SAR Monitoring of Small-Scale Dynamics in Marginal Seas (SADyMaS)

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Driven by multiple factors, including tides, wind fields, ocean currents, and seafloor topography, the marginal seas exhibit abundant dynamic processes. Among these, sub-mesoscale oceanic eddies are the key driver in the mixing of the upper ocean layer and the transport of heat, salt, and nutrients. Spaceborne synthetic aperture radar (SAR), with its high spatial resolution and wide coverage, is the superior sensor for studying ocean sub-mesoscale eddies.

During the first year of DRAGON 6, we have been focusing on the detection and identification of multi-scale eddies on SAR imagery and on their spatio-temporal variation and coverage. Ten years of Sentinel-1 SAR-C data of the Western Mediterranean Sea have been used for an automated detection of oceanic eddies by the EOLO system, an AI technique developed during DRAGON 5. A comparison with results of visual inspections of SAR-C data of the same region reveals that the results achieved by EOLO show the same seasonalities and spatial distributions.

Given the robustness of the EOLO on the large volume of SAR data acquired in the Mediterranean Sea, the EOLO is further applied to multiple sources of SAR-C data acquired in the global ocean, including Sentinel-1 and Envisat SAR imagery, with a total of 3,192,002 scenes. The detected 82,750 eddies, 97% of which have a diameter less than 40 km, are compared with the concurrent mesoscale eddies detected by radar altimeter. The spatial comparison results show a high consistency of sub-mesoscale and mesoscale eddies. Quantitative analysis indicates about 50% of sub-mesoscale eddies are located within twice the radius of mesoscale eddies, where sub-mesoscale eddies in the core area of mesoscale eddies only account for approx. 9%.

Using the spatial variation of the mesoscale strain rate (MSR) in the normalized mesoscale eddy-center coordinate system, we found that the high MSR band is located within a ring-shaped area, i.e., 0.5 to 1.5 times the normalized radius of mesoscale eddies around the eddy center. The radial distribution further shows that the MSR is positive in the ring-shaped area, while it is negative in the core area. This quantitative analysis shows that about 50% of the global sub-mesoscale eddies are generated by shear instabilities along mesoscale eddies.

星载 SAR 边缘海小尺度动力过程观测研究 (SADyMaS)

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受潮汐、风场、洋流及海底地形等多重因素驱动，边缘海呈现出丰富的动力过程。其中，亚中尺度海洋涡旋对海洋上层混合及热量、盐度、营养物质输送起着关键调控作用。星载合成孔径雷达（SAR）凭借高空间分辨率与宽刈幅的优势，已充分展示了在亚中尺度涡旋观测的能力。

在"龙计划"第六期第一年的研究中，我们重点开展了星载 SAR 影像多尺度涡旋检测及其时空变化研究。基于西地中海 10 年的 Sentinel-1 SAR-C 数据，研究利用"龙计划"第五期所研发的 EOLO 人工智能模型实现了海洋涡旋的自动检测，与人工目视解译结果对比分析后，发现 EOLO 模型展现出和人工解译结果相同的季节性和空间分布特征。

我们进一步将 EOLO 应用于全球范围收集的多源、多模式星载 SAR 数据上，包括 Sentinel-1 和 ENVISAT 卫星的 SAR 影像，数据量为 3,192,002 景。EOLO 共检测到 82,750 个涡旋，其中约 97%的涡旋直径小于 40km。通过与雷达高度计同期检测的中尺度涡旋对比发现，亚中尺度涡旋与中尺度涡旋在空间分布上具有高度一致性。进一步定量分析表明，约 50%的亚中尺度涡旋位于中尺度涡旋两倍半径范围内，但中尺度涡核区域的亚中尺度涡旋仅占 9%左右。

通过使用合成分析法将中尺度拉伸率（mesoscale strain rate, MSR）的空间变化合成到归一化的中尺度涡旋涡心坐标系下，发现其分布在中尺度涡旋 0.5-1.5 倍归一化半径区间呈现 MSR 高值环形带状。径向分布进一步表明，环形带状区域的标准化 MSR 为正值，而涡核区域则为负值，定量揭示了全球约 50%的亚中尺度涡旋由中尺度涡旋的拉伸作用产生。