Development of JMA's New Turbulence Index

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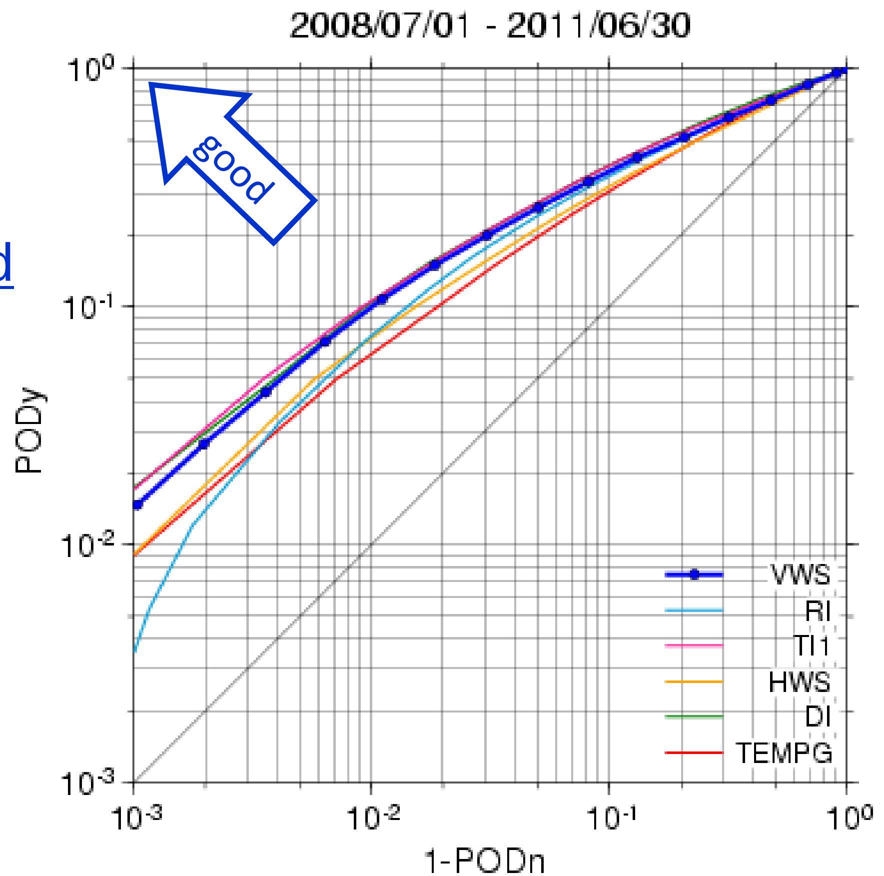
Previous Method in JMA

Cause of Turbulence	Forecasting Method
KH instability (CAT)	mainly VWS
Convective clouds	Empirical method
Mountain waves	Empirical method
Mid-level cloud bases	Empirical method
Transverse bands	Empirical method
other	



Problems

- Although VWS has the same or better accuracy compared to other indices, the accuracy is not enough
- VWS is not adequate to forecast turbulences unrelated to KH instability
- We had not used quantitative indices for non-CAT turbulences

Ideas for Improvement

Cause of Turbulence	Forecasting Method
KH instability (CAT)	mainly VWS
Convective clouds	Develop an index
Mountain waves	Develop an index
Mid-level cloud bases	Develop an index
Transverse bands	Develop an index
other	

- Skew wind shear
- Convective cloud index
- Lee wave index
- Vertically propagating mountain wave index
- Mid-level cloud-base index
- Transverse band index

Combine newly-developed indices and existing indices by using logistic regression method

→ JMA's new turbulence index (TBindex)

Expected Effect

- To be able to predict various kinds of turbulences
- To improve forecast accuracy

Making procedure

Step 1. Select Independent Indices

Become easy to understand which indices contribute to TBindex

6 newly-developed indices

- ⊙ Skew wind shear
- ⊙ Convective cloud index
- ⊙ Lee wave index
- ⊙ Vertically propagating mountain wave index
- ⊙ Mid-level cloud-base index
- ⊙ Transverse band index

9 existing indices

- ⊙ Richardson number
- ⊙ Temperature gradient
- ⊙ Miyakoshi's Index (TPI, TSI)
- ・ VWS
- ・ HWS
- ・ Ellrod's Index (TI1, TI2)
- ・ Dutton's empirical index

Indices whose correlation coefficient is 0.6 or less are selected

10 indices are selected for explanatory variables

Making procedure

Step 2. Logistic Regression Method

- Logistic regression is a kind of multiple liner regression
  - Objective variable : Log-odds ratio ln(p/1-p)
    - Probability of occurrence p can be calculated from the log-odds ratio
  - Training data set : Two years from 2008 to 2009
  - Observation data : PIREPs
    - We have about 1.8 million reports include 16 thousand (0.89%) MOG turbulence reports in this period
- The regression equations are stratified by altitude
  - Cause of turbulence is different in altitudes

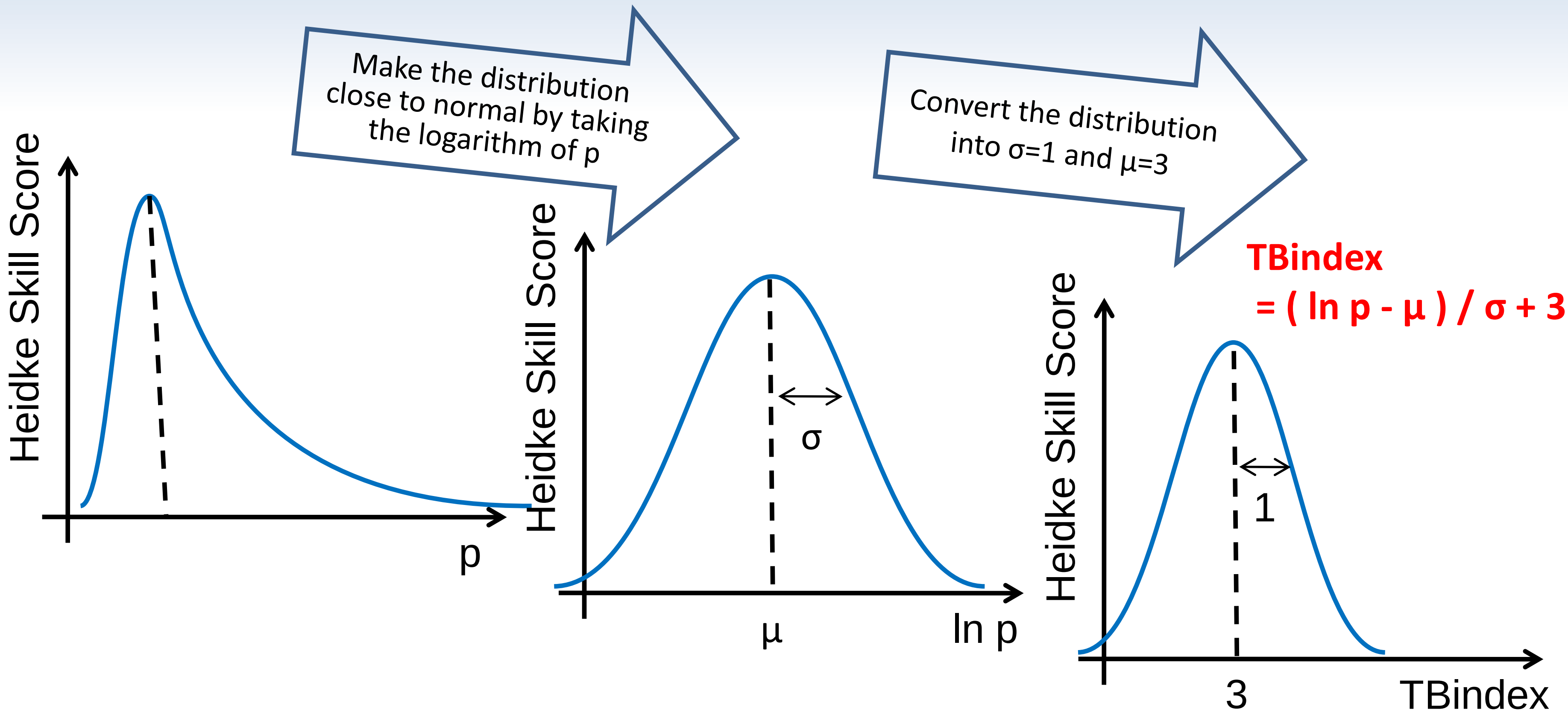
Step 3. Adjustment of the Index

It is unfavorable to regard the probability value as a "probability of turbulence"

1. The probability is NOT a probability of turbulence in the real sense
   - Observation data (PIREPs) tend not to be reported in no-turbulent conditions
2. The optimal threshold is generally different by altitude
   - Operators have to change a threshold by altitude when they attempt to make optimal forecast

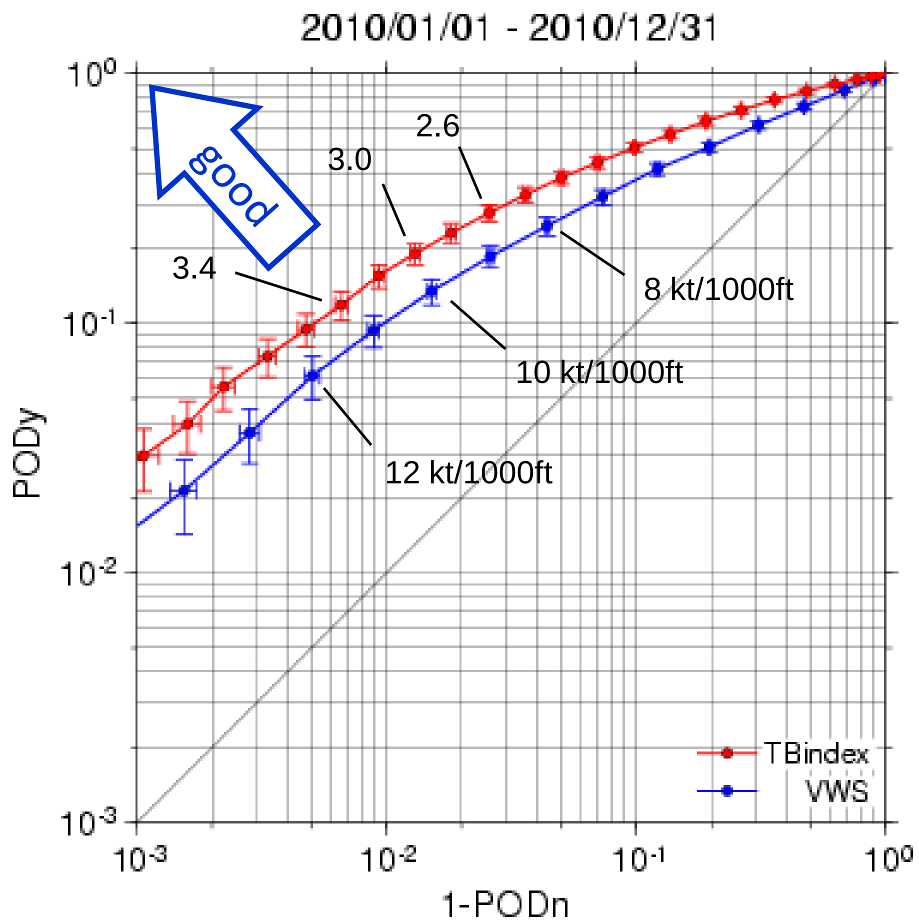
In stead of using the probability value as a "probability of turbulence", adjust the value to be able to forecast optimally regardless of altitude by a single threshold

Step 3. Adjustment of the Index



By taking this conversion for every altitude, the optimal thresholds are expected to become 3.0 regardless of altitude

Verification Jan. – Dec. 2010 (independent on the training data)



※ Error bars : 95% confidence interval

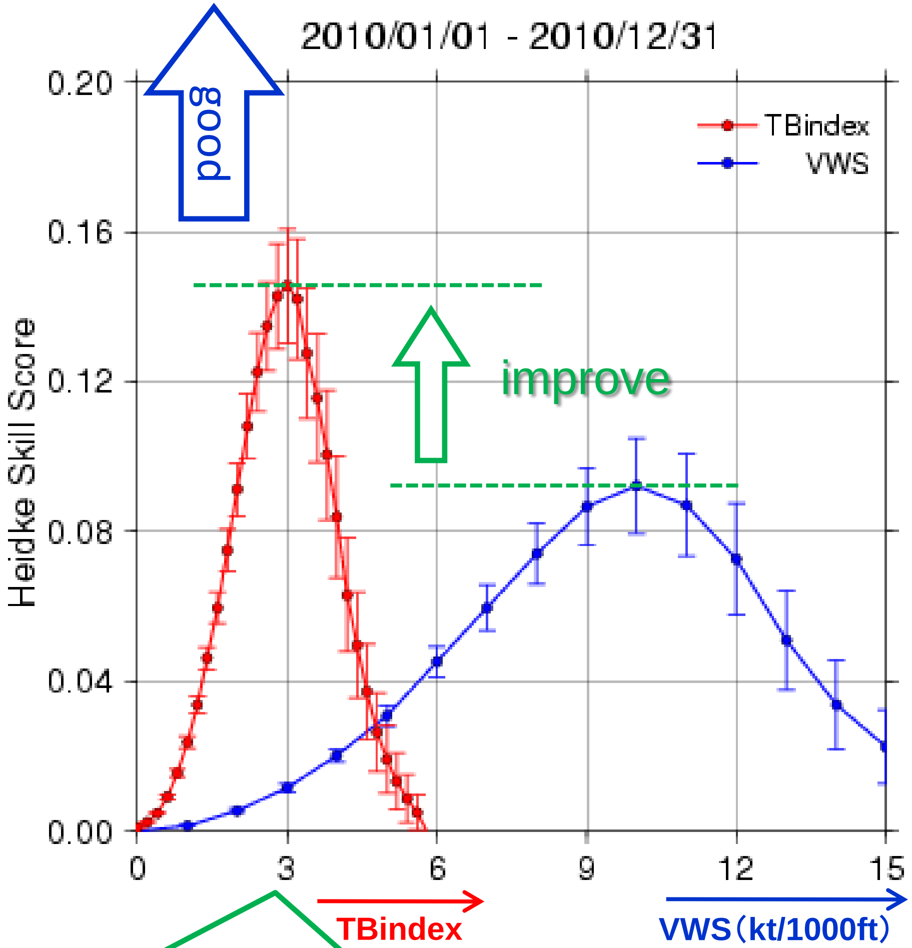
PODy:
Probability of Detection "YES" events

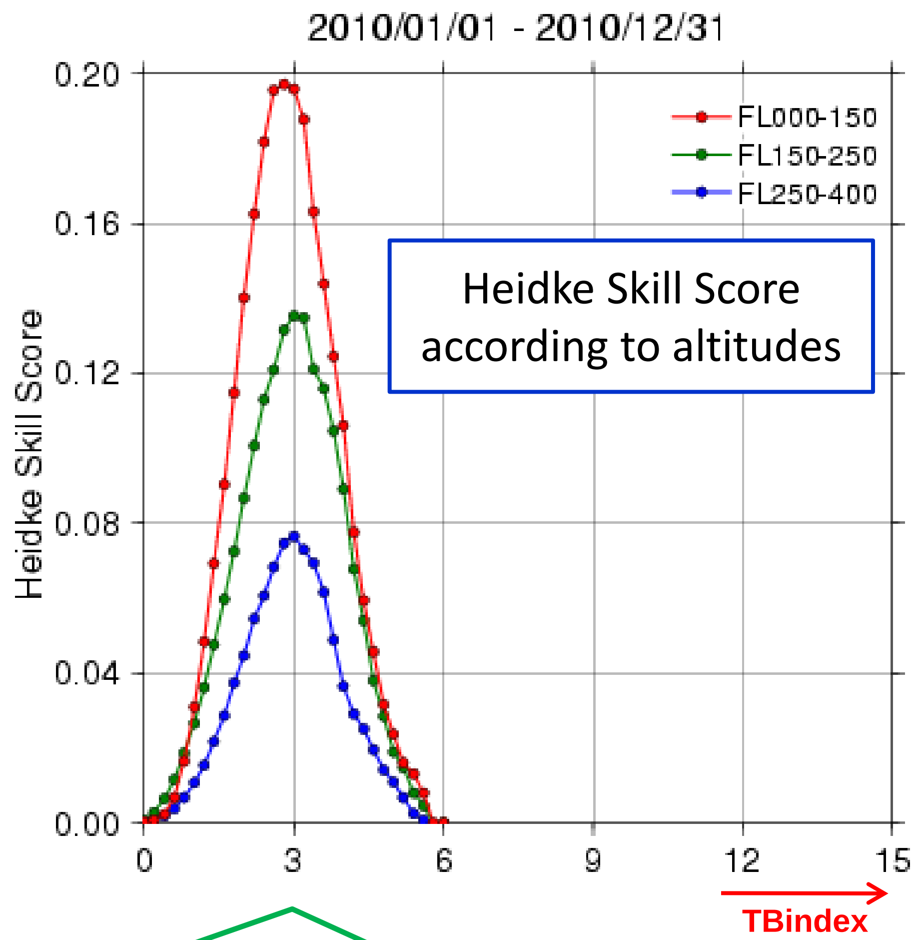
PODn:
Probability of Detection "No" events

Forecast with low 1-PODn and high PODy is good

TBindex improves forecast accuracy significantly compared to VWS

Verification Jan. – Dec. 2010 (independent on the training data)





The peak value is larger than that of VWS

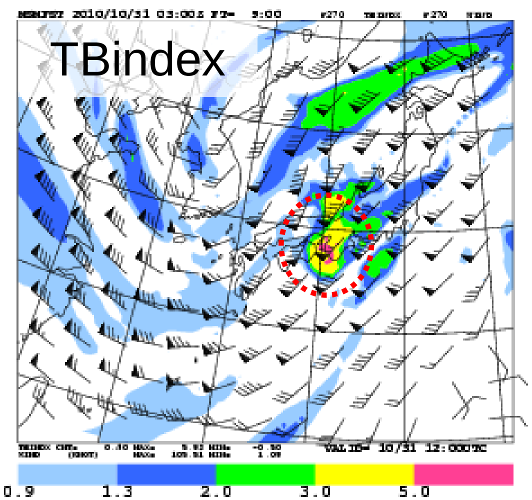
HSS reaches the maximum at about TBindex=3.0 in every altitudes → 3.0 become the optimal threshold regardless of altitude as expected

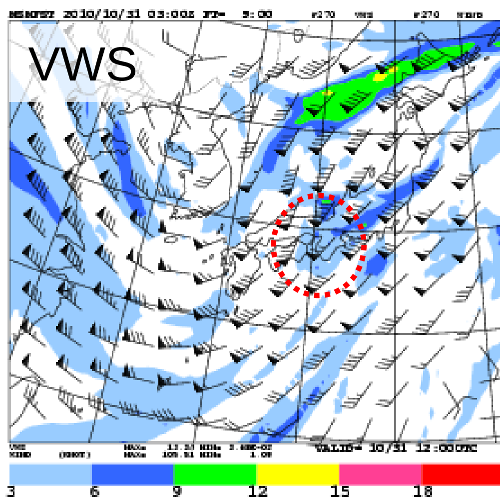
Case Study 1

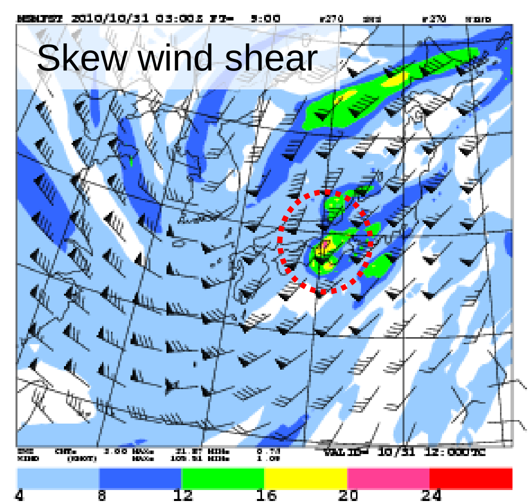
In and Top of Cloud

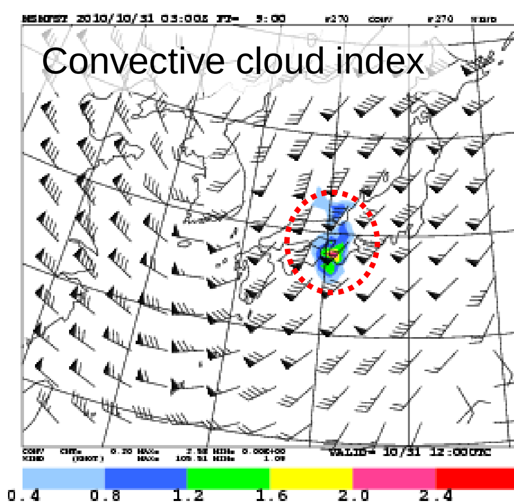
Turbulences occurred in and top of convective clouds. A severe turbulence reported around the cloud top (FL270-250)

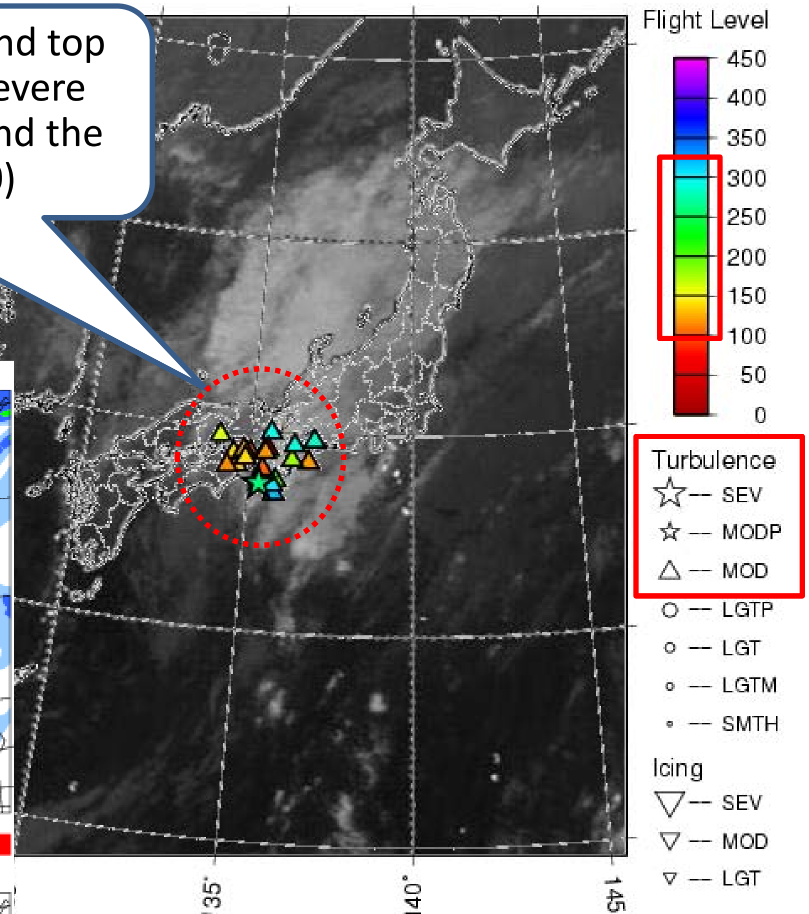
↓ 9-hour forecast at FL270
Initial time : 03 UTC 31st Oct 2010











↑ IR imagery at 12 UTC 31st Oct 2010 and MOG turbulences observed between 11 and 13 UTC

← VWS is small (3 ~ 6 kt/1000ft) in the area of severe turbulence, but TBindex is large because of large skew wind shear and large convective cloud index

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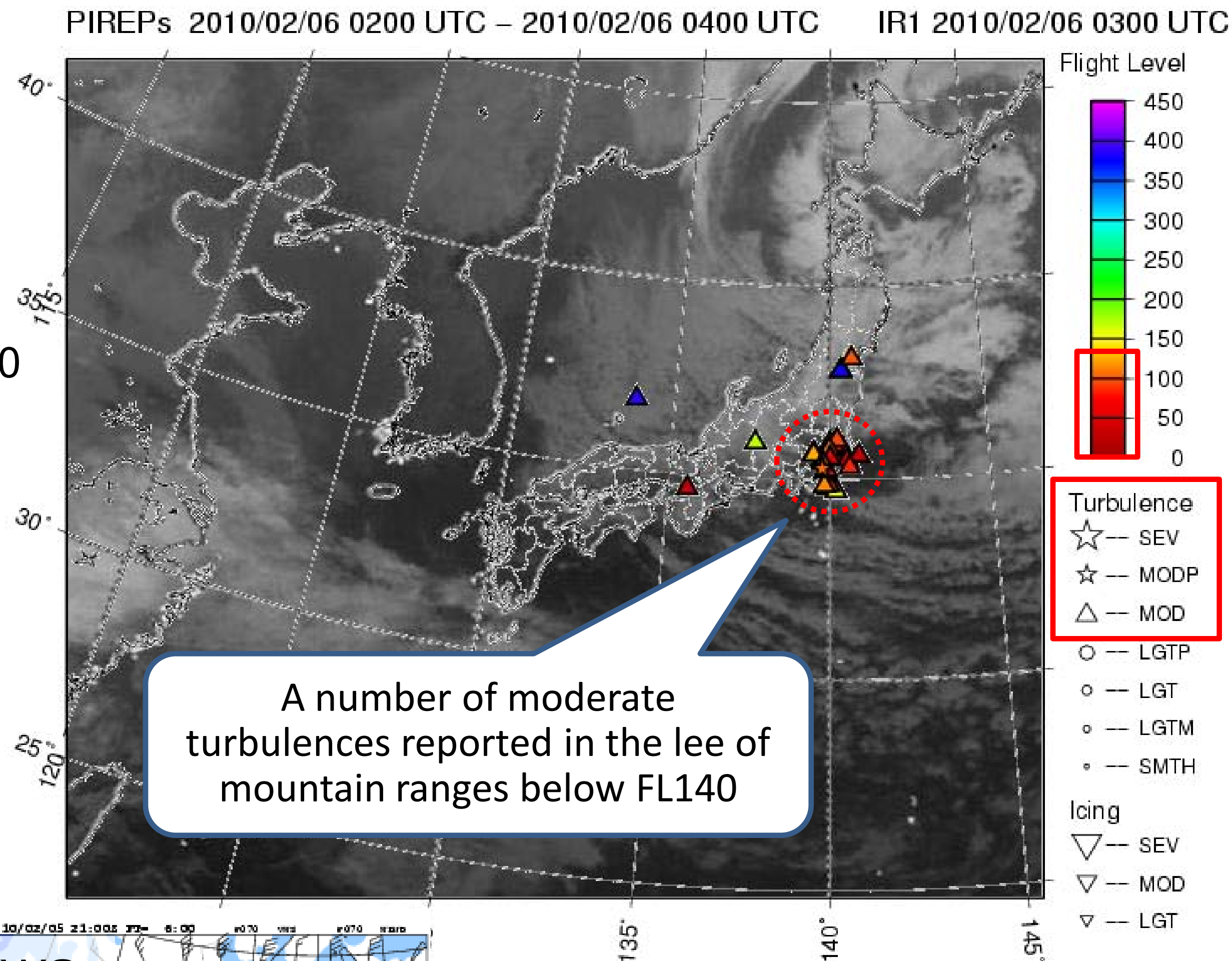
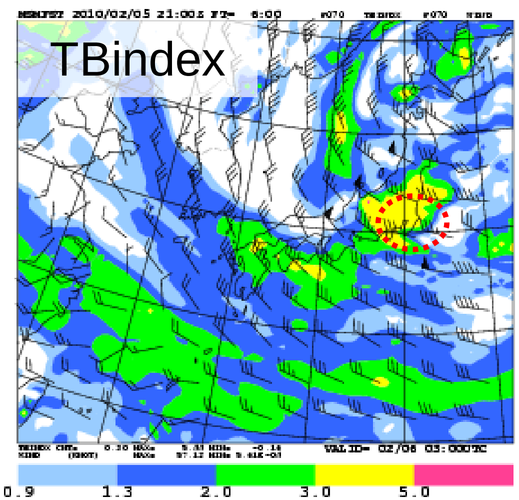
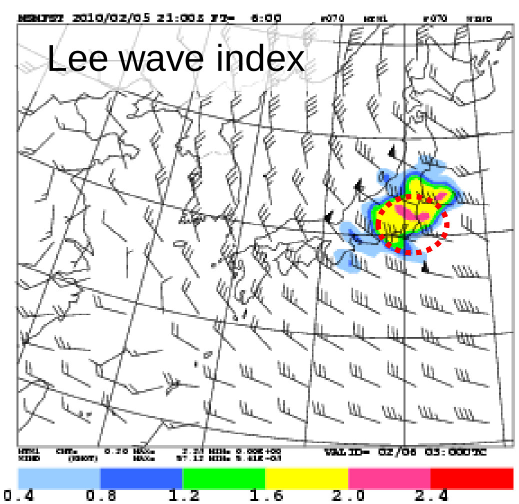
Case Study 2

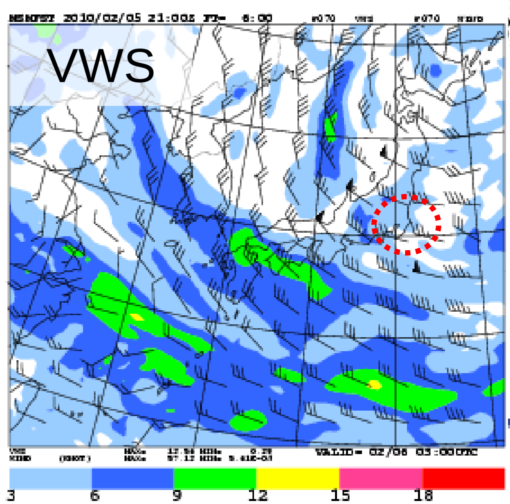
Lee Wave

↓ 6-hour forecast at FL070
Initial time : 21 UTC 5th Feb 2010









↑ IR imagery at 03 UTC 6th Feb 2010 and MOG turbulences observed between 02 and 04 UTC

← VWS is small (3 ~ 6 kt/1000ft) in the area of turbulence, but TBindex is large because of large lee wave index.

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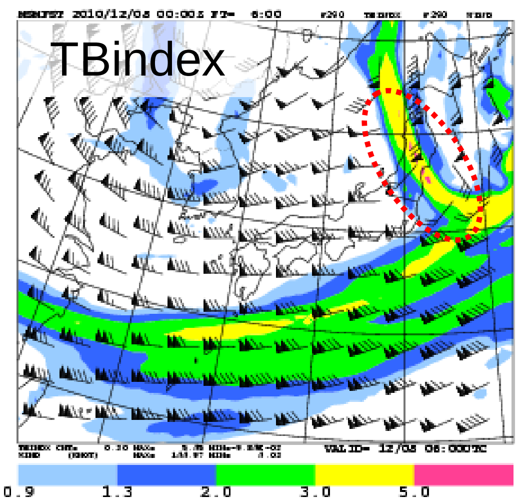
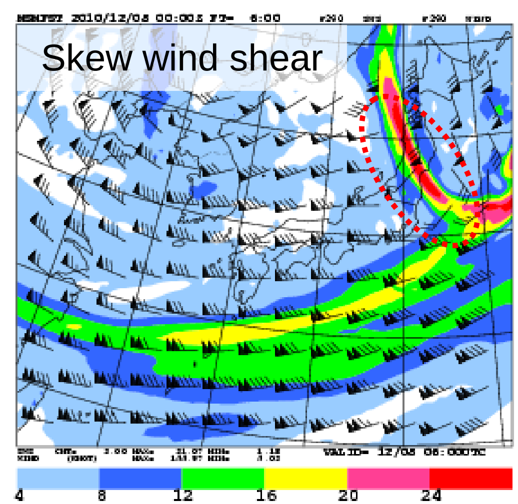
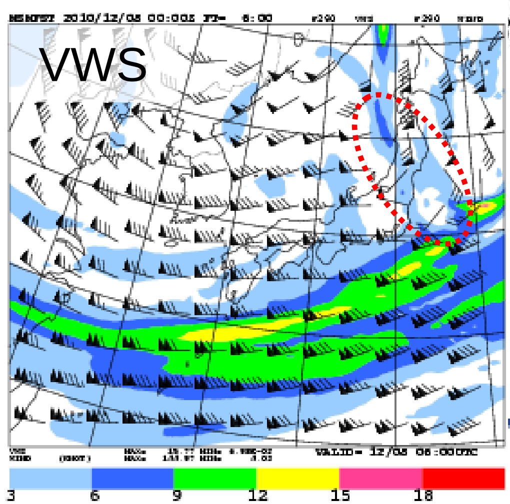
Case Study 3

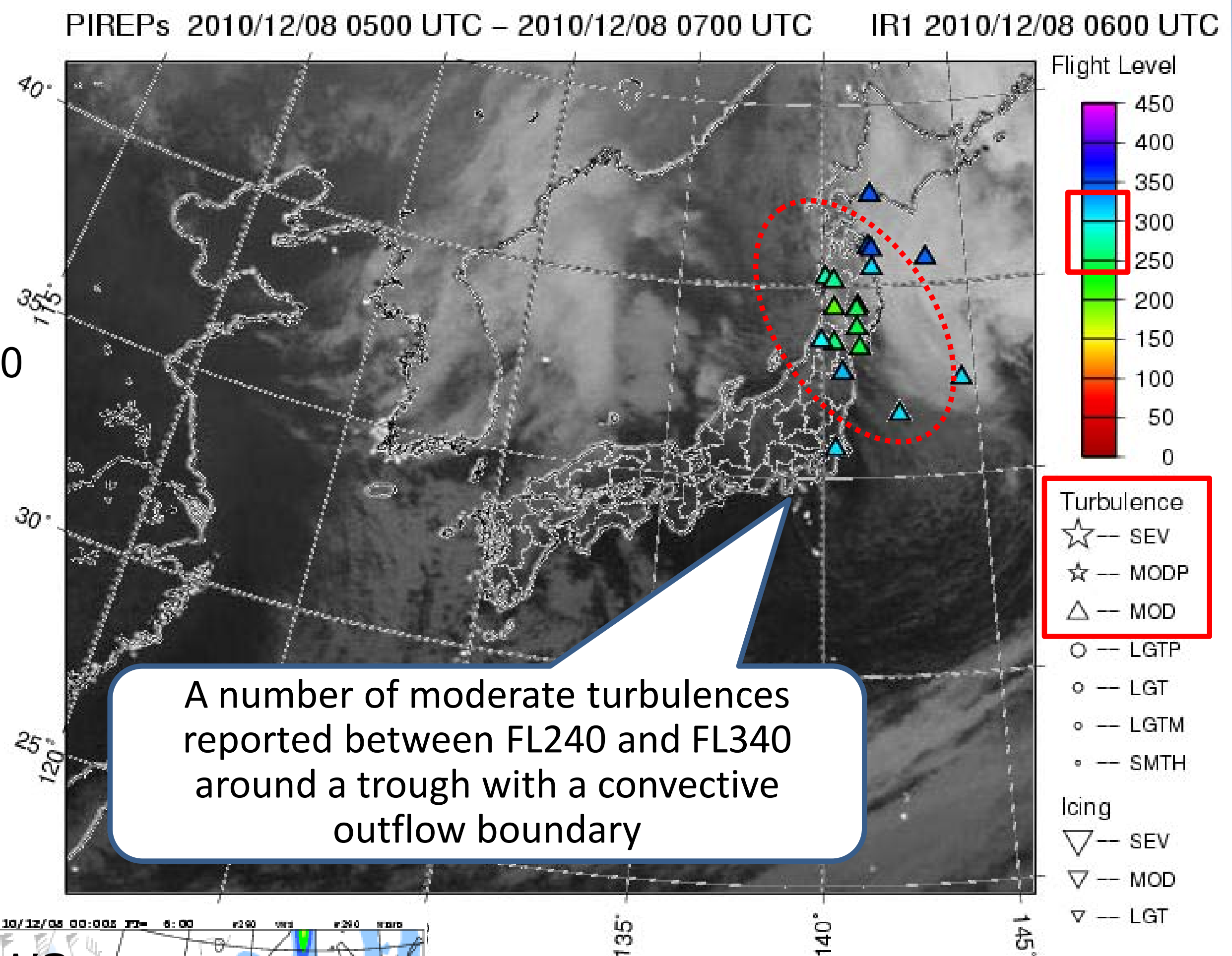
Clear Air Turbulence

↓ 6-hour forecast at FL290
Initial time : 00 UTC 8th Dec 2010









↑ IR imagery at 06 UTC 8th Dec 2010 and turbulences observed between 05 and 07 UTC

← VWS is small (3 ~ 6 kt/1000ft) in the area of turbulence, but TBindex is large because of large skew wind shear

Summary

JMA developed a new turbulence index (TBindex)

- Existing indices and newly-developed indices are combined by logistic regression method
- By using only independent indices for explanatory variables, operators can easily understand which indices contribute to TBindex
- TBindex can predict various kinds of turbulence in a comprehensive manner by a single threshold (TBindex = 3.0)
- TBindex improves forecast accuracy significantly compared to VWS