impact is tropical, duplicate to SPPT

VC – big impact is high latitude



850hPa tropical zonal wind



250hPa tropical zonal wind

SST Schemes (operation) and 2-tier SST approach - Assimilate coupling

- **Operational**

$$SST_f^t = \left[SST_a^{t_0} - SST_c^{t_0}\right] e^{-(t-t_0)/90} + SST_c^t$$

- **CFSBC**

$$SST_f^t = (1-w) * \left[SST_a^{t_0} - SST_{cfsrc}^{t_0} + SST_{cfsrc}^t\right] + w * [SST_{cfs}^t - (SST_{cfs\_c}^t - SST_{cfsrc}^t)]$$

$$w(t) = \frac{(t - t_0)}{35}$$

$SST_a^{t_0}$ -- SST analysis at initial time (RTG)

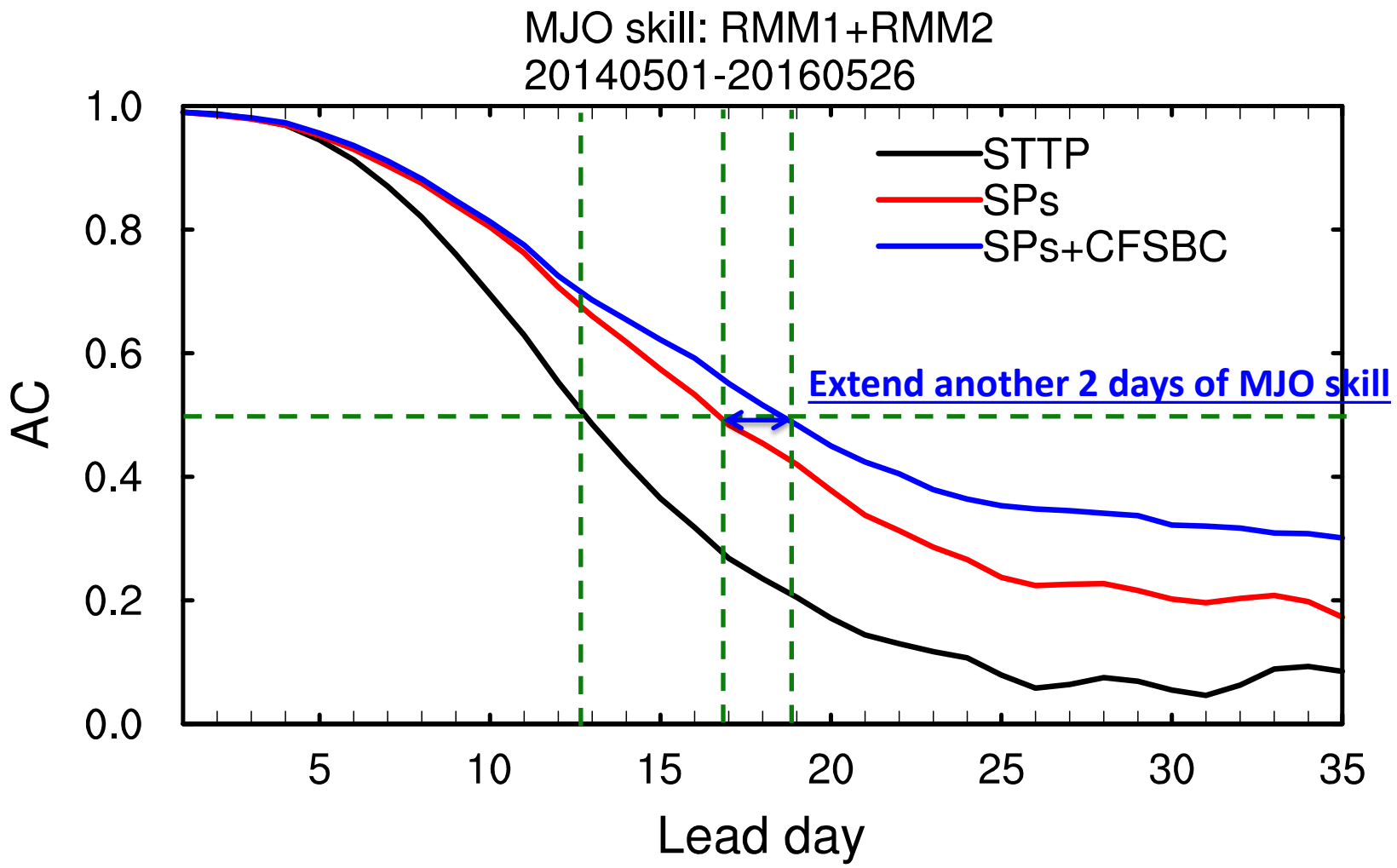
SST_c^t -- Climatological daily SST from RTG analysis for forecast lead-time t

SST_{cfs}^t -- CFS predictive SST (24hr mean) for forecast lead-time t

$SST_{cfs\_c}^t$ -- CFS model climatology (predictive SST) for forecast lead-time t

SST_{cfsrc}^t -- CFS reanalysis daily climatology for forecast lead-time t

GEFS week 3&4 forecasts (May 2014-May 2016)

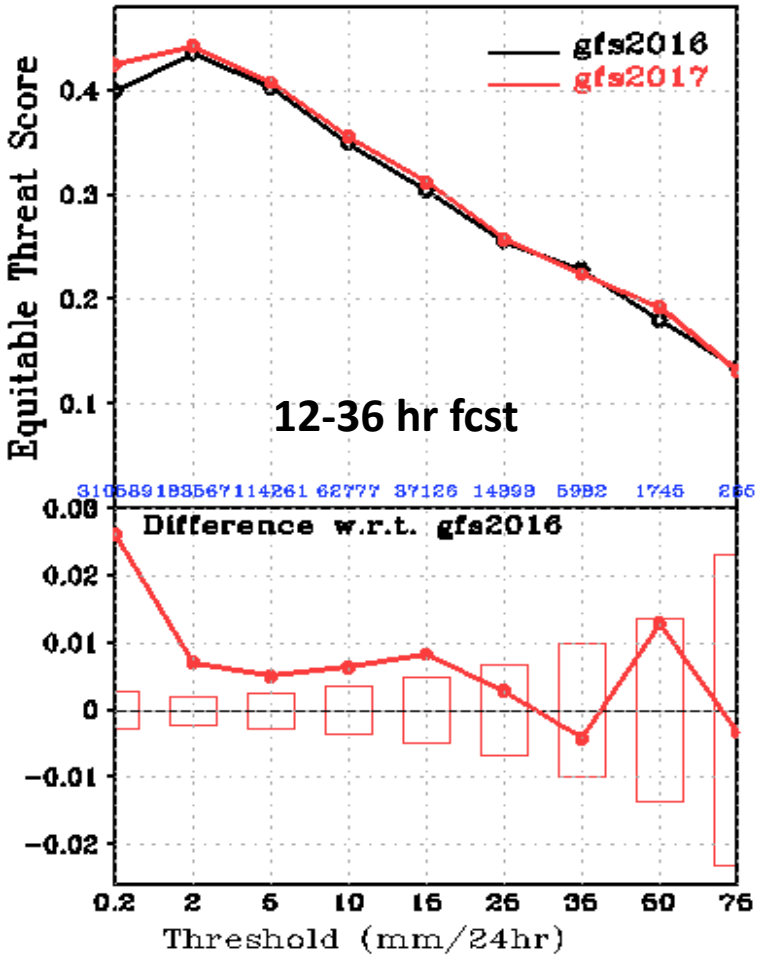


2-Tier SST approach (assimilate coupling)

Higher resolution (~50km) for week 3&4 with different SPs

Update GFS convection scheme

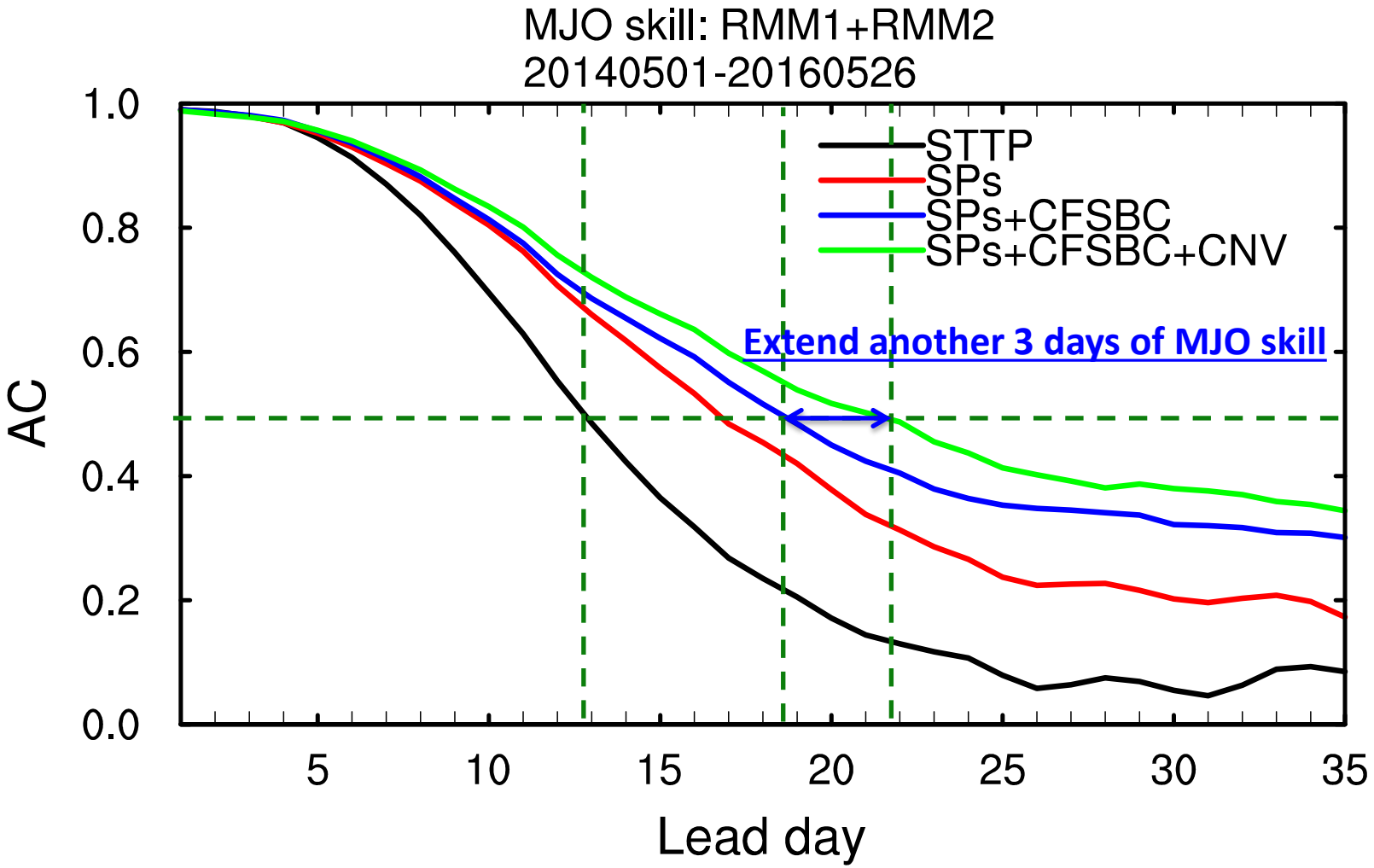
- Scale-aware, aerosol-aware parameterization
- Rain conversion rate decreases with decreasing air temperature above freezing level.
- Convective adjustment time in deep convection proportional to convective turn-over time with CAPE approaching zero after adjustment time.
- Cloud base mass flux in shallow convection scheme function of mean updraft velocity.
- Convective inhibition (CIN) in the sub-cloud layer additional trigger condition to suppress unrealistically spotty rainfall especially over high terrains during summer
- Convective cloudiness enhanced by suspended cloud condensate in updraft.
- Significant improvement especially CONUS precip in summer.



Courtesy of Dr. Vijay Tallapragada

Reference: Han, J. and et al., 2017 (in process)

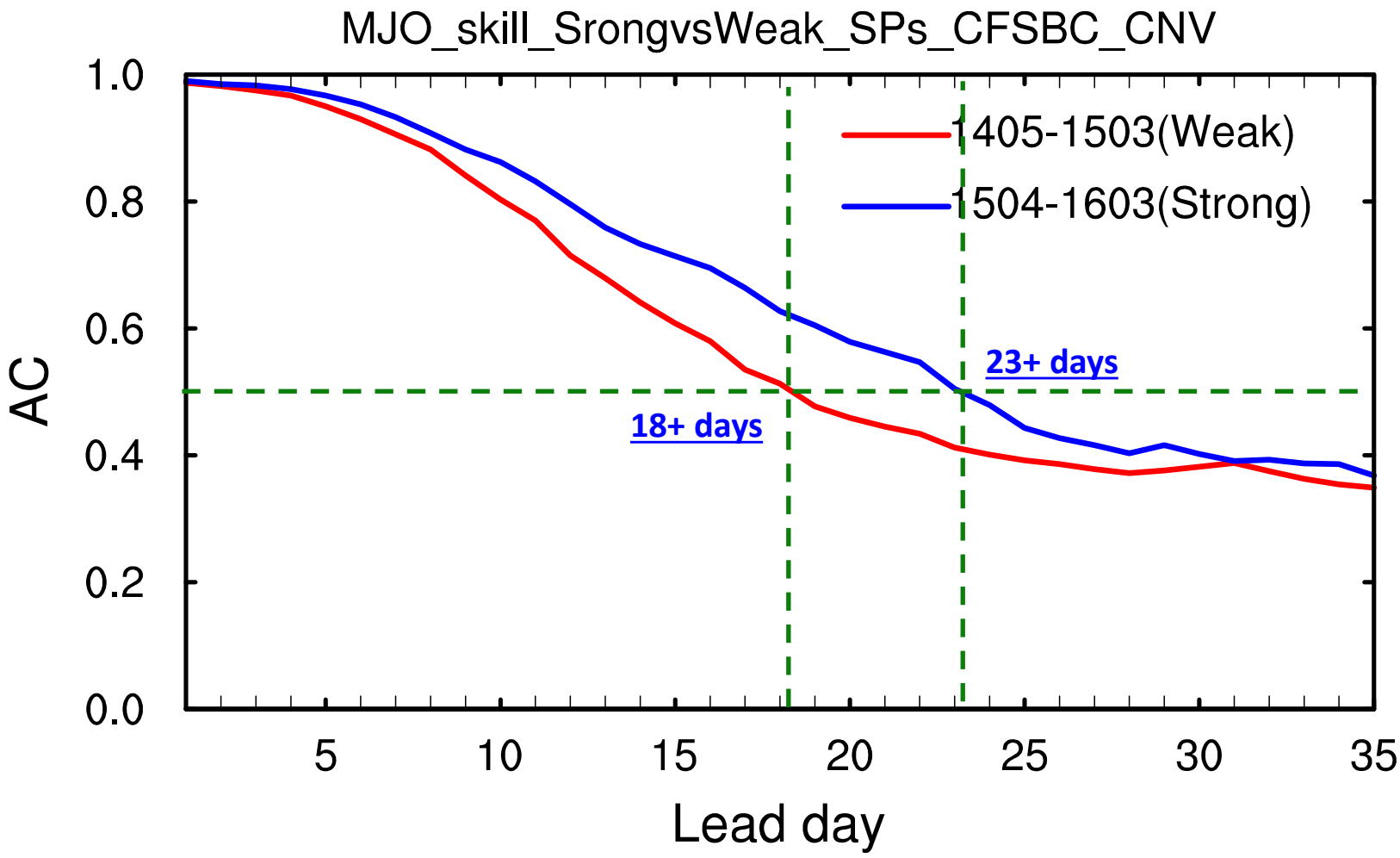
GEFS week 3&4 forecasts (May 2014-May 2016)



Apply scale aware convective scheme

Higher resolution (~50km) for week 3&4 with different SPs

GEFS week 3&4 forecasts (May 2014-May 2016)



Apply SPs + 2-Tier SST + SA-CNV

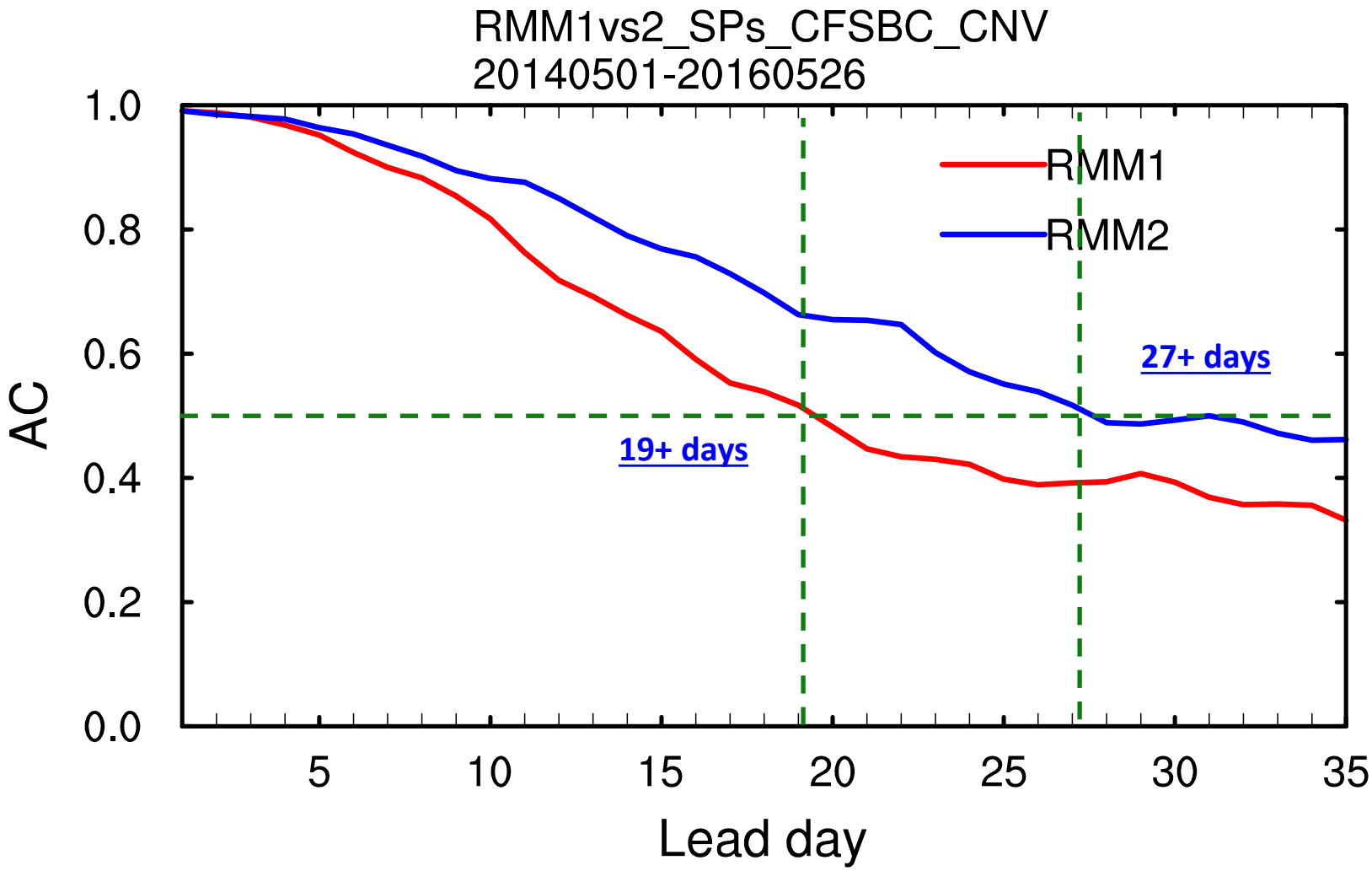
Higher resolution (~50km) for week 3&4

WH MJO skill (ACC=0.5)

20140501-20160526

Configurations	Weak	Strong	2-yr
STTP (CTL)	12.2	12.8	**12.5**
SPs (CTL)	15.8	18	**16.8**
SPs+CFSBC	17	19.5	**18.5**
SPs+CFSBC+SA-CNV	18+	23+	**22.0**
GEFS_v10			**12.5**

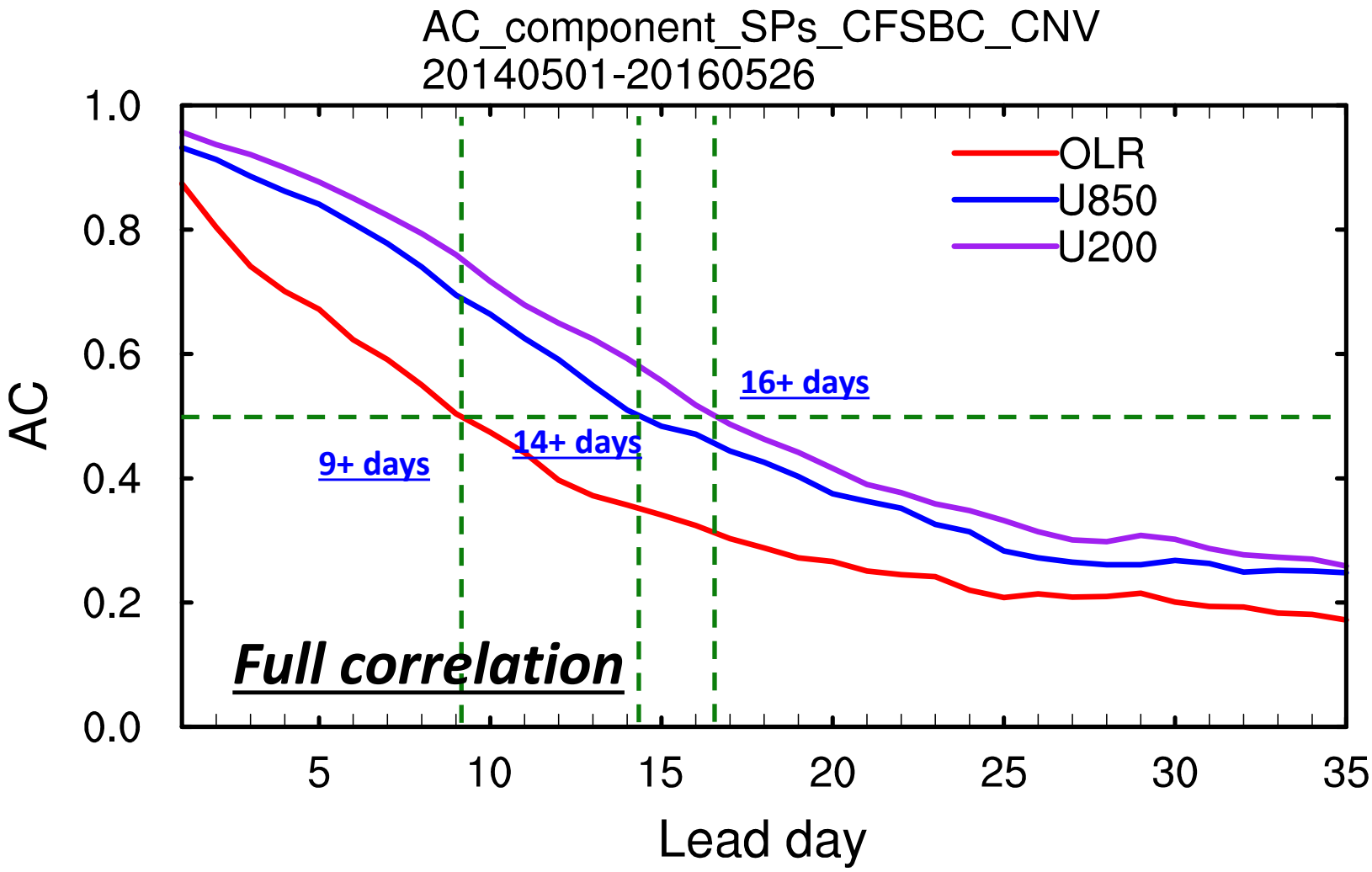
GEFS week 3&4 forecasts (May 2014-May 2016)



Apply SPs + 2-Tier SST + SA-CNV

Higher resolution (~50km) for week 3&4

GEFS week 3&4 forecasts (May 2014-May 2016)



Apply SPs + 2-Tier SST + SA-CNV

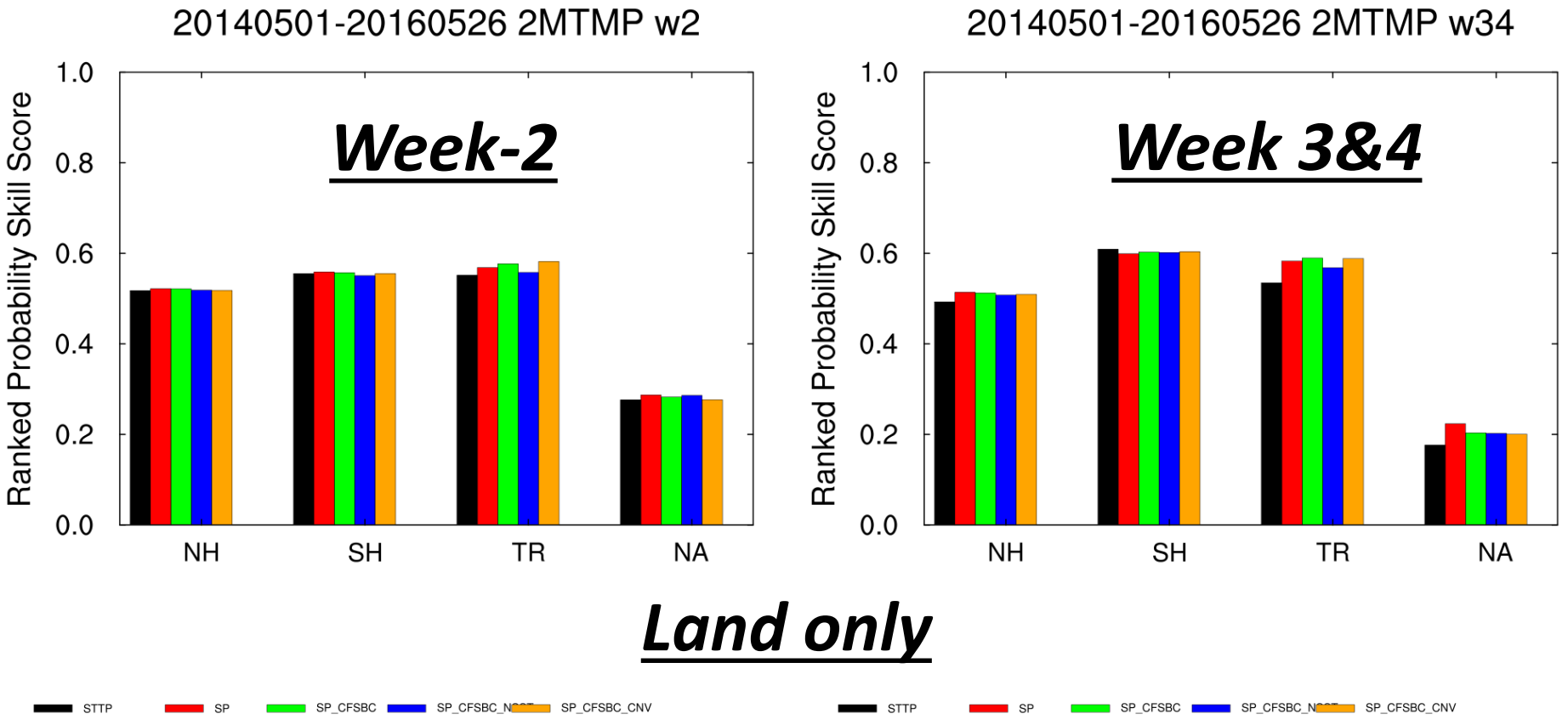
Higher resolution (~50km) for week 3&4

Evaluation of T2m and Precipitation

RPS scores for week-1 and week 3&4

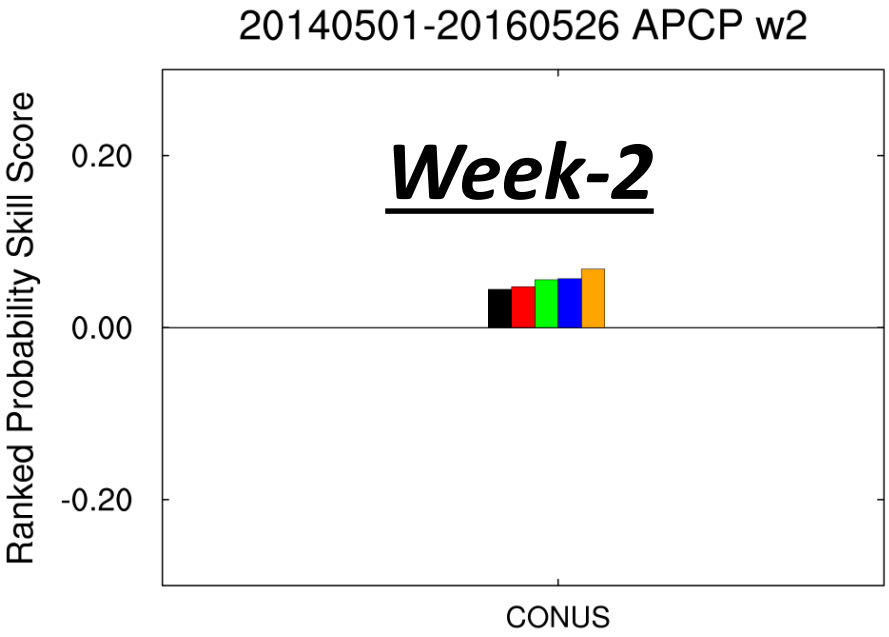
http://www.emc.ncep.noaa.gov/gmb/esinsky/images/STTP_SPs_CFSBC_CNV/

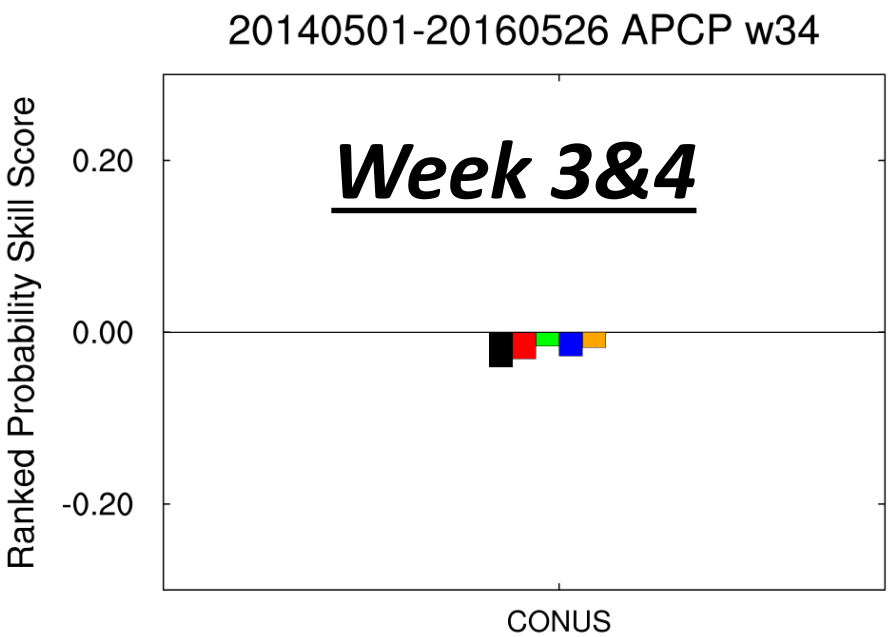
RPS scores for 2-meter temperature



http://www.emc.ncep.noaa.gov/gmb/cmelhauser/rpss_14-16/index.html

RPS scores for CONUS precipitation





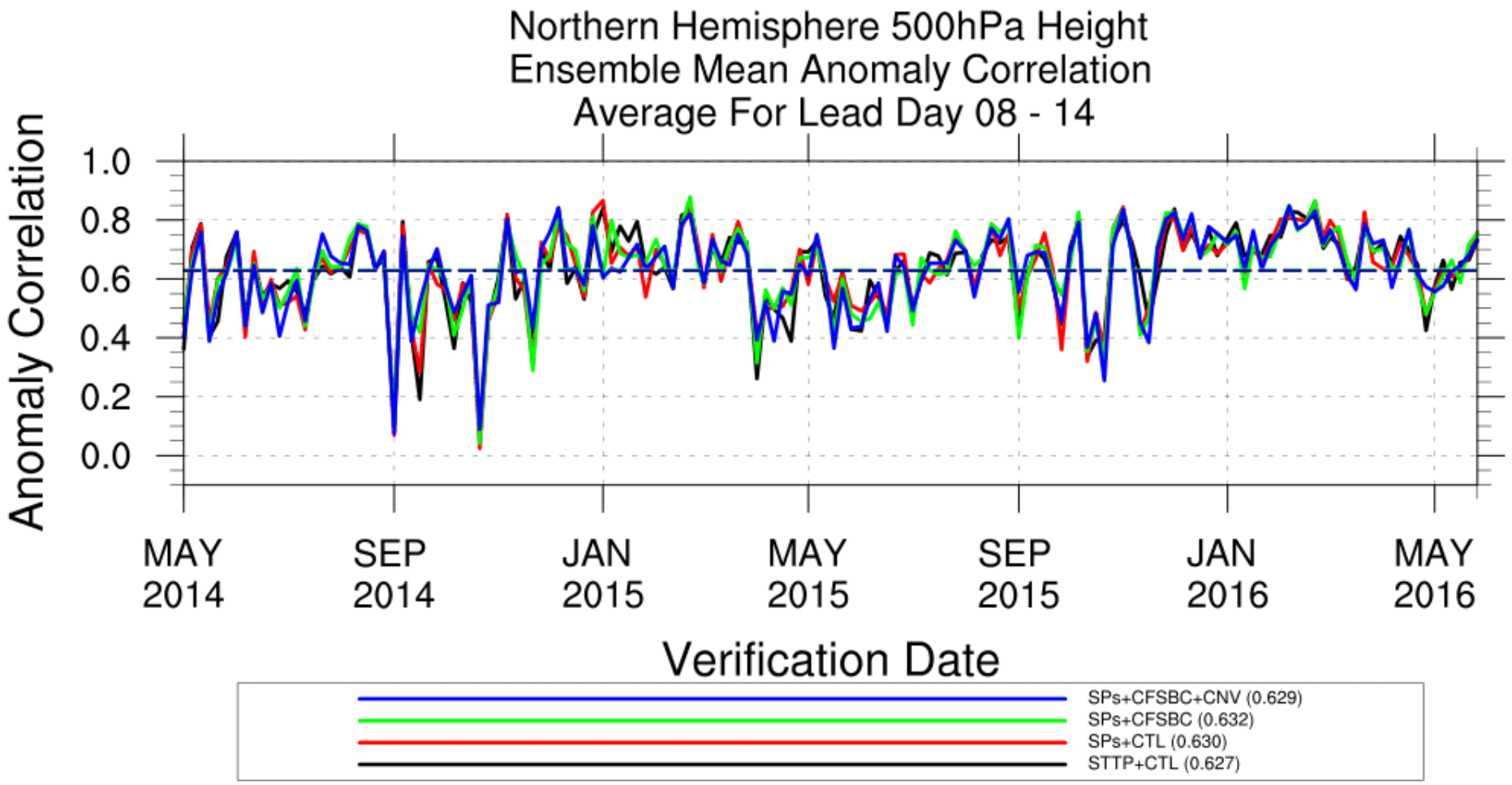
CONUS only

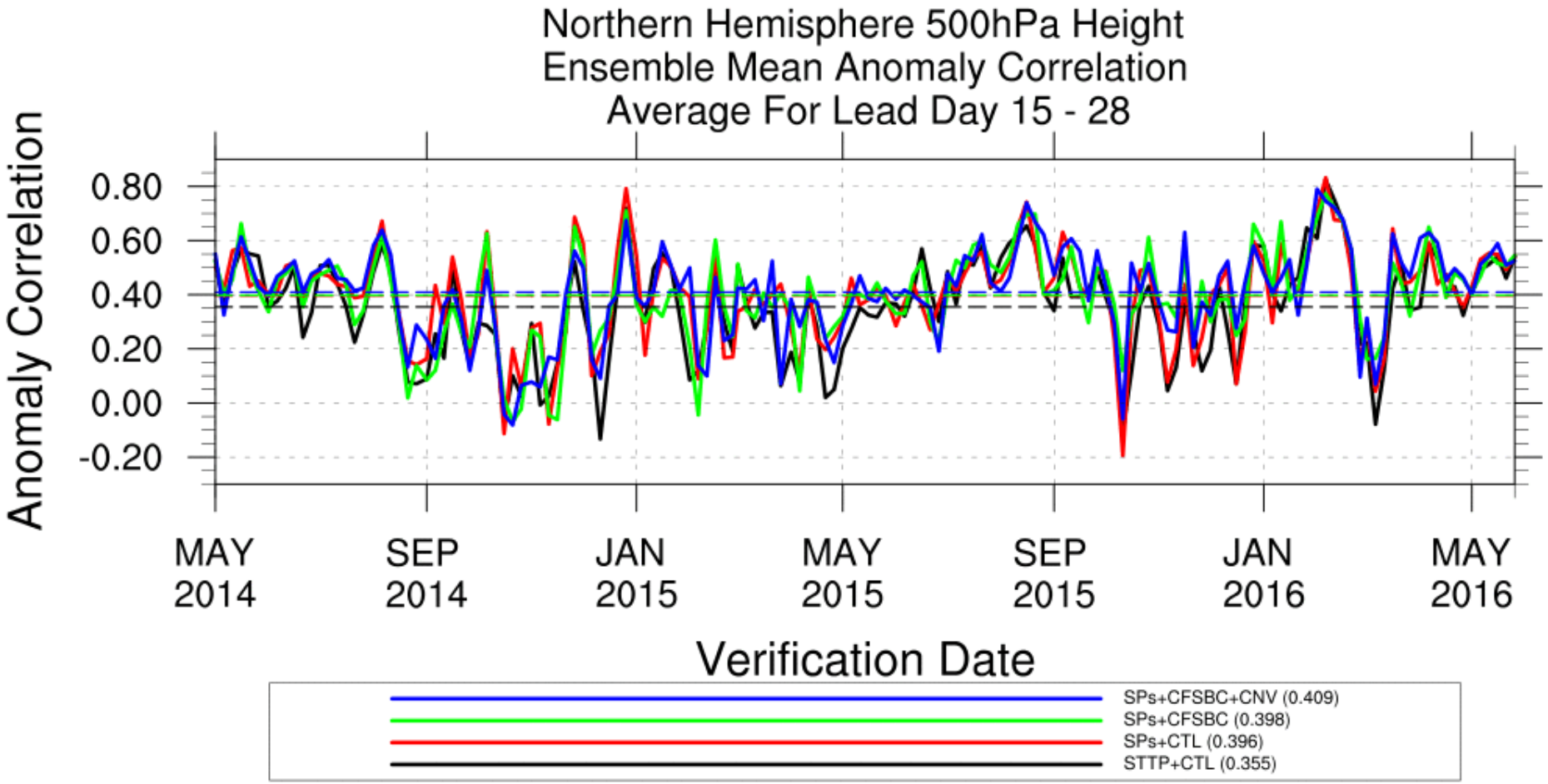
http://www.emc.ncep.noaa.gov/gmb/cmelhauser/rpss_14-16/index.html

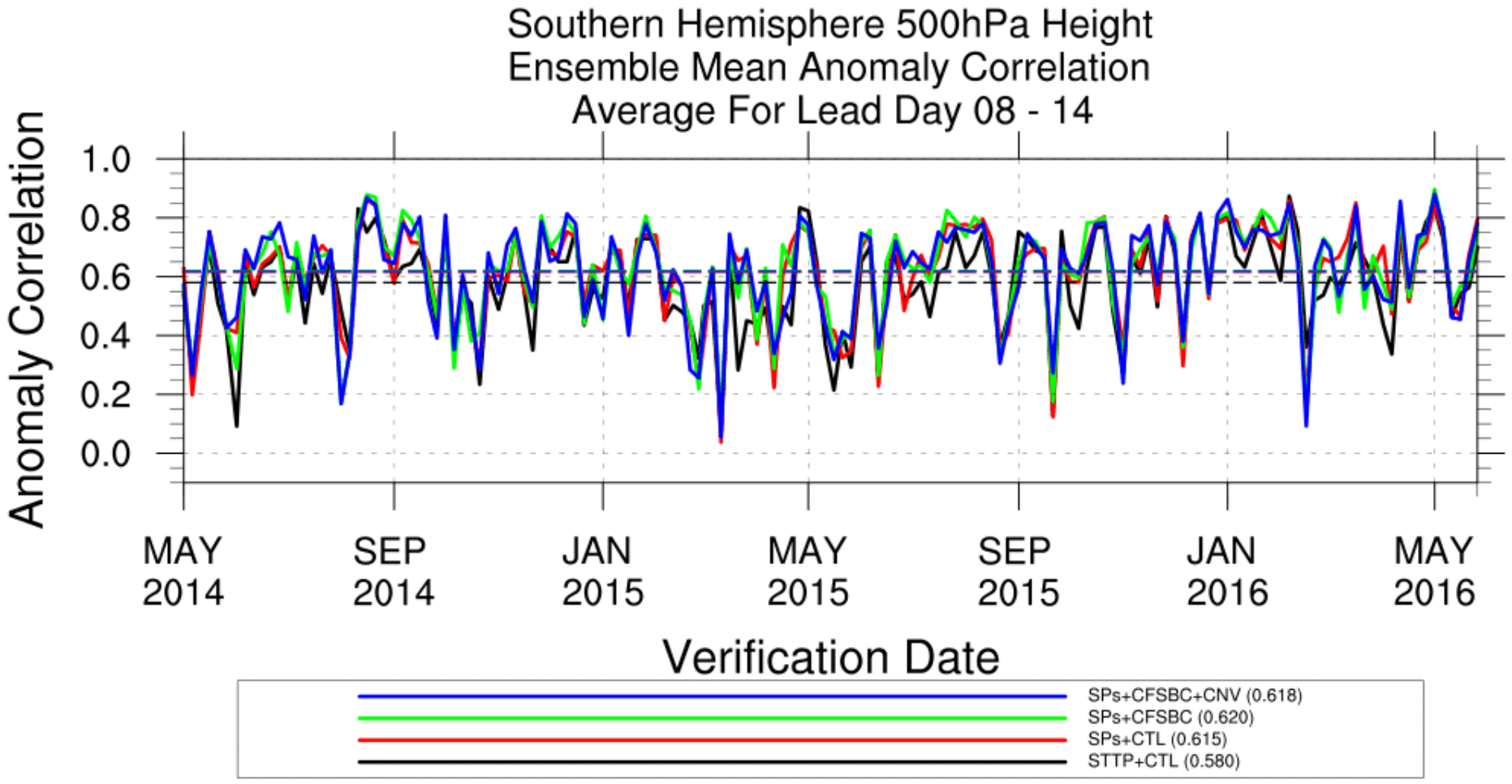
Evaluation of 500hPa height

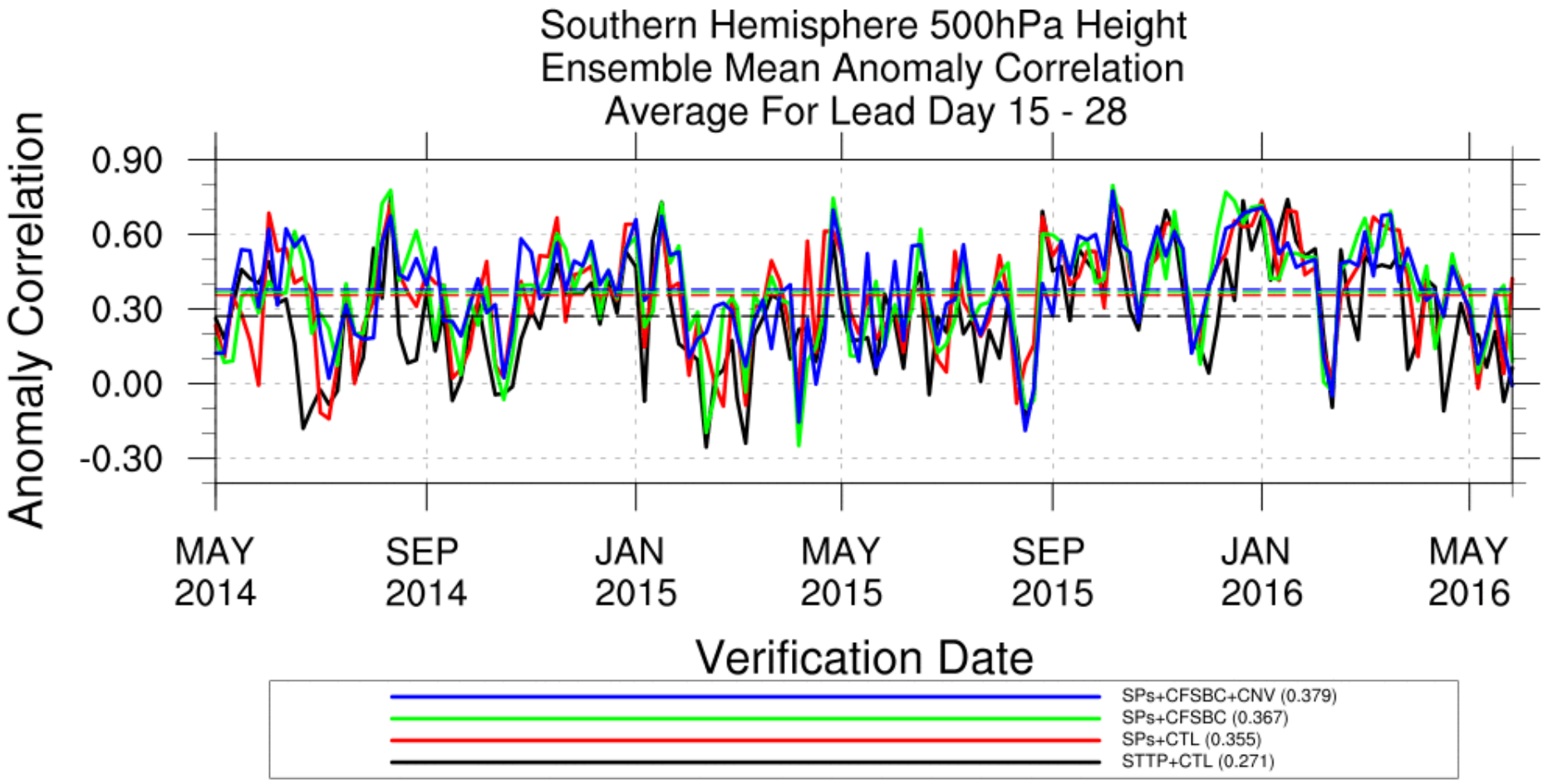
ACC scores for week-1 and week 3&4

http://www.emc.ncep.noaa.gov/gmb/esinsky/images/STTP_SPs_CFSBC_CNV/


Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 08 - 14
Anomaly Correlation
1.0
0.8
0.6
0.4
0.2
0.0
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
SPs+CFSBC+CNV (0.629)
SPs+CFSBC (0.632)
SPs+CTL (0.630)
STTP+CTL (0.627)

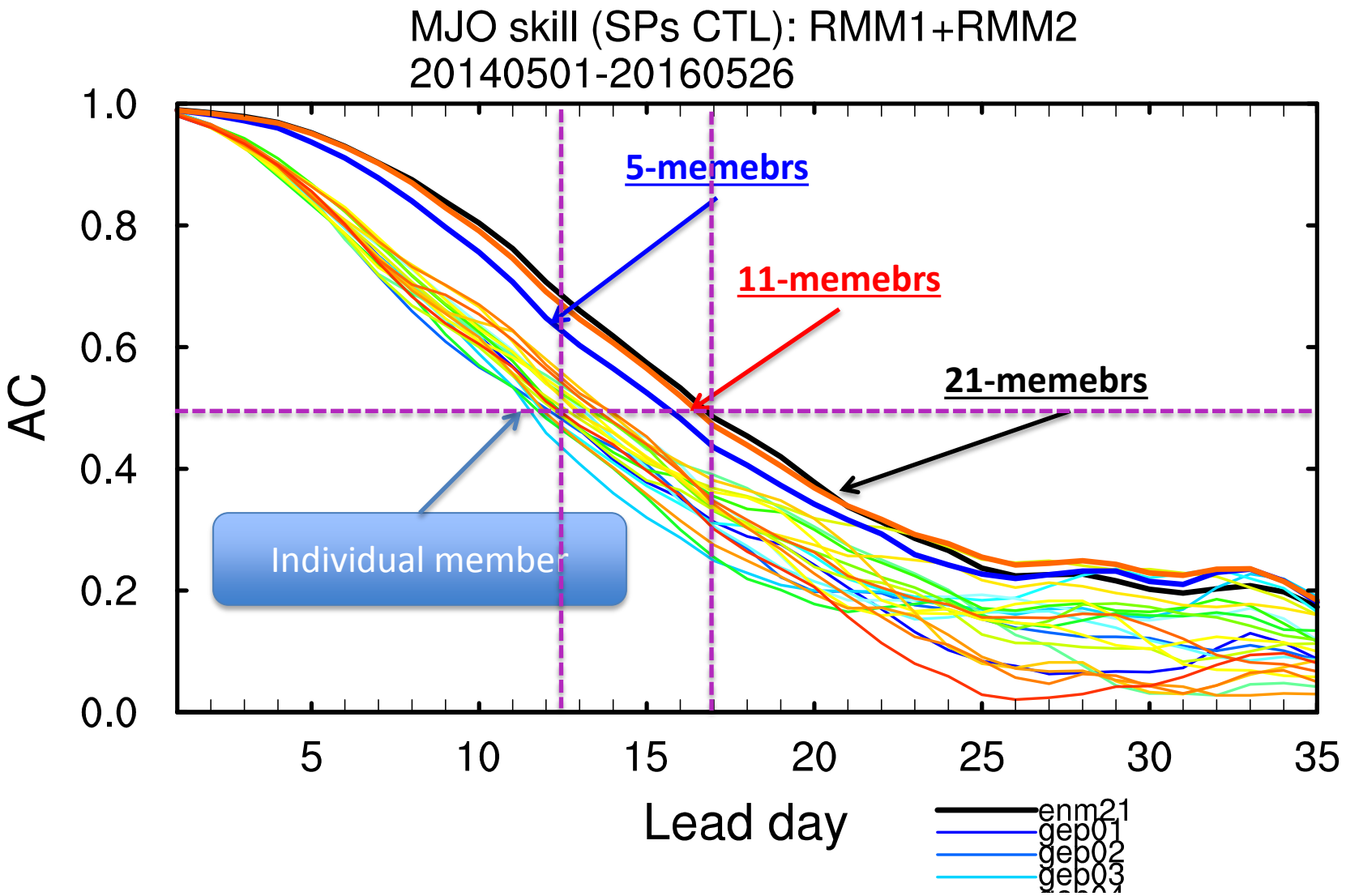

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 15 - 28
Anomaly Correlation
0.80
0.60
0.40
0.20
0.00
-0.20
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
SPs+CFSBC+CNV (0.409)
SPs+CFSBC (0.398)
SPs+CTL (0.396)
STTP+CTL (0.355)

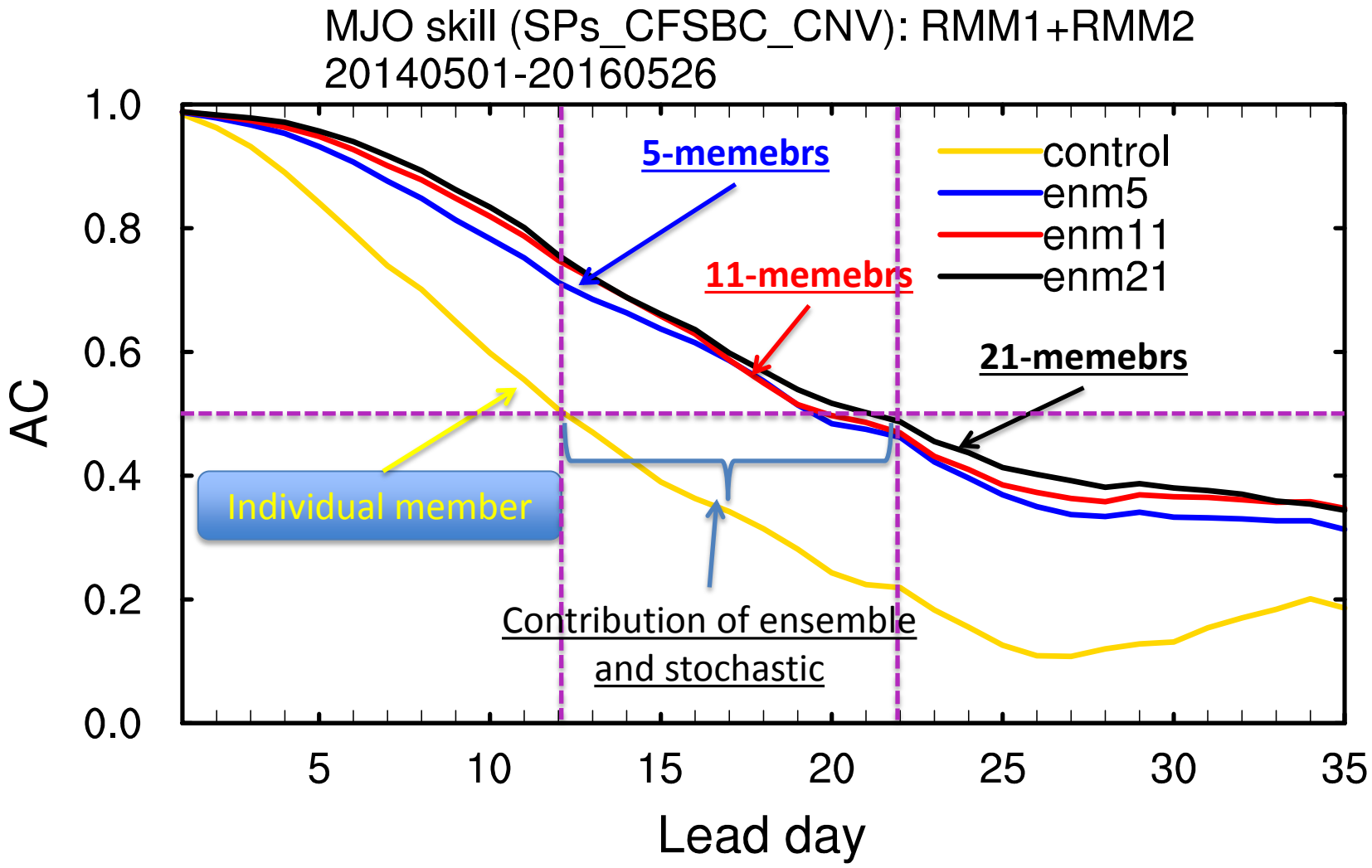

Southern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 08 - 14
Anomaly Correlation
1.0
0.8
0.6
0.4
0.2
0.0
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
SPs+CFSBC+CNV (0.618)
SPs+CFSBC (0.620)
SPs+CTL (0.615)
STTP+CTL (0.580)

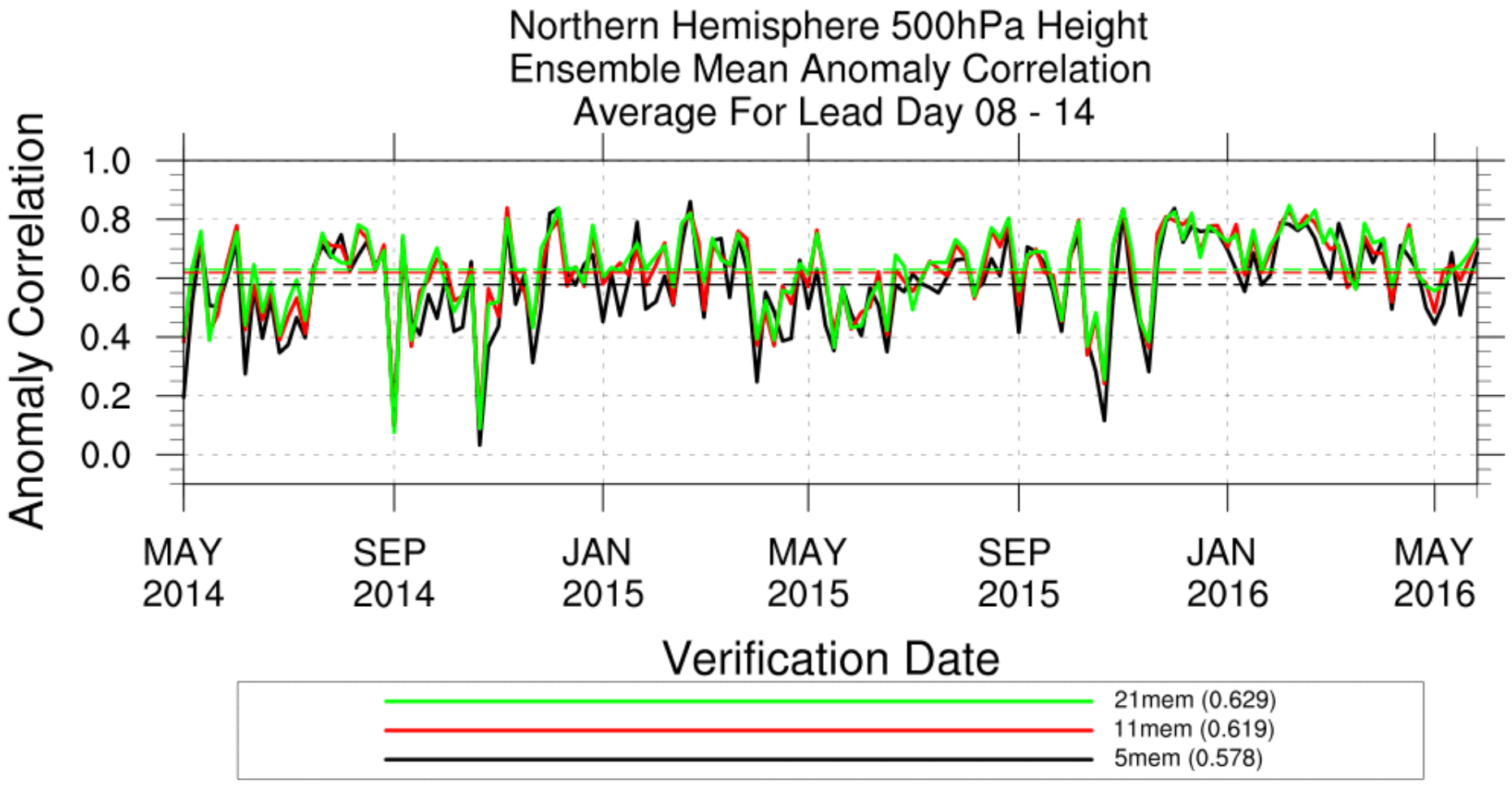

Southern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 15 - 28
Anomaly Correlation
0.90
0.60
0.30
0.00
-0.30
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
SPs+CFSBC+CNV (0.379)
SPs+CFSBC (0.367)
SPs+CTL (0.355)
STTP+CTL (0.271)

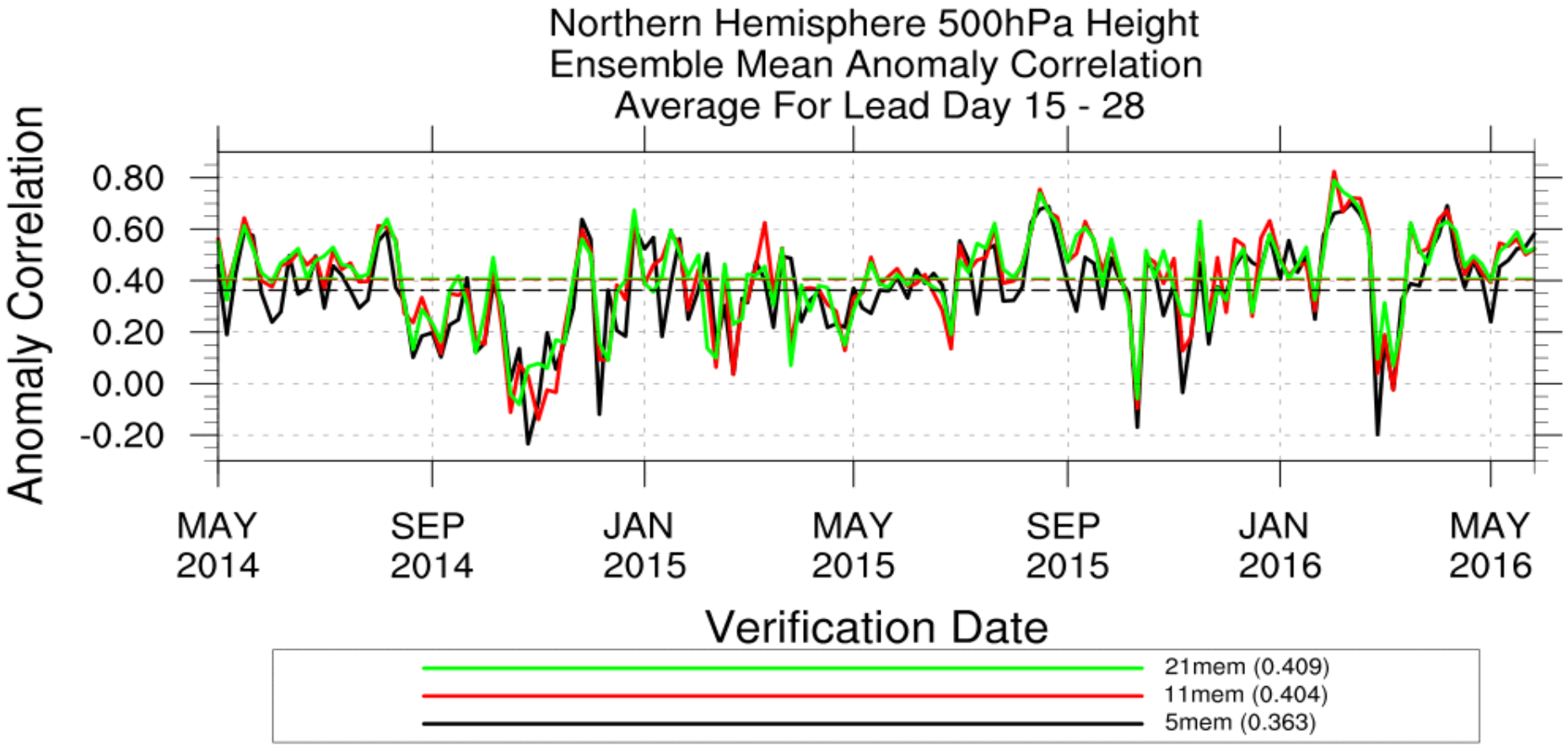
Impact of ensemble size

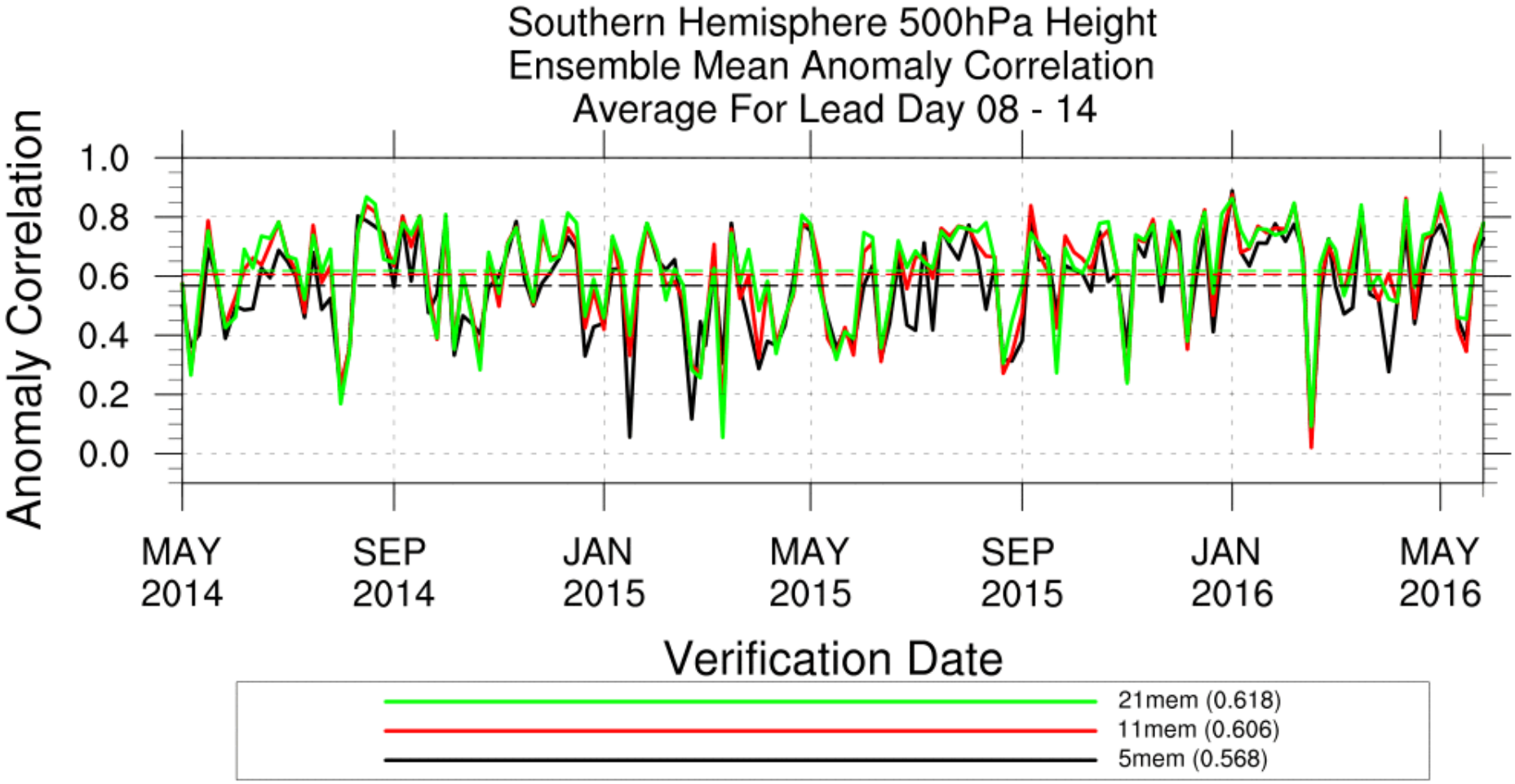
Configuration of reforecast

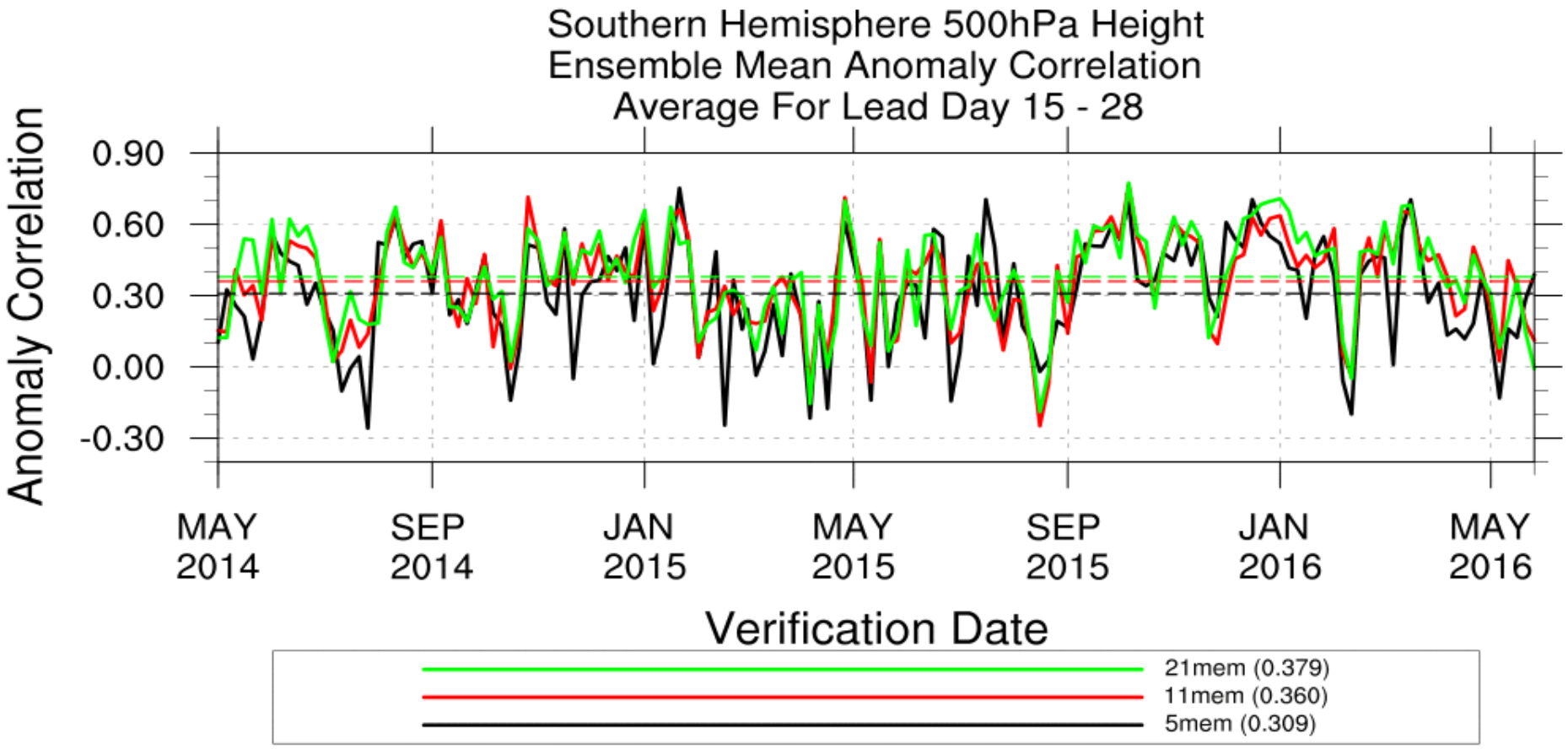

MJO skill (SPs CTL): RMM1+RMM2
20140501-20160526
AC
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
25
30
35
Lead day
5-memebrs
11-memebrs
21-memebrs
Individual member
enm21
gep01
gep02
gep03

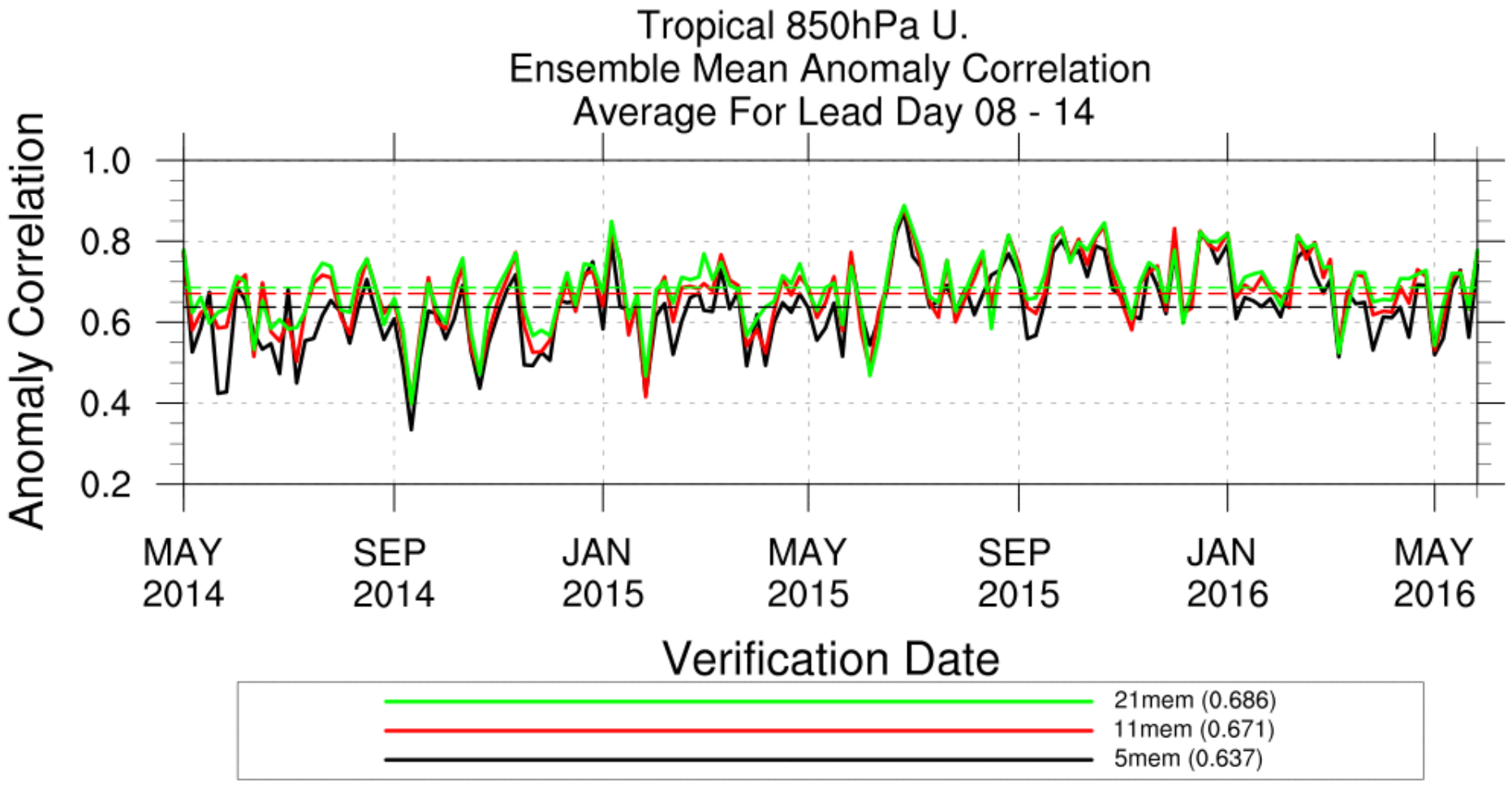

MJO skill (SPs_CFSBC_CNV): RMM1+RMM2
20140501-20160526
AC
Lead day
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
25
30
35
5-memebrs
11-memebrs
21-memebrs
control
enm5
enm11
enm21
Individual member
Contribution of ensemble
and stochastic

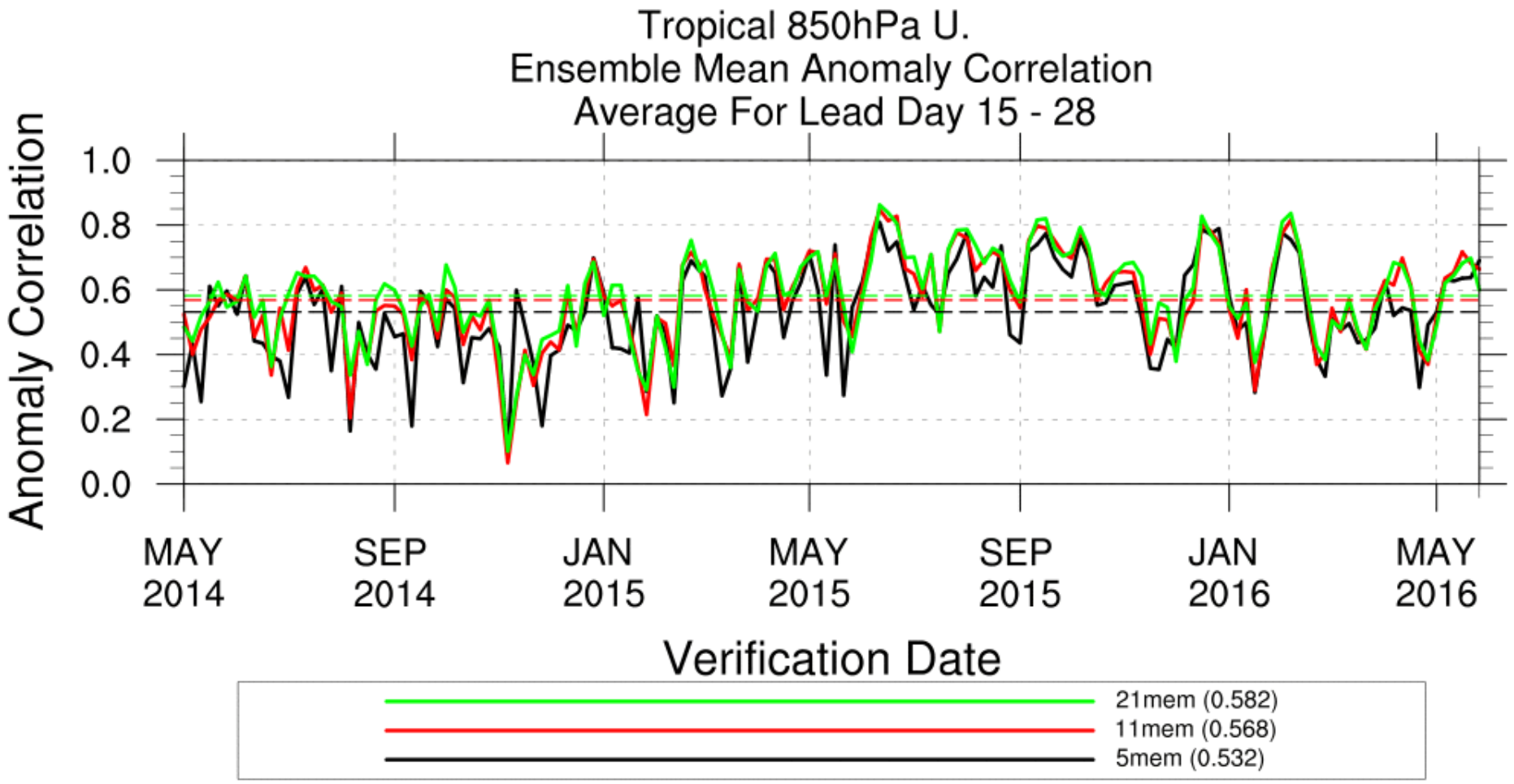

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 08 - 14
Anomaly Correlation
1.0
0.8
0.6
0.4
0.2
0.0
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
21mem (0.629)
11mem (0.619)
5mem (0.578)

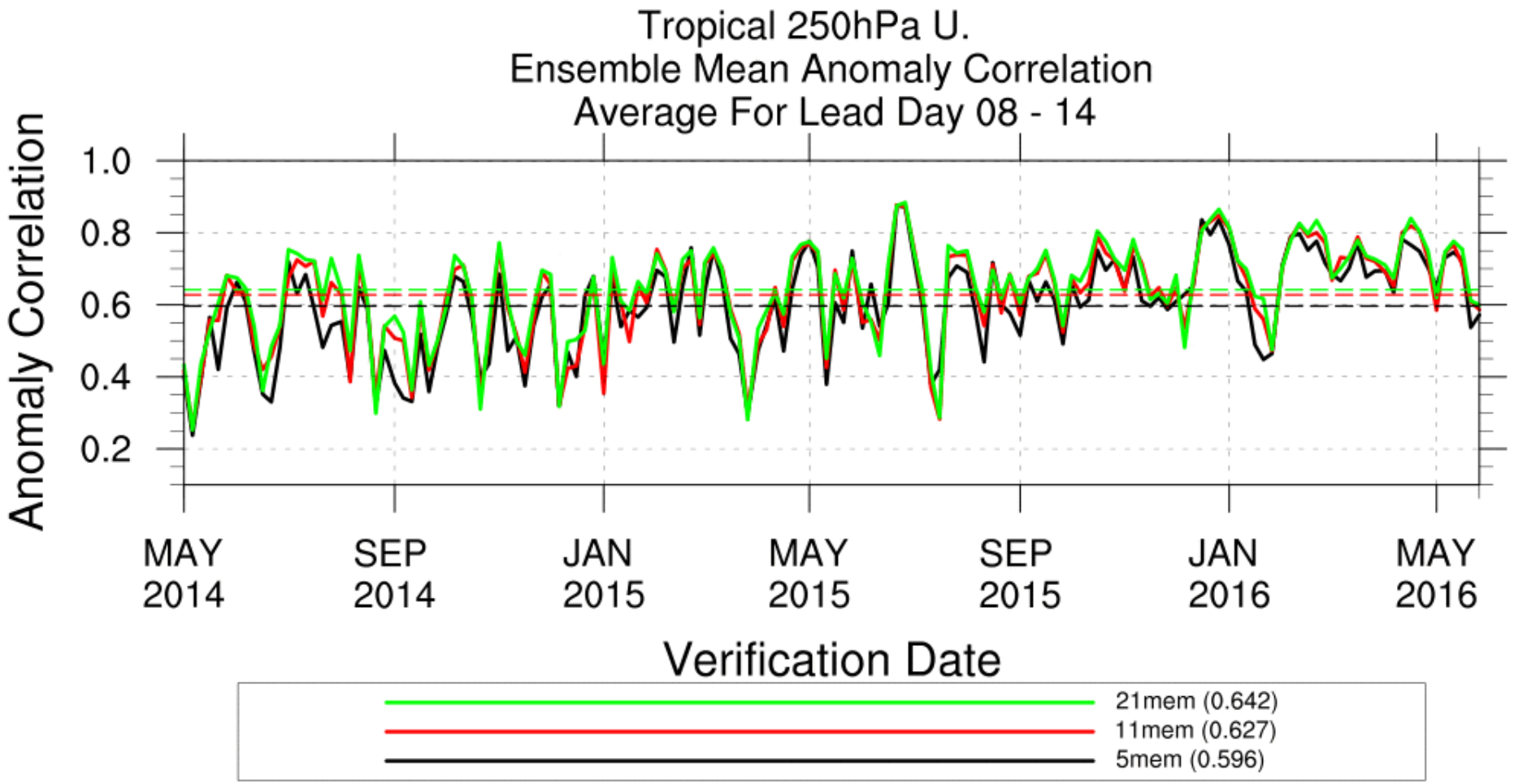

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 15 - 28
Anomaly Correlation
0.80
0.60
0.40
0.20
0.00
-0.20
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
21mem (0.409)
11mem (0.404)
5mem (0.363)

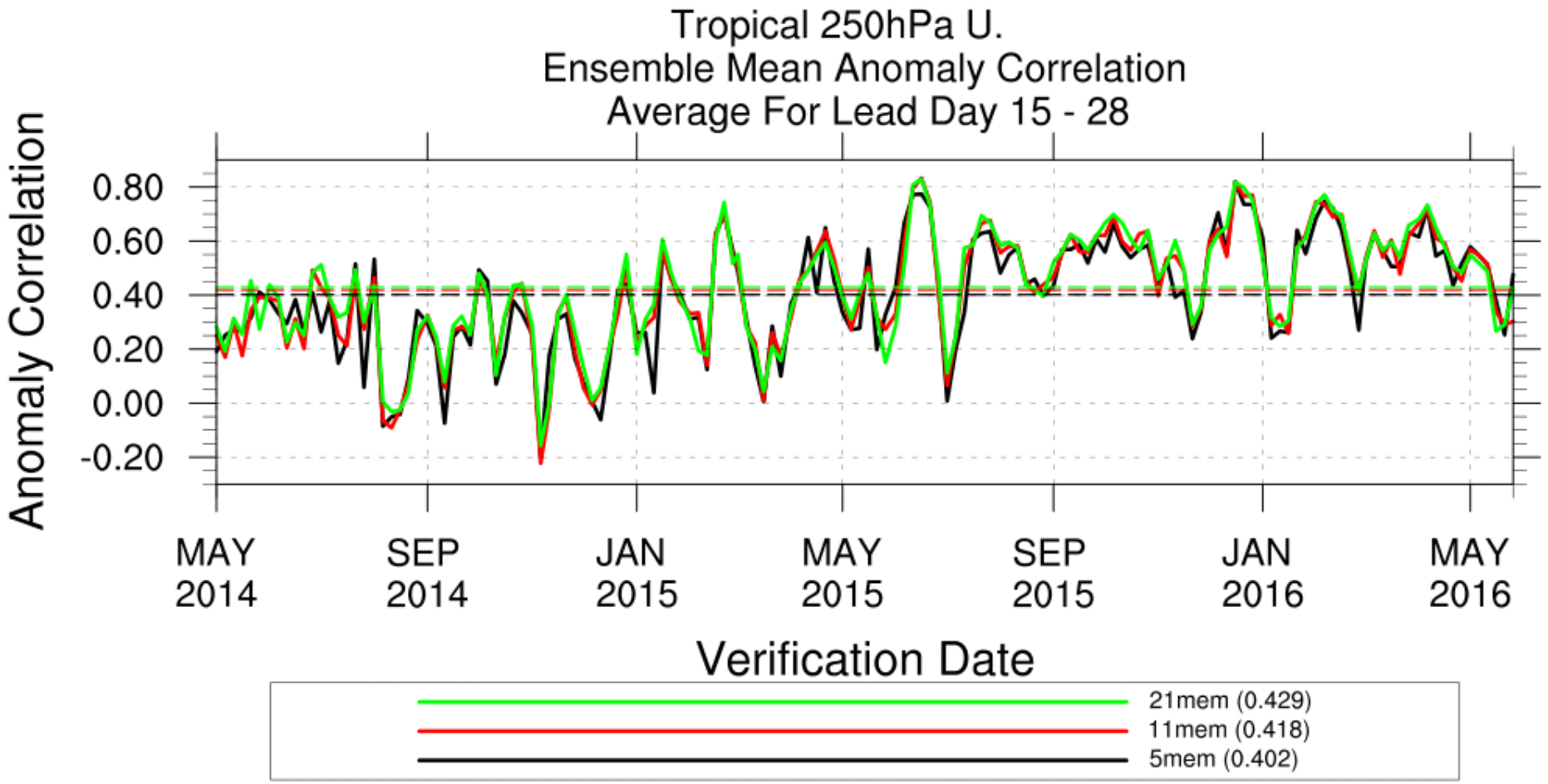

Southern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 08 - 14
Anomaly Correlation
1.0
0.8
0.6
0.4
0.2
0.0
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
21mem (0.618)
11mem (0.606)
5mem (0.568)


Southern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 15 - 28
Anomaly Correlation
0.90
0.60
0.30
0.00
-0.30
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
21mem (0.379)
11mem (0.360)
5mem (0.309)


Tropical 850hPa U.
Ensemble Mean Anomaly Correlation
Average For Lead Day 08 - 14
Anomaly Correlation
1.0
0.8
0.6
0.4
0.2
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
21mem (0.686)
11mem (0.671)
5mem (0.637)


Tropical 850hPa U.
Ensemble Mean Anomaly Correlation
Average For Lead Day 15 - 28
Anomaly Correlation
1.0
0.8
0.6
0.4
0.2
0.0
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
21mem (0.582)
11mem (0.568)
5mem (0.532)


Tropical 250hPa U.
Ensemble Mean Anomaly Correlation
Average For Lead Day 08 - 14
Anomaly Correlation
1.0
0.8
0.6
0.4
0.2
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
21mem (0.642)
11mem (0.627)
5mem (0.596)


Tropical 250hPa U.
Ensemble Mean Anomaly Correlation
Average For Lead Day 15 - 28
Anomaly Correlation
0.80
0.60
0.40
0.20
0.00
-0.20
MAY 2014
SEP 2014
JAN 2015
MAY 2015
SEP 2015
JAN 2016
MAY 2016
Verification Date
21mem (0.429)
11mem (0.418)
5mem (0.402)

GEFS 35d reforecast configuration

Ensemble team
Environmental Modeling Center
NCEP/NWS/NOAA
April 24 2017

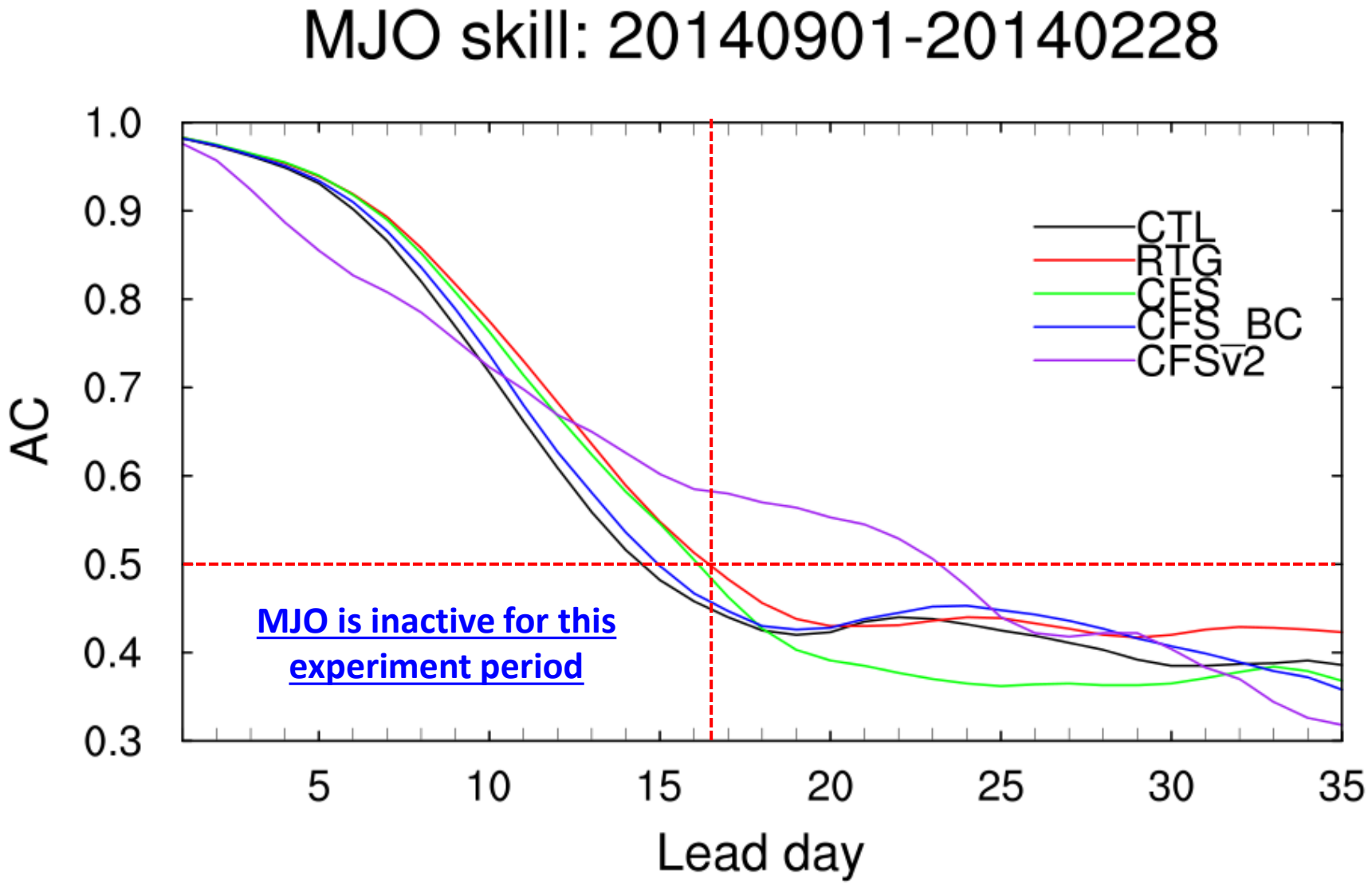
Reforecast configuration

- Period: 1/1/1999 – 12/31/2016
  - 18 years
  - Once per week – every Wednesday (include leap year)
- Initial analysis and perturbations
  - CFSR: 1/1/1999 – 1/1/2011; GSI: 1/1/2011 – end
  - BV-ETR: 1/1/1999 – 12/2/2015; EnKF f06: 12/2/2015 - end
- Resolution and ensemble members:
  - T574L64 for 0-8 days; T382L64 for 8-35 days
  - 11 members (decide on April 24 2017)
- Model configuration
  - SPs (with adjustment)+CFSBC+SA-CNV
- Data saving
  - HPSS
    - All pgrb2a+pgrb2b at 0.5d
    - All Flux files
  - Disk
    - CPC's requirement (priority #1, #2, #3)
    - Our evaluation and monitoring
  - ftp for data access
- Real-time
  - Start from July (will practice on June 2017)
- Current status
  - 50%+ has been finished of 18 years reforecast

Upcoming ……

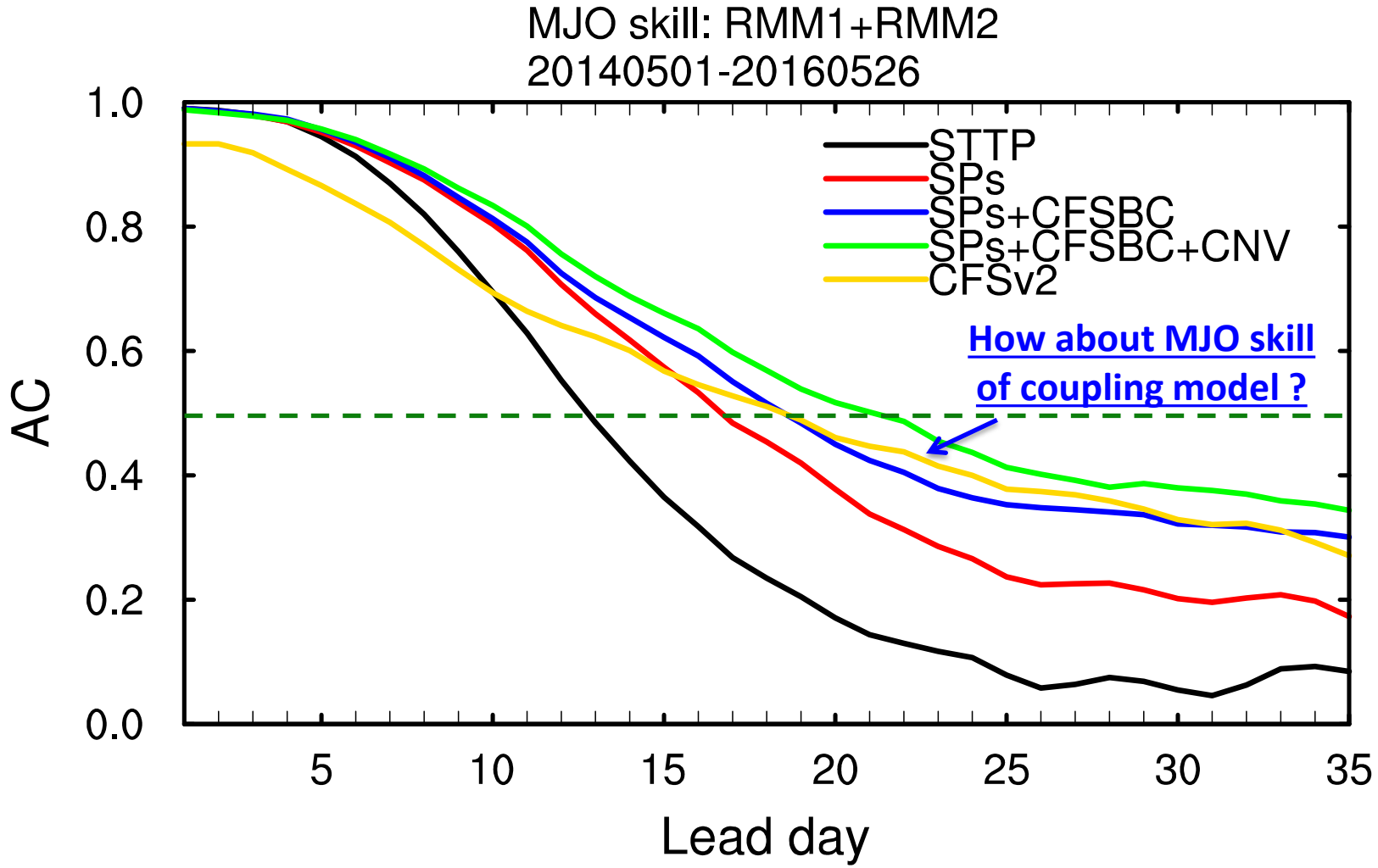
- The configuration is supporting “SubX” only
- All 35 days GEFS experiments will move to
  - FV3 based GEFS (testing is on going)
  - Full coupling (testing is on going)

Extra slides

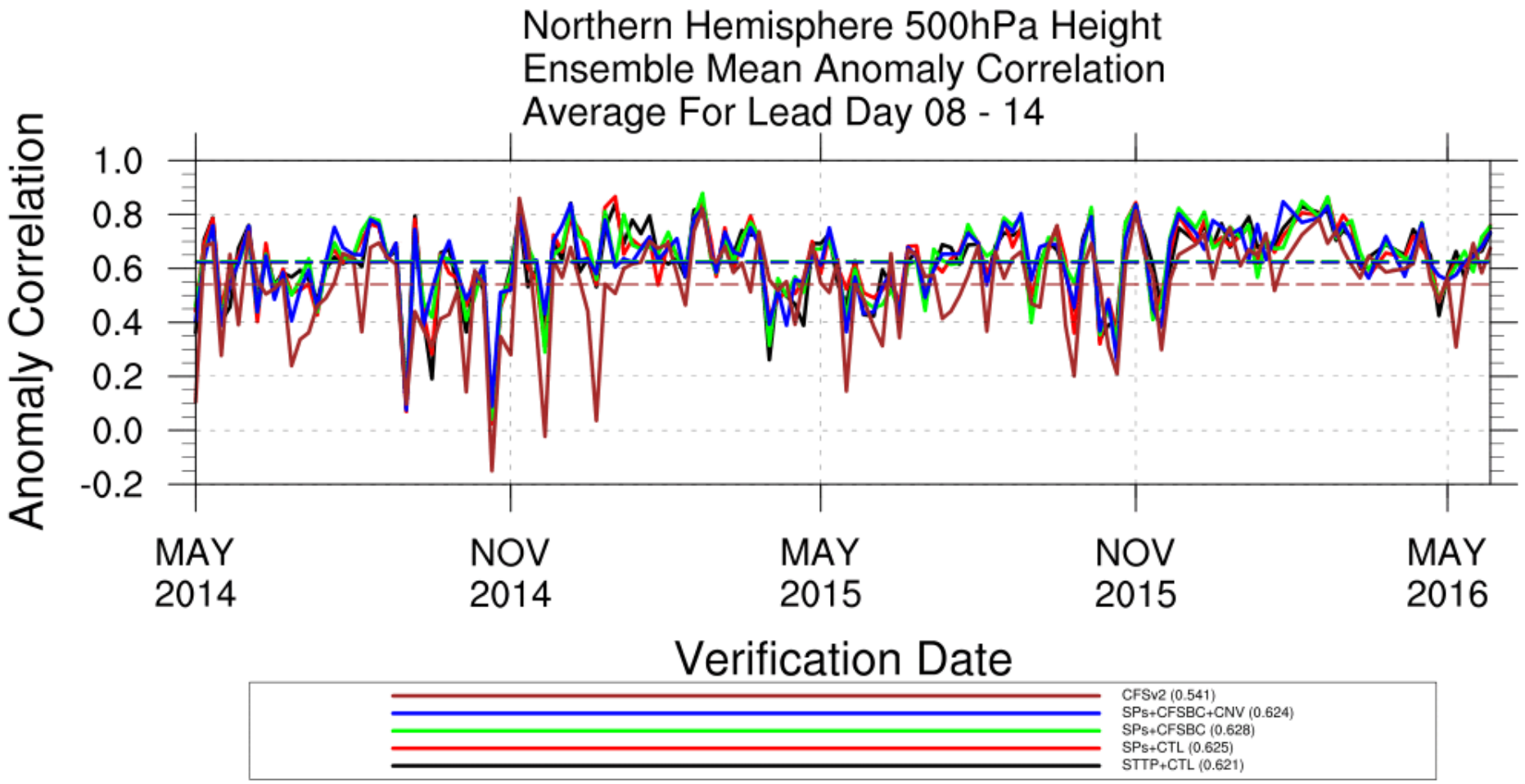


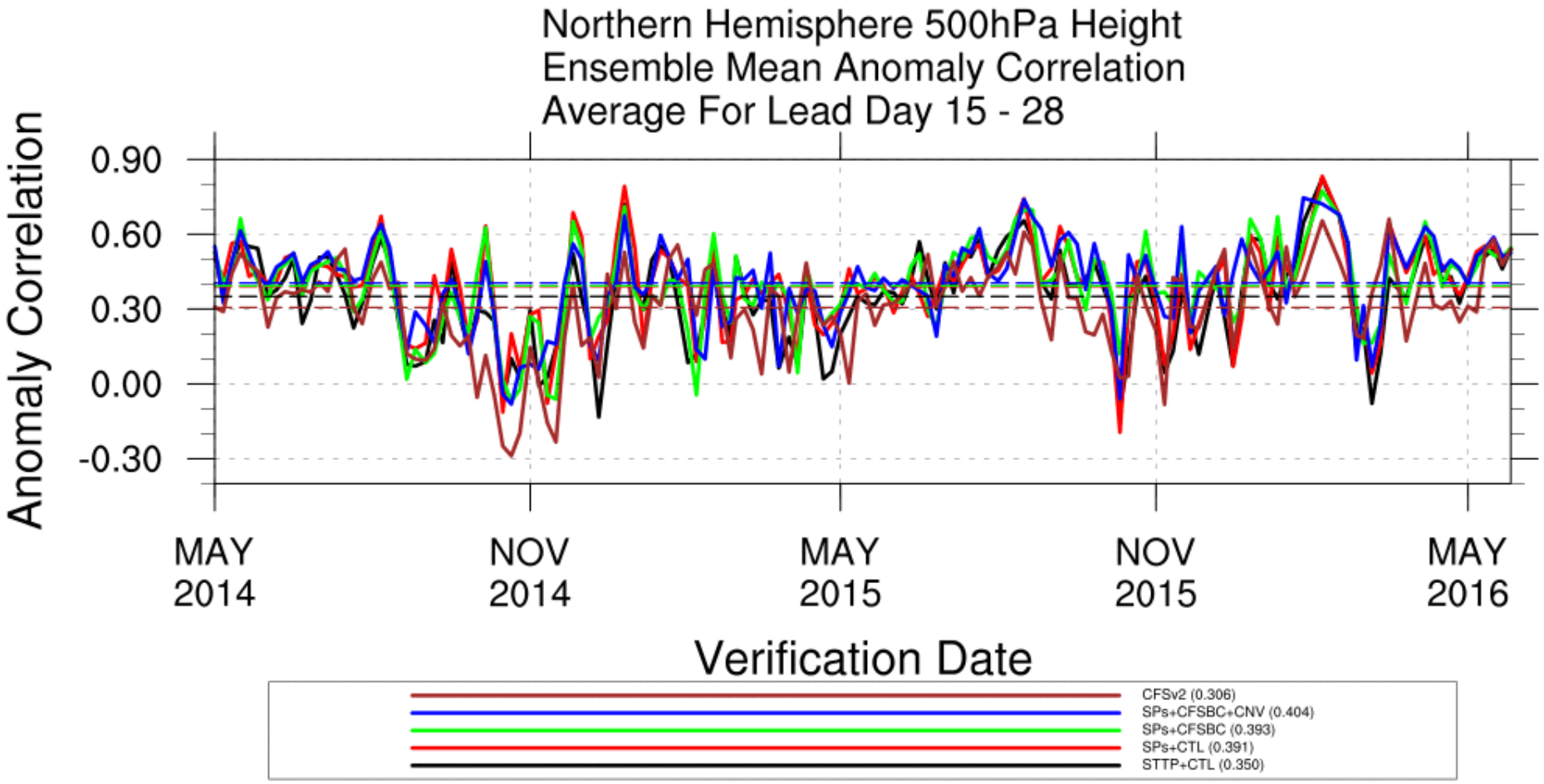
Lower resolution (70km) for week 3&4 with STTP

GEFS week 3&4 forecasts (May 2014-May 2016)



CFSv2 is NCEP operational climate forecast system (coupling) implemented on 2011 – 16 members leg (24 hours) ensemble


Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 08 - 14
Anomaly Correlation
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
MAY 2014
NOV 2014
MAY 2015
NOV 2015
MAY 2016
Verification Date
CFSv2 (0.541)
SPs+CFSBC+CNV (0.624)
SPs+CFSBC (0.628)
SPs+CTL (0.625)
STTP+CTL (0.621)


Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For Lead Day 15 - 28
Anomaly Correlation
0.90
0.60
0.30
0.00
-0.30
MAY 2014
NOV 2014
MAY 2015
NOV 2015
MAY 2016
Verification Date
CFSv2 (0.306)
SPs+CFSBC+CNV (0.404)
SPs+CFSBC (0.393)
SPs+CTL (0.391)
STTP+CTL (0.350)