STUDY TITLE: Study of Subsurface, High-Speed Current Jets in the Deepwater Region of the Gulf of Mexico

REPORT TITLE: Subsurface, High-Speed Current Jets in the Deepwater Region of the Gulf of Mexico: Final Report

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BACKGROUND: There are four major classes of energetic currents in the Gulf of Mexico that are of primary concern to offshore petroleum operators. These are: 1) currents resulting from energetic, episodic atmospheric events, 2) currents associated with the Loop Current and related eddies, 3) vertically coherent currents below 1000 m (e.g. those believed to be associated with topographic Rossby waves), and 4) high-speed sub-surface intensified currents.

Based on observations, high-speed subsurface intensified currents, also known as jets, typically have temporal durations on the order of a few hours to one day, have subsurface speed maxima that can exceed 4 knots (200 cm/s), have peak speeds that occur between 150-350 m below the surface, and have little or no surface expressions. Offshore operators design drilling and production systems to account for forces exerted by currents at all depths; therefore frequency, persistence, and speed characteristics of jets are important design criteria.

OBJECTIVES: The objectives of the study are to characterize subsurface jets that occur in the Gulf of Mexico and speculate on the physical mechanisms responsible for their generation.

DESCRIPTION: There are several activities to achieve these goals which include: 1) identify and acquire data sets believed to contain subsurface jets, 2) characterize each identified jet and jet environment (through collection of ancillary data such as satellite, meteorological, and CTD data), 3) examine relationships between jets occurrence and potential forcing mechanisms, 4) identify and analyze jets found in numerical model output, 5) attempt to identify physical and other mechanisms responsible for jet generation. Additional objectives are, 6) to provide guidance to MMS as to how data collection should be improved on oil and gas industry platforms, 7) apply analysis schemes to outputs of model runs both with and without data assimilation, 8) consider internal/inertial and filamentary causal mechanisms.

SIGNIFICANT CONCLUSIONS: Thirteen candidate cases of jets were identified in our observational database. The candidate jets occur over a twelve-year period (1990-2001); this period is coincident with the period in which acoustic Doppler current profiler (ADCP) records have become available. Only profiling current meters possess the necessary vertical resolution to detect and measure a jet event. One of the jets consists of an inertial wave packet caused by Hurricane Georges that propagated downward to at least 500 m depth. Several of the observed jets have unusually large (> 10 $cm \cdot s^{-1}$) vertical velocities, suggesting possible measurement error.

We have not ruled out the possibility that the measurement limitations of acoustical instruments may be responsible for certain biases in the data record. In particular, we have simulated a non-homogeneous flow field passing a realistic alignment of off-axis acoustic beams (typical of standard acoustic current instrumentation). We find that current inhomogeneities, both vertical and horizontal, can significantly affect the estimates of both horizontal and vertical current velocities. Further, for beam angles of 20°, oppositely directed vertical velocity components in each beam path can correspond to the appearance of horizontal velocities 2.74 times the vertical velocity magnitude. Such inhomogeneities could be caused by structural interference, internal waves, or motions attributed to ship/rig thrusters and could masquerade as energetic features in data records.

Some candidate mechanisms seem more likely than others. For example, the more likely mechanisms include: (a) motions derived from the Loop Current and associated eddies in the form of filaments and meanders, (b) motions due to eddy/eddy and/or slope-shelf/eddy interaction, (c) manifestations of internal waves with unusually large speeds, e.g. internal soliton, (d) the combined effects of transient surface winds and deep flow over an undulating sea bed, (e) reversed geostrophic flow, (f) inertial wave packets, and (g) frontal instabilities and the development of small-scale (15-25 km) preferentially cold-core features along frontal boundaries. Unlikely candidates (and reasons) include association with: coastal buoyancy fronts (too far from shore and river plume), upwelling (slower peak speeds and usually surface-trapped motions), and undercurrents (no evidence these exist in the Gulf of Mexico).

STUDY RESULTS: Although most of the observations of jets have serious instrumentation and data quality issues associated with the current measurements, there is sufficient evidence to assert that unusually high-speed and short-lived sub-surface current events exist.

Model outputs were analyzed for the presence of subsurface jets in several numerical circulation models of the Gulf of Mexico including two versions of the Princeton Ocean Model. Model output were searched for jet events in the vicinity of the north-central Gulf of Mexico observational jet candidates and at comparable water depths and placement over the slope. However, model jets could be associated with motions of filamentary structures extending from the Loop Current or eddies associated with the Loop Current. We believe the filaments are caused by the interaction of the Loop Current with bottom topography and/or eddy-eddy interaction. We note the apparent disparity of time scales between jets observed in the real world and the jets found in the model output. The observed jets usually have time scales of the order of several hours to 1 day; we see no evidence in the model output of jets lasting less than one day. Model jets seem to occur higher in the water (not deeper than 200 m) and last 1-3 days.

Recommendations are made regarding general oceanographic data collection as well as specific data collection strategies for capturing subsurface jets. The general recommendations include: the use of downward-looking long range (38 kHz) ADCPs on rigs, the routine collection of temperature and salinity profiles and meteorological data at such sites, the collection of near-bottom current data in deep water, the use of simple and portable acquisition system, regular backup and archival procedures for data, and the telemetry of data to a central onshore data facility. Recommendations specific to the detection and study of jets include: establish long term moored measurements in regions thought to contain jets, obtain temperature and salinity profiles during events, carry out targeted ship surveys during instability events (i.e., cyclone formation from eddy-topography interaction), and use standardized collection procedures. We recommend targeted field studies using moored instrumentation as well as ship surveys to capture jet events and provide evidence of their generation mechanisms and estimates of their spatial and temporal scales. Without such information, the real causes will remain questionable.

STUDY PRODUCT(S): DiMarco, S. F., M. K. Howard, W. D. Nowlin, Jr., and R. O. Reid, 2004. Subsurface, high-speed current jets in the deepwater region of the Gulf of Mexico. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2004-022. Contract No. 1435-01-99-CT-31026. 98 pp.