

1 **TABLE 4.1: Key characteristics of water vapour treatment in reanalyses**

Reanalysis	Assimilation of satellite humidity radiances?	Highest level of analyzed WV	Stratospheric WV used in radiative transfer	Stratospheric WV treatment	Stratospheric methane oxidation parameterization
NCEP R1	No	300 hPa	Climatology	None	N/A
NCEP R2	No	300 hPa	Climatology	None	N/A
CFSR	Yes	250 hPa	Analyzed. Negative values set to 0.1 ppmv	Prognostic	None
ERA-40	Yes	Diagnosed tropopause. Radiosonde humidity generally used to 300 hPa	Analyzed	Prognostic	Relaxation to 6 ppmv WV
ERA-I	Same as ERA-40	Same as ERA-40	Same as ERA-40	Same as ERA-40	Relaxation to 6.8 ppmv WV
JRA-25	Yes	100 hPa	Constant 2.5 ppmv used	None. WV set to 2.5 ppmv.	None
JRA-55	Same as JRA-25	Same as JRA-25	Same as JRA-25	Same as JRA-25	Same as JRA-25
MERRA	Yes	300 hPa	Analyzed	3-day relaxation to zonal-mean monthly-mean satellite-based climatology	None
MERRA-2	Same as MERRA	Same as MERRA	Same as MERRA	Same as MERRA	Same as MERRA

3 **TABLE 4.2: Key characteristics of ozone treatment in reanalyses**

Reanalysis	Primary TCO data source	Vertical profile data	Stratospheric O <sub>3</sub> used in radiative transfer	Stratospheric O <sub>3</sub> treatment	Photochemical parameterization
NCEP R1	None	None	Climatology	None	N/A
NCEP R2	None	None	Climatology	None	N/A
CFSR	SBUV	SBUV	Analyzed	Prognostic	CHEM2D-OPP
ERA-40	TOMS	SBUV	Climatology	Prognostic	CD86
ERA-I	Same as ERA-40	SBUV, GOME, MLS, MIPAS	Same as ERA-40	Same as ERA-40	Same as ERA-40
JRA-25	TOMS (1979 - 2004) <sup>1</sup> OMI (2004 - )	Nudging to climatology profile	Daily values provided by offline CCM	Daily values provided by offline CCM	N/A
JRA-55	Same as JRA-25	None	Same as JRA-25	Same as JRA-25	Same as JRA-25
MERRA	SBUV	SBUV	Analyzed	Prognostic	Stajner et al. (2008)
MERRA-2	SBUV (1980 – 9/2004) OMI (9/2004 – )	SBUV, MLS	Same as MERRA	Same as MERRA	Same as MERRA

4 <sup>1</sup> Offline CCM nudged to TOMS/OMI data.

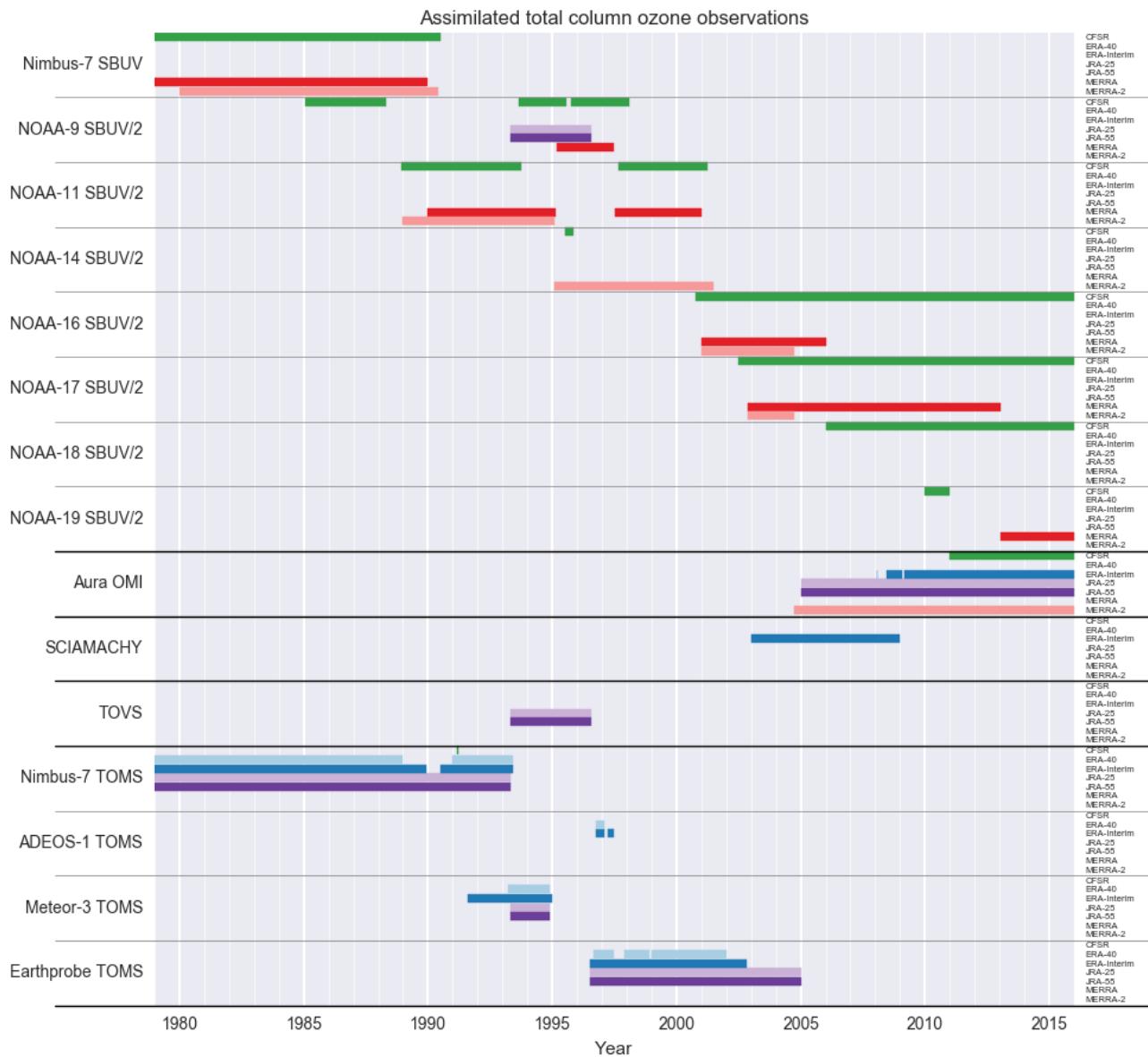
5

**TABLE 4.3: Ozone hole mean area model differences from TOMS/OMI for 21 September to 20 October, 1981–2010**

Reanalysis	Mean Difference <sup>1</sup> (million km <sup>2</sup> )	Root-mean-square difference (million km <sup>2</sup> )	(%)
MERRA	-2.6	5.0	79.3
MERRA-2	-0.6	2.8	44.5
ERA-Interim	-0.8	0.9	14.6
ERA-40 <sup>2</sup>	-3.8	5.1	75.4
JRA-55	-1.0	0.6	10.2
NCEP-CFSR	-0.7	0.9	14.1

<sup>1</sup>TOMS\_OMI average = 19.6 million km<sup>2</sup>, standard deviation = 6.9 million km<sup>2</sup>)

<sup>2</sup>ERA-40 statistics here encompass the period from 1981 through 2001.



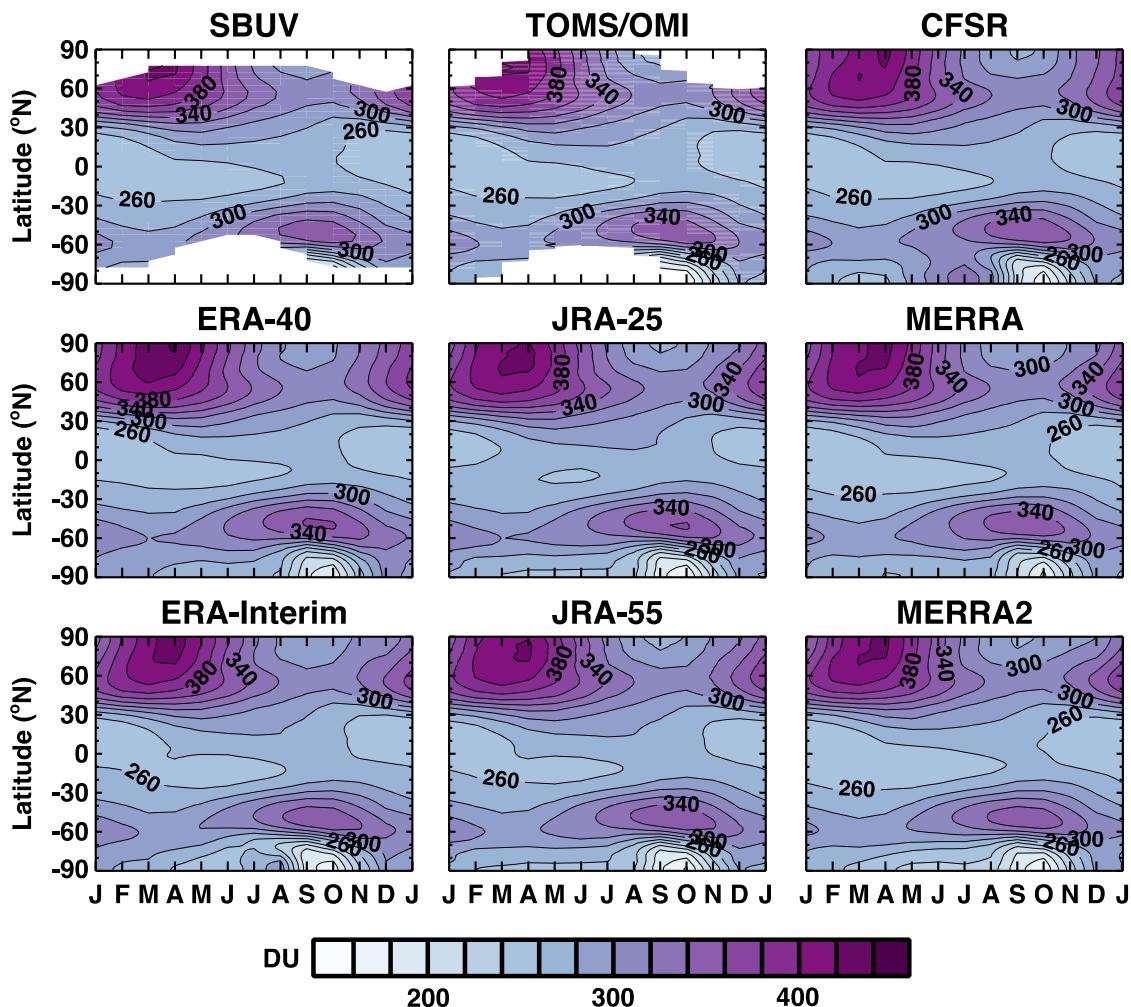
12  
13 **Figure 4.1. Total column ozone data assimilated by reanalyses.**



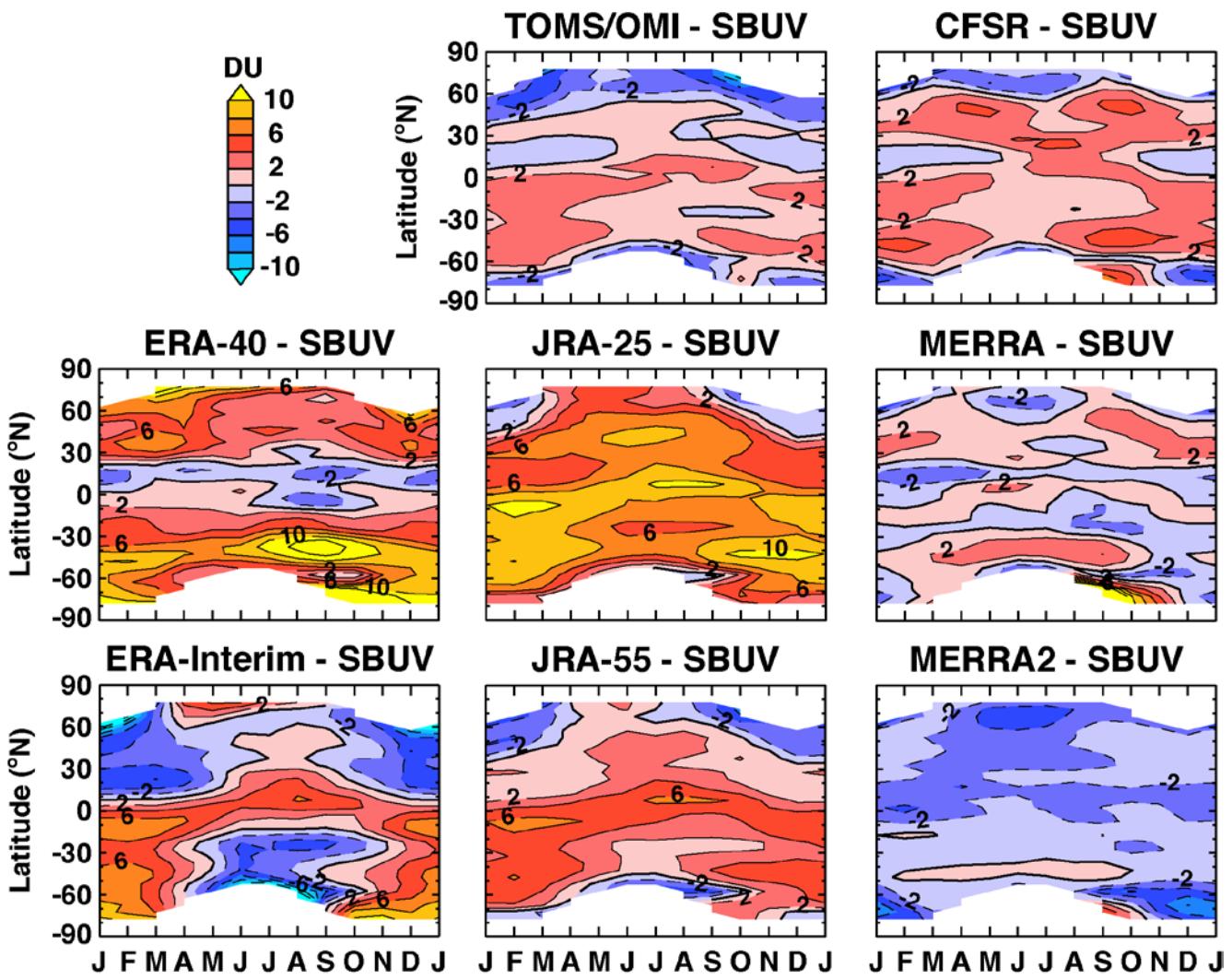
14

15

**Figure 4.2. Ozone vertical profile observations assimilated by reanalyses.**

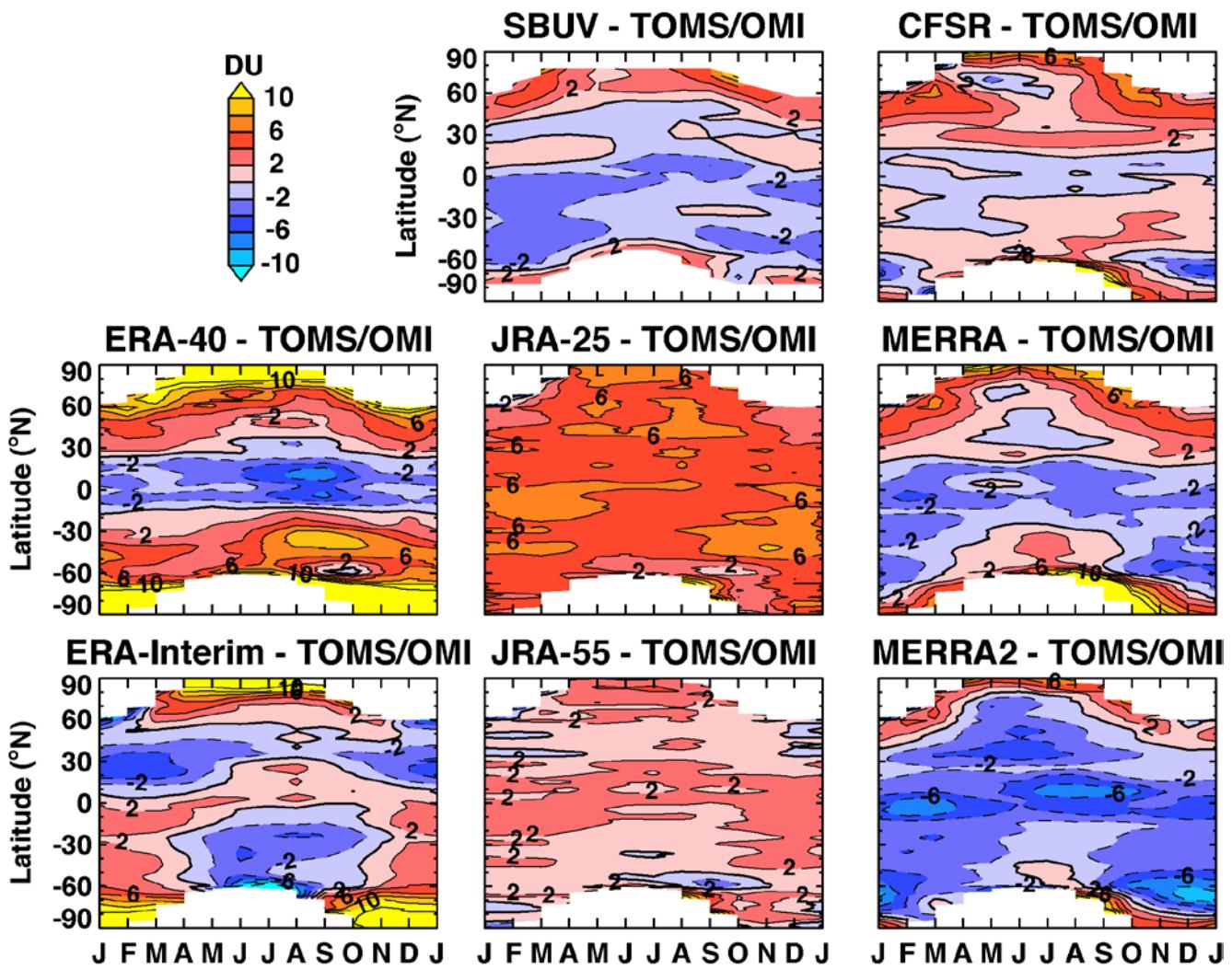


16  
17      **Figure 4.3.** Zonal- and monthly-mean total column ozone climatology over 1981–2010 for  
18      observations and reanalyses (with the exception of ERA-40 that is only available until Aug 2002).  
19  
20



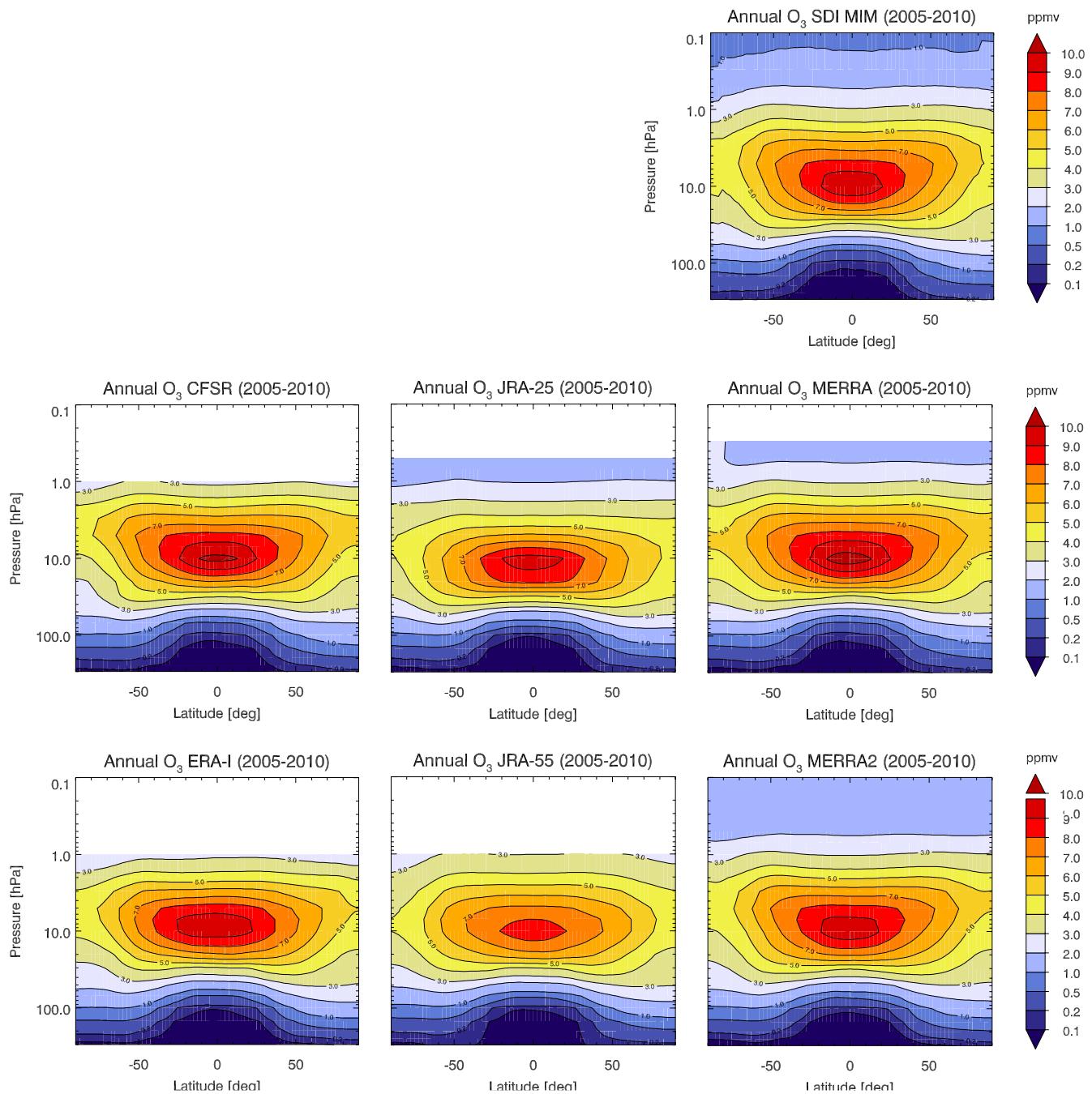
21  
22  
23  
24

Figure 4.4. Zonal- and monthly-mean total column ozone climatology (1981–2010) differences between reanalyses and SBUV. Also included is the TOMS/OMI difference with SBUV.

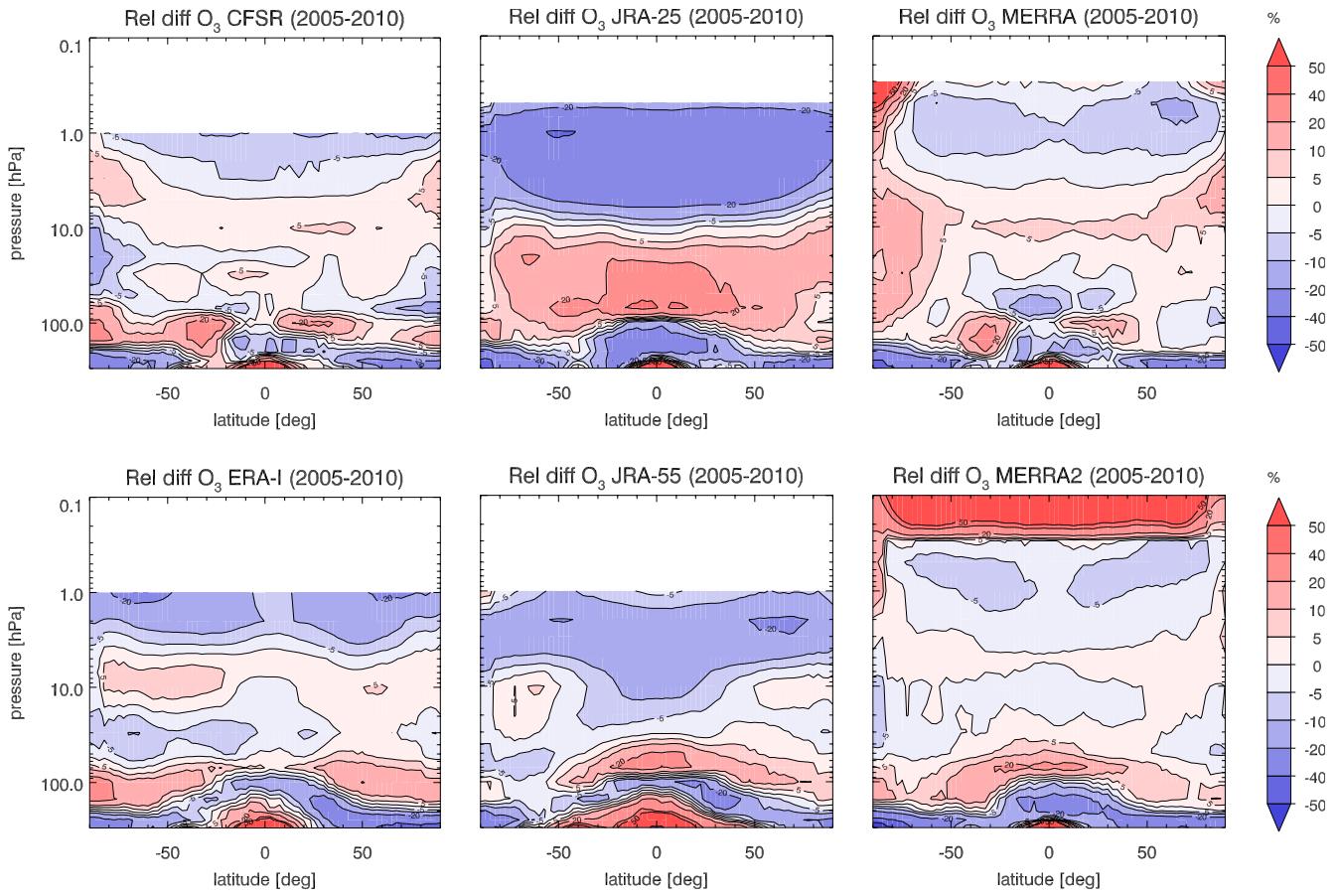


25  
26

Figure 4.5. Same as Fig. 4.4, but for TOMS/OMI.



27      **Figure 4.6. Multi-annual mean zonal mean cross sections of ozone averaged over 2005-2010 for**  
 28      **the SPARC Data Initiative multi-instrument mean (MIM) (upper right) and the different**  
 29      **reanalyses.**

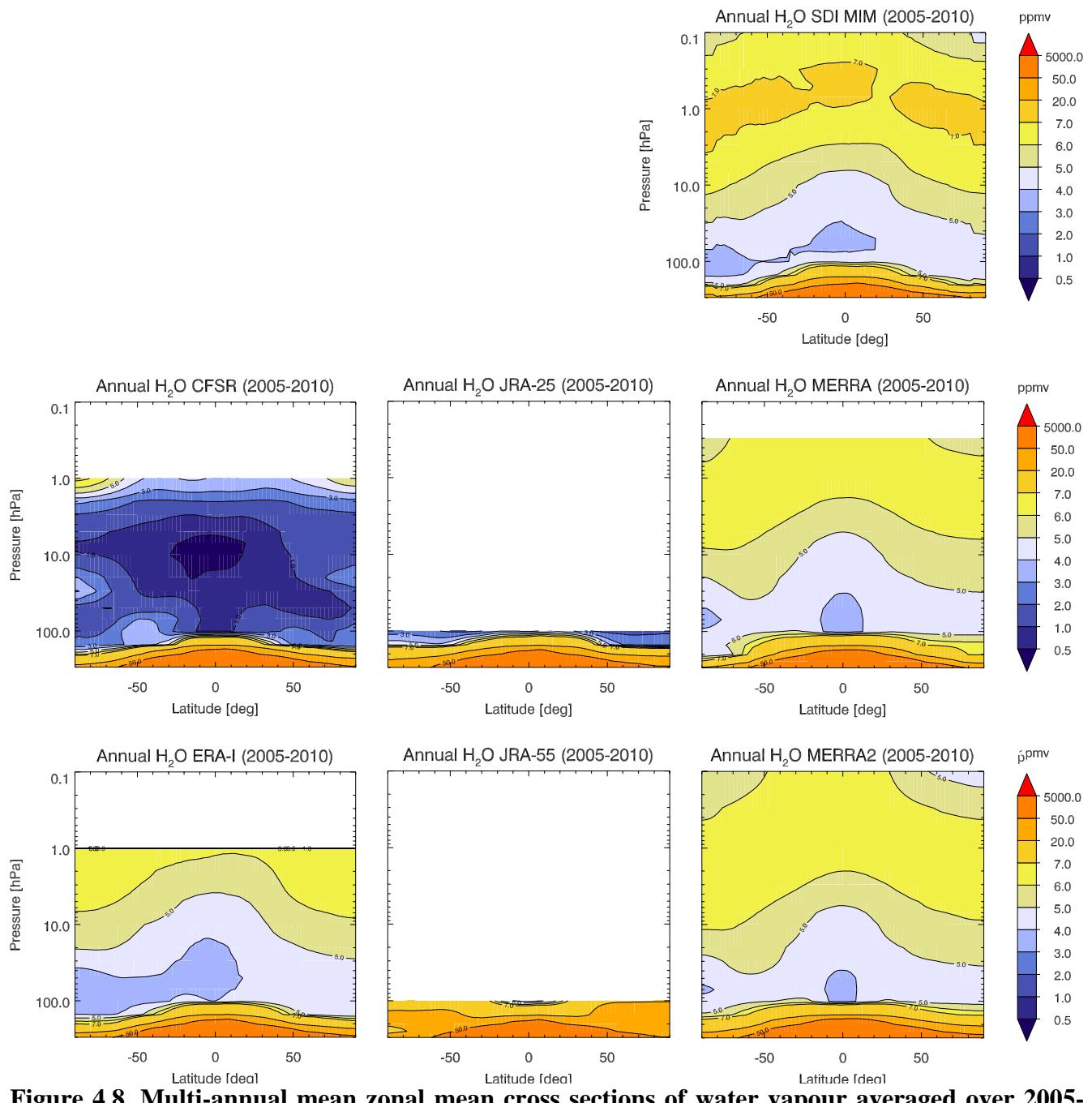


32 **Figure 4.7. Relative percentage differences of the multi-annual mean zonal mean cross sections**  
33 **of ozone averaged over 2005-2010 between the SPARC Data Initiative multi-instrument mean**  
34 **(MIM) and the different reanalyses using  $(R_i - MIM)/MIM * 100$ .**

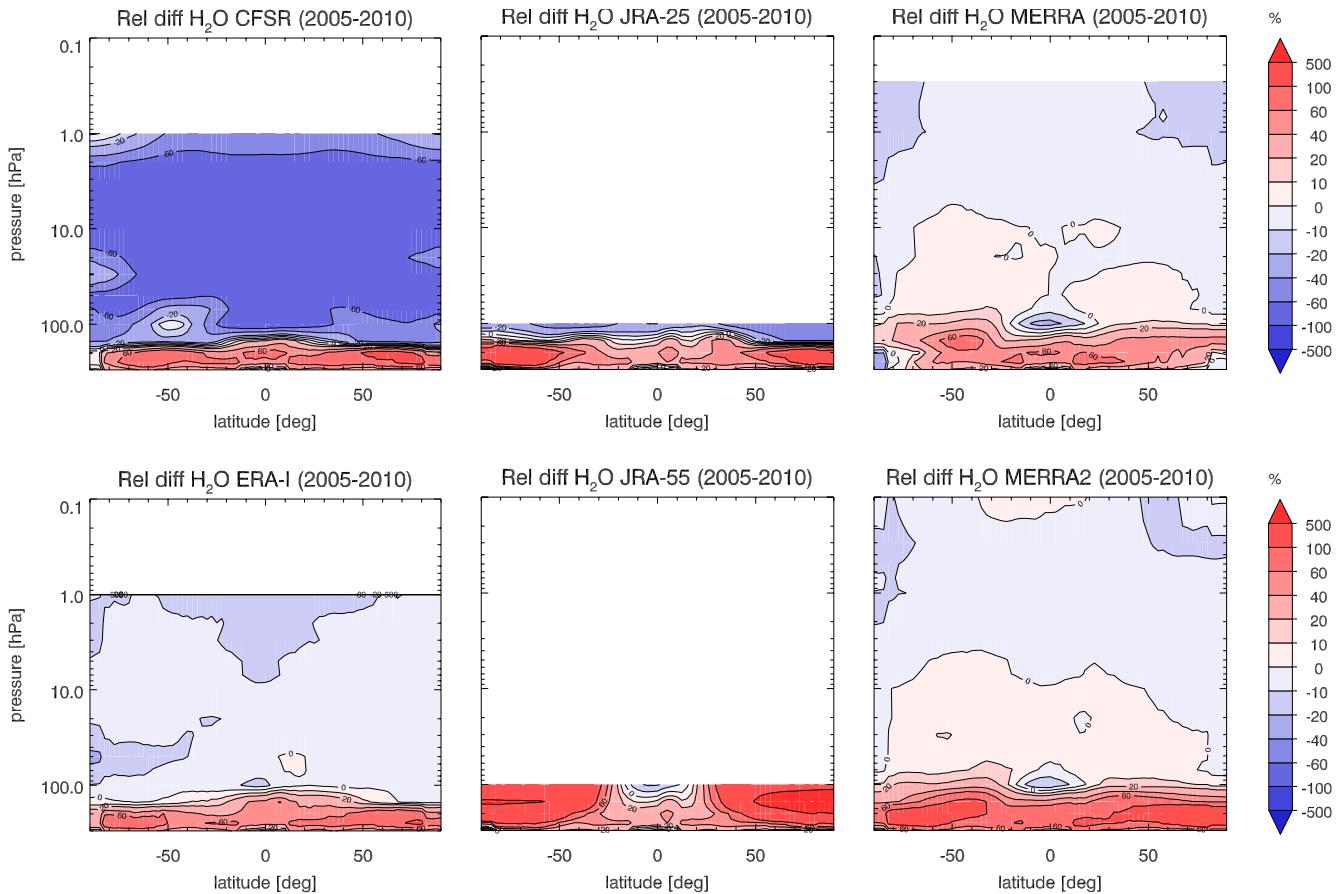
35

36

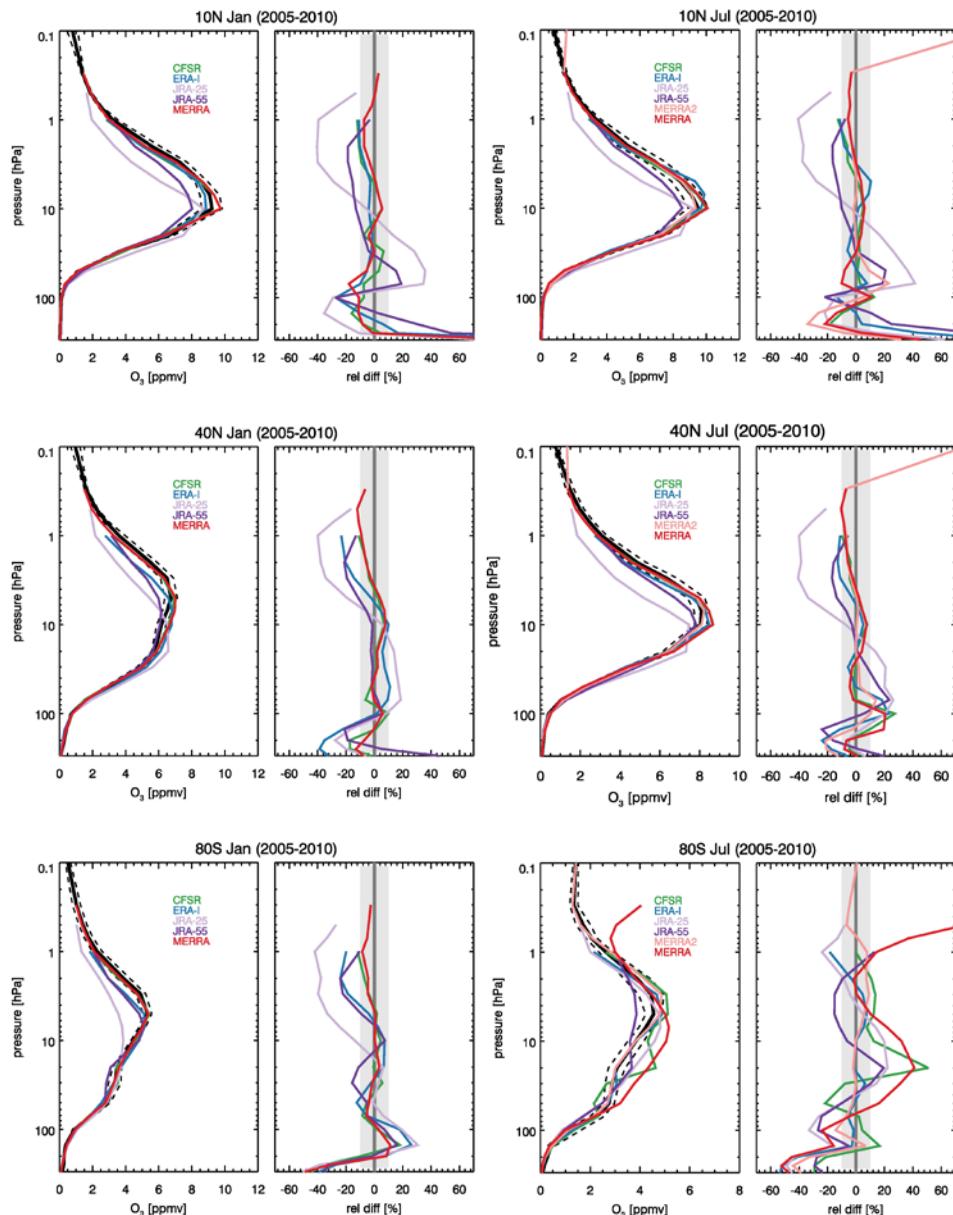
37



38  
39 **Figure 4.8. Multi-annual mean zonal mean cross sections of water vapour averaged over 2005-**  
40 **2010 for the SPARC Data Initiative multi-instrument mean (MIM) (upper right) and the**  
41 **different reanalysis.**

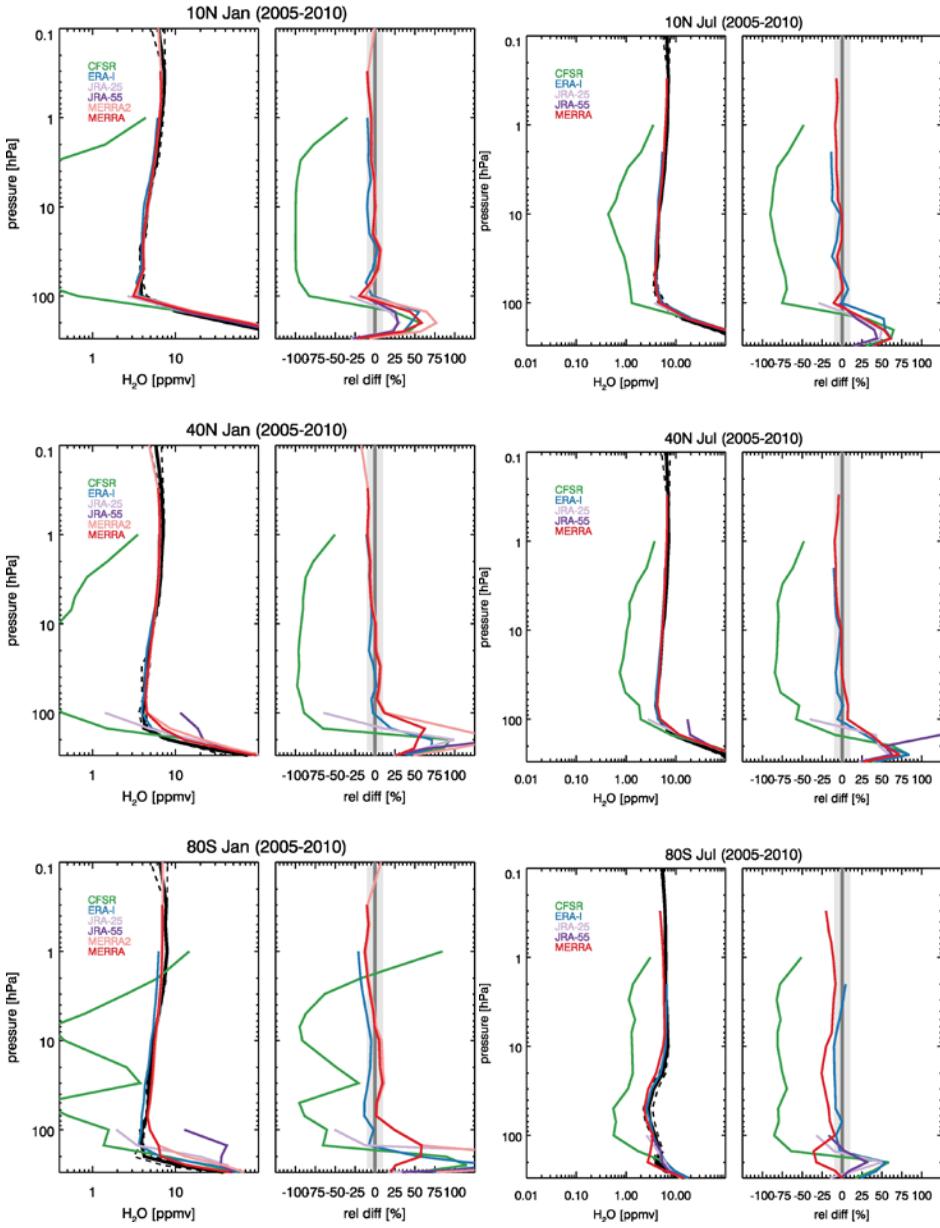


42  
43 **Figure 4.9. Relative percentage differences of the multi-annual mean zonal mean cross sections**  
44 **of water vapour averaged over 2005-2010 between the SPARC Data Initiative multi-instrument**  
45 **mean (MIM) and the different reanalyses using  $(R_i\text{-MIM})/\text{MIM} \times 100$ .**



46  
47  
48  
49  
50  
51

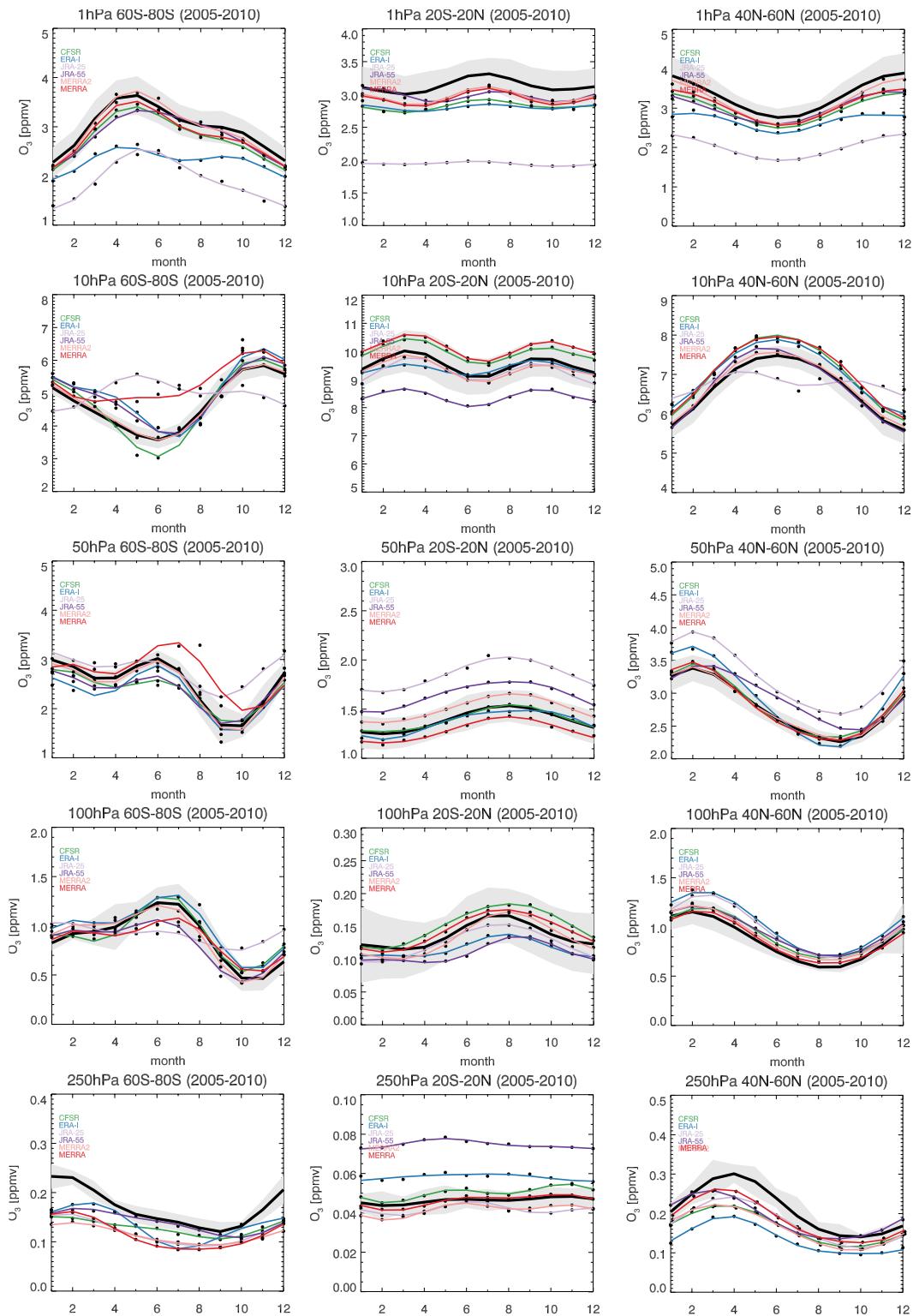
**Figure 4.10.** Monthly mean vertical profiles of ozone for January (left column) and July (right column) at different latitudes averaged over 2005-2010, for the SDI MIM (black) and the different reanalysis (coloured). Absolute values are shown in the left hand panels, relative differences between each reanalysis and the MIM in the right hand panels using  $(R_i - MIM)/MIM * 100$ .



52  
53

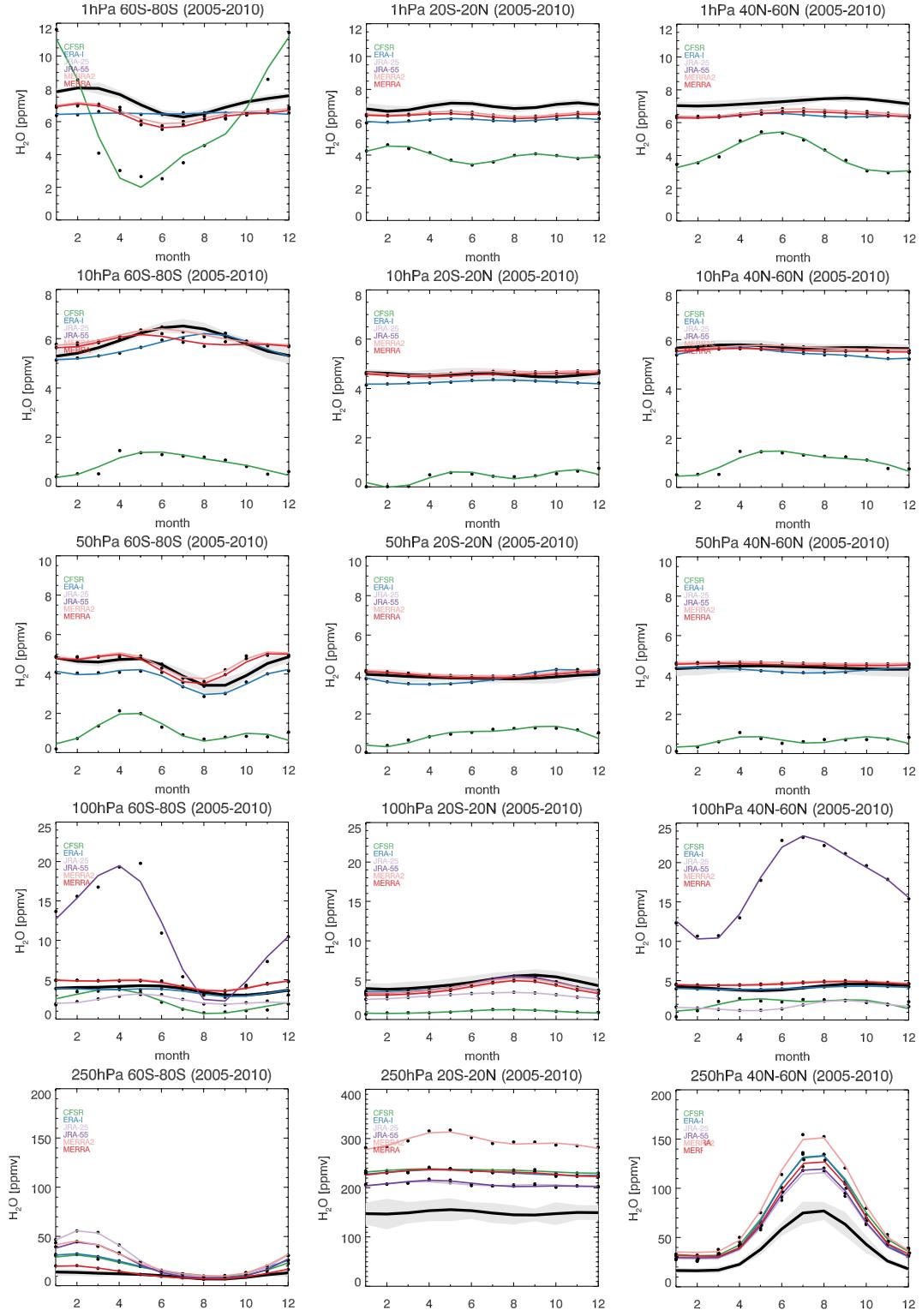
54  
55  
56  
57  
58

**Figure 4.11.** Monthly mean vertical profiles of water vapour for January (left column) and July (right column) at different latitudes averaged over 2005-2010, for the SDI MIM (black) and the different reanalysis (coloured). Absolute values are shown in the left hand panels, differences between each reanalysis and the MIM in the right hand panels using  $(R_i - \text{MIM})/\text{MIM} * 100$ .



59  
60  
61  
62  
63  
64  
65

**Figure 4.12.** Seasonal cycle of ozone averaged over 2005-2010 for the SPARC Data Initiative multi-instrument mean (MIM, black) and the different reanalysis (coloured) at different pressure levels (top to bottom: 1, 10, 50, 100, and 250 hPa) and latitude ranges (left to right: 60S-80S, 20S-20N, 40N-60N). Grey shading indicates the observational uncertainty ( $\pm 1$ -sigma). The dots are the monthly mean values, and the lines are fits including annual and semi-annual components to the available data points.



66

67

68

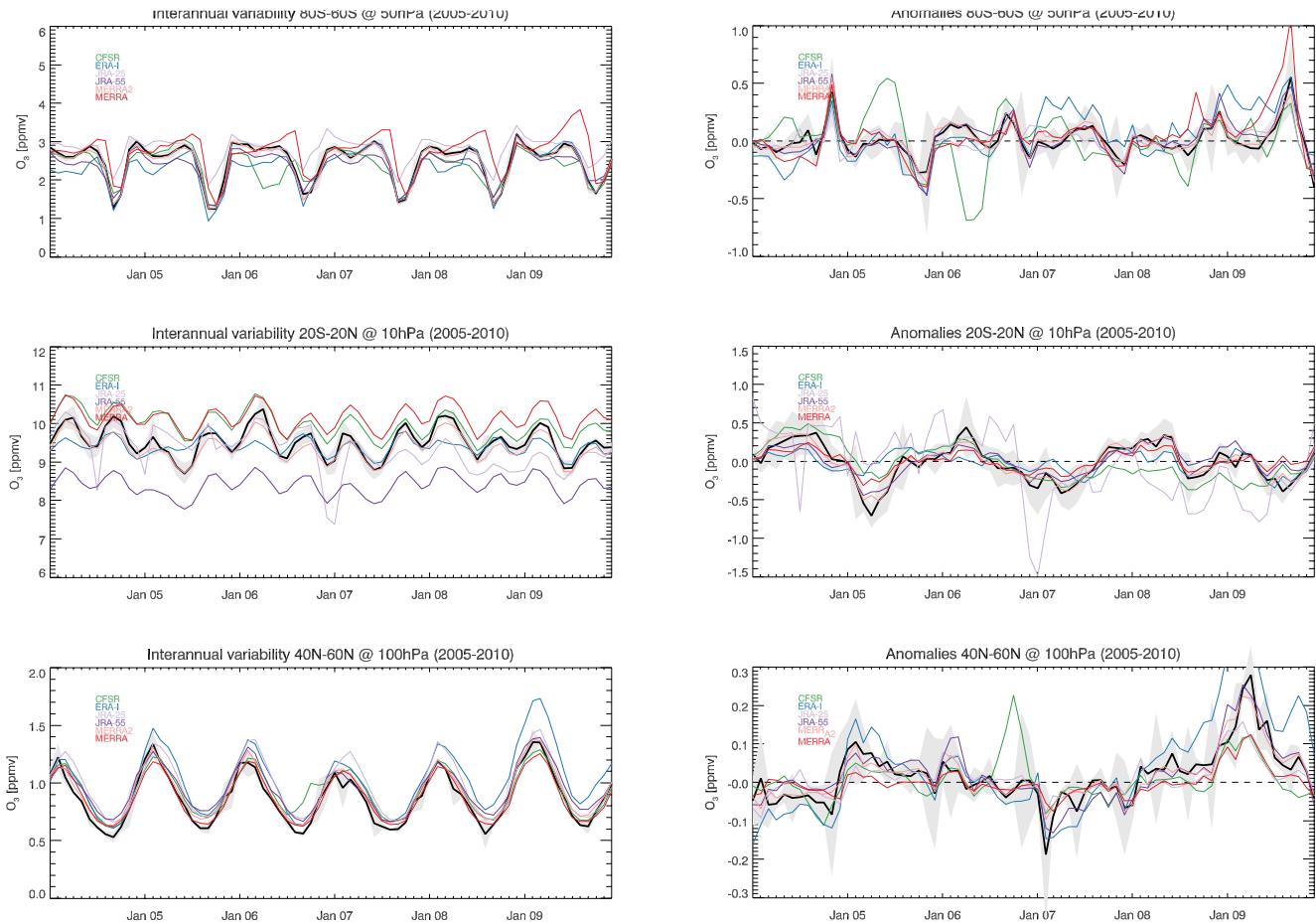
69

70

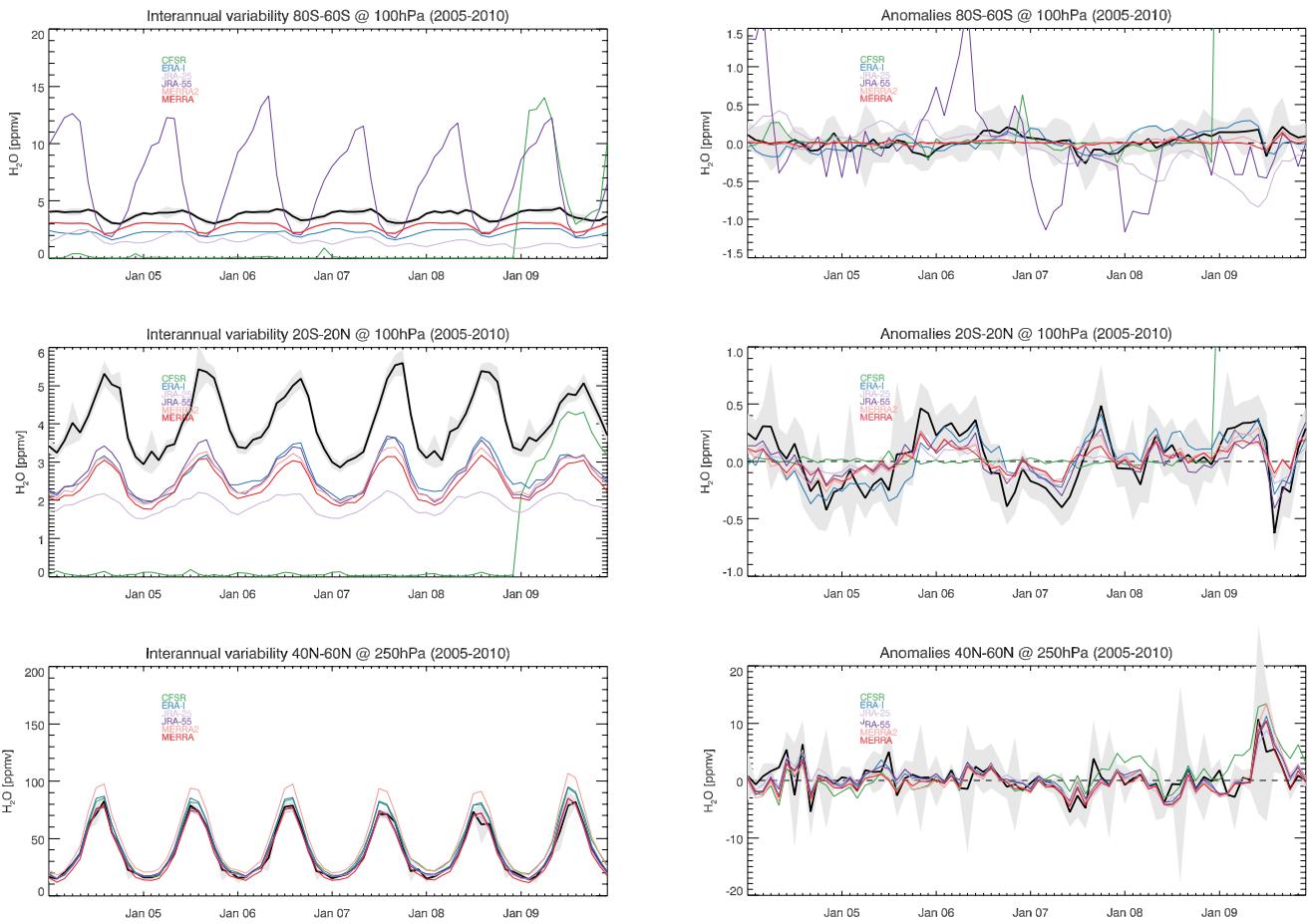
71

72

**Figure 4.13. Seasonal cycle of water vapour averaged over 2005-2010 for the SPARC Data Initiative multi-instrument mean (MIM, black) and the different reanalysis (coloured) at different pressure levels (top to bottom: 1, 10, 50, 100, and 250 hPa) and latitude ranges (left to right: 60S-80S, 20S-20N, 40N-60N). Grey shading indicates the observational uncertainty ( $\pm 1$ -sigma). The dots are the monthly mean values, and the lines are fits including annual and semi-annual components to the available data points.**



75 **Figure 4.14 Interannual variability (left column) and deseasonalized anomalies (right column)**  
76 for ozone between 2005 and 2010 for the SPARC Data Initiative multi-instrument mean (MIM,  
77 black) and the different reanalysis (coloured). Results are shown for different pressure levels and  
78 latitude ranges (top to bottom: 50 hPa at 60S-80S, 10 hPa at 20S-20N, and 100 hPa at 40N-60N).  
79 Grey shading indicates the observational uncertainty ( $\pm 1\sigma$ ).  
80



81

82

83

84

85

86

87

88

89

90

91

92

93

94

95

96

97

98

99

100

101

102

103

104

105

106

107

108

109

110

111

112

113

114

115

116

117

118

119

120

121

122

123

124

125

126

127

128

129

130

131

132

133

134

135

136

137

138

139

140

141

142

143

144

145

146

147

148

149

150

151

152

153

154

155

156

157

158

159

160

161

162

163

164

165

166

167

168

169

170

171

172

173

174

175

176

177

178

179

180

181

182

183

184

185

186

187

188

189

190

191

192

193

194

195

196

197

198

199

200

201

202

203

204

205

206

207

208

209

210

211

212

213

214

215

216

217

218

219

220

221

222

223

224

225

226

227

228

229

230

231

232

233

234

235

236

237

238

239

240

241

242

243

244

245

246

247

248

249

250

251

252

253

254

255

256

257

258

259

260

261

262

263

264

265

266

267

268

269

270

271

272

273

274

275

276

277

278

279

280

281

282

283

284

285

286

287

288

289

290

291

292

293

294

295

296

297

298

299

300

301

302

303

304

305

306

307

308

309

310

311

312

313

314

315

316

317

318

319

320

321

322

323

324

325

326

327

328

329

330

331

332

333

334

335

336

337

338

339

340

341

342

343

344

345

346

347

348

349

350

351

352

353

354

355

356

357

358

359

360

361

362

363

364

365

366

367

368

369

370

371

372

373

374

375

376

377

378

379

380

381

382

383

384

385

386

387

388

389

390

391

392

393

394

395

396

397

398

399

400

401

402

403

404

405

406

407

408

409

410

411

412

413

414

415

416

417

418

419

420

421

422

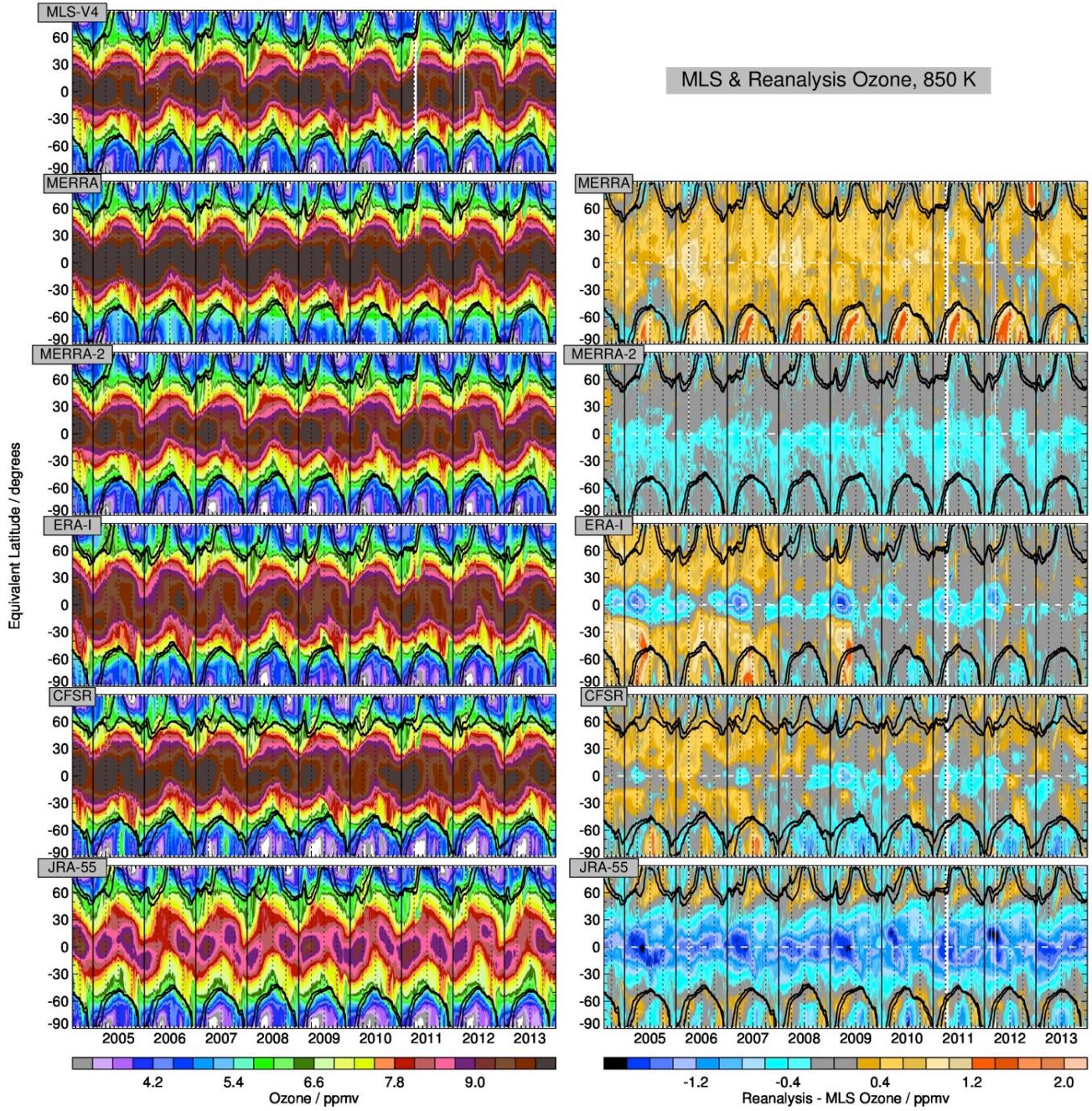
423

424

425

426

427



90

91

92

93

94

95

96

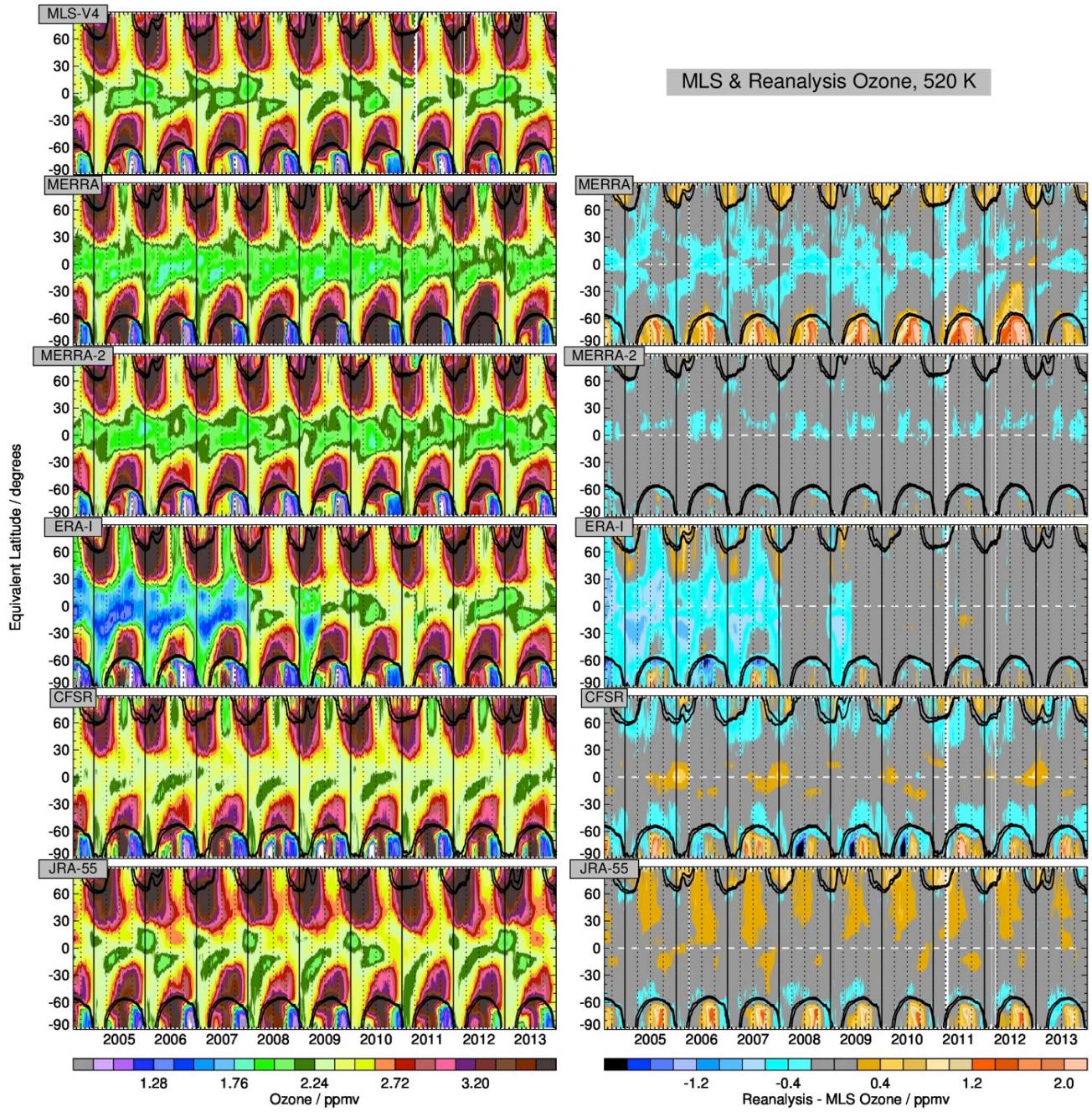
97

98

99

100

**Figure 4.16. Comparison of equivalent latitude-time evolution of reanalysis ozone with that from MLS on the 850K isentropic surface (near 30km, 10hPa) during the Aura mission (September 2004 through December 2013). (Left) Mixing ratios (ppmv) for (top to bottom) MLS and the MERRA, MERRA-2, ERA-Interim, CFSR, and JRA-55 reanalyses. (Right) differences (ppmv) between each reanalysis and MLS (expressed as Reanalysis minus MLS). Overlays are scaled PV (Manney et al., 1994) contours of  $1.4$  and  $1.6 \times 10^{-4} \text{ s}^{-1}$ , indicating the polar vortex edge region in winter, from the corresponding reanalysis, with MERRA contours overlaid on the MLS panel.**

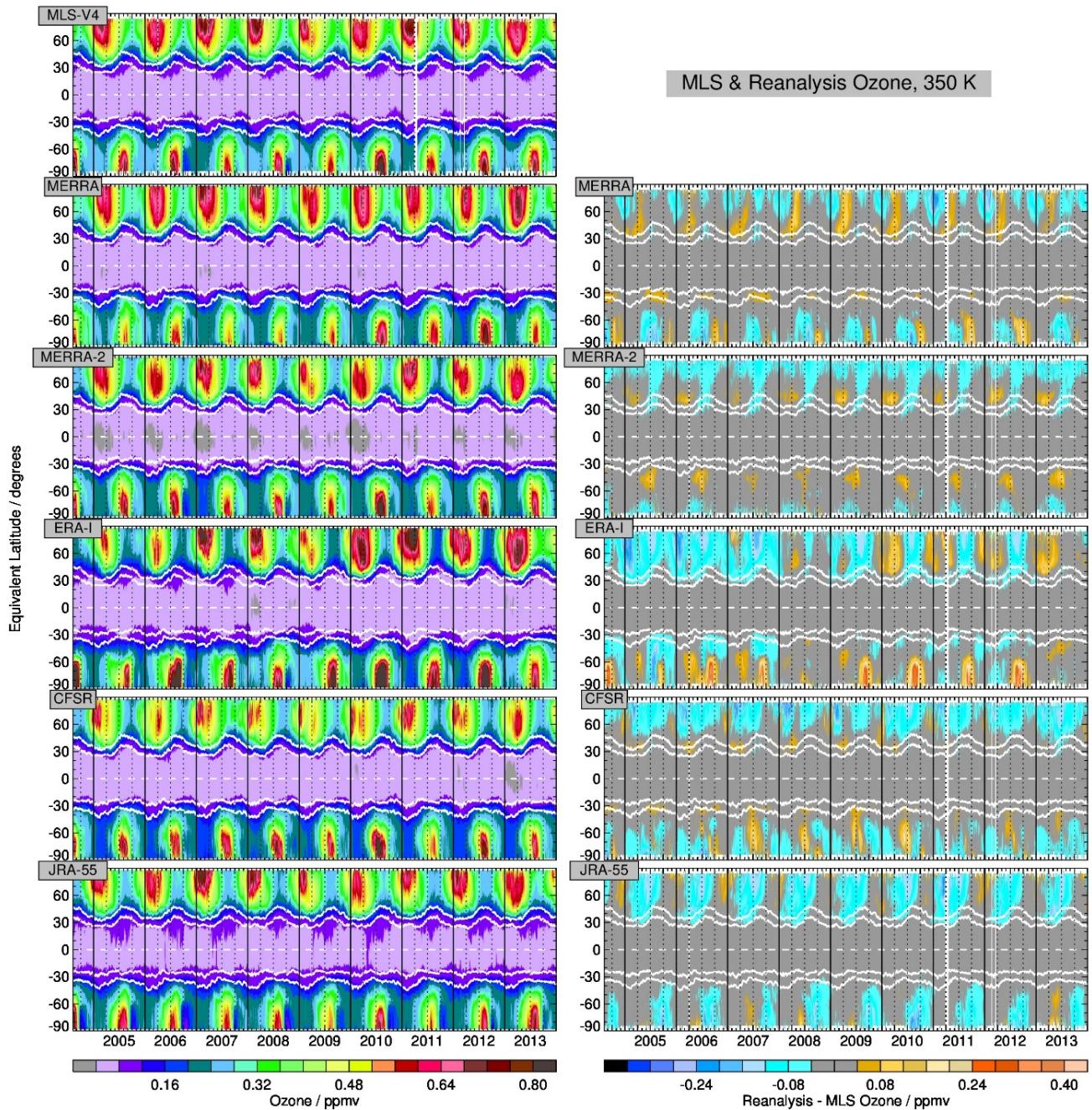


101

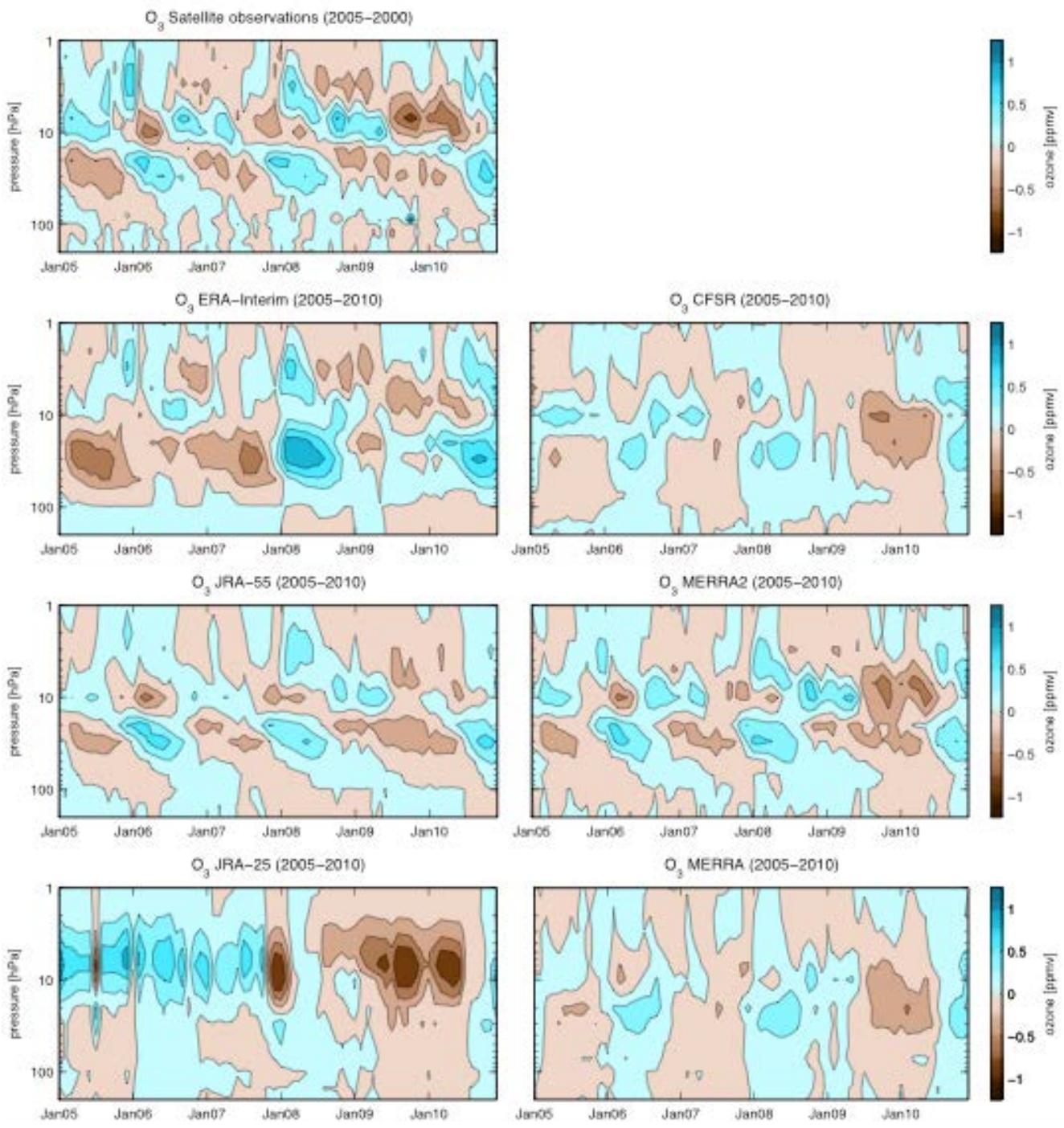
102

103

**Figure 4.17.** As is Figure 4.15, but for 520K (near 20km, 50hPa).

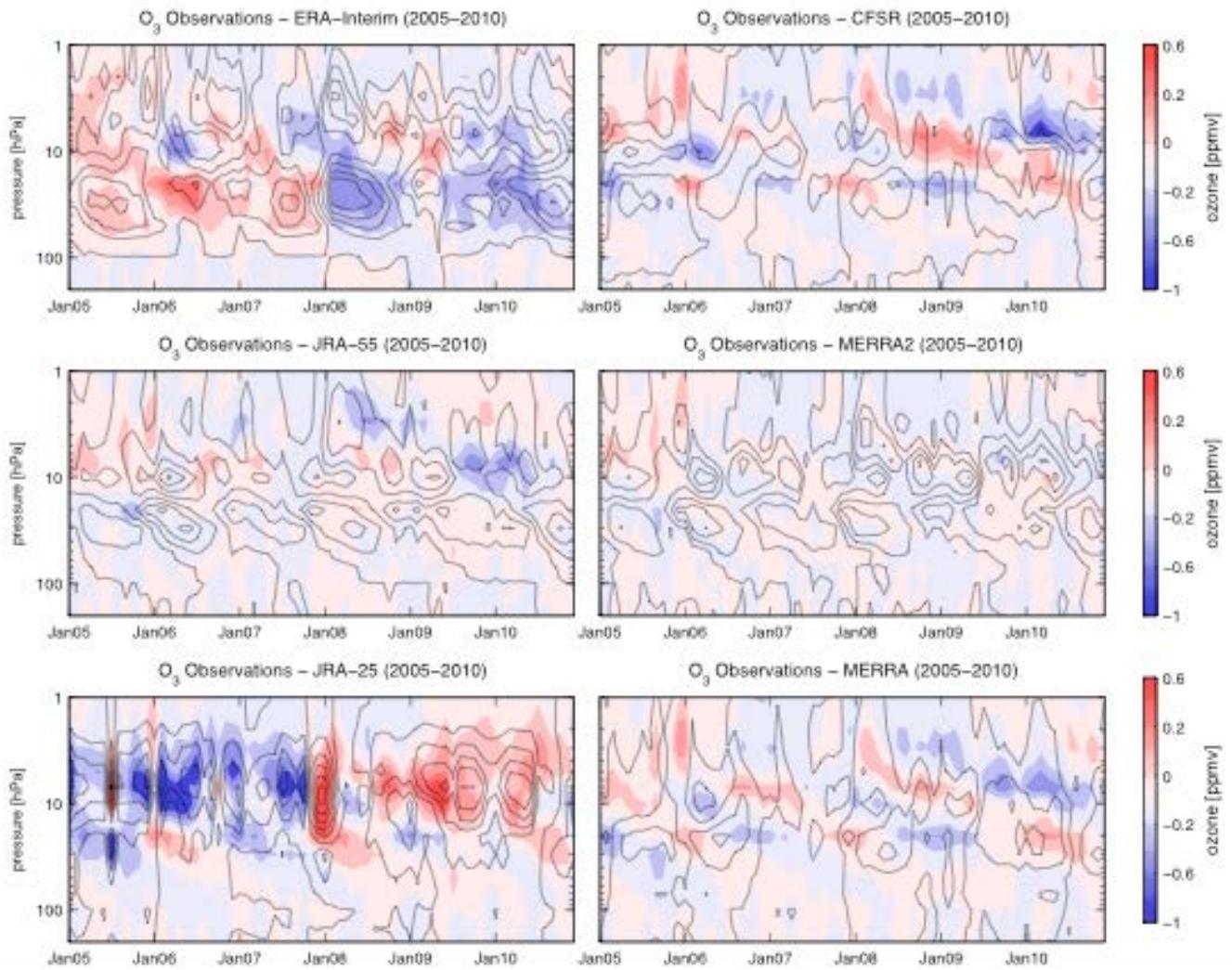


**Figure 4.18.** As is Figure 4-15, but for 350K (near 11km, 200hPa), and without vortex-edge sPV contours. The white contours are PV values of magnitude 1.5 and 4.5PVU, bounding the range commonly used to define the dynamical tropopause.

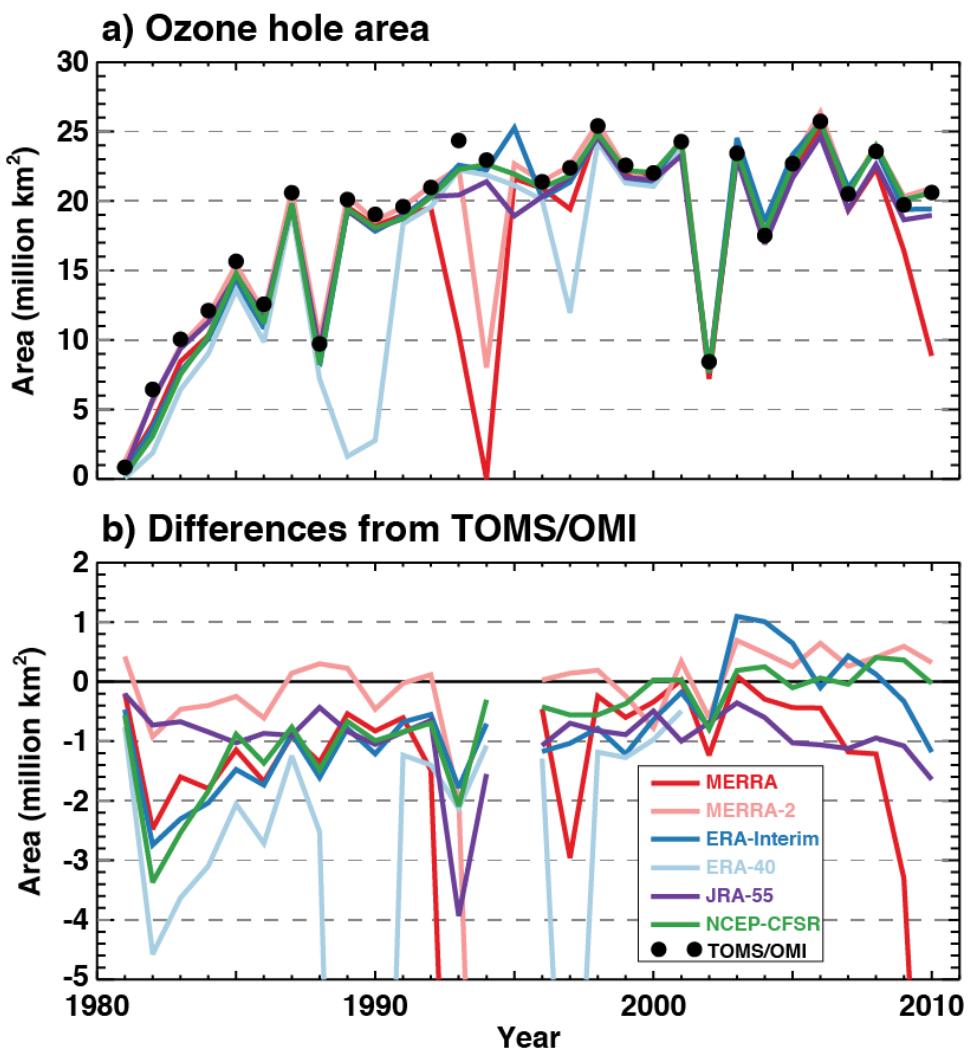


117  
118

119 **Figure 4.19. QBO signal for 2005-2010.** Altitude-time sections of deseasonalized ozone anomalies  
120 for 10°S-10°N from 2005 to 2010 are shown. The observations are based on three satellite data  
121 sets.  
122  
123  
124  
125  
126



**Figure 4.20. Differences with respect to observations for QBO ozone signal for 2005-2010.** Altitude-time section of ozone anomaly differences between the observational data set and each reanalysis are shown by color contours. The black contours present the ozone anomalies of the respective reanalysis data set.



**Figure 4.21.** (a) Ozone hole mean area calculated from six models and from TOMS/OMI observations for 21 September – 20 October 1981–2010. (b) Differences between the reanalyses and TOMS/OMI TCO observations.

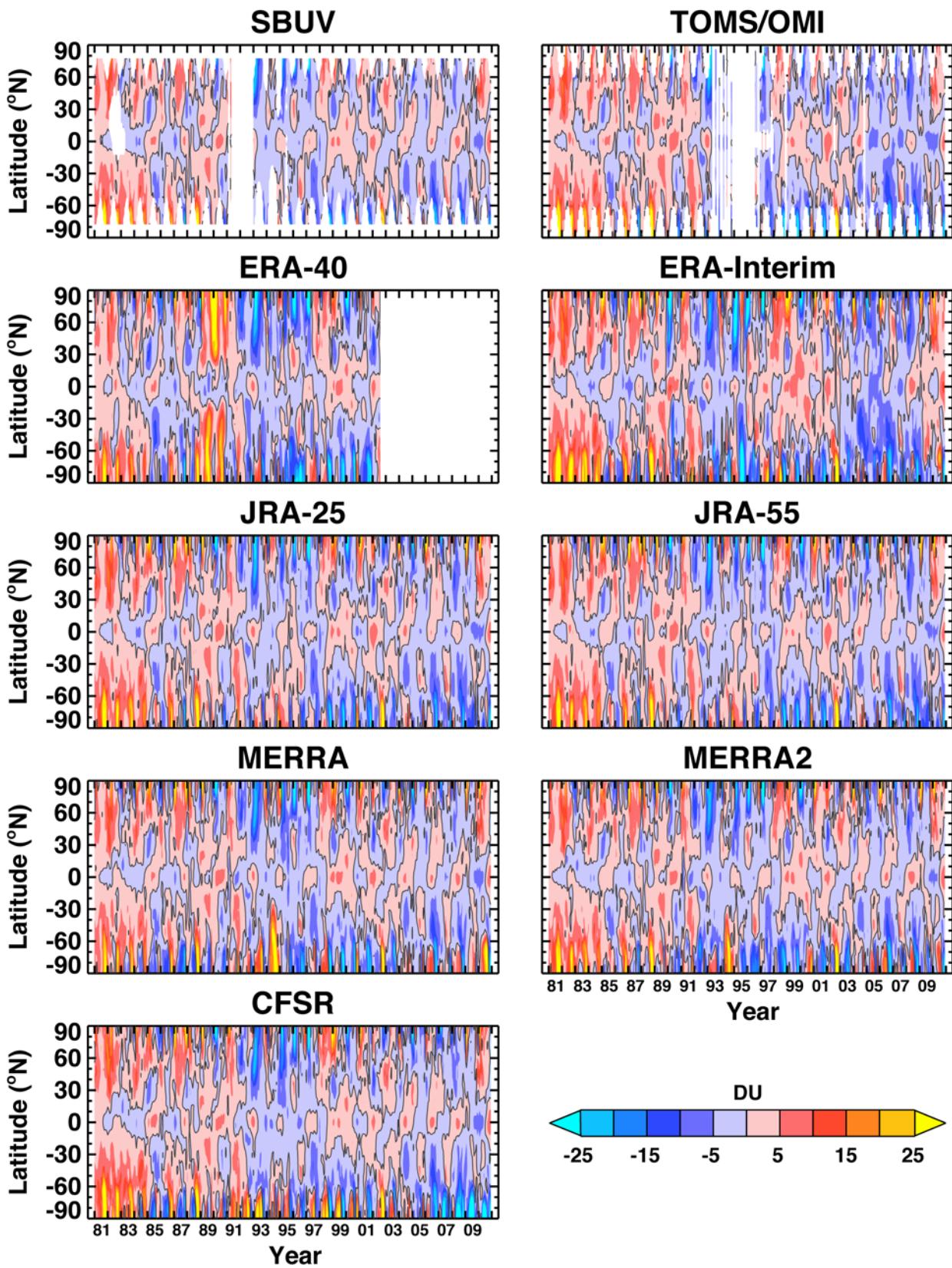
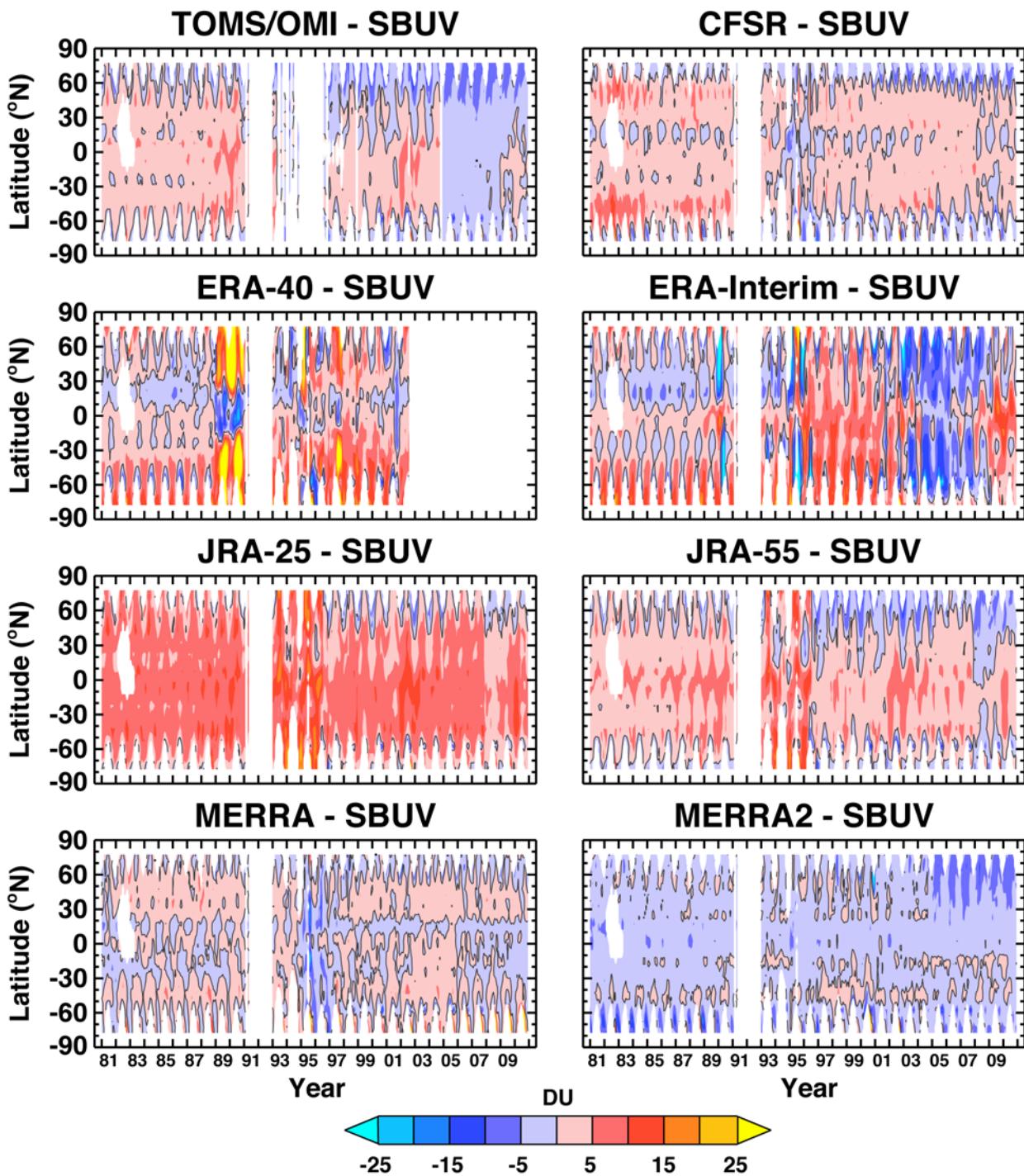
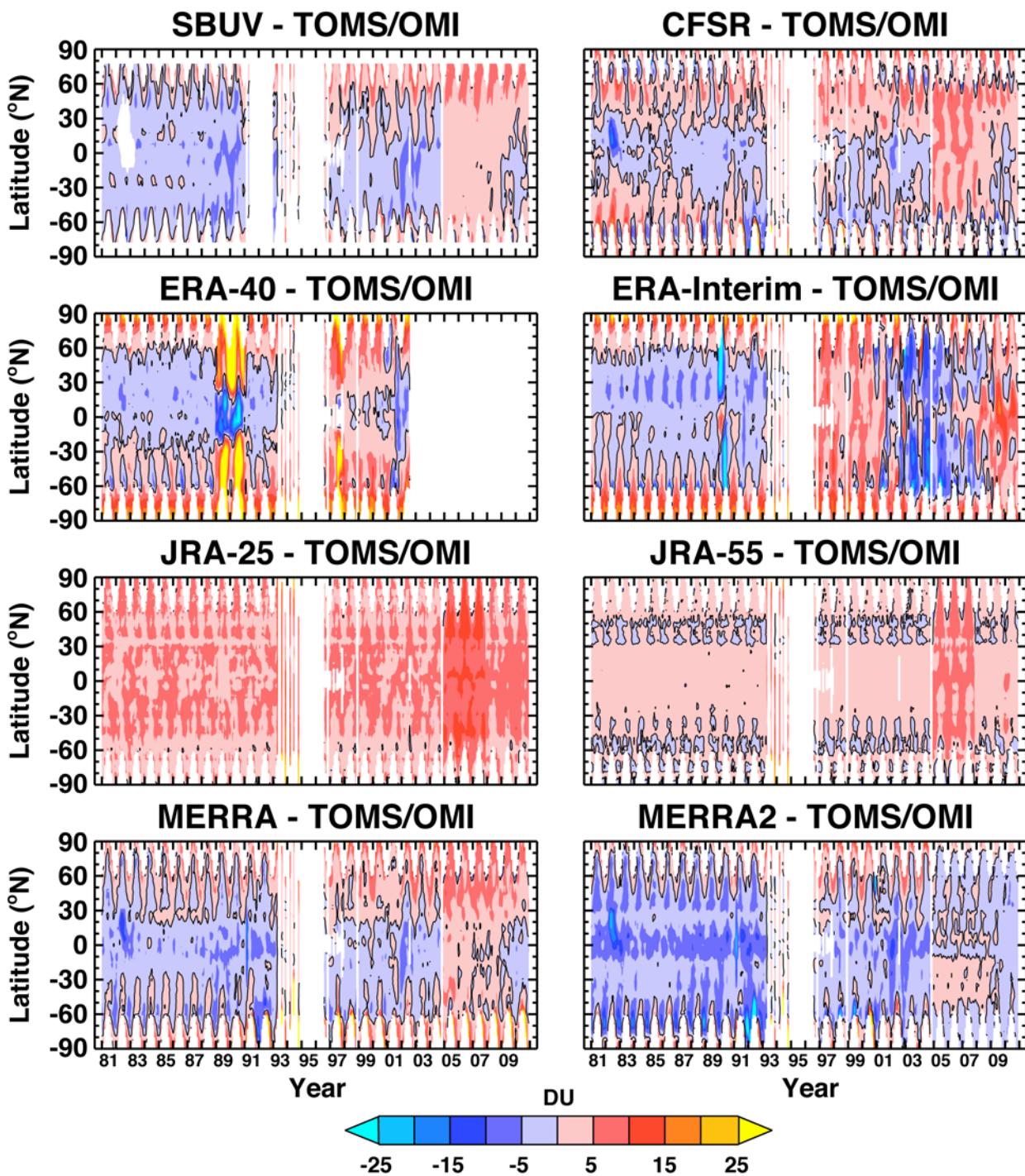


Figure 4.22. Departures of zonal- and monthly-mean total column ozone from climatology (1981–2010) for observations and reanalyses.



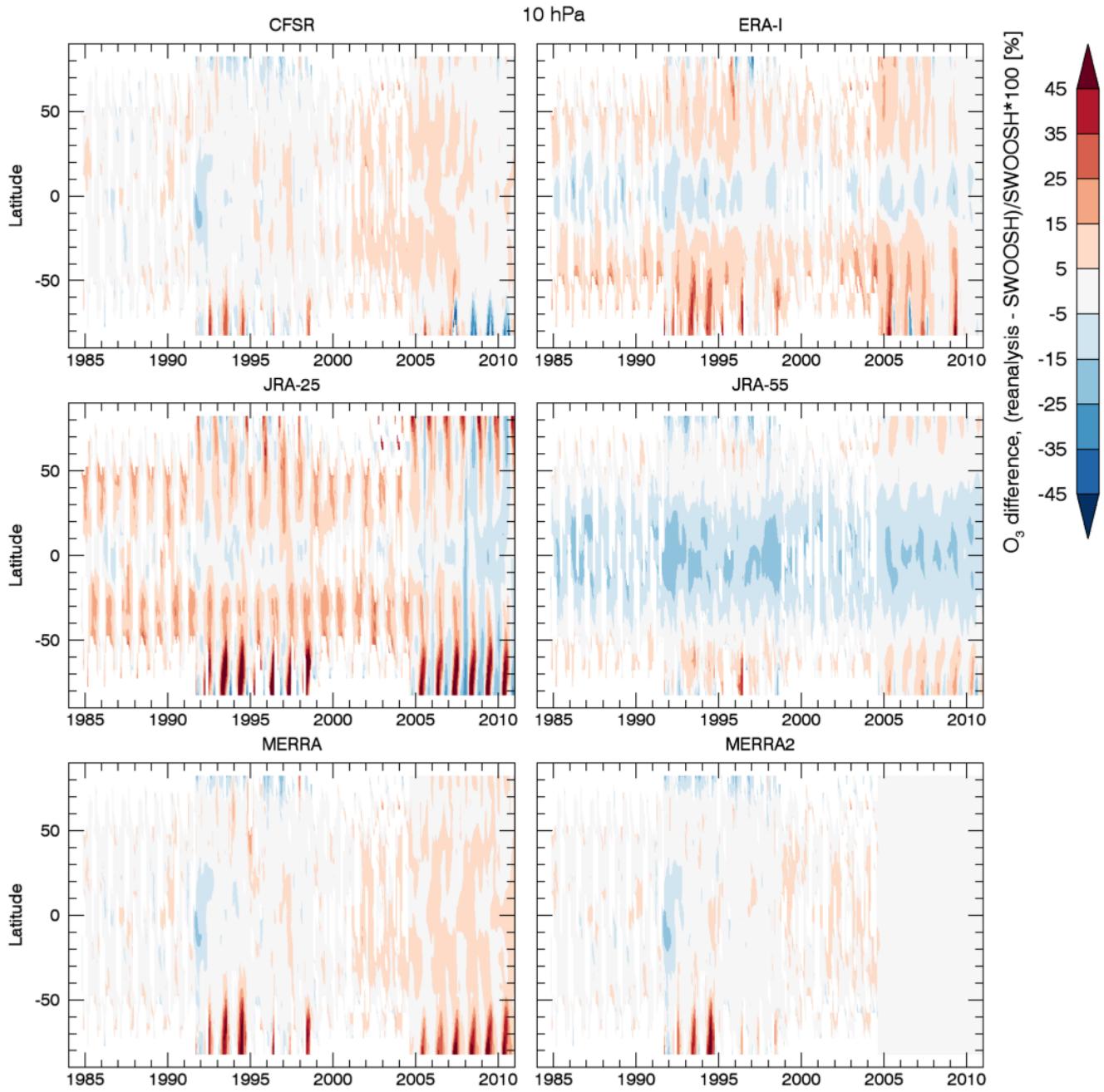
144  
145

146 **Figure 4.23.** Zonal- and monthly-mean total column ozone differences of TOMS/OMI and  
147 reanalyses with SBUV.



148  
149  
150  
151

Figure 4.24. Zonal- and monthly-mean total column ozone differences of reanalyses with TOMS/OMI.



**Figure 4.25. Plot of the percent differences between the reanalyses and the SWOOSH ozone record at 10 hPa.**

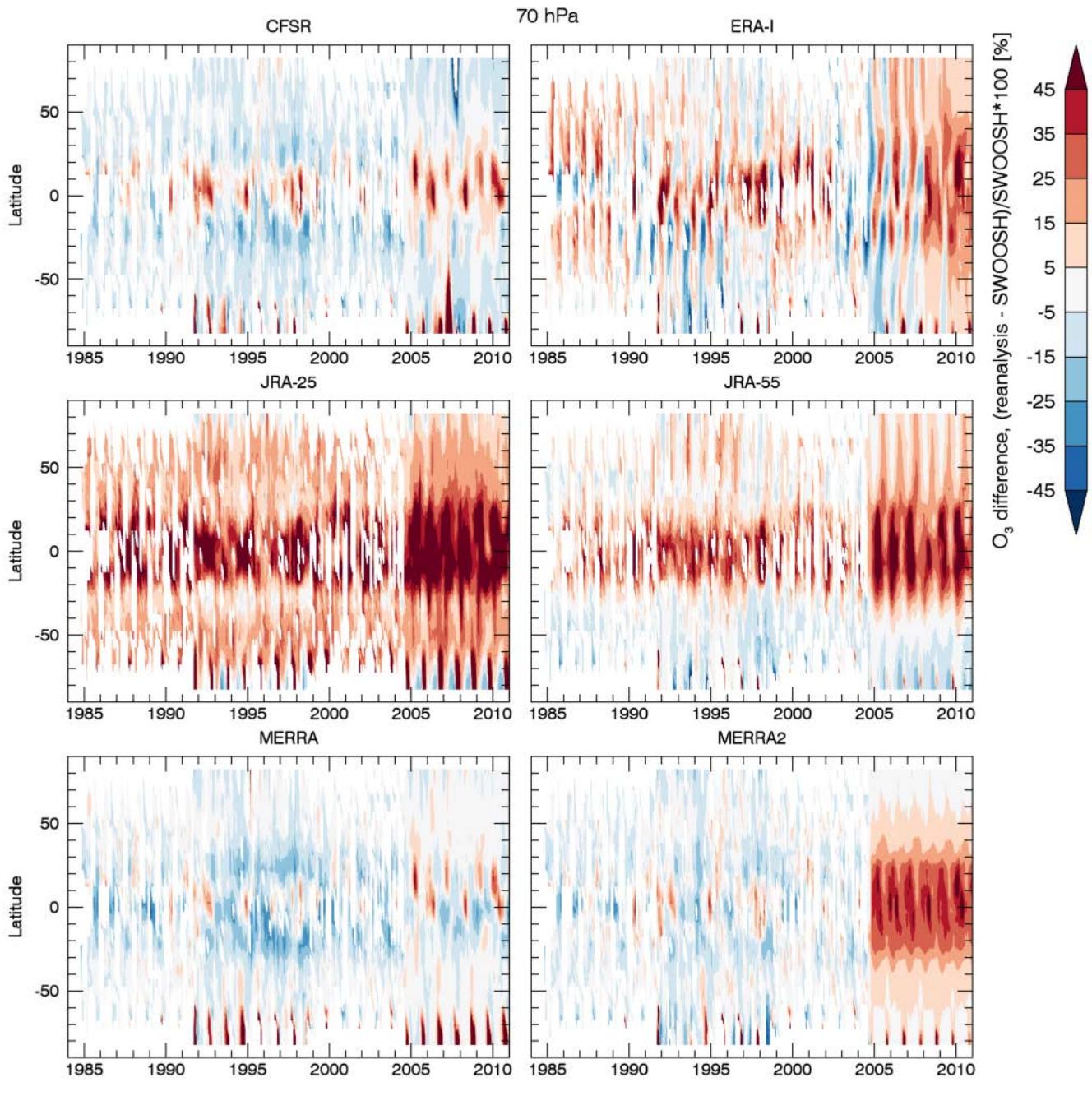
152

153

154

155

156



157  
158

159 **Figure 4.26.** Same as Figure 4.25, but for 70 hPa.