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Operational Challenges for Numerical Weather Prediction Models in Mountainous Terrain

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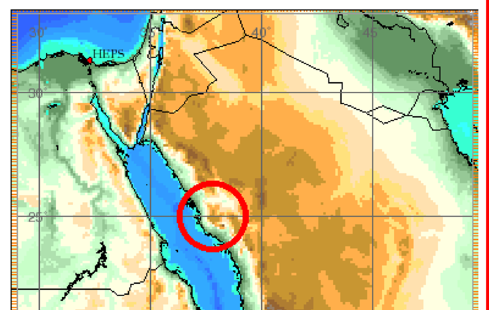
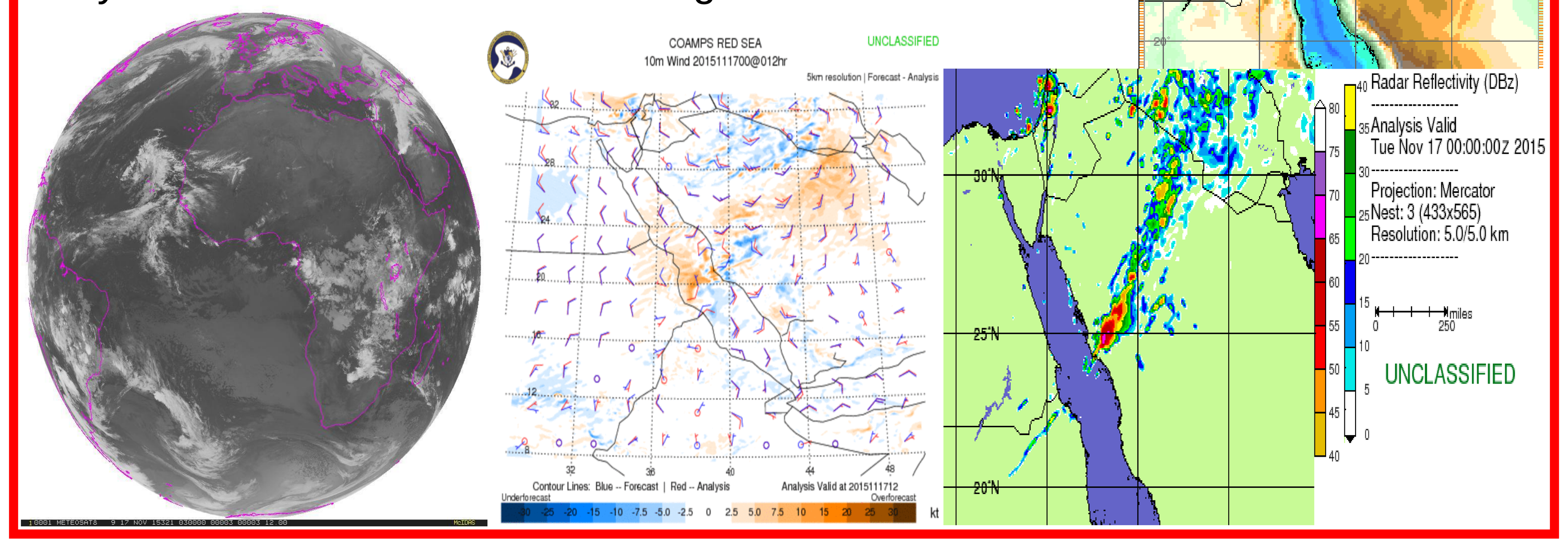
Introduction

Fleet Numerical Meteorology and Oceanography Center (FNMOC), under the direction of the Commander, Naval Meteorology and Oceanography Command, has the mission to operate global and limited area meteorological and oceanographic numerical weather prediction (NWP) models in support of the US DoD in operations, exercises, humanitarian assistance and disaster relief. High impact and high priority events require rapid responses to maintain safety and security for the DoD forces involved. High resolution NWP models in areas with mountainous terrain test the limits of this rapid response capability by presenting many unique issues that need to be resolved for a successfully operational model region. We show cases of few of the more common issues in this poster.

Courant–Friedrichs–Lewy Conditions

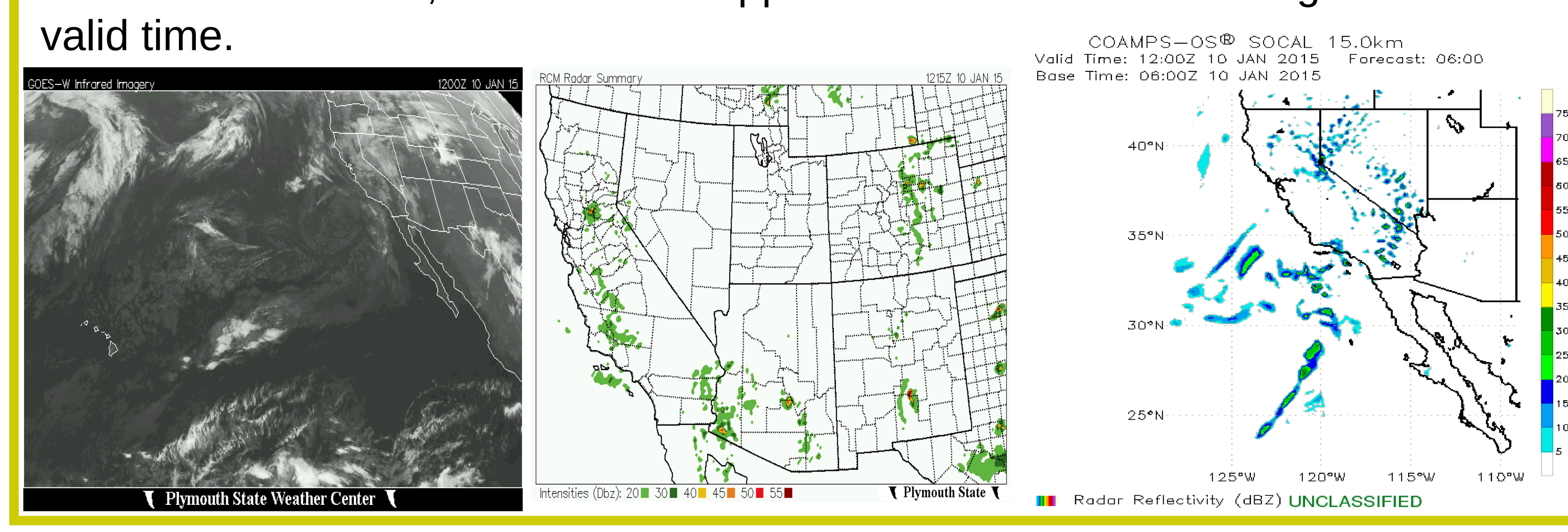
Meteorological conditions and terrain effects that create strong downslope flow can upset the numeric CFL condition limit. [(V * T) / grid space <= constant] CFL exceedance leads to model instability and crashes, and is our most common problem in complex terrain. Time step decrease, which increases model runtime in the operational environment, can usually resolve these problems. In the case below, a dying thunderstorm over a small ridge was correctly forecast to send downslope winds the length of the Red Sea, however they exceeded the CFL limit creating a model crash.





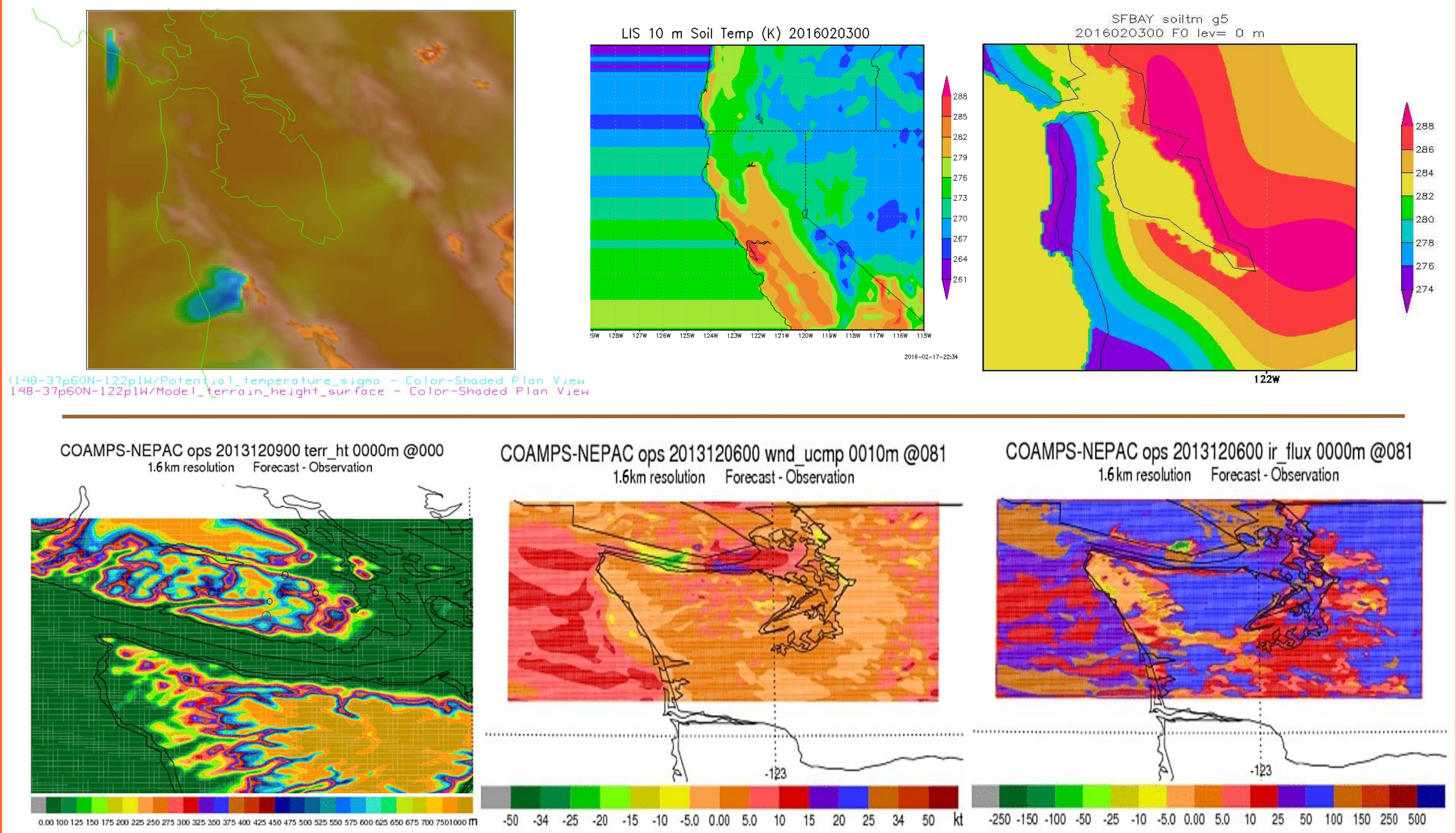
Data Assimilation -Standing Lee Waves

When NEXRAD data is assimilated, NWP model limitations can occasionally create linear structures of higher modeled reflectivity values downstream from mountainous terrain, forming a series of apparent 'cloud streaks' strong or dense enough to create modeled reflectivity returns. The image below corresponded to a time where no returns were in Nevada, yet the model was forecasting a series of lee waves to form, which did not appear in radar or satellite images at the valid time.



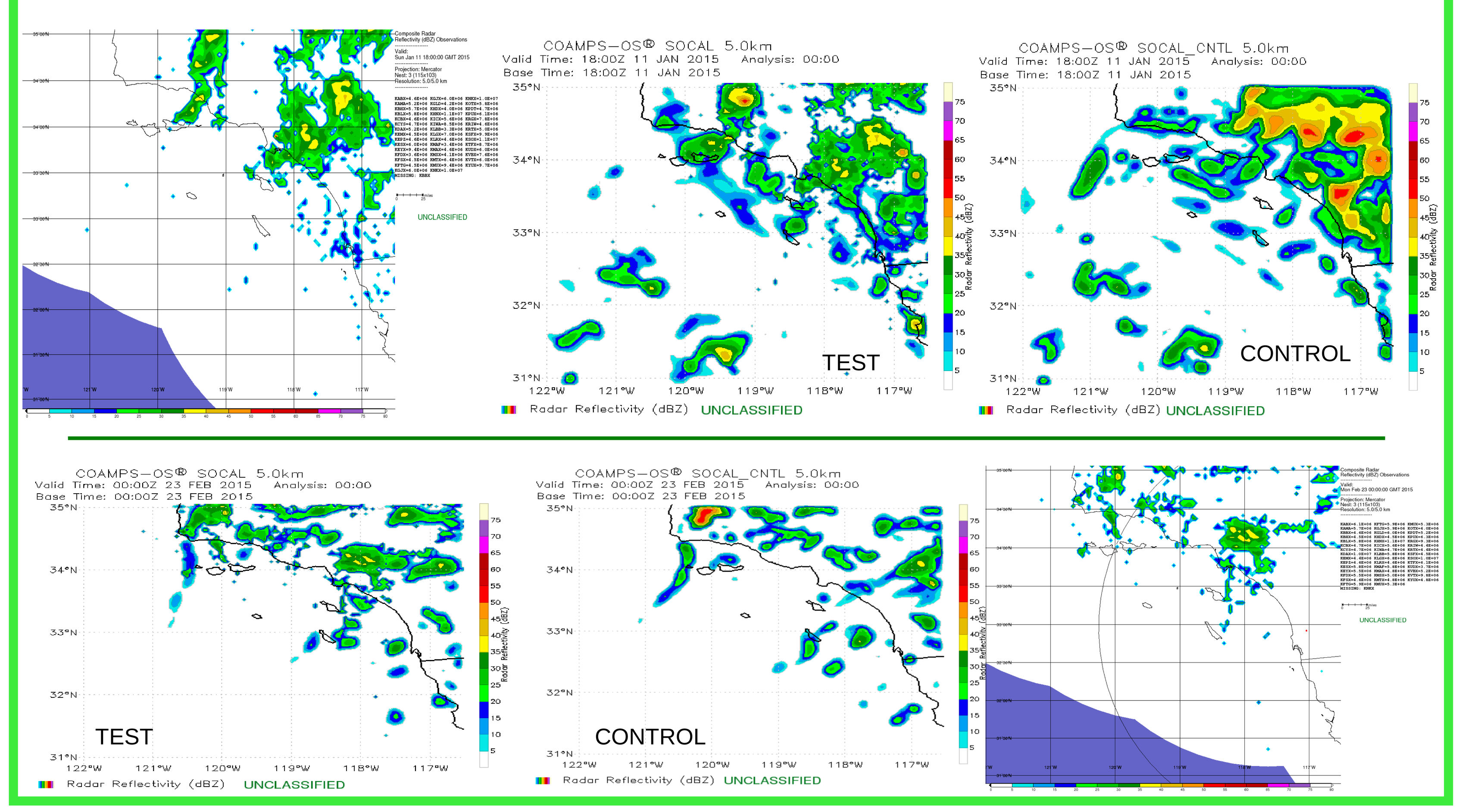
Steep Coastal Terrain Issues

Steep coastal boundaries can play havoc with model initialization and radiation schemes. In the top images, mismatches between Land Surface Model (LSM) and the Air Force's Land Information System analysis, used to initialize LSM, led to erroneous sea surface temperatures and extreme cold surface temperatures (< - 70 Deg C, in blue) near or over elevated terrain away from the initialization mismatches. In the lower images, vertical mixing coefficient issues in the lowest model level led to an anomalous cold pool, resulting in erroneous wind acceleration over Puget Sound.



Upslope Convection – Precipitation Accuracy

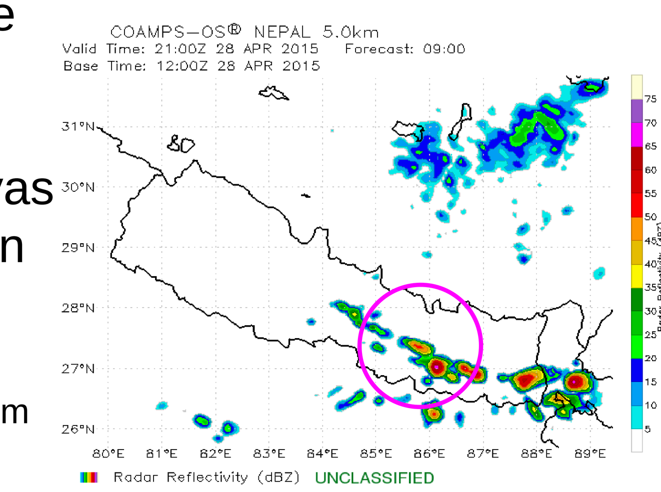
Having accurate convective forecasts is a major safety factor to aviation operations. Working with the Naval Research Lab, FNMOC recently added the capability for NEXRAD reflectivities to be assimilated into the forecast model for Rapid Environmental Assessments (Nowcasts). The period of evaluation showed this capability improved the model skill in forecasting upslope convection and precipitation over the mountainous terrain of Southern California. Two cases are shown below, one where the NEXRAD prevented over-prediction, one where it prevented under-prediction.

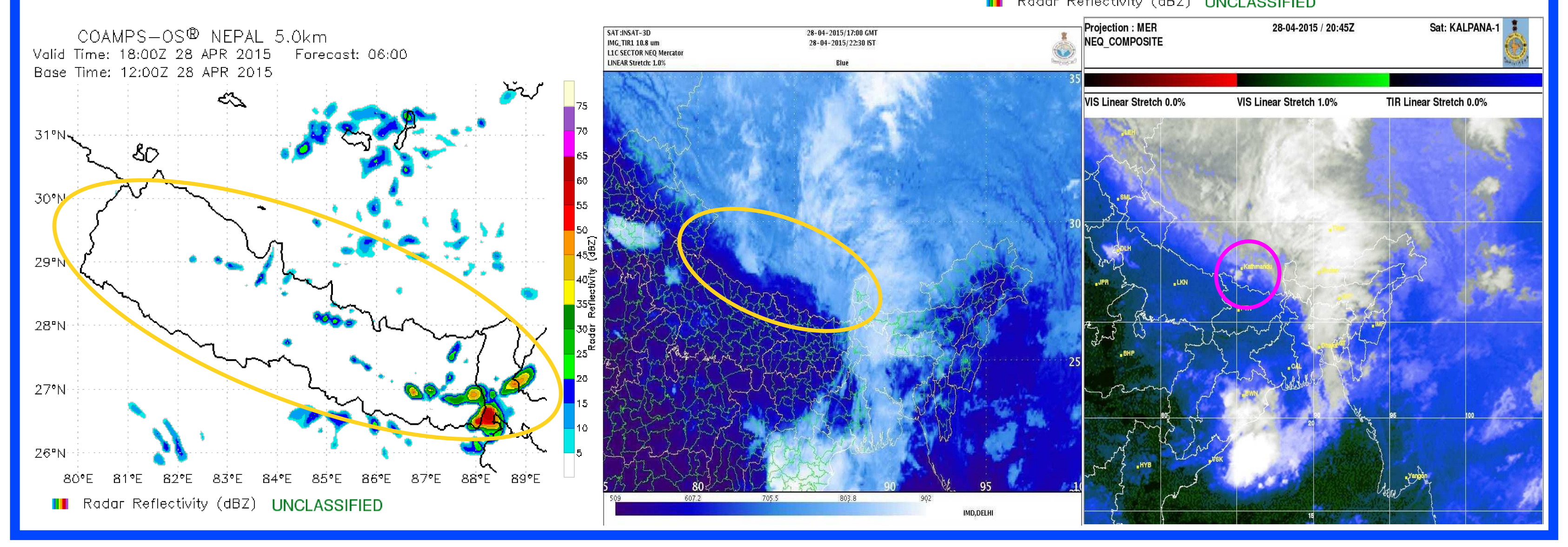


Resolution Choices -Convection over Terrain

After the 2015 Nepalese earthquake, FNMOC was tasked with providing weather support models for DoD Humanitarian Missions. Working in conjunction with the forecasters on the ground, FNMOC was able to provide forecasts of convective events over the region with fairly good accuracy. The Nepalese region created multiple unique challenges in modeling from the extreme terrain. FNMOC ran a 1.67km horizontal grid spaced nest over the worst affected regions to provide the highest detail forecasts possible to the forecasters on site for their missions. The case here was a COAMPS® forecast that accurately depicted the development of convection over the footsteps of the Himalayas a few hours after a general lack of convection in the region on the 5km forecast nest grid spacing.

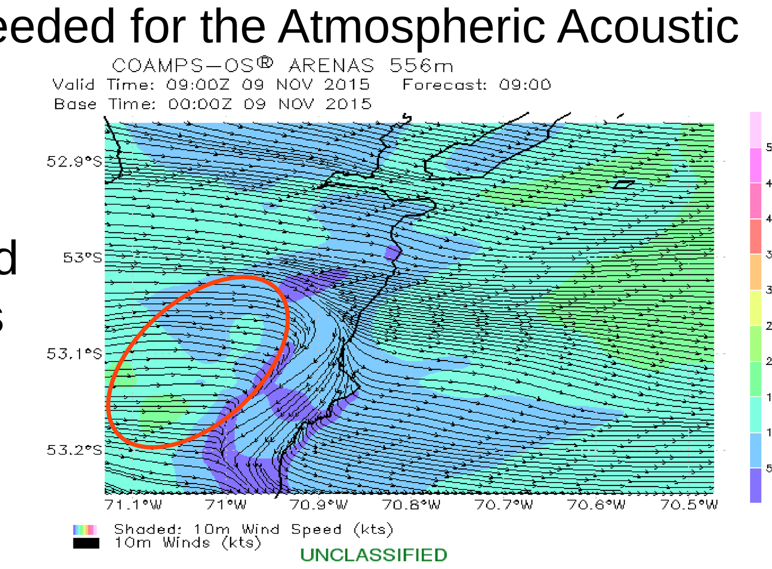
COAMPS® – Coupled Air-Ocean Mesoscale Prediction System

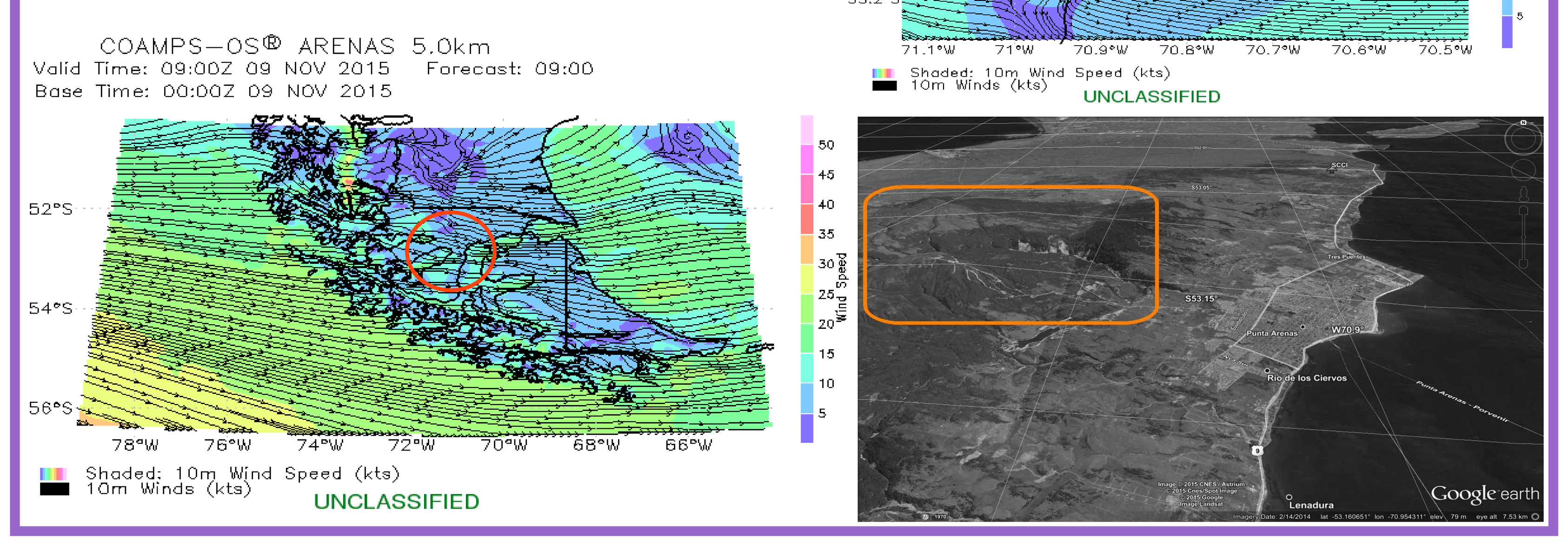




Resolution Choices - Wind Flow

Recent developments at FNMOC have been focused on improving the NWP models' horizontal grid spacing to provide better higher resolution forecasts. Initial experiments indicated that running the COAMPS® model at 555m horizontal resolution shows improved terrain induced wind flow as seen in a terrain induced wind direction shift in the lee of a plateau near Punta Arenas, Chile not seen in coarser resolution grids supporting a vessel transit. Sub 1km grid spacing is also needed for the Atmospheric Acoustic Propagation (AAP) application run at FNMOC to calculate helicopter audible Detection ranges. Wind flow strongly affects the distance and direction sound Waves carry in mountainous terrain, as predicted by AAP.





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