Impact of Satellite Observations on Forecasting Sudden Stratospheric Warmings

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Introduction & Experimental Settings

◆ **JRA-55 & JRA-55C** (its equivalent assimilating **C**onventional observations only)

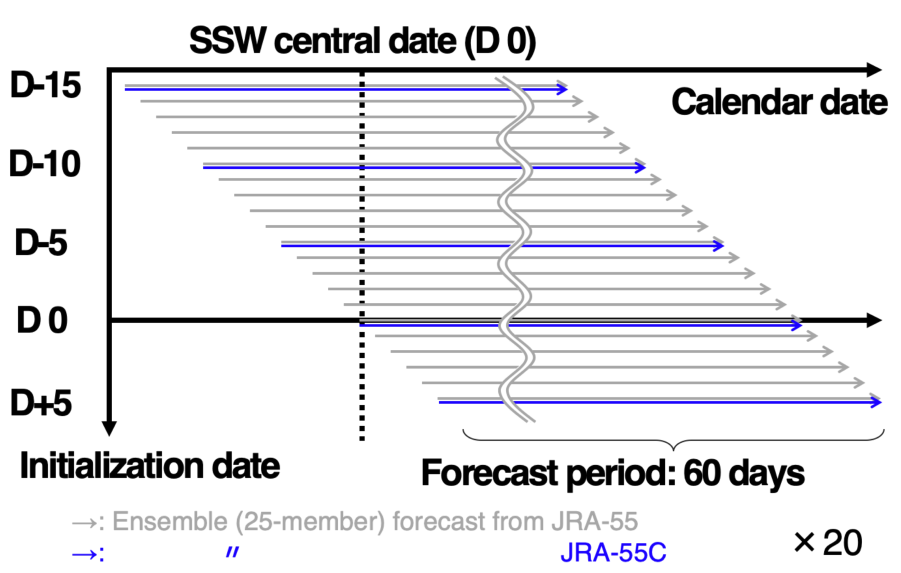
- ✓ These enable us to examine the impact of satellite data assimilation on the reproducibility of phenomena in reanalysis by simple comparisons

◆ **Large impact on an SH SSW, but not on NH SSWs in (re)analysis**

- ✓ Absence of a vortex-splitting SSW in JRA-55C Noguchi & Kobayashi (2018)
- ✓ Since the observational anchoring is stronger in NH, stratosphere-tropo. coupled variabilities are well reproduced, except for the upper stratosphere

◆ **Ensemble forecast experiment by using JRA-55 & JRA-55C**

- ✓ This study investigates the satellite impact on forecasts of NH SSWs by conducting reforecasts for 20 events (in 1978/1979–2011/2012 winters) as follows



Model: **MRI-AGCM**
(Global spectral model whose fundamental part is close to **JMA-GSM**)

Resolution	TL159 (Δ~110 km) **L60** (Top: **0.1 hPa**, Hybrid) ⟷	TL319 (Δ~55 km) **L60** (Top: **0.1 hPa**) **JRA-55** (Low resolution setting as of Dec. 2009)
SST	Initial anomaly + climatology	

Ensemble Forecast System: **MRI-EPS**
(Extended version of the JMA operational 1-month forecast system)

Perturb. Method	Breeding of Growing Modes
Initial Condition (25 members)	1 Control run (from **JRA-55/55C**) 24 Perturbed runs (〃 ± ptb {#1-12})

Almost same as Noguchi et al. (2016)

Impact on Forecasting the Onset of SSWs

◆ **~20% decrease of SSW capture rate in forecasts from D-5**

- ✓ JRA-55 fcsts initialized after D-5 can predict SSW onset deterministically
- ✓ Skill beyond one week depends strongly on cases
- ✓ At lead times beyond one week, the impact from the difference in the initial conditions would be hidden in nonlinear growth of forecast errors

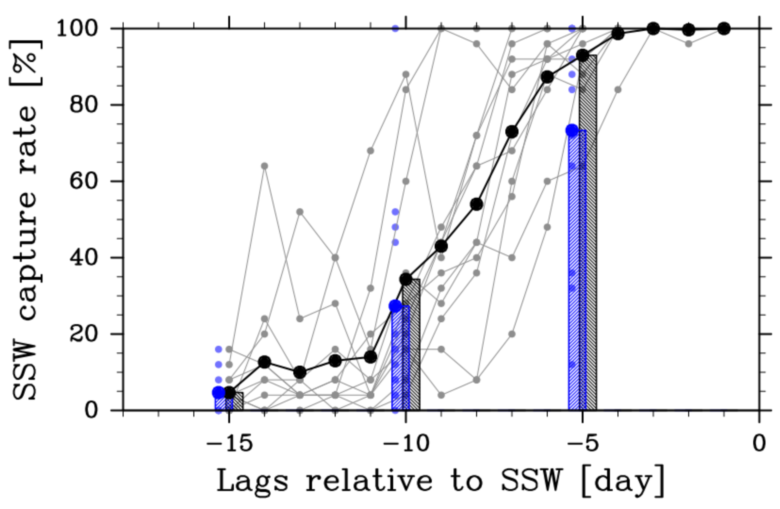


Figure 1. Percentage of ensemble members that predict the reversal of zonal-mean zonal wind within ±3 days of the onset date of SSW. Capture rate of forecasts starting from D-15 to D-1 for 12 prominent* SSW events (JRA-55: gray lines with circles, JRA-55C: blue lines with circles), the average (JRA-55: black line with circle). The values of forecasts starting from D-15, D-10, D-5 are also shown (JRA-55: gray bars, JRA-55C: blue bars).

*Events which show under -10 m s^{-1} easterly within 5 days after D0

Impact on Forecasting Anomalies After SSWs

◆ **Positive (but significant only 5–10 days after the initialization)**

- ✓ Longer predictable period in the stratosphere (~25–27 days if forecasts are initialized after D-5) compared to that in the troposphere (~7–9 days)
- ✓ Large (but not always significant) improvements of the forecasts could be found in the stratosphere after the onset of the SSW in D-15 & D-10 forecasts

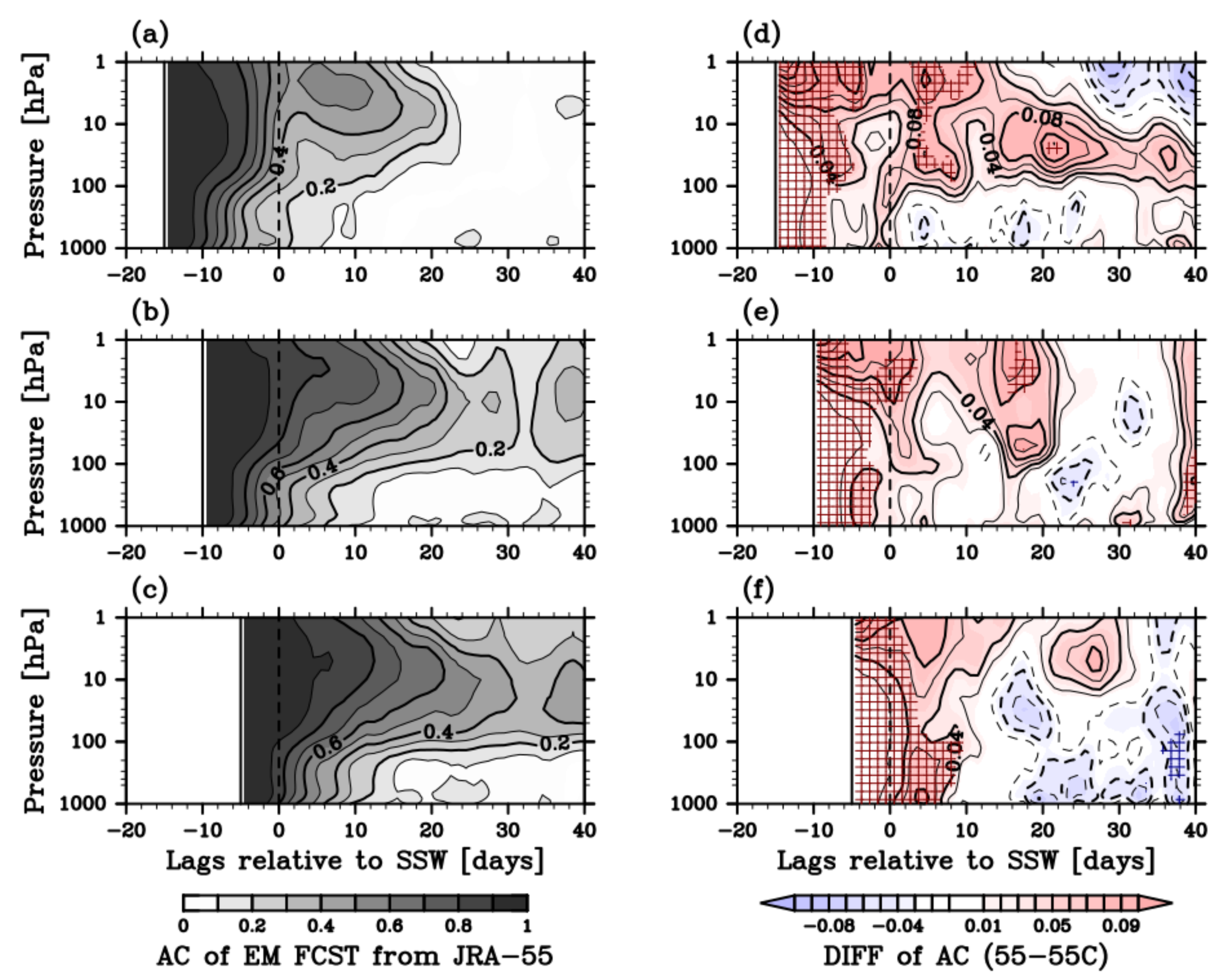


Figure 2. Time-height cross sections of the forecast skill measured by Anomaly Correlation (AC) coefficient (validated by JRA-55) for geopotential height fields in the NH (north of 20°N). Forecast results from D-15, D-10, D-5 are distributed from top to bottom. D0 is represented by a vertical broken line. **(a)–(c)** Composite AC coefficient of ensemble mean JRA-55 forecasts averaged for all (20) SSWs. **(d)–(f)** Differences of averaged AC coefficient of ensemble mean JRA-55 forecasts from those of JRA-55C forecasts. The hatched regions are where the difference is significant at 95% confidence (estimated by Welch's *t*-test).

Summary

◆ The upper stratospheric initial conditions play an important role in forecasting the onset and development of SSWs

◆ The 5-day lead capture rate of the onset of major SSW (wind-reversal) degrades ~20% if satellite data are not assimilated

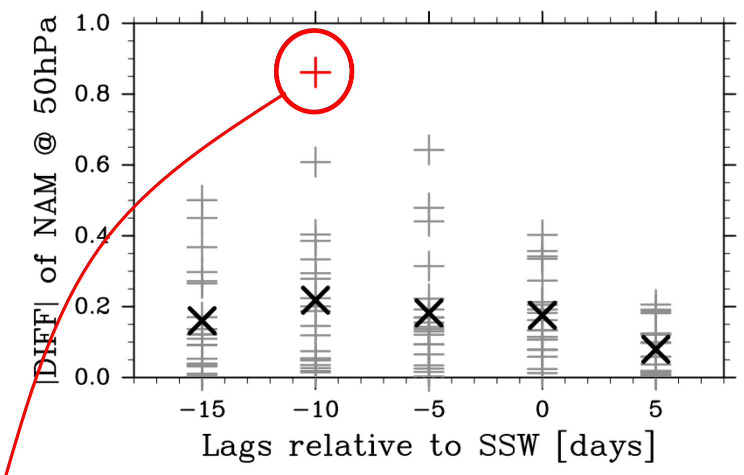
◆ The absence of satellite observations could affect the extended-range forecast skill related to stratospheric downward influences

Details of the Impact in an Extreme Case

◆ **Initial upper S. diff. triggers completely different time evolution**

- ✓ A failure to capture SSW in JRA-55C fcst is clear, although JRA-55C is not so bad
- ✓ The polar vortex in the JRA-55 fcst splits into two pieces with almost barotropic structure, while the JRA-55C fcst holds its shape as a single vortex
- ✓ The growth of EPFz slows down after D-7 in the JRA-55C forecast

Figure 3. Satellite impact on forecasts of lower stratospheric circulation after SSWs. Absolute differences (gray crosses) between JRA-55 and JRA-55C forecasts and averaged differences (black crosses) of the normalized polar-cap (north of 60°N) height anomalies at 50 hPa for approximately one month after SSWs (from D+5 to D+35).



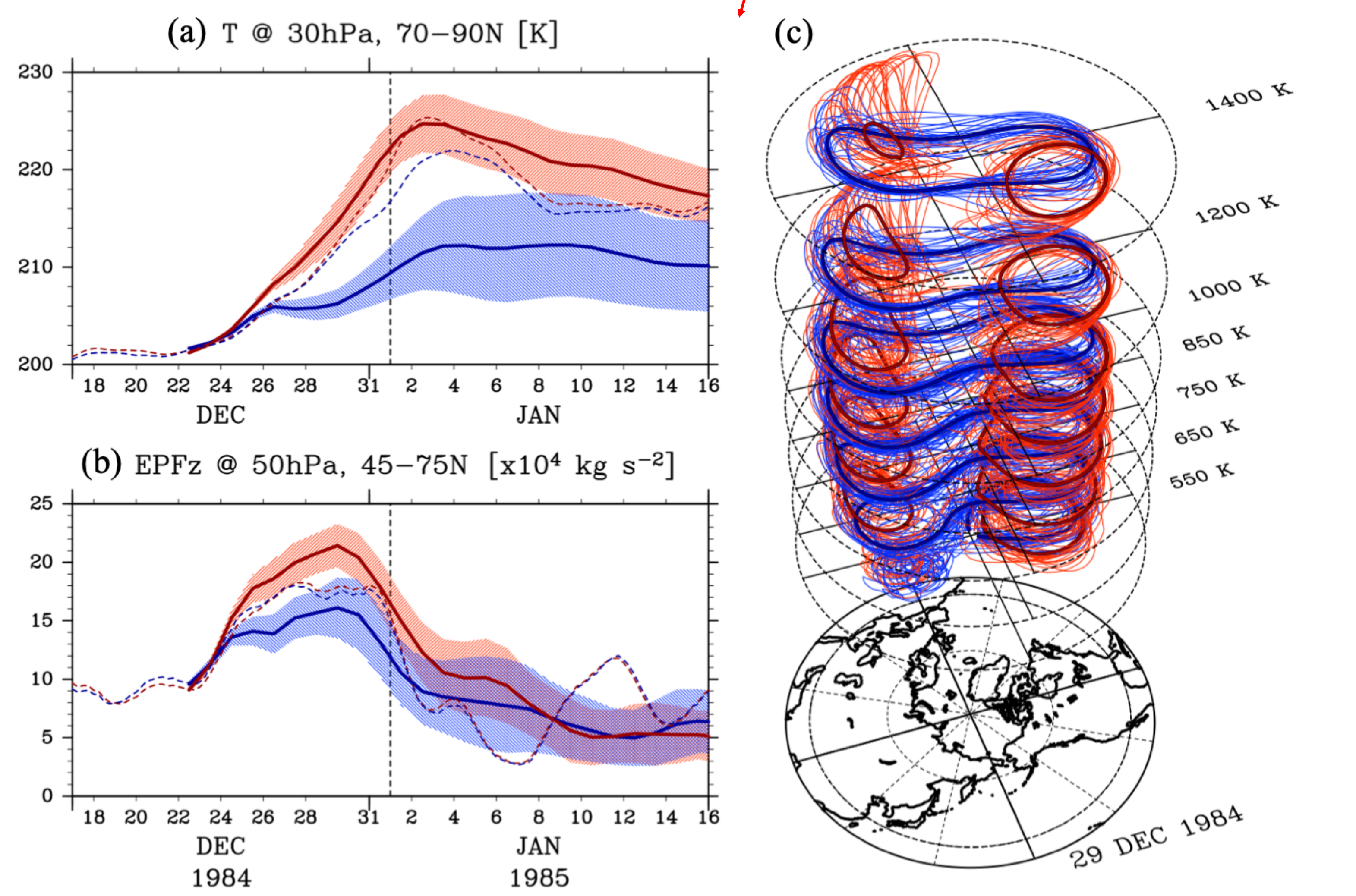


Figure 4. Satellite impact on forecasts of SSW onset in an extreme case. JRA-55 (red line) and JRA-55C (blue line) ensemble forecasts starting from D-10 are shown for an SSW occurred on 1 January 1985. Time series of **(a)** 30-hPa temperature averaged northward of 70°N and **(b)** vertical component of 50-hPa Eliassen-Palm (E-P) flux averaged over 45–75°N, from D-15 to D+15. Thick lines and shades indicate the ensemble mean values and 0.5 standard deviations among ensemble members. JRA-55 and JRA-55C are also shown by dotted lines. **(c)** Three-dimensional distributions of the vortex edges (isolines of the vertically weighted potential vorticity), of the stratospheric polar vortex, for a 7-day forecast field (validated at D-3). As a vortex edge, 38 PVU contours of Lait's PV at isothermal surfaces are plotted for each ensemble forecasts. Thick lines indicate the ensemble means.

- ✓ Due to the absence of observational corrections near the model top, the convergence of E-P flux in the upper stratosphere just after the initialization is prevented by a too strong westerly mean-wind field (the uncured bias of JRA-55)

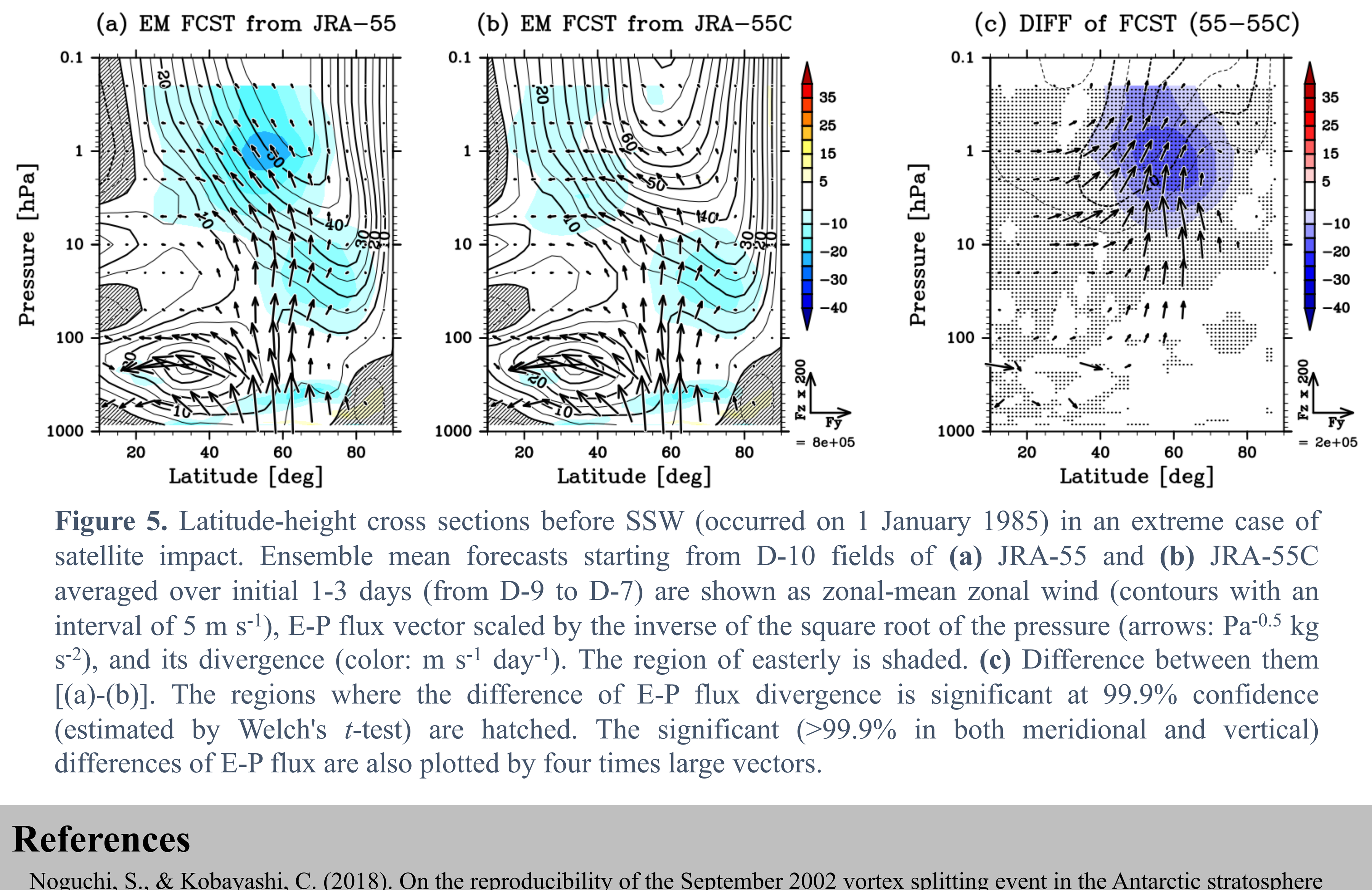


Figure 5. Latitude-height cross sections before SSW (occurred on 1 January 1985) in an extreme case of satellite impact. Ensemble mean forecasts starting from D-10 fields of **(a)** JRA-55 and **(b)** JRA-55C averaged over initial 1-3 days (from D-9 to D-7) are shown as zonal-mean zonal wind (contours with an interval of 5 m s^{-1}), E-P flux vector scaled by the inverse of the square root of the pressure (arrows: Pa$^{-0.5}$ kg s^{-2}), and its divergence (color: m s^{-1} day^{-1}). The region of easterly is shaded. **(c)** Difference between them [(a)-(b)]. The regions where the difference of E-P flux divergence is significant at 99.9% confidence (estimated by Welch's *t*-test) are hatched. The significant (>99.9% in both meridional and vertical) differences of E-P flux are also plotted by four times large vectors.

References

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Preprint of this work can be found in ESSOAr: https://doi.org/10.1002/essoar.10501209.1