Relationship between tropical cyclogenesis and large-scale environment in global cloud-system resolving and high-resolution hydrostatic model

Yohei Yamada[1)], Kazuyoshi Oouchi[1)], Masaki Satoh[1) 2)], Hirofumi Tomita[1)], Tomoe Nasuno[1)], Hiroshi Taniguchi[1)], Chihiro Kodama[1)] and Masato Sugi[1) 3)]

1) Japan Agency for Marine-Earth Science and Technology, Japan

2) Atmosphere and Ocean Research Institute, the University of Tokyo, Japan

3) Meteorological Research Institute, Japan

2010 International Workshop of TCCIP Project on Climate Change

Nov. 2, 2010

Contents

Introduction

It is absolutely imperative to use high-resolution model for providing reliable information about climate change.

On the high-resolution approaches with hydrostatic global models Tropical Cyclone (TC):
The intensity is underestimated in the present-day climate (IPCC, 2007).

Uncertainty in cumulus parameterization is the most compelling obstacle to research advancement (Oouchi et al, 2006).

Introduction

One of method available for avoiding the uncertainty is a framework for global cloud resolving model (GCRM), NICAM: Non-hydrostatic Icosahedral Atmospheric Model (Satoh, 2008: Tomita & Satoh, 2004)

Focusing on extremes, tropical cyclone (TC) NICAM is available for TC analysis, as case studies have been reported (Taniguchi et al, 2010: Yanase et al, 2010, Fudeyasu et al, 2010a,b: Oouchi et al, 2009: Fudeyasu et al 2008)

High-resolution experiment demands an enormous amount of computer resources.

With the aid of the Athena project (Kinter et al, 2010 in preparation), **we'll show TC climatology and seasonal change using a framework for GCRM.**

Contents

The Athena project

- **Collaborating groups**
  - **COLA** : Center for Ocean-Land-Atmosphre Studies, USA
  - **ECMWF** : European Centre for Medium-range Weather Forecasts, UK
  - **JAMSTEC** : Japan Agency for Marine-Earth Science and Technology, Japan
  - **AORI** : Atmosphere and Ocean Research Institute , the University of Tokyo, Japan
  - **NICS** : National Institute for Computational Science, USA
  - **Cray inc.**
- **Model**
  - **NICAM** : Non-hydrostatic ICosahedral Atmospheric Model **(Satoh, 2008: Tomita & Satoh, 2004)**
  - **IFS** : ECMWF Integrated Forecast System **(Molteni et al 2006)**
- **Supercomputer**
  - **Athena** : Cray XT4-4512 quad core Opteron node (18048)

The Athena project

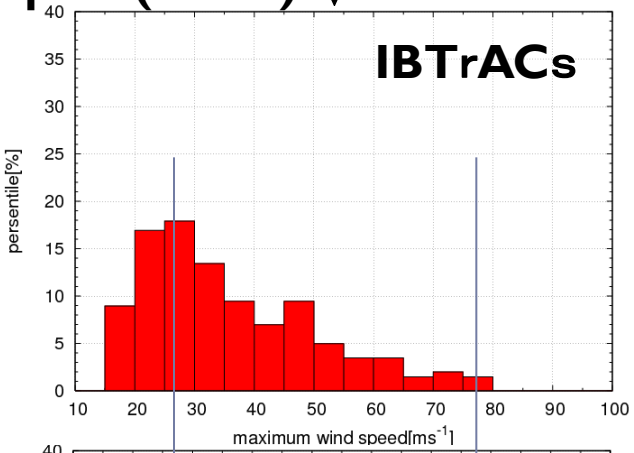
Model configuration & Experimental design

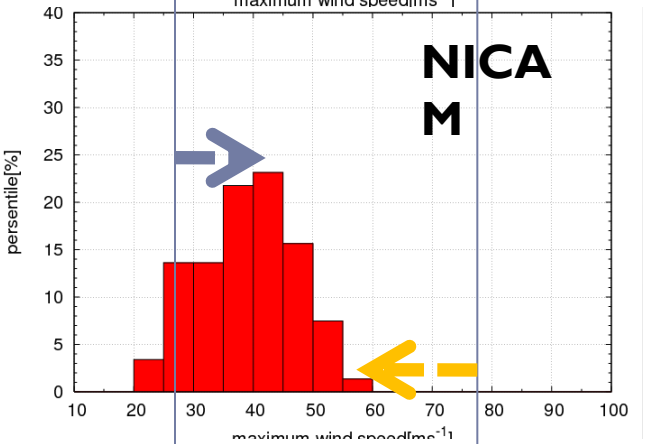
Model	NICAM	IFS
Horizontal resolution	7 km	10 km
# of Vertical layer	40 layers	62 layers
Basic equation	Non-hydrostatic	Hydrostatic
Cumulus pram.	Not use	Tiedtke, 1989
Radiation scheme	Sekiguchi & Nakajima, 2008	Morcrette et al, 2008
Turbulent model	Nakanishi & Nino, 2004 A.T. Noda et al, 2009	Siebesma & Cuijpers, 1995
Boundary condition (SST)	Slab ocean with nudging	Fixed
Period	May 21 – August 31 of the years 2001 – 2009 excluding 2003	

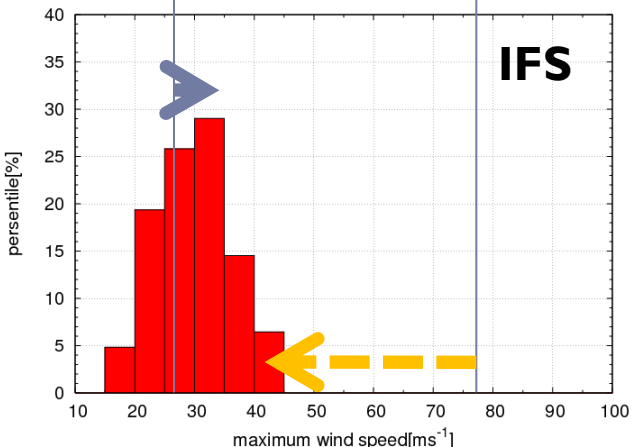
Contents

Obs.(IBTrACs) vs. NICAM vs. IFS

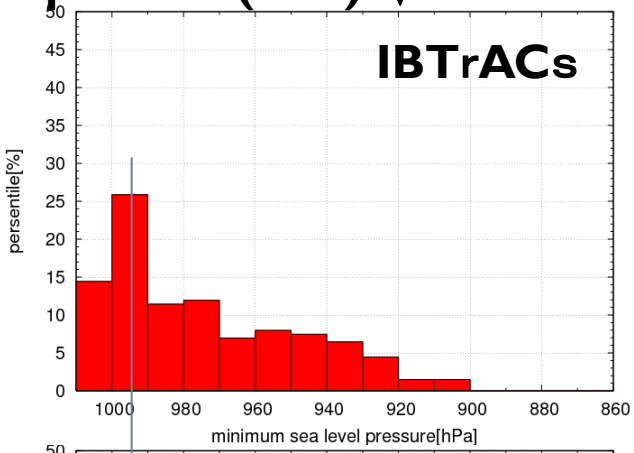
Maximum attained wind speed(MWS) ↓

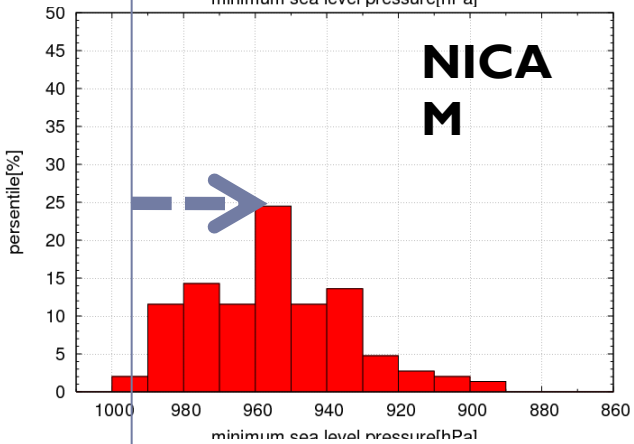


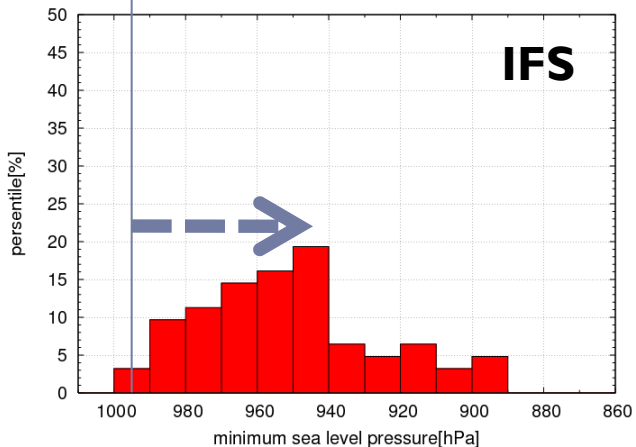


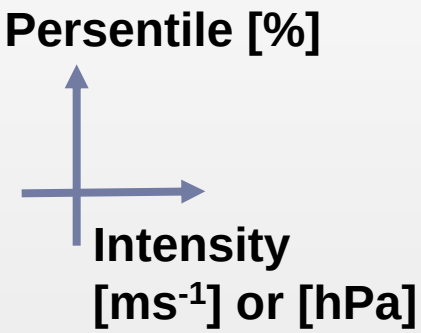


Minimum sea level pressure(SLP) ↓



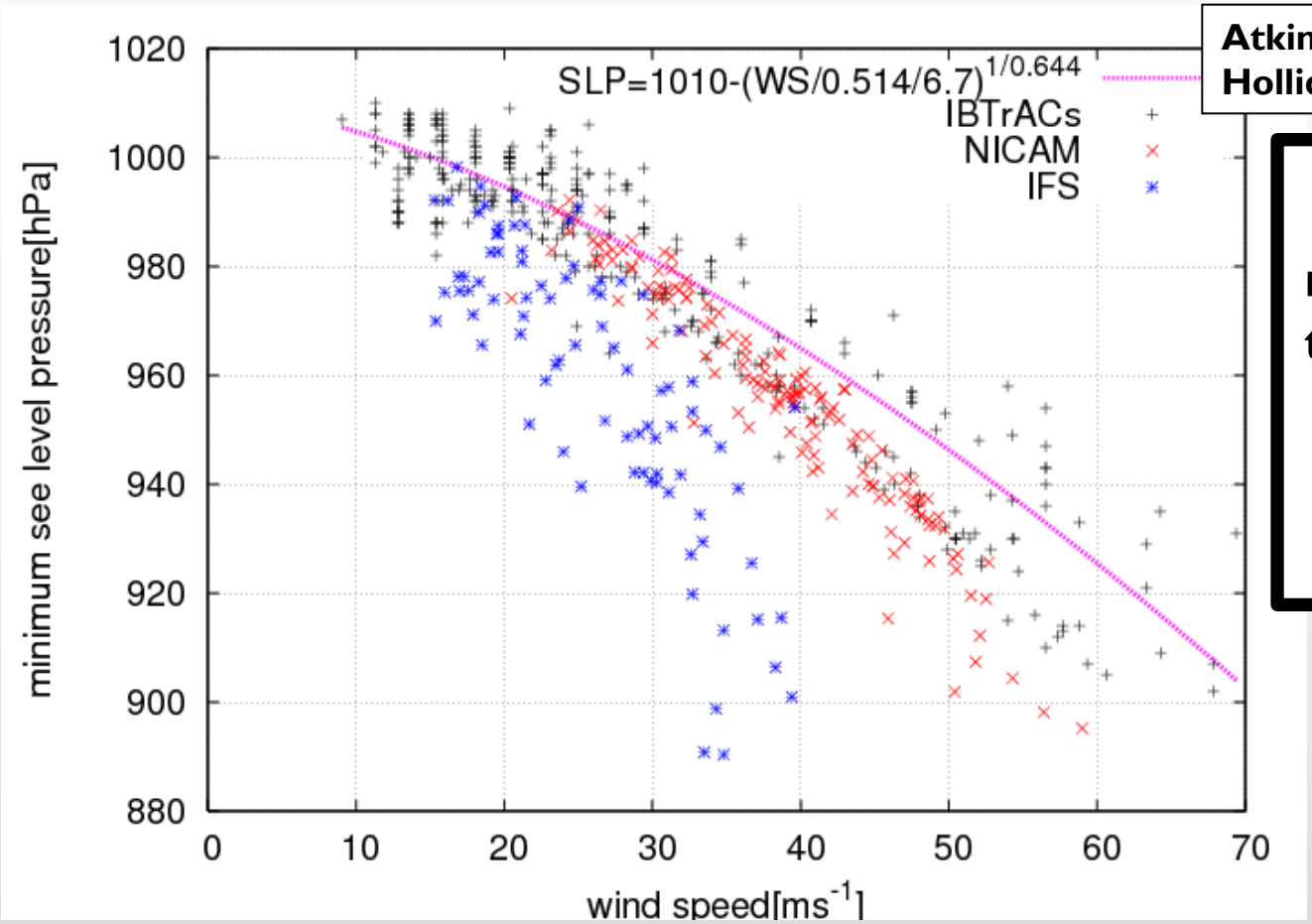






Compared with OBS, Both models peak is strong. Max is weak only for MWS.

Minimum Sea Level Pressure (SLP) vs. Maximum Wind Speed (MWS)



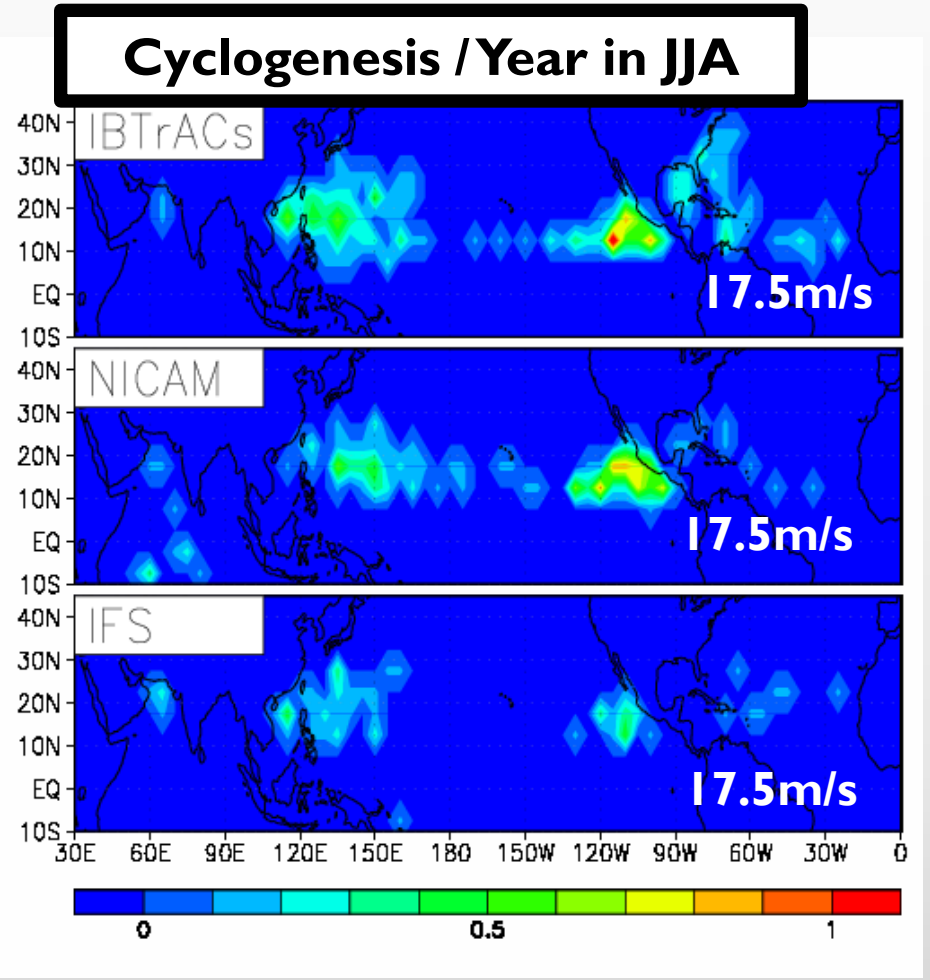
Atkinson & Holliday 1977

For individual TC, relationship between the wind speed when the TC attained minimum SLP in its life-cycle

Cloud-resolving model (NIACM) represents MWS-SLP better than parameterization model (IFS).

Cyclogenesis & Distribution

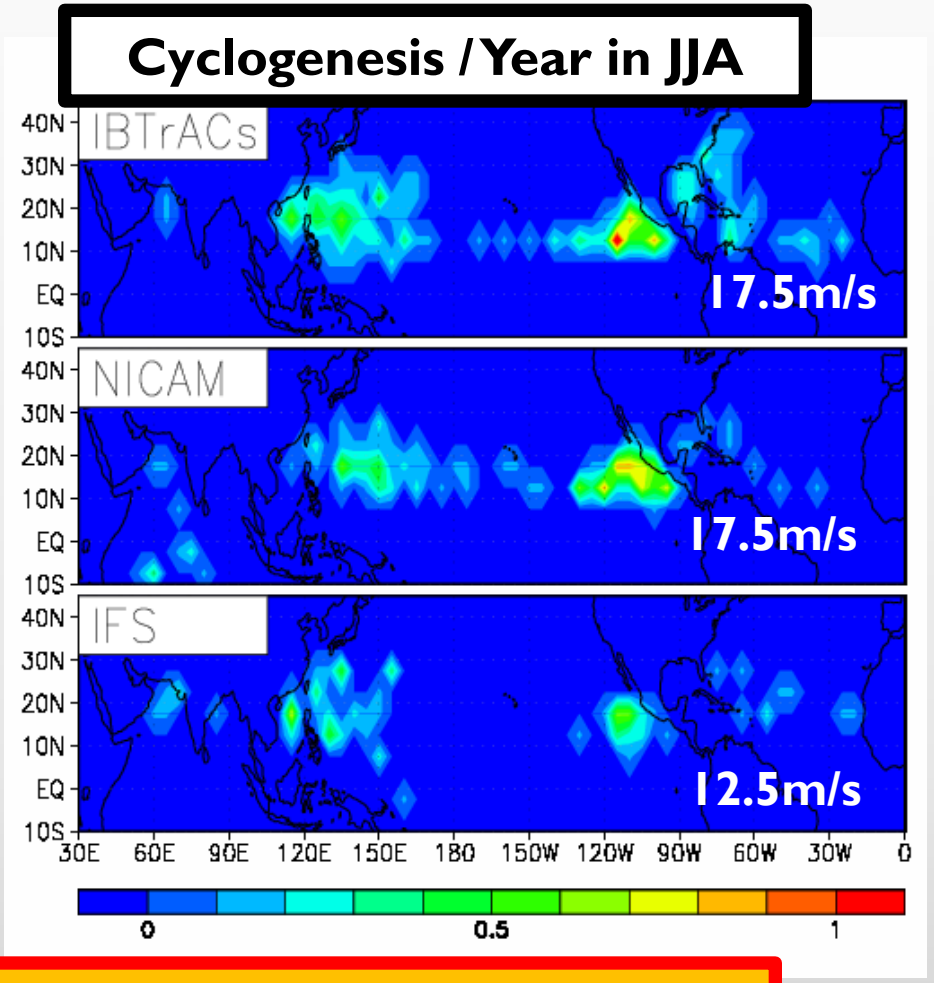
CASE	In.	W. P.	E.P.	At.	Gl.
IBTrACs / JJA	3	76	60	38	177
JUNE	3	15	8	3	29
JULY	0	24	22	9	55
AUGUST	0	37	30	26	93
NICAM / JJA	11	44	65	7	127
JUNE	4	11	8	3	26
JULY	2	23	28	2	55
AUGUST	5	10	39	2	56
IFS 17.5 / JJA	4	31	17	7	59
JUNE	4	4	2	0	10
JULY	0	13	8	2	23
AUGUST	0	14	7	5	26



TC frequency is sensitive to wind speed threshold.
It may be necessary to adjust threshold to Model.

Cyclogenesis & Distribution in JJA

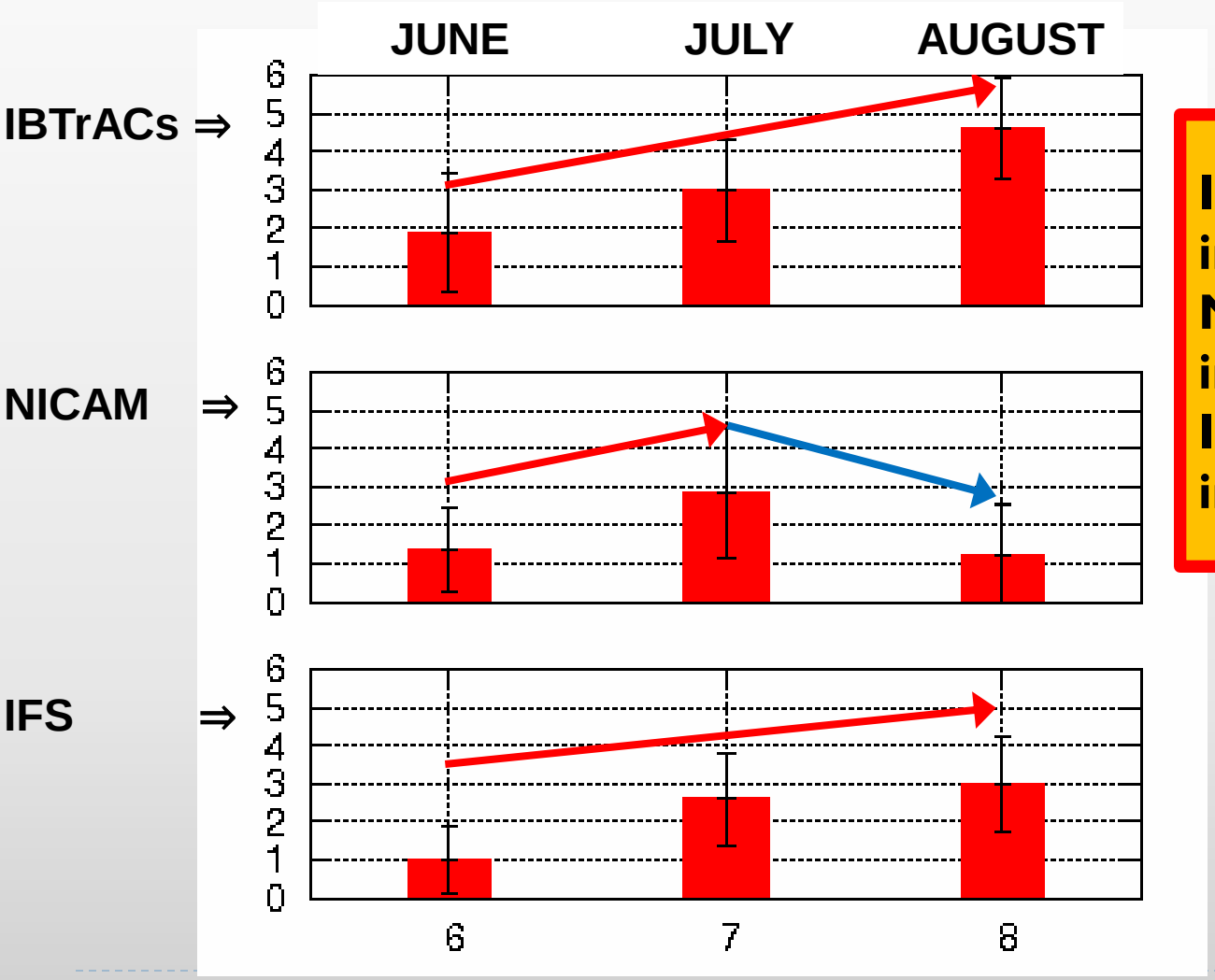
CASE	In.	W. P.	E.P.	At.	Gl.
IBTrACs / JJA	3	76	60	38	177
JUNE	3	15	8	3	29
JULY	0	24	22	9	55
AUGUST	0	37	30	26	93
NICAM / JJA	11	44	65	7	127
JUNE	4	11	8	3	26
JULY	2	23	28	2	55
AUGUST	5	10	39	2	56
IFS 12.5 / JJA	8	63	39	15	115
JUNE	7	8	9	3	27
JULY	1	21	14	6	42
AUGUST	0	24	16	6	46



Cyclogenesis:
IFS is comparable to NICAM.

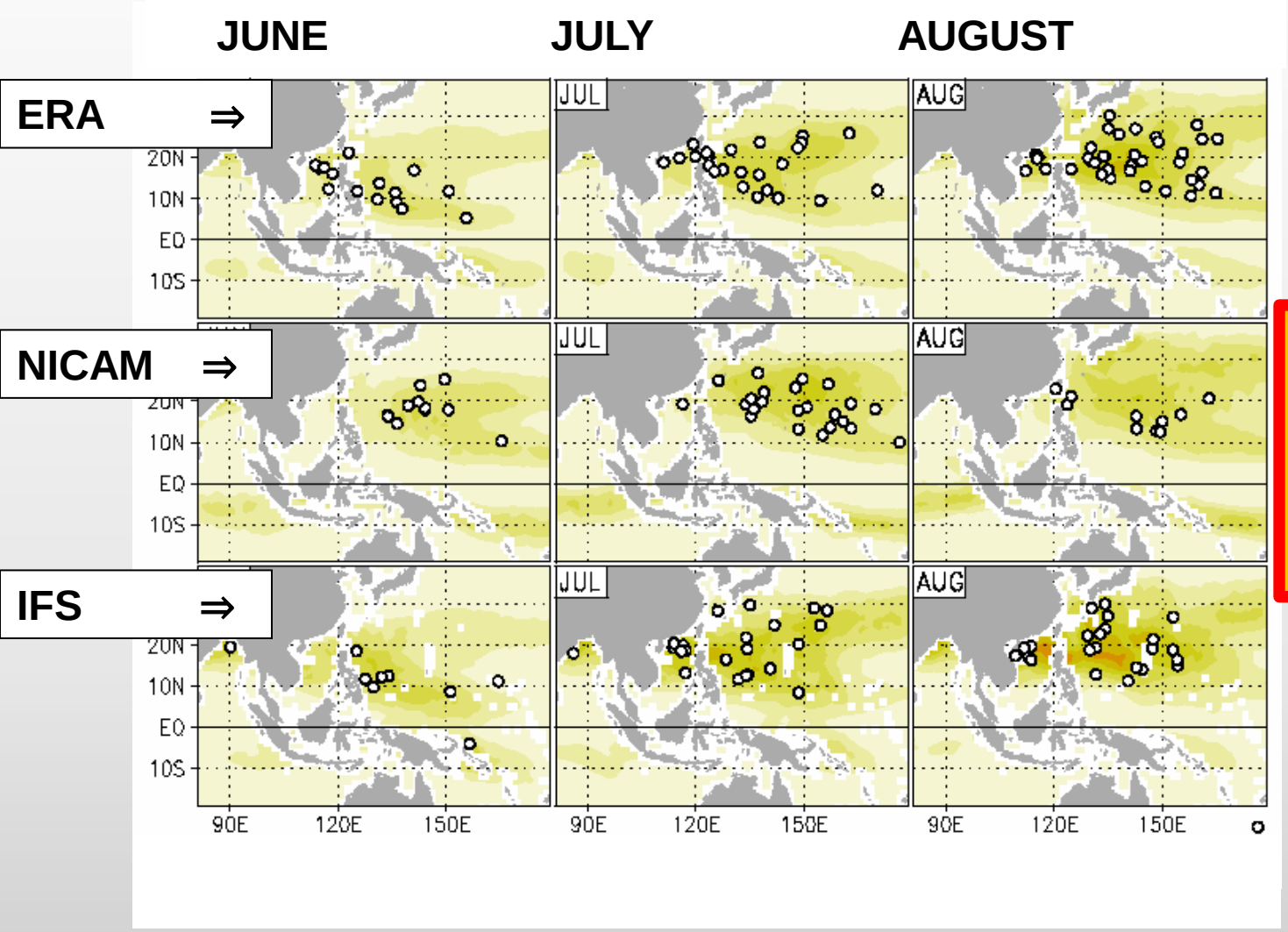
Contents

Cyclogenesis (per Year) & its seasonal change over the western Pacific basin



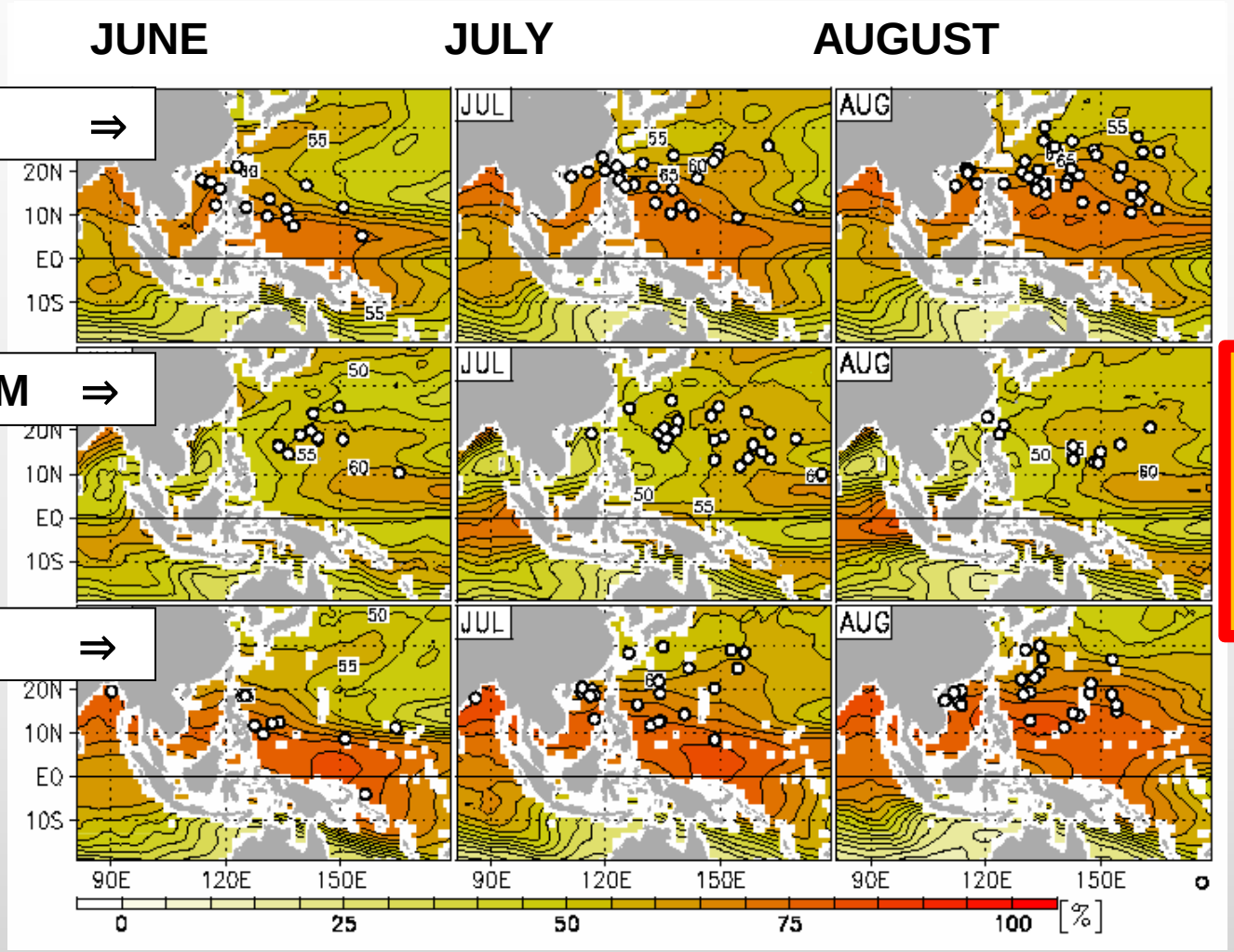
IBTrACs:
increasing
NICAM:
increasing&decreasing
IFS:
increasing

Genesis Potential Index (Emanuel & Nolan, 2004: Camargo et al, 2007) over the western Pacific basin



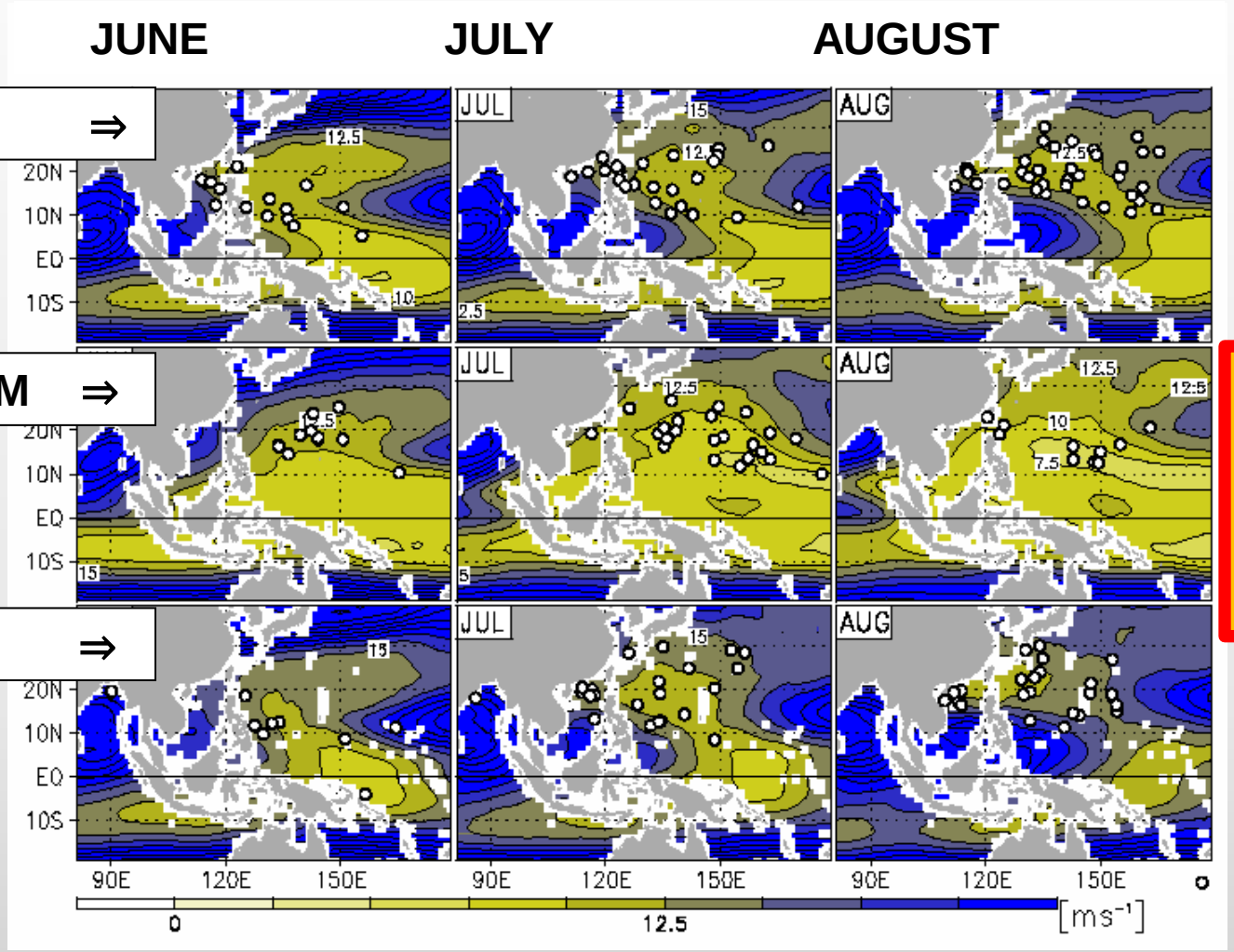
Cyclogenesis: decreasing
GPI: Not unfavorable

the Relative Humidity [%] @ 700[hPa] over the western Pacific basin



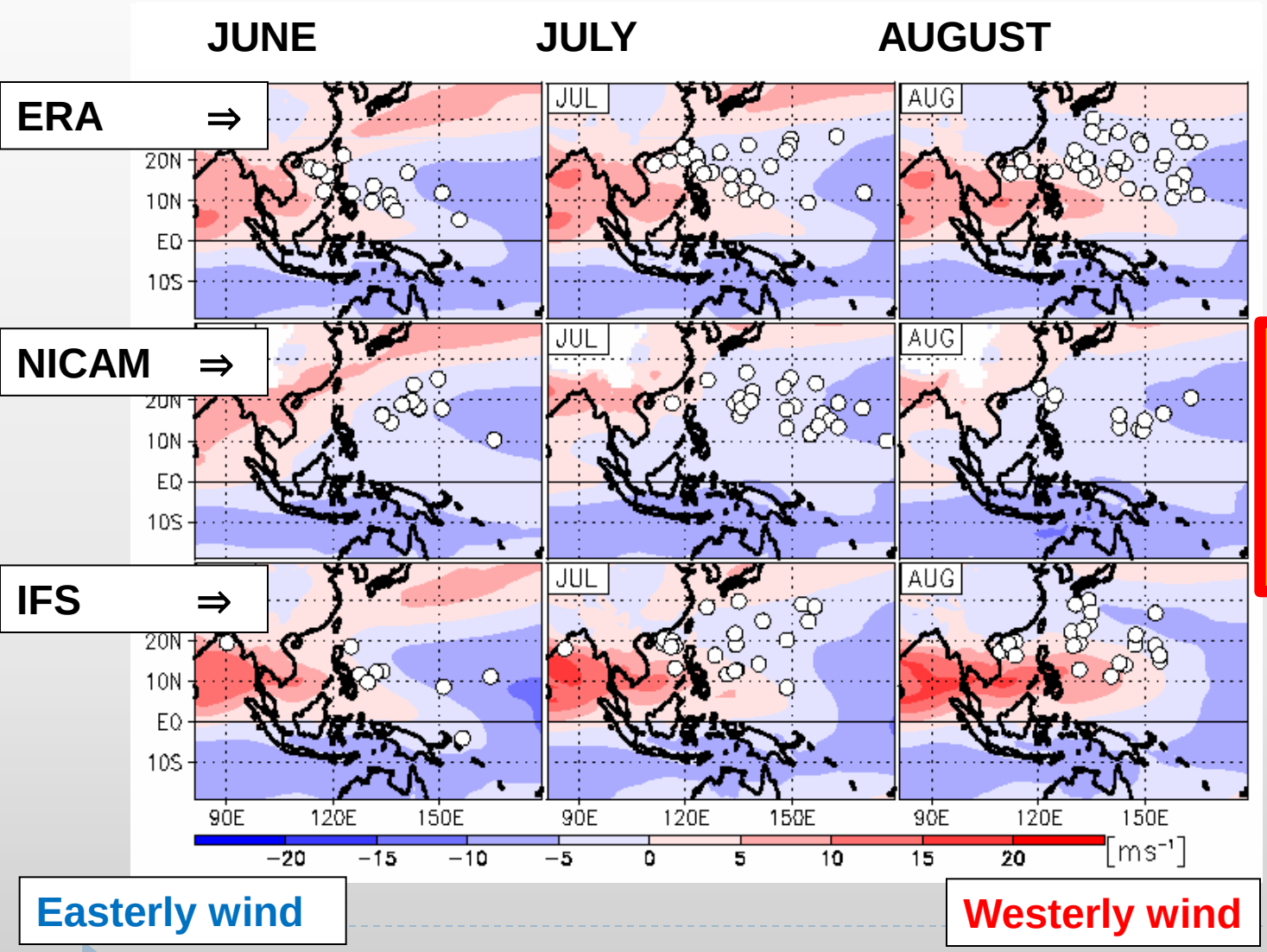
NICAM:
the relative humidity is low.
Unfavorable!

the Vertical wind Shear [ms^{-1}] (250-850[hPa]) over the western Pacific basin



NICAM:
the vertical wind shear is low.
Favorable!

Zonal wind [ms^{-1}] @ 850[hPa] over the western Pacific basin

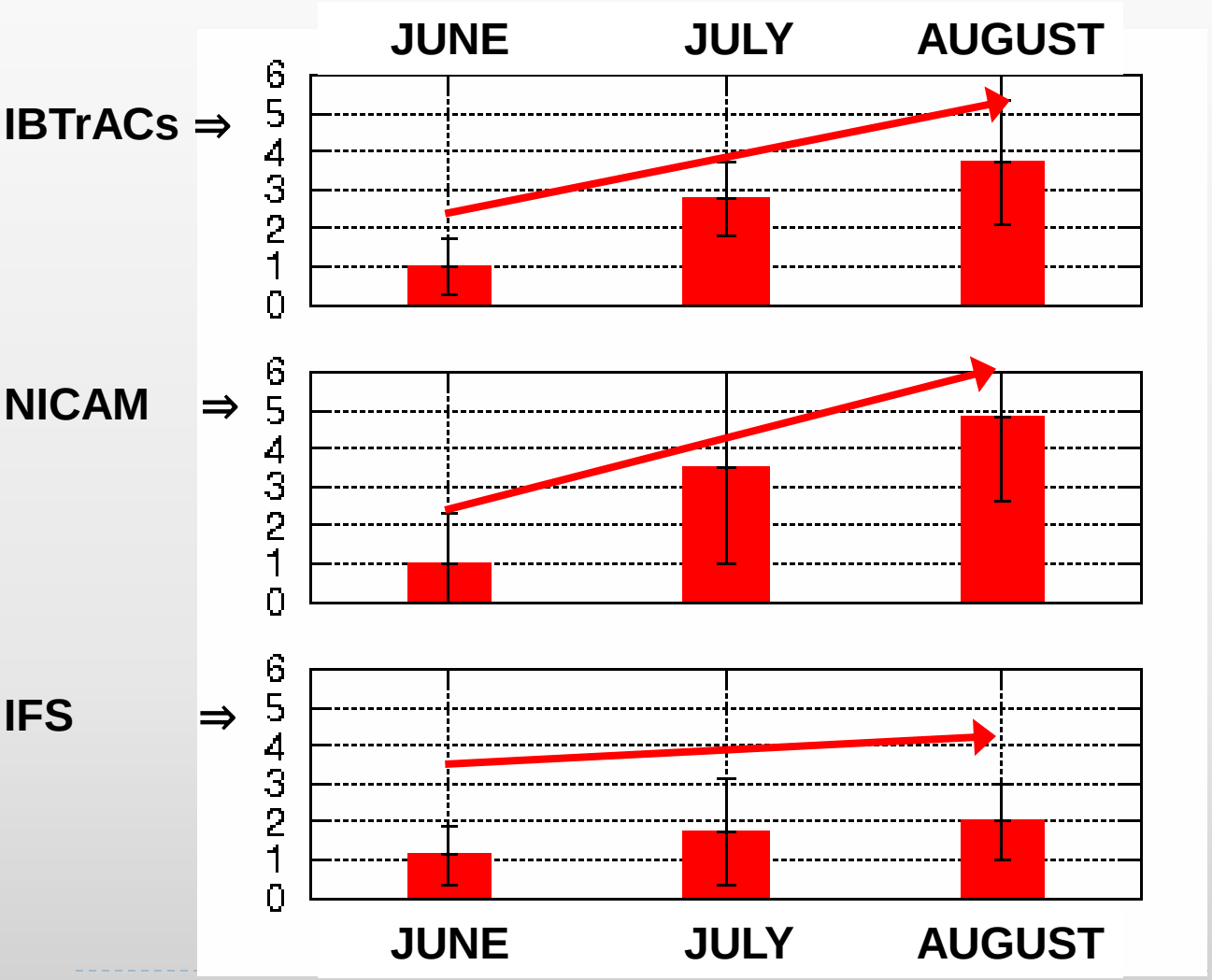


NICAM: Westerly wind is not reproduced around 10N.

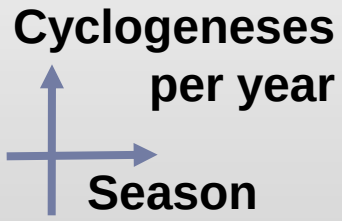
Easterly wind

Westerly wind

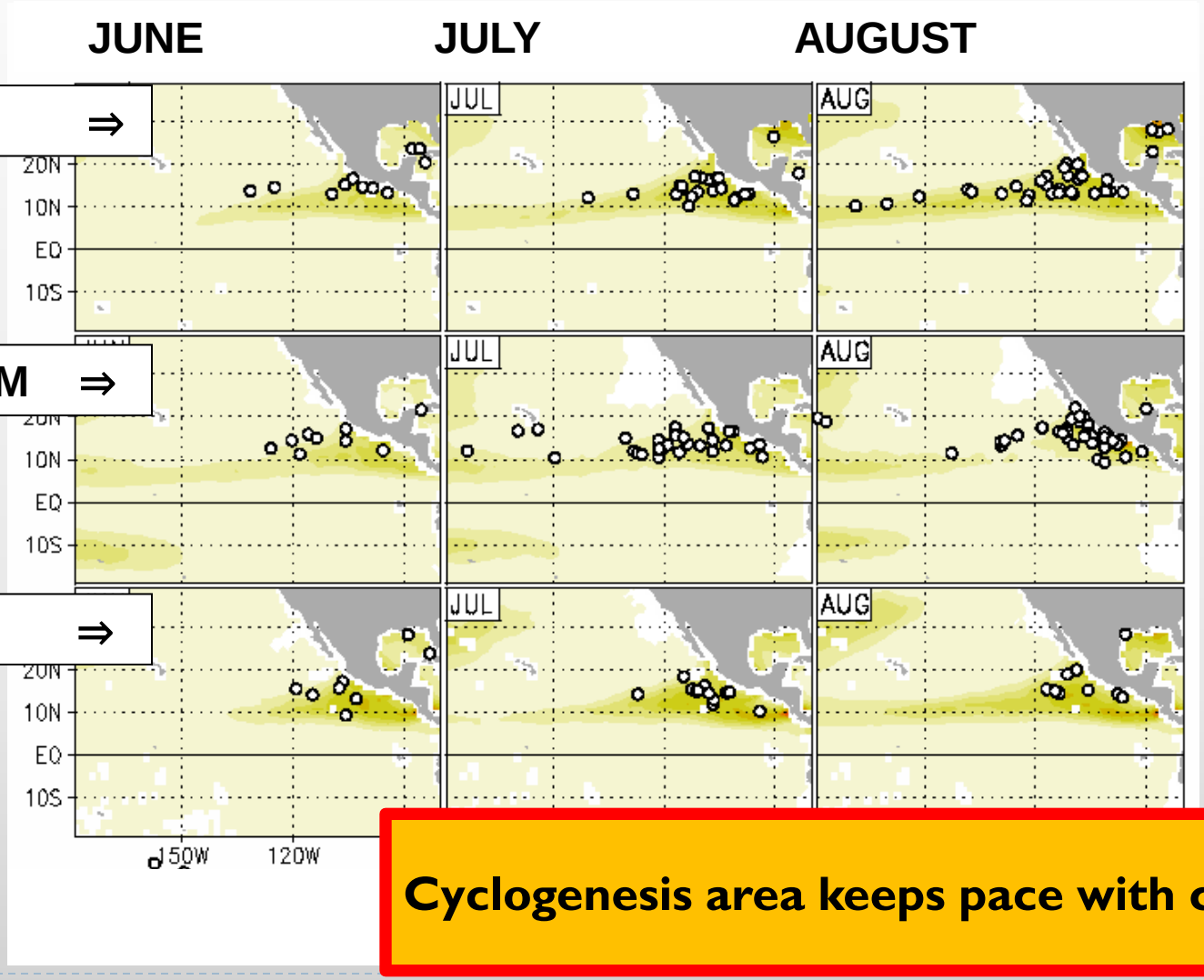
Cyclogenesis (per Year) & its seasonal change over the eastern Pacific basin



IBTrACs:
increasing
NICAM:
increasing
IFS:
Slightly increasing

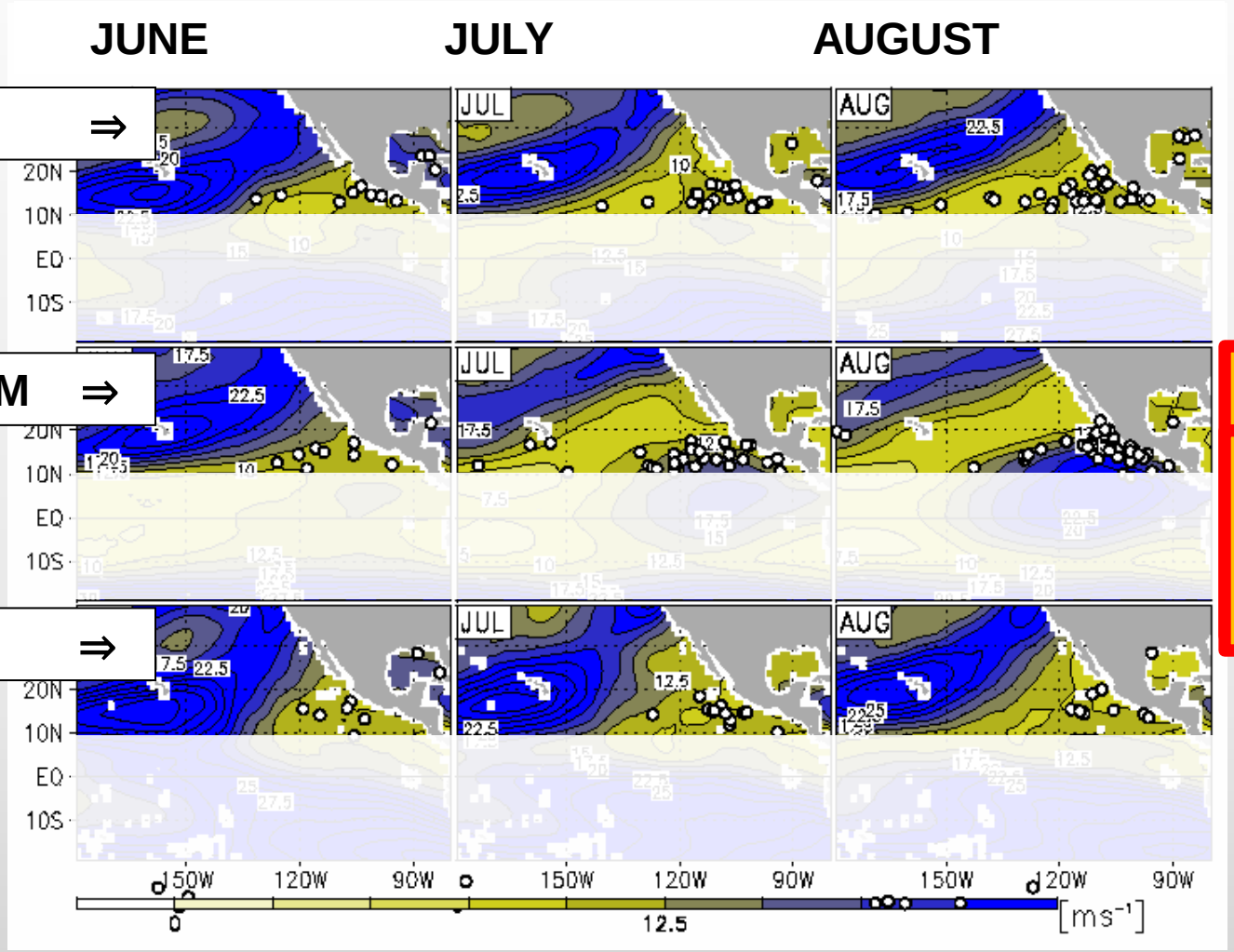


Genesis Potential Index (Emanuel & Nolan, 2004: Camargo et al, 2007) over the eastern Pacific basin



Cyclogenesis area keeps pace with changes of GPI.

the Vertical Wind Shear [ms^{-1}] (250-850 [hPa]) over the eastern Pacific basin



NICAM:

the vertical wind shear is low.
Favorable!

Contents

Summary

- **NICAM reproduces relationship between the maximum wind speed and the sea level pressure better than IFS.**
  - **It seems that NICAM resolve cumulus explicitly without cumulus parameterization.**
- **Over the western Pacific, IFS reproduces Large scale environment associated with cyclogenesis, such as westerly wind better than NICAM.**
- **Over the eastern Pacific, NICAM reproduces Large scale environment associated with cyclogenesis more than IFS.**

Future works & Other works

- **Future works**
  - To examine why the wind speed is weak to the see level pressure compared with observation by focusing on TC structure.
  - Whether general circulation links cyclogenesis over the Pacific or not.
  - Cyclogenesis associated with Intra Seasonal Variation (ISV)
- **Other works associated with the Athena project**
  - Dr. T. Nasuno
    - Detailed analysis on the monsoon evolution and ISO (northward propagation in the Indian ocean), especially for the first month.
  - Dr. H. Taniguchi
    - MJO phase and power spectrum analysis and their relation to TCs.

Acknowledgements

- *In this study, we use dataset conducted by COLA with the Athena super computer, Cray XT4 in NICS. We appreciate Dr. James L. Kinter and the others in COLA.*
- *We also appreciate Drs. T. Matsuno, A. T. Noda, S. Iga, M. Hara in JAMSTEC and Drs. W. Yanase and T. Seiki in the University of Tokyo for giving us so much advice and tools.*
- *We thank ECMWF and NOAA for providing ERA Interim and IBTrACs.*
- *We use GrADs and gnuplot for drawing figures.*
- *We appreciate that the organizers invite me to TCCIP workshop*

and thank you for kind attention!

Appendix