Volume II
SENSITIVITY and UNCERTAINTY ANALYSIS
Applications to Large-Scale Systems
III. FORWARD AND ADJOINT SENSITIVITY ANALYSIS PROCEDURES FOR AUGMENTED SYSTEMS

A. THEORETICAL BASIS FOR THE ASAP FOR AUGMENTED SYSTEMS
   1. Sensitivity Analysis of the Primary (Nonaugmented) System 124
   2. Sensitivity Analysis of the Augmented System 131
   3. Discussion: Constructing the Augmented Adjoint Sensitivity Model from the Original Adjoint Sensitivity Model and Viceversa 143

B. ILLUSTRATIVE EXAMPLE: ASAP FOR THE COUPLED TWO-FLUID WITH HEAT STRUCTURES MODEL IN RELAP5/MOD3.2 (REL/TF+HS)
   2. Summary Description of the QUENCH-04 Experiment 158

IV. FORWARD AND ADJOINT SENSITIVITY ANALYSIS PROCEDURES FOR RESPONSES DEFINED AT CRITICAL POINTS

A. FSAP AND ASAP FOR RESPONSES AT CRITICAL POINTS: GENERAL THEORY
   1. The Forward Sensitivity Analysis Procedure (FSAP) 174
   2. The Adjoint Sensitivity Analysis Procedure (ASAP) 177
   3. Discussion 181
   4. Illustrative Example: A Simple Particle Diffusion Problem 183

B. ILLUSTRATIVE EXAMPLE: ASAP FOR THE MAXIMUM CLAD TEMPERATURE PREDICTED BY A REACTOR SAFETY CODE 194

V. USING THE ASAP TO GAIN NEW INSIGHTS INTO PARADIGM ATMOSPHERIC SCIENCES PROBLEMS

A. A PARADIGM RADIATIVE-CONVECTIVE MODEL (RCM) OF THE ATMOSPHERE 232

B. APPLYING THE ASAP FOR EFFICIENT AND EXHAUSTIVE SENSITIVITY ANALYSIS OF THE RCM 237
### C. PHYSICAL INTERPRETATION OF SOLUTIONS, EIGENVALUES, AND EIGENVECTORS OF THE ADJOINT SENSITIVITY SYSTEM FOR ATMOSPHERIC MODELS

1. Physical Interpretation of the Adjoint Functions 250
2. Interpretation of Eigenvalues and Eigenvectors Associated with the Adjoint Functions 253
3. Numerical Efficiency 258

### D. EFFICIENT ESTIMATION OF FEEDBACK EFFECTS FOR CLIMATE MODELS 259

### E. AN ISENTROPIC TWO-LAYER MODEL FOR NUMERICAL WEATHER PREDICTION 262

### F. APPLYING THE ASAP FOR EFFICIENT SENSITIVITY ANALYSIS OF BLOCKING INDEXES IN THE TWO-LAYER ISENTROPIC MODEL 270

1. Blocking Index in Physical Space 275
2. Blocking Index in Spectral Space 278
3. Illustrative Sensitivity Analysis Results 278
4. Computational Costs 281

### VI. ADJOINT SENSITIVITY ANALYSIS PROCEDURE FOR OPERATIONAL METEOROLOGICAL APPLICATIONS 283

### A. ADJOINT SENSITIVITY ANALYSIS PROCEDURE (ASAP) FOR THE EARTH'S RADIATION BUDGET IN THE NCEP MEDIUM-RANGE FORECASTING MODEL 283

1. Derivation and Verification of the Adjoint Sensitivity Model Corresponding to the NCEP Nonlinear Radiation Model 284
2. Illustrative Sensitivity Analysis Results 288

### B. FSU-GSM FORECAST ERROR SENSITIVITY TO INITIAL CONDITIONS: APPLICATION TO INDIAN SUMMER MONSOON 306

1. Modeling the Nominal Conditions on June 8, 1988 with the FSU GSM 307
2. Illustrative Sensitivity Analysis Results 310
C. SENSITIVITY TO LARGE-SCALE ENVIRONMENTAL FIELDS OF THE RELAXED ARAKAWA-SCHUBERT PARAMETRIZATION IN THE NASA GEOS-1 GCM

1. Sensitivity Analysis of the GEOS-1 GCM Using the ASAP 320
2. The RAS Parameterization Scheme in GEOS-1 GCM 323
3. Sensitivity Analysis Results 327

REFERENCES 343

INDEX 351