# Estimations of suspended sediment concentration from Echo Intensity using ADCP, OBS and LISST-100

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# Outlines

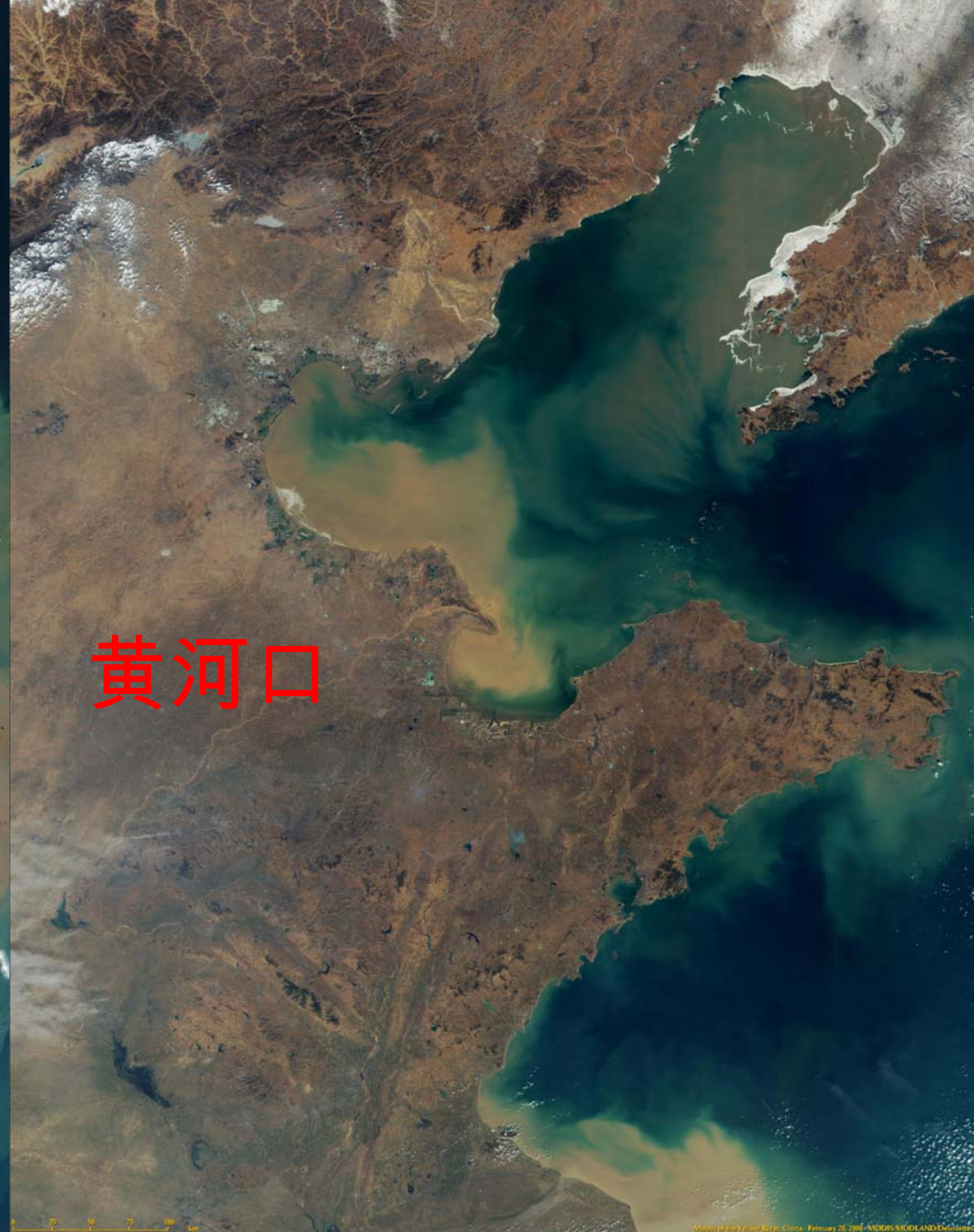
- Background
- Methods for estimating Suspended Sediment Concentration (SSC)
- Determining SSC using Acoustic Doppler Current Profiler (ADCP)
- Observations and instrumentation
- Discussion and analysis
- Conclusion

# 1. Background

Chinese coastal seas is well-known for their high turbidity. Yellow River and Yangtze River carry billions of tons of sands into the oceans every year, which accounts for 10% of total sediment loads all over the world.

- Influence on ports: The blocking of sea-route, safety of near-shore construction
- Influence on ecosystem: Sediment particles are carrier of nutrients; attenuate and scatter sunlight, thus affect the efficiency of photosynthesis
- Influence on environment: Sediment particles can carry toxic agricultural and industrial compounds.


长江口


黄河口

**To better understand the dynamics of suspended particulate matter (SPM), it is necessary to explore new approaches for determination of SSC, especially in bays and estuaries.**

goal

Determining SSC using ADCP Echo Intensity(EI) to get high spatial & temporary resolution SSC data

Ref: Deines, 1999; Land, 2001; Gartner, 2004; Hoitink, 2005

To verify it, we carried out two 25-hours anchored observations separately in two bays in which the characteristics of SPM are distinct. Based on the former research, we have made some discussions and improvements on it.

# 2. Methods for estimating SSC

- Direct bottles sampling
- Optical Backscatter Sensor (OBS)
- Laser In-Situ Scatter & Transmissometry (LISST-100)
- Acoustic Doppler Current Profiler(ADCP)

⇩

Need carefully corrections and calibration

# Method Ⅰ: Niskin water sampling bottle

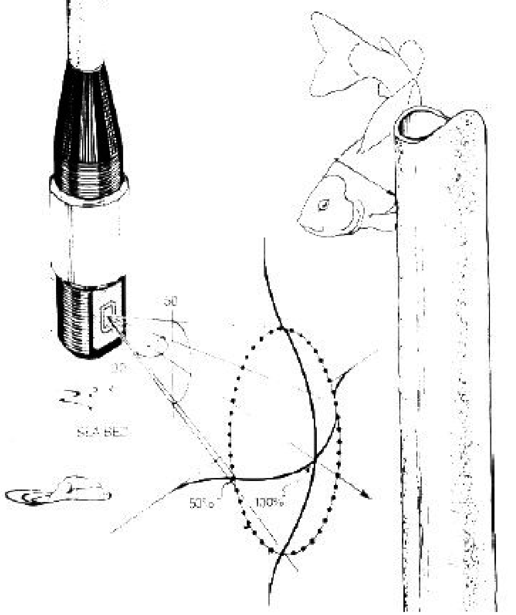
Niskin bottle can collect water samples in specified depth. After retrieving the bottles, we filter the water samples onto pre-weighed filters and re-weigh the filters after they are dried, the difference in weight is due to the SPM.

# **Method II:** Optical Backscatter Sensor (OBS)

- Sending a beam of infrared light into the water, the beam is scattered by SPM and then measures the quantity of light that is reflected back to sensor.

***Light backscattered***

- The OBS is calibrated each sampling data by comparing the OBS values to collected water samples.`



# **Method III:** Laser In-Situ Scatter & Transmissometry (LISST-100)

- The LISST-100 is an optical instrument for in-situ measurement of particle size spectra in waters.
- Based on the principle of laser diffraction, the LISST-100 could record the volume concentration (μl/l) of 32 different sizes of SPM, ranging from 1.25μm to 250μm

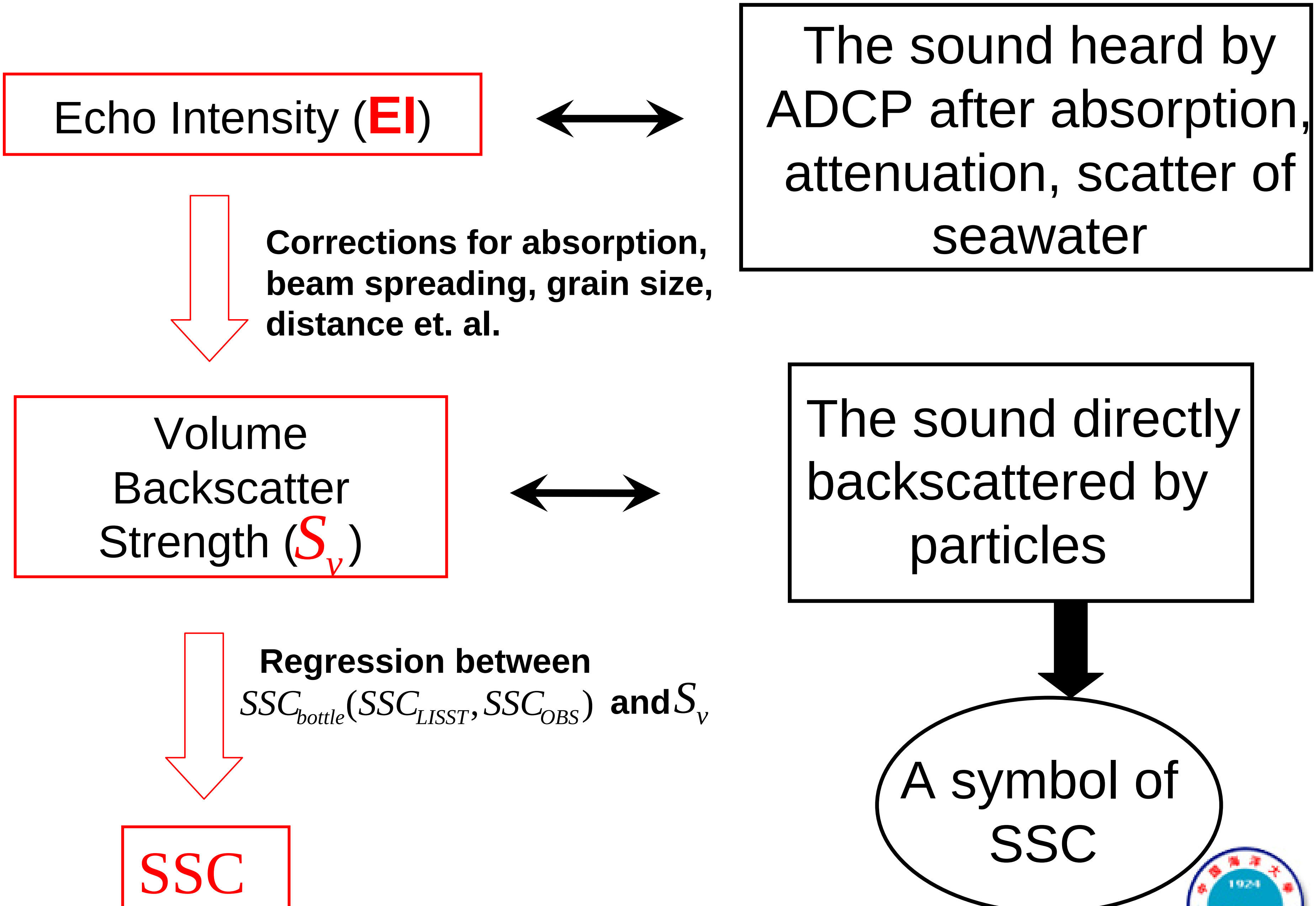
***Light transmitted***

# Method IV: Acoustic Doppler Current Profiler (ADCP)

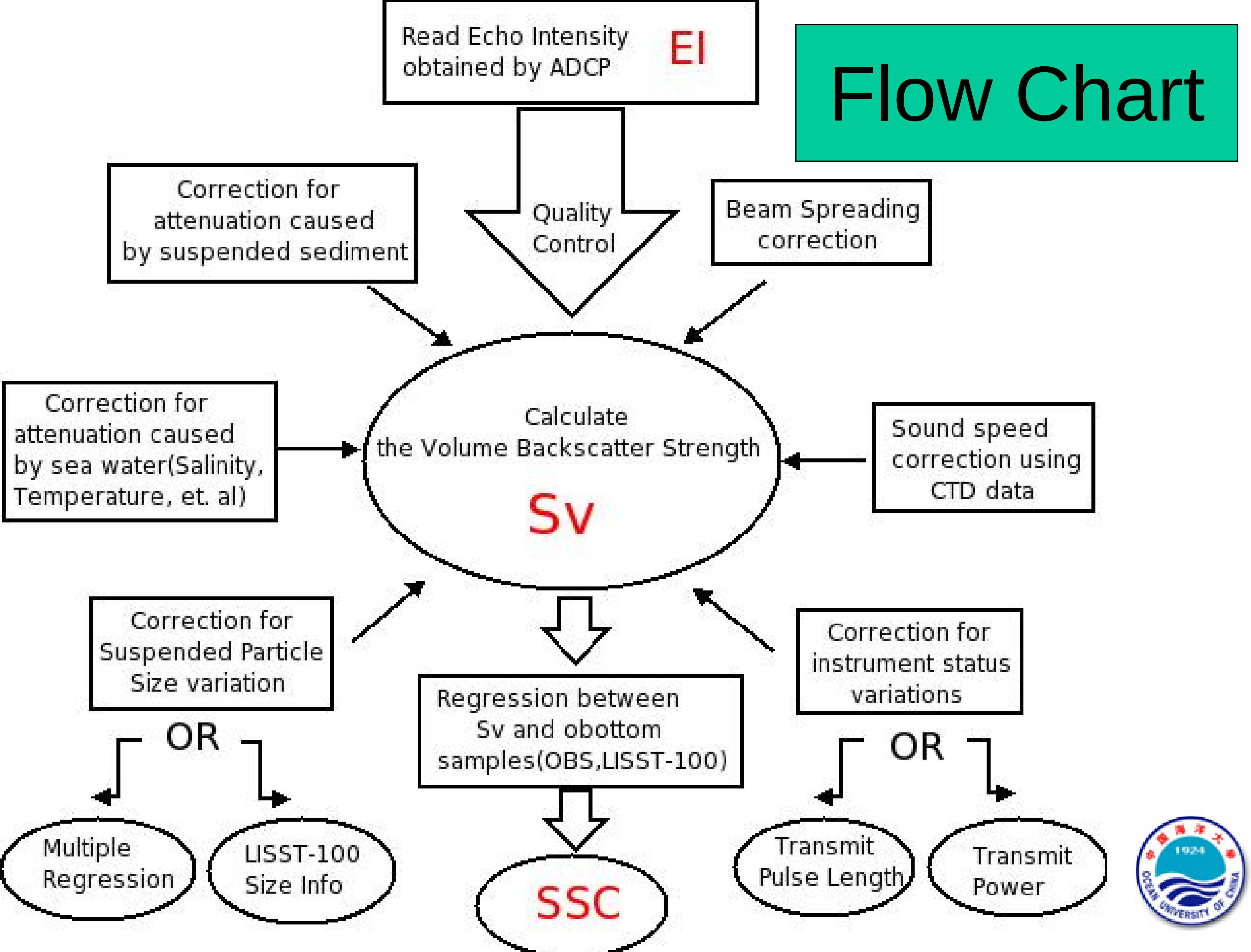
Based on the principle of Doppler effect, ADCPs are designed to measure the water velocity profiles. ADCPs transmit sound at a fixed frequency, and receive echoes returning from sound scatterers, such as particles, plankton. So Echo Intensity(EI) that is heard by ADCP is a measure of SPM concentration.

| Method | Advantage | Disadvantage |
|---|---|---|
| Bottle Sampling | 1. Conceptually simple<br>2. Maybe **more accurate**<br>3. Need no calibration | 1. Intrusive<br>2. **Labor intensive and time wasting**, can't sample more intensely |
| OBS | 1. Relatively inexpensive<br>2. Small, thus relatively non-intrusive<br>3. Easy to handle and post-process | 1. **Sensitive to grain size** (more sensitive to fines than ADCP)<br>2. Require calibration<br>3. **Bio-fouling** |
| LISST-100 | 1. Ability to measure time series of particle size distribution (**PSD**)<br>2. One calibration factor holds over a wide range grain sizes<br>3. Easy to handle and post-process | 1. Large and would cause flow obstruction<br>2. More expensive than OBS<br>3. Fragile because of optical lens |
| ADCP/ ABS | 1. Can simultaneously sample a full SSC profile with single instrument<br>2. High resolution in space<br>3. Non-intrusive, Non-biofouling | 1. Echo intensity highly **susceptible to absorption and scattering** by sea water and grains<br>2. **More sensitive to larger grain size** |

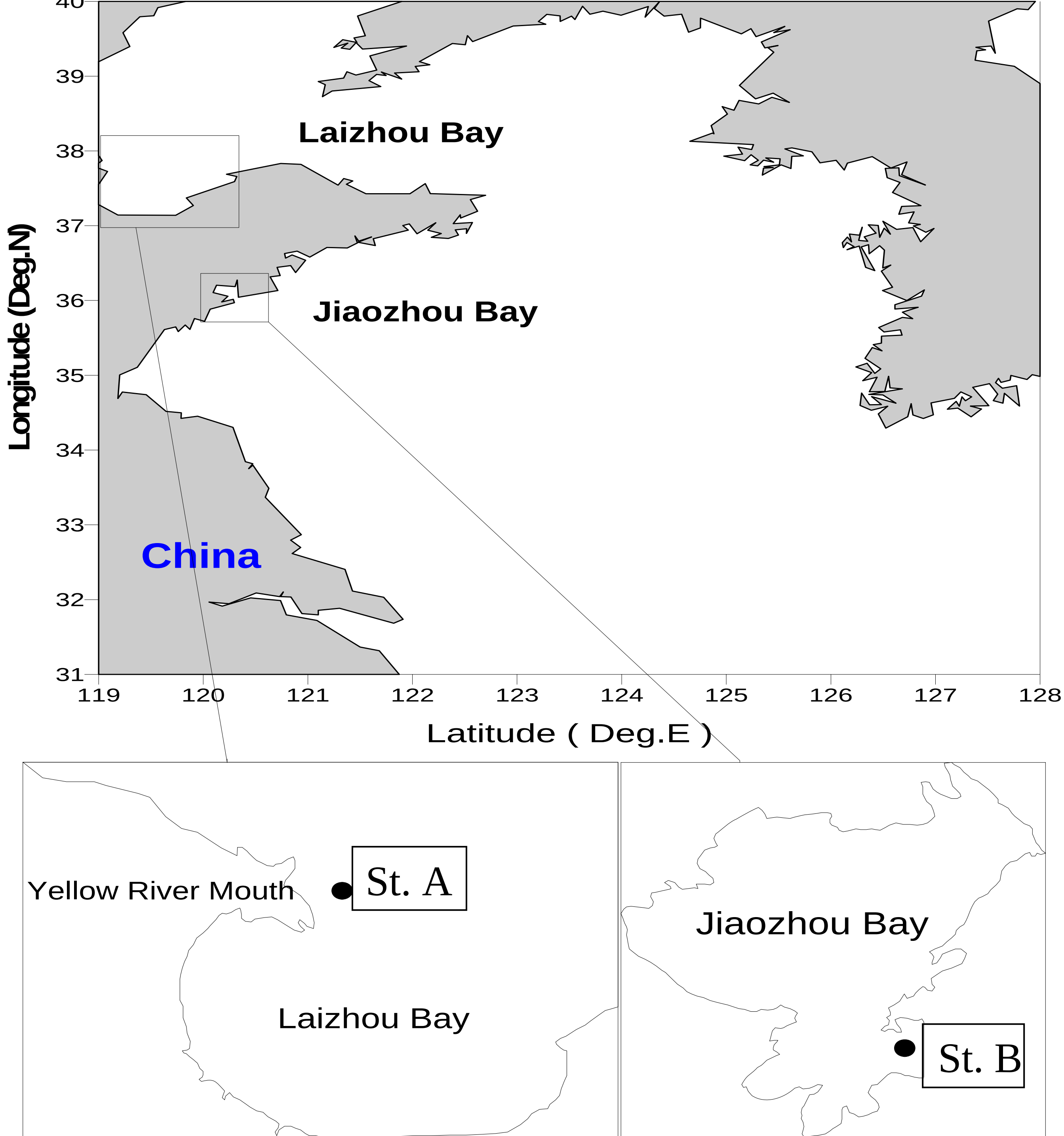
# 3. Determining SSC using Echo Intensity (EI)


Echo Intensity (EI)
The sound heard by ADCP after absorption, attenuation, scatter of seawater
Corrections for absorption, beam spreading, grain size, distance et. al.
Volume Backscatter Strength ($S_v$)
The sound directly backscattered by particles
Regression between $SSC_{bottle}(SSC_{LISST}, SSC_{OBS})$ and $S_v$
A symbol of SSC
SSC

# Flow Chart


Read Echo Intensity obtained by ADCP
EI
Quality Control
Correction for attenuation caused by suspended sediment
Beam Spreading correction
Correction for attenuation caused by sea water(Salinity, Temperature, et. al)
Calculate the Volume Backscatter Strength
Sv
Sound speed correction using CTD data
Correction for Suspended Particle Size variation
Regression between Sv and obottom samples(OBS,LISST-100)
Correction for instrument status variations
OR
OR
Multiple Regression
LISST-100 Size Info
SSC
Transmit Pulse Length
Transmit Power

# 4. Observations and Instrumentation


Laizhou Bay
Jiaozhou Bay
China
Longitude (Deg.N)
Latitude ( Deg.E )
40
39
38
37
36
35
34
33
32
31
119
120
121
122
123
124
125
126
127
128
Yellow River Mouth
St. A
Laizhou Bay
Jiaozhou Bay
St. B

# The distinct characteristics of two stations

| | | |
|---|---|---|
| St. A (Laizhou Bay) | High turbidity because of the discharge of Yellow River | Mineral grains such as silt, sand dominate |
| St. B (Jiaozhou Bay) | Very low turbidity because of no runoff and rocky coastlines, with a limited supply of fine sediment | non-mineral component dominates, such as plankton debris, bio-genic particles (diatom, nannofossils et. al.) |

**Makes the results more confident!!**

# **Instrumentation:** Laizhou Bay (St. A)

- A 23-hours anchored observation was carried out between May 15 and 16, 2005.

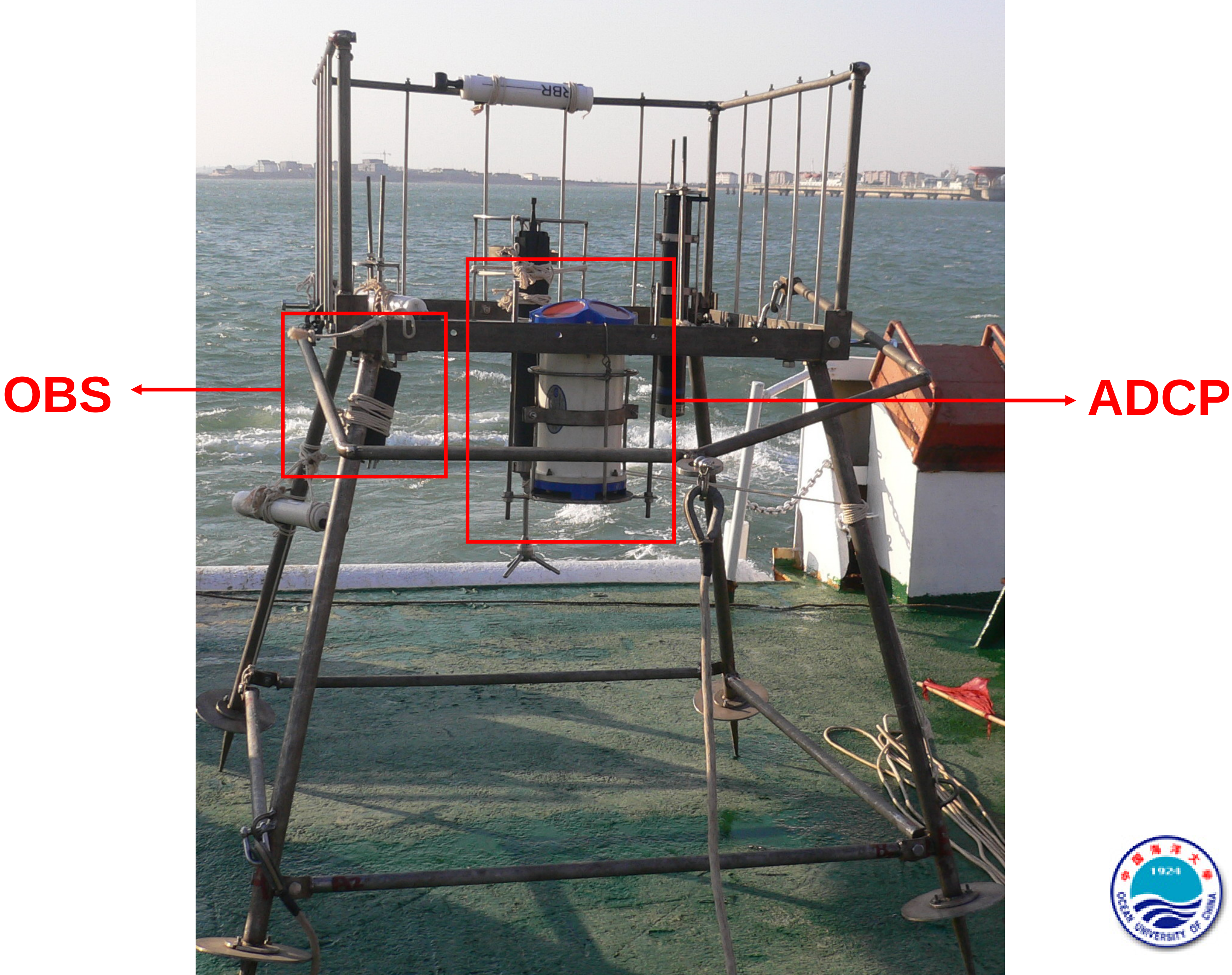
| |
|---|
| RDI 600kHz ADCP |
| LISST-100 |
| RBR multi-parameter CTD |
| Niskin Bottles |

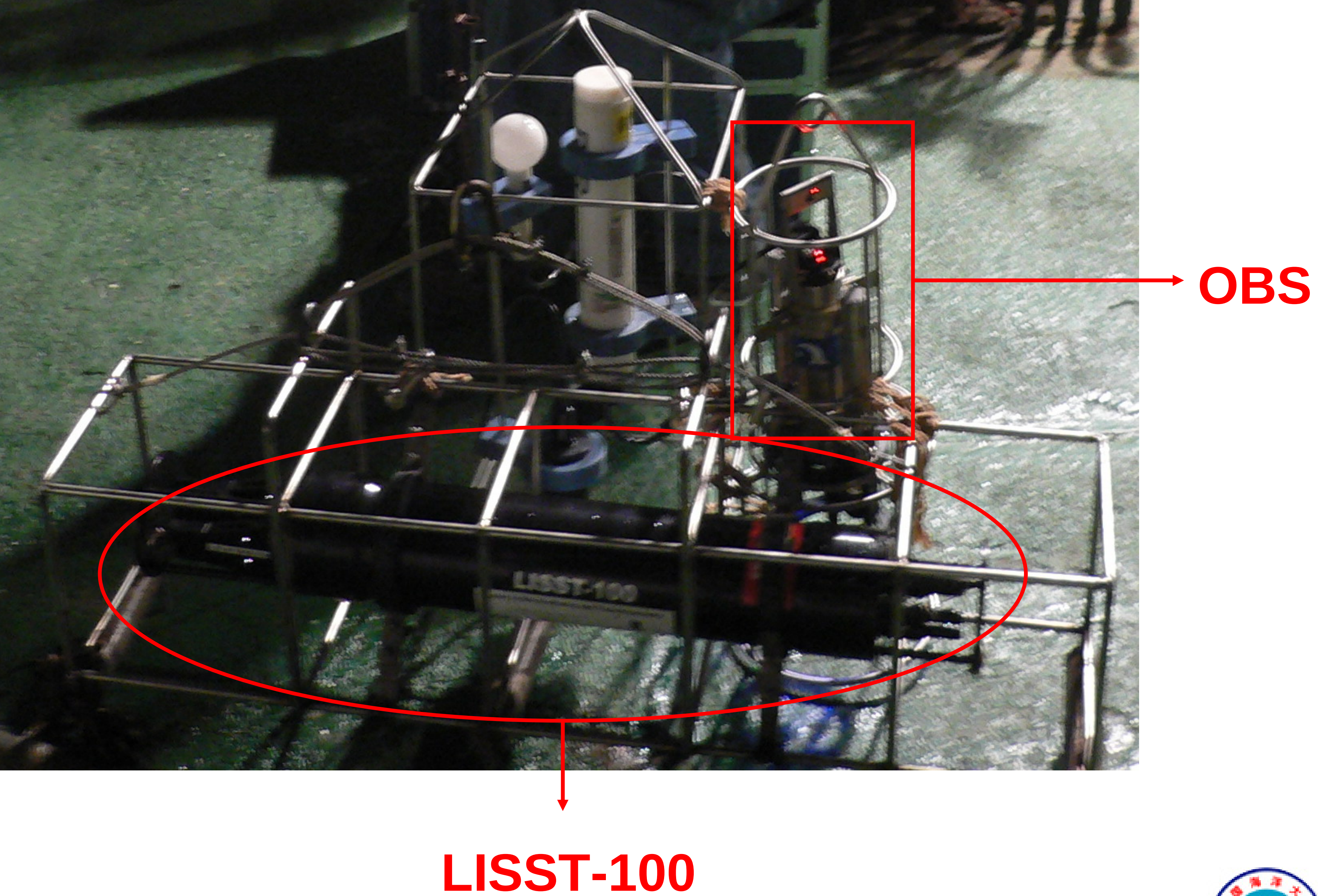
# **Instrumentation:** Jiaozhou Bay (St. B)

- An instrument platform equipped with a variety of instruments was deployed above the seabed from December 14 to 15, 2005.

| |
|---|
| RDI 600kHz ADCP |
| Alec OBS (Mounted 0.8m above seabed) |
| Alec OBS Profiler |
| RBR multi-parameter CTD |
| LISST-100 |
| Niskin Bottles |

# Photos of Instruments


OBS
ADCP


OBS
LISST-100

Niskin Water Sampling Bottles

# 5. Discussion and analysis

# **DiscussionI:** Regression

In the original procedures, when performing regression between volume backscatter strength($S_v$) and bottle samples($SSC_{bottle}$), the fitting curve is not convincing because of limited bottle samples, especially for the highly variable property of SPM.

On the other hand, OBS and LISST-100 profiles can sample the SSC intensely through the whole water column. Thus substituting calibrated LISST-100 or OBS mass concentration($SSC_{LISST}$ , $SSC_{OBS}$) for $SSC_{bottle}$ would considerably improve the reliability of the fitting curve.

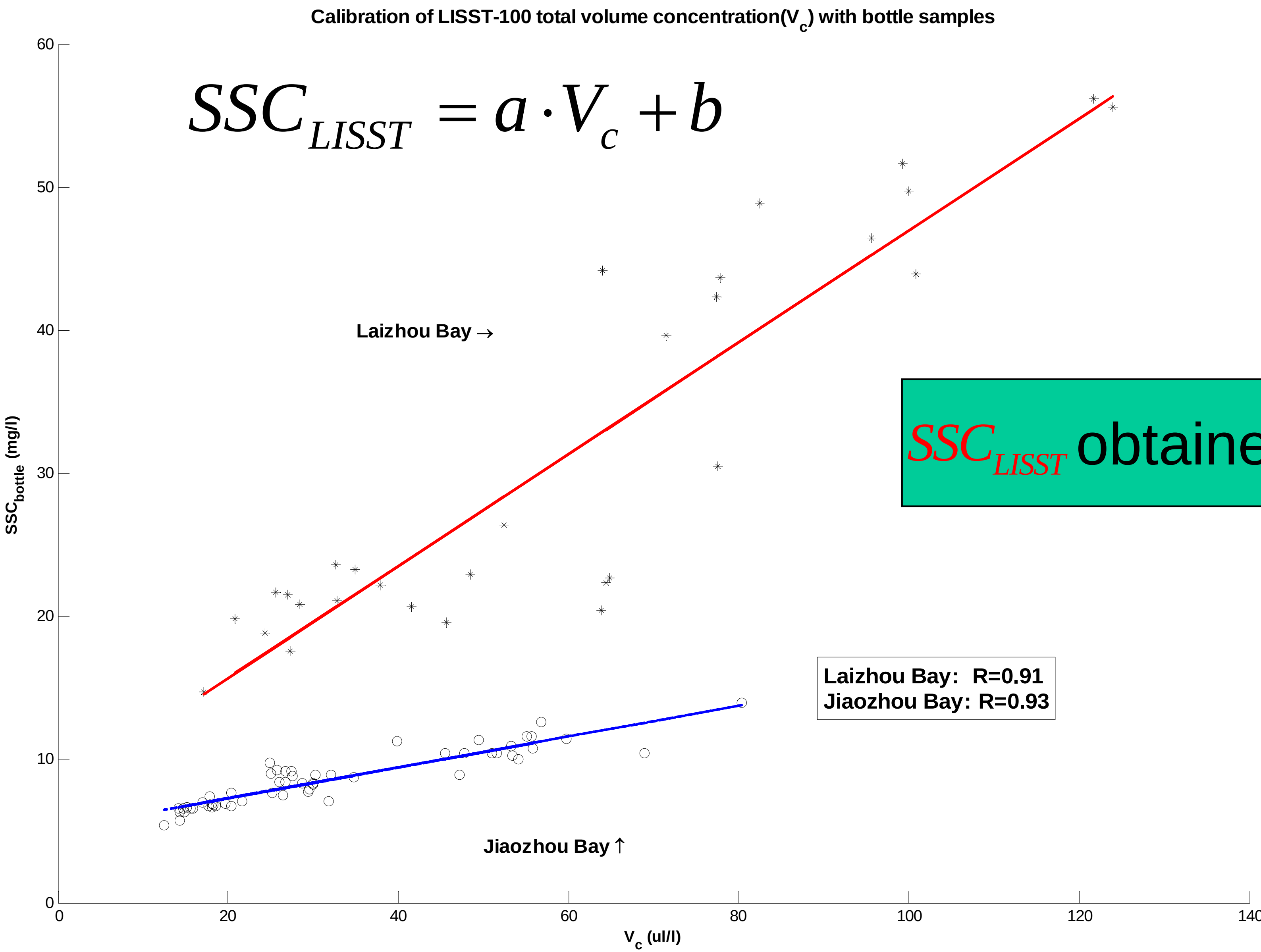
# **DiscussionII:** Particle Size Correction

A practical limitation of predicting SSC from EI is that EI is sensitive to the particle size distribution(PSD). Independent PSD measurements (LISST-100) are needed to perform particle size correction.

Based on the Rayleigh Scattering Theory, an improved calibration equation that include the PSD information is derived to calculate $S_v$ (LAN Zhi-Gang, et. al., 2004). The results is discussed in detail.

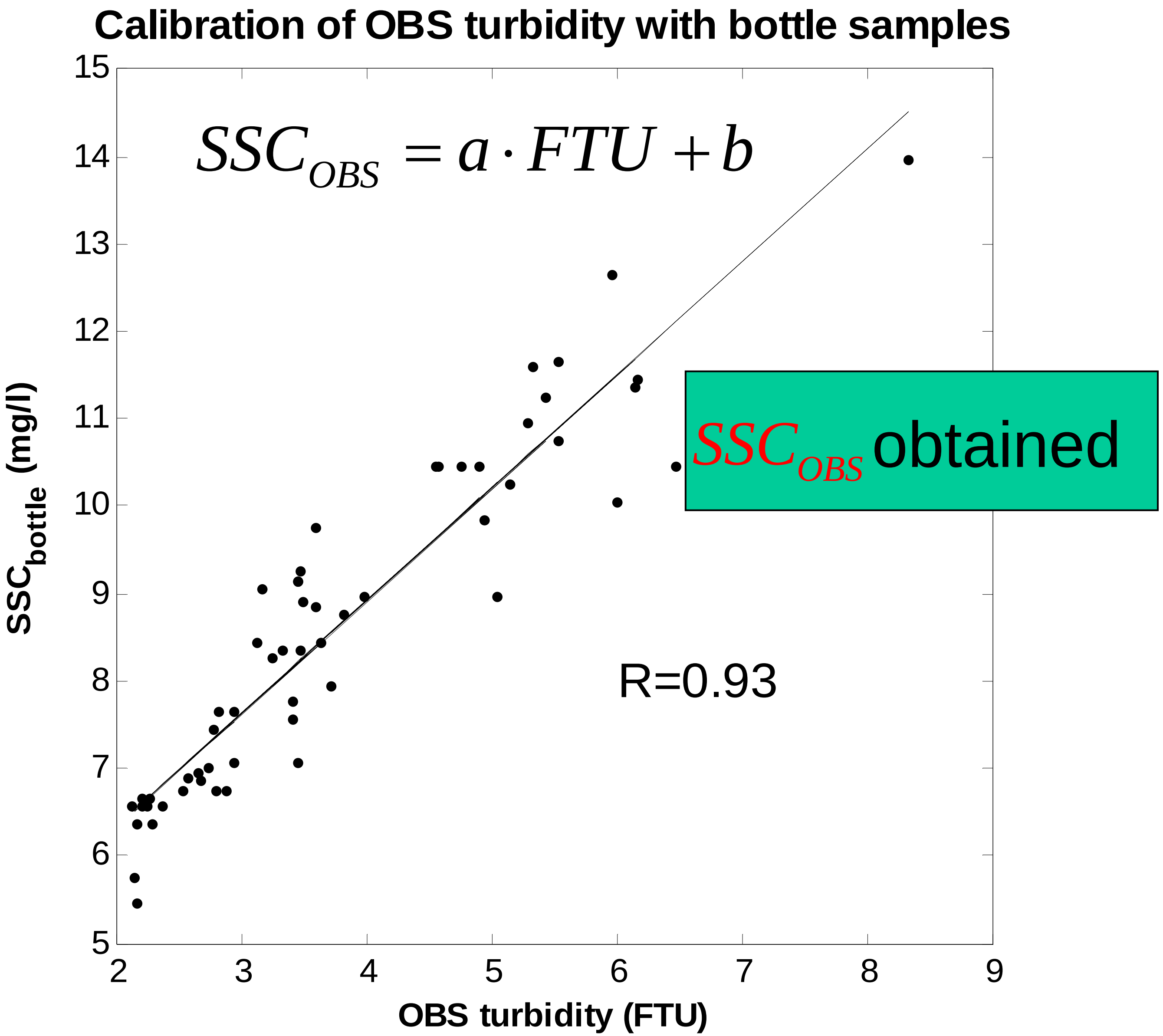
# 5.1. Calibrations

# §5.1.1. LISST-100 calibration using bottle samples



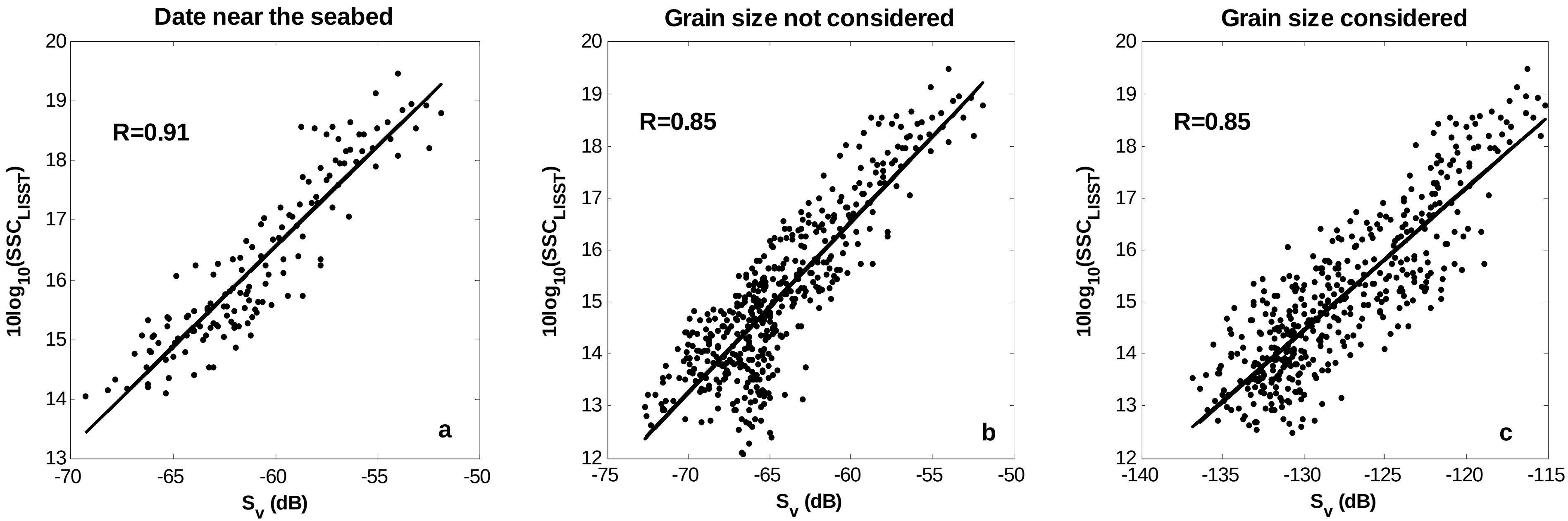

$SSC_{LISST}$ obtained

# §5.1.2. OBS calibration with bottle samples



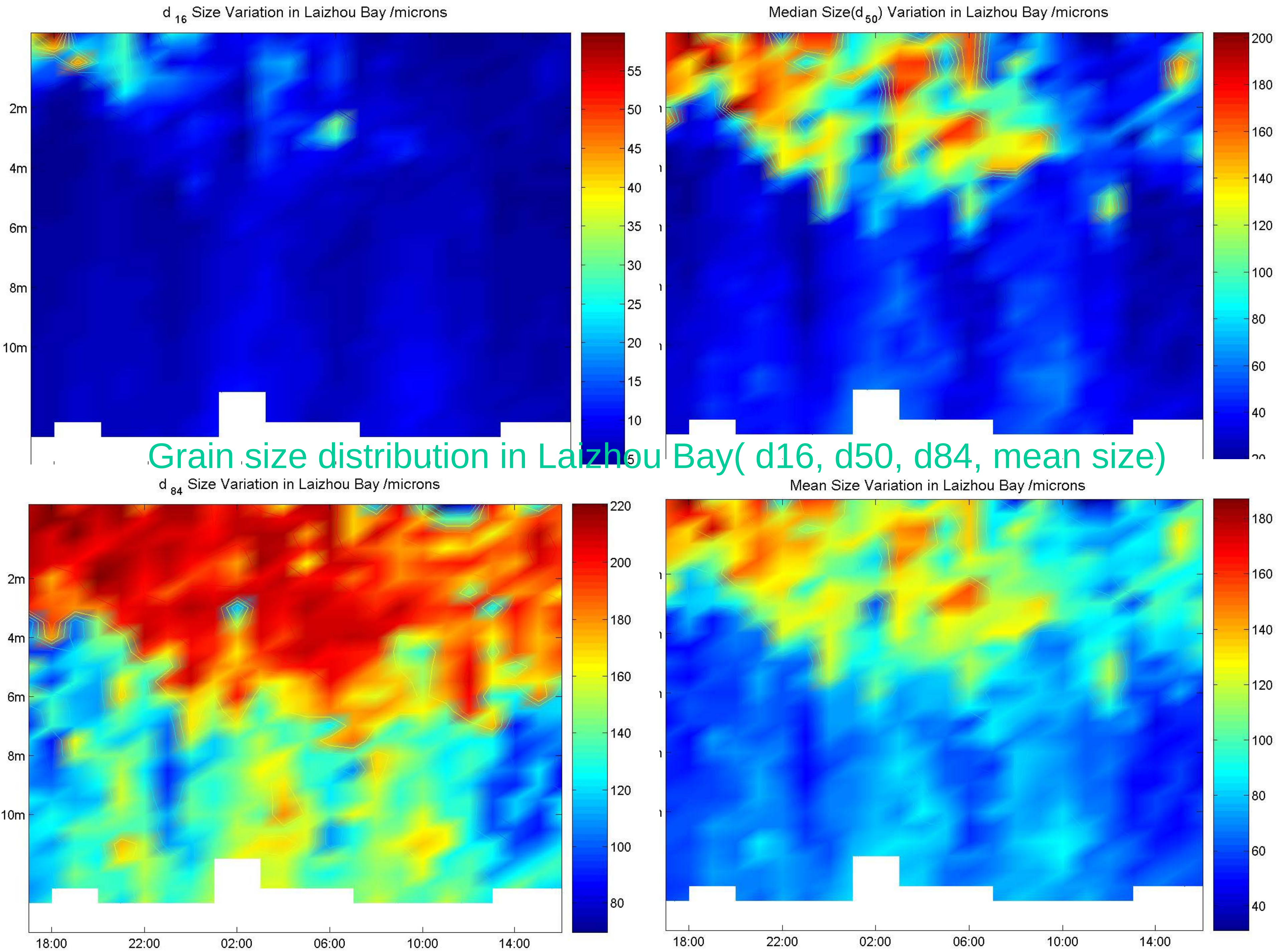
# §5.1.3. ADCP calibrations with LISST-100, OBS and bottle samples

## Calibration of $S_v$ with $SSC_{LISST}$ in St. A

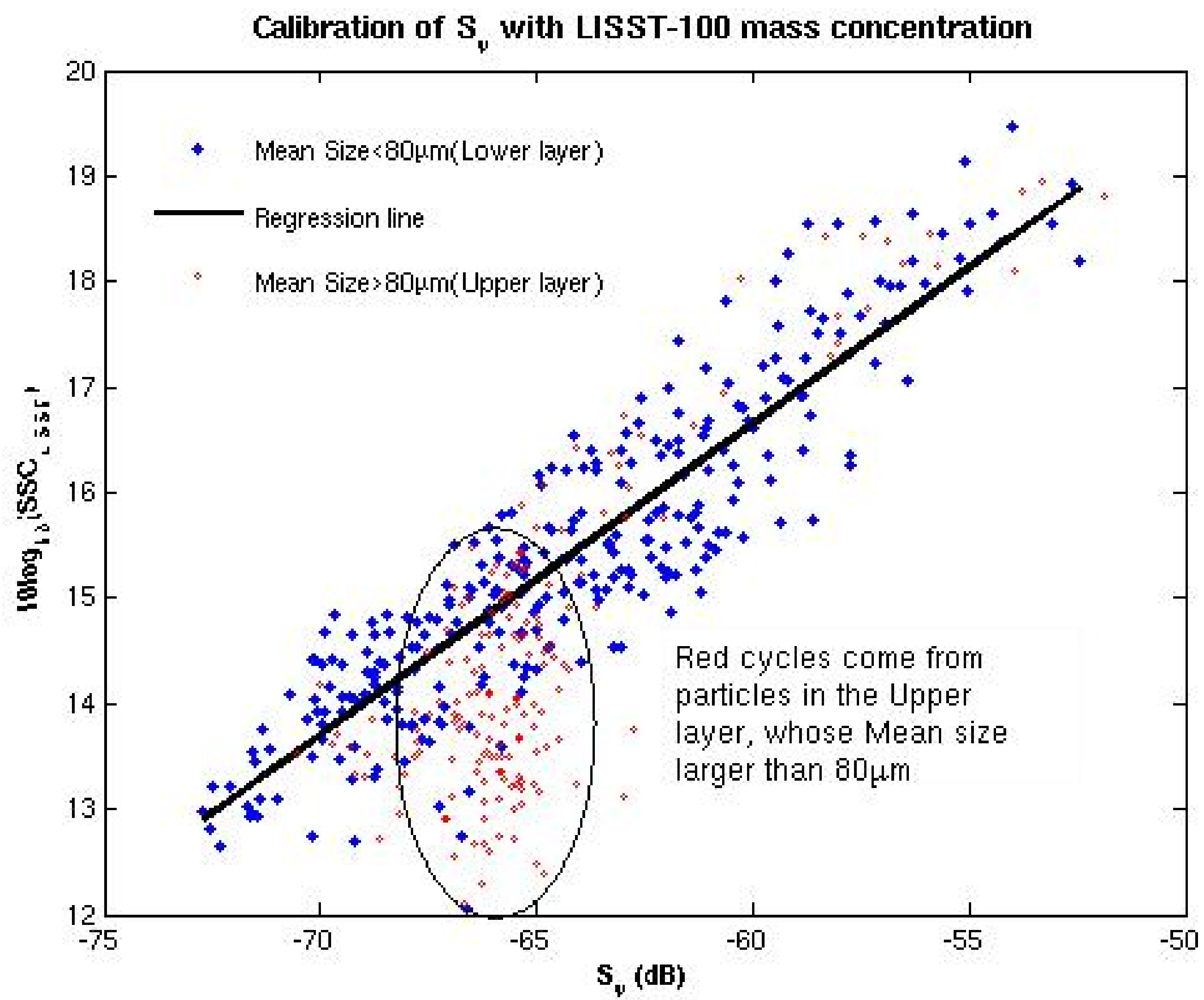



$$10\log_{10}(SSC_{LISST}) = a \cdot S_v + b$$

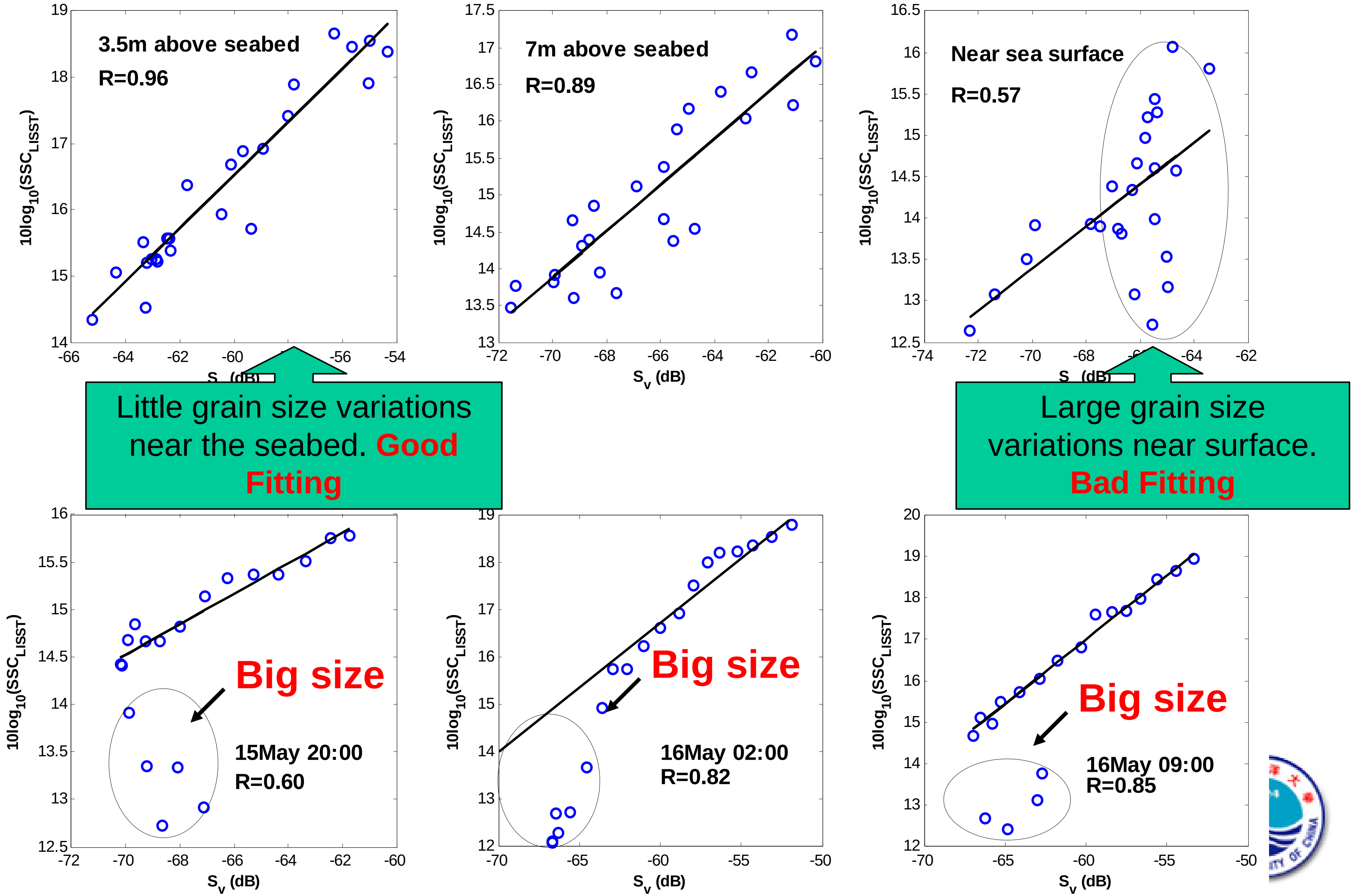
# Grain size distribution in Laizhou Bay( d16, d50, d84, mean size)



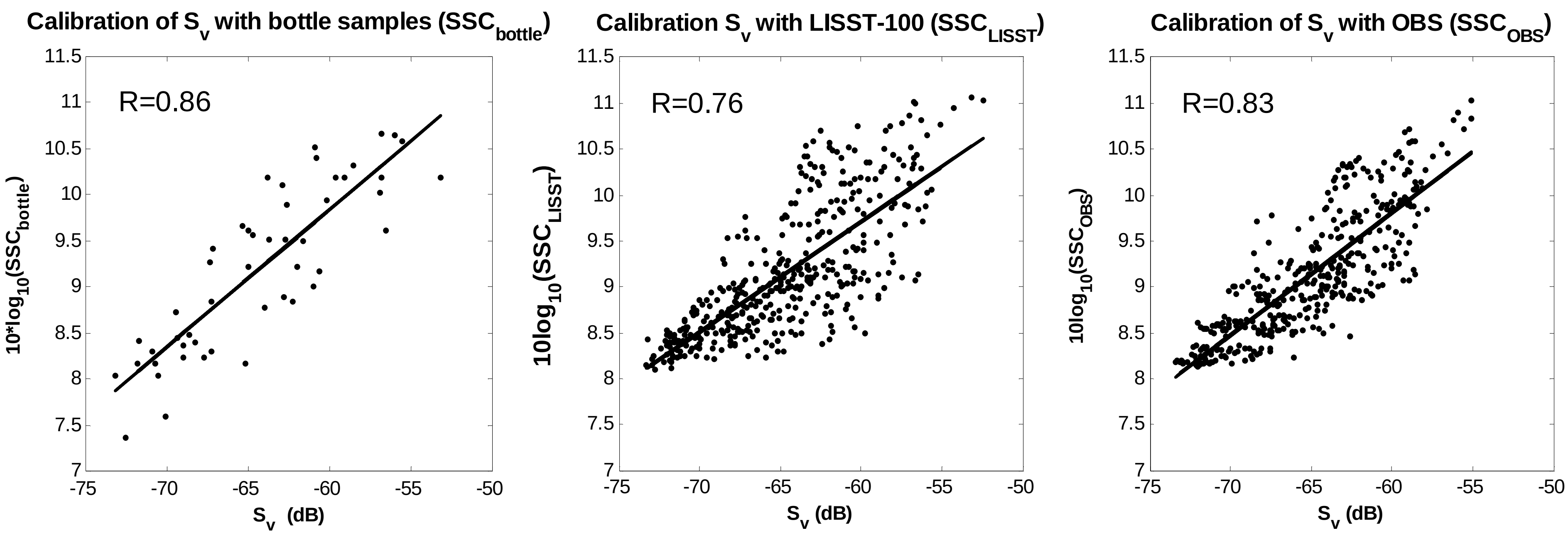
# DiscussionⅡ:
# Influence of PSD on the regression



# Take Laizhou Bay as an example



# Calibration of $S_v$ with $SSC_{bottle}$, $SSC_{LISST}$, $SSC_{OBS}$ in St. B

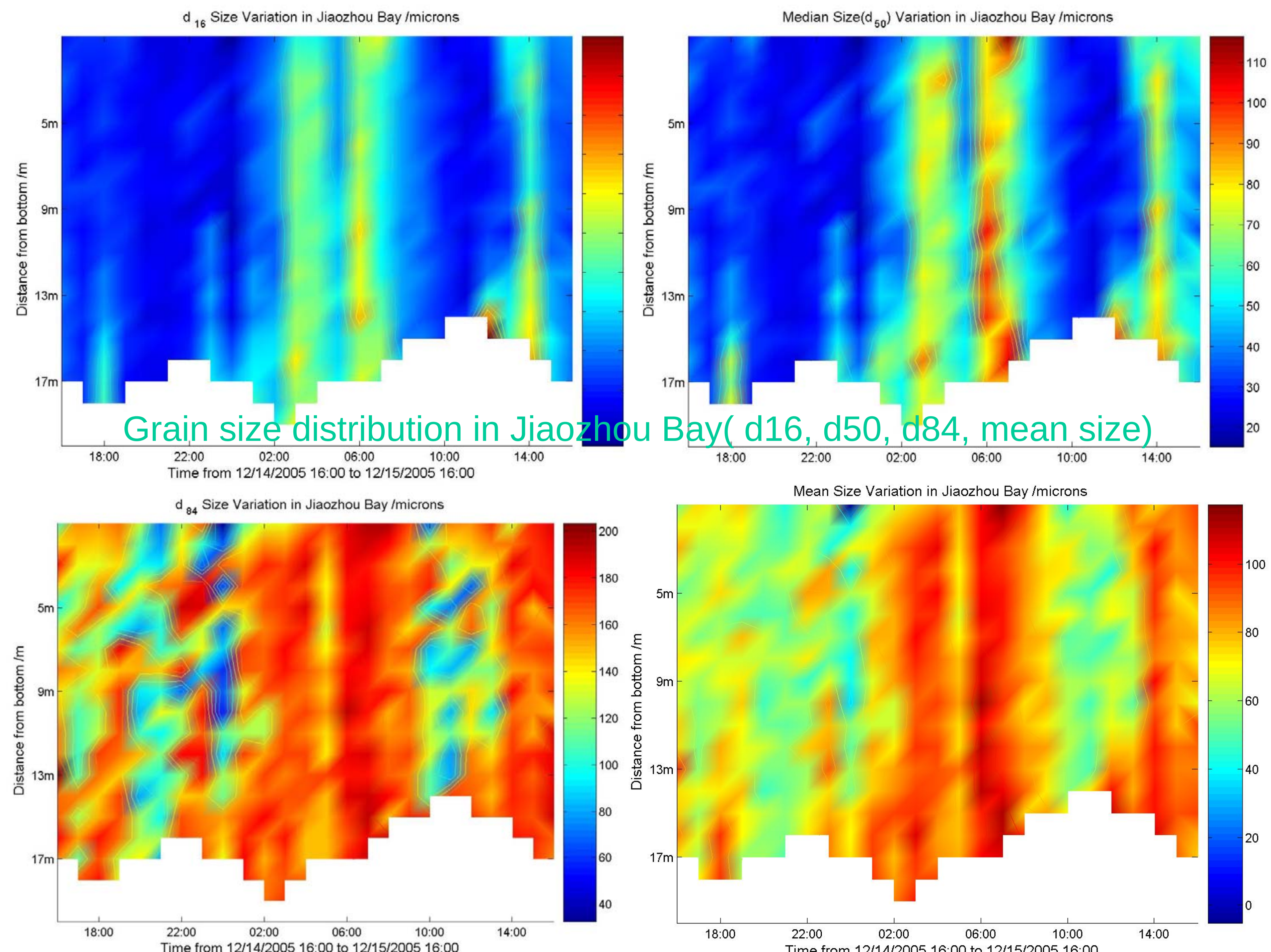



$$10\log_{10}(SSC_{bottle}) = a \cdot S_v + b$$

$$10\log_{10}(SSC_{LISST}) = a \cdot S_v + b$$

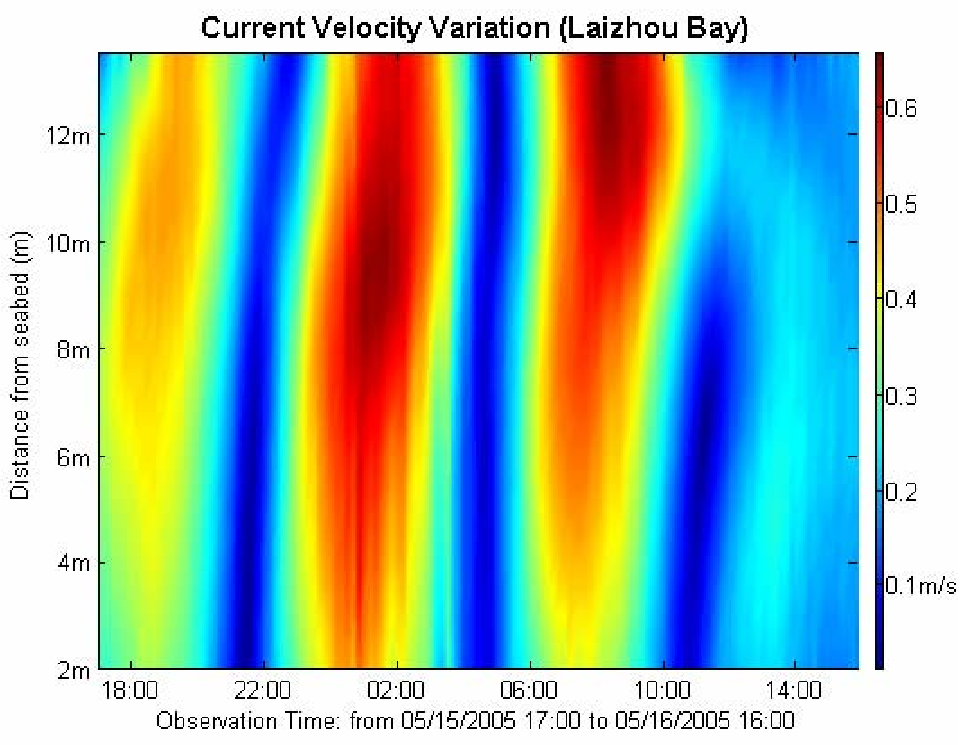
$$10\log_{10}(SSC_{OBS}) = a \cdot S_v + b$$

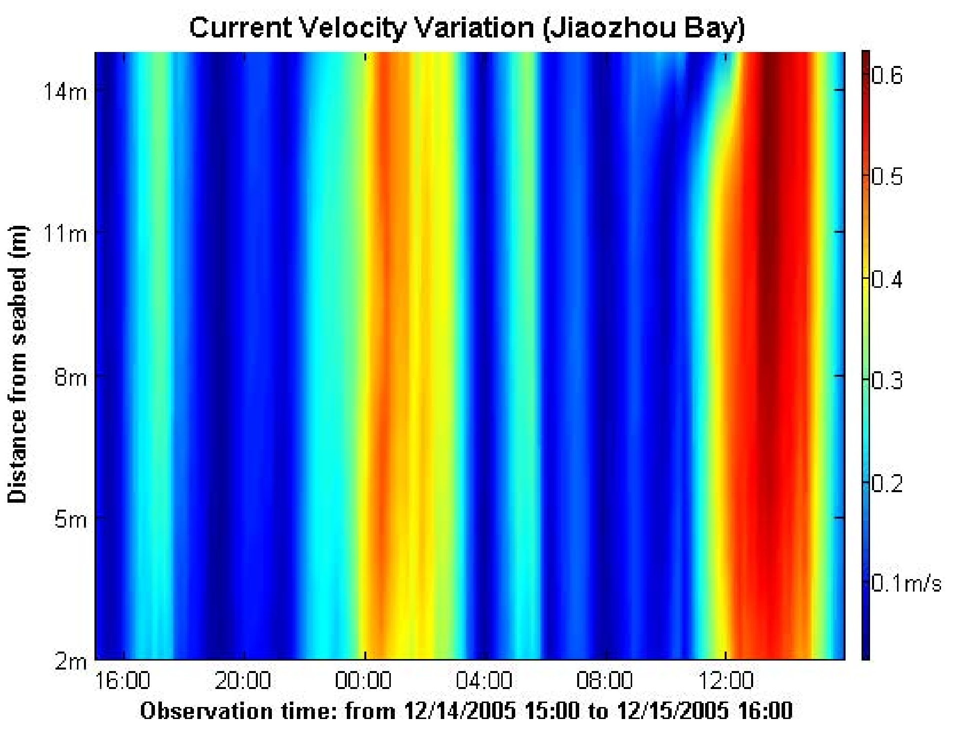
Grain size distribution in Jiaozhou Bay( d16, d50, d84, mean size)



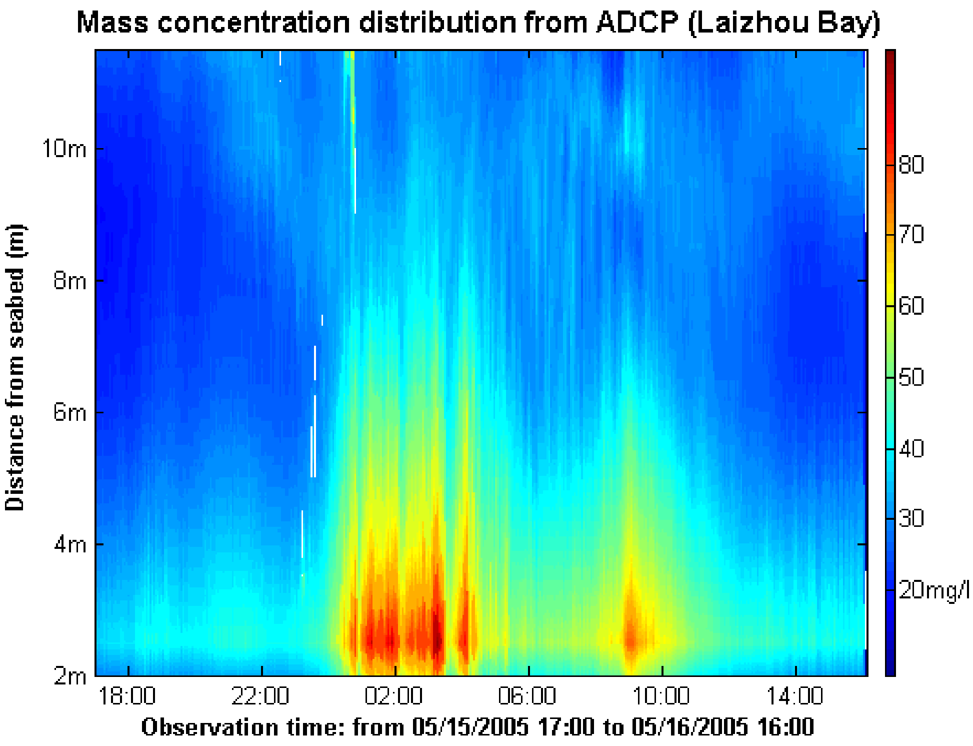
# 5.2. Comparison of LISST-100, OBS and ADCP estimates of mass concentration (SSC)

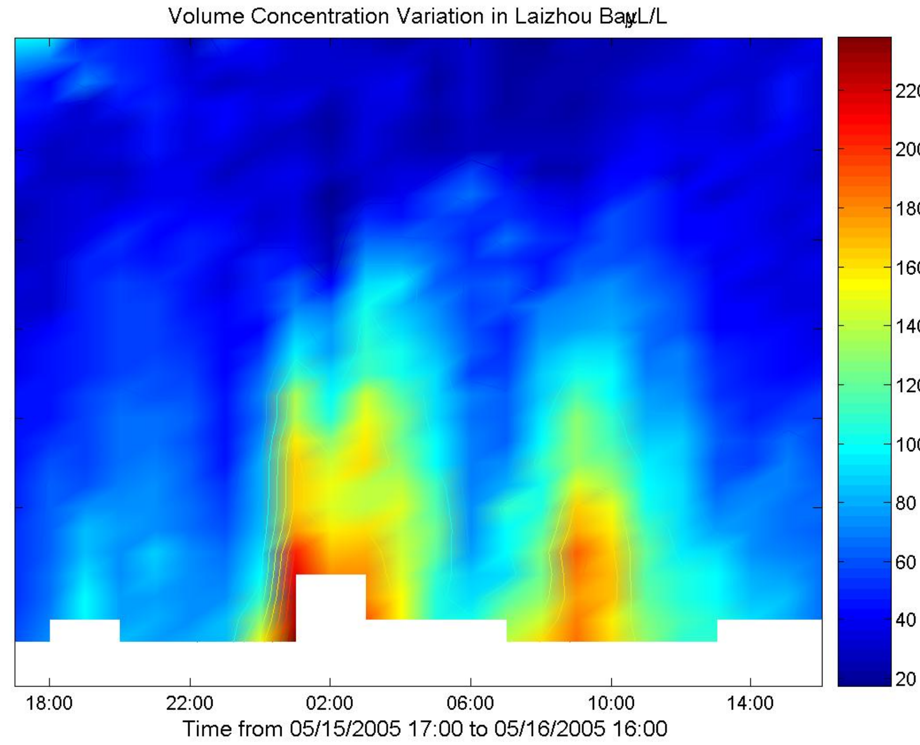
# §1. Velocity variation

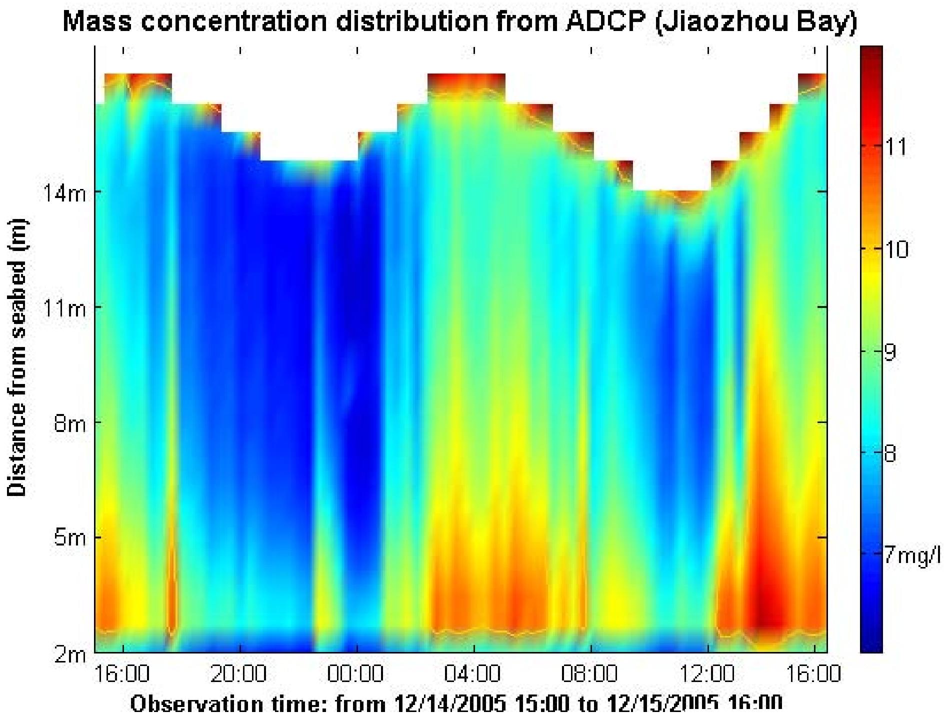


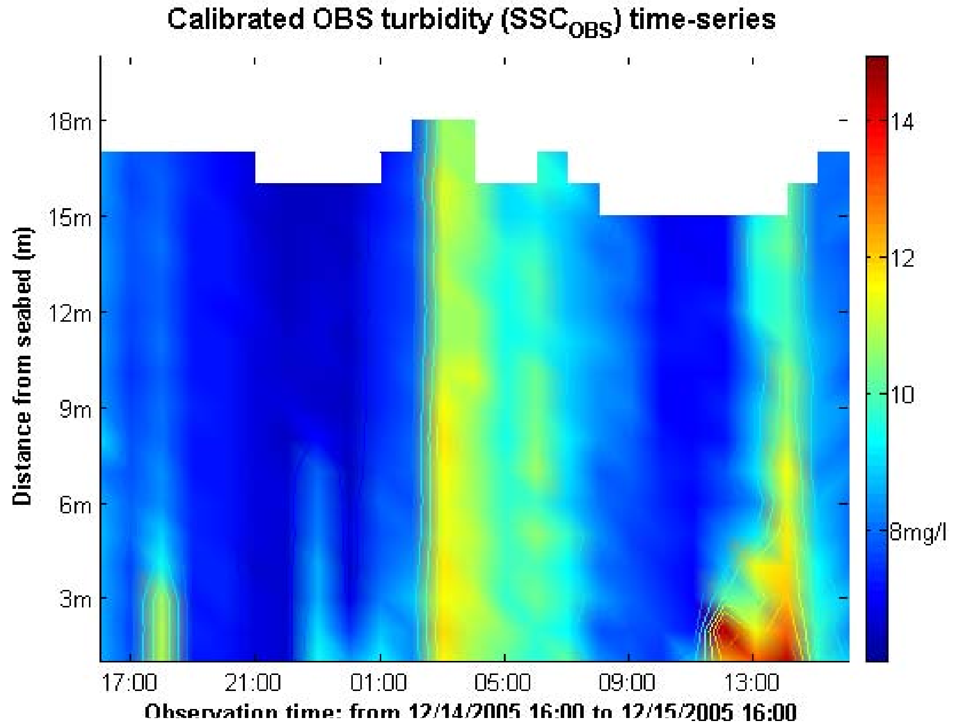



# §2. Comparison of $SSC_{ADCP}$, $SSC_{LISST}$, $SSC_{OBS}$ Laizhou Bay (St. A)

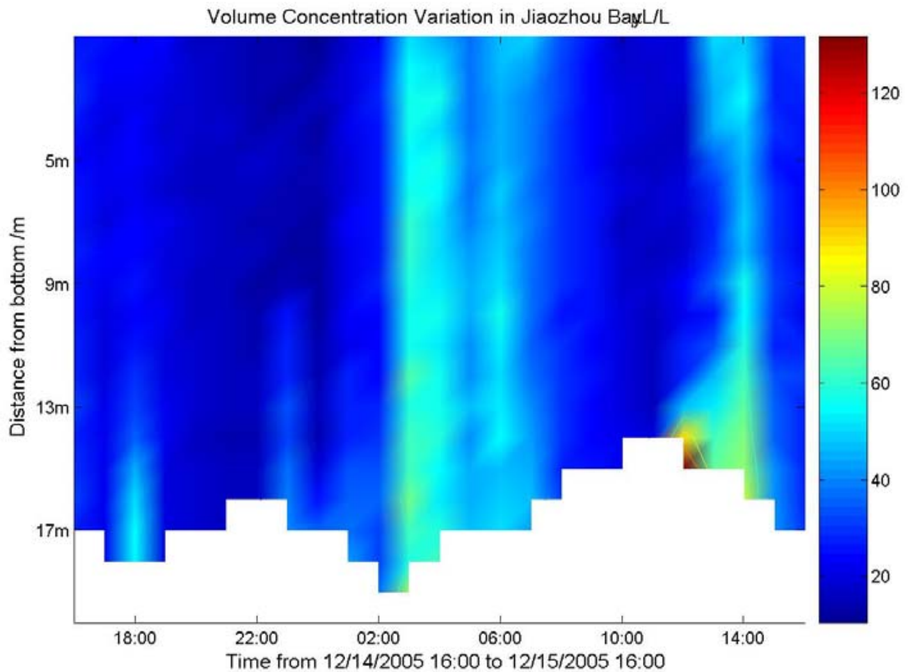


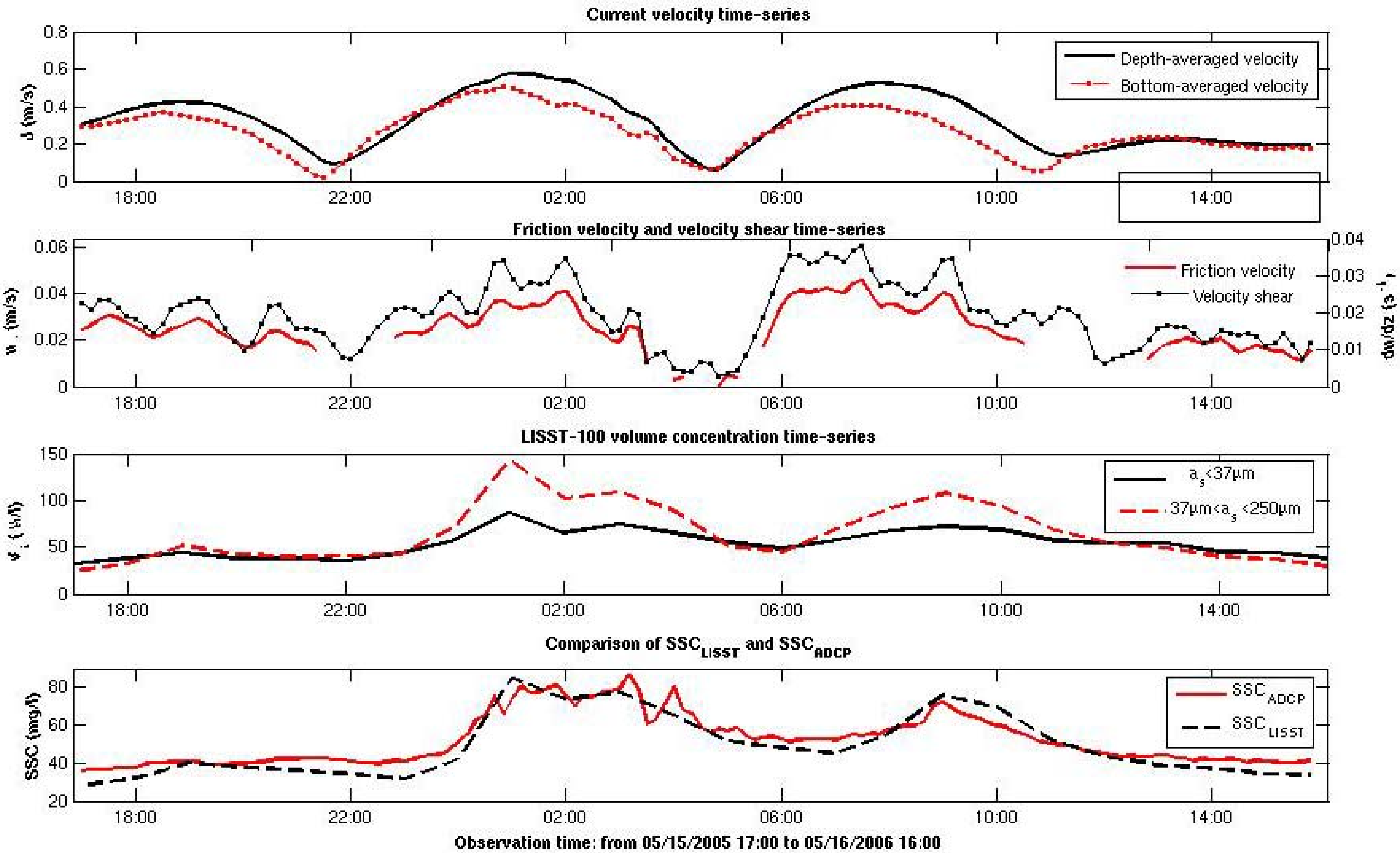


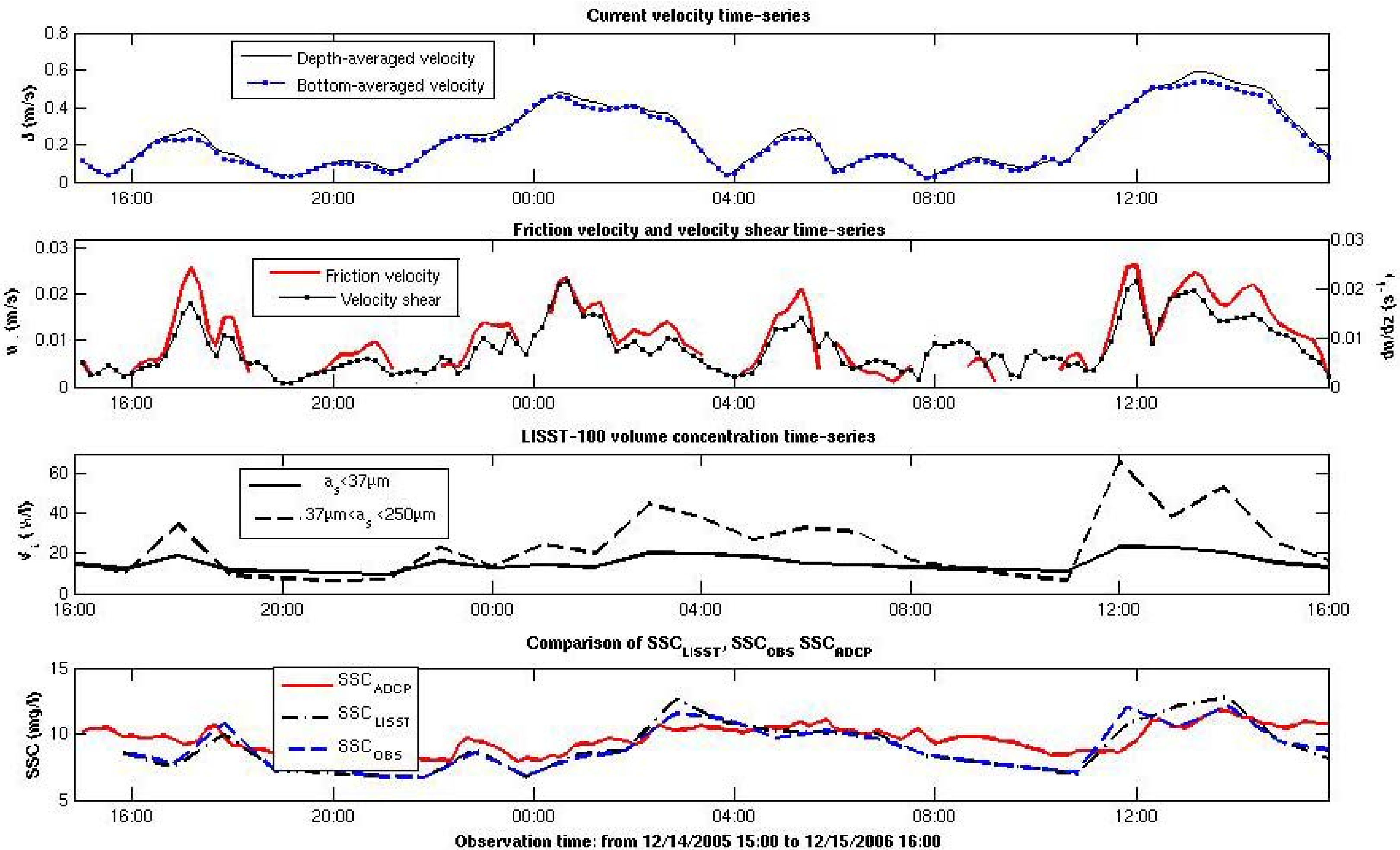

# Jiaozhou Bay
# St. B

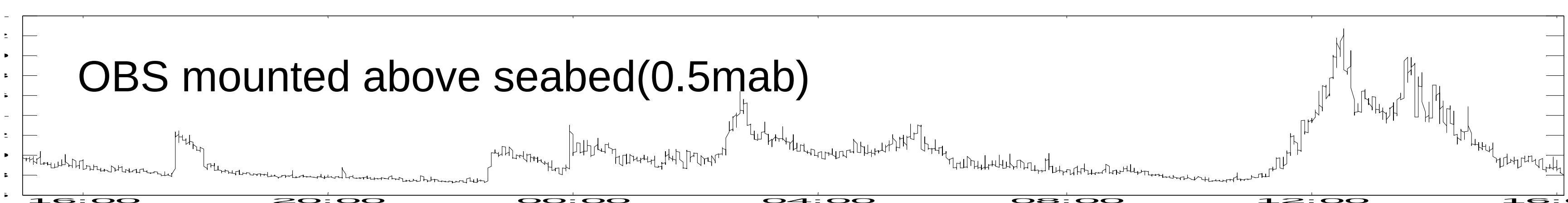


# Laizhou Bay (St. A) Near the seabed



# Jiaozhou Bay (St. B) Near the seabed



OBS mounted above seabed(0.5mab)

# 6. Conclusion

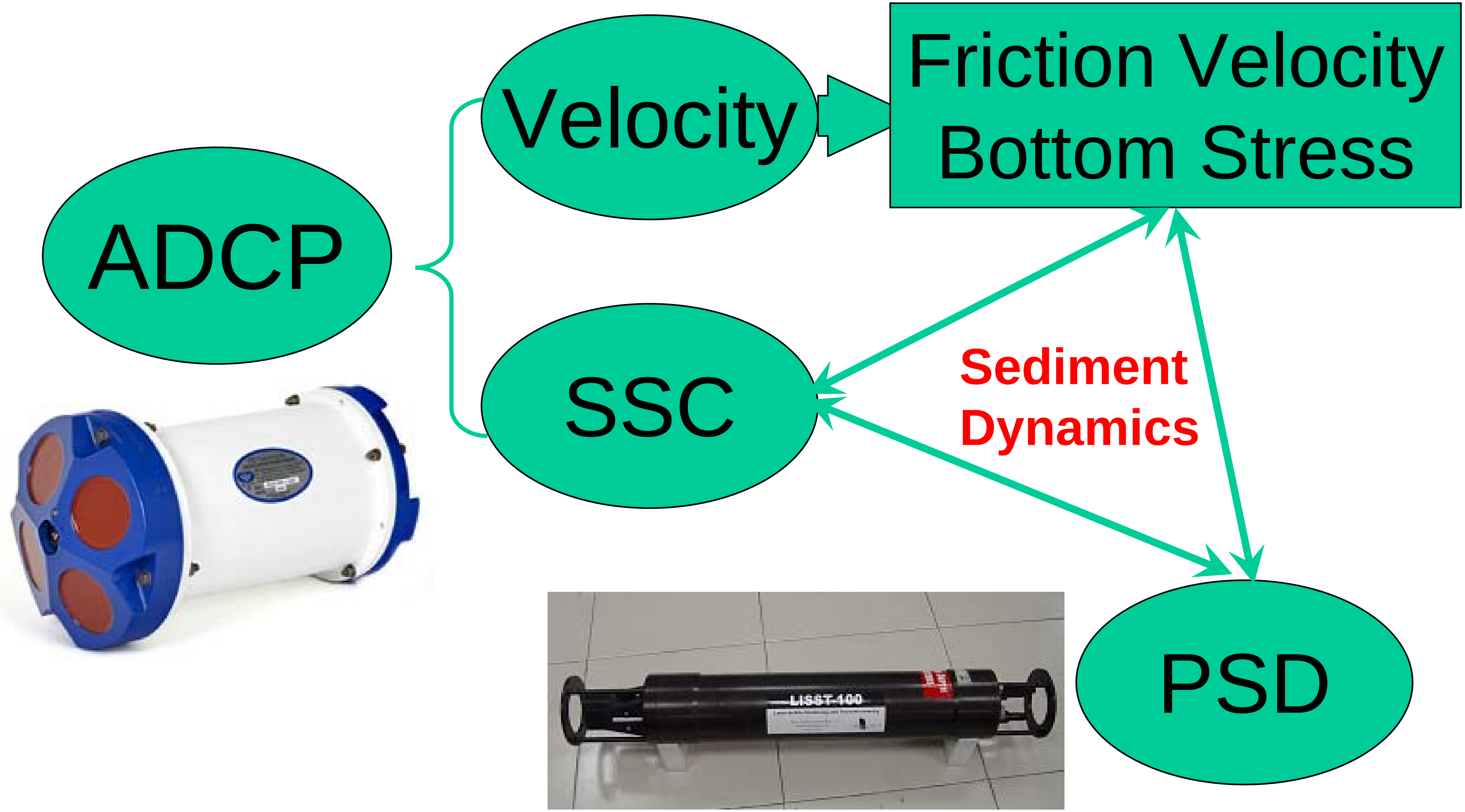
- Making use of ADCP Echo Intensity to estimate SSC is a reliable method under the assumption of that Particle Size Distribution remains stable during the observation.  Regression tests have verified it successfully in two experiment sites.

- Based on the Rayleigh Scatter Theory, Volume Backscattering Strength($S_v$) is proportional to the cubic grain size. So error would be introduced if PSD varies considerably.

In our experiment in St. A, ADCP under-estimate SSC because large grain size dominated near the surface while small grains existed everywhere.

- Introducing PSD information into $S_v$ calculation procedures could decrease the error to some extent coming from size variation. But two points should be noted:

1. The method suits for water with high turbidity
2. In our experiments, the size range measured by LISST-100 is quite narrow (<250micron), while ADCP working on the frequency of 600kHz have highest sensitivity on particles with a diameter of hundreds of microns. So the correction of size would be probably unconvincing because of dis-matched size range.



ADCP
Velocity
SSC
Friction Velocity
Bottom Stress
Sediment
Dynamics
PSD
LISST-100

- Large grains would suspend when tidal current is strong (Increasing bottom stress), then deposit immediately when tidal current become weak; while small grains would stay in the water column all the time.

The Velocity and SSC profiles from ADCP can be used to study the bottom boundary dynamics.