MUSIC法應用於 高頻雷達陣列天線訊號解算之研究

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守護海上交通安全

交通部中央氣象局新聞稿

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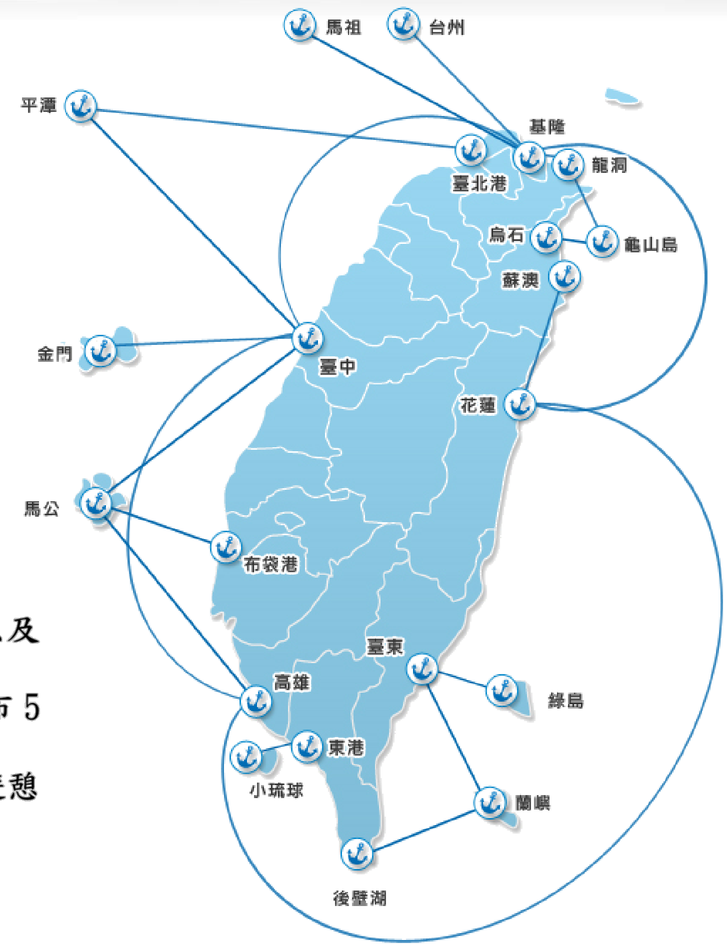
藍色公路海況預報

中央氣象局表示，為增進本島離島間海上航線航行的安全以及提升海上活動海氣象資訊服務的品質，該局由 100 年 2 月 1 日起發布 5 條藍公路未來 24 小時之海況預報資料，供航行船隻及民眾於海上遊憩參考。



圖片來源：中央氣象局網頁

觀測與預測技術之整合

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Assimilation of decomposed in situ directional wave spectra into a numerical wave model of typhoon waves

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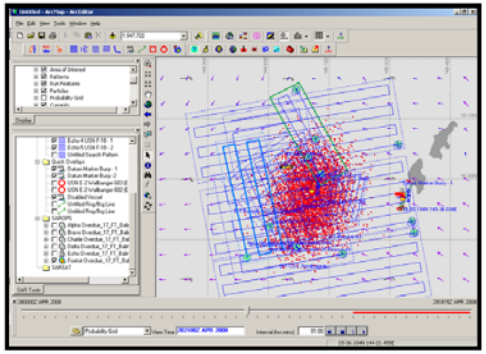
Search and Rescue Optimal Planning System (SAROPS)



SAROPS is written as a series of extensions to ESRI's ArcGIS 9.2 (COTS, not part of the SAROPS distribution). SAROPS makes requests to and receives from an Environmental Data Sever (EDS) real-time gridded environmental products. SAROPS also allows manual inputs of winds and currents input via a 'sketch' tool using objective analysis techniques. SAROPS uses the latest drift algorithms to project the drift of the survivors and craft.

Search Rescue Unit (SRU) allocation is automated in SAROPS by maximizing Probability of Success (POS). Each SRU gets a recommended search pattern that accounts for the relative motion between the SRU and the drifting particles. This is done by using the Probability of Detection as function Lateral Range to update the probability of detection for each particle.

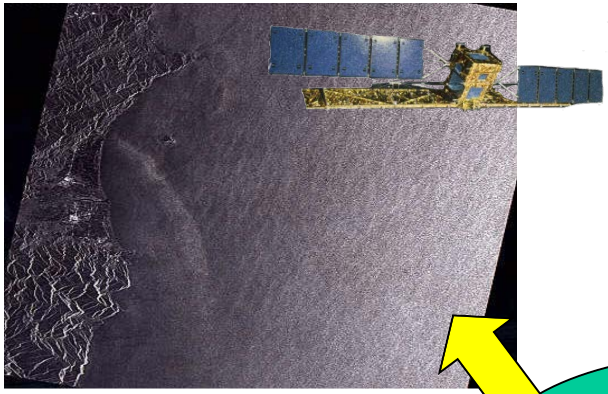
SAROPS is the software used by the U.S. Coast Guard for Maritime Search Planning. SAROPS is a Monte Carlo based system that uses thousands of simulated particles generated by user inputs in a wizard based Graphical User Interface. SAROPS has the ability to handle multiple scenarios and search object types; model pre-distress motion and hazards; and account for the affects of previous searches.

Search pattern summaries are available in several formats. Search effectiveness reports are also generated. There are capabilities for exporting and importing SAROPS case files

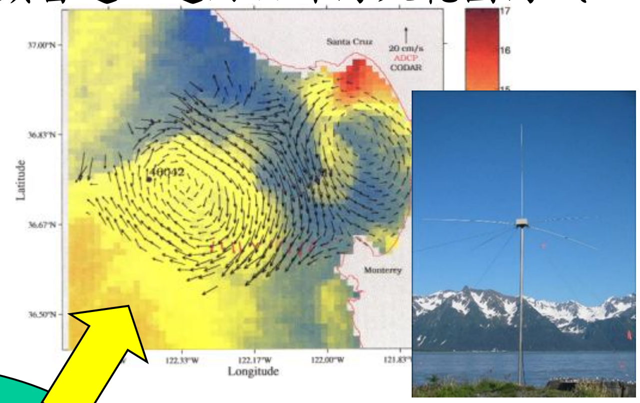
- 將觀測資料輸入至模式後，可有效改善預測結果。

非接觸式遙測技術發展現況

衛星：適用於外海極大範圍海域

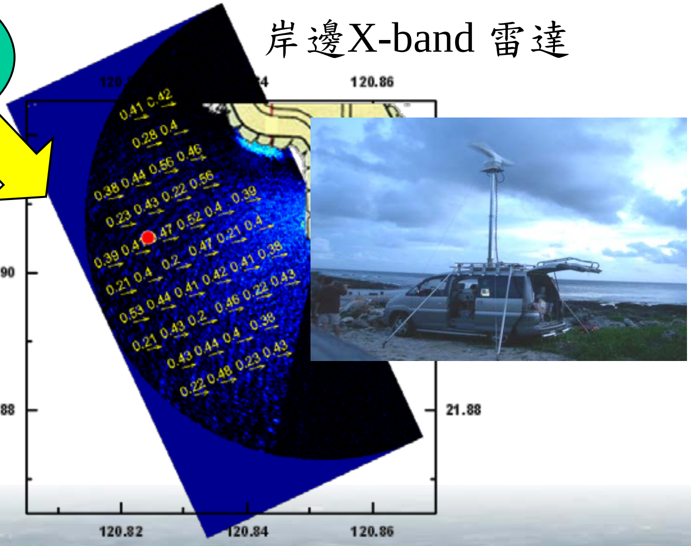


高頻雷達：適用於外海大範圍海域



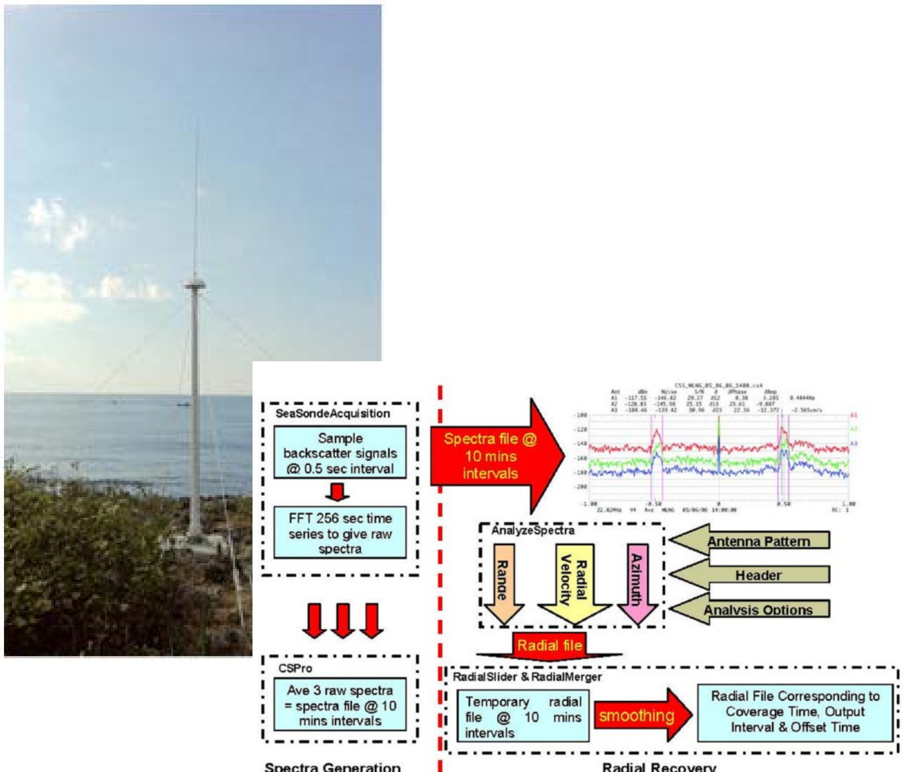
非接觸式遙測

岸邊X-band 雷達

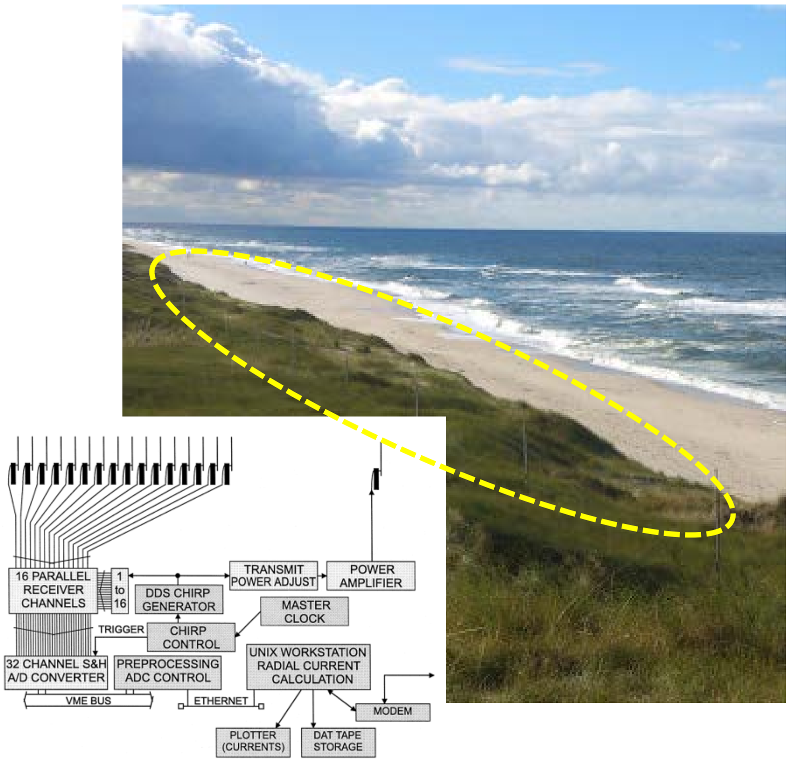


光學攝影機：適用於能見度佳之近岸環境

高頻雷達觀測技術現況



SeaSonde系統



WERA系統

Toh, K.W.D. (2005) " Evaluation of surface current mapping performance by SeaSonde high frequency radar through simulations "
Gurgel, K.W. (1999) "Wellen Radar (WERA): a new ground-wave HF radar for ocean remote sensing."

台灣海域高頻雷達觀測現況

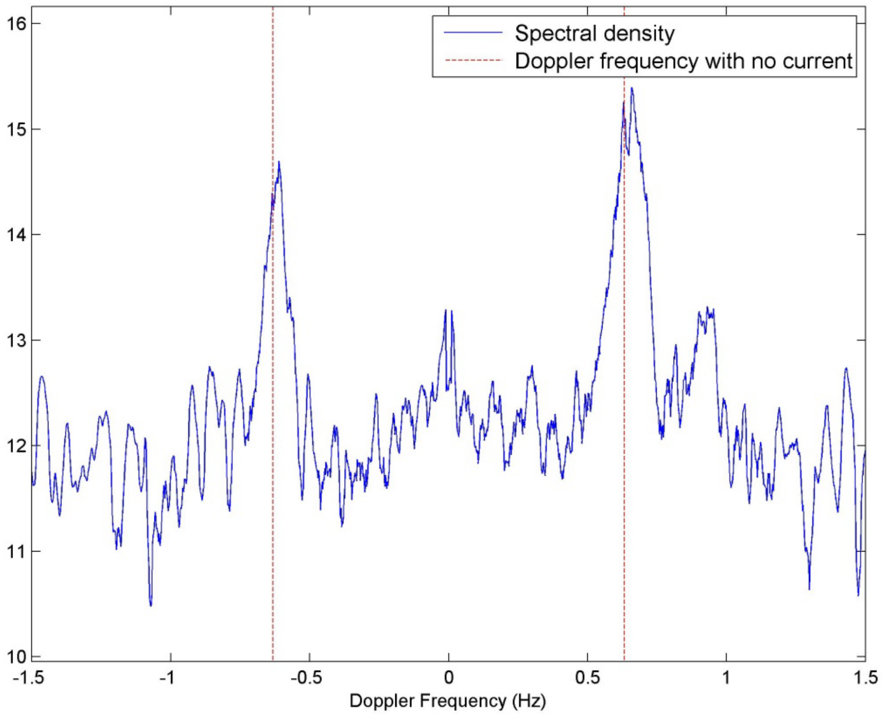
- 國家實驗研究院台灣海洋科技研究中心
- 海軍軍官學校與臺灣大學海洋研究所

→ SeaSonde系統

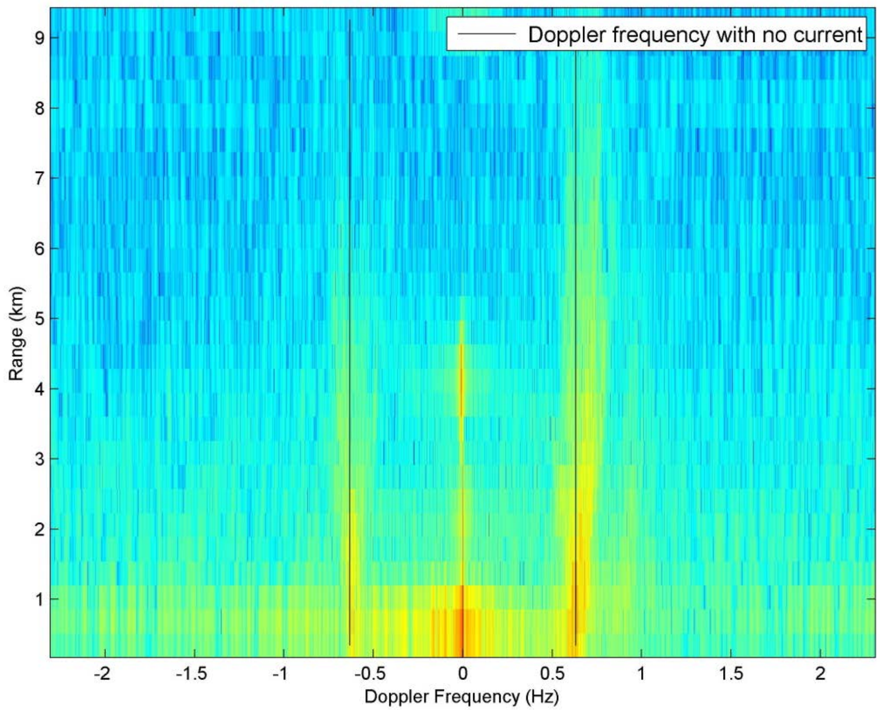
- 交通部運輸研究所 → WERA系統

台北港的WERA測站

WERA雷達資料分析及探討

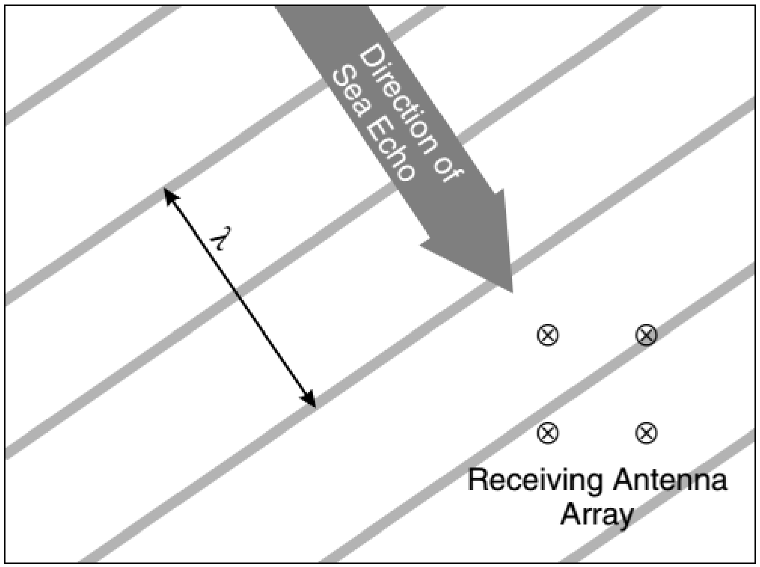


單一距離單元之雷達回波都卜勒能譜

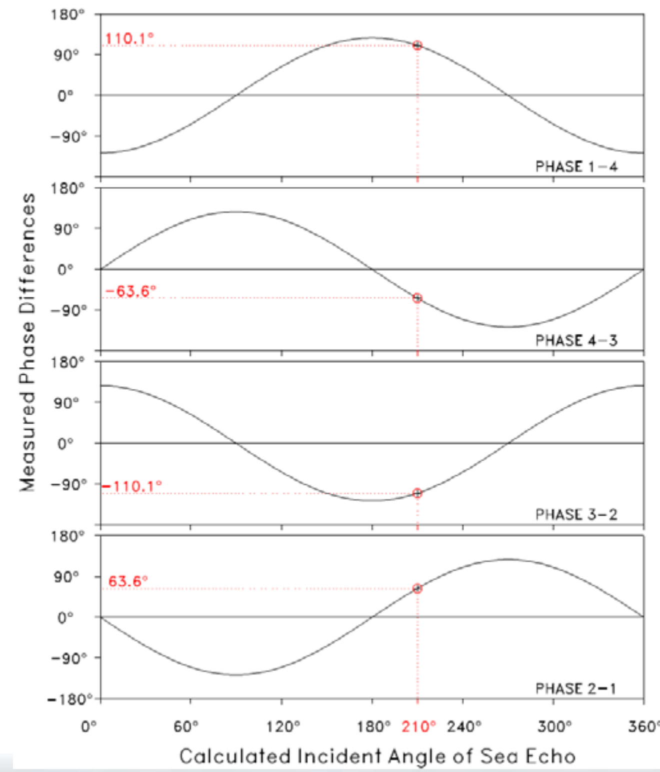


不同距離單元之雷達回波都卜勒能譜

陣列天線辨識訊號方位之基本原理



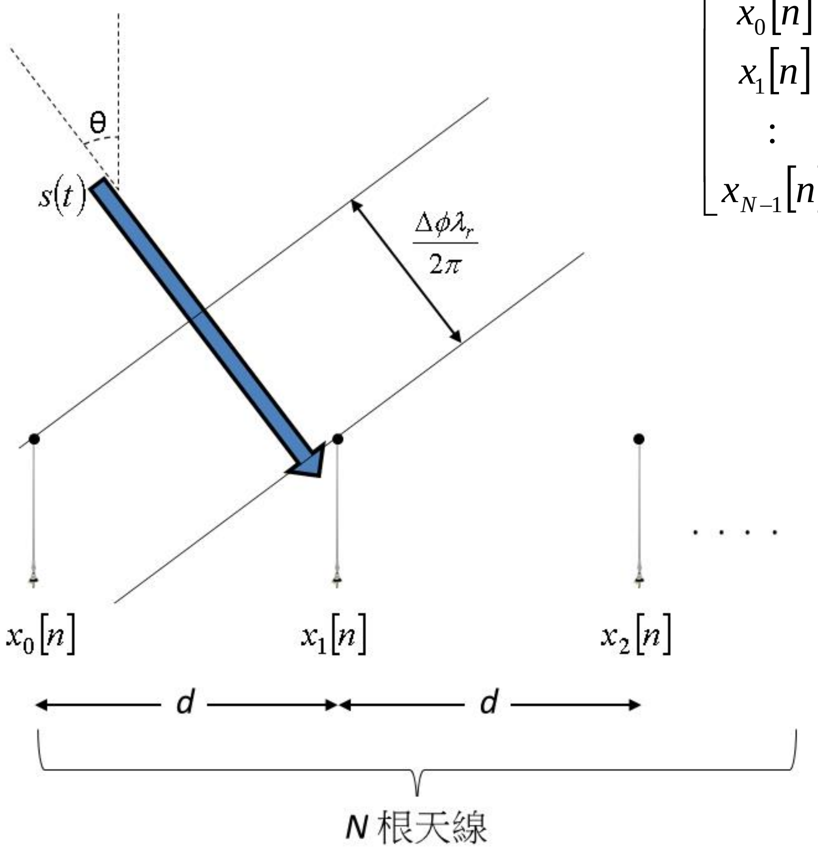
$$\theta = sin^{-1}(\frac{\Delta\phi \cdot \lambda}{2\pi d})$$



$$\varepsilon(\Theta) = \sum_{i=1}^{4}(\min(|\,\varphi_i^{\star} - \varphi_i(\Theta)\,|\,, 360 - |\,\varphi_i^{\star} - \varphi_i(\Theta)\,|))^2$$

$$\varepsilon(\Theta) \Longrightarrow Minimum$$

陣列天線辨識訊號方位之解算-Beam forming



$$\begin{bmatrix} x_0[n] \\ x_1[n] \\ : \\ x_{N-1}[n] \end{bmatrix} = \left\{ \begin{bmatrix} a_0(\theta_0) & a_0(\theta_1) & .. & a_0(\theta_{r-1}) \\ a_1(\theta_0) & a_1(\theta_1) & .. & a_1(\theta_{r-1}) \\ : & : & .. & : \\ a_{N-1}(\theta_0) & a_{N-1}(\theta_1) & .. & a_{N-1}(\theta_{r-1}) \end{bmatrix} \begin{bmatrix} s_0[n] \\ s_1[n] \\ : \\ s_{N-1}[n] \end{bmatrix} \right\} + \begin{bmatrix} v_0[n] \\ v_1[n] \\ : \\ v_{N-1}[n] \end{bmatrix}$$

$$a(\theta) = \begin{bmatrix} 1 & e^{-i\omega} & e^{-i2\omega} & .. & e^{-i(N-1)\omega} \end{bmatrix}^T$$

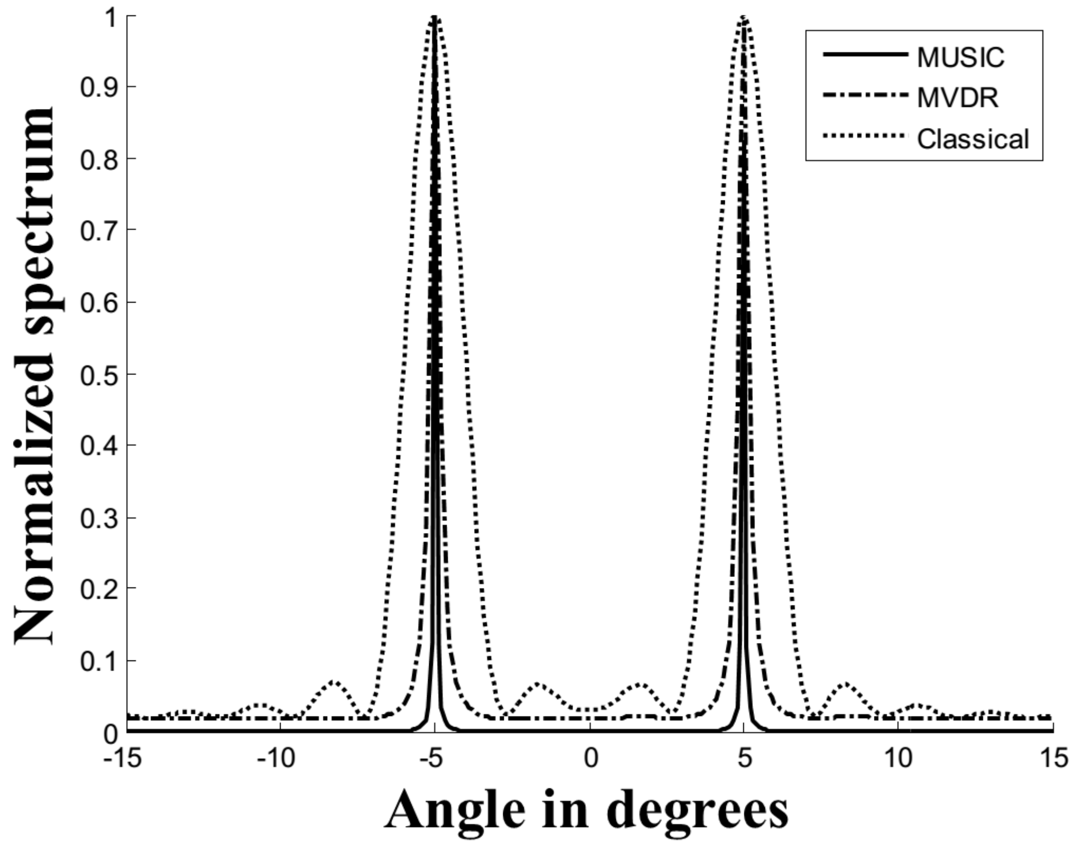
$$y[n] = \sum_{k=0}^{N-1} w_k x_k[n]$$

$$\mathrm{P}(\theta) = \mathrm{E}\left[y[n]^{\mathrm{H}} y[n] \right] = \mathrm{E}\left| \left[w[n]^{\mathrm{H}} x[n] \right] \right|^2$$

$$= \mathrm{E}\left| \left[a(\theta)^{\mathrm{H}} x[n] \right] \right|^2 = a(\theta)^{\mathrm{H}} R_{xx} a(\theta)$$

$$R_{xx} = \frac{1}{K} \sum_{i=0}^{K-1} x[n] x[n]^H$$

不同訊號方位辨識技術之結果



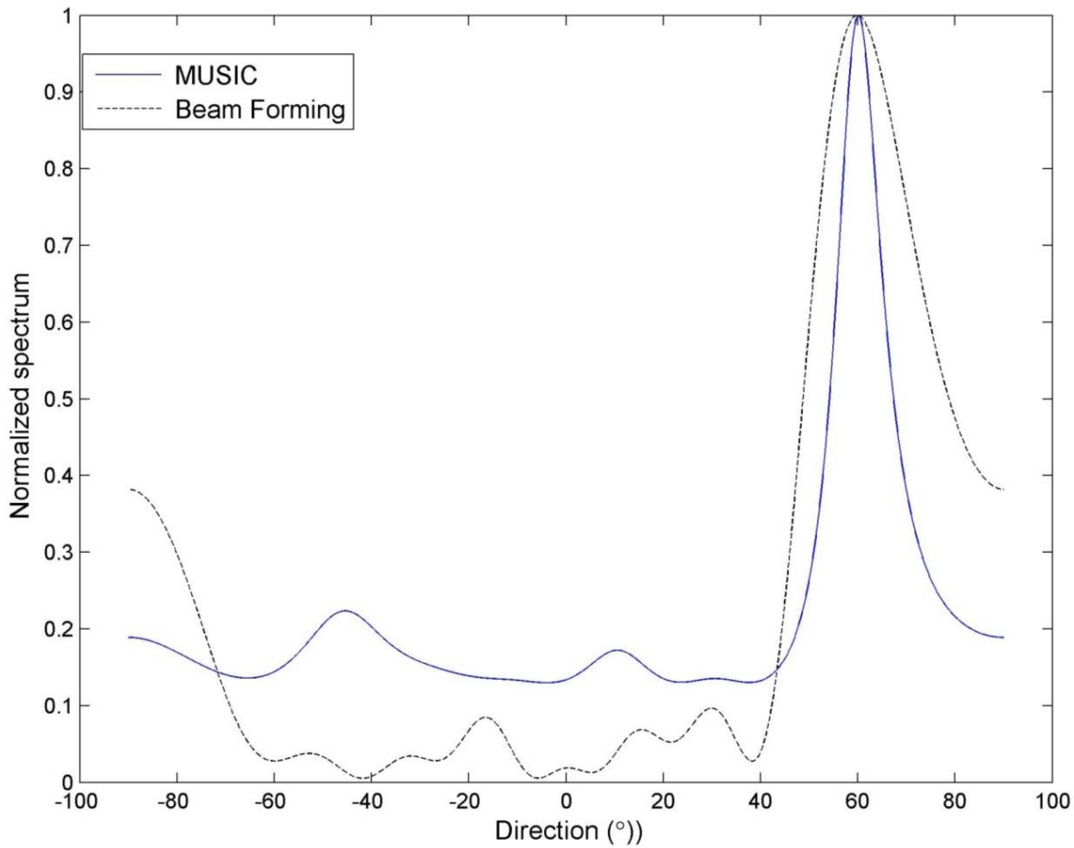
MUSIC空間訊號方位辨識技術

$$C=\begin{vmatrix} C_{11} & C_{12} & \cdots & C_{1n} \\ C_{21} & C_{22} & \cdots & C_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ C_{n1} & C_{n2} & \cdots & C_{nn} \end{vmatrix} = \begin{vmatrix} \langle S_{11} \rangle & \langle S_{12} \rangle & \cdots & \langle S_{1n} \rangle \\ \langle S_{21} \rangle & \langle S_{22} \rangle & \cdots & \langle S_{2n} \rangle \\ \vdots & \vdots & \vdots & \vdots \\ \langle S_{n1} \rangle & \langle S_{n2} \rangle & \cdots & \langle S_{nn} \rangle \end{vmatrix}$$

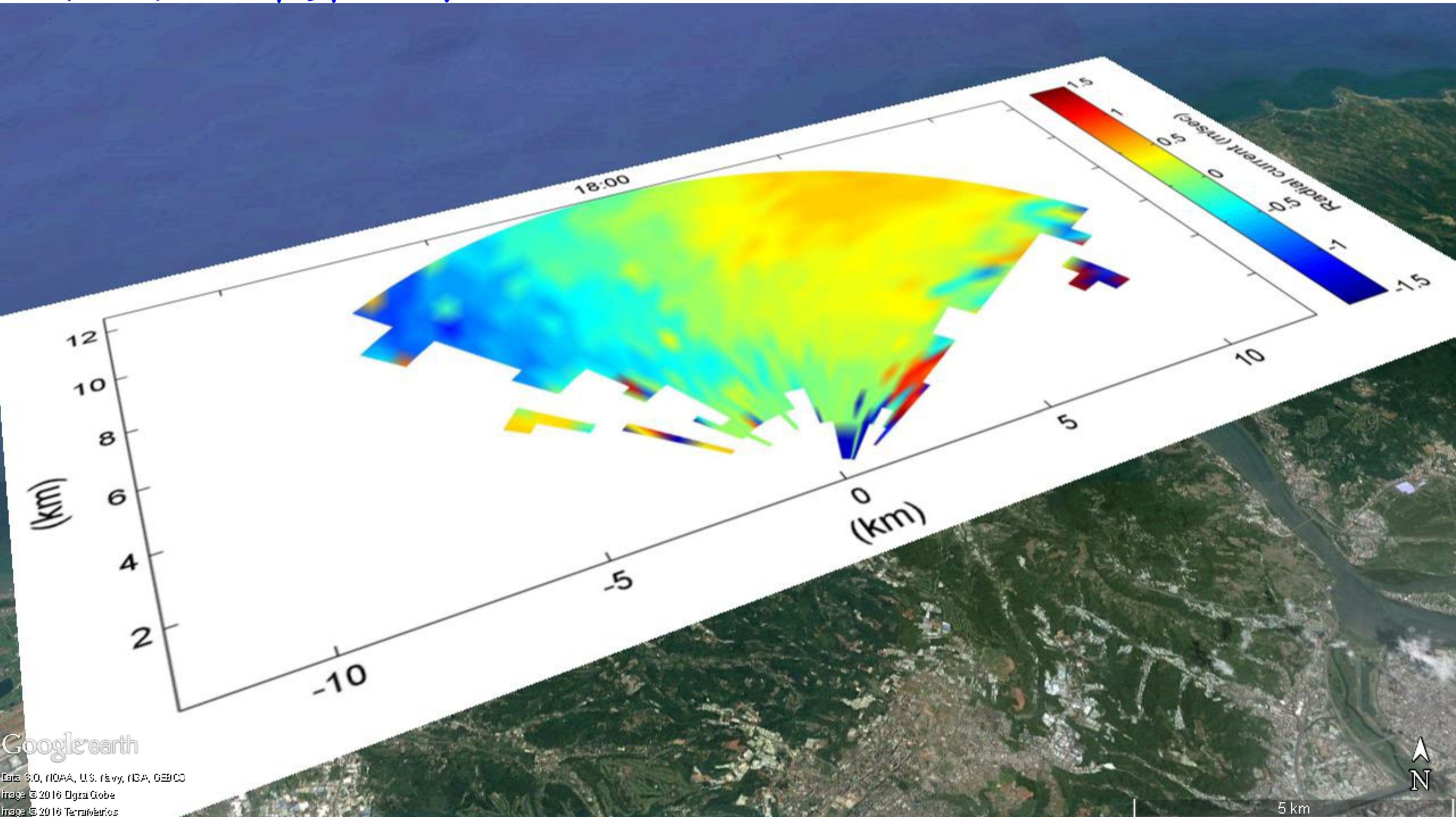
$$\mathrm{DOA}(\theta)=\frac{1}{\mathrm{A}^{*}(\theta)\mathrm{E}_{n}\mathrm{E}_{n}^{*}\mathrm{A}(\theta)}$$

1. 讀取原始觀測資料
2. 透過迴圈將原始觀測資料解碼成為不同距離單元與天線所對應的複數回波時序列
3. 利用傅立葉轉換計算上述時序列的能譜
4. 選定頻率條件，並針對上述之能譜進行濾波
5. 針對上述濾波結果求取自譜與交錯譜
6. 求取共變異數矩陣
7. 從共變異數矩陣解算特徵向量
8. 透過特徵向量判定雜訊子空間與訊號子空間
9. 求解目標訊號方位到達(DOA)函數

MUSIC辨識訊號方位之結果

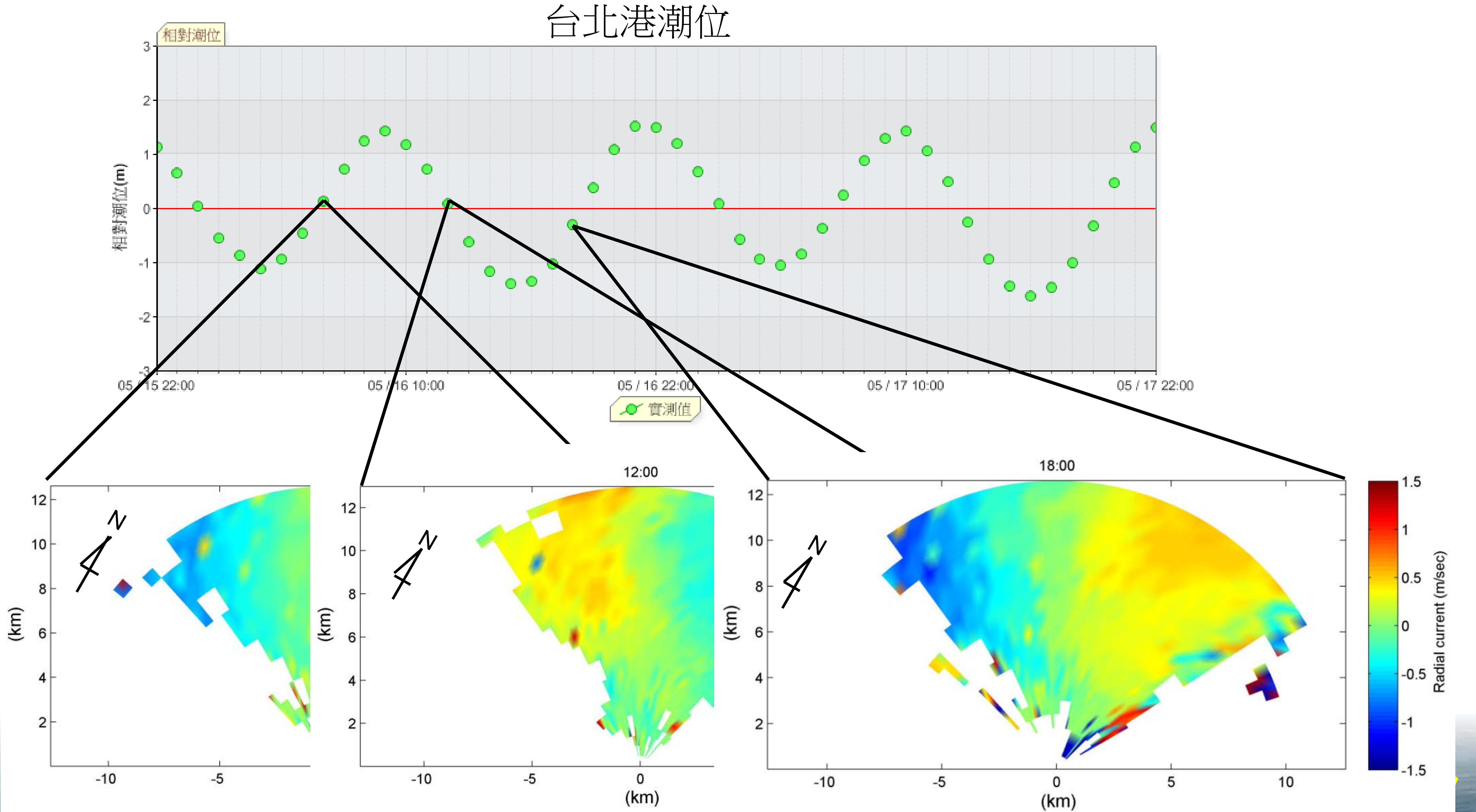


徑向流解算結果

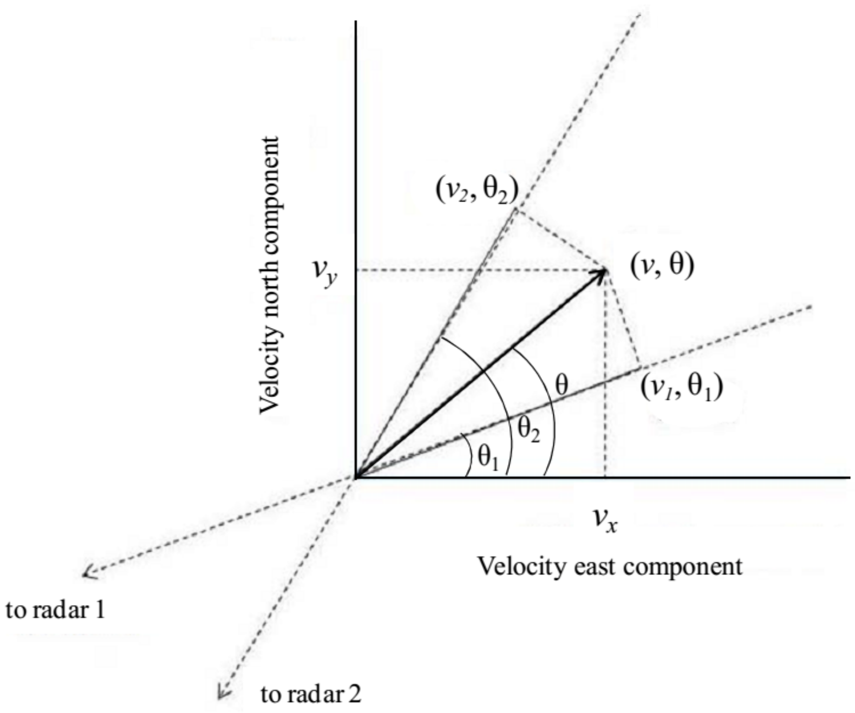


18:00
Radial current (m/sec)
1.5
1
0.5
0
-0.5
-1
-1.5
12
10
8
6
4
2
(km)
-10
-5
0
5
10
(km)
Google earth
5 km
N

高頻雷達方位辨識技術


台北港潮位
相對潮位
相對潮位(m)
3
2
1
0
-1
-2
-3
05 / 15 22:00
05 / 16 10:00
05 / 16 22:00
05 / 17 10:00
05 / 17 22:00
實測值
12:00
18:00
(km)
Radial current (m/sec)
1.5
1
0.5
0
-0.5
-1
-1.5

徑向流之合成

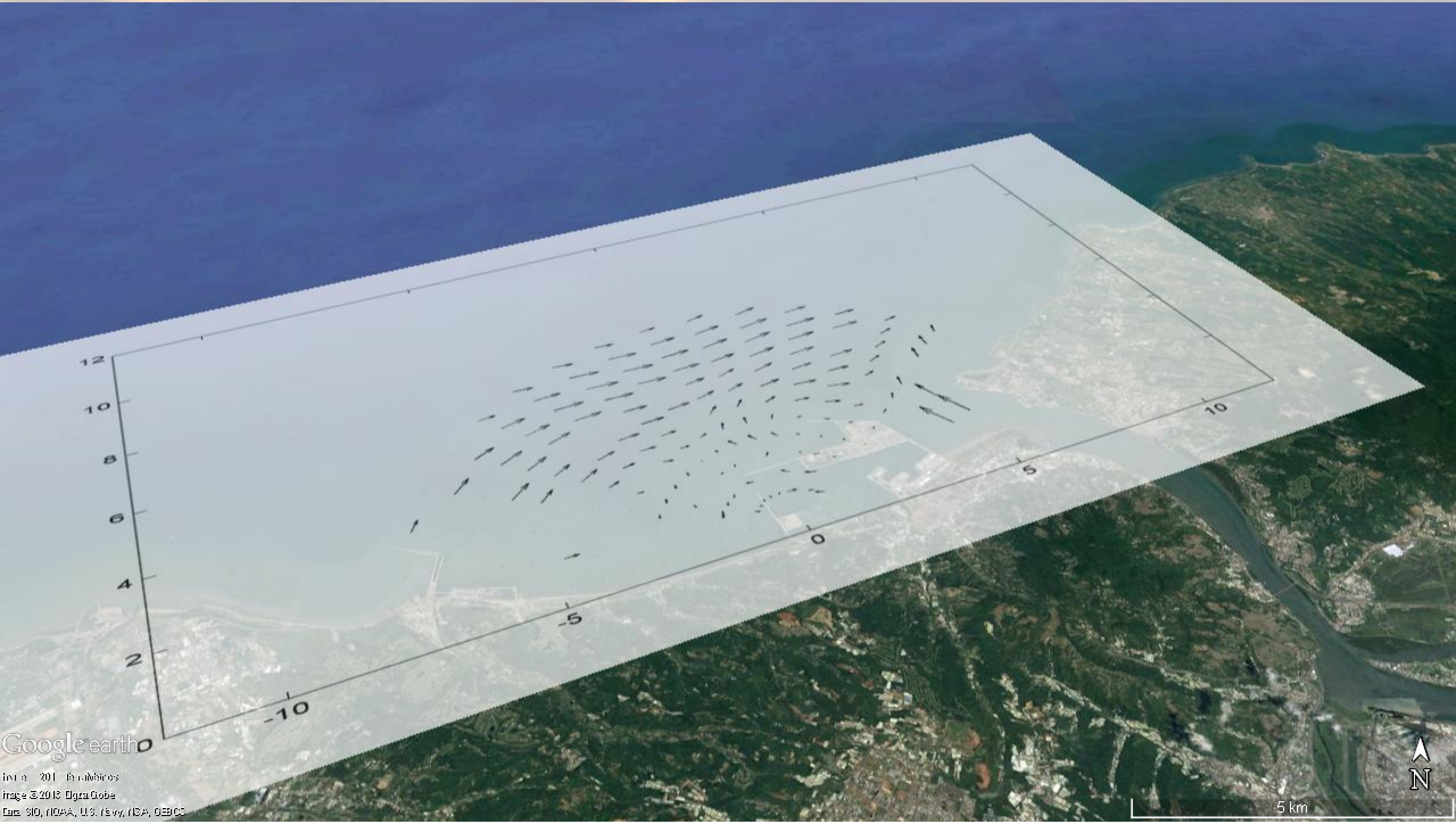


$$t_x = v_1 \sin\theta_2 - v_2 \sin\theta_1$$

$$t_y = v_2 \cos\theta_1 - v_1 \cos\theta_2$$

$$v_x = t_x / \sin(\theta_2 - \theta_1)$$

$$v_y = t_y / \sin(\theta_2 - \theta_1)$$


12
10
8
6
4
2
0
-10
-5
0
5
10
Google earth
N
5 km

小結

- 有別於國外之商業軟體，本研究嘗試將MUSIC此一演算法引入陣列式高頻雷達觀測資料的解算過程中，藉以更有效進行訊號之方位辨識。
- 分析結果證實了MUSIC演算法所解算之訊號方向分布較為集中，這更有助於解算出高準確度徑向海面流速資訊。
- 本研究透過徑向流合成技術，自行分析台北港兩站高頻雷達資料。所取得之流場向量與漲退潮之特徵一致。未來將透過現場流場資料進行更完整的比對工作。

Thank you