Application of Support Vector Machine Theory for Combined Active/Passive Observations of HY-2A under rainy conditions

(A combined wind retrieval model over ocean for HSCAT and HRAD onboard HY-2A satellite under rainy conditions)

Xingou Xu[1], Xiaolong Dong[1,2], Wenming Lin[3], Risheng Yun[1], Di Zhu[1]

1 The Key Laboratory of Microwave Remote Sensing, National Space Science Center, Chinese Academy of Sciences

2 University of Chinese Academy of Sciences

3 Institute of Marine Science, Spain (ICM-CSIC)

xuxingou@mirslab.cn

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Outlines

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- Method
- Experiments
- Results
- Summary & Future Research

Introduction

Problem description:

- Rains affect accuracy of wind field retrieving:

  - Combined observations of scatteromenter and muti-frequency / polarization radiometer.

- Physical progress being considered:

  - Support Vector Machine.

Introduction

- **Support Vector Machines (SVMs) （V.Vapnik, 1998, 1999）：**

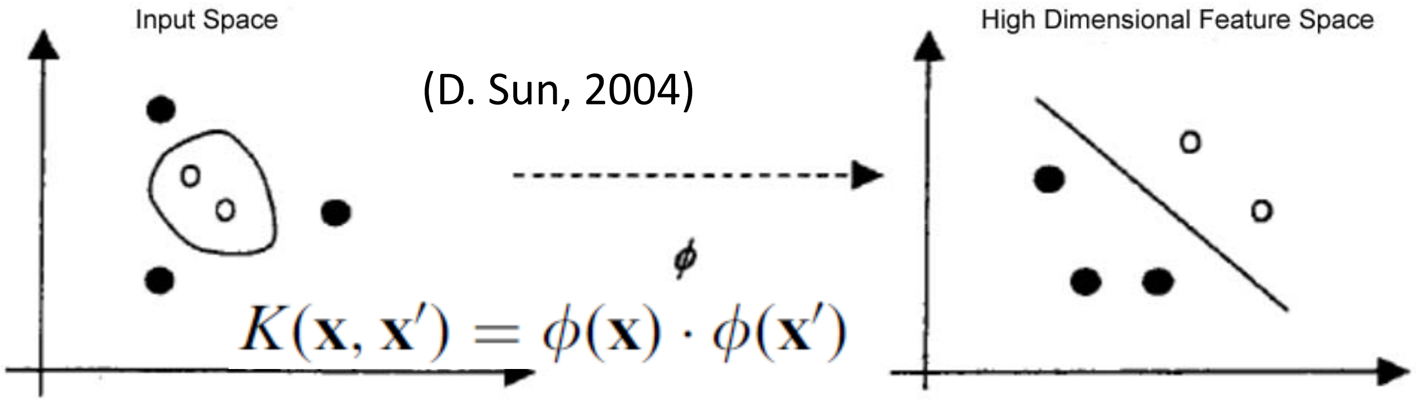
- Nonlinear classifier (regression tool)

S = {x} → Mapping → F = {(x)}

Mapped patterns, need not compute explicitly

Kernel Function: $K(\mathbf{x}, \mathbf{x}') = \phi(\mathbf{x}) \cdot \phi(\mathbf{x}')$

Maximum-margin Hyperplanes in a transformed feature space.



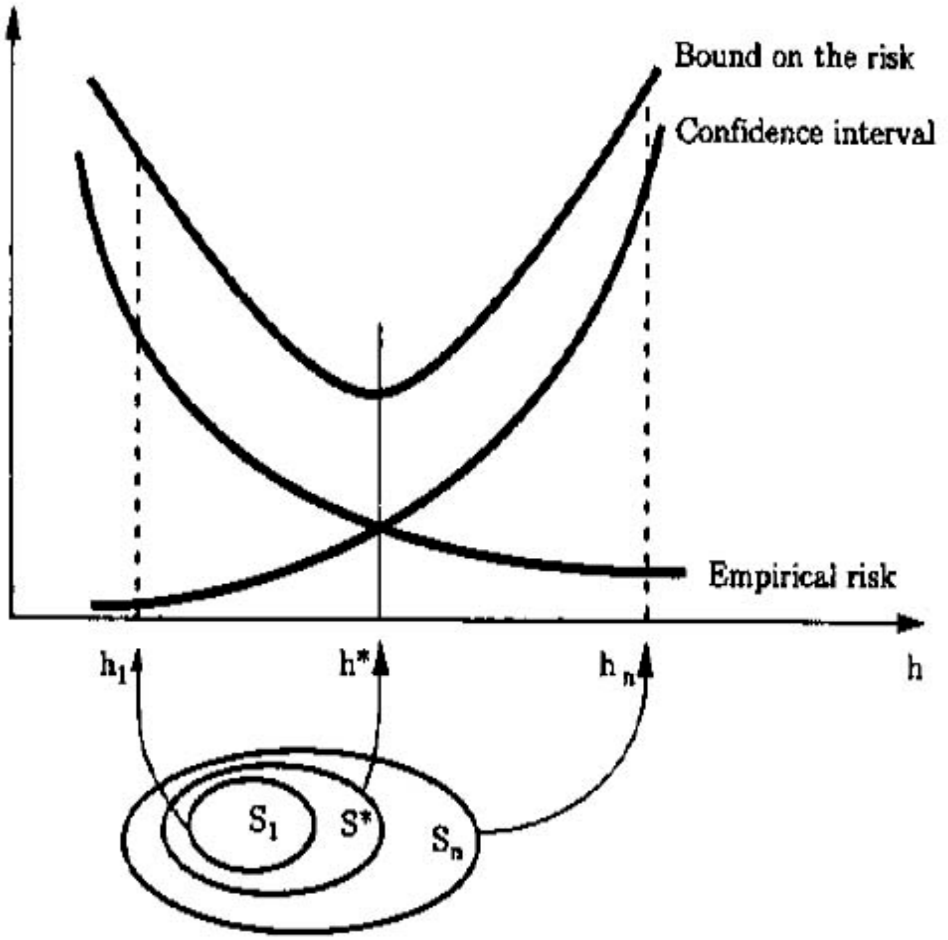
(D. Sun, 2004)

Structural Risk Minimization (SRM)

- To complement Empirical risk minimization with VC (Vapnik-Chervonenkis) confidence.

- Statistical inference method *yet* without requiring a priori distributions and gives no regional minimum.

(V.Vapnik, 1998, 1999)



The bound on the risk is the sum of the empirical risk and the confidence interval. The empirical risk decreases with the index of the element of the structure, while the confidence interval increases. The smallest bound of the risk is achieved on some appropriate element of the structure.

Kernel Function

- Generated from:

  -Expansion on polynomials

  -Splines with infinite numbers of knots

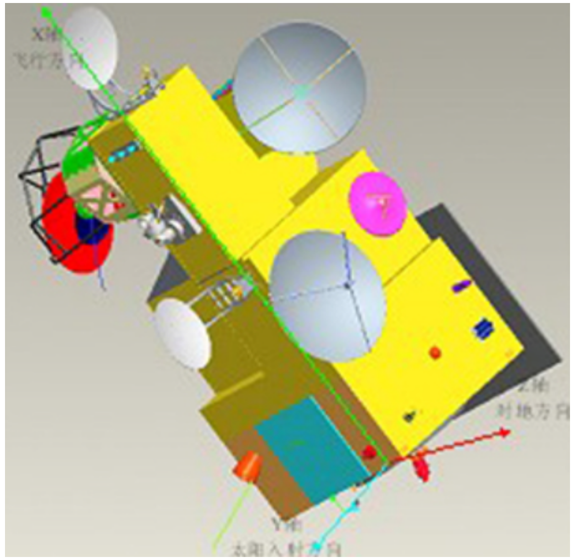
  …

  -Fourier expansions (Regularized)

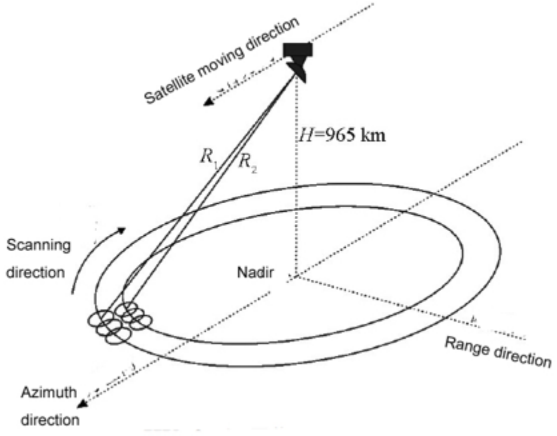
$$K(x_i, x_j) = \frac{1}{2} + \sum_{k=1}^{\infty} q^k (\cos kx_i \cos kx_j + \sin kx_i \sin kx_j)$$

$$= \frac{1}{2} + \sum_{k=1}^{\infty} q^k \cos k(x_i - x_j) = \frac{1 - q^2}{2(1 - 2q\cos(x_i - x_j) + q^2)}.$$

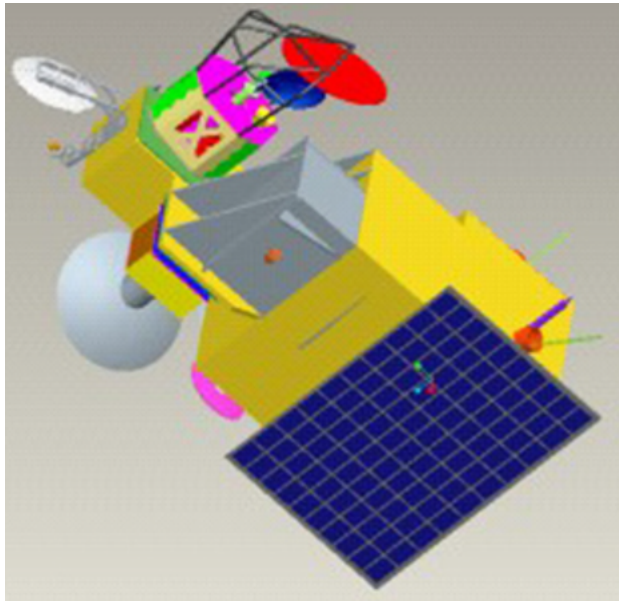
HSCAT



HY-2A Scatterometer（HSCAT）



Schematic diagram of the HY−2A scatterometer observation

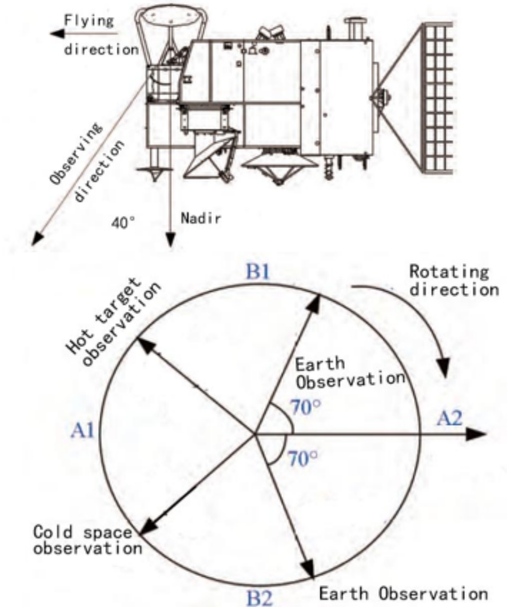


The technical specification of HSCAT

Parameters	Specifications	
Working Frequency (GHz)	13.256	
Swath(km)	Outer beam: ≥ 1700	Inner beam: ≥ 1400
Resolution (km)	25	
Sigma0 measuring accuracy (dB)	0.5	

HRAD

HY-2A Scanning Radiometer（HRAD）



The technical specification of HRAD

Frequency（GHz）	6.6	10.7	18.7	23.8	37.0
Pol	VH	VH	VH	V	VH
swath（km）	≥1600				
footprit（km）	100	70	40	35	25
Sensitivity（K）	Better than 0.5				≥0.8
Measurement range	3~350K				
Calibration accuracy	1.0K（180~320K）				

Method: A Kernel function for combined observation

$$K(X, X_i) = \frac{1 - q^2}{2(1 - 2q cos(X - X_i) + q^2)} \times (X \cdot X_i + pX + 1)^4$$

Satisfy Mercer's condition

A 4th order polynomial and 4th order Fourier kernel is used.

Experiment

- Data (2013, 2014):
  - ➢HSCAT (L1B, sigma0 with observation properties)
  - ➢HRAD (L1A, BTs & L2A rain products)
  - ➢Windsat (wind field products)
  - ➢All moored Buoy data
- Data Preparation
  - ➢ Data registration to HSCAT WVCs of other data sets. (15km, 30min for Windsat data; 20 km, 1hr for buoy data)
  - ➢ Select rainy area with reference of rain product of HRAD
  - ➢Half of the data sets used for training and the other half for validation.

Experiments

- Training:

  Inputs: HRAD BTs of all frequencies and polarizations, HSCAT sigma0s of *HH* and *VV*, observing geometry.

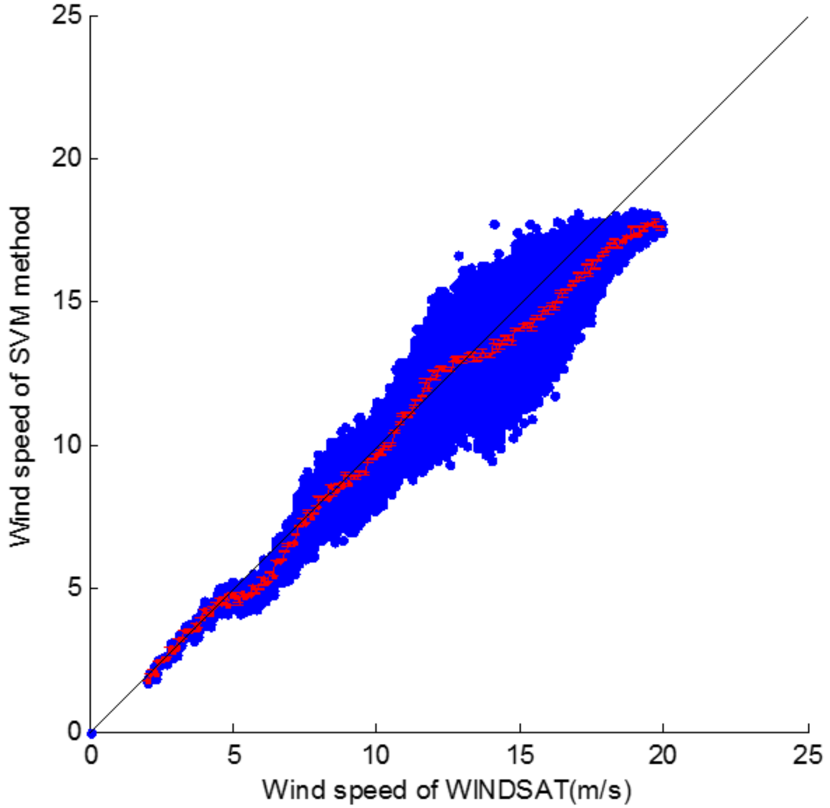
  True values: Windsat wind fields products.

- Validation:

  Inputs: HRAD BTs of all frequencies and polarizations, HSCAT sigma0s of data sets have ***not*** been used in training.

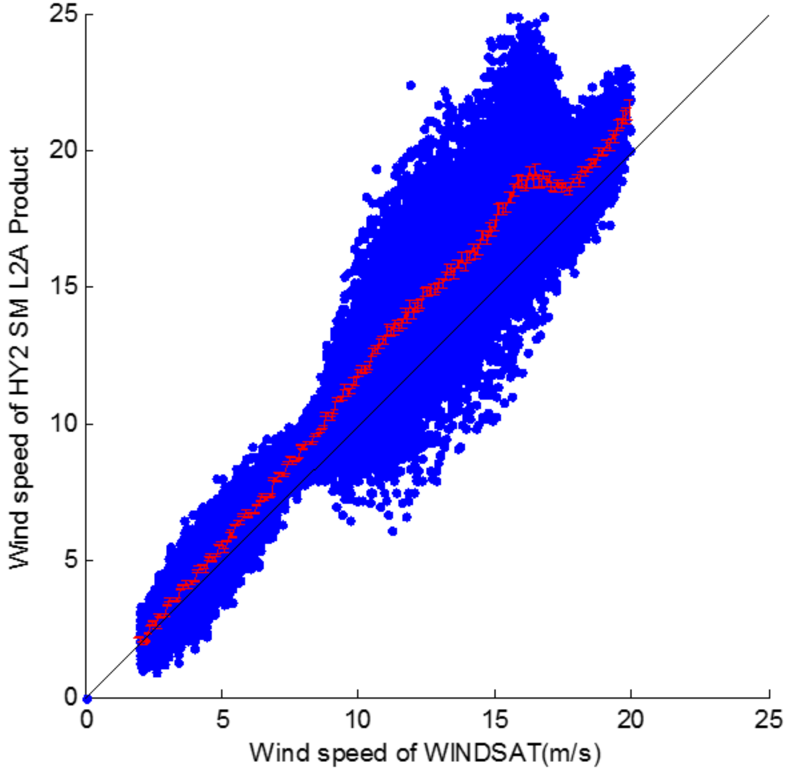
  Outputs: Wind fields. *Validation realized by compared with buoy data.*

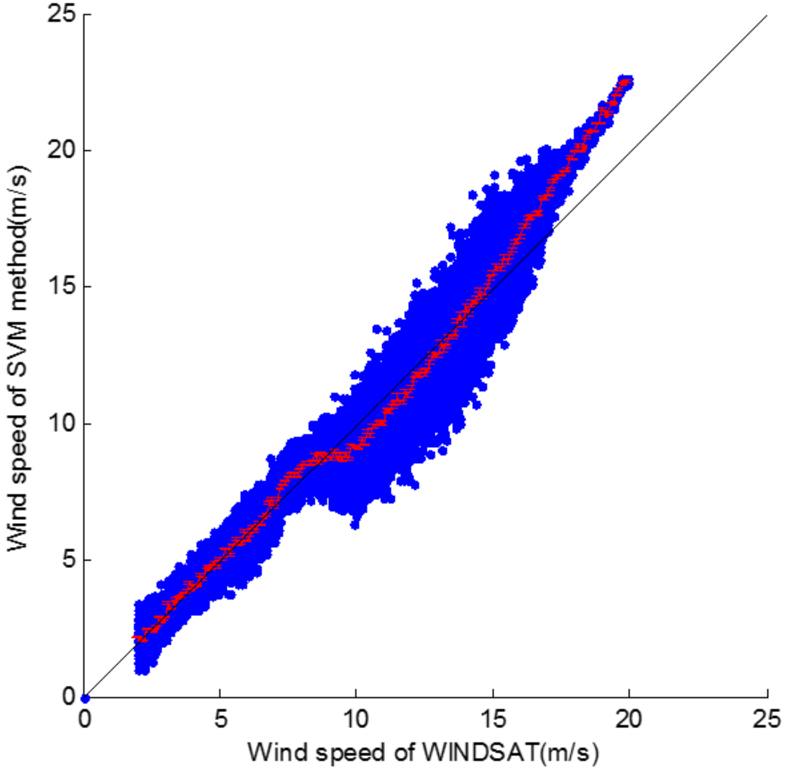
Application of SVM of HSCAT and HRAD for non rainy areas (wind speed result)



Windsat wind speed	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
SVM rst mean	1.8	3.1	4.1	4.8	5	6.4	8.1	8.8	9.6	11.2	12.6	12.9	13.2	14.1	14.8	15.4	16.1	16.5
SVM rst var.	0.02	0.03	0.05	0.07	0.1	0.18	0.25	0.27	0.29	0.37	0.47	0.54	0.61	0.6	0.5	0.63	0.6	0.45

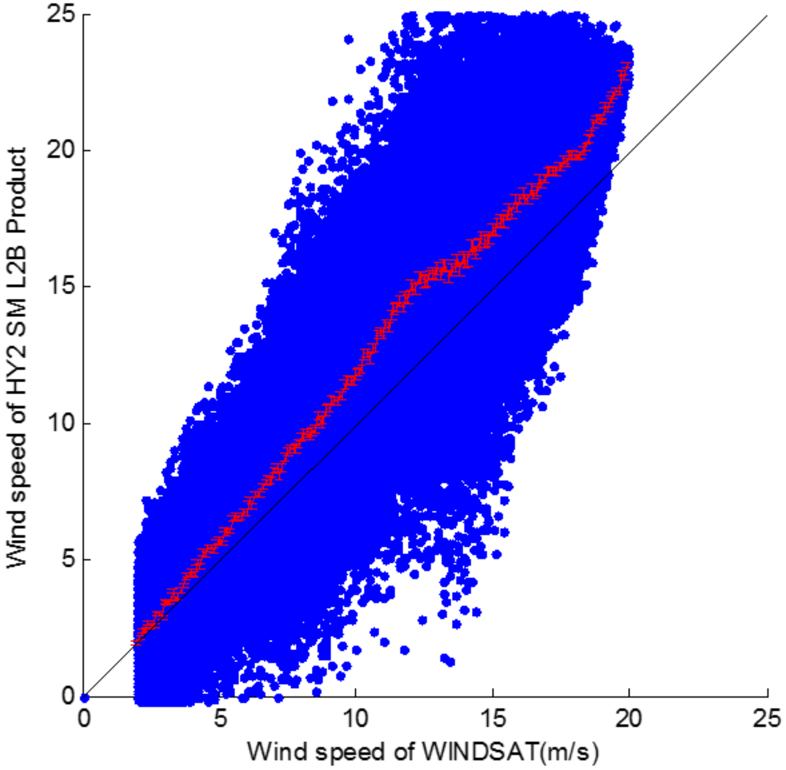
Application of SVM of HSCAT and HRAD for rainy areas (wind speed result, rain rate about 2-6mm/h)

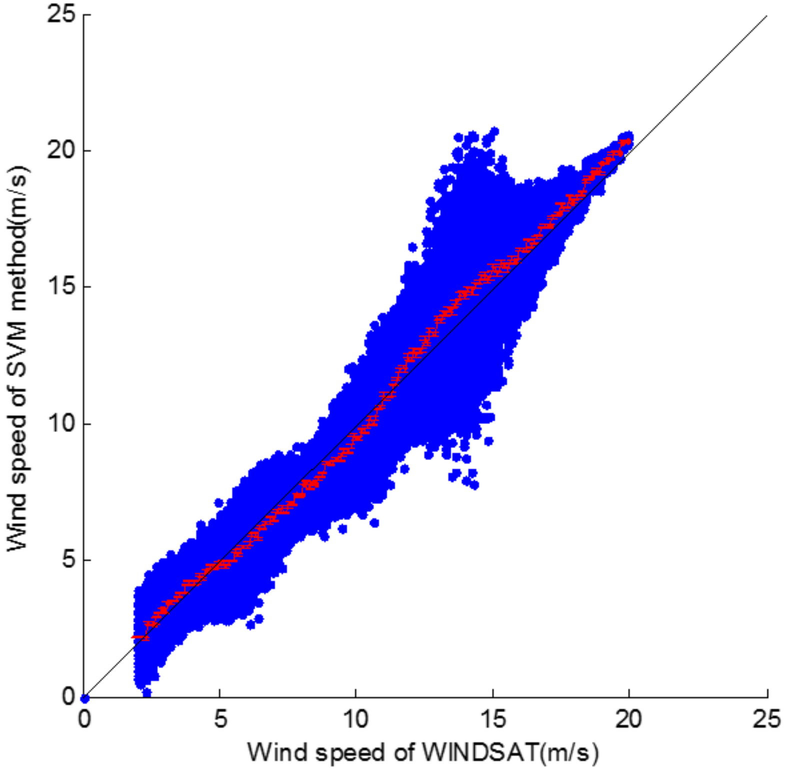




Windsat wind spd	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HSCAT L2B mean	1.81	3.04	4.71	5.58	6.7	8.05	9.14	10.4	12.1	13.5	14.9	15.5	16.1	17.2	17.9	18.7	20.5	22.1
HSCAT L2B var.	0.64	0.83	0.93	0.99	1.05	1.31	1.53	1.55	1.53	1.62	1.83	2.05	2.32	2.6	2.91	2.43	3.03	2.01
SVM rst. mean	1.83	2.92	3.98	4.79	5.79	6.81	7.86	8.53	9.22	11	12	13.2	14.5	15.3	16.5	17.9	20.9	22.7
SVM rst. var.	0.3	0.27	0.25	0.32	0.4	0.32	0.25	0.34	0.46	0.51	0.57	0.82	1.05	0.93	0.53	1.03	1.45	1.03

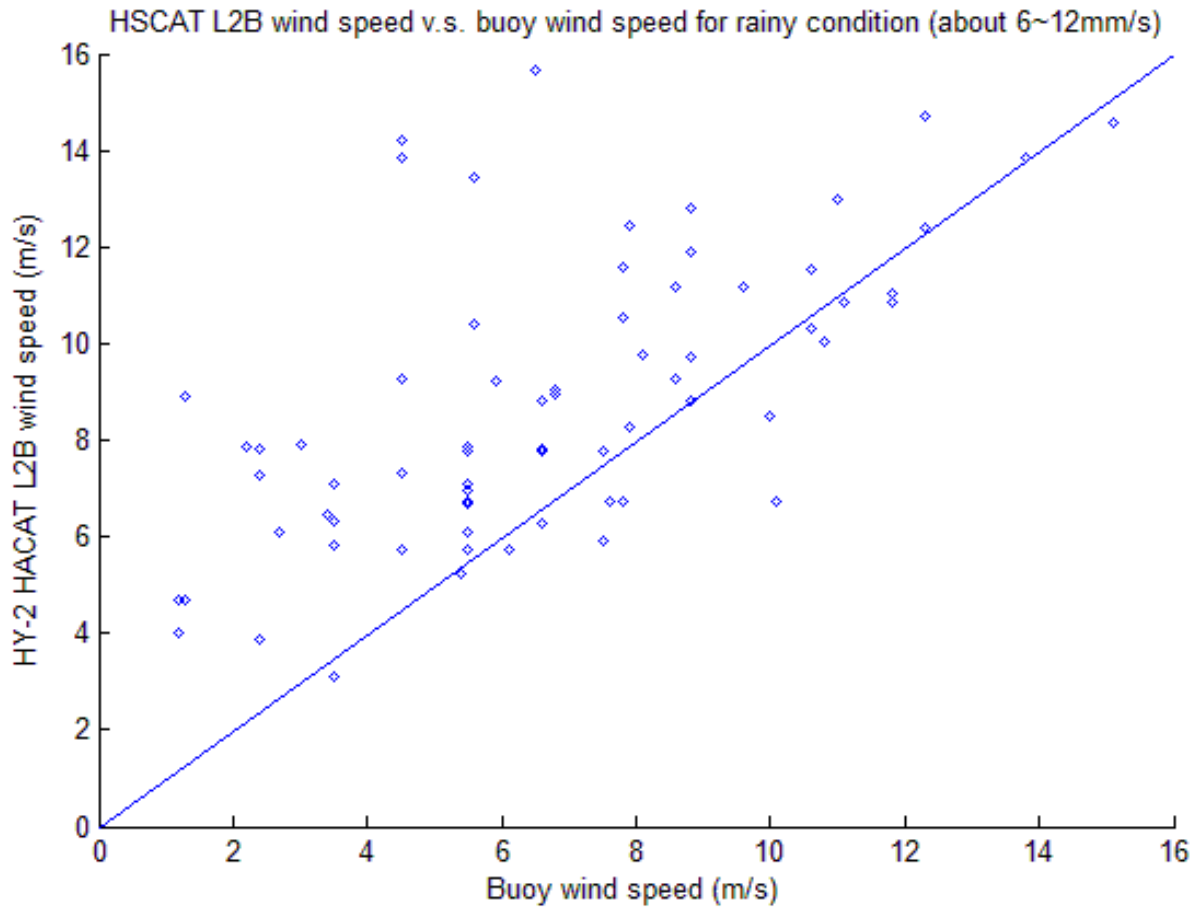
Application of SVM of HSCAT and HRAD for rainy areas (wind speed result, rain rate about 6-12mm/h, the same SVM)

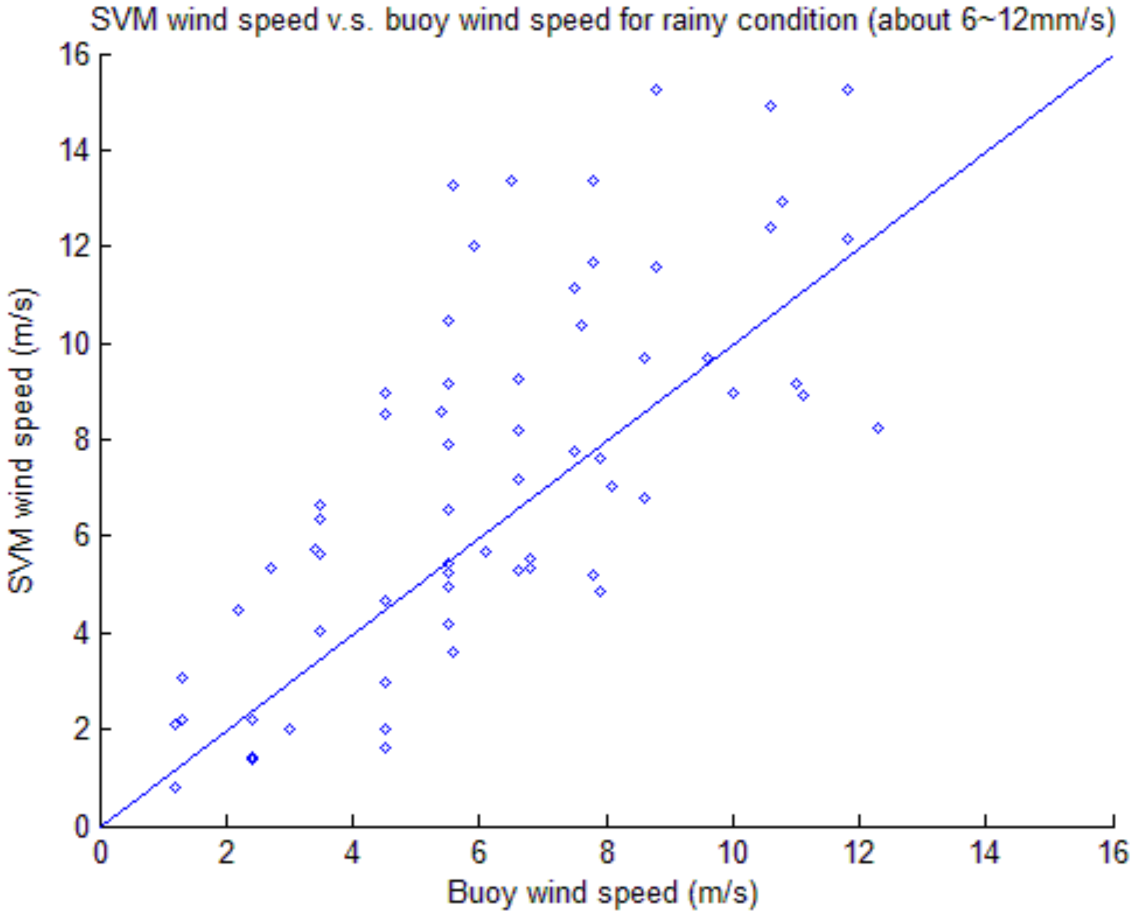




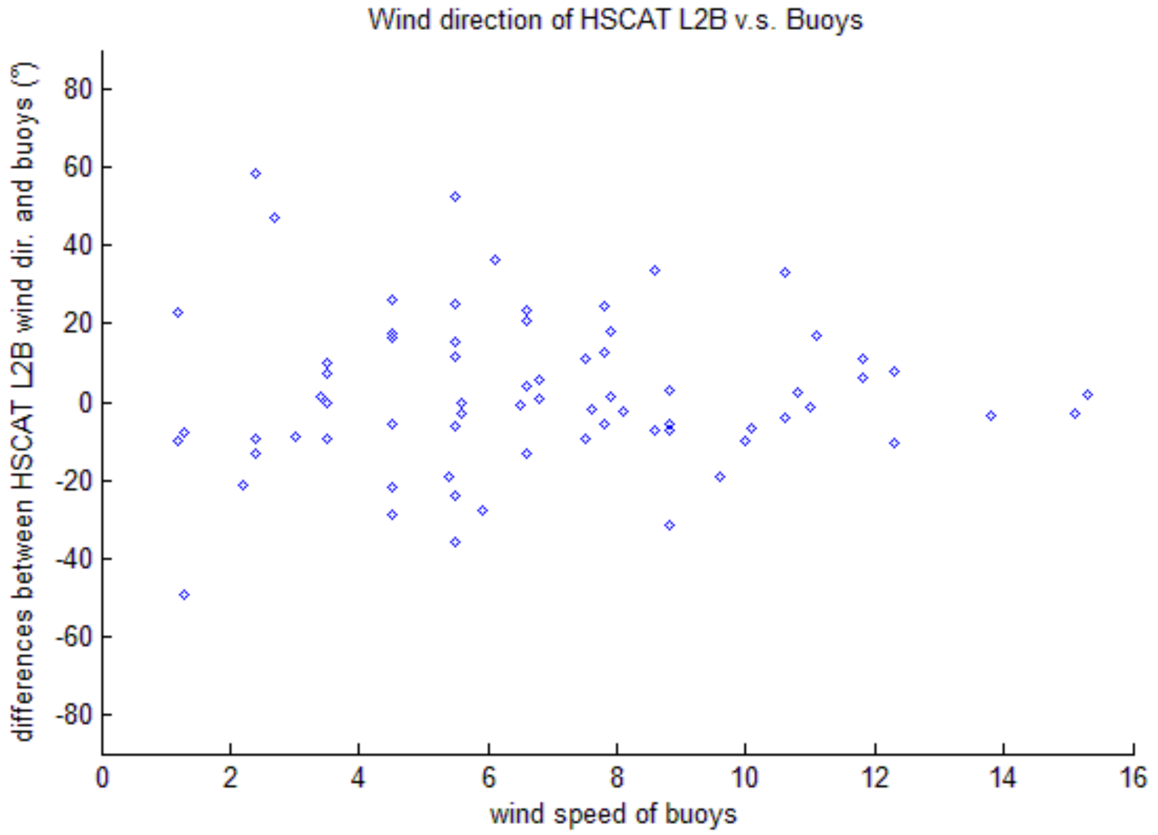
Windsat wind speed	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HSCAT L2B mean	2.19	3.15	4.25	5.4	6.8	7.65	9.34	10.39	11.74	13	14.2	14.99	16.03	17.12	18.61	19.87	21.33	23.7
HSCAT L2B var.	0.28	0.45	0.55	0.53	0.49	0.37	0.29	0.67	1.2	1.53	1.69	1.72	1.69	1.82	2.06	2.34	3.13	2.67
SVM rst. mean	2.29	3.13	4.31	4.99	6.1	7.04	8.17	8.74	9.34	10.32	11.59	12.48	13.96	15.49	16.85	17.61	18.35	19.71
SVM rst. Var.	0.28	0.24	0.21	0.28	0.35	0.31	0.28	0.39	0.57	0.71	0.81	0.89	0.92	0.88	0.74	0.65	0.91	0.34

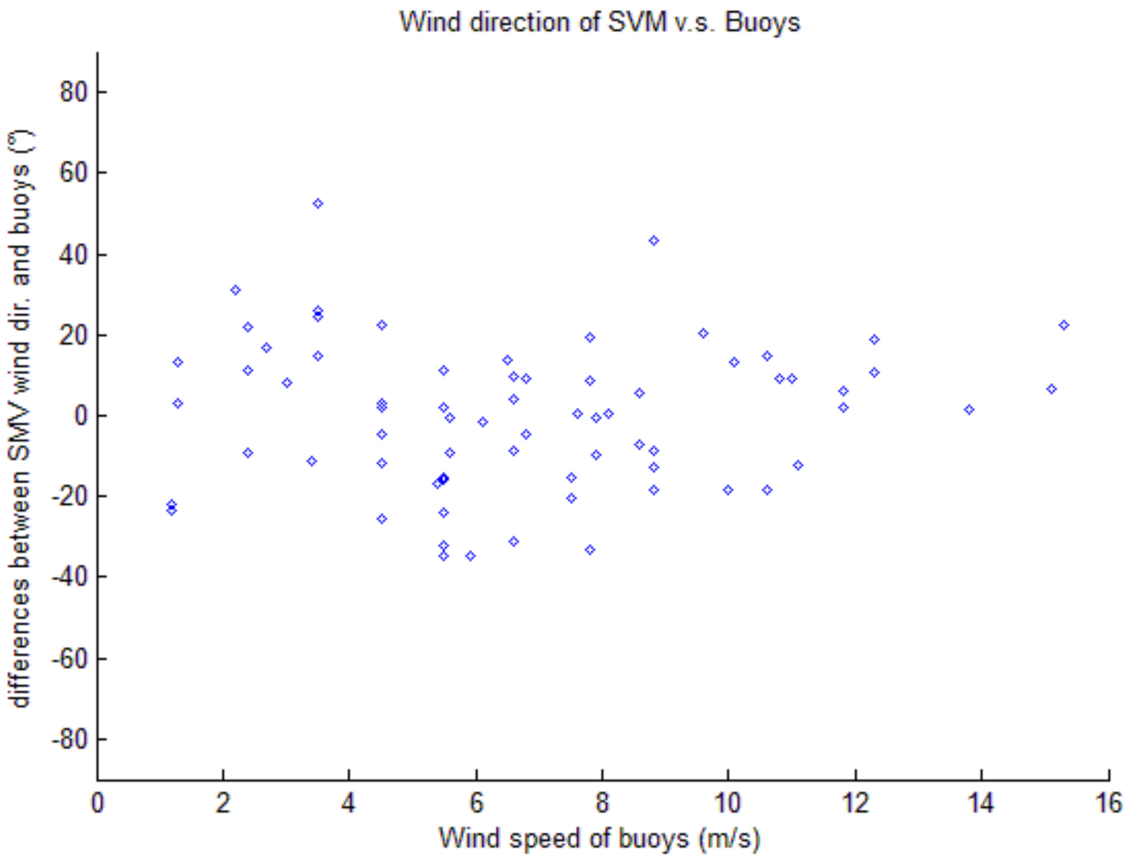
Results compared with Buoy data (wind speed.)





Results compared with Buoy data (wind direction)





Summary & Future Research

- SVM is effective in estimation of wind fields under rainy conditions for low and medium wind fields.

- Consider the regional properties of data to improve wind direction results.
- Increase buoy data set.
- Systematic analysis of observations v.s. rain rates under different wind speeds.
- Form a model for combined observations for HY-2A under rainy conditions.
- Kernel function modification and physical meaning analysis.

Acknowledgment

The Hy-2A data HSCAT and HRAD data sets are provided by National Satellite Ocean Application Service (NSOAS).

The buoy data are obtained from http://www.pmel.noaa.gov/ and cover a Wide range of networks: NDBC moored buoys: TAO, PIRATA, and RAMA buoy arrays.

WindSat data are produced by Remote Sensing Systems and sponsored by the NASA Earth Physical Oceanography Program. Data are available at www.remss.com/missions/windsat.

The SVM program used in our experiments are based on the *LIBSVM* developed by Prof. Chih-Jen Lin from Taiwan University.

Thanks