Will the best WRF please identify itself?

Choosing the best WRF configuration for precipitation and circulation simulations over West Africa

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National Aeronautics and Space Administration
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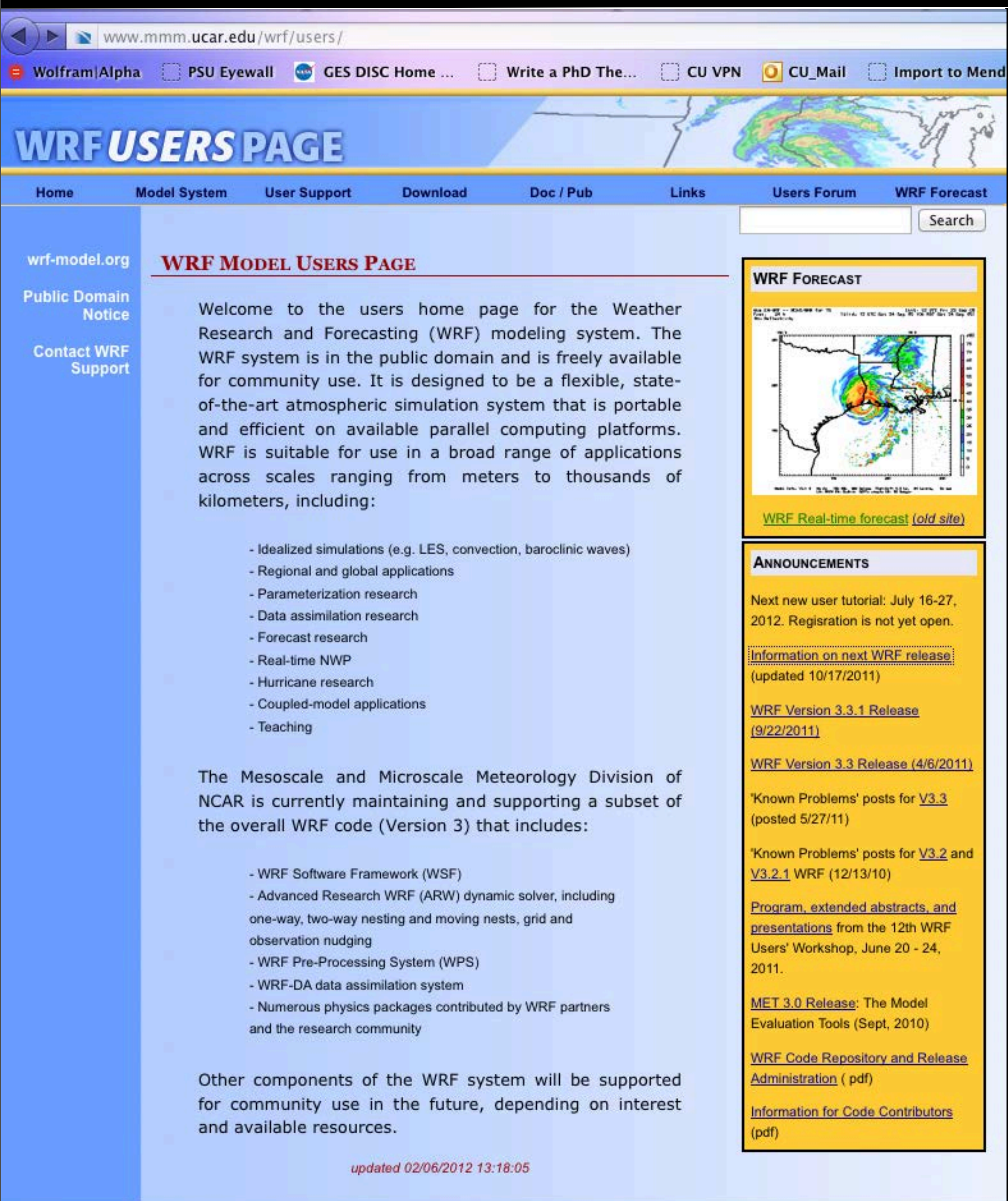
Goal of Talk

- To introduce the WRF model
- To introduce WRF simulations of daily variability over West Africa
- To discuss this work as a first step towards using WRF as a Regional Climate Model (RCM)

Thesis Work - Evaluation of WRF for West African simulations

- I assess a couple aspects of model performance:
  - to reproduce *daily* variability of West African Monsoon (WAM) features
  - to determine an optimal set of physics for monthly to intra-seasonal time scales
    - by *benchmarking* results to another RCM tuned for this region

Model - The WRF



www.mmm.ucar.edu/wrf/users/

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WRF USERS PAGE

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wrf-model.org

Public Domain Notice

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WRF MODEL USERS PAGE

Welcome to the users home page for the Weather Research and Forecasting (WRF) modeling system. The WRF system is in the public domain and is freely available for community use. It is designed to be a flexible, state-of-the-art atmospheric simulation system that is portable and efficient on available parallel computing platforms. WRF is suitable for use in a broad range of applications across scales ranging from meters to thousands of kilometers, including:

- Idealized simulations (e.g. LES, convection, baroclinic waves)
- Regional and global applications
- Parameterization research
- Data assimilation research
- Forecast research
- Real-time NWP
- Hurricane research
- Coupled-model applications
- Teaching

The Mesoscale and Microscale Meteorology Division of NCAR is currently maintaining and supporting a subset of the overall WRF code (Version 3) that includes:

- WRF Software Framework (WSF)
- Advanced Research WRF (ARW) dynamic solver, including one-way, two-way nesting and moving nests, grid and observation nudging
- WRF Pre-Processing System (WPS)
- WRF-DA data assimilation system
- Numerous physics packages contributed by WRF partners and the research community

Other components of the WRF system will be supported for community use in the future, depending on interest and available resources.

updated 02/06/2012 13:18:05

WRF FORECAST

WRF Real-time forecast (old site)

ANNOUNCEMENTS

Next new user tutorial: July 16-27, 2012. Regisration is not yet open.

Information on next WRF release (updated 10/17/2011)

WRF Version 3.3.1 Release (9/22/2011)

WRF Version 3.3 Release (4/6/2011)

'Known Problems' posts for V3.3 (posted 5/27/11)

'Known Problems' posts for V3.2 and V3.2.1 WRF (12/13/10)

Program, extended abstracts, and presentations from the 12th WRF Users' Workshop, June 20 - 24, 2011.

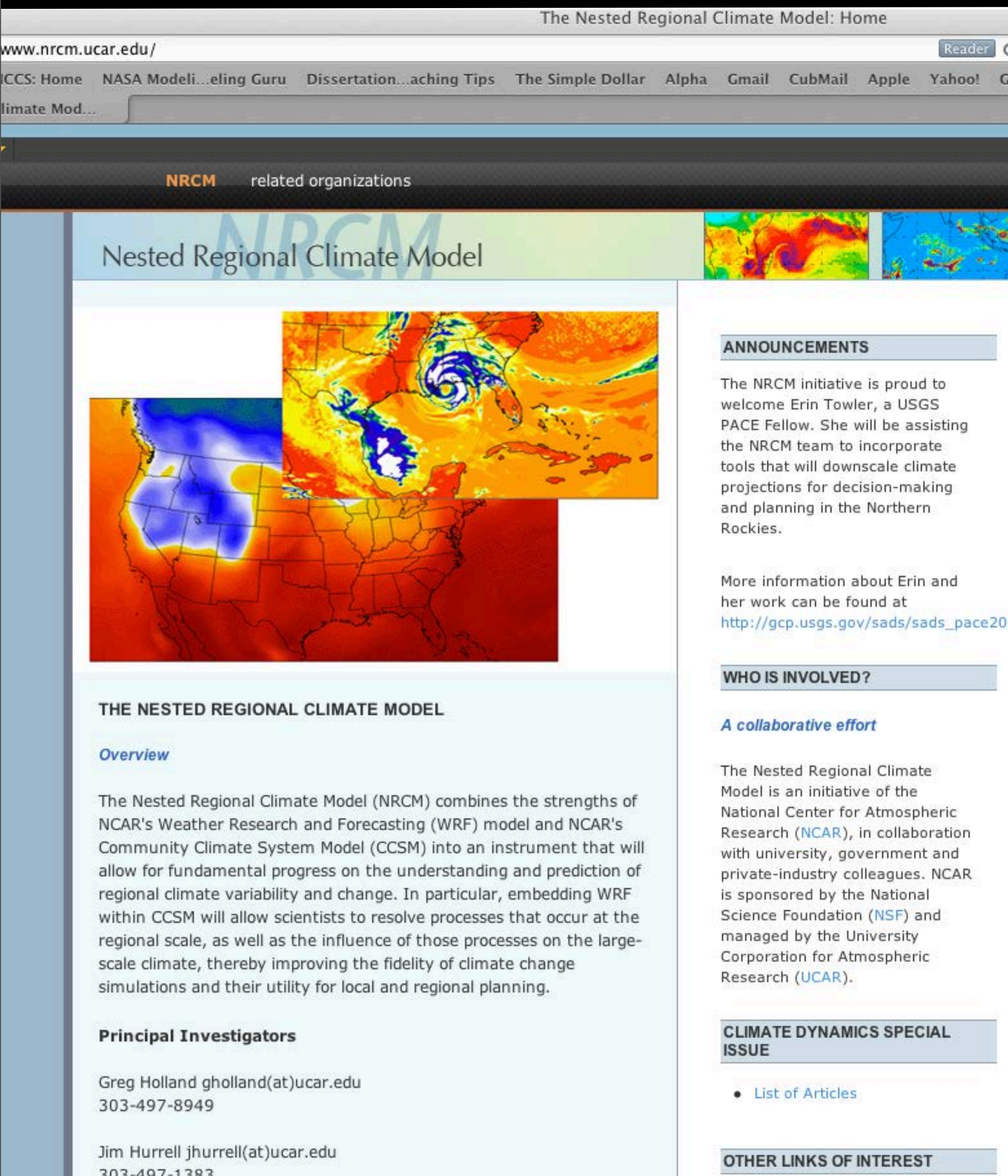
MET 3.0 Release: The Model Evaluation Tools (Sept, 2010)

WRF Code Repository and Release Administration (pdf)

Information for Code Contributors (pdf)

- The National Center For Atmospheric Research (NCAR) Weather Research & Forecasting (WRF) model.
- developed primarily as a mesoscale forecast model and data-assimilation system for shorter-range simulations.
- a community model with many versions
  - community - anyone can use it and change it at their will.
  - approximately 7,000 research users and 22 operational centers in 95 countries
  - U.S. National Centers for Environmental Prediction (NCEP)
  - U.S. Air Force.

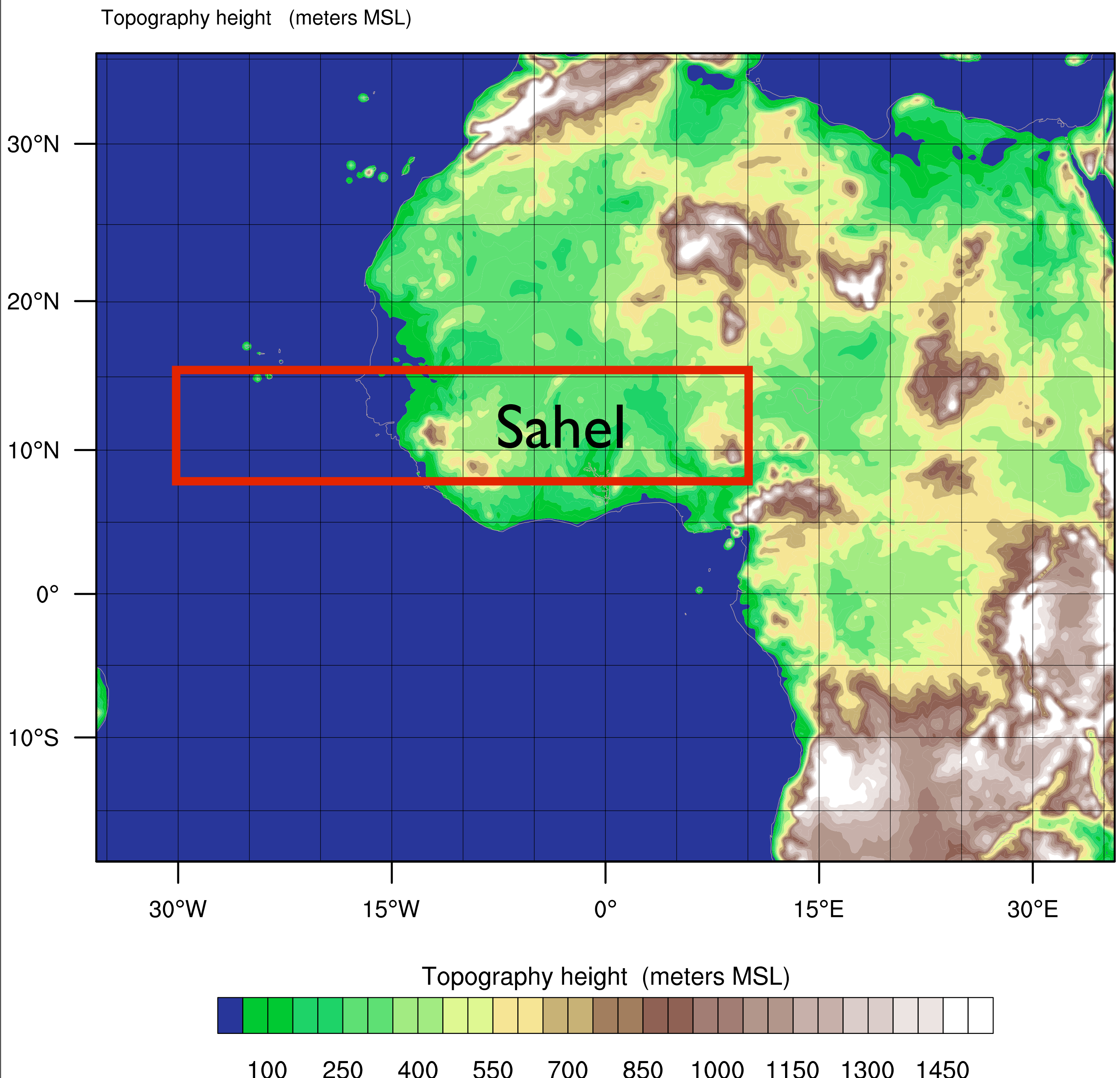
Model - The WRF



- There are several versions of the WRF model:
- Research Version:
  - Advanced Research version of WRF (WRF - ARW)
  - Hurricane model (HWRF)
  - Wildfire model (WRF-FIRE)
- Operational Version used by NCEP and NOAA
  - Nonhydrostatic Mesoscale Model (WRF - NMM)
- Regional Climate Model version? Answer: not quite black and white
  - in 2009 - a blending of WRF-ARW and the NCAR Community Climate System Model (CCSM)
  - "An ambitious, strategic goal is to combine the WRF and CCSM models into a Nested Regional Climate Model (NRCM) that will allow for fundamental progress on the understanding and prediction of regional climate variability and change."

* Dr. Jim Hurrel - 2009 "BRIEFING TO THE WESTERN GOVERNORS' ASSOCIATION"

Setup: West African Domain
Focus: Sahel Region



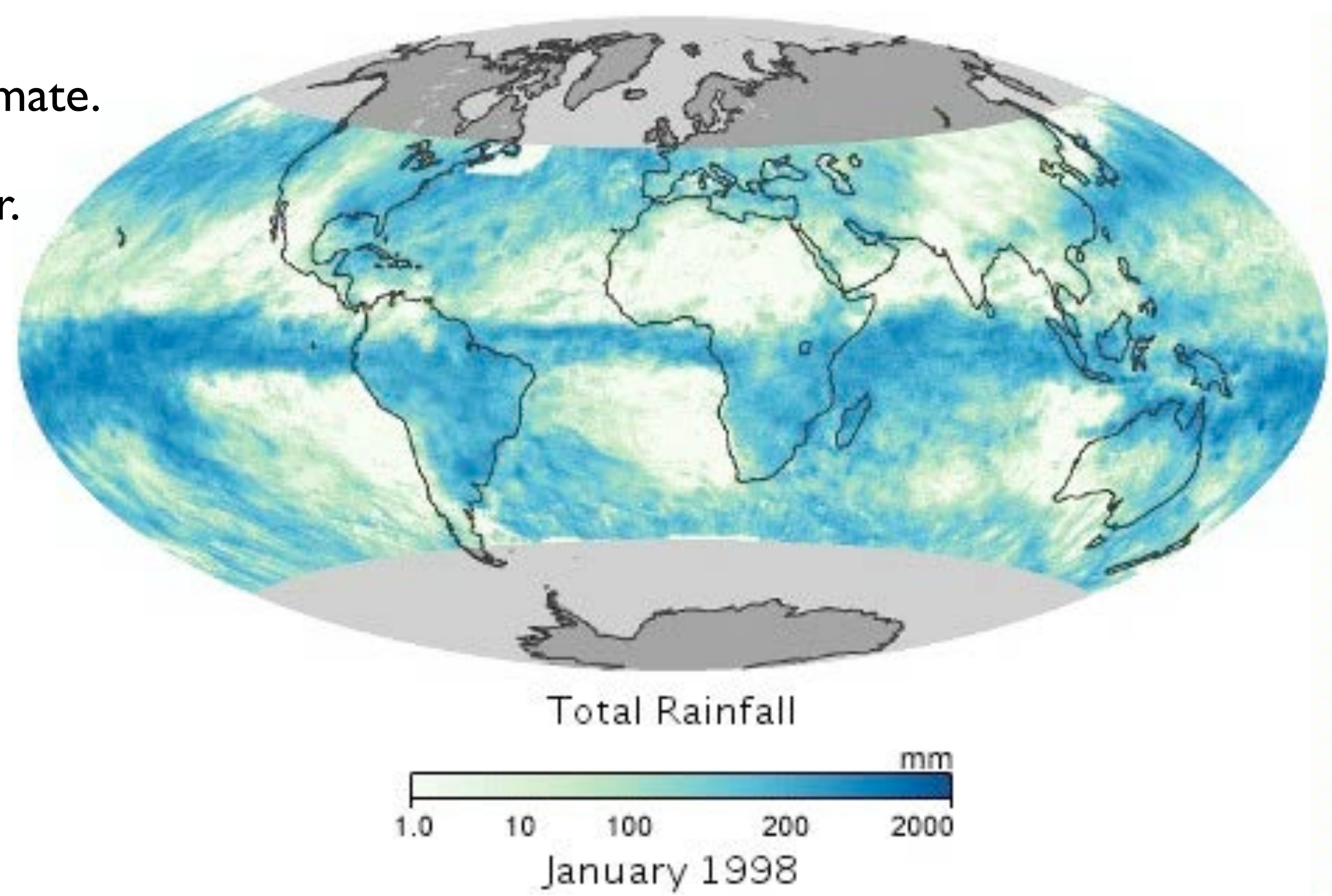
- Advanced Research version of NCAR's Weather Research & Forecasting (WRF) model (v3.2.1)
- The picture shows the domain used in model simulations (all of West Africa, central Africa,...)
- 20x20 km^2 horizontal grid increment
- 30 variably-spaced sigma layers (sfc-100 hPa)
- 2 min time-step; 6-hourly diagnostics
- Initial Conditions (IC) & Lateral Boundary Conditions (LBCs) provided by NCEP-DOE Reanalysis II (NNRP2)
- 9-pt boundary zone (outermost is specified and the adjacent 8 are Newtonianlly relaxed).
- No nudging (conventional or spectral) in the domain interior

My region of interest - the Sahel - is outlined in red.

Why West Africa

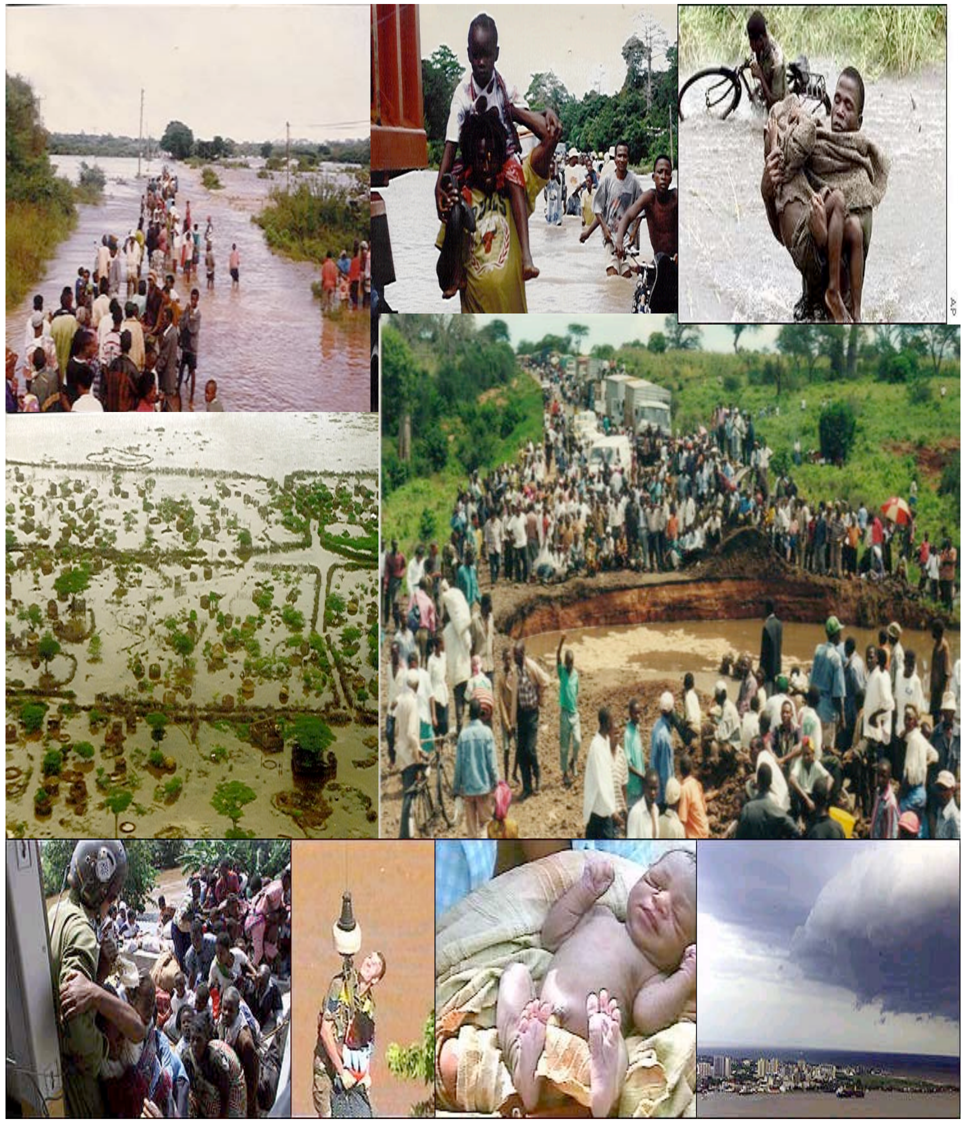
The rainfall animation shows total monthly rainfall in mm as recorded by NASA's Tropical Rainfall Measuring Mission (TRMM) satellite

- West Africa has a Monsoon climate.
- Rain only comes in the summer.
- Dry season: October – April (Not a drought)



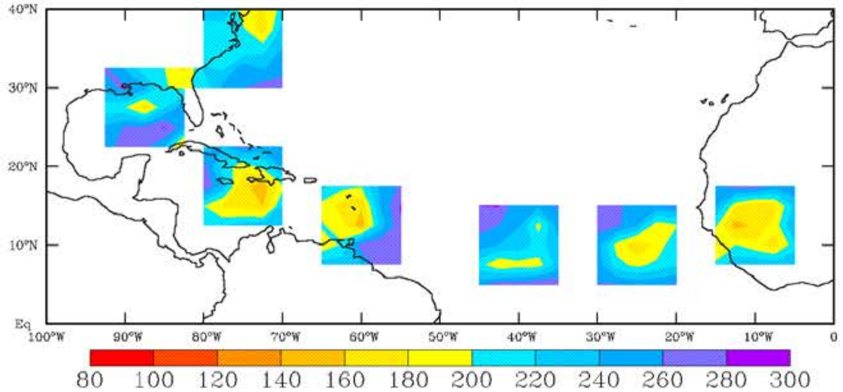
Movie is available at http://earthobservatory.nasa.gov/GlobalMaps/

Variability in the West African Monsoon Matters!

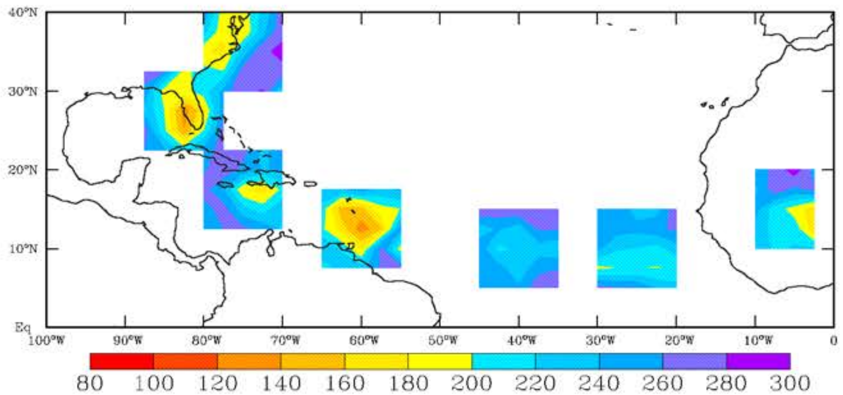


Variability in the WAM impacts the US!

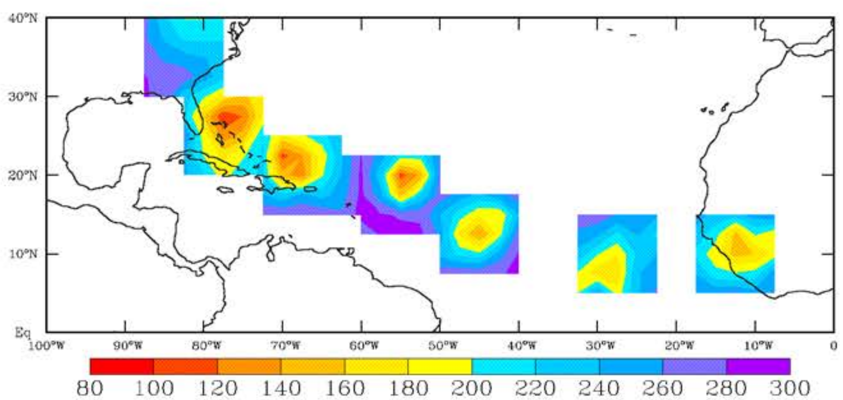
Bonnie (05)



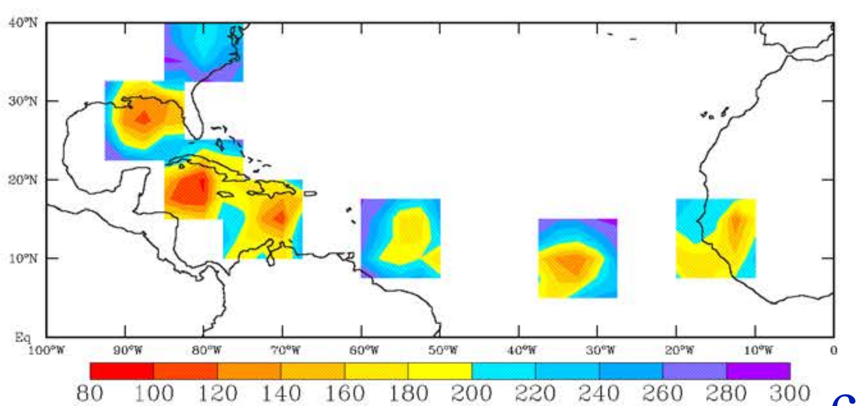
Charlie (05)



Frances (05)



Ivan (05)



Flooding in New Orleans due to Katrina

(courtesy NOAA)

courtesy A. Aiyyer and C. Thorncroft

My time period for this initial study: September 2006 during AMMA campaign

AFRICAN MONSOON MULTIDISCIPLINARY ANALYSIS

An International Research Project and Field Campaign

BY JEAN-LUC REDELSPERGER, CHRIS D. THORNCROFT, ARONA DIEDHIOU, THIERRY LEBEL, DOUGLAS J. PARKER, AND JAN POLCHER

AMMA strives to improve our understanding of the West African Monsoon system and will facilitate the multidisciplinary analysis needed to improve prediction of its variability and its associated societal impacts.

African Monsoon Multidisciplinary Analysis (AMMA) is an international project to improve our knowledge and understanding of the West African monsoon (WAM) and its variability with an emphasis on daily-to-interannual time scales. AMMA is motivated by an interest in fundamental scientific issues and by the societal need for improved prediction of the WAM and its impacts on West African nations. Vulnerability of West African societies to climate variability is likely to increase in the next decades as demands on resources increase in association with one of the world's most rapidly growing populations. Vulnerability may be further increased in association with the effects of climate change and other factors linked to the fast-growing population, such as land degradation and water pollution.

Recognizing the societal need to develop strategies that reduce the socioeconomic impacts of the variability of the WAM, AMMA will facilitate the multidisciplinary research required to provide improved predictions of the WAM and its impacts. The international AMMA project has three overarching aims:

1) To improve our understanding of the WAM and its influence on the physical, chemical and biological environment regionally and globally;
2) To provide the underpinning science that relates variability of the WAM to issues of health, water resources, food security and demography for West African nations and defining and implementing relevant monitoring and prediction strategies; and
3) To ensure that the multidisciplinary research carried out in AMMA is effectively integrated with prediction and decision making activity.

AFFILIATIONS: REDELSPERGER—CNRM/GAME CNRS and Meteo-France, Toulouse, France; THORNCROFT—State University of New York at Albany, Albany, New York; DIEDHIOU AND LEBEL—LTHE, IRD, Niamey, Niger; PARKER—University of Leeds, Leeds, United Kingdom; POLCHER—LMD, CNRS, Paris, France
CORRESPONDING AUTHOR: Chris Thorncroft, Department of Earth and Atmospheric Sciences, University at Albany, SUNY, Albany, NY 12222
E-mail: chris@atmos.albany.edu

The abstract for this article can be found in this issue, following the table of contents.
DOI:10.1175/BAMS-87-12-1739

In final form 7 July 2006

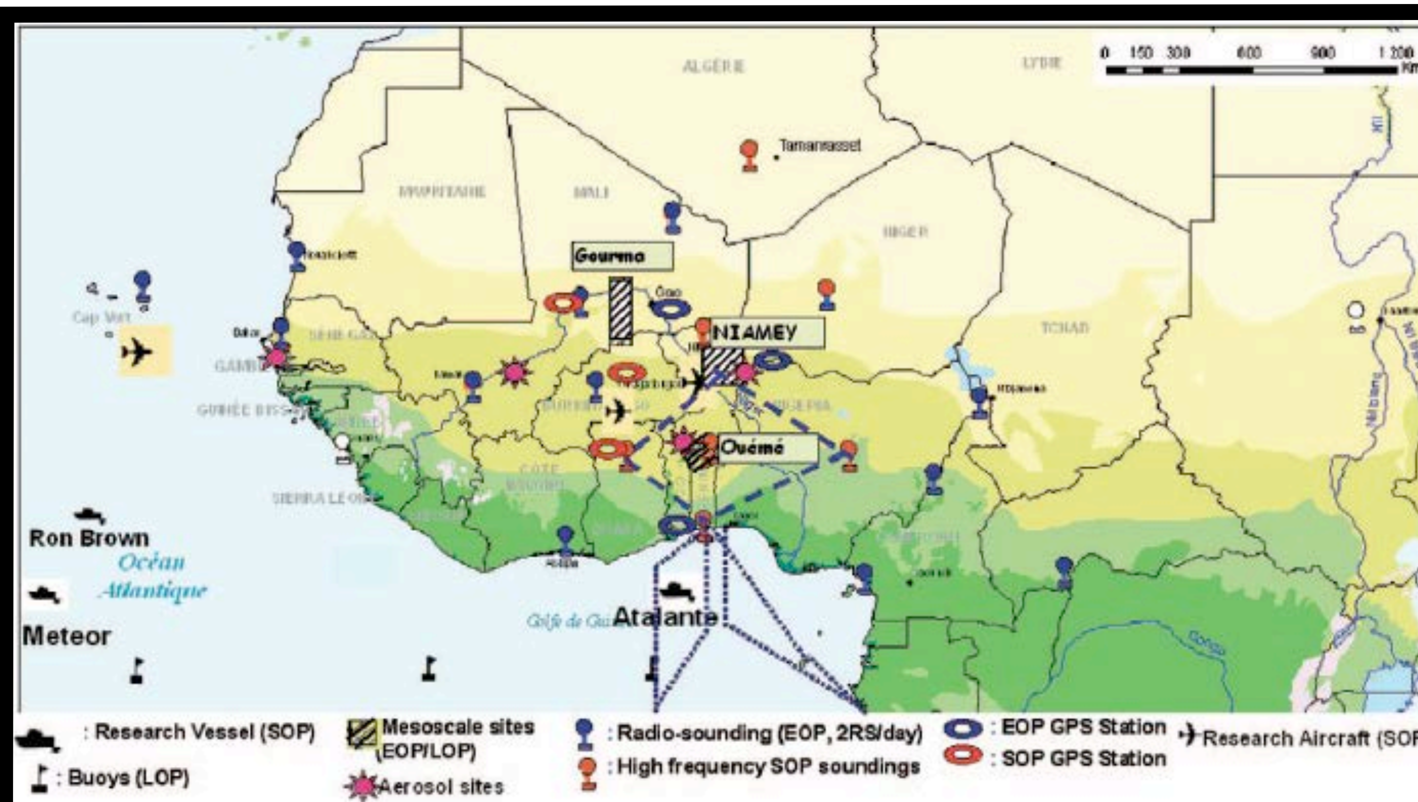


FIG. 3. Field implementation of AMMA observations based on nested networks. Circles indicated the atmospheric sounding network activated during the SOP.

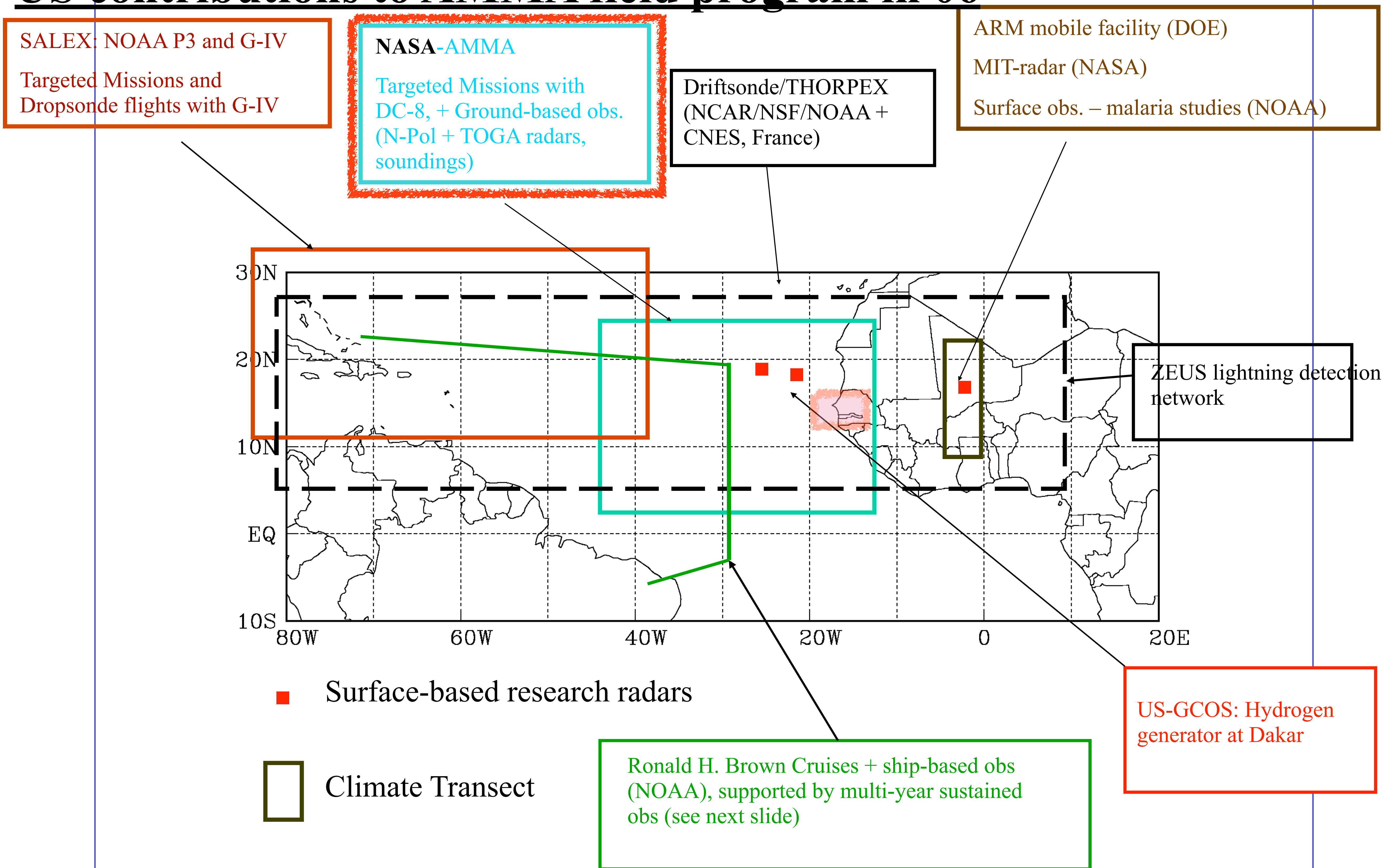
- **The Long term Observing Period (LOP)** is concerned with observations of two types:
  i. historical observations to study interannual-to-decadal variability of the WAM (including currently unarchived observations) and
  ii. additional long term observations (2002-2010) to document and analyse the interannual variability of the WAM.
- **The Enhanced Observing Period (EOP)** is designed to serve as a link between the LOP and the SOP (below). Its main objective is to document over a climatic transect the annual cycle of the surface conditions and atmosphere and to study the surface memory effects at the seasonal scale. The EOP will be 2-3 year duration (2005-2007).
- **The Special Observing Period (SOP)** will focus on detailed observations of specific processes and weather systems at various key stages of the rainy season during three periods in the summer of 2006:
  i. the Dry season (Jan-Feb),
  ii. Monsoon onset (15 May-30 June),
  iii. Peak monsoon (1 July - 14 August) and
  iv. Late monsoon (15 August-15 September).

My period of study.

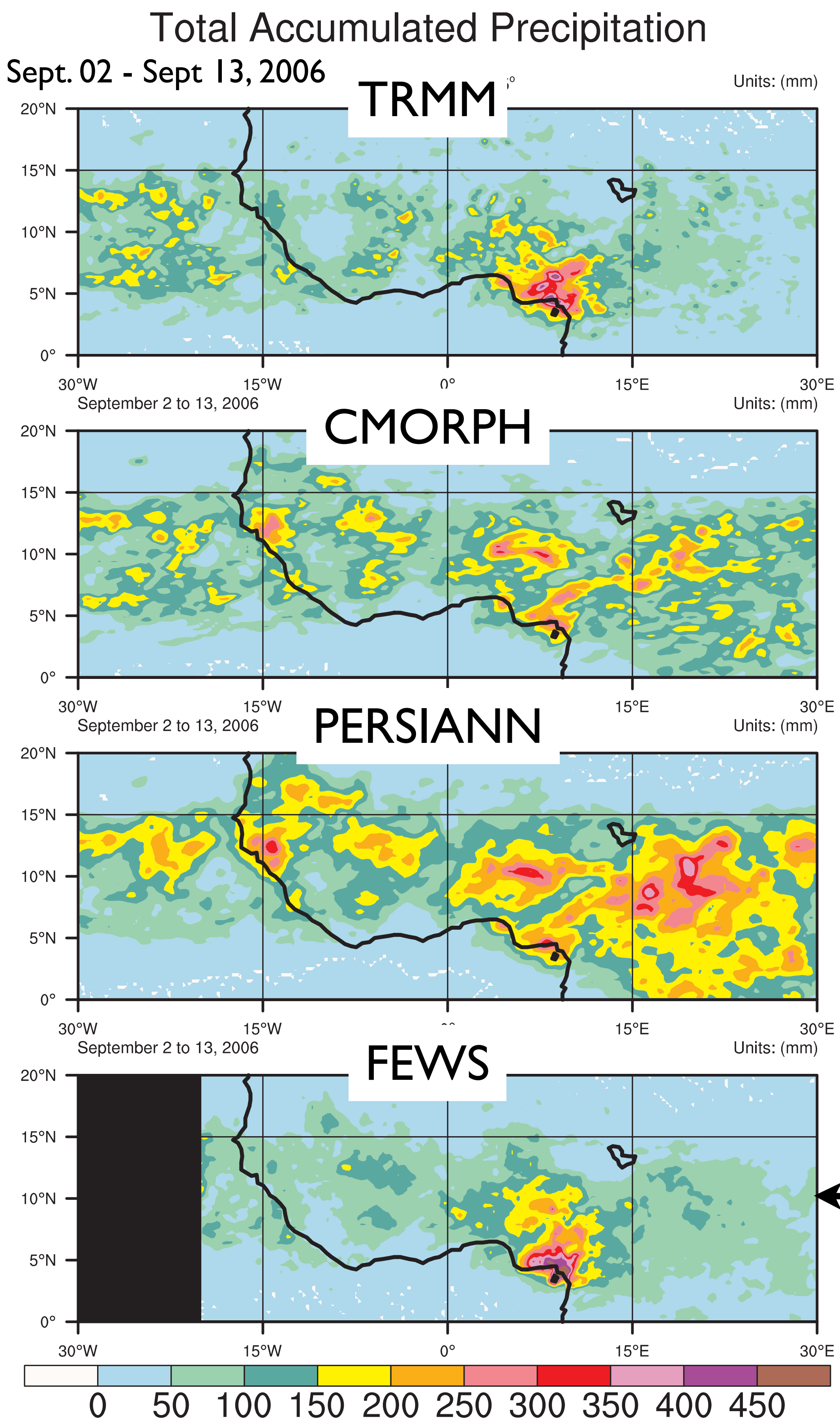
Wednesday, February 8, 12

This work is relevant to NASA, too!

US contributions to AMMA field program in 06



Observational Data Sets



Satellite Rainfall Estimation Products

Product	Spatial resolution	Temporal resolution	Data Acquired from:	Available since:
Tropical rainfall Measuring Mission (**TRMM**) 3B42	0.25°x0.25°	3h	NASA Goddard Space Flight Center	1997
CMORPH (CPC MORPHing technique)	0.25°x0.25°	3h	NOAA Climate Prediction Center	2008
PERSIANN	0.25°x0.25°	6h	University of California Irvine	2000

← Climate Prediction Center Famine Early Warning System (FEWS)

*Not used, but nice to compare with...

Observational Data Sets

Circulation: meridional wind, Relative Vorticity

Product	Spatial resolution	Temporal resolution	Data Acquired from:	Available since:
NCEP/DOE Reanalysis II (**NNRP2**)	2.5°	6h	NCEP	1996
Modern Era Retrospective-analysis for Research and Applications (**MERRA**)	2/3° lon. x 0.5° lat	3h	NASA Goddard	2007

Benchmark RCM

NASA GISS Regional Model version 3 (RM3)

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **28**: 1293–1314 (2008)
Published online 26 October 2007 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/joc.1636

RMetS
ROYAL METEOROLOGICAL SOCIETY

The impact of vertical resolution on regional model simulation of the west African summer monsoon

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[b] *The NASA/Goddard Institute for Space Studies, 2880 Broadway, New York NY 10025 USA*

ABSTRACT: The RM3 regional climate model is used to simulate the west African summer monsoon for six June–September seasons using NCEP reanalysis data for lateral boundary forcing. The study compares the performance of the previously published 16-level version with a newly tested 28-level version, both running on a horizontal grid with 0.5° spacing, in order to determine what improvements in simulations are achieved by increased vertical resolution. Comparisons between the performances include diagnostics of seasonal mean precipitation rates and circulation, vertical profiles of cumulus heating rates, frequencies of shallow and deep convection and diagnostics related to transient African easterly waves (AEWs). The characteristics of a composite AEW simulated at both vertical resolutions are presented. Results show that the most significant impact of increasing the vertical resolution is stronger circulation, stronger vertical wind shear and higher amplitude AEWs. The simulations with higher vertical resolution also achieve higher peaks of cumulus latent heating rates. Spatial–temporal correlations between simulated daily 700 mb meridional winds *versus* corresponding NCEP reanalysis data and simulated daily precipitation *versus* estimates from the Tropical Rainfall Measurement Mission (TRMM) archive were equally high at both vertical resolutions.

KEY WORDS west African monsoon; regional climate model; African easterly waves

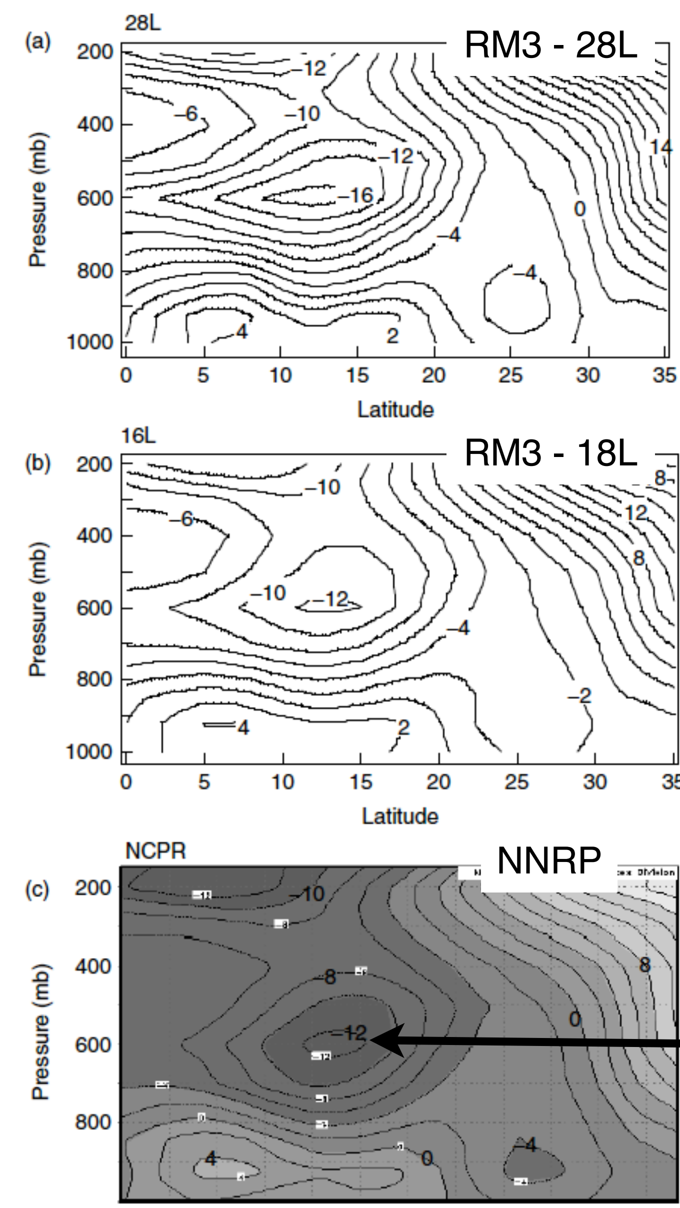
Received 25 January 2007; Revised 4 September 2007; Accepted 8 September 2007

1. Introduction

This article analyses aspects of the simulated June–September west African monsoon (WAM) climate, with particular attention to the characteristics of African easterly wave disturbances (AEWs). Simulations are made with a regional/limited area model (LAM) on a 0.5° latitude by longitude grid, integrated at two vertical resolutions, at 16 and 28 vertical levels, respectively. The regional model is referred to as RM3 since it has undergone two major improvements (Druyan *et al*., 2004; Druyan and Fulakeza, 2005) since its first application to WAM studies (Druyan *et al*., 2000, 2001).

The impact of the increased vertical resolution is evaluated by comparing simulations to each other and to empirical evidence in order to better appreciate the relevance of results to the real world. Druyan *et al*. (2006) previously used lateral boundary conditions from NCEP and land surface (LS) characteristics. Accordingly, downscaled representations of the climate can be quite different from the driving analysis. Druyan *et al*. (2006) showed that NCPR-driven RM3 simulations produce time-space distributions of WAM precipitation that are highly correlated with Tropical Rainfall Measuring Mission (TRMM) daily estimates in continuous 4-month summer simulations with no perceptible deterioration trend. However, RM3 daily precipitation rates generally had a smaller range than corresponding TRMM data. The simulations achieved too few very high and very low rates.

The summer WAM climate features a northward meridional temperature gradient over west Africa that creates a westward-directed vertical wind shear (thermal wind). Accordingly, near-surface monsoon southwesterlies reverse direction with altitude, ultimately creating the mid-tropospheric African easterly jet (AEJ). The AEJ



African Easterly Jet (AEJ)

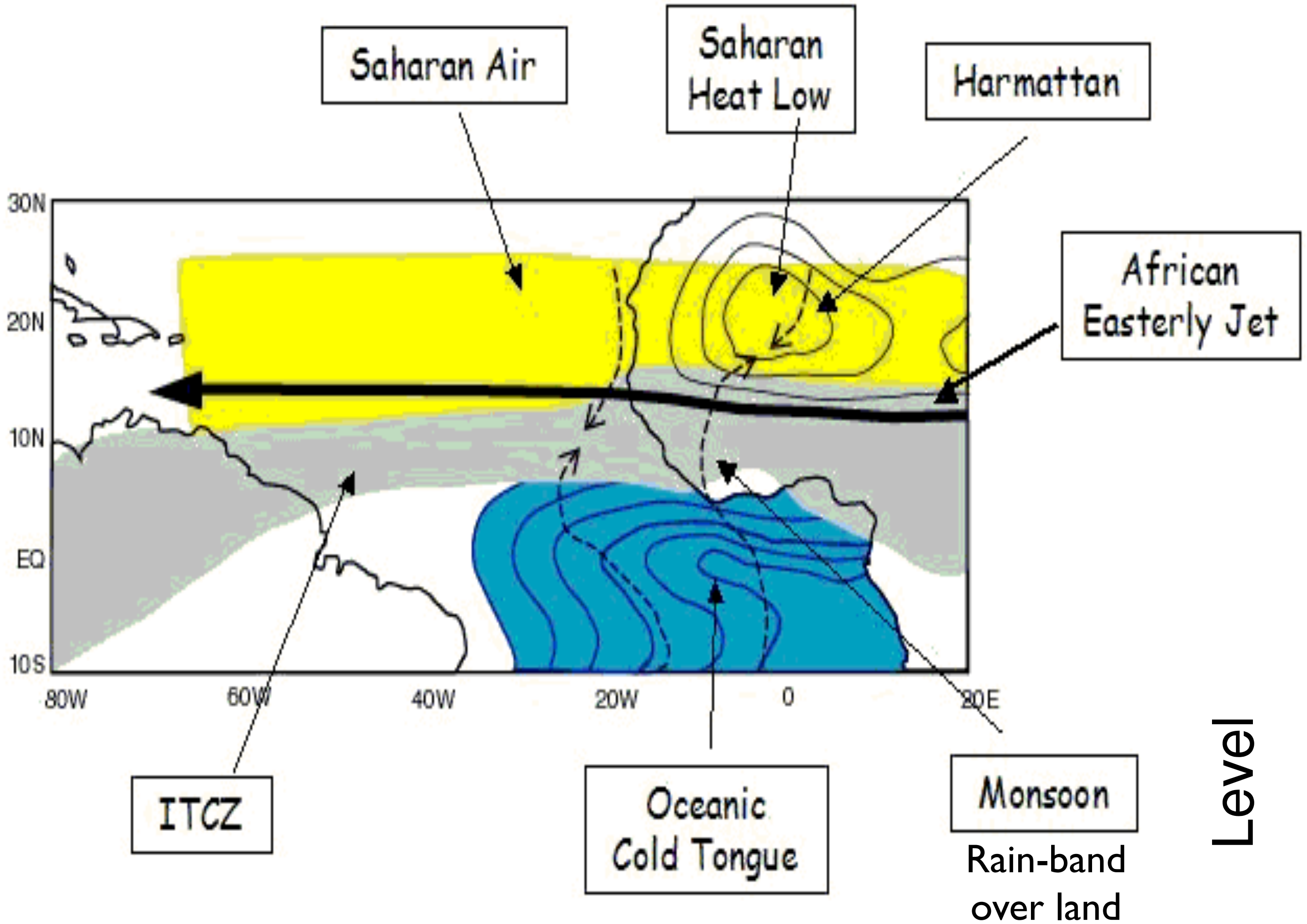
Figure 1. Cross-sections of zonal winds (m s^{-1}) along 0° longitude, for June–September 1998–2003. (a) RM3.28L, (b) RM3.16L and (c) NCPR (courtesy NOAA/CDC).

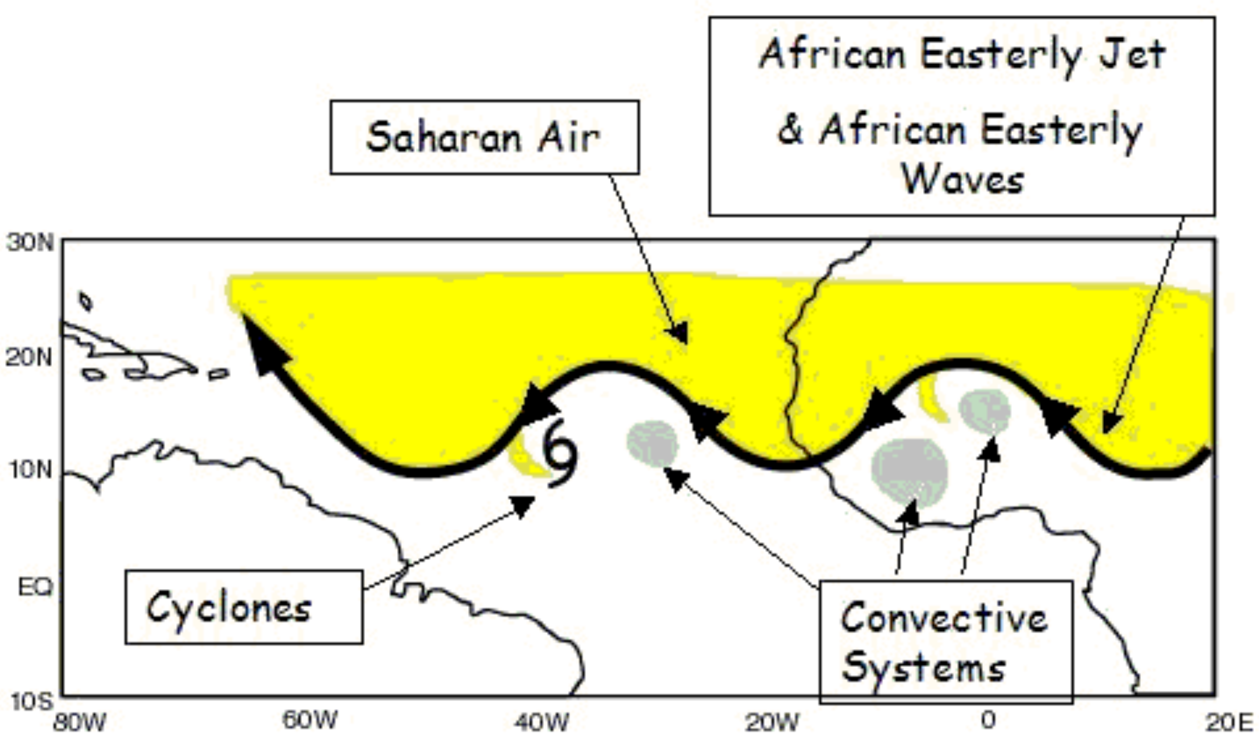
It makes sense to compare the WRF model to another regional model that has already been tuned to this area.

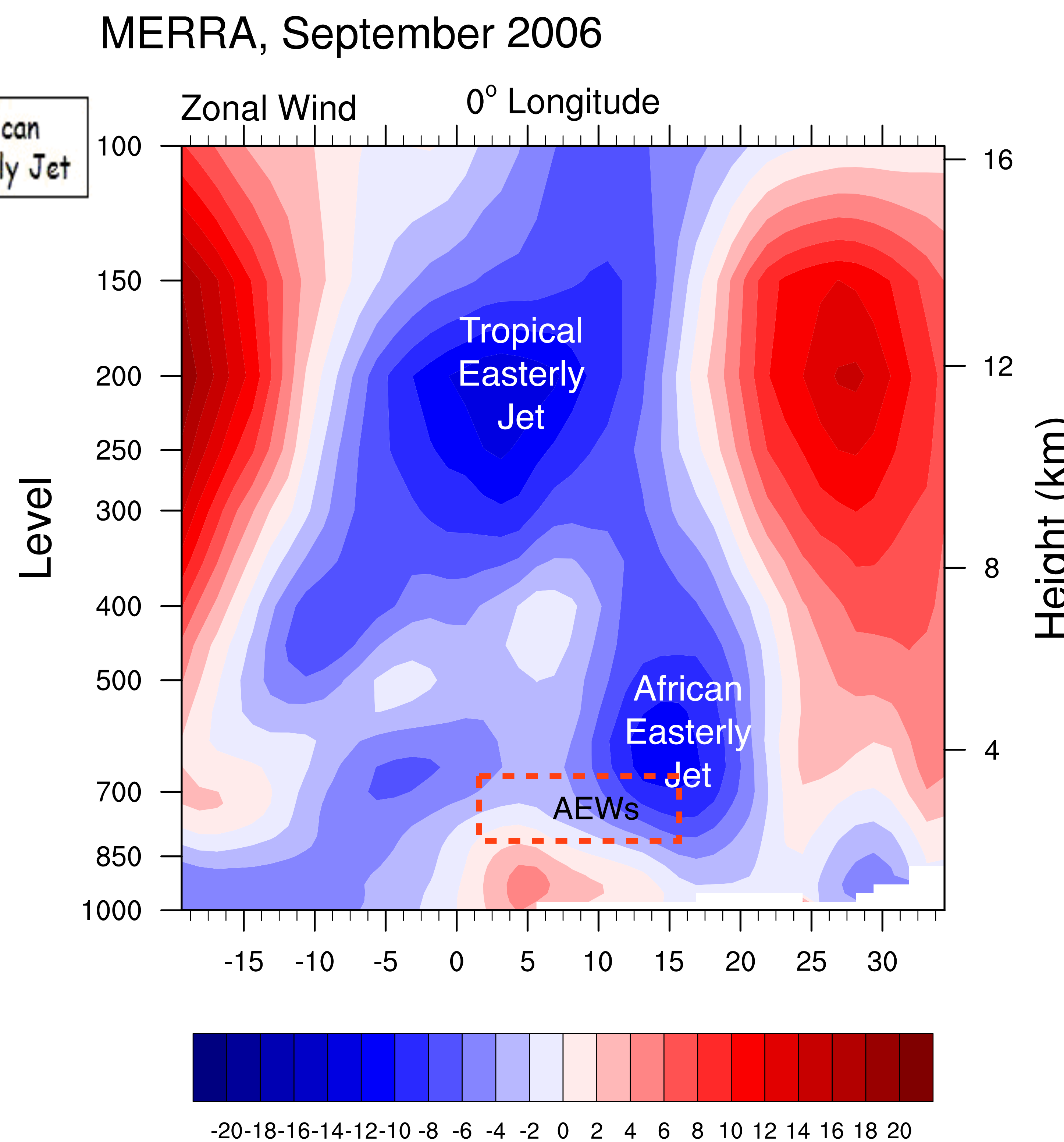
Statistical Evaluation

- All precipitation results presented are for daily-accumulation from each model experiment
- All circulation results presented are for 00Z from each model experiment
- I calculate domain-wide statistics for Sahel region only between WRF and observations
- Statistics: Correlation, Standard Deviation, RMSE, Bias
- Variables: precipitation, meridional wind, and relative vorticity

WAM components

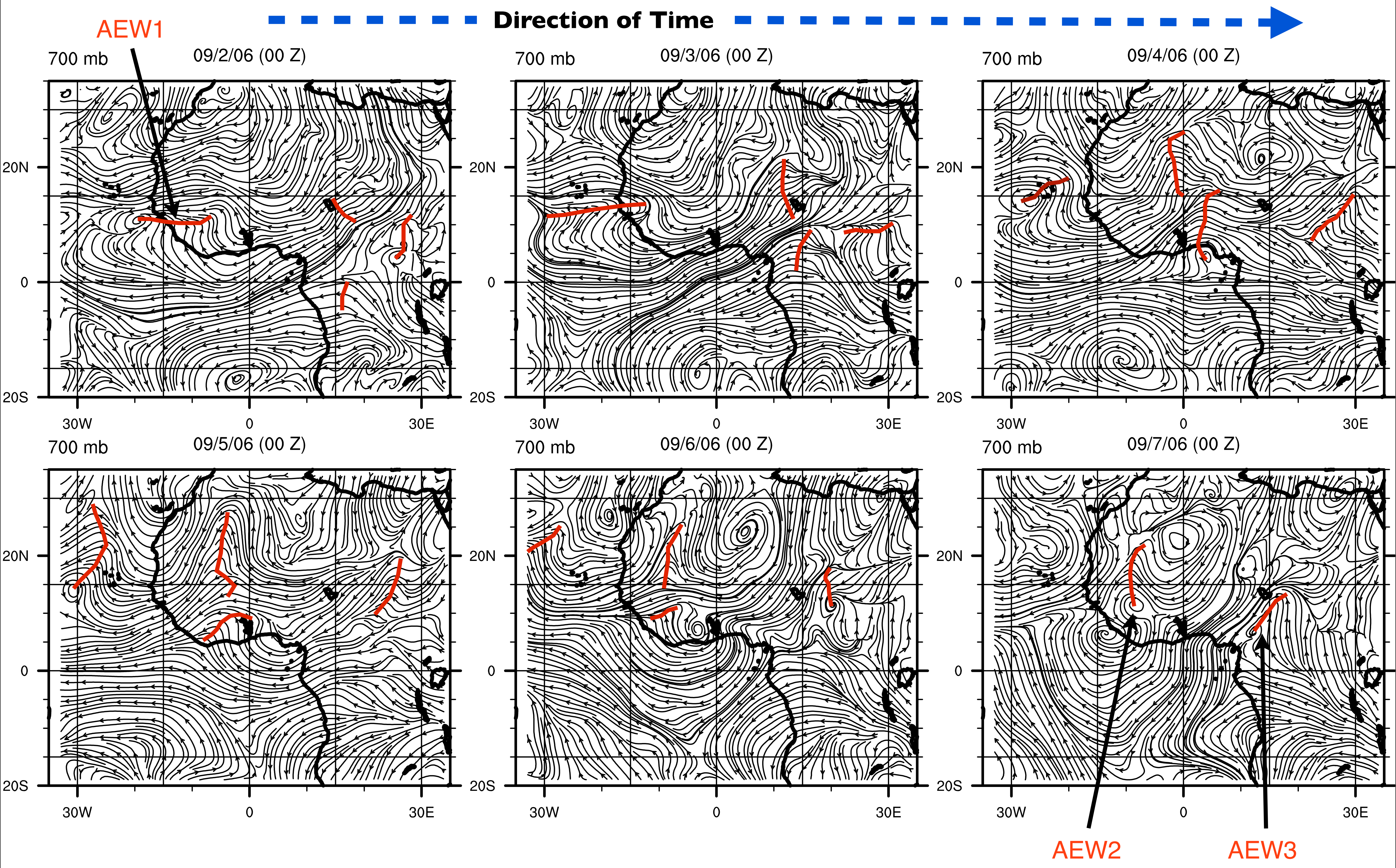






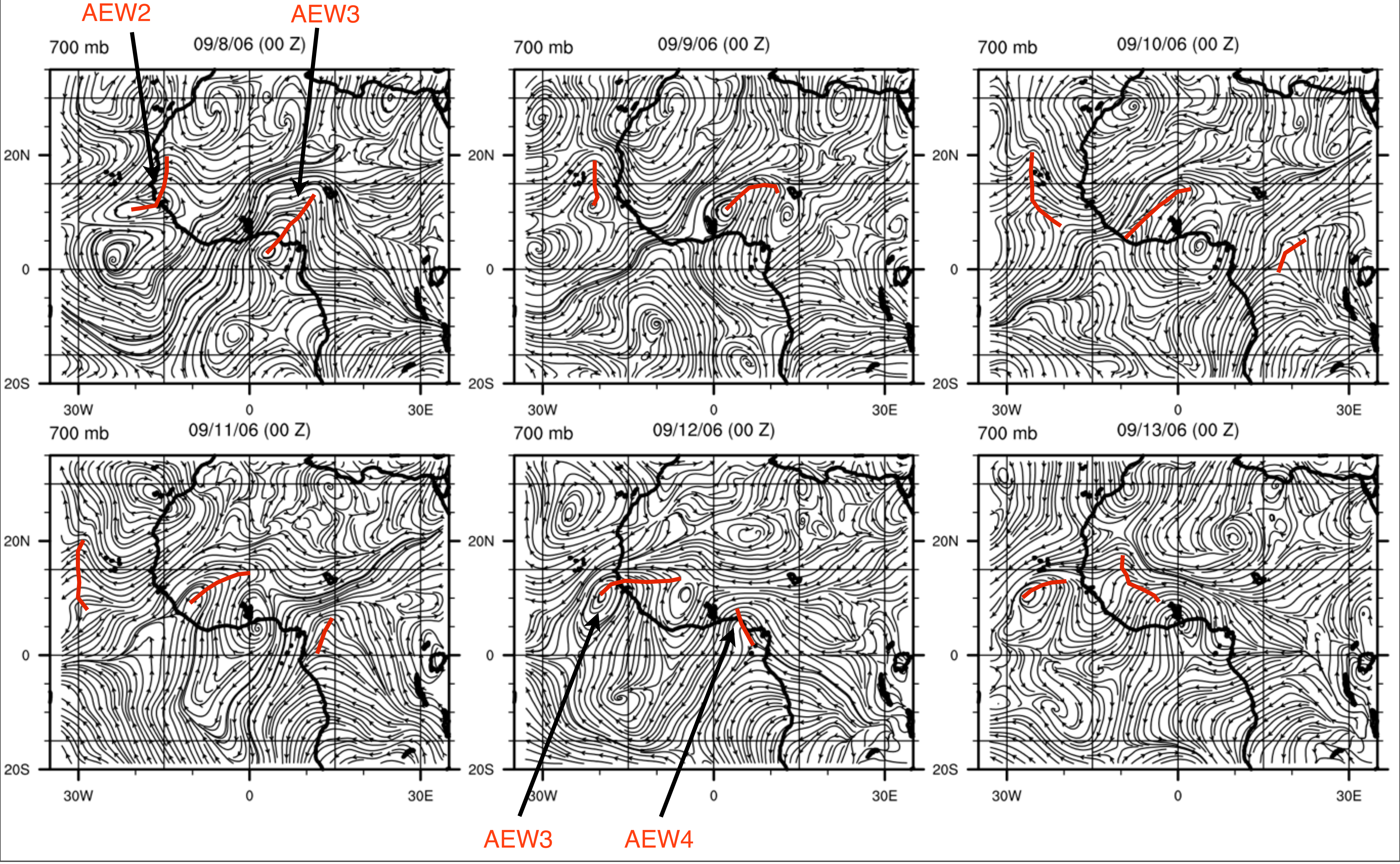
African Easterly Waves over West Africa

Streamlines, MERRA @700 mb, Sept. 02 to Sept. 07, 2006



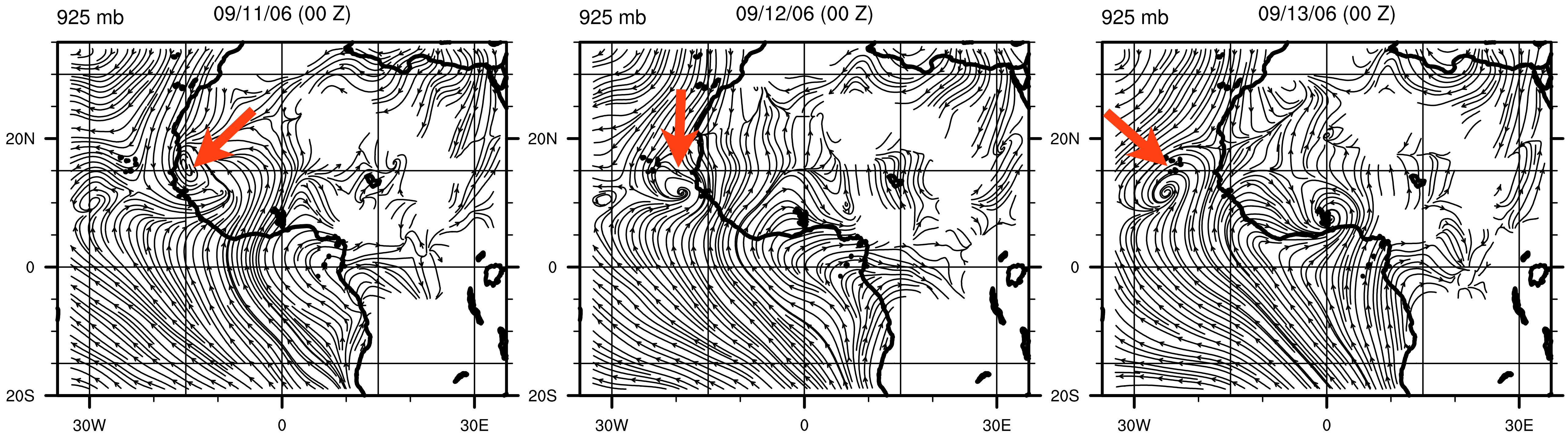
African Easterly Waves over West Africa

Streamlines, 700 mb, MERRA, Sept. 08 to Sept. 13, 2006



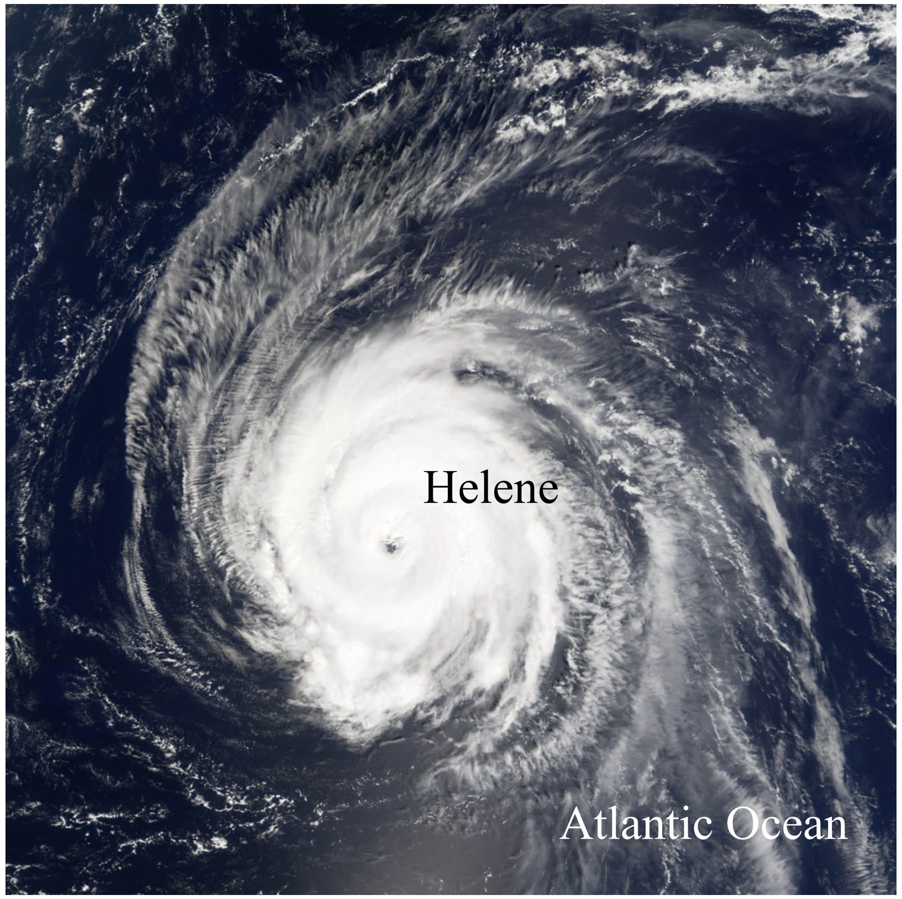
African Easterly Waves over West Africa

Streamlines, 925 mb, MERRA, Sept. 11 to Sept. 13, 2006



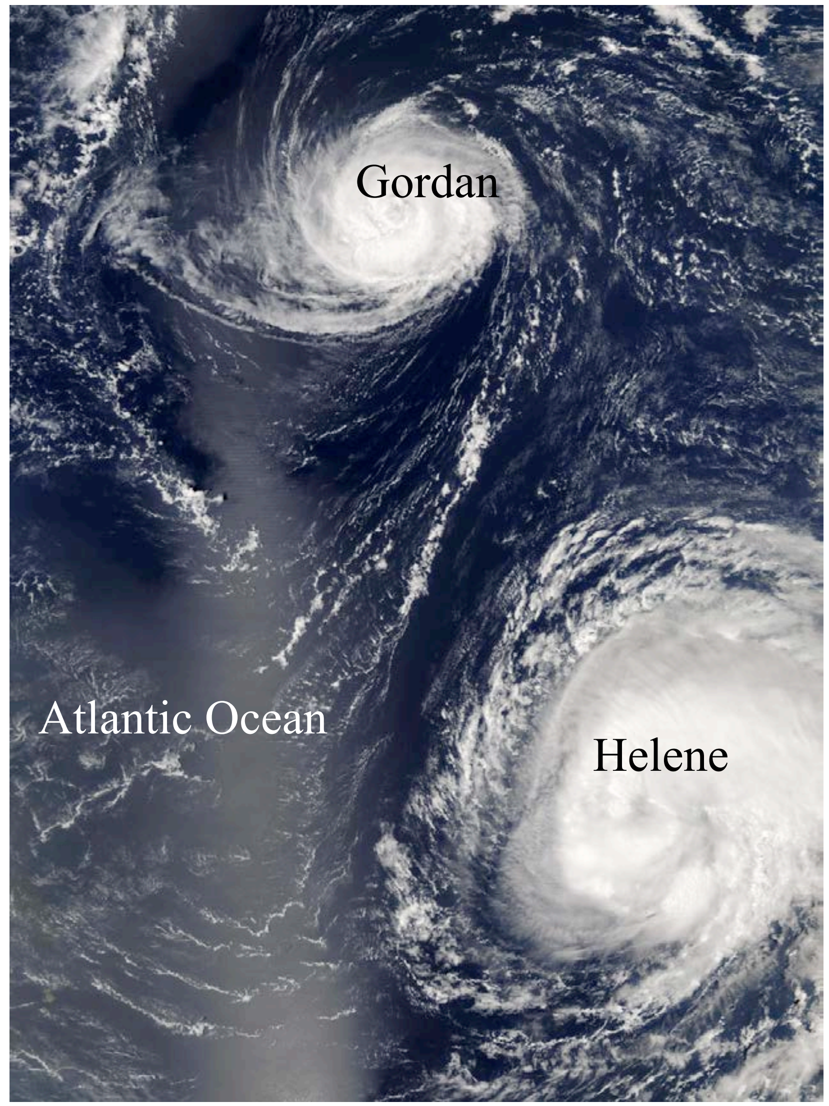
Closed low moving off the coast is very noticeable at 925 mb.

Hurricane Helene was the 8th named storm of 2006 Atlantic hurricane season.



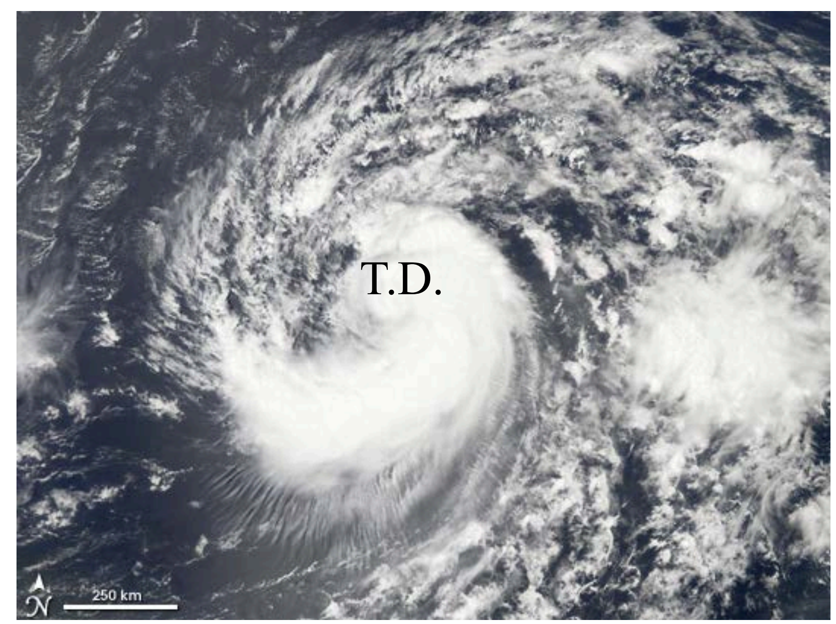
September 19, 2006

Category 3 Hurricane - September 17, 2006



September 17, 2006

Tropical Depression - September 12th 2006, south of the Cape Verde Islands



September 15, 2006

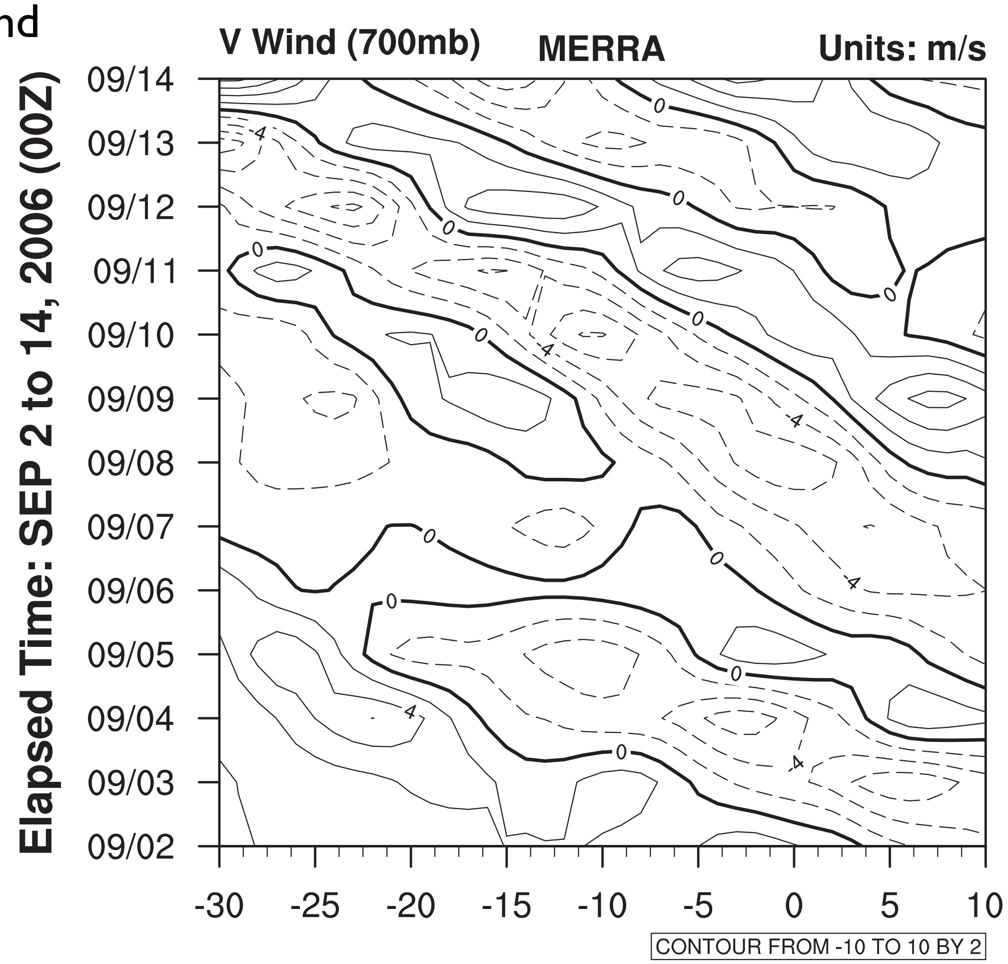
Time Lapse

NASA image - Earth Observatory, using data provided courtesy of the MODIS Rapid Response team.

MERRA 700 mb meridional wind
September 2 to 13, 2006

95% of the precipitation events are due to convective systems, isolated or organized in AEWs

Average size of AEWs :
700 km x 300 km
Associated mean rain :
25 mm
Mean traveling speed :
15 m/s
Lifetime:
few hours to a few days



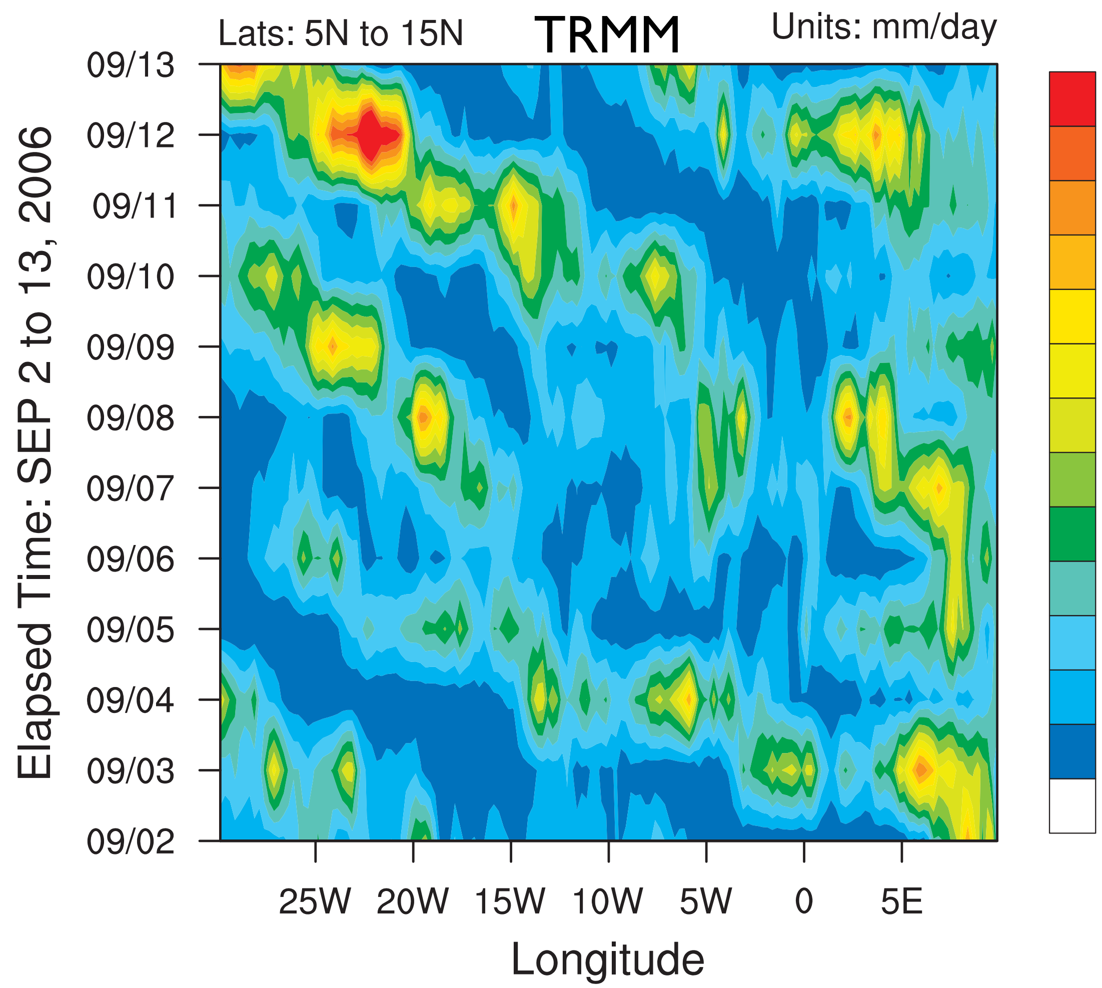
There is an easier way to examine the waves.

Use Hovmoller Plots!

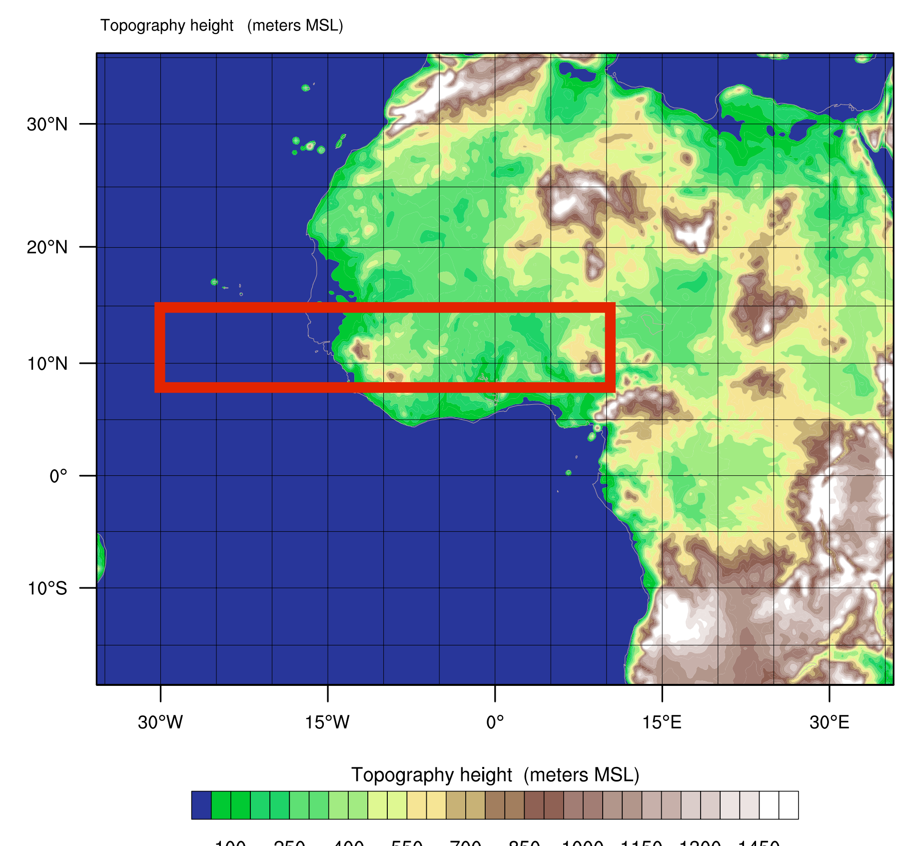
Hovmoller Plots are useful for showing wave movement

All values are averaged between 5°N and 15°N

TRMM Daily Accumulated Precipitation
September 2 to 13, 2006



Hovmoller plots show Sahel Region Only.



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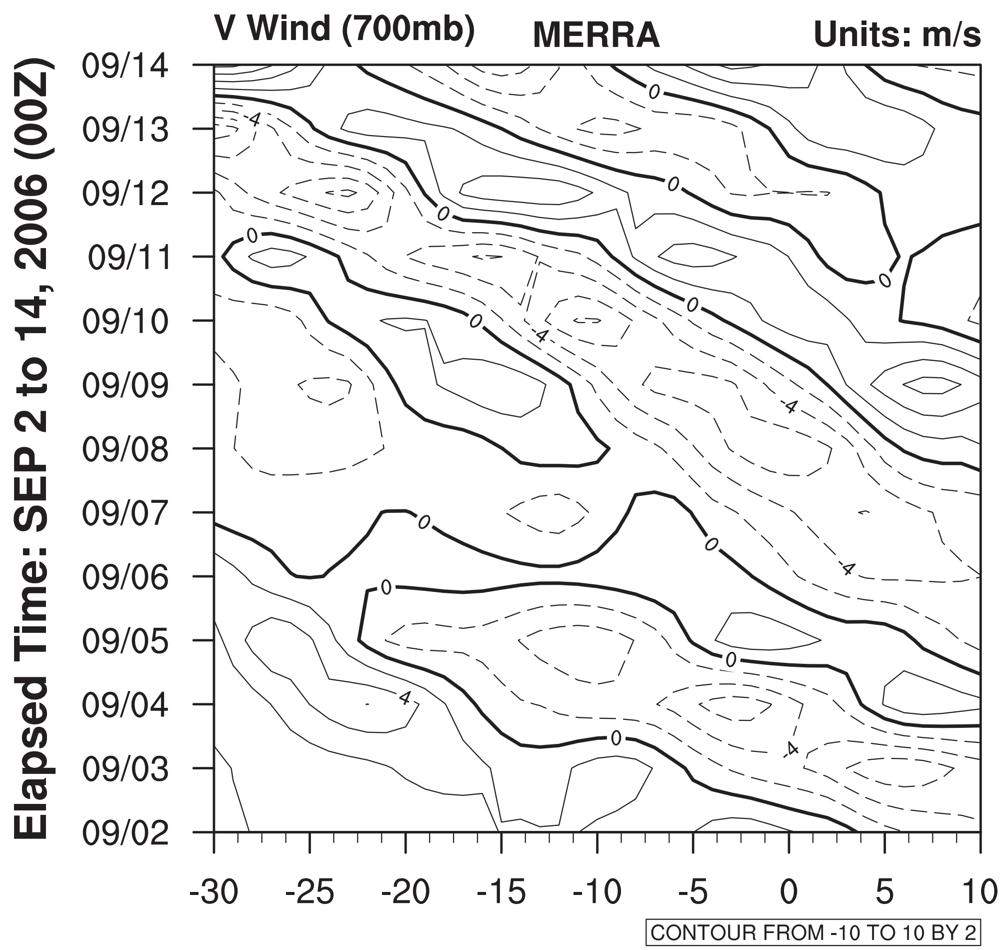

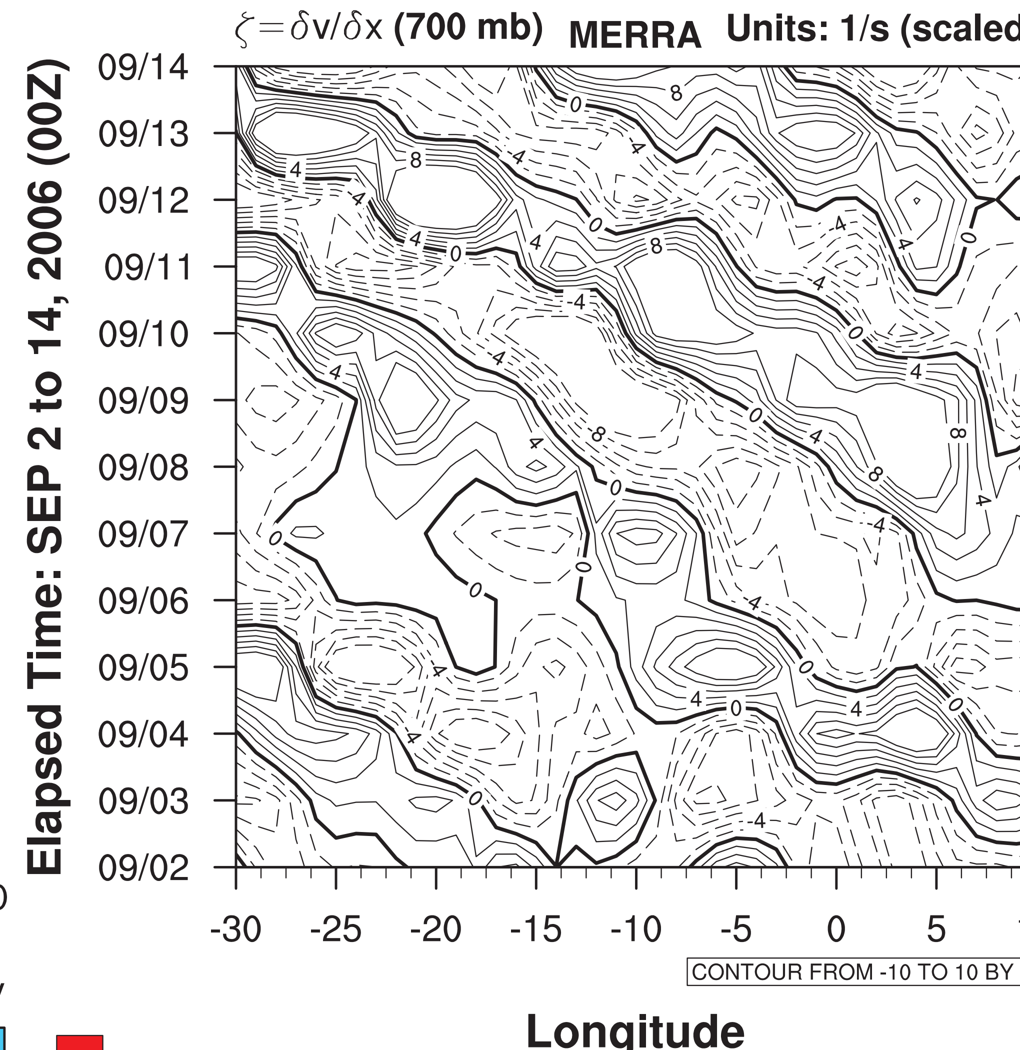

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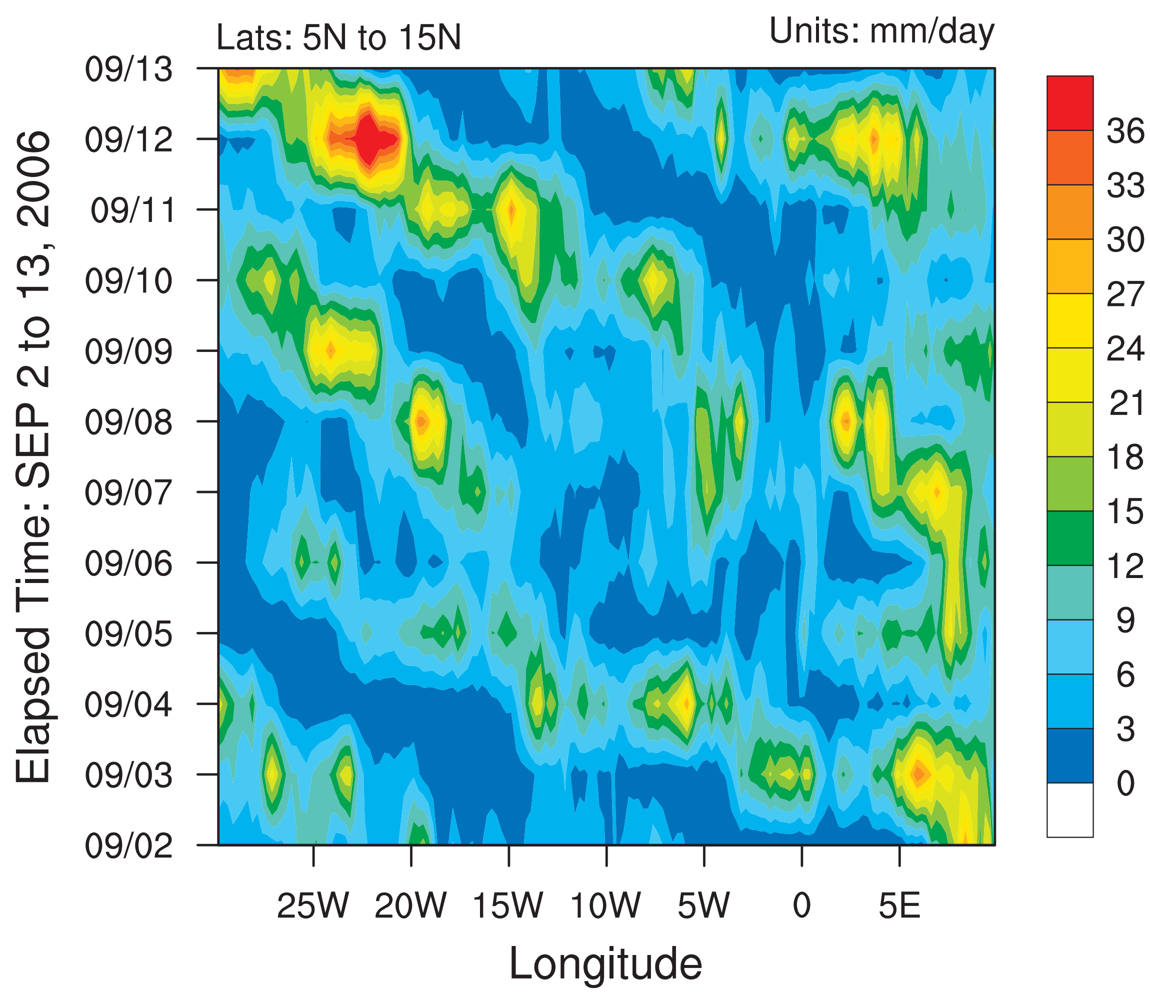


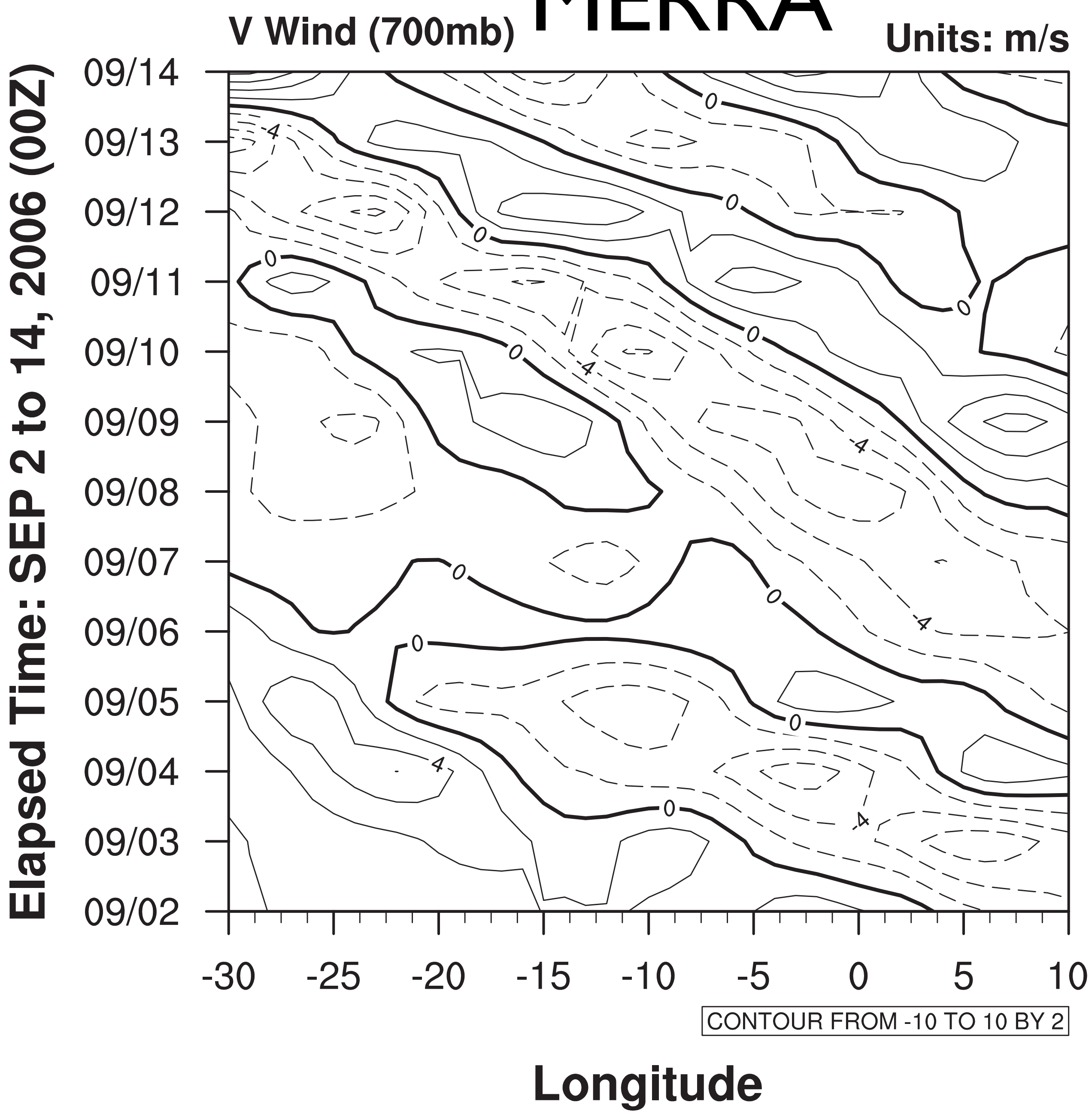
Relative Vorticity

the meridional component only

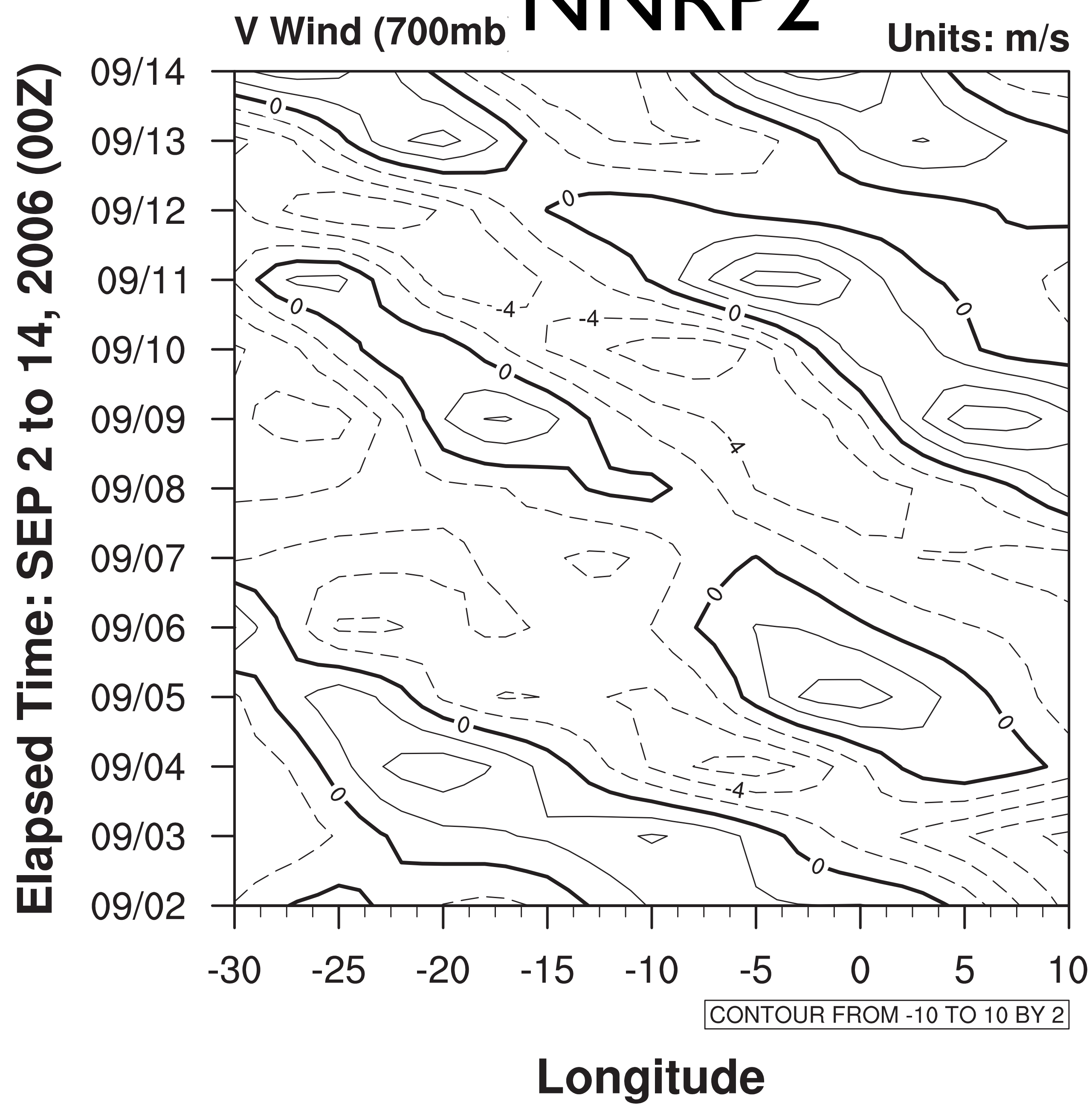
$$\zeta = \frac{\partial v_r}{\partial x} - \frac{\partial u_r}{\partial y}$$

Hovmoller Plots of Meridional Wind at 700 mb

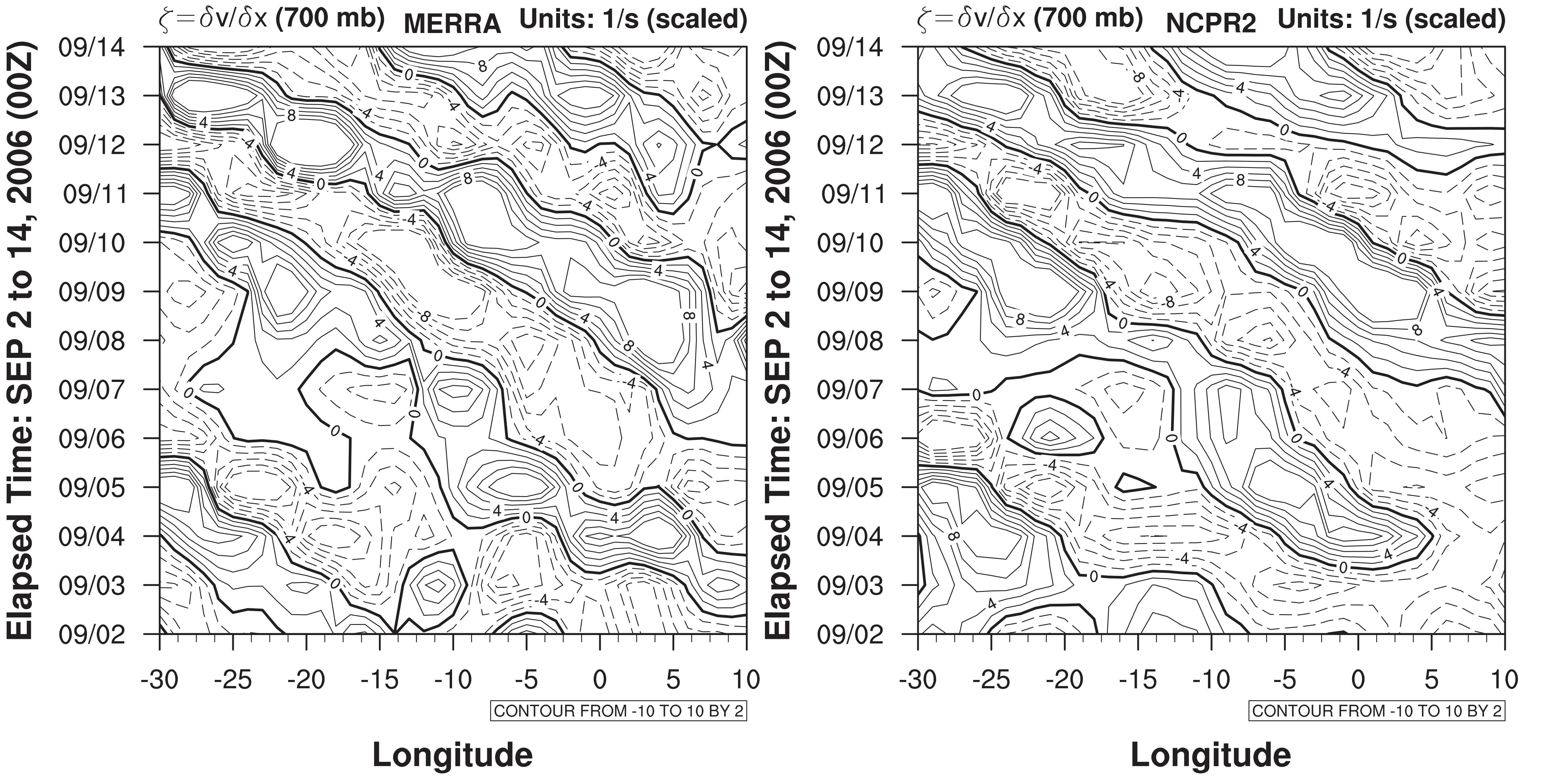
MERRA



NNRP2

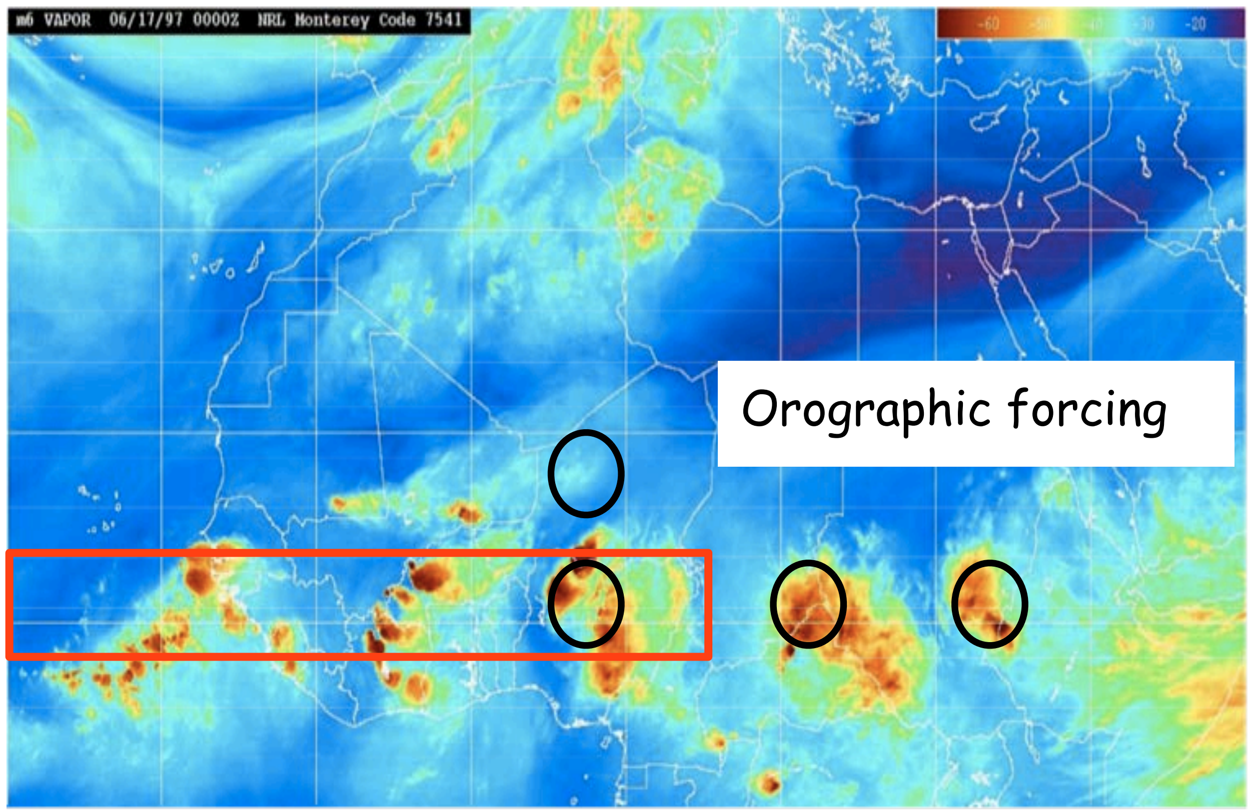


Hovmoller Plots of Vorticity at 700 mb



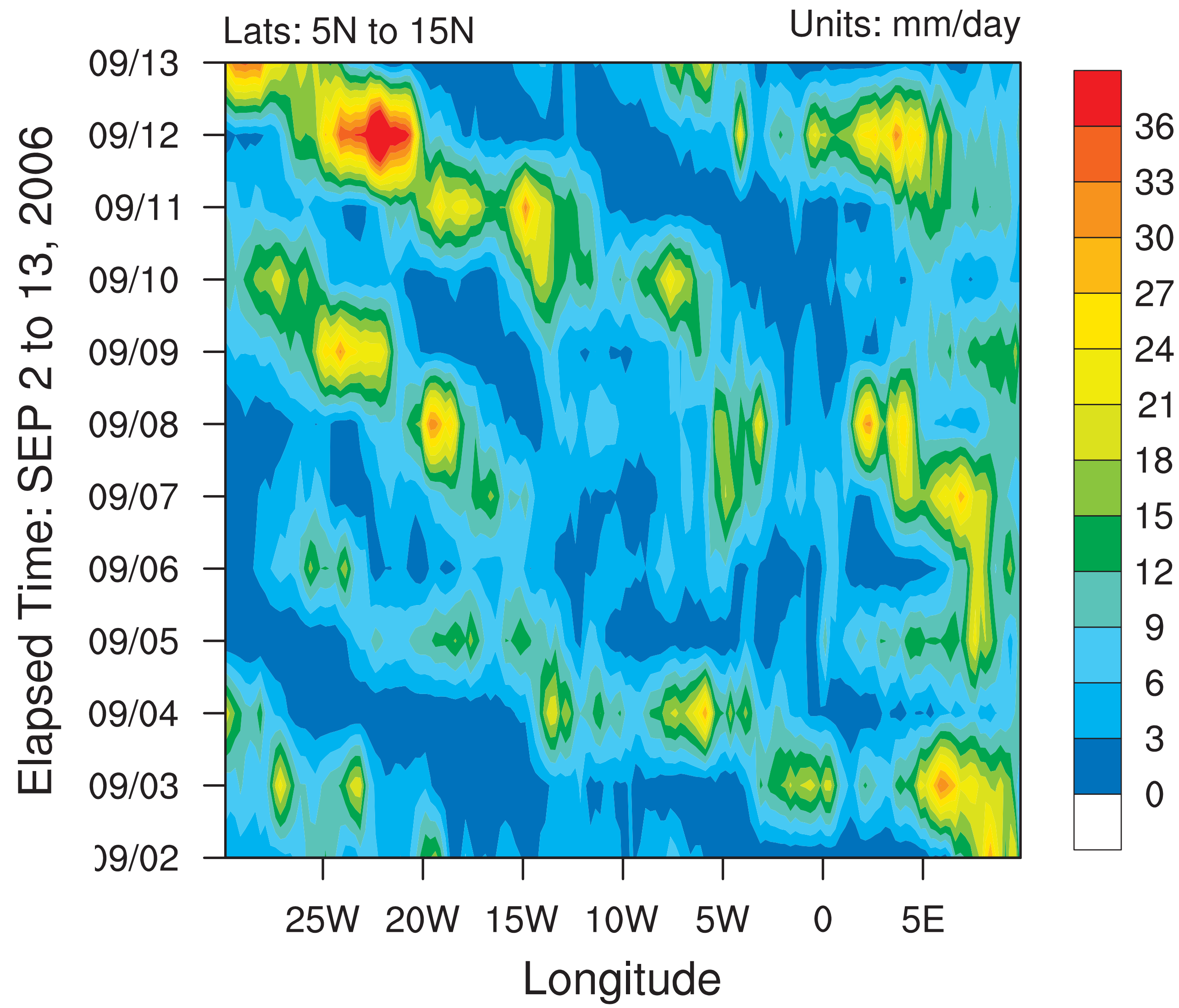
African Easterly Waves over West Africa

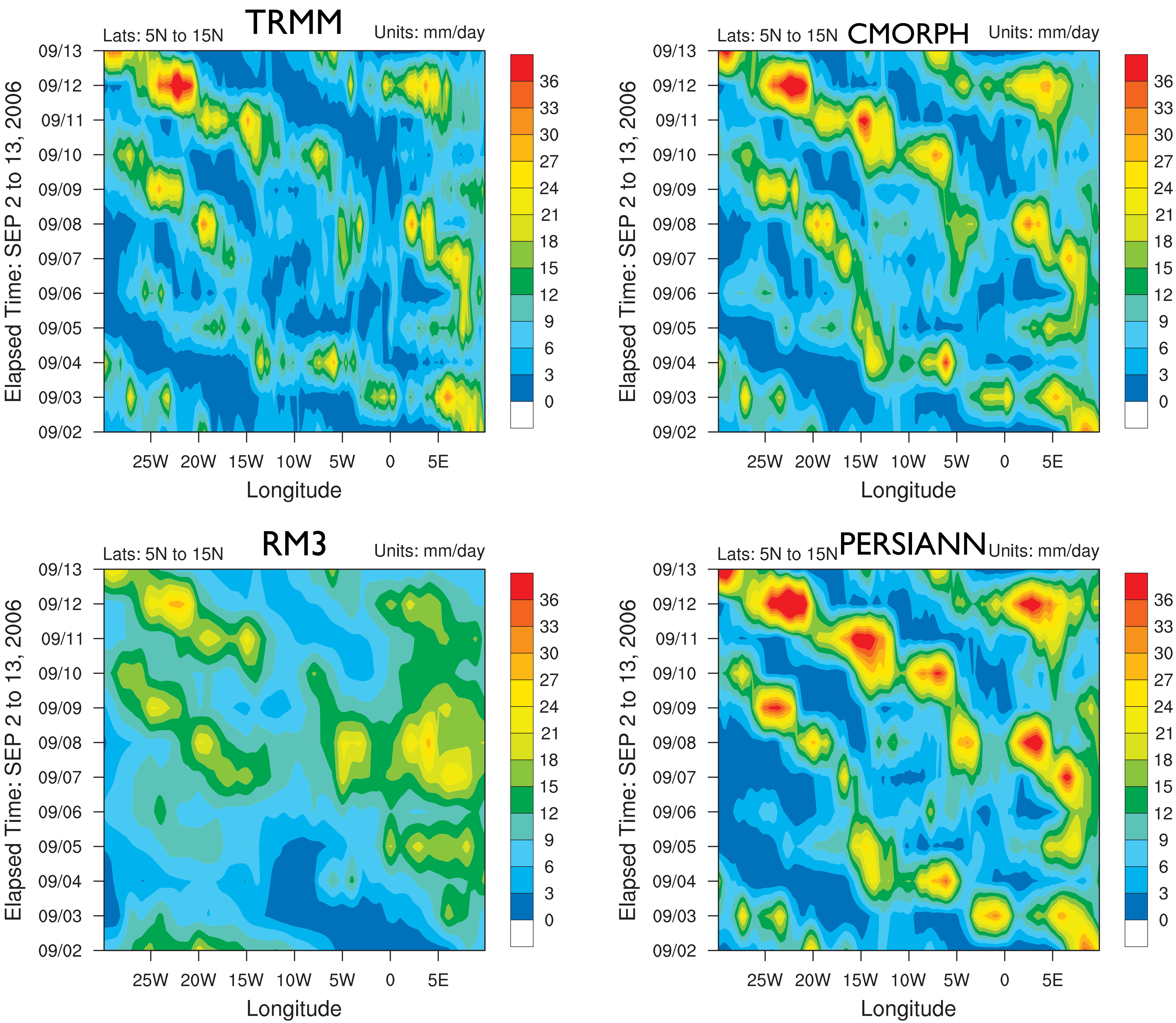
Water vapor imagery from Meteosat-7
10 Sept 2006



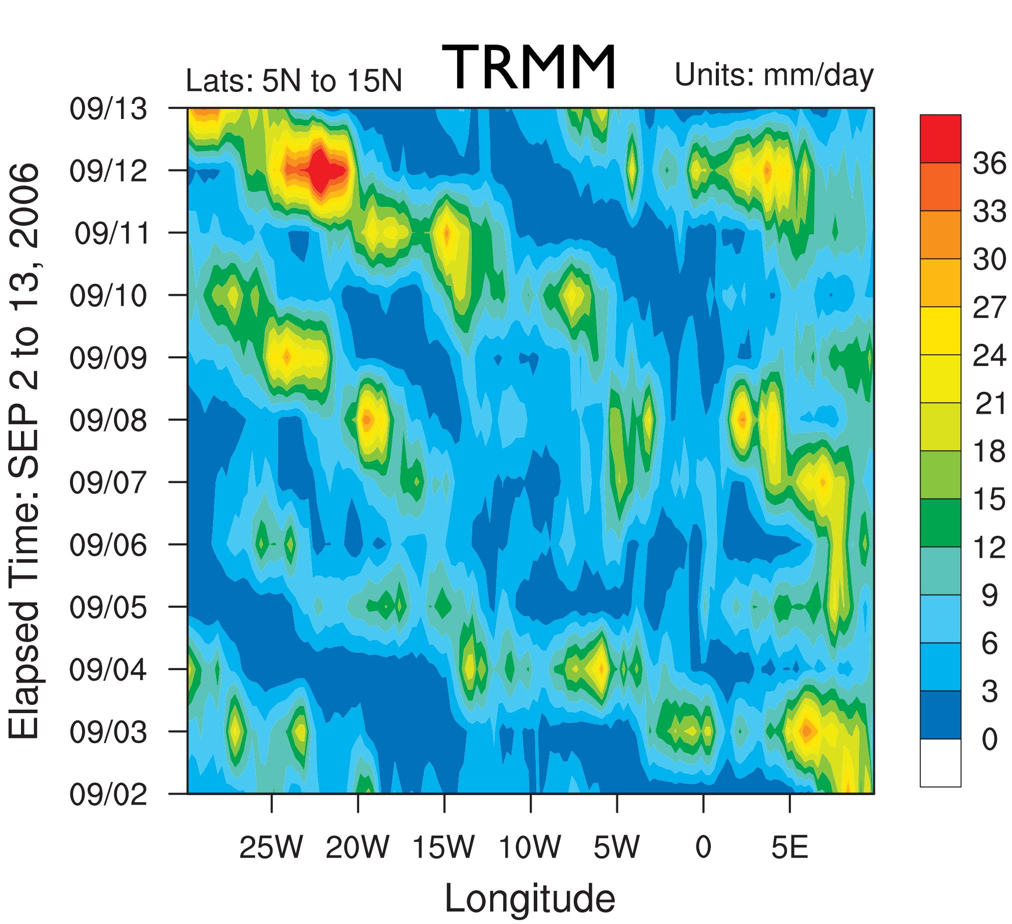
At any given moment, convection occurs in waves

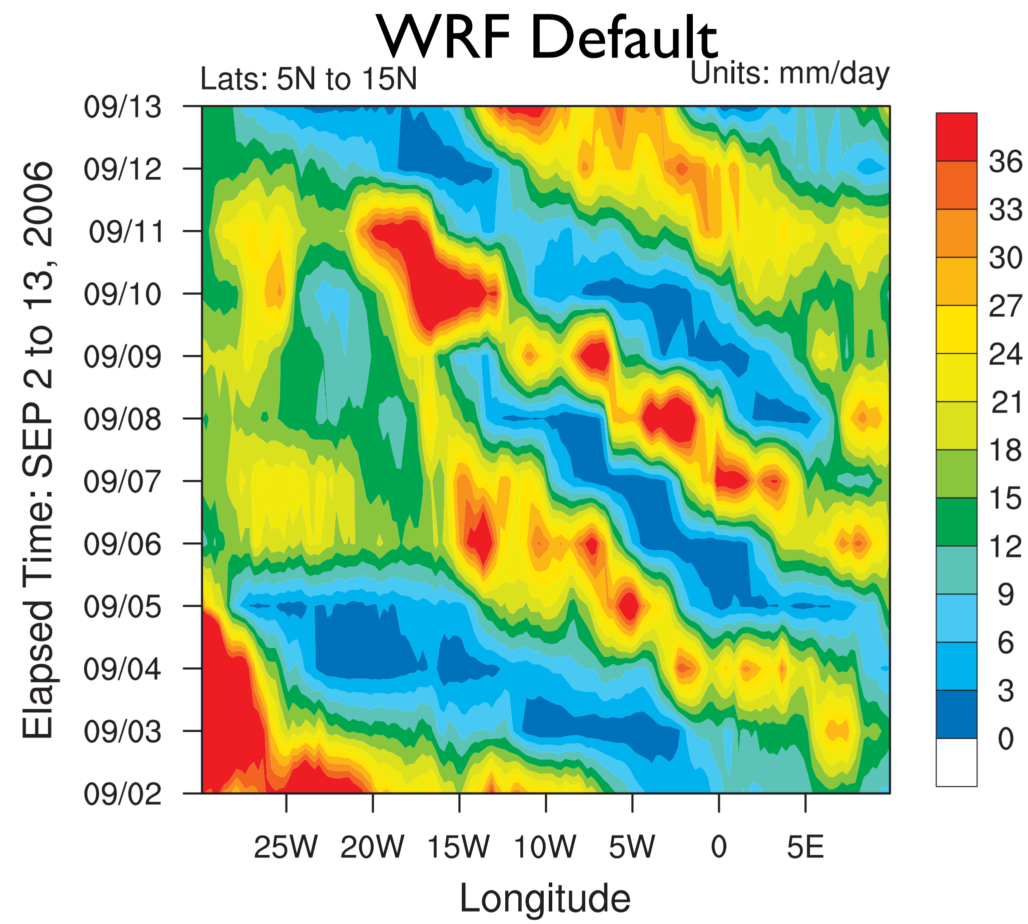
TRMM Daily Accumulated Precipitation
September 2 to 13, 2006

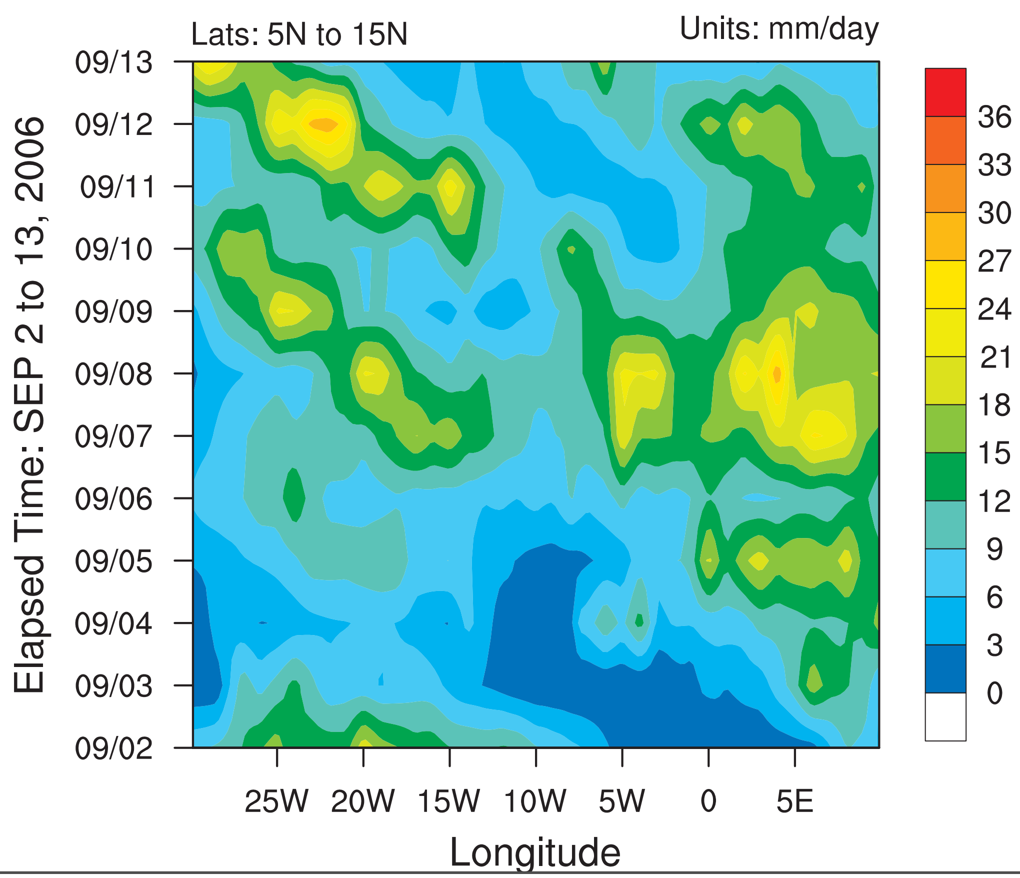



TRMM
Lats: 5N to 15N
Units: mm/day
CMORPH
Lats: 5N to 15N
Units: mm/day
RM3
Lats: 5N to 15N
Units: mm/day
PERSIANN
Lats: 5N to 15N
Units: mm/day
Elapsed Time: SEP 2 to 13, 2006
09/02
09/03
09/04
09/05
09/06
09/07
09/08
09/09
09/10
09/11
09/12
09/13
25W
20W
15W
10W
5W
0
5E
Longitude
0
3
6
9
12
15
18
21
24
27
30
33
36

Hovmoller Plots of Daily Accumulated Rain





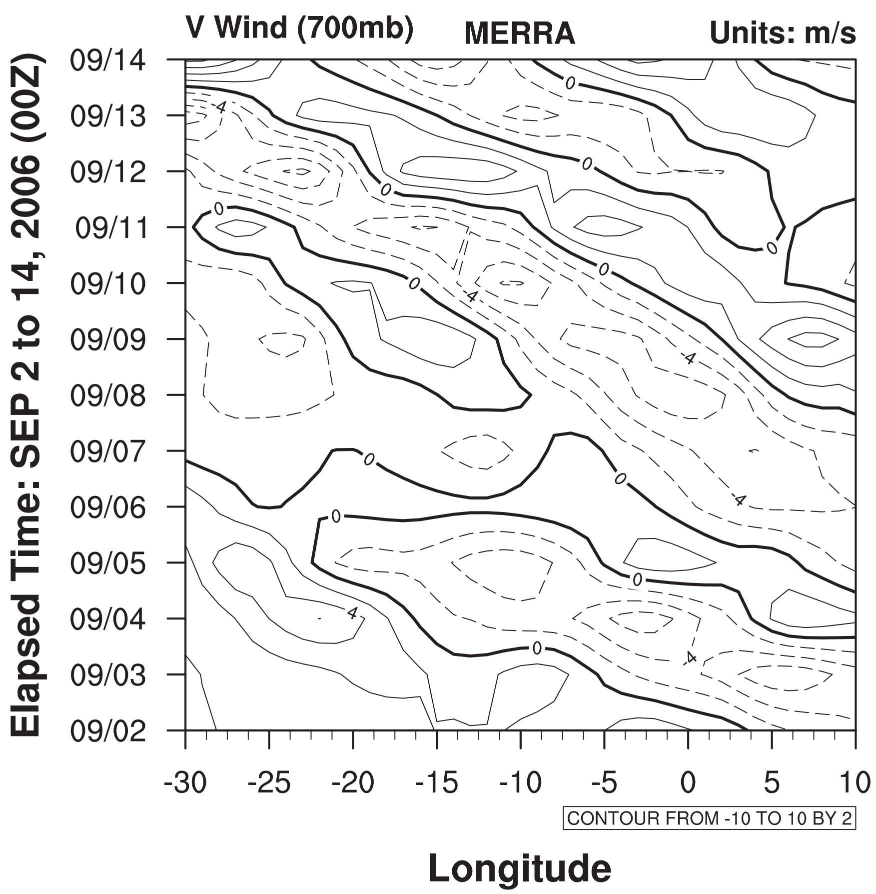


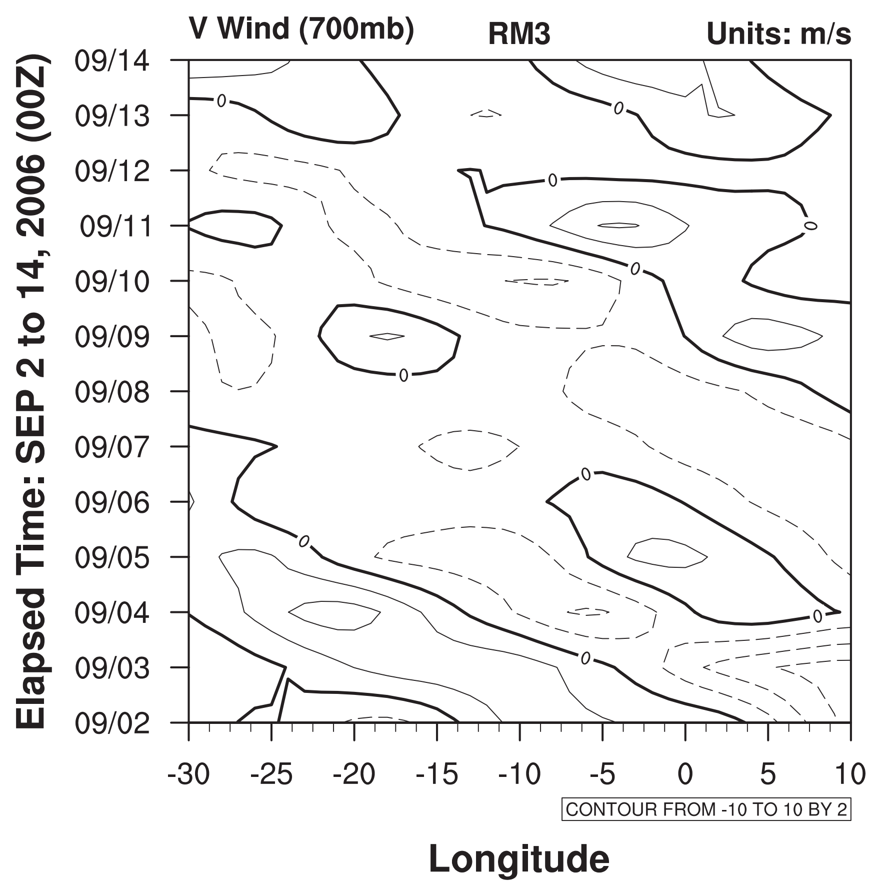
Statistical scores of the Hovmoller plots
(daily accumulated rain for all 12 days)

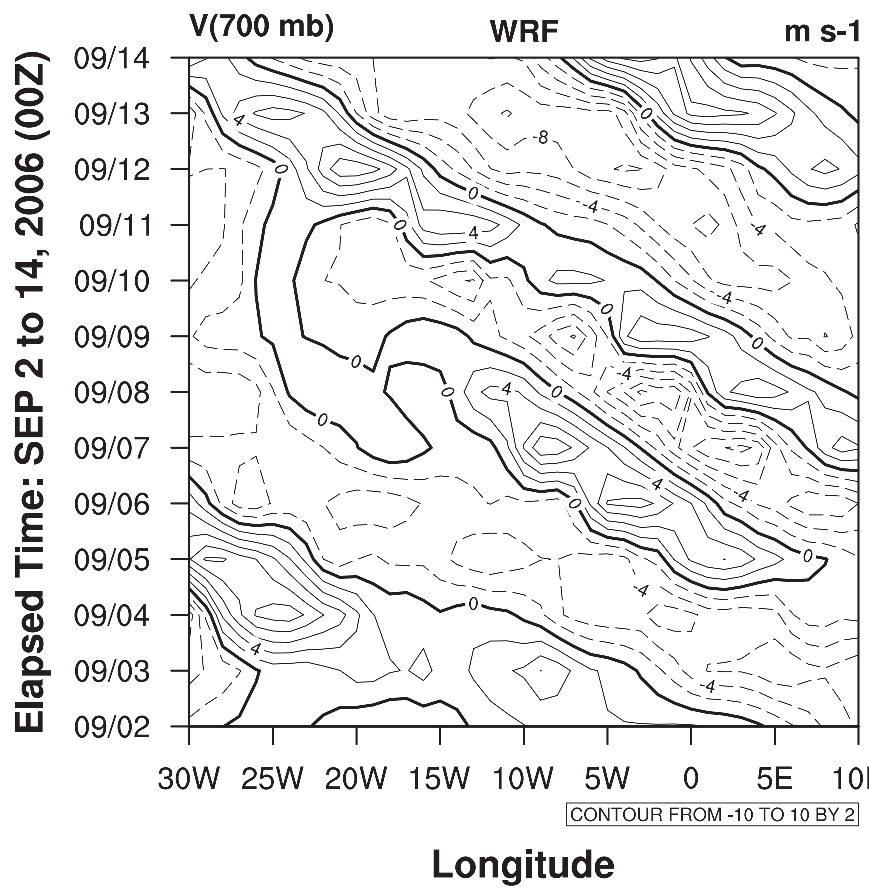
Model vs. TRMM	R	STD	RMSE	Bias	MAE
RM3	0.68	5.23	5.73	2.35	4.76
WRF (Default)	0.05	12.34	16.21	8.34	12.42

What's up with WRF?

Hovmoller Plots of Meridional Wind at 700 mb



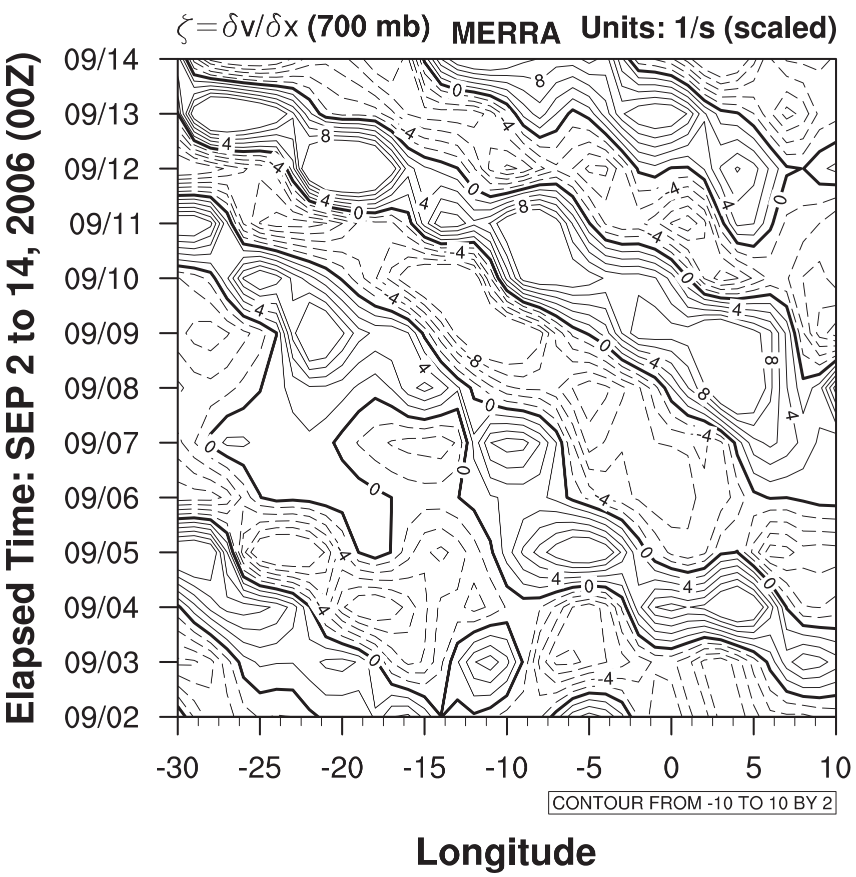


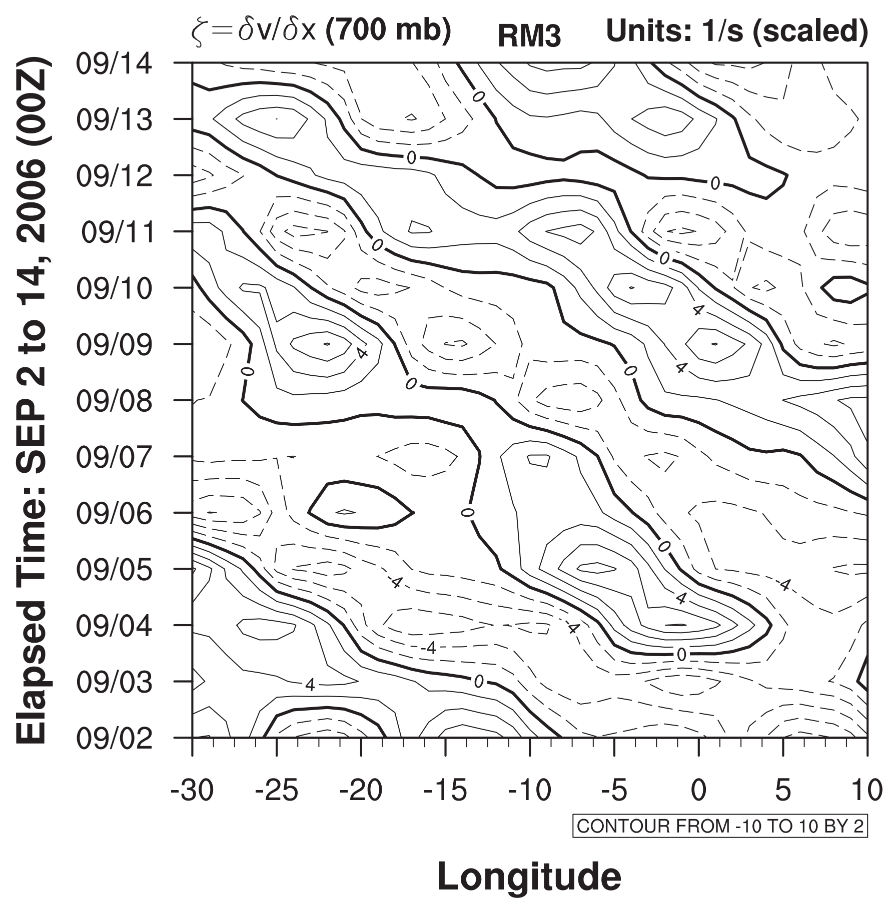


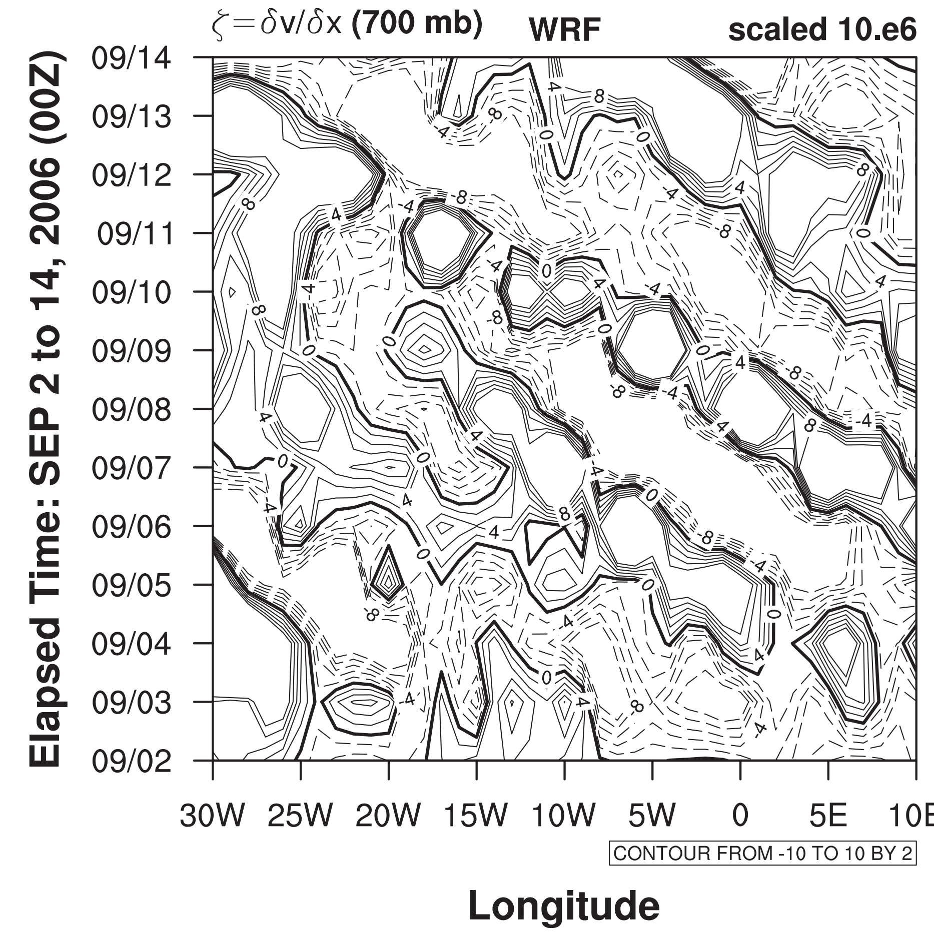
Statistical scores of the Hovmoller plots
(700 mb meridional wind for all 12 days)

Model vs. MERRA	R	STD	RMSE	Bias	MAE
RM3	0.79	2.11	2.16	0.09	1.68
WRF (Default)	0.38	4.61	4.61	-0.4	3.53

Hovmoller Plots of Meridional Wind at 700 mb







Statistical scores of the Hovmoller plots
(700 mb vorticity for all 12 days)

Model vs. MERRA	R	STD	RMSE	Bias	MAE
RM3	0.69	4.01	5.82	-0.1	4.56
WRF (Default)	0.37	13.31	13.13	0.37	9.99

What's up with WRF?

Alternate configurations in WRF

PARAMETERIZATION	SHORT NAME	OPTION	ABBREVIATION
Cumulus Convection Scheme	CPS	1. Kain-Fritsch cumulus scheme 2. Grell-‐‑Devenyi cumulus ensemble scheme	KF GD
Planetary Boundary Layer	PBL	1. Yonsei University PBL–Eta Similarity Theory 2. Mellor-Yamada-Janjic PBL–MM5 Similarity Theory 3. Pleim-Based Asymmetrical Convective Model (v.2) PBL 4. Mellor-Yamada-Nakanishi-Nino PBL	YU MJ A2 MN
Land Surface Model	LSM	1. 5-Layer Thermal Diffusion Model 2. Unified Noah Model 3. Rapid Update Cycle (RUC) Model 4. Pleim-Xiu Model	5L NO RU PX
Long-Wave Radiation Scheme	LWS	1. Rapid Radiation Transfer Scheme for climate models (RRTMG) 2. Community Atmospheric Model Radiation Transfer Scheme (CAM)	Rt CM
Short-Wave Radiation Scheme	SWS	1. Rapid Radiation Transfer Scheme for climate models (RRTMG) 2. Community Atmospheric Model Radiation Transfer Scheme (CAM)	Rt CM
Microphysics	MPS	1. WRF-Single-Moment Class 5 scheme (WSM5)	W5

Alternative Configurations

WRF RUN	CPS	PBL	LSM	LWS	SWS	MPS	WRF RUN	CPS	PBL	LSM	LWS	SWS	MPS
Experiment 1	KF	YU	5L	Rt	Rt	W5	Experiment 33	KF	YU	5L	CM	CM	W5
Experiment 2	KF	YU	NO	Rt	Rt	W5	Experiment 34	KF	YU	NO	CM	CM	W5
Experiment 3	KF	YU	RU	Rt	Rt	W5	Experiment 35	KF	YU	RU	CM	CM	W5
Experiment 4	KF	YU	A2	Rt	Rt	W5	Experiment 36	KF	YU	A2	CM	CM	W5
Experiment 5	KF	MJ	5L	Rt	Rt	W5	Experiment 37	KF	MJ	5L	CM	CM	W5
Experiment 6	KF	MJ	NO	Rt	Rt	W5	Experiment 38	KF	MJ	NO	CM	CM	W5
Experiment 7	KF	MJ	RU	Rt	Rt	W5	Experiment 39	KF	MJ	RU	CM	CM	W5
Experiment 8	KF	MJ	A2	Rt	Rt	W5	Experiment 40	KF	MJ	A2	CM	CM	W5
Experiment 9	KF	PX	5L	Rt	Rt	W5	Experiment 41	KF	PX	5L	CM	CM	W5
Experiment 10	KF	PX	NO	Rt	Rt	W5	Experiment 42	KF	PX	NO	CM	CM	W5
Experiment 11	KF	PX	RU	Rt	Rt	W5	Experiment 43	KF	PX	RU	CM	CM	W5
Experiment 12	KF	PX	A2	Rt	Rt	W5	Experiment 44	KF	PX	A2	CM	CM	W5
Experiment 13	KF	MN	5L	Rt	Rt	W5	Experiment 45	KF	MN	5L	CM	CM	W5
Experiment 14	KF	MN	NO	Rt	Rt	W5	Experiment 46	KF	MN	NO	CM	CM	W5
Experiment 15	KF	MN	RU	Rt	Rt	W5	Experiment 47	KF	MN	RU	CM	CM	W5
Experiment 16	KF	MN	A3	Rt	Rt	W5	Experiment 48	KF	MN	A3	CM	CM	W5
Experiment 17	GD	YU	5L	Rt	Rt	W5	Experiment 49	GD	YU	5L	CM	CM	W5
Experiment 18	GD	YU	NO	Rt	Rt	W5	Experiment 50	GD	YU	NO	CM	CM	W5
Experiment 19	GD	YU	RU	Rt	Rt	W5	Experiment 51	GD	YU	RU	CM	CM	W5
Experiment 20	GD	YU	A2	Rt	Rt	W5	Experiment 52	GD	YU	A2	CM	CM	W5
Experiment 21	GD	MJ	5L	Rt	Rt	W5	Experiment 53	GD	MJ	5L	CM	CM	W5
Experiment 22	GD	MJ	NO	Rt	Rt	W5	Experiment 54	GD	MJ	NO	CM	CM	W5
Experiment 23	GD	MJ	RU	Rt	Rt	W5	Experiment 55	GD	MJ	RU	CM	CM	W5
Experiment 24	GD	MJ	A2	Rt	Rt	W5	Experiment 56	GD	MJ	A2	CM	CM	W5
Experiment 25	GD	PX	5L	Rt	Rt	W5	Experiment 57	GD	PX	5L	CM	CM	W5
Experiment 26	GD	PX	NO	Rt	Rt	W5	Experiment 58	GD	PX	NO	CM	CM	W5
Experiment 27	GD	PX	RU	Rt	Rt	W5	Experiment 59	GD	PX	RU	CM	CM	W5
Experiment 28	GD	PX	A2	Rt	Rt	W5	Experiment 60	GD	PX	A2	CM	CM	W5
Experiment 29	GD	MN	5L	Rt	Rt	W5	Experiment 61	GD	MN	5L	CM	CM	W5
Experiment 30	GD	MN	NO	Rt	Rt	W5	Experiment 62	GD	MN	NO	CM	CM	W5
Experiment 31	GD	MN	RU	Rt	Rt	W5	Experiment 63	GD	MN	RU	CM	CM	W5
Experiment 32	GD	MN	A2	Rt	Rt	W5	Experiment 64	GD	MN	A2	CM	CM	W5

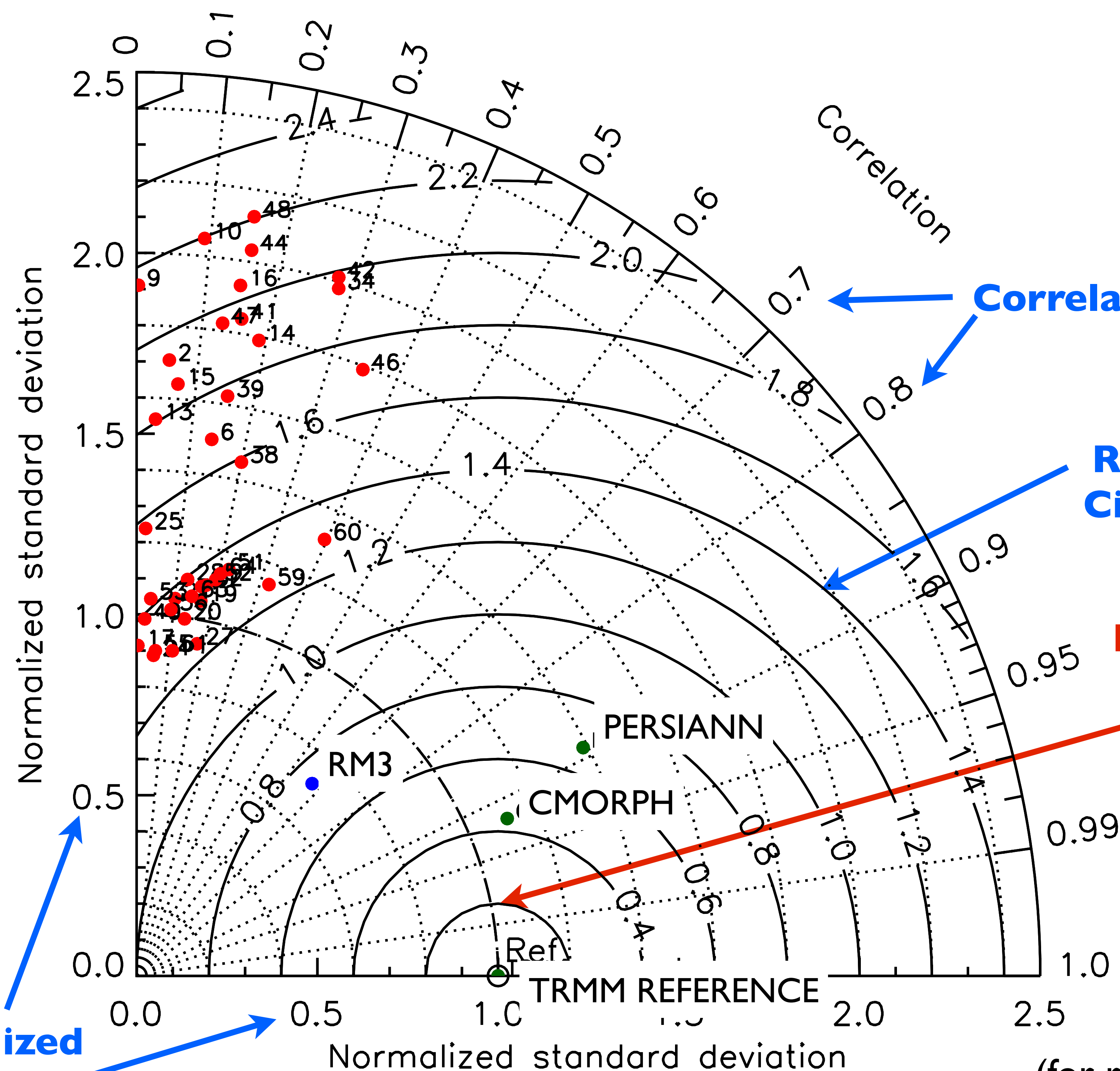
- 64 Experiments
- Changing the CPS, PBL, LSM & radiation parameterizations one at a time
- Options in Light Blue color were kept constant in all experiments

Taylor Plot of WRF Hovmollers vs. TRMM Daily Accumulated Precipitation

This Taylor Plot shows the statistical scores of the Hovmoller plots of daily accumulated rain for all 12 days.

Taylor Plots allow you to show 3 complementary statistics on one plot.

TRMM is the reference field.



Correlation

RMSE Circles

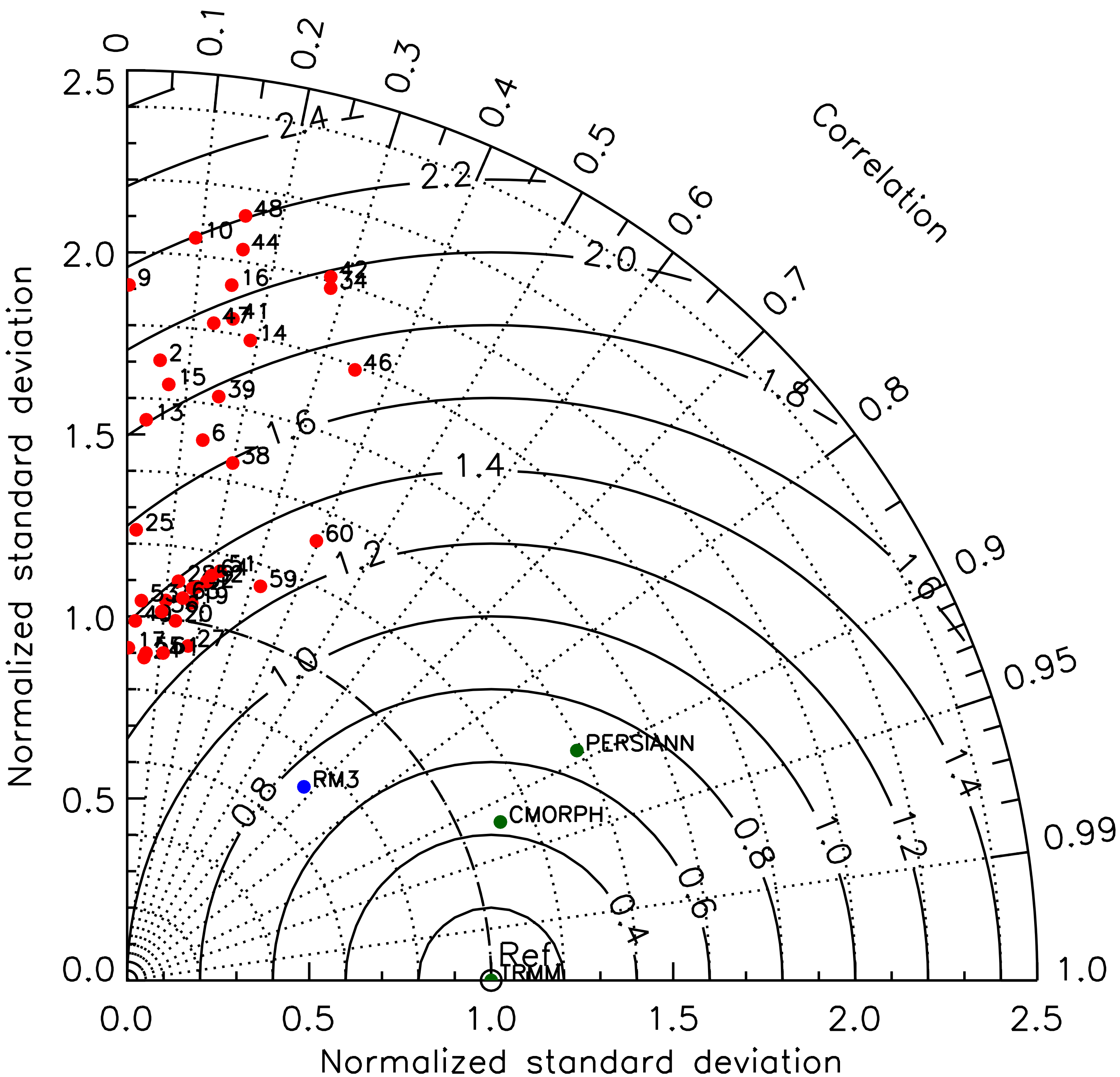
Ideally, you want to be here.

Normalized Variance

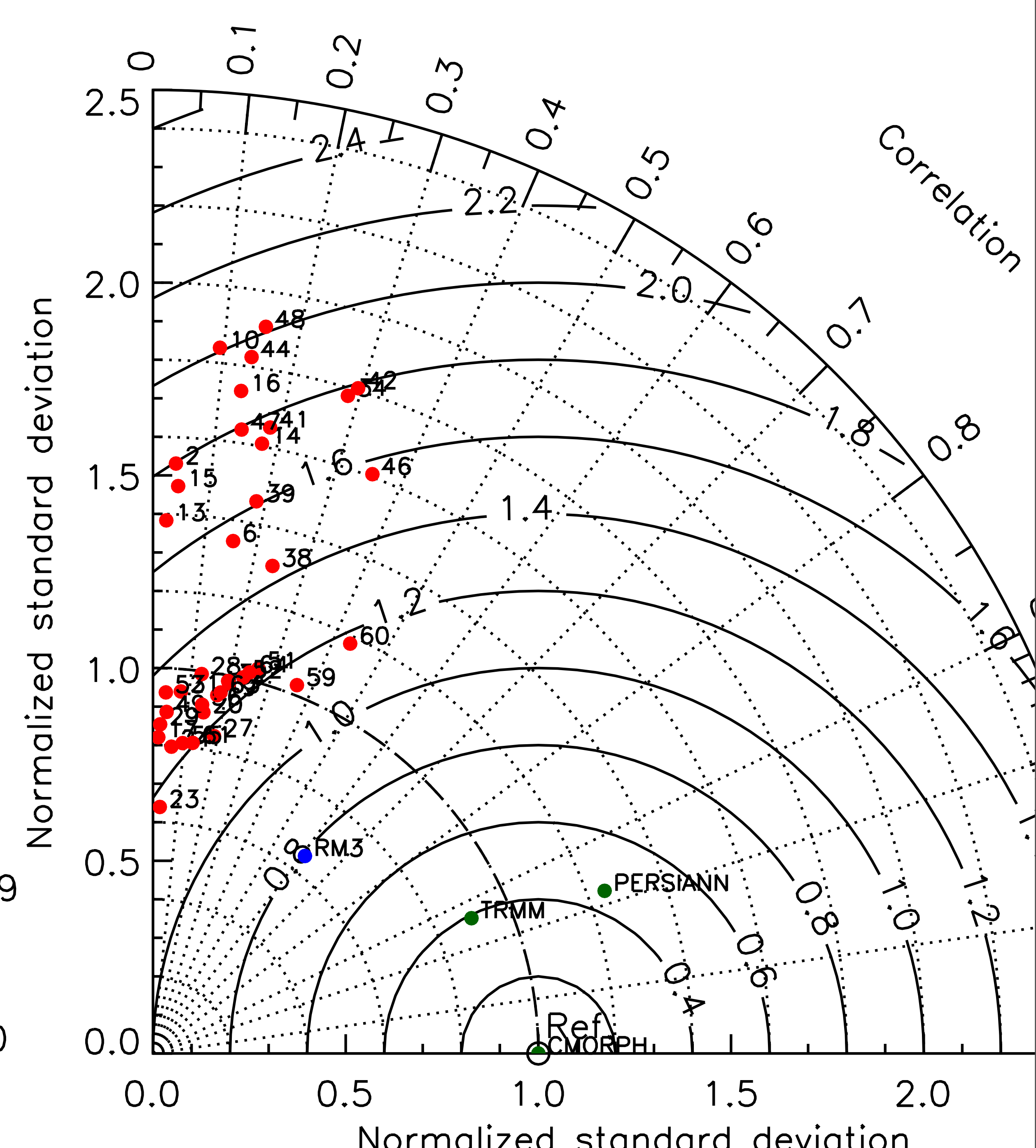
(for reference, see Taylor, 2001)

Taylor Plot of WRF Hovmollers vs. TRMM Daily Accumulated Precipitation

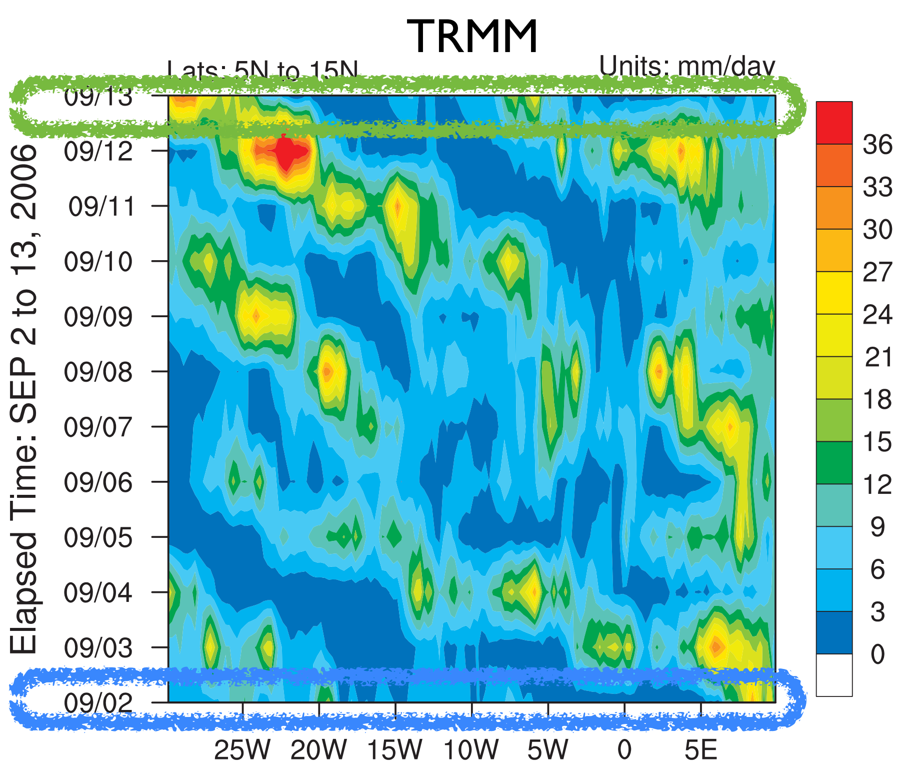
WRF vs. TRMM

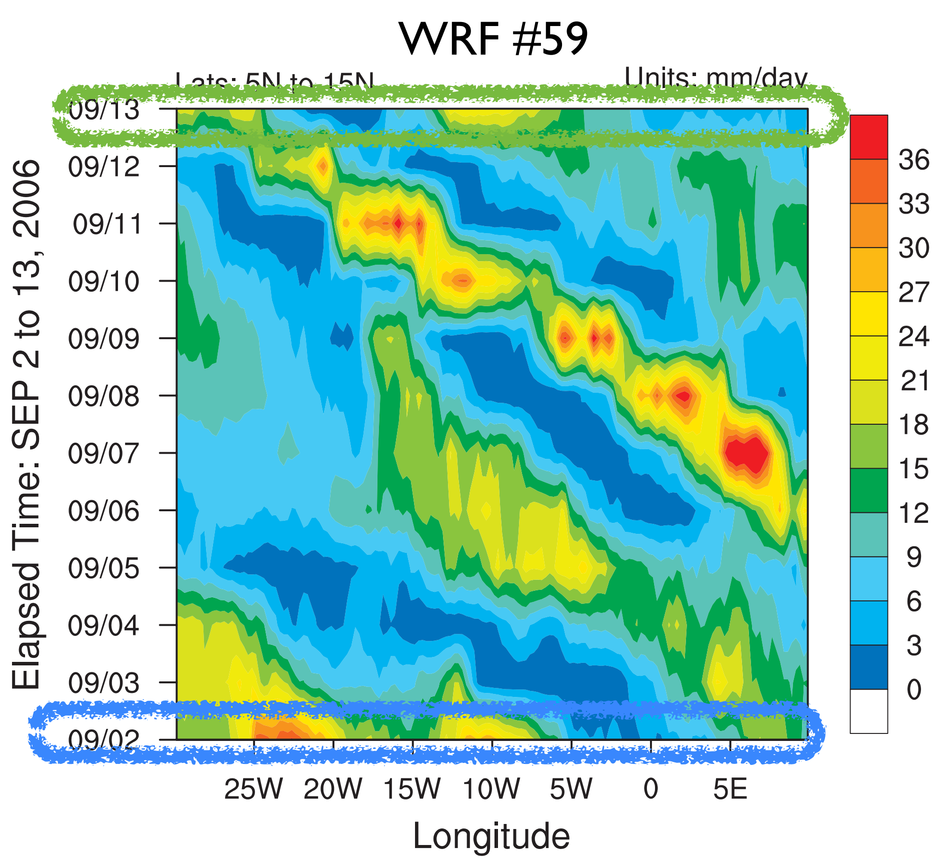


WRF vs. CMORPH

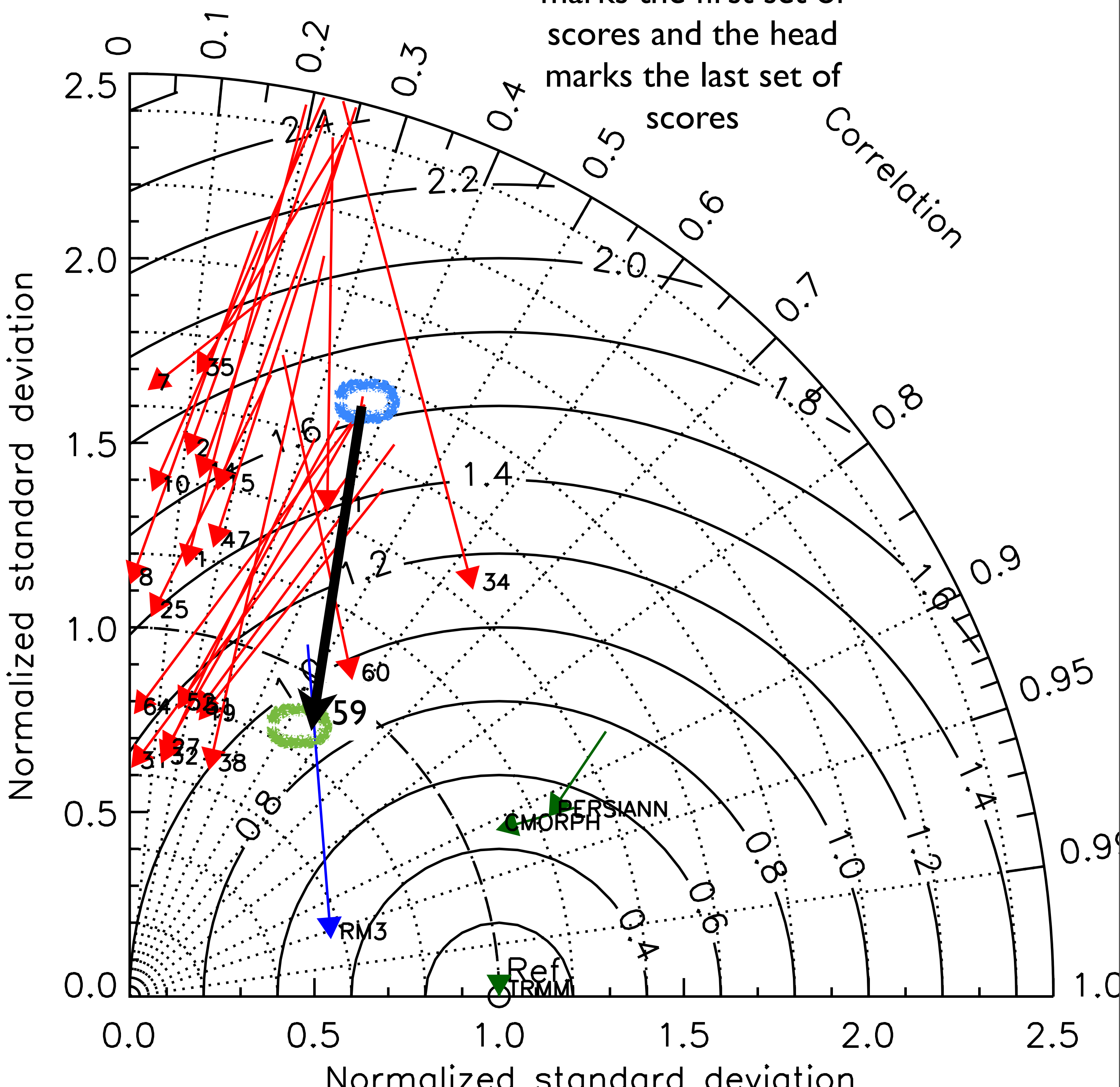


Comparison of Hovmoller scores:
Scores of "first" 24 hours plotted with the "last" 24 hours



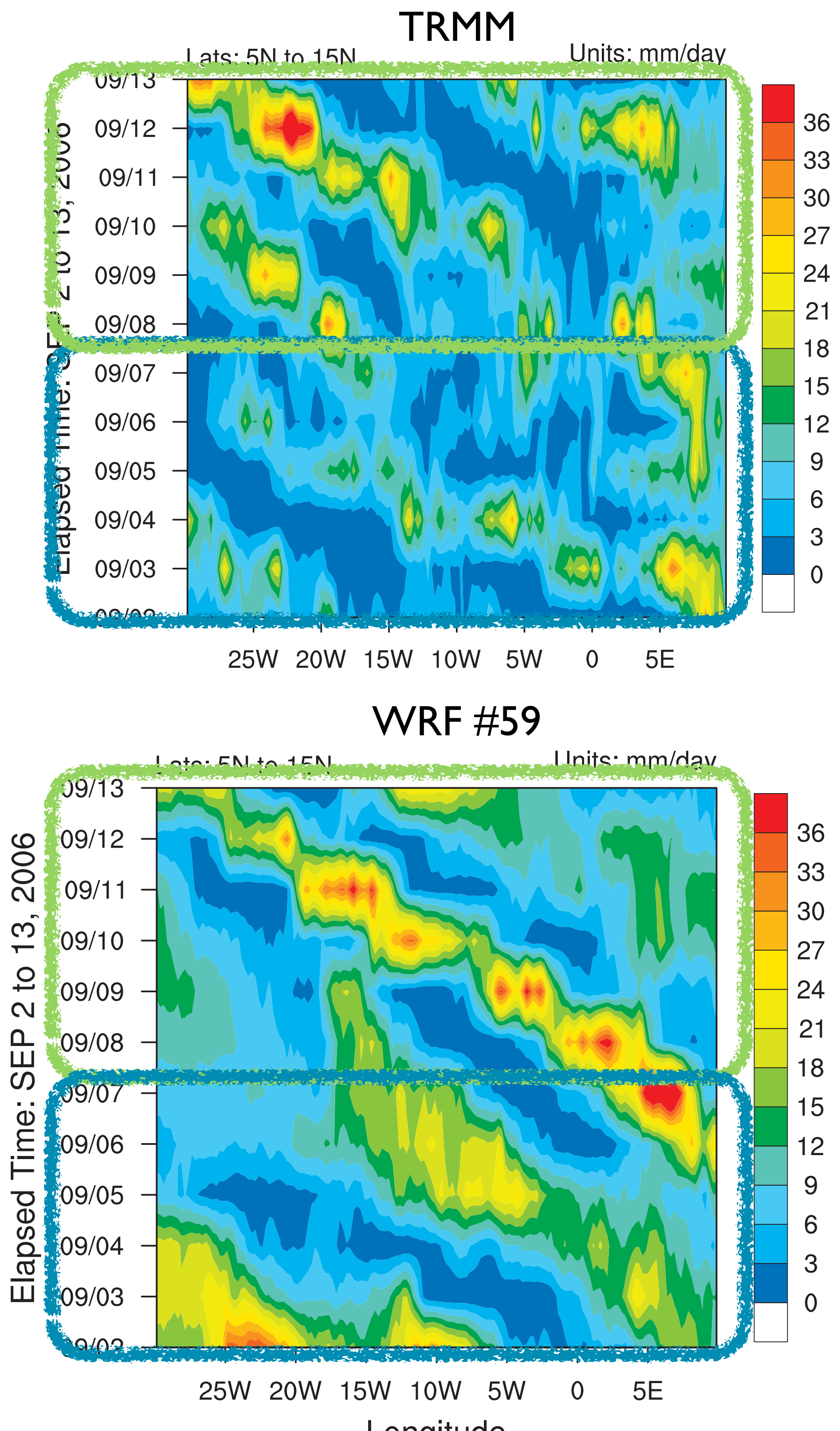


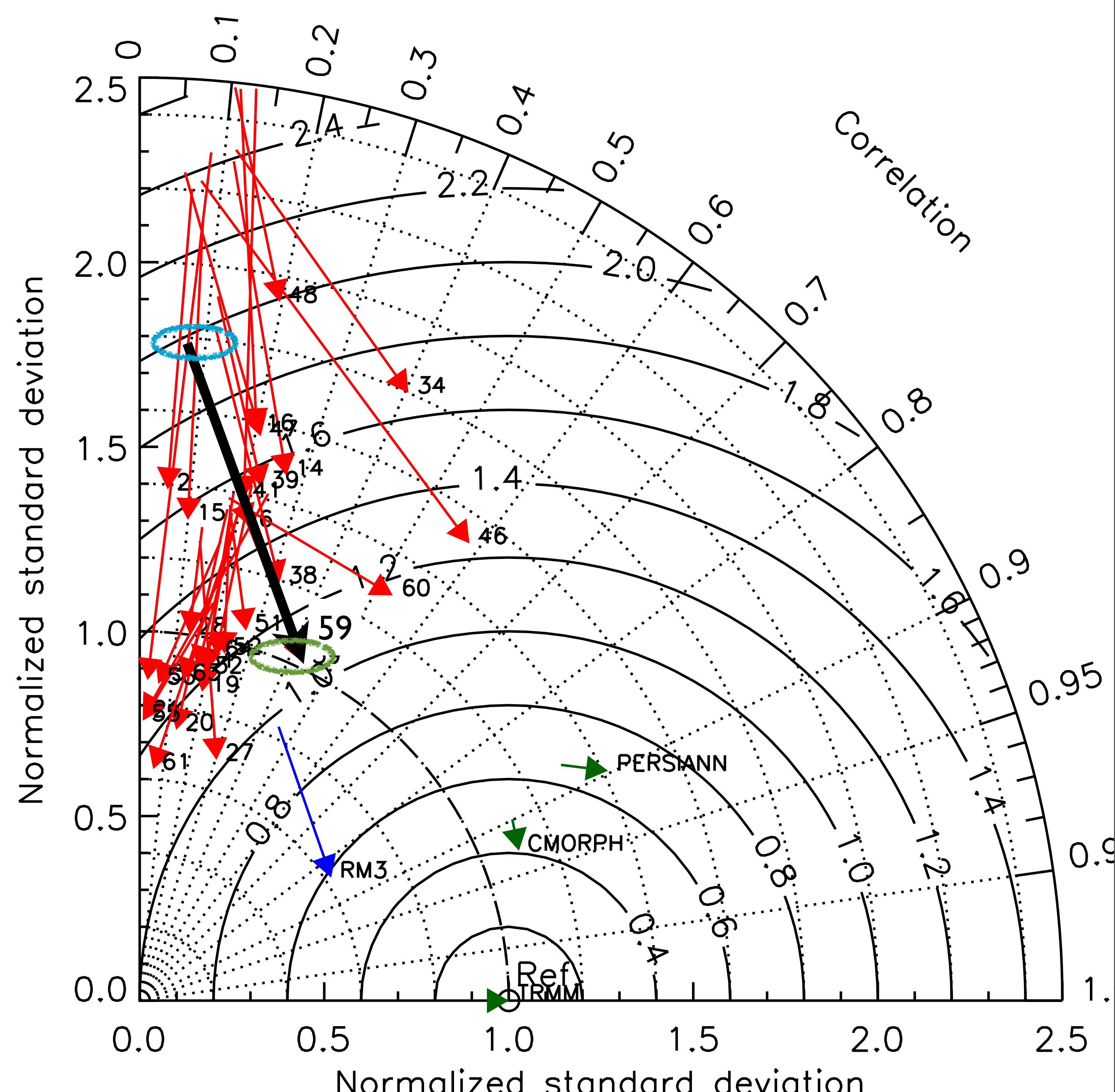
The tail of the arrow marks the first set of scores and the head marks the last set of scores



Comparison of hovmoller scores:
Scores of "first" days plotted with the "last" 6 days

*Explores the idea of a Spin-up





Best scores for precipitation

Scores from Hovmoller plots for12-day period

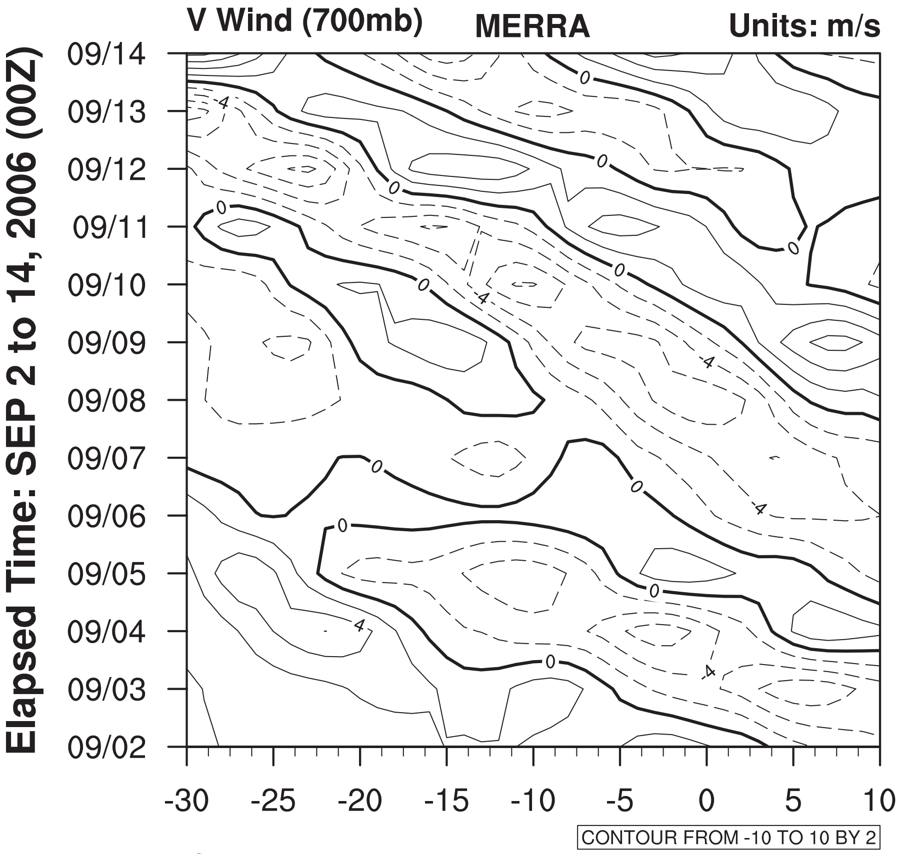
WRF RUN	CPS	PBL	LSM	LWS	SWS	MPS	σ	R	E'	E	BIAS
Experiment 27	GD	PX	RU	Rt	Rt	W5	6.89	0.18	9.15	9.72	3.27
Experiment 59	GD	PX	RU	CM	CM	W5	8.43	0.32	9.25	9.80	3.22
Experiment 60	GD	PX	A2	CM	CM	W5	9.70	0.40	9.48	9.59	3.00
Experiment 46	KF	MN	NO	CM	CM	W5	13.21	0.35	12.68	14.17	6.33
Experiment 34	KF	PX	NO	CM	CM	W5	14.63	0.28	14.40	16.38	6.53
Experiment 42	KF	YU	NO	CM	CM	W5	14.84	0.28	14.62	16.98	8.62
RM3	----	----	----	----	----	----	5.31	0.67	5.46	5.96	2.40
MERRA	----	----	----	----	----	----	7.38	1.00	0.00	0.00	0.00

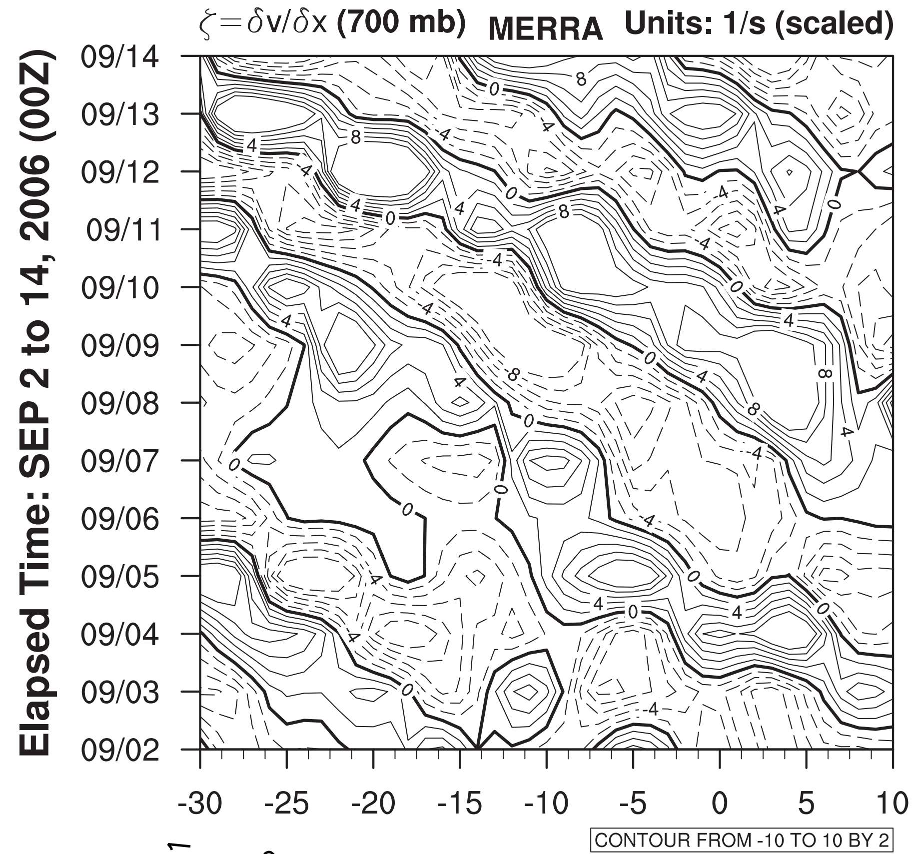
Scores from Hovmoller plots for 6-day adjustment period

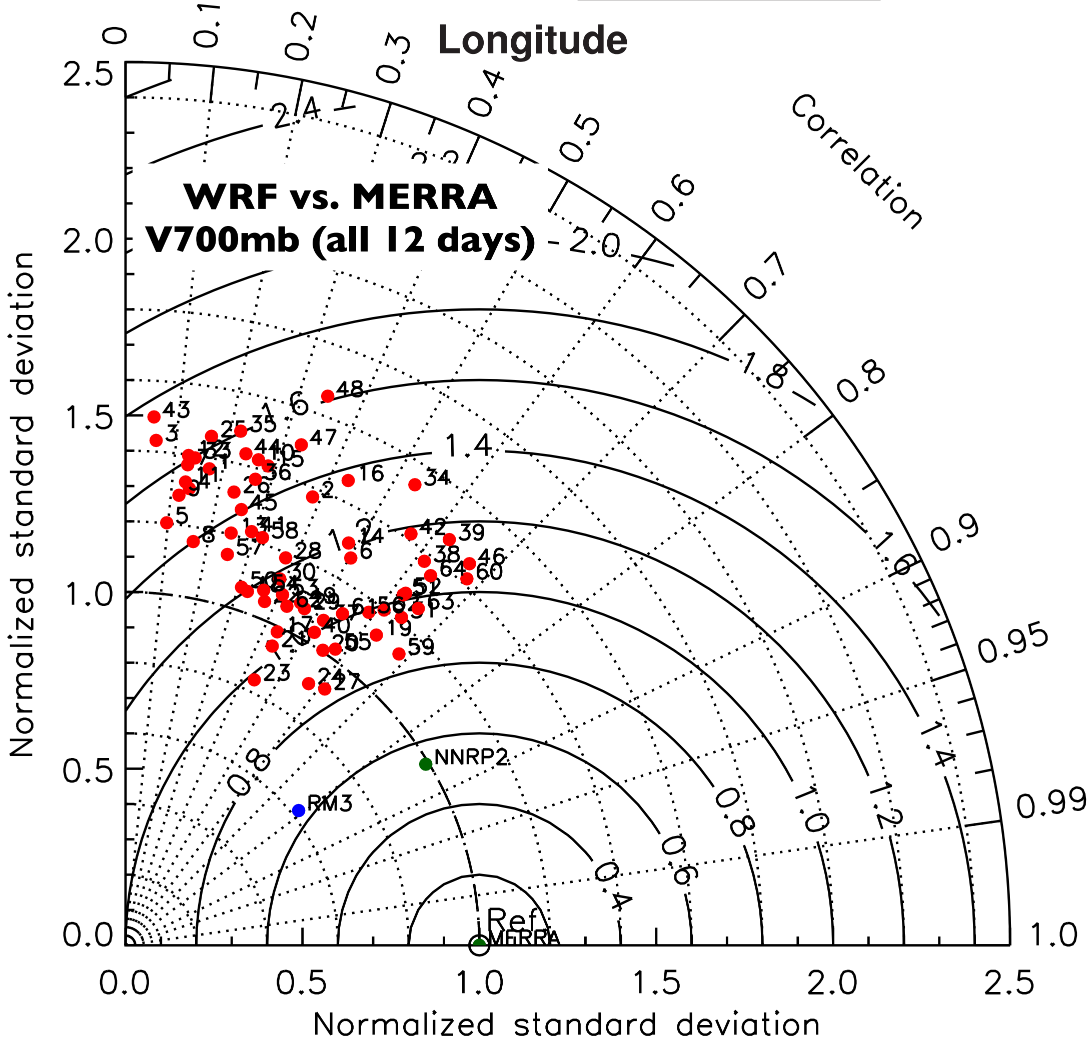
WRF RUN	CPS	PBL	LSM	LWS	SWS	MPS	σ	R	E'	E	BIAS
Experiment 27	GD	PX	RU	Rt	Rt	W5	7.94	0.30	8.53	8.60	1.11
Experiment 59	GD	PX	RU	CM	CM	W5	8.45	0.44	8.89	9.05	1.60
Experiment 60	GD	PX	A2	CM	CM	W5	10.76	0.53	9.48	9.71	2.07
Experiment 46	KF	MN	NO	CM	CM	W5	12.69	0.59	10.32	11.66	5.40
Experiment 34	KF	PX	NO	CM	CM	W5	13.92	0.43	12.81	15.11	8.00
Experiment 42	KF	YU	NO	CM	CM	W5	14.96	0.41	13.86	13.87	7.17
RM3	----	----	----	----	----	----	5.12	0.84	4.86	5.63	2.83
MERRA	----	----	----	----	----	----	8.31	1.00	0.00	0.00	0.00

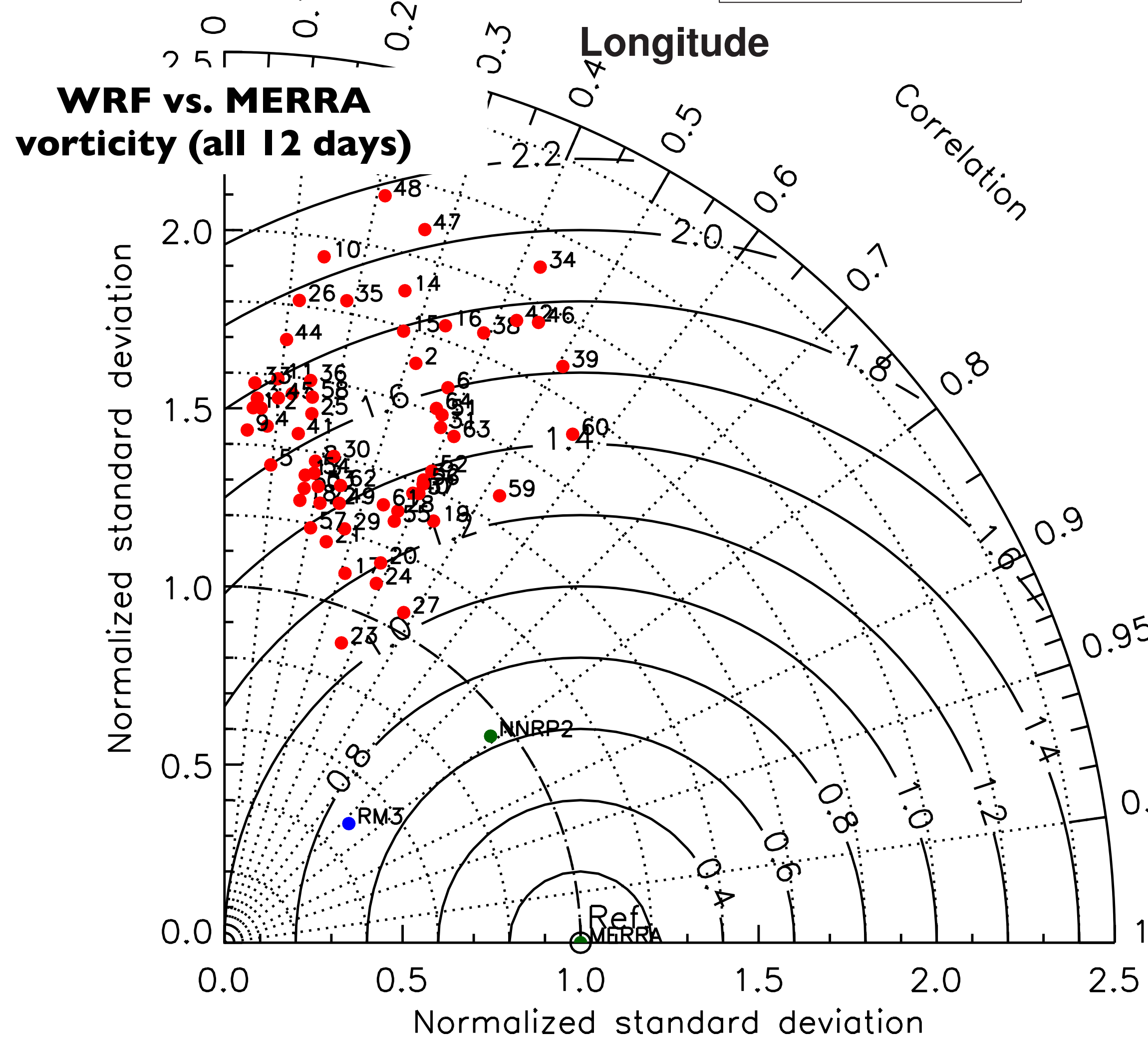
* There is an improvement in the 2nd set of scores.

Taylor Plot of WRF Hovmollers vs. MERRA



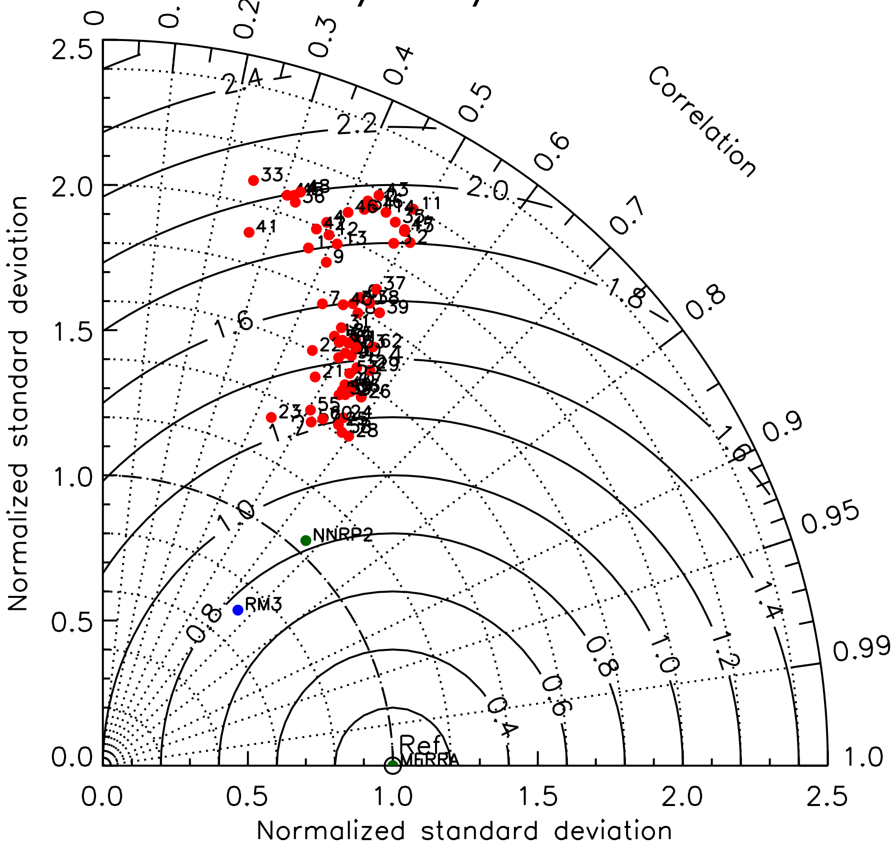




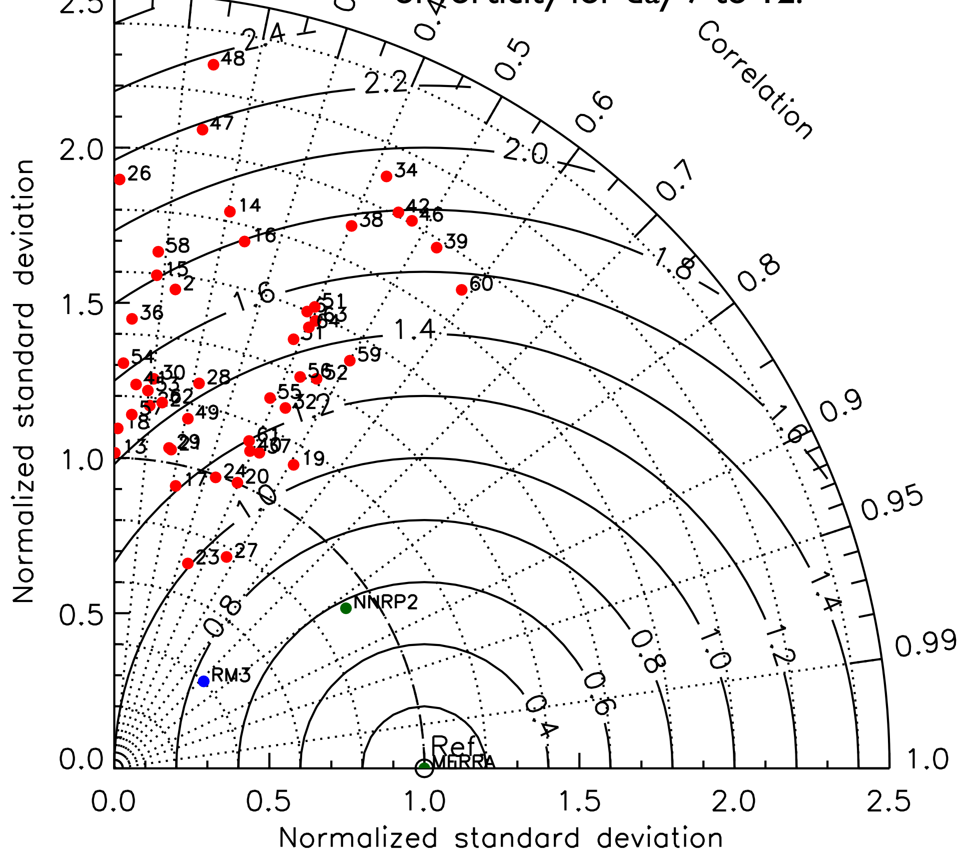


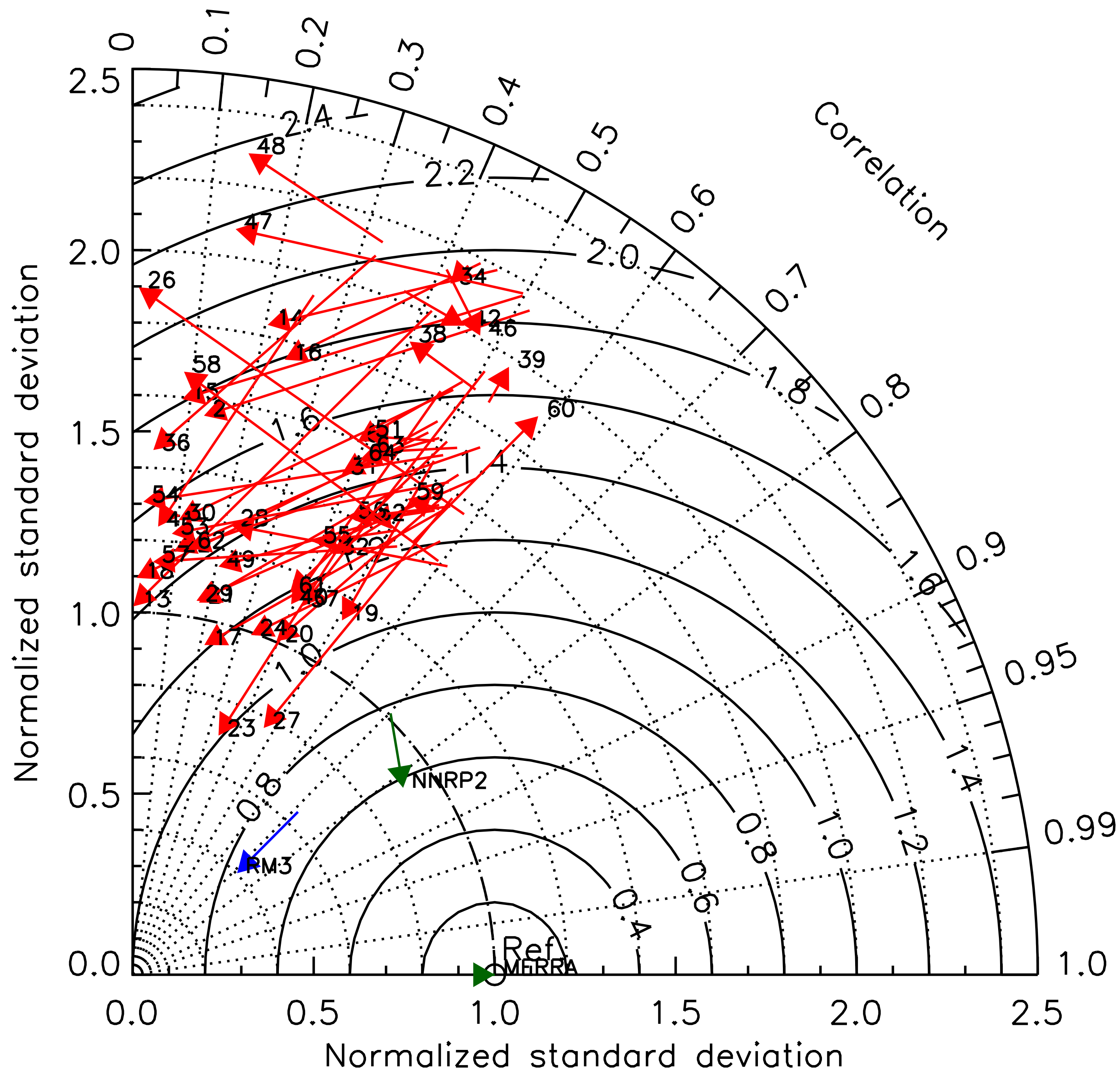
Adjustment period for vorticity?
- doesn't help...

Scores of vorticity Hovmoller plots of vorticity for day 1 to 6.



Scores of vorticity Hovmoller plots of vorticity for day 7 to 12.





Vorticity winners

Only considering scores from hovmoller plots for12-day period

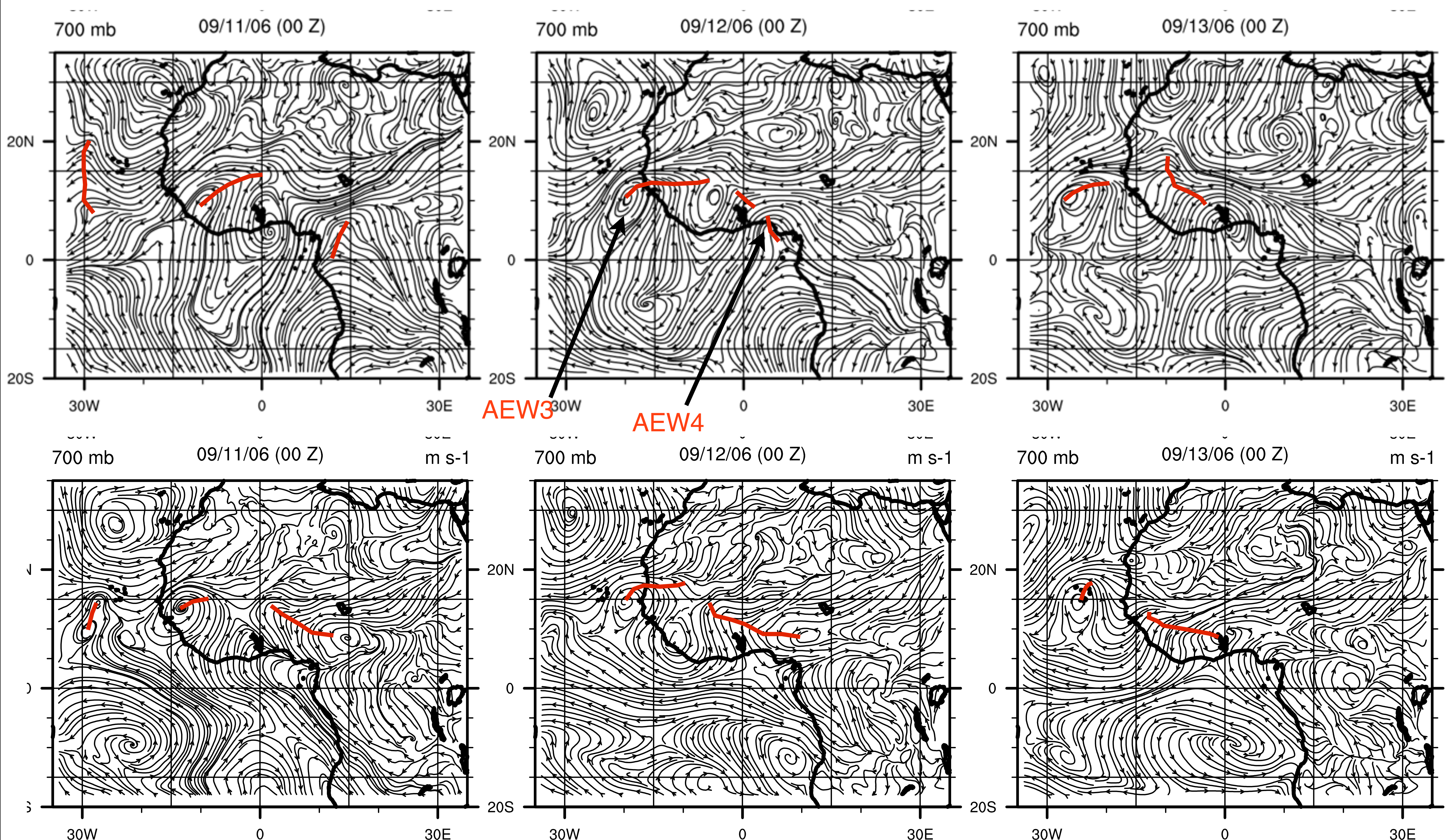
WRF RUN	CPS	PBL	LSM	LWS	SWS	MPS	σ	R	E'	E	BIAS
Experiment 27	GD	PX	RU	Rt	Rt	W5	8.27	0.48	8.22	8.24	0.19
Experiment 59	GD	PX	RU	CM	CM	W5	11.47	0.53	9.30	9.94	-0.06
Experiment 60	GD	PX	A2	CM	CM	W5	13.44	0.56	11.09	11.11	-0.09
Experiment 46	KF	MN	NO	CM	CM	W5	15.14	0.45	13.53	13.55	0.21
Experiment 42	KF	PX	NO	CM	CM	W5	14.97	0.42	13.61	13.63	0.18
Experiment 34	KF	YU	NO	CM	CM	W5	16.23	0.42	14.71	14.73	0.16
RM3	----	----	----	----	----	----	5.31	0.69	5.46	5.12	-0.07
MERRA	----	----	----	----	----	----	7.80	1.00	0.00	0.00	0.00

- Note that top 2 experiments share same physics, except for radiation
- Note that this is the same top set of experiments from the precipitation analysis.

What does this say about WRF

- Over the Sahel region, in this context:
- the WRF model has difficulty with simulating precipitation.
- Precipitation simulations can, perhaps, be improved with an adjustment
- WRF simulates the circulation well in the beginning, but deteriorates with time, which is expected of a *forecast* model
- One might expect that if the model lets circulation variables deteriorate, it will not get rainfall in the right place, it miss it altogether.

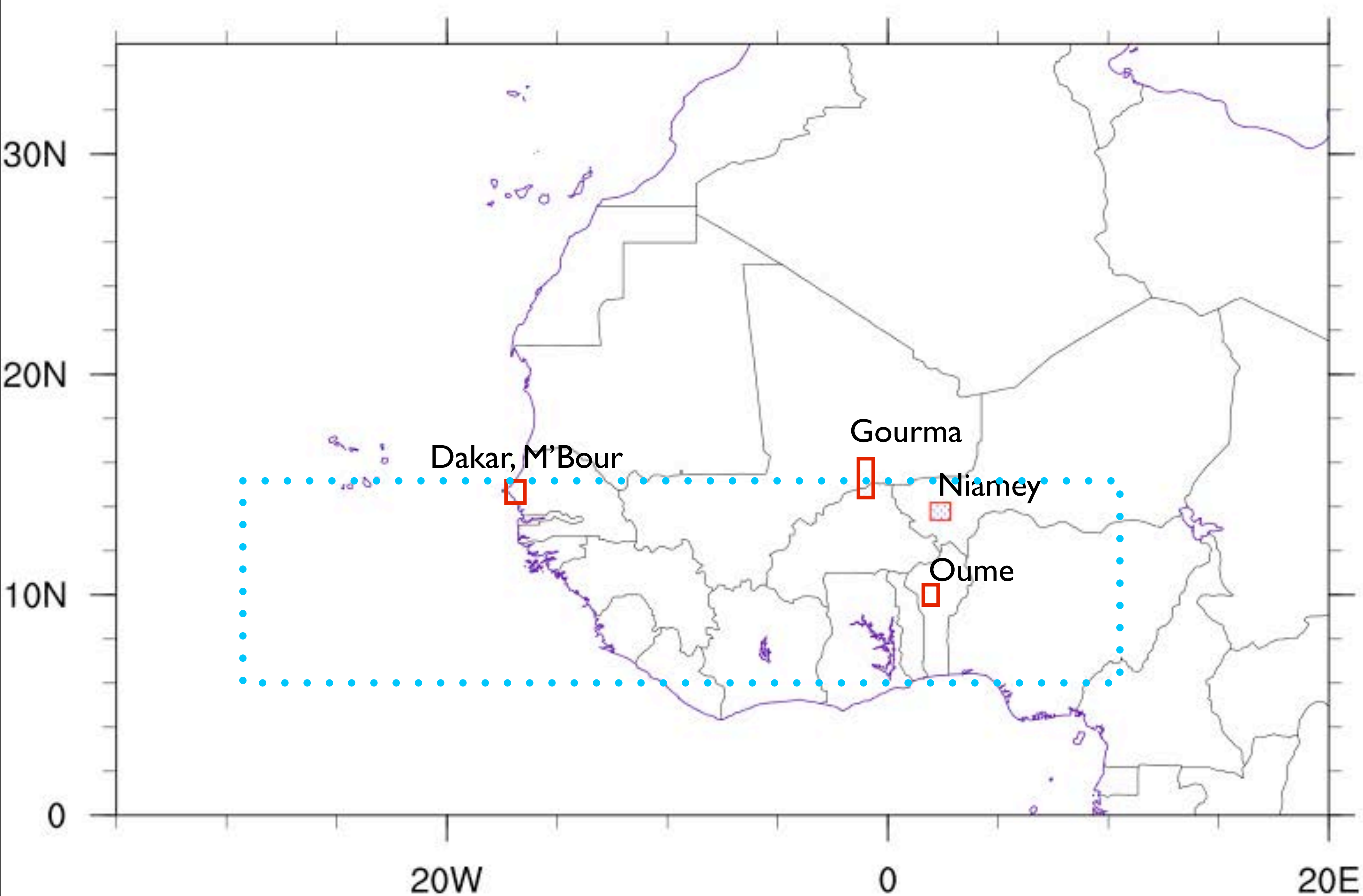
Streamline comparison: (Top) MERRA V700 (Bottom) WRF #59



Next Steps

- This paper
    - examine phase shift of modeled waves
    - examine relative sensitivity between parameterizations
    - validate few more variables (T2m, RH,...)
    - Run WRF NMM
    - Take top 6 Experiments and start...
        - 6 days earlier - look for adjustment period
        - 15 days earlier - One Month - AMMA Period
- Next Work
    - Seasonal simulations

Oh my, we have AMMA in situ data, ... finally!



- Station data
- Sodar
- Precipitation
- Dropsondes

Compare models with

Climate Dynamics (2006) 27: 459–481
DOI 10.1007/s00382-006-0141-9

Leonard M. Druyan · Matthew Fulakeza
Patrick Lonergan

Mesoscale analyses of West African summer climate: focus on wave disturbances

Received: 5 April 2005 / Accepted: 9 March 2006 / Published online: 1 April 2006

Abstract A mesoscale climate data set is created from simulations with a regional (limited area) model over West Africa on a 0.5° grid, covering six summers (June–September), 1998–2003. The Regional Model 3 (RM3) is the latest version run at the National Aeronautics and Space Administration Goddard Institute for Space Studies and the (Columbia University) Center for Climate Systems Research. RM3 simulations are driven by synchronous lateral boundary data four times daily from the National Center for Environmental Prediction reanalysis (NCPR) on a 2.5° grid and sea-surface temperatures from the reanalysis. Characteristics of African wave disturbances (AWD) are analyzed from the mesoscale data set and compared to prior published descriptions. Results show a remarkably high correlation in time and space between RM3 modeled precipitation and Tropical Rainfall Measurement Mission daily estimates, although the RM3 underestimates the frequency of the most extreme (high and low) precipitation rates. In addition, regional model precipitation was validated against gridded seasonal means from the East Anglia University data set and against a time series of daily rain gauge observations near Niamey, Niger. RM3 700 mb circulation shows evidence of considerable interannual variability in spectral properties that relate to AWD. Spectral amplitudes for 700 mb meridional wind time series peak most often in the range of 4 to 6-day periods over swaths traversed by AWD, often detected along 17°N and 4°N. AWD also create westward propagating bands of alternating southerlies and northerlies in NCPR, European Center for Medium-range Weather Forecasting 40-year reanalysis (ERA-40) and RM3 700 mb circulations. RM3 700 mb meridional winds are highly correlated with corresponding NCPR and ERA-40 values, but are usually weaker, so RM3 AWD generally have lower amplitudes. Significant rain events are not always associated with AWD. The RM3 shows good potential for sensitivity experiments that will contribute to our understanding of the physical mechanisms underlying the variability of the West African monsoon. An RM3 West Africa mesoscale climatology could also prove useful for future climate research.

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1 Introduction

Given the serious socio-economic impact of periodic droughts on the fragile agriculturally based societies of West Africa's Sahel, it is desirable to improve our understanding of the region's climate variability, especially rainfall variability. Ultimately, seasonal predictions relating to the summer monsoon would be beneficial. Better understanding requires more modeling studies and more empirical investigations. The sparse distribution of meteorological stations throughout West Africa encourages the exploitation of gridded data sets from reanalyses for which internally consistent three-dimensional interpolation has somewhat compensated for the paucity of observational data. Archived NCEP reanalysis (Kistler et al. 2001) and ECMWF reanalysis (Gibson et al. 1997; Uppala et al. 2005) data sets have been created by global spectral model assimilations of observational data at equivalent grid spacings of about 210 and 125 km, respectively, updated four times per day and archived on 2.5° grids. However, the spatial scales of important weather-making systems, such as squall lines and African wave disturbances (AWD), may

Time Series Example

RM3 vs. Rain Gauges vs. TRMM

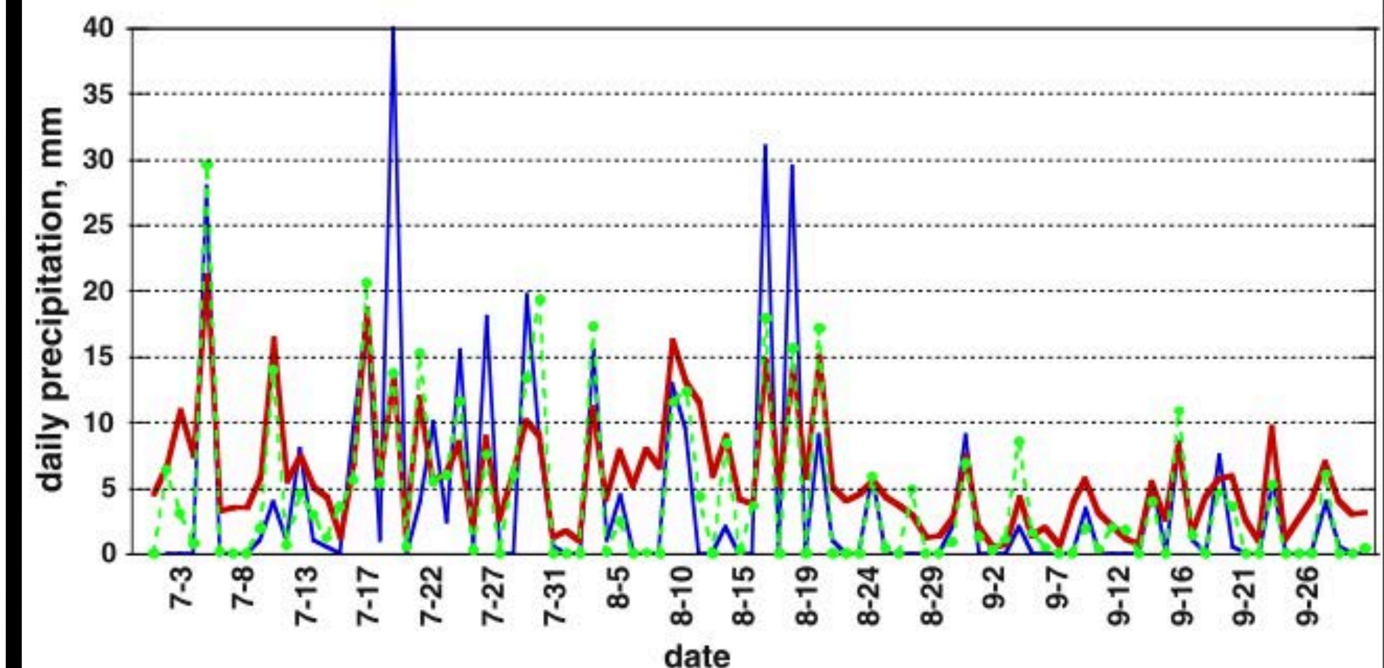

Fig. 12 Time series of the mean of 34 daily rain gauge observations (*blue*) within the area bounded by 13–13.9°N, 1.7–3.1°E (Thorncroft et al. 2003) versus RM3 daily values (*red*) for 15 co-located grid elements and TRMM daily estimates (*green*) for four co-located 1° squares, July–September 2000

Finished.

Questions please.