Fifth Session of the East Asia winter Climate Outlook Forum (EASCOF-5)
8 – 10 November 2017 @ Tokyo, Japan

Session 2: Climate variations associated with the East Asian monsoon (I)

Predictability of the Polar-night Jet Oscillation and Its Impact on the Skill of Tropospheric Forecasts

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Outline

1. (Quick) Review of the Predictability of Stratospheric Extreme Events and Their Influence on the Tropospheric Climate

2. Examination of Extended-range Forecast Skills from the View of Polar-nigh Jet Oscillation (PJO)

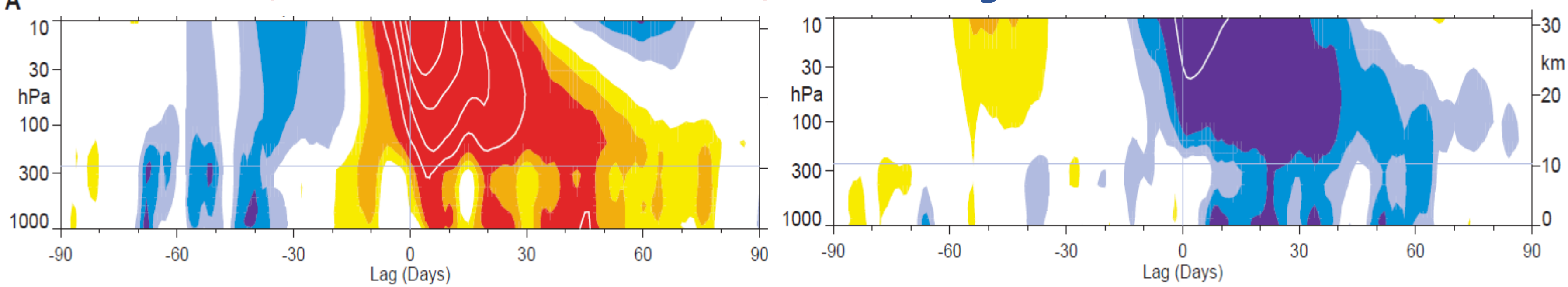
3. Further Application of the PJO framework to the Probabilistic Outlook in Seasonal Time Scale

1. (Quick) Review of the Predictability of Stratospheric Extreme Events and Their Influence on the Tropospheric Climate

Stratospheric influence on the troposphere

- Downward propagation of **NAM** (Northern Annular Mode) anomalies after extreme events of the stratospheric polar vortex

Weak events (~ **SSW** : Stratospheric Sudden Warming) **Strong** events (~ **VI** : Vortex Intensification)



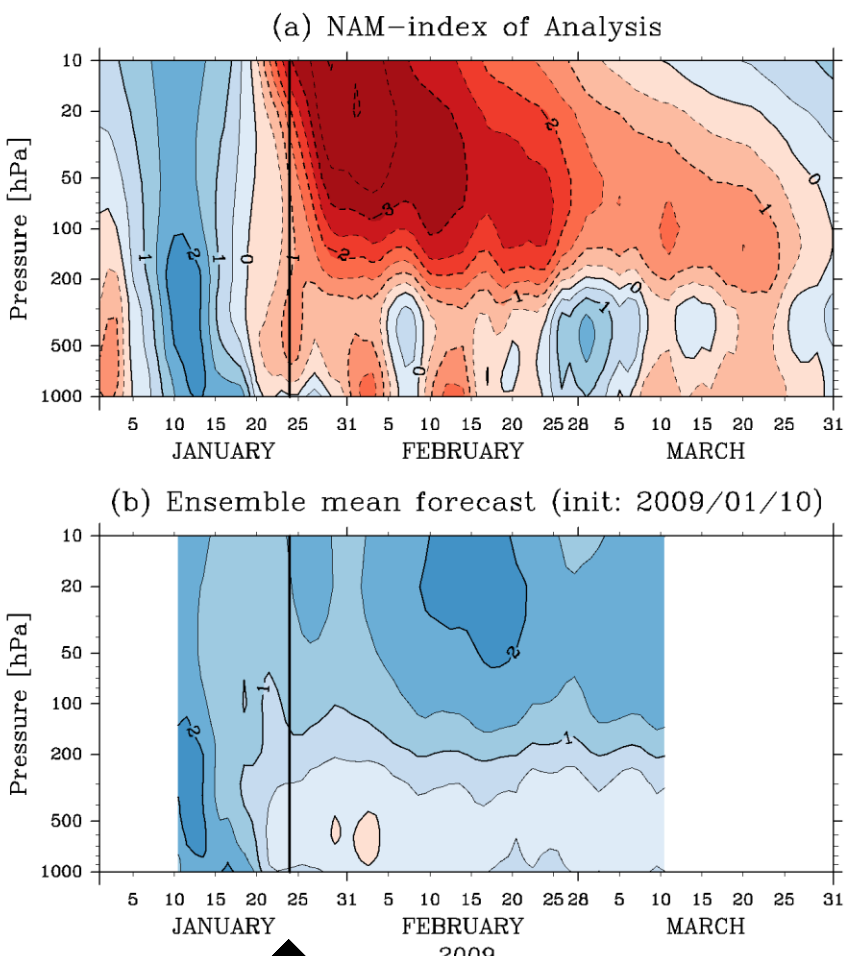
Baldwin & Dunkerton (2001)

- Expectation for this process to improve the tropospheric forecast skill beyond the limit of predictability (~2 weeks)
  - ➢ Stratospheric anomaly as a good predictor of surface signals (e.g. **AO**, **NAO**) in statistical forecasts e.g. Baldwin et al. (2003)
  - ➢ Enhancement of tropospheric forecast skills when extended-range forecasts are initialized at onset date of extreme events

e.g. SSW: Sigmond et al. (2013), VI: Tripathi et al. (2015b)

Predictability of SSW: An example of forecast experiment

- Predictability of the onset timing of SSW event is limited, and tropospheric signals appear only after the set of it



Onset date of SSW

Reanalysis (JRA-55)

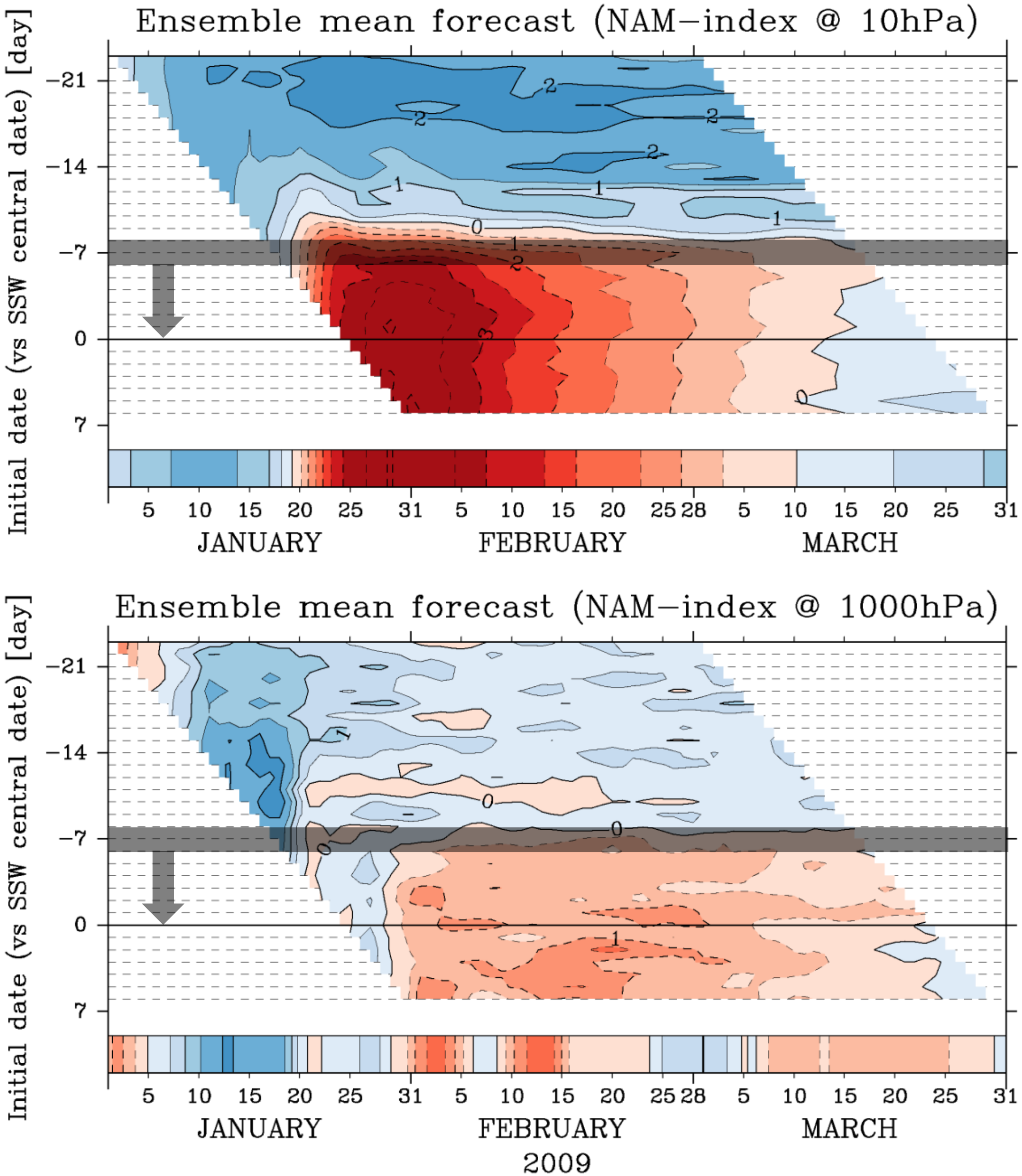
- The largest SSW occurred 24 January 2009
- Downward prop. of negative NAM anomaly
- Negative NAM tendency in the surface lasting a few months after SSW

Forecast (60-day) by MRI-AGCM

- Ensemble mean of 25 member predictions initialized at **Day 0 (Onset date of SSW)**
  → ◎ **predict well**
- 〃 initialized at **Day -14 (2 weeks earlier)**
  → × **worse** (rather opposite tendency!!)

Arranged from exp. data of Noguchi et al. (2016)

- Overview of the result of the FCST EXP (initialized everyday):



Predictable period of this SSW is only about **one week**

Negative NAM tendency
(in the lower atmosphere)
is captured only when forecasts
are initialized within the range

Noguchi et al. (2016)

Current understanding & what we need

- Limited predictable range of the onset of extreme events
  - ➢ Depends largely on cases, but generally between 5 and 15 days (This is no better than that of tropospheric weather systems)

    cf. Tripathi et al. (2015a), and references therein
  - ➢ Tropospheric forecasts (beyond the limit of deterministic predictability) might be swung/brandished by (false) stratospheric forecasts

- Not all stratospheric events affects deep into the surface
  - ➢ Only about half (or less) of SSWs show long-lasting anomalies

    e.g. Runde et al. (2016), Karpechko et al. (2017)

⬇

- **Constant monitoring** of current stratospheric state (& forecasts, especially whether extreme events penetrates deeply or not) is necessary not to underestimate (or overestimate) its downward influence on tropospheric forecasts

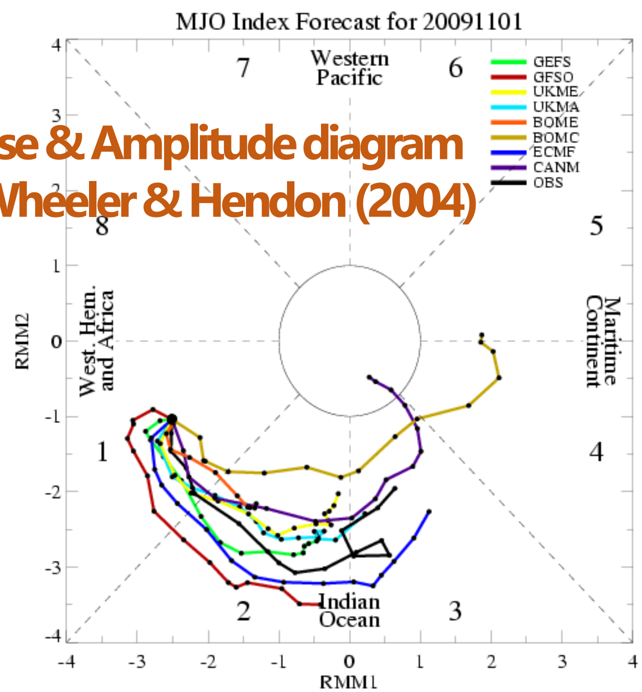
Purpose of this study

Sophisticate the monitoring methodology of the stratosphere (especially) focusing on its downward influence

How?

→ By introducing the monitoring framework similar to a well-known method for Madden-Julian Oscillation

Phase & Amplitude diagram of Wheeler & Hendon (2004)



http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml

Eastward propagation of anomalies in the tropics

through the reinvestigation of a novel framework termed as **Polar-night Jet Oscillation**

Downward- (& poleward-) propagation of anomalies in the extratropical stratosphere

2. Examination of Extended-range Forecast Skills from the View of Polar-nigh Jet Oscillation (PJO)

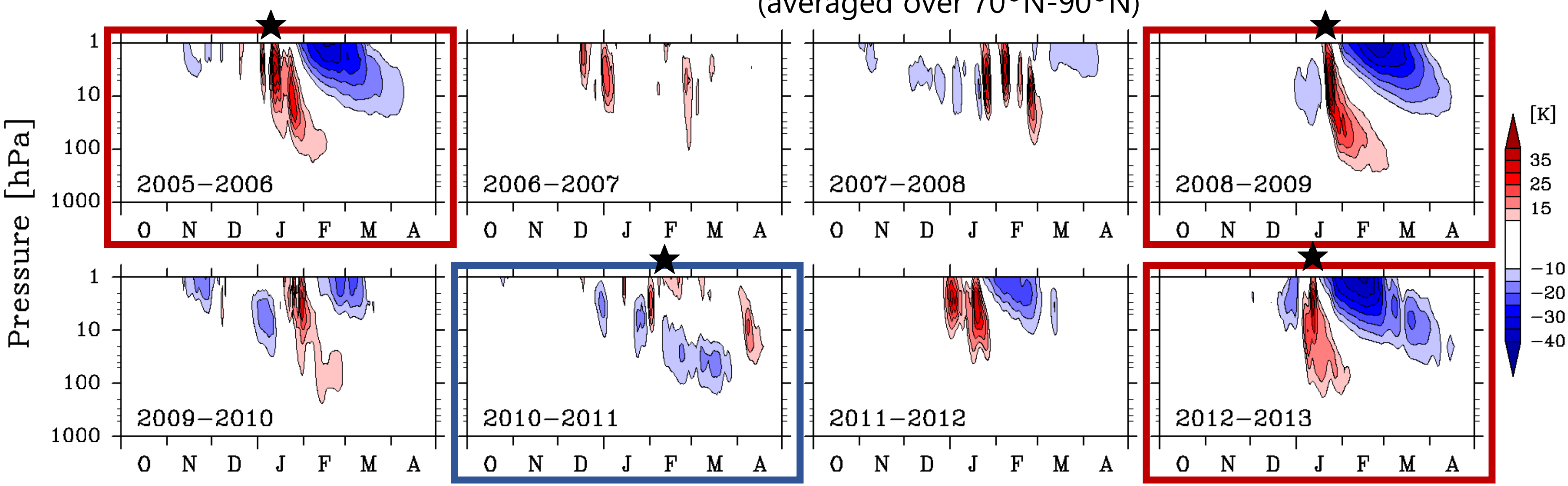
Polar-night **J**et **O**scillation (**PJO**)

- Dominant low-frequency var. in the winter stratosphere
  - ➢ Slow (monthly time scale) down- & pole-ward prop. of U anomaly
  - ➢ Quasi-periodic appearance of deceleration/weakening (**SSW**) and acceleration/intensification (**VI**) of the polar-night jet
  - ➢ Sharing large part with the down prop. of NAM (especially in Strat.)

(Kodera et al. 1990, 2000, Kuroda & Kodera 1999, 2001, 2004, Kuroda 2002, 2008)

- Downward prop. signal of $\mathbf{T}_{\mathbf{NP, anom}}\mathbf{(t, z)}$ as an easy proxy

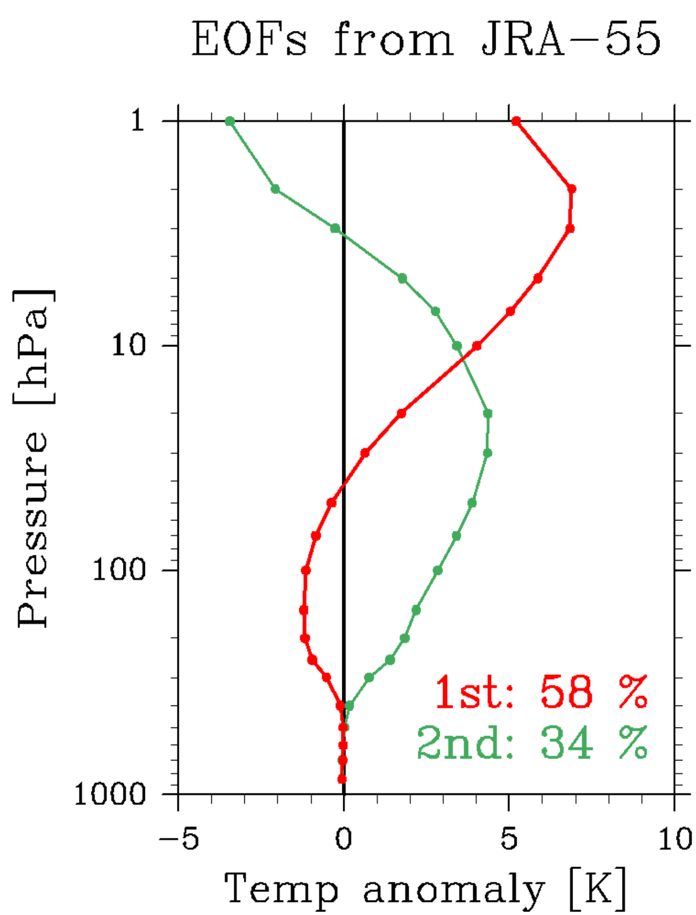
(averaged over 70°N-90°N)



Introduction of PJO phase space

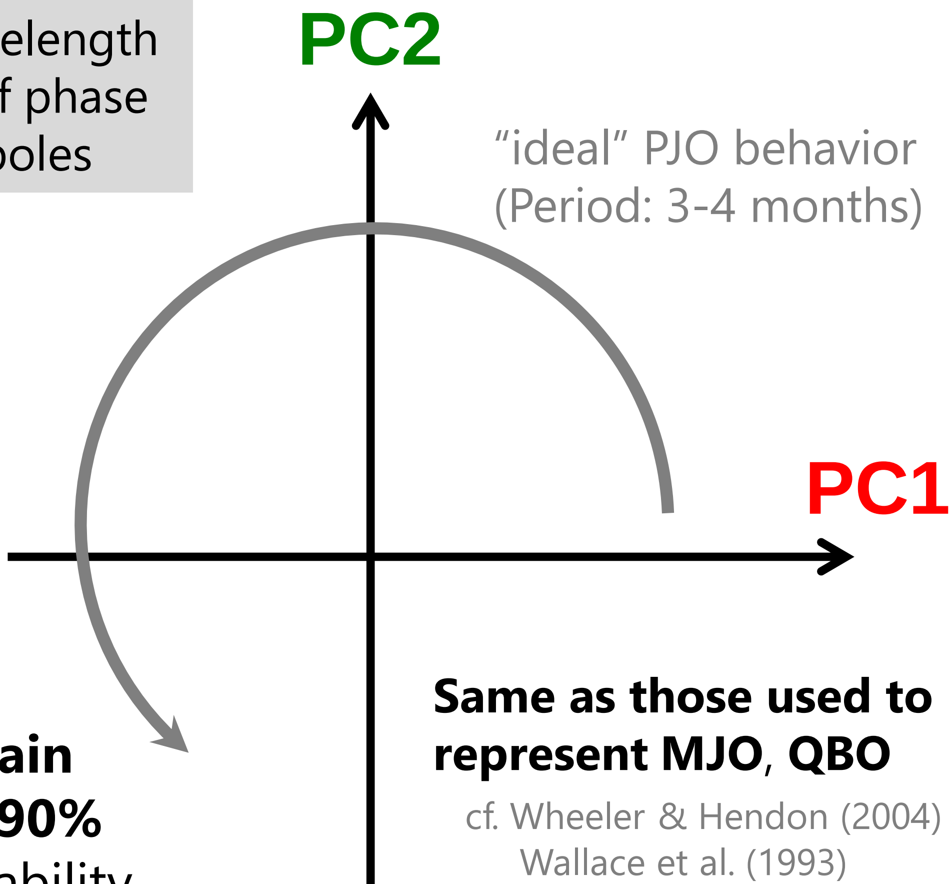
Kuroda & Kodera (2004)

- 2D space spanned by **PC1** & **PC2** which are obtained by applying an EOF analysis to the smoothed* $\mathbf{T_{NP,\,anom}\ (t, z)}$



¼ wavelength out of phase dipoles

Explain over **90%** of variability



Same as those used to represent MJO, QBO

cf. Wheeler & Hendon (2004)
Wallace et al. (1993)

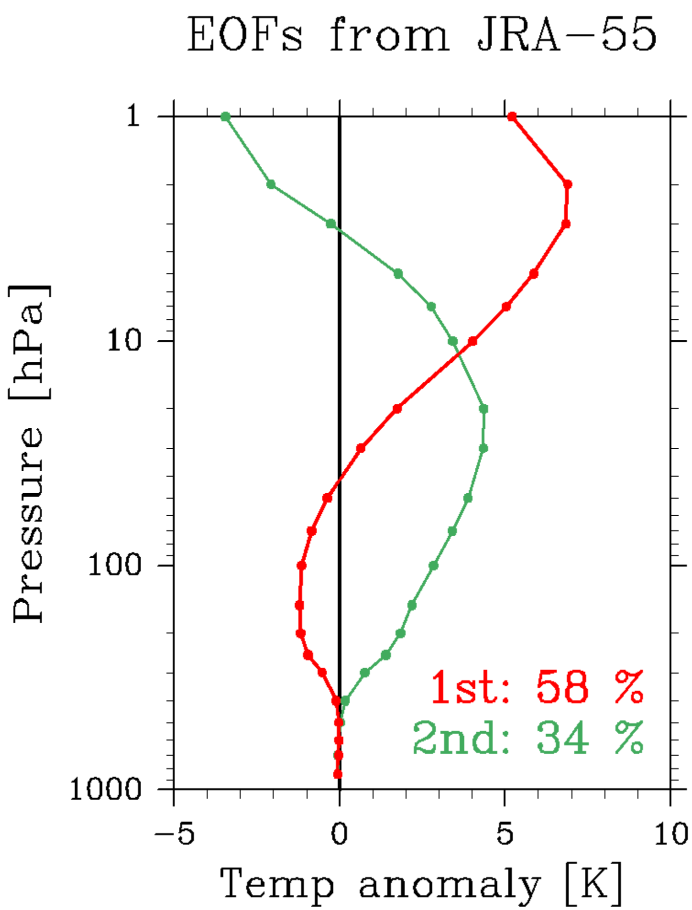
Good agreement with Hitchcock et al. (2013a)

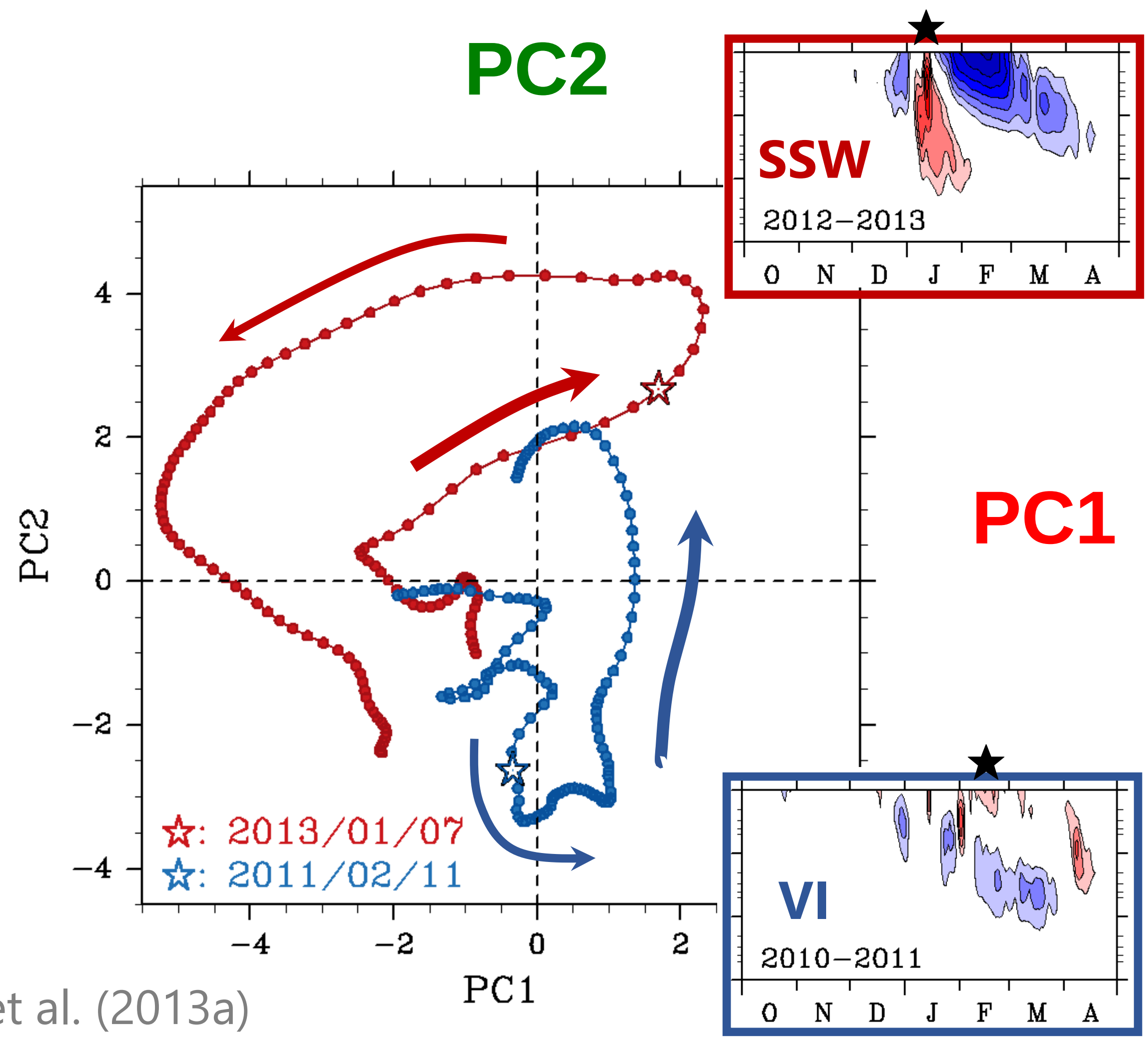
* 15-day-running averaged

Introduction of PJO phase space

Kuroda & Kodera (2004)

- 2D space spanned by **PC1** & **PC2** which are obtained by applying an EOF analysis to the smoothed* $\mathbf{T_{NP,\,anom}}$ **(t, z)**





Good agreement with Hitchcock et al. (2013a)

- This study projects ↓ to the PJO phase space
  - Uncertainty (spread) of the state of stratospheric anomalies
  - Skill of the tropospheric forecast beyond the lead time of 2 weeks

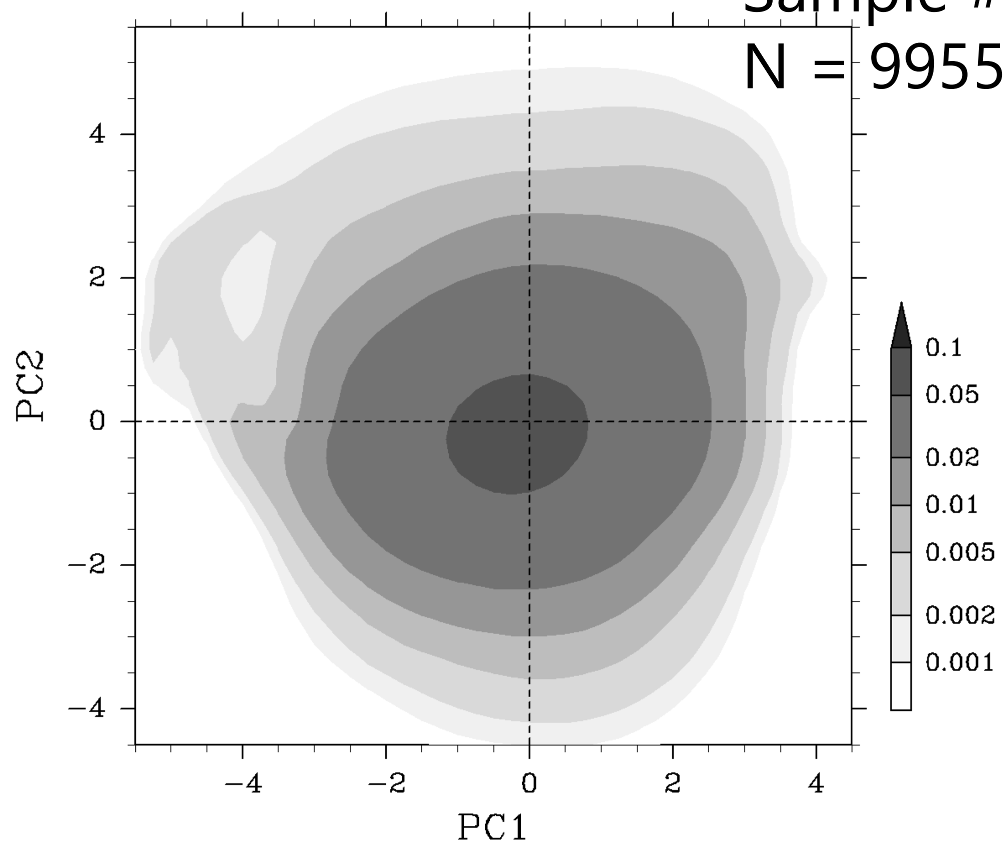
➡ **Summarize a priori information of forecast skills**

Sample #:
N = 9955

Distribution of daily state points of 55 extended winters (**JRA-55**)
(NDJFM of 1958/1959—2012/2013)

∗15-day-running averaged

Estimate a PDF of statistics by **Kernel density estimation**
(Silverman 1986, Kimoto & Ghil 1993)
as used in several studies of the **flow-dependent** predictability
(e.g. Frame et al. 2013, Inatsu et al. 2015)



Data & Usage

- JRA-55 ➡ Verification of forecasts & Calculation EOF
- Operational data of JMA one-month ensemble forecasts
  - ➢ Execution & Providing manner of forecasts:

Prediction period: **34 days**	Model settings:
Initialized: **twice a week** (Wed & Thu)	• SST: Initial anomaly + climatology
Ensemble size: **25** (13 before Mar 2006)	• Resolution: T_L159L60 (Top: 0.1hPa)
Provided for **22 p levels (~1hPa)**	(L40 before Mar 2007)

  - ➢ Archived all member data of ensemble forecasts initialized in 12 extended winters (ONDJFM) from 2001/2002 to 2012/2013 are utilized

➡ Check stratospheric uncertainty (ensemble spread among members) & forecast skills of the ensemble mean in LS & Tropo

- Hindcast data of JMA 1-m EPS (version as of March 2011)

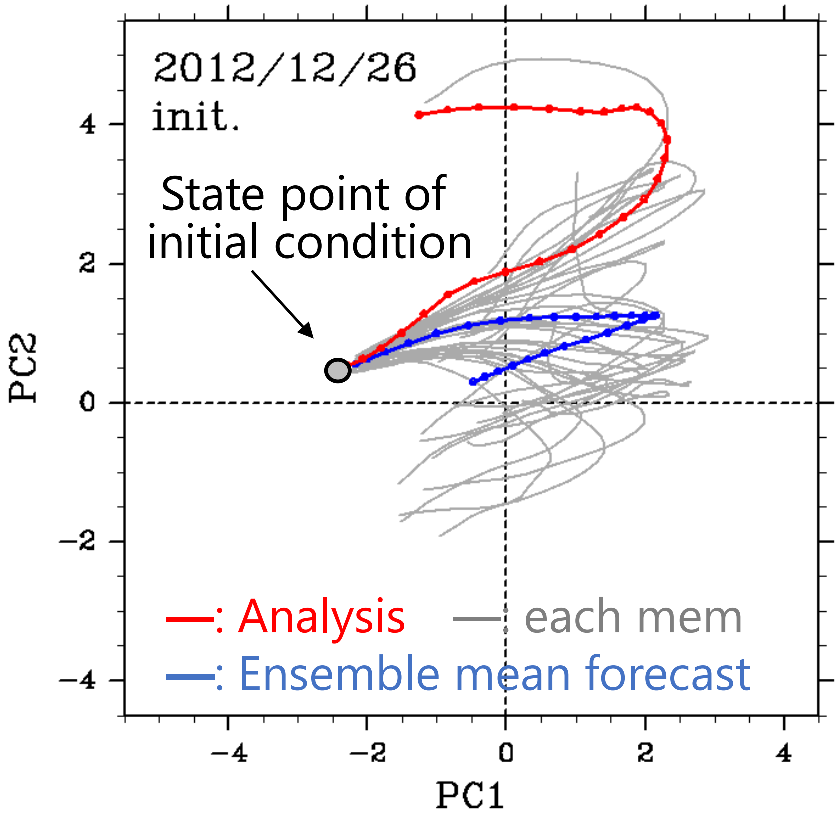
➡ Check (tropospheric) skills for lager samples (30 yrs)

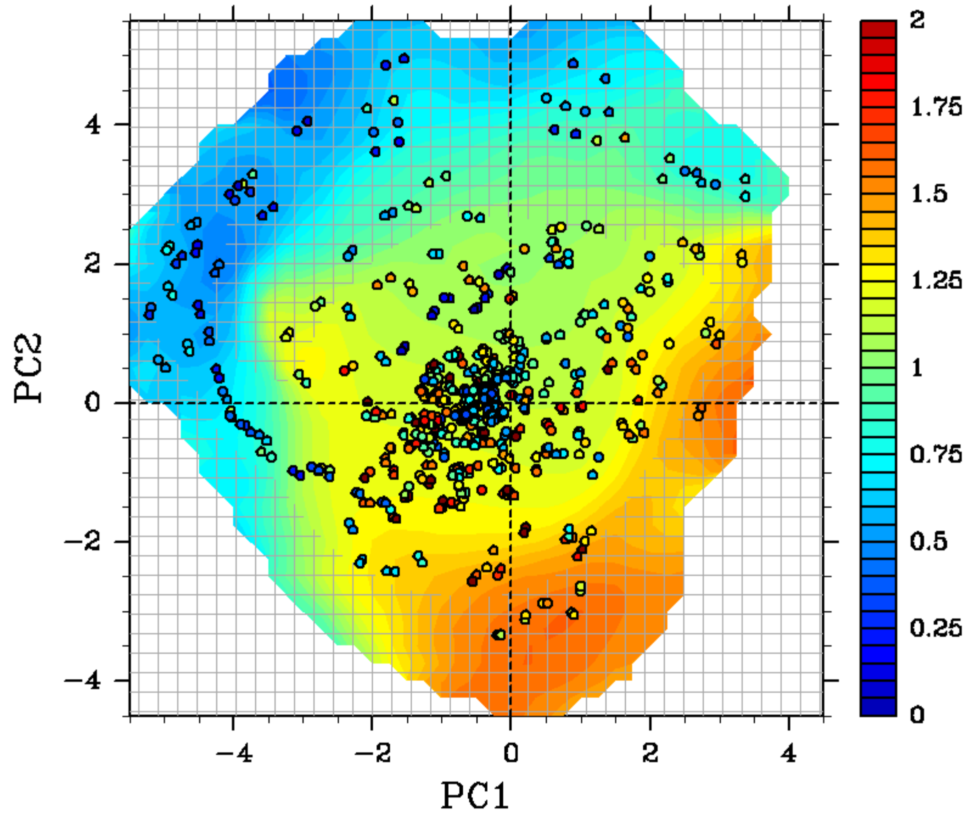
No time to talk today

Uncertainty of stratospheric forecasts

- Distribution of ensemble spread: **Asymmetric**
  - **Small uncertainty** when FCSTs start from 2nd quadrant
  - **Large uncertainty** when FCSTs start from 3rd - 4th quadrant

One example of ens. FCST





*Averaged over the lead time from day 14 to day 34

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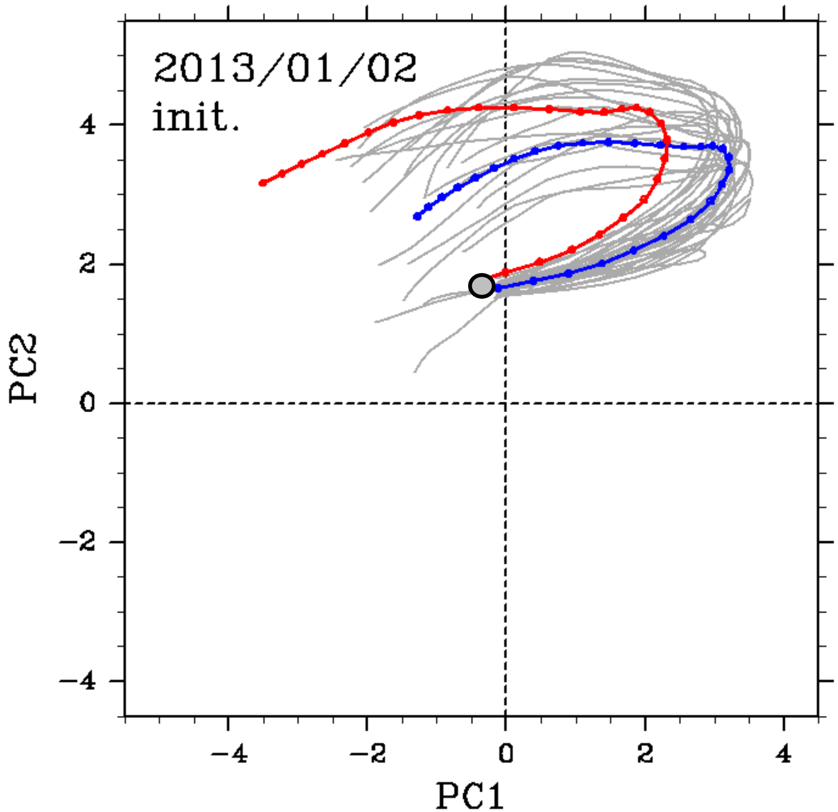

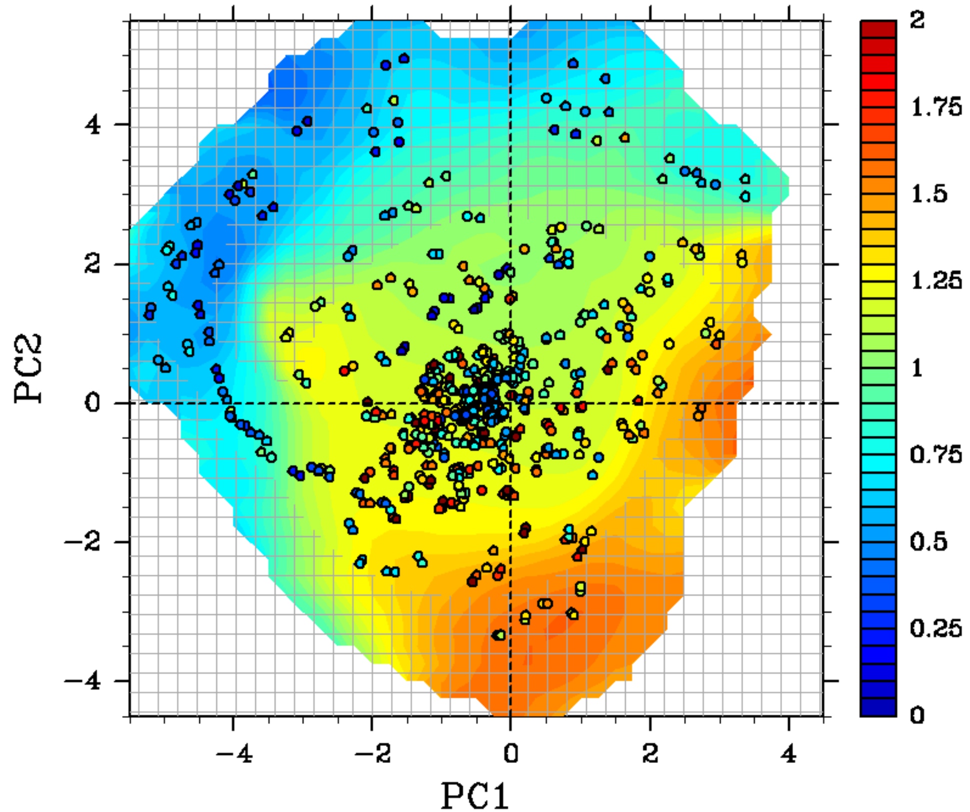

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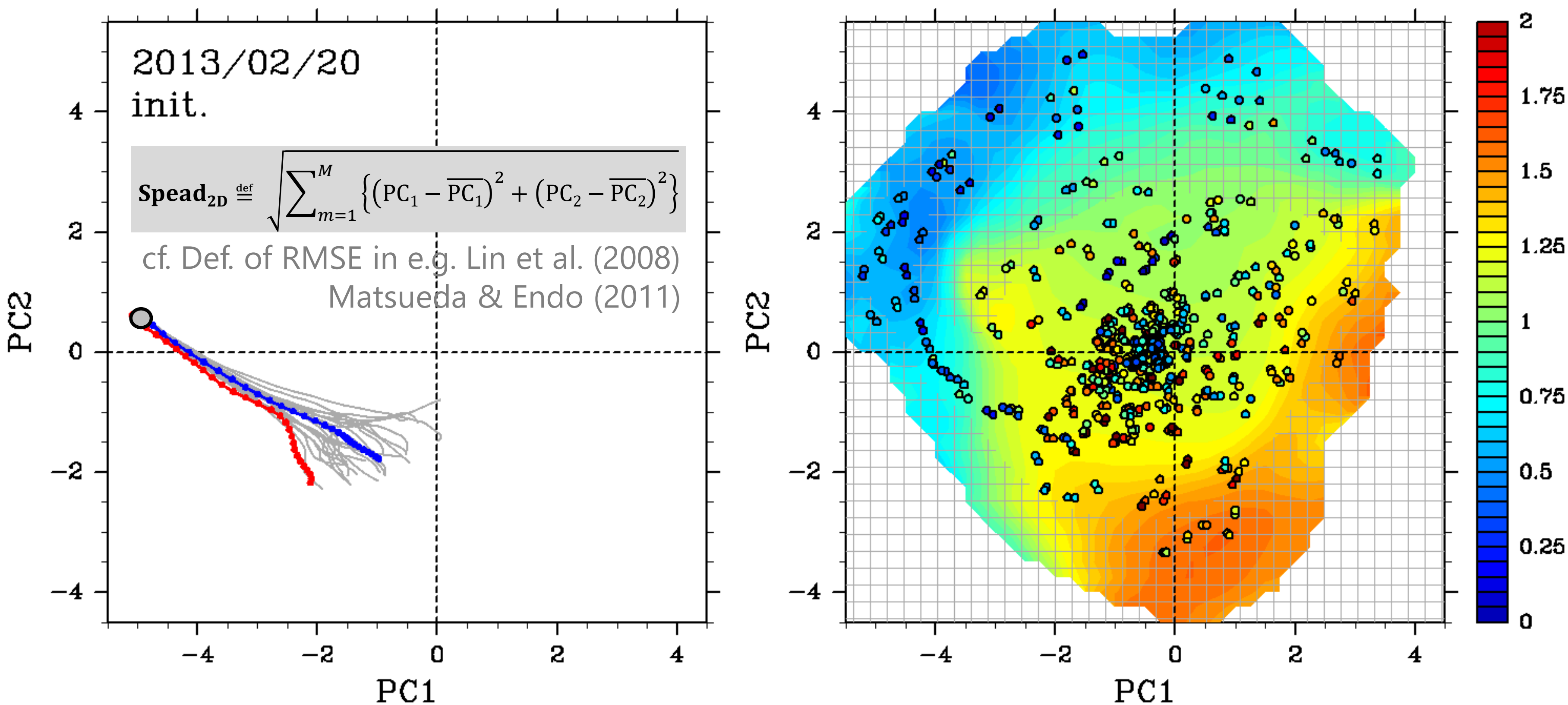


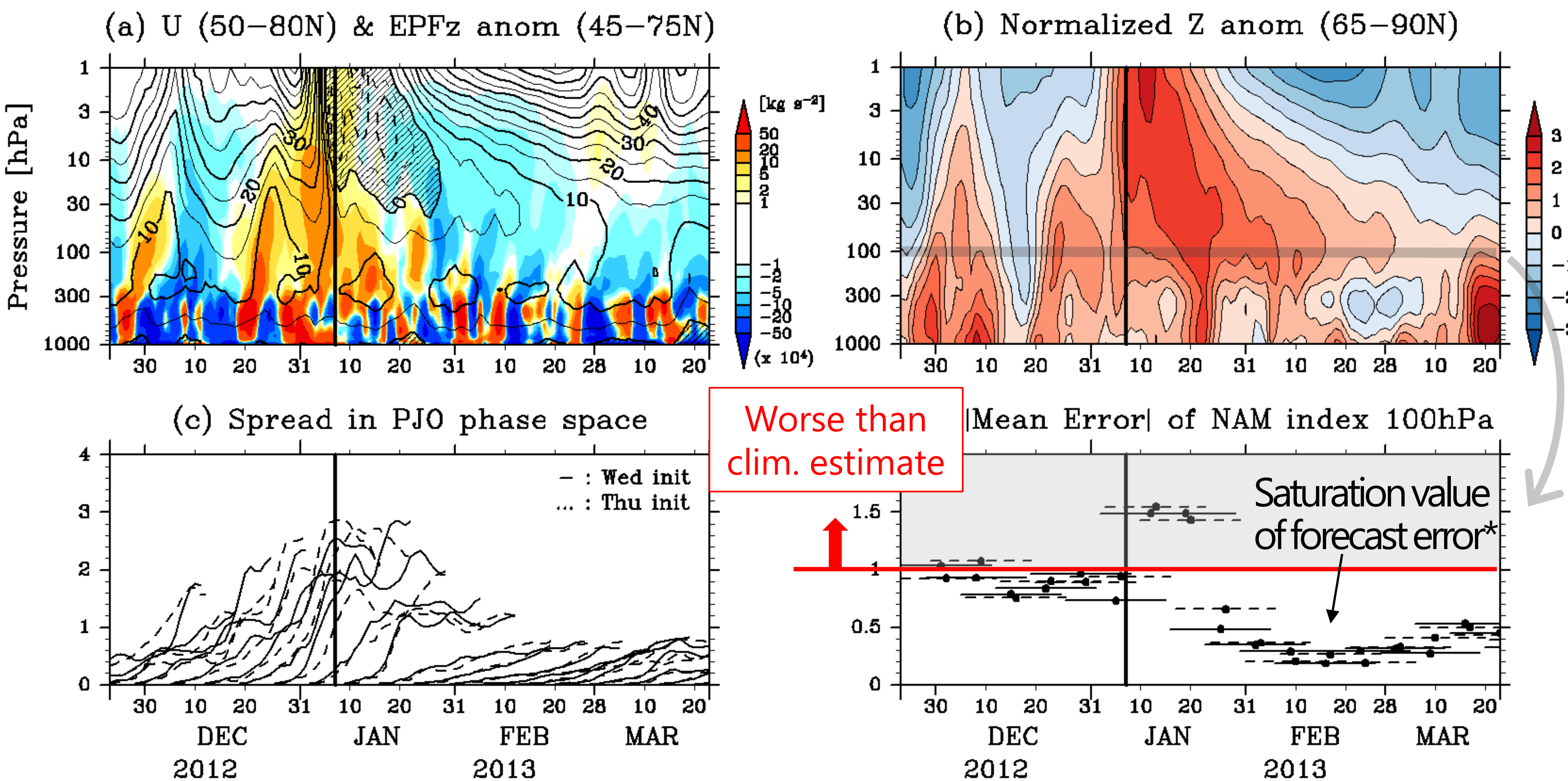
*Averaged over the lead time from day 14 to day 34

Example of typical PJO winter including **SSW**

- **2012-2013 winter**

Suppression of EPFz↑ after SSW
→ **Small uncertainty** in Strat.

Persistence of LS anomalies
→ **Small Forecast Error** of NAM in FCSTs initialized after SSW



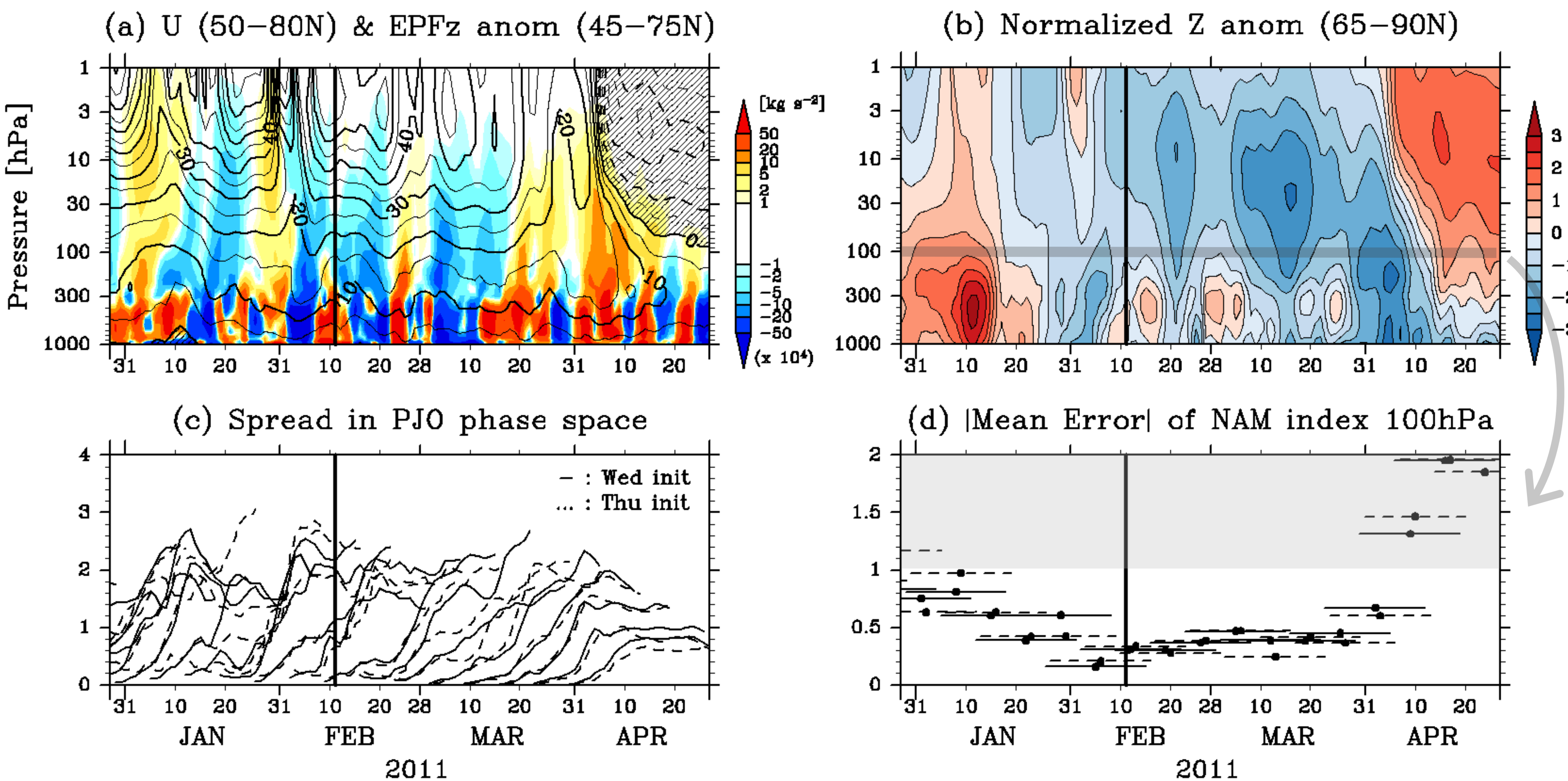
*Averaged over the lead time from day 14 to day 34

Example of typical PJO winter including **VI**

- **2010-2011 winter**

  Intermittent EPFz↑ during VI
  → **Large uncertainty** in Strat.

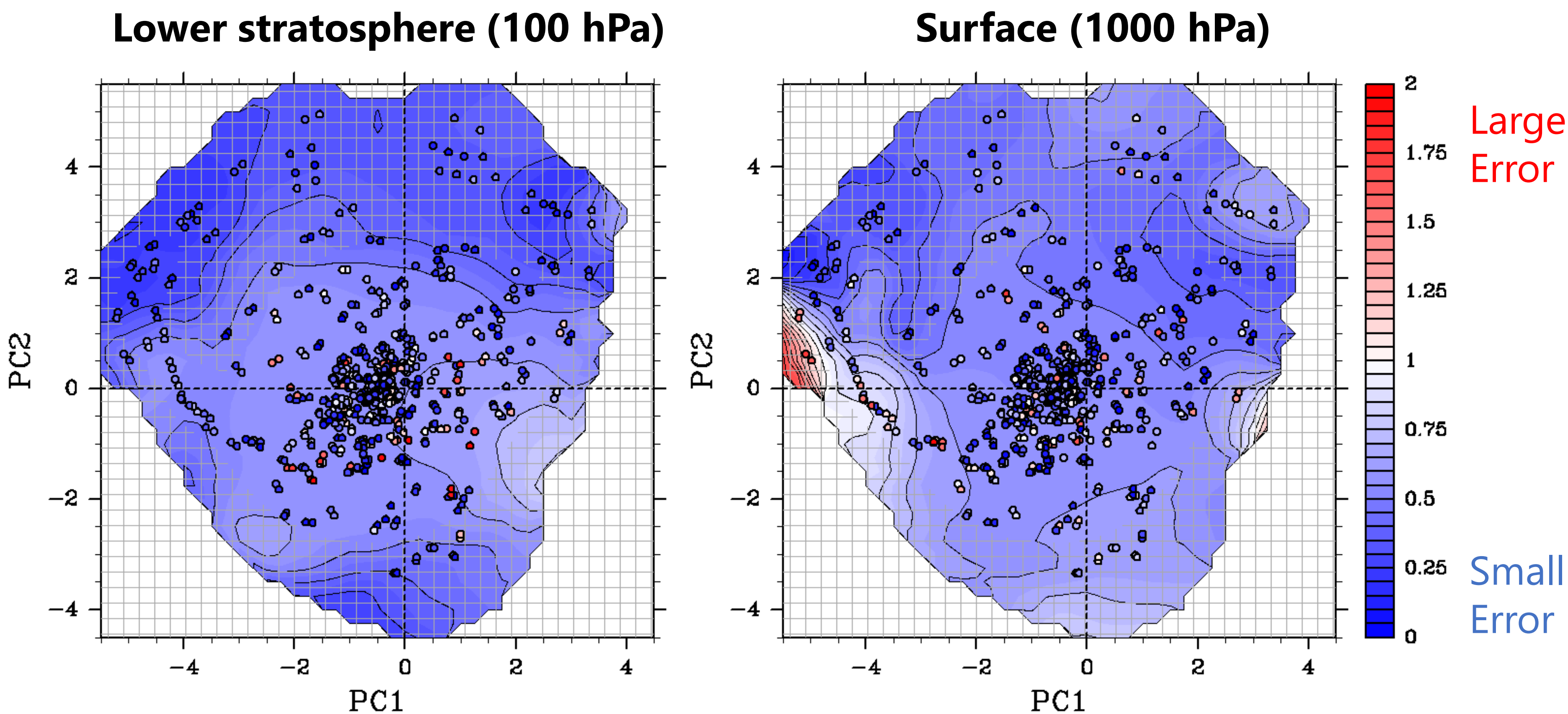
Persistence of LS anomalies
→ **Small Forecast Error** of NAM in FCSTs initialized during VI



*Averaged over the lead time from day 14 to day 34

Mean error of NAM-index @ 100 & 1000 hPa

- Distribution of forecast skills: somewhat **Symmetric**
  - ➢ **Small error** in both positively and negatively large PC2 region
    - → Enhancement of skills when FCSTs are initialized at mature phases of SSW or VI



*Averaged over the lead time from day 14 to day 34

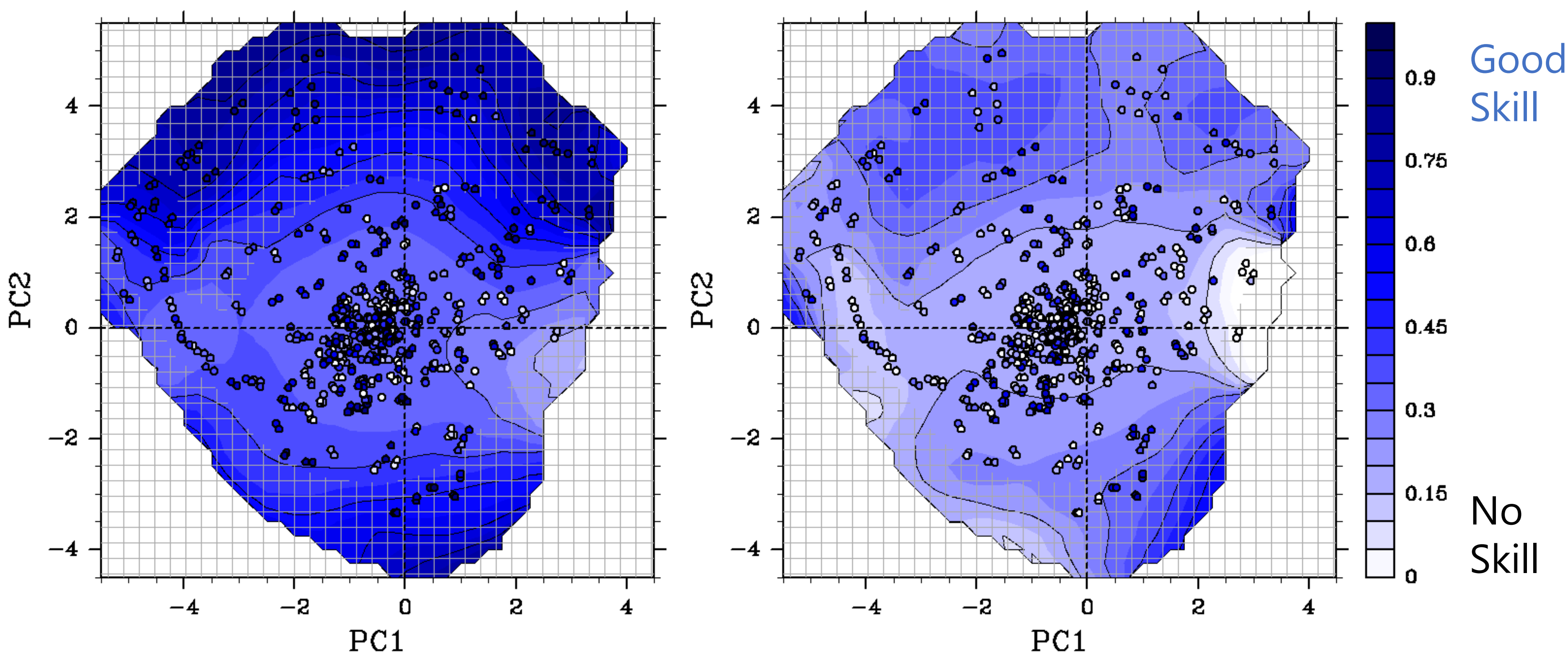
Anomaly corr. of Z (20-90N) @ 100 & 1000 hPa

- Distribution of forecast skills: somewhat **Symmetric**
  - ➢ **Small error** in both positively and negatively large PC2 region

    → Enhancement of skills when FCSTs are initialized at mature phases of SSW or VI

    (Same statement can be provided from more general metric of forecast verifications)

Lower stratosphere (100 hPa) **Surface (1000 hPa)**



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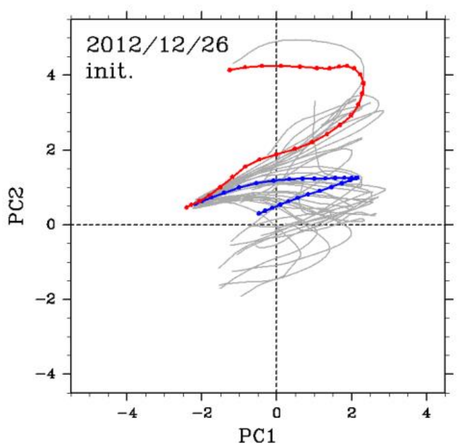
Summary of results (so far)

- As an effective monitoring framework of S-T coupling, projecting FCSTs to the PJO phase space is introduced
- Obtained a priori information of forecast characteristics:
  - ➢ Asymmetry in the uncertainty of stratospheric forecasts
    (Large spread during VI, small spread after deep SSW)
  - ➢ Symmetry in forecast skills of lower atmosphere
    (Enhancement of skills at mature phases of both SSW and VI)

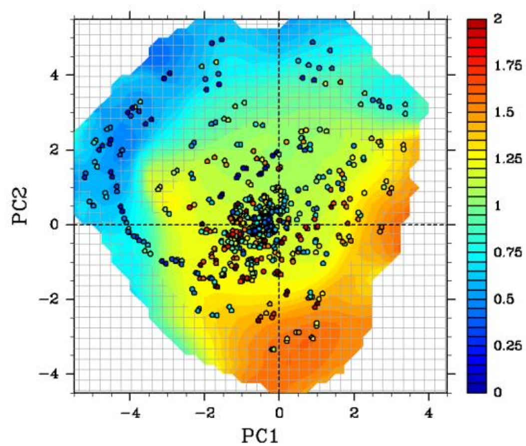
One example of ensemble forecast



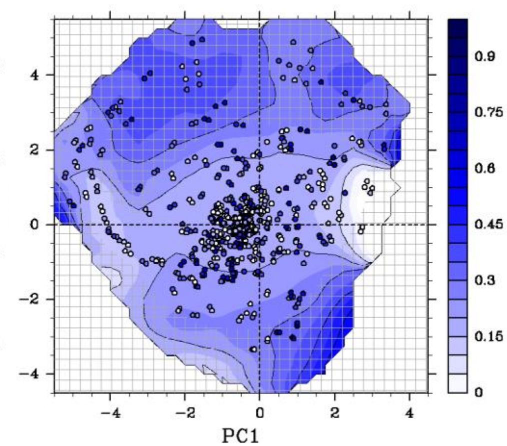
A priori information of forecast statistics

再掲

Uncertainty @ Strat.



Skill (AC) @ Surface

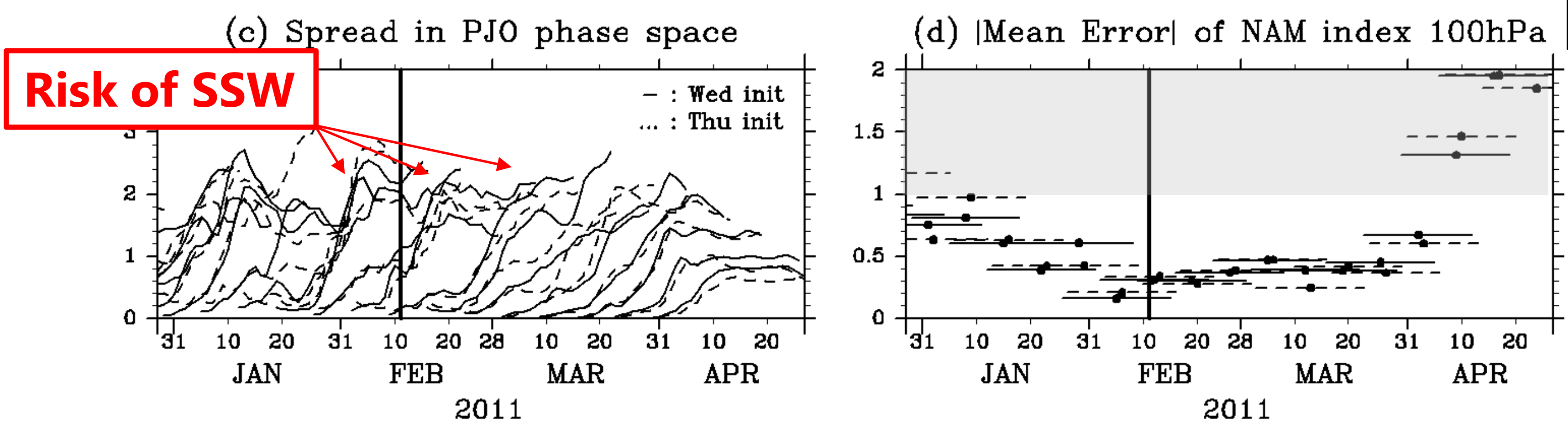


Implications for real-time monitoring

- Since downward influence is conditional (expected only after a event has occurred), we have to care the uncertainty of stratospheric state

e.g. The VI condition would have positive impact on the tropospheric forecast. However, the stratospheric state in the forecast is uncertain throughout the event. Therefore, in real-time monitoring of forecast, **it might be difficult** to expect the stratospheric effect on the tropospheric circulation **confidently** during the VI event.

再掲



- Comprehensive view for the uncertainty & impact of the stratosphere would be provided by the PJO framework

(If we have time ...)

3. Further Application of the PJO framework to the Probabilistic Outlook in Seasonal Time Scale

Further Expansion to Seasonal Time Scale

- 2^{nd} kind predictability of stratospheric extreme events?

  Although the deterministic (1^{st} kind) predictability of extreme events is limited, we can consider the probabilistic occurrence freq. of an event (e.g. during next winter).

- The PJO framework also provides a good perspective by considering the response of PDF to external forcing (if sample is large enough to construct PDF according to each condition)

⬇

- Demonstration of PJO response to ENSO (El Niño / LaNiña) by using **large ensemble simulations by MRI-AGCM**

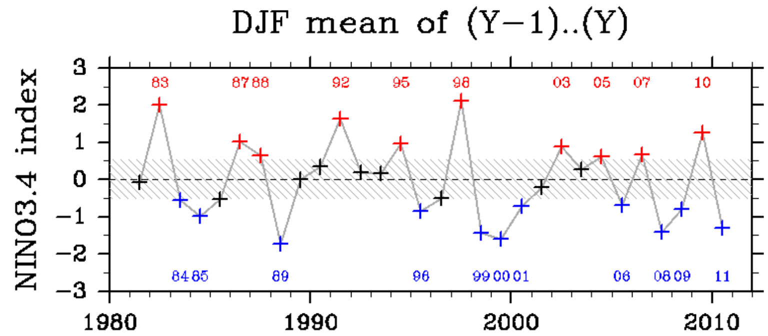
Data: **d4PDF** (database for Policy Decision making for Future climate change)

- **100 ensemble members** for historical climate simulations
- **Prescribed SST & Sea ice** (with small perturbations)
- Model resolution: T_L319 L64 (Top: 0.01 hPa)

Mizuta et al. (2017)

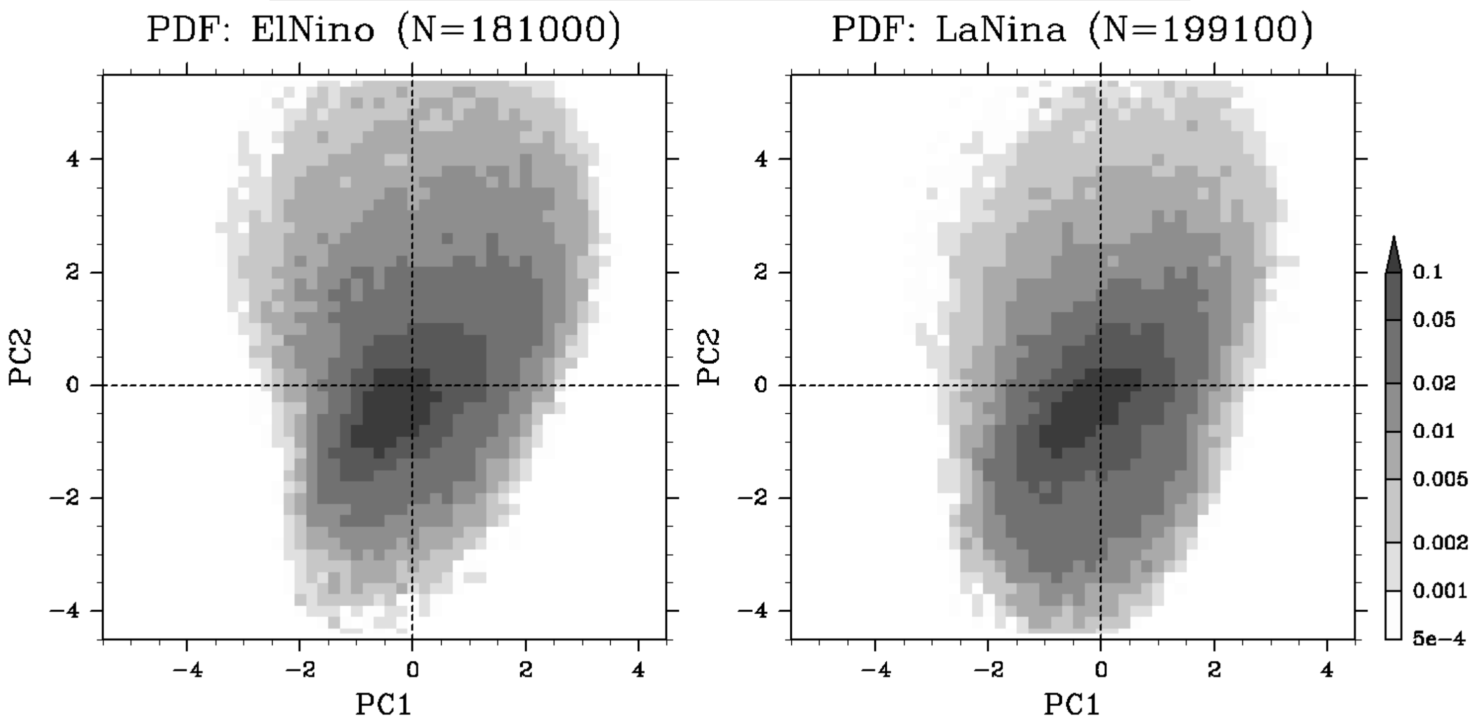
PJO Response to Tropical SST

- Divide recent 30 yrs (1981/82-2010/11) to **EL** (10), **NE** (9), **LA** (11) winters by NINO3.4 index (theres: 0.5 σ)



- PDF (of daily state point in the PJO phase space) of each winter:

2D PDF of daily sate points in NDJFMA



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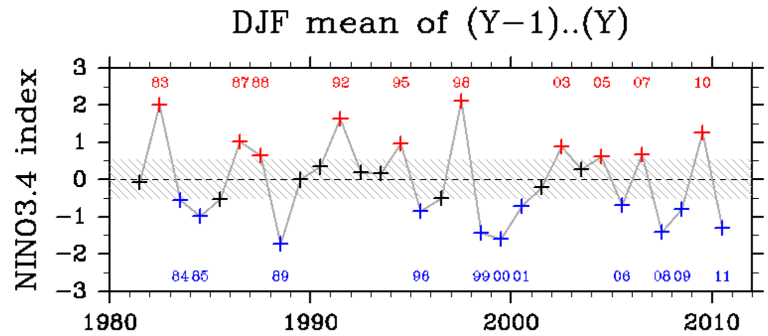
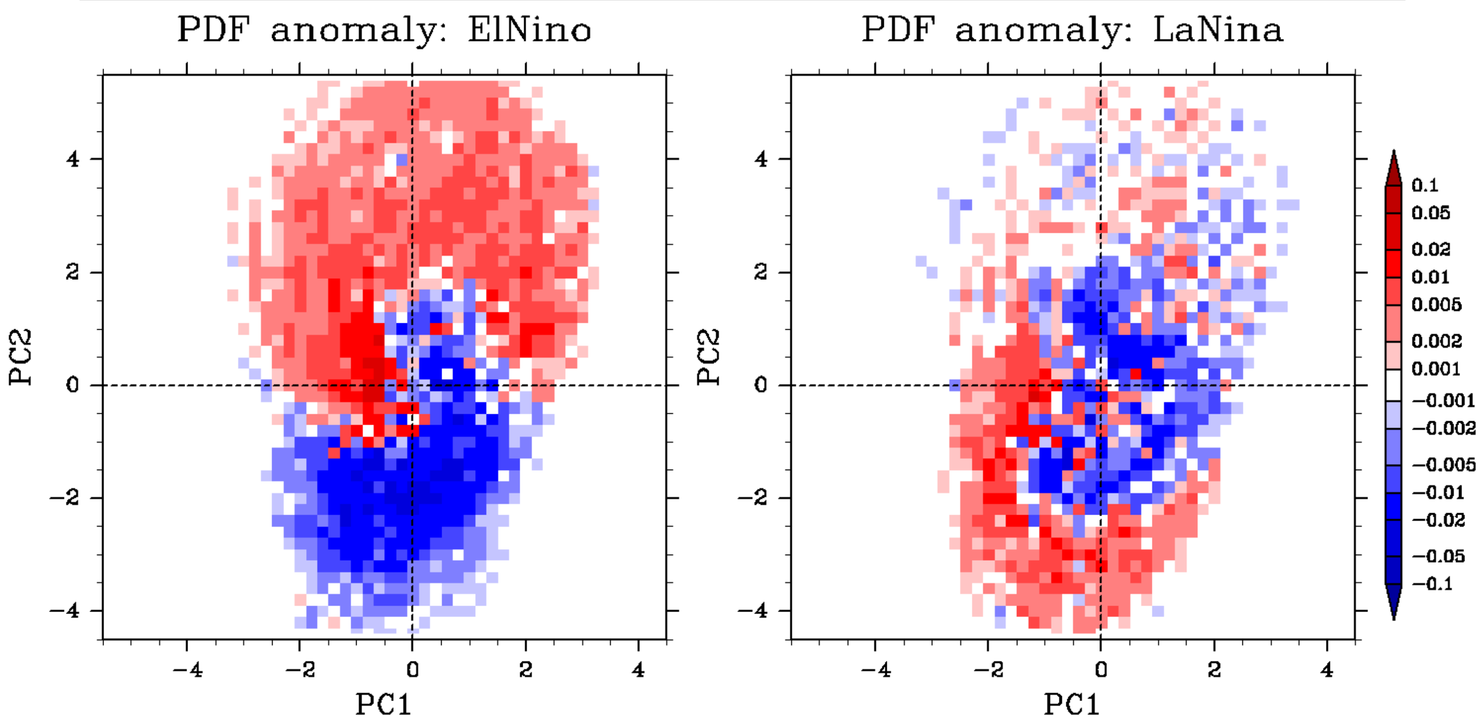


- PDF (of daily state point in the PJO phase space) of each winter:

2D PDF anomaly from NE of daily sate points in NDJFMA

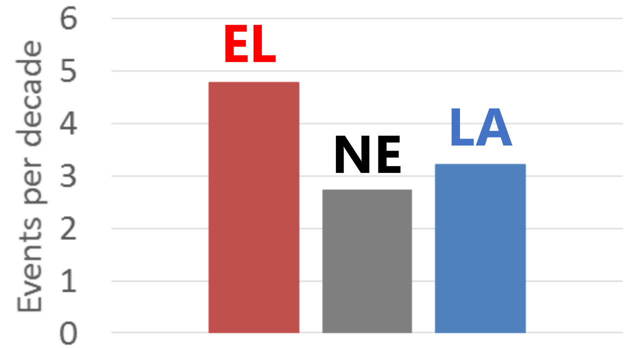
EL SSW ↑
VI ↓

LA SSW **?**
VI ↑



Remarks on the LaNiña condition (~ 2017-2018 winter?)

- PJO response to LaNiña: **Increase of variable range?**
  - ➢ Chance of strong VI increases
  - ➢ Chance of SSW doesn't decrease, rather slightly increase (compared to NE).
    → Not symmetric to EL (about 2 times ↑ risk)
    *in consistent with Garfinkel et al. (2010, 2012)



SSW frequency for each SST condition, judged by the def. of Bancalá et al. (2012).

- Although strong and cold vortex state (Positive NAM / AO) is expected as winter climate (e.g. monthly to seasonal mean), it would be easily overturned by the onset of SSW
- Further care should be taken for the forecast uncertainty in the stratosphere throughout the winter season

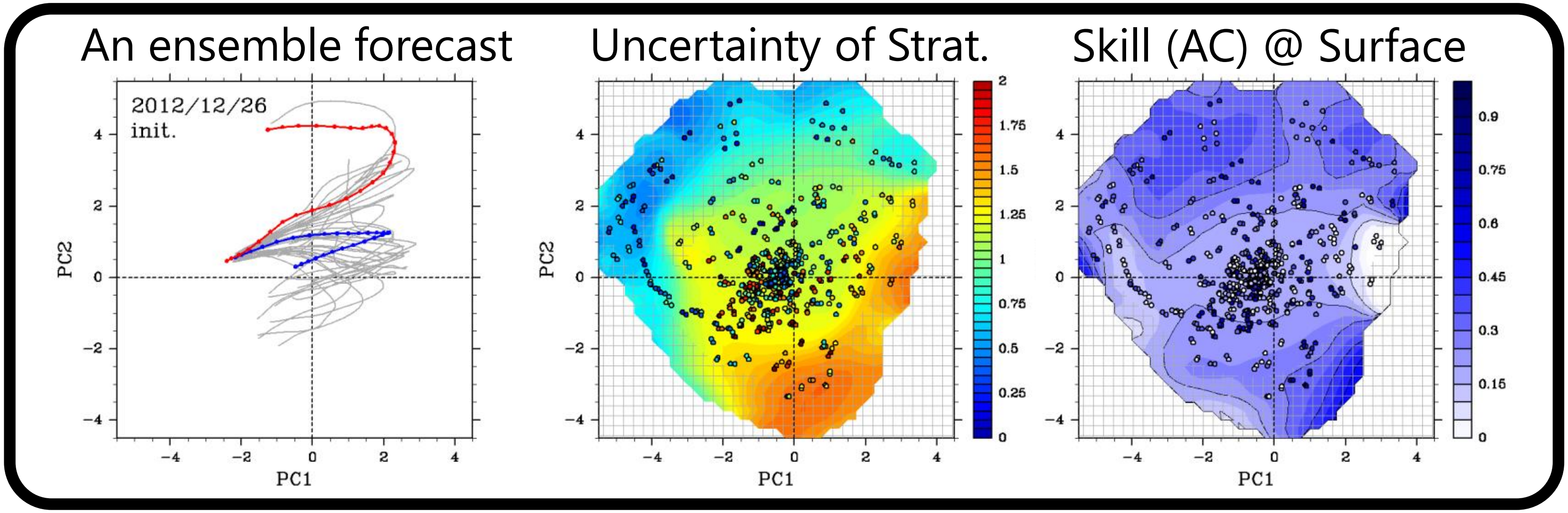
Summary of this talk

1. (Quick) Review of the Predictability of Stratospheric Extreme Events and Their Influence on the Tropospheric Climate

➡ **Need of constant monitoring of stratospheric state**

2. Examination of Extended-range Forecast Skills from the View of Polar-nigh Jet Oscillation (PJO)

➡



3. Further Application of the PJO framework to the Probabilistic Outlook in Seasonal Time Scale

➡ **Be careful for increased variability during LaNiña**

ご清聴ありがとうございました

Thank you

谢谢

감사합니다

баярлалаа