声学多普勒流速剖面仪（ADCP）及其应用
Introduction of ADCP and its application

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Beijing, China

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Outline

中国科学院声学研究所
Institute of Acoustics, CAS

1. Introduction to ADCPs
2. Product Classification
3. Application (QA/QC)
4. About Us (Institute of Acoustics, CAS, China)

1. Introduction to ADCPs （1/4）

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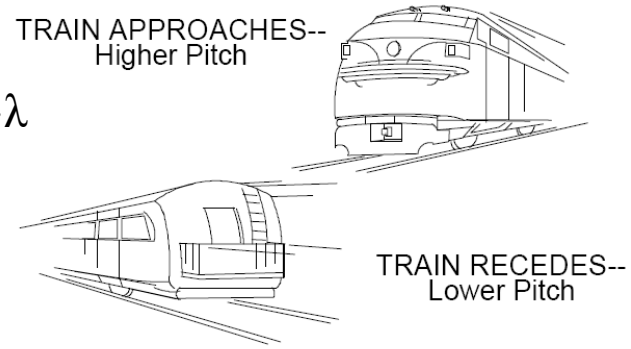
- **The Doppler Effect**

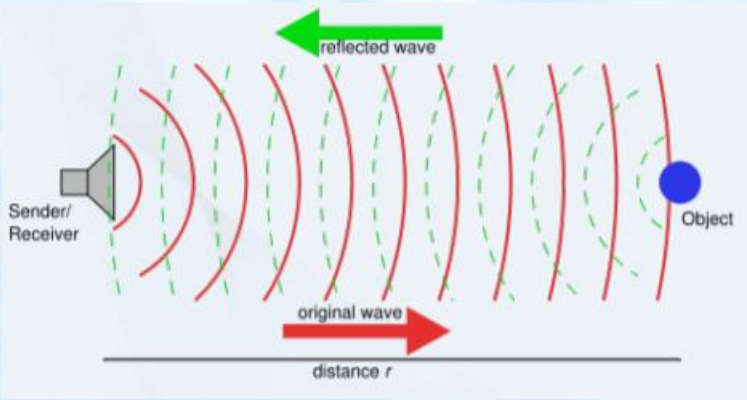
  Speed of sound = frequency × wavelength: $C = f \cdot \lambda$

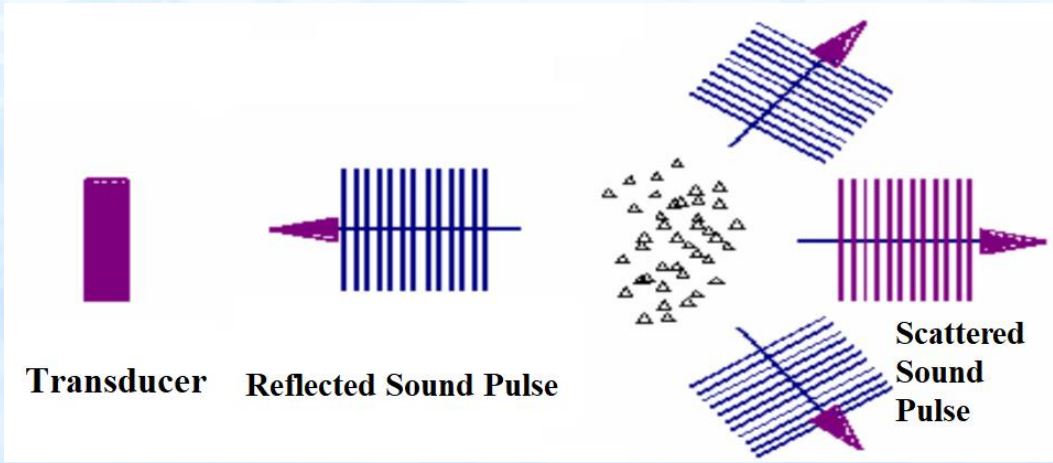
  The *Doppler Shift* : $F_d = F_s(V/C)$.



- **The Doppler RADAR**
- **Doppler SONAR (like RADAR in air)**

  SOund NAvigation & Ranging





1. Introduction to ADCPs （2/4）

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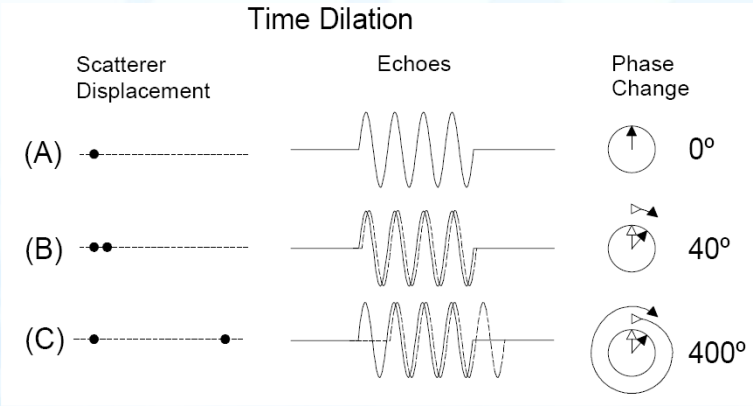
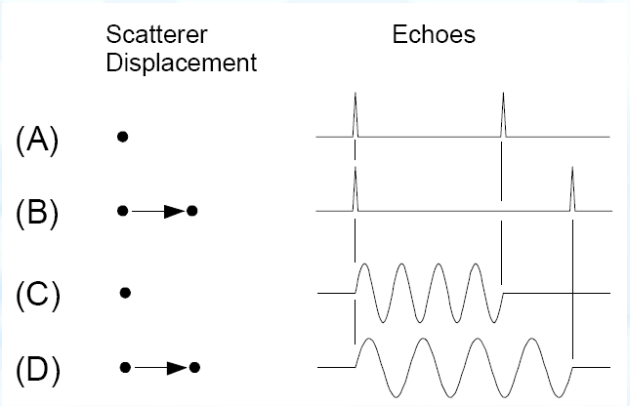
BroadBand Doppler Processing

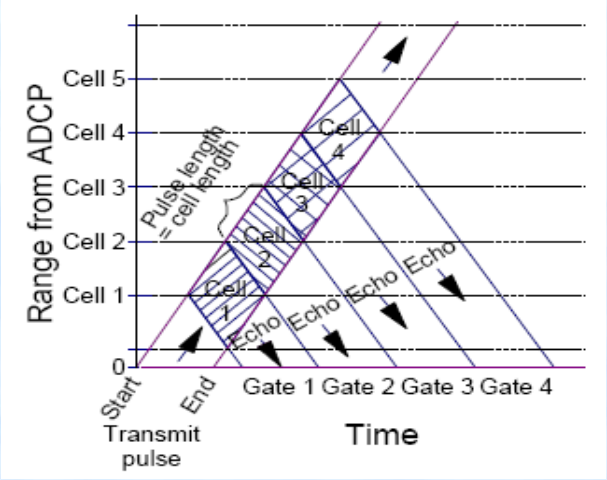
- Doppler frequency shift and time dilation are equivalent.
- Autocorrelation techniques





Depth Cells and Range Gating

- Profiles are produced by range-gating the echo signal
- Velocity is averaged over the depth of the entire depth cell



1. Introduction to ADCPs （3/4）

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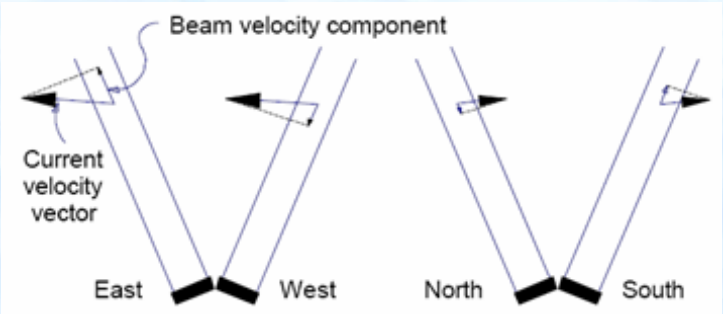
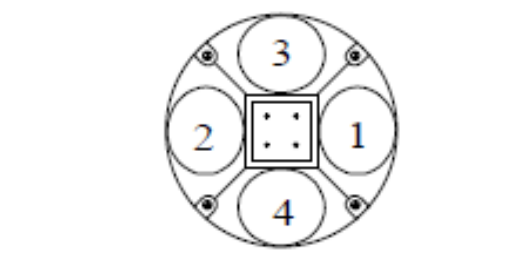
❑ Multiple Beams BroadBand Doppler Processing

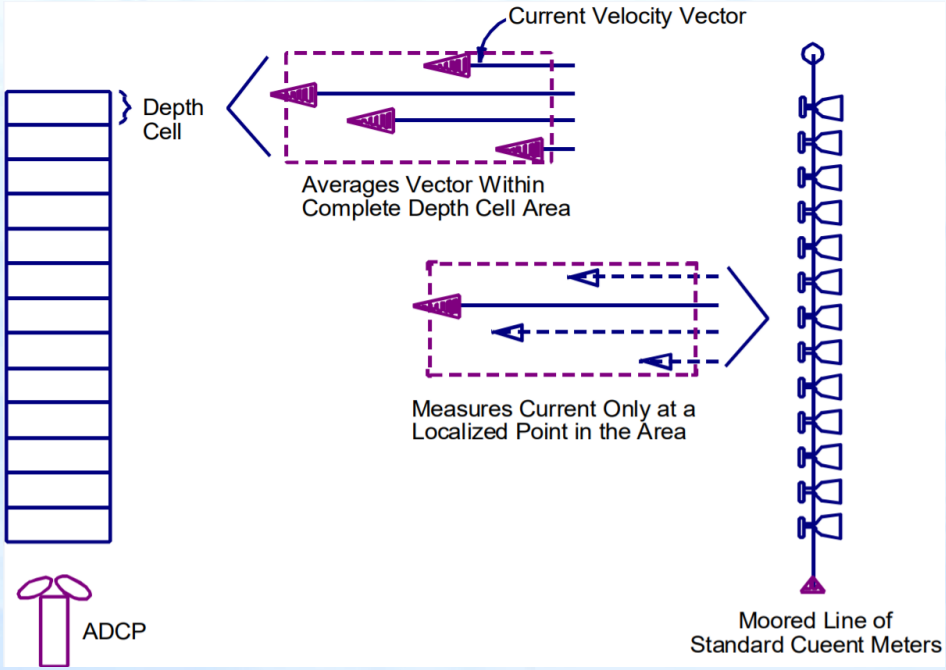
- ❖ from each pair of beams get 1 component of horizontal velocity + 1 component vertical velocity
- ❖ Assumes current Homogeneity in a Horizontal Layer
- ❖ Calculation of Velocity with Four or Five ADCP Beams

$u_1 = v \sin\theta + w \cos\theta$ $\quad$ $u_2 = -v \sin\theta + w \cos\theta$

$u_3 = u \sin\theta + w \cos\theta$ $\quad$ $u_4 = -u \sin\theta + w \cos\theta$

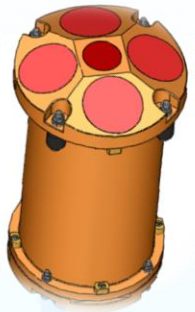






1. Introduction to ADCPs （4/4）

- **Acoustic Doppler Current Profiler（ADCPs）**
- **are the most universal sensor packages in Ocean and River Observing Systems in the world.**



conventional

1. Current profiling
2. Acoustic Ranging

present

1. Water Resource Management - flow in rivers and channels
2. Environmental Monitoring
3. Hydraulic Engineering
4. Scientific Research: sediment transport, environmental
5. Impact studies, modeling

prospective

1. Turbulence
2. Wave
3. Echo profiling - particle or plankton concentration

2. Product Classification (1/5)

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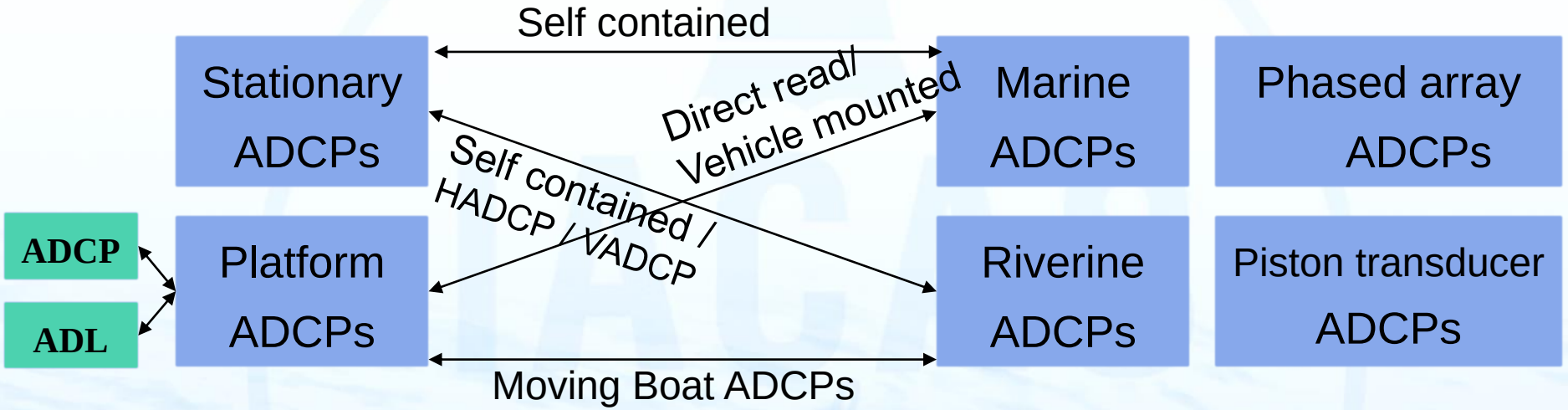
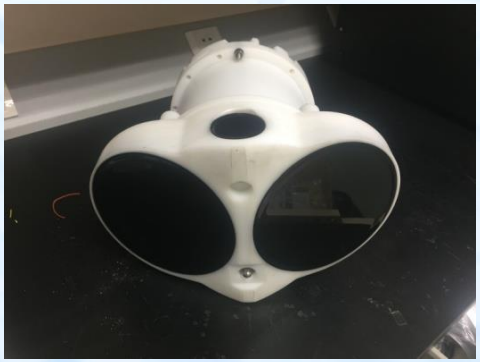


US Xylem
Sontek M9

US Teledyne
RDI RiverPro

China HaiYin
RIV-F ADCP



China HaiYin
RIV HADCP

2. Product Classification (2/5)

- **ADCP finishing painting**

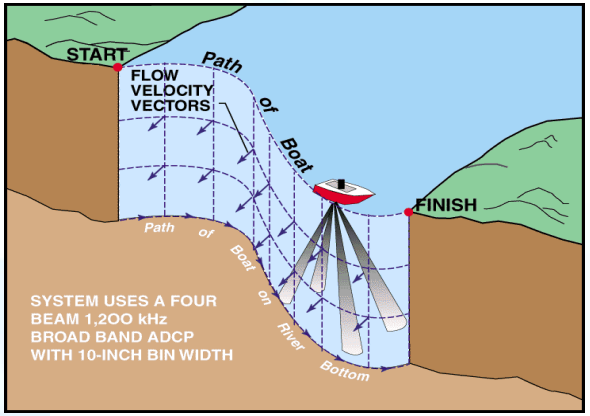
Transducer acoustic transmission layer

water-tight housing：engineering plastic or alloy

2. Product Classification (3/5)

（1）Moving Boat ADCPs

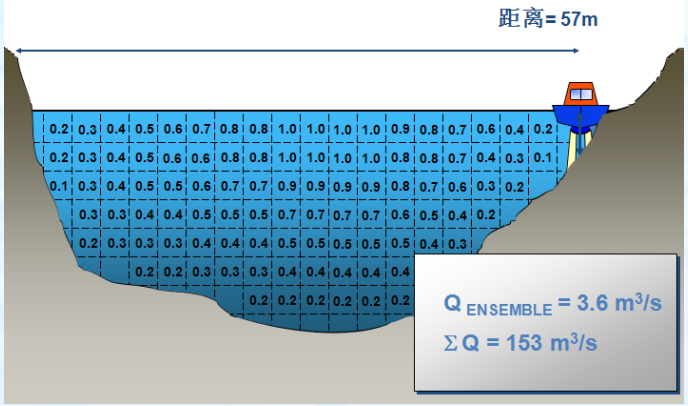
- Velocity profiling
- velocity frome bottom tracking / GPS
- bottom depth



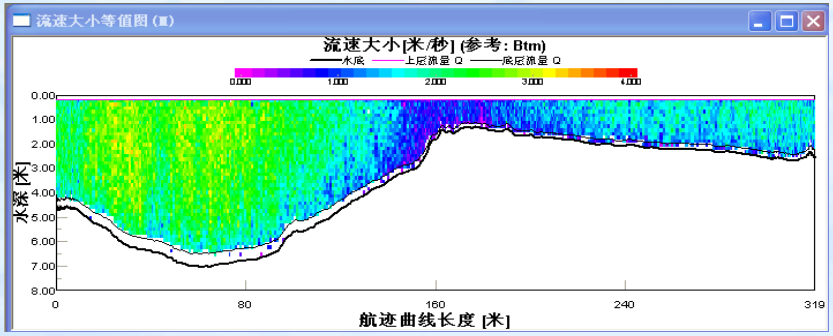
Manned vessel

Trimaran

Autonomous Vehicle



- Flow measurement
- exquisite profiling information
- fixed measuring line (Not required)
- section shape (Not required)



2. Product Classification (4/5)

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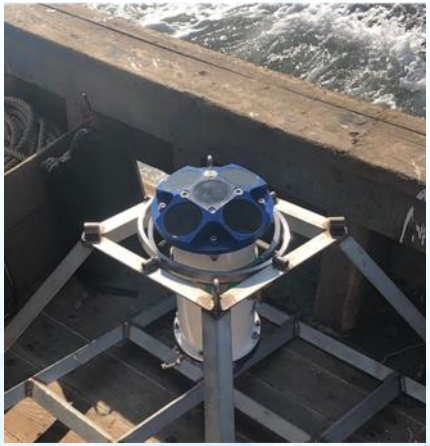
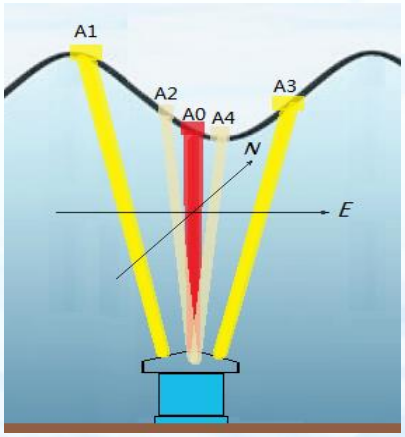
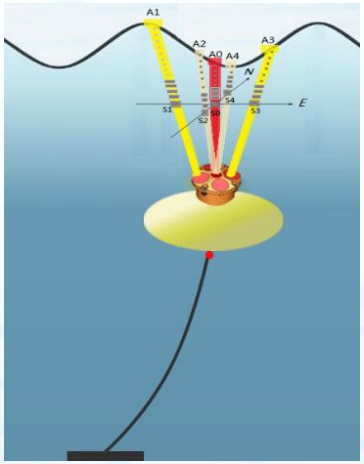
（2）Platform ADCP / ADL

- Seabed based platform

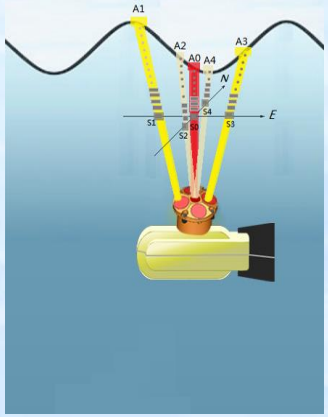




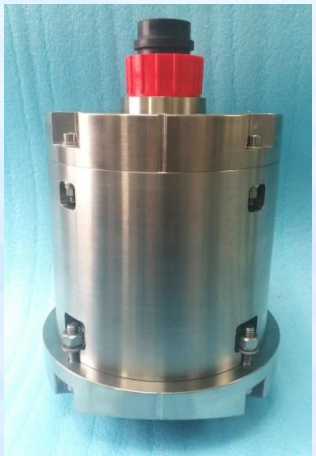
- Submerged buoy



- Vehicle mounted ADCP



- Vehicle mounted ADL



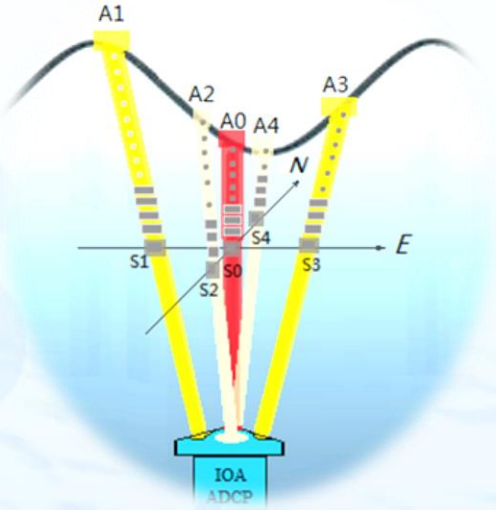
2. Product Classification (5/5)

（3）Wave ADCPs

- **Wave spectrum from ADCP measurements**

$$\frac{1}{4}\sum_{i=1}^{4} S_{V_i}(\omega,z,d) = T^2(\omega,z,d)\,S_H(\omega) + S_N(\omega)$$

$$T^2 = \left\{\omega\frac{\sinh\left[k(z+d)\right]}{\sinh(kd)}\cos\beta\right\}^2 + \frac{1}{2}\left\{\omega\frac{\cosh\left[k(z+d)\right]}{\sinh(kd)}\sin\beta\right\}^2$$



- **Reynolds stresses from ADCP measurements**

$$u_1 = v\sin\theta + w\cos\theta \qquad u_2 = -v\sin\theta + w\cos\theta$$

$$u_3 = u\sin\theta + w\cos\theta \qquad u_4 = -u\sin\theta + w\cos\theta$$

$$\overline{u'w'} = \frac{\overline{u_3'^2} - \overline{u_4'^2}}{4\sin\theta\cos\theta} \qquad \overline{v'w'} = \frac{\overline{u_1'^2} - \overline{u_2'^2}}{4\sin\theta\cos\theta}$$

- **Turbulence dissipation from ADCP measurements**

3. Application (QA/QC) (1/6)

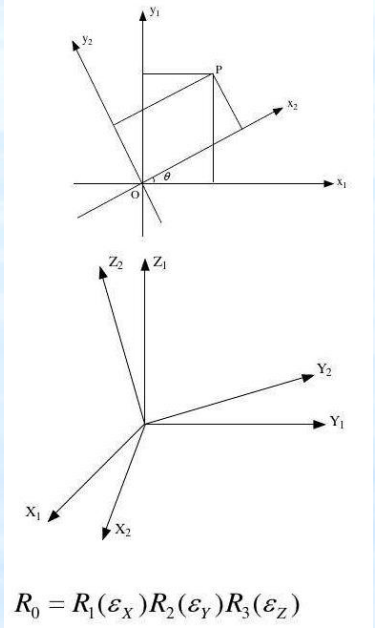
- Velocity (Beam, ADCP, Ship & Earth coordinates)
- Echo Intensity
- Correlation Index
- Percent good (PG)
- Bottom-track Data (As ADL)

Echo intensity influencing factor

$$R_1(\varepsilon_X)=\begin{bmatrix}1 & 0 & 0\\ 0 & \cos\varepsilon_X & \sin\varepsilon_X\\ 0 & -\sin\varepsilon_X & \cos\varepsilon_X\end{bmatrix}$$

$$R_2(\varepsilon_Y)=\begin{bmatrix}\cos\varepsilon_Y & 0 & -\sin\varepsilon_Y\\ 0 & 1 & 0\\ \sin\varepsilon_Y & 0 & \cos\varepsilon_Y\end{bmatrix}$$

$$R_3(\varepsilon_Z)=\begin{bmatrix}\cos\varepsilon_Z & \sin\varepsilon_Z & 0\\ -\sin\varepsilon_Z & \cos\varepsilon_Z & 0\\ 0 & 0 & 1\end{bmatrix}$$



$$R_0 = R_1(\varepsilon_X)R_2(\varepsilon_Y)R_3(\varepsilon_Z)$$

Coordinates transform

Echo intensity scaled differences between Water body and material interface

3. Application (QA/QC) (2/6)

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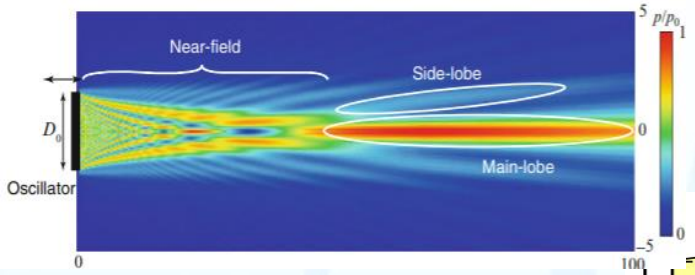
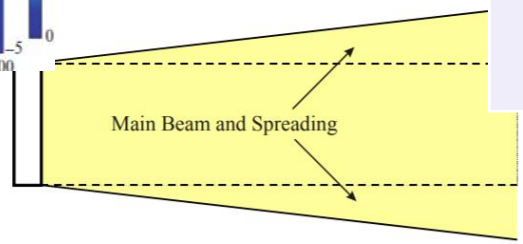
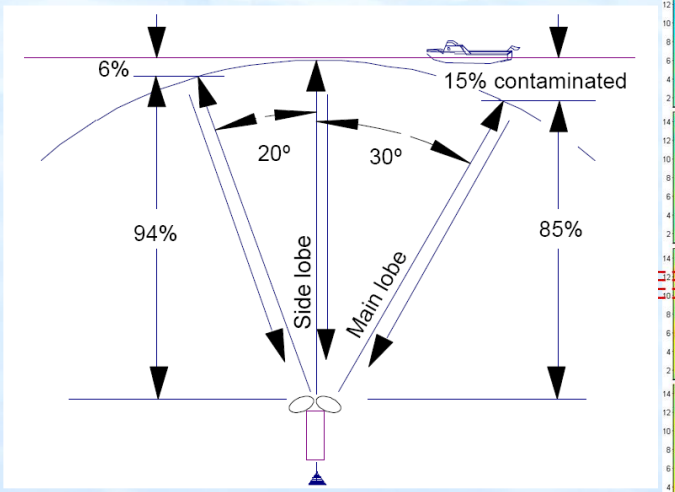
❑ Beam Spreading Clearance Zone

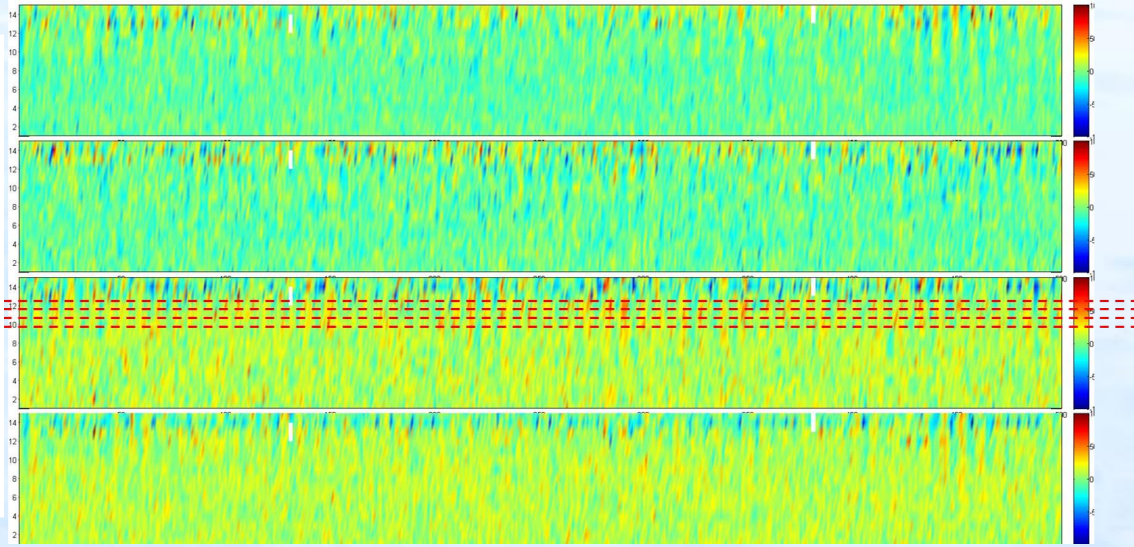




	Beam inclination angle	Keep unobstructed
ADCP	20°	10~30
ADL	25 or 30°	5~40 15~45

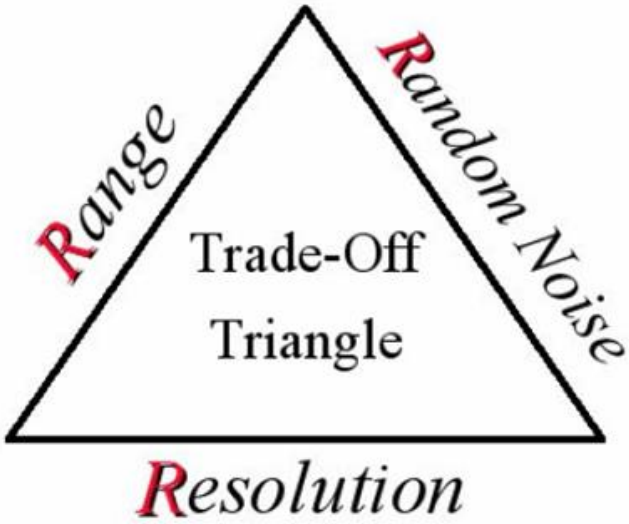
❑ Near Surface or Bottom Zone





3. Application (QA/QC) (3/6)

- **Setup Parameters**
  - Depth range of measurements
  - Cell size and quantity
  - Spacing between measurements: in depth and time
  - Data averaging
  - Deployment duration



Trade-off Triangle

- **What's more significant?**

According to the battery capacity, we should estimate data quantity and Deployment duration.

As to Direct-Reading / Vehicle-Mounted ADCP or ADL, we should estimate Fastest output rate and transmission speed by serial port or inductive coupling or network transmission.

3. Application (QA/QC) (4/6)

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❑ Resolution

Cell Size
Sampling Fs

Random Noise

Cell Size

Sampling Rate

power consumption

data quantity

power consumption

❑ Range

Frequency

Pulse duration

Bandwidth Noise

Scatterer concentration & Absorption loss

❑ Random Noise

Random Noise vs. Resolution

Velocity precision improves by

$$\sqrt{\text{No. pings} \times \text{Depth Cell size}}$$

Dynamic Conditions

greater heave, pitch and roll of the ADCP
turbulence changes velocity uniformity

Signal processing noise

Transmitting pulse coding
Electronics noise

$$\sigma_{ping} = \lambda/(4\pi t_\tau)\sqrt{(0.5/M)\left(\rho^{-2} - 1 + \max\left\{0, 2(1 - M_\tau/M)\right\}\right)}$$ (Brumly 1991)

3. Application (QA/QC) (5/6)

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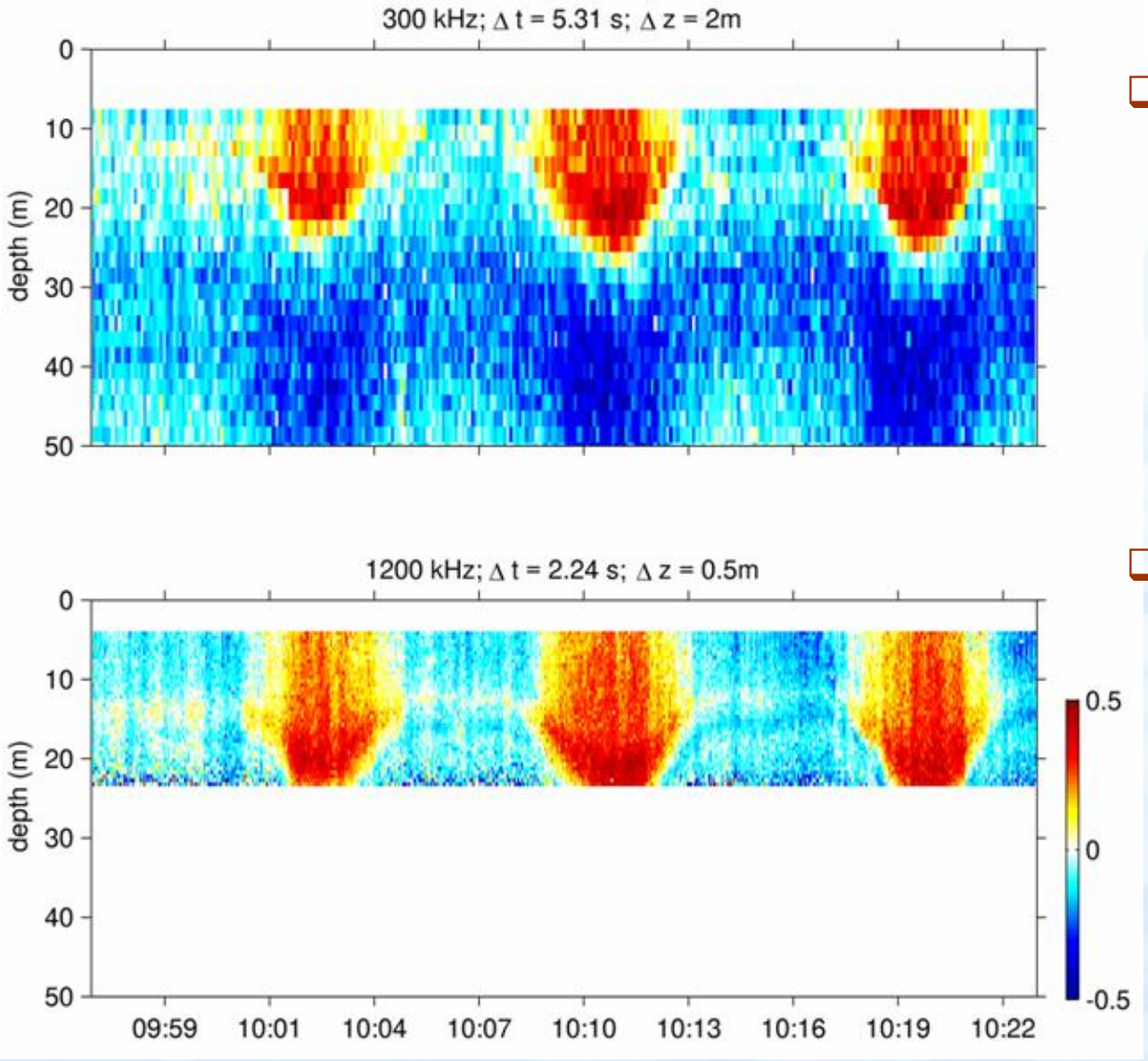

TRDI workhorse ADCP

- **Lower frequency**
  - Bigger Cell Size
  - Longer Range
  - Lower Sampling Rate

  Deep-sea observation

- **Higher frequency**
  - Smaller Cell Size
  - Shorter Range
  - Higher Sampling Rate

  shallow sea, nearshore, rivers observation

  Wave or turbulence Research

3. Application (QA/QC) (6/6)

- **ADCP Data QA/QC**
  - **preliminary quality control** （Missing data or Echo Intensity abnormal ）
  - **correlation test** (Correlation Index)
  - **global test** (element range test)
  - **spike test** (rationality test / Deviation value removal)
  - **Chi-squared Test** (Statistical analysis)
  - **gradient test** (Continuity test/ Jump point removal)
  - **good percentage** (Quality mark/Lag)
  - **manual quality control**

4. About Us - IOA, CAS(1/6)

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- The Institute of Acoustics, CAS (Chinese Academy of Sciences)
- (1) was established in 1964 as a spinoff of the CAS Institute of Electronics
- (2) Locations: Beijing, China
- (3) major R&D unit of ADCP/ADL in China

Current measurement and Velocity Log Research Group

4. About Us -- Marine ADCP(2/6)

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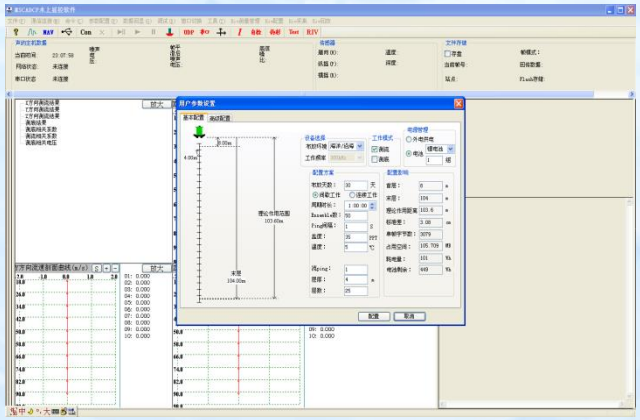
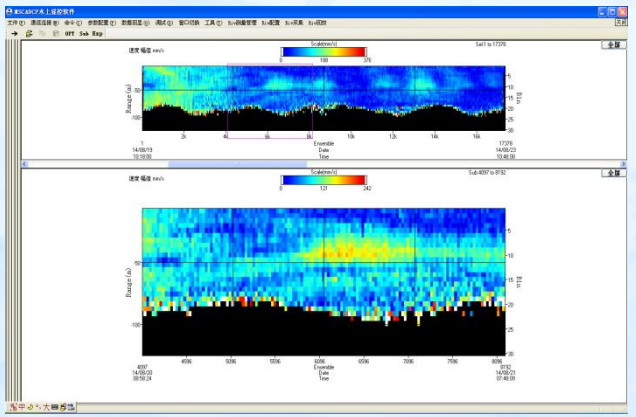
- Series of self contained and direct reading ADCP for long-term fixed-point flow measurement
- supporting software
- Inspection testing equipment for ADCP fast factory test on land
- Effectively pool tested and offshore tested





4. About Us -- Marine ADCP(3/6)

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- applied in China's territorial waters, the global oceans and the antarctic and Arctic Poles.
- Self-sustaining application obtained data for **2 years Maximum**.
- **deep-sea ADL** has been used in 6000m AUV, Jiaolong manned submersible, 6000m ROV and acoustic deep tow, etc.

4. About Us -- Marine ADCP(4/6)

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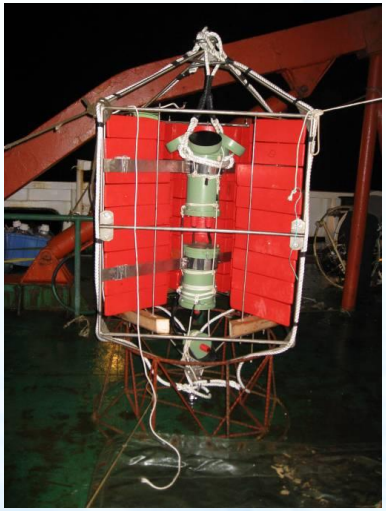
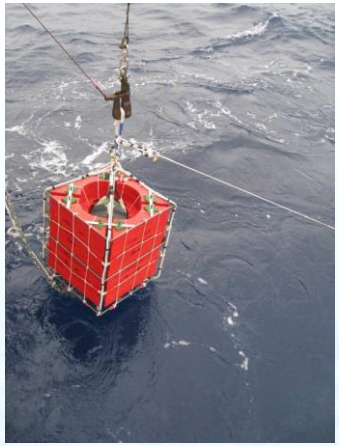
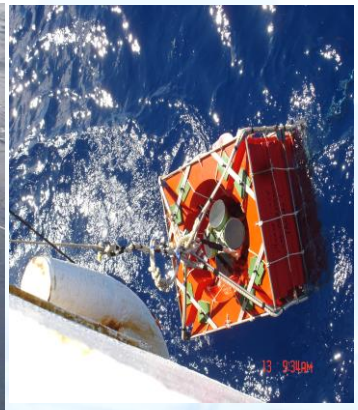
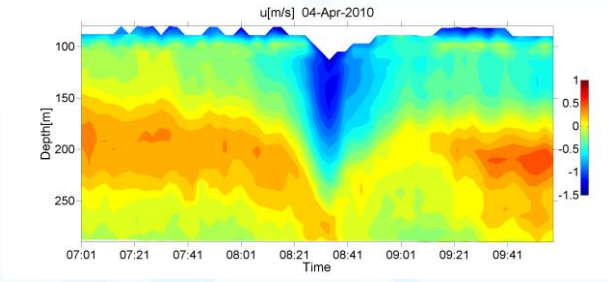
❑ Reliability verification test on submarine buoy

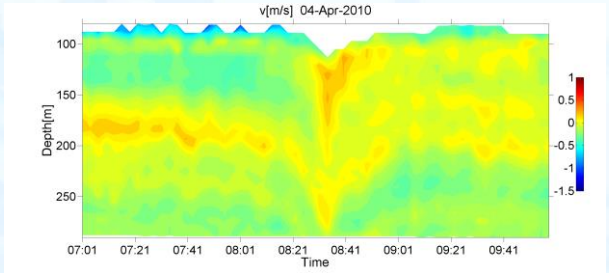






Long-term deployment of self contained ADCP on submersible buoys





An example of internal solitary wave

- over 5 months, 1000 m depth, ADCP at 250 m below sea surface
- observed several internal wave processes
- ADCP transducers, structure and hardware have verified at actual deep-sea environment

4. About Us - Riverine ADCP(5/6)

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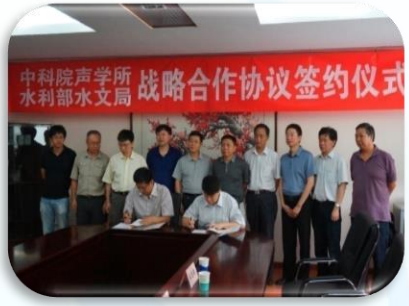
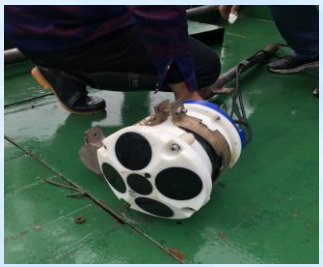
- **IOA-CAS signed cooperation agreements** with the Hydrological Bureau of the Ministry of Water Resources, the Hydrological Bureau of the Yangtze River Commission and the Hydrological Bureau of the Yellow River Commission to promote the R&D of Riverine ADCP
- **RIV-600 ADCP** as new product appraisal of the Ministry of Water Resources
- River or steam flow measurement technology and **real-time observation system**
- Supporting software IOARiver
- **RIV-1200 ADCP** suitable for shallow river or steam
- **H-ADCP and 5-Beams ADCP**





4. About Us - Riverine ADCP(6/6)

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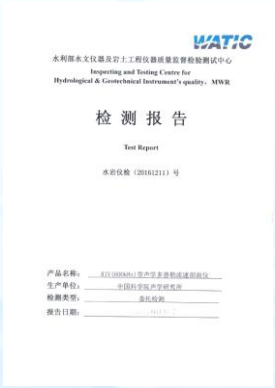
- **Comprehensive performance test of Riverine ADCP**

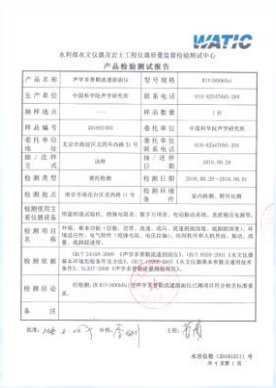

WATIC

水利部水文仪器及岩土工程仪器质量监督检验测试中心
Inspecting and Testing Centre for Hydrological & Geotechnical Instrument's quality, MWR

检 测 报 告

Test Report

水岩仪检（20161211）号


WATIC

水利部水文仪器及岩土工程仪器质量监督检验测试中心

产品检验测试报告

2013年9月小浪底水文站试验

2015年4月长江南京站试验

2015年4月
上海松浦大桥站试验

2015年5月
江西峡江站试验

2015年6月
广东马口站试验

4、Contact Us

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- **Marine and Riverine ADCP have been used in oceanographic scientific research and river hydrological operational observation**
- **High cost performance Rate**
- **Advanced technology & Convenient technical support, greatly improves the use efficiency of ADCP**
- **University-industry Cooperation, improves the research level and systematizes hydrological monitoring**

谢谢

Thank You