Towards a new tropical cyclone risk assessment system – A linear stochastic model of tropical cyclone intensity

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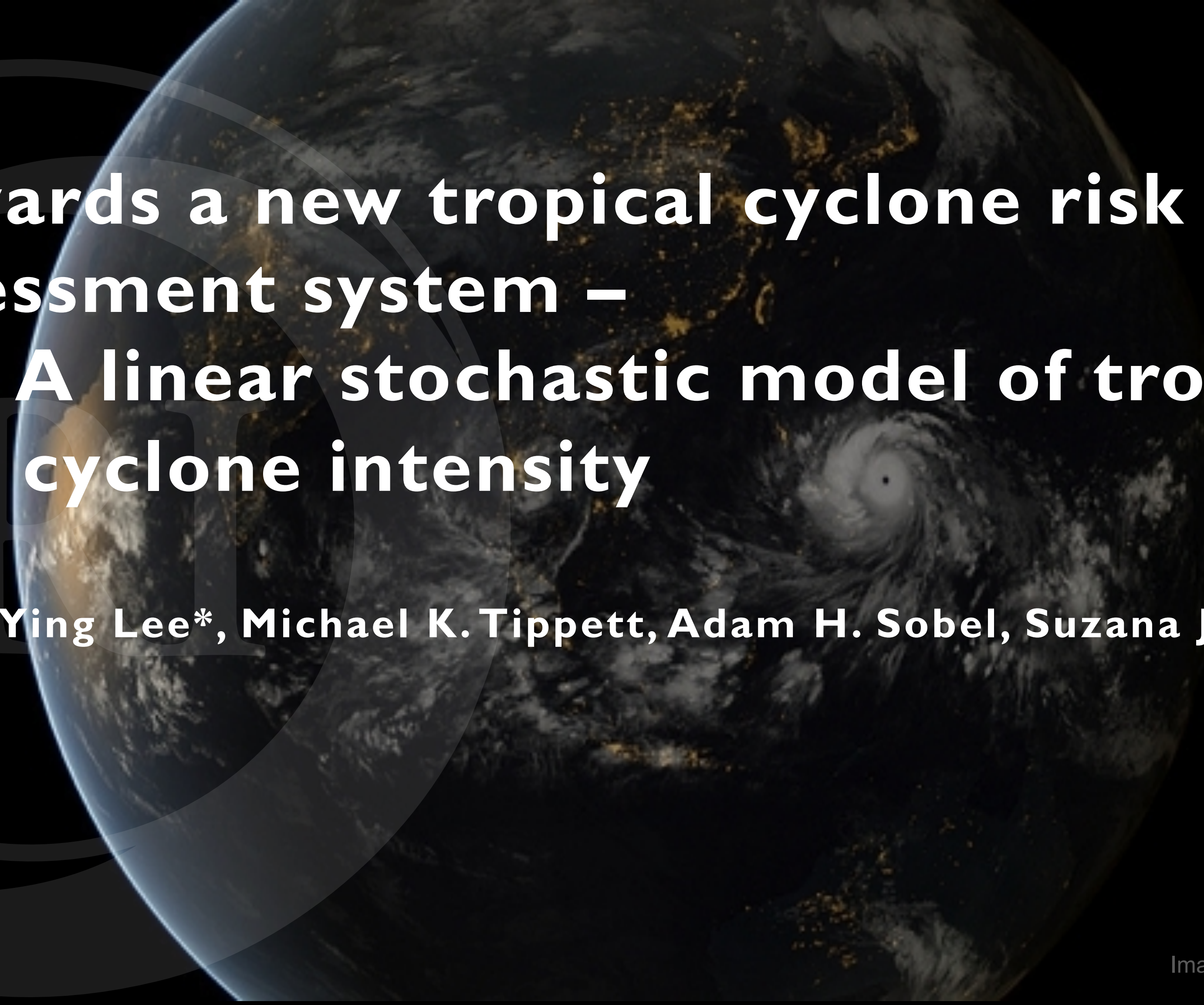

Image : EUMETSTAT

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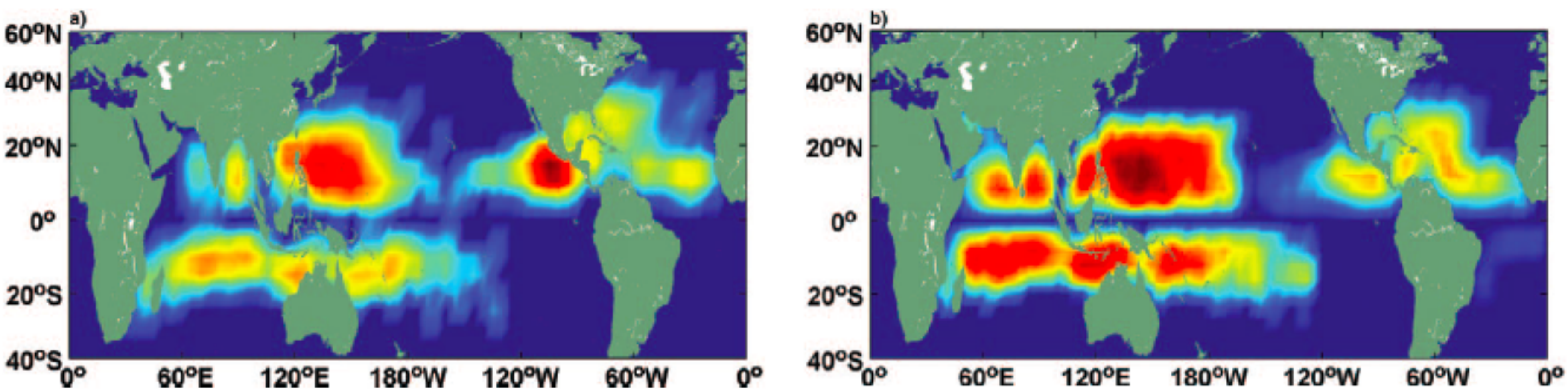
- What is the probability of a category 4 hurricane in New York city? (or anywhere else that has never had one)

- How does it depend on climate (including low frequency variability)?

We aim to produce a tropical cyclone "risk model", aka "downscaling system" – generator of synthetic TC tracks & intensity as function of environment.

Applications to climate change, variability, risk assessment, insurance.

Emanuel et al. (2008): Observed & downscaled genesis index.

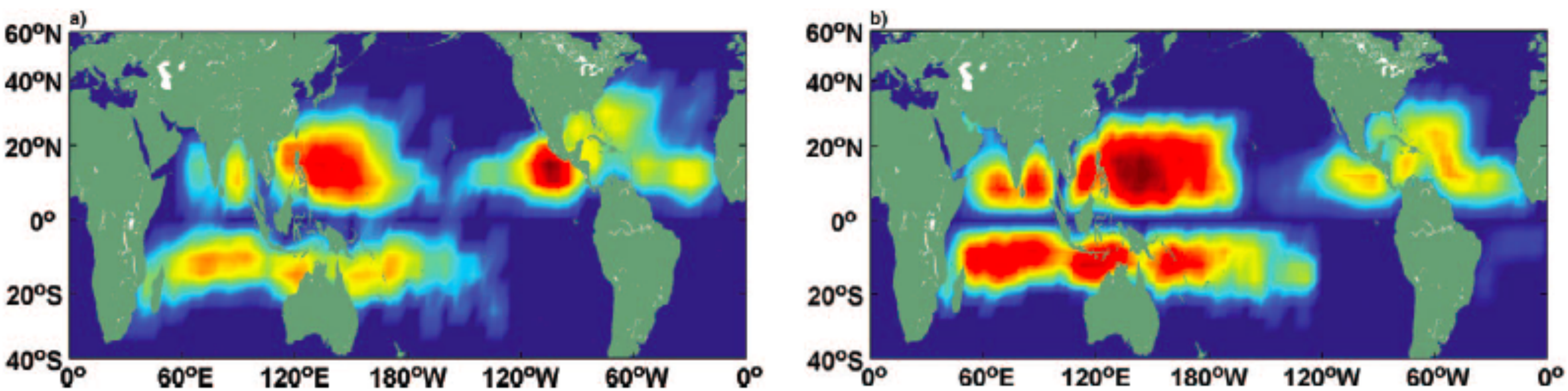


We aim to produce a tropical cyclone “risk model”, aka “downscaling system” – generator of synthetic TC tracks & intensity as function of environment.

Applications to climate change, variability, risk assessment, insurance.

The critical component is a model for TC intensity as function of environment. We are using a statistical-dynamical model with a stochastic component.

Emanuel et al. (2008): Observed & downscaled genesis index.



Approaches:

Statistical (or statistical-dynamical) intensity models from DeMaria et al. (SHIPS or STIPS) are still competitive with full NWP models for operational TC intensity forecasting. Such models are essentially a form of downscaling model.

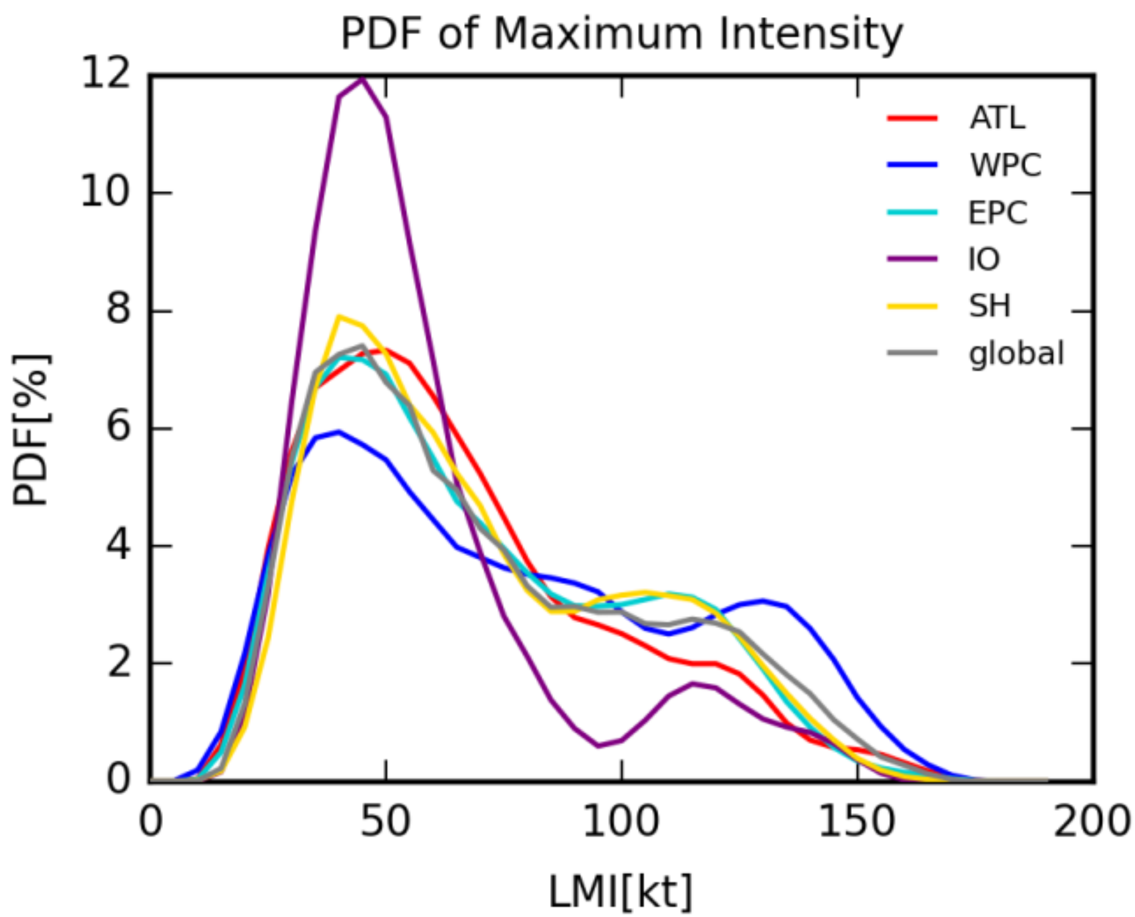
These models however regress towards the mean and cannot handle rapid intensification. A **stochastic component** could remedy this.

1. We first develop a deterministic multiple linear regression (MLR) model similar to those used operationally, but with a few differences reflecting our different interest.

2. Then, we add the stochastic component.

Specific questions:

What is the distribution of the storm intensity, **Lifetime Maximum Intensity (LMI),** that is consistent with the given environment? What is it that controls the distribution in the current climate?

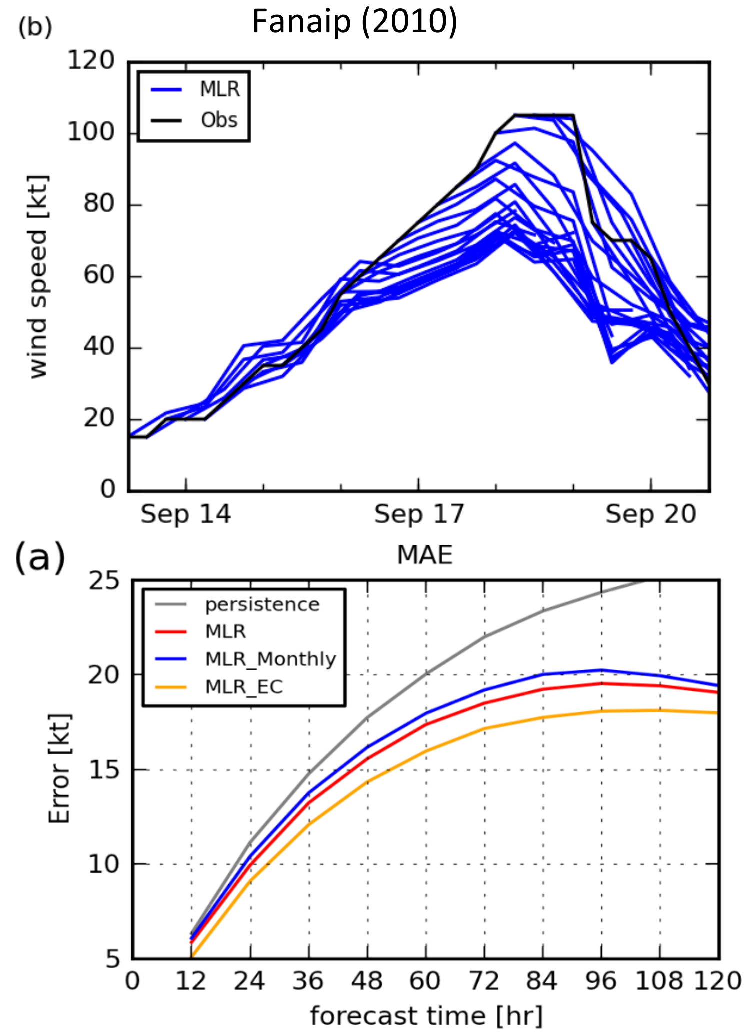


Multiple Linear Regression Model (MLR):

$$v_{o+\Delta t} - v_o = MLR(X_t, X_{o+\Delta t}, v_o, v_{-12hr}) + e$$

1. V_0	initial storm intensity
2. dVdt	Previous intensity change
3. trSpeed	storm translation speed
4. dPI_V_0	Potential intensity (deviated from V_0)
5. SHRD	850-200 hPa shear magnitude
6. RHMid	300-500mb RH

- PI = potential intensity, allows dealing with climate change (as opp. to SST threshold)
- NHC, JTWC **best-track data**
- 2.5° X 2.5° NCEP daily, monthly, and **ERA-Interim monthly** **reanalysis datasets**
- Training-1981~1999; testing-2000~2012



The performance of the MLR is comparable to that of current operational models, even when monthly reanalysis datasets are used

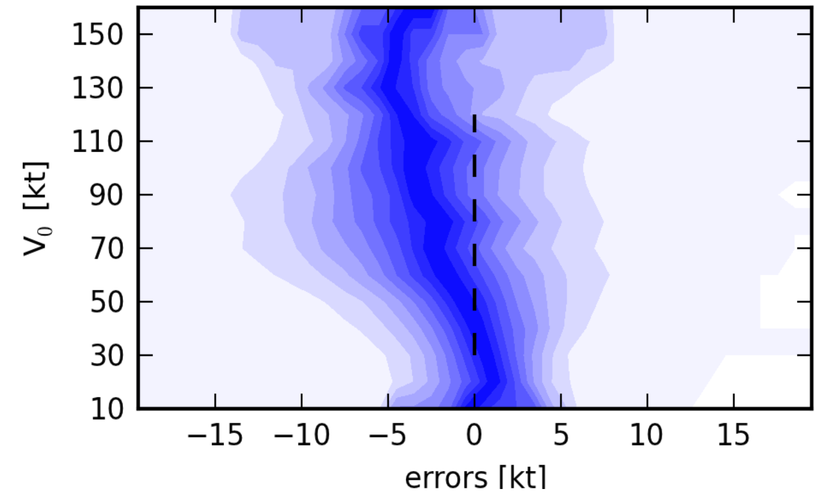
[Lee et al. 2015a, MWR]

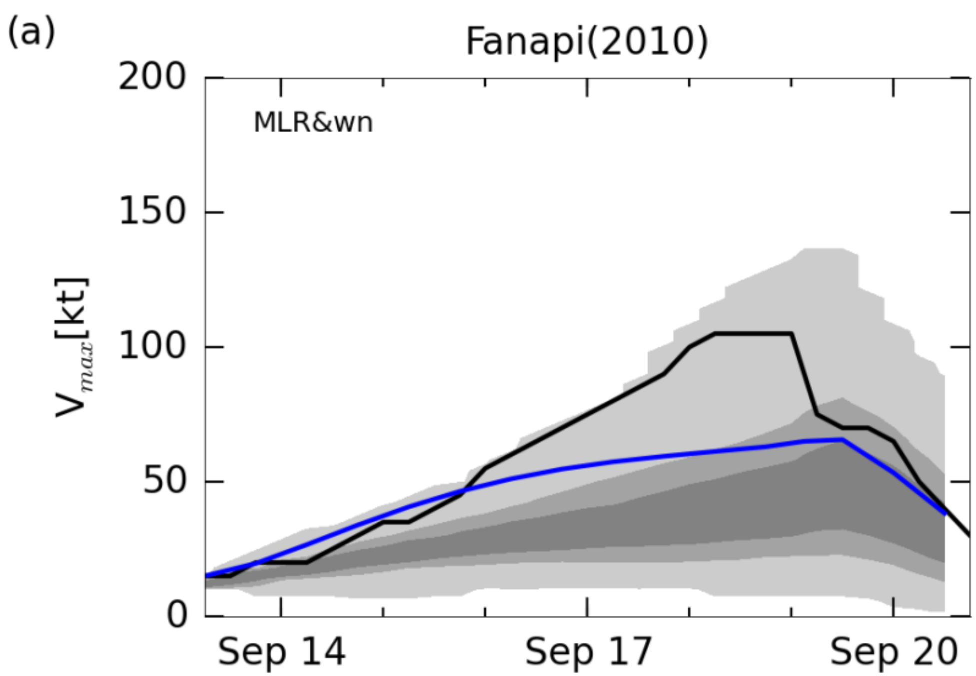
Stochastic lifetime intensity forecast:

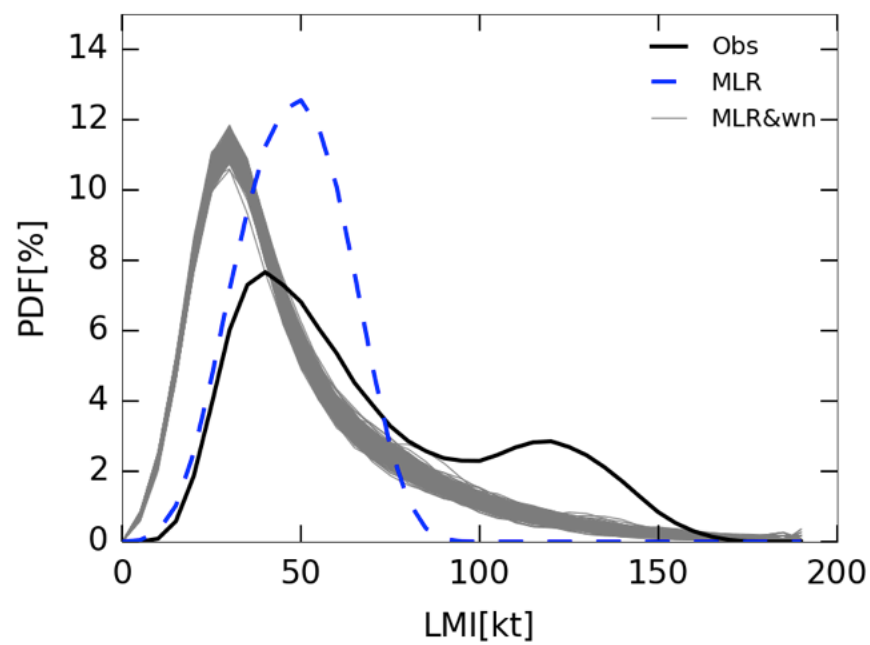
$$v_{o+\Delta t} - v_o = MLR(X_t, X_{o+\Delta t}, v_o, v_{-12hr}) + e$$

- Δt = 12 hours
- Deterministic MLR: e=0
- MLR&wn: white noise error from empirical error distribution

PDF of errors







Stochastic lifetime intensity forecast:

$$v_{o+\Delta t} - v_o = MLR(X_t, X_{o+\Delta t}, v_o, v_{-12hr}) + e$$

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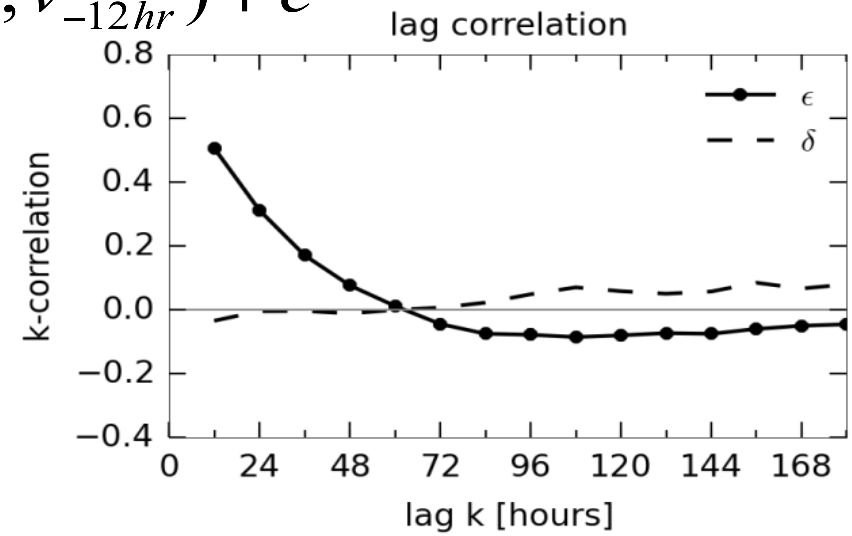
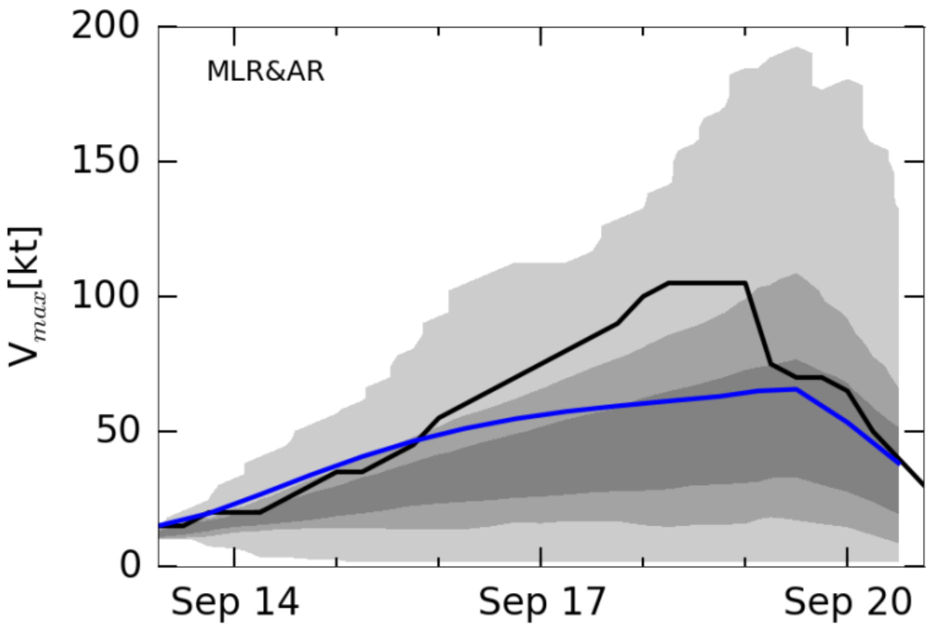
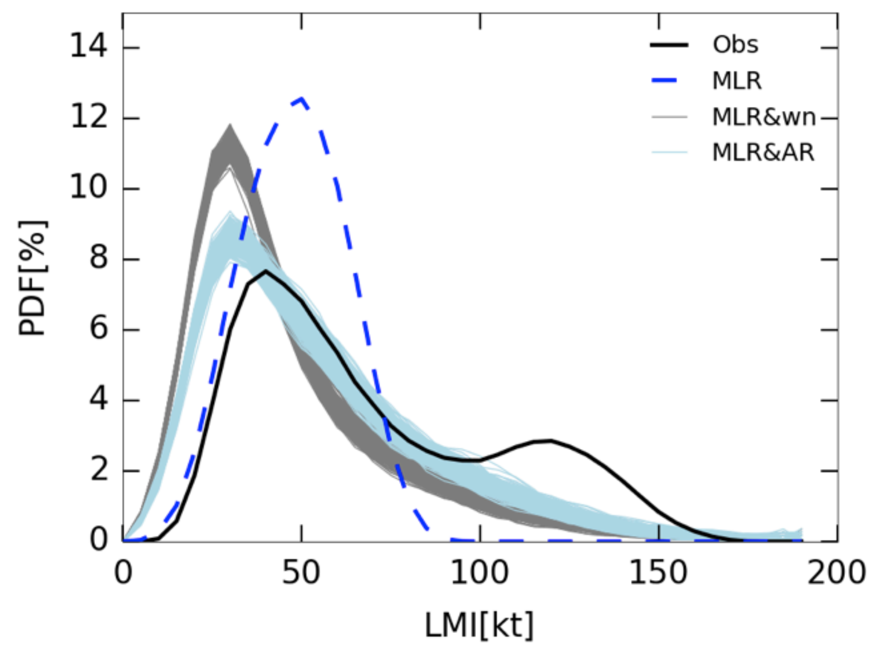
- MLR&AR: auto-correlated error

$$e_t = \alpha e_{t-1} + \delta$$



(b)





Stochastic lifetime intensity forecast:

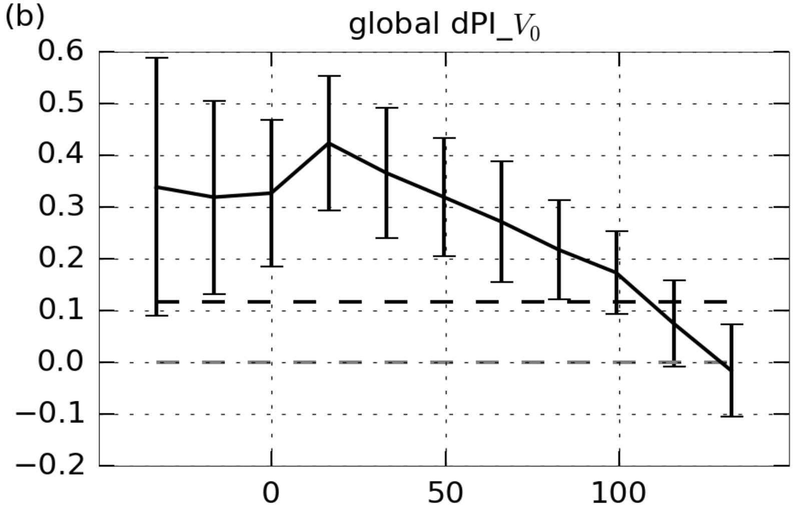
$$v_{o+\Delta t} - v_o = MLR(X_t, X_{o+\Delta t}, v_o, v_{-12hr}) + e$$

- Δt = 12 hours
- Deterministic MLR: e=0
- MLR&wn: white noise error from empirical error distribution
- MLR&AR: auto-correlated error

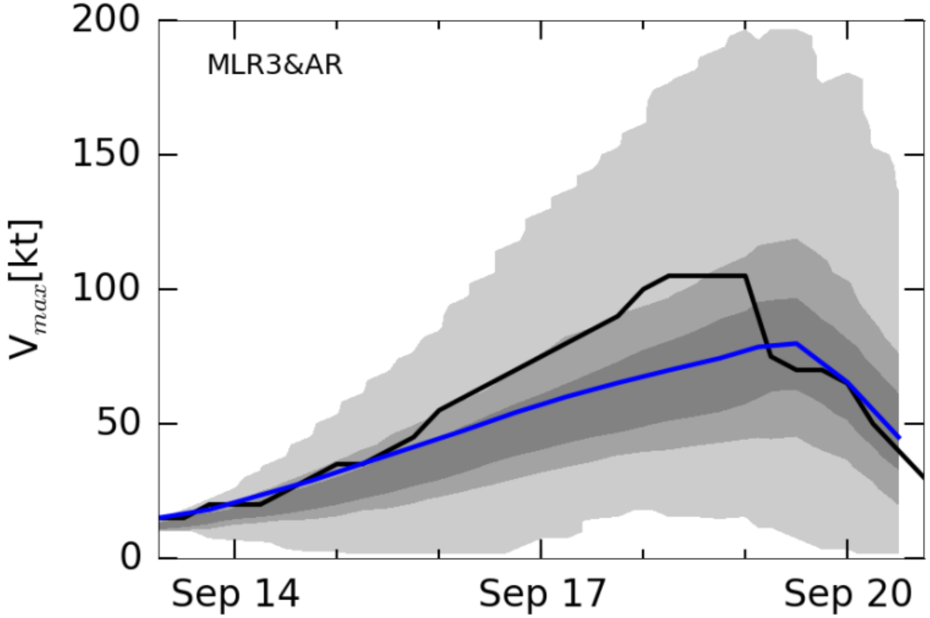
$$e_t = \alpha e_{t-1} + \delta$$

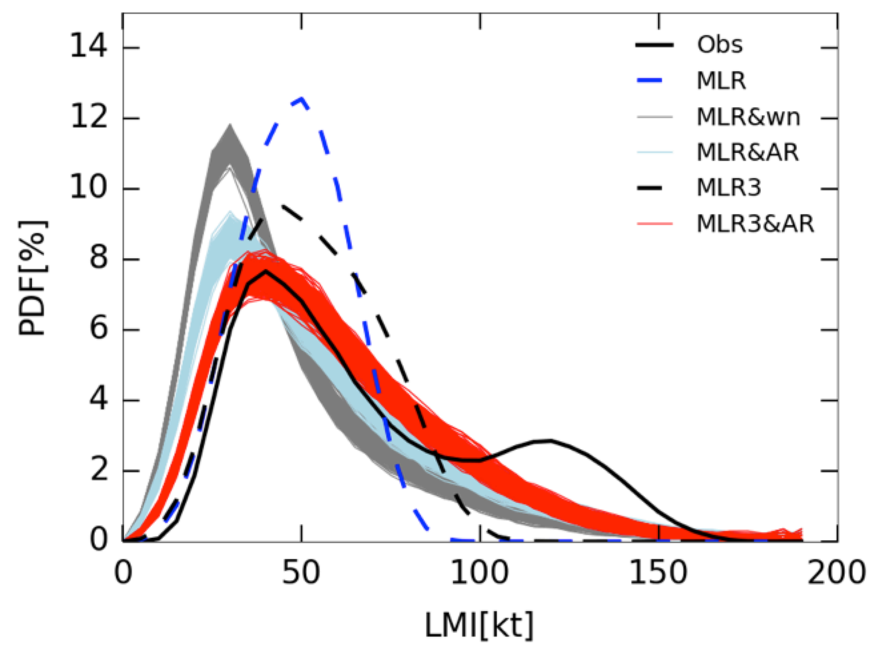
- MLR3&AR: using nonlinear terms for PI

(b)

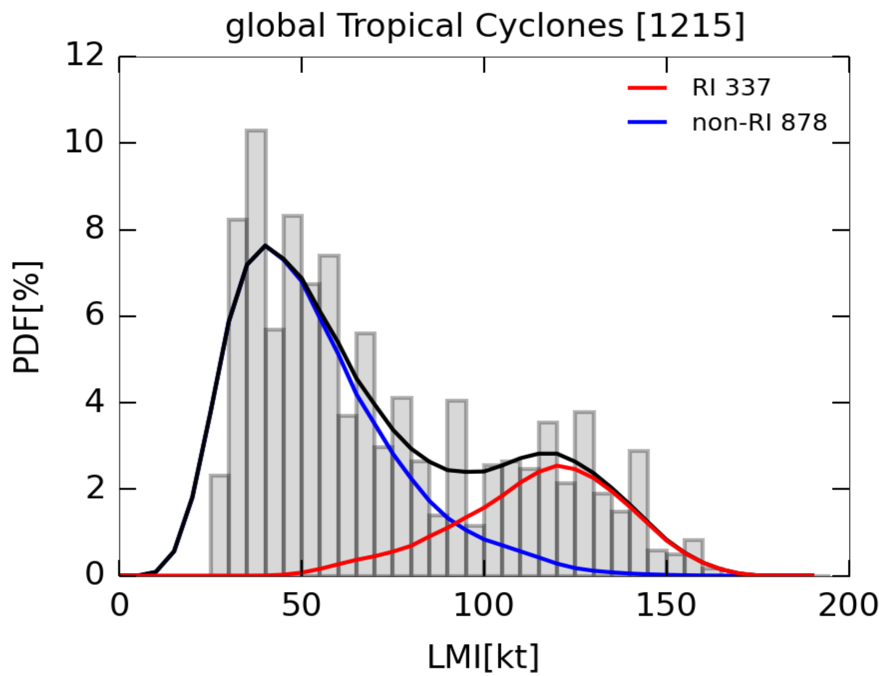


(c)

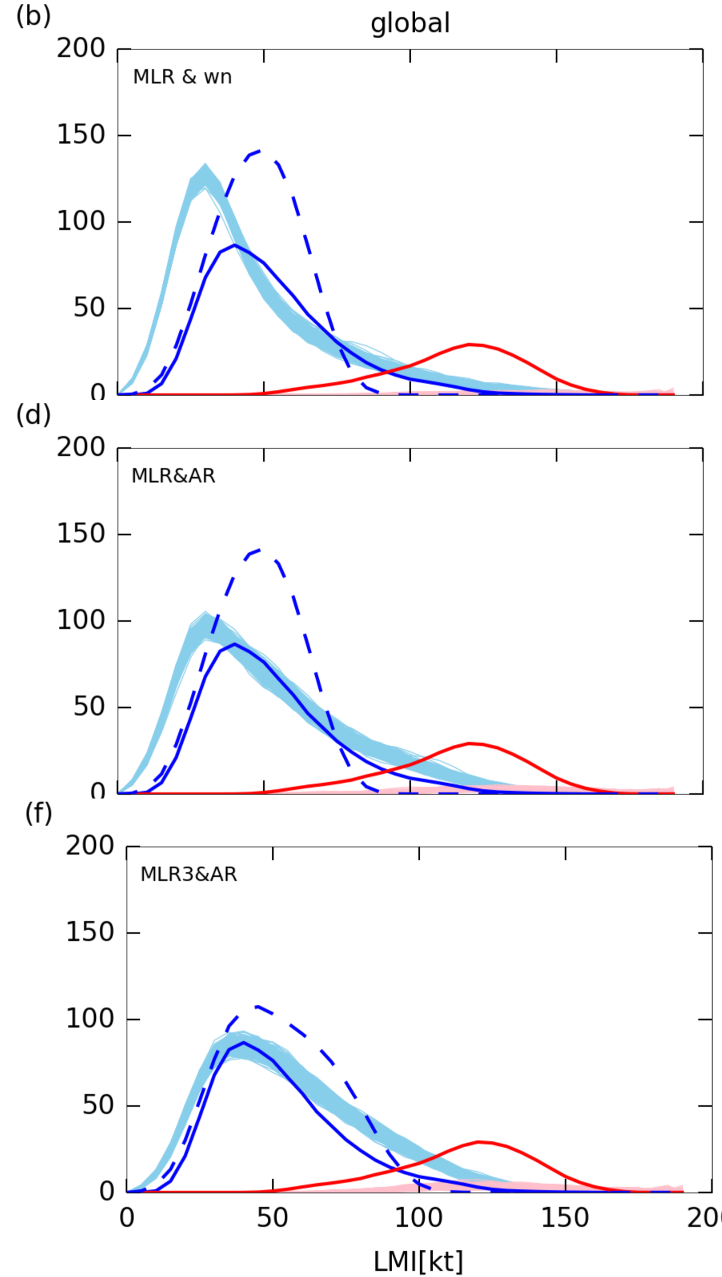




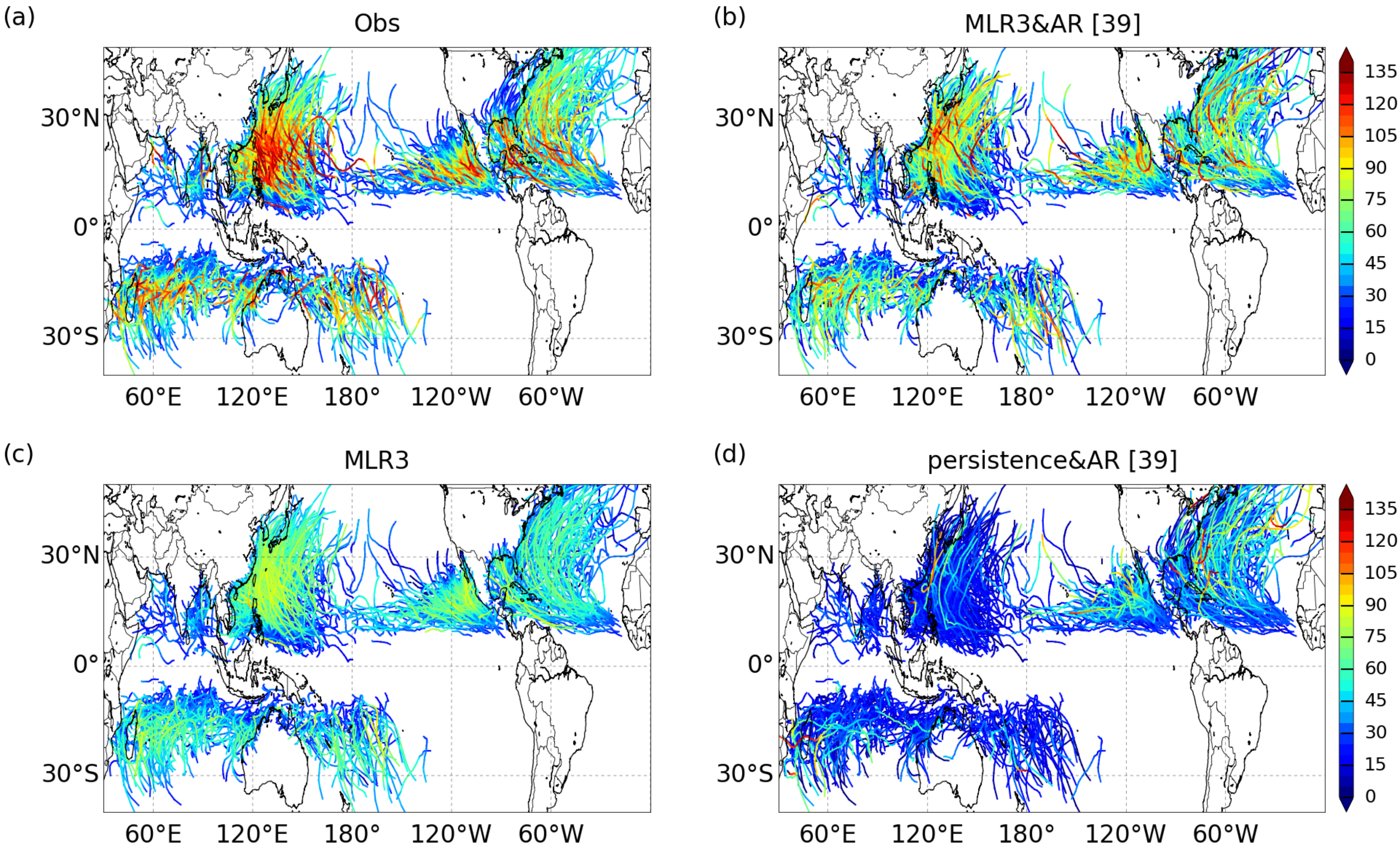
The bimodal distribution of lifetime maximum intensity has proved an interesting feature. It's due to rapid intensification!

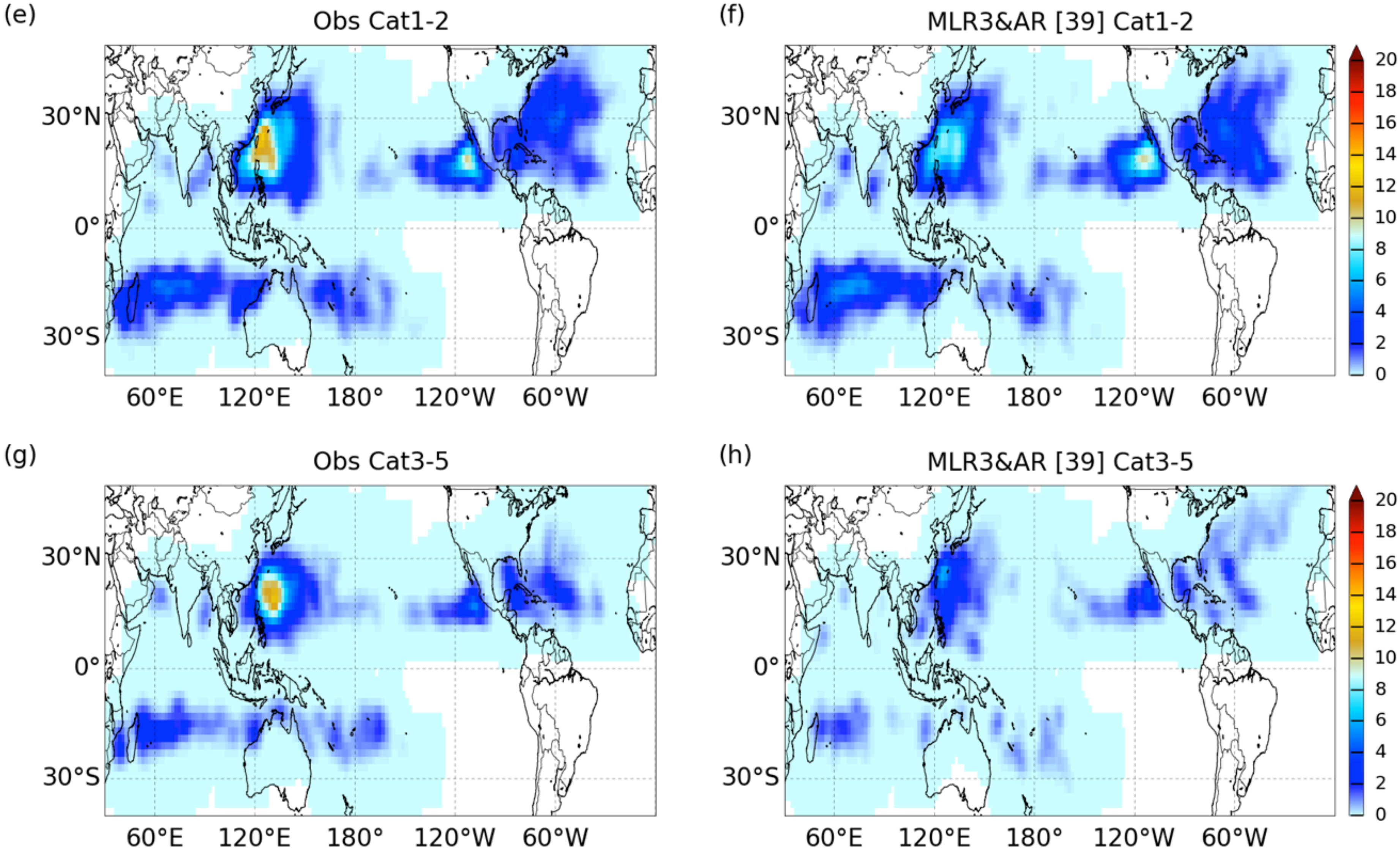


[Lee et al. 2015b, Nat Commun, (in review).]



Spatial distribution of V_{max} (not just LMI):




(e)
Obs Cat1-2
(f)
MLR3&AR [39] Cat1-2
(g)
Obs Cat3-5
(h)
MLR3&AR [39] Cat3-5
30°N
0°
30°S
60°E
120°E
180°
120°W
60°W
20
18
16
14
12
10
8
6
4
2
0

Conclusions

- We have developed a MLR model whose forecast skill is comparable to operational models (but can handle climate applications)
- We have developed a stochastic model which gives a decent simulation of the global distribution of intensities - Autocorrelation in the stochasticity is essential.
- The upper peak of the LMI distribution is due to rapid intensification. Model doesn't yet do this well enough.
- The spatial distribution of the storm intensity can be qualitatively simulated with only deterministic model. However, to be quantitatively accurate require the stochastic component.

- This current design of this model is good for its application to climate study, because we need only the first recorded storm intensity form the model, when the storm is weak and we have better confident for low-res models to get the intensity right.

Future Work

- Systematically determine appropriate level of complexity (nonlinearity, time layers) to reproduce bimodal lifetime max intensity distribution
- Thoroughly evaluate global model for all basins

- Synthetic track model
- Add TC size & landfall components to the model
- Collaborations!