mixing, additional small-scale terms, one in the momentum and one in the energy conservation equations, were identified as requiring modeling. These additional terms were due to the tight coupling between dynamics and real-gas thermodynamics. It was inferred that if these terms would not be modeled, the high density-gradient magnitude regions, experimentally identified as a characteristic feature of these flows, would not be accurately predicted without the additional term in the momentum equation; these high density-gradient magnitude regions were experimentally shown to redistribute turbulence in the flow. And it was also inferred that without the additional term in the energy equation, the heat flux magnitude could not be accurately predicted; the heat flux to the wall of combustion devices is a crucial quantity that determined necessary wall material properties.

The present work involves situations where only the term in the momentum equation is important. Without this additional term in the momentum equation, neither the SGS-flux constant-coefficient Smagorinsky model nor the SGS-flux constant-coefficient Gradient model could reproduce in LES the pressure field or the high density-gradient magnitude regions; the SGS-flux constant-coefficient Scale-Similarity model was the most successful in this endeavor although not totally satisfactory. With a model for the additional term in the momentum equation, the predictions of the constant-coefficient Smagorinsky and constant-coefficient Scale-Similarity models were improved to a certain extent; however, most of the improvement was obtained for the Gradient model. The previously derived model and a newly developed model for the additional term in the momentum equation were both tested, with the new model proving even more successful than the previous model at reproducing the high density-gradient magnitude regions. Several dynamic SGS-flux models, in which the SGS-flux model coefficient is computed as part of the simulation, were tested in conjunction with the new model for this additional term in the momentum equation. The most successful dynamic model was a “mixed” model combining the Smagorinsky and Gradient models.

This work is directly applicable to simulations of gas turbine engines (aeronautics) and rocket engines (astronautics).

*This work was done by Josette Bellan and Ezgi Taşkinoğlu of Caltech for NASA’s Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47040*

# Tropospheric Correction for InSAR Using Interpolated ECMWF Data and GPS Zenith Total Delay

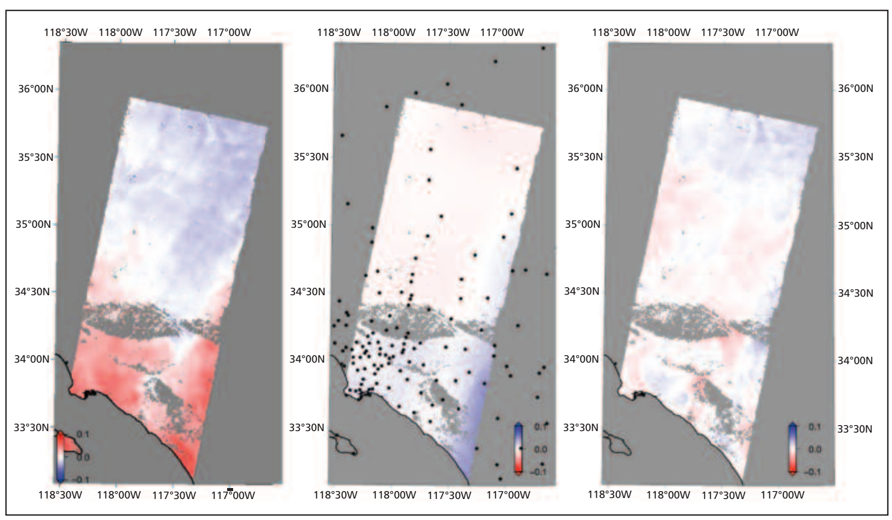
## This technique could be used in environmental remote sensing applications.

*NASA’s Jet Propulsion Laboratory, Pasadena, California*

To mitigate atmospheric errors caused by the troposphere, which is a limiting error source for spaceborne interferometric synthetic aperture radar (InSAR) imaging, a tropospheric correction method has been developed using data from the European Centre for Medium-Range Weather Forecasts (ECMWF) and the Global Positioning System (GPS).

The ECMWF data was interpolated using a Stretched Boundary Layer Model (SBLM), and ground-based GPS estimates of the tropospheric delay from the Southern California Integrated GPS Network were interpolated using modified Gaussian and inverse distance weighted interpolations. The resulting Zenith Total Delay (ZTD) correction maps have been evaluated, both separately and using a combination of the two data sets, for three short-interval InSAR pairs from Envisat during 2006 on an area stretching from northeast from the Los Angeles basin towards Death Valley. Results show that the root mean square (rms) in the InSAR images was greatly reduced, meaning a significant reduction in the atmospheric noise of up to 32 percent. However, for some of the images, the rms increased and large errors remained after applying the tropospheric correction. The residuals showed a constant gradient over the area, suggesting that a remaining orbit error from Envisat was present. The orbit reprocessing in ROI_pac and the plane fitting both require that the only remaining error in the InSAR image be the orbit error. If this is not fulfilled, the correction can be made anyway, but it will be done using all remaining errors assuming them to be orbit errors. By correcting for tropospheric noise, the biggest error source is removed, and the orbit error becomes apparent and can be corrected for.

After reprocessing the InSAR images using re-estimated satellite orbits, the overall rms reduction (using both tro-




The **Original InSAR Image** (left), the **GPS ZTD Difference Correction Map** (center), and the corrected **InSAR Image** (right). The black dots in the middle image correspond to the locations of the GPS stations.

pospheric and orbit correction) spanned from 15 to 68 percent. With this tropospheric correction, low-frequency errors can be removed from InSAR images. Additionally, results show that for days with high-quality ECMWF data, the SBLM ZTD correction performs as well as the GPS ZTD correction. Finally, the tropospheric correction enabled orbit correction, and by correcting for both errors, the quality of the InSAR images increased significantly.

By correcting for the troposphere, other errors become visible. The main contributor to the remaining errors is uncertainties with determining the satellite orbit. Because the orbit error is now separated from the tropospheric error, the orbit can be corrected for more accurately.

*This work was done by Frank H. Webb, Evan F. Fishbein, Angelyn W. Moore, Susan E. Owen, Eric J. Fielding, and Stephanie L. Granger of Caltech and Fredrik Björndahl and Johan Löfgren of Chalmers University of Technology for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).* NPO-46918

# Technique for Calculating Solution Derivatives With Respect to Geometry Parameters in a CFD Code

*John H. Glenn Research Center, Cleveland, Ohio*

A solution has been developed to the challenges of computation of derivatives with respect to geometry, which is not straightforward because these are not typically direct inputs to the computational fluid dynamics (CFD) solver. To overcome these issues, a procedure has been devised that can be used without having access to the mesh generator, while still being applicable to all types of meshes. The basic approach is inspired by the mesh motion algorithms used to deform the interior mesh nodes in a smooth manner when the surface nodes, for example, are in a fluid structure interaction problem. The general idea is to model the mesh edges and nodes as constituting a spring-mass system. Changes to boundary node locations are propagated to interior nodes by allowing them to assume their new equilibrium positions, for instance, one where the forces on each node are in balance.

The main advantage of the technique is that it is independent of the volumetric mesh generator, and can be applied to structured, unstructured, single- and multi-block meshes. It essentially reduces the problem down to defining the surface mesh node derivatives with respect to the geometry parameters of interest. For analytical geometries, this is quite straightforward. In the more general case, one would need to be able to interrogate the underlying parametric CAD (computer aided design) model and to evaluate the derivatives either analytically, or by a finite difference technique. Because the technique is based on a partial differential equation (PDE), it is applicable not only to forward mode problems (where derivatives of all the output quantities are computed with respect to a single input), but it could also be extended to the adjoint problem, either by using an analytical adjoint of the PDE or a discrete analog.

*This work was done by Sanjay Mathur of Jabiru Software and Services, LLC, for Glenn Research Center. Further information is contained in a TSP (see page 1)*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18499-1.*

# Acute Radiation Risk and BRYNTRN Organ Dose Projection Graphical User Interface

## This program estimates the whole-body effective dose, organ doses, and acute radiation sickness symptoms.

*Lyndon B. Johnson Space Center, Houston, Texas*

The integration of human space applications risk projection models of organ dose and acute radiation risk has been a key problem. NASA has developed an organ dose projection model using the BRYNTRN with SUM DOSE computer codes, and a probabilistic model of Acute Radiation Risk (ARR). The codes BRYNTRN and SUM DOSE are a Baryon transport code and an output data processing code, respectively. The risk projection models of organ doses and ARR take the output from BRYNTRN as an input to their calculations. With a graphical user interface (GUI) to handle input and output for BRYNTRN, the response models can be connected easily and correctly to BRYNTRN. A GUI for the ARR and BRYNTRN Organ Dose (ARRBOD) projection code provides seamless integration of input and output manipulations, which are required for operations of the ARRBOD modules.

The ARRBOD GUI is intended for mission planners, radiation shield designers, space operations in the mission operations directorate (MOD), and space biophysics researchers. BRYNTRN code operation requires extensive input preparation. Only a graphical user interface (GUI) can handle input and output for BRYNTRN to the response models easily and correctly. The purpose of the GUI development for ARRBOD is to provide seamless integration of input and output manipulations for the operations of projection modules (BRYNTRN, SLMDOSE, and the ARR probabilistic response model) in assessing the acute risk and the organ doses of significant Solar Particle Events (SPEs).

The assessment of astronauts' radiation risk from SPE is in support of mis-