Implementation and testing of MG microphysics and its coupling with shallow and deep convection and aerosol

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NEMS/FV3 Technical Meeting

Outline

- A brief comparison of Morrison-Gettleman (MG) double moment and other microphysics parameterizations.
- Issues on Coupling of MG with other physical processes such as macrophysics, SHOC, CS, aerosol, and radiation etc.
- Discussion on NEMS/GSM T1534 cycling testing on hurricane Matthew and T574 testing for coupling with Gocart on 2016 Louisiana flooding.

Microphysics Scheme Comparison

	Zhao & Carr (1997)	GMAO-MG	Thompson (2014)
prognositic variables	qv, qc (water or ice)	qv, ql,nl, qi, ni, qr, nr, qs,ns	qv, ql, qi, qs, qr, qg, nl, ni, nr (double)
Condensation and evaporation	Sundqvist et al (1989)	Uniform, triangle, and normal pdf based	Yau and Austin (1997), and can be coupled with SHOC or Zhao & Carr cloud scheme
mixed-phase clouds	No (simple ice)	Yes	Yes
precipitation sedimentation	no storage in the air and instantaneous fallout.	qv, ql,nl, qi, ni, qr, nr, qs,ns advected in 3D ql, nl, qi,ni, qr, nr, qs, ns sediment vertically	qv, ql,nl, qi, ni, qr, nr, qs, and qg are advected 3D, ql, nl, qi, qr, nr, qs, qg sediment vertically
Aerosol types processed	None	13 modes (5 dusts, 5 SS, Sulfate, BC, and OC)	2 modes (water and ice “friendly” aerosols)

MG, GMAO aerosol activation and GOCART

- Coupling is based on prognostic GOCART via internal tracers.
- An affordable aerosol awareness approach is to use 'prescribed' GOCART aerosols via external files, either GEOS-4 GOCART monthly climatology or NGAC output or MERRA2 aerosol reanalysis (proposed).
- Subgrid-scale vertical velocity depends on turbulence and gravity wave drag and can use the vertical velocity from SHOC.
- A uniform, Triangle or normal based PDF of total water is used to calculate condensation and cloud fraction in non-convective region, setting a stage for microphysics

MG and SHOC

- MG takes the cloud condensation and cloud fraction from SHOC and turns off GMAO macrophysics. MG does not compute cloud fraction and condensation.
- SHOC needs higher-order moments, total water, and liquid water potential to calculate the condensation and cloud fraction.
- The effects of number concentration of ice, liquid, rain, and snow are treated very simply without considering the joint-double Gaussian PDF.

MG and radiation

- MG inputs ice and liquid separately to radiation instead of total cloud condensate in Zhao and Carr.
- MG feeds effective radius of ice, liquid, rain, and snow into radiation instead of constant value or simplified formula in Zhao and Carr.
- Radiation outputs optical depth in window regime and near IR emissivity for low, middle, high-level, and total cloud for diagnostic purpose.

MG and deep convection

- MG takes the cloud liquid and ice and convective cloud fraction detrained from deep convection and combines them with those from macrophysics/SHOC for various microphysics process computation.
- MG changes the structure of the vertical profiles by microphysical heating/cooling and the sediment of the large-scale rain, snow and their numbers.
- Scale awareness and dependence on precipitation: With grid-size decrease from hundreds kms to less than 1 km, the parameterized global mean deep convective precipitation is expected to decrease from near 2.5 mm/day to 0 mm/day. The global mean total precipitation, however, should be scale independent, keeping at 3 mm/day.

Deep convection comparison

	SAS	RAS	CS
Quasi-equilibrium (QE) Assumption	Yes	Yes	Not needed (CKE approach)
Cloud types	The deepest cloud type for each time step	A spectrum of cloud types defined by the highest-level each cloud type can reach	A spectrum of cloud types defined by cloud base vertical velocity
Entrainment	A function of RH	Quadratic function of height	Proportional to parcel buoyancy
Arakawa-Wu	No, scale awareness based on cloud fraction computed based on entrainment at the cloud base.	No, but built-in scale awareness, such as critical CW and relax to QE	Yes
Downdraft	Mass flux is a function of updraft	Sophisticated with updraft tilting	Simple plumes initiated by precipitation

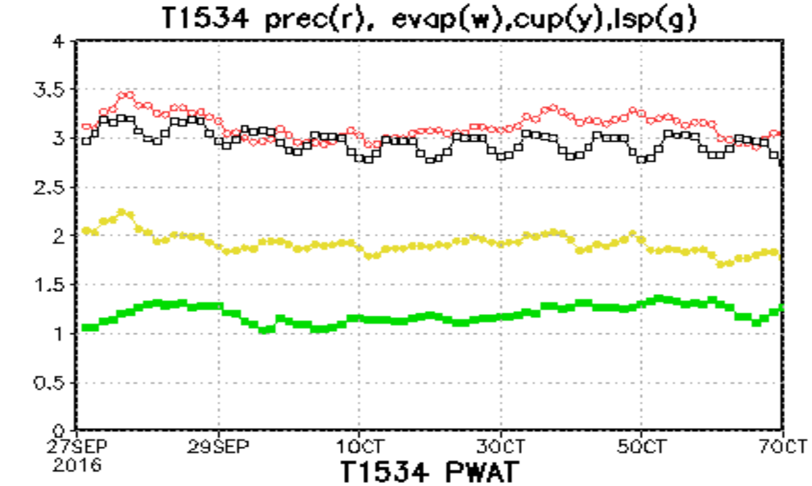
Experiment Design

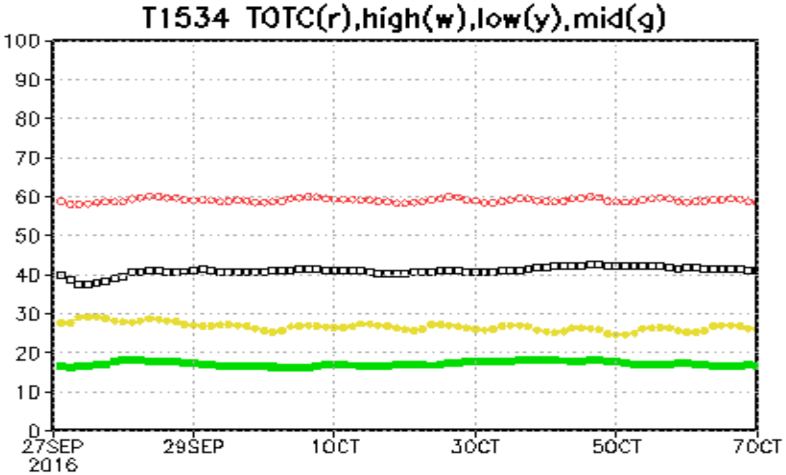
EXP Name	Microphys	Shallow cumulus scheme	Macrophys	Deep convection	Cost for 1 day T1534 with 460 tasks
SAS-SHL-Zh (operational)	Zhao and Carr	SHL	Large-scale condensation	SAS	N/A
RAS-SHL-Zh (GSM)	Zhao and Carr	SHL	Large-scale condenstion	RAS	6.185 minutes
RAS-SHL-MG	MG	SHL	GMAO Macro	RAS	9.511 minutes
RAS-SHOC-MG	MG	SHOC	SHOC	RAS	9.888 minutes
CS-SHL-MG	MG	SHL	GMAO Macro	CS-AW (non flux)	9.322 minute
CS-SHOC-MG (FV3GFS)	MG	SHOC	SHOC	CS-AW (flux)	N/A

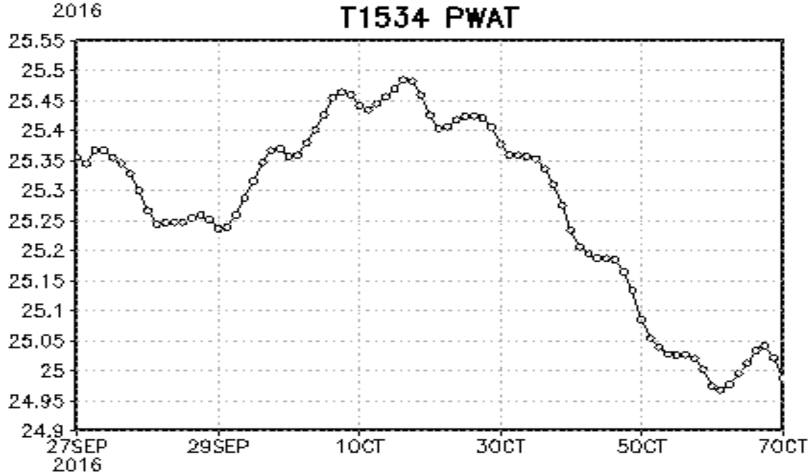
Hurricane Matthew

http://www.emc.ncep.noaa.gov/gmb/acheng/vsdb/

Time series for SAS-SHL-ZH

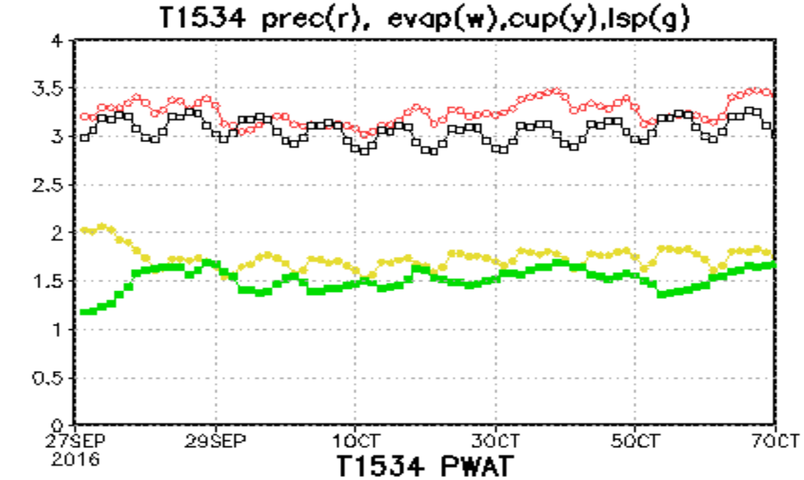


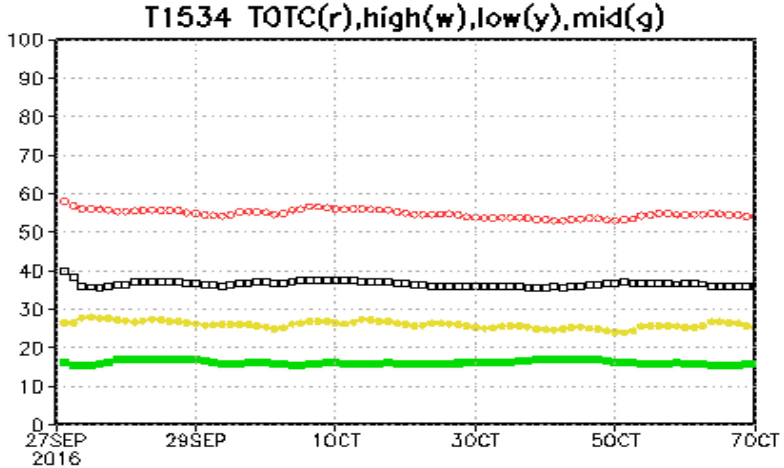


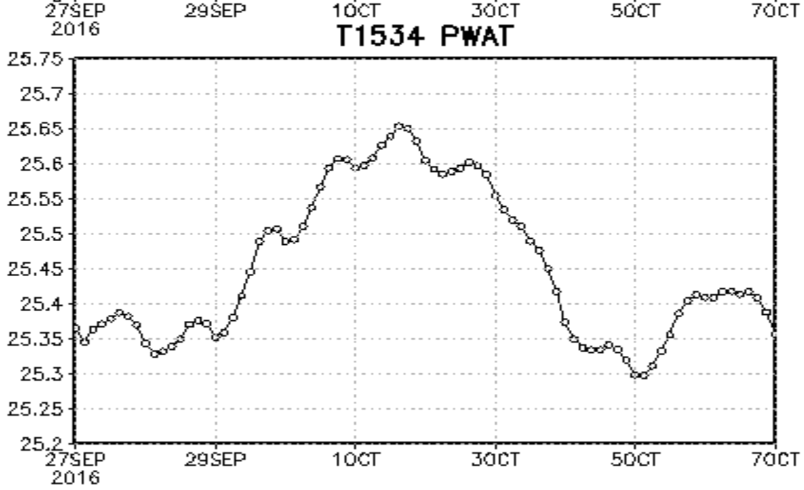


PWAT more sensitive to decreased precipitation
Good high, middle, and low cloud amount

Time series for RAS-SHL-ZH

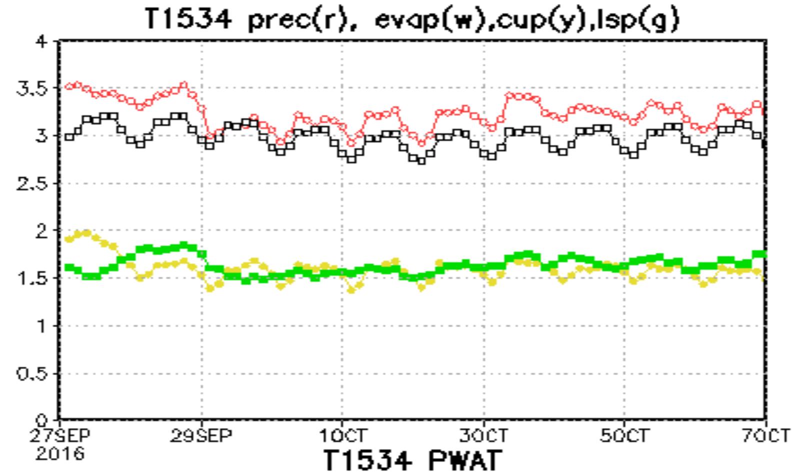


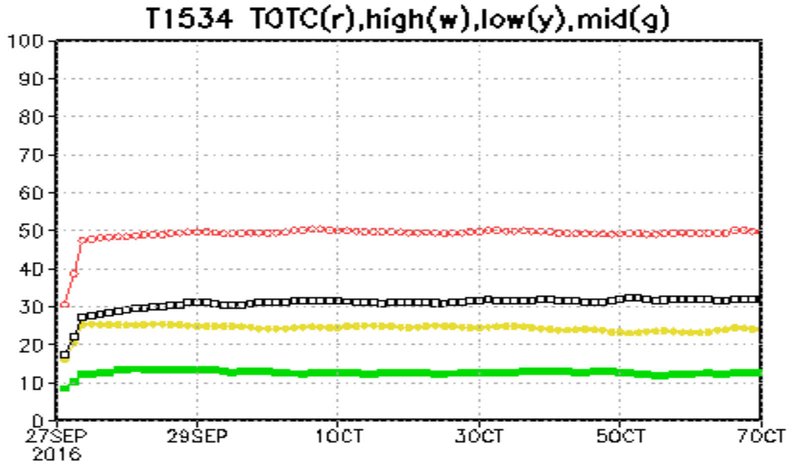


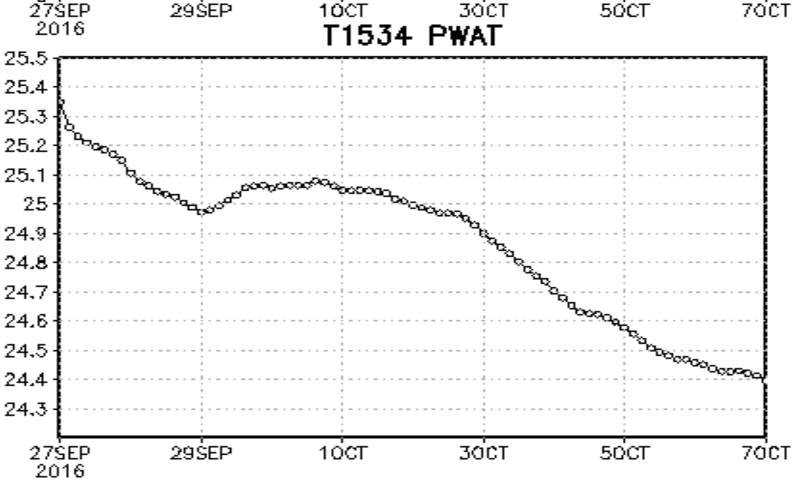


Similar to operational/retrospective
Scale awareness for precipitation is better

Time series for RAS-SHL-MG

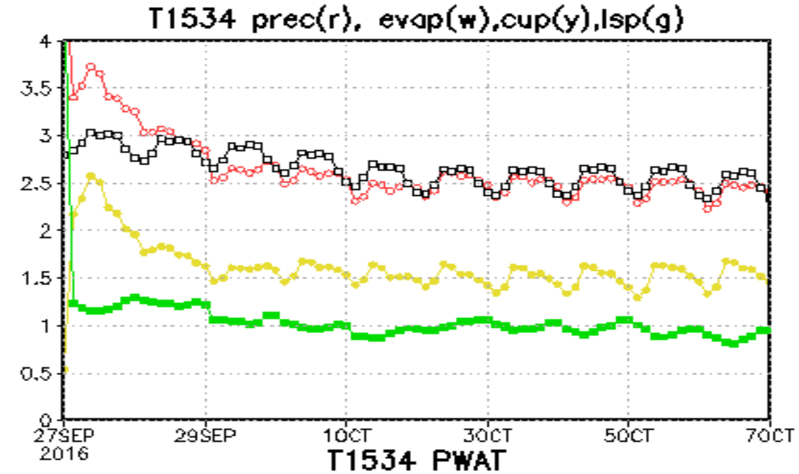


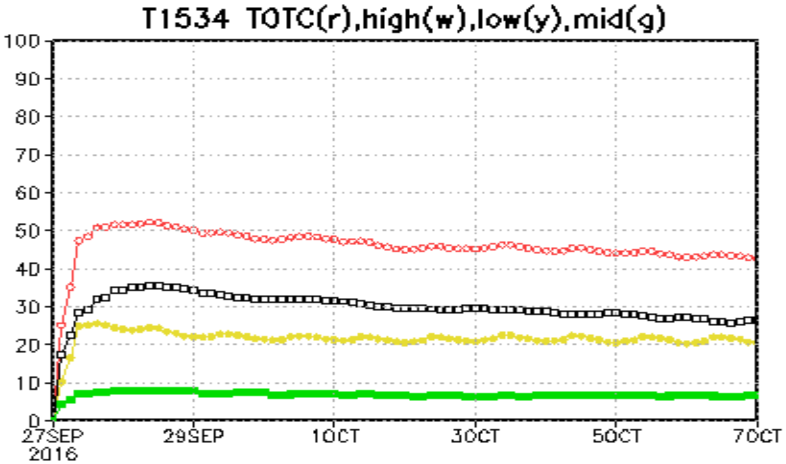


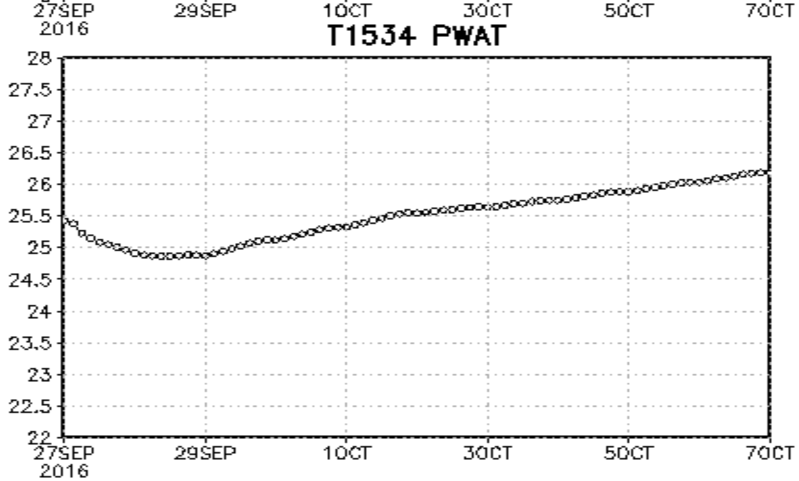


Large precipiation, but good moisture conservation
Cloud fraction lower than Zhao-Carr

Time series for RAS-SHOC-MG



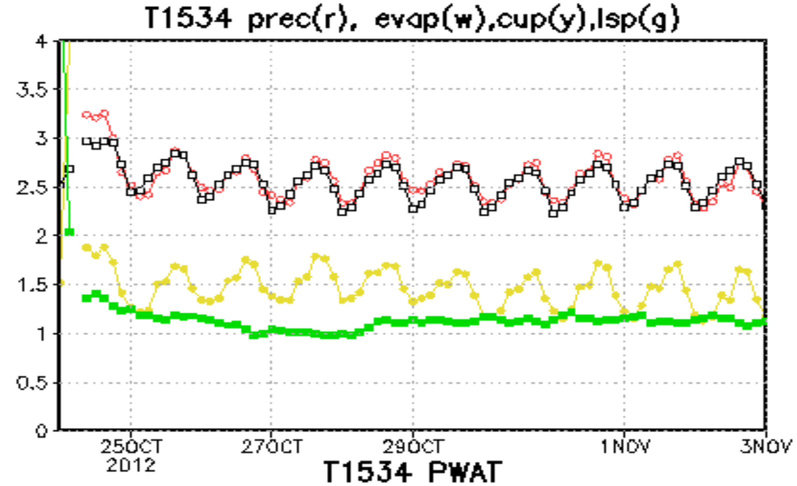


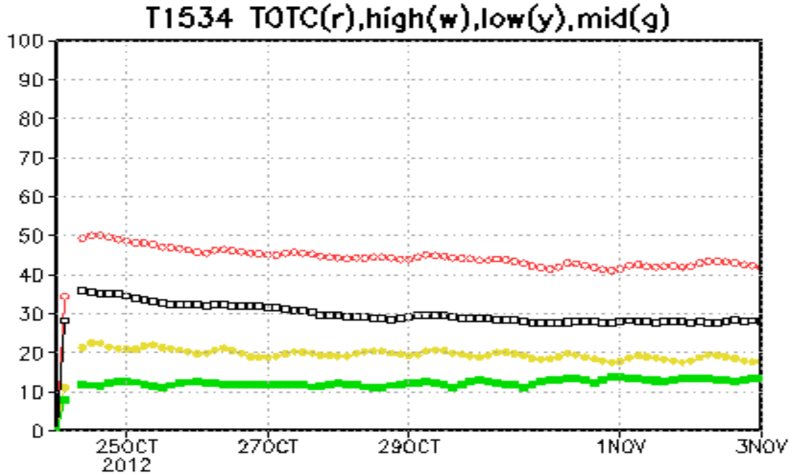


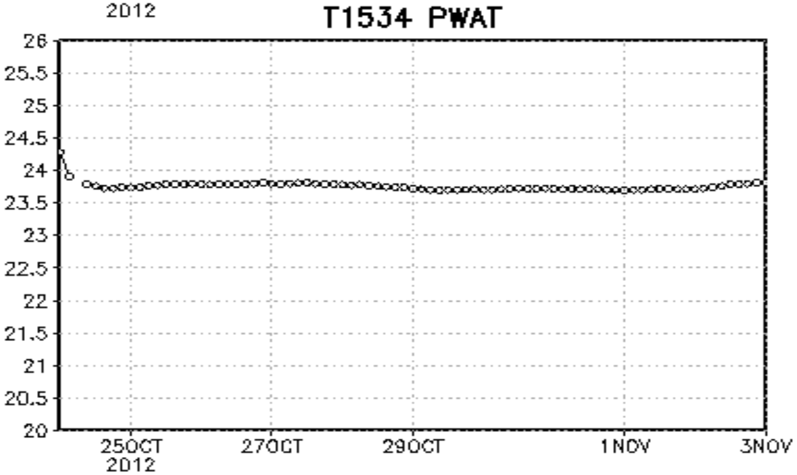
Overall good evaporation and precipiation balance

Cloud fraction low

Time series for CS-SHL-MG

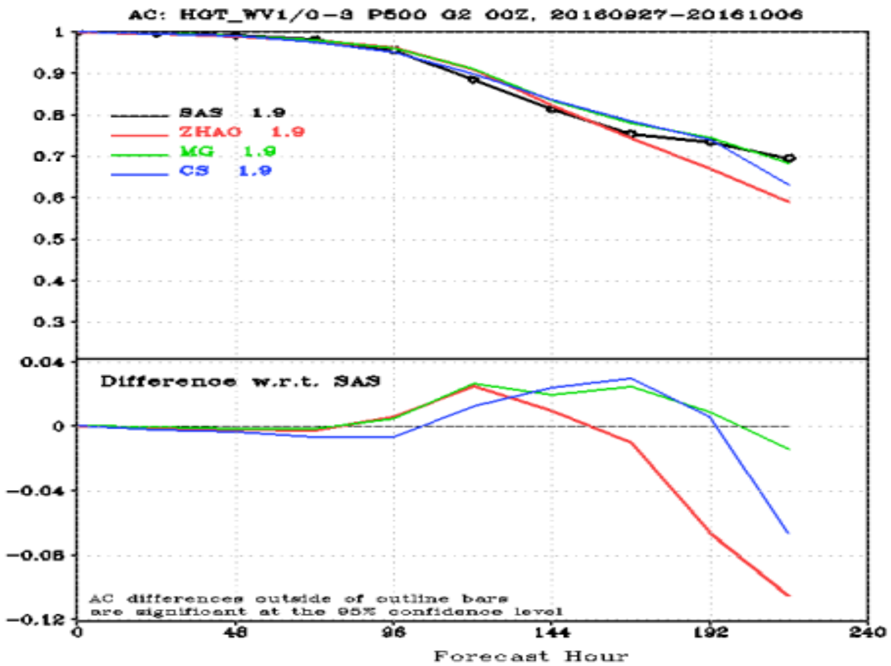






Good Diurnal cycle
Nice evaporation and precipitation balance
Low cloud amount

AC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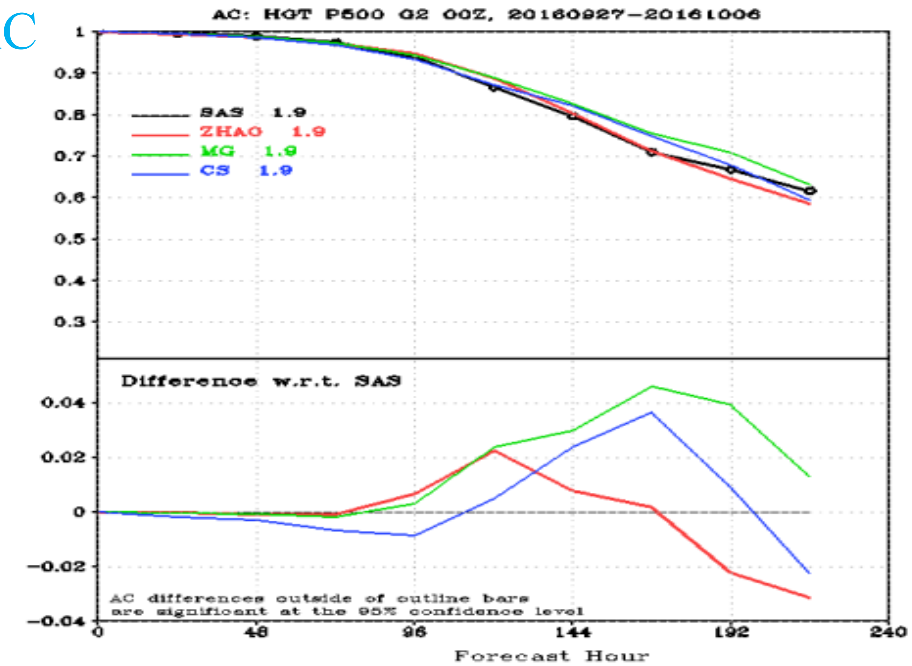
SAS 1.9
ZHAO 1.9
MG 1.9
CS 1.9
Difference w.r.t. SAS
AC differences outside of outline bars
are significant at the 95% confidence level
Forecast Hour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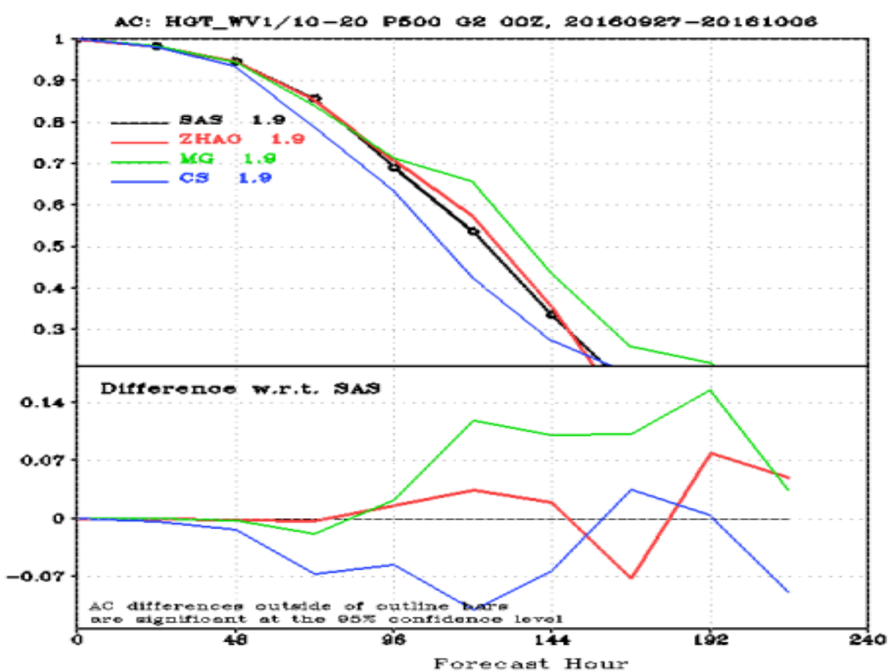
Forecast Hour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ZHAO 1.9
MG 1.9
CS 1.9
Difference w.r.t. SAS
AC differences outside of outline bars
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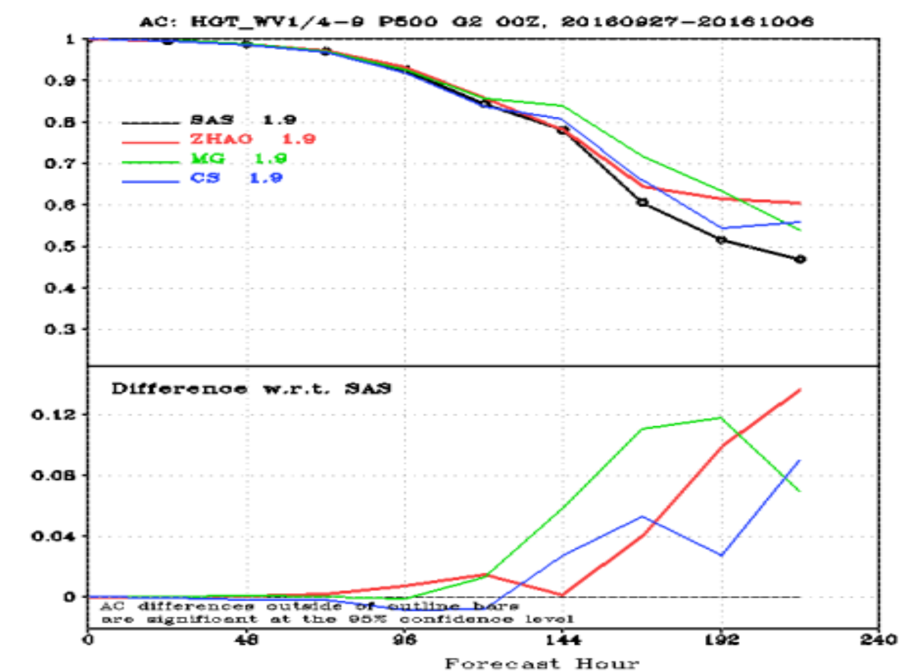
Forecast Hour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SAS 1.9
ZHAO 1.9
MG 1.9
CS 1.9
Difference w.r.t. SAS
AC differences outside of outline bars
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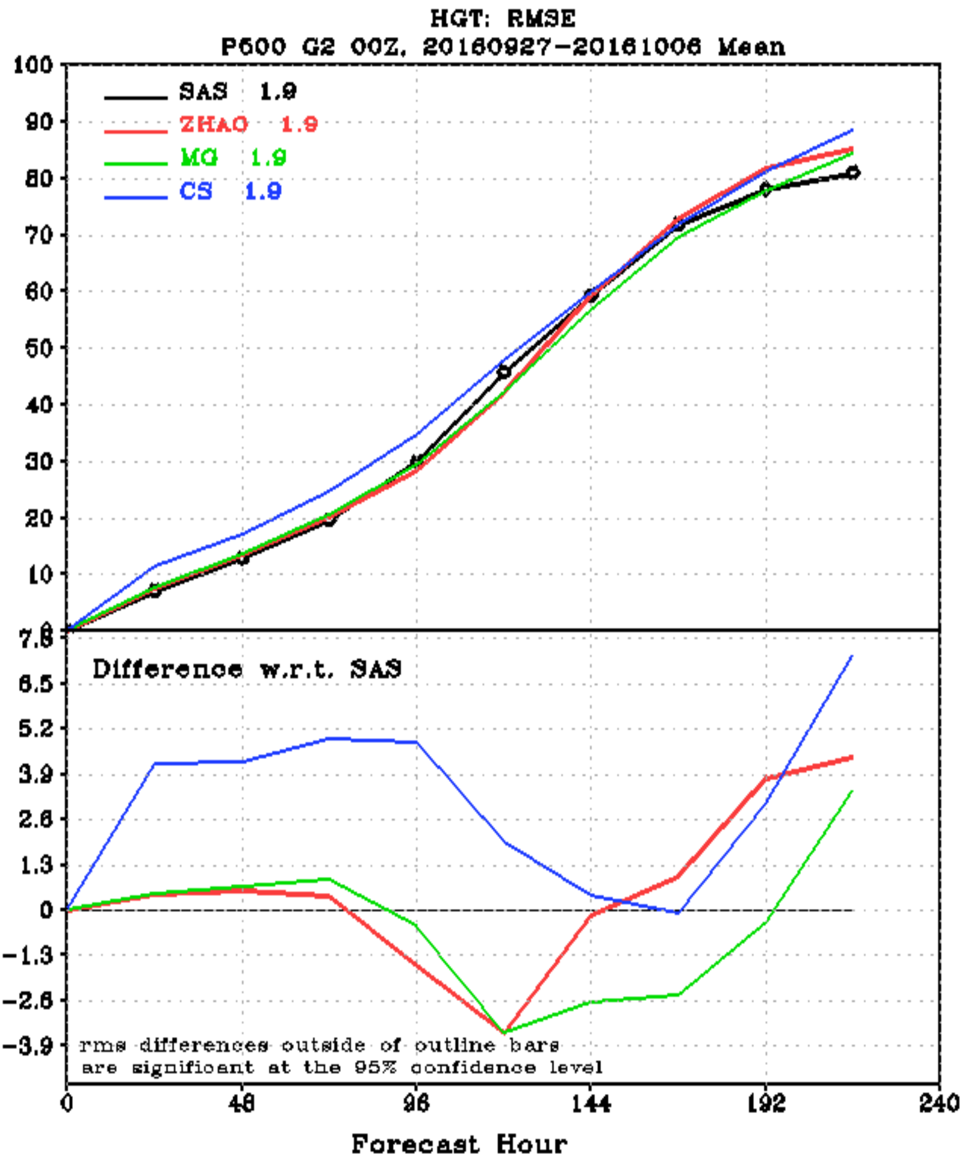
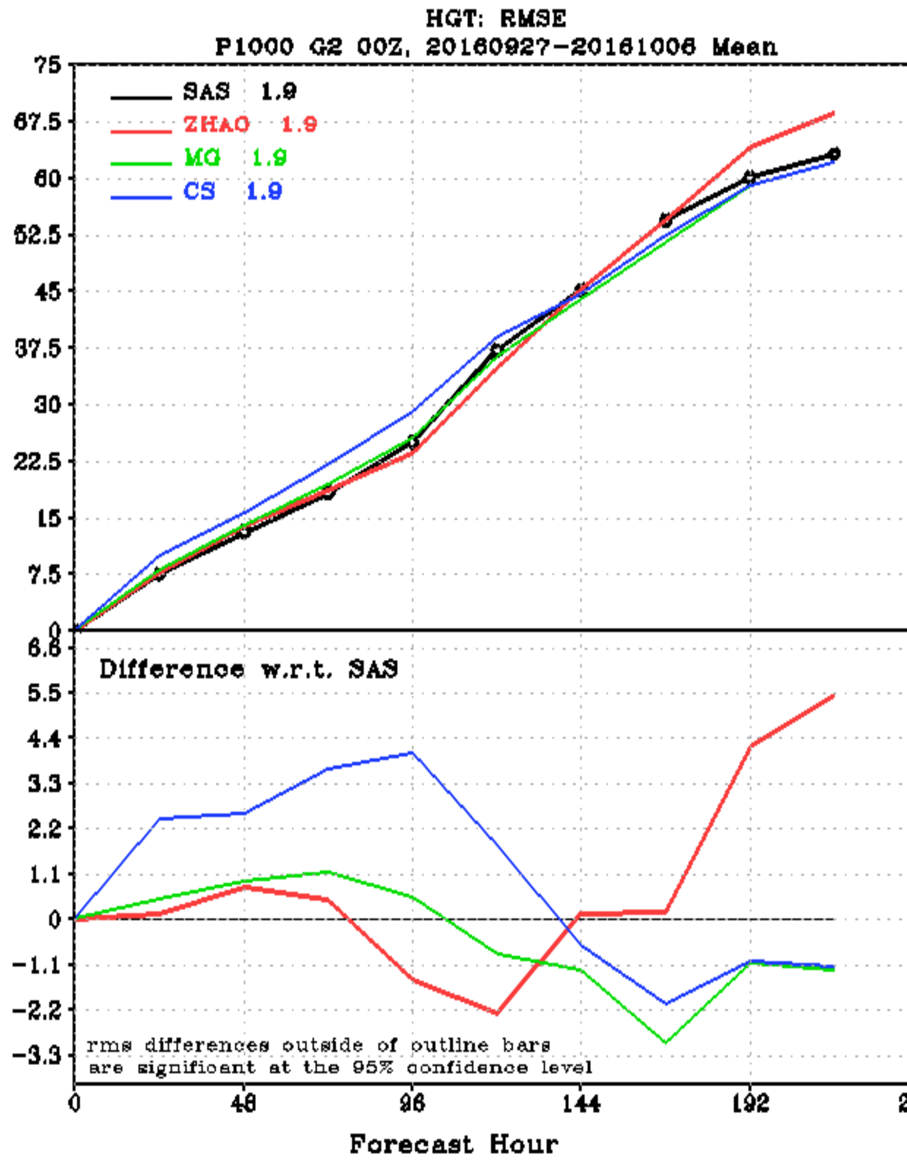
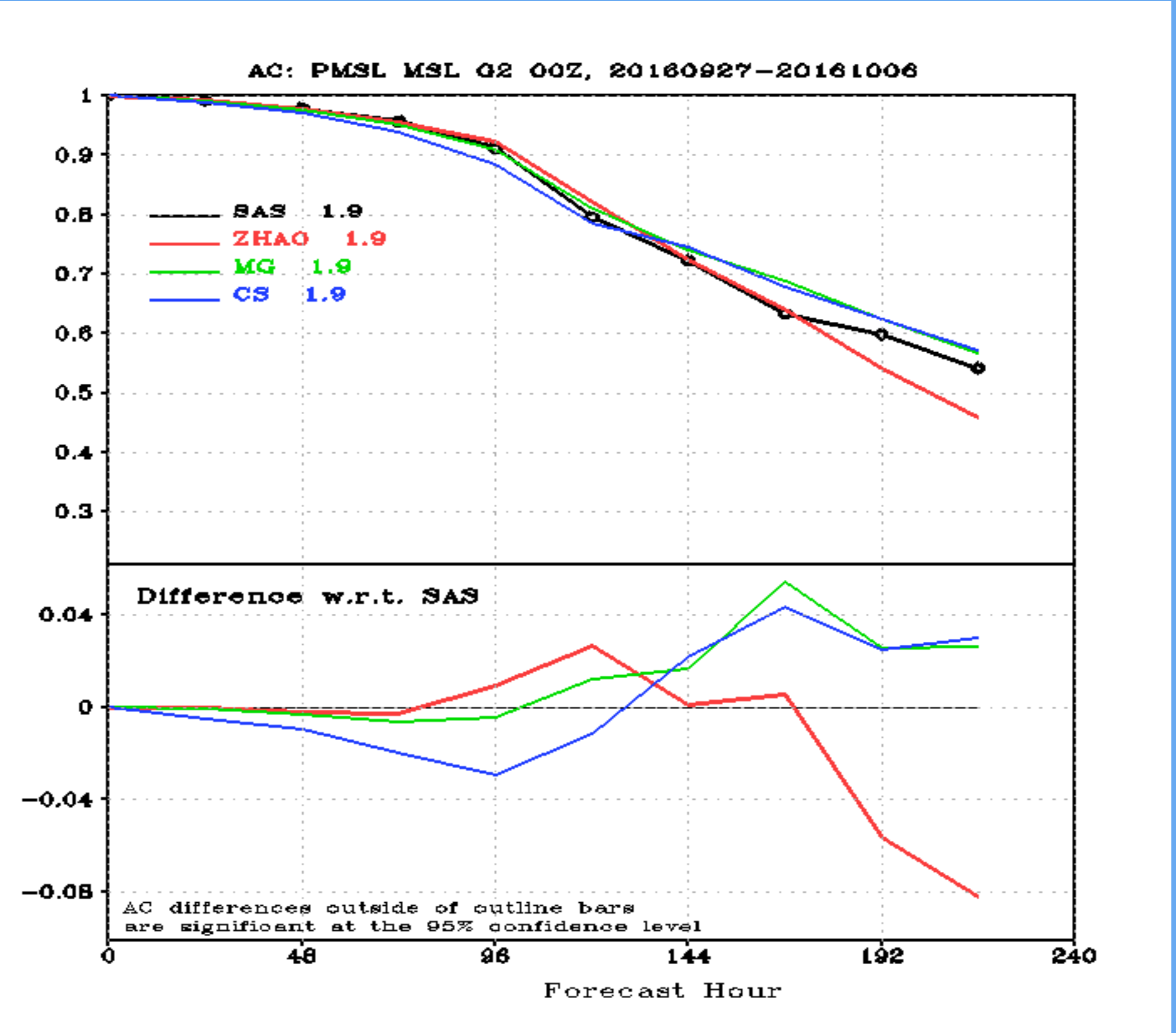
Forecast Hour

RMSE

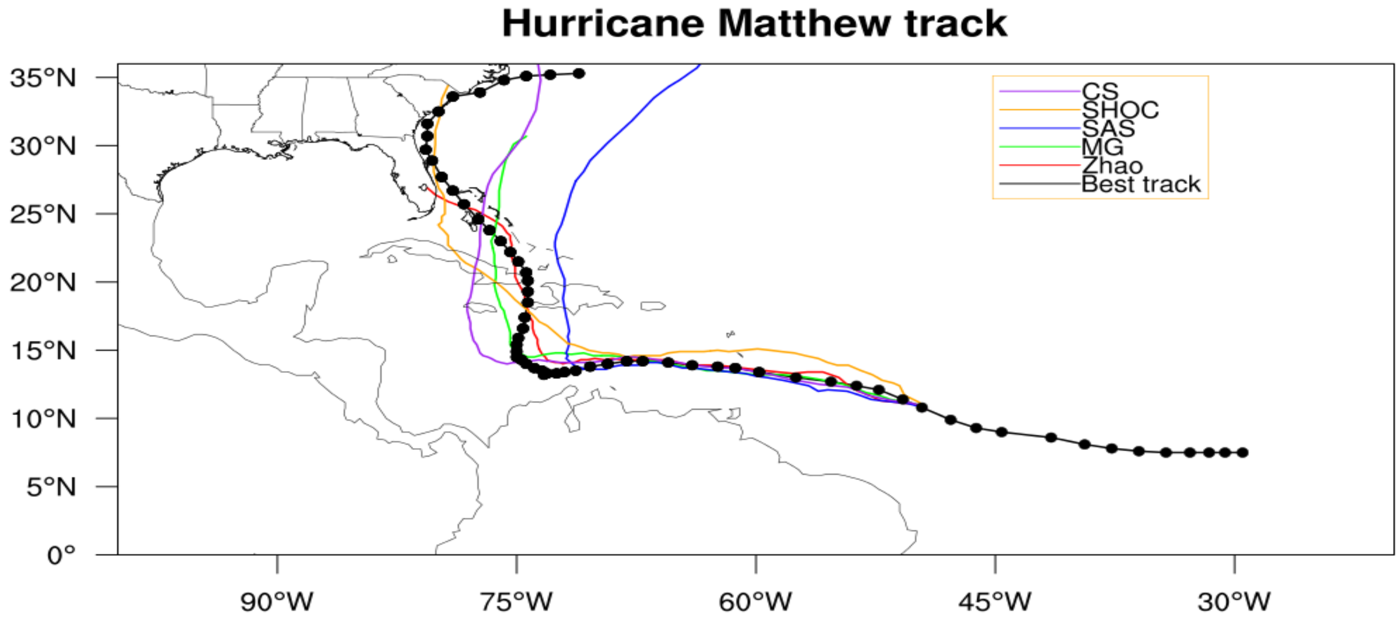

HGT: RMSE
P500 G2 00Z, 20160927-20161006 Mean
SAS 1.9
ZHAO 1.9
MG 1.9
CS 1.9
Difference w.r.t. SAS
rms differences outside of outline bars
are significant at the 95% confidence level
Forecast Hour


HGT: RMSE
P1000 G2 00Z, 20160927-20161006 Mean
SAS 1.9
ZHAO 1.9
MG 1.9
CS 1.9
Difference w.r.t. SAS
rms differences outside of outline bars
are significant at the 95% confidence level
Forecast Hour

SLP anomaly correlation

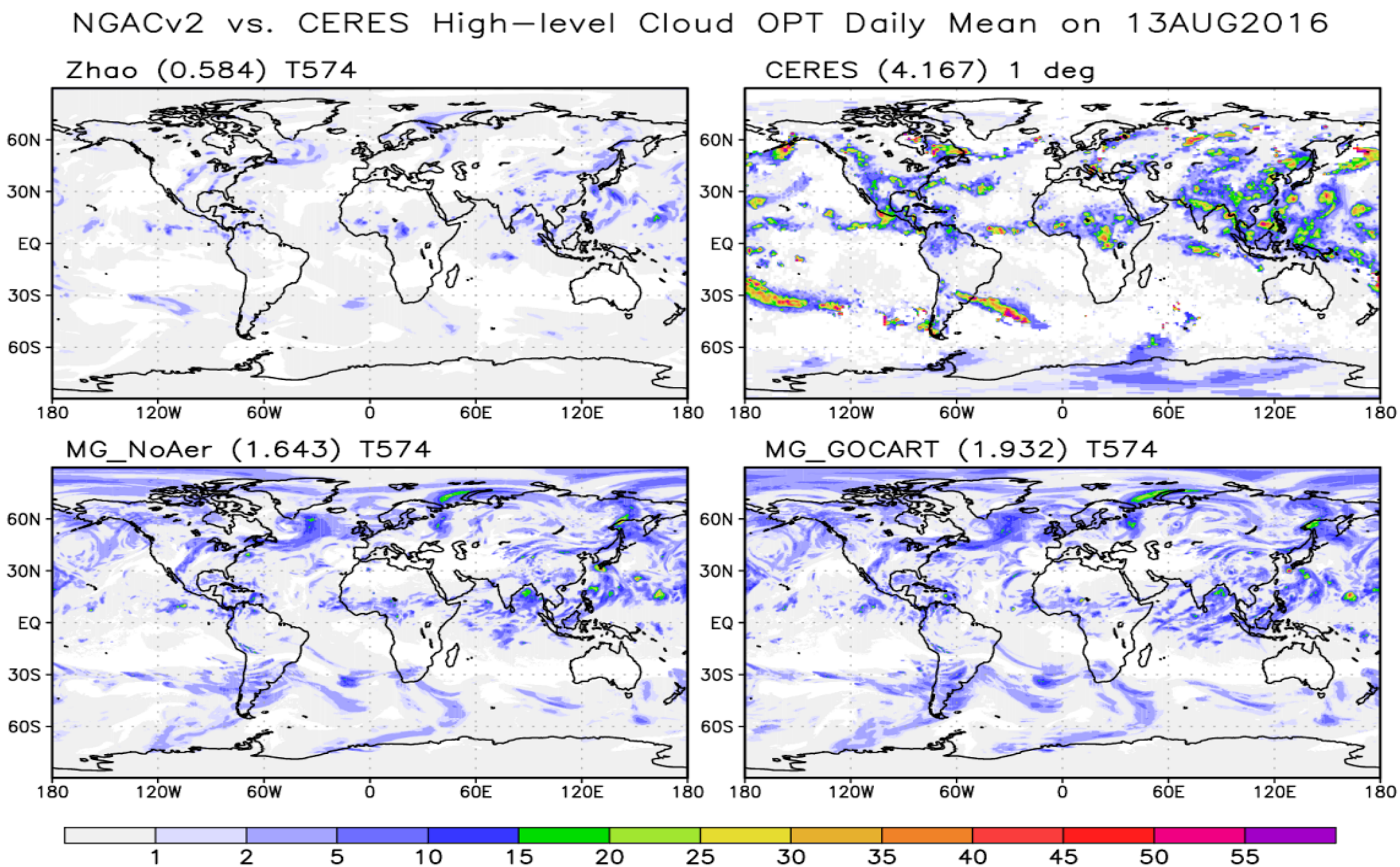


10-day track forecasting

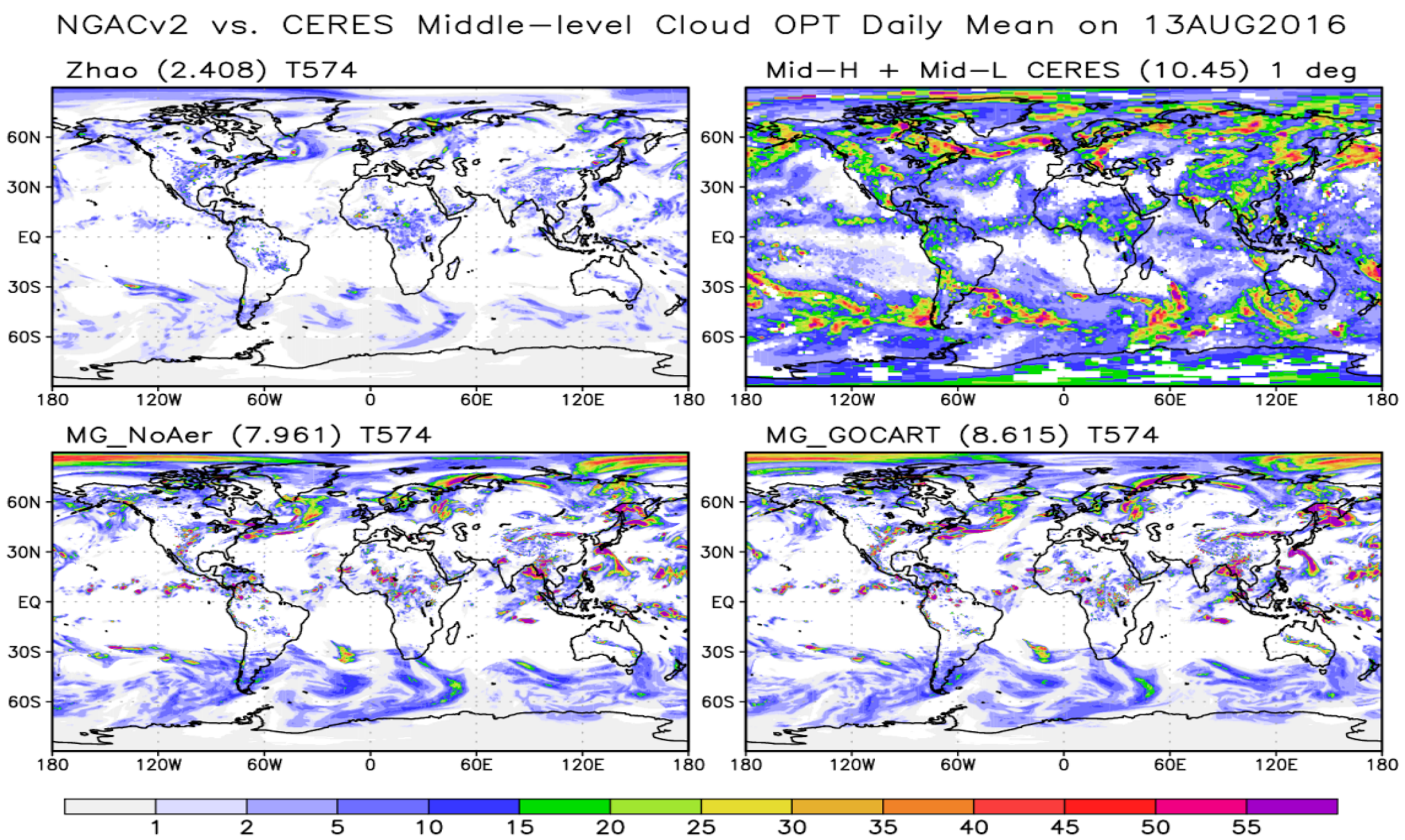


2016 Lousiana Flooding

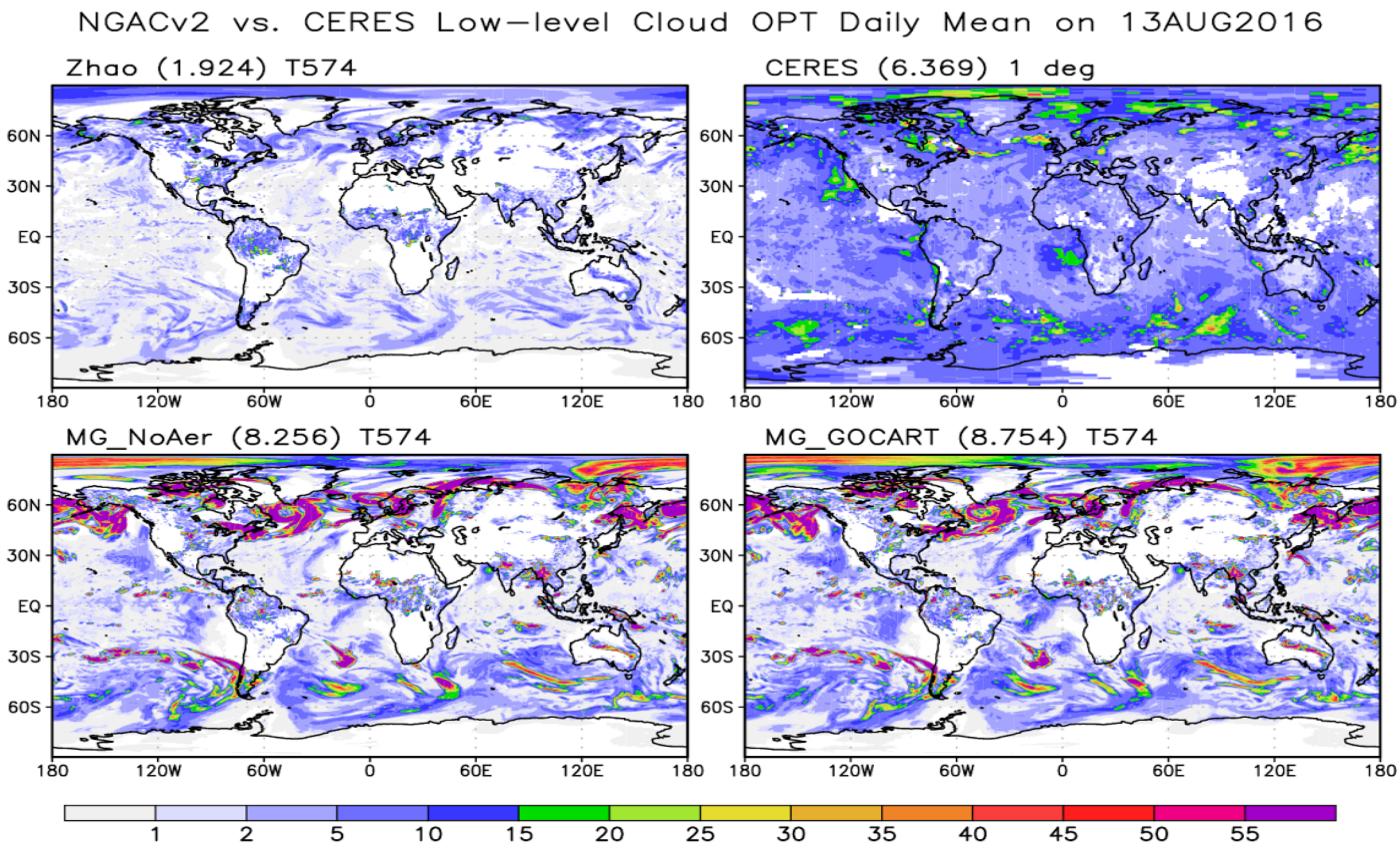
High-cloud optical depth at day 5



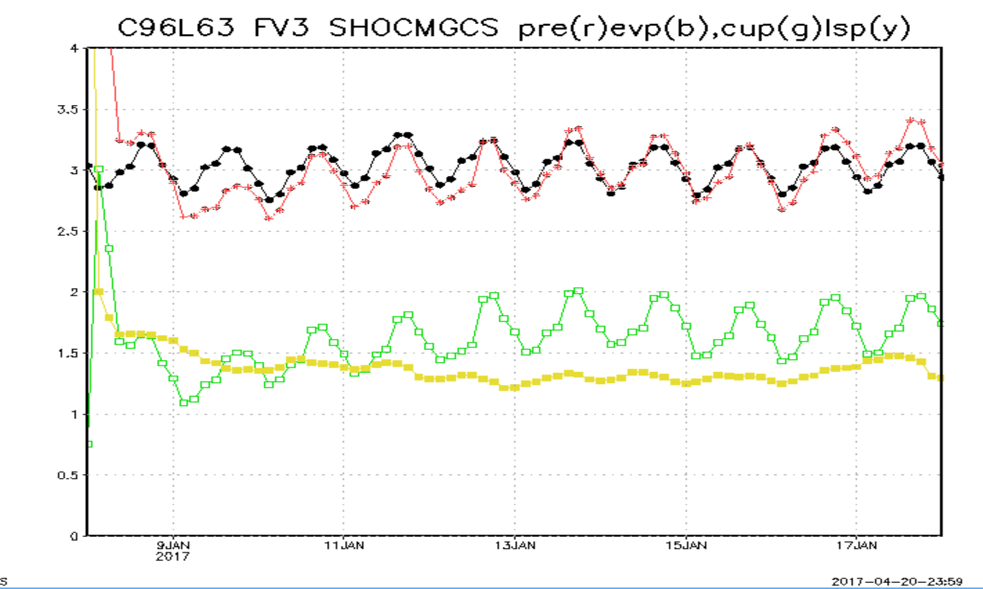
Middle cloud optical depth at day 5

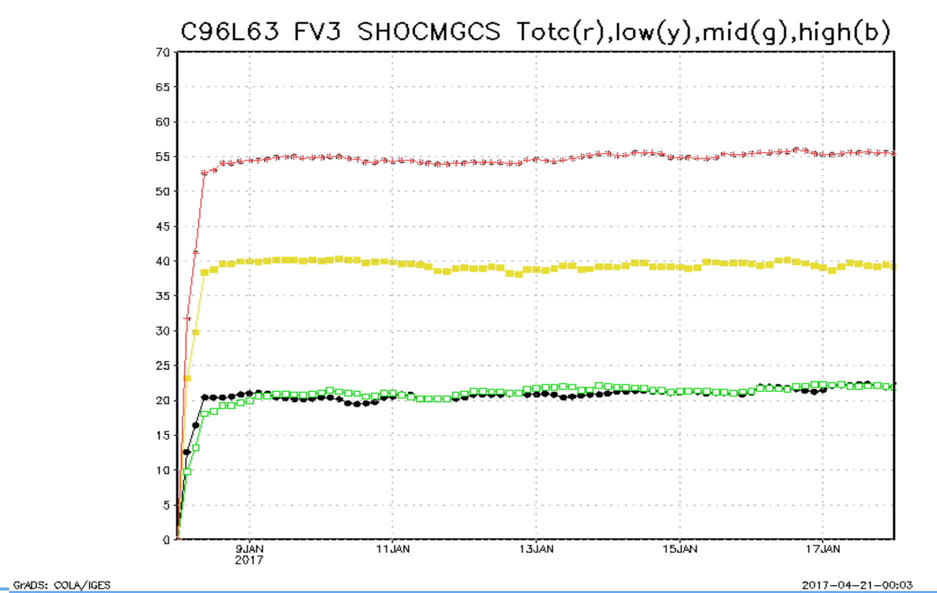


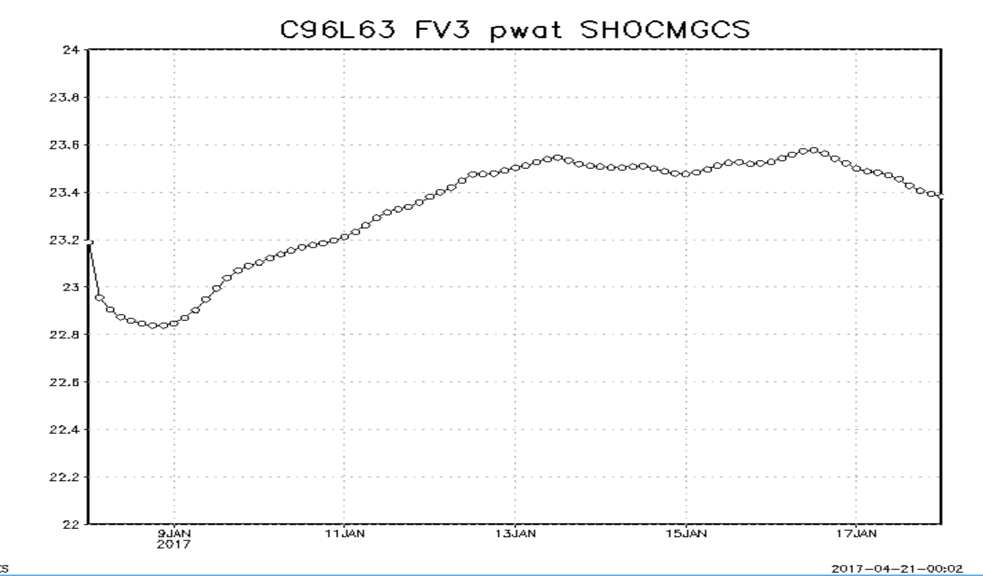
Low cloud optical depth at day 5



Time series for CS-SHOC-MG (fv3)







Good Diurnal cycle
Nice evaporation and precipiation balance
Some work needed for cloud fields\

Discussions

- Good anomaly correlation, RMSE, hurricane track, and optical depth obtained from MG. Zhao-Carr tends to produce optical thin clouds.
- Nice precipitation and evaporation balance and hurricane track from SHOC.
- Strong diurnal cycle, good anomaly correlation and hurricane track when MG coupled with CS-AW.

Future work

- Transfer all the code to NEMS/FV3.
- More sophisticated coupling of MG/MP, SHOC, and CS.
- More case testing and tuning.


Thank you!