The 3rd Research Meeting of Ultrahigh Precision Meso-Scale Weather Prediction
Kobe, Japan
2013/03/21

非静力学4次元変分法データ同化システムの高度化

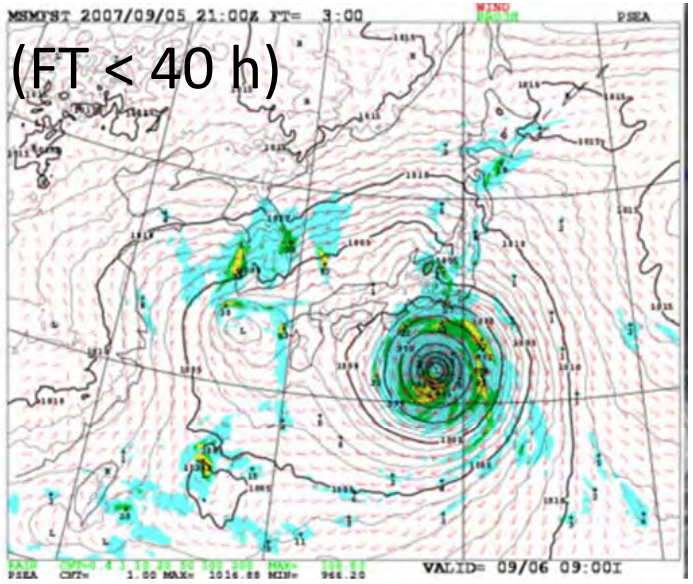
Development of nonhydrostatic meso 4D-VAR data assimilation system

Kosuke Ito

JAMSTEC, Japan

Acknowledgements: Takuya Kawabata, Yuki Honda, Teruyuki Kato, Yoichi Ishikawa, Toshiyuki Awaji, Kazuo Saito and Chun-Chieh Wu

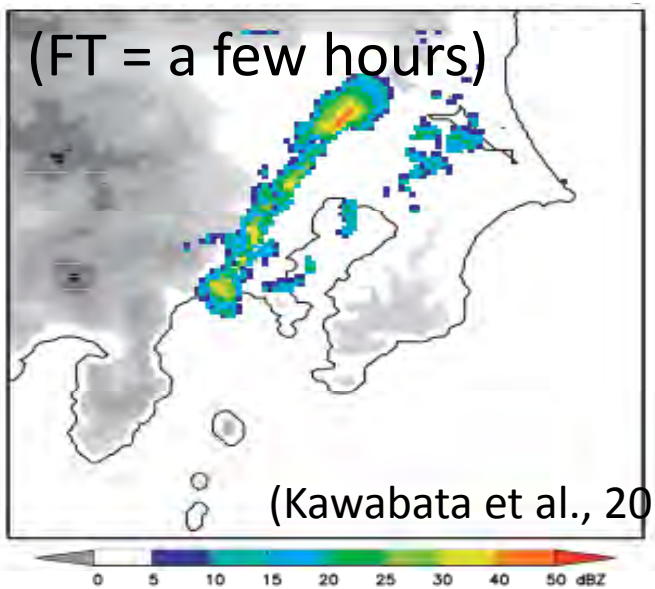
JNoVA (⊿x=5km, 15km; 4D-VAR; MPI)



In this talk

Nhm-4dvar (⊿x=2km; 4D-VAR; no MPI)

conventional obs + reflectivity + lidar + slant_delay + etc



Toward further improvement

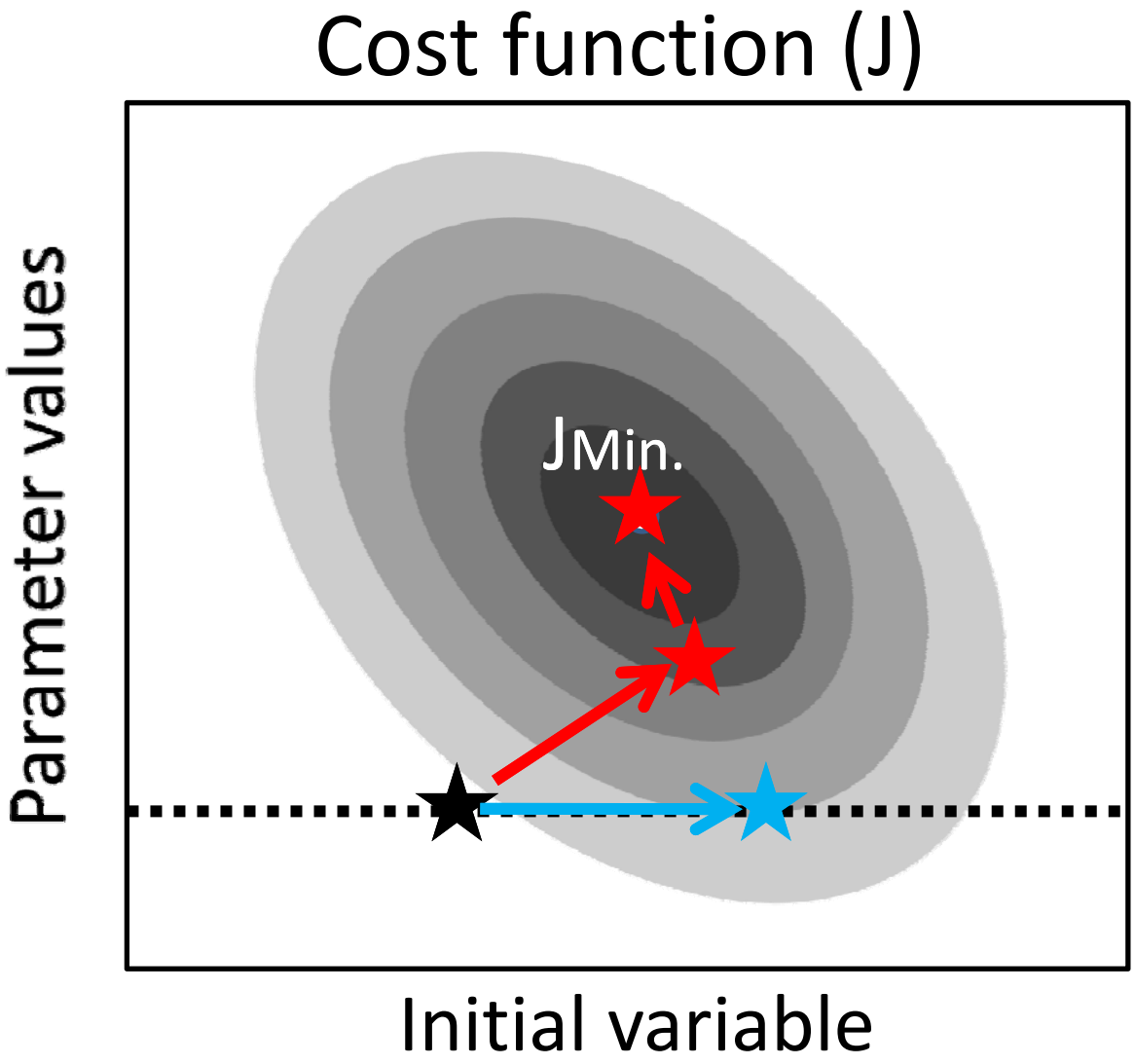
- Unified model (previous talk by Kawabata-san)
- Parameter optimization
- Coupling to the ocean model

In this talk

- Weak constraint
- Hybrid EnKF-4DVAR system

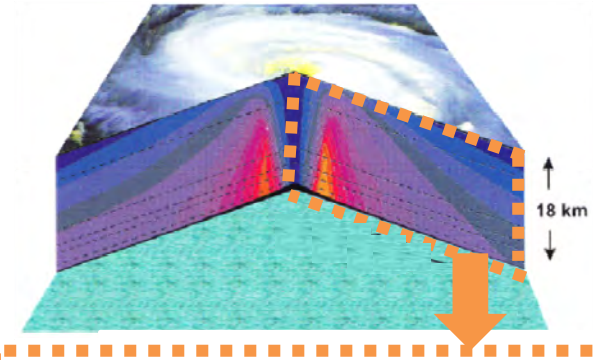
Simultaneous optimization of air-sea exchange coefficients and initial condition around a tropical cyclone (TC)

Simultaneous optimization:
Schematic illustration in the phase space



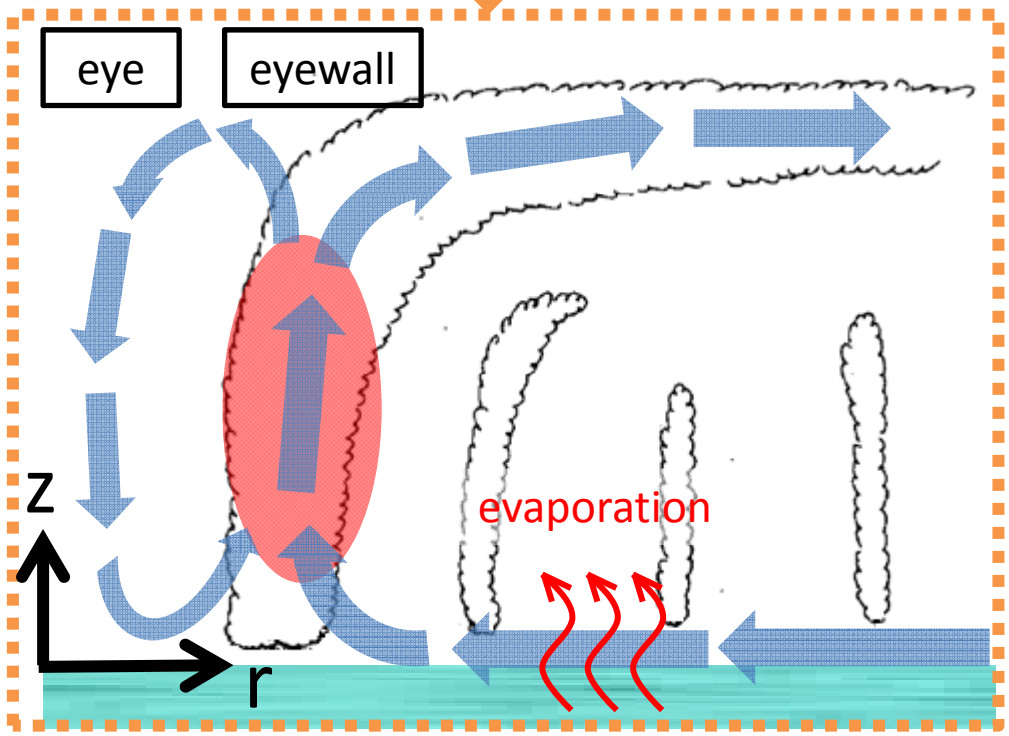
Air-sea exchange coefficients and TC intensity

- For simplicity, consider an axisymmetric TC-like vortex with an eye.



Max. wind speed in equilibrium (Emanuel, 1986)

$$V_{\max} = \sqrt{\frac{T_s - T_o}{T_o}\frac{C_k}{C_D}(k_o^* - k_a)}$$



C_k: Heat exchange coef.

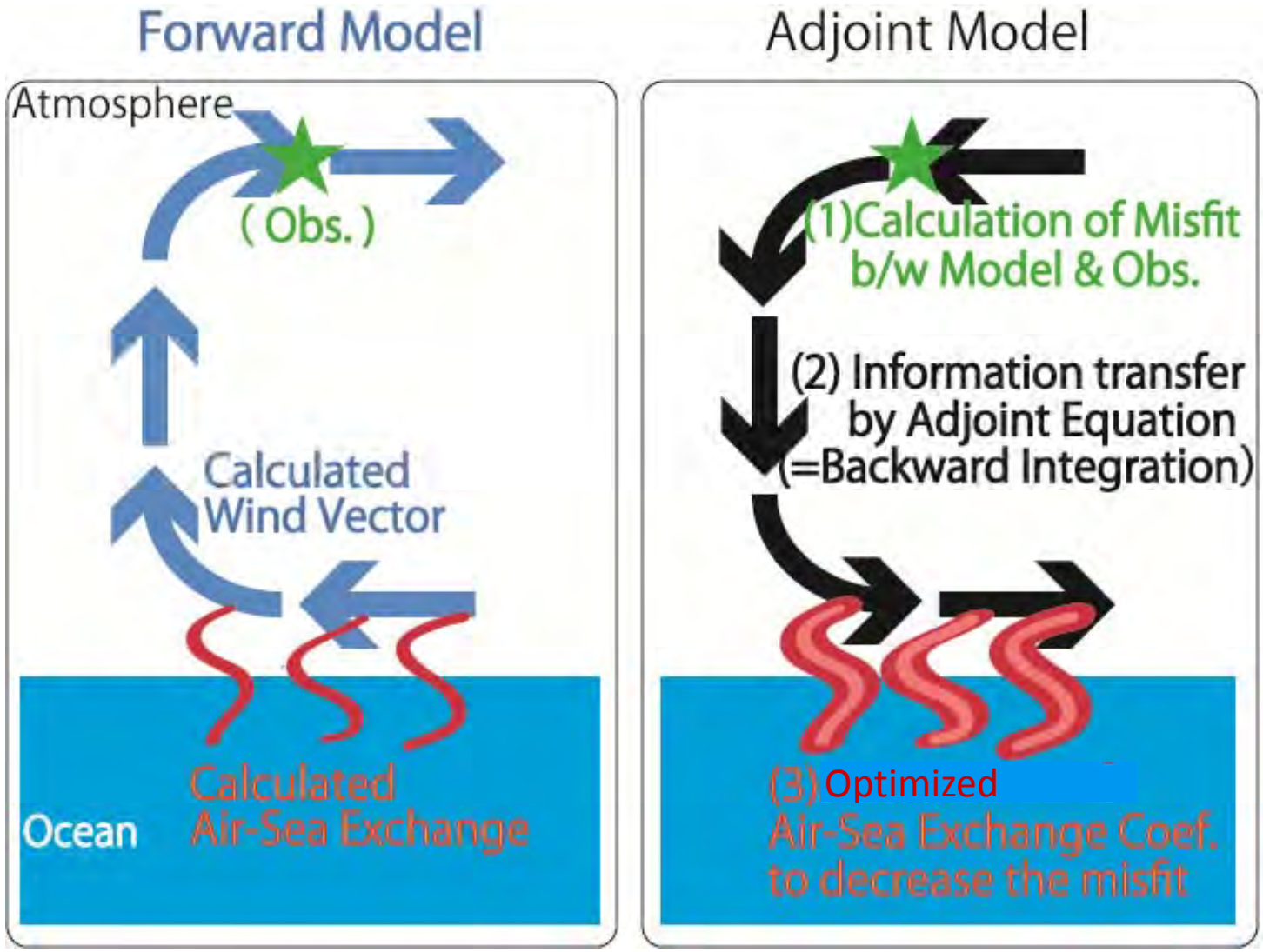
(~C_E: latent heat exchange)

C_D: Drag coef.

(Determining the magnitude of frictional force)

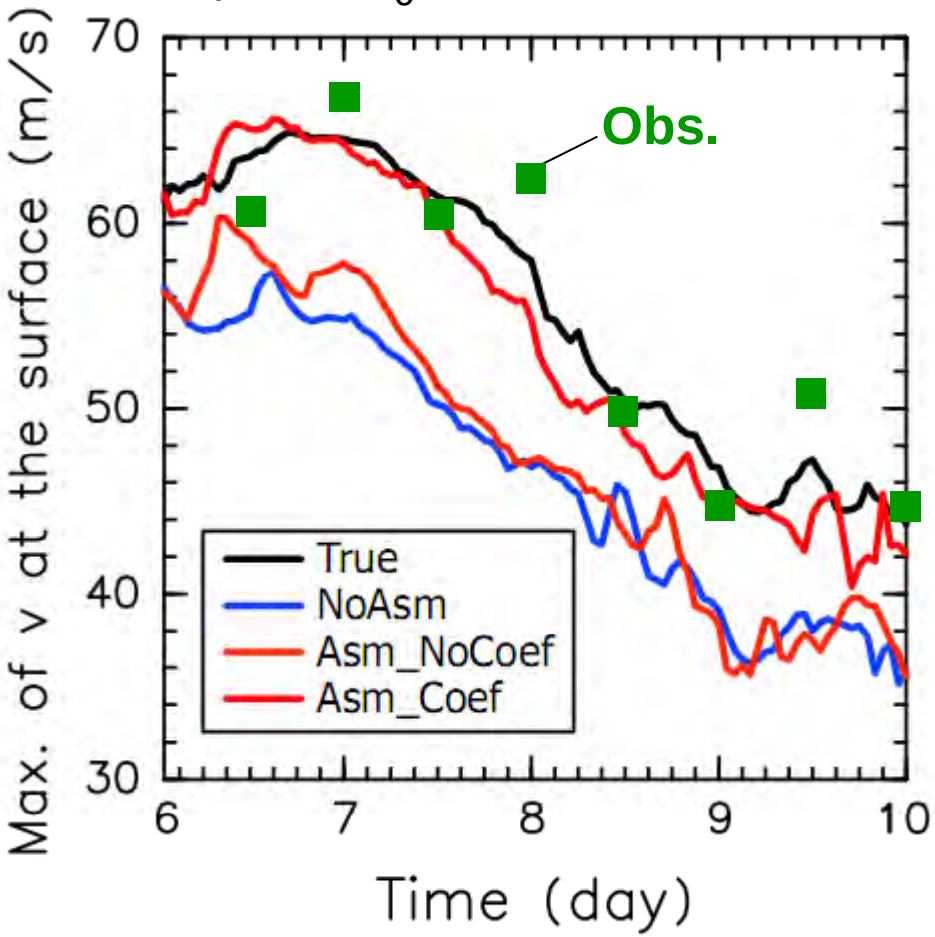
Schematic diagram: Optimization of C_D and C_E

(For simplicity, consider an advection-diffusion eqs.)



Idealized 4D-VAR experiment: Axisymmetric TC case (Ito et al., 2010)

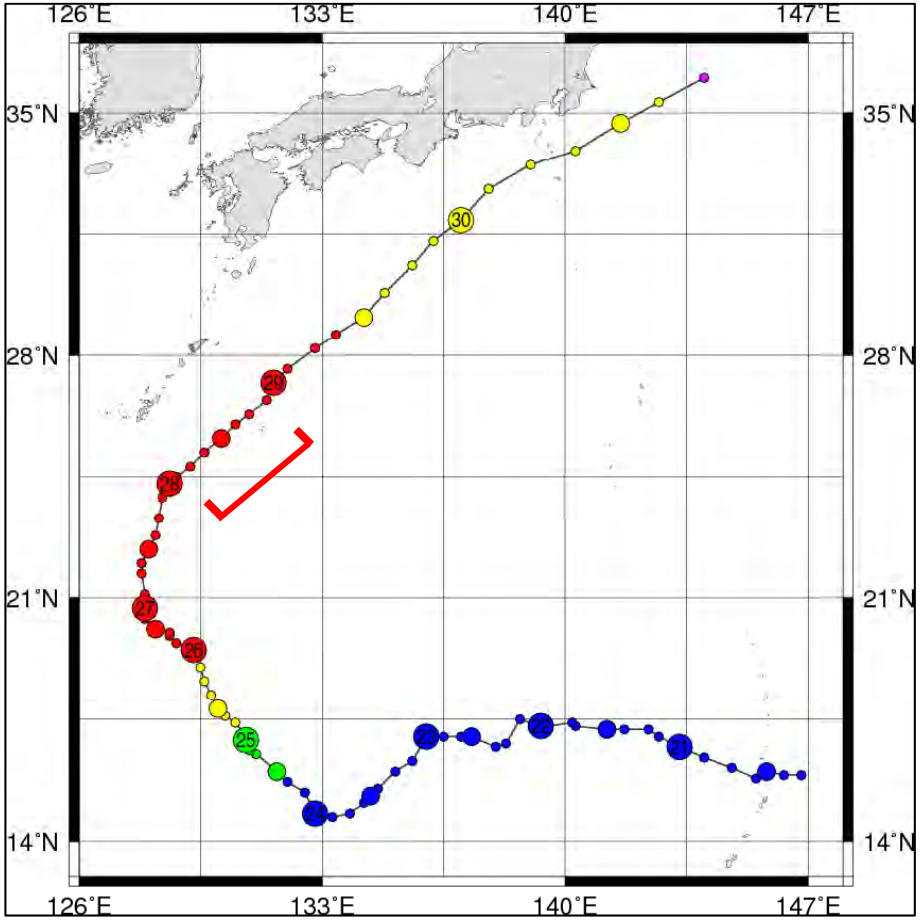
Maximum Tangential Wind Speed V_θ at the surface



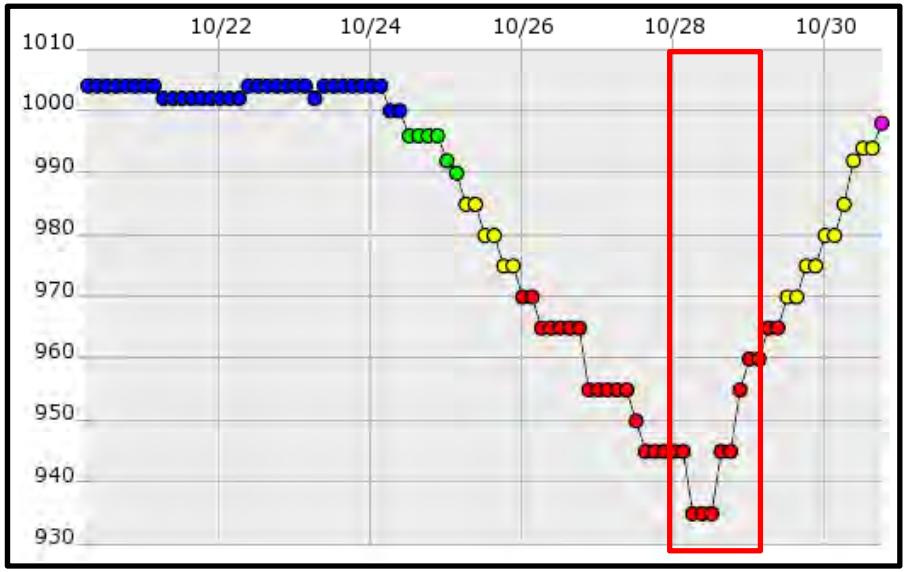
- RMSE from "True" case
  - "NoAsm": 8.9 m/s
  - "Asm_NoCoef" 7.9 m/s
  - "Asm_Coef" 2.1 m/s
- TC intensity largely controlled by C_D and C_E.

Application to the operational mesoscale DA system (JNoVA) used in JMA: TC Chaba (2010)

Typhoon Chaba's track



Minimum sea level pressure (hPa)



（Digital Typhoon Archives）

Framework of DA experiments

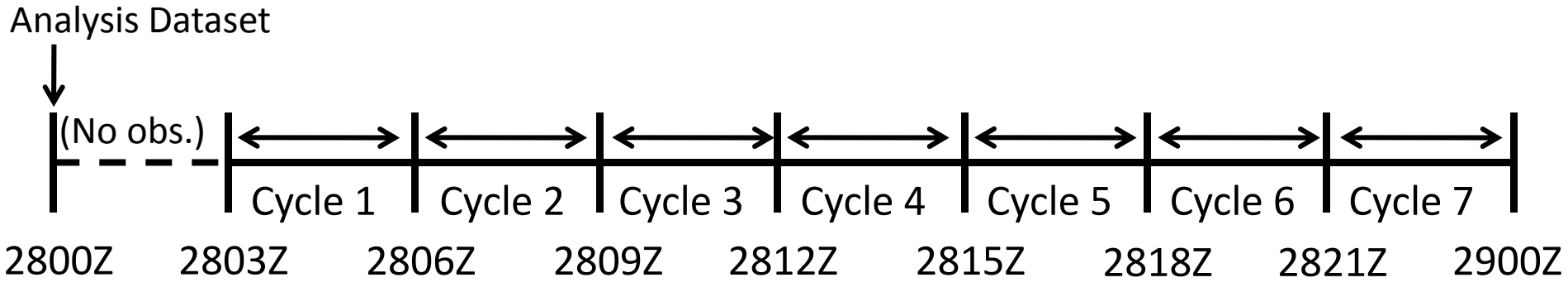
- JMA Nonhydrostatic Variational DA system (JNoVA) used for daily forecasts. ⊿x = 5km (outer loop)

  "NoCoef": Optimization of initial condition alone

  "Coef": Optimization of C_D, C_E and initial condition

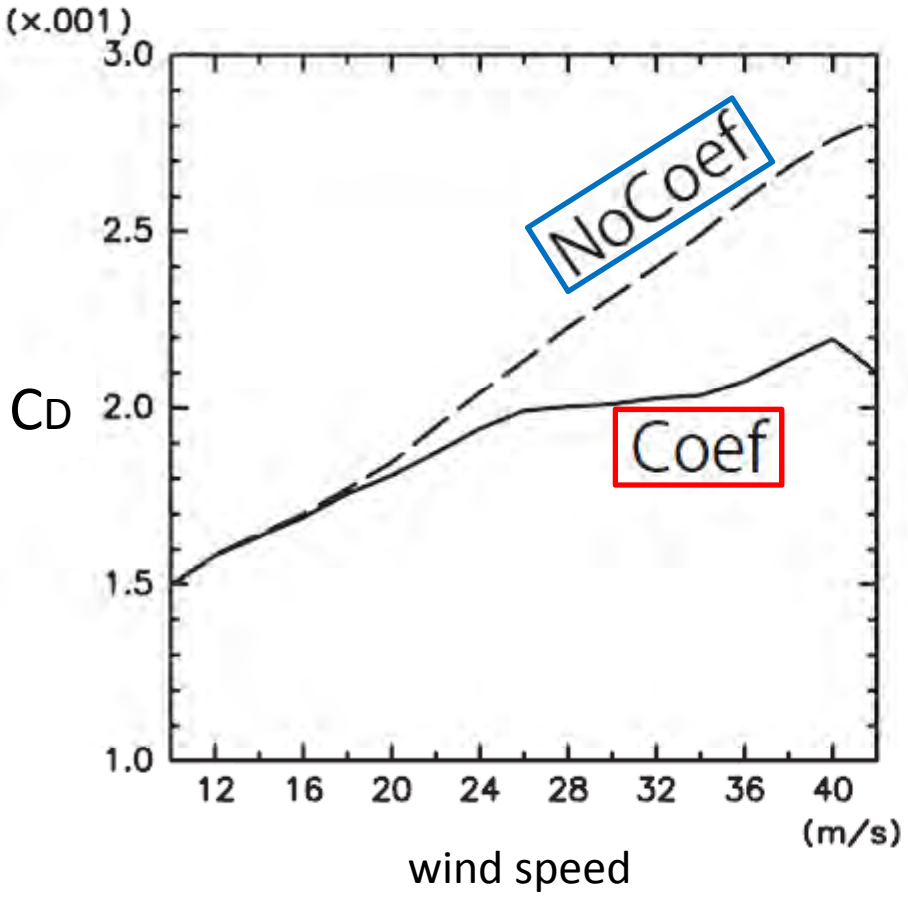
- Observational Dataset :
  Same as operational forecast archived at Japan Meteorological Agency

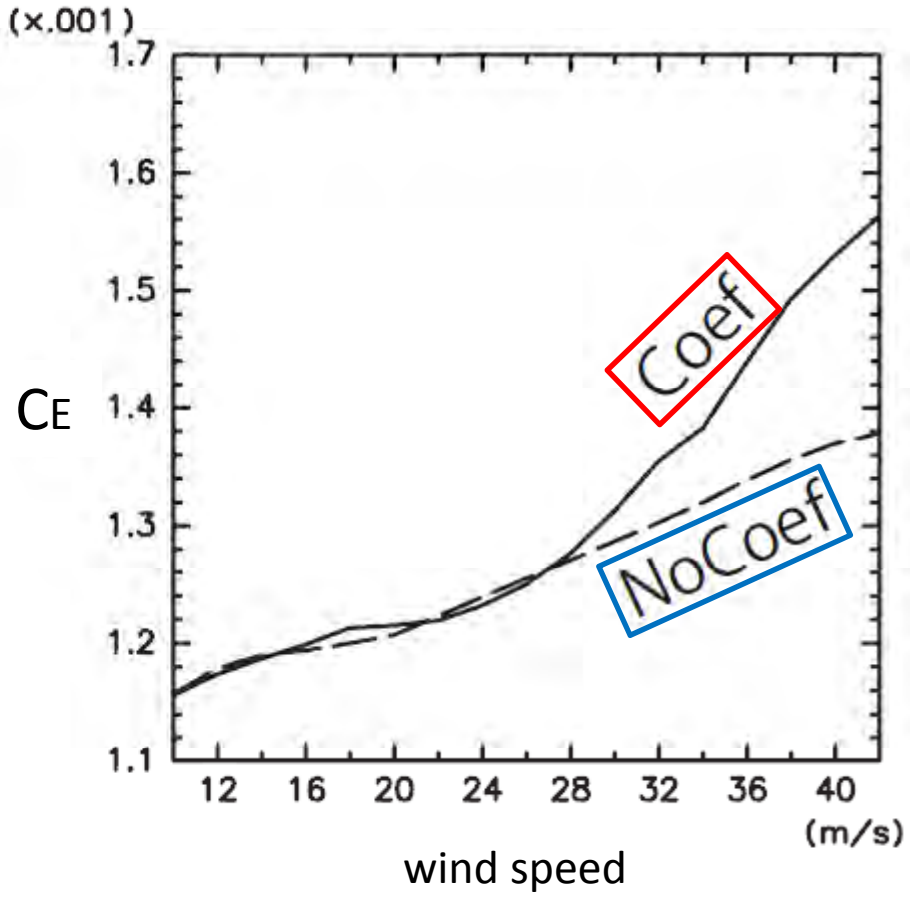
- Period of DA experiments : 21 hours => 7 Cycles
  (from 03UTC October 28 to 00UTC October 29)



C_D and C_E: Dependency on wind speed

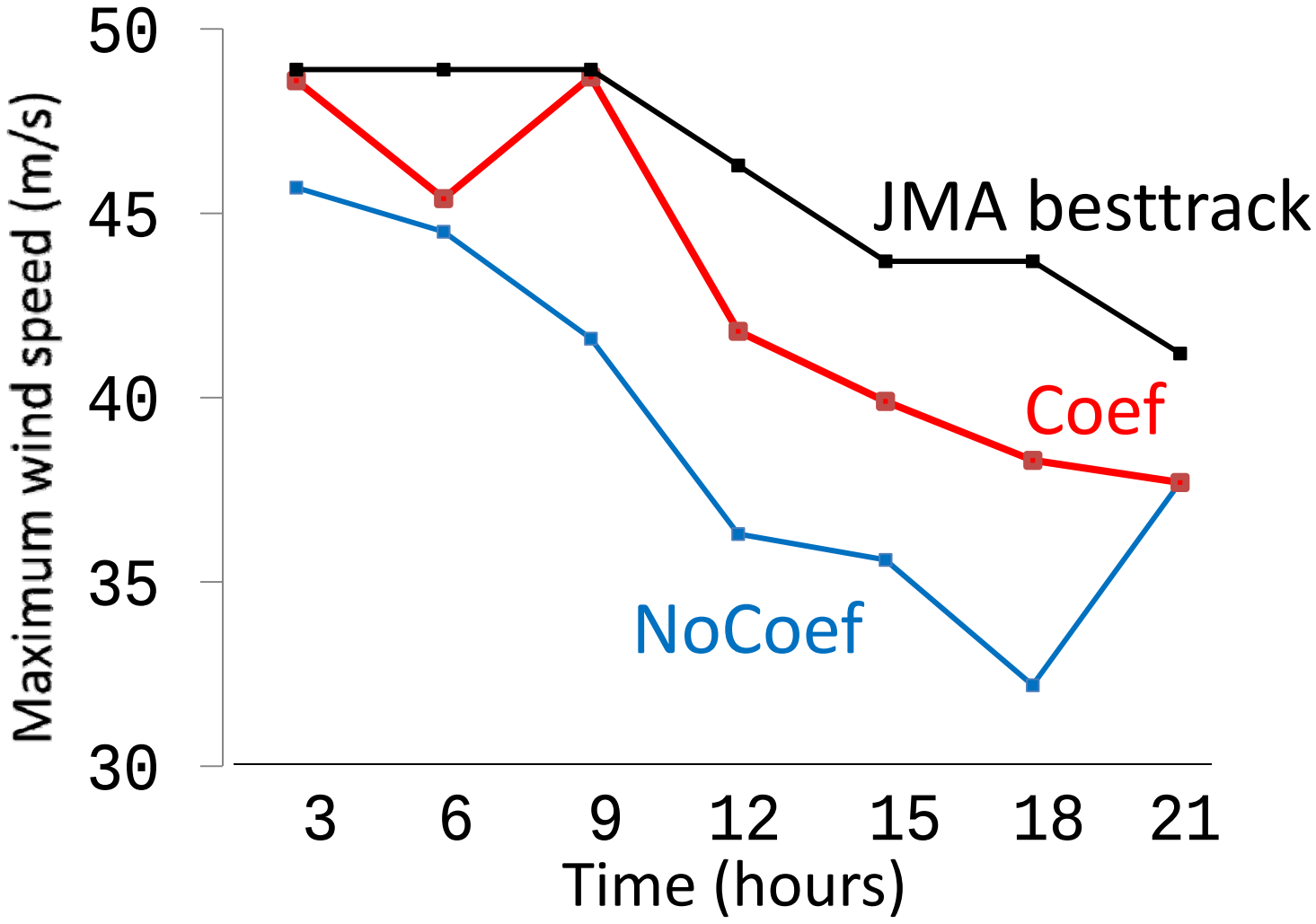
- C_D in Coef: Saturated over the wind speed of 24 m/s.
- C_E in Coef: Further enhanced (in comparison to NoCoef)





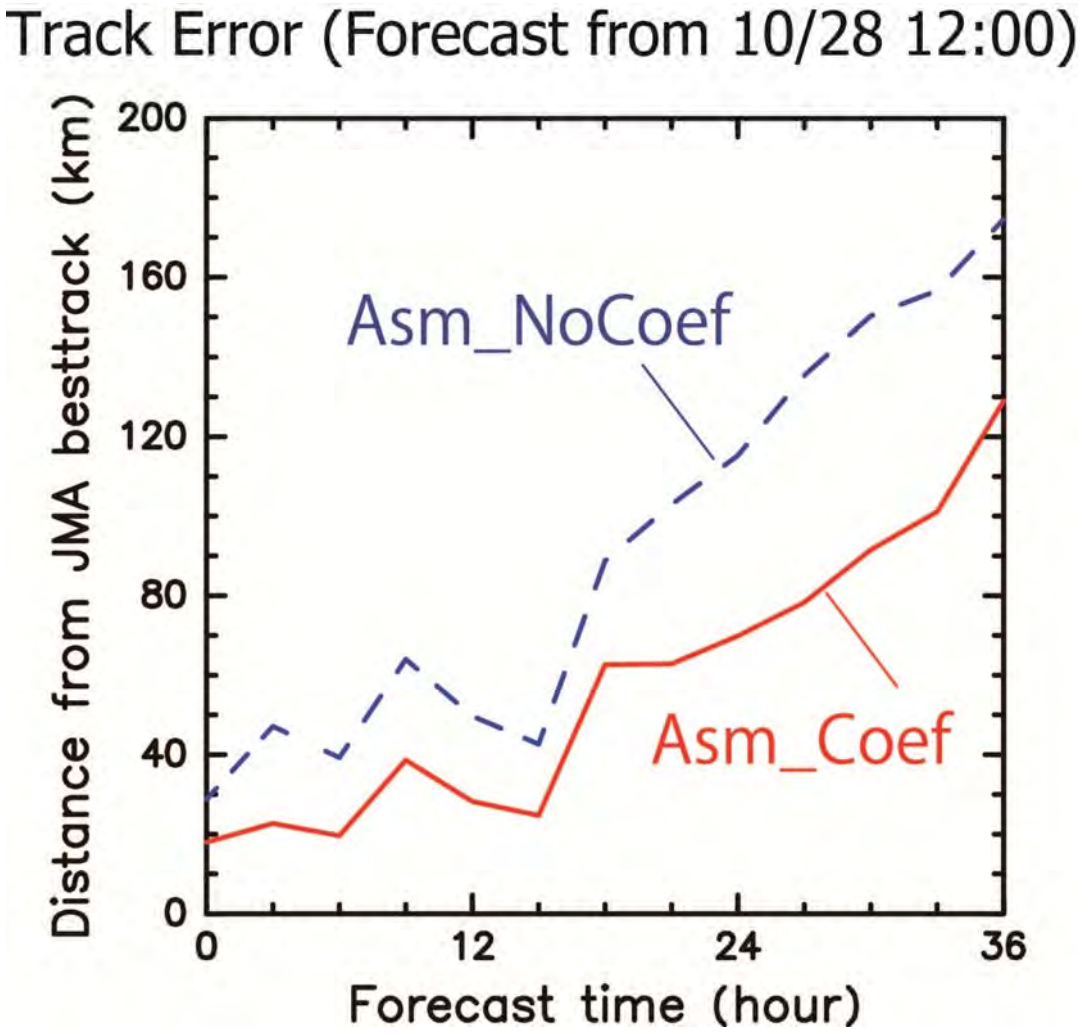
Maximum Wind Speed

- JMA Besttrack: Based on satellite and statistical data.
- Differences: |Coef-JMA|=3.6m/s, |NoCoef-JMA|=7.5m/s



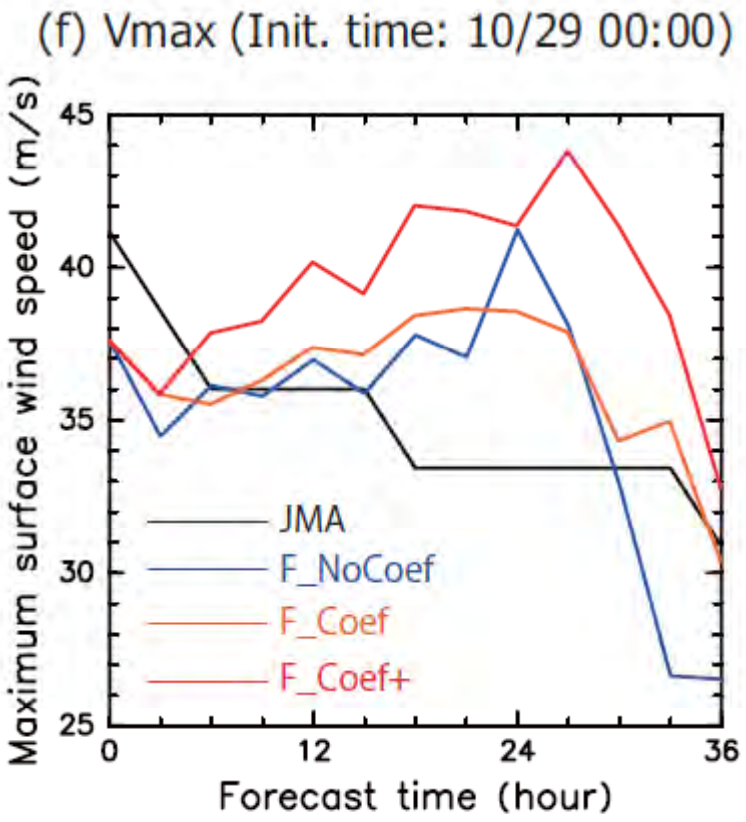
Potential impact on TC track forecast

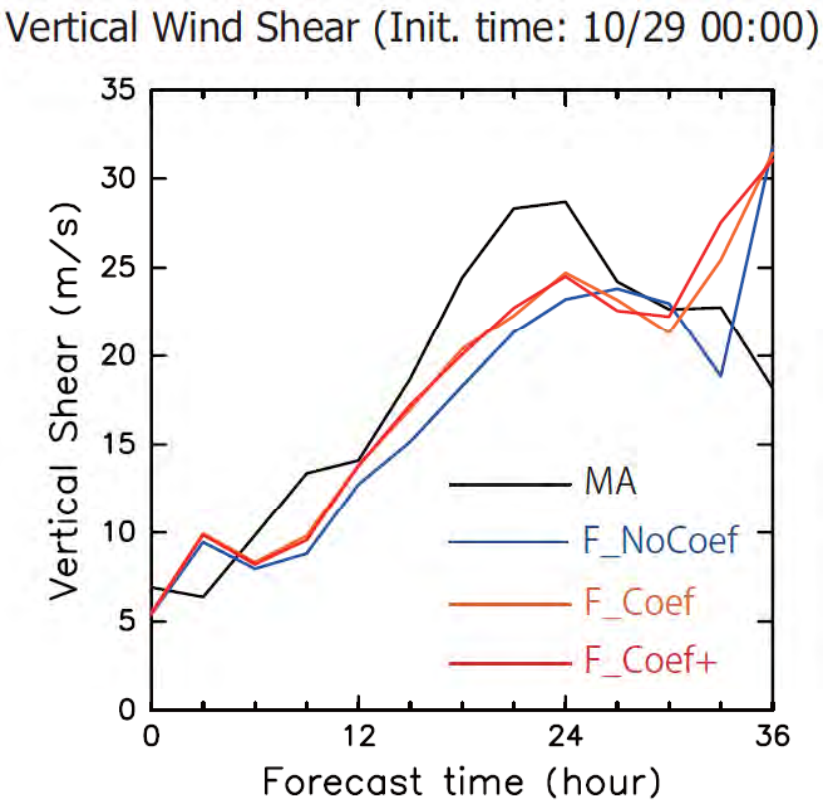
- Simultaneous optimization yields the better track forecast.



TC Intensity forecast in a decay stage

- The situation becomes more complicated.
- Several other factors (vertical shear of horizontal wind and decreases in SST) affect the TC intensity.



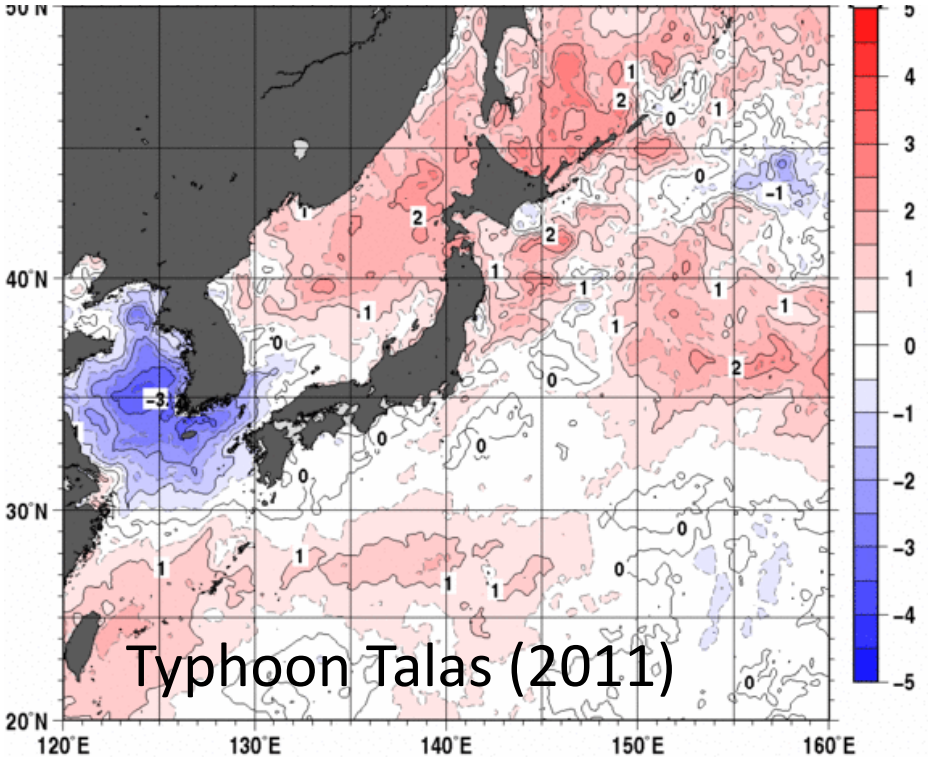


Coupling to the ocean model

TC-ocean interaction

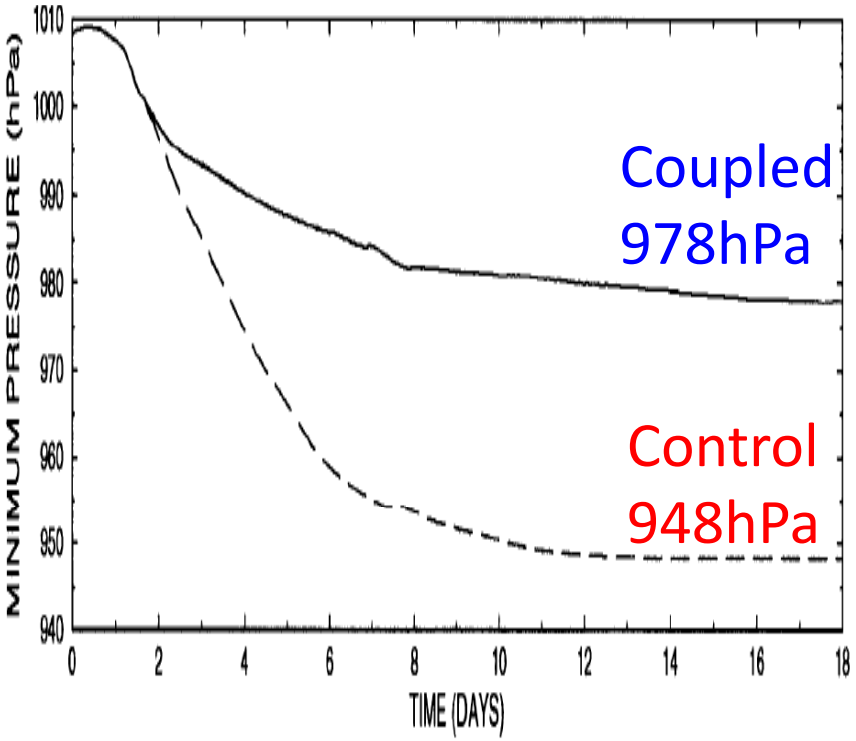
- SST decreases in the right of the TC pathway by 1-2 K.
- Negative feedback on TC intensity (e.g., Schade and Emanuel, 1999)

SST anomaly relative to the climatology (Aug. 24 – Sep. 7)



(JMA website)

Idealized numerical experiment: Minimum sea level pressure (hPa)



(Schade and Emanuel, 1999)

JNoVA using a coupled atmosphere-ocean model

- PWP model: 1-D ocean mixed layer model (Price et al., 1986)
  --> Vertical mixing due to the shear instability in the upper ocean
- It reasonably reflects the SST response to the TC forcing unless translation speed < 5 m/s
  (Emanuel et al., 2004; Yablonsky and Ginis, 2009)

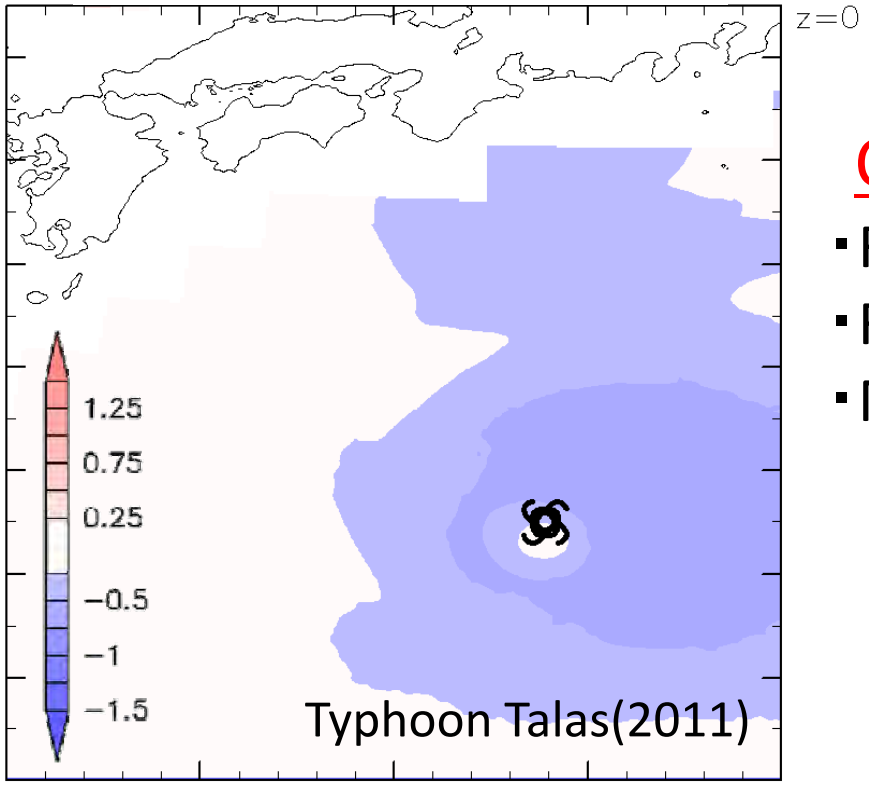
		Control	Coupled
Analysis	Outer Loop (⊿x=5km)	Atmos	Atmos+PWP
	Inner Loop (⊿x=15km)	Atmos	Atmos
Forecast		Atmos	Atmos+PWP

- Ocean Initial temperature: SST + climatology (WOA2009)
- Ocean Initial salinity and velocity: climatology (WOA2009)

JNoVA using a coupled atmosphere-ocean model

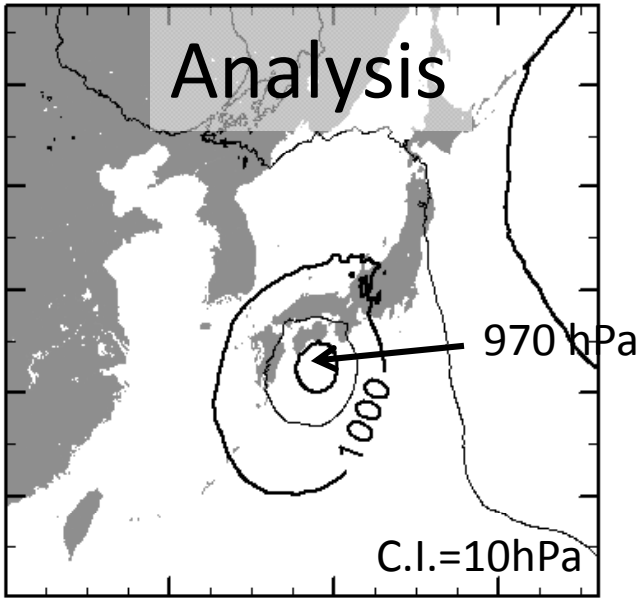
- For the case of TC Talas (2011), SST decreases by 1-2 K in the right of TC pathway (consistent with the satellite observation).

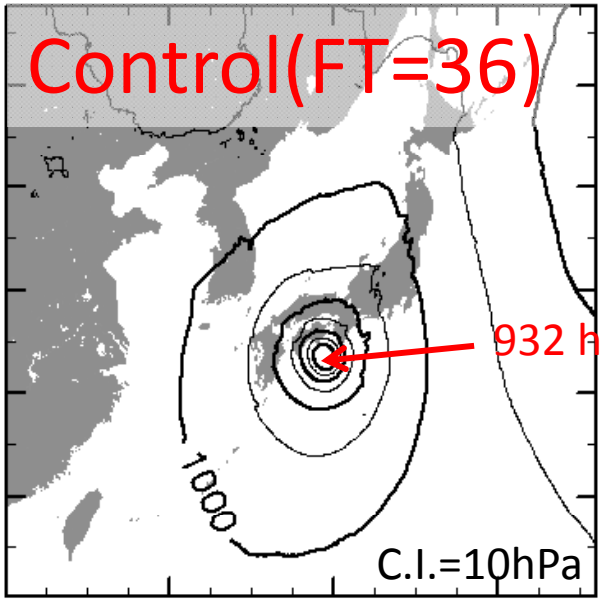
Analysis field: ⊿SST (K)

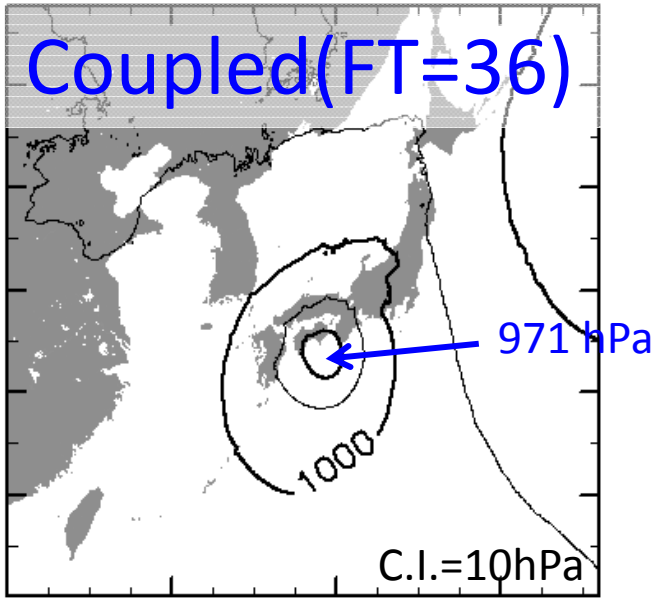


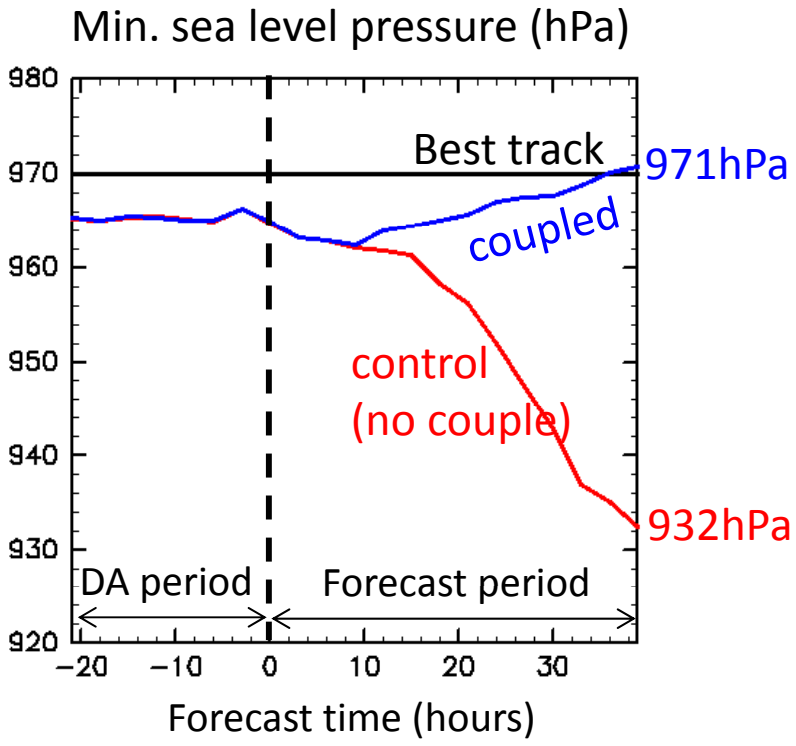
Ctrl VS Coupled (8 DA cycles)

- RMSE of Vmax: 2.26m/s → 1.72m/s
- RMSE of Pmin: 4.77hPa → 4.67hPa
- Mean of minimized J: 2431 → 2408


Analysis
970 hPa
1000
C.I.=10hPa

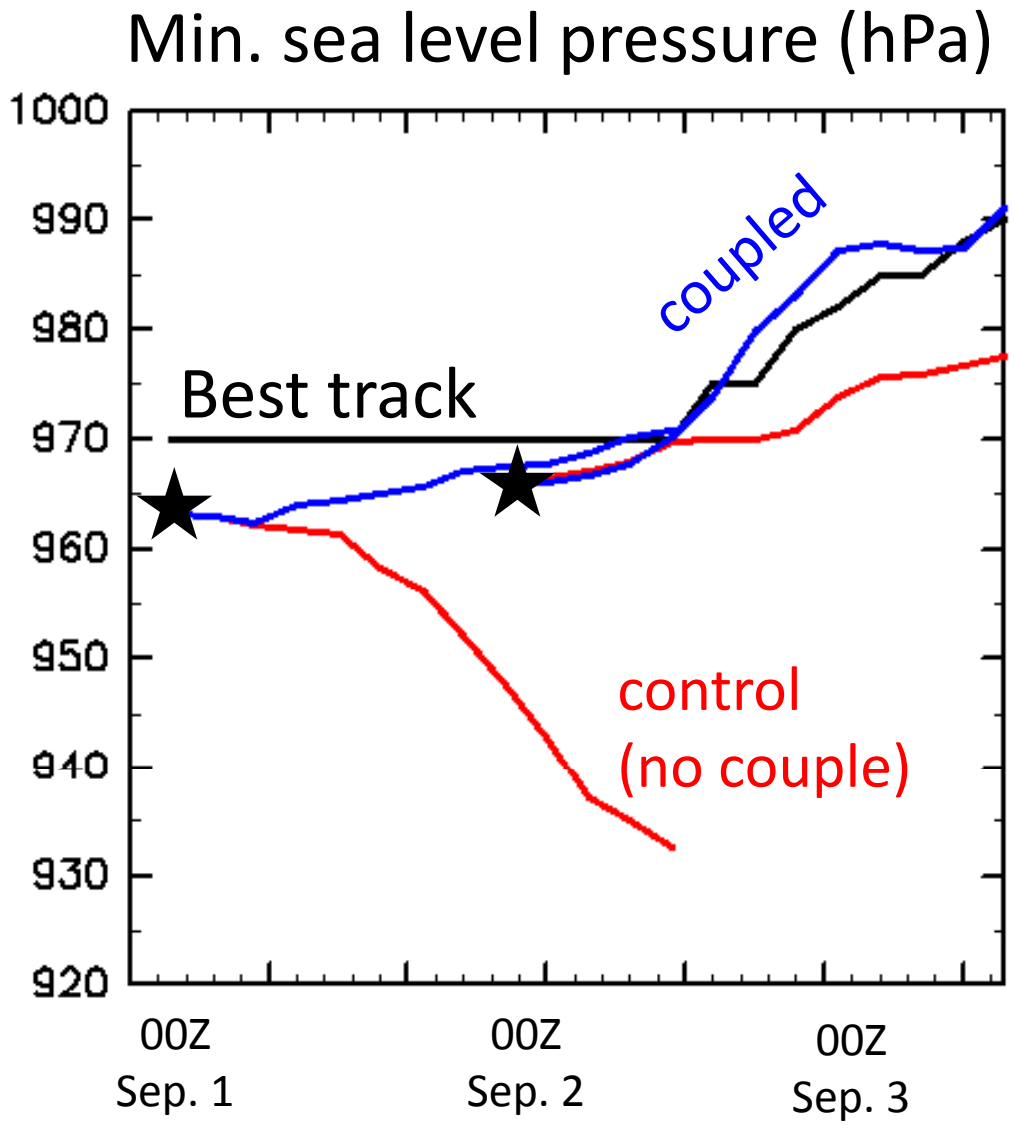

Control(FT=36)
932 hPa
1000
C.I.=10hPa


Coupled(FT=36)
971 hPa
1000
C.I.=10hPa


Min. sea level pressure (hPa)
980
970
960
950
940
930
920
Best track
971hPa
coupled
control
(no couple)
932hPa
DA period
Forecast period
−20
−10
0
10
20
30
Forecast time (hours)

Forecast experiments

(From 00Z Sep. 1 and from 00Z Sep. 2)



Summary

- Further improvements of 4D-VAR, including:
  - High-resolution unified model
  - Parameter estimation
  - Coupling to the ocean model
  - Hybrid EnKF-4DVAR
- In this talk, we show that parameter estimation and ocean coupling enhance the skill of the system.
- We plan to apply to other cases for checking the statistical superiority of the system.

Thank you.