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# A novel sea state classification scheme of the global CFOSAT wind and wave observations

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# Motivation

- Sea state is often a mixture of wind-waves and swell.
- The wind waves are generated by local winds
  - strongly coupled to local wind
  - downward momentum from the atmosphere to the ocean
- Swell is generated by remote storm:
  - weakly coupled to the local winds
  - occasional upward momentum
- To better understand wind–wave interactions that accounts for both wind waves and swell systems, monitoring and **categorization** of sea state are both significant.
- **CFOSAT now provides concurrent wind and wave observations at global scale, laying great opportunity for such study.**

# CFOSAT observations

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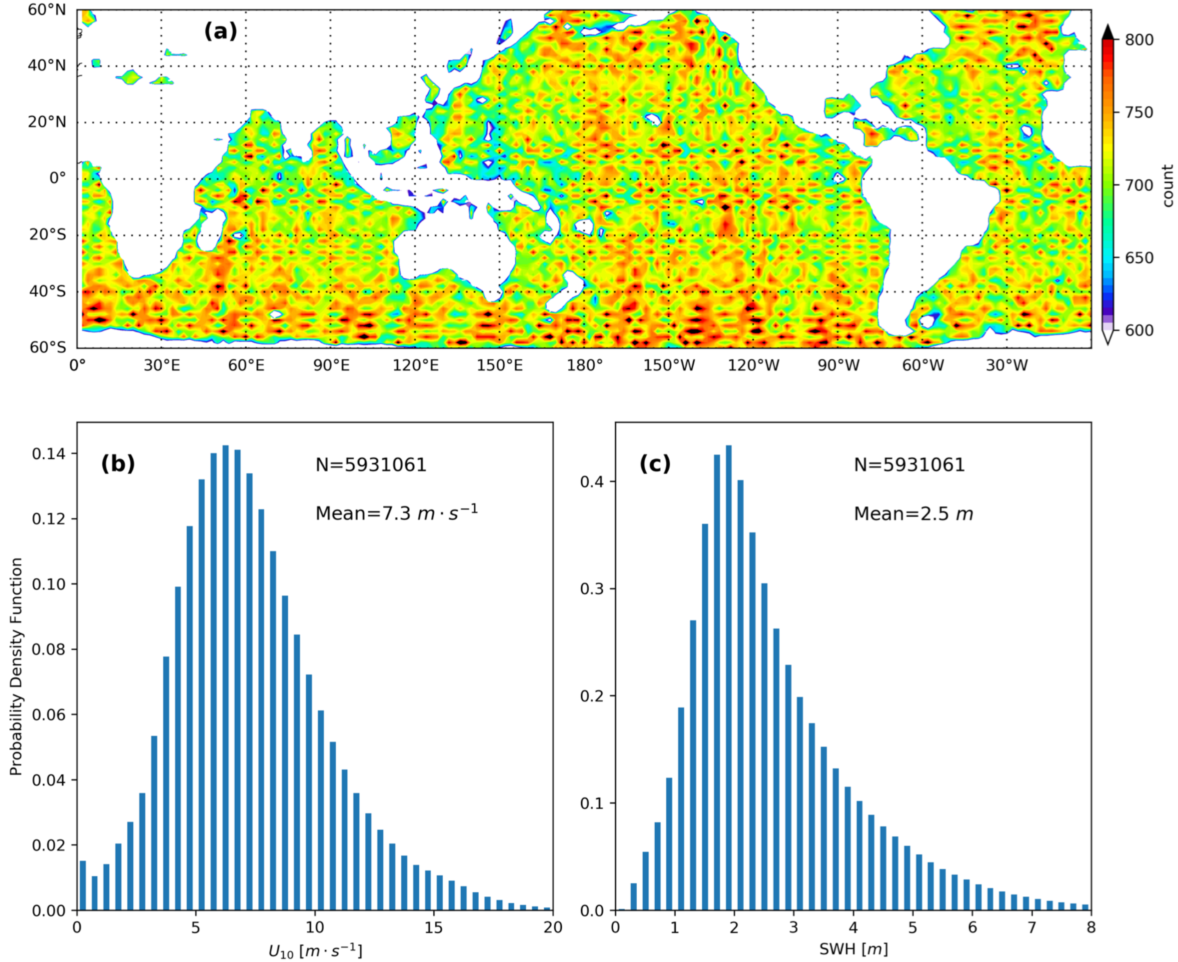
- **SWIM observed waves and SCAT derived wind vectors are collocated.**
    - $H_s$ annotated in the L2 wave products
    - $U_{10}$ and direction in the L2 wind products
- **Time period: 2019.05-2021.04**
    - the IPF upgraded in 2020.09 (ver 5.1.2)

- **Upper plot:** the count map of collocated data points with a bin of 2°✕2°. Numbers of data points are larger than 700 in most of the grids.
- **Bottom plot:** PDF of the collocated u10 and Hs with the mean of 7.3 m·s$^{-1}$ and 2.5 m, respectively.



# CFOSAT observations

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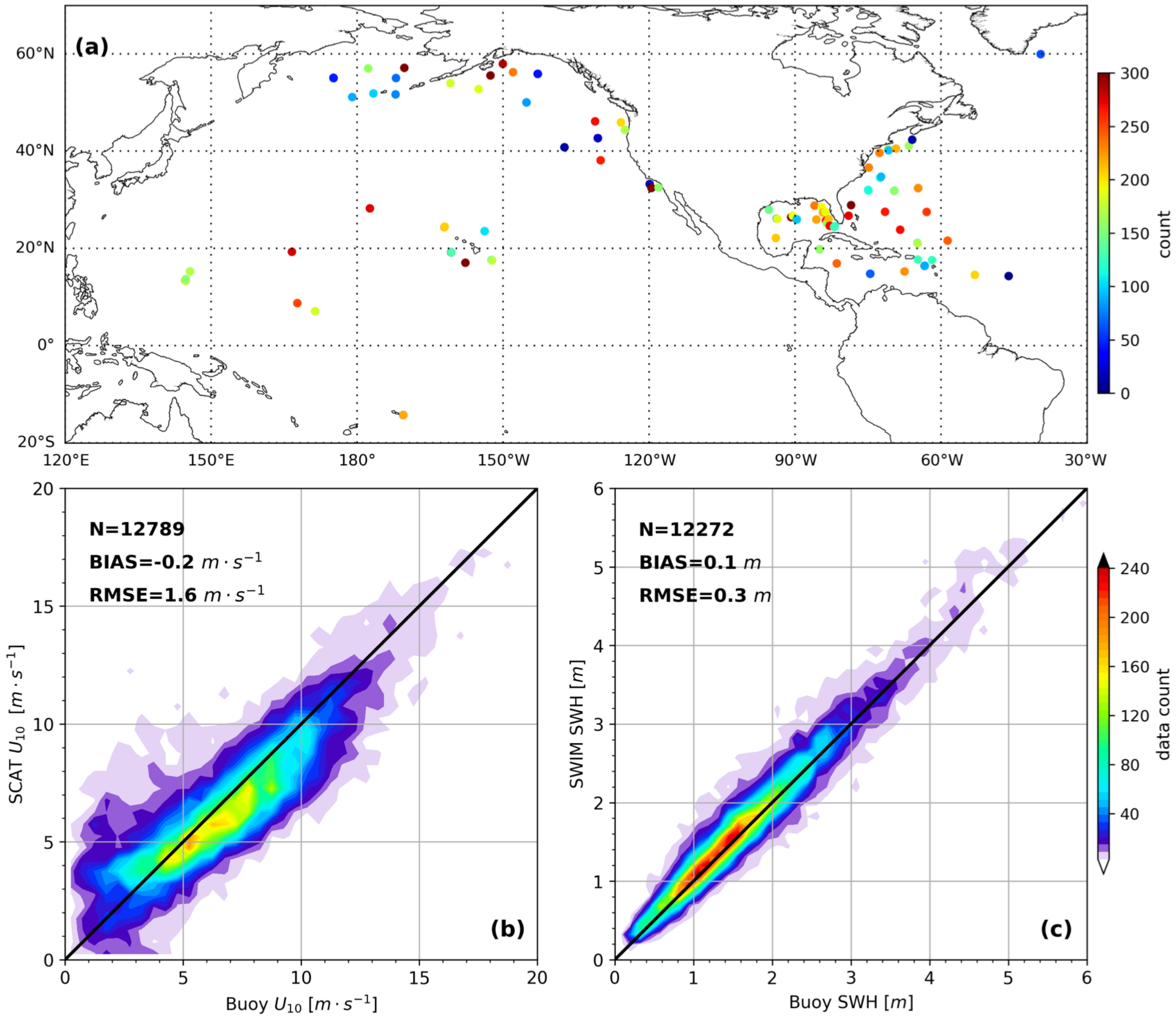
- Accuracy of $H_s$ and $U_{10}$ is validated in comparison with *in-situ* buoy measurements.
  - All buoys located within 50 km to the shoreline are excluded in the analysis.
  - The collocation criteria is 70 km in space and 30 mins in time.

- The bias and RMSE of $H_s$ and $U_{10}$ is within the sensor design expectation.



# CFOSAT observations



Using the directional wave height spectrum $F(k,\varphi)$ from the L2 product, the following wave parameters are calculated:

**Inverse wave age:**

$$IWA = U_{10}/c_p$$

where $c_p$ is the phase speed of peak waves

**Mean square orbital velocity:**

$$MSV = \int kF(k,\varphi)kdkd\varphi$$

# CFOSAT observations

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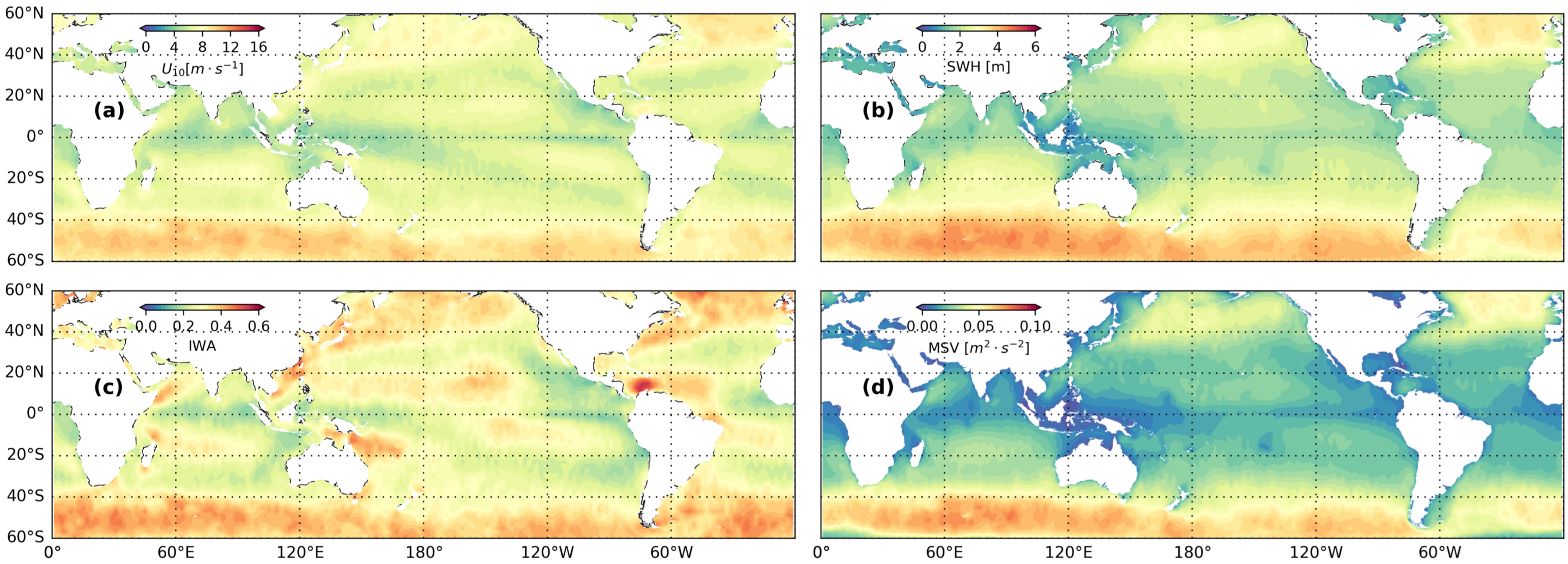
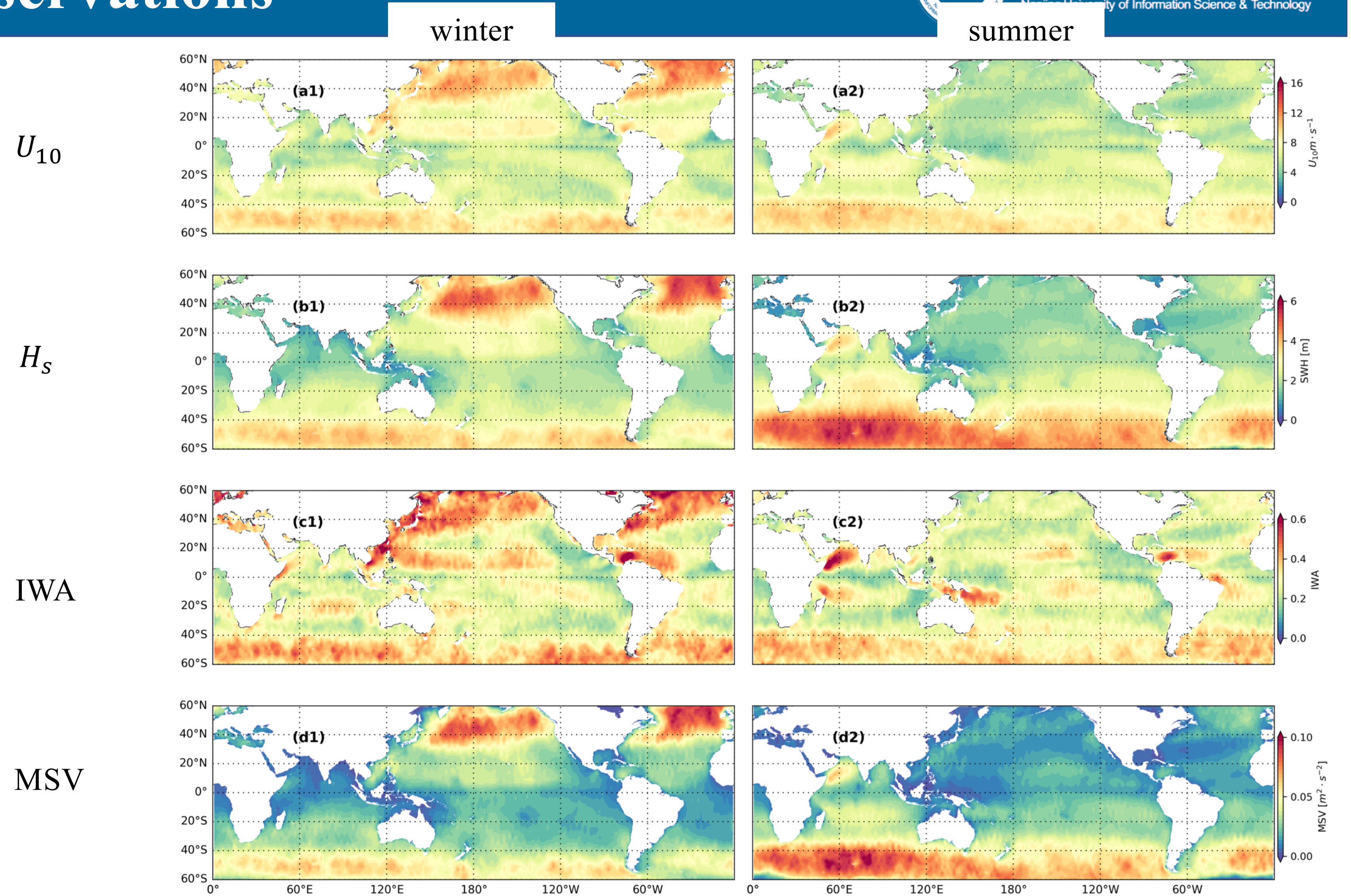
Global average of $U_{10}$, $H_s$, IWA and MSV



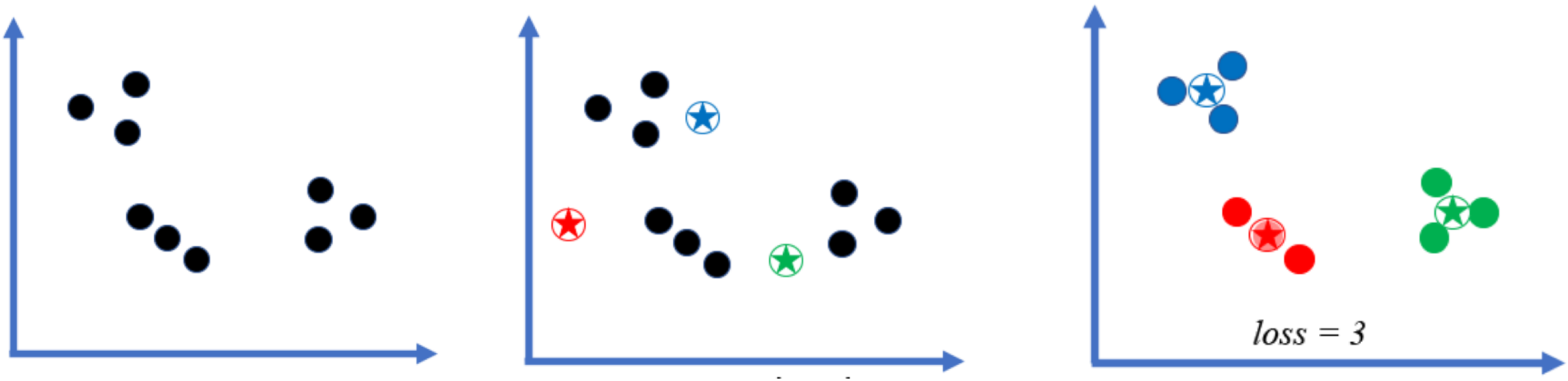
# CFOSAT observations

Seasonal average



# k-means clustering

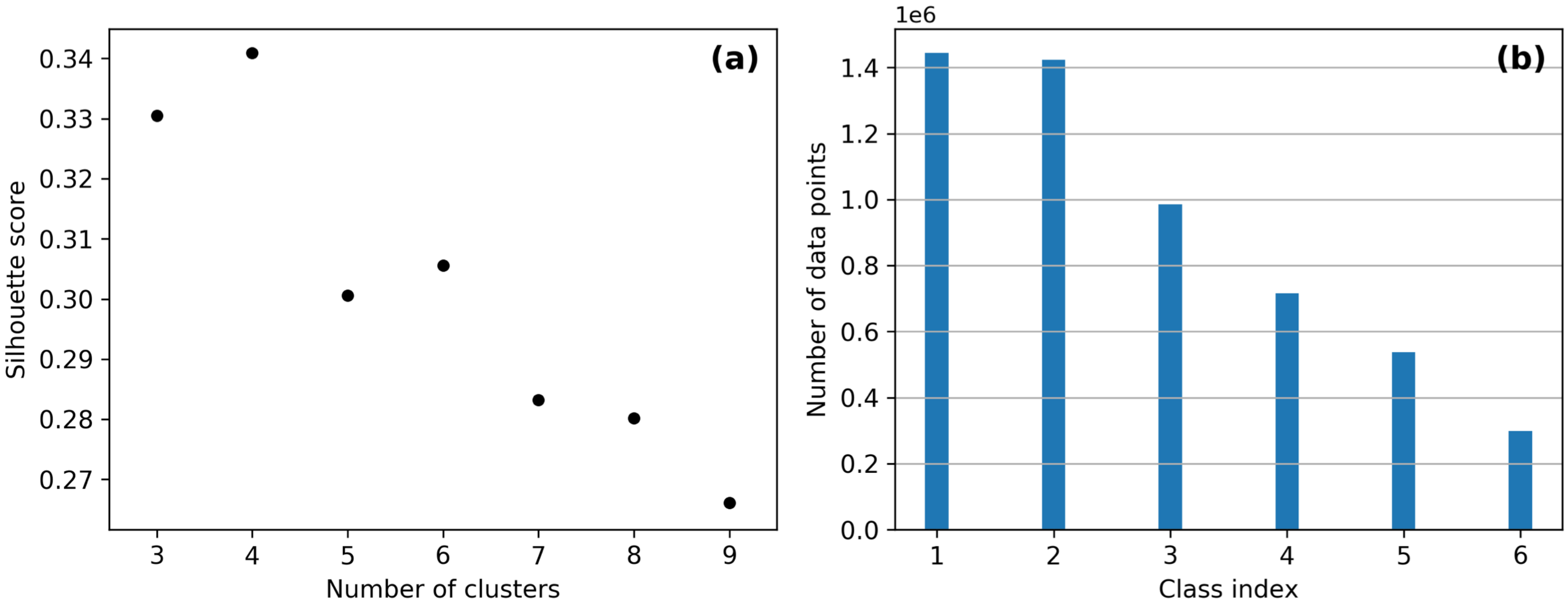
- K-means clustering is an unsupervised clustering technique that assigns the multivariate observational data vectors into different groups based on their similarity.
    - divides the input into a priori k groups, each characterized by a cluster centroid as the prototype;
    - the clustering process is to minimize the point-to-centroid distance within each group.



# k-means clustering



- The number is predefined as k=6 by taking into account the wind conditions (low, medium and high) as well as the wave maturity (wind-sea and swell).
- Silhouette score is a value in the range of [-1,1], used to represent goodness of the clustering results.



# Wind-wave clustering

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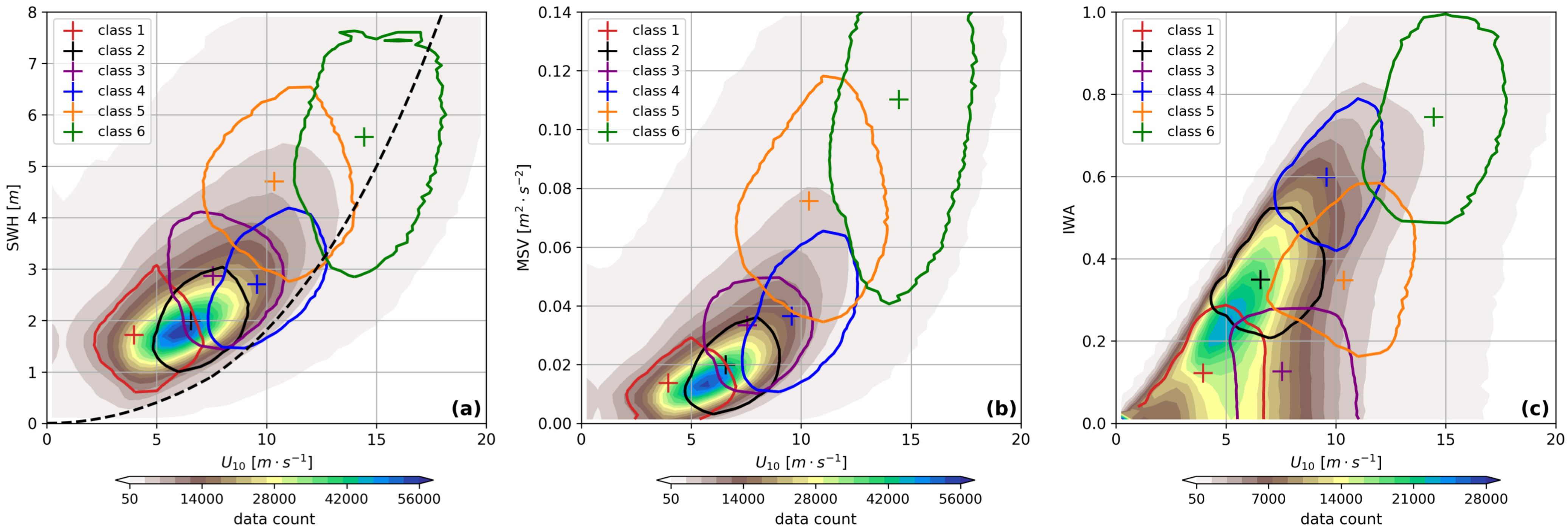
- Higher wind speed corresponds to larger SWH and MSV.
- Lower IWA, swell-dominated sea state, characterizes larger SWH for similar wind speed range.

Table 1: Details of clustered centroids.

| Class index | U10 $[m \cdot s^{-1}]$ | SWH [m] | IWA | MSV $[m^2 \cdot s^{-2}]$ |
|---|---|---|---|---|
| 1 | 3.96 | 1.72 | 0.122 | 0.014 |
| 2 | 6.57 | 2.00 | 0.350 | 0.020 |
| 3 | 7.55 | 2.87 | 0.126 | 0.033 |
| 4 | 9.57 | 2.70 | 0.599 | 0.037 |
| 5 | 10.36 | 4.71 | 0.348 | 0.076 |
| 6 | 14.45 | 5.57 | 0.745 | 0.110 |

# Wind-wave clustering

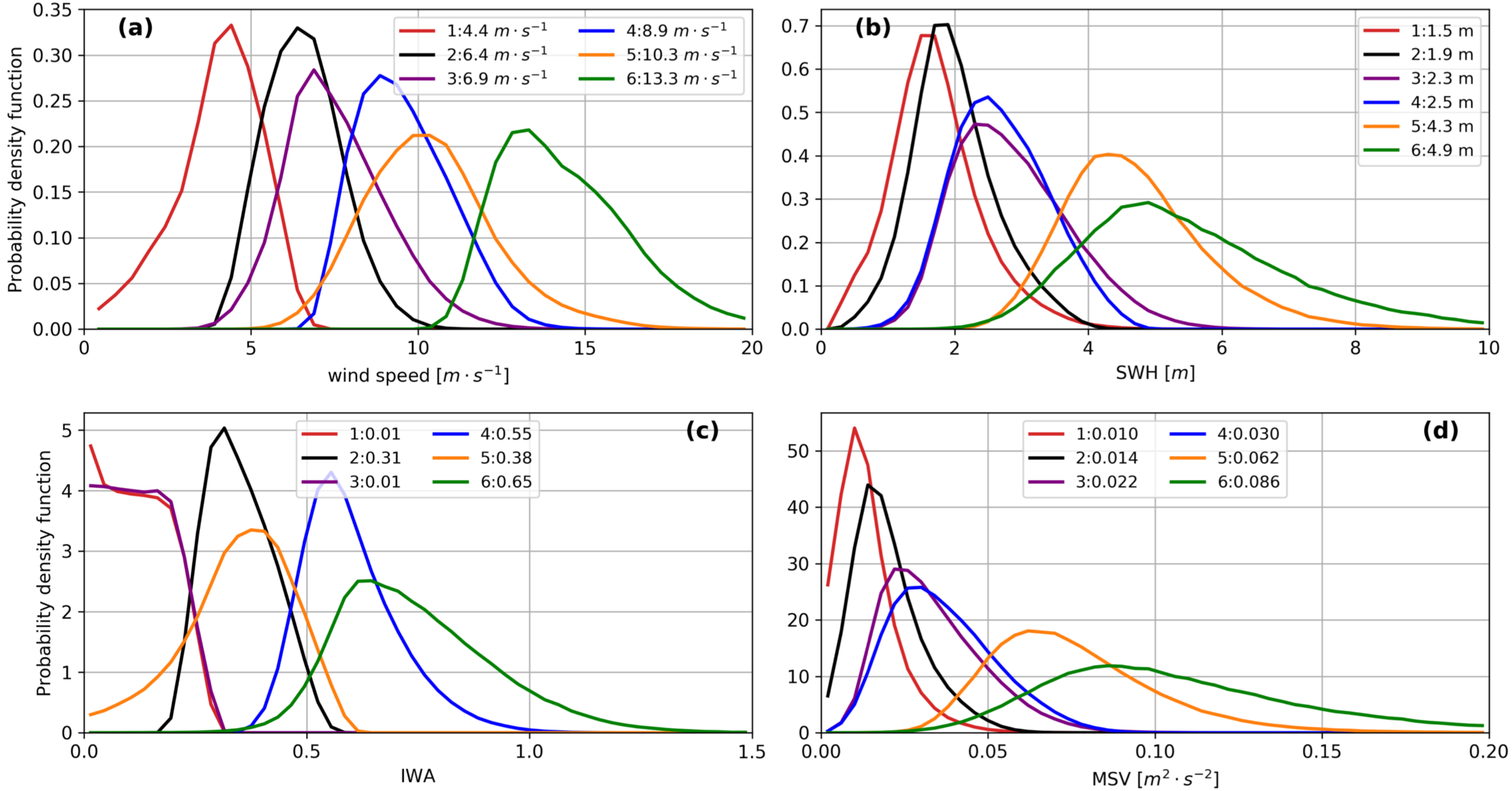
- Class 1 and 2 of low to median wind conditions are the most popular, while class 6 of high winds is the rarest.
- Monotonous increase of SWH and MSV with wind speed.
- Lower IWA of class 3 w.r.t. class 2 at similar $U_{10}$ results in much larger SWH.



# Wind-wave clustering

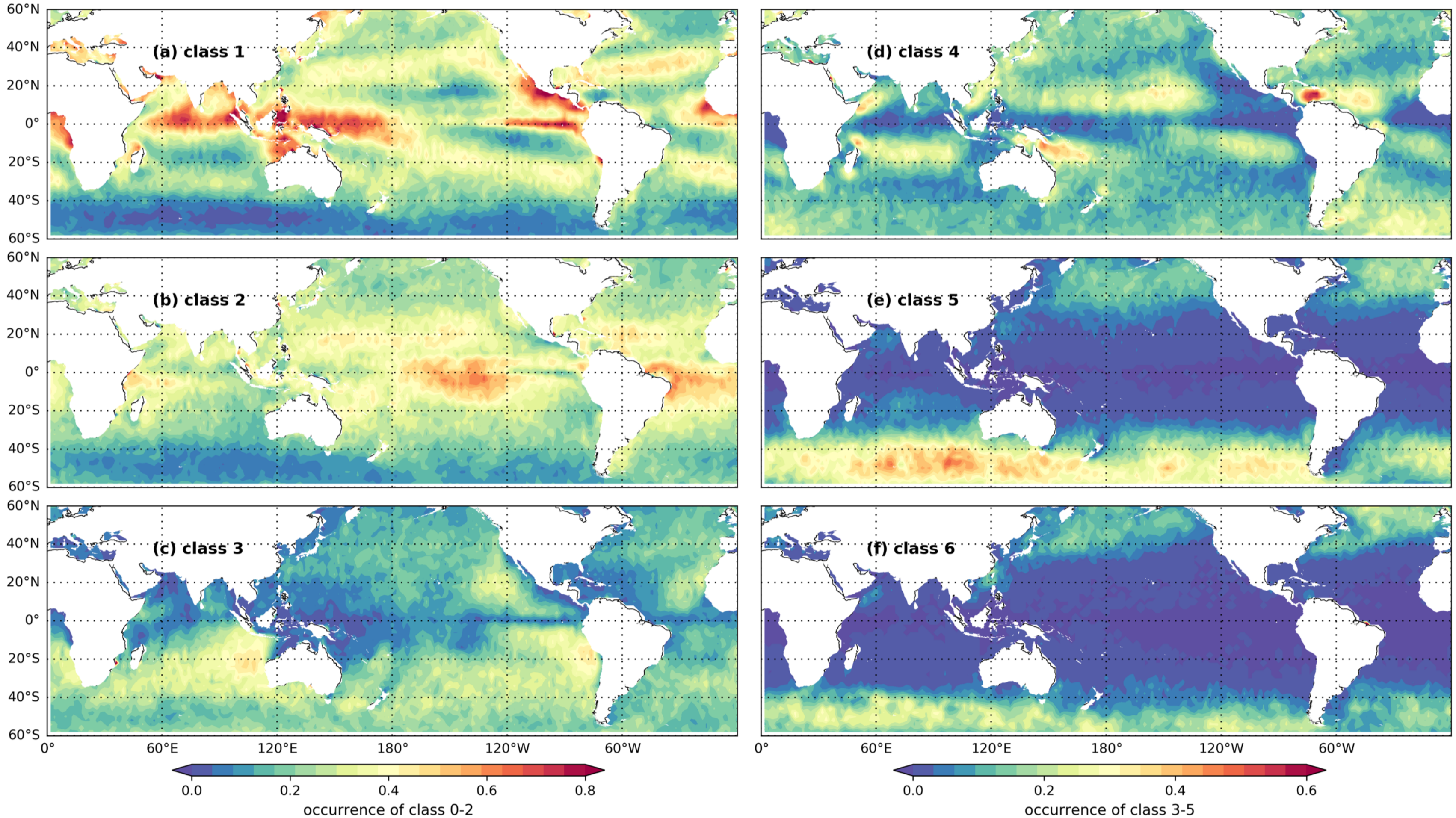


- PDF of each class: overlapping for each individual variate but disjoint in the 4D feature space.



# Wind-wave clustering

- Global occurrence of frequency of the obtained 6 classes



# Summary

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- A novel sea state classification scheme using the k-means clustering algorithm is presented based on the concurrent CFOSAT wind and waves observations.
- Six classes are considered in terms of wind condition (low, median, high) and wave maturity (young and old sea), complementary to the previous studies of wind-sea dominated and swell dominated.
- The result also provide additional information on the regional variations of swell dominated sea state, like class 2 and 3 of low IWA.
- Sea state clustering based on long-term data series might give new perspectives on the global wave climate.

# Thank you !

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